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Manhattan District History

Book II - Gaseous Diffusion [K-25] Project

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Vol. 3 - Design

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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

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FOREWORD

Volume 3 presents an account of K-25 design, engineering, and procurement activities, excluding work connected with the special chemicals development and procurement program, which is covered in Book VII. The purpose, administration, preliminary planning, and basic design principles are discussed, and an account is presented of the development and final design of the diffusion process system and its component parts, the equipment used, and the various auxiliary installations. The volume concludes with a descriptive résumé of assistance obtained from British sources, safety and security features, costs, organization, and personnel. Other phases of the K-25 Project are dealt with in separate volumes of Book II as follows:

Volume 1 - General Features
Volume 2 - Research
Volume 4 - Construction
Volume 5 - Operation

Activities described extend from the earliest OSRD contracts, negotiated in July 1941, for the study of the diffusion process, to 31 December 1946, by which time the basic K-25 design had been completed, and administrative responsibility passed from the Manhattan District to the United States Atomic Energy Commission.

A number of appendices are attached to illustrate the text by means of tabulations, plan drawings, charts, graphs, photographs, file references, documentary exhibits, and a glossary. References indicated by parentheses, as (App. B1), (App. C12), etc., refer to Item 1 of Appendix B, Item 12 of Appendix C, etc. Reference to the Glossary, Appendix E, is made by means of an asterisk.*

The Summary contains an abstract of every major subject treated in Volume 3. Paragraph numbers in the Summary correspond to section numbers in the main text.

A detailed descriptive account of the K-25 Project with special emphasis on design and development has been prepared by the Kellex Corporation: "Completion Report on the K-25 Gas Diffusion Plant" (Contract No. W-7405-eng-23) January 1, 1946 - H. B. Levey, J. F. Hogerton, and J. H. Arnold. This report has provided an outstanding source of reference during the preparation of the present work. More extensive treatment of the design and engineering underlying many of the subjects discussed in this volume may be found by consulting the Kellex report, frequent references to which are inserted in the text. Also referred to are the Kellex Engineering Descriptions, which are tabulated in Appendix D5 of this volume, and the Kellex Operating Manuals, which are tabulated in Appendix C3 of Volume 5. These reference works are on file in the K-25 Division Office of the U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

15 April 1947

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

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SUMMARY

1. Introduction. - K-25 Project design, engineering, and procurement activities involved work by many of the Nation's leading equipment manufacturers, and considerable assistance from British sources. Overall responsibility was vested initially in The M. W. Kellogg Company under OSRD contract OEMsr-406, and finally in The Kellex Corporation under Manhattan District contract W-7405-eng-23, which was administered by the New York Area of the Manhattan District.

2. Initial Work under the Office of Scientific Research and Development. - By January 1942 Columbia University workers had obtained some fundamental gaseous diffusion design data. At this time The M. W. Kellogg Company was awarded OSRD contract OEMsr-406 which called for engineering and production studies, and pilot plant construction and operation, directed toward the design of a large scale gaseous diffusion plant for the isotopic concentration of Uranium-235. On the basis of this work, the K-25 production plant was later authorized under Manhattan District contract W-7405-eng-23.

3. Negotiations and Preliminary Planning. - On 12 November 1942, the Military Policy Committee decided that the work should be continued, and that the Kellogg Company should be authorized to proceed with the engineering of a 600 stage plant contingent upon demonstration of scientific and technological ability. On 14 November 1942, at a meeting with General Groves, Manhattan District officials, and representatives of the Kellogg Company, the OSRD S-1 Executive Committee resolved that the work be pressed forward on both the Kellogg pilot

plant and the 600 stage production plant. A priority rating was assigned to the gaseous diffusion plant after the first 2000 units of the proposed electromagnetic plant, and after the first contemplated plutonium production pile. The plant was estimated to have a net transport of 1/2 to 1 kilogram per day of U-235 at double concentration, and was to be so designed that it could be fitted, if desired, into a larger plant for the production of 90 per cent material. On 21 November 1942, General Groves appointed a Reassessment and Reviewing Committee in order to study relative advantages and disadvantages of the gaseous diffusion process. This committee recommended proceeding immediately with design and construction of a 4600 stage plant with a capacity of one kilogram per day of U-235. On 10 December 1942 the Military Policy Committee authorized General Groves to arrange for construction of the 4600 stage plant with the Kellogg Company as engineers. On 14 December 1942, letter contract W-7405-eng-23 was executed with Kellogg for design, development, procurement, and related services in connection with the construction of a 90 per cent gaseous diffusion plant. The formal fixed-fee contract was signed on 11 April 1944, effective as of the letter contract date. Estimated cost was $254,560,698.00 and the fee was set at $2,424,347.00. The Under Secretary of War approved the contract on 28 March 1944.

4. <u>Design Principles of the Gaseous Diffusion Process.</u> - The process material is uranium hexafluoride, which vaporizes at subatmospheric pressures and moderate temperatures. The normal concentration of the U-235 isotope is 0.71 mol per cent. The principle of

gaseous diffusion (more properly "molecular effusion") refers to the tendency of confined gas molecules to ~~the~~ escape through fine apertures in the retaining walls. In the case of a mixture of two types of molecules, the relative rates of escape are in proportion to the respective mean velocities, and therefore in inverse proportion to the square roots of the respective molecular masses. In order to maintain a steady pressure and concentration state, gas must be continuously withdrawn, while enriched diffusate is concurrently removed from the outer receiving space. In the case of separation of $U^{235}F_6$ (molecular weight 349) from $U^{238}F_6$ (molecular weight 352), the theoretical maximum concentration obtained in a single stage process using normal feed is 1.0043 times 0.71, or 0.713 per cent. To effect significant enrichment, it therefore becomes necessary to repeat the basic operation many times in a continuous multi-stage recycling operation. A gaseous diffusion cascade consists of a multiplicity of stages. Diffusate ("A" stream) from a given stage is pumped to the next higher stage for reprocessing, and partially depleted material ("B" stream) is piped to the next lower stage. Each stage is thus fed with a combination of enriched diffusate from the stage below, and partially depleted residue from the stage above. Cascade feed is introduced at an intermediate stage, final product is withdrawn from the top of the cascade, and waste is taken off at the bottom. The process material, UF_6, possesses the indispensable characteristic of ease of volatility, but presents a grave disadvantage by reason of its extraordinary corrosiveness. Its extreme reactivity severely narrows the field of available materials of construction, and imposes numerous restrictions on plant design. Thus, the tremendous internal exposed surface areas of the plant require that extreme precautions be taken in order to limit the corrosive consumption of valuable process material. The necessity for operation at sub-atmospheric pressures, together with the deleterious consumptive and plugging effects of interaction of UF_6 with water vapor makes it necessary to insure that the entire process system will be extremely tight against inleakage of atmospheric air and moisture. A further necessity imposed by the aggressive nature of the substance is the conditioning of all process equipment with elemental fluorine, which minimizes corrosive attack by formation of a protective fluoride film. Effective conditioning, in turn, requires that all equipment previously be scrupulously cleaned. Multi-step chemical cleaning procedures were accordingly set up both at the site and at the plants of a number of equipment suppliers.

5. Small Scale Testing of Plant Design. - A test floor was constructed at the Kellogg Jersey City Laboratories in 1942. In April 1944 the construction and testing of a ten-stage cascade was completed, and operations were started. Equipment and operating conditions simulated those of the K-25 plant, but dummy diffuser tubes were used, since diffusion barrier was not yet available. Test operations confirmed the feasibility and soundness of proposed equipment designs, vacuum-tightness features, cleaning and conditioning techniques, and process control. In addition to the operation of the ten-stage cascade, a number of pump and cold trap tests were run in order to obtain design and performance data.

6. Plant Site. - The K-25 plant was located within the Clinton

Engineer Works military reservation since this area was suitable, and had already been obtained by the District for other projects. A specific site for the K-25 power plant was chosen adjacent to the Clinch River and to Poplar Creek. After consideration of nineteen possible process area sites within the C.E.W., the plant was placed at a location due west of McKinney Ridge on 24 June 1943. The selection was based upon considerations of topography, isolation and dispersion of C.E.W. plants, and accessibility to rail, water, and power facilities.

7. Process Design. - The gaseous diffusion plant, as originally planned in the Kellex Corporation's "First Progress Report" (15 March 1943) was designed to produce 1 kilogram per day of 90 per cent U-235.

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On 18 August 1943 the District Engineer authorized the construction of a one kilogram per day 36.6 per cent plant. On 16 January 1945 Kellex was authorized to proceed with engineering and procurement work necessary to extend the plant for the production of 85 per cent material. On 16 March 1945 this proposed extension was cancelled, and on 31 March 1945 the construction of the K-27 plant was authorized as a 540 stage side feed annex in order to increase the production capacity of 36.6 per cent material. An ideal diffusion cascade calls for continuously varying equipment size, or process pressure, from stage to stage. The actual K-25 cascade is set up in nine process sections with equipment size and pressure level varying from section to section. It contains 2,622 stages above the point of feed introduction, and 270 below.

Each stage contains a diffuser which encloses the diffusion barrier, and a process cooler which utilizes perfluorodimethylcyclohexane as coolant, and which is fabricated integrally with the diffuser to form the "converter". Two centrifugal pumps are provided: the "A" pump for moving enriched diffusate to the next higher stage, and the "B" pump for supplying the converter with a mixture of diffusate from the stage below and partially depleted residue from the stage above. A control valve is used to regulate stage pressure, and suitable instruments are provided for measurement of process pressures, temperature, and interstage flow. Six stages are grouped to form a cell, which is the smallest individually operable process unit. The piping arrangement permits of by-passing a cell, operating on inverse recycle, or operating on direct recycle. The ~~former~~ inverse recycle method is a mode of recirculation wherein the "A" stream leaving the sixth stage is sent to the "B" pump of the first stage, and "B" stream leaving the first stage is sent to the "B" pump of the sixth stage. Direct recycle operation involves sending the flow from the top stage "A" pump to the suction of the "B" pump of the same stage, and is employed when a back pressure tends to develop in the discharge line of the sixth stage "B" pump. Cell connections are available for withdrawal of process samples, for cell evacuation, and for admission and removal of conditioning and test gases. The next larger process unit above the cell is the process building, of which there are 51, each containing from 3 to 14 cells. As with the individual cells, piping and valving facilities have been provided to permit by-passing of an entire building, and operating on inverse recycle. Two lines are provided for handling interbuilding upflow, and two for interbuilding downflow. Flow measuring equipment is installed at the building instrument boards. The nine process sections are the largest individually operable portions of the cascade, and consist, respectively, of banks of from one to twelve process buildings containing equipment of identical size, and served from separate sources of power. Bottom intersectional cells provide surge capacity, and top intersectional cells provide nitrogen purging facilities to permit of independent operation of individual sections.

In order to provide facilities for preliminary purification of feed material, a two-step distillation system was constructed involving a stripping tower operating at total reflux and removing non-condensables, and a re-run tower operating at a 3:1 reflux ratio and removing non-volatile impurities. Since the feed material is received in greater purity than was originally anticipated, and since it has been possible to relax the feed specifications somewhat, it has been unnecessary to operate the feed purification system, which is in standby status and available if it should ever be desired to accept sub-specification hexafluoride. A surge and waste system was provided to absorb cascade flow and pressure fluctuations, and to afford a means for withdrawing depleted material from the cascade. A surge drum reservoir connected to the cascade receives downflow from the bottom stage. Recycle flow pumped back to the cascade is held constant and independent of surge drum pressure fluctuations. The three buildings of Section 312 comprise a purging system utilizing the principle of gaseous diffusion in order to remove light diluent gases from the process stream. Purge stages contain flat plate diffusers, external process coolers, and a single bellows-sealed reciprocating pump. Each building contains 21 two-stage cells. The process gas recovery system provides a means for removing the process material from a cell to be opened for maintenance. The system employs a process gas vacuum pump discharging to a refrigerated heat exchanger ("cold trap") wherein the UF_6 solidifies. Each process building was originally designed with a two-trap recovery room. Improved methods of operation have eliminated the use of the equipment in present operations, but the process recovery system provides a standby method for process stream purging. K-25 product is withdrawn by passing process material through product containers immersed in liquid nitrogen. Connecting lines run from the line recorder manifold in Building K-306-7. Differential process pressure drives the material through the product trap, the light diluents passing on through and back to the line recorder manifold. Portions of the cascade were placed in operation as rapidly as completed. Temporary purging and product removal facilities were therefore required, and were installed at the top of Sections 2a and 2b. The principle of operation is based on selective condensation of UF_6 in the presence of light gases by means of cold traps, rejection of non-condensables, and return of the purged material to the cascade.

8. Design and Procurement of Process Equipment. - As the result of an intense research program, the material known as A barrier was selected for initial small scale production and further study in pilot plants. Further development was carried on by the Houdaille-Hershey

Corporation at Decatur, Illinois. Prominent contributing contractors included the Sharples Corporation, who conducted various experimental investigations and research studies, and A. S. Campbell, Inc., who developed special production techniques. In January 1944, the work on A barrier was discontinued because of inordinate manufacturing difficulties, and plans were made for the conversion of the Houdaille-Hershey plant to the manufacture of K-1 or DA barrier. With the cooperation of a large number of firms, mass production was achieved in ten months, under a program coordinated by the Carbide and Carbon Chemicals Corporation.

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The basic Kellex design was developed by the Chrysler Corporation who manufactured the units at their facilities in Detroit which were expanded for this purpose. The Whitehead Metal Products Company manufactured flat-plate converters for the purge cascade using rectangular backing strips produced by the Herron-Zimmers Moulding Company.

The centrifugal stage pumps were produced by the Allis-Chalmers Manufacturing Company at a specially constructed plant in Milwaukee, Wisconsin, using nickel-clad stock supplied by the Lukens Steel Company. Reciprocating, bellows-sealed, purge pumps were manufactured by the Valley Iron Works, conditioning pumps by the Elliott Company, coolant pumps by Pacific Pumps, Inc., process gas vacuum pumps by the Beach-Russ Company, fluorine vacuum pumps by the F. J. Stokes Machine Company, and high vacuum pumps by the Westinghouse Electric and Manufacturing Company.

Process gas coolers are of shell and tube design, and use perfluorodimethylcyclohexane, C_8F_{16}, as the coolant medium. External (inter-cell and inter-sectional) coolers were supplied by the A. O. Smith Company, using finned copper tubes produced by the Wolverine Tube Company. The integral stage coolers form a part of the converters produced by Chrysler. Coolant coolers were produced by the Whitlock Manufacturing Company. Monel tubing for process piping was supplied by the International Nickel Company in sizes up to four inch diameter. Large sizes were produced by the Bart Laboratories who developed a method for nickel plating steel using the rotating piping itself as the plating tank, and circulating electrolyte at high velocity. Process valves were required to be resistant to corrosion, vacuum-tight, and of minimum resistance to flow. A special valve seat material was developed by the British, consisting of a fluorocarbon wax-impregnated "C" rubber. This material was the best available and therefore was installed in K-25 process block valves. However, a program is under way at present to replace all valve seats with the later developed and more satisfactory MFP-10 fluorinated plastic. The principal valve used is the G-17A block valve which involves a double-seat, bellows-sealed, gate design with a wedge-type actuating mechanism capable of exerting seating pressures up to the fatigue point of the metal. In all, about a dozen valves of specialized design were developed for process and auxiliary purposes. The process valves were manufactured by the Crane Company.

A central control room at the midpoint of the cascade is equipped with measuring, recording, and controlling devices for coordinating cascade operations. Control of the basic process variable, stage inventory, is accomplished by means of a vast system of pressure, transmitting, recording, and controlling equipment. At each stage, the pressure of the converter tails stream actuates a transmitter which converts a fixed range of process pressure to a fixed range of air pressure to be fed to a controller, the latter then actuating the stage control valve. The controller is of the proportional plus automatic reset type with provision for reset cut-out; the control valve is of the diaphragm-actuated, bellows-sealed, butterfly type. Pressure control of the process cascade is based on the use of a datum system which utilizes a nitrogen header at an accurately maintained pressure as a reference for pressure measurement. The majority of the K-25 electronic instruments were designed, engineered, and produced by the General Electric Company. The Taylor Instrument Companies furnished consultant and engineering services, and manufactured many of the specialized and standard pneumatic instruments. Butterfly control valves were produced by the Republic Flow Meter Company and by the Fisher Governor Company.

The cold trap is a device which serves the purpose of separating UF_6 from non-condensable gases by solidification. Efficient cold trap design depends upon proper arrangement of heating surfaces and gas flow passages so as to effect deposition of solid without obstructing either heat transfer or flow of gas. Two basic designs were ultimately worked out and applied. The larger size cold traps are of the double shell radial fin type, and were manufactured by the Patterson-Kelley Company. The smaller sizes are of the single shell, parallel fin type, and were manufactured by the Schock-Gusmer Company. The shells are equipped with calrod heaters for use in warming the trap contents for removal, and all types are heavily insulated with 8 to 10 inches of asbestos felt. Carbon traps are used to supplement the use of cold traps in the recovery of UF_6 from vent gases. As finally designed, the carbon trap consists of a cylindrical steel shell tapering at the bottom to form a conical section. The cone is charged with alumina, and the main body with mixed carbon-alumina. The carbon acts as an adsorbent; the alumina prevents excessive temperature rise and caking. In higher sections of the plant the alumina is impregnated with cadmium oxide so as to avoid special hazards. The carbon traps were manufactured by the Alco Products Division of the American Locomotive Company.

9. Process Buildings and Utilities. - In external appearance, the process plant proper appears as a large "U"-shaped structure. It is made up of a series of 54 contiguous buildings, three of which house the purge cascades, and 51 of which house the isotope separating stages. All process buildings are similar in form and general arrangement. The basement of each contains coolant and lubricating oil handling equipment, process gas recovery equipment, and ventilating fans and air filters. An enclosed vault houses electrical switch-gear and transformers. The cell floor contains the banks of sheet-metal-enclosed cells each with six converters, twelve process pumps, and various auxiliary equipment. The cells are arranged in two parallel rows separated by a motor alley, and the cell floors of adjacent buildings are separated by withdrawal alleys. The pipe gallery level includes process piping and valves enclosed in sheet metal dry air compartments. Operation of each building is controlled from the top floor level which contains instrument

panel boards and control equipment. Each building is provided with an extensive ventilation system designed to dissipate heat, and systems for heating by unit heaters, lighting, and communication. Converters, leak detectors, and other heavy equipment, are moved in and out of the buildings by means of trailers, tractors, and trucks.

10. Design of Process Service Installations. - Five 10,000-gallon tanks are provided within the cascade court for storage of process coolant, perfluorodimethylcyclohexane, C_8F_{16}. These are connected by pipeline to the process building coolant headers. The C_8F_{16} is circulated through stage coolers, intercell coolers, and intersectional coolers. Each building is equipped with a coolant transfer pump taking suction for the building drain drum, by means of which contaminated coolant is pumped back to the wet coolant storage tank. The coolant purification system removes water, grease, lubricating oil, and other non-volatile impurities by distillation. The recirculating cooling water system includes a recirculating pump house, a make-up pump house, two cooling towers, and two individual supply and return loops. A total continuous circulation of about 120,000 GPM is maintained through the two loops, and respective process coolers and cooling towers, by means of a battery of recirculating pumps. About 5000 GPM of make-up is supplied by means of a second and smaller battery of pumps. The dry air plant supplies minus 75°F dew point air for equipment enclosures, pump and valve seals, and for various purging purposes. The installation includes recirculation air compressors and coolers, make-up air compressors and coolers, alumina dryers, an ammonia refrigeration system, a brine circulation system, and a dry air piping distribution system. It was originally

designed as a circulating system but has been converted to a more efficient "dead-end" arrangement. Air for instruments located within the dehumidified equipment enclosures is taken from this plant and compressed to 55 p.s.i.g. 100 p.s.i.g. air is used for various instruments, maintenance, and miscellaneous services. It is dehumidified to minus 50°F dew point in order to provide a supplementary source of supply in cases where the output of the dry air plant may fall below the demand. The compressor house contains five compressors.

Facilities are provided for storing, pumping, filtering, and cooling lubricating oil, and for circulating it through the shaft bearings of all process pumps of the cascade. Dry nitrogen is supplied for various equipment purging and sealing operations, and as a reference pressure medium to the building and cell instrument datum system. Mobile high vacuum pumping units are used in leak detection work, n-perfluoroheptane supply, pumping, and disposal and ~~units were used~~ in connection with preliminary equipment performance testing. Fluorine supply units are used to supply conditioning gas as required. A temporary mobile fluorine disposal unit was also provided, but spent conditioning gases are normally sent to the disposal plant in the conditioning area by means of a permanent piping system and portable fluorine vacuum pumps. Two temporary UF_6 absorption units were provided for evacuating and disposal of process gas when necessary, before the permanent process gas recovery system could be set in operation.

11. Conditioning Area Design. - The conditioning building was designed basically as an extensive and specialized maintenance plant where equipment could be prepared for service in the process area. The

building was designed by Ford, Bacon, and Davis, Inc. On the basis of best analyses of the cleaning, conditioning, and maintenance activities planned, a one-story steel frame and brick wall building was designed, 400 feet in width, 1000 feet long, and with a 72,000 square foot basement. Floor area was allocated among a conditioning furnace room, test stand area, cleaning and vacuum testing areas, and various repair and maintenance shops, equipment storage areas, offices, and miscellaneous service facilities.

Eighteen large size, and eighteen small size converter conditioning stands were designed to provide a means for pre-treating the stage converters by circulating fluorine-nitrogen mixtures, leak-testing the assembly, and checking barrier porosity before and after conditioning. The heart of each conditioning stand is an electrical, horizontal, bell type furnace furnished by the General Electric Company. It is provided with an insulated, welded steel casing and a refractory brick floor. Heated air is circulated through the casing, and over three separate heating elements, by means of three centrifugal fans. The upper portion of the furnace consists of a semi-cylindrical, removable head with a skirt-and-trough water seal arrangement to prevent the escape of heated air at the joint during operation. The lower portion is fitted with a completely flexible alignment device for centering converters of varying size and aligning in all directions for proper connection to monel conditioning gas circulating piping which passes through the floor and connects with the conditioning pipes, vacuum pumps, and fluorine removal pumps located in the basement, together with the gas feed lines, exhaust lines, and furnace instrument panels.

Twenty process pump conditioning stands were provided, each consisting principally of a control panel, pump sub-base, and a hood for enclosing the pump casing during fluorination. Sixteen 800 watt strip heaters are installed in the lower section of the hood. Suitable auxiliary systems are installed for the supply, respectively, of fluorine, nitrogen, lubricating oil, instrument air, and electrical power, and for fluorine disposal, seal and hood exhaust, and instrumentation.

It was originally proposed that each converter should be tested after conditioning to determine its porosity and separation performance under conditions closely simulating process operation, and 19 "running test stands" were planned for this purpose. Subsequent work with a prototype test stand at Chrysler later ~~subsequently~~ corroborated the basic permeability transformation theory which had been developed, and the approximate accuracy of calculated friction drops inside the unit. It followed, therefore, that measurements of permeability made on the conditioning stand with nitrogen at atmospheric pressure and low pressure drops could be safely translated, by calculation, to permeability of process gas under operating conditions. It also developed that a circulating method would be preferable to a static treatment on the conditioning stands. Flow measurements would therefore be available at that point, and the running test became unnecessary as a final acceptance test. Four running test stands were finally installed for the purpose of measuring separation efficiency of converters of each of the four standard sizes. The test stands are arranged in a row along a trench in which are located C_7F_{16} supply and return mains, nitrogen supply and exhaust mains, and water, instrument air, and lubricating oil lines. The trench leads to a service pit containing equipment for supply and removal of C_7F_{16} and C_8F_{16}. Each test stand assembly includes a base for receiving the converter, and permanently installed "A" and "B" pumps of sizes corresponding to the size of the converter to be tested.

The pipe assembly shop was used by the Midwest Piping and Supply Company for assembling of process piping before installation. Cleaning area facilities include a degreasing tank, five small auxiliary solution tanks, a set of turning rolls for large cylindrical vessels, filters, drying units, and twelve 34 x 5 x 4 feet deep cleaning tanks used for alkaline cleaning, water rinsing, acid pickling, scratch brushing, and surface passivation. The vacuum testing area adjoins the cleaning area, and contains six portable vacuum stands for leak testing pipe assemblies.

After completion of the initial activities involved in cleaning, conditioning, assembling, and preparing for installation, the large quantities of process equipment and piping required for the diffusion cascade, a number of internal design and arrangement changes were made in the conditioning building. Six converter conditioning stands and eight pump conditioning stands have been moved in order to make room for development work now being carried out in this area. Maintenance shops have been greatly expanded and diversified, and a converter re-tubing and testing area has been set up in the northern third of the building. Construction of a barrier testing laboratory in the northwest corner of the building was begun in October 1946, and is now about 95 per cent complete.

Accessory conditioning structures include a control house containing electrical and control equipment for apparatus located in the conditioning furnace room, a fan house containing five 50,000 CFM exhaust fans for handling fumes from cleaning area activities, and a storage and pump house for handling hydrochloric and sulfuric acids required for cleaning operations.

The K-25 fluorine plant was designed to manufacture, handle, and store the large quantities of elemental fluorine gas required by the Project for conditioning purposes. The general design was developed by the Hooker Electrochemical Company. Detailed designs and construction drawings were prepared by Ford, Bacon and Davis, Inc. Several special features were worked out jointly by Hooker, Kellex, and Carbide. The fluorine plant consists of three buildings of steel frame and brick wall construction located several hundred feet north of the conditioning building. The generating building houses generating and auxiliary equipment, mechanical compressors, an office, and a laboratory. Fluorine is generated by electrolysis at 100°C of a solution of potassium fluoride in hydrogen fluoride. A maximum of 2000 amperes of direct current at 9.5 volts is supplied to each cell by means of eight copper oxide rectifiers. Carbon anodes and steel cathodes are separated by a screen. Hydrogen fluoride contained in the crude, generated fluorine, is removed by passage through sodium fluoride tray absorbers, and the gas is piped to surge tanks (located in the storage building) which provide damping of pressure variations so as to minimize the load on the automatic control system. Three additional nickel clad tanks 6 feet in diameter, and 20 feet long, provide storage for about 1-1/2 days' fluorine production. After various means of handling the fluorine were considered, pressuring by liquefaction was selected as the best available method, but provision was made for subsequent conversion to mechanical compression in the event of successful development of a suitable compressor. Twelve cubicles were set up in the liquefaction and bottling building each capable of liquefying the gas and re-vaporizing it into either the storage tanks or portable cylinders. The design called for gas admission to an all-nickel bomb immersed in liquid nitrogen, and for subsequent warming up of the bomb and pressuring of the contents. However, by August 1944, Hooker, aided by Kellex, developed a satisfactory diaphragm-type pump which was fabricated by the Wilson Pulse-feeder Company. Two compressors and control equipment were then installed in the generating building, and a revised method of operation was begun in February 1945, wherein generated fluorine is compressed and delivered to the storage tanks in a straight-forward pumping operation.

The fluorine disposal plant was designed to absorb the toxic and corrosive fluorine and hydrogen components of various waste gases before venting to the atmosphere, by means of a 200 cubic foot absorption tower (or alkaline scrubber) lined with carbon bricks and packed with carbon Raschig rings. Gas flow is maintained countercurrently to a descending stream of 5-10 per cent caustic solution flowing at 50-100 GPM. A 4 inch diameter, 70 foot high, emergency stack was also constructed to allow for direct venting of gases at times when the tower may be temporarily out of service. Fluorine disposal plant auxiliaries include a 2250 gallon water tank in which tower effluent containing dissolved sodium fluoride is treated with lime slurry in order to precipitate calcium fluoride and regenerate the caustic, a 22,000 gallon settling tank for decantation of regenerated clear liquor, two 26,500 gallon caustic storage tanks, and a control laboratory. In present operations, spent gases from cascade conditioning operations are allowed to enter the process stream for ultimate removal in the purge cascade, and all gases routed to the disposal area are vented directly through the emergency stack. These procedures are made possible because of the small quantities of spent conditioning gases handled in present operations.

An acid neutralizing plant, constructed for the purpose of disposing of acid waste fromcleaning operations in the conditioning building, includes a small storage building containing a lime hopper, feeder and slaker tank. Slaked lime slurry is run to a 25 foot diameter, 10 foot deep,neutralizing pit, and mixed with the waste acids. The neutralized solution is discharged to a holding pond 410 feet long, 160 feet wide, and 5 feet deep, from which clear effluent overflows to Poplar Creek.

Process and equipment design for a nitrogen plant,designed to supply Project requirements for moisture-free gaseous nitrogen and liquid nitrogen, was supplied by the Linde Air Products Company; building design was handled by Ford, Bacon, and Davis, and the work was coordinated by Kellex. The installation consists of equipment for receiving, storing, and filtering liquid nitrogen, vaporizing the liquid, and supplying gas by pipeline at constant pressure to the process and conditioning areas as required.

In a large number of carbon traps throughout the K-25 plant, the carbon charge must be diluted with alumina pellets in order to avoid caking of the carbon in the event of a flow of concentrated UF_6. A carbon mixing plant was therefore provided in order to carry out the necessary combining operation in such a way as to form a uniformly mixed charging material. A feed hopper and vibrating feeder deck for carbon, and another set for alumina, deliver to a common blending hopper which empties through a flexible sock into the drums to be filled.

A 120,000 pound per hour steam plant supplies steam at 175 p.s.i. for building and process heating purposes to the process, conditioning, and administration areas. The original facility contained three 40,000 pound per hour boilers, one 175 foot chimney, and water treatment and miscellaneous auxiliary equipment. When the K-25 plant was constructed, steam generating facilities were increased by installing three additional 50,000 pound per hour boilers, the necessary additional auxiliary equipment, and a second chimney. The steam plant was engineered by Sargent and Lundy under Kellex supervision.

12. <u>Power Plant Design.</u> - The power plant area covers 160 acres, and is located on the Clinch River about 8800 feet southwest of the main process area. Generation facilities are designed to supply electrical power of extremely high dependability factor at frequencies varying from 45 to 130 cycles. Total design capacity is 238,000 KW. An additional 110,000 KW of 60 cycle power is available through connections with the Tennessee Valley Authority. The decision to construct an on-site power plant was based on the importance of an uninterrupted supply, relative ease of protection, the variable

nature of required frequencies, and limited availability of T.V.A. Power. Considerations of simplicity and reliability of design and installation led to the decision to generate power at desired frequencies by means of steam-driven turbo-generators. An underground system was designed for transmission of power to the process area, using three-conductor, paper-insulated, lead-covered cables, at a transmission voltage of 13,800 volts, which is the level of generation. Three 750,000 pound per hour boilers were required. Two of the desired type and capacity had already been constructed for use by another project. These were obtained and a third one was ordered of identical design. Fourteen turbo-generators were procured. Design and engineering for the power plant were handled by Sargent and Lundy under Kellex supervision.

An extensive coal handling system includes eight conveyors furnished by Robins Conveyors, Inc., a track scale, two duplex truck hoppers, a transfer house, a breaker house, a screen house, and a 250,000 ton storage yard. Each boiler is served by a 1,000 ton bunker. Raw crushed coal is delivered from the bunker through automatic scale feeders which supply the pulverizers. Coal is discharged tangentially through three burners at each corner of each furnace. Combustion air is supplied to each furnace by two 96,000 CFM forced draft fans. In the spring of 1946 one boiler was adapted for oil burning service. Combustion gases pass through a superheater, economizer, air heater, and fly ash precipitator. A flexible control system permits either automatic, semi-automatic, or manual control. The boiler house contains three Combustion Engineering Company boilers, each rated for 750,000 pounds per hour of superheated steam at 1325 p.s.i. and 935°F. Each unit consists of a three-drum, bent-tube boiler equipped with water-cooled furnace walls, a superheater with by-pass control, an economizer, and a tubular air heater. Six eight-inch, six-stage Worthington centrifugal boiler feed pumps have a capacity, each, of 600,000 pounds per hour against a head of 1600 p.s.i. Twenty-four Allis-Chalmers condensate pumps range in capacity from 40 to 600 GPM, and in discharge head from 840 to 900 feet. A 75,000 pound per hour Permutit Company cold carbonaceous water treating plant is installed for initial treatment of raw make-up.

Fourteen turbo-generators range in capacity from 1,500 to 35,000 KW. The condensers operate at vacuums of 28 to 29 inches of mercury, have a total heat transfer area of 224,870 square feet, and a total condensing capacity of 1,737,846 pounds per hour, using 254,000 GPM. of cooling water. Cooling water from the Clinch River passes through a crib house and pump house to the condensers. It is sent to Poplar Creek (which delivers to the river at a point downstream from the intake) by way of a 1,006 foot reinforced concrete discharge tunnel, a 2200 foot stone-lined flume, and a second concrete tunnel.

The electrical distribution system includes a constant frequency system supplying 60 cycle power, and a variable frequency system including seven sub-systems which operate separately at desired frequencies between 45 and 65 cycles, and two which operate between 90 and 130 cycles. Utilization voltages are 2400, 480, 208, and 115. The main switch house is the control center for power transmission to the process plant. Connection with the T.V.A. system is made through an outdoor switchyard containing three 40,000 KVA transformers which step incoming power at 154,000 volts down to 13,800 volts. The yard receives power over direct feed line from the T.V.A. plant at Fort Loudon, a tie line from the No. 2 Elza Substation, and a tie-line from the K-27 switchyard. Power is carried to the utilization area by means of underground cables enclosed in fibre ducts encased in concrete. There are thirteen banks of 6 ducts each.

13. The Administration Area. - The administration area includes four laboratories, a two-story, four-wing main administration building, an industrial relations office building, two field office buildings, and various personnel facilities, warehouses, guard houses, and garages. Most of these are of a temporary, low-cost type, and most are situated in an area southeast of the main process area.

14. The K-27 Area. - The K-27 plant is a structurally separate annex to the main K-25 cascade designed to increase total U-235 production by 35-60 per cent. In most cases, specific portions of the K-27 work were performed by the same contractors who had handled corresponding phases of the original K-25 plant. K-27 buildings occupy a 60 acre plot of land just southwest of the main cascade "U". Design principles are identical with those of the main K-25 plant. In order to expedite ~~the speed of~~ construction, the general policy was followed of extending the diffusion plant process facilities by constructing duplicates of one of the process buildings of Section 2a of the main cascade. Only those changes were made which were absolutely necessary, or by means of which significant improvement could be effected without delaying the progress of construction.

The K-27 cascade consists of 540 stages housed in nine process buildings, each containing 10 six-stage cells. Feed to the K-27 cascade is obtained as fresh, normal concentration UF_6 from the Harshaw Chemical Company, and as partially processed UF_6 recycled from the bottom of the K-25 cascade. No purification equipment is necessary for the former material, fresh feed stock being vaporized directly by immersion in hot water baths and sent through feed filters to the K-27 cascade. The recycled stock may be passed through a batch still purification system in order to remove such impurities picked up during prior processing as coolant and light diluents. The installation consists principally of a packed tower and re-boiler, a still pot, condenser, and reflux drum. A UF_6 disposal system is provided in order to recover hexafluoride from vent gases, purge gases, and relief valve discharges by absorption in water, precipitation with caustic, and filtration in a plate and frame press.

A completely spared surge and waste system is provided, similar in design and purpose to that of the main cascade. The building is equipped with a unique ventilation system in which certain areas where process gas is handled at super-atmospheric pressures are maintained at pressures below atmospheric, so that leakage of process gas to the atmosphere will not contaminate other parts of the building. In those parts of the building where process pressures are below atmospheric, the pressures are held slightly above the normal barometric level in order to minimize further the flow of contaminated atmosphere into such areas.

The purging system for the K-27 cascade is based upon the use of the top two to five process cells of the cascade to produce light diluent of high purity. A purge stream is taken from the "A" stream of the uppermost stage, which normally operates on direct recycle, and compressed to atmospheric pressure by means of a Beach-Russ vacuum pump. It is then passed through a cold trap-carbon trap system and exhausted to the atmosphere.

The K-27 process gas recovery system differs from that of K-25, in that a single, central station is provided. Three two-pump vacuum pumping stands, spaced at equal intervals along the cascade, exhaust gas from process equipment when necessary, and discharge through mist filters to a header leading to the recovery station, which includes three cold traps, and auxiliary carbon traps and controls.

The K-27 product withdrawal system serves to transfer K-27 product to K-25 at a metered rate, and provides a means for stockpiling K-27 product, and continuing operation of either K-25 or K-27 when the other may be shut down. Product is taken off from a cell near the top, where light diluent concentration approximates three mol per cent. It is normally transferred to K-25 in the vapor phase by means of interconnecting pipelines, but facilities are also available for liquefying the process material and transporting it to K-25 in tared drums.

K-27 converters are identical with the Size 2 converters of the K-25 cascade, but are equipped with "Z" barrier which is an improved form of blocked DA barrier, and makes it possible to operate at somewhat higher process pressures and interstage flow rates. For this reason the "A" and "B" stage pumps are respectively equipped with 75 horsepower and 150 horsepower motors. The various other special pumps required are similar to those utilized in the main K-25 process area with the exception of one new model developed for service in both the waste system and product system of K-27, where a positive displacement machine was required to compress UF_6 to 35-55 p.s.i.a. prior to liquefaction. A number of design modifications were made in a Beach-Russ process gas vacuum model, and a two-stage unit was developed with increased cylinder clearance and an improved lubrication system. The K-27 cascade contains no intercell coolers, and utilizes stage coolers identical with those of the K-25 cascade. The only change in process piping at K-27 involved the use of nickel-plated steel in the three and four inch sizes. Process block valves contain improved seat rings utilizing MFP-10 fluorinated plastic. Changes in stage control valve design and other instrumentation were made in cases when it was found possible to effect simplification or improvement without delaying the program. Cold traps used in the purging system were salvaged from cancelled recovery rooms of the K-27 cascade. K-27 recovery traps were specially designed, and represent a modification of the radial fan design. Carbon traps are similar but somewhat larger than those of K-25.

The K-27 process coolant system differs from that of K-25 in that it contains a number of minor mechanical improvements. The 55,000 GPM K-27 recirculating cooling water system contains a 14 cell induced draft tower, and draws make-up from the K-25 system. K-27 dry air distribution operates as a dead end system,and is supplied from the K-25 dry air plant, as is all instrument air, which is compressed to 10-55 p.s.i.g. by means of four compressors. "Plant air" for miscellaneous purposes is drawn ~~for~~ from the K-25 compressor house. The lubricating oil and dry nitrogen supply systems resemble those of K-25 except in minor details.

The K-27 plant was designed to run entirely on constant frequency 60 cycle power. The K-27 switchyard receives 154,000 volt power from the T.V.A. Watts Bar Station, the Elza No. 1 Substation, or the K-25 switchyard, and steps it down to 13,800 volts. It supplies the K-27 switch house which is similar to the larger K-25 switch house. In order to provide for possible future expansion, all electrical equipment down through the 13,800 volt switchgear has been designed for a maximum load of 150,000 KW. From this point on, the K-27 electrical distribution system is designed for 100,000 KW, which is based on a stream efficiency of 100 per cent.

The K-27 plant is served by the conditioning and administration areas in the same way as in the main K-25 cascade.

15. Assistance from British Sources. - Preliminary talks with the British group were begun in February 1942, at which time the principle of diffusional separation was discussed. The plant design was reviewed in the fall of 1943. Included in this review were barrier materials, the stage recycle principle, the cascade of cascades principle, the purge cascade, pressure control, flat plate diffusers, and cold traps. Although their suggestions were not always concordant with American theories, they were valuable, and later assistance with theoretical problems, such as exact calculation of equilibrium time, helped

anticipate problems of plant design. The British suggestion for the development of scraper cold traps was followed, although this type of trap, after having been successfully engineered, was abandoned because of the difficulties anticipated in controlling its process gas inventory.

16. Safety and Security. - The New York Safety Committee, comprised of Kellex personnel, a liaison officer from the District Medical Section, and a representative of the SAM Laboratories, served in a consultant and advisory capacity to the New York Area Engineer in safety matters pertaining to handling of fluorine, uranium hexafluoride, and other hazardous chemicals. By April 1945 the responsibility of this activity was transferred to the Carbide and Carbon Chemicals Corporation. The security program included personnel clearance, visitor control, educational programs, and designation of restricted areas.

17. Costs. - K-25 design, engineering, and procurement costs (exclusive of the special chemicals program) amounted to $253,672,173 as of the close of the fiscal year 1946, at which time the current total estimate for completion of contracts was $275,449,699.

18. Organization and Personnel. - The New York Area Engineer was responsible for supervision of all Kellex design, engineering, and procurement activities. To facilitate the work and permit close association with all contractors, additional sub-areas were established to handle administrative details connected with Allis-Chalmers Manufacturing Company activities at Milwaukee, Wisconsin, Houdaille-Hershey Corporation activities at Decatur, Illinois, and Chrysler Corporation activities at Detroit, Michigan. On 7 January 1943 Lt. Colonel J. C.

Stowers was designated both as Unit Chief of the K-25 Project and New York Area Engineer. After 28 February 1946, the latter position was held by Major W. C. Campbell until the Area was dissolved on 23 August 1946. On 23 February 1943 the Milwaukee Office was opened and Lt. Colonel R. C. Gregory was assigned as Project Engineer. Captain R. C. Hill assumed the position of Area Engineer on 15 July 1943. This position was subsequently held by Major J. L. McCormick, Jr., and Captain J. D. Anderson. The Milwaukee Area was dissolved on 30 June 1946. Captain J. H. Brannan was assigned to the Decatur Office as Project Engineer on 24 May 1943. He assumed the position of Decatur Area Engineer on 20 July 1943 and was succeeded in that position by Major C. E. Choate, Major J. J. Moran, and Captain R. L. Crawford. The Decatur Area was dissolved as f 1 July 1946. The Detroit Office was opened by Major N. R. Archer on 17 May 1943. On 21 July 1943 Lt. Colonel A. Tammaro was assigned as Area Engineer. He was succeeded by Major F. H. Belcher. The position is now held by Captain J. D. McCormick.

Because of the magnitude of the undertaking contracted for in W-7405-eng-23, for accounting and security purposes, The M. W. Kellogg Company organized the subsidiary Kellex Corporation for the purpose of prosecuting the work in the K-25 Project. As of 31 March 1945, total Kellex personnel amounted to 1,676 persons with 354 stationed in the field, and the remainder operating in or out of the New York Office. The K-25 activities of the Kellex Corporation were directed by P. C. Keith, vice-president of the corporation, and A. L. Baker, general manager.

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

SECTION 1 - INTRODUCTION

1-1. Purpose. - The design, engineering, and procurement activities described in this volume were aimed at the specification and planning of facilities, equipment, and materials required for the rapid construction of the large scale gaseous diffusion production plant which was to form the heart of the K-25 Project.

1-2. Scope. - The unusual nature and size of the plant, the first of its kind ever attempted, presented a large number of practical and technical problems which frequently appeared insoluble (Vol. 1, Sect. 5). It was necessary to call in for consultation many of the nation's leading equipment manufacturers to permit subsequent development and manufacture of especially designed equipment. In order to meet construction schedules, important decisions often had to be made before complete data were available regarding performance and properties of equipment and material. In this connection, valuable cooperation was obtained from a group of British scientists and engineers (Sect. 15).

1-3. Authorization. - Authorization of the activities described in this volume was handled similarly to other phases of the K-25 Project as mentioned in Volume 1 of this book, and described more fully in Volume 1 of Book I.

1-4. Administration. - Overall responsibility for the design engineering, and procurement of equipment for the K-25 plant was vested in the Kellex Corporation (initially in the parent organization, the M. W. Kellogg Company), originally under OSRD contract OEMsr-406, and finally under Manhattan District contract W-7405-eng-23. The administration of this contract and its subcontracts was handled by the New York Area of the District, aided by sub-areas established to cover procurement sources of the Kellex Corporation, and located at Milwaukee, Wisconsin; Detroit, Michigan; and Decatur, Illinois.

SECTION 2 - INITIAL WORK UNDER THE OFFICE OF

SCIENTIFIC RESEARCH AND DEVELOPMENT

2-1. <u>Introduction.</u> - When the M. W. Kellogg Company began their work, a method of preparing uranium hexafluoride had been worked out (Book VI, Par. 2-3b; Book VII), and Columbia University had obtained some fundamental data on production and testing techniques, barriers, barrier plugging, sealants, materials inert to UF_6, and methods of measurement of quantities and pressures for infinitely small changes. A system of close cooperation was now set up between the Columbia University group and the Kellogg Company in the development of the gaseous diffusion process. The Kellogg Company, and later, The Kellex Corporation, took these fundamental data, developed them further, and applied them to the design of the gaseous diffusion production plant at the Clinton Engineer Works.

2-2. <u>Preliminary Work by the M. W. Kellogg Company.</u>

a. <u>Contract OEMsr-406.</u> - In January 1942, the Office of Scientific Research and Development awarded contract OEMsr-406 (App. F1) to the M. W. Kellogg Company, providing for preliminary investigation of the gaseous diffusion method as applied to the production of Uranium-235.

b. <u>Scope of Contract.</u> - The scope of the work authorized by the contract, with its subsequent modifications, included five principal items:

1. An engineering study looking toward:

   a. Design of a pilot plant to carry out the separation of Uranium-235.

b. An analysis of the requirements of a large plant to effect such separation.

2. Studies and experimental investigations principally in connection with:

a. The corrosion of various metals when subjected to uranium hexafluoride.

b. The suitability of various types of small pumps.

c. Tests of diffusion membranes.

3. Construction of a pilot plant and accessory equipment for production.

4. A study of methods of improvement of production.

5. Operation of the pilot plant.

c. Accomplishments. - Work under this contract resulted primarily in the design of a pilot plant, development of a process flow diagram for a large production plant, preliminary estimates of requirements for materials of construction, special equipment, chemicals, and utilities, and preliminary designs of principal mechanical equipment such as pumps, diffusers, coolers, and valves. This work is summarized in a report entitled "The Diffusion Plant - First Progress Report", (App. F2).

d. Subsequent Action. - On the basis of those studies, the construction of a production plant was later authorized under Manhattan District contract W-7405-eng-23 (App F3). Experimental and research work under contract OEMsr-400 was terminated as of 1 April 1943, except for the completion of the pilot plant building construction, which extended through 30 June 1943. Experimental and research work, as included in the scope of this contract, was carried on after 31 March 1943, under the Manhattan District contract by the M. W. Kellogg Company and the Kellex Corporation.

SECTION 3 - NEGOTIATIONS AND PRELIMINARY PLANNING

3-1. General.

a. Decision to Continue the Pilot Plant. - On 12 November 1942, after considering various aspects of the Manhattan Project, the Military Policy Committee decided (App. F4): first, that work on the gaseous diffusion pilot plant, being handled by the M. W. Kellogg Company, under contract OEMsr-406, should be continued, but that requirements for critical materials for this work would not be allowed to interfere with the pile and electromagnetic plant construction projects; and, second, that if the M. W. Kellogg Company should present satisfactory evidence of scientific ability to the OSRD S-1 Executive Committee, and satisfactory evidence of engineering ability to Brigadier General L. R. Groves, they would be authorized to proceed with the engineering of a 600-stage gaseous diffusion production plant.

b. The 600-Stage Diffusion Plant. - The term "600-stage" was derived from the initial concepts of what would comprise the primary portion of the plant. Design and engineering plans were not fully crystallized at that time, and the exact number of stages was still a tentative figure.

3-2. OSRD Approval of 600-Stage Production Unit.

a. Resolution of the OSRD S-1 Executive Committee. - On 14 November 1942, representatives of the M. W. Kellogg Company met with General Groves, representatives of the Manhattan District, and members of the OSRD S-1 Executive Committee (App. F5). After the Kellogg Company representatives had reported on their previous work in connection with the gas diffusion process, the OSRD S-1 Executive Committee passed a resolution, the essense of which was as follows:

1. That it was feasible, and would fit into the program, to proceed with the Kellogg gaseous diffusion pilot plant and the proposed 600-stage production plant simultaneously.

2. That, on a priority basis, the 600-stage plant should come after the first 2000 production units of the proposed electromagnetic plant, and after the first, but before the second, pile of the contemplated pile process for the production of plutonium.

3. That the plant referred to in the resolution was one which, at double concentration of U-235, would have an assured net transport of 1/2 kilogram per day, with a reasonable expectation that, by improvement of the barrier material, the net transport would be increased to one kilogram per day.

4. That the plant referred to should be so designed that it could fit into a plant which would be capable of producing material containing 90 per cent U-235.

b. <u>Relative Priority.</u> - Dr. A. H. Compton of the S-1 Executive Committee, reserved opinion as to the relative priority of the proposed plant and of the pile plant, and Dr. L. J. Briggs, also on the committee, was of the opinion that the Gaseous Diffusion Project should come after the first 1000 but before the second 1000 tanks of the electromagnetic plant. In accordance with the previous decisions of the

Military Policy Committee, General Groves stated that, prior to authorization of design and construction, further study should be made to determine the extent to which the 600-stage plant would interfere with other war production.

3-3. Review and Reassessment of Gas Diffusion Method.

a. Reassessment and Reviewing Committee. - In order to review the gaseous diffusion process completely, not only as to its own possibilities and problems, but also as to its advantages and disadvantages when compared with the pile and electromagnetic projects, General Groves appointed a Reassessment and Reviewing Committee on 21 November 1942, consisting of Dr. W. K. Lewis, of the Massachusetts Institute of Technology, Dr. E. V. Murphree, of the Standard Oil Development Company, and Messrs. Roger Williams, T. C. Gary, and C. H. Greenewalt, of E. I. du Pont de Nemours and Company. This committee, after careful consideration of the three methods, recommended (App. F6) proceeding immediately with the design and construction of a 4600-stage diffusion plant with a capacity of 1 kilogram per day of U-235.

b. The 4600-Stage Diffusion Plant. - The "4600-stage plant" represented the design, as then contemplated, of a gaseous diffusion plant that would produce 1 kilogram of material per day, which would consist of 90 per cent U-235. Subsequent investigation and studies, however, proved the feasibility of constructing a diffusion plant that would produce material considerably less concentrated in U-235, and which could serve as a feeder plant for the electromagnetic project.

3-4. Selection of the Contractor.

a. Decision to Construct a 4600-Stage Plant. - The report of the Reassessment and Reviewing Committee, as well as a favorable report as to the engineering ability of the M. W. Kellogg Company, was presented to the Military Policy Committee by General Groves, and on 10 December 1942 (App. F4), this committee authorized General Groves to arrange for the construction of a 4600-stage gaseous diffusion plant with the M. W. Kellogg Company as engineers.

b. Letter Contract W-7405-eng-23. - On 12 December 1942, the M. W. Kellogg Company was informed by General Groves of the government's desire for them to proceed with the design of the diffusion plant. Two days later secret letter contract W-7405-eng-23 was executed (App. F3) for design, development, and procurement services and for all other things necessary to procure all process equipment for a plant to enrich uranium hexafluoride from the normal 0.71 per cent to 90 per cent U-235 by the gaseous diffusion process.

3-5. The Kellogg Contract.

a. Scope of Work. - The negotiations for the Kellogg Company contract extended over a considerable period of time. Because of the many basic problems that required solution, it was necessary to await a preliminary analysis of the Project before a realistic determination of the scope of the work and the estimated cost could be made. The formal contract W-7405-eng-23 (App. A, F3) was executed on 11 April 1944, effective as of 14 December 1942, and provided that the contractor would furnish "research and development, procurement, architectural, engineering and supervisory, and consultant services", on a cost-plus-a-fixed-fee basis, leading to the construction of a complete plant near Wheat, Tennessee, for the manufacture of a "Product". The word "Product" was defined, and the quantity and purity thereof set forth, in a secret letter dated 14 December 1942 (App. F7). The scope of the work included, in addition to the design of the main process plant and the procurement of the process equipment, the design of a complete steam-electric power plant, with all auxiliary facilities.

b. <u>Unusual Provisions.</u> - The unusual provisions of the contract are as follows:

1. Because of the unusual nature of the process, and because of the fact that it was in an experimental stage, the contract relieved the contractor of any guarantee of responsibility that the plant could be successfully designed, engineered, constructed, or operated.
2. For purposes of fee computation, the period of service was estimated as thirty months from 14 December 1942. Provisions were made for an extension beyond this period with equitable adjustment of the fixed fee.
3. For reasons of security, and to facilitate accounting, the right was granted the contractor to organize a wholly-owned subsidiary corporation, The Kellex Corporation, for the sole purpose of prosecuting the work called for by the contract.
4. Because of the magnitude of the Project, the contractor requested, and the government granted, relief from the financial burden involved in the procurement program.

Accordingly, much of the equipment and materials were purchased under standard Government supply contracts, with the Kellex Corporation acting as a representative of the Contracting Officer on inspection, tests, acceptance, and other technical phases of the work. Kellex also purchased certain other materials. Shipments were usually consigned directly to the constructor at the plant site.

5. It was recognized that it would probably be necessary to employ unusually qualified personnel at salary rates over the maximum rates prescribed by the Secretary of War for cost-plus-fixed-fee contractors. Provisions were therefore made for the reimbursement of salaries, as approved by the Contracting Officer, up to $25,000 per year for top executives in the New York home office. Salaries were limited, however, to $9,000 per year for personnel at the plant site, the normal salary limits for government cost-plus-fixed-fee contracts.

e. <u>Fee.</u> - The fixed fee agreed upon after negotiations was $2,424,347.00 on an estimated cost of $254,560,698.00 (App. F8), which was approved by the Under Secretary of War on 24 February 1944. The Under Secretary approved the contract on 28 March 1944. A breakdown of the estimated cost of $254,560,698.00 is shown in Appendix G1.

SECTION 4 - DESIGN PRINCIPLES OF THE GASEOUS DIFFUSION PROCESS

4-1. General. - As indicated in a previous section, the gaseous diffusion plant is designed to concentrate the Uranium-235, or U-235, by diffusion of the chemical compound, uranium hexafluoride. This compound is a salt of sufficient volatility to exist as a gas at moderate temperatures and sub-atmospheric pressures. The distribution of the uranium isotopes in the hexafluoride as received at the plant is precisely the same as in all natural uranium ores, i.e., approximately 0.71 per cent Uranium-235 and 99.29 per cent Uranium-238, with only a trace of Uranium-234. Thus the diffusion process is essentially one of partial separation of the two isotopes, U-235 and U-238.

4-2. Separation by Gaseous Diffusion.

a. Definition. - The generic term "gaseous diffusion" is applied to the dispersion of a gas through space. The dispersion may result from a variety of causes, one of which is motion of air masses as in gas convection. The gaseous diffusion process, however, has a more limited definition, being confined to the dispersal of a gas due solely to the motion of the individual molecules, independent of mass movements of the gas.

b. Concept of Molecular Effusion. - A mass of pure gas consists of billions of minute, identical particles called molecules, the size of which is negligible compared to the average distance between them. These molecules possess considerable energy, and move at relatively high velocities. They travel about in a random fashion so that they experience frequent collisions with one another and with the walls of confining vessels. The number of such collisions is proportional to the mean speed of the gas molecules. If a number of very fine holes are pierced in the container walls, the gas will escape from the vessel because of this molecular motion. This type of gas transport is referred to as molecular effusion.

c. Gas Mixtures.

(1) Molecular Speed versus Molecular Mass. - Consider a mixture of gases such as helium and hydrogen whose molecular masses are in the ratio of two to one. The laws of physics state that the lighter hydrogen molecule will travel at a higher mean speed than the heavier helium molecule, and that these speeds will be inversely proportional to the square roots of their masses. Thus the hydrogen molecule, with a mass approximately half that of helium, travels with a velocity about 1.41 (square root of 2) times as great.

(2) Separation by Effusion. - In a 50-50 mixture of hydrogen and helium, 141 molecules of hydrogen collide with the walls for every 100 of helium. If the walls of the vessel are perforated with openings, the diameters of which are larger than the molecules, but smaller than the average distance between molecules, then gas will escape by molecular effusion, and 141 molecules of hydrogen will leave the box for every 100 helium molecules. Consequently, the diffused gas now contains 58.5 per cent hydrogen as compared to the 50 per cent originally present. Thus the light component is enriched by molecular effusion.

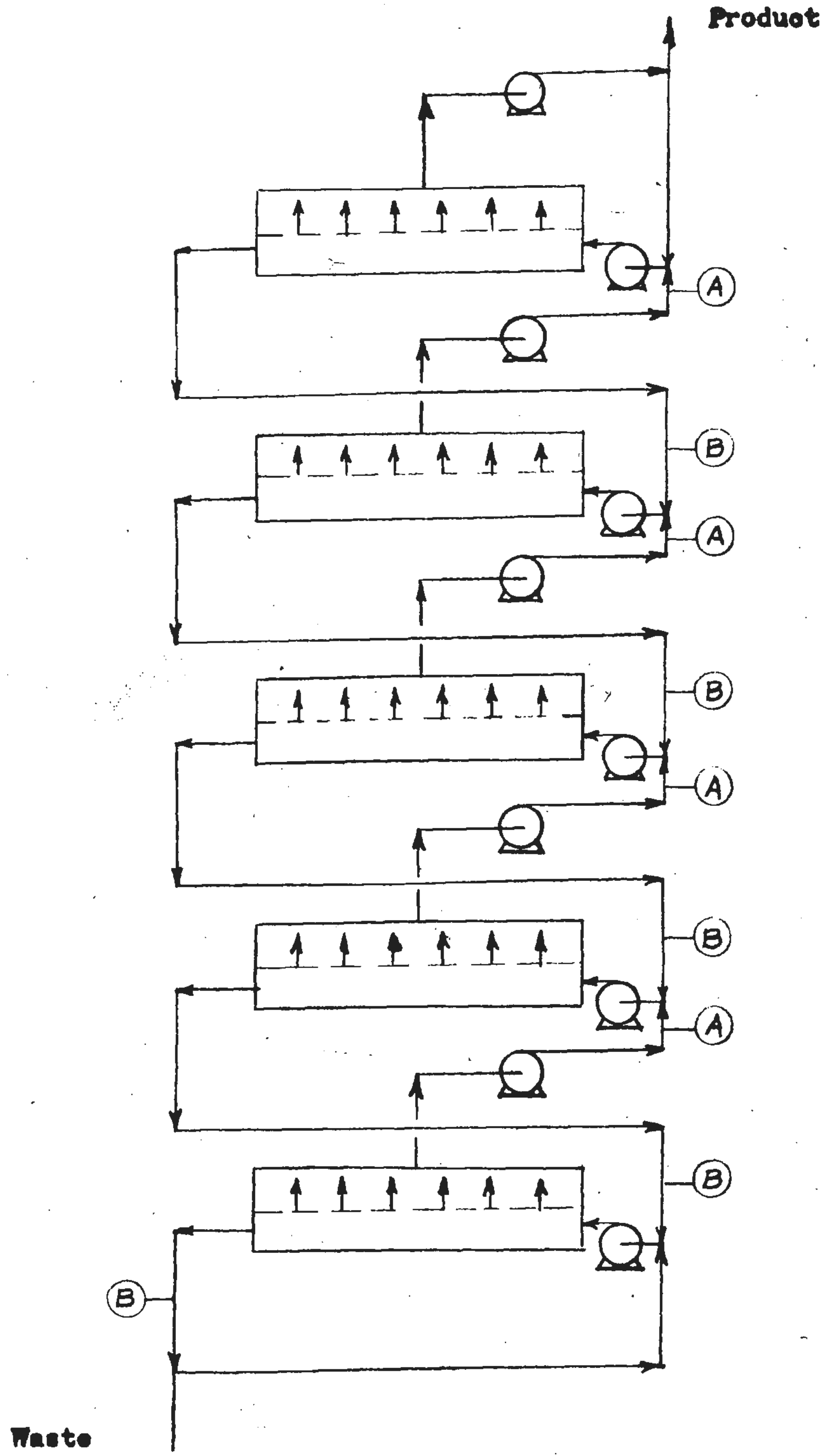
d. Circulation of Feed. - As the diffusion or passage of gas through the perforated wall continues, the hydrogen in the original mixture obviously becomes depleted. Therefore, the number of hydrogen molecules diffusing for each 100 of helium decreases. For example, once the number of hydrogen molecules within the box has fallen to 80 per cent of the helium molecules, only 80 per cent of 141, or 113 molecules of hydrogen, will diffuse for each 100 molecules of helium. Therefore, if a certain enrichment of hydrogen is required, it becomes necessary either to interrupt the process periodically, or to replenish the supply of hydrogen molecules continuously. The latter method is preferable from the engineering point of view, since a continuous process is desirable, and is readily accomplished by pumping a steady stream of fresh gas mixture into the container, and withdrawing steady streams of enriched and partially depleted gas.

e. Removal of Enriched Gas. - As the diffusion continues, the molecules in the diffused fraction outside the container collide with one another, changing direction as they do so until their motion is again entirely random. As a result, there is a tendency for some of the enriched gas to flow back into the container. This tendency, usually referred to as "back diffusion", if allowed to prevail, completely vitiates any separation. Since the gas flowing back ultimately reaches the same composition as the diffusing gas, the net effect is zero separation. Back diffusion can be eliminated to a large degree by evacuating the outside of the box and thereby sweeping away the molecules almost as fast as they diffuse. The higher the vacuum, the more effective is this method. However, there is a practical limit to the vacuum attainable, imposed by the size of pump required and by the power demanded. Therefore, some back diffusion occurs in all systems, thereby reducing the efficiency of separation.

f. Application to Process Gas. - The above considerations apply equally as well to the separation of the two predominant isotopes of uranium in the gaseous hexafluoride (commonly referred to as Process Gas) as they do to mixtures of helium and hydrogen. Again, there are involved two types of molecules having different masses and, hence, travelling at different mean speeds. However, the relative difference between masses is now much smaller. For example, the relative mass of uranium hexafluoride containing Uranium-238 is 352, whereas that made from Uranium-235 is 349. Thus, the masses of the isotopic components in the process gas differ only by 0.85 per cent, and the speed of the lighter compound is only 1.0043 times as great as that of the heavier form. Thus, if the concentration of the light hexafluoride in the circulating stream is 0.71 per cent, the theoretical maximum concentration in the diffused fraction attainable by a single diffusion step is only 0.713 per cent. Furthermore, the actual separation to be realized in practice would be only 50 to 70 per cent of this theoretical maximum, because of back diffusion and other unavoidable inefficiencies of the separation system. (Vol. 2, Par. 3-2d).

4-3. The Diffusion Cascade.

a. Multiplicity of Stages. - In view of the small separation realized in a single diffusion step or stage, it is obvious that a gas mixture must be reworked a number of times to achieve a significant increase in concentration over that of the original feed. In fact, to produce the design concentration of the diffusion plant, literally thousands of stages are required.



SCHEMATIC DIAGRAM
SIMPLE DIFFUSION CASCADE

FIG. 1

b. <u>Schematic Representation.</u> - The stages are arranged most effectively when linked into a single series or cascade, as illustrated by Figure 1. Five stages are shown, each portrayed by a rectangle. Broken lines, representing porous diffusion barriers, divide the rectangles into two sections, a lower section which represents the feed circulation side, and an upper section which contains the enriched diffusate from a given stage.

c. <u>Stage Operation.</u> - The middle, or third, stage in the diagram is typical of all stages of a cascade, with three exceptions to be noted presently. The gas mixture enters the lower section of the middle stage from the right. Part diffuses to the upper section, denoted by the vertical arrows, and is swept out by the pump "A". The residue flows out of the lower section to the left. The diffused fraction "A" is pumped to the stage above, or fourth stage, where it joins the residual fraction "B" flowing down from the top, or fifth, stage. The mixture is then subjected to a second diffusional operation. The residual fraction "B" from this second diffusional operation returns to form part of the feed to the middle stage. The residual fraction "B" from the middle stage flows down to the stage below, or second stage, where it joins with the diffused fraction from the bottom, or first, stage, and this mixture is also subjected to another diffusional operation. The diffused fraction "A" from this diffusional operation is pumped to the middle, or third, stage and, with the residual fraction from the fourth stage, forms the feed to the middle stage.

d. <u>Net Flow Pattern.</u> - The pattern of flow for the plant becomes clear from the foregoing description of a typical stage. There is a continual flow of diffused material towards the top of the plant, and a counter flow of residual material toward the bottom of the plant. The diffused material becomes richer and richer in light component as it travels upward from stage to stage, and the residual fraction becomes heavier as it flows downward. The flow of materials described is the result of pressure differences across diffusion barriers produced by the pumps, and is controlled by automatic valves. The terms "top" and "bottom" of the plant are used for convenience only, and have no relation to elevations, since the force of gravity is not involved.

e. <u>Critical Stages.</u> - The three exceptions to the typical stage are the top stage, the bottom stage, and the feed stage. At the top stage a small portion of the diffused stream is withdrawn as product with the bulk circulated back as part of the charge to the same stage. In a typical stage this part of the charge is the residual stream from the stage above. Likewise, at the bottom stage a small amount of the residual stream is withdrawn as waste, and the remainder circulated back to the same stage. The feed stage differs from the typical stage in that a portion of the charge to this stage is the net charge or feed to the system. The feed stage is located somewhere between the top and bottom stages, and it divides the cascade into two sections, the upper or enriching section, and the lower or stripping section.

4-4. <u>Factors Determining Separation Efficiency.</u>

a. <u>Cascade Characteristics.</u>

(1) <u>Feed Point.</u> - Obviously, the degree of sepa-

ration attainable with any cascade is partially determined by the number of stages in the cascade. Somewhat less obvious is the fact that the concentration of the product is chiefly affected by the number of stages above the feed point, and the concentration of the waste by the number of stages below the feed point.

(2) Circulation Rate. - A second factor contributing to the degree of separation is the rate of circulation of material through a stage relative to the feed rate. The higher the rate of circulation, the greater the separation.

(3). Optimum Combination. - Both increased number of stages and increased circulation rate represent increased capital investment and increased operating cost. The design of the most economical plant for any particular job involves the establishment of the optimum combination of the two.

b. Volatility of Uranium Hexafluoride. - The uranium hexafluoride molecule, as the name implies, is composed of six atoms of fluorine and one of uranium. The hexafluoride is a white solid at room temperature and normal barometric pressure; however, it sublimes as the pressure is reduced or the temperature increased. For example, it will completely change to gas if the temperature is raised to 140°F. It will also change to gas at 85°F if the pressure is reduced to less than one-fifth of an atmosphere. At higher temperatures and pressures, e.g., 160°F and two atmospheres, the hexafluoride exists as a liquid. In the range of operating conditions maintained in the diffusion plant cascade, the hexafluoride exists as a gas; otherwise, the process would be inoperable.

c. Reactivity of Uranium Hexafluoride.

(1) Corrosive Action. - Uranium hexafluoride is one of the most reactive and corrosive chemicals known. At elevated temperatures it reacts violently with almost all substances except nitrogen, the rare gases, saturated fluorides, and fluorine. Even at the moderate operating temperatures of the diffusion plant, 100-180°F, the hexafluoride reacts instantly with water vapor and with all metals and most non-metals. The extreme reactivity or corrosive nature of the hexafluoride has markedly narrowed the selection of materials of construction, and has imposed a number of other restrictions on the plant design.

(2) Consumption of Process Gas. - The corrosion problem has been aggravated by the tremendous surfaces over which the gas passes. The diffusion plant has literally thousands of times the surface of an ordinary chemical plant processing an equal amount of material. The consumption of the gas because of corrosive action is far more serious than the ultimate weakening of the equipment. If the rate of corrosion were allowed to increase indefinitely, the entire product of the plant would be consumed, and hence the plant output would drop to zero long before the rate of corrosion could reach serious proportions in terms of the structural weakening of equipment.

(3) Reaction with Water Vapor. - Another source of destruction of the hexafluoride is interaction with water vapor. The bulk of the equipment operates under vacuum, and if the equipment were no tighter than ordinary commercial vacuum installations, and moist air from the atmosphere were allowed to leak into the plant, the destruction of process gas would be prohibitive. To avoid this condition,

all equipment has been made far tighter than customary for industrial installations, and, in addition, has been blanketed with dry air.

4-5. <u>Conditioning.</u> - The extremely corrosive effect of uranium hexafluoride has made necessary the "conditioning" of all surfaces which come into contact with the process gas. Prior to operation, all active plant surfaces are exposed to fluorine under conditions leading to the formation of protective surface films of saturated fluorides. Since the hexafluoride is reactive only as a fluorinating agent, that is, it gives up fluorine which enters the molecule of the material being attacked, it will not react with materials already saturated with fluorine. By selecting materials which form stable fluoride films, the consumption rate of the hexafluoride has been reduced to a very low value.

4-6. <u>Cleanliness.</u> - Successful conditioning, resulting in the formation of an adherent, protective fluoride film, requires that the surface to be fluorinated first be made scrupulously clean. Furthermore, contamination by foreign matter leads to process stream consumption or dilution, and to barrier plugging. Specifications for barrier plugging rates, and for UF_6 consumption rates as a result of barrier corrosion, have been set forth in Volume 2, Paragraph 4-2. In the specification and maintenance of cleanliness standards for all metal equipment surfaces to be exposed to the process gas, the closest practical approach was made to surgical conditions. Cleaning procedures are aimed at complete removal of dirt, grease, oxides, scale, fluxes, and other extraneous matter. Such material, aside from its tendency to consume UF_6, can work loose and clog barriers, valves, and instruments.

Cleaning methods were set up by the Kellex Corporation based upon procedures developed by the Chrysler Corporation. The individual steps chosen are not unusual in industrial practice. It is their combination, rigorous enforcement, and comprehensive application to the thousands of equipment items in the K-25 plant which is most noteworthy. Depending upon the initial condition of the equipment surface to be cleaned, any number of steps up to ten or more were required. The following procedure for nickel plated steel pipe is typical:

1. Solvent degreasing.
2. Hot alkaline cleaning.
3. Warm water rinsing.
4. Pickling with concentrated hydrochloric acid.
5. Cold water rinsing.
6. Pickling with dilute hydrochloric acid.
7. Cold water rinsing.
8. Passivation with sulfuric acid and sodium dichromate.
9. Hot water rinsing.
10. Hot water rinsing.

In most cases the cleaning was performed at the equipment manufacturer's plant under the guidance and supervision of Kellex inspectors. Cleaning steps were inserted into the production lines at appropriate points so that each cleaning operation would be performed at the point in the manufacturing procedure where it would most effectively clean a certain part without damaging other components of the assembly. Cleaning programs were instituted at the plants of the following equipment suppliers:

Chrysler Corporation - tubular converters
Allis-Chalmers Manufacturing Company - process pumps
Lukens Steel Company - nickel clad parts
Crane Company - valves
Fisher Governor Company - valves
Republic Flow-Meter Company - valves
Whitehead Metal Products Company - flat plate converters
A. O. Smith Corporation - coolers
Fulton Sylphon Company - bellows
Clifford Manufacturing Company - bellows
The William Powell Company - valves
Westinghouse Electric and Manufacturing Company - mist filters
The F. J. Stokes Machine Company - vacuum pumps
Patterson-Kelly Corporation - cold traps
Schock-Gusmer Company - cold traps
Cook Electric Company - bellows
The Beach-Russ Company - vacuum pumps
Chapman Valve Company - valves
Moore Products Company - differential pressure transmitters
Valley Iron Works Company - pumps
The Elliot Company - pumps
The Watson Automotive Equipment Company - mobile C_7F_{16} units
The York Corporation - mobile C_7F_{16} units

In the case of certain pipe assemblies and miscellaneous equipment items, it was found more convenient to carry out cleaning operations at the K-25 plant site. This circumstance led to the design and construction of the conditioning area (Sect. 11).

SECTION 5 - SMALL SCALE TESTING OF PLANT DESIGN

5-1. __Introduction.__ - The early development of the design of the gaseous diffusion plant was done under The M. W. Kellogg Company's OSRD contract OEMsr-406. With the selection of this company by the Manhattan District, and the formation of The Kellex Corporation early in 1943, the design and engineering of the production plant proceeded at an increased tempo. At the same time, experimental research and development on fundamental problems were centralized at Columbia University. Experimental pilot plants constructed and operated for the purpose of studying and solving problems involved in the K-25 research program have been discussed in Section 7 of Volume 2. Volume 5 presents an account of the experimental operation of one of the process buildings as a "54 stage pilot plant". The present section treats of installations operated for the purpose of determining or confirming various data utilized in K-25 equipment and process design. All installations described below were erected at the Test Floor, a part of the Kellex Jersey City Laboratory.

5-2. __The Test Floor.__

a. __Construction of Pilot Plant.__ - Contract OEMsr-406 provided for the design of a pilot plant to test the separation of uranium hexafluoride by gas diffusion methods. This contract was supplemented to provide for the construction and operation of the pilot plant. Work was started about 1 July 1942 on the buildings to house the pilot plant, the control laboratories, and the maintenance facilities. These buildings were erected within the yard of the Jersey City plant of the M. W. Kellogg Company.

b. __Conversion to Test Floor.__ - Originally, a 15-stage cascade pilot plant was planned, with its objective the procurement of basic engineering data from which a production plant could be designed. However, in view of the urgency of the gaseous diffusion program as a whole, and the necessity for obtaining quantities of U-235 at the earliest possible moment, it was foreseen that the K-25 production plant would have to be designed, and orders for certain equipment would have to be placed, before it would be possible to obtain full and complete engineering data from a pilot plant. The pilot plant was accordingly converted to a test floor, where the design principles of certain specialized equipment for the production plant could be proved before full scale manufacture of these items was begun. On 31 March 1945, the pilot plant program was placed under the Kellex Corporation contract W-7405-eng-23.

c. Operation of Test Floor. - Considerable preliminary work was conducted on various pieces of equipment concurrent with the design of the large plant. The fundamental studies on the chemistry and physics of the process were also continued. Emphasis was placed upon various phases of the experimental work, as dictated by process and mechanical engineering requirements. The chief objective was to get the large plant into operation at the earliest possible date. Therefore, the accomplishment of more limited objectives, such as completing the test floor cascade, ~~were~~ was given lower priority.

5-3. The Ten-Stage Cascade.

a. Construction of the Cascade. - Once preliminary work on equipment development for the full-scale plant was sufficiently advanced to give a reasonable probability of success to the undertaking, plans were laid for the erection of a ten-stage cascade pilot plant. It was considered advisable to have those manufacturers providing the principal equipment for the large plant produce the units for the test floor cascade. This led to some delay in delivery because of higher priorities generally given to orders for the large plant.

b. Operation of the Cascade. - In April 1944, the construction and testing of the ten-stage cascade were completed, and operations were started. The equipment of this plant was similar in all important respects to that being manufactured for the production plant, with the exception of the diffusers. The diffusers did not contain barrier tubes because material for their construction was still in the research stage and, therefore, was not available in time for their manufacture. Perforated tubes were used instead, so that flow conditions could be reproduced, although no separation could be effected. However, pressures and temperatures simulated design conditions of the large plant, and flow conditions were similar to, but slightly lower than, those of Section 3 of the large plant (Par. 7-8). Operation of the cascade was continued through December 1944. Some difficulty was encountered with various mechanical features of the plant, particularly pump seals. The frequency of such troubles was reduced as operating experience was gained, and smooth operation was achieved during the last few months of operation. A large number of technical men, later concerned with the operation of the production plant, were trained at the test floor cascade.

c. Results of Cascade Operations. - The cascade performance was equal to all expectations. Detailed results of the test floor cascade operations are presented in a series of ten technical reports (App. F10). Among other things, it was demonstrated for the first time that:

1. Equipment designs for the large plant were fundamentally sound.
2. Equipment of this type and size could be assembled so as to be initially vacuum tight, and remain so during extended operation.
3. Equipment of this type and size could be made scrupulously clean, and could be maintained in this condition during assembly.
4. The inner surfaces of a cascade of this size could be readily fluorinated, under controlled conditions, by circulation of fluorine-nitrogen mixtures.
5. Adequate control of pressure, temperature, and flow could be realized with the instruments developed for the large plant, and all surges which could be initiated in a cascade of this number of stages could be quickly damped.
6. Operation with the hexafluoride was no more difficult than with the inert gases, if certain precautions were observed.
7. Inert gases could be continually purged from the system by cold traps of the same fundamental design as planned for the large plant.
8. The fluorocarbon coolant circulation system could be assembled and maintained sufficiently clean so that after

several months' use the coolant would continue to pass the rigid specifications for chemical inertness.

5-4. Pump Test Loops.

a. Flow Test Loop. - The first Test Floor unit was built for the purpose of testing an Allis-Chalmers pump, a Republic Flow Meter Company magnetic clutch butterfly control valve, and a Fisher Company pneumatic butterfly control valve. Flow properties for uranium hexafluoride were desired at various pressures and velocities. Operation of the unit also provided data pertaining to the problems of vacuum tightness and leak detection. Improved piping designs and welding techniques were indicated. The experience in general led to the creation of a vacuum engineering school (Vol. 2).

b. Kinney Pump Test Loop. - It was originally thought that any standard vacuum pump would be suitable for UF_6 or fluorine service assuming the use of a suitable inert oil. As a result of tests made on a model produced by the Kinney Manufacturing Company, in which it was found that K-25 tightness specifications could not be met, and that the pump was not easily adaptable to redesign for vacuum tightness, use of the Kinney pump was limited to rough vacuum service.

c. Stokes Pump Test Loop. - A vacuum pump manufactured by the Stokes Manufacturing Company presented a partial solution to the problem. Upon redesign, the improved model was found satisfactory for fluorine service (Vol. 2, Par. 5-9).

d. Beach-Russ Pump Test Loop. - A loop was set up for testing a specially developed vacuum pump manufactured by the Beach-Russ Manufacturing Company (Vol. 2, Par. 5-8). Data obtained were utilized in the design and manufacture of the K-25 process gas vacuum pumps.

c. American Machine Defense Pump Test Loop. - A sample reciprocating pump for use in the K-25 purge cascade was built by the American Machine Defense Company, and was studied in uranium hexafluoride service at the Test Floor (Vol. 2, Par. 5-5b). Difficulties encountered, particularly with vacuum leakage and excessive vibration, led to the development of a greatly modified and improved design, which was used as the basis for quantity manufacture of purge pumps by the Valley Iron Works.

5-5. Allis Chalmers Pump Seal Testing. - A series of tests were run to determine the life and operating characteristics of sleeve and disc seals (Vol. 2, Par. 5-2). It was found that the sleeve seal had a tendency to seize the shaft and destroy itself at times of pump shutdown. Thus, in the velocity range of 200-500 RPM, gas lubrication was poor. This finding, together with the fact that the sleeve seal could not take the full differential from atmospheric to process pressure, disclosed the unsuitability of the sleeve seal. Disc seal tests, on the other hand, demonstrated superior ruggedness and ability to take the full pressure differential, and confirmed the choice of the disc type seal for general process pump use.

5-6. Cold Trap Testing. - Two experimental cold traps, built respectively by the Schock-Gusmer Company, and Joseph Kopperman and Sons, were tested for capacity, heat transfer, and carry-over. The units were studied under a wide range of conditions in order to collect data which would apply in the special temperature range required, and which would cover the heat transfer properties of the UF_6 process fluid and metallic construction materials of suitable corrosion resistance.

SECTION 6 - PLANT SITE

6-1. <u>Site Selection.</u> - Immediately following the decision to build a gaseous diffusion production plant, consideration was given to the selection of a suitable site. Prior to the selection of the actual site, and before accurate data were available regarding space requirements for the process equipment, the Kellex Corporation, in collaboration with the Carbide and Carbon Chemicals Corporation, (App. F23), which had been selected as the operating contractor, began to formulate ideas concerning the plant arrangement.

a. <u>Location within Clinton Engineer Works.</u> - Primary consideration was given to the selection of a site within the Clinton Engineer Works military reservation (C.E.W.), since this area had already been acquired (Book I, Vol. 10) for other Manhattan District activities. The first internal site inspection for the purpose of locating the gaseous diffusion plant was made on 18 January 1943 by representatives of the District Engineer, Kellex, and Carbide (App. F27). A series of further inspections was made by Kellex personnel during succeeding months. In addition, surveys conducted by Kellex disclosed two other suitable locations: A site on the Big Bend of the Columbia River in the state of Washington with power available from the Grand Coulee Dam, and a site in the Sacramento River Valley in California adjacent to the Shasta River Project. Some slight advantage would have obtained an account of the lower natural humidity of these areas, but because of the availability and suitability of the C.E.W. area, and the appreciable time delay which would have been involved, if it had been decided to acquire additional land, the District decided that the K-25 plant would be located within the Clinton Engineer Works. The definite decision to locate the K-25 plant within the C.E.W. reservation was made by General Groves in April 1943 (App. F28). The assembling of meteorological data and information regarding soil conditions, sources of water supply, and other facilities was then begun.

b. Method of Selecting Specific Site. - The factors affecting selection of a suitable site for the gaseous diffusion plant within C.E.W. boundaries are briefly stated below:

(1) Topography. - A fairly level site was desired, of sufficient size to accommodate the plant, with good drainage, and with good foundations.

(2) Safety Distances. - It was deemed advisable, and recommended by Kellex, that a safety distance be provided of three miles with natural ridge protection, or four miles without ridge protection, from other plants and permanently settled centers of population. This recommendation was based upon security considerations and upon the possibility of bombing attacks. Further reasons for selecting an isolated site were the radioactive nature of the process material, and the obvious hazards associated with the handling of the working substance of atomic bombs.

(3) Dispersion. - Bunching or straight-lining of plants within the Clinton Engineer Works was to be avoided if possible, as a safeguard against possible enemy bombing action.

(4) Other Considerations. - Rail service, water, and power facilities were required.

c. Original Choice of Process Area Site. - Nineteen sites within the Clinton Engineer Works area were initially considered. The application of factors 1, 2, and 3, above, to these narrowed the number of suitable sites down to five. These were studied in detail, and a site in the valley due south of McKinney Ridge, near Wheat School was tentatively selected in February 1943 (App. F11). At the time of this decision, production plant design was at a stage which indicated that all required power could be obtained from the Tennessee Valley Authority.

d. Power Plant Site. - As discussed in Section 12, subsequent estimates of power requirements led to the decision to construct a steam-electric power generating unit to serve the production plant. The site for the power plant was selected by Kellex with the approval of General Groves, on 3 May 1943 (App. F29). It was situated roughly one mile southwest of the process area, and immediately adjacent to the Clinch River, on the western extremity of a bend just above its intersection with Poplar Creek. This site was chosen because it provided a means of obtaining cool condenser water from the Clinch River, and of discharging it into Poplar Creek, where it would not affect the temperature of the water at the intake. It also had suitable terrain features for rail facilities and coal storage.

e. Final Choice of Process Area Site. - After the site for the K-25 plant near Wheat School had been selected, it was determined that an estimated saving of over one and one-half million dollars could be made if the main plant were moved from the Wheat School site to a location due west of McKinney Ridge and near Poplar Creek. Furthermore, as more definite knowledge became available of the space requirements for process equipment housings and structures, detailed studies disclosed that a somewhat larger site than that originally chosen would be de-

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TABLE 1. - K-25 SITE SECTIONAL DESIGNATIONS

SITE SECTION	NAME
100	Feed Purification System
300	Main Cascade
400	K-27 Cascade
600	Surge and Waste System
700	Power Plant
800	Recirculating Cooling Water System
1000	Administration Area
1100	Dry Air Plant
1200	Compressed Air Plant
1300	Fluorine Generating Plant
1400	Conditioning Area
1500	Auxiliary Steam Plant

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sirable. The newly proposed location was also more accessible to railroad sidings, and closer to the power plant site. Consequently, on 24 June 1943, the new site was formally approved, after the concurrence of the Kellex Corporation and the Carbide and Carbon Chemicals Corporation had been obtained. A description of the terrain and a discussion of site preparation activities are presented in Volume 4. Various maps and plot plans of the K-25 area are shown in Appendix A of Volume 1, and B of Volume 4. Photographs are shown in Appendix E of Volume 3, E of Volume 4, and D of Volume 5.

6-2. Sectional Site Designations. - For reference and accounting purposes, the K-25 plant site has been broken down into a number of sectional parts, each containing a group of buildings which serve related functions, or which are accessory to one another. The numerical section designation provides a key for numbering individual buildings: the ~~first digit~~ hundreds part of a building number is identical with the ~~first digit~~ hundreds part of the section number. Thus, building K-704 is located in Section 700. Section designations are shown in Table 1. This system of identification is used throughout the remainder of Book II.

SECTION 7 - PROCESS DESIGN

7-1. Introduction. - It is theoretically impossible to produce a product of 100 per cent isotopic concentration of U-235, by means of the gaseous diffusion method. In order to accomplish the complete separation, an infinite number of stages would be required, or the production rate would have to be lowered to an infinitesimal value. There will always be present at least a trace of U-238 in the product of any actual gaseous diffusion plant. However, this trace can be lowered, by suitable plant design and operation, to as low a value (above zero) as may be desired or required for any particular purpose.

a. Original Design. - Early in the investigation of the ultimate uses of the end product of the plant, it appeared that a uranium compound in which U-235 accounted for 90 per cent of the total uranium content would be satisfactory. The gas diffusion production plant, as conceived on 15 March 1943, and described in The Kellex Corporation's "First Progress Report" (App. F2), was accordingly designed to produce 1 kilogram per day of material at 90 per cent concentration of Uranium-235 (App. F15).

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b. Need for Further Investigation. - The above quantities were based upon preliminary design data. Although the general overall design of the plant was in the blueprint stage, there remained to be performed a considerable amount of investigation and experimental work before the plans could be translated into a working plant. As related in Volumes 1 and 2, especially difficult problems appeared in connection with the corrosion of metals and other plant materials by the uranium hexafluoride process gas. Barrier development required the exploration of a number of materials and manufacturing methods. Process design necessitated intensive research and development, especially for those units required for the upper stages of the plant handling material highly concentrated in Uranium-235. Plant design was further complicated by the precautions necessary for the protection of personnel against the process gas itself, which is an extremely toxic chemical, and also emits certain types of injurious radiations. In addition, protection against possible chain-reaction hazard, the extent of which was uncertain, had to be provided for by appropriate equipment design.

7-2. <u>Major Policy Decisions.</u> - Delays encountered in the research and development work mentioned above materially affected the decisions that had to be made relative to the size of the plant, and the order in which various stages of the plant were to be designed, developed, and constructed. The progress of design calculations involving cascade characteristics and number of stages necessary is discussed in the Kellex Completion Report, Section III, (1) B. Major decisions of District policy are summarized below in chronological order.

a. <u>Decision of 18 August 1943.</u> - By August 1943, a good many of the various detailed equipment problems were partially or wholly solved. At this time General Groves asked the Kellex Corporation to report on the probable cost and completion dates for 5, 15, 36.6, and 90 per cent production plants (App. F16). Based upon these data, the construction of a 36.6 per cent production plant was authorized by the District Engineer on 18 August 1943 (App. F13). Design, engineering, and construction activity was now limited to equipment required for the 36.6 per cent plant. Development work however, was continued on a small scale for the higher sections of the plant, in case construction of additional stages should later be authorized in order to produce a higher concentration product. The significance of the 36.6 per cent point, is that at this point design calculations showed that radical changes would be necessary in various important features of process design. At lower concentrations, tubular converter designs are most effective; in higher sections, the flat plate type is preferable. Similarly, in passing from plant sections handling material of concentration lower than 36.6 per cent, to higher sections, the most practical stage pump design changes from a centrifugal type with rotating seals, to the gas bearing type (Vol. 2, Par. 5-3). By concentrating on the lower sections of the plant(up to the 36.6 per cent point) it would be possible to avoid all of the process and equipment designs peculiar to the upper sections, the lower plant program could be carried on at an accelerated pace, and the first production of partially enriched UF_6 could be realized at a much earlier date. Furthermore, successful design, construction, and operation of the lower sections might very well provide a logical basis at a later date for turning attention to the new problems involved in the extension of the plant to higher concentrations.

b. Decision of 16 January 1945. - On 16 January 1945, when the first cells of the plant were about to come into operation (Vol. 5). The Kellex Corporation was authorized to proceed with the engineering and procurement of critical materials and equipment necessary to extend the plant for production of material at 85 plus or minus 5 per cent concentration (App. F20). This extension was to be designed as Section 5, a revision of the originally planned Sections 5 and 6 of the 90 per cent plant, in that only one type of equipment was to be used in lieu of the two types originally contemplated.

c. Design Change of 3 March 1945. - Utilizing the latest available data, and the most effective and accurate methods of design calculation, Section 5 was changed on 3 March 1945 by increasing the number of stages from 1008 to 1440 (App. F21).

d. Decision of 16 March 1945. - On 16 March 1945, after intensive study of the performance and capabilities of both the electromagnetic plant and the abridged gaseous diffusion plant, the plans for the construction of Section 5 of the gas diffusion plant to produce 90 per cent material were abandoned (App. F22).

e. Addition of K-27 Facility. - On 31 March 1945, the District Engineer authorized an addition to the plant consisting of 540 stages as a side feed, which greatly increased its output of 36.6 per cent material. This addition was known as the K-27 plant (App. F24).

7-3. Plant Capacity.

a. Design Capacity. - That portion of the gaseous diffusion plant originally constructed (i.e., the K-25 plant proper, excluding K-27) was designed to process 960 kilograms per day of natural uranium hexafluoride, and to extract from it 4.1 kilograms of hexafluoride having an isotopic concentration of 36.6 per cent Uranium-235. Such a product contains 1.0 kilogram of Uranium-235 metal or 22 per cent of the U-235 initially present in the feed. Under such conditions, the residue or waste contains approximately 0.5 per cent of the 235 isotope.

b. Flexibility of Operations. - There is considerable flexibility of operation inherent in the design of the diffusion plant. The capacity of the plant will vary with the isotopic compositions of the product and waste, and with the quantity of hexafluoride processed per day. The relationship between these factors is complex; for purposes of illustration two examples may be cited. With the feed rate remaining unaltered at 960 kilograms per day, but with the isotopic concentration of the product reduced to 20 per cent, typical design calculations predicted a product rate of 9.1 kilograms per day of hexafluoride, equivalent to 1.2 kilograms of Uranium-235 metal. Similarly, maintaining the product concentration at 20 per cent, and increasing the charge rate to 1430 kilograms per day, the design product rate was increased to 9.6 kilograms of hexafluoride or 1.5 kilograms of Uranium-235 metal per day.

7-4. The Plant Cascade (Section 500). -

a. Ideal Designs. - The most efficient plant to accomplish the design separation, i.e., the plant requiring the least power, and the least barrier surface, and having the lowest inventory of hexafluoride, is one in which there is no mixing of streams of unequal concentrations. In such a cascade, the light fraction from one stage and the heavy fraction from the second stage above (Fig. 1, facing p. 4.5) have identical concentrations. To satisfy this condition in a plant of uniform barrier quality requires a variation in flow from stage to stage. In the K-25 cascade, this would mean that the upflow would have to decrease from a value many times the production rate at the feed point, to a value at the topmost stage equal to the production rate.

(1) Variable Stage Control Pressure. - Stage upflow is directly proportional to stage equipment size and to stage control pressure. A limiting plant which could function as an ideal cascade can be conceived with equipment of uniform size and variable stage control pressure. The practical disadvantages of such a design are:

1. Pressures must be controlled over a wide range. For K-25 operation there would be a 200,000 fold pressure range.
2. If operated at comparatively low pressure, the equipment at the ends of the cascade is unnecessarily large and therefore uneconomical.
3. If operated at comparatively high pressures, converter efficiency is adversely affected.

(2) Variable Equipment Size. - A second type of ideal cascade would involve variable equipment size and constant stage control pressure. The largest size stage would be at the feed point, and each succeeding stage, in either direction, would be slightly smaller than its predecessor. The process pumps would vary in capacity from over 12,000 cubic feet per minute at the feed point, to less than 2,000 cubic feet per minute at the top of the plant. All other basic stage elements would be sized proportionally. Obviously, such an

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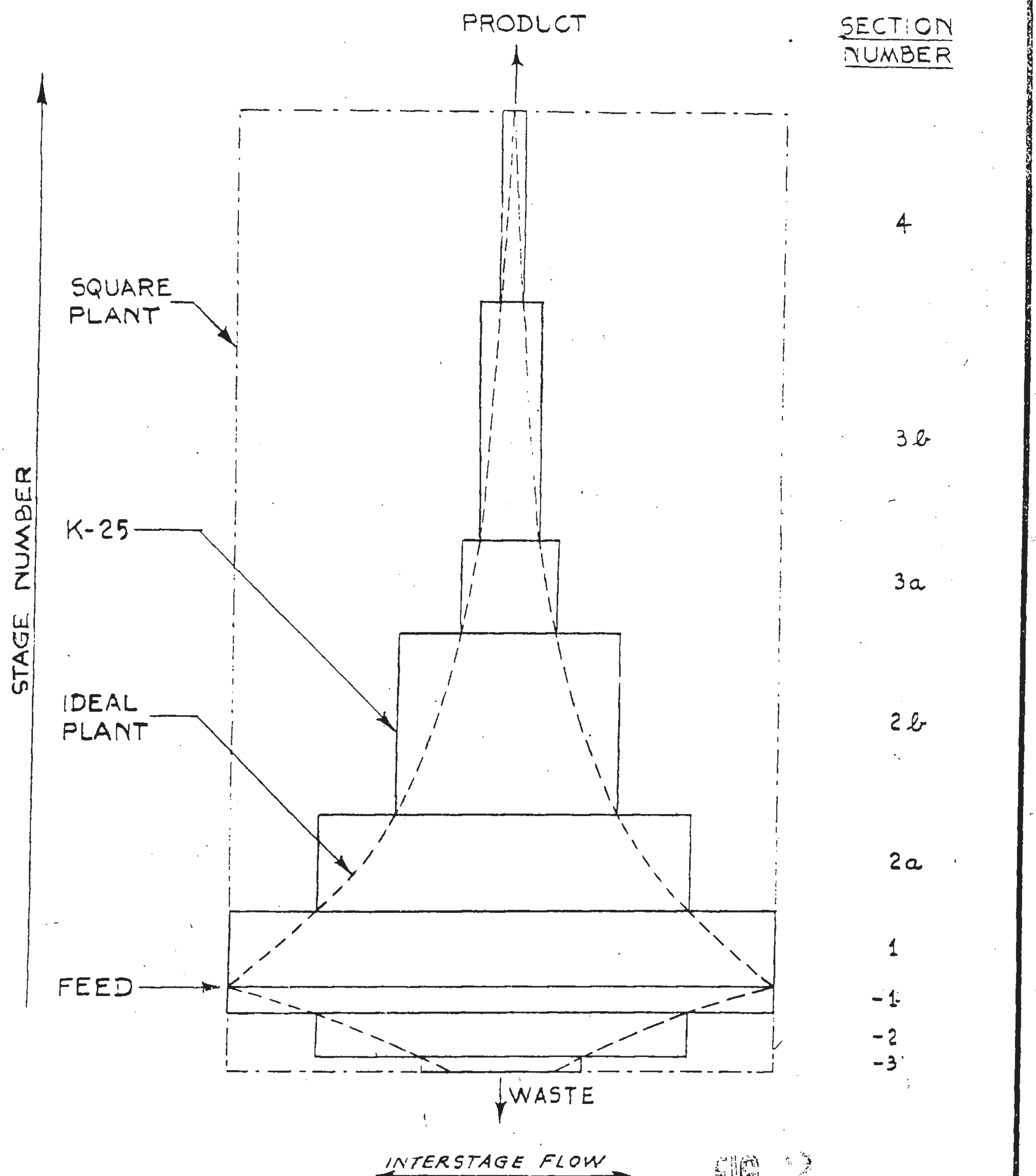

FIG. 2

TITLE CASCADE CIRCULATION RATES

DESCRIPTION	DATE	CHECKED	THE KELLEX CORP.	SCALE ___ DATE 6·26·45 AP. / DR. A.J. TR. ___ / CKD. JAF No. 488 -DP
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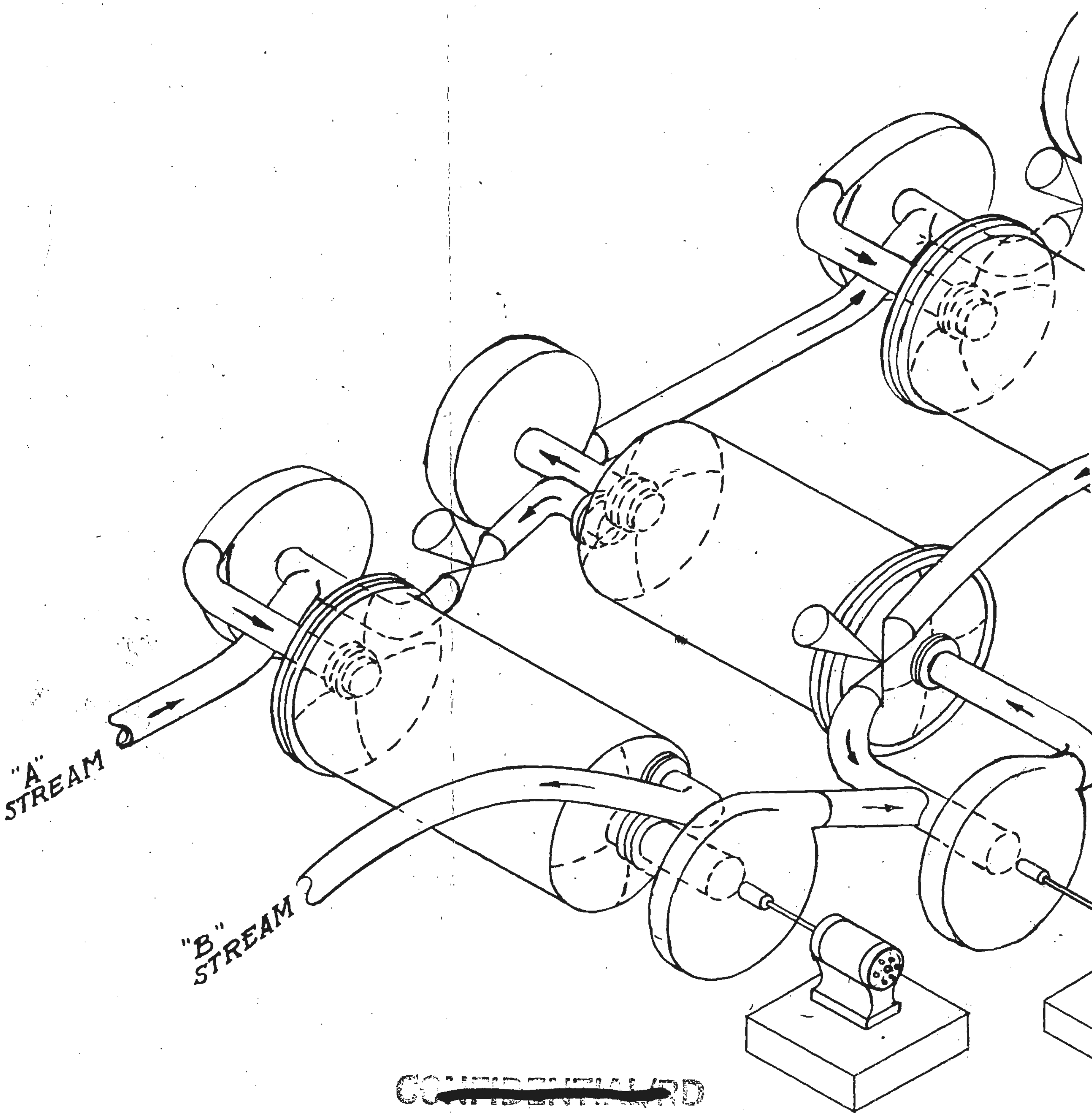
arrangement would not be practicable for a plant of this size. It would involve a stupendous manufacturing job, requiring an enormous number of sizes of equipment, each with its own spare.

b. <u>Square Plant.</u> - A third fundamental type of plant is a square cascade in which the equipment is all of identical size and the upflow is the same for all stages. A plant of this type requires a converter tube area many times that required for an ideal cascade, however, and the time required for the plant to come to equilibrium during the period after the plant has been started, but before production can begin, is much greater than for an ideal cascade. The principal advantage of the square cascade is simplicity of design and operation.

c. <u>Actual Design.</u> - The K-25 design is a compromise combining features of each of the three fundamental designs. The cascade is divided into nine sections. Equipment size and pressure level vary from section to section (Par. 7-8). By sectionalizing the equipment, it has been possible to approach closely the most efficient plant, using only five sizes of centrifugal compressors, and four sizes of diffusers. The K-25 cascade is compared graphically with the ideal cascade and the square cascade in Figure 2, in which interstage flow rates are plotted horizontally, and stage serial numbers vertically. Thus, for the actual K-25 plant, represented by the block diagram, each rectangle stands for a cascade section, with its length proportional to the interstage flow rate in the section, and its height proportional to the number of stages in the section. An overall process flow diagram for the K-25 cascade is shown in Appendix B2.

d. <u>Number of Stages.</u> - The main cascade contains 2892


"A"
STREAM
"B"
STREAM

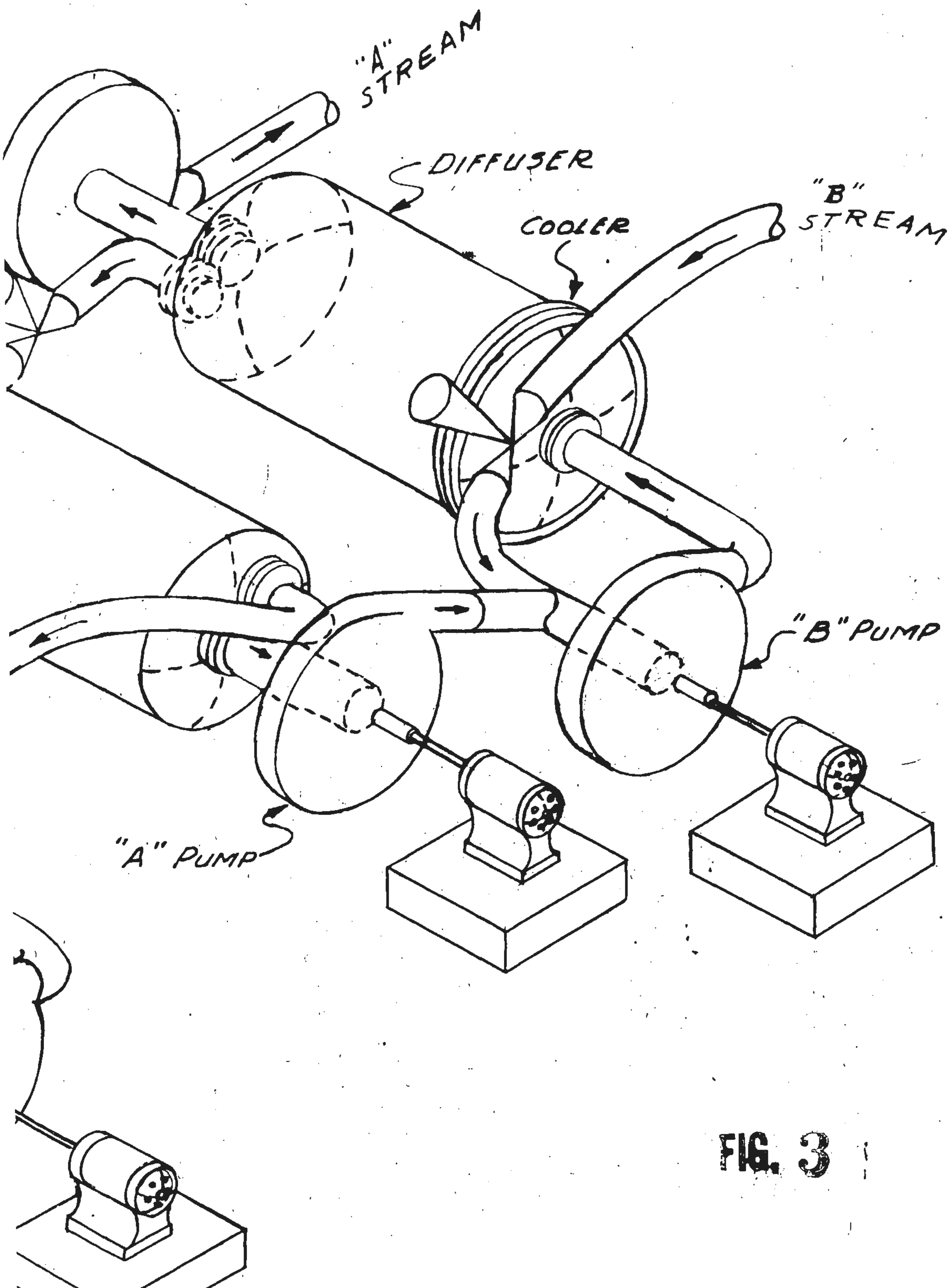


FIG. 3

CASCADE OF FOUR STAGES

installed stages. All are arranged in a single series, with 2622 above the feed point, and 270 below. The K-27 plant contains an additional 540 diffusion stages of which the top 12 to 30 may be used for purging purposes. The remaining paragraphs of this section deal with the main cascade and its auxiliaries; description of the K-27 plant is presented in Section 14.

e. Typical Four-Stage Cascade. - Figure 3 presents an isometric drawing showing the basic elements of four stages of a diffusion cascade. Fixing attention on any one stage, the diffused gas leaving the shell of the diffuser, is picked up and compressed by one of the two centrifugal compressors, the "A" pump. This stream joins the undiffused fraction from the second higher stage, and the mixture is compressed further by the "B" pump of the stage immediately above, where the gas is subjected to an additional separation. The residual stream from the stage under consideration is throttled by flowing through the control valve. The expanded gas joins the diffused fraction from the second stage below at the suction of the "B" pump of the stage immediately below. At this stage the separation is again repeated. The diffused fraction from the stage below, and the residual fraction from the stage above, join at the suction of the "B" pump of the stage in question to form the charge for this stage. The flow pattern for all normal stages is the same.

7-5. Stage Design. - The term "stage" is applied to the fundamental operating unit within the K-25 plant (Fig. 4, facing p. 7.9).

a. Basic Elements.

(1) Diffuser. - The diffuser (also known as "gas

filter") is the heart of the stage, and carries the diffusion barriers. Barrier research and development is (are) discussed in Volume 2, Section 4.

(2) Cooler. - The cooler consists of a series of coils made of small copper tubes housed in a monel metal casting at the entrance end of the diffuser. A coolant circulated through these tubes maintains the desired operating temperatures. Thus, the cooler and diffuser are fabricated integrally to form the "converter". Converter design is discussed in Paragraph 8-4, and shown by Figure 14, facing p. 8.9. The development and procurement of the special coolant, perfluorodimethylcyclohexane, C_8F_{16}, is treated in Book VII.

(3) Pumps. - Two centrifugal pumps, (sometimes referred to as "blowers" or "compressors") are provided for each process stage. It is theoretically possible to design a diffusion cascade using only one pump per stage. Such an arrangement would necessitate throttling the "B" stream, from the next higher stage, down to the pressure equal to that of the "A" stream from the next lower stage before blending these two streams at the suction line of each stage "B" pump. Reducing the pressure of a gas in this manner before re-pumping it to a higher pressure would be inefficient. A second objection to the single-pump system is the very large compression ratio (approximately 6) which would be required. This ratio is not easily handled by centrifugal pumps. The two-pump arrangement is therefore employed, in which the stage "B" pump feeds to the stage converter a stream consisting of a mixture of diffusate from the next lower stage and partially depleted material from the next higher stage, and the stage "A" pump removes diffusate from the converter, feeding it to the "B" pump suction line

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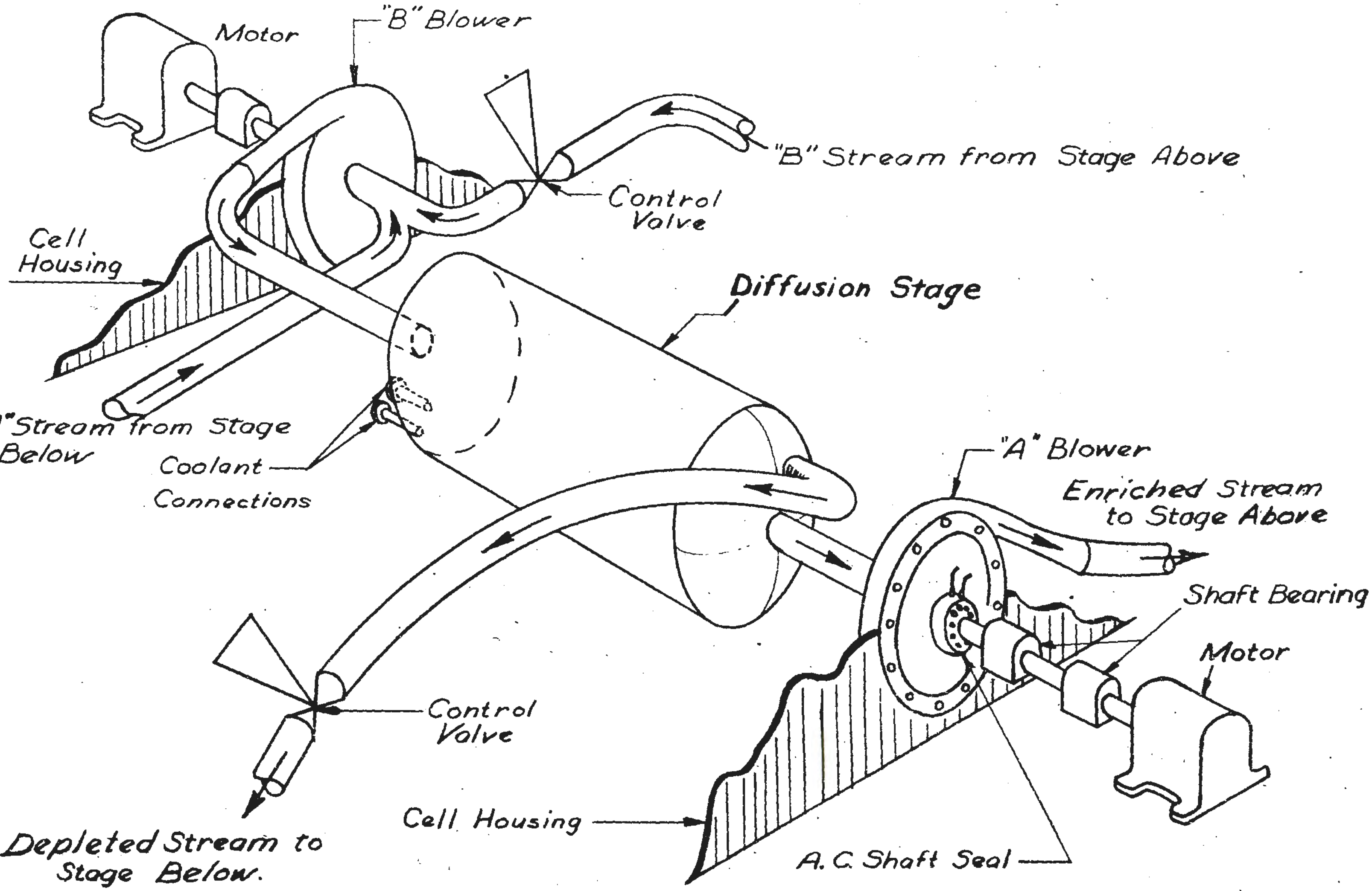
FIG. 4



TYPICAL STAGE

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of the next higher stage. Process pump research, development, and design is covered in Volume 2, Section 5, and Volume 3, Paragraph 8-6.

(4) Control Valve. - The control valve (Par. 8-12) is of the butterfly type, especially modified to suit the needs of the K-25 plant. It accomplishes the regulation of process stage pressures.

b. Stage Instrumentation.

(1) Converter Temperature. - For measurement of converter temperature, a thermo-element is set in a well in the "B" stream line leaving the diffuser.

(2) Inter-Stage Flow. - The flow rate of partially depleted process fluid leaving a converter is indicated by the position of the stage control valve. In most of the stages of the plant, a venturi method of measuring the flow rate is also available, based upon the measurement of impact pressure at the "A" pump discharge, and the difference in pressure between this point and the "A" pump suction.

(3) Stage Pressure. - Pressure is measured and controlled at a point in the "B" stream line carrying partially depleted material from the stage toward the suction of the "B" pump of the stage below. The selection of this point for the control valve is based upon the fact that pressure loss in this line is unavoidable, and no process inefficiency is caused by the introduction of a flow resistance at this point. Located anywhere else in the stage piping system, it would reduce the pressure ratio across the barrier for the same pump capacity and brake horsepower, and thus reduce the enrichment per stage for equipment of a given size. For possible future use in pressure measurement, blanked off taps have also been provided at the "A" pump suction,

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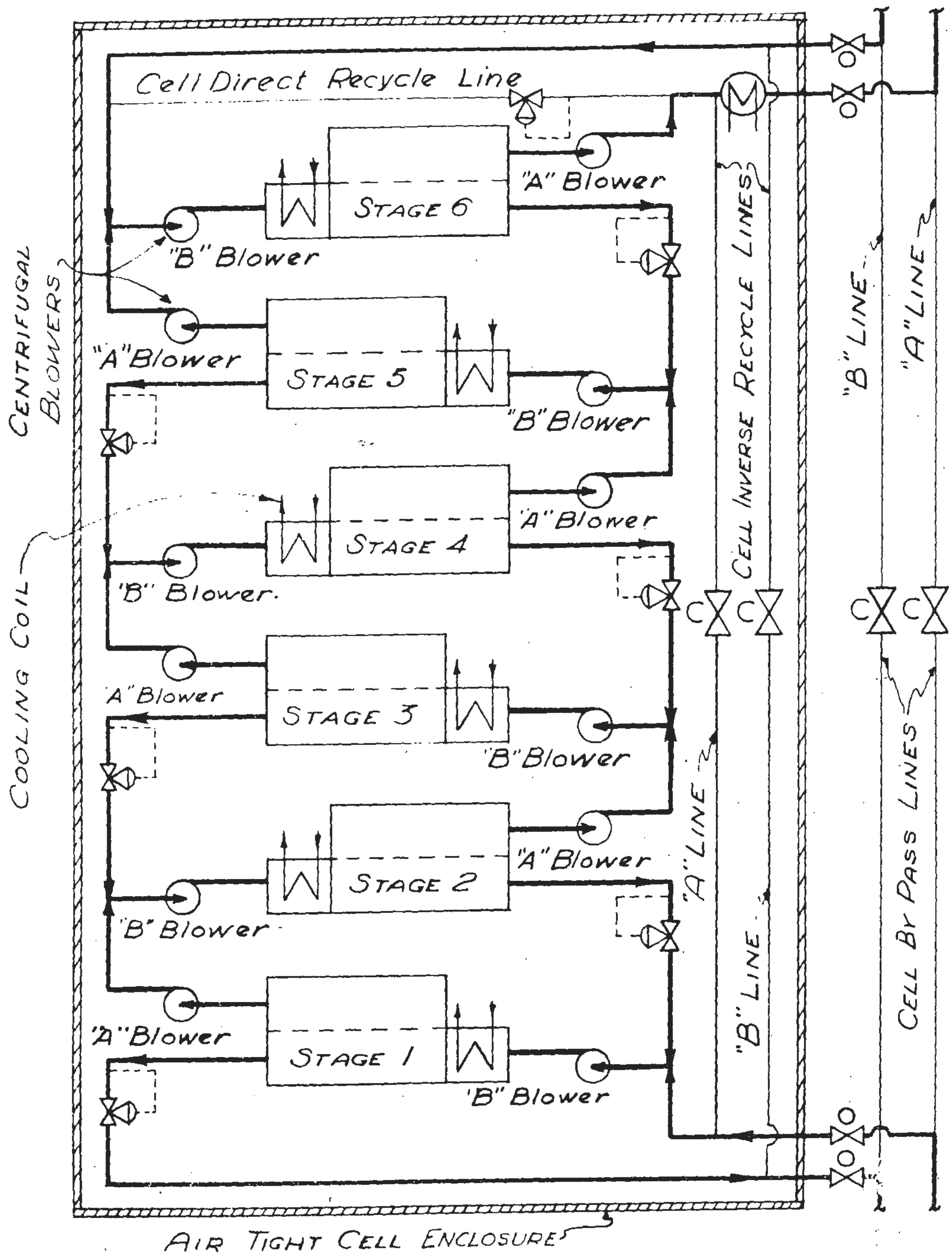

Diagram of a Typical Cell
(Heavy lines indicate normal gas flow.)

FIG. 5

O Valves normally open

C Valves normally closed

Automatic pressure regulating valve.

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and at the converter feed point. The stage pressure control equipment is described in greater detail in Paragraph 8-12.

7-6. Cell Design. - The "cell" is the smallest individually operable unit in the cascade (Fig. 5). It is impossible to by-pass or shut down a single stage, or any number of stages less than a complete cell. The cell is provided with piping, valves, and instrumentation so that it may be normally operated as an integral part of the cascade; so that it may be alternately operated, under abnormal conditions, as a separate unit; or so that it may be shut down for maintenance or other purposes without shutting down the rest of the cascade.

a. Number of Stages per Cell. - All process cells in K-25 and K-27 contain six stages. There are 2892 stages, or 482 cells, in the K-25 main cascade. The decision to employ six stages per cell involves a compromise between two opposing considerations: providing each stage with its own piping and valving for separate shut-down or by-passing would give greatest flexibility of operation and highest stream efficiency; on the other hand, the use of a great many stages per cell would result in a vastly simplified valving and piping system, but would necessitate shutting down a large number of stages when any one has to be taken off stream for repairs. Expected maintenance schedules led to the prediction of a stream efficiency of 85 per cent when six stages were taken as a cell. ("Stream efficiency" is the ratio of the number of stages operating to the total number of stages in the plant.) The cell is a self-contained operating unit with its own control board, cooling system, pump sealing system, and other auxiliaries.

b. Cell Inverse Recycle Lines. - In addition to the piping provided for by-passing a cell, provision has been made for the operation of a cell on "inverse recycle". Cell inverse recycle lines permit recycling the "A" stream flow from the top stage of the cell to the "B" pump of the bottom stage, and the "B" stream flow from the bottom stage to the "B" pump of the top stage. Such an arrangement permits operation of the cell as a recirculating unit, or as an individual six-stage cascade, in which the enrichment may be carried on, but no product is removed. One example of the use of such a method of operation is for the purpose of allowing cell temperatures and pressures to reach specified values after starting up operation of the cell, and before putting the cell on stream.

c. Cell Direct Recycle Line. - If the "A" and "B" stream cell inlet valves, and the cell inverse recycle lines should all be closed simultaneously (Fig. 5), or if the resistance in the discharge line of the top-stage "A" pump should increase appreciably (as when an abnormally large number of consecutive cells above the pump in question are by-passed), flow through this "A" pump might decrease so far as to result in pump surging and overheating. The cell direct recycle line was therefore provided, to direct flow from top stage "A" pump discharge back to the "B" pump suction of the same stage, in cases where the suction volume of the "A" pump decreases to a pre-determined minimum value.

d. Cell Instrumentation.

(1) Inverse Recycle Flow Measurement. - It was felt that a means of measuring flow rate would be desirable for a cell

operating as a separate entity (on inverse recycle). A flow indicator was therefore provided in the cell "B" stream inverse recycle line. The original purpose of this item was for use in comparison of the downflow in an isolated recycle operation with the upflow as indicated by the stage "A" pump Venturi flow indicators. This serves to permit adjustment of cell inventory before placing the cell in the main cascade, which was considered desirable in order to reduce cascade surges at the time of cell addition. In present operations, the cell is ordinarily filled, however, with material drawn directly from the process stream. Exact inventory adjustment is not important.

(2) Direct Recycle Flow Control. - It was originally intended that the control of the cell direct recycle flow at the sixth stage would be made by regulation of the static and impact pressure of gas flowing through the sixth stage "A" pump, the direct recycle control being designed to maintain a pre-determined minimum flow through this pump. A control valve in the direct recycle line would open if this flow tended to fall below the minimum, thus opening to the pump discharge a new, low-resistance flow path. Circuit balance studies later showed that the pressure and flow characteristics at this point were such that the differential flow element would not control the valve properly. The difficulty was most simply solved by piloting the direct recycle control valve off the "A" pump discharge static pressure.

(3) Process Stream Analyses. - Provision is made for withdrawing samples for analysis from the "A" stream leaving the top stage. The head across the "A" pump is used to actuate flow through a

sample line.

e. Miscellaneous Cell Connections.

(1) Cell C_7F_{16} Connection. - A charging and evacuation connection for the introduction and removal of n-perfluoroheptane, C_7F_{16}, is provided for each cell at the suction of the "B" pump of the fifth stage (Par. 10-6b). It was originally planned to test all process equipment by operation with C_7F_{16} before placing it on stream. Subsequent start-up operations showed that it is unnecessary to run preliminary mechanical C_7F_{16} tests on all equipment. However, the C_7F_{16} connections have proven useful for such purposes as the connection of portable carbon absorbers or cold traps.

(2) Cell Fluorine Connections. - For conditioning purposes, a special fluorine connection is provided at the suction of the fifth stage "B" pump (Par. 10-6c). An adjacent connection is provided for the evacuation of conditioning gas from the cell to the permanent disposal system piping (Par. 10-6d).

(3) Cell Process Gas Recovery Connections. - For use in connection with the process gas recovery system (Par. 7-12; Par. 10-6e), a cell charging header and a cell evacuation header were installed in each building. A branch from the charging header was connected to the "B" pump suction of the sixth stage of each cell, and a branch from the evacuation header was connected to the "B" pump suction of the fifth stage of each cell.

7-7. Building Design. - The building is the next larger operating unit above the cell. The term "building" does not imply a structurally separate housing, since all 54 process and purge buildings

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Fig. 6

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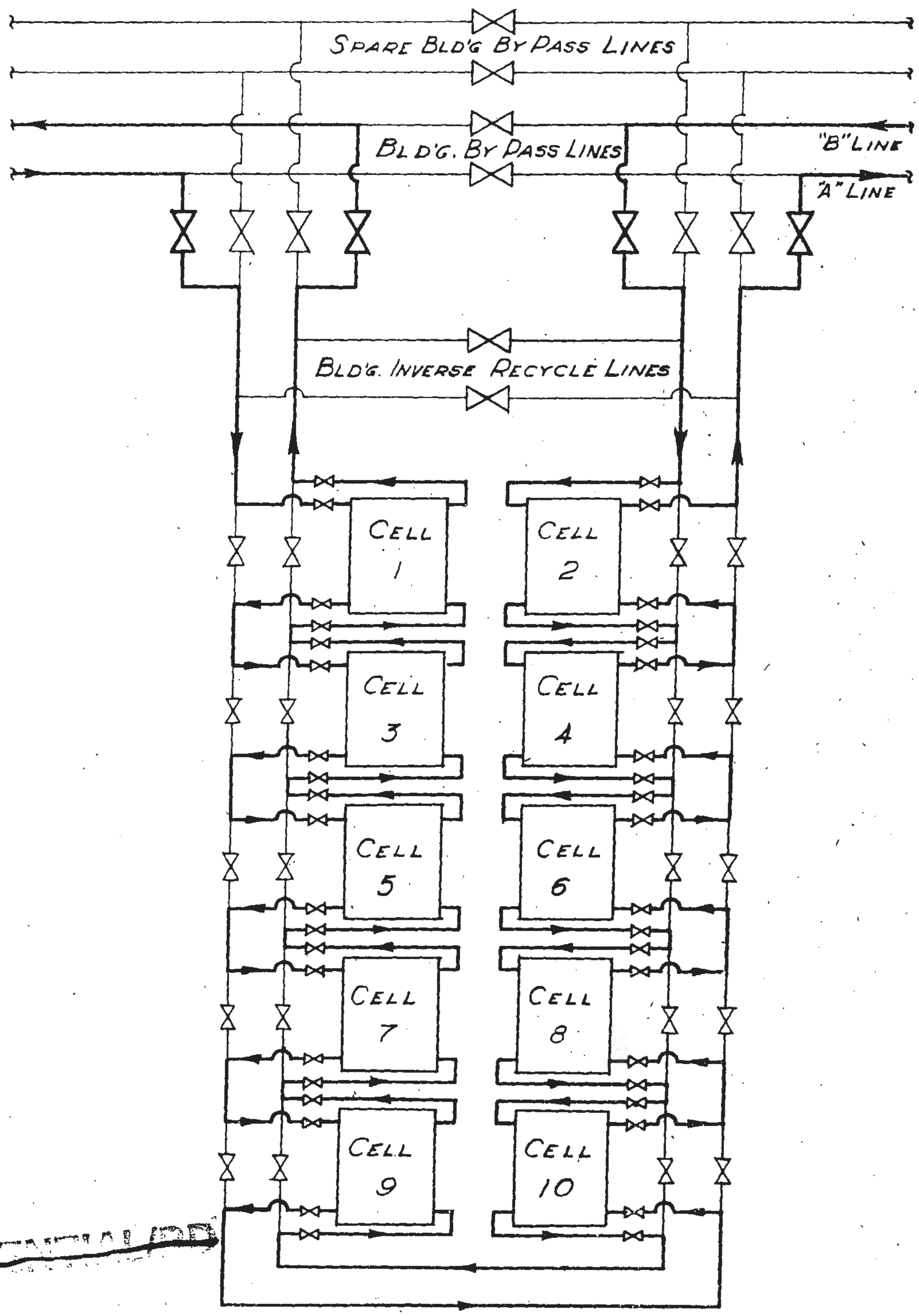

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Diagram of Piping & Valves in a Typical Building

(Heavy lines indicate normal gas flow).

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are contiguous, and form a huge integrated structure. Structural design of process buildings is described in Section 9.

a. Number of Cells per Building. - On the basis of approximately uniform building size, and decreasing stage size from the feed point to the ends of the cascade, the number of cells per building is a quantity which varies between the limits of three and fourteen (App. B1, B2). As with the choice of number of stages per cell, this range represents a compromise between a large number of cells per building with the advantage of minimum valving and instrumentation, and a small number of cells per building with the advantage of relatively small removal of cascade inventory when a building is by-passed. Figure 6 shows a diagram of a typical process building.

b. Building By-pass and Recycle Lines. - As with the individual cells, piping and valving facilities have been provided in order to permit by-passing of an entire building and operation of the building on inverse recycle.

c. Inter-building Lines. - Two lines (A-1 and A-2) are provided for handling upflow from a building to the next higher building, and two lines (B-1 and B-2) for downflow to the next lower building. One of each is normally in use, the other serving as a spare.

d. Building Instrumentation. - The building instrument board provides a record of:

1. A-1 or A-2 flow from building.
2. A-1 or A-2 flow to building.
3. B-1 or B-2 flow from building.

4. B-1 or B-2 flow to building.

5. Building "B" inverse recycle line flow.

These flows are all measured by impact and differential pressure developed in Venturi-pitot flow elements.

7-8. <u>Section Design.</u> - It has been pointed out that ideal considerations call for a slight change in equipment size from stage to stage throughout the entire cascade. Practical considerations led to the standardization of equipment at four different sizes, splitting the cascade into nine sections, using equipment of uniform size throughout a section, and using progressively smaller equipment sizes in sections further and further removed from the point of introduction of cascade feed. A "section" is therefore to be visualized as a uniform portion of the cascade, or as a bank of identical process buildings. Aside from the entire cascade, a section is the largest individually operable process unit. The use of the term "section" within the meaning of this paragraph is not to be confused with the use of the same word to convey a different meaning as explained in Paragraph 6-2.

a. <u>Number of Buildings per Section.</u> - As finally designed, the K-25 cascade consists of three sections below the feed point and six sections above the feed point. The number of buildings in each section varies from one to twelve, and is shown by Appendix B1. The evolution of this design is traced in Section III, (1) B of the Kellex Completion Report.

b. <u>Numbering System for Process Units.</u> - All process buildings in the main cascade are assigned a number consisting of two parts separated by a hyphen. The first part is a three digit number

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TABLE 2. - CASCADE SECTION DATA

CASCADE SECTION NUMBER	BUILDING DESIGNATION	NUMBER OF BUILDINGS	NUMBER OF CELLS	NUMBER OF STAGES	SIZE OF EQUIPMENT	TYPICAL CONVERTER PRESSURE (p.s.i.a.)	INTERNAL CONVERTER TEMPERATURE °F	RATED PUMP CAPACITY "A" (c.f.m.)	RATED PUMP CAPACITY "B" (c.f.m.)
-3	K-311	1	9	54	3	2.0	140	3800	3800
-2	K-310	3	21	126	2	2.3	140	9200	9200
-1	K-309	3	15	90	1	2.3	140	9600	11200
1	K-301	6	37	222	1	2.3	140	9600	11200
2a	K-302	5	46	276	2	2.2	140	9200	9200
2b	K-303	10	92	552	2	1.5	140	9200	9200
3a	K-304	5	48	288	3	1.3	110	3800	3800
3b	K-305	12	118	708	3	0.7	110	3800	3800
4	K-306	7	96	576	4	0.5	110	1200	1200
		51	482	2892					

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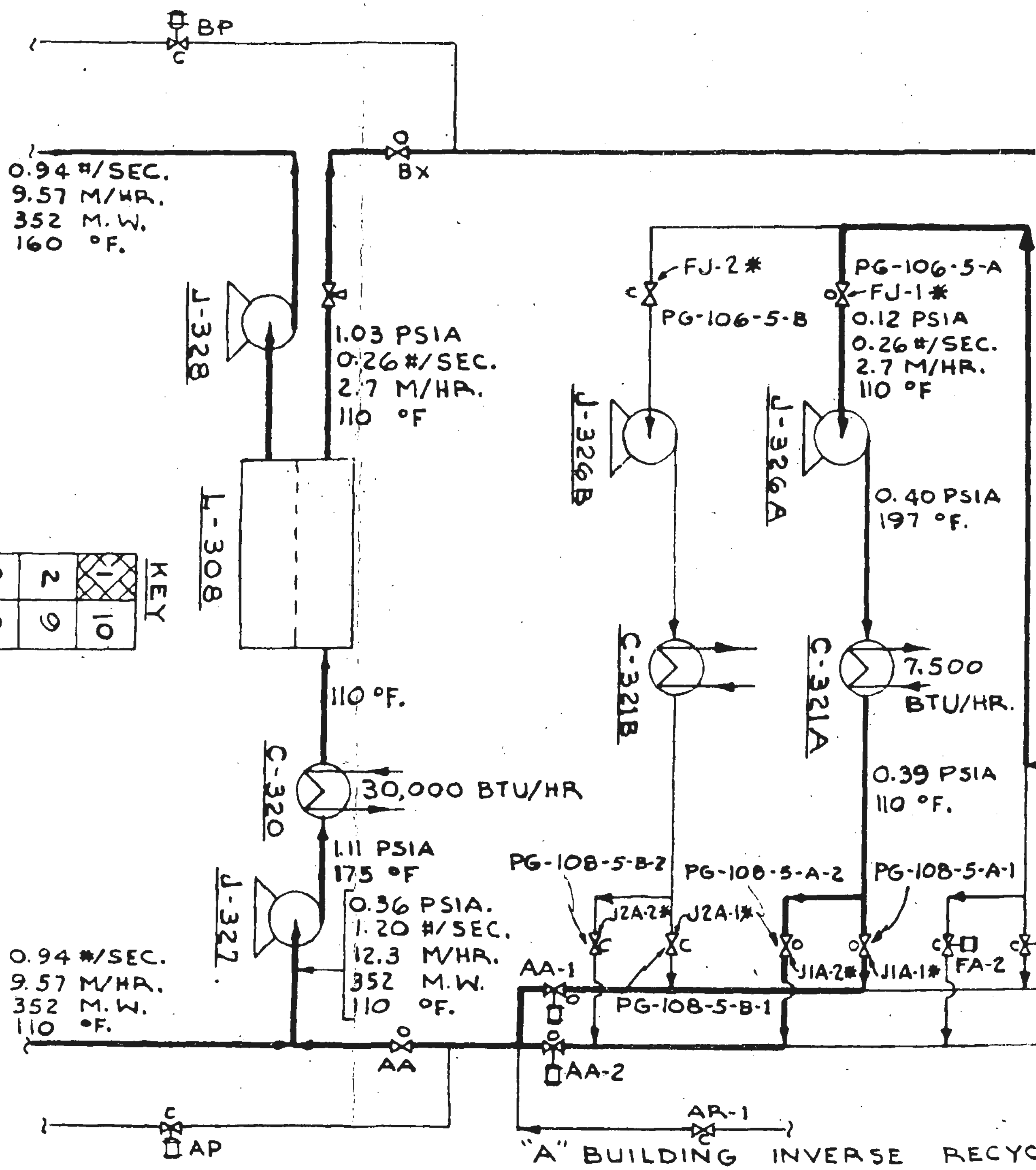
beginning with a "3" (Par. 6-2). The specific number for each cascade section is shown in Appendix B1. The second part is obtained simply by numbering the buildings consecutively within each section. Thus, for example, K-302 would be the prefix for any building in section 2a, and K-302-4 would refer to the fourth building in this section. A decimal terminology is sometimes used to indicate cells. Thus K-302-4.5 would refer to the fifth cell in the fourth building of the 302 section (section 2a). In numbering the sections, the one adjacent to, and above, the feed point is Section 1. The higher enriching sections are numbered consecutively as follows: 2a, 2b, 3a, 3b, 4. The "a" and "b" designations indicate a difference in operating conditions, rather than of equipment size, which is the distinction between sections of different numbers. Starting at the feed point and proceeding downward, the stripping sections are numbered -1, -2, -3. The four sizes of equipment used in the main cascade are numerically equal to the section in which they are installed. Thus, for example, size 2 equipment is used in sections -2, 2a, and 2b. Significant descriptive data for cascade sections are presented in Table 2.

e. <u>Intersectional Equipment.</u> - Each section has its own source of variable frequency power. Provision was made for rapid isolation of portions of the plant served by individual sources of power, while maintaining stable operation in the rest of the cascade. No provision has been made for by-passing sections because of the large lines required, and the undesirable mixing, which would be entailed, of process streams containing widely differing concentration of Uranium-235.



"A" BUILDING INVERSE RECYC

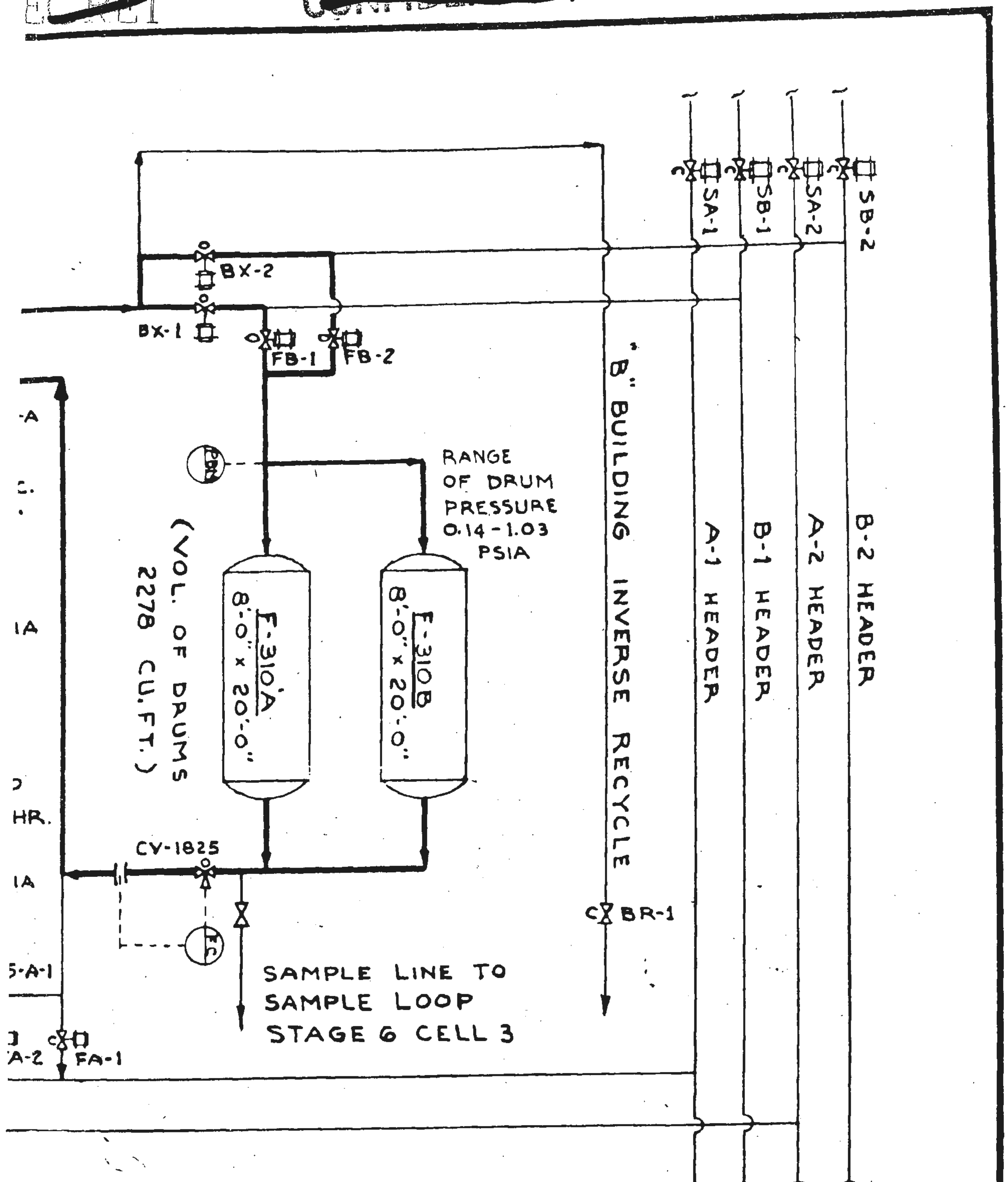
PROCESS FLOW DIAGRAM-

* VALVE DESIGNATION IN MASTER CONTROL ROOM.

MOTOR OPERATED VALVES

(BOTTO

[redacted] [redacted]



ECYCLE LINE

M-K-305-1.1

TOM INT. CELL)

FIG. 7

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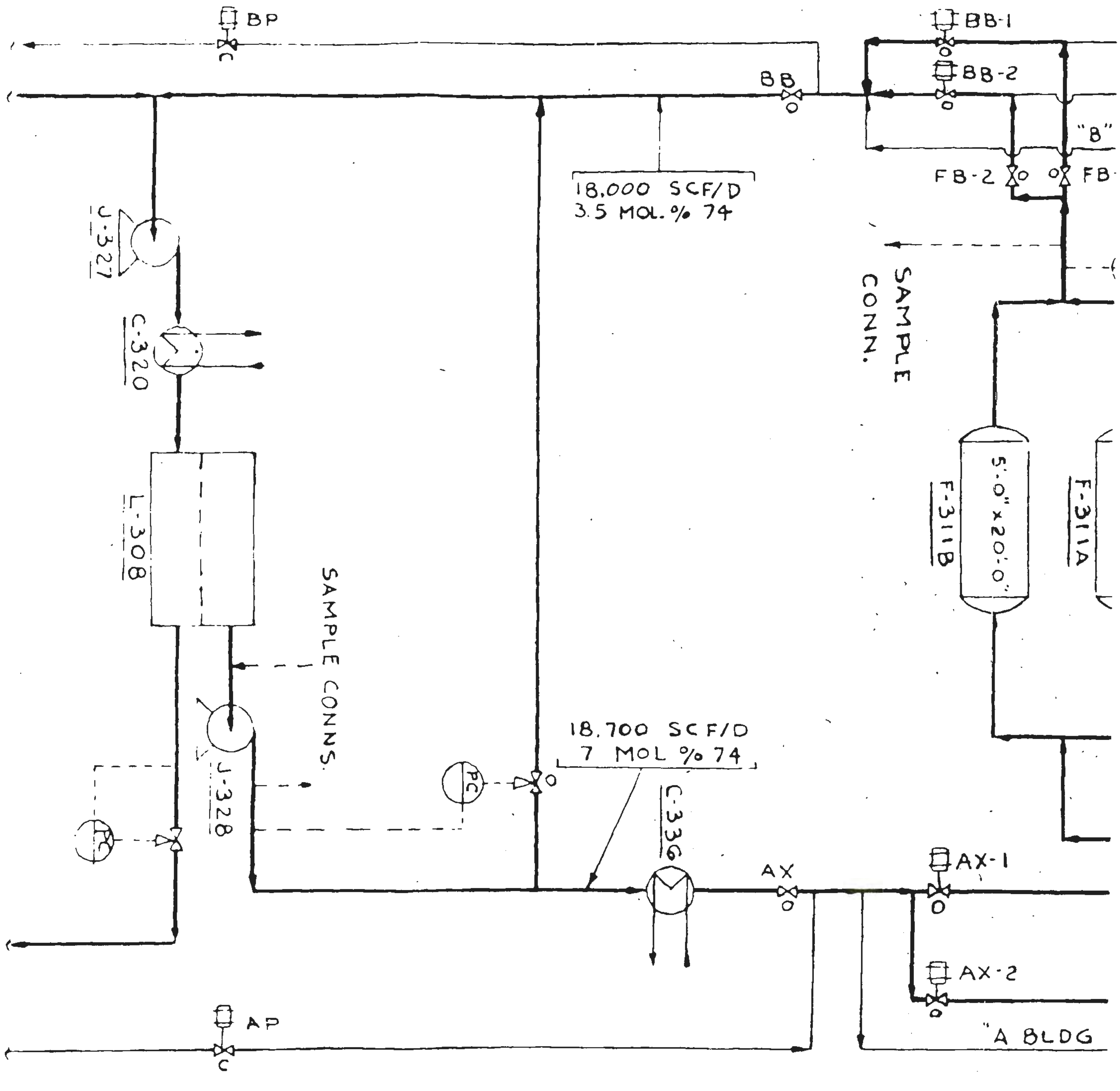

PROCESS FLOW DIAGRAM - K-3

KEY
BLDG. K-305-12

5	4	3	2	1
6	7	8	9	10

MOTOR OPERATED VALVE.

* VALVE DESIGNATION IN MASTER CONTROL ROOM.

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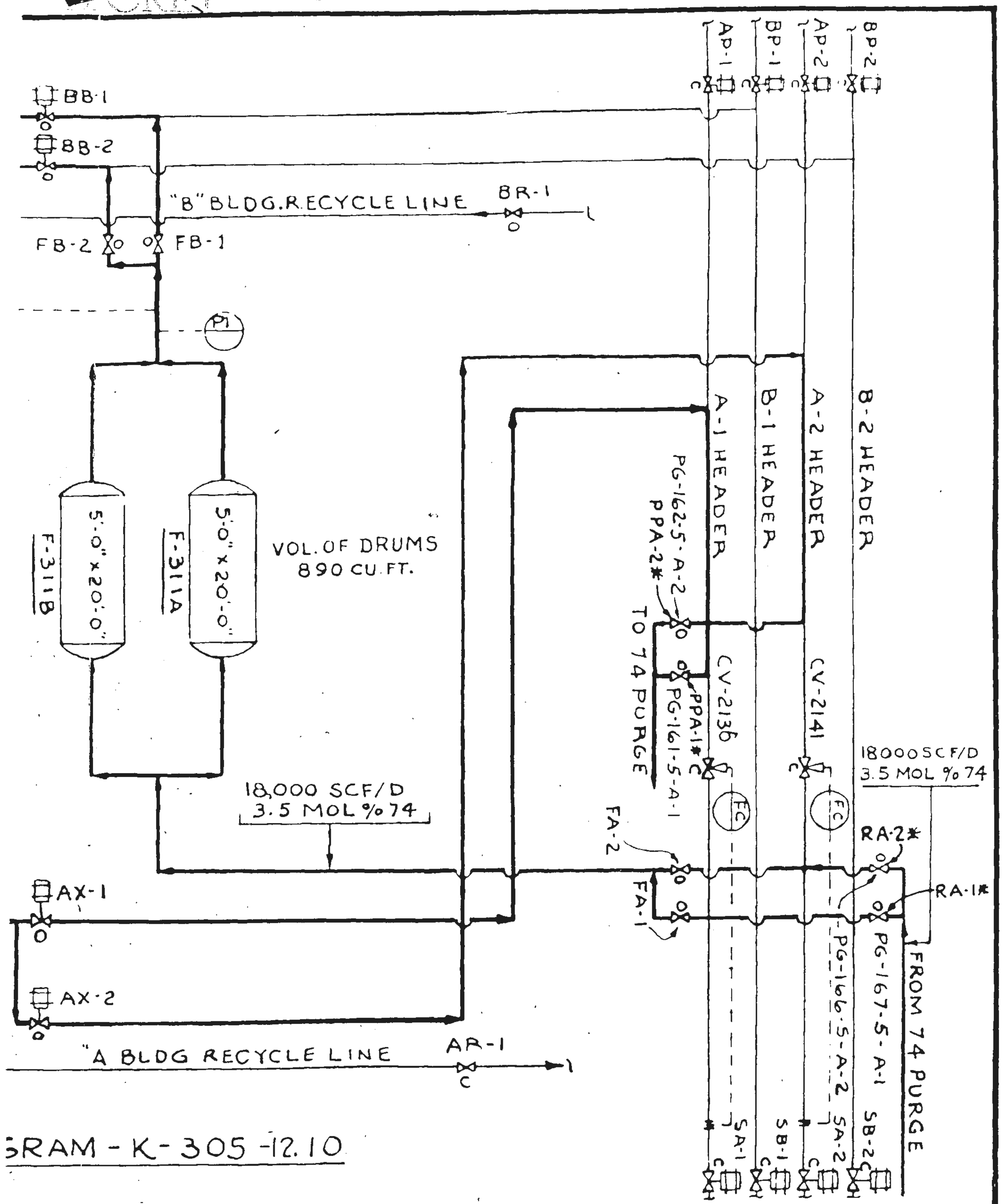

(TOP INT. CELL)

FIG. 8

(1) Valves. - Motor-operated "block valves" (Par. 8-11) are installed on the four lines connecting adjacent sections. This facilitates rapid isolation of sections at time of emergency.

(2) Flow Control Equipment. - Flow is controlled at all junctions between sections above Section 1. This prevents the possibility of overloading the bottom stage of the section containing smaller equipment.

(3) Intersectional Cells. - Surge capacity is provided by a set of drums which run at variable pressure, and booster pumps which increase the capacity of the drums to absorb changes in inventory. This equipment is located in the "intersectional cells" at the bottoms of the sections (Fig. 7). A second type of intersectional cell is located at the top of each section, and contains drums, recycle lines, valves, and controls intended to purge the nitrogen accumulating at the top of the section when it is isolated from the cascade (Fig. 8). Intersectional cells (shown as black rectangles in Appendix B1), contain no converters. A detailed description of design and operation of intersectional cells is available in Volume XXIX of the Kellex Operating Manuals.

4. Section Recycle Lines. - Section recycle lines were originally provided, connecting the top of each section with the bottom, so that, during sectional operation, nitrogen concentration, which would otherwise build up at the top of the section, could be equalized. This was done because it was throught that process pumps could not operate satisfactorily at high nitrogen concentrations. The pumps were subsequently found suitable for use at any nitrogen concentration. The

sectional recycle lines have therefore been removed.

7-9. Feed Purification System (Section 100).

a. Purpose. - It was originally considered that feed stock for the K-25 plant would have to conform to the maximum impurity specifications summarized in the second column of the tabulation shown below. The first column summarizes the technical grade specifications, the highest degree of purity which it was thought reasonable to expect of industrial manufacturers of UF_6:

	Technical Grade UF_6	Purified UF_6
HF	0.03 wt. per cent	0.003 wt. per cent
MoF_6	0.01	0.001
Non-Volatile Matter	0.2	0.02
Fluorocarbons (as C_7F_{14})	0.1	0.03

A feed purification plant was therefore constructed at the site in order to provide facilities for refining the technical material to the desired purity.

b. Operating Status. - Before the start-up of operations in Section 100, it became apparent that the feed purification plant would not normally be required. Experience in the production of technical grade UF_6 showed that the manufacturer could meet more rigorous specifications than originally assumed. Furthermore, it was found that cascade feed material specifications could be somewhat relaxed. Specifications for technical-grade UF_6 were, accordingly, changed to the values tabulated below. Material of this degree of purity was then acceptable as cascade feed without refining at the site:

HF	0.015 wt. per cent
MoF_6	0.002
Fluorocarbons (as C_7F_{14})	0.03
Non-Volatile Matter	(no specification)

The feed purification system has, therefore, not been used, but it has been maintained in stand-by status for use at any future time in the event that it should be desired or necessary to accept for processing a raw feed stock of lesser purity.

c. Capacity. - The feed purification plant was designed to provide 2650 pounds per day of purified UF_6 with a recovery of 99.5 per cent.

d. Design Principles. - The feed purification plant uses a two-step distillation system.

e. Description. - The only laboratory or pilot plant data available was the experience gained with a small batch still at the SAM Laboratories, which indicated qualitatively that the desired purity could be obtained by distillation. On the basis of standard chemical engineering calculations, two distillation towers were designed, and connected in series, to serve, respectively, for the stripping of volatile impurities, and the separation of UF_6 from heavy impurities. The stripping tower consists of a 5/16 inch Monel metal shell eight inches in diameter, and contains an eleven foot Raschig ring* section. An auxiliary hydrolysis tower was provided to neutralize and dissolve traces of UF_6, MoF_6, and HF present in off gases, by means of potash solution sprays, thereby forming a non-corrosive solution for disposal. The hydrolysis tower accepts overhead vapor from the stripping tower, Q-2

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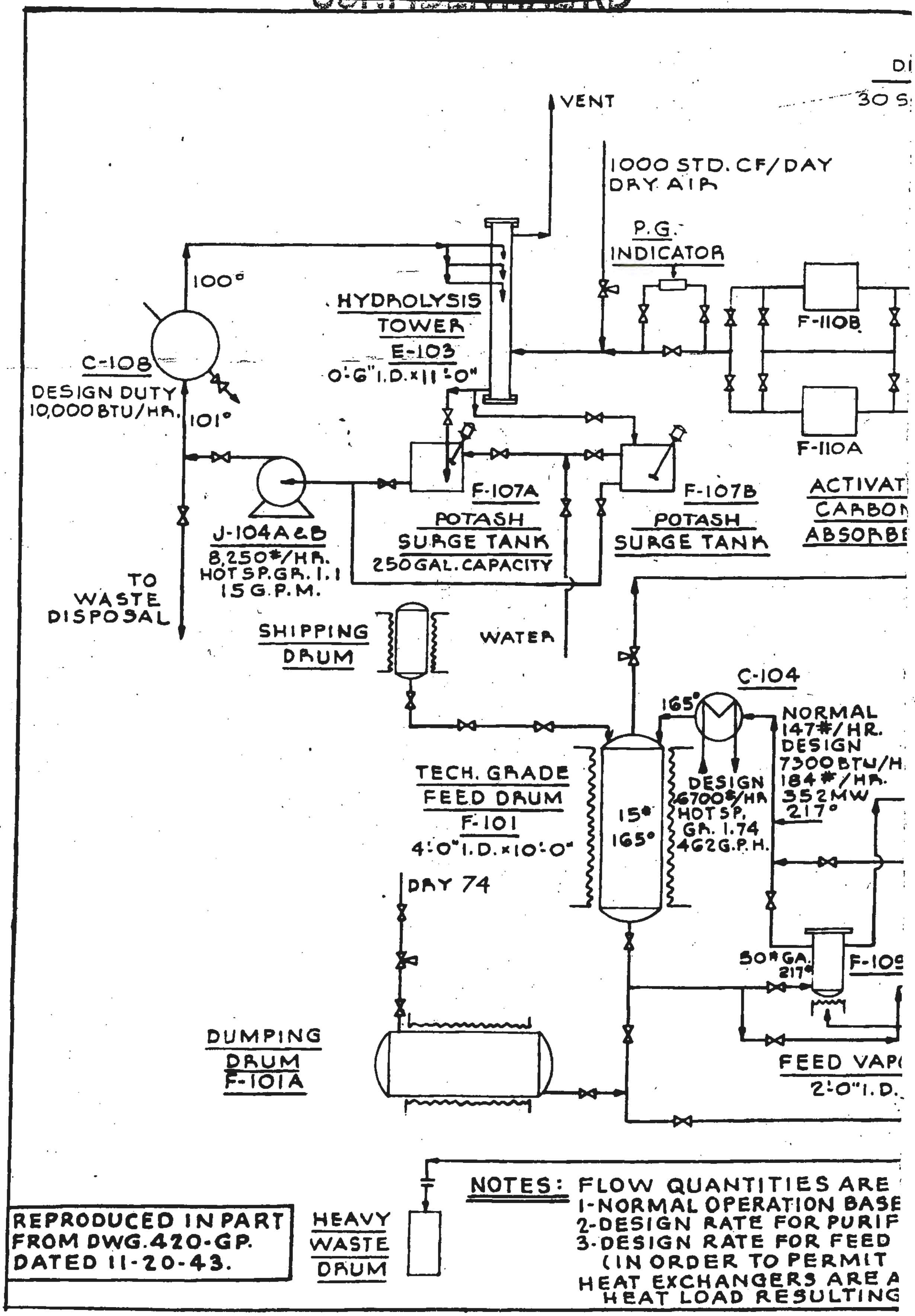

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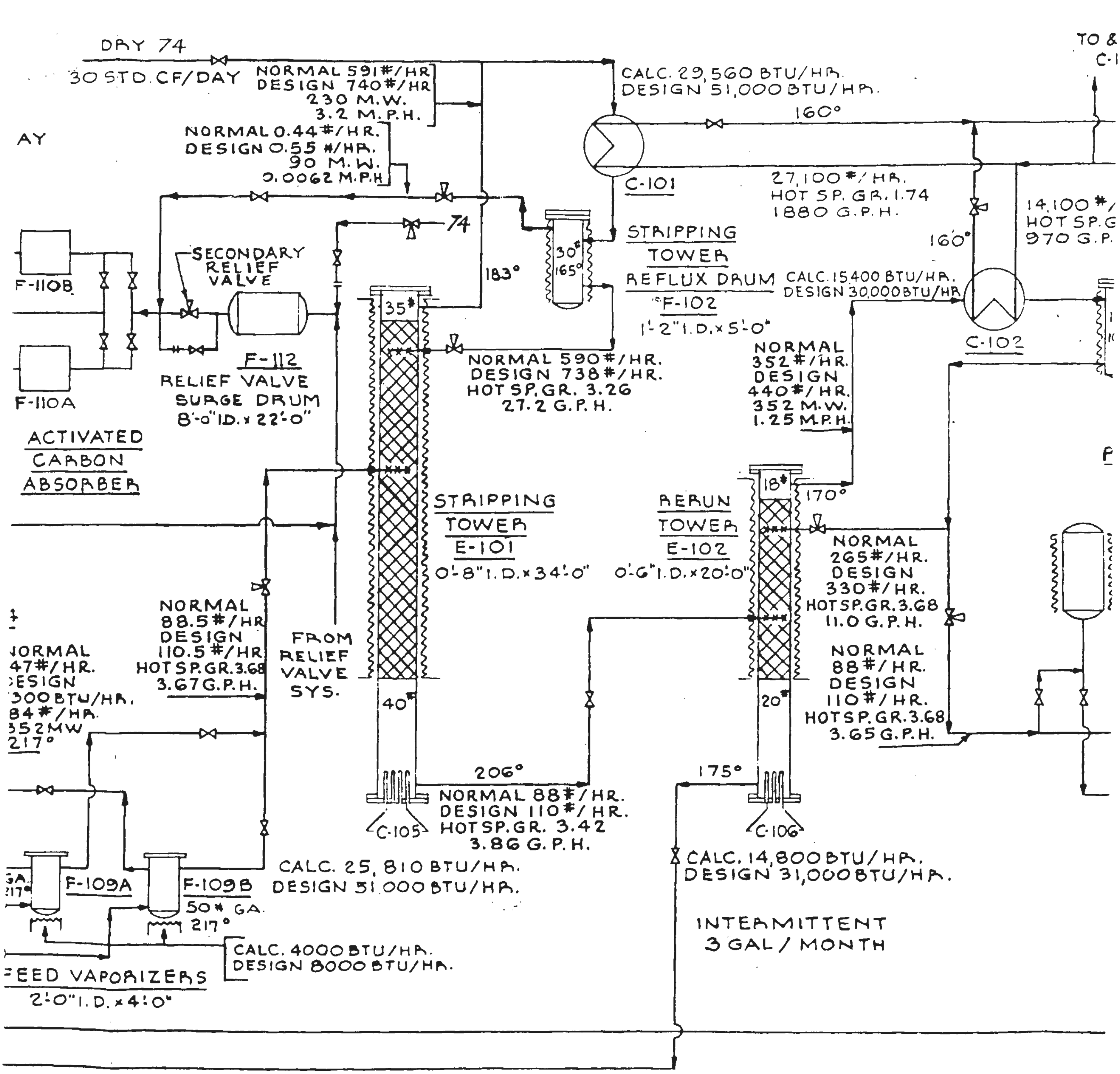

IES ARE SHOWN FOR:
TION BASED ON FEED RATE TO THE MAIN PLANT OF 2,108#/DAY.
FOR PURIFICATION EQUIPMENT 25% ABOVE NORMAL.
FOR FEED VAPORIZERS BASED ON FEED RATE OF 15,000#/DAY
PERMIT FILLING ENTIRE CASCADE IN 48 HRS.
ERS ARE ALL DESIGNED FOR APPROXIMATELY TWICE THE
ESULTING FROM DESIGN RATES OF FLOW.

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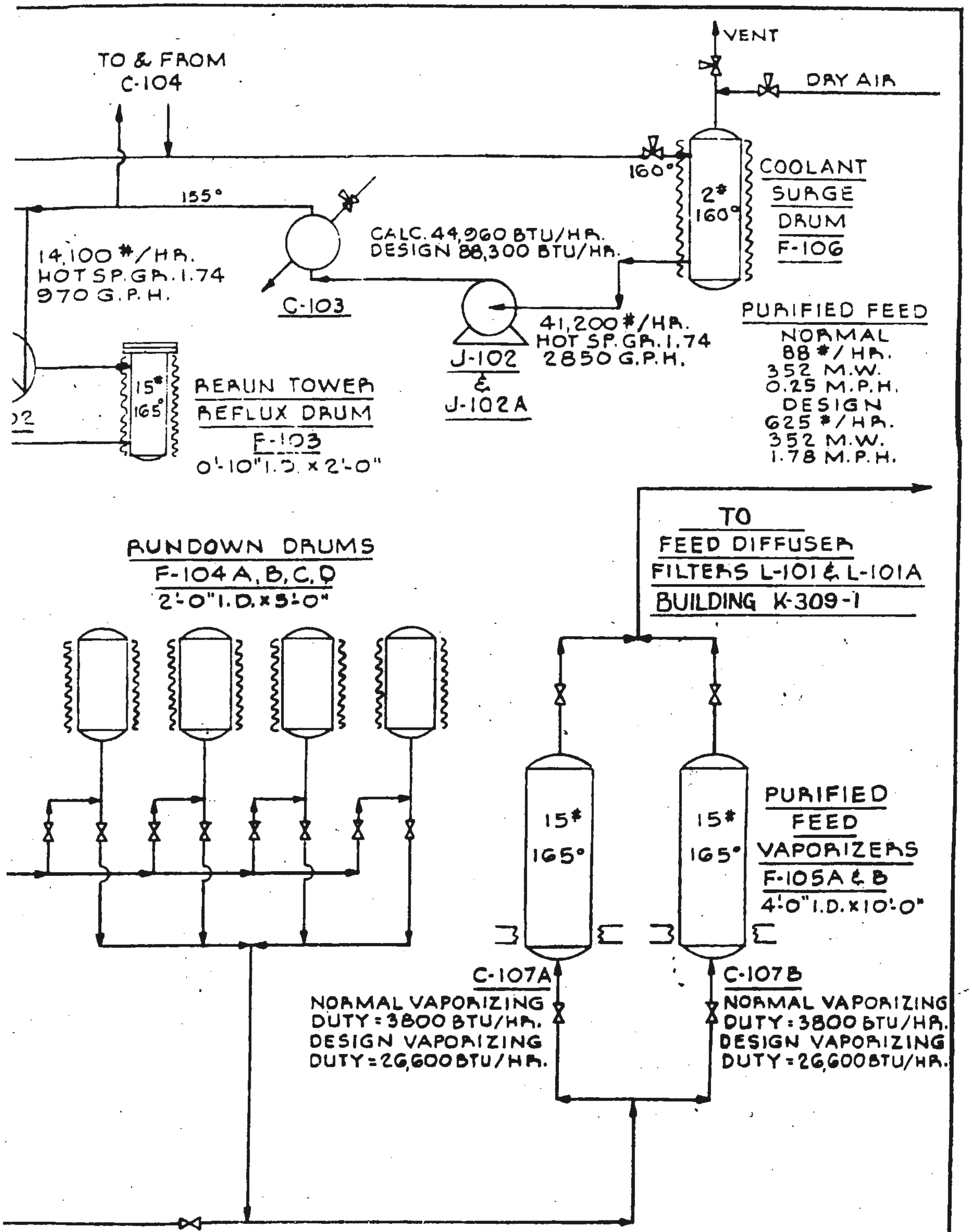

TITLE- PROCESS FLOW SHEET
FEED PREPARATION UNIT

FIG. 9

THE KELLEX CORP.	SCALE NONE DATE 11-20-43 AP.
	DR. NLD TR. FD
	CKD. No. 202 O.D.

[redacted]

and vent gases from the feed drums and other accessory vessels. A schematic flow chart containing significant design data for the feed purification plant is presented in Figure 9. Raw UF_6 is melted in shipping drums (App. E7), and dropped by gravity to a feed tank equipped with electrical jacket heaters. Two vaporizers (also electrically heated), charged by gravity flow from the feed tank, are used to supply the stripping tower. The overhead stream from this tower is passed through a condenser and run to a reflux drum from which the non-condensable gases are vented to activated carbon absorbers, and thence to the hydrolysis tower. Condensed liquid process material for the reflux drum is returned to the top of the stripping tower, which operates essentially at a total reflux ratio. The base of the tower is equipped with an electrically heated reboiler. Stripping tower bottoms are supplied by pressure differential to the re-run tower, which is similarly equipped with reboiler and reflux facilities. Non-volatile impurities are removed intermittently by drawing off re-run tower bottoms at the rate of 90 pounds per month. The re-run tower reflux ratio is 3:1, and purified UF_6 is run to a bank of run-down drums. These drums supply the purified feed vaporizers, which in turn supply the process cascade. The cooling system for the condensers employs C_8F_{16}, and is similar in principle to the main process cooling systems.

f. Special Considerations. - In the main process system, the process material is handled as a gas at sub-atmospheric pressures; in the feed purification system, design was based upon pressures above atmospheric, upon relatively high temperatures, and upon the necessity for handling UF_6 in the liquid state. Thus, corrosion problems were accentuated, and new problems were encountered in the design of electrical heating equipment. The leakage problem was one of preventing the escape of a corrosive and toxic chemical, rather than preventing the inleakage of contaminating atmosphere or sealant. Evolution of feed purification plant design is discussed in the Kellex Completion Report, Section III, (1) C, and a full description of the final design is presented in Volume VII of the Kellex Operating Manuals.

7-10. Surge and Waste System (Section 600).

a. Purpose. - Effective diffusion plant operation demands constant and undisturbed operating conditions, particularly process pressure, at all times. A pressure disturbance originating at some point in the cascade tends to set up a train of pressure waves or surges which travel from stage to stage up and down the cascade, resulting in the mixing of process streams of unequal concentrations, and consequent decrease in cascade productivity. The surge and waste system was designed to smooth out fluctuations in process stream flow rate and pressure, and to provide a means for removing depleted waste material from the bottom of the cascade at a controlled rate.

b. Capacity. - To provide for extreme conditions, a maximum surge rate of 3280 pounds per hour was specified, and a maximum variation in surge inventory of 1500 pounds, corresponding to a variation in cascade inventory of five per cent. Recycle flow from the surge system to the main cascade was set at 5460 pounds per hour. Normal waste rate was established at 88 pounds per hour with a maximum design rate of 130 pounds per hour. The cascade bottoms stream, "waste", is

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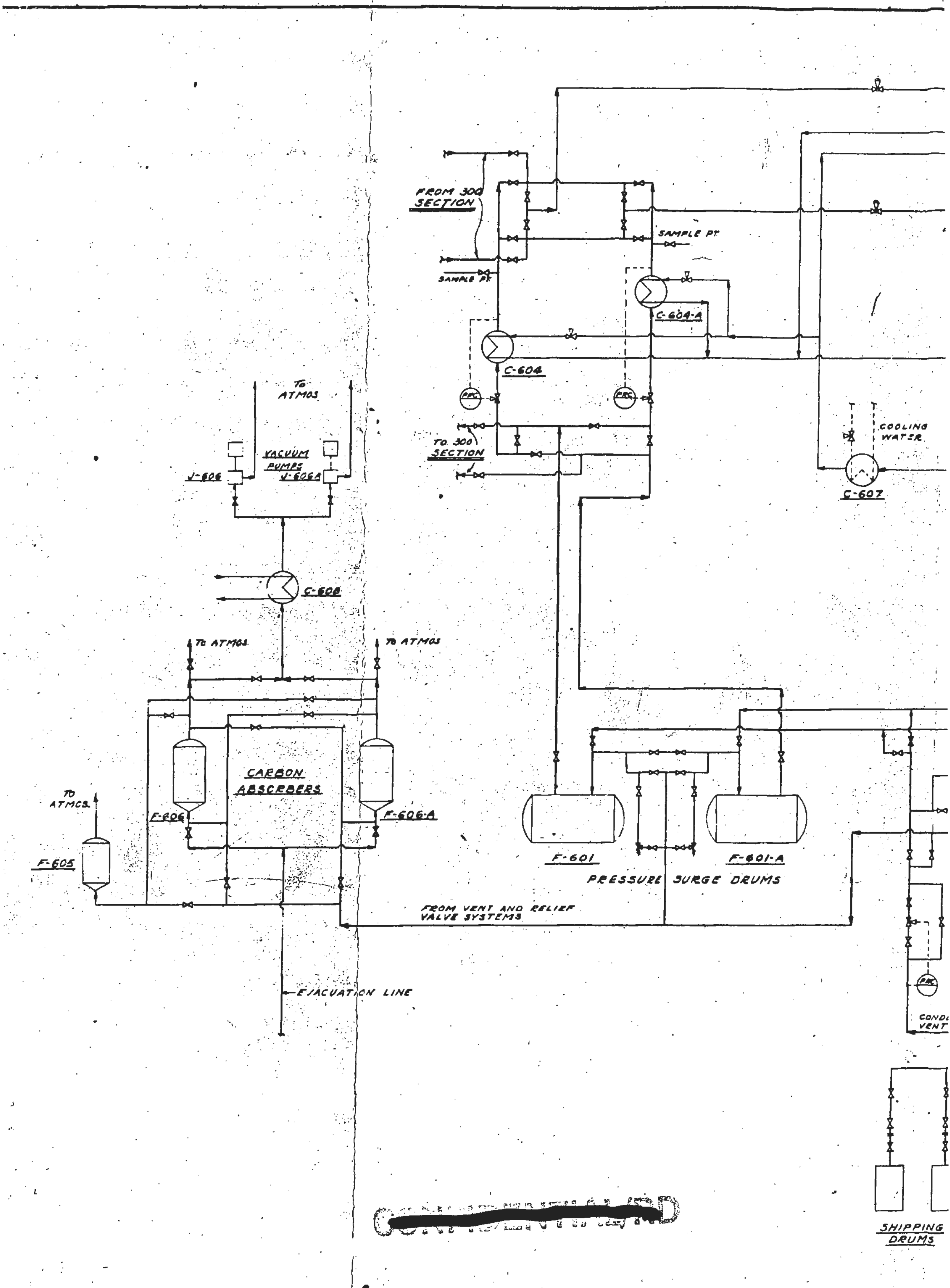

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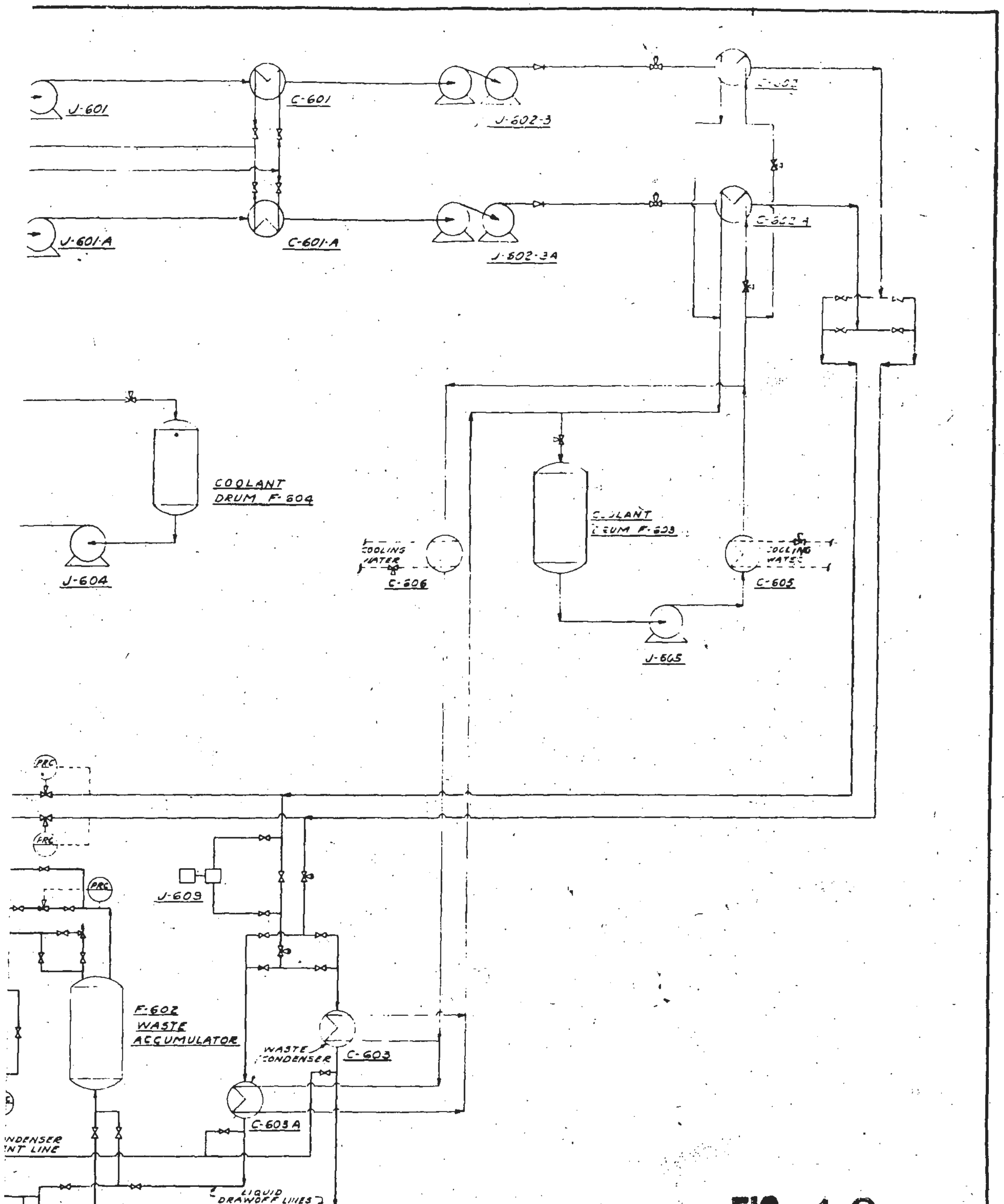

FIG. 10

THE KELLEX CORPORATION

PROCESS FLOW SHEET FOR SURGE AND WASTE SYSTEM

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piped from the Section 600 waste system to chlorine-type cylinders with a capacity of 8000 pounds of UF_6 each. Sufficient cylinder storage capacity was provided for holding the anticipated quantities of waste expected prior to K-27 plant operation.

c. Design Principles. - A reservoir is set up at the bottom of the cascade. When pressure waves occur in the cascade, as a result of a disturbance in process conditions at some point, abnormally high or low flow occurs from the bottom stage of the cascade to the reservoir where the pressure waves are absorbed. The flow of material fed back to the bottom stage from the reservoir is held constant and independent of the varying downflow to the reservoir. The effect is one of stabilization, and absorption of fluctuations.

d. Description. - A schematic flow diagram is shown in Figure 10. The surge system consists essentially of a system of pumps (App. B8), a surge drum, and the necessary appurtenances for control of flow, evacuation, purging, circulation of coolant, etc. The waste system includes a UF_6 condenser, a liquid UF_6 accumulator, and the necessary lines and valves for filling the shipping drums. All equipment is completely spared. Connection to the main cascade is normally made through intersectional cell K-311-1.1 (App. B1). A complete description may be found in Volume XXI of the Kellex Operating Manuals.

7-11. Purging System (Section 312).

a. Purpose. - It is the function of the purging system to remove continuously from the process stream the various contaminating gases ("light diluents") which find their way into the process system primarily from the following sources:

1. Ambient atmosphere surrounding process equipment is maintained at a pressure slightly above barometric pressure (Par. 10-4). Process pressure is below atmospheric. The presence of any small external leak in the vast process system will result in inleakage of air into the process stream. Elaborate precautions taken have minimized this source of inleakage, but the tremendous size and complexity of the plant prevents perfect avoidance of a certain amount of penetration.
2. Nitrogen used as a valve and pump sealant passes into the process stream, and residual nitrogen in stages being placed on stream mixes with the process material.
3. Small amounts of residual fluorine remain in process equipment after conditioning.
4. Hydrogen fluoride results from the reaction of process gas with any moisture which may penetrate into the process system.

b. Capacity. - Three separate cascades are provided, each with a capacity of 6000 standard cubic feet of nitrogen per day. The purge system was designed to separate a purged diluent containing less than 0.002 mol per cent UF_6. This would correspond to a loss of not more than 0.0032 pounds per day of UF_6 at the normal purge rate of 1740 standard cubic feet per day. This material was not actually to be "lost", since the exit gases were first to be passed through carbon traps to retain the UF_6.

c. Design Principles. - The operating principle in the purge section is the same as throughout the process cascade: gaseous diffusion. The four basic elements of the purge stages are the same, in principle, as for the process stages, but the design is different in the following respects:

(1) Diffuser. - Each purge diffuser contains 100 square feet of barrier area arranged in the shape of flat parallel plates. This is preferable to tubular construction because of the small barrier area. Purge cascade converter design is discussed in Paragraph 8-5.

(2) Cooler. - The coolers are exterior to the converters rather than integral with them, for convenience of manufacture.

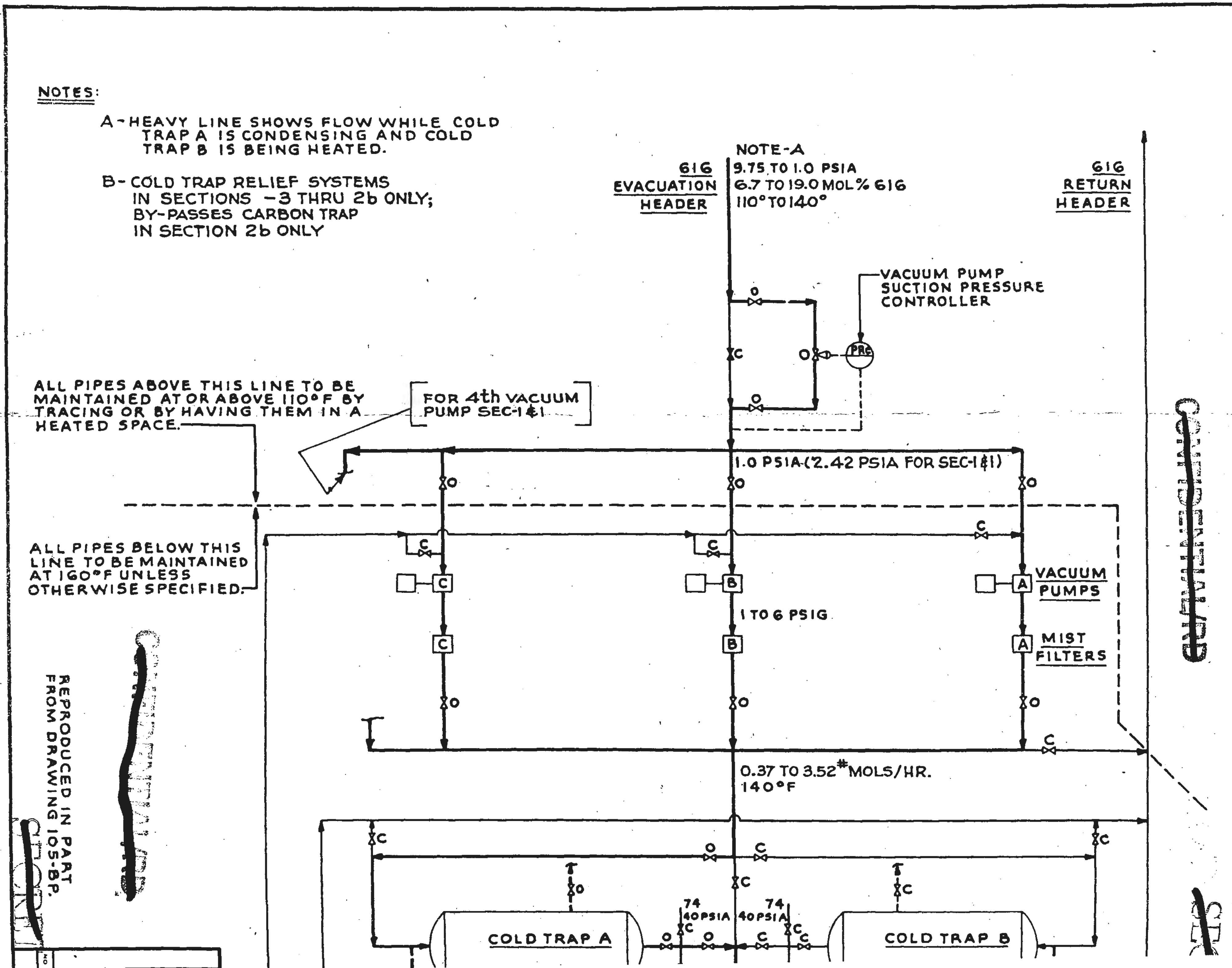
(3) Pump. - The purge pumps are of the reciprocating type, and are bellows-sealed. Moreover, only one pump is used per stage. Purge pump research and design is discussed in Paragraph 8-7a, and Volume 2, Paragraph 6-5.

d. Description. - The purge cascade is housed in Section 312, which contains three buildings (App. B1). Each building contains 21 cells. Each cell contains two stages. The 42 stages of each building form a separate cascade. Most of the diluent nitrogen and air enters the process system at the lower part of the main cascade where equipment sizes are large. In order to provide a means for removing light gases from the process stream before they reach the top section of the cascade where equipment is small, one purge building can be used for purging the main process stream at an intermediate point. A second building is used for purging the top of the plant, and a third is held in stand-by. Process gas may be sent from any one of the top three sections of the main cascade to any one of the three purge cascades. Alternative purge systems considered are described in the Kellex Completion Report, Section III, (1) C. A complete description of purge cascade design and operation may be found in Volume XXVIII of the Kellex Operating Manuals.

7-12. Process Gas Recovery System. -

a. Purpose. - Design of the process gas recovery system for section 300, the main cascade, was aimed at providing a means for evacuating and flushing process gas from equipment to be opened for maintenance, and for recovering this material, storing it temporarily, and returning it to the cascade. It was also planned that process gas recovery facilities should be able to serve as alternate purge facilities in the event of an emergency in which the Section 312 permanent purge cascades might become temporarily unavailable. As described in Volume 5, improved methods of operation have been worked out, eliminating the use of the process gas recovery system except in special circumstances.

b. Capacity. - Original design calculations were based on the specification of a maximum UF_6 partial pressure of 10^{-6} atmospheres in equipment about to be opened for repair. It was desired to make possible the removal of UF_6 from a cell, and its return to process equipment, within five hours. The figure of thirty hours was considered a reasonable time for recovery of UF_6 from a building in one of the larger sections, and sixty hours recovery time for the entire plant was considered satisfactory. Plans were made for facilities which would permit recovery of material from two cells of a building simul-


NOTES:
A- HEAVY LINE SHOWS FLOW WHILE COLD TRAP A IS CONDENSING AND COLD TRAP B IS BEING HEATED.
B- COLD TRAP RELIEF SYSTEMS IN SECTIONS -3 THRU 2b ONLY; BY-PASSES CARBON TRAP IN SECTION 2b ONLY
616 EVACUATION HEADER
NOTE-A
9.75 TO 1.0 PSIA
6.7 TO 19.0 MOL% 616
110° TO 140°
616 RETURN HEADER
VACUUM PUMP SUCTION PRESSURE CONTROLLER
PRC
ALL PIPES ABOVE THIS LINE TO BE MAINTAINED AT OR ABOVE 110°F BY TRACING OR BY HAVING THEM IN A HEATED SPACE.
FOR 4th VACUUM PUMP SEC-1&1
1.0 PSIA (2.42 PSIA FOR SEC-1&1)
ALL PIPES BELOW THIS LINE TO BE MAINTAINED AT 160°F UNLESS OTHERWISE SPECIFIED.
VACUUM PUMPS
MIST FILTERS
1 TO 6 PSIG
0.37 TO 3.52# MOLS/HR.
140°F
74
40 PSIA
74
40 PSIA
COLD TRAP A
COLD TRAP B
REPRODUCED IN PART FROM DRAWING 105-BP.

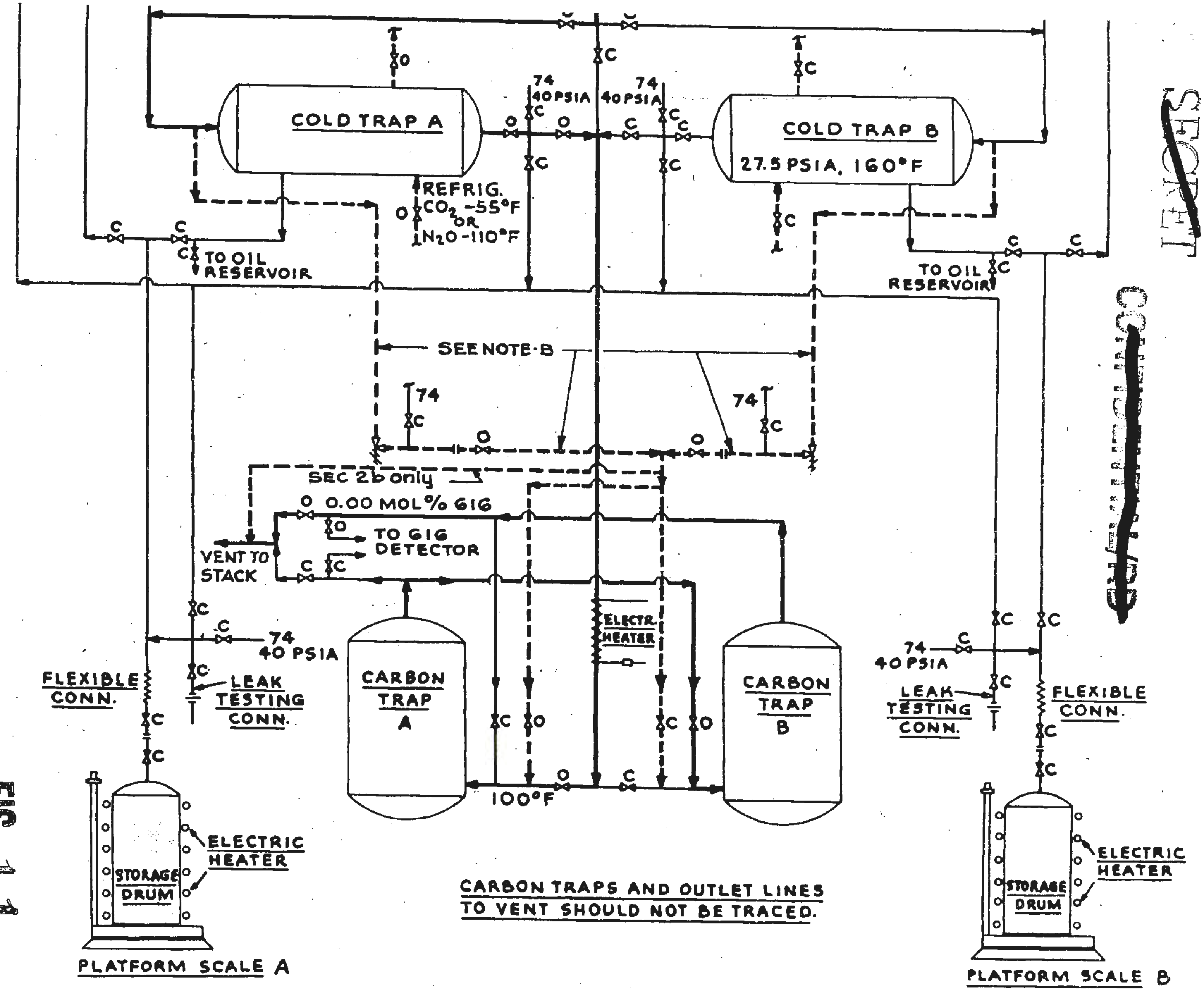


FIG. 11

THE KELLEX CORPORATION

SCHEMATIC FLOW DIAGRAM

PROCESS GAS FLOW 616 RECOVERY SYSTEMS

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taneously. Assuming that an average of 42.4 cells would have to be serviced daily by process gas recovery equipment, a rate of loss of one per cent of enriched light component produced by the plant per day was considered permissible in recovery operations.

c. Design Principles. - Packed column absorption tower systems were considered, but were discarded because of the complexity involved both in equipment design and in operating procedures. The "cold trap" method, chosen instead, involves the evacuation of equipment by a pump which discharges to a refrigerated heat exchanger wherein the UF_6 is caused to solidify.

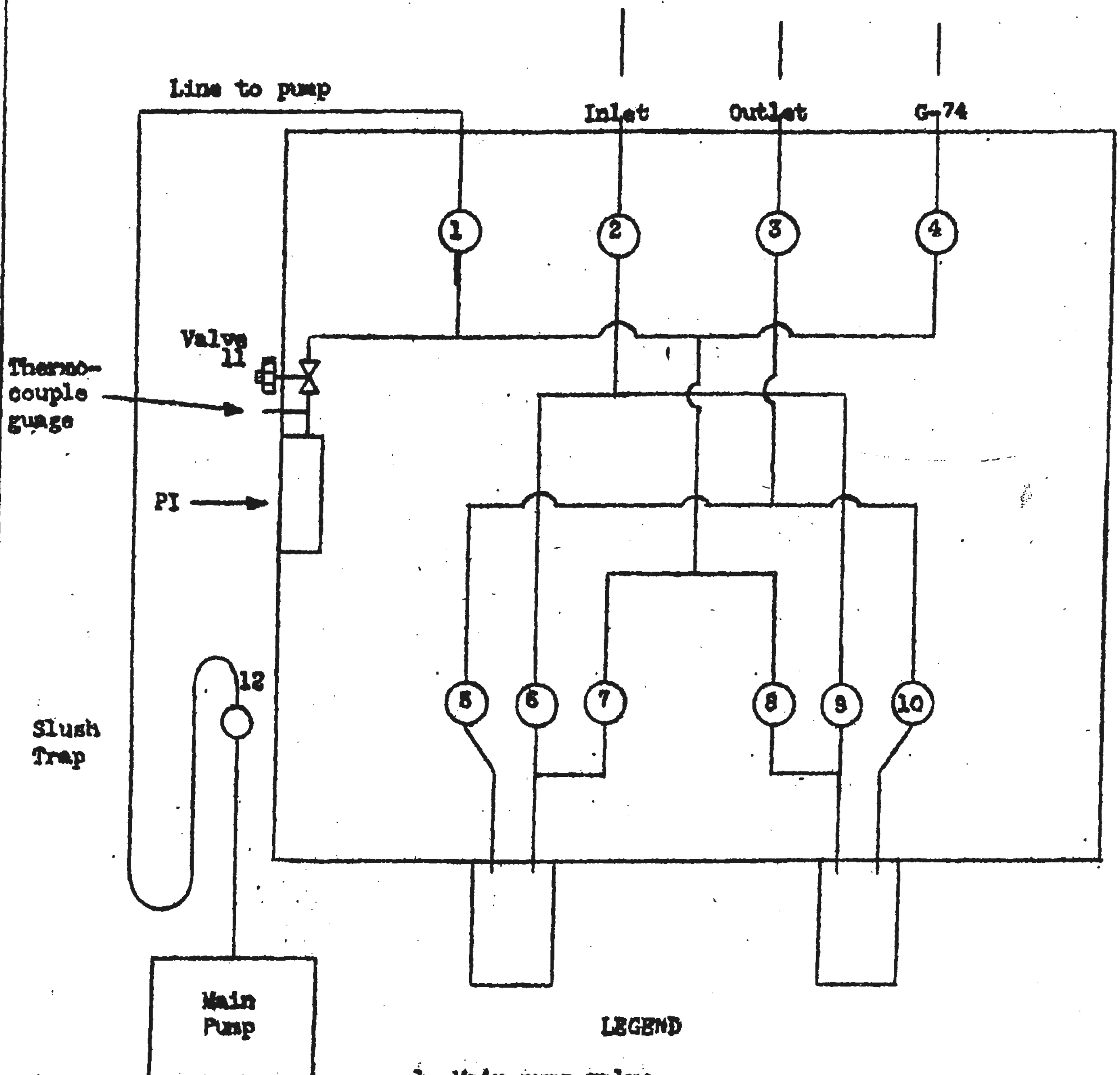
d. Description. - A schematic flow diagram of a typical process gas recovery system is shown in Figure 11, and a photograph of a cold trap room in Appendix E4. The vacuum pump is located ahead of the trap instead of after it, although the latter system would have avoided the necessity of developing a special pump capable of handling UF_6. The alternate system would have required a much lower trap temperature, and piping and trap spaces would have had to be increased to minimize pressure drop. Furthermore, the resultant lower heat transfer coefficients would have required greater cooling area, higher trap weights, and additional refrigeration capacity. All cells and process lines in the main cascade which can be isolated were equipped with evacuation and nitrogen purging connections. Each building was provided with a recovery room containing two cold traps. Two process gas vacuum pumps were furnished in the cold trap room of a building using size 3 or 4 equipment, and in the purge buildings, three pumps in buildings using size 2 equipment, and four in the buildings of Sections

1 and -1. Each pump was provided with an oil mist filter to reduce the oil carryover at the pump discharge. Recovery rooms contain sufficient drum storage capacity to hold the entire plant inventory. Cold trap design is described in Paragraph 8-13. The research and development pertaining to the process gas vacuum pumps is treated in Volume 2, Paragraph 5-8. Further discussion of the K-25 process gas recovery system is available in the Kellex Completion Report, Section III, (1) C, and in Volume XV, Part I, of the Kellex Operating Manuals.

(1) CO_2 Refrigeration Units. - Refrigeration of the cold traps of the process gas recovery systems for Sections -3, -2, -1, 1, and 2a during the condensing cycle, and cooling of the traps after the heating cycle, is accomplished by the direct expansion of carbon dioxide, CO_2. Three central CO_2 units are provided. All are identical and have a refrigeration capacity of 32 tons. Each unit consists of a high temperature stage using Freon-12 as the refrigerant, and a low temperature stage using CO_2. The carbon dioxide is circulated through several low temperature cold traps where it evaporates at -55°F. It then returns to the refrigeration unit where it is cooled by Freon-12, which is in turn cooled by water at 85°F. Extensive description of pumps, piping, and heat exchange equipment is available in Volume XV, Part II, of the Kellex Operating Manuals.

(2) N_2O Refrigeration Units. - Refrigeration of the cold traps for sections 2b, 3a, 3b, 4, and the purge cascades, is accomplished by direct expansion of nitrous oxide, N_2O. Ten central N_2O units are provided. All are essentially similar, but differ in capacity and in details of equipment arrangement. Each unit consists

PRODUCT WITHDRAWAL SYSTEM



LEGEND

1. Main pump valve.
2. Main inlet valve.
3. Main outlet valve.
4. G-74 valve.
5. Left cylinder outlet valve.
6. " " inlet "
7. " " pump "
8. Right " " "
9. " " inlet "
10. " " outlet "
11. Hoke valve on line to guage.
12. Valve on monel trap.

FIG. 12

of two stages, the higher temperature stage using Freon-12 as refrigerant, and the lower stage using N_2O. Pre-cooled liquid N_2O flows to the cold traps where it is evaporated at -110°F. The N_2O then returns to the refrigeration unit where it is cooled by Freon-12, which is in turn cooled by water at 85°F. Extensive description of facilities is available in Volume XV, Part III, of the Kellex Operating Manuals.

7-13. Product Withdrawal System. - The final product of the K-25 plant, uranium hexafluoride enriched in isotopic concentration of Uranium-235, is drawn off at a point near the top of the cascade. Ordinarily, the operation is carried out in Building K-306-7. The product withdrawal system is shown in schematic form by Figure 12. Two stands are provided for accommodating product cylinders, which are made of aluminum, silver, or, more commonly, monel metal. The containers have flanged heads and are bolted securely in place using a high quality vacuum-tight connection. A mechanical vacuum pump (protected against traces of UF_6 by means of a dry ice slush trap) is used to evacuate the container to several microns. Nitrogen purge lines are available (indicated in the diagram by the code name for nitrogen, G-74). Product process material flows through the cylinder which is immersed in liquid nitrogen. The product container acts as a trap, solidifying UF_6, and allowing non-condensable diluent gases to leave by way of the outlet line. The inlet and outlet lines are connected to the line recorder sample manifold (Vol. 2, Par. 8-3). Differential process pressure drives the process material into the product system, and the light gases back to the line recorder manifold. A thermocouple gauge and indicator are provided as shown for measuring pressure within the product system. Product container capacity is so designed as to prevent the possibility of accumulating dangerous quantities of fissionable material.

7-14. Temporary Purge and Product Systems.

a. Case Operation. - In order to obtain earliest and fullest utilization of the K-25 plant, portions of the cascade were placed into operation as soon as completed. The production operations were thus carried on under five separate "cases" which included cascade sections as tabulated below:

Case I	Sections -2, 2a
Case II	Sections -3, -2, 2a, 2b
Case III	Sections -3, -2, -1, 1, 2a, 2b
Case IV	Sections -3, -2, -1, 1, 2a, 2b, 3a, 3b
Case V	Sections -3, -2, -1, 1, 2a, 2b, 3a, 3b, 4 (i.e., entire cascade)

A discussion of case operation is presented in Volume 5.

b. Function of Temporary Purge and Product Systems. - The permanent purge cascade of Section 312 was not scheduled for completion during the period of Case I, II, or III operation. Temporary purge and product systems were therefore designed and provided at the top of section 2a (which was the top of the operating cascade during Case I), and at the top of section 2b (which was the top of the operating cascade during Cases II and III). The Section 2a system provides the following services:

1. Continuous purging from the top of Section 2a when the buildings of Case I are operating as a unit.

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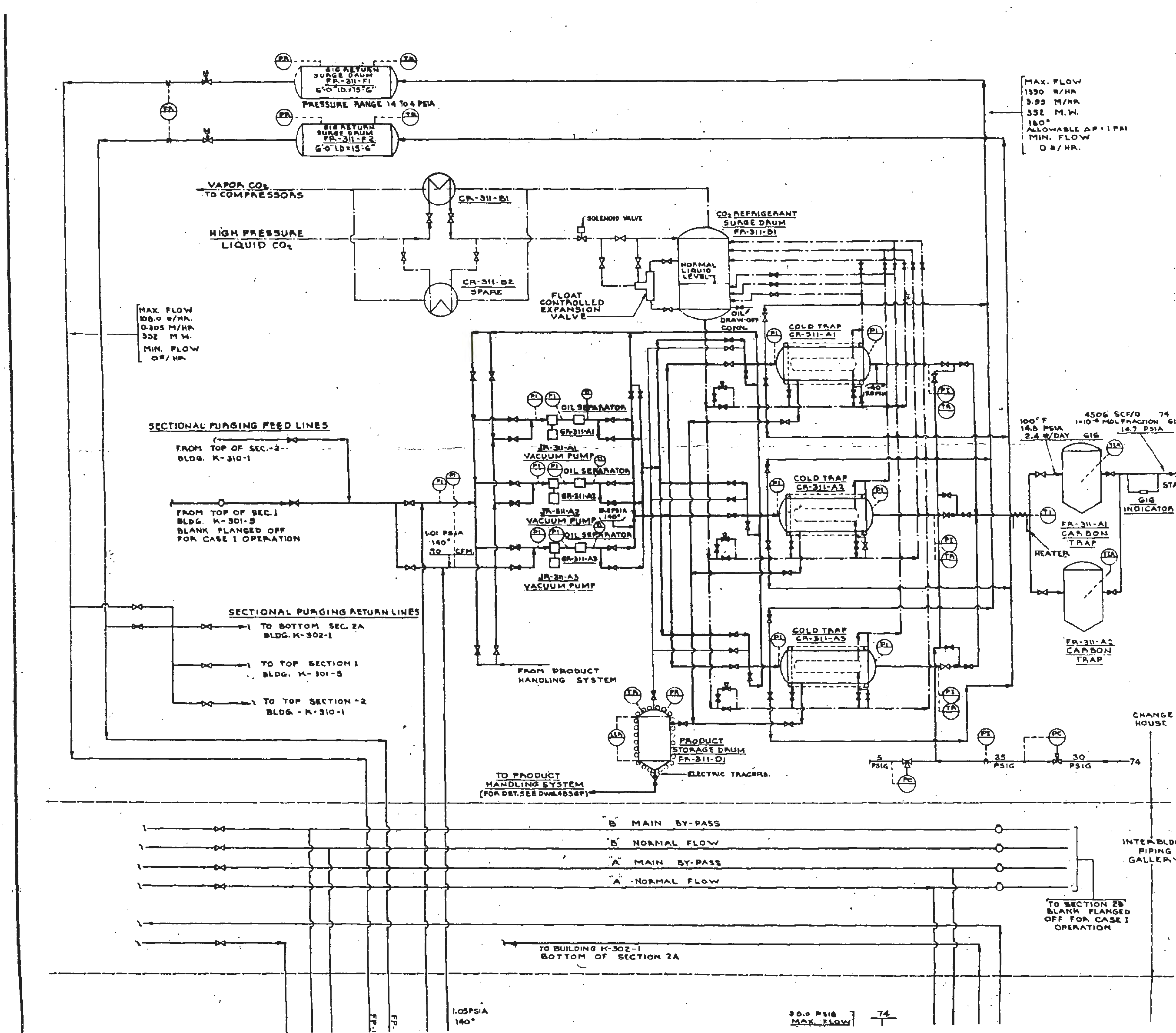

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TEMPORARY PURGE AND PRODUCT SYSTEM (SECTION 2A)

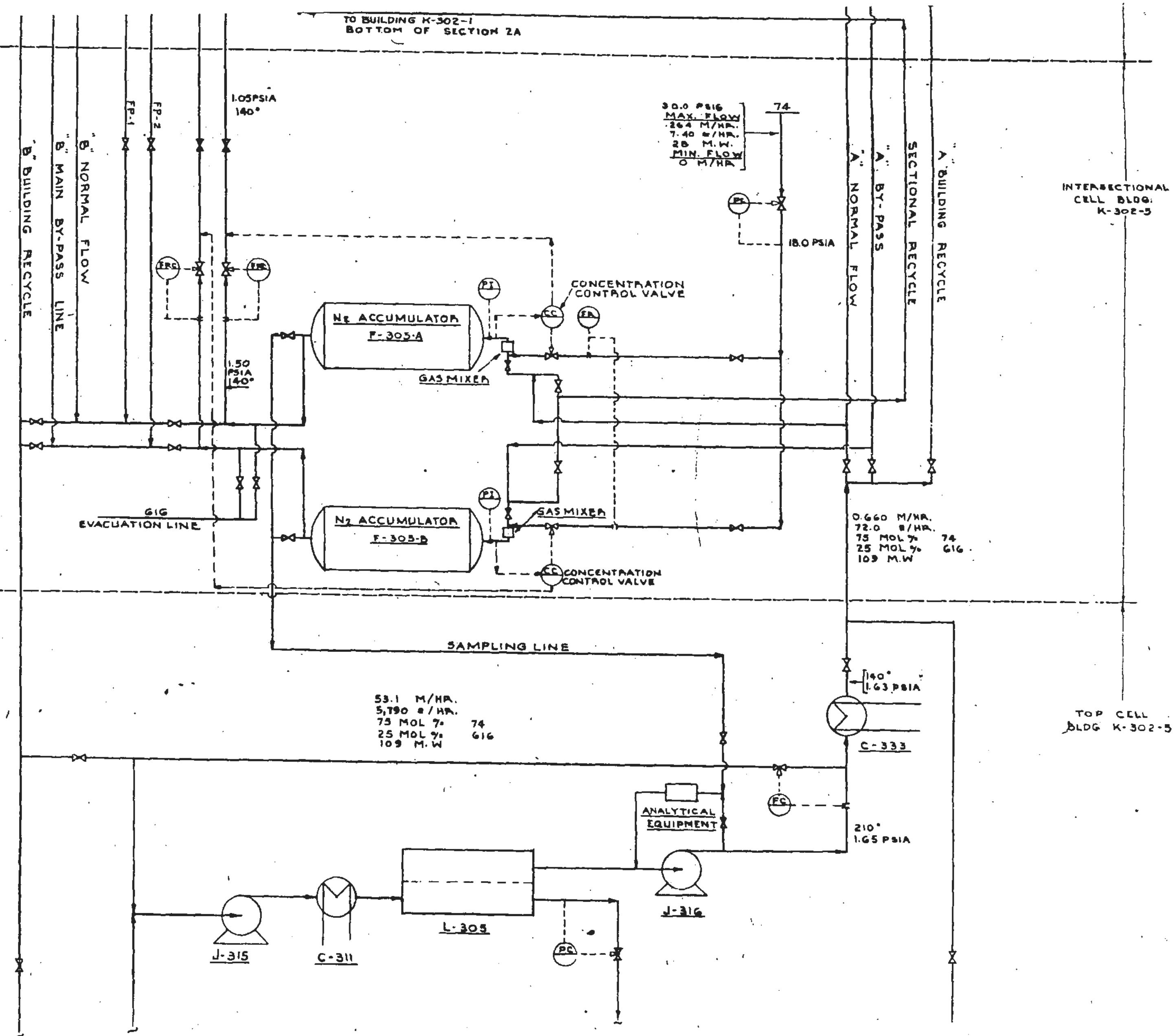

FIG. 13

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2. Product withdrawal at some given rate for Case I operation.

3. Purging from the top of Section -2, 1, or 2a, in the event of any sectional operation, Case I, Case II Case III, etc.

4. Return of purged process gas to the process stream at top of 2a.

The 2b system was designed to serve similar purposes during Case II and III operation.

c. <u>Description.</u> - The operating principle of the permanent purge cascade (Section 312) is gaseous diffusion as in the stages of the process cascade proper. However, the temporary purge and product systems separate light non-condensable diluents from the process stream by condensing the UF_6 present, rejecting the waste gases, and re-vaporizing and returning the uranium hexafluoride to the cascade. The following description applies to the section 2a system. A detailed discussion is presented in Volume XVI of the Kellex Operating Manuals. The Section 2b system is the same in principle, differing somewhat in equipment size and arrangement. Details may be found in Volume XXII of the Kellex Operating Manuals.

(1) <u>Condensing System.</u> - Two of three available 50 cubic feet per minute vacuum pumps take their suction from either of two common headers (Fig. 13). The pumps discharge through mist filters into separate discharge headers. The two headers lead to the three cold traps. The outlet gas from the cold traps flows through a single header to two of three carbon traps connected in series. The third is connected only to the product withdrawal equipment.

(2) Process Return System. - An electrical heater system for each cold trap is used to heat the trap and vaporize the deposited solid UF_6. There are two UF_6 return headers, either of which may serve any cold trap. Each header leads directly to a 500 cubic foot return surge drum located in the intersectional cell in Building K-302-5. Either surge drum may be discharged to the process cascade at any of four points.

(3) Product Withdrawal System. - The cold trap electric heaters are used to liquefy the UF_6 when draining it as product. A drain line from the bottom of each trap connects it to a holding or storage drum located below it on the side of a pit. Another line, connecting the top of the storage drum to the vapor inlet of each trap is opened to equalize the trap and drum pressures when draining. The storage drum drains to the shipping drums, which may be connected at three positions at the bottom of the pit. The shipping drum connections may be purged to the suction of the pumps or to the third carbon trap. A 6 cubic feet per minute pump is located on the outlet of this carbon trap and serves to evacuate the shipping drum and the connection below the normal operating suction pressure of the 50 cubic feet per minute pumps.

SECTION 8 - DESIGN AND PROCUREMENT OF PROCESS EQUIPMENT

8-1. Introduction. - This section presents a description of the design of process equipment installed in the gaseous diffusion plant. Flow charts, in Appendices C1, C2, C3, and C4 illustrate the flow of materials, equipment, and component parts thereof between the principal contractors. Chart C1 shows the relationship between the Architect-Engineer or designer, the various suppliers, and the final fabricator of equipment for the diffusion process plant. Charts C2, C3, and C4 depict, in greater detail, the procurement of pumps, barrier tubes, and diffuser units, respectively. Contracts of major importance are discussed in connection with procurement activities. Development and procurement of special chemicals is covered in Book VII. A complete listing of all other Manhattan District design, engineering, and procurement prime contracts attributable to the K-25 Project (including K-27) is presented in Appendix A. As a supplement to the following discussions, reference should be made to this appendix for such information as contract types, effective dates, methods of letting, and costs.

8-2. Role of The Kellex Corporation. - Under the terms of their contract with the Government, The Kellex Corporation was required, among other things, to furnish procurement, engineering, supervisory, and consultant services. Because of the nature of the gaseous diffusion process, many new materials and items of equipment had to be developed and, in a number of cases, manufacturing plants had to be designed for their manufacture. Because of the intensity of the engineering and design problems, the work was performed, in part, by a large number of firms under the general supervision of the Kellex Corporation. In many cases, the individual problems could be solved only by the joint efforts of several contractors. Most of the equipment was obtained under Government supply contracts, with The Kellex Corporation acting as the Contracting Officer's authorized representative on technical phases of the work, inspection, and tests. Contract specifications were prepared by The Kellex Corporation or by other firms and institutions working under their general supervision.

8-3. Barrier.

a. Selection of Barrier Type. - A description of the work on research, development, and evolution of materials and methods for barrier manufacture, is presented in Volume 2, Section 4. As the result of this research, the A, or Norris-Adler, type of barrier was selected for initial small scale production and further study in pilot plants. This was later supplanted by the DA barrier.

b. Preliminary Engineering.

(1) Houdaille-Hershey Corporation. - The Houdaille-Hershey Corporation, under contract W-7405-eng-55, had constructed a pilot plant in a portion of their plant at Decatur, Illinois. Their contract also called for research and development of barrier, and the operation of the pilot plant for small scale production. Previous laboratory production of this barrier indicated that it would be satisfactory for use in the K-25 plant. The production of the barrier on a large scale was therefore undertaken, and another contract, W-7405-eng-149, was negotiated with the same firm. DELETED

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Subsequently, it was determined that facilities available at the Houdaille-Hershey plant were insufficient. The contract was therefore modified and a Government-owned plant was erected by the George A. Fuller Company under contract W-7405-eng-131 (App. E18).

(2) The Sharples Corporation. - The Sharples Corporation, under contract W-7405-eng-143, also conducted research studies, experimental investigations, and production tests on barriers.

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(3) A. S. Campbell, Inc. -

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They installed and operated a small test plant for the production of this tubing on an experimental basis. The manufacture of this special tubing was proven to be feasible if required for the upper sections of the plant.

c. Production.

(1) Final Choice of Barrier. - As indicated in Volume 2, work on the A barrier was abandoned after 16 January 1944 (App. F18), on account of difficulties encountered in its manufacture.

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Accordingly, plans were made for the immediate conversion of the plant to the production of the K-1 or DA type of barrier. Part of the procedure and equipment was directly applicable to the new type of barrier.

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(2) <u>Cooperating Firms.</u> - However, some new procedures had to be developed. Through the cooperation of several firms, mass production was attained in ten months.

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(3) Principal Subcontractor. -

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This subcontract was cancelled 16 January 1944, when the decision was made to change from the A barrier to the K-1 barrier. Subsequent to the cancellation of the above subcontract, this firm was awarded several additional subcontracts for equipment required for the manufacture of K-1 barriers.

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8-4. Process Converters.

a. Development of Design.

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(2)

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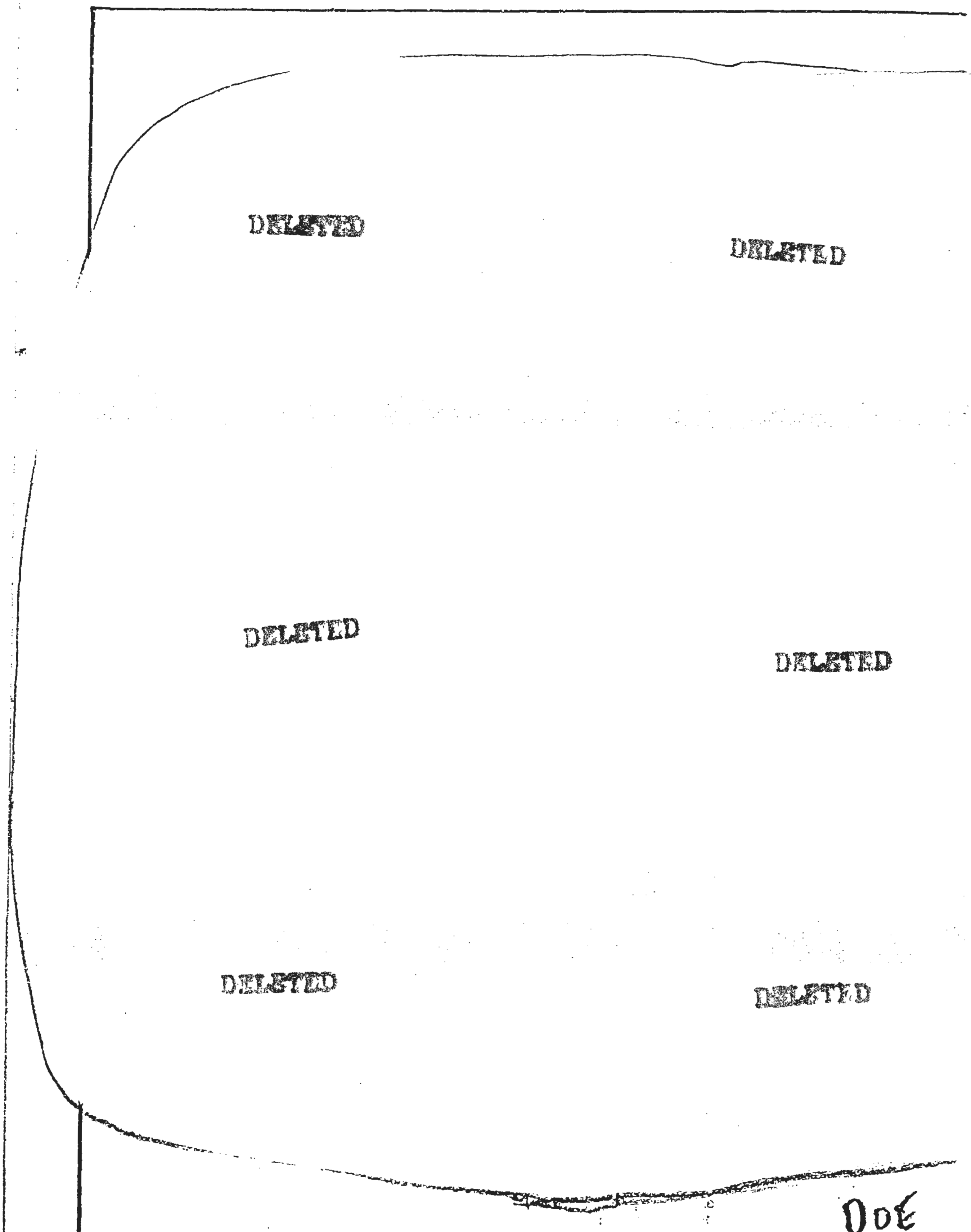
(6) Integral Converter-Cooler-Pump Design. - It was planned at one time to build the converter, cooler, and pumps into a common stage casing with the whole enclosed in an air-conditioned shell. Advantages of compactness and minimum process piping were apparent, but practical difficulties were met in the working out of manufacturing schemes because of divided responsibility for the units, which would have to be fabricated in part by diffuser manufacturers, and in part by

pump manufacturers. It was ultimately decided to arrange the pumps as separate and distinct units from the converter, but to include the gas cooler integrally with the diffuser. An advantage in this decision, which later became apparent, was the relative ease with which the several changes, which were subsequently made in pump design, could be incorporated. Anticipating problems in the repair and maintenance of cooler tubes which might fail in service, the Carbide and Carbon Chemicals Corporation, operating contractor for the K-25 Plant, suggested that the cooler also (in addition to the pumps) be removed from the diffuser and fabricated as a separate, and therefore more accessible, unit. The designer (Kellex Corporation) believed that such a change, at such a stage in the progress of converter design, would be likely to disrupt delivery schedules. Two important changes were incorporated in a modified design which, though retaining the cooler as an integral part of the converter (and therefore requiring a minimum amount of change in manufacturing procedures), effected great simplification of maintenance. Whereas the coolant inlet and outlet lines were previously located at diametrically opposite points in the process fluid entrance head (coolant flow dividing between two semi-circular banks of tubes), the coolant outlet was now relocated to a point adjacent to the inlet, and all coolant flow directed through a completely circular path. The second change consisted of arranging a small bolted (i.e., removable) cover plate at the coolant connections. This makes possible the testing and blanking off of defective tubes without cutting away the entire converter head. Some 896 size 2 converters had been built with the old style coolers before this change was made. From that point on, the new type was manufactured. Appendix B1 shows the distribution of converters installed at K-25, classified according to type of cooler. All cells



GAS COOLER

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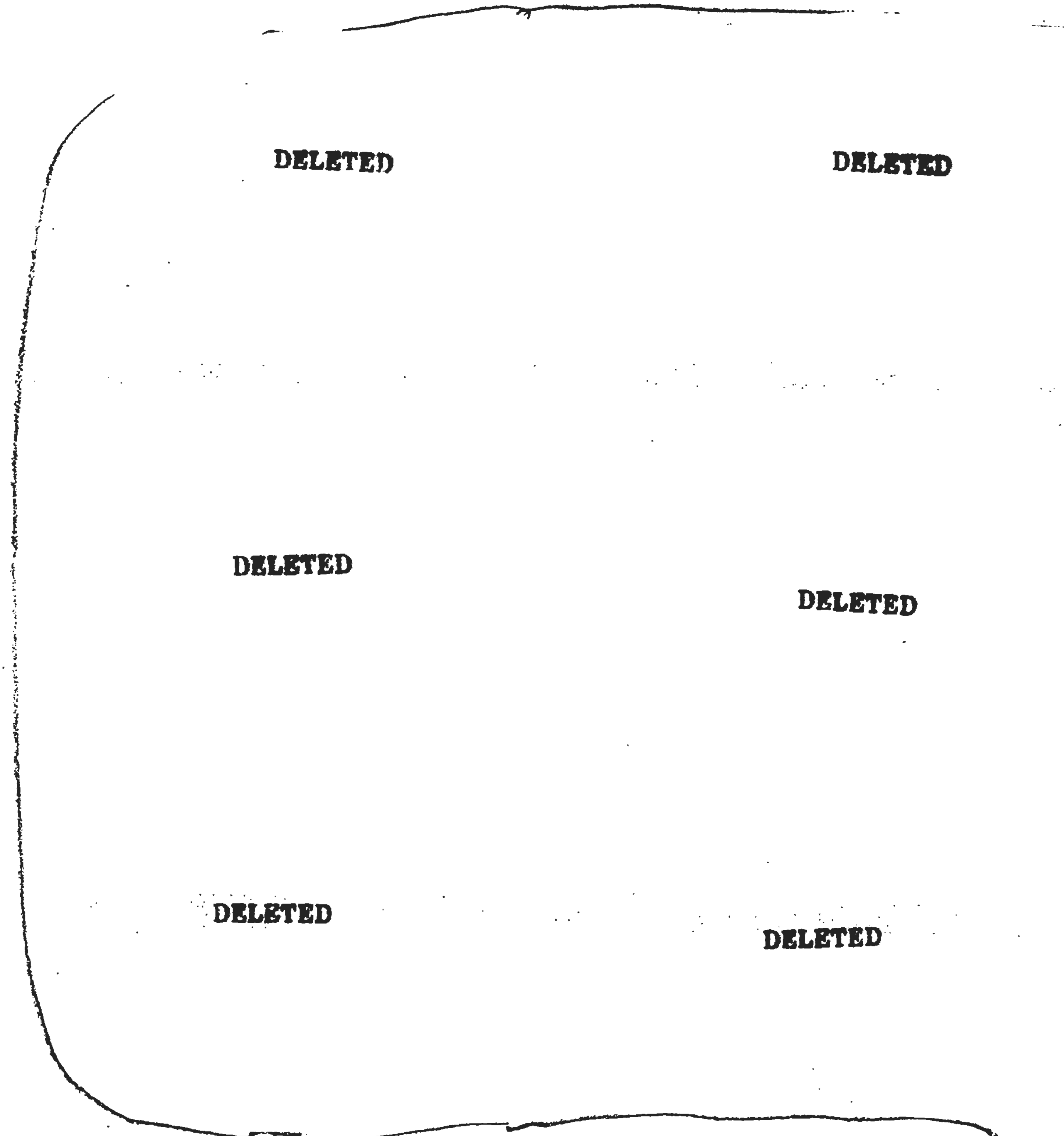

TUBULAR CONVERTER
WITH COOLER

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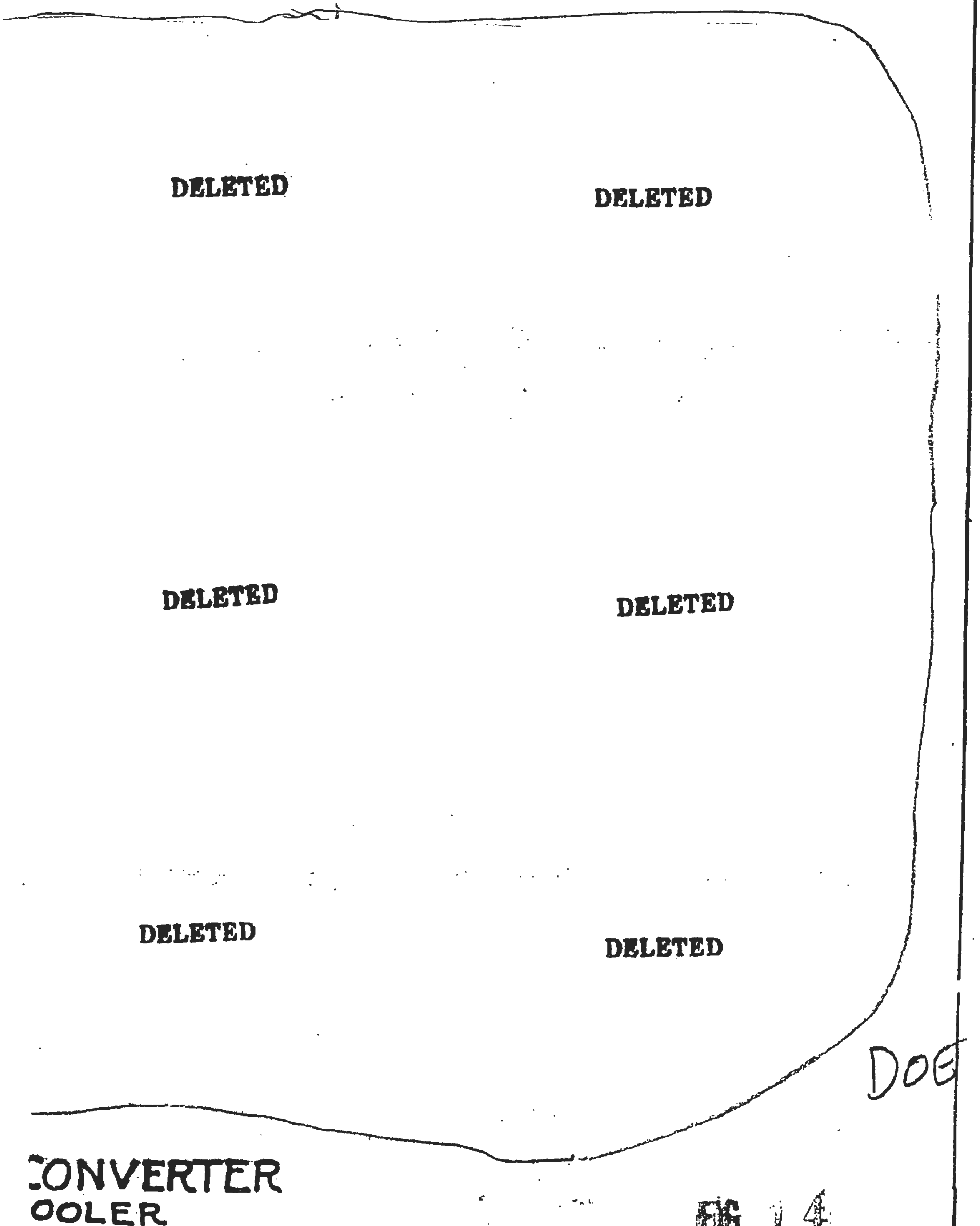
b(3)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ONVERTER
OOLER

FIG. 14

DOE b(3)

there designated by "N" contain converters of the new type as described above.

b. Final Design. - Final converter design is shown in Figure 14 and Table 8, facing page 8.10. The barrier tubes are supported by circular tube sheets at the ends, and by two plates at intervening points. The whole is made rigid by ribs on the inside of the tube sheet attached to a central core. Pipe struts running between tube sheets afford further bracing of the tube bundle. One end of the tube sheet is free to move in thermal expansions. No appreciable difference exists between the expansion coefficients of the tubes and the supporting core. DOE b(3)

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Stamped monel is used for cross over covers. All other parts are nickel plated. The cooling coils had to be brazed into a tube sheet. This represented a bottleneck until a furnace, especially designed for this purpose, was adopted. An important feature of the converter design is the absence of any pockets which would be difficult to clean and drain.

c. Production.

(1) Development Contract. - The Chrysler Corporation was awarded contract W-7405-eng-56, on the basis of reimbursement for cost including an overhead allowance. This contract provided for the development of the basic Kellex design and methods of procedure for the volume production of diffusion units (with coolers installed) and for the determination and design of facilities appropriate for each production operation. Chrysler produced all final detail and assembly designs and drawings, and worked out the detailed procedures for each

TABLE 3. - CONVERTER DATA

SIZE	NUMBER INSTALLED	CONVERTER DIAMETER	CONVERTER LENGTH	TUBE DIAMETER	TUBE LENGTH
1	512	6' 8-1/2"	11' 5"	5/8"	7' 5-5/8"
2*	616	5' 8-1/2"	11' 1-1/2"	5/8"	7' 5-5/8"
2	138	5' 8-1/2"	10' 8"	5/8"	7' 5-5/8"
3	1050	4' 2"	8' 4"	5/8"	5' 2-5/8"
4	676	3' 8"	5' 6"	5/8"	3' 2-5/8"
	[illegible]				

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* Old style fabrication, without removable coolant connection plate.

NOTE: 540 Size 2 converters are installed in K-27. These are in addition to, and are identical with, those described by the third horizontal line in the table.

manufacturing step. This data was studied and approved by Kellex, Carbide, and the Manhattan District. The contract was modified to include provision for the construction of pilot plants, and the training of personnel for volume production.

(2) Production Contract. - Subsequently, contract W-7405-eng-127 was awarded this firm on a cost-plus-fixed-fee basis. This contract provided for the following:

1. Removal of existing operations in the contractor's Lynch Road Plant in Detroit, and its renovation for use for the manufacture of diffusers.
2. Construction of a new building by the Government to house additional facilities, known as the "Mound Road" Plant.
3. Procurement and installation of production equipment.
4. Manufacture of approximately 3300 diffuser units in four sizes.

(3) Plant Facilities. - During the early negotiations, it was contemplated that a building of approximately 800,000 square feet would be required for this operation. But, in view of a War Production Board request that this construction in the Detroit Area be avoided, if possible, other arrangements were made. Chrysler agreed to use its Lynch Road facilities, which were then occupied by other work, for converter manufacture, provided the Government would pay the cost of re-locating and moving existing equipment to other facilities of the contractor. New construction was limited to a building of approximately 150,000 square feet which was to be provided by the Government on the

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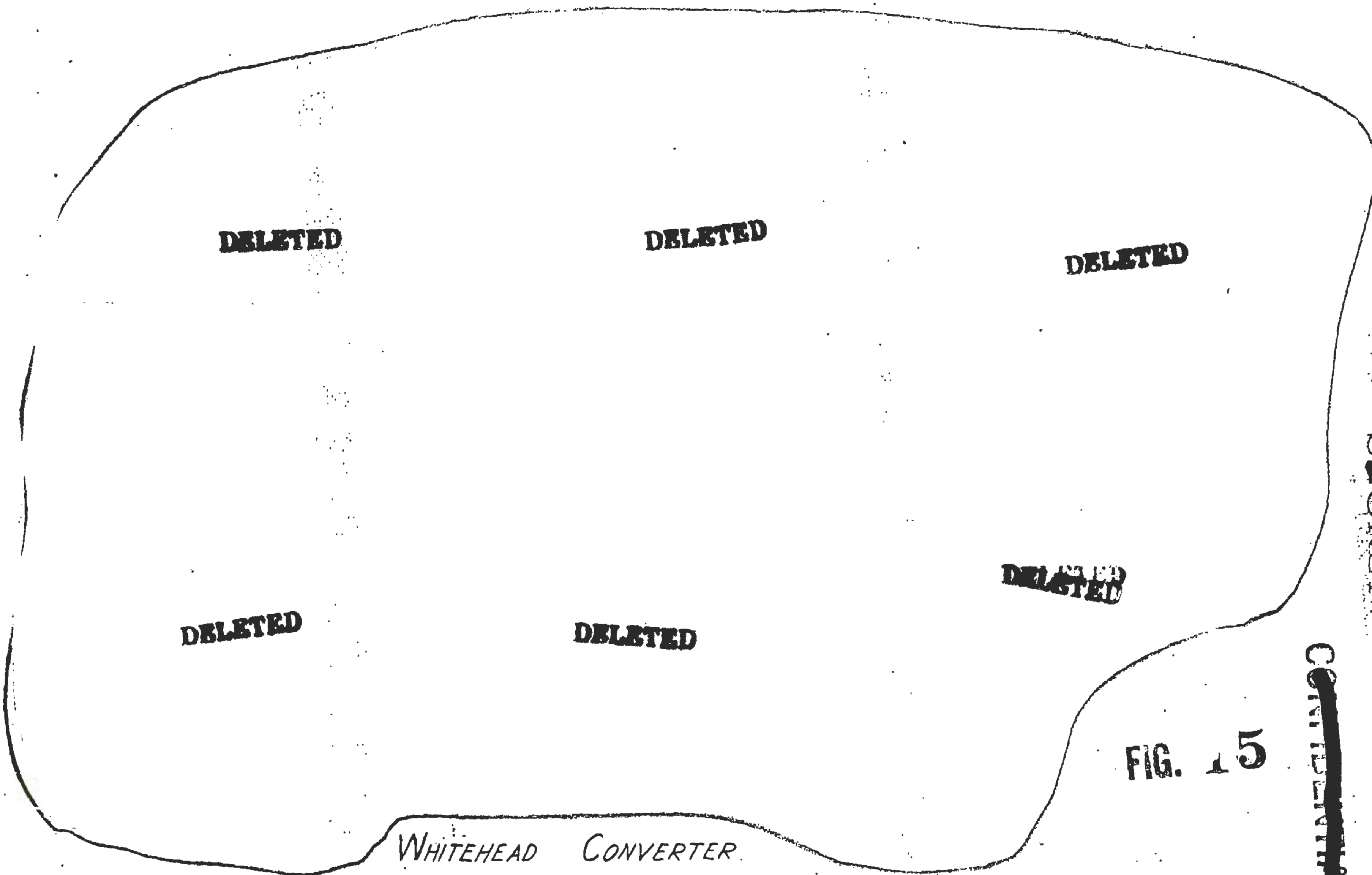

FIG. 15

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DOE b(3)

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contractor's property adjacent to the Mound Road Plant. All material required for the manufacture of the diffuser units was contractor-procured, except the barrier tubes which were furnished by the Government under separate contract with the Houdaille-Hershey Corporation. Albert Kahn, Inc., acted as architect-engineer for the plant construction under contract W-7405-eng-129.

8-5. Purge Converters. - Flat plate converters were originally designed for installation in Sections 5 and 6 of the gaseous diffusion plant. These sections were never built, but the design of these converters was used without major change for service in the purge cascade.

a. Design. - Application of the theory of viscous flow indicated that a 3/32 inch clearance between plates would result in adequate mixing efficiency. With such a small clearance, pressure drop considerations limited the flow path to less than two feet.

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The purge stage cooler (Par. 8-8, and Fig. 16, facing p. 8.14) is fabricated separately and connected directly to the converter. An account of the evolution of purge stage design may be found in the Kellex Completion Report, Section III, (9).

b. Production. -

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DOE b(3)

8-6. Process Pumps. - An account has been presented in Volume 2, Paragraph 5-1, of the research, development, and evolution of process pump design. This paragraph outlines the history of the process pump program from the point of view of procurement.

a. Preliminary Engineering. - The early design of the process pumps was performed by Kellogg under OSRD Contract OEMsr-406 (App. F1) with technical assistance from their subcontractor Ingersoll-Rand. At the same time, the Kellogg group worked with the Elliott Company (App. F19) on centrifugal blower and seal designs. The Westinghouse Electric and Manufacturing Company also designed and developed six gas bearing sealed motors for experimental use under contract W-7415-eng-61. Later Kellogg collaborated with the Allis-Chalmers Manufacturing Company in the final design of the process pumps. Under the terms of contract W-7405-eng-62, which was negotiated on the basis of reimbursement for cost including an overhead allowance, Allis-Chalmers was to provide for the design, development, and manufacture of twenty centrifugal pumps and drivers for the pilot plant of The Kellex Corporation. The contract was subsequently extended from August 1943 through December 1944, and increased to twenty-two pumps. The work performed under this contract led to a suitable design for the large scale production required for the gaseous diffusion plant.

b. Production.

(1) Plant Facilities. - Contract W-7405-eng-34 was negotiated on a cost-plus-fixed-fee basis with the Allis-Chalmers Manufacturing Company. This contract called for the construction by sub-contract of a building (App. E19) suitable for the manufacture of special

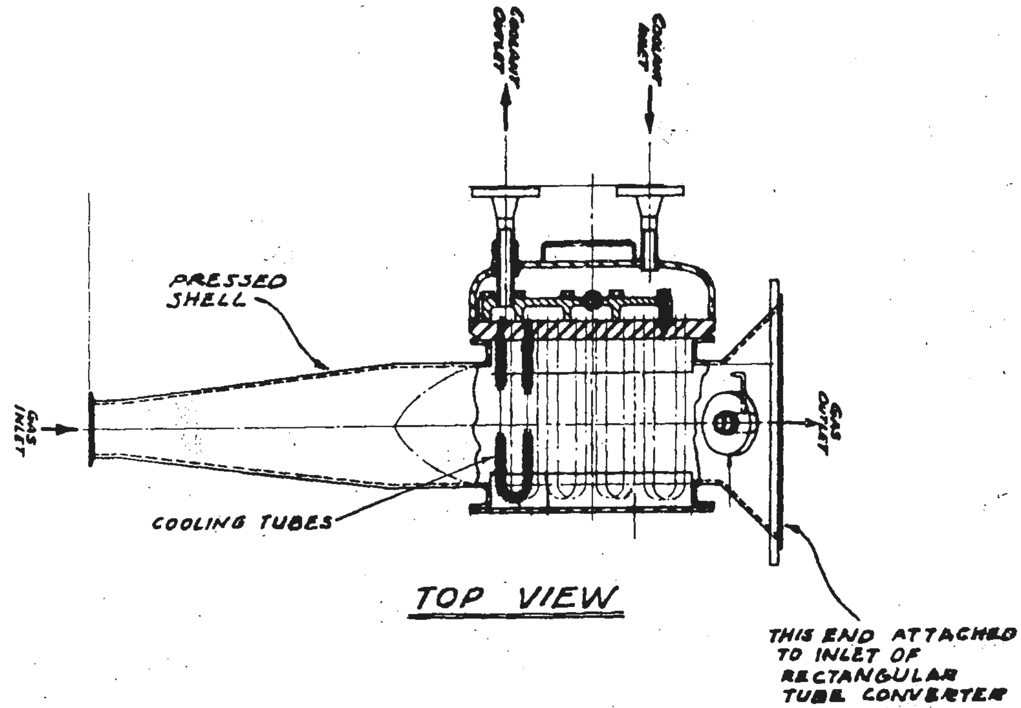
pumps and drivers, and the procurement and installation of the necessary machinery and equipment for manufacturing operation. Subsequent modification provided for the installation of some of the equipment in the contractor's own plants, the subcontracting of the machinery installation, and the installation of a cleaning line.

(2) <u>Production Contract</u>. - Contract W-7405-eng-63 was also negotiated with this firm on a cost-plus-fixed-fee basis. This contract provided for the manufacture of 6102 pumps in five sizes, varying from 11,200 CFM (cubic feet per minute) with an 85 horsepower motor, to 1200 CFM with a 6.3 horsepower motor. The contract was subsequently modified several times, finally providing for 6185 pumps and 5872 motors varying from 100 to 7-1/2 horsepower, 53 special lubricating systems, and changing the motors from a totally enclosed type to a standard type.

(3) <u>Nickel Clad Stock</u>. - The Lukens Steel Company, under contract W-7405-eng-67, furnished facilities for the installation of Government-owned equipment, and for the manufacture of nickel clad plates, bars, and cylinders necessary for the pumps manufactured by Allis-Chalmers. This contract was negotiated on a unit price basis with periodic adjustment provisions.

8-7. <u>Service Pumps</u>. - For research, development, and final designs evolved, reference should be made to Volume 2, Section 5. Procurement activities are outlined in this paragraph.

a. <u>Purge Pumps</u>. - The Valley Iron Works, under contract W-7407-eng-49 designed, developed, and manufactured 140 bellows-sealed reciprocating piston pumps and base plates for the purge cascade system. This contract was negotiated on the basis of unit price with provisions



TOP VIEW

INLET COOLER
FOR RECTANGULAR TUBE
CONVERTER

FIG. 16

for periodic adjustments.

b. Conditioning Pumps. - The Elliott Company furnished the conditioning pumps under contract W-7421-eng-14.

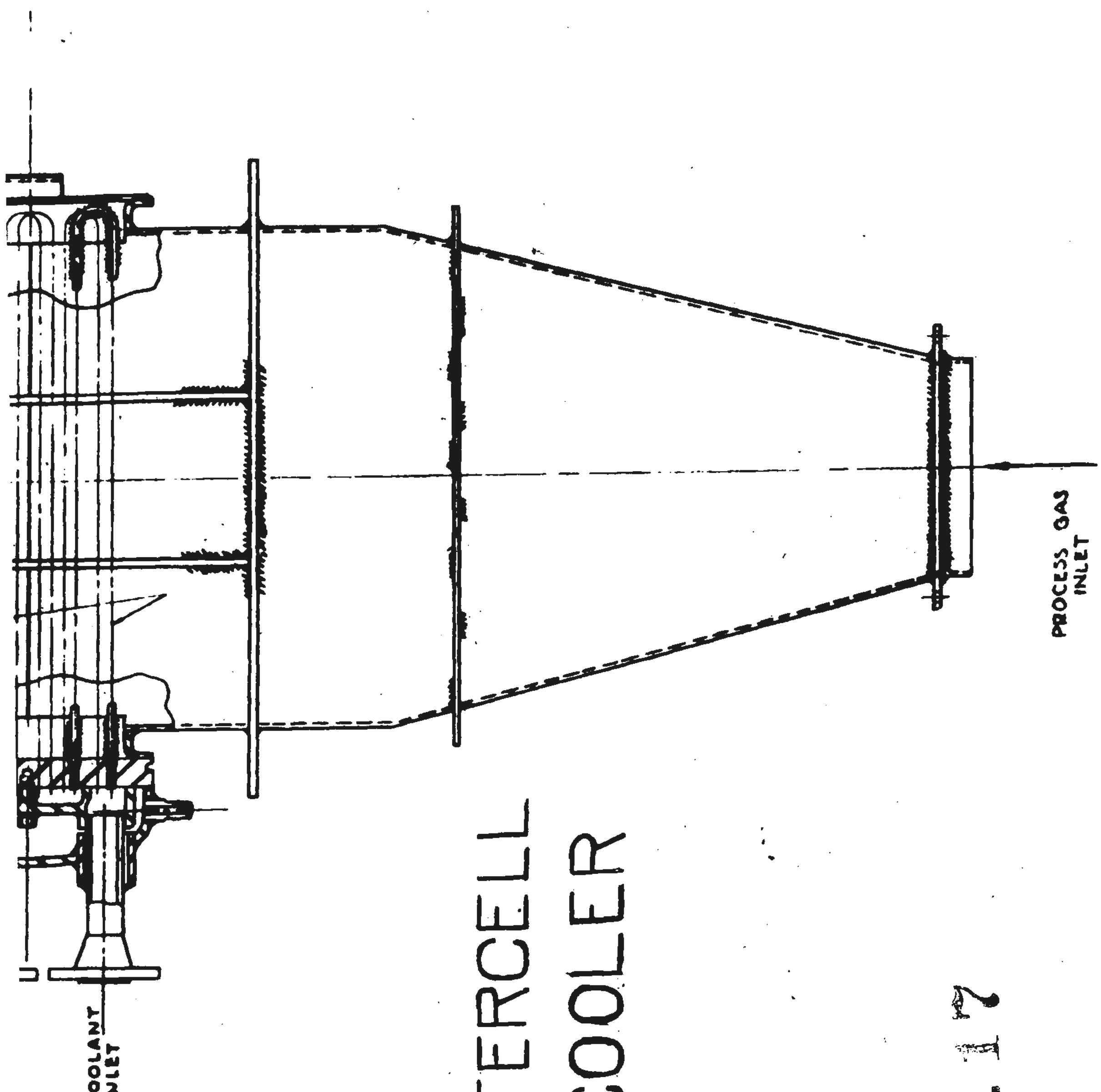
c. Coolant Pumps. - The coolant circulating pumps were manufactured under contract W-7401-eng-85 by Pacific Pumps, Inc.

d. Vacuum Pumps. - Process gas vacuum pumps were supplied under contract W-7415-eng-34 by the Beach-Russ Company. Fluorine vacuum pumps were supplied under contract W-7415-eng-21 by the F. J. Stokes Machine Company. High vacuum pumps were supplied under contract W-7418-eng-40 by Westinghouse.

8-8. Process Gas Coolers. - In addition to the internal gas coolers (one of which is located at the inlet head of each process stage converter for the purpose of removing heat of compression) and the analogous external purge stage coolers, external coolers (serving a supplementary purpose) are located at various points in the cascade as follows:

1. One intercell cooler on the discharge side of the "A" pump at the top of every cell, in the line feeding the next higher cell.
2. One intercell cooler on the discharge side of pumps in intersectional surge cells.

a. Design. - All process gas coolers use perfluorodimethylcyclohexane as the coolant medium. The coolers are of shell-and-tube design with process gas flowing through the shell, and coolant flowing through the tubes. Integral copper finned tubing of 3/8 inch diameter was chosen. The intercell coolers (Fig. 17) and purge cascade stage coolers (Fig. 16, facing p. 8.14) were designed with "U"-shaped finned



INTERCELL COOLER

FIG. 17

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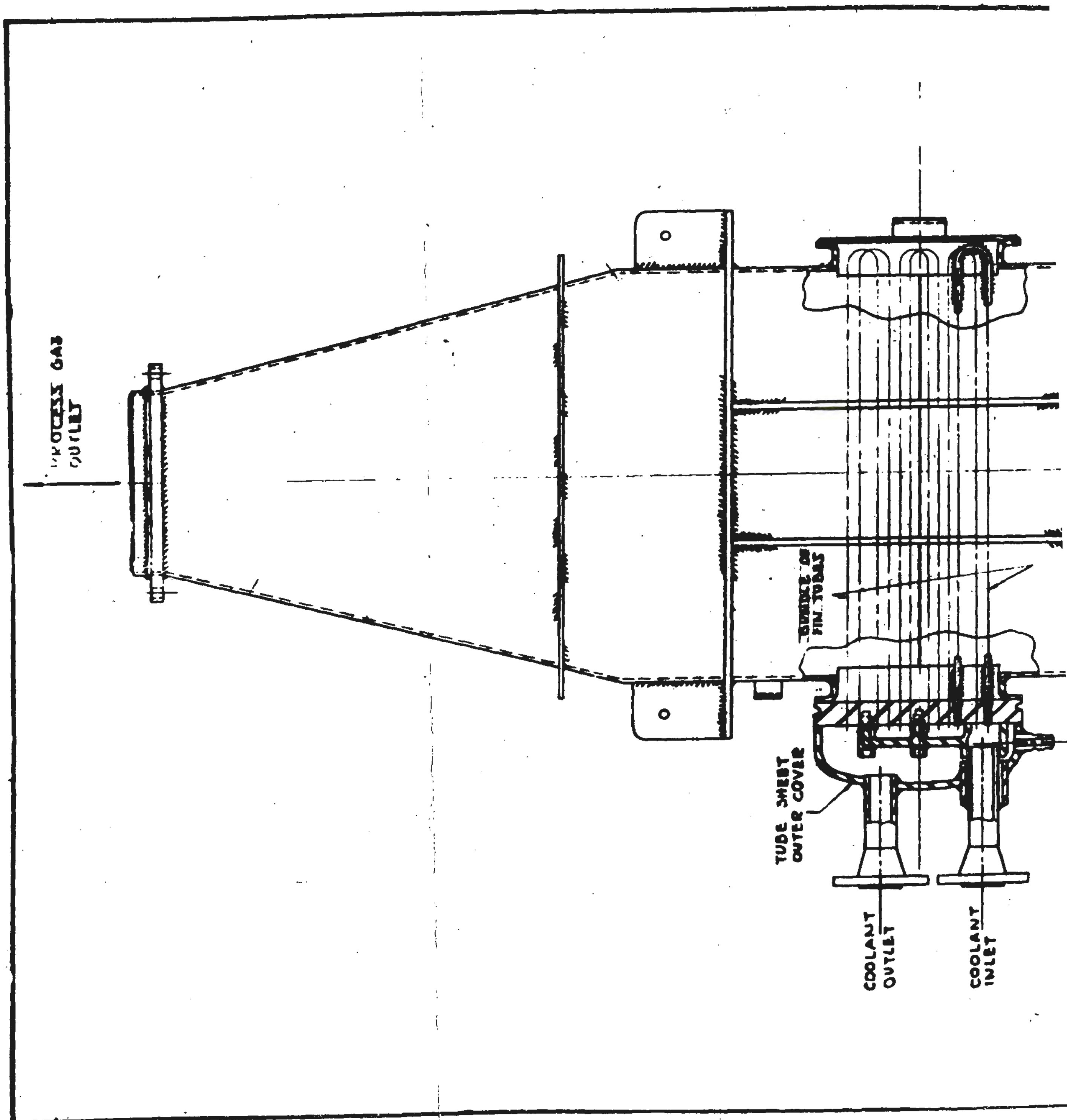

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tubes. The shell contains a transition piece from the circular piping to the square cross section of the cooler proper, where the gas flows outside and across the "U"-shaped finned tubes in one pass. The gas leaving the intercell cooler passes through another suitable transition piece to the outlet piping. In the purge converter cooler, exit gas flows directly into the converter. In all cases the gas flows through the cooler in only one pass. The coolant flows in six passes through most of the coolers, and eight passes in the remainder.

b. Production. - The external coolers were manufactured under contract W-7415-eng-35 by the A. O. Smith Company, using finned tubes supplied by the Wolverine Tube Company.

8-9. Coolant Coolers. - Coolant coolers are installed for the purpose of cooling the process coolant by removing the heat of compression initially transferred from the process gas. Each cell is provided with its own coolant circulation system containing principally a pump and storage drum, six stage coolers, one inter-cell cooler, and one coolant cooler. The coolant system (Par. 10-2) forms the connecting link between the process system (Section 7) and the cooling water system (Par. 10-3). The Whitlock Manufacturing Company furnished 490 coolers under contract W-7415-eng-25.

8-10. Process Piping.

a. Requirements. - The K-25 cascade required about 100 miles of process piping in various sizes. Since this was to be exposed to fluorine conditioning gas, and to uranium hexafluoride, and since more than the merest trace of corrosive action was intolerable (Vol. 1, Par. 5-3), all process piping had to be formed from, or lined with, critically scarce metals of extremely high resistance to chemical attack by UF_6 and F_2. Further requirements were those of rigorous cleanliness and tightness of the fabricated installations. The activity of the process gas, and the lack of prior industrial experience in handling it, made it desirable to provide an electroplated nickel coating of several mils thickness, whereas, industrial plating practice is ordinarily in the range of 1/10 mil, rarely exceeding 1/2 mil in thickness, and is seldom applied to internal pipe surfaces.

b. Development. - Preliminary research studies and initial piping stress calculations were carried out early in 1943. On the basis of corrosion resistance, mechanical strength, and cost considerations, as well as availability of the various types of piping, copper tubing was initially chosen for the material of construction in the large pipe sizes. Monel was to be used in the small sizes. The use of any critical metal tubing such as copper or monel required that the pipe wall thickness be the minimum possible without resulting in pipe collapse under vacuum. During the latter part of 1943, the shortage of copper resulted in the changing over to nickel-plated pipe for sizes of 5 to 16 inches. The available plating methods were not applicable to smaller sizes, but there was enough monel to be spared for sizes up to 4 inches.

(1) Electroplating Methods. - No commercial process was available for nickel-plating steel pipe. The Republic Steel Corporation worked on development of a method involving plating of steel followed by rolling to form tubes. Bart Laboratories developed a novel method

for nickel plating finished pipe in diameters above four inches, and lengths up to 22 feet. Their method used the pipe itself as a tank. The solution was pumped through at high velocity to prevent depletion of nickel at the cathodic pipe face. Insoluble platinum-coated copper anodes were used in order to maintain constant and uniform current densities. The pipe to be plated was rotated during operation in order to obtain a uniform thickness of deposit.

c. Production.

(1) Monel Tubing. - Monel tubing of standard dimensions was procured from the International Nickel Company during the latter half of 1944 and the first two months of 1945. Specifications required that silicon and carbon content of the metal be held to a minimum, since these substances are especially susceptible to corrosion by fluorine and UF_6.

(2) Nickel-plated Steel Piping. - Bart Laboratories were awarded contracts W-7409-eng-19 and W-7415-eng-39 for nickel plating of finished pipe in diameters above four inches, and lengths up to 22 feet. Work was begun in February 1944. Because of development problems, and lack of manufacturing experience, production reached only 15 per cent of schedule by May 1944. Nevertheless, the total requirement was increased from 230,000 to over 280,000 lineal feet without change in the completion date. Since quality of the electroplating was good, and in order to meet the necessary production schedule, the manufacturing organization was increased, and additional plating facilities were installed. The equipment was obtained and placed in operation by September 1944. 290,000 feet of pipe were completed by January 1945. The thickness of

the plate averaged 0.0035 inches.

(a) Production Problems. - In this work severe corrosion problems were encountered. Acid corrosion continually caused the breakdown of the plating machines and the Duriron* pumps. Overload and acid fumes affected the electric motors. The heat of dilution of sulphuric acid used to wash out pipe was so great that finally special refrigeration equipment had to be installed. The heat exchangers for this equipment were also corroded by the acid. Although all pipe was to be received in 22-foot lengths, it was found necessary to accept a large amount of odd short lengths. It would have been quite inconvenient to adjust the equipment to plate this size and, if this were done, it would cut down considerably on the production rate. A temporary welding shop was therefore set up to weld all short lengths into the standard size.

d. Installation. - All nickel pipe was thoroughly cleaned at the site prior to installation. The treatment included solvent and acid washing. Immediately after cleaning the pipe, the ends were capped and kept so until the time when the pipe was welded into position. It was decided to weld or hard-solder all joints. Vacuum tight joints were known to be possible, but the life of these joints was unpredictable. Pilot plant experience (Vol. 2, Par. 7-5) showed that 20 leaks per thousand feet of commercial shop arc welding was the least that could be expected. This amount was intolerable, in view of the fact that about 170 miles of welding was required on process gas piping at the K-25 plant. Pilot plant experience further disclosed that approximately 20 per cent of all silver soldered joints in small copper tube lines would be defective. On the basis of a total of approximately 800,000 silver solder joints, this would mean the re-making of some 160,000 joints. Further difficulties foreseen with the use of commercial welding and soldering techniques, were contamination of inside surfaces with flux and weld spatter, embrittlement and porosity (caused by nickel pick-up), cracking of monel and high nickel copper alloys with the use of silver solder (caused by intergranular penetration of the cadmium in the solder), difficulty in finding methods suitable for alloy welding and joining of dissimilar metals, training of welders in these methods, and the control and use of various types of welding rods and silver solders on a project of such size. Study and development of these problems led to several specialized welding techniques and designs (Kellex Completion Report Section III, (9)). The Midwest Piping and Supply Company was awarded contract W-7421-eng-12 for the supply of 6200 tons of pre-fabricated assemblies and process piping. This company was also responsible for erection and installation of process piping under subcontract No. 26 which was let by the J. A. Jones Construction Company under prime contract W-7421-eng-11 (Vol. 4). In order to meet the rapid delivery and installation schedules, and the stringent tightness and quality requirements, the maximum use was made of shop fabrication techniques, and particularly of automatic welding procedures.

8-11. Process Valves. - Approximately one half million valves are required to operate the K-25 plant. They vary in size from 1/8 inch to 36 inches, and in type from conventional globe valves for water and air service, to special units designed in accordance with the most rigid specifications for cleanliness, corrosion resistance, and tightness. Two general types of special process valves were required: shut-off or "block" valves, and pressure control valves. The latter type (stage control valve) is discussed in Paragraph 8-12.

a. Requirements. - Exact requirements for K-25 valves vary depending upon specific application. The larger type block valves form the most important class; specifications for these are typical:

1. The valve must be vacuum tight, both to the atmosphere from without, and across the seats within. The process specification permitted a maximum inleakage rate to the body of 0.1 to 7.0 micron cubic feet per hour, depending on the size of the valve. (At a rate of one micron cubic foot per hour, it would take 87 years 88 for one standard cubic foot of gas to leak through.)
2. There must be a minimum pressure drop through the valve when open.
3. The materials of fabrication must not be excessively attacked by fluorine or uranium hexafluoride.

b. Development. - Special valve development was started by Kellogg in the spring of 1942, and early in 1943 a special department of the Kellex Corporation was organized to accelerate this work.

(1) Early Designs. - Initial designs (e.g. "tear drop" and "rotary plug" types) were influenced primarily by minimum pressure drop requirements. In the spring of 1943 the St. Paul Engineering Company worked on the "tear-drop" type valve, and the Hammel-Dahl Company developed the "rotary plug" type. Discussion of these experimental models is presented in the Kellex Completion Report, Section III, (9). Progress on this work was not encouraging. In June 1943, the Crane Company was asked to work on these types, and was given an order to supply the valves for the Jersey City Test Floor (contract W-7418-eng-17).

(2) Final Designs. - After critical analysis by Crane and Kellex, the tear drop and rotary plug designs were discarded as unsatisfactory, and further development was mainly centered around designs based on the common gate valve. Preliminary designs proved encouraging. The basic features included a double seat gate with a buffer zone between seats, and a bellows-sealed, wedge-type actuating mechanism capable of exerting sealing pressures up to the fatigue point of the metal.

(3) Seating Materials. - The development of a resilient material, suitable for use in contact with process and conditioning gas, and capable of forming a vacuum-tight closure, constituted a serious problem. Polytetrafluoroethylene was the first material seriously considered for valve seats, but early samples exhibited severe cold flow properties, and built up electrostatic charges which attracted dust particles to the seat. In England experiments were made with a number of plastics and rubbers for use in contact with UF_6. A natural composition ("C" rubber) was found which best satisfied the requirements. Kellex ran a series of tests on this material. It was found that exposure of "C" rubber to concentrations in the range of 50 per cent fluorine resulted in charring of the material, but that the stability could be markedly improved by conditioning with five per cent fluorine. When "C" rubber valve seats were installed at the plant, the test results were confirmed. Although the "C" rubber was the best material then available, service life was limited. Butyl rubber was next investigated, and showed good stability, but was unsatisfactory because of low mechanical strength. Development work was also continued on "C" rubber, and a considerable improvement was effected by impregnation with fluoro-

TABLE 4. - SPECIAL VALV

VALVE	TYPE	SIZE (Inches)	SERVICE	OPERATED BY	METHOD OF SEALING	LUBRICANT
G-17A	Gate	3 to 16	UF_6	Hand or motor	Bellows and stuffing box	C-2144 to st box; SCG to wheel.
G-17AM	Gate	3 to 16	UF_6	Hand or motor	Bellows and stuffing box	C-2144 to st box; SCG to wheel
H	Globe angle tee	1/4	UF_6	Hand	Bellows	SCG to cap t
Drum	Angle	1/4, 1/2	UF_6	Hand (wrench)	Plastic packing rings	C-2144 to pa rings
SM	Globe	1/4 to 2	UF_6	Hand	Two concentric bellows	SCG to valve
SS	Globe	1/4 to 2	N_2	Hand	Two concentric bellows	SCG to valve
Air-Op	Globe	1/4 to 2	UF_6	Air	Two concentric bellows	None
A-3B	Angle	3 to 10	N_2	Hand	Bellows and stuffing box	C-2144 to st box; SCG to wheel
A-17A	Angle	3 to 16	UF_6	Hand	Bellows and stuffing box	C-2144 to st box; SCG to wheel
Check	Swing	3, 6	UF_6	System flow	None	None
Tee	3-port	1/2	UF_6	Hand (wrench)	Two concentric bellows	SCG to valve
Relief	Angle	1	UF_6	Air	Bellows and stuffing box	None

SCG - denotes standard commercial grease.
C-2144 - is a special fluorocarbon oil (Book VII).

BLE 4. - SPECIAL VALVES

	LUBRICANT	MATERIAL OF CONSTRUCTION	WORKING PRESSURE p.s.i.a.	MAXIMUM TEMPERATURE °F
ing	C-2144 to stuffing box; SCG to hand-wheel.	Nickel-plated steel	0-30	160
ing	C-2144 to stuffing box; SCG to hand-wheel	Nickel-plated steel	0-30	330
	SCG to cap threads	Monel	0-125	300
ings	C-2144 to packing rings	Monel	0-200	300
llows	SCG to valve stem	Monel	0-75	300
llows	SCG to valve stem	Steel body, stellite seat, brass bellows	0-125	200
llows	None	Monel	0-75	300
ing	C-2144 to stuffing box; SCG to hand-wheel	Steel body, brass bellows	0-125	200
ing	C-2144 to stuffing box; SCG to hand-wheel	Nickel-plated steel body, aluminum bronze seat face, monel bellows	0-30	250
	None	Nickel-plated steel	0-30	300
llows	SCG to valve stem	Monel	0-75	300
ing	None	Monel	0-75	300

carbon wax. Impregnated "C" rubber valve seats were installed in a portion of the K-25 plant. Two new plastics were later found highly inert to UF_6 and fluorine, MFP-10, and copper-filled Poly TFE. The former is a highly fluorinated hydrocarbon polymer. The latter is the polytetrafluoroethylene which had been studied earlier, but with the addition of 45 per cent of copper. A program is under way for replacing all rubber valve seats at K-25 with MFP-10 according to schedules laid out so as to avoid serious interruption of plant operation and production. A more extensive account of the development and procurement of valve seat materials is presented in Book VII.

c. Description of Types Used. - The final design for process block valves of sizes four to sixteen inches was known as type G-17A. Nearly 10,000 of these valves are installed in the K-25 cascade. A description of this valve and of the other special types developed for auxiliary plant purposes is presented in the remainder of this paragraph, and is supplemented by Table 4. Further details may be found in Volume X of the Kellex Operating Manuals. The special valves for the K-25 plant were procured from the Crane Company under contract W-7418-eng-18.

(1) G-17A Valve. - The G-17A process block valve is shown in Figure 18. Two parallel discs are moved in and out of the pipe line by the valve stem. To make a closure, seat rings in the discs contact metal tube seats. In order to provide for accurate alignment of disc seat and tube seat, the discs are attached to guides which follow guide grooves on the side of the valve body. As the valve stem is moved downward in the closing direction, the two valve discs,

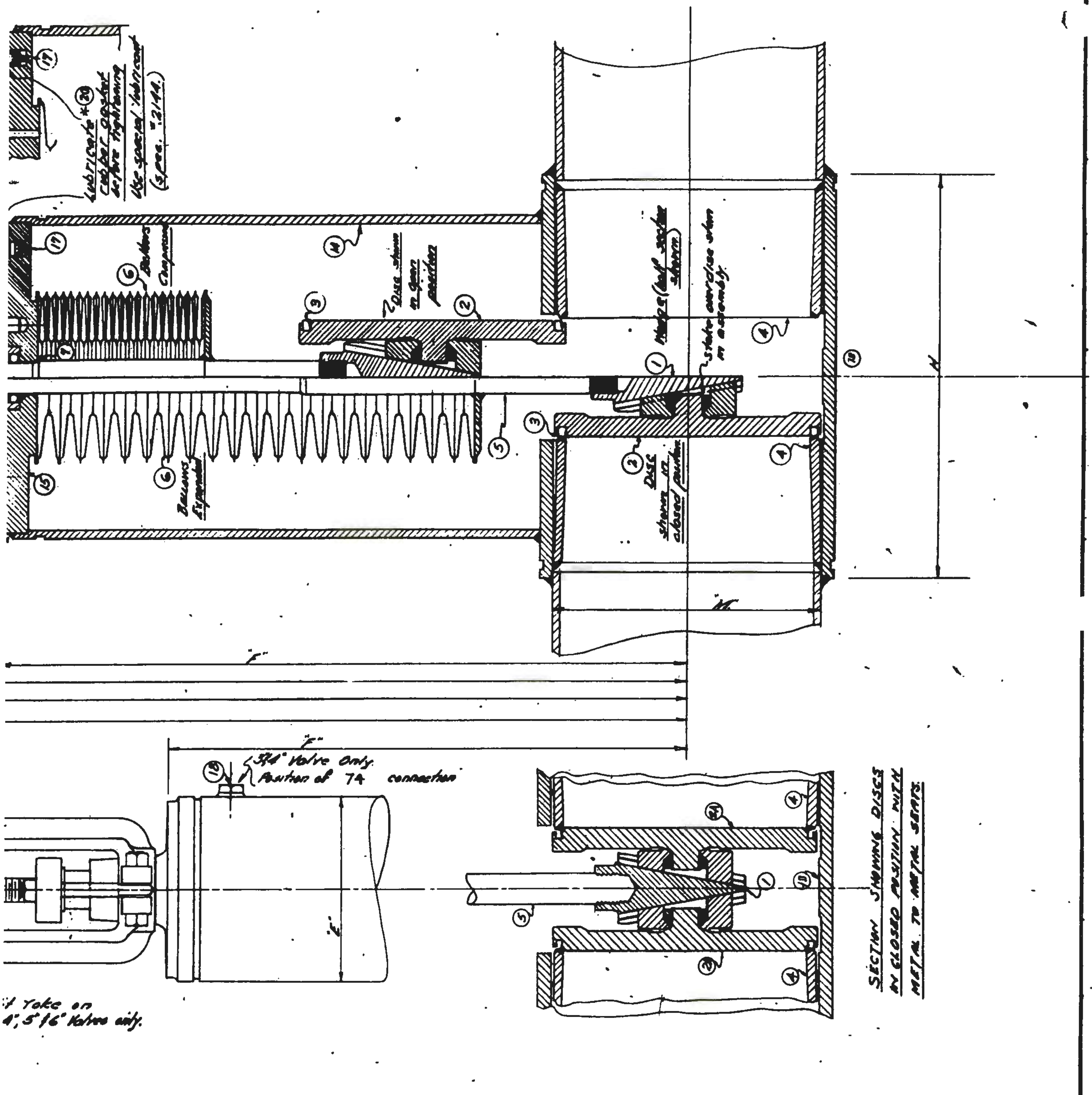

FIG. 18

THE KELLEX CORPORATION

STYLE "G" VALVES
General Cross Section & Dimensions

REVISIONS

No. H-63-A

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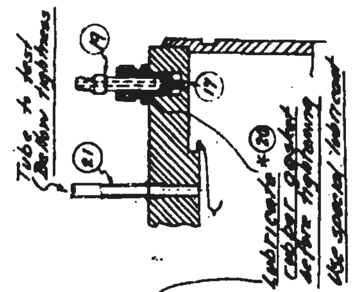
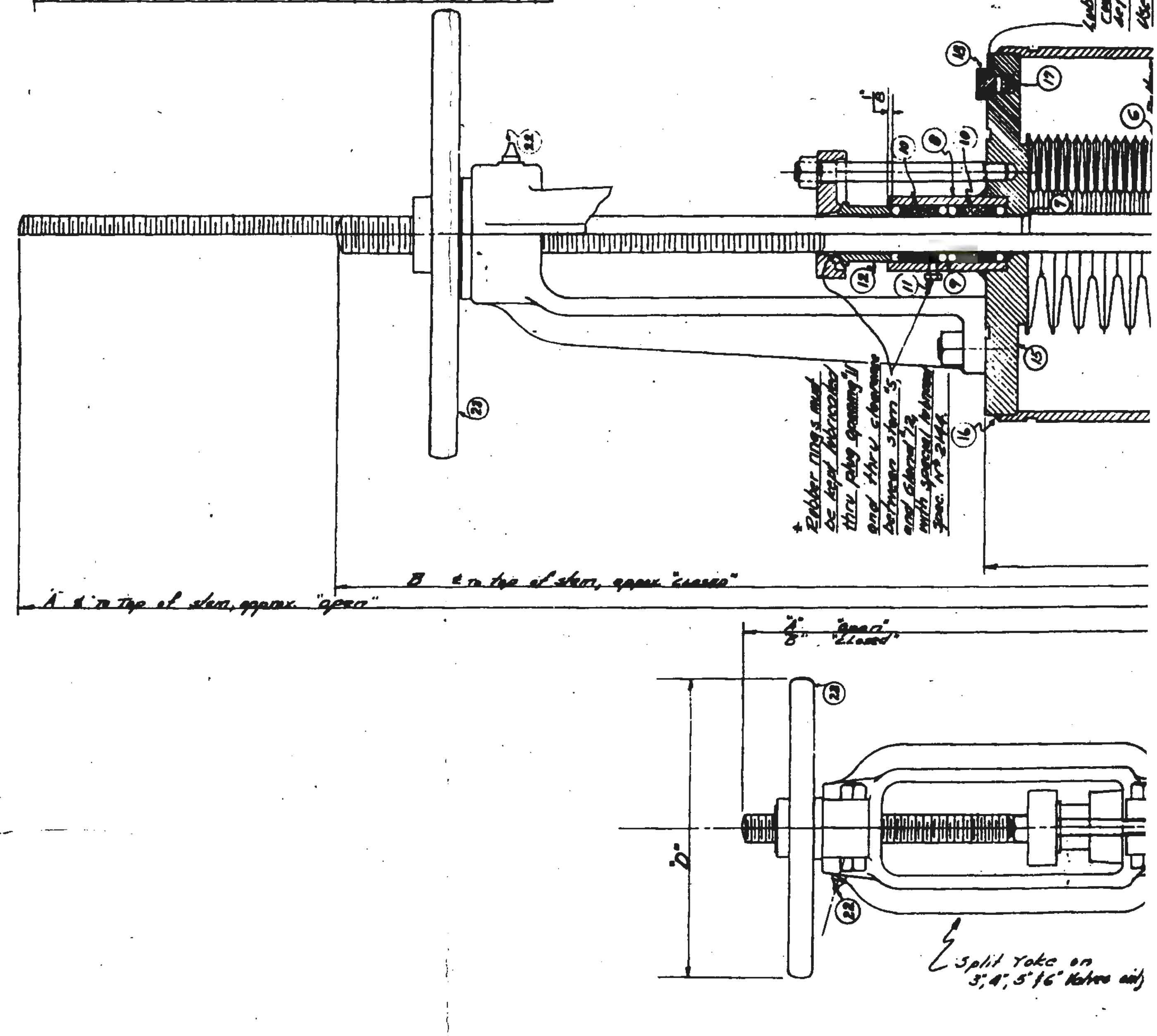
•	
1	Needles
2	Disc Rubber seat
2A	" Metal Seat
3	Rubber Seat Ring
4	Metal Tube Seat
5	Stem
6	Bellows
7	Back Seat
8	Stuffing Box
9	Rubber Packing Rings
10	Compression Springs
11	Plug for Lubricant
12	Gland
13	Body Run
14	Body Neck
15	Bonnet
16	Bonnet Weld
17	7A VALVE
18	7A SEAL PLUG
19	7A CONNECTION
20	Rubber Gasket
21	Tube for Testing
22	Grease Connection
23	Hand wheel





VALVE SIZE	A	B	D	E	F	H	M	
3	36	30[illegible]	9	6	17[illegible]	9	3[illegible]	
4	36	30[illegible]	9	6	17[illegible]	8	4[illegible]	
5	50	42[illegible]	12	8[illegible]	24[illegible]	12	5[illegible]	
6	50	42[illegible]	12	8[illegible]	24[illegible]	10[illegible]	6[illegible]	
8	54[illegible]	44[illegible]	14	10[illegible]	26[illegible]	13[illegible]	8[illegible]	
10	63[illegible]	51[illegible]	16	12[illegible]	28[illegible]	16	10[illegible]	
12	72	58[illegible]	18	15	32[illegible]	18[illegible]	12[illegible]	
14	80	64[illegible]	20	16	36[illegible]	20[illegible]	14	
16	91[illegible]	73[illegible]	22	18[illegible]	42[illegible]	23	16	

[redacted]/RD

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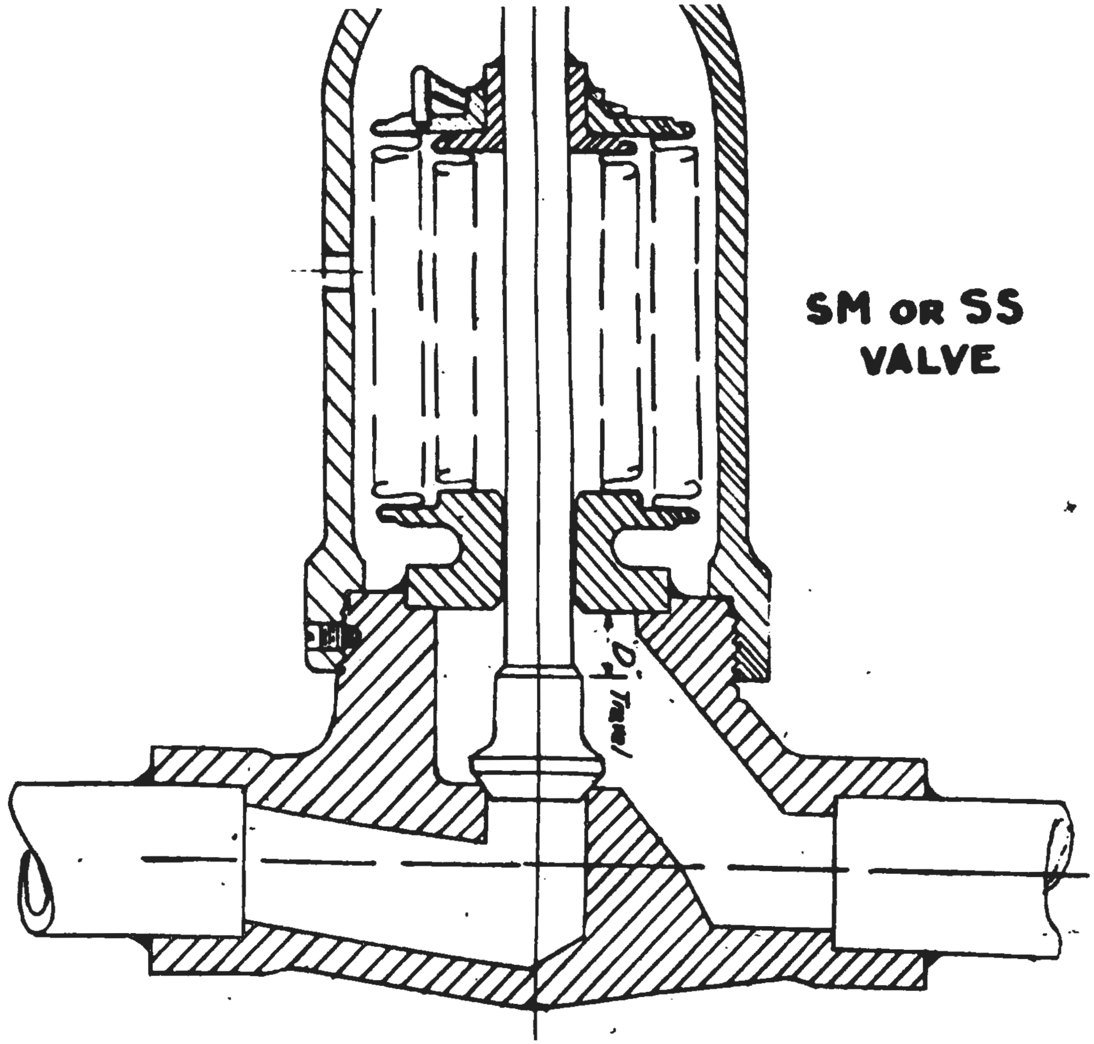
with the spreaders to which they are attached, are restrained from moving axially by two vertical and parallel guides, terminating at the center of the valve run. When the center of the discs reaches the centerline of the valve run, the spreaders are prevented from traveling further down by horizontal guide grooves at each side of the valve body. Continued motion of the stem and wedge then causes movement of the valve disc along the axis of the valve run. During this movement, the discs are guided by the horizontal grooves. Continued closing of the valve causes the central wedge to force the valve disc against the valve seats to effect closure. When the valve is being opened, the reverse action takes place in which the valve discs and spreaders first move along the axis of the valve run until they are drawn back over the ends of the parallel horizontal guides. Further movement of the valve stem causes the entire wedge assembly, spreaders, and discs, to move upward and entirely out of the stream. An indicator rod at the top of the valve shows the valve position. The valve stem controlling the discs may be actuated either by a handwheel or by electric motor. Motor operation can be arranged by extending the valve stem from the pipe gallery up to the operating floor, or the motor may be direct-connected. The stem speed of motor-operated valves is approximately 20 inches per minute.

(a) <u>Seat Rings</u>. - The required tightness was achieved with metal to metal seat contact. However, it was not known whether this degree of tightness would be possible on a production basis, or if the tightness could be maintained under plant conditions of operation. Therefore, it was decided to obtain even greater tight-



THREE SPECIAL VALVES

FIG. 19

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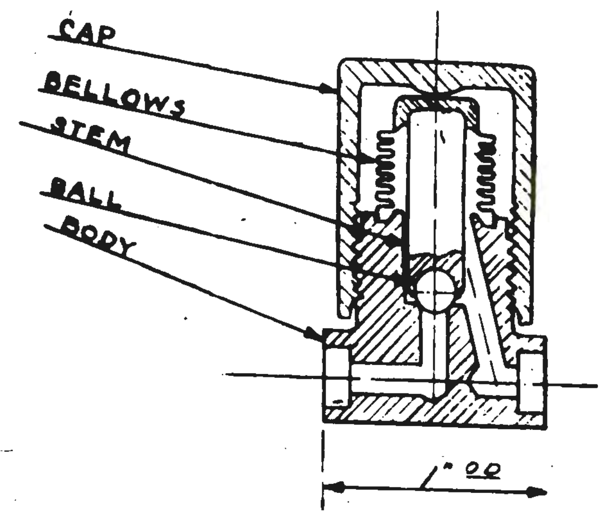
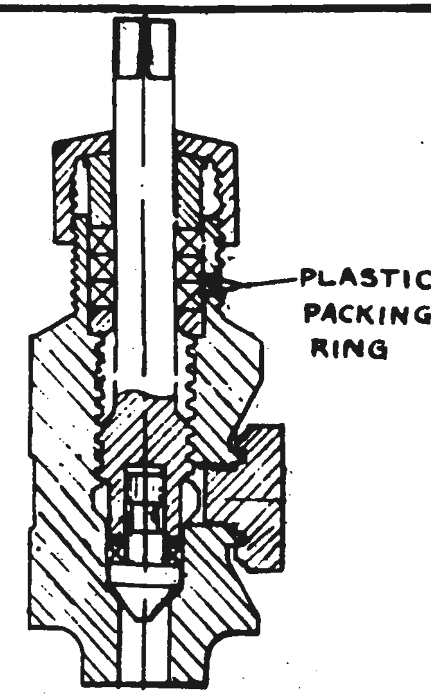
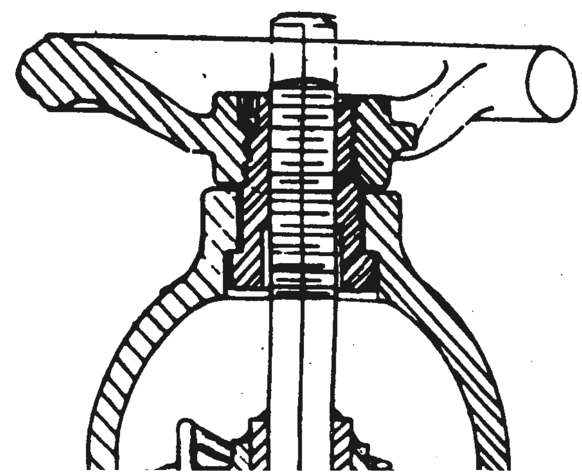


H VALVE



DRUM VALVE



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ness by inserting a resilient seating ring (discussed above) into the valve disc, and having this ring make the initial contact with the metal tube seat.

(b) Bellows Seal. - The G-17A valve is made vacuum tight to the atmosphere by means of a bellows seal inside the body. The bellows is welded to the valve bonnet and to the valve stem, thus preventing any access of process gas to the gland at the valve bonnet through which the stem must pass. As a safety precaution against a broken or leaky bellows, there is a stuffing box on the bonnet and a back seat on the valve stem. For eight-inch valves and larger sizes, the standard one-piece bellows was unsuitable since the required expansion ratio could not be obtained. A multiple monel welded diaphragm bellows was developed by the Cook Electric Company. To overcome the problem of edge-welding the thin 0.025 inch bellows plates into a vacuum tight assembly, a method was worked out involving the use of an atomic hydrogen weld and special jigs. The bellows so fabricated has an expansion ratio of nearly 3 to 1.

(c) Buffer Zone. - The buffer zone between seats can be pressured with nitrogen through a connection in the valve body. On small sizes, this connection is made into the side of the body, while on the large models, it is inserted into the bonnet. On some installations, the connection is a permanent nitrogen line; in others, a portable connection must be made. By pressuring the buffer zone with nitrogen, outleakage of process gas through the closed valve is prevented. Any leakage will be in the form of nitrogen leaking past the valve seats into the system.

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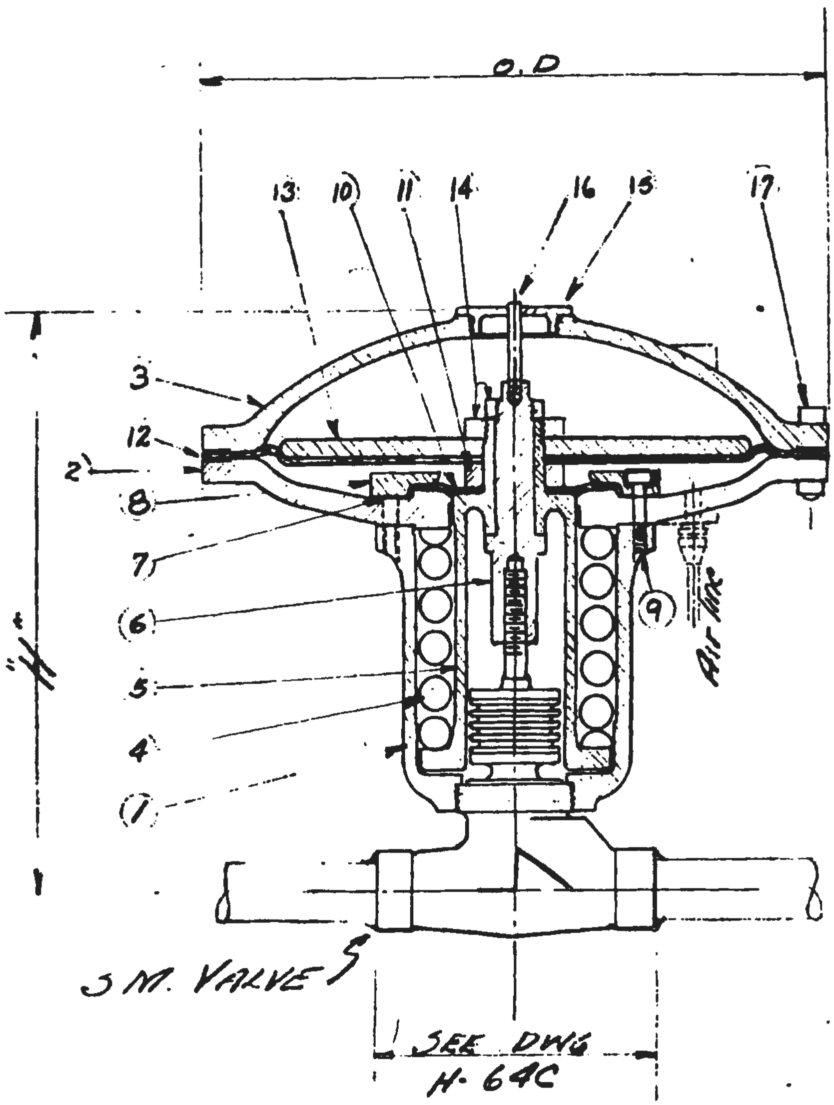

Nº	NAME
1	BODY
2	BODY FLANGE
3	COVER
4	SPRING
5	SPRING CARRIER
6	ADJUSTING NUT
7	GASKET
8	SEAL PLATE
9	BOLT
10	SEAL DISC
11	SPACER
12	DIAPHRAGM
13	PLATE
14	LOCK NUTS
15	CAP
16	INDICATOR
17	BOLTS

VALVE SIZE	OD	H
1/4	11 3/4	9 9/16
1/2	11 3/4	9 3/4
3/4	15 1/4	13 3/8
1	15 3/4	14 1/16
1 1/2	21	19 3/4
2	21	20 1/4

FIG. 20

TITLE AIR OPERATED VALVE (AIR TO OPEN TYPE)

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				CKD. ___ No. H-154 -D

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(d) Body. - The body of the G-17A valve is of all welded fabrication, including body run, tube seat, and bellows. The material for the welded body and the disc seats is nickel-plated steel. The guide and wedge assembly are cast aluminum bronze, while the stem and bellows are monel.

(e) Leak Test Connection. - In 3 to 6 inch sizes a copper tube bellows leak test connection is provided (Fig. 18). Larger sizes have a special connection known as a sealing valve. If a leak test is made, and it is found that the valve seats or bellows are leaking, the weld at the top of the bonnet is cut out by means of a special milling cutter designed specifically for this purpose. The valve can then be disassembled and repaired.

(2) G-17AM Valve. - This valve is the same as the G-17A type, but does not employ rubber disc rings, and is suitable for higher temperature service (Table 4).

(3) H Valve. - The H valve is a small instrument line valve with minimum internal volume and surface area. Seat contact is made by means of a highly polished ball fixed on the end of the valve stem. Globe, angle, and tee designs were supplied. The knurled cap (Fig. 19) serves as a handwheel. H Valves have a 1/4 inch socket and connections. Port openings are either 1/8 or 3/16 of an inch in diameter.

(4) Drum Valve. - This type (Fig. 19) is a monel metal angle type valve designed principally for service on drums. It is installed by welding the bottom inlet to a portable drum nozzle, and inserting an adapter and pipe assembly into the side outlet. The side outlet is held in place by means of an adjustable clamp. The valve

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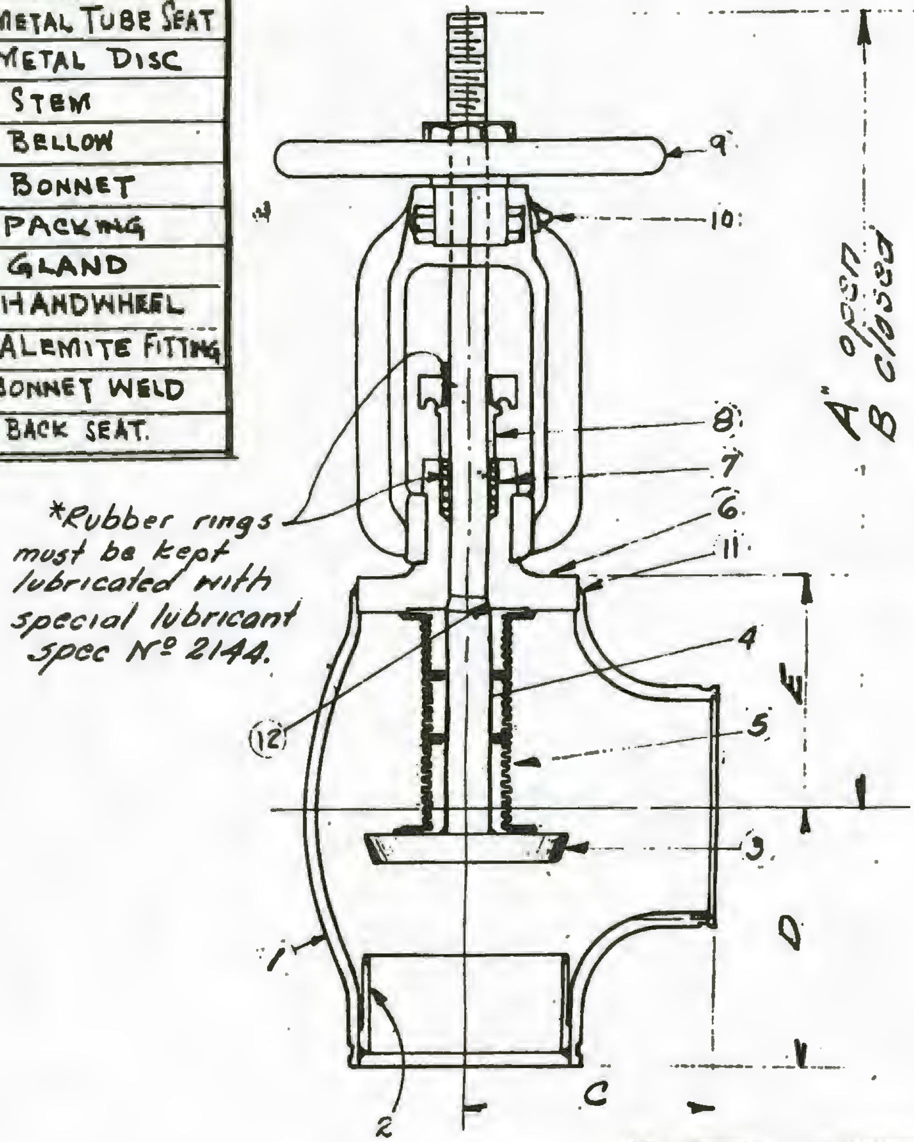
Nº	NAME
1	BODY
2	METAL TUBE SEAT
3	METAL DISC
4	STEM
5	BELLOW
6	BONNET
7	PACKING
8	GLAND
9	HANDWHEEL
10	ALEMITE FITTING
11	BONNET WELD
12	BACK SEAT.



PIPE SIZE	A	B	C	D	E
3"	$16\frac{1}{8}$	$13\frac{1}{2}$	$4\frac{5}{8}$	$5\frac{1}{2}$	$5\frac{3}{4}$
4"	$17\frac{1}{4}$	$15\frac{1}{2}$	$5\frac{11}{16}$	[illegible]	$5\frac{1}{2}$
6"	24	21	$7\frac{3}{4}$	$7\frac{3}{4}$	7

FIG. 21

TITLE A-3B VALVE

JOB NO.

DESCRIPTION	DATE	CHECKED
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THE KELLEX CORP.

SCALE ___ DATE 9-25-44 AP. ___

DR. WCB TR. ___

CHD. ___ No. H-15 - -D

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can be adapted for general service by removing the clamp and making minor adjustments. The special feature is a plastic ring behind the seat, which is compressed after the metal seats make contact.

(5) <u>SM Valve</u>. - The SM valve (Fig. 19) is similar to a conventional globe valve, but uses a conical plug disc against a conical seat. To meet rigid leak-proof requirements, it is equipped with two concentric bellows as a double seal, instead of the usual stuffing box. It is used on process gas lines of two inch and smaller diameters.

(6) <u>SS Valve</u>. - This type is similar in design to the SM valve, but is intended for service with nitrogen instead of uranium hexafluoride and, therefore, is made up of different materials of construction (Table 4).

(7) <u>Air-operated Valve</u>. - The air-operated valve consists of the body, stem, and bellows assembly of an SM type valve, but instead of the handwheel, an air-operated spring and diaphragm assembly is used. By variation in spring design and air pressure control, these valves can be adapted to either open-and-shut service or throttling service. The former type is designed either to close on air failure (as shown in Fig. 20) or to open on air failure. The throttling type may be operated either by direct control, or through the use of a valve positioner.

(8) <u>A-3B Valve</u>. - The A-3B valve (Fig. 21) is similar to a standard angle valve except that it is equipped with a bellows seal in addition to the conventional stuffing box, and a sleeve type seat instead of a standard type seat. Rubber rings are used for stem packing. This valve is suitable for use on three to ten inch nitrogen lines.

(9) <u>A-17A Valve</u>. - The A-17A valve is identical with the

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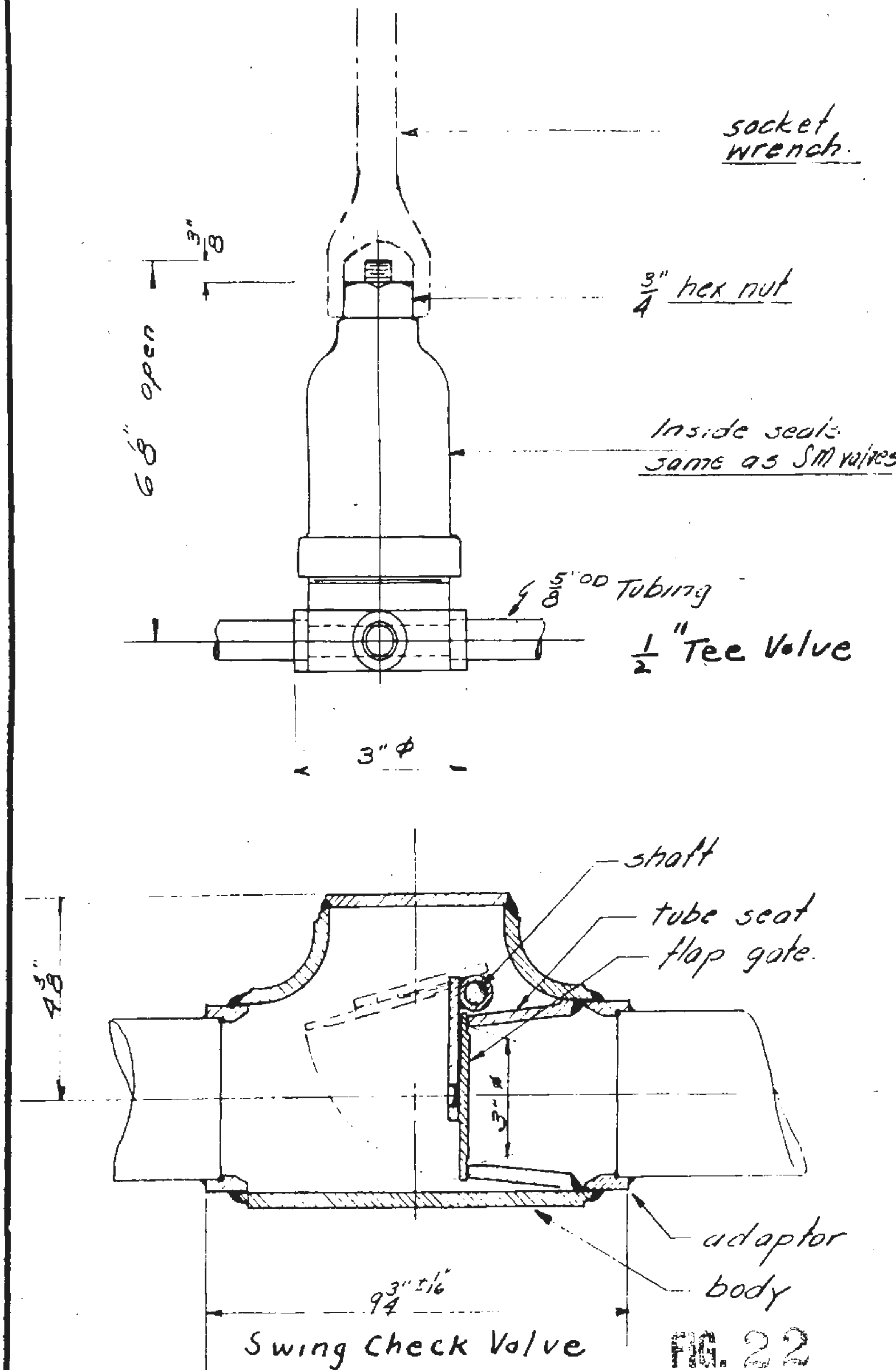

FIG. 22

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A-3B valve except in material of construction, since it is designed for service with UF_6 instead of nitrogen.

(10) Check Valve. - Special check valves (Fig. 22) were manufactured in essentially standard designs but internally nickel-plated for resistance to attack by UF_6. This valve is used in the suction lines of all cold trap vacuum pumps.

(11) Tee Valve. - The tee valve (Fig. 22) is a special leak-proof valve designed principally for test manifold assemblies. It has three port openings which permit straight through flow with sample take-off. The monel bellows seal is the same as for the SM valve.

(12) Relief Valve. - The special relief valve (Fig. 23) is a monel angle valve held shut by an air motor operator of the close-on-air-failure type. A pressure transmitter, incorporated in the line, operates a relay valve which supplies air to the air motor operator. The valve body is of the SM type. These valves are used for process relief in the cold traps.

8-12. Instruments.

a. Cascade Instrumentation. - A large number of highly specialized measuring and control devices are required at various points throughout the K-25 process cascade, to serve such purposes as process stream analysis, leak detection, isotopic assay testing, and process pump sealant flow measurement. The complex technical nature of these items, and the absence of prior industrial experience in design and application, required a large amount of research and development. This work, together with a description of the finally evolved designs and methods of operation, is treated in Section 6 of Volume 2.

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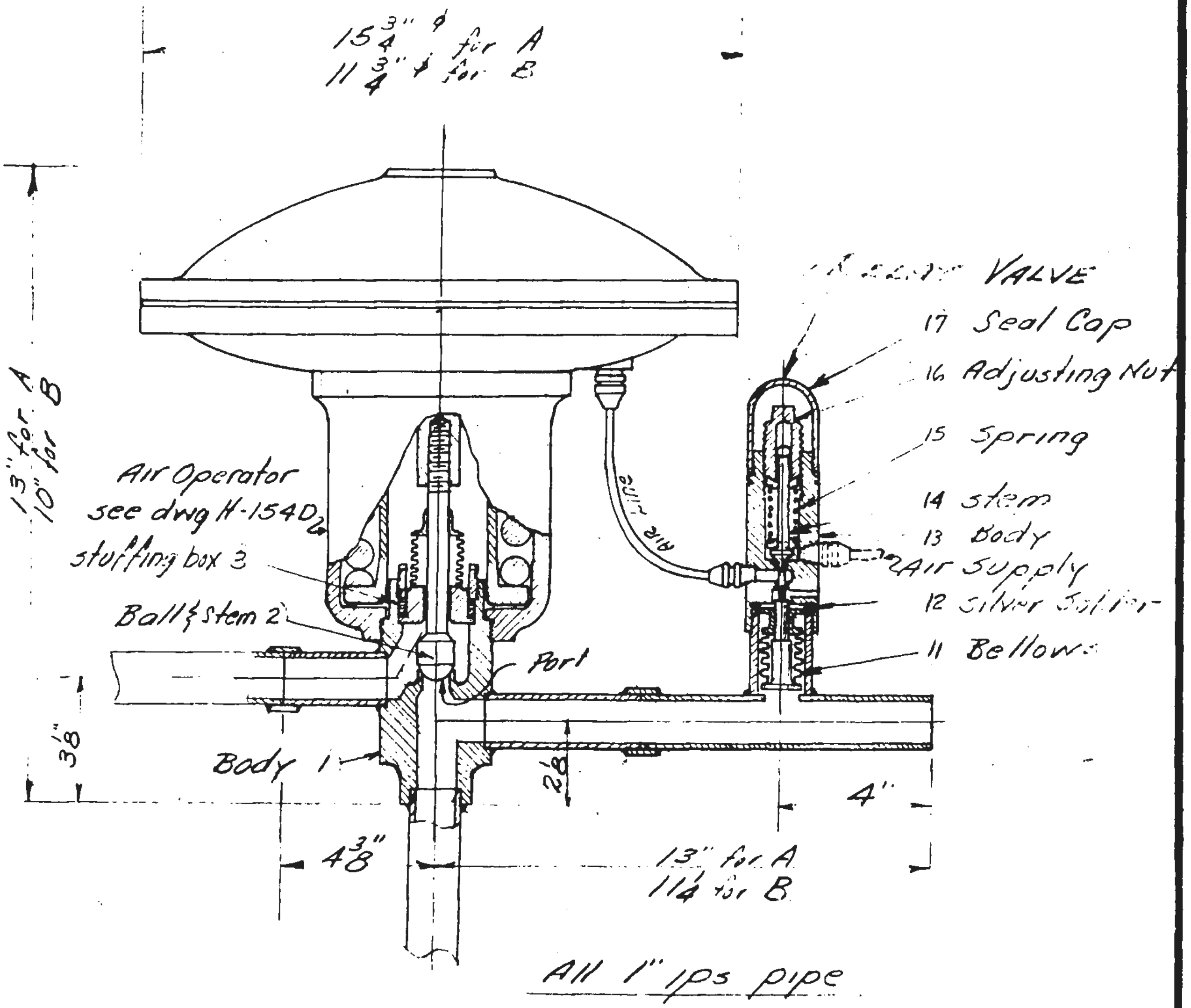

FIG. 23

A- $\frac{3}{4}$" port
B- $\frac{1}{2}$" port

TITLE RELIEF VALVE

JOB NO.

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(1) Central Control Room. - An essential design feature of the diffusion cascade is the provision for a master control station, centrally located, and containing equipment and facilities for coordinating operating activities. Such a central control room (also called "emergency control room") has been set up on the operating floor level at the base of the cascade "U" between Buildings K-303-7 and K-303-8. The principal feature of the room is the central control board which consists of an array of 64 panels arranged in the form of a semi-circular arc. These panel boards are classed as follows: 51 standard building panels; 3 purge building panels; 7 intersectional panels; 1 surge and waste panel; and 2 miscellaneous panels which deal, respectively, with miscellaneous process service controls, and the interconnecting system between K-25 and K-27. The panels contain the following features:

- a. Mimic piping of the main process headers (exclusive of cell connections).
- b. Symbols for equipment in, or connected to, the main headers.
- c. Remote control of each motorized valve in, or connected to, the main headers.
- d. Automatic position indication of all valves in item (c) as well as other important valves in, or connected to, the main headers.
- e. Automatic "on-off" indication for booster pumps in intersectional cells and the purge buildings (K-312).
- f. Remote pressure indication for surge drums.
- g. Position indication of important control valves.
- h. Line recorder slaves for continuous indication of process stream concentration.

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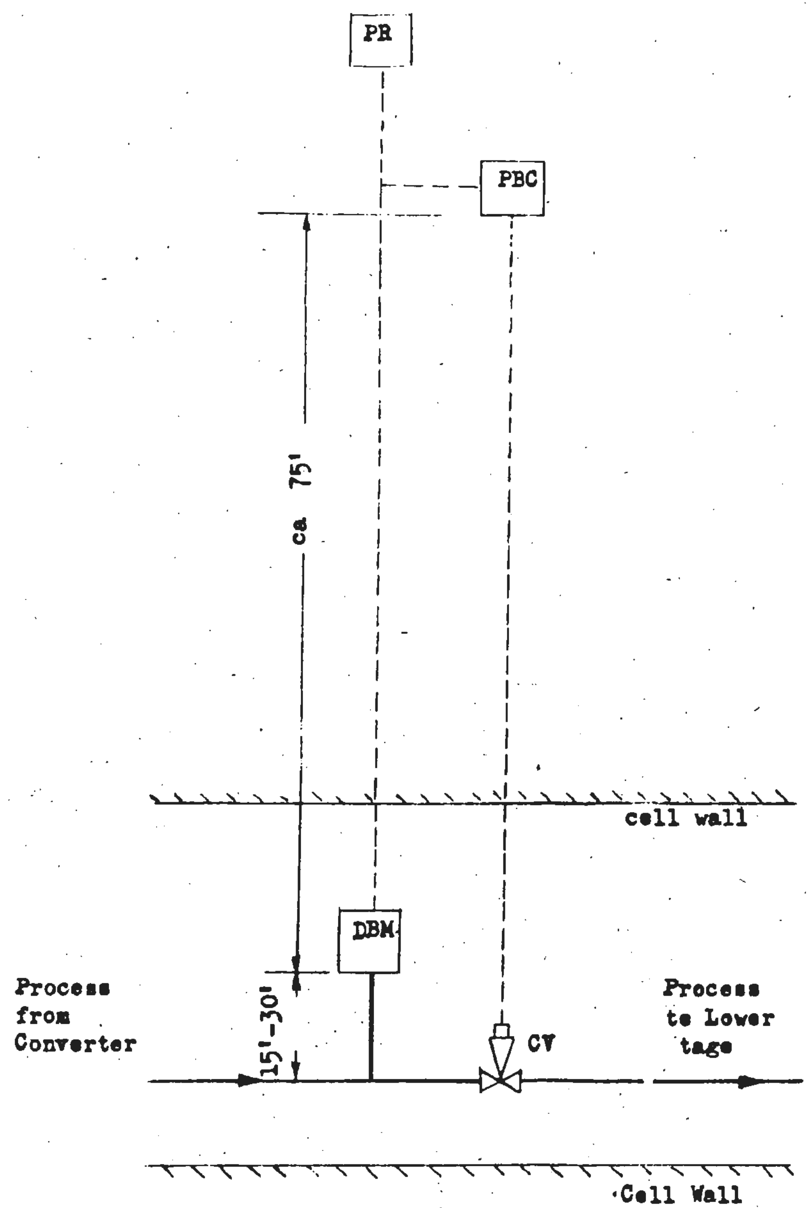
SCHEMATIC OF CONTROL INSTRUMENTATION OF A SINGLE STAGE



DBM - Pressure Transmitter
PR - Pressure Recorder
PBC - Pressure Controller
CV - Control Valve

——— Process Lines
- - - Air Lines
——— Dimension Lines

FIG. 24

TITLE

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CKD. No. 1880-D

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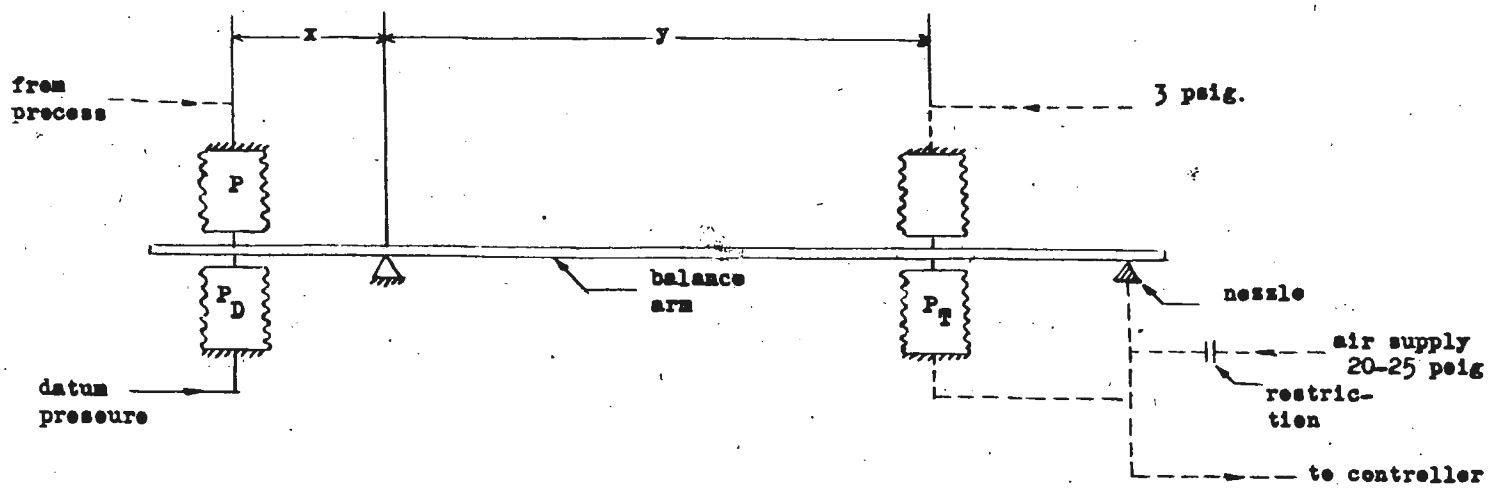
i. Telephonic (sound powered) communication systems. By means of this equipment, central control operators can coordinate the rapid detection and isolation of various types of inleakage (air, nitrogen, coolant, etc.) into the process system, and so prevent the spreading of process disturbances throughout the cascade. In addition to the normal plant telephone system (Par. 9-7), a public address system and a voice-powered telephone system are provided for use with the emergency control board. A detailed description of the central control room is available in Volume XXVII of the Kellex Operating Manuals.

b. Stage Pressure Control Equipment. - In connection with stage instrumentation (Par. 7-5b), the pressure control system is worthy of special description. The basic process variable to be controlled for effective diffusion plant operation is stage inventory of process material. This is accomplished by means of a vast system of pressure transmitting, recording, and controlling devices which are installed as an essential part of the K-25 plant. The pressure control instrumentation for a single diffusion stage is depicted schematically in Figure 24. The pressure of the converter tails stream actuates a pressure transmitter (DBM), which converts a fixed range of process gas pressure (e.g., 0 to 5 p.s.i.a.) into a fixed range of air pressure (3 to 18 p.s.i.g.). The transmitted pressure is charted continuously on a pressure recorder (PR). It then feeds a pressure controller, (PBC), the function of which is to send a signal to the control valve (CV), whenever the pressure is not at the set point. The valve will then move to a new position so as to correct the pressure level. The

SCHEMATIC OF PRESSURE TRANSMITTER (DBM)



P - process pressure

P_D - datum pressure (loaded)

P_T - transmitted pressure

FIG. 25

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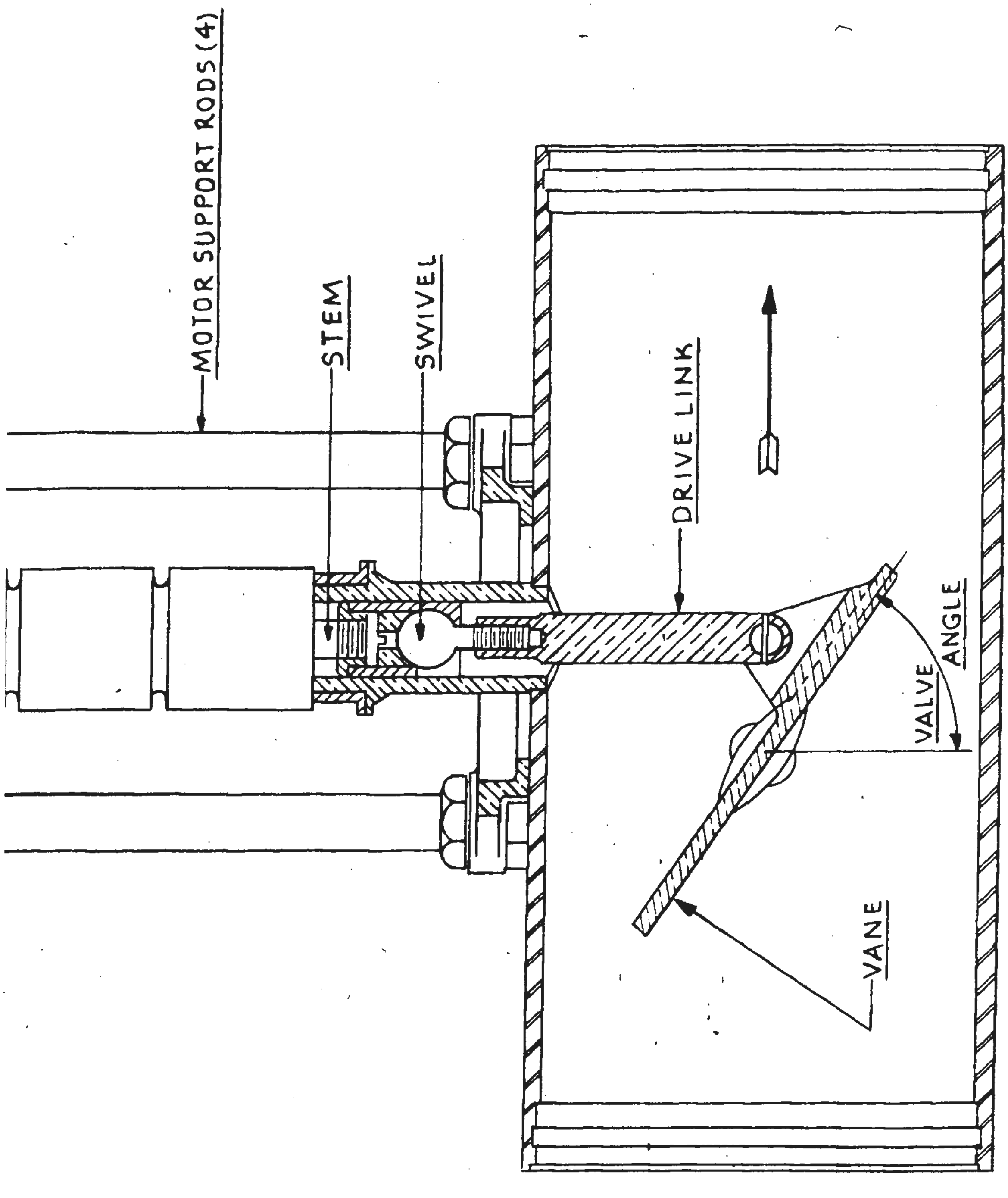

FIG. 27

TITLE FISHER GOVERNOR CO.-BUTTERFLY CONTROL VALVE WITH POSITIONER

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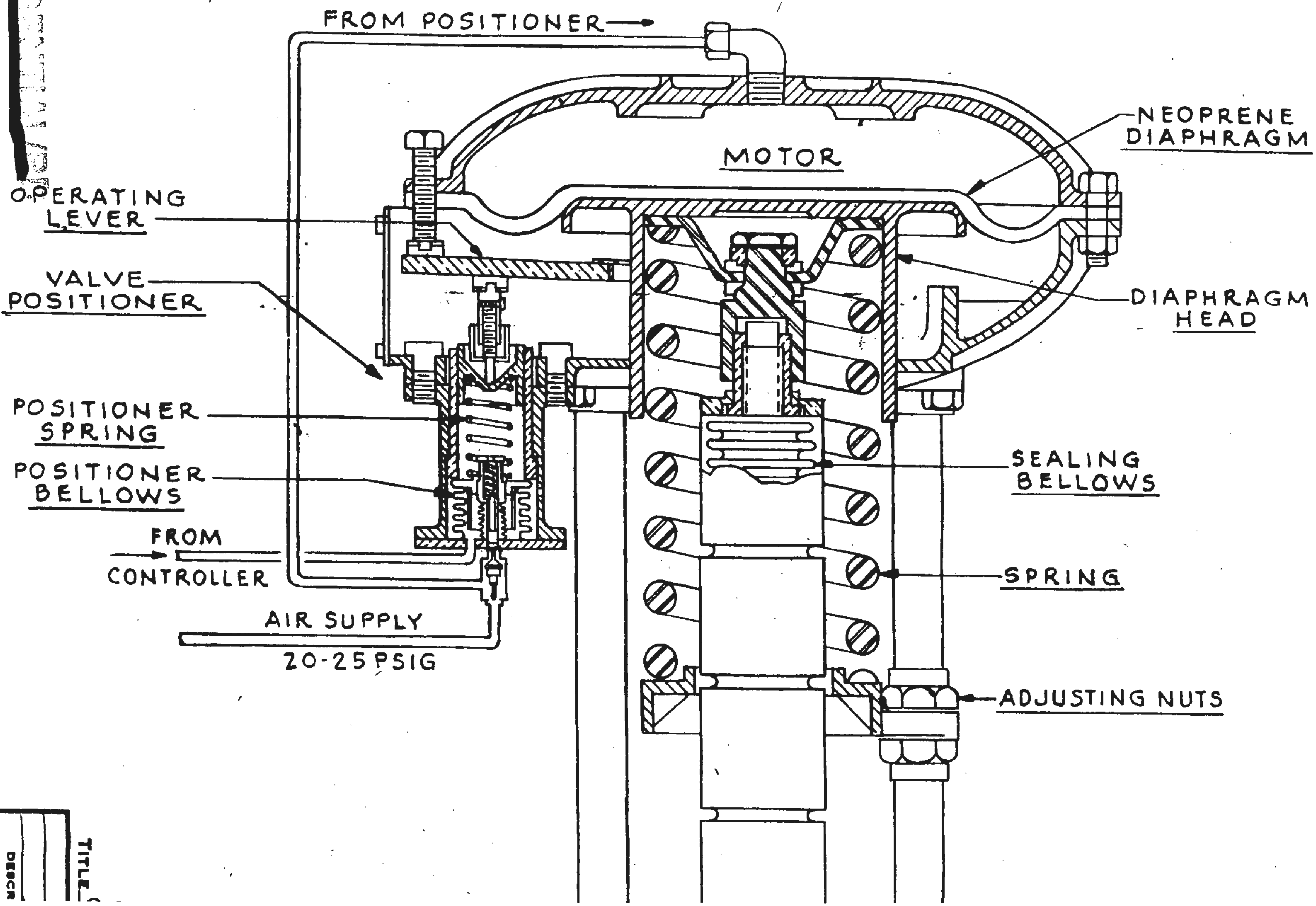
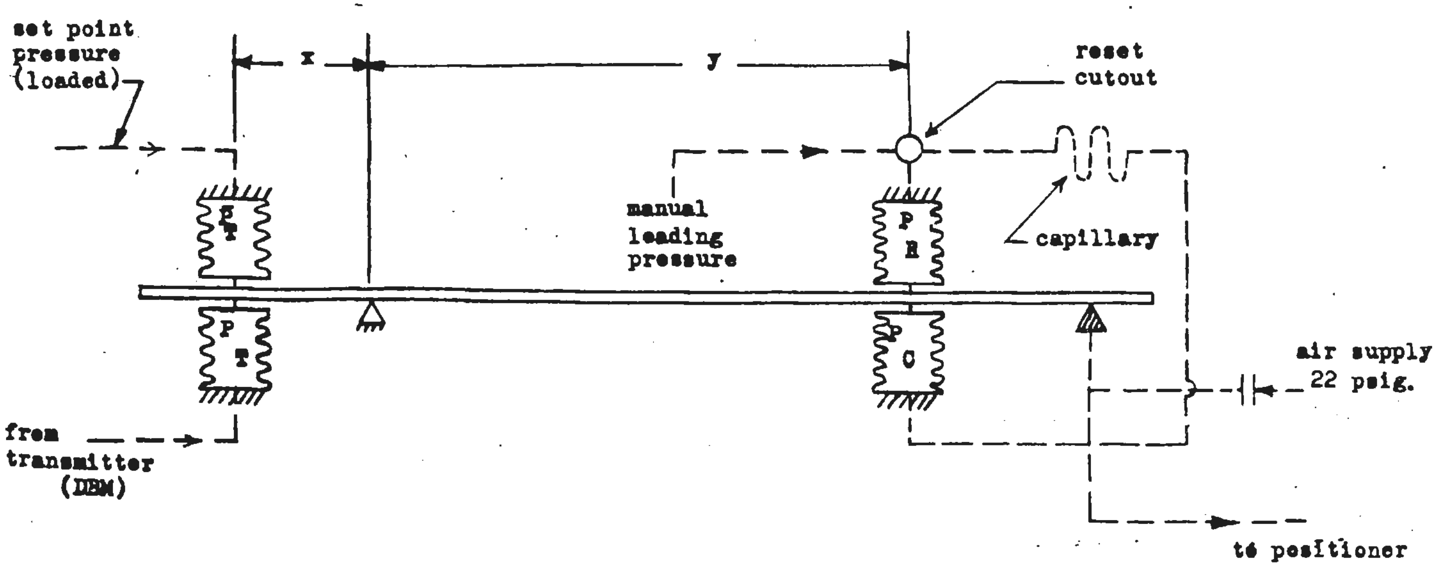

FROM POSITIONER
NEOPRENE DIAPHRAGM
MOTOR
OPERATING LEVER
VALVE POSITIONER
DIAPHRAGM HEAD
POSITIONER SPRING
SEALING BELLOWS
POSITIONER BELLOWS
FROM CONTROLLER
SPRING
AIR SUPPLY
20-25 PSIG
ADJUSTING NUTS

valve is equipped with a positioner which guarantees that the valve will come to the exact position demanded by the controller, despite friction and hysteresis effects in the valve mechanism.

(1) <u>Transmitter</u>. - A schematic diagram of the transmitter is shown in Figure 25. The instrument may be represented as four identical mounted bellows attached to a balance arm which pivots on a fulcrum. The upper left bellows is connected to process pressure (P), the lower left is loaded with a datum pressure (P_D) which is greater than process pressure, the upper right is loaded with the minimum pressure in the output range (3 p.s.i.g.), and the lower right bellows is at the transmitted pressure (P_T). When the instrument is in balance, a fixed quantity of air (about 0.1 cubic foot per minute) escapes through the nozzle, which has a clearance of 0.001 inch from the baffle. If process pressure falls, the balance arm immediately presses the baffle closer to the nozzle, forcing air into bellows P_T. The pressure P_T will rise until the lever arm is balanced, at which time the balance arm will again be horizontal, and approximately the same quantity of air as before will be escaping through the nozzle. The transmitter is inverse acting, falling process pressure causing a rising transmission, and vice versa.

(2) <u>Controller</u>. - The controller (Fig. 26) is of the proportional plus automatic reset type. A reset cutout allows the instrument to be operated with or without the automatic reset feature. With reset removed, the controller is a proportional instrument, and operates the same as the transmitter previously described. In this mode of operation, the reset bellows is loaded manually with some

TITLE: SCHEMATIC OF PRESSURE CONTROLLER (PBC)



P_T = transmitted pressure

$\bar{P}_T$ = set point of transmitted pressure

P_R = pressure of reset bellows or manual loading pressure

P_C = controller output pressure

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No. 1860-D.

pressure, P_R, between 3 and 18 p.s.i.g.

(3) Control Valve and Positioner. - The controller output actuates a positioner, which positions the control valve (Fig. 27). The valve is of the butterfly type, and is bellows-sealed, thereby avoiding the friction inherent in a stuffing box design. It is driven by a pneumatic motor whose air supply is controlled by the positioner. The function of the positioner is two-fold:

1. To reduce the hysteresis of the valve (caused principally by stem friction) to a negligible value.
2. To provide an accurate indication of the position of the valve vane.

The action of the positioner-valve combination is as follows (Fig 26): When controller output pressure, P_C, rises, the positioner bellows inflates, causing the plate to which it is attached to move upward and compress the positioner spring. The upward motion of the plate is communicated mechanically to the pilot valve, opening it and releasing air to the motor, which inflates. The diaphragm expands, pushing downward on the diaphragm head, which slides down, pulling with it the operating lever, and causing compression of the positioner spring. The plate moves downward, pushing the pilot valve toward its balance position. The downward motion of the diaphragm head depresses the stem which, through a drive link mechanism, moves the valve vane toward its closed position. The instrument is in balance when the forces acting on the positioner spring are equal, i.e., when the upward force exerted by the positioner bellows is balanced by the downward force applied by the motor through the diaphragm head. The positioner maintains a linear relationship between controller output pressure and valve stem position. The positioner input pressure is, consequently, a good indication of stem position which, in turn, is almost a linear function of vane angle. Actually, there may be a small amount of lost motion between the stem and the vane of the valve, but this is quite negligible.

(4) Datum Headers. - The control system described above is duplicated for each of the 3432 stages of the K-25 and K-27 cascades, and operates in conjunction with a nitrogen datum header system (Par. 10-7), which supplies a very accurately maintained datum pressure which is used as a reference for measurement of stage pressures, making it possible to take accurate readings of process pressures over the full range (0 - atmospheric) required by production, conditioning, and process gas recovery operation. Individual cell datum headers are connected to a main header for each process building. A pressure control system is provided for the building header and for each cell header. The system is valved so that any cell in the entire building may be operated from a datum set by either the cell or building control systems. Each datum system consists of a vacuum control valve ("inverting booster relay") actuated by a pressure controller, which is piloted from the datum pressure. A full description of the stage pressure control system may be found in Volume XI of the Kellex Operating Manuals.

c. Procurement. - Design and development of the special instruments required for K-25 was handled by a number of manufacturing firms, with the Kellex Corporation participating actively, and furnishing overall supervision. Suppliers of major importance are discussed below, prime contract summaries are included in Appendix A.

(1) General Electric Company. - The General Electric Company engineered, designed, and produced mass spectrometers, leak detectors, acoustic gas analyzers, space recorders, and differential pressure panels and transmitters. The development work was administered under contract W-7405-eng-70, which was made broad in scope in order that various phases of the instrument problems could be assigned to this company for development by subsequent instructions from the Contracting Officer. Under contract W-7415-eng-40, the General Electric Company supplied 485 differential pressure panels and 6318 differential pressure transmitters. They also supplied 16 acoustic gas analyzers, 30 mass spectrometers, and 324 leak detectors under contract W-7418-eng-53, and 6 space recorders and 116 recording gas analyzers under contract W-7405-eng-271.

(2) Taylor Instrument Companies. - The Taylor Instrument Companies undertook to develop, design, engineer, manufacture, assemble, test, and deliver various process and experimental instruments, and to procure certain additional instruments from others. Taylor also provided procurement, to supervise the testing and inspecting of the instruments procured from others. They manufactured several types of test floor instruments and pneumatic instruments for the process plant, and various other special items together with some of standard design. This work was done under contract W-7418-eng-14, which was negotiated on a unit-price basis with provisions for periodic price adjustment.

(3) Republic Flow Meter Company. - The Republic Flow Meter Company, under contract W-7418-eng-52, designed, tested and manufactured 684 four inch magnetically operated butterfly control valves, to provide for automatic control of the flow of the process gas.

(4) Fisher Governor Company. - The Fisher Governor Company

was awarded contract W-7421-eng-13 which provided for the production of butterfly control valves, varying in size from 4 to 12 inches, bellows assemblies, and various spare parts for these valves.

8-13. Cold Traps. - The cold trap is a device developed for the K-25 plant to serve the purpose of separating UF_6 from non-condensable gases. It operates by lowering the temperature of a gaseous mixture below the solidification point of uranium hexafluoride. It was designed for use in the process gas recovery system (Par. 7-12) and at points where waste gases, which might contain traces of UF_6 are to be vented to the atmosphere.

a. Development. - Cold traps were first proposed for use in process gas recovery in September 1943. Efficient cold trap design depends upon proper arrangement of heat transfer surfaces and gas flow passages to effect deposition of solid without obstructing either heat transfer or flow of gas. As with other types of process equipment, the cold traps have been designed in four sizes corresponding to the cascade sections in which they are installed. In January 1944, the Kellex Corporation began work on fabrication drawings of cold traps.

(1) Internal Vertical Tube Type. - The first important cold trap design consisted of a round horizontal shell with vertical tubes to be kept filled with refrigerant from a jacket completely encasing the shell. Tubes were spaced farther apart at the inlet end than at the outlet, in order to accommodate larger deposits at that point. This principle has been carried over into the finally accepted design. Disadvantages were encountered in excessive weight, and difficulties of fabrication.

(2) Internal Vertical Bar Type. - The design was first modified by replacing the vertical tubes with solid bars. Since the fins were mounted within the internal shell, all joints between the process and refrigerant regions were eliminated. For a given central pipe size, available volume for solid deposit was increased. In June 1944, the Schock-Gusmer Company furnished one plant-size unit based on this design.

(3) External Radial Fin Type. - In order to simplify the methods of fabrication, it was desired to place the fins on the outside of the shell rather than the inside. A new design was therefore prepared, involving radial fins externally soldered to the central shell. The fins were cooled by refrigerant evaporating in the outer jacket and the outer shell was cooled by pipes soldered circumferentially to the outside. Baffle plates were mounted in the exit tube assembly to catch entrained solid UF_6. A drawback was presented by this design in the possibility of refrigerant leaking into the shell, but when it became urgent to produce cold traps for the first portion of the plant to be operated, Case I, fabrication of this type, which came to be known as the two-shell radial fin type, was undertaken by Joseph Kopperman and Sons in May 1944 and a trial cold trap was delivered the following September.

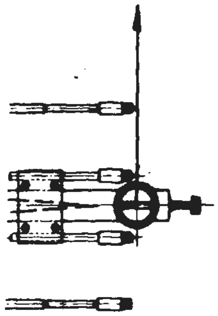
(4) Reversion to Single Shell Parallel Fin Type. - In June 1944 it was planned that the Schock-Gusmer Company should begin production of two-shell radial fin type traps in sizes suitable for the upper section of the plant. Before the manufacture of these traps was begun, it was realized that the design would entail special safety

hazards unless the inner shell could be cadmium coated. Thus, in the higher sections of the plant, the accumulation of considerable quantities of liquid or solid UF_6, highly enriched in isotopic concentration of U-235, presented the possibility of approaching a critical mass. The cadmium would act to absorb neutrons and prevent the occurrence of a chain reaction. However, such an internal coating would offer serious difficulties, both in initial deposition, and future inspection and maintenance. Improved methods of fabricating the single shell parallel fin type traps had been developed in the meantime, and it was therefore decided in July 1944 to revert to this design for all Section 3 and 4 cold traps. Fabrication drawings were ready by August 1944, and the size 3 design was accepted; the size 4 design, still too long and heavy, needed further revision. Radial design was retained for Case I and II purge cold traps (Par. 7-14), but Case II traps still required the internal cadmium coating.

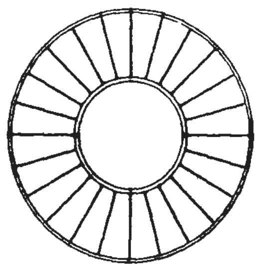
(5) Further Modifications. - By October 1944, test results in the experimental trap indicated the need for additional cooling surfaces. This need was confirmed in December by tests in the trial radial fin trap delivered by Kopperman. The following steps were taken:

1. At this time, all Case I traps had been delivered. The necessity for changes was eliminated by sufficient alteration of process conditions to achieve satisfactory functioning.
2. The three Case I traps (which had been delivered) were sent back for alteration along with the unfinished ones.

PROCESS GAS
OUTLET FLOW

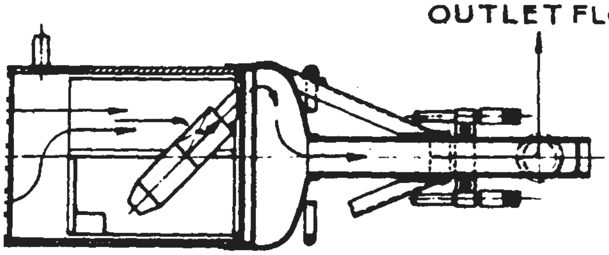


FINS CROSS SECTION
NEAR OUTLET END



RANT INLET
& JACKET

PROCESS GAS
OUTLET FLOW



FINS CROSS SECTION
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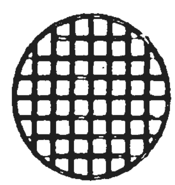

FIG. 28

COLD TRAPS

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ON	DATE	CHECKED		DR. F.L. TR.
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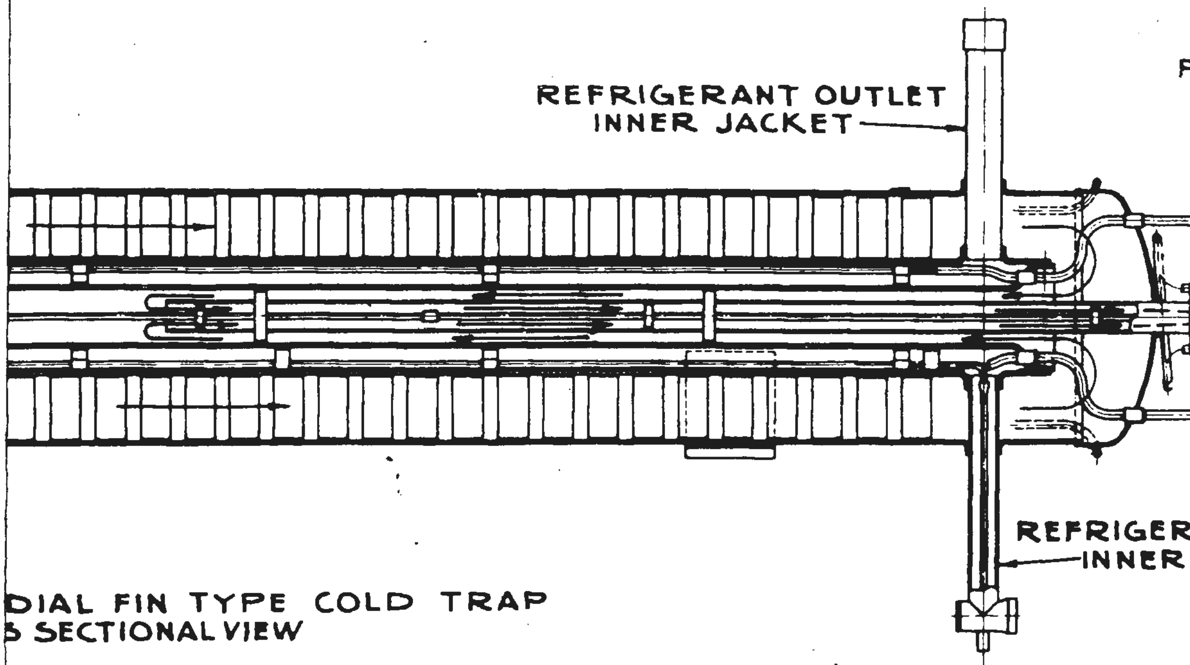
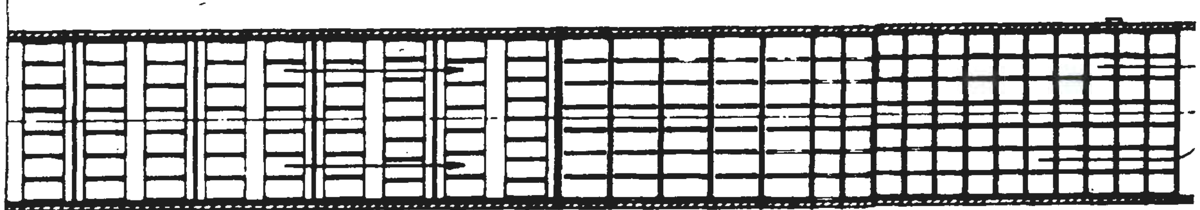
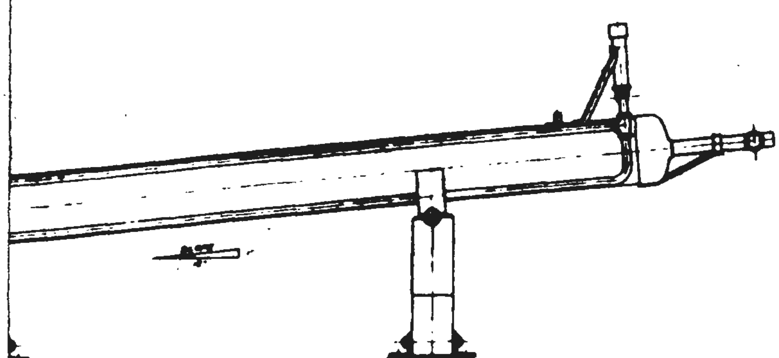


DIAL FIN TYPE COLD TRAP
S SECTIONAL VIEW



L PARALLEL FIN TYPE COLD TRAP
CROSS SECTIONAL VIEW



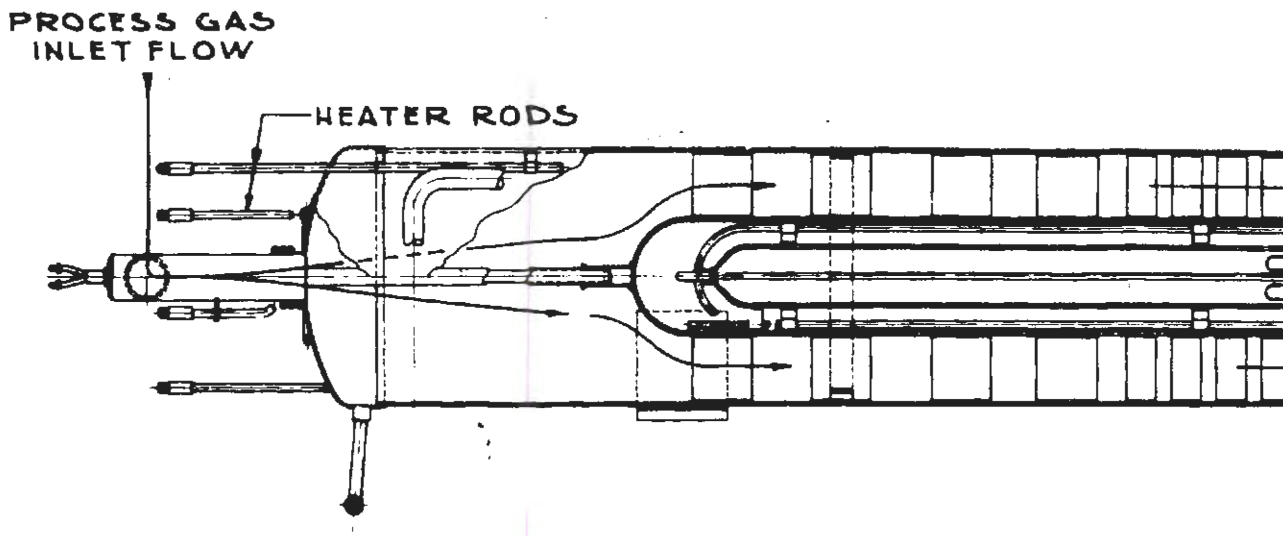
TYPICAL SIDE VIEW
INSTALLED COLD TRAP

[redacted]

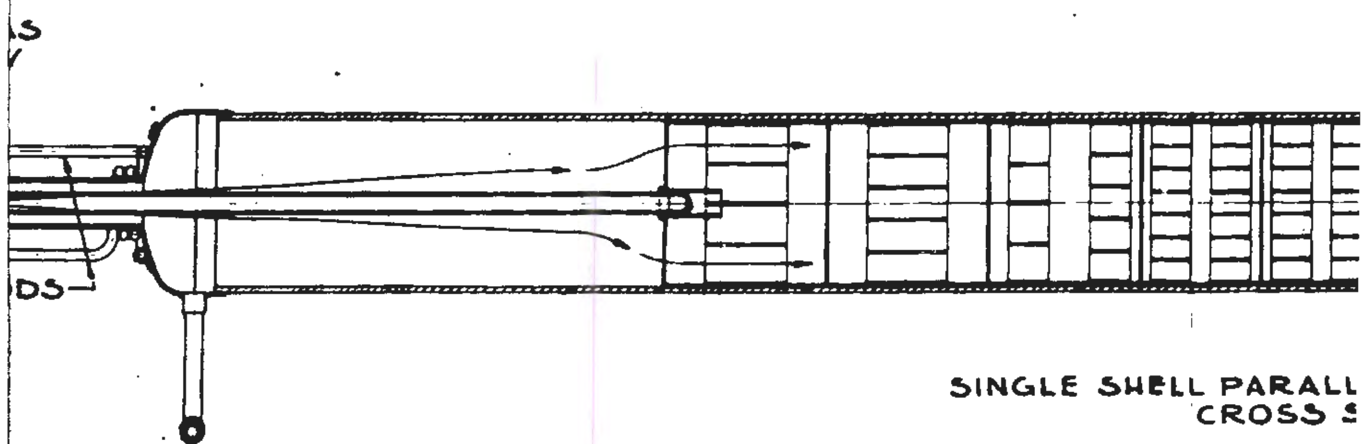
TITLE

DESCRIPTION

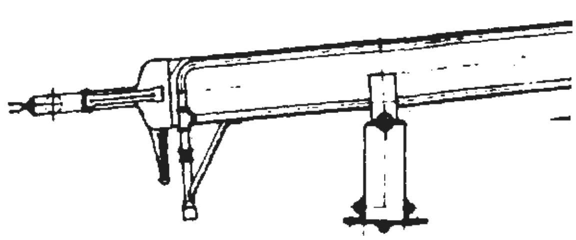
[redacted]



DOUBLE SHELL RADIAL FIN
CROSS SECTION



SINGLE SHELL PARALL
CROSS S



TYPICAL
OF INSTALLI

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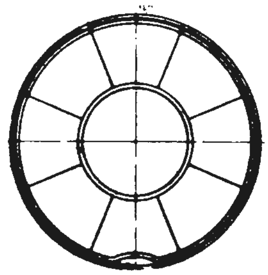
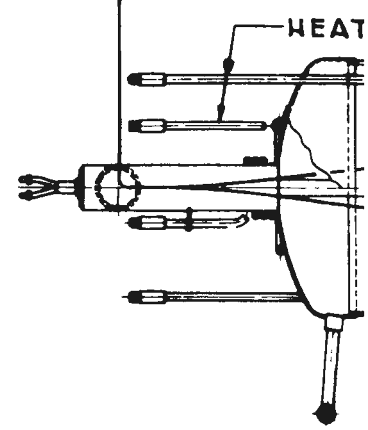
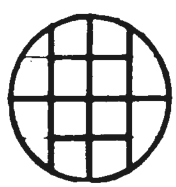
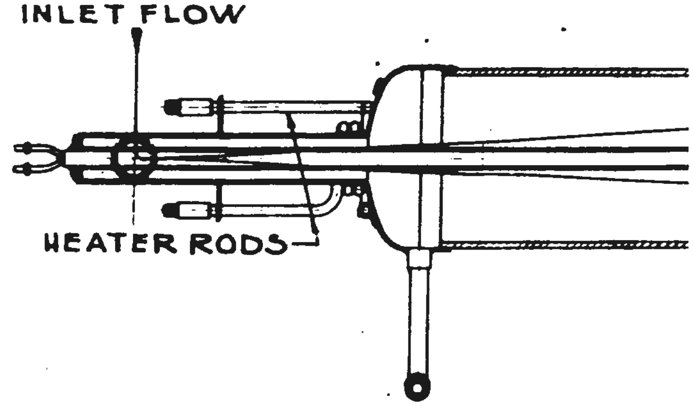


FINS CROSS SECTION
NEAR INLET END





FINS CROSS SECTION
NEAR INLET END



[redacted]

Checker work fin rings were added in the front end of the Case I and II units, and all fins were replaced by annular disc baffles fixed in the inner shell.

3. For the Case II groups, cyclone separation units were to be installed as separate items at the cold trap outlet.

4. The large, Section 1, radial fin type traps required only the addition of baffles.

(6) Fume Recovery. - In February 1945, results of fume carryover tests showed that fume losses from the section 4 cold trap would be serious. A three-foot end section was added, containing a new and larger cyclone separator with a special collecting tank below. This was followed by a nickel wool filter for trapping last traces of UF_6 mist. The fabrication drawing was ready by March 1945.

b. Final Design. - The three largest sizes (of 19, 16, and 10 inch diameters) are of the double shell radial fin type, and are installed in process gas recovery systems of Sections 1 and 2, and temporary purge and product systems of Cases I and II. Parallel fin, single shell traps (of 8 and 4 inch diameters) are installed in the upper sections of the plant. Cold trap design is illustrated by diagram in Figure 28, and by photograph in Appendix E3.

(1) Radial Fin Type. - The radial fin cold traps consist of a thin round copper shell, sealed on either end by monel heads, and supported on wooden blocks in a slightly tilted position. The outer shell encloses a second copper shell with groups of copper fins attached radially. The fins in each group are evenly spaced around

the inner shell, but the number of fins in each group increases toward the outlet end of the shell. The inner copper shell is closed at the lower end, and has a cooling jacket on the inside with refrigerant connections. The process gas mixture is pumped in at the lower end of the cold trap, and passes along the fins between the inner and outer shell until it reaches the upper end of the trap. The gas then reverses direction of flow, and passes inside the inner shell between the refrigerant jacket and the outlet tube, which is projected down the middle of the trap. When the gas reaches the end of the outlet tube, it reverses direction again, and leaves the cold trap via the outlet tube.

(2) Parallel Fin Type. - The parallel fin type cold traps are simpler devices, but are similar with respect to outward shape, inclined position, and outer copper shell capped on the ends by monel heads. The fins, however, are silver soldered to fin rings which are then slipped inside the shell and soldered to it. All refrigeration is accomplished by cooling the outside of the shell with refrigerant pipes. The flow is straight through the trap past the parallel fin sections. In most of the eight-inch traps, baffles are included to increase the flow rate per unit area cross section, and in most 4 inch and 8 inch traps, a small cyclone separator is placed at the upper end of the trap to help remove any solid UF_6 mist present.

(3) Heater Elements. - On all cold traps, electric Calrod heaters are attached to heat the shells. In the case of the radial fin traps, there are additional heating rods in the inner refrigerant jacket. The main purpose of these heaters is to melt and drive out the UF_6 when discharging the trap. A small amount of power

is also used to warm the inlet end of the trap during the condensation operation to prevent plugging of the inlet with solid UF_6. The necessary thermocouples and pressure connections are provided on the traps so that the operating conditions of pressure and temperature can be recorded. All cold traps are heavily insulated with asbestos felt of thickness varying from 8 inches to 10 inches.

c. Procurement. - A description of manufacturing techniques and progress is presented in the Kellex Completion Report, Section III, (9). The Schock-Gusmer Company produced the single-shell parallel fin type under contract W-~~7418~~ 7415-eng-~~62~~ 43. The Patterson-Kelley Company produced the double-shell radial fin type under contract W-7418-eng-62.

8-14. Carbon Traps. - Carbon traps are installed at a number of points in the plant to supplement the use of the cold traps in recovery of UF_6 from vent gases. There are two carbon traps piped together in series in every cold trap recovery system. These serve to trap out any UF_6 which was not retained in the cold trap. Thus, carbon traps serve the following functions:

1. The clean-up of UF_6 in the gases leaving the cold traps.
2. The absorption of the UF_6 content of one cell in an emergency when cold traps are out of service.
3. The absorption of UF_6 blown into a carbon trap by the cold trap relief valve in Sections -3 through 2a.

Function (1) is the normal service for the carbon traps, but this service does not set the design for carbon traps. It does, however, determine the normal life of the charge. The carbon traps have been sized and the charge specified on the basis of function (2), the absorption of the contents of one cell.

a. Development. - Test work done in the Kellex Jersey City Laboratories was directly responsible for the ultimate design and operation of the process gas recovery system carbon absorbers. This work was begun late in 1943 and continued until June 1945. Among the various solid materials tested as UF_6 absorbents were silica gel, sodium fluoride, sodium bifluoride, Florite* desiccant, activated alumina, and activated carbon. The latter gave the most efficient absorption. The possibility of overheating and caking of the carbon bed when absorbing gases rich in UF_6 led to tests on various diluents. Crystalline alumina was found to be satisfactory, and tests performed on a plant-size carbon absorber gave results which determined the optimum carbon-alumina ratio, and the method of charging a trap to avoid segregation of the alumina and carbon in the charge. At the same time, a satisfactory cadmium oxide-impregnated alumina was developed for carbon absorbers to be used for absorbing UF_6 with high light component concentration. An investigation was made on the effect of various concentrations of fluorine on activated carbon. It was found that, under certain conditions, an unstable compound was formed which detonated on impact. These tests indicated that it would be necessary to keep the weight of fluorine charged to carbon absorbers below two per cent of the weight of carbon in the absorber.

b. Final Design. - All carbon traps are of the same basic design, differing in size according to sectional location.

(1) Shell. - The steel shell consists of an upper

cylindrical section and a lower conical section. The gas enters the side of the conical section, which is charged with alumina, through a cylindrical strainer. It passes up through the cylindrical section, loaded with mixed carbon charge, and leaves at the top of the trap. The vertical cylindrical section is welded, at its lower end, to a cone, 11-3/4 inches in bottom diameter. The cylindrical body varies in diameter from 17-1/4 inches to 28 inches. Each trap is provided with a charging nozzle at the top, and a dump gate at the bottom.

(2) Bed. - The conical portion of the carbon trap is charged with 4-mesh crushed alumina; this serves as a non-reactive support for the absorbent charged to the cylindrical portion of the trap. The cylindrical portion is charged with a uniform mixture of crushed alumina and high activity carbon pellets, the alumina acting to prevent excessive temperature rise. The proportional composition of the charges for various traps is discussed in Paragraph 11-8. The alumina charged to the carbon traps in all sections above Section 1 is impregnated with 2.5 per cent by weight of cadmium oxide. The carbon removes UF_6 from the gas stream by a combination of surface adsorption, and chemical conversion to non-volatile uranium fluorides and volatile carbon fluorides.

c. Procurement. - K-25 carbon traps were supplied by the Alco Products Division of the American Locomotive Company under contract W-7415-eng-38.

1

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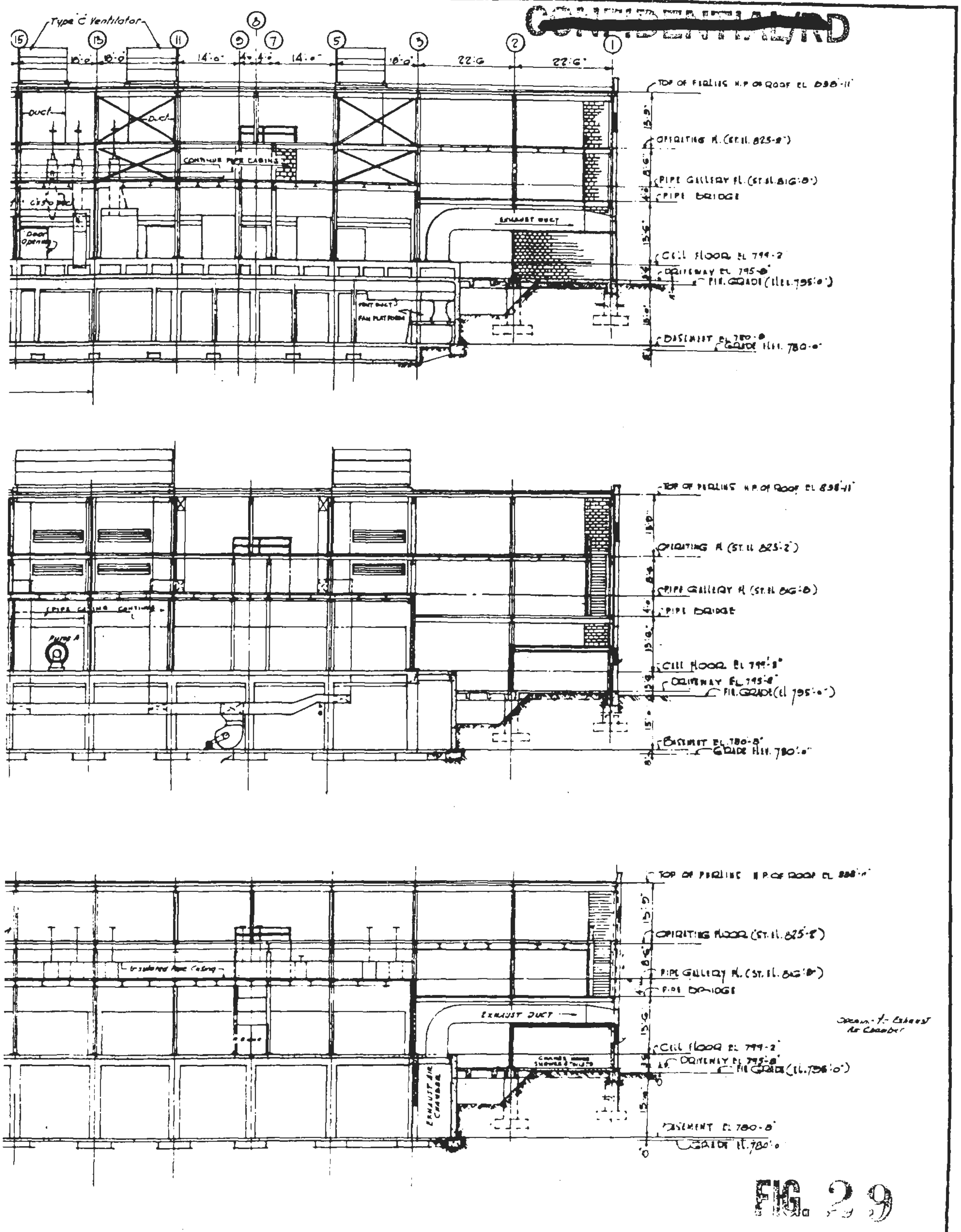


FIG. 29

THE KELLEX CORPORATION

FOR

LONGITUDINAL SECTIONS

BLDGS K-302-1,2,3,4 AND 5

NO.	DESCRIPTION	DATE	BY	CHECKED
1	General revisions to agree with 1/8" scale drawing	6-23-44	HF	CAC

REVISIONS

DRAWN Kruger CAC TRACED SCALE 1/16" = 1'-0" DATE 5-6-44

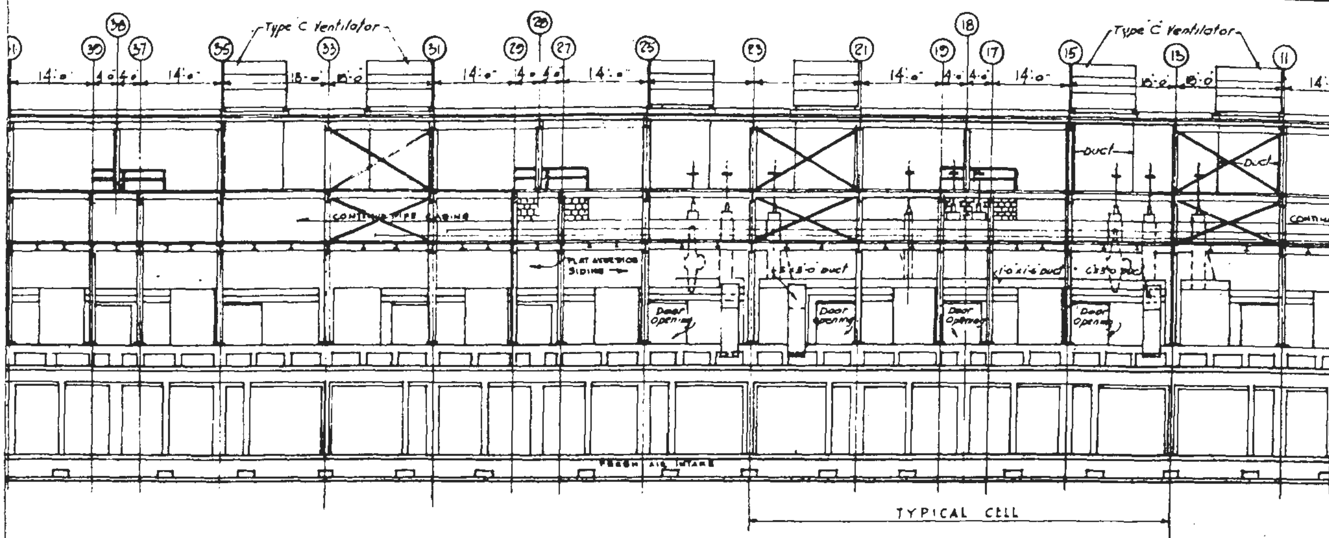
CHECKED C Mills

APPROVED NM Dean 5-6-44 NO. 302-1-K-30 GA

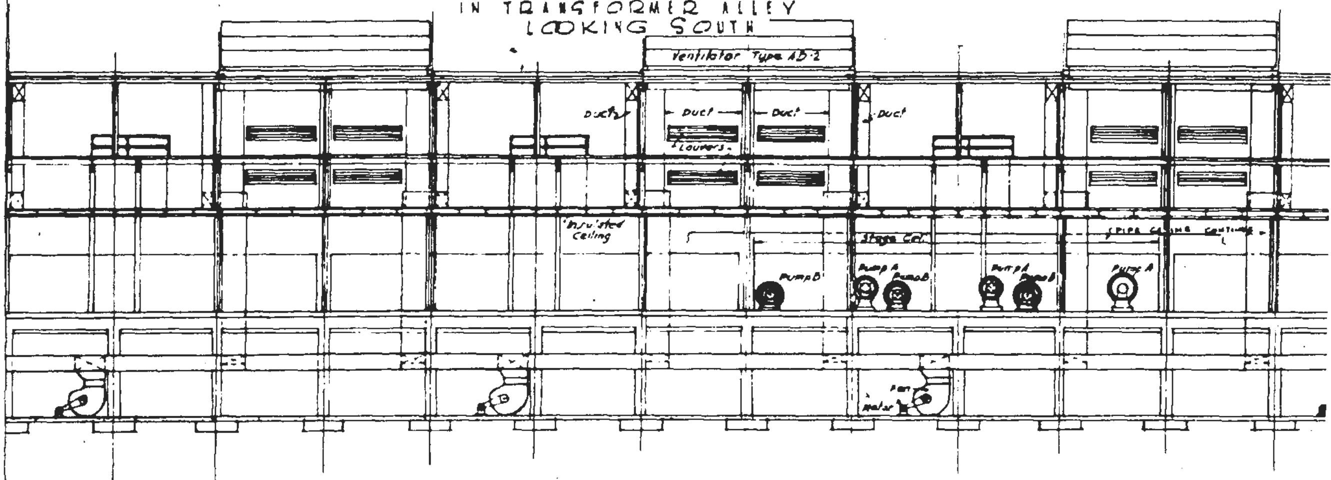
[redacted]

2

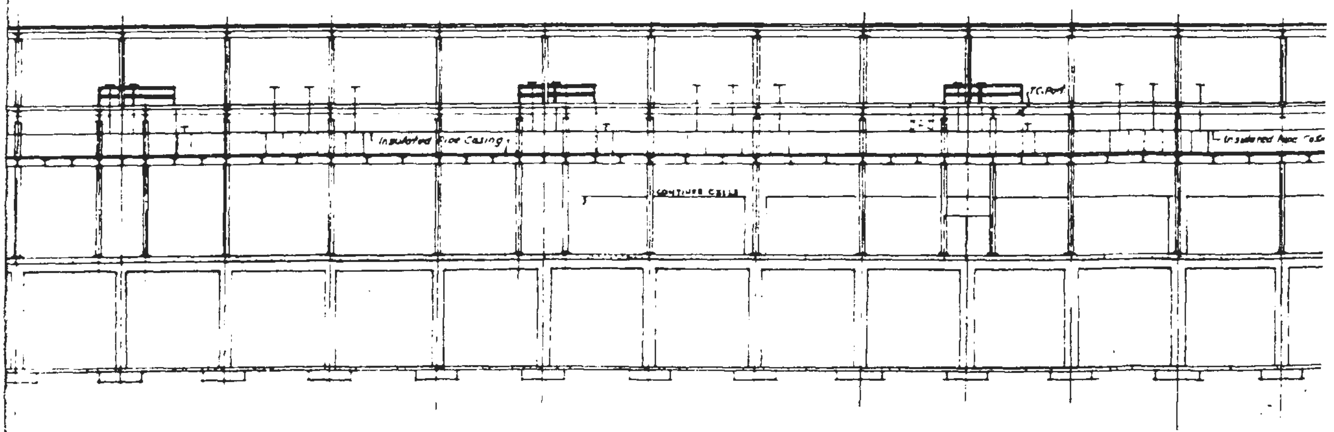
[redacted] SECRET



SECTION BETWEEN "A & L" COL LINES
IN TRANSFORMER ALLEY
LOOKING SOUTH



SECTION BETWEEN "H & J" COL. LINES
LOOKING SOUTH



SECTION BETWEEN "J & K" COL. LINES
LOOKING SOUTH

300 K 5 AD	GETTER DETAIL
300 K 5 AB DA	RIVER STA. R
302 5 K 50 RA & SA	TRANSFORMER ALLEYS
302 5 K 50 FA	CROSS SECTION
302 5 K 50 EA	ROOF PLAN
302 5 K 50 DA	OPERATING FLOOR
302 5 K 50 CA	PIPE GALLERY
302 5 K 50 BA	CELL PLAN
302 5 K 50 AA	BASEMENT PLAN
302 B M 50 AA / THRU 50 LA	STEEL
302 5 L 40 FA	RETAINING WALLS
302 B A 40 BA / AND CA	FLOORS

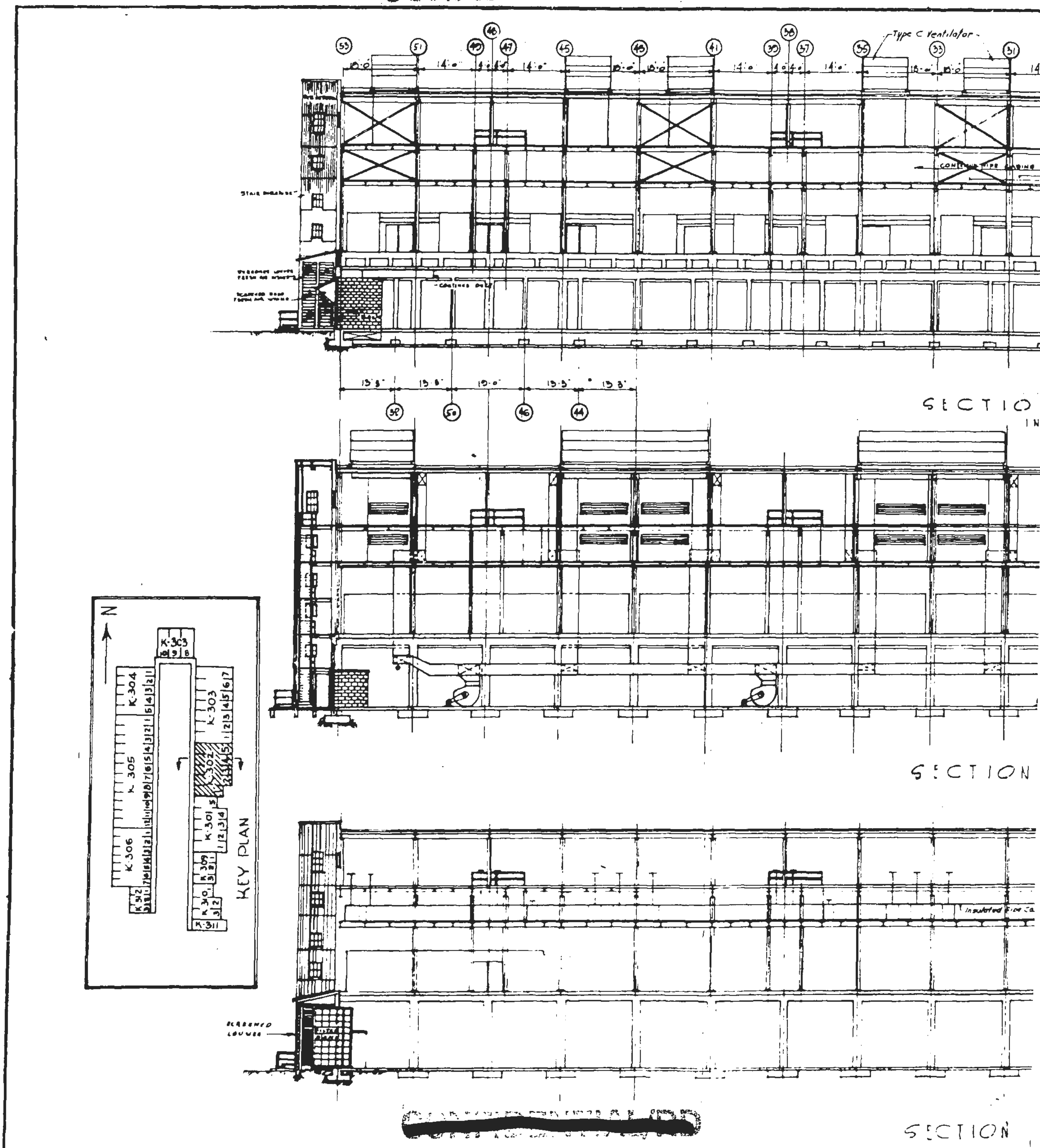
MATERIAL LIST

REFERENCE DRAWINGS

[redacted]

[redacted]

[redacted]



[redacted]

1 BUILDING K-302-1 1-72'-0" LENGTH CELL SHAFT			
NOTES		MATERIAL LIST	REFE…

SECTION 9 - PROCESS BUILDINGS AND UTILITIES

9-1. Introduction. - Volume 4 presents an account of the size, cost, material of construction, and construction history of the buildings housing equipment and facilities described in foregoing and subsequent sections. This section presents a general discussion of the most important buildings, namely the cascade process buildings, including a typical description of a single process building and a résumé of the building utilities. Major utility installations of direct and prime importance to the production process, such as the power plant (Sect. 12) and the process cooling water system (Par. 10-3) are described at other points in the text. Utilities covered in this section are of indirect service to the process, chiefly systems required for maintaining practical working conditions, and facilitating production and maintenance activities. A more detailed description of process buildings and utilities may be found in Volume IX of the Kellex Operating Manuals.

9-2. The Cascade "U". - The geometrical arrangement of the main process area plot plan has been mentioned and illustrated by means of Appendices B1 and B2, and the various plans shown in Appendix A of Volume 1. In external appearance, the process plant proper (excluding auxiliary structures and the K-27 annex) appears as a huge "U"-shaped structure. Actually, it is made up of a series of 54 contiguous buildings, three of which house the purge cascades (Section 312), and 51 of which house the isotope separating stages.

9-3. Typical Process Building. - These latter buildings (as well as those of K-27) are all similar in form and general arrangement,

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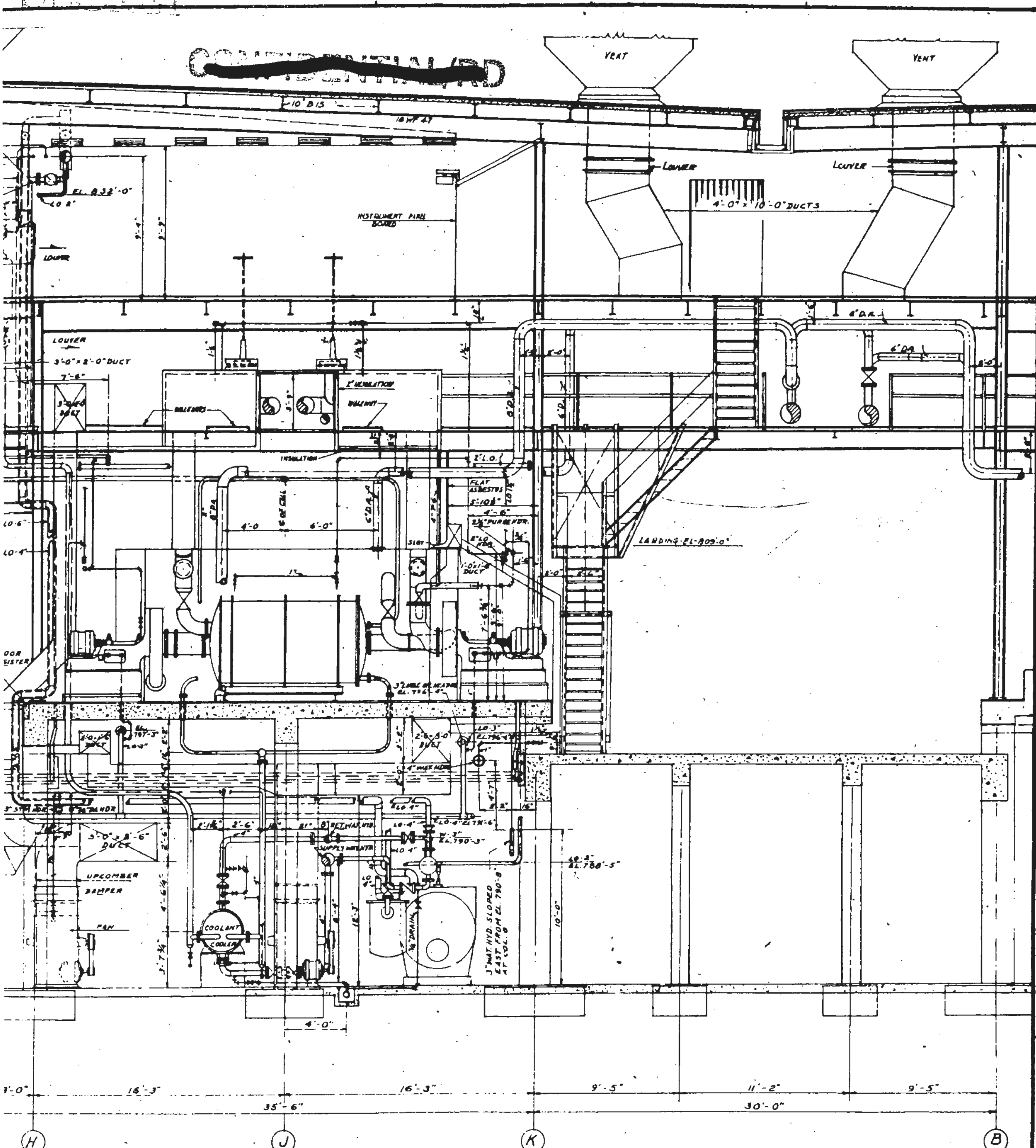
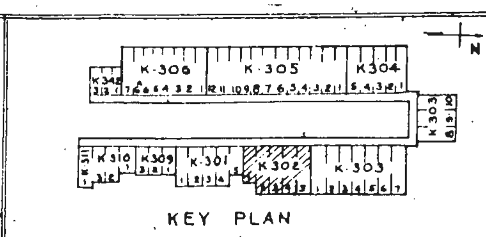


FIG. 30



SEE REISSUE NO. 4 DATE FOR LATEST REVISION

REVISIONS

THE KELLEX CORPORATION

TYPICAL CROSS SECTION
BUILDINGS # 302-1-TO 5

DRAWN F. J. MEYERS   TRACED   SCALE 1/8" = 1'-0"   DATE 2-19-44
CHECKED C. MILLS
APPROVED

NO. 302-1K-30-FA

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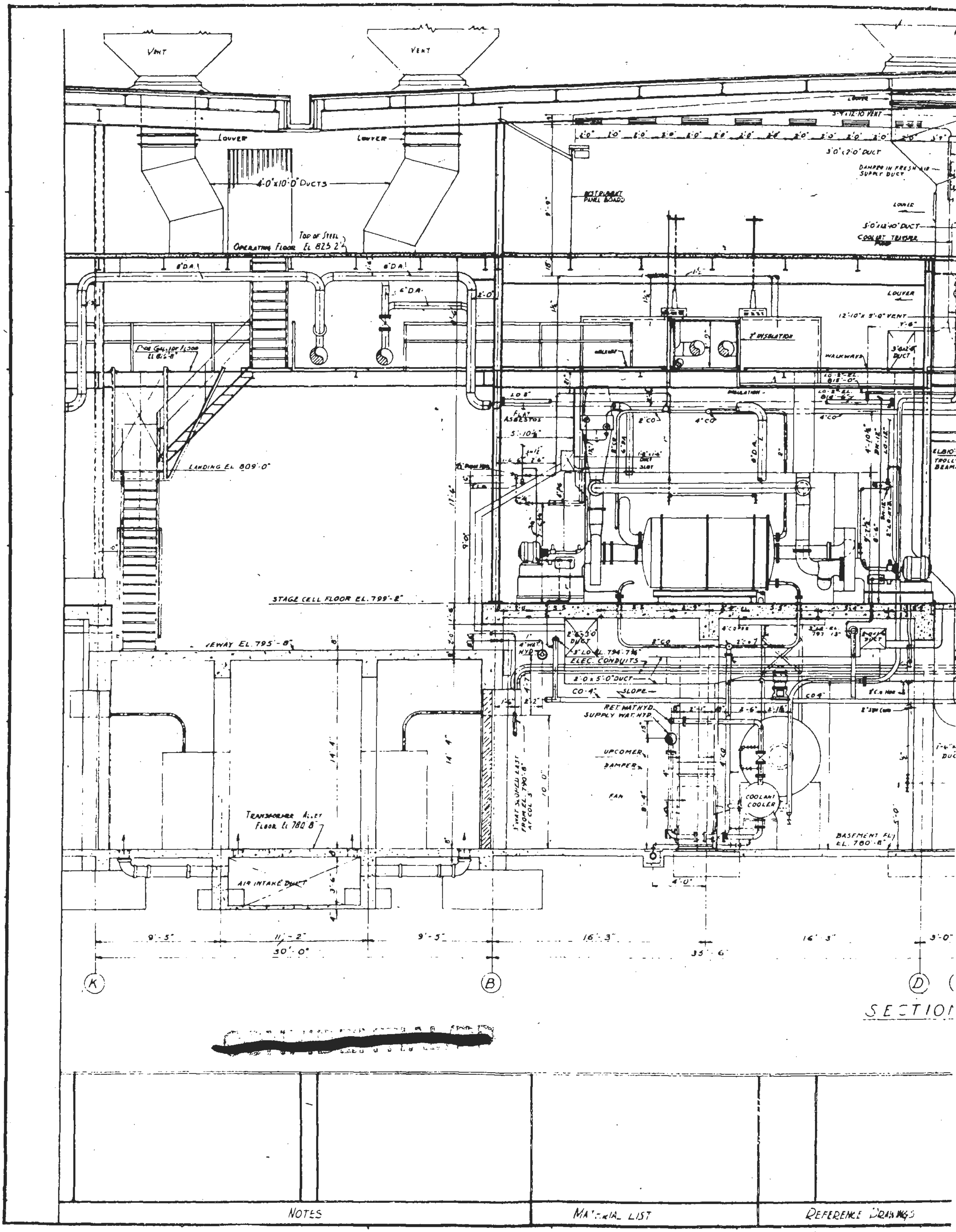

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differing in size as outlined in Paragraph 7-7. Longitudinal and cross-sectional views are shown in Figures 29 and 30, respectively. The remainder of this paragraph describes the general design and arrangement of each of the four levels of a typical building. Drawings shown apply specifically to Building K-302-3.

a. Basement. - The basement floor is approximately level with grade at one end of the building, and about 15 feet below grade at the opposite end. This arrangement makes it convenient to move equipment to and from the basement area at the lower grade level. The following equipment is located in the basement (Fig. 31):

Coolant Coolers
Coolant Drain Drum
Coolant Transfer Pump
Lubricating Oil Pump
Lubricating Oil Cooler
Lubricating Oil Drum and Filter
Operating Floor Ventilating Fans
Cell Floor Ventilating Fans
Cold Trap and Evacuating Pumps
Air Filters

(1) Transformer Vaults. - A transformer vault is provided to serve each pair of adjacent buildings, and is located on the basement level in between the two buildings. Each transformer vault (App. E6) is enclosed by concrete cinder block walls, and contains variable and constant frequency transformers, switchgear, and transformer vault ventilating fans.

b. Cell Floor. - The converters, each with its "A" and "B" pumps, are located in groups of six on the converter cell floor. Each group of six converters, together with interconnecting piping and auxiliary service lines, is contained in a cell compartment made up of 16 gauge steel panels. This sheeting is tightly welded to prevent gas

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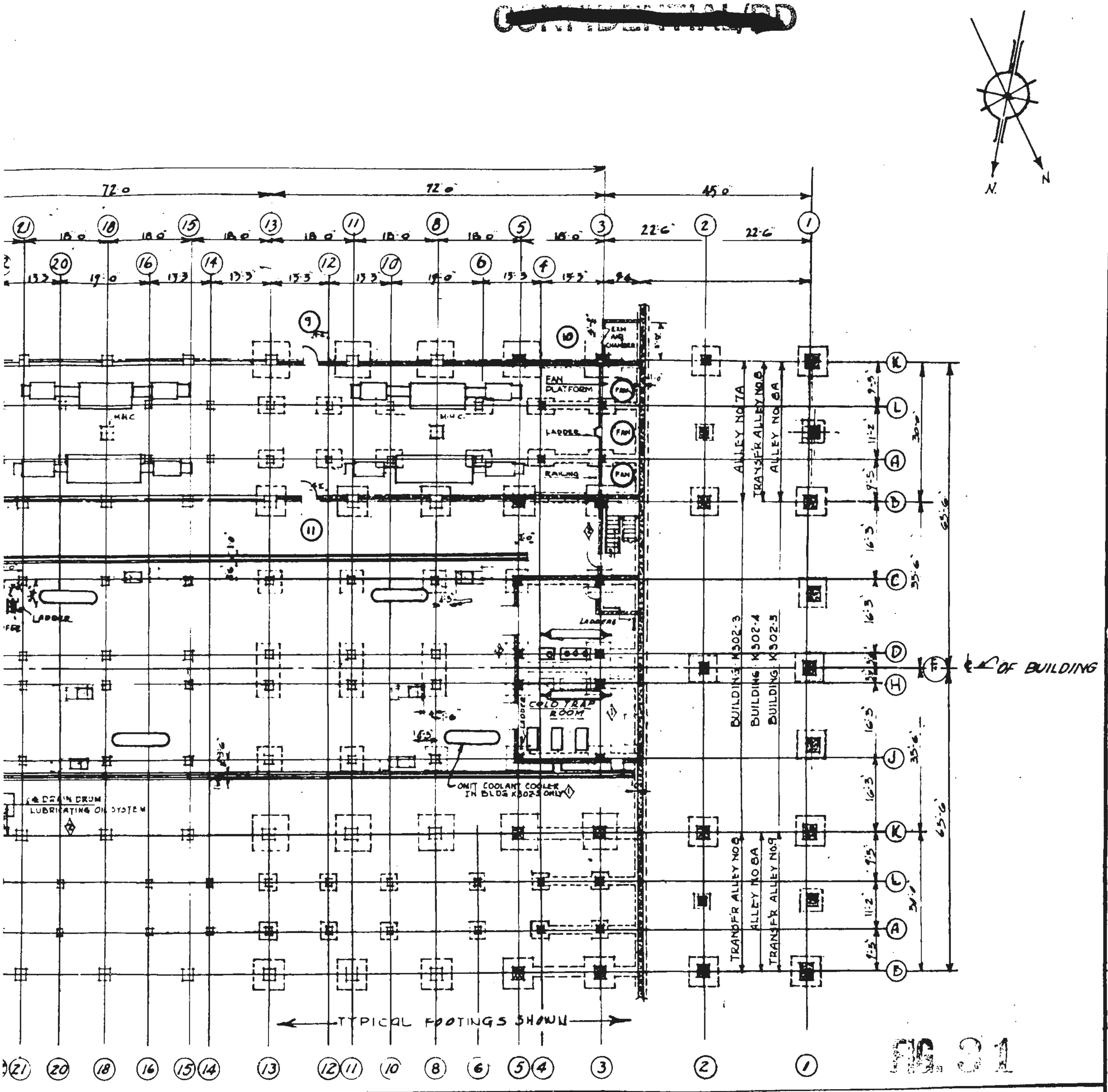
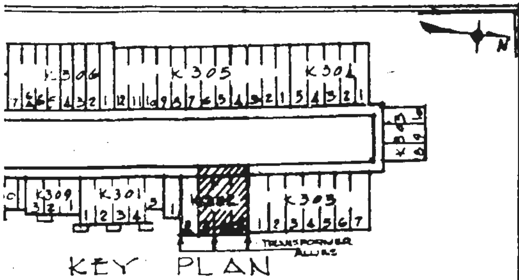


FIG. 31



KEY PLAN

NO.	DESCRIPTION	DATE	BY	CHECKED
2	STAIRS & DOORS NUMBERS ADDED	9-8-44	C.N.S.	M.A.S.
1	COLD TRAP ROOM ADDED & TRENCH EXTENDED	9-1-44	C.N.S.	F.W.S.

REVISIONS

THE KELLEX CORPORATION

BASEMENT PLAN (GRADE EL. 780-0)
BUILDINGS K302 3-4-5

DRAWN A.H. DE ROSE TRACED SCALE 1/16"=1'-0" DATE
CHECKED C. MILLS
APPROVED HAYDEN 4-6-44 No. 302-3-K30AA

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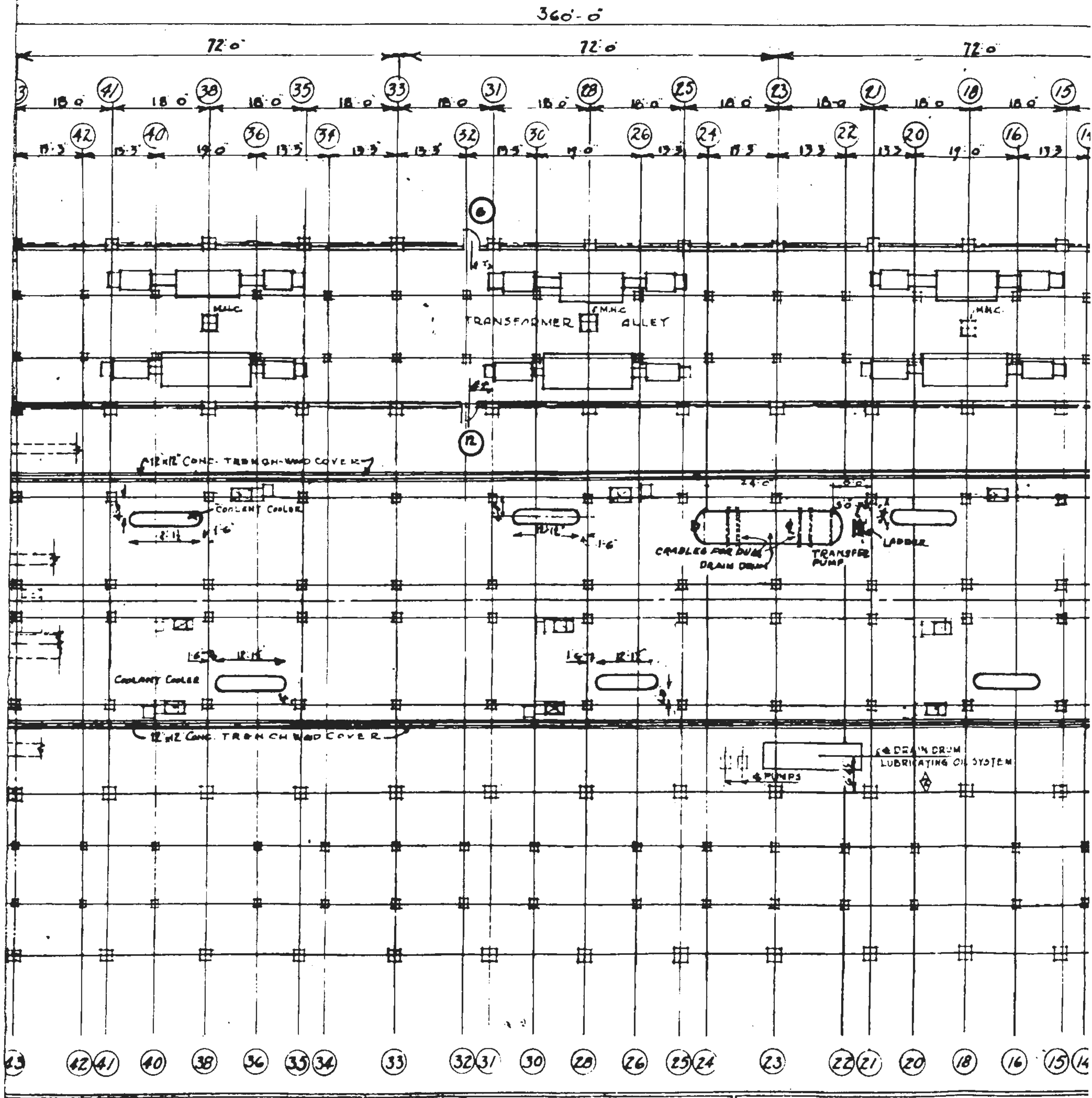
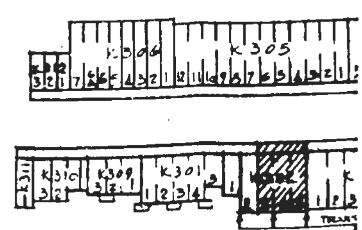


MATERIAL LIST	REFERENCE DRAWINGS	
TRENCH COVER - WOOD (2-1"x8" CLEATED)	312-1-K-30 QA	BASEMENT PLAN
MANHOLE COVERS - PRECAST CONCRETE	300-K-31-HA&PA	DOOR SCHEDULE
FLOORS - CONCRETE	300-K-31-DA&EA	REAR STAIR
WALL EXTERIOR - 8" CONC BLOCKS.	312-3-K-30-GA	LONGITUDINAL SECTION
TRANSFORMER ALLEY 8" CINDER BLOCKS.	302-3-K-30 FA	CROSS SECTION
TOILETS 6" T.C. BLOCKS.	300-K-30-AA	PLOT PLAN
REAR STAIR - STEEL COVERED WITH CORRABOARD	312-1-K-30 PA	TRANSFORMER ALLEYS.
CONCRETE / T.C. BLOCKS	312-3-A-20-AA&BA	FOUNDATIONS
CINDER BLOCK		



KEY PLAN

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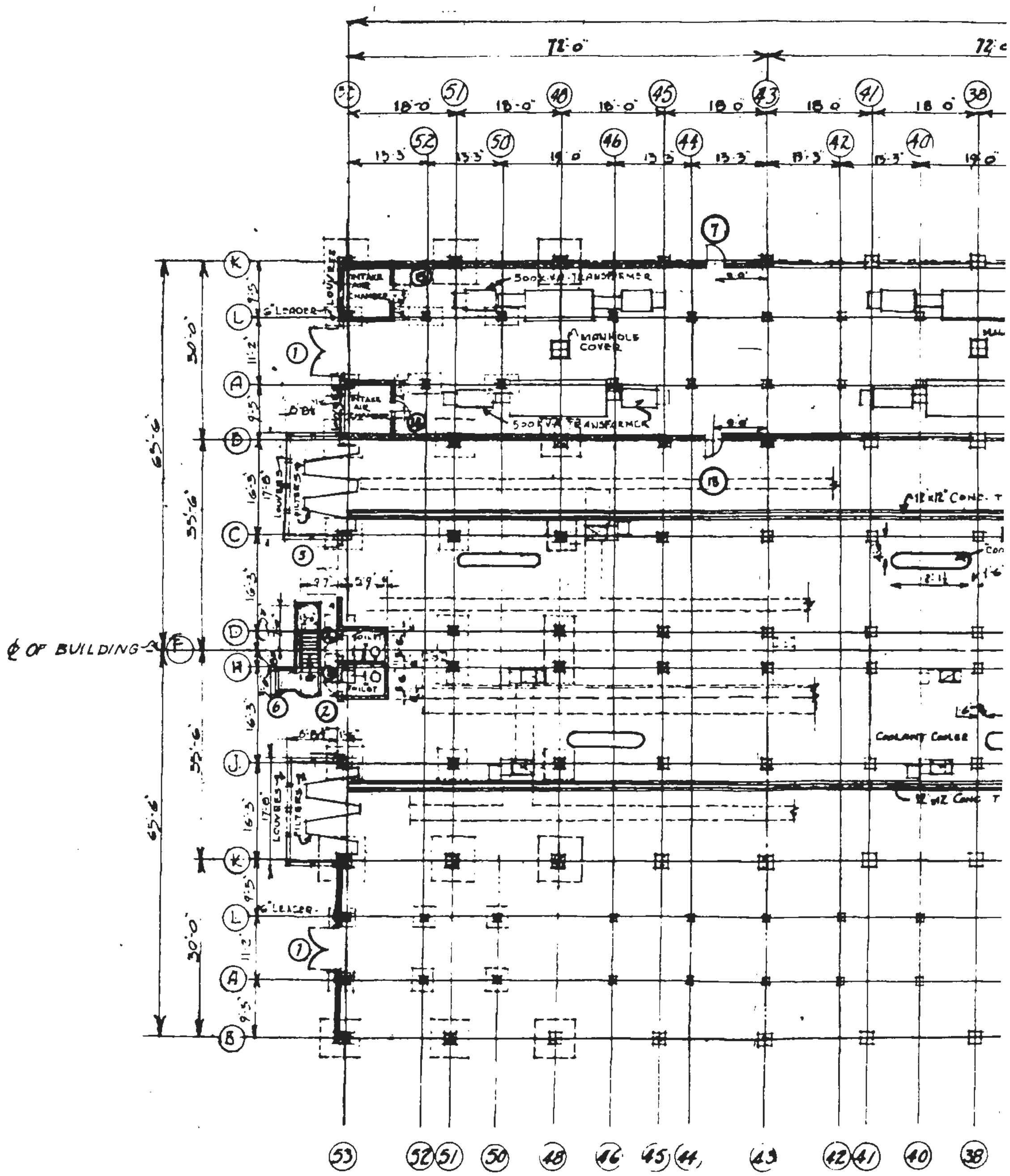
[redacted]



1	FOR LOCATION TRANSFORMER ALLEY SEE KEY PLAN

NOTES

TRENCH COVER - WOOD (2-1"x8
MANHOLE COVERS - PRECAST C
FLOORS - CONCRETE
WALL EXTERIOR - 8" CONC
TRANSFORMER ALLEY 8"
TOILETS 6"
REAR STAIR - STEEL COVERED
CONCRETE
CINDER BLOCK

MATERIAL

[redacted]

leakage from the cell and back diffusion of moisture into the cell enclosure.

(1) Motor Alley. - The cells are arranged in two parallel rows with an equal number in each row, and an alley between called the motor alley, or escape alley. Motors for driving one half of the process pumps are located in the motor alley, and space is provided for workmen to check performance and operating conditions. An overhead trolley is provided in the center of the alley, to be used for removing motors and pumps from the building.

(2) Withdrawal Alley. - The remainder of the pump motors are located between the cell bank and withdrawal alleys, with a similar arrangement. Figure 32 shows the general plan of a cell floor, which, in Building K-302-3, contains ten cells. The withdrawal alleys run adjacent and parallel to the long sides of the building. The withdrawal alley floors are located about truck bed height below the cell floor level, to facilitate movement of equipment to and from trucks. The withdrawal alleys serve as roadways on which equipment is transported on special trucks into the main buildings, and connect to highways outside of the building.

e. Pipe Gallery. - On the pipe gallery level are located piping and valves so provided that any cell can be by-passed, if conditions arise that necessitate the shutting down of a cell. The by-pass piping and the necessary by-pass valves are also enclosed in a steel paneled, air-tight compartment. A compartment runs lengthwise over each row of cells with extensions to the sides wherever the piping runs down to the converters. The compartments are supplied with dry

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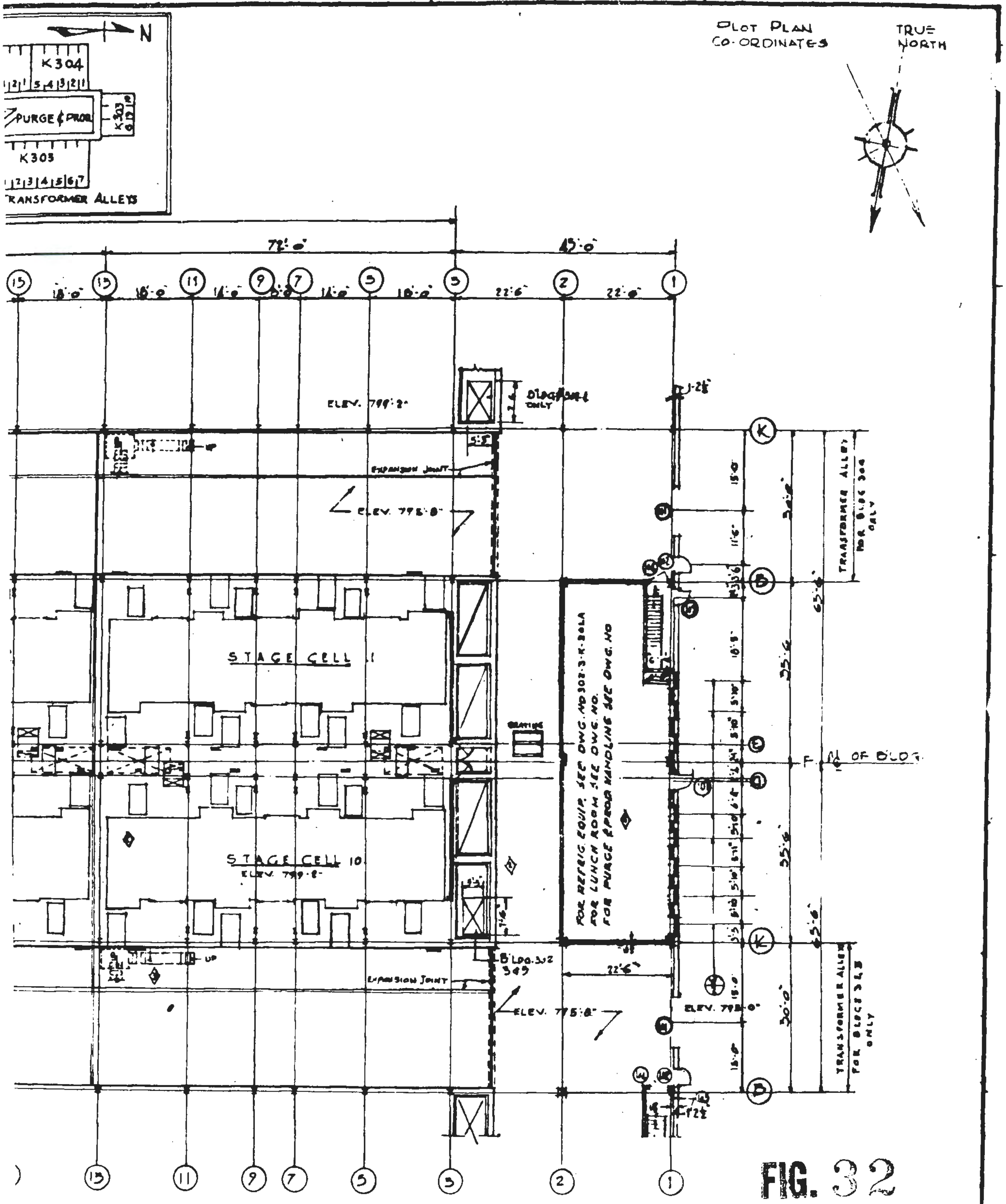


FIG. 32

No.	Description	Date	By	Checked
4	CHANGE HOUSE OUT; WALKWAY ADDED ALONG REAR WALL OF BLDGS.	9-1-44	J.L.S.	C.H.B.
3	STAIRS ADDED IN DRIVEWAYS; MOTOR ALLEYS SLABBED OVER; MANHOLES INDICATED	6-20-44	N.K.	C.H.B.
2	STAGE CELLS REVISED & STEEL GRATINGS ADDED	5-24-44	C.H.B.	N.K.
1	DOOR NO. 109 WAS NO. 102; DOOR NO. 111 REMOVED	4-18-44	M.L.	C.H.B.

REVISIONS

THE KELLEX CORPORATION

STAGE CELL FLOOR PLAN (GRADE EL. 799 ...)

BUILDINGS: K302-... 3-1-5

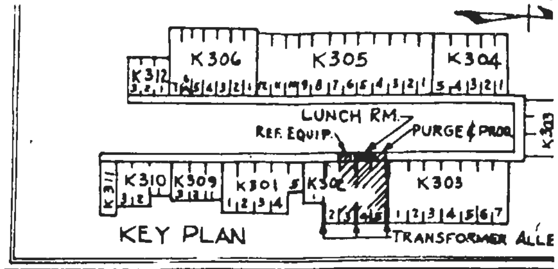
DRAWN: A.M. DeRosa — TRACED: ...
SCALE: 1/16" = 1'-0" — DATE: 4-6-44
CHECKED: C. Mills
APPROVED: ... 6-6-44

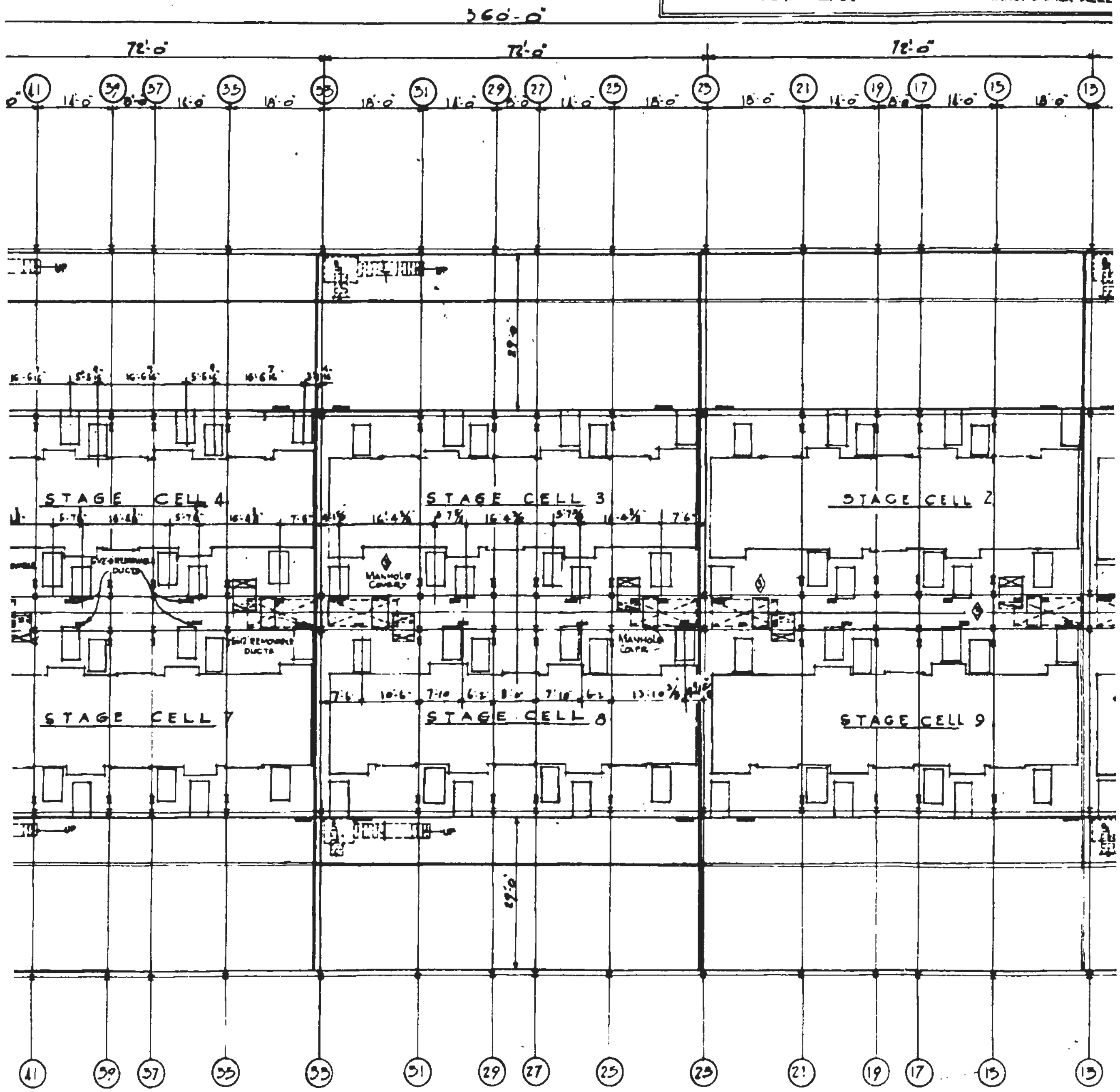
No. 302-3K 30 BA

[redacted]

[redacted]

SCHEDULE OF ROOM USAGE	
REFRIG. ROOM	K 302-3
LUNCH ROOM	K 302-4
PURGE & PROD.	K 302-5





CONCRETE RIOR - CORR. ASBESTOS ON STEEL STUR STAIR 6" T.C. STEEL COVERED WITH CORR. ASBESTOS BLOCK	
ATERIAL LIST	

300EA-51KA	WALKWAY DETAILS
300-EA-52AA	DETAILS INT STAIRS IN DRIVEWAY AREAS
302-1-K-30-BA	CELL FLOOR PLAN
300-K-31CA	WINDOW DETAIL
300K-31DA	REAR STAIR
302-3K-30GA	LONGITUDINAL SECTION
302-3K-30FA	CROSS SECTION
300K-30AA	PLOT PLAN
302-2EA-50AA	COL. SCHEDULE
302-2-A-10RA	SLAB OPENINGS
302-2-A-60PA	RETAINING WALL
302-2-30BA	FLOORS
REFERENCE DRAWINGS	

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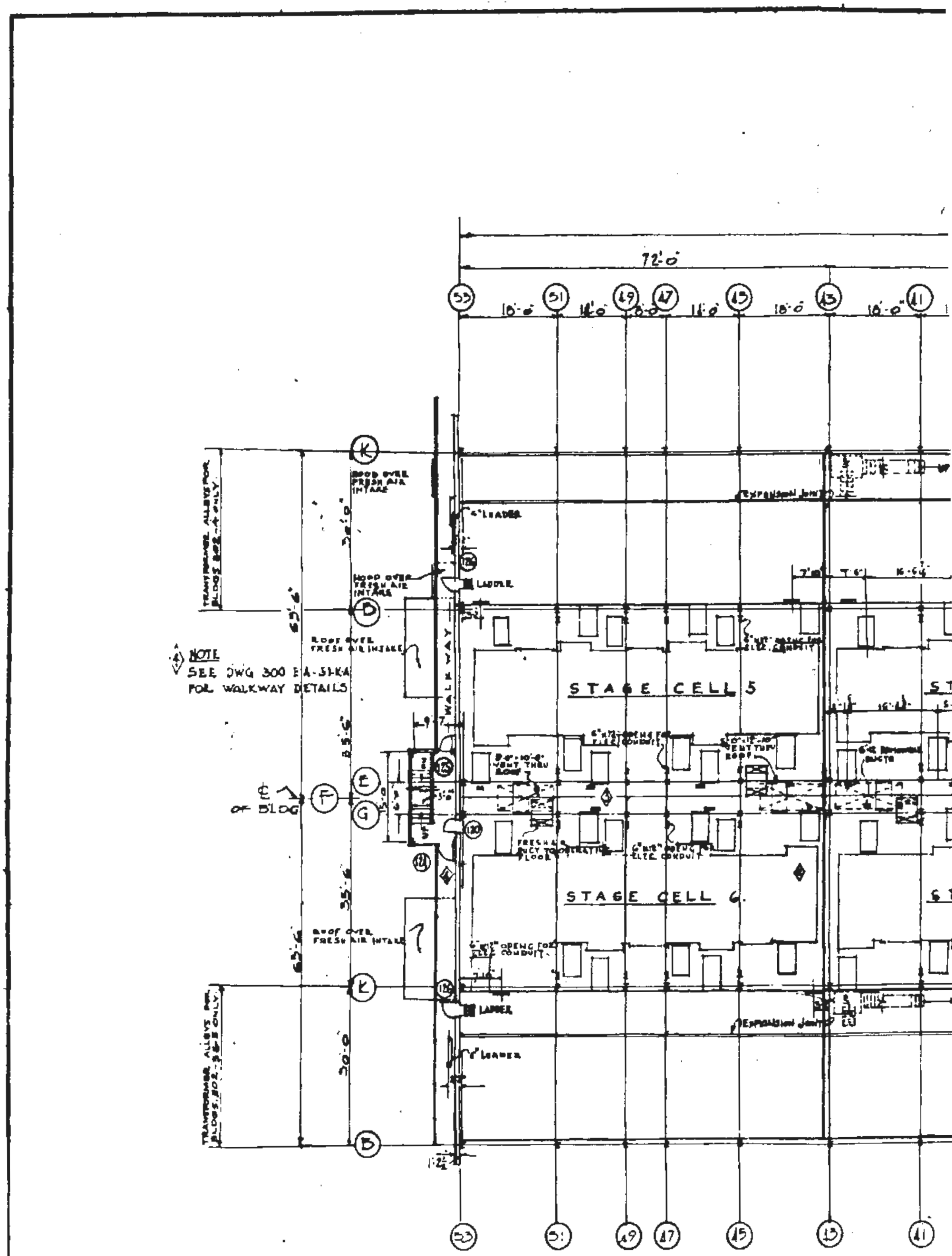

2	1'-2½" EXTERIOR WALL DIM - TAKEN TO OUTSIDE STEEL GIRT
1	BUILDING K-302-1 AS SHOWN OMIT 1-72FT. CELL FOR LOCATION TRANSFORMER ALLEY & CHANGE HOUSE, LUNCH RM. & AUX. EQUIP. RM. SEE KEY PLAN.

NOTES

FLOOR - CONC
WALLS EXTERIOR -
PARTITIONS STAIR

REAR STAIR - STE
T.C. BLOC

MATE

[redacted]

air (Par. 10-4). The valves are arranged so that their stems extend up through the operating floor. Figure 33 shows a floor layout of the pipe gallery. That portion of the pipe gallery floor immediately above the cell structure is lined with insulation.

(1) Walkways. - Walkways are provided on the pipe gallery floor to give access for servicing valves and piping on this level. These walkways may be reached by ladders leading from the operating floor to the pipe gallery floor, or by the stairways leading from the withdrawal alley to landings on each of the floors.

d. Operating Floor. - Operation of each building is controlled and directed from the top floor level. Figure 34 is a plan view of an operating floor showing floor details and arrangement of equipment.

(1) Equipment. - Instruments which indicate the operating conditions in each cell are located on a separate panel board. The instrument boards are arranged in pairs so that one operator can control the operation of equipment contained in two consecutive cells. A small instrument board, on which are mounted instruments that indicate the operating data for the building as a whole, is located over the building by-pass piping area. Electric switchgear for pump motors is mounted on panel boards which are located in pairs along the longitudinal center-line of the operating floor directly over the alley between the two rows of cells. Variable frequency control panels for the motors in each cell are similarly located. Coolant pumps, one for each cell, which force coolant through the gas coolers in the converters, are located along the longitudinal centerline of the operating floor level

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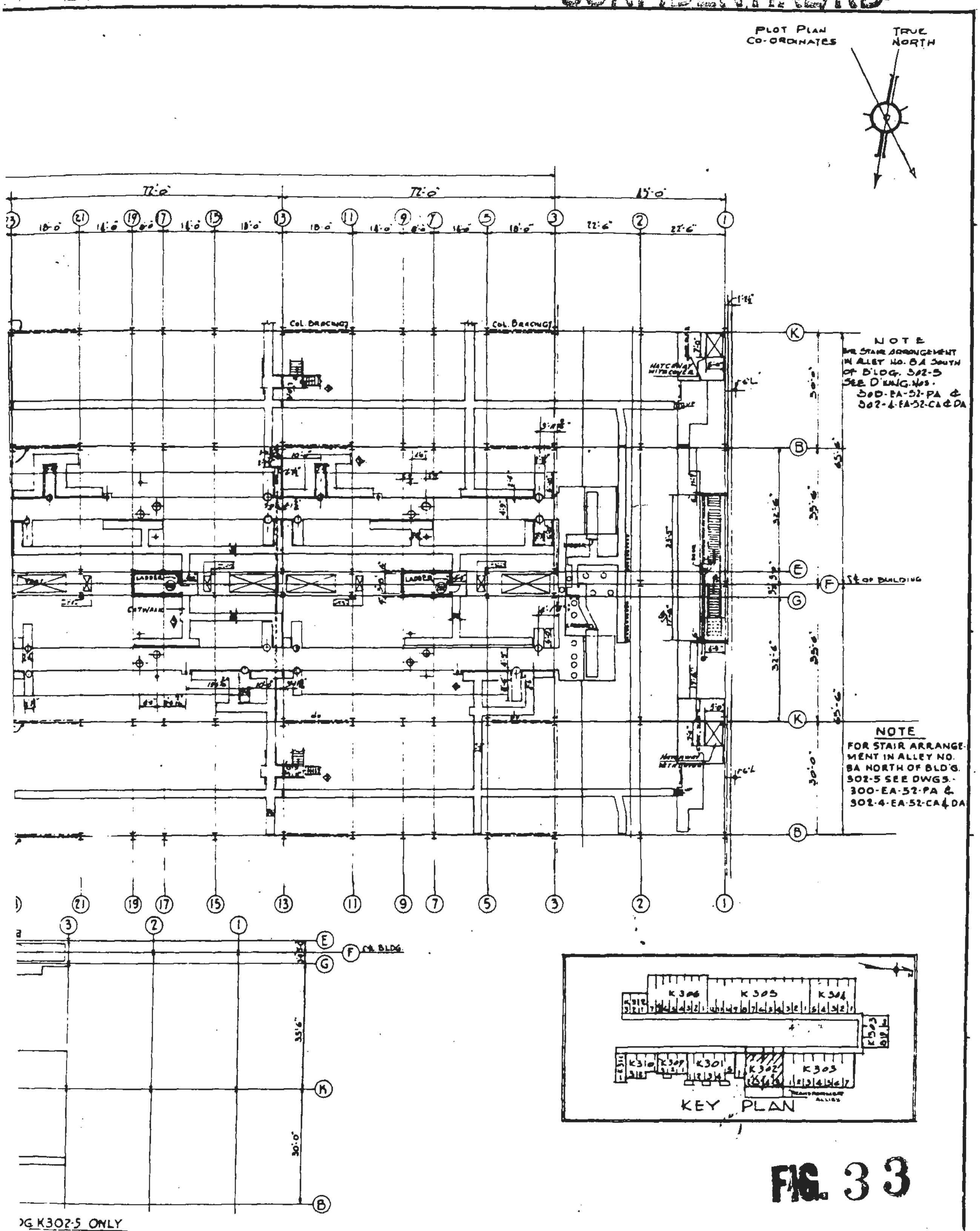

FIG. 33

THE KELLEX CORPORATION

PIPE GALLERY FLOOR PLAN (STEEL EL 816'-0")
BUILDINGS K302- 3-4-5

DRAWN A.M. DeRuo TRACED SCALE 1/16" = 1'-0 DATE 5-9-44
CHECKED D. MILLS
APPROVED W. DEAN 5-9-44

NO. 302-3-K-30-CA

NO.	DESCRIPTION	DATE	BY	CHECKED

REVISIONS

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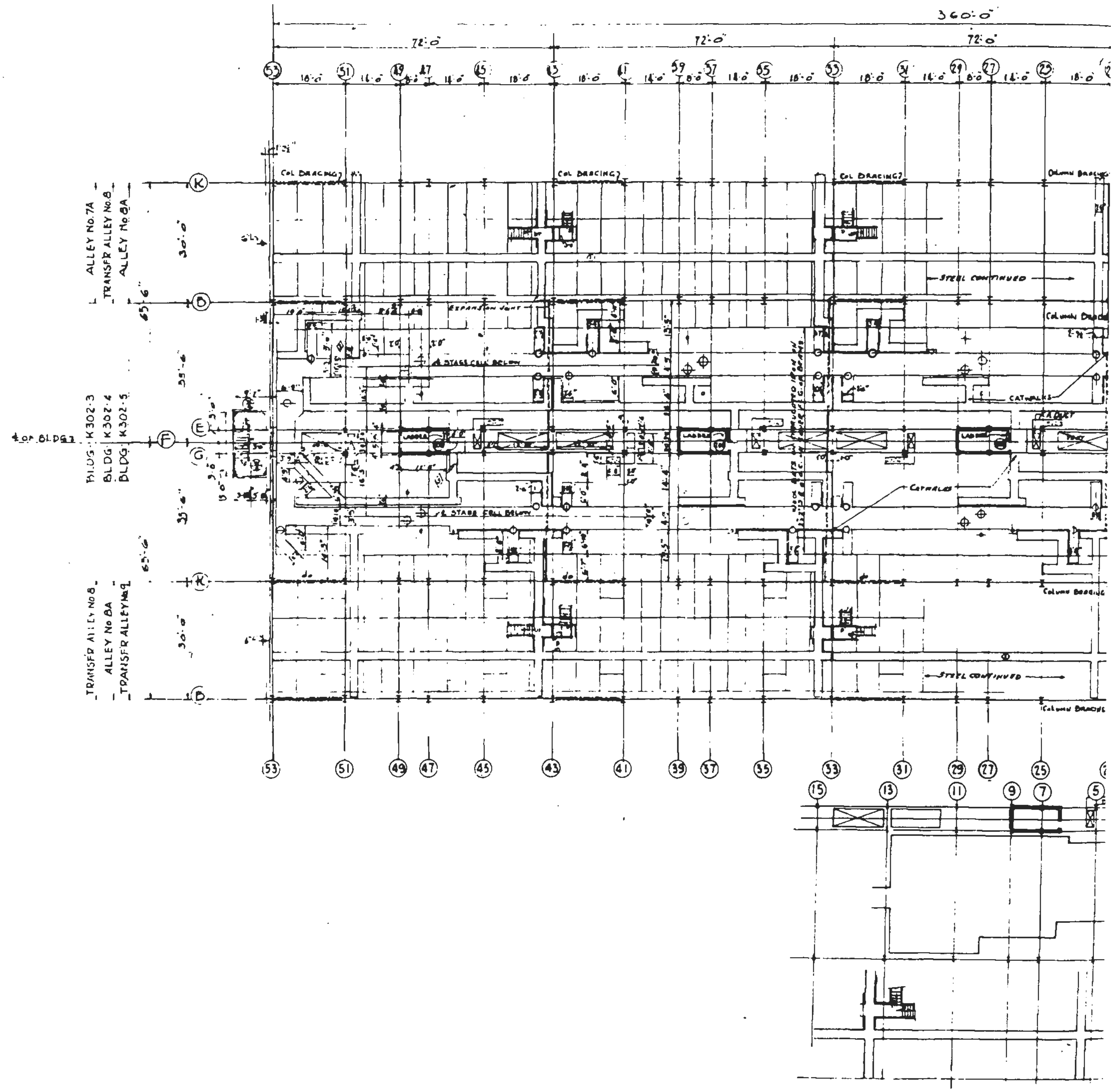


PART PLAN FOR B

NOTES
3 PIPE ENCLOSURE DIMENSIONS ARE INSIDE DIMENSIONS
2 1-28 EXTERIOR WALL DIM. TAKEN TO OUTSIDE OF STEEL GIRT
1 FOR LOCATION TRANSFORMER ALLEY SEE KEY PLAN

MATERIAL LIST
FLOORS:
EXTERIOR WALLS: CORR. ASBESTOS ON STEEL STUD
PARTITIONS: STAIRWAY G.T.C. BLOCKS PUMP RM. ETC.
REAR STAIR: CORR. ASBESTOS ON STEEL STUD
BOX T.C. BLOCKS

REFERENCE DRAWINGS	
302-5-EA-5EA	BY-PASS PIPE HOUSING
302-5-EA-30EA	STL. PLAN AT PIPE GALLERY FLOOR PARTS 1&2
302-1-K-30SE	PIPE GALLERY FLOOR PLAN
300-E-3F-D&E4	REAR STAIR
302-3K-30-HA	ELEVATION
302-3K-30-GA	LONGITUDINAL SECTION
302-3K-30-FA	CROSS SECTION
300-K-30-AA	PLOT PLAN
302-2-EA-30-DA	FRAMING
302-2-EA-30-AA	COL. SCHEDULE

[redacted]

adjacent to centerline columns. The stems for the valves in the cell by-pass gallery extend through the floor in the area immediately above the center of each cell. A large part of that portion of the operating floor level located above the withdrawal alleys is occupied by offices, spectrometer stations, and vent-ducts.

(2) Floor Structure. - The floor of the operating level is constructed of pre-cast concrete tile, and is designed for a live load of 100 pounds per square foot. Special pre-cast concrete floor slabs, designed with a removable plate, have been provided so that valves can be lifted onto the operating floor when necessary for repair. In the floor are located a number of gratings that can be manually opened or closed. Otherwise, the floor is sealed off from the rest of the building.

(3) Stairways. - There are two main stairways for each building, leading from the ground level to the operating floor. These are located, one at the front or court end, and one at the rear. Both stairways have landings at each intermediate level for access to the cell and pipe gallery floors. An operational ladder is located in each coolant pump pit on the operating floor. These ladders extend down to the pipe gallery floor for purposes of maintenance and operation. A door in each pump pit opens onto the cat-walks on the pipe gallery floor. Three stairways extend from each withdrawal alley to the operating floor, with landings at the pipe gallery floor, connecting to the cat-walks. These stairways are counter-weighted in the withdrawal alley so that they may be swung clear in the case of any traffic requiring the space.

[redacted]

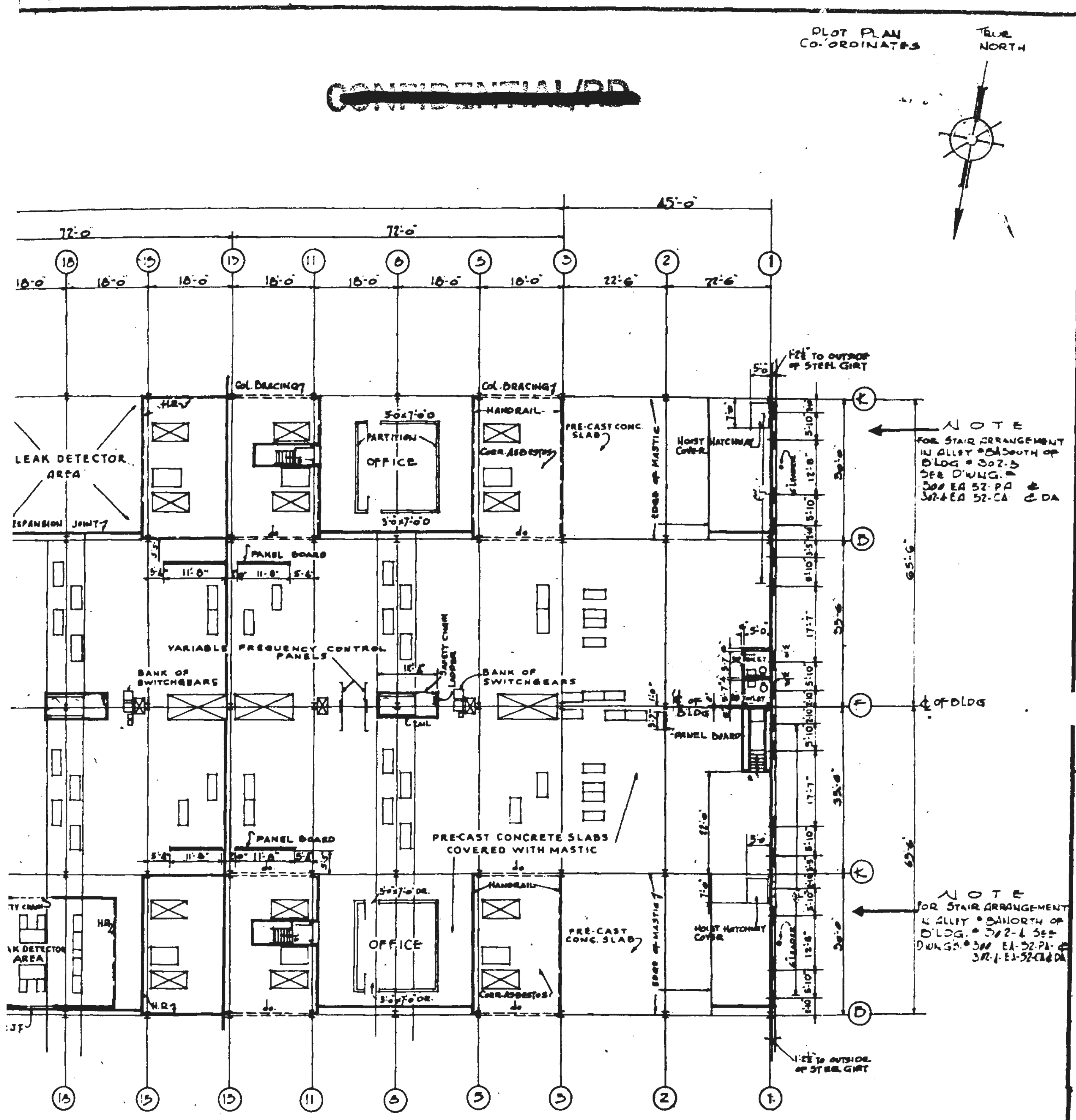
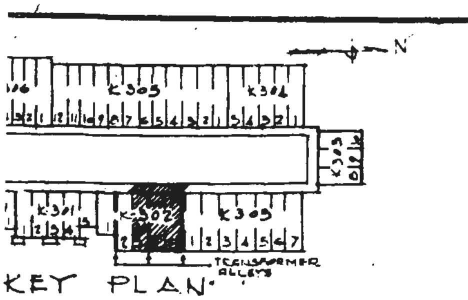


FIG. 34



NO.	DESCRIPTION	DATE	BY	CHECKED
REVISIONS				

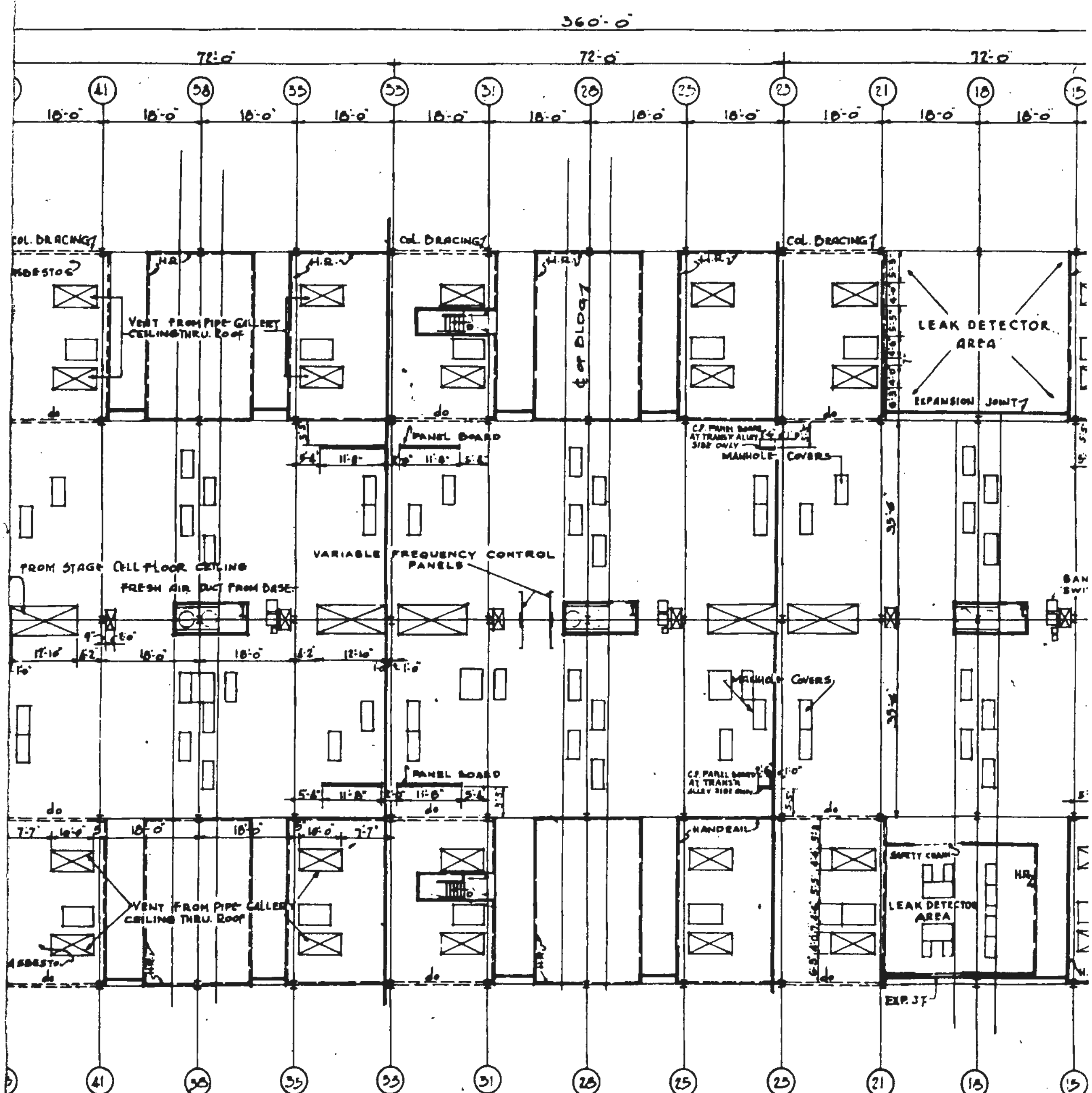
THE KELLEX CORPORATION

OPERATING FLOOR PLAN (STEEL EL 825-2")
BLDGS K 302.3.4.5

DRAWN A.M. DeRose TRACED SCALE 1/16"=1'-0" DATE 3-6-[illegible]
CHECKED C. Mills
APPROVED H.W. Dean 4-6-43 No. 302-3-K-31 DA

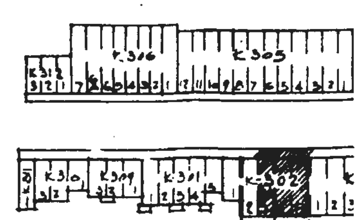
[redacted]

C/RD

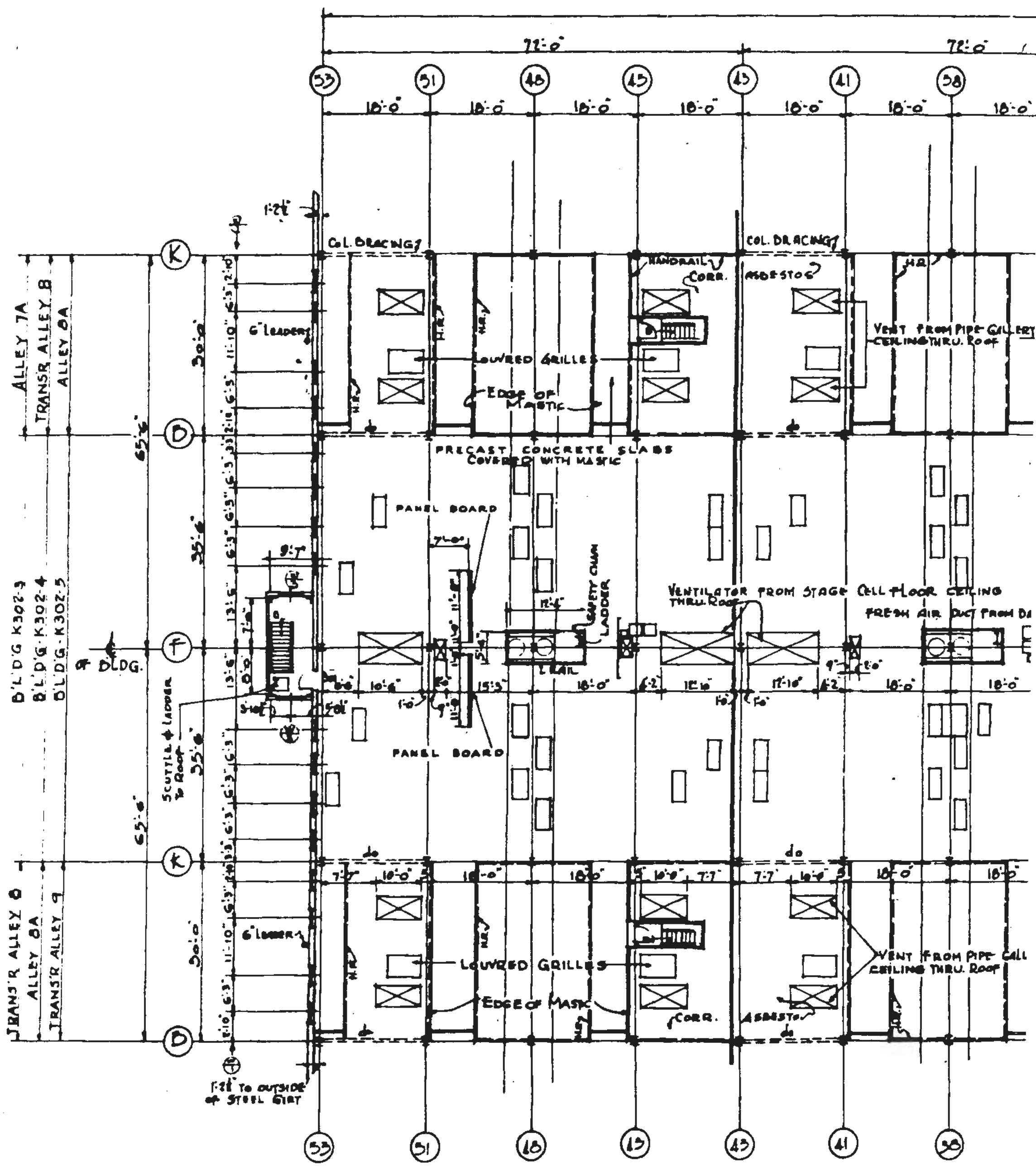


C/RD

MATERIAL	REFERENCE DRAWINGS	
WINDOWS - WOOD FIXED	302-2-EA-52EA	LEAK DETECTOR EQUIPMENT
REAR STAIR STEEL-COVERED WITH CORR. ASBESTOS.	302-1-K-30TA	OPERATING FLOOR
FLOORS.	300-K-[illegible]-37-CA	WINDOW DETAIL
TOILET ROOM PARTITIONS - 6" T.C. BLOCKS.	300-K-31-DA&EA	REAR STAIR
EXTERIOR WALLS - CORR. ASBESTOS ON STEEL STUD.	302-3K-30-HA	ELEVATION
T.C. PARTITION.	302-3K-30-GA	LONGITUDINAL SECTION
	302-3K-30-FA	CROSS SECTION
	300-K-30-AA	PLOT PLAN
	302-3-EA-50CA	FRAMING.
	302-1EA-50-AA	COL. SCHEDULE



KEY PLAN



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NOTES	MATERIAL
(2) 1'-2" EXTERIOR WALL DIM.-TAKEN TO OUTSIDE OF STEEL GIRT (1) FOR LOCATION OF TRANSFORMER ALLEY, SEE KEY PLAN	WINDOWS.- WOOD FIXED REAR STAIR STEEL-COVERED WITH CORR FLOORS- TOILET ROOM PARTITIONS- 6" T.C. BLO EXTERIOR WALLS-CORR. ASBESTOS ON S T.C. PARTITION

9-4. Process Building Ventilation System.

a. Purpose. - The primary object of ventilation in the process buildings is the dissipation of heat; the air circulation is greatly in excess of breathing requirements. This heat is generated in transformer windings, motor windings, lights, and from solar heat through the roof, with the main source of heat coming from within the cells. The coolant system has a rated capacity to carry off the total heat of process pump adiabatic compression, but the pump casings, converters, and connected piping run sufficiently hot to liberate large quantities of additional heat which must be removed. There are two principal requirements to be met by the ventilating system:

1. Removal of sufficient heat under maximum summer temperature conditions to maintain within the cells the stipulated temperature of the process material, and to maintain a temperature outside the cells in the alleys and the operating floor that can be tolerated by the operating crew.

2. To retain within the buildings as much heat as possible under extreme winter conditions, or all that is desirable during spring and fall, and still maintain the stipulated temperature within the cells.

b. Design. - The first of the above conditions is the more difficult to meet, and all calculations of air quantity have been made on that basis. The maximum assumed average condition of atmospheric air was taken at 95°F and 70 per cent relative humidity. The general design calls for the circulation of an ample quantity of air over the warmer component parts. This air absorbs heat and is discharged through ventilators in the roof. The basement is well sealed from the converter floor. The motor alley and space over the cells is sealed from the pipe gallery floor and withdrawal alleys. The operating floor seals the operating room from the rest of the building. It is possible to get an air flow between these different sections by opening dampers and louvres.

(1) Basement Ventilating System. - The air supply for the cells and operating floor ventilating systems enters at the rear of basement of each building through two penthouses which enclose the the filters. Air enters the penthouses through louvred openings and passes through a screened filter bank, into the basement level atmosphere. Higher building levels are supplied with basement air by the basement ventilating fans (App. E5). The filter bank consists of a number of frames each composed of several twenty inch units. Two 20 x 20 x 1 inch filter cartridges fit into each unit in series. The filter cartridges were supplied by Owens-Corning Fiber-Glass Corporation and Research Products Corporation. The Owens-Corning filters are constructed of interlaced glass fibers in a grille frame. The Research Products filter consists of a paper filter pad sandwiched between two wire grids.

(2) Transformer Vault Ventilation. - The transformer vault ventilation system has the function of keeping the vault ambient air temperature below set limits. Air flow is induced through each vault by three Buffalo Forge axial flow fans, varying in size from 20 to 36 inches, depending upon the quantity of air required.

(3) <u>Cell Ventilating System.</u> - The "cell ventilating system" refers to air circulated in the vicinity of the process cells as a part of the building atmosphere. It is entirely distinct from the dry air supplied to the interior of the cells (Par. 10-4). The cell ventilating system helps maintain the correct intra-cell ambient temperature, and keeps the cell floor temperature at a level suitable for the operating crew. Atmospheric air (after passing through the air filtering system and entering the building basement) is picked up by the cell ventilating fans one of which is located in the basement under each cell, in the case of all buildings except those of Section 4, which contain two rows of three fans each for the fourteen cells. Cell ventilating fans were supplied by the Buffalo Forge Company, B. F. Sturtevant, and American Blower Company. Fan capacity ranges from 16,000 to 24,000 cubic feet per minute. Air is distributed throughout the building at a series of three locations for each row of cells, as follows:

1. At the curbing between the withdrawal alleys and the converter floors.
2. Across the top of the cells on the withdrawal alley side.
3. In the motor alley and a little above the converter floor.

(4) <u>Operating Floor Ventilation.</u> - The fans for the operating floor are located at the center of the basement floor between the two rows of cell fans. The number of ventilating fans for the operating floor varies with the size of the building. With the exception of Section 4, all ten-cell buildings have five operating floor fans, all eight-cell buildings contain four fans, and all six-cell buildings

have three operating floor fans. Each building in Section 4 is provided with three operating floor fans.

9-5. Process Building Heating System.

a. Unit Heaters. - During extreme winter conditions, the retention of heat by the recycling process may not be adequate to maintain desired temperatures for the operating crew. Heat may then be added to the buildings by means of unit type Trane Company steam heaters, which have been installed in separate suction ducts in a number of operating floor fans in every building. The six-cell buildings contain two of these heaters. All other buildings have three.

b. Steam Radiators. - Lavatories on the basement and operating floors each contain two steam radiators for heating. The basement floor proper has no heating facilities. The recycling of ventilating air, and the heat given off from pumps and motors contained in the basement is adequate for winter conditions.

9-6. Process Building Lighting System. - The building lighting and instrument circuits for each building are powered by two sets of constant frequency transformers. At each transformer bank, there is one normal and one emergency transformer, and a control center from which feeders radiate to the various panels. The panels are in pairs, one normal and one emergency, and are located on the basement and operating floors. Each transformer bank furnishes the lighting and instrument power for half of two buildings. Two control centers are provided and are each equipped with an automatic transfer switch. In case of power failure, the switch activates emergency feeders and panels with power from the emergency transformer. All essential items such as

[redacted]

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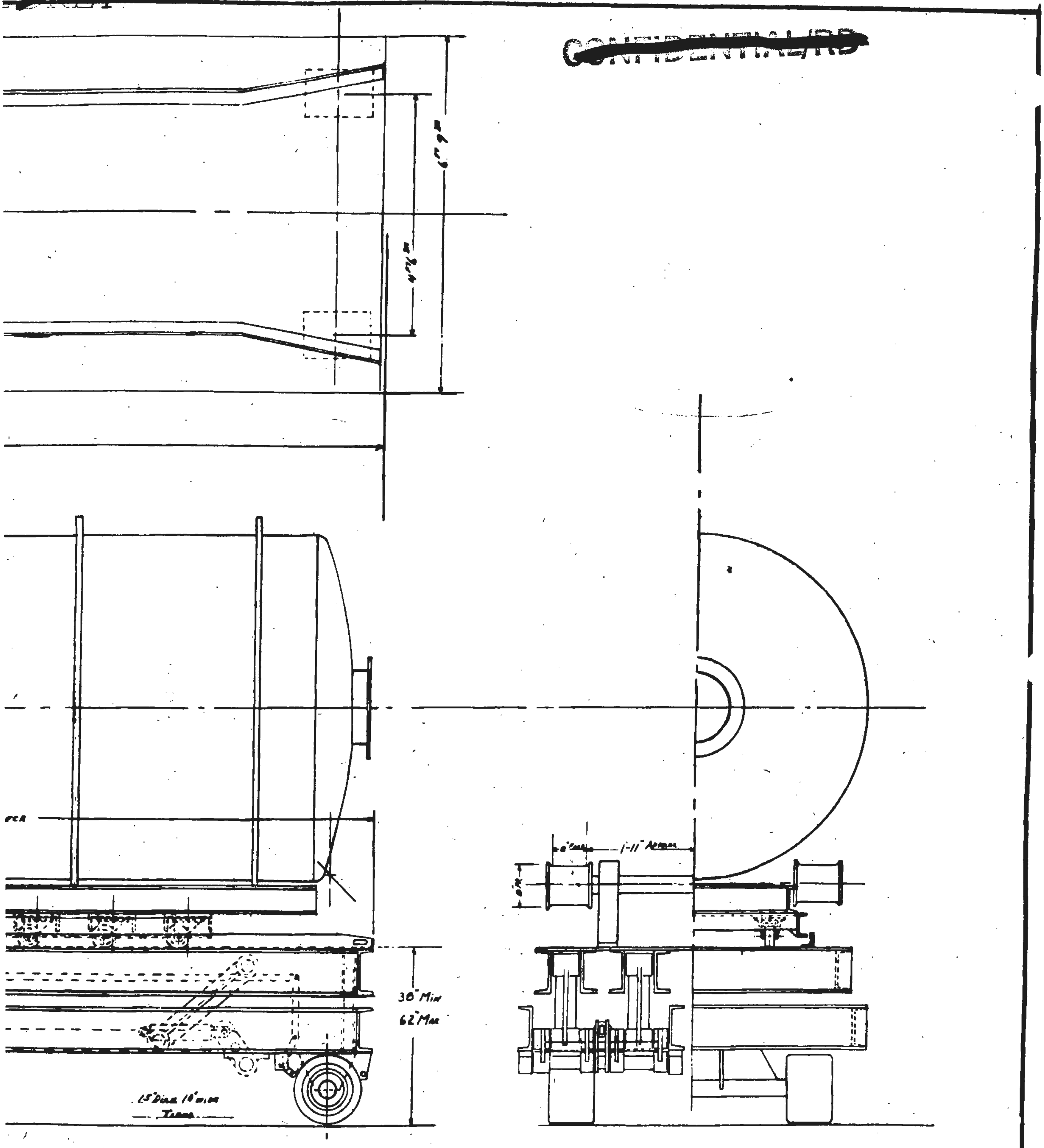


PARKELL ENGINEERING CO.
50 CHURCH STREET
NEW YORK

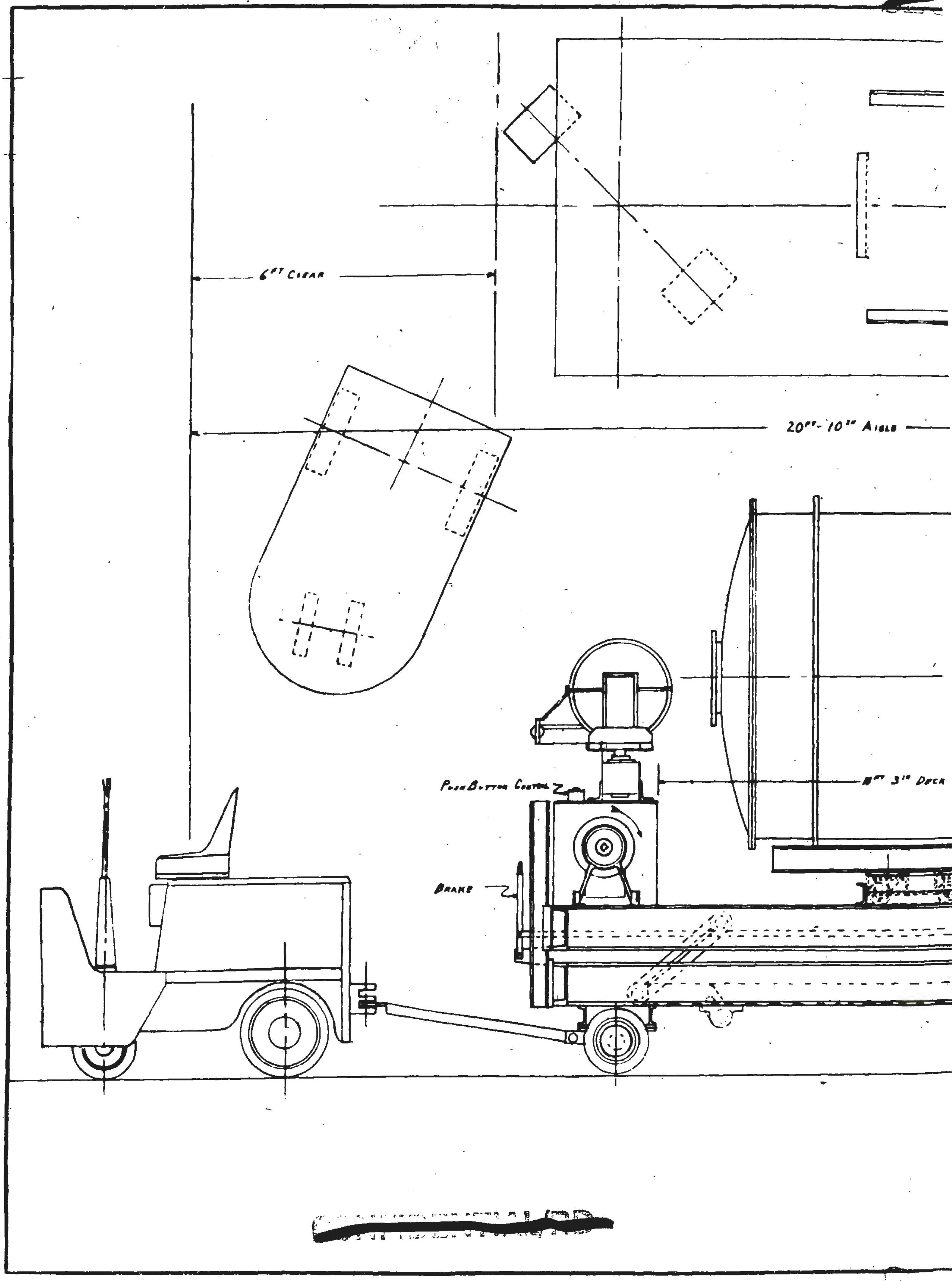
ELEVATING TRAILER
GENERAL ARRANGEMENT

SCALE 1"=1' JAN. 21, 1944 DWG# [redacted]

[redacted]

FIG. 35

[redacted]


6FT CLEAR
20FT-10IN AISLE
PUSH BUTTON CONTROL
BRAKE

instrument circuits, receptacles, instrument board lighting, stair risers, basement area, transformer vaults, and various lights throughout the cell, pipe gallery, and operating floors are fed from this emergency circuit. Most of the circuits, except those not in continual use, are controlled from the panels. Local switching has been cut to a minimum.

9-7. Process Building Communication System. - A sound-powered telephone system is provided for each of the process buildings. The system consists of ten call stations and one master station per building. Each system provides complete inter-communication between stations in the system proper on a common talking, selective ringing basis. The master station provides for simultaneously ringing all stations on its respective system in the case of an emergency. The master stations and three call stations are located on each operating floor. The cell floors and withdrawal alleys contain four call stations, and the basement floors house three call stations.

9-8. Converter Handling Equipment. - This equipment is furnished for the purpose of handling the converters when they are installed or withdrawn from the cell rooms, and for transporting portable leak test equipment. Converters are mounted on dollies and transported by truck from the conditioning building to the front end of the withdrawal alley of the desired building. A tractor-drawn trailer (Fig. 55) is provided for delivering the converter to its point of installation. The trailer is equipped with a hydraulic jack and lever mechanism by means of which its height can be adjusted to that of the truck. It is further equipped with a power-driven winch which serves to move the converter and dolly from the truck to the trailer. The trailer is also used for transporting other equipment into the process buildings, such as pumps, motors, etc.

SECTION 10 - DESIGN OF PROCESS SERVICE INSTALLATIONS

10-1. Introduction. - This section treats of process service installations designed and constructed for use with the main cascade. Additional facilities, later constructed for service with K-27, are discussed in Section 14. Location of installations described in this section is shown in the plot plans of Volume 1, Appendix A, and the photographs of Volume 5, Appendices D16 and D17.

10-2. Coolant Drying and Storage Plant (Section 300-C).

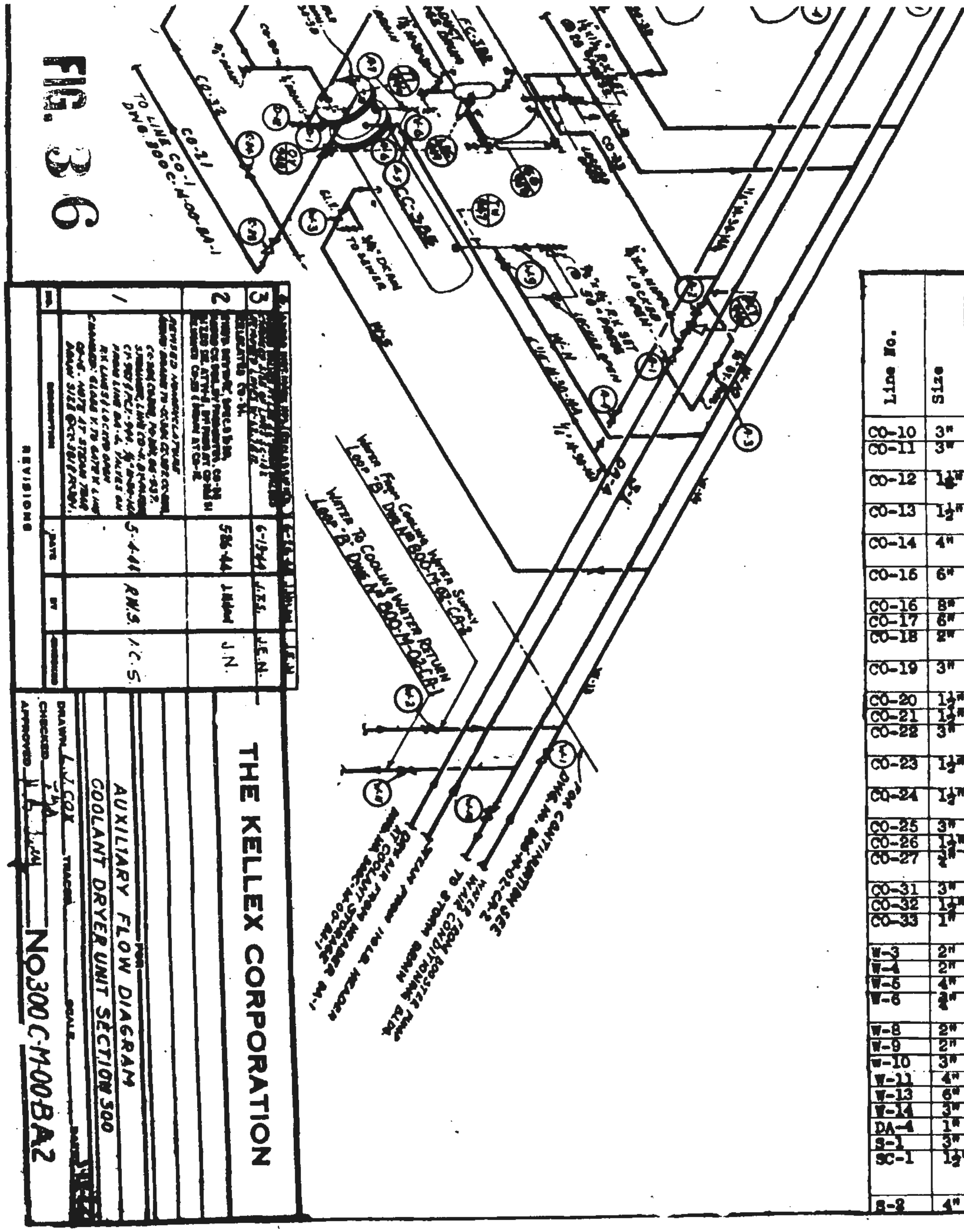
a. Purpose. - Situated in the central court within the main cascade "U", Section 300-C serves the purposes of storing process coolant, purifying it as necessary, and distributing it to the process coolers throughout the plant.

b. Design.

(1) Coolant Storage. - Five storage tanks, each of 10,000 gallons capacity, are used for storage of C_8F_{16}. These tanks are charged with fresh, dry coolant from shipping drums, or with purified coolant from the drying system. Total plant inventory of C_8F_{16} in use and storage is over 200,000 gallons.

(2) Coolant Distribution. - The storage tanks are connected to a coolant header in each process building through a closed distribution loop piped along the entire inside of the cascade "U". The cell circulation systems are initially filled from the storage tanks. Thereafter, pumping is intermittent, and necessary only to replace losses, or contaminated coolant removed for purification.

(3) Coolant Circulation. - C_8F_{16} is circulated through



Line No.	Size	M-30 Spec.	NOMENCLATURE DESCRIPTION: FLOWING MEDIUM	FROM	TO	Temp. °F.	Press P.S.I.	Pipe Wt.
CO-10	3"	3D	Wet 816 Liquid	Tank FC-380E	Line CO-11	90	5	STD
CO-11	3"	3D	Do	Tank FC-383	Pumps JC-381 JC-382A	90	5	STD
CO-12	1½"	3D	Do	Pumps JC381 382A	Exch. CC384	90	125	XH
CO-13	1½"	3D	Do	Exch. CC-384	Strip. Twr. EC-381	186	125	XH
CO-14	4"	3D	Dry 816 Liquid	Strip. Twr EC-382A	Reboiler CC-382	232	5	STD
CO-15	6"	3D	Dry 816 Vapor	Reboiler CC-382	Strip. Twr. EC-381	232	5	STD
CO-16	8"	3D	Do	Do	Exch. CC-384	232	5	STD
CO-17	6"	3D	Do	Exch. CC-384	Exch. CC-383	232	5	STD
CO-18	2"	3D	Dry 816 Liquid	Exch. CC-383	Surge Drum FC-382	232	5	STD
CO-19	3"	3D	Do	Surge Drum FC-382	Pump JC-382	232	5	STD
CO-20	1½"	3D	Do	Pump JC-382	Exch. CC-385	232	125	XH
CO-21	1½"	3D	Do	Exch. CC-385	CO-1	100	125	XH
CO-22	3"	3D	Wet 816 Vapor	Strip. Twr. EC-381	Exch. CC-381	200	2	STD
CO-23	1½"	3D	Wet 816 Liquid	Exch. CC-381	Water Sep. FC-381	115	0	XH
CO-24	1½"	3D	Do	Water Sep. FC-381	Coolant Tank FC-383	115	2	XH
CO-25	3"	3D	Dry 816 Liquid	Line CO-10	Line CO-11	232	5	STD
CO-26	1½"	3D	Do	Line CO-12	Line CO-20	232	125	STD
CO-27	¾"	3D	Water	Exch. CC-381	Water Sep. FC-381	200	2	XH
CO-31	3"	3D	Wet 816 Liquid	Line CO-29	Tank FC-383	100	175	STD
CO-32	1½"	3D	Dry 816 Liquid	Line CO-21	Line CO-31	100	175	XH
CO-33	1"	3D	Dry Air & 816 Vapor	Surge Drum FC-382	Pumps JC-381, JC-382A	232	0	XH
W-3	2"	15	Do	Junc.W-4,W-14	Exch. CC-381	85	50	STD
W-4	2"	15	Do	Junc.W-3,W-14	Exch. CC-383	85	50	STD
W-5	4"	15	Do	Junc.W-13,W-14	Exch. CC-385	85	50	STD
W-6	¾"	15	Do	Line W-4	Samp. Cool. CC-386	85	50	STD
W-8	2"	15A	Do	Exch. CC-381	Junc.W-9,W-10	150	50	STD
W-9	2"	15A	Do	Exch. CC-383	Junc.W-8,W-10	150	50	STD
W-10	3"	15A	Do	Junc.W-8,W-9	Junc.W-11,W-12	150	[illegible]	STD
W-11	4"	15A	Do	Exch. CC-385	Junc.W-10,W-12	150	50	STD
W-13	6"	15	Do	Junc.W-1,W-7	Junc.W-14,W-5	85	50	STD
W-14	3"	15	Do	Junc.W-5,W-13	Junc.W-3,W-4	85	50	STD
DA-4	1"	14A	DryAir	Line DA-1	PCV-944	100	100	XH
S-1	3"	10	Steam	Headers	S-2	350	110	STD
SC-1	1½"	13	Condensate	Exch. CC-382	Condensate Pumping Unit sect. 1100			XH
S-2	4"	13	Steam	Line S-1	Exch. CC-382	260	25	STD

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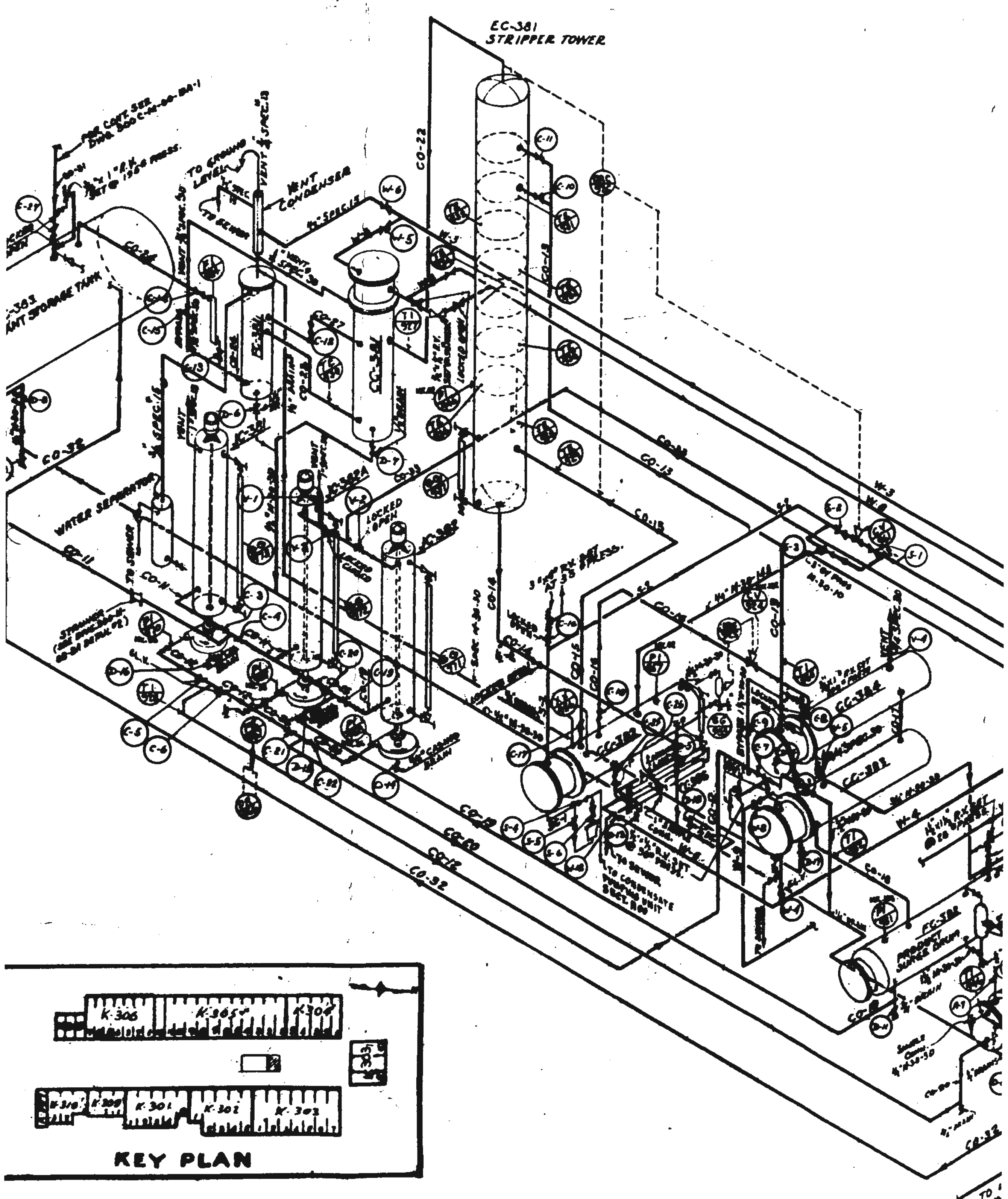
SEC



Note: The Midwest Piping & Supply Co. is to furnish material and fabricate all coolant lines; and furnish pipe and block valves from coolant lines to other systems.

FIG.

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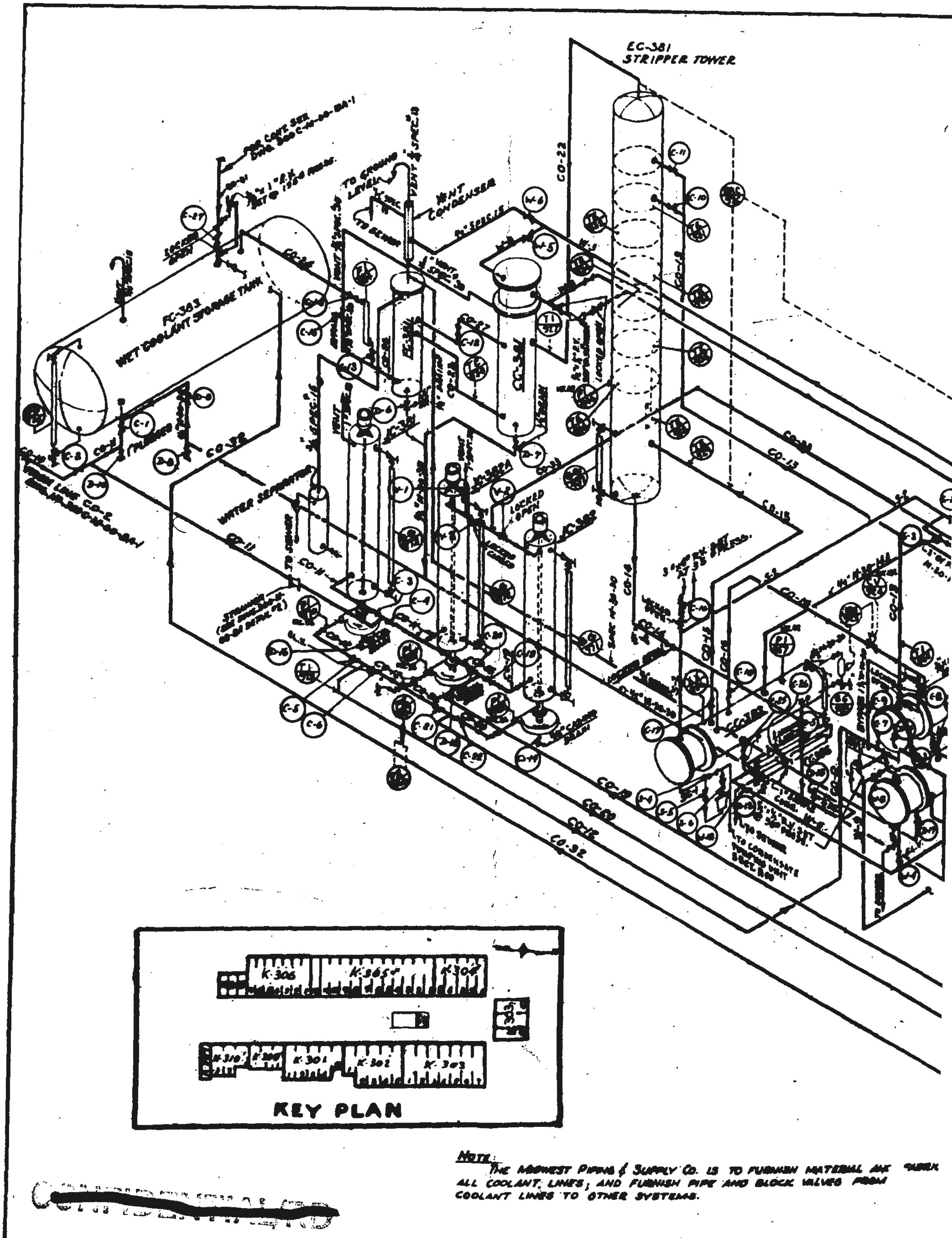
EC-381
STRIPPER TOWER
WET COOLANT STORAGE TANK
VENT CONDENSER
WATER SEPARATOR
CO-22
CO-18
CO-13
CO-15
CO-14
CO-11
CO-32
CO-12
LOCKED OPEN
KEY PLAN
K-305
K-302
K-301
K-303
NOTE: THE MIDWEST PIPING & SUPPLY CO. IS TO FURNISH MATERIAL AND ALL COOLANT LINES; AND FURNISH PIPE AND BLOCK VALVES FROM COOLANT LINES TO OTHER SYSTEMS.

stage coolers, intercell coolers, and intersectional coolers. Each cell is provided with an individual system for circulating coolant to the six stage coolers, and an intercell gas cooler. Additional systems are provided for intersectional coolers at the top of the surge and waste system, and at the bottom of most cascade sections. In each of these circulation systems, C_8F_{16} is pumped from a small surge drum, through a water-cooled heat exchanger (coolant cooler), and through the process gas coolers, thence back to the surge drum. Each coolant circulation system connects to a building drain drum (App. E2) of sufficient capacity to hold all the C_8F_{16} of the circulation systems in the building. Coolant can be pumped from the drain drum, located in the basement of each building, either back to the circulating system, to the plant storage tanks, or to the coolant purification and drying system.

(4) Contaminated Coolant Return. - Each building is equipped with a transfer pump, taking suction from the drain drum by means of which contaminated coolant is pumped back to the wet C_8F_{16} storage tank in Section 300-C, via a special coolant return piping system.

(5) Coolant Purification and Drying System. - The coolant purification system (Fig. 36) is designed to remove water, grease, lubricating oil, and other non-volatile impurities. Coolant, which has become contaminated because of leaks, is pumped from a feed tank, through a heat exchanger, and into a stripping tower. Dry C_8F_{16} is recovered from the bottom of the tower, and water vapor and some C_8F_{16} vapor are removed from the top. The top vapors are condensed to form a two-phase liquid, which flows into a receiver where the C_8F_{16} phase

is separated from the water, and returned to the wet storage tank. The aqueous layer is sent to an auxiliary separator which removes the remainder of the C_8F_{16} present, before the water is discarded. Dry C_8F_{16} from the bottom of the tower flows by gravity to a steam heated re-boiler, where it is vaporized, with all non-volatile materials remaining behind. Thus, the major part of the vapor is withdrawn as purified C_8F_{16}, and the remainder is returned to the bottom of the distillation column. A more extensive discussion of the K-25 coolant system may be found in Volume II of the Kellex Operating Manuals.

10-3. Recirculating Cooling Water System (Section 800).

a. Purpose. - The principal function of the recirculating cooling water system is to supply water continuously, at a controlled temperature, to the process coolant coolers. An extensive description of the system may be found in Volume V, Part IV of the Kellex Operating Manuals.

b. Capacity. - The following tabulation summarizes the design estimates for plant requirements:

Section	Building	Maximum Flow (GPM)
100	Feed Purification Plant	50
300	Main Cascade	84,893
300-C	Coolant Drying Plant	300
500	Product Handling System	100
600	Surge and Waste System	25
800	Water System (line losses, etc.)	40
1000	Laboratories	500
1100	Dry Air Plant	15,000

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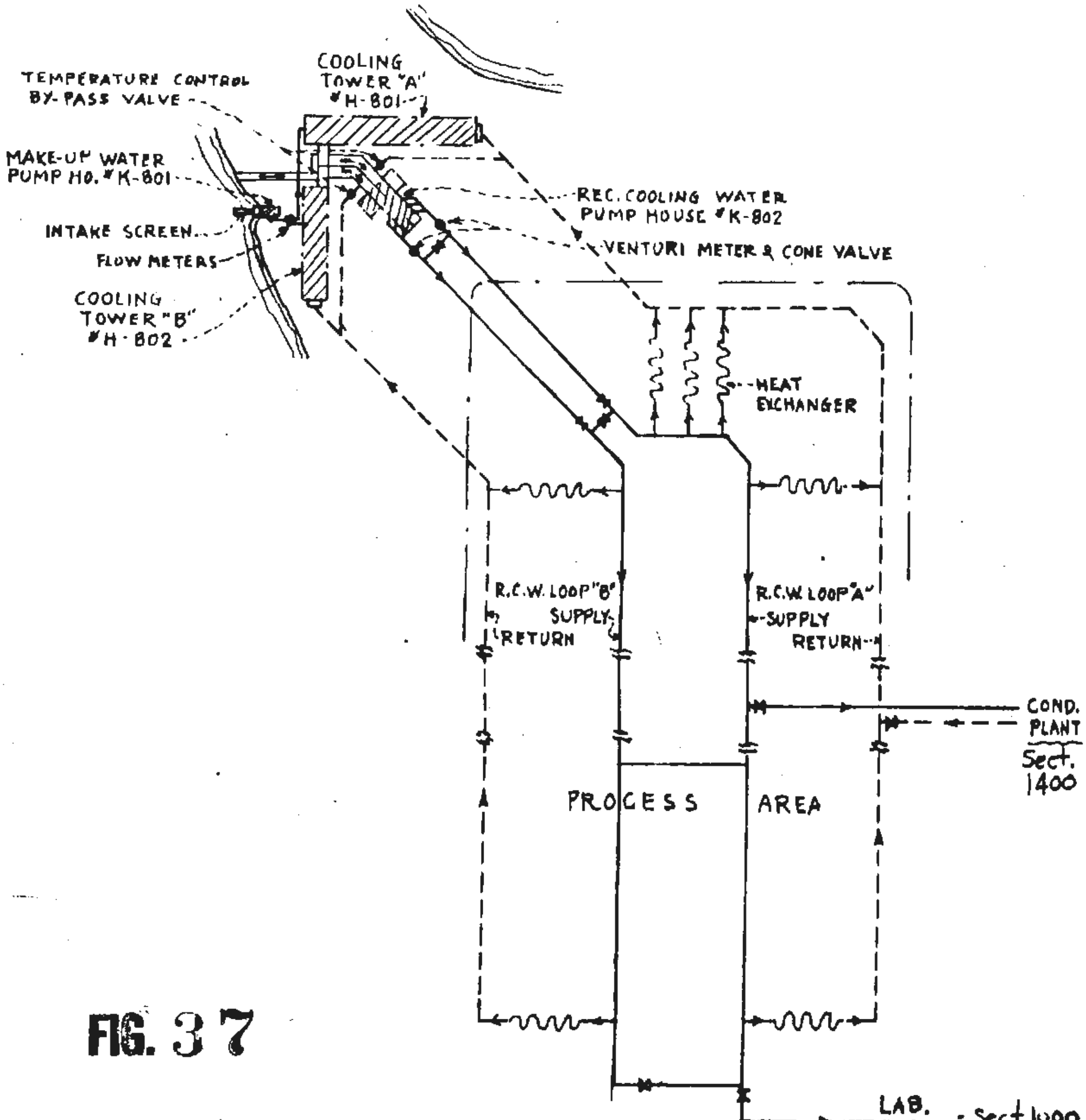

FIG. 37

TITLE GENERAL LAYOUT - SECTION 800 JOB NO.

DESCRIPTION	DATE	CHECKED	THE KELLEX CORP.	SCALE DATE AP. DR. TR. CH. No. 119-0-D
REVISIONS				

~~CONFIDENTIAL/RD~~ ~~SECRET~~

1300	Fluorine Generating Plant	265
1400	Conditioning Plant	2,350
1500	Auxiliary Steam Plant	120
		103,643

The total design load was taken as 120,000 GPM or somewhat over 170,000,000 gallons per day, a flow approximately equal to the total water requirements of a city the size of Philadelphia. Of the 103,643 gallons estimated above, some 2000 GPM was to discharge to waste. Adding to this 2500 GPM as estimated evaporation loss, and a blowdown of 800 GPM, the plant make-up requirement was taken as 5300 GPM.

c. Design. - The recirculating cooling water system (Fig. 37) includes two pump houses, two water cooling towers, and two individual supply and return loops. Loop "A" serves the laboratories, the conditioning area, and the east leg of the cascade "U". Loop "B" serves the west half of the cascade. Connecting flumes with sluice gates are provided, and tie lines with suitable valving, so as to permit of cross-connecting the two circuits when desired. Continuous circulation is maintained through the two loops, and respective process coolers and cooling towers, by means of a battery of recirculating pumps. Make-up is supplied by means of a second and smaller battery of pumps. The pump houses and cooling towers are located just northwest of the main process building "U".

(1) Make-up Pump House (K-801). - Water from Poplar Creek flows through an intake channel which is protected by a trash rack, stop logs, and a travelling screen. The make-up pump house is a 41 x 20 foot building with accommodations for four pumps. Three two-

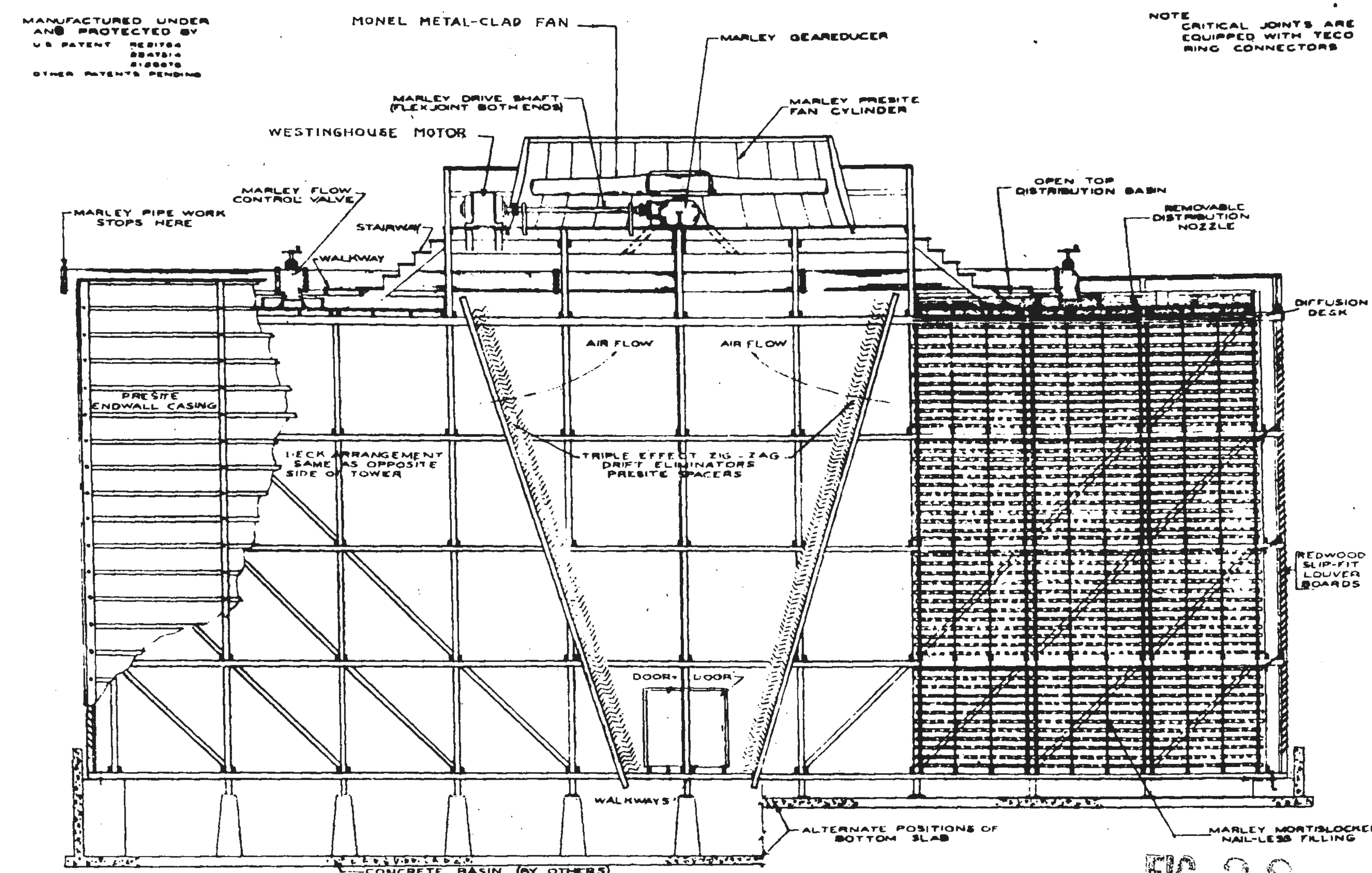

FIG. 28

MARLEY DOUBLE FLOW HEAVY INDUSTRIAL TYPE COOLING TOWER stage deepwell turbine type pumps are installed, manufactured by Pacific Pumps, Inc., each rated at 2000 GPM against a 50 foot head. These pumps deliver water through 12 inch discharge connections into a 16 inch make-up water header. The flow is then divided into two 12 inch lines which lead respectively to the basins of the cooling towers.

(2) Cooling Towers (H-801, H-802). - Two, cooling towers were supplied by the Marley Company, with induced draft facilities, part or all of which may be shut off during cold weather. Figure 38 shows the general construction features of one of the towers. At the base of each tower a 54 inch warm water main returning from the cascade area divides and feeds into two 36 inch mains, which in turn connect with the wood distribution piping over the towers. From this point, water trickles down and is cooled in its travel to the tower basins. These basins are connected by flumes to the cold wet wells under the recirculating pump house. Cooling tower "A", containing 18 cells and fans, serves loop "A". Cooling tower "B", containing 14 cells and fans, serves loop "B". In combination, the towers are designed to cool 120,000 GPM from or near an inlet temperature of $100^{\circ}F$, down to $85^{\circ}F$ with a wet bulb temperature of $78^{\circ}F$.

(3) Recirculating Pump House (K-802). - The recirculating pump house overall dimensions are 165 by 94 feet. It houses twelve vertical Pacific deepwell turbine pumps (six rated at 15000 GPM, and six rated at 7500 GPM) and two fire water pumps. Space accommodations are provided for additional pumps of the smaller size. The building also houses such accessories as an office, electrical bay, chlorinator rooms, and storage facilities. The 7500 GPM pumps are of

the two-stage type, and size 30 inches. They are driven by 350 horsepower, 2300 volt motors. The 15,000 GPM pumps are of the single-stage type and size 36 inches. They are driven by 700 horsepower, 2300 volt motors.

(4) Supply and Return Main Loops. - The twelve recirculating pumps take their suction from the cold wells, and discharge into headers supplying the two recirculating water loops. The mains range in size from 48 inches at the north end of the process area, down to 8 inches at the south end. Branch connections are taken off these mains, and run into each of the process buildings to supply the process coolant coolers. The warm water from the process is run into branches which connect with the return mains. The warm water return lines range in size from 12 inches at the south end, to 54 inches at the base of the cooling towers. Before reaching the towers, both return headers are provided with a by-pass connection to the recirculating pump house supply flume. These by-pass lines serve as an aid in holding constant water temperature under varying weather conditions.

(5) Process Building Cooling Water Piping. - Cool water enters each process building through a 10 inch pipe which divides to form a lead (ranging in diameter from 8 inches to 4 inches) extending down each side of the basement of the building. Water to each coolant cooler passes from the supply header through a three inch line to the water inlet on the bottom of the coolant cooler. Flow through this line is limited by a control valve which is actuated by a temperature controller. The quantity of water flowing through the coolant cooler is governed by the temperature of C_8F_{16} leaving the cooler. Building

water return piping is parallel and similar to the supply piping, and feeds finally through a 10 inch pipe into the main recirculating return loop, which leads back to the cooling towers.

10-4. Dry Air Plant (Section 1100).

a. Purpose. - The extreme necessity for excluding all traces of moisture from the process system led to the construction at the K-25 site of one of the largest air conditioning and drying installations in the world. The dry air plant, located within the cascade court, was designed to serve the following purposes:

1. Provide purge capacity to flush wet air from the Section 300 cell enclosures prior to placing equipment in operation.
2. Provide a dry air seal for equipment enclosures located within Section 300.
3. Provide a limited amount of sealing medium for Section 300 process pump seals.
4. Provide an internal dry air blanket atmosphere over coolant systems in Sections 100, 300, and 600.
5. Provide continuous normal operating purge of cell enclosures in Section 600 through carbon absorbers to the atmosphere.
6. Provide dry air for instruments which are located within the conditioned enclosures, and which bleed air into these enclosures.

b. Capacity. - Ambient air in cell, piping, and equipment enclosures is maintained at a dewpoint of -40°F, by a suitable supply

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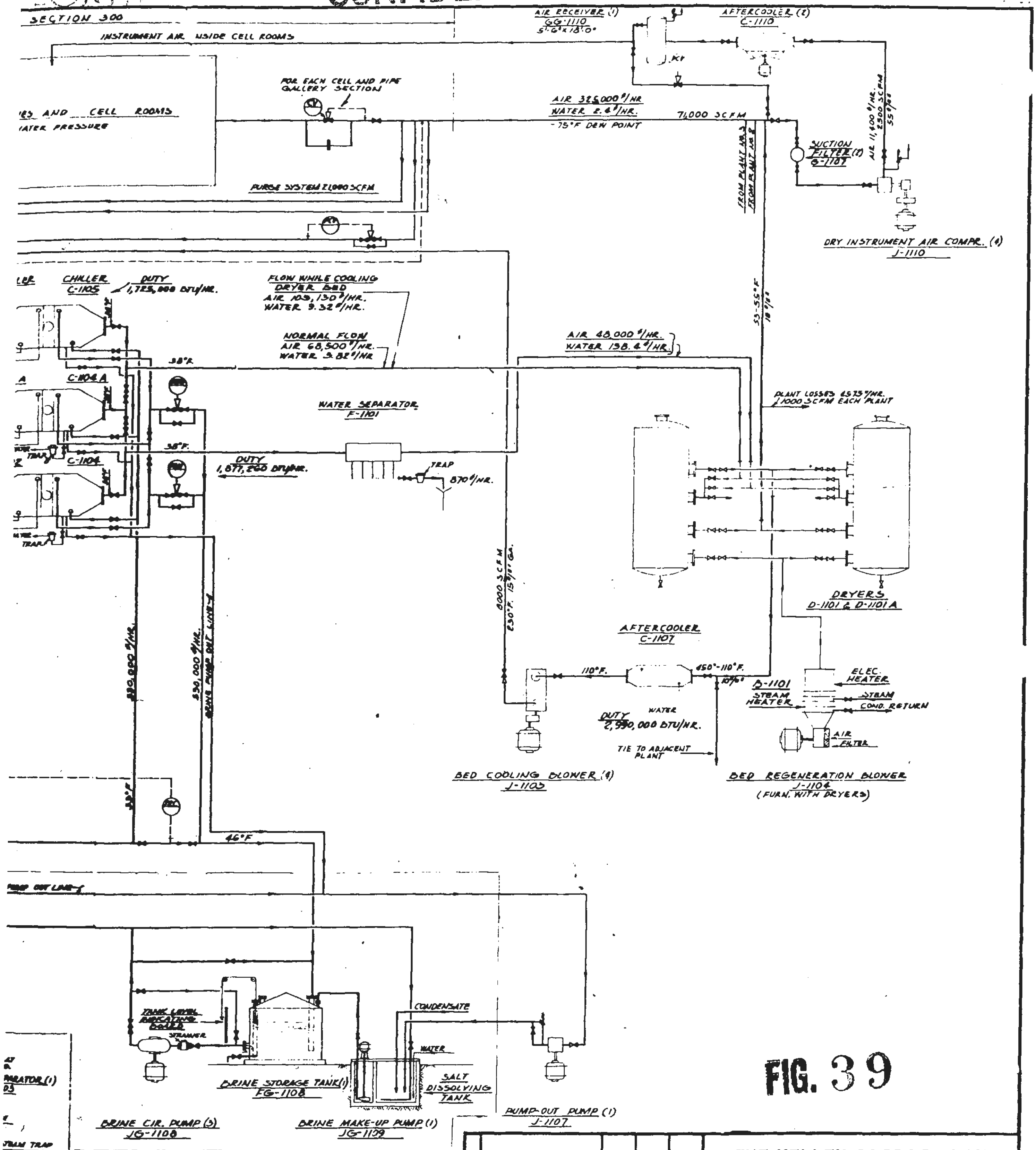

FIG. 39

THE KELLEX CORPORATION

AIR HUMIDITY CONDITIONING SYSTEM
SECTION 1100

NO.	DESCRIPTION	DATE	BY	CHECKED
	GENERAL REVISION		HALL	
	ADDED EQUIP. & LINES, REVISED LINES ETC. AS NOTED	2-28-44	HALL	
1.	ADDED & REVISED QUANTITIES		HALL	

REVISIONS

DRAWN J. HALL TRACED SCALE DATE
CHECKED T.G.R.
APPROVED T.G.R.
No. 291 AP

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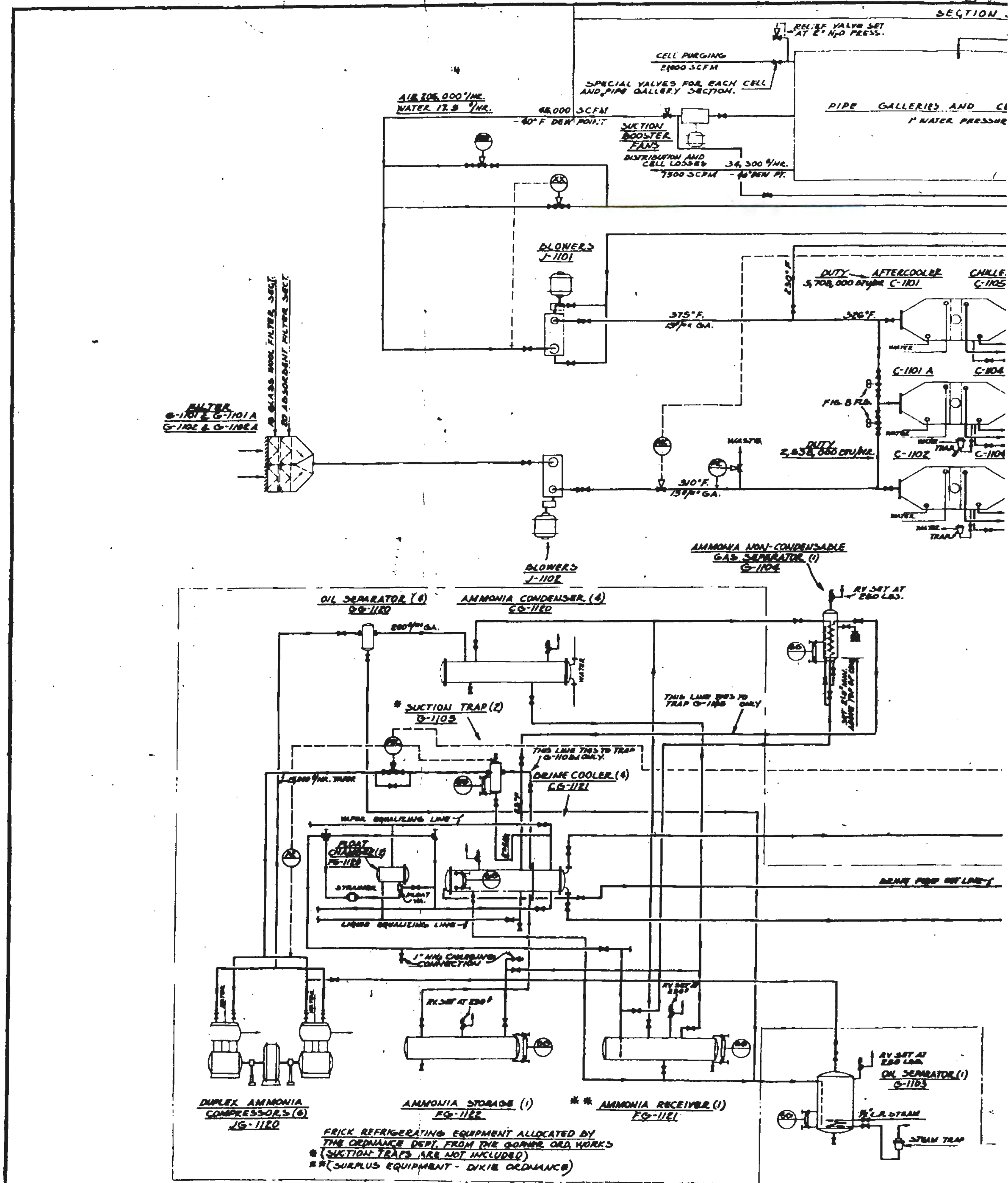


REFRIGERATION SYSTEM IS FOR AIR CONDITIONING PLANTS NO. 1, 2 A

AIR CONDITIONING EQUIPMENT SHOWN ON THIS DWG IS FOR PLANT NO. 1 ONLY, NO. 2 AND 3 ARE IDENTICAL EXCEPT FOR DRY INSTRUMENT AIR TO CELL ROOMS.

CONFIDENTIAL/RD

SECRET

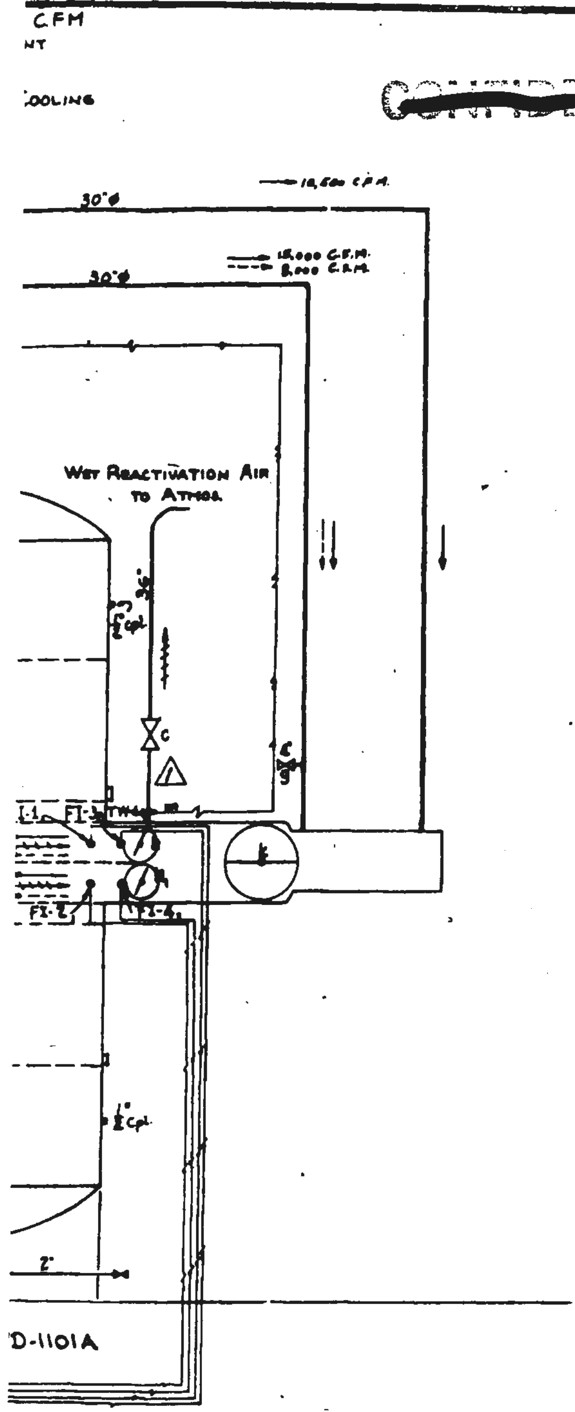
of -75°F dew point air. The following tabulation summarises the estimated design requirements for -75°F air in standard (measured at 60°F and 14.7 p.s.i.a.) cubic feet per minute.

	SCFM
Losses	
Weld leakage (total plant)	2000
Process pump seals (Section 300)	2500
Constant purge (Section 600)	1000
Valve casing seals, valve stems, compressor seals, etc. (whole plant)	2000
Drying plant exclusive of valves (Section 1100)	3000
Total losses	10,500
Purge capacity (72 large cells per day; 30 continuously)	21,000
Recirculation	45,000
Total	76,500

c. Design. - The dry air system comprises recirculation air compressors and coolers, make-up air compressors and coolers, air dryers, an ammonia refrigeration system, a brine circulation system, a network of distribution mains and branch piping necessary for the supplying and return of the dry air services, and a dry compressed air system for supplying air to instruments located within the dry air equipment enclosures. The general arrangement of this system is shown in the process flow diagrams, Figures 39 and 40. The total demand of 76,500 SCFM of dry air is divided equally among three identical and parallel divisions of the dry air system. The dehumidifying plant

[redacted]

[redacted]



— LEGEND —

TRC.	Temp Recording Controller
IT	Temp Indicator
TW	Thermometer Well
RT	Recording Thermometer
*	Rubber Seated Valves
IPG	Indicating Pressure Gauge
FI	Flow Indicator
■	Board Mounted Instrument
⊙	Expansion Joint
DPG	Differential Pressure Gauge
———	Flow When Drying
- - - -	" " Cooling Bed
~~	" " Reactivating

Air Quantities Are at 14.7 psi A

To Place Hydryer #1 in Service for Dehydration
- Open Valves D_1 and D
- Place Damper K in a horizontal position
- Open Dampers H and H_1
- Open Valves A and B
- Adjust H and H_1 for equal flow in FI-1 and FI-2

To Reactivate Hydryer #2 after having been in Dehydration Service
- Close Valves d_1 and d
- Close Valves a and b
- Close damper k

- △1 Open Valve c
- Open Valve g
- Open Valves e_1 and e
- Start Blower Motor
- Adjust Dampers h & h_1 for equal Flow in FI-3, and FI-4,
- Open Steam Valve L
- Close Electric Heater Switch
- Cycle is Complete when temperature at m is 450°F.

To cool Hydryer #2 after Reactivation.
- Open Switch on Electric Heater
- Close steam valve L
- Stop Blower Motor
- Close Valves e and e_1
- △1 Close Valve c
- Open Valves f and f_1
- Place Damper k in a horizontal position
- Close Valve g
- Open Valve b
- Open Dampers h and h_1 and Adjust for equal flow in FI-3 and FI-4
- Continue Cycle until temperature at n is 40°F. at which time Hydryer #2 is ready to be placed into drying service as listed for Hydryer #1

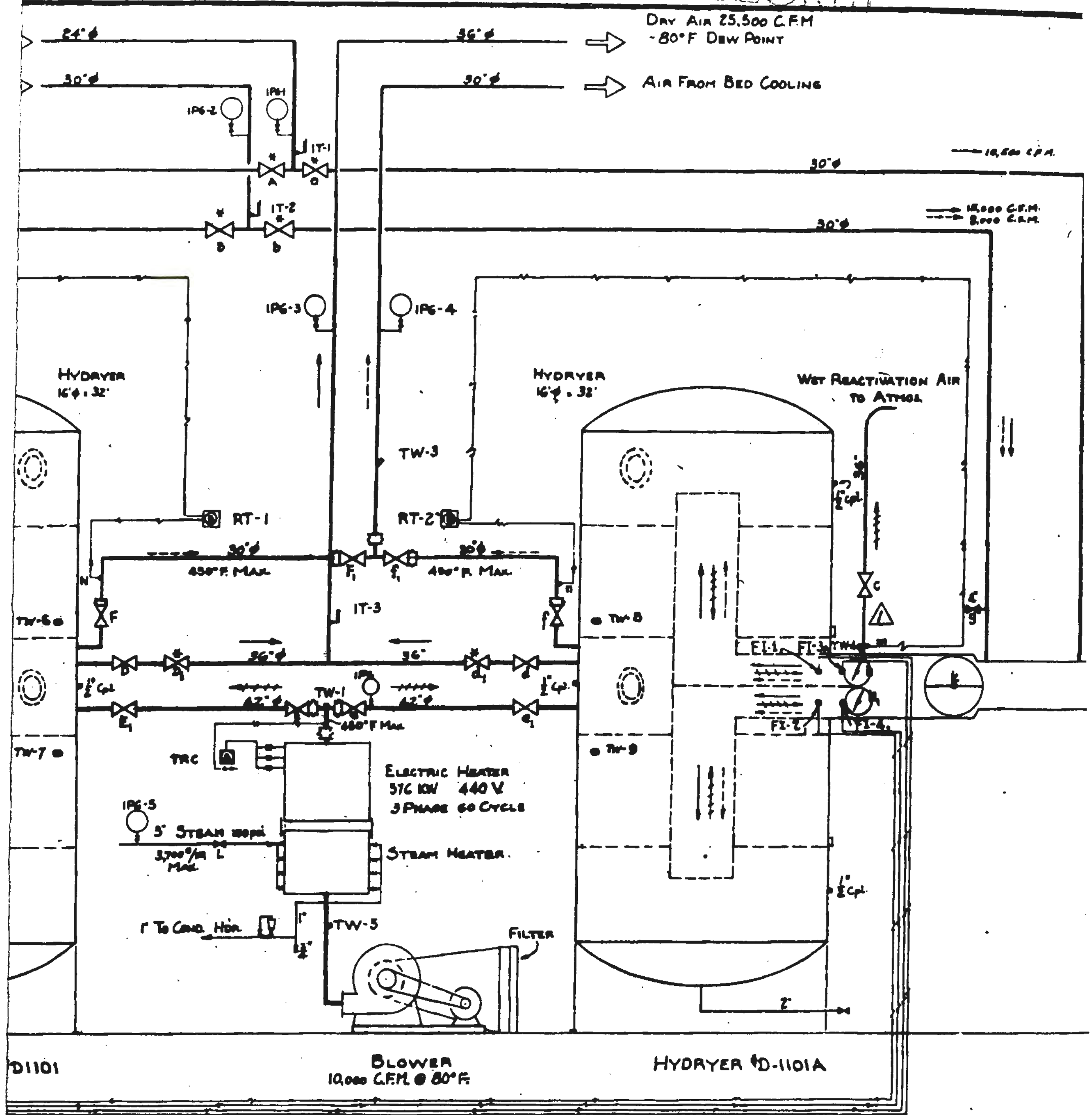
FIG. 40

[redacted]

ontract.
1A

J. F. PRITCHARD & CO. KANSAS CITY, MO.			
THE KELLEX CORPORATION, BLAIR, TENN. HYDRYER UNIT FLOW SHEET			
SCALE None / DATE 3-24-44	DRAWN LAW / CHECKED / APP'D	JOB NO. C-1078	DWG. NO. O-1

1

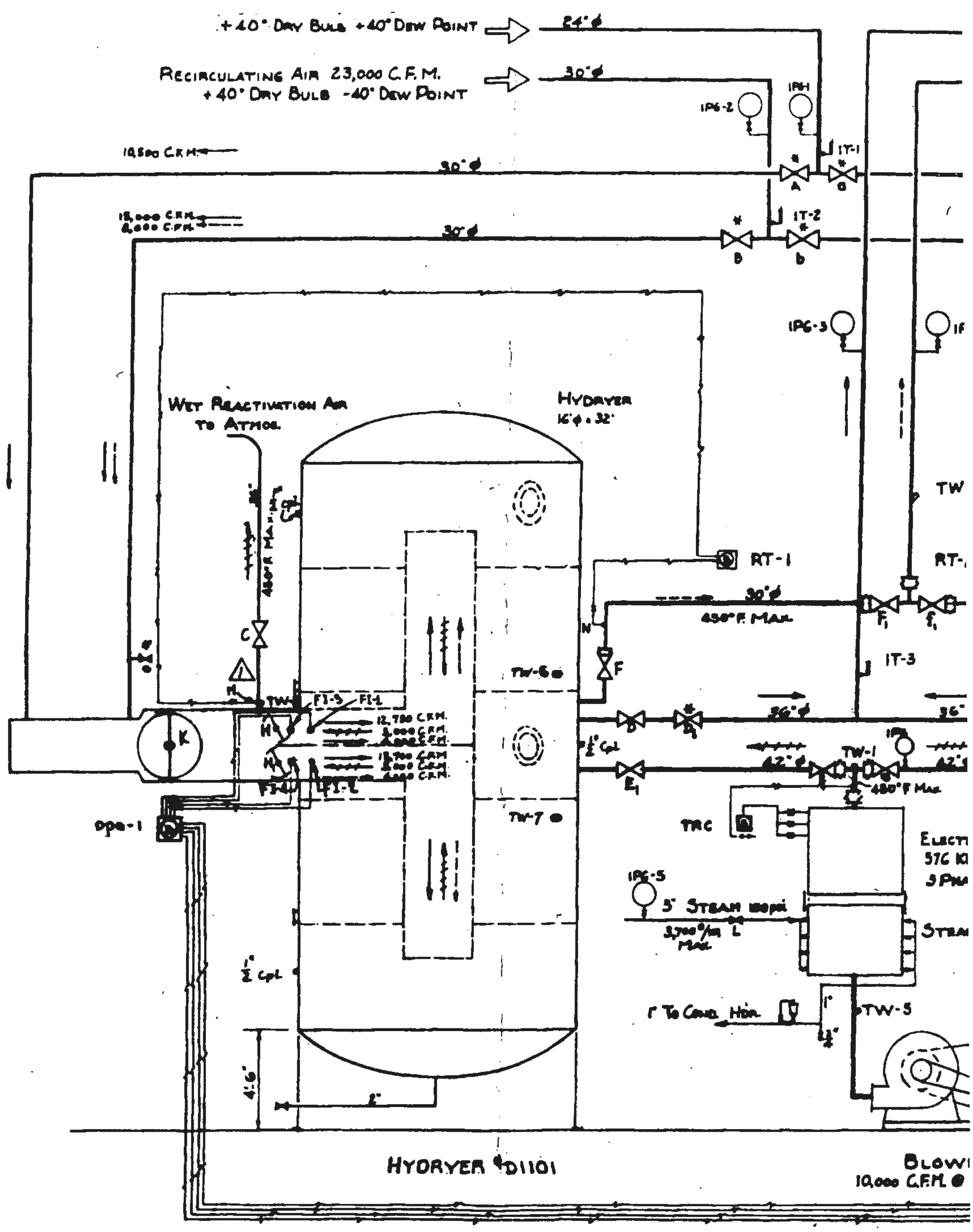


Kellex Notation
Vs 1100 - D - 501
Tagged D-1101, D-1101A
DA-1101, DA-1101A
DB-1101, DB-1101A

I-2, FI-1, F-I-2,
f
T DPG-1
lves F & f

△3 1 Complete Unit as Shown Hydryers D-1101 & D-1101A on Original Contract.
2 Complete Units - Hydryers DA-1101 & DA-1101A, DB-1101 & DB-1101A on Supplemental Contract.

[redacted]



Revision	By	Date
...tterfly Valves C,G & cg ...e Valves C & c Repo.	LAW	[illegible]
Revision Requested ...of Corp. As Noted	[illegible]	[illegible]
...o Include Customers ...ion & Added Note.	[illegible]	6-12-[illegible]
TW-6&7 on PD-H01 & ...o #D1101A/K&R	[illegible]	7-17-[illegible]

Removed ladders & platforms
Relocated flow indicators FI-1, FI-2, FI-1, FI-2
Relocated valves A,B,G,E,F, a,b,g,e, & f
△2 Added board mounted instrument DPG-1
Added expansion joints at valves F & f
Relocated top manways
Revised Hydryer Nos.

△3 1 Complete Unit as...
2 Complete Units...
on Supplemental...

[redacted]

was designed to process air received from two sources; recirculation air returned from the various enclosure casings of Section 300, and atmospheric make-up air used for supplying loss and purge requirements.

(1) Recirculation Air. - Recirculation air is taken from a branch header in each of three plant divisions by two recirculation air compressors, which compress it from a gauge pressure of 2 inches of water, to 15 p.s.i.g. (Fig. 39). It is then sent to the series-arranged water cooler and brine chiller unit provided for each division, where it is cooled to 38°F, and is conducted to one of the two activated alumina drying units ("Hydryers") connected to each of the three divisions of the dry air plant. The air, which is now mixed with make-up air at the entrance to the Hydryer, is split into two equal streams within the dryer, and passes through two alumina beds arranged in parallel (Fig. 40). The streams join at the Hydryer outlet, where the temperature is 38°F., pressure 10 p.s.i.g., and the dew point minus 80°F. The alternate Hydryer is always on a regeneration cycle during normal operation. Regeneration is accomplished by stripping the adsorbed water by means of hot atmospheric air, which is discharged back to the atmosphere. The hot beds are then cooled with 38°F air bled from the recirculation air line. The bed-cooling air is recycled to the recirculation system after being cooled and recompressed.

(2) Make-up Air. - Atmosphere air is drawn through a glass wool filter and an absorbent cotton filter arranged in series, and is then compressed to 15 p.s.i.g. It is next cooled to 38°F, and partially dehumidified by a water cooler and brine chiller. From the chiller it is passed through a baffled separator to remove any entrained

condensed moisture. The make-up air pipes are then connected into the recirculation air stream at the inlet to the Hydryer.

(3) <u>Refrigeration System.</u> - A direct expansion ammonia compression refrigeration unit maintains the brine solution temperature at 33°F. The ammonia compressor takes suction from the evaporating ammonia in the brine coolers, for which peak load pressure is 37 p.s.i.g., corresponding to an ammonia temperature of 23°F. The compressor discharge pressure is 200 p.s.i.g. Flow is then through an oil separator and a water-cooled condenser, from which liquid ammonia leaves at a temperature of 101°F. From the condenser, ammonia flows through a receiver and an expansion valve to the brine cooler, which acts as the ammonia evaporator. Flow is then through suction traps and back to the compressors. A photograph of the refrigeration system is shown in Appendix E12.

(4) <u>Brine Circulation.</u> - The brine circulation system was designed for use of a calcium chloride solution of 1.1 specific gravity. The brine circulation pumps take suction from an insulated brine storage tank, and discharge through the ammonia-cooled brine coolers. The brine then flows through the air chillers and returns to the storage tank.

(5) <u>Distribution and Return.</u> - The dry air distribution system consists of one main supply header, secondary supply headers located in the withdrawal alleys between buildings, and branch headers to the points of delivery. The outlet pressure of the air conditioning plant (10 to 12 p.s.i.g.) is maintained in the distribution system, and is reduced at the point of delivery by means

of orifices or control valves. The return system consists of various branch systems, each with a booster fan which delivers the air to the collecting main leading back to the drying plant (K-1101). The enclosures and secondary return system are held at approximately one inch of water column gauge by a control valve located in the booster fan discharge line.

(a) Instrument Air. - A separate supply system furnishes dry compressed air to instruments located within the enclosure casings. Dry air is taken from the Section 1100 main supply header, passed through a suction filter, and compressed to 55 p.s.i.g. Heat of compression is removed by air-to-air aftercoolers. The air then flows to a receiver, where it is maintained at a constant pressure of 50 p.s.i.g. Dry compressed air may also be fed into the plant nitrogen system (Par. 10-7b (2)) should the pressure in the nitrogen distribution line fall below a pre-determined level. For a full description of the K-25 dry air plant, reference may be made to Volume VIII of the Kellex Operating Manuals.

d. Operating Status. - It was discovered during early plant operation that a "dead end system" would be more efficient than the recirculation system. Accordingly, suitable changes were made in the piping system and operating procedure so as to enable operation without returning the air from the process buildings to the dry air plant. Instead, the process buildings are supplied with air at a constant pressure and essentially no flow (except that required to make up for small continuous leakage losses and periodic bleedings). At various points in the system, provision is made for bleeding the

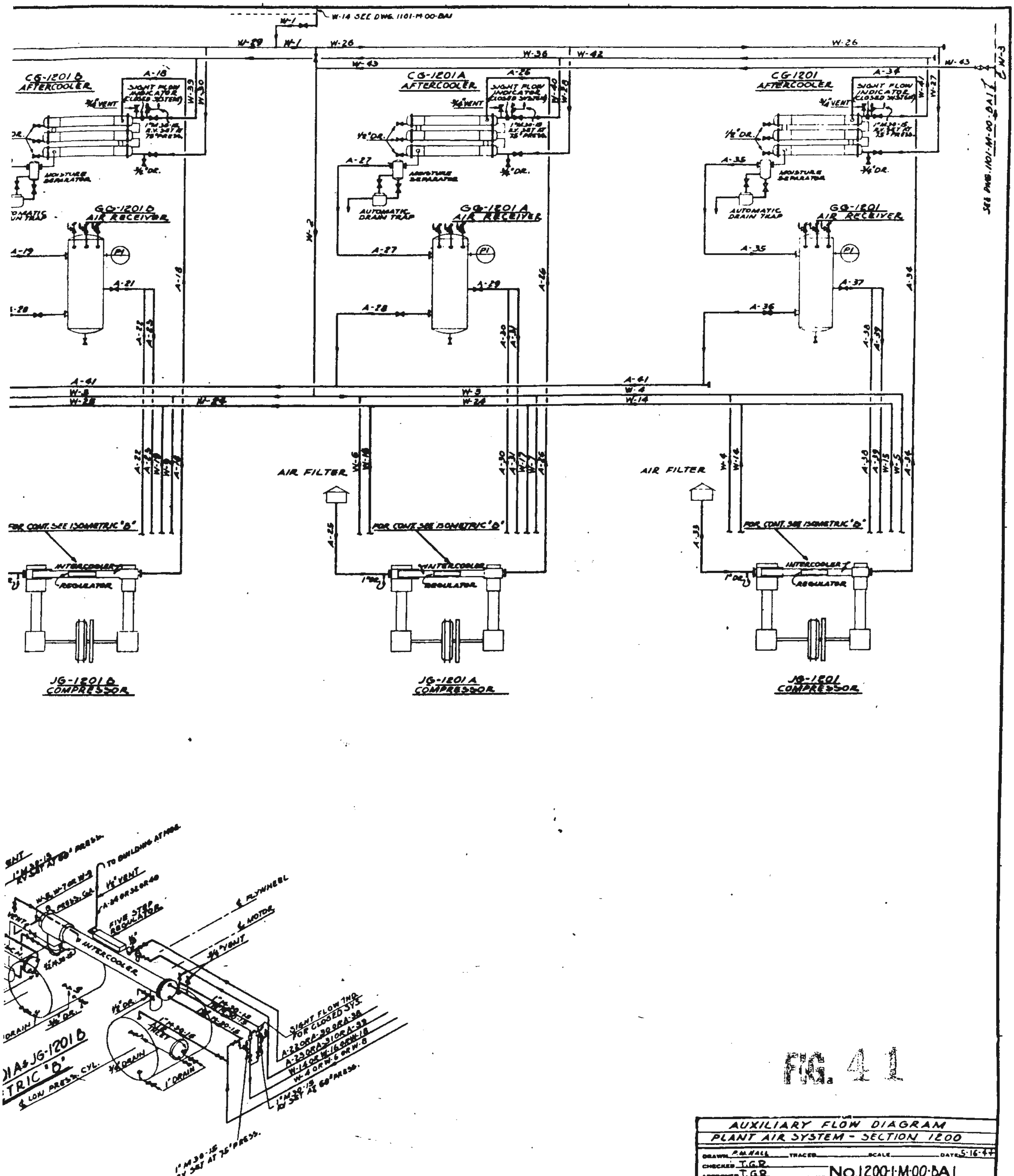


FIG. 41

AUXILIARY FLOW DIAGRAM
PLANT AIR SYSTEM - SECTION 1200

DRAWN P.M. HALL TRACED SCALE DATE 5-16-44
CHECKED T.G.R.
APPROVED T.G.R.
No. 1200-1-M-00-BA1

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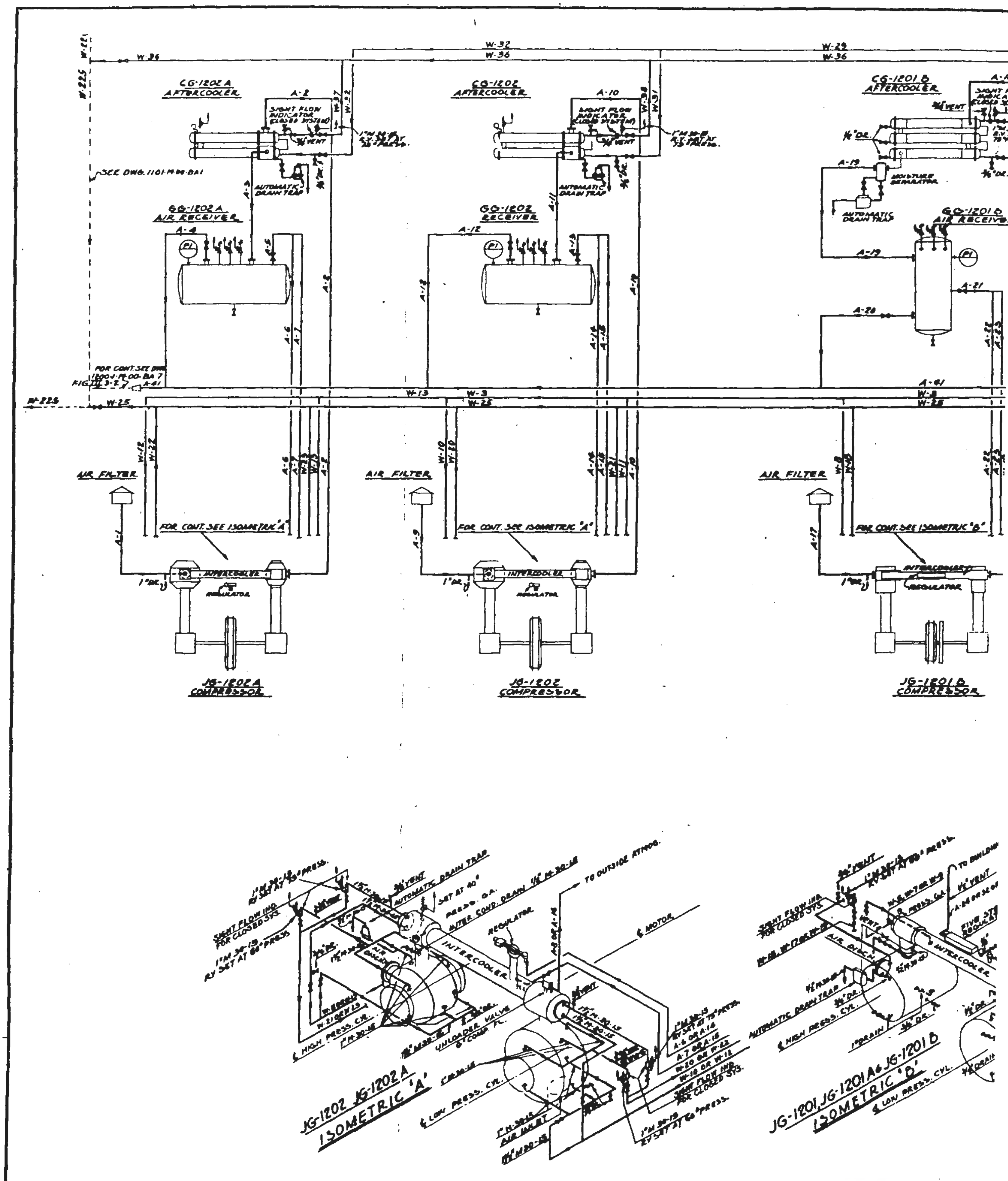

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dry air to the atmosphere when the dew point has risen to minus 40°F. This air is then replaced with minus 75°F air from Section 1100.

10-5. Compressed Air Plant (Section 1200).

a. Purpose. - The function of the "plant air system" is to deliver air at a pressure at 100 p.s.i.g. to points of Section 300 and other parts of K-25 where it is required for miscellaneous instruments, (not located within the dry air equipment enclosures), maintenance, and other services. A secondary function is to provide a supplementary source of minus 50°F dew point air for use in cases when the output of the dry air plant (Section 1100) may fall below the demand.

b. Capacity. - The compressor house (K-1201) contains five air compressors, including two 3400 CFM Ingersoll-Rand units, and three 2000 CFM Chicago Pneumatic compressors. (App. E11).

c. Design. - Five air receivers (Fig. 41) connect to a common header which discharges through two afterchillers and two drying units to the plant air distribution system. The latter consists essentially of a loop skirting the process area and serving the main process buildings, and branch headers leading from the loop to auxiliary buildings. One or more pressure control valves in each building reduce the air pressure to a desired level when necessary for particular services. Plant air, at a dew point of minus 50°F., is used for all services not requiring the minus 75°F dew point compressed air produced in section 1100. The plant air system described in this paragraph is interconnected with the special compressed dry air system (Par. 10-4c (5) (a)) at Sections 1100 and 300. At Section 1100, the arrangement is such that, should the pressure in the dry air header fall below a

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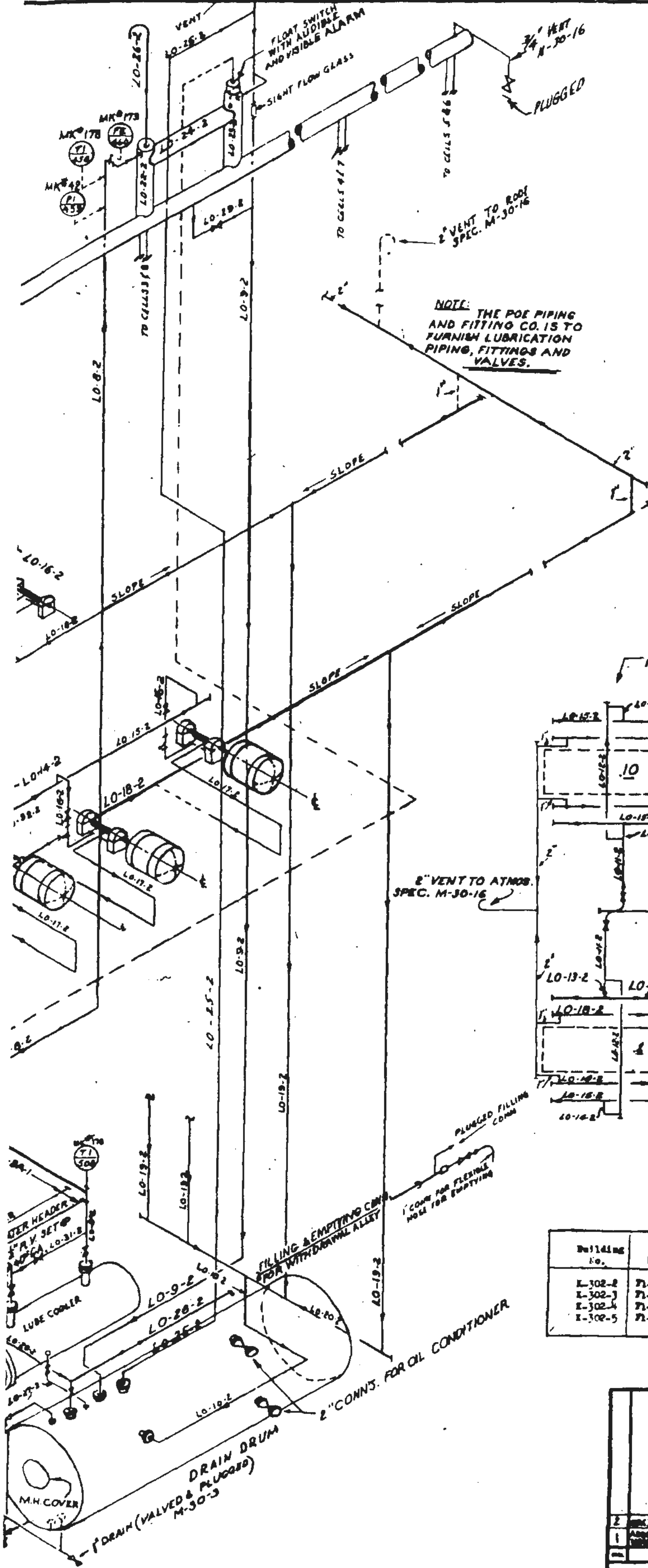
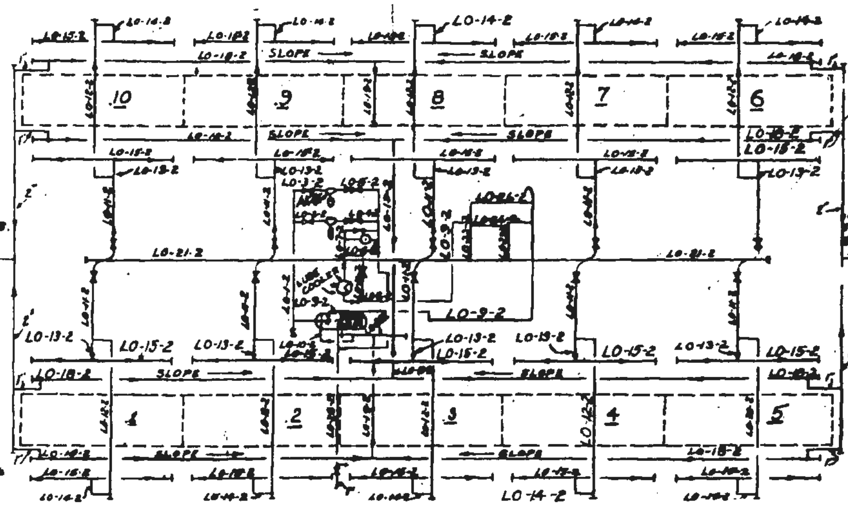


NOMENCLATURE

LINE NO.	SIZE	SPEC. M-30	FLOWING MEDIUM	FROM	TO	TEMP. °F	PRESS. P.S.I.	PIPE MAT.
			BUILDING K-302-2 TO 5					
LO-1-2	6"	13	Lube Oil	Drain Drum	Lines LO-2-&3-2	150	3	Std.
LO-2-2	4"	13	Do Do	Line LO-1-2	Lube Pump	150	3	Std.
LO-3-2	4"	13	Do Do	Line LO-1-2	Lube Pump	150	3	Std.
LO-4-2	4"	13	Do Do	Lube Pump	Line LO-6-2	150	65	Std.
LO-5-2	4"	13	Do Do	Lube Pump	Line LO-6-2	150	65	Std.
LO-6-2	4"	13	Do Do	Lines LO-4-&5-2	Oil Filter	150	65	Std.
LO-7-2	4"	13	Do Do	Oil Filter	Lube Cooler	150	60	Std.
LO-8-2	4"	13	Do Do	Lube Cooler	Line LO-22-2	140	50	Std.
LO-9-2	6"	13	Do Do	Lines LO-23-&26-2	Drain Drum	140	20	Std.
LO-10-2	6"	13	Do Do	Line LO-20-2	Drain Drum	140	20	Std.
LO-11-2	10-2"	13	Do Do	Line LO-25-2	Lines LO-12-&13-2	140	10	Std.
LO-12-2	10-2"	13	Do Do	Jct. LO-11-&LO-13-2	Line LO-14-2	140	10	Std.
LO-13-2	10-1½"	3	Do Do	Jct. LO-11-&LO-12-2	Line LO-15-2	140	10	X.S.
LO-14-2	10-1½"	3	Do Do	Line LO-12-2	Line LO-15-2	140	10	X.S.
LO-15-2	20-2"	13	Do Do	Lines LO-13-&14-2	Lines LO-16-2	140	10	Std.
LO-16-2	120-¼"	13	Do Do	Line LO-15-2	Stage Pumps	140	10	Type K
LO-17-2	120-¼"	13	Do Do	Stage Pumps	Lines LO-18-2	160	5	Type K
LO-18-2	4-3"	13	Do Do	Lines LO-17-2	Line LO-19-2	150	5	Std.
LO-19-2	4-3"	13	Do Do	Line LO-18-2	Line LO-20-2	160	5	Std.
LO-20-2	4"	13	Do Do	Line LO-19-2	Line LO-10-2	150	10	Std.
LO-21-2	8"	13	Do Do	Lines LO-22-&23-2	Lines LO-25-2	140	10	Std.
LO-22-2	8"	13	Do Do	Lines LO-8-2	Line LO-21-2	140	10	Std.
LO-23-2	6"	13	Do Do	Lines LO-21-2	Line LO-9-2	140	10	Std.
LO-24-2	6"	13	Do Do	Line LO-[illegible]	Line LO-23-2	140	10	Std.
LO-25-2	5-6"	16	Do Do	Line LO-21-2	Line LO-11-2	140	10	Std.
LO-26-2	1"	16	Vent	Line LO-22-2	Line LO-9-[illegible]	140	0	Std.
LO-27-2	1"	3	Drain	Lube Cooler	Drain Drum	140	0	X.S.
LO-28-2	2"	13	Lube Oil	Jct. LO-[illegible] Withdrawal Alley	Drain Drum	150	65	Std.
LO-29-2	3"	13	Drain	Line LO-21-2	Line LO-9-2	140	20	Std.
LO-30-2	4"	13	Lube Oil	Line LO-6-2	Line LO-7-2	150	65	Std.
LO-31-2	4"	13	Do Do	Line LO-7-2	Line LO-8-2	150	62	Std.
LO-32-2	20-1"	13	Drain	Line LO-15-2	Line LO-17-2	150	10	Type K

QUANTITIES FOR ONE 10 CELL BUILDING ONLY



BUILDING LAYOUT
10 CELL UNITS

Building No.	Drum No.	Drum Size	Lub. Cooler	Lube Pumps
K-302-2	F1-314	5'x21'	C1-314	J1-314 & 314-A
K-302-3	F1-315	5'x21'	C1-315	J1-315 & 315-A
K-302-4	F1-316	5'x21'	C1-316	J1-316 & 316-A
K-302-5	F1-317	5'x21'	C1-317	J1-317 & 317-A

FIG. 42

THE KELLEX CORPORATION

AUX. FLOW DIAGRAM - PERM. LUBRICATION FOR STAGE PUMP BEARINGS
BLDGS. K-302-2 TO K-302-5 SECTION 300

DRAWN D.B. SLIVINSKI

REVISIONS

No. 302-2-M-00-BA-2

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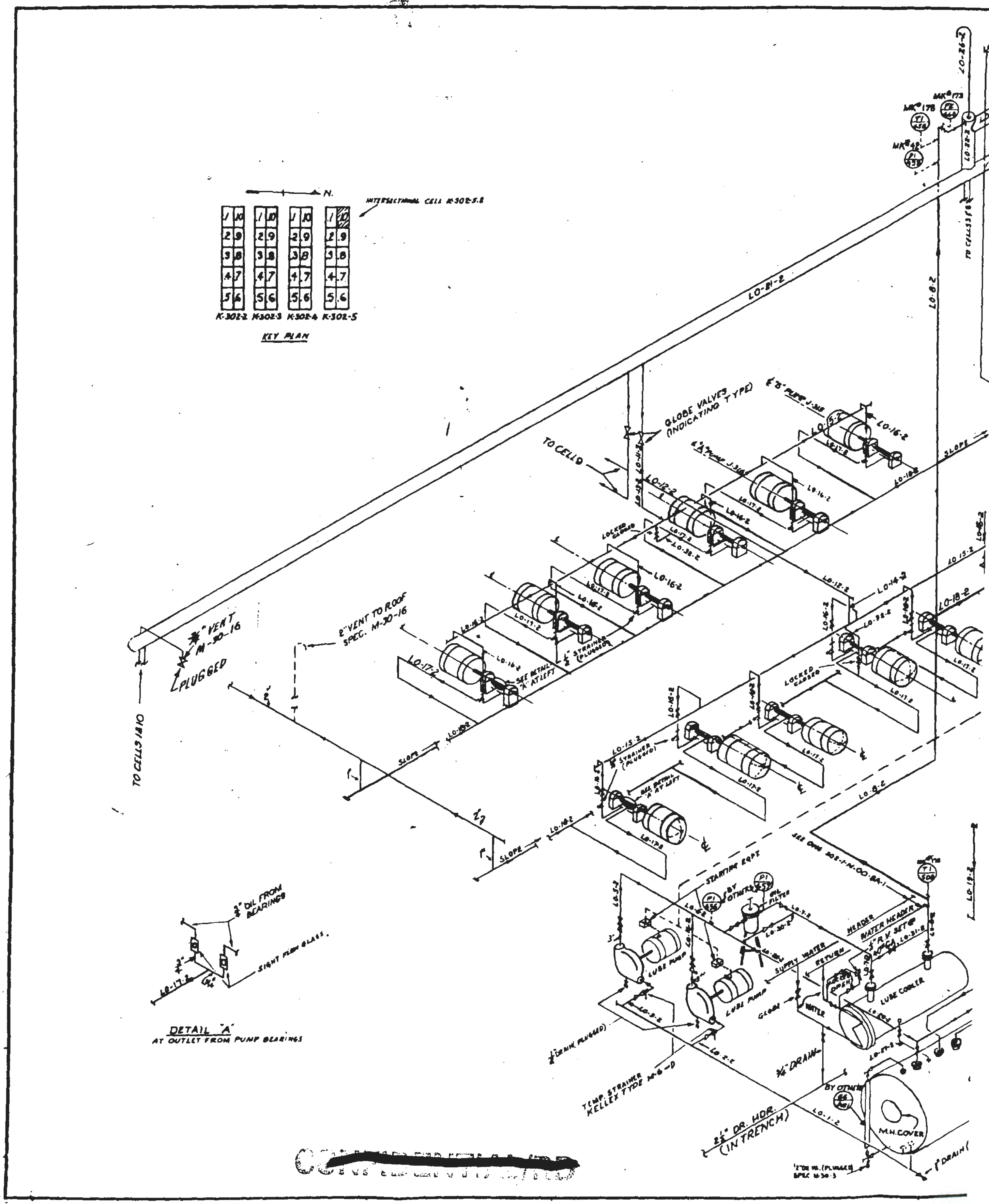

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specified level, the plant air will automatically discharge into the dry air system to increase the pressure. At Section 300, the systems are complementary; that is either system will supply the other. Air from Section 1200 is dried to a lesser extent than that from Section 1100, but its dew point is low enough so that it may be temporarily used for dry air services without undue contamination of valuable materials. Further details can be found in Volume V, Part III of the Kellex Operating Manuals.

10-6. Lubricating Oil System. - Because the importance of the process pumps to K-25 plant operation ranks second only to that of the stage converters, and since successful operation of these pumps is totally dependent upon proper lubrication, provision for an extensive and carefully designed lubricating oil system formed a basic requirement for plant design.

a. Purpose. - Facilities are provided for storing, pumping, filtering, and cooling lubricating oil, and for circulating it through the shaft bearings of all process pumps of the main cascade, in number approximately 5800.

b. Design. - Each building in Section 300 is equipped with its own independent gravity feed oiling system shown schematically in Figure 42.

(1) Drain Drum. - A horizontal, cylindrical, lubricating oil drain drum is located in the basement of each cascade building (App. E1), and is capable of holding the entire oil inventory of the building. Drum size is in proportion to the number of cells in the building. A typical capacity is 3080 gallons for a ten-cell building.

(2) Oil Conditioner. - A portable centrifuge has been provided for use at required points in occasional oil cleaning operations, which are necessary because of slight sludge build-up in the drain drum. The unit is a product of the De Laval Separator Company, and is capable of removing water and foreign particles from oil at the rate of 300 GPM.

(3) Oil Pumps. - Two oil pumps are required for each building. Under normal conditions, one is operating, and delivers 25 per cent excess oil to the header. The overflow is returned to the building drain drum, and may be observed through a sight glass in the run-down line to the basement. In case the pump fails to deliver sufficient oil to the header, an automatic float-controlled alarm and cut-in switch is actuated, and the spare pump is started. The pumps are of the centrifugal type, and were supplied by Allis-Chalmers, by the Aurora Pump Company, and by the Worthington Pump and Machinery Corporation. The size of the driving motor varies with the number of cells per building. A typical rating is 25 horsepower for a ten-cell building using 340 GPM of oil flow.

(4) Filters and Strainers. - Foreign particles may damage process pump bearings; it is therefore imperative that the oil be kept free from dirt and grit. Toward this end, each building is equipped with an oil filter designed to remove particles larger than 0.008 inches, and a strainer which removes particles down to 0.005 inches. The filter is located in the discharge line of the oil pump in the basement, and the strainer is located in the line leading to the process pump bearings.

(5) Coolers. - The lubricating system was designed

for a 30°F temperature rise of the oil passing through the bearings. On the assumption of a 20°F drop caused by radiation losses in the system, the oil cooler was designed to reduce the oil temperature by 10°F. The coolers are standard Schutte and Koerting two-pass, water-oil heat exchangers. Oil flows through the shell in a single pass. Cooling water makes two passes through the tubes.

(6) Instrumentation. - The lubricating oil system is provided with suitable pressure, temperature, and flow indicators.

(7) Piping. - The lubricating oil system of each building is served by an eight-inch pipe header running the full length of the building, and located nine feet, four inches above the operating floor. The building header is fitted with a branch for each cell, and is provided with an "H"-shaped riser in which is located an overflow line and a float-controlled switch which operates the spare pump. Oil flows by gravity from the main header to the cell branch headers, which supply the process pumps to be lubricated. A valve just before the cell headers, maintains the pressure at 4 p.s.i.g. At this pressure, the orifices in the bearing feed lines will meter the flow to 0.5 GPM for the load bearing, and 1.75 GPM for the thrust bearing. After passing over a process pump shaft, the oil discharges to the building drain drum through a 3/4 inch line. Further details may be found in Volume VI of the Kellex Operating Manuals.

c. Lubricating Oil. - The oil used in the lubricating system is a turbine oil with an approximate rating of SAE #10, and has a specific gravity of 0.865. The total inventory of lubricating oil for Section 300 is approximately 120,000 gallons.

10-7. Dry Nitrogen Supply System.

a. Purpose. - The function of the dry nitrogen system is to deliver a suitable dry inert gas for the various purging and sealing operations required in the process area. Operations requiring the use of dry nitrogen may be divided into two general classifications; those which require nitrogen to be continually available but do not require a continuous flow, and those which do require a continuous flow. In the first group nitrogen is used to perform the following "purge and bleed" functions:

1. As a medium for purging process equipment and piping during the process of removing UF_6.
2. As a sealing medium to prevent leakage of atmospheric air into piping or equipment containing process gas.
3. In certain cases as a sealing medium between double valves on process gas lines of diameters under 3 inches, where single-seated valves are used.
4. For purging of portable C_7F_{16} units (Par. 10-6b).
5. For operating the blow-out preventer device in the process gas pump. (Vol. 2, Par. 5-1c).

A continuous flow of nitrogen is required for the following functions:

1. As a sealant material for the process gas pumps.
2. As an inert gas for the instrument datum header.
3. As an inert gas for the buffer zones in instruments and control valves.

b. Design.

(1) Vaporizer Plant. - A description of the nitrogen

generating plant (which is physically located in the conditioning area) is presented in Paragraph 11-7.

(2) <u>Distribution System.</u> - The dry nitrogen (code name: G-74) is distributed by means of a special piping system arranged to connect the generating plant (K-1408) with points of use in the process and conditioning areas. Any building can be supplied with nitrogen at a pressure of 30 p.s.i. The maximum flow in the loop was calculated on the assumption that 42.4 cells per day might be taken off stream and purged, with half that number being purged simultaneously. The maximum volume flowing was calculated upon the basis that the 21 cells which might be purged simultaneously would be distributed among the various sections of the process area in proportion to the number of cells in the sections. Provision has been made for dry air to replace nitrogen whenever an interruption in the nitrogen supply causes the pressure in the loop to drop to a dangerous point. Sufficient air is provided for those services which must operate continuously such as pump seals, buffer zones, and datum headers.

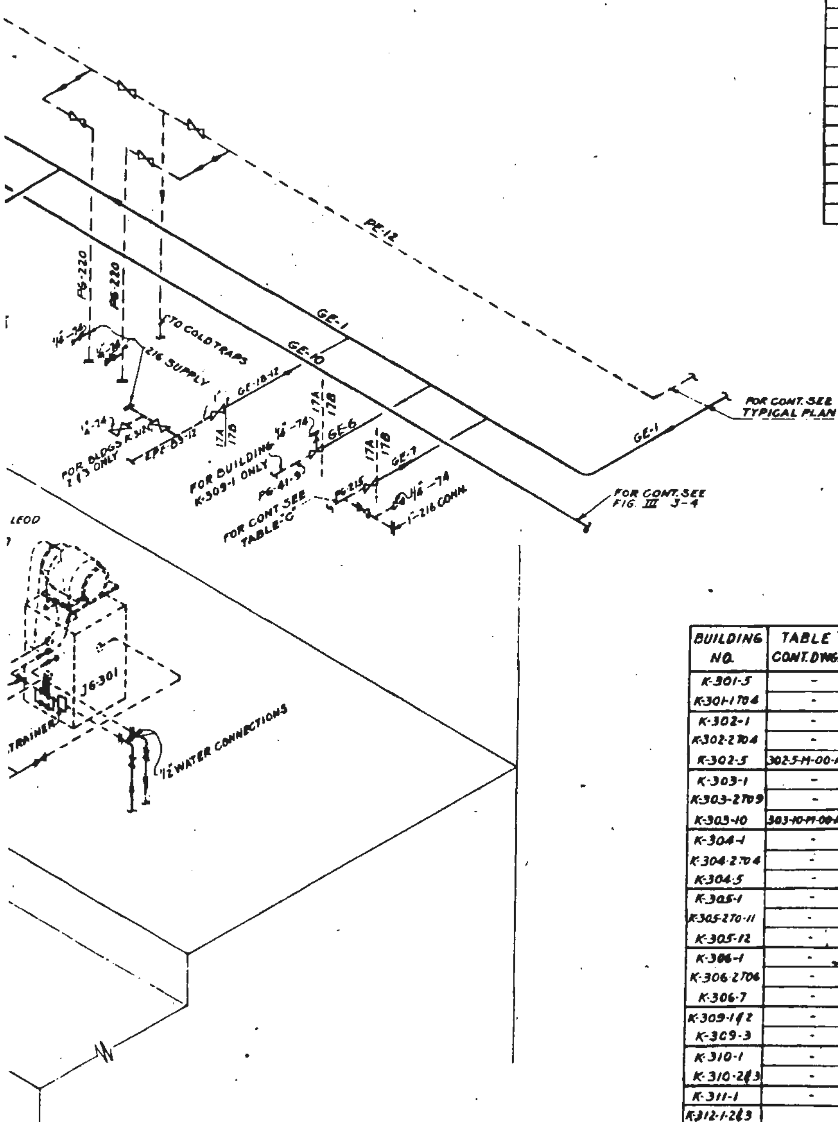
(3) <u>Purge and Bleed System.</u> - The function of the purge and bleed system is to provide dry nitrogen for purging equipment and piping containing UF_6, and for sealing valves and dead-end lines. During the purging of equipment, nitrogen acts as a diluent to reduce the concentration of UF_6 below 33 per cent, which is the maximum concentration the cold traps can handle. Each cell is filled with nitrogen to atmospheric pressure, evacuated to cold traps, re-filled with nitrogen to approximately 3. p.s.i.a., and again evacuated to cold traps. The concentration of UF_6 in the cells is then at a point where

it will be safe to open equipment. Purging of lines and drums is handled in a similar manner. To avoid confusion in nomenclature, it should be pointed out that purging UF_6 from equipment amounts to "process gas recovery" (Par. 7-12), and is entirely distinct from purging nitrogen from the process stream (Pars. 7-11 and 7-14). The headers and branches of the purge system are designed so that the time required to fill the equipment and piping in a cell, from 1 mm. pressure up to atmospheric pressure, will not exceed 7 minutes. All of the cells in a typical 10 cell building can be filled with nitrogen in slightly over 30 minutes.

(4) <u>Pump Sealing System.</u> - Pump seals are supplied from a storage drum through a spring-loaded pressure control valve and a surge tank. As nitrogen is consumed by the seals, the pressure control valve allows more to bleed in from the storage tank, which has been designed to hold enough nitrogen for approximately a 12 hour run. Because of the small clearances involved in the pump seals, it is essential that the nitrogen be filtered to remove any foreign particles in the line. Each cell system is supplied with three filters for this purpose. The final filter is capable of trapping out particles whose greatest dimension is 0.0006 inches. A choke in the feed line to each seal is provided, so that in the event of a broken seal the inleakage will be no greater than twelve times the greatest normal inleakage. In addition to restricting the flow, the choke provides a convenient means of indicating and locating a broken seal from the increased pressure drop across the choke (Vol. 2, Par. 6-14).

(5) <u>Buffer Zone System.</u> - A buffer zone header

SECRET [redacted]



NOMENCLATURE

LINE NO.	SIZE	SPEC. M-30-	NORM. TEMP. °F	MAX. TEMP. °F
GE-1	SEE TABLE "E"	17B	160	212
GE-5	4"	17B	160	212
GE-6	3"	17B	160	212
GE-9	4"	17B	160	212
GE-10	8"	17B	160	212
GE-7	SAME AS PG-215	17B	160	212
GE-8	SAME AS PG-368	17B	160	212
GE-4	1"	17B	160	212
GE-15	3"	17B	160	212
GE-16	3"	17B	160	212
GE-17	SAME AS [illegible]	17B	160	212
GE-18	1"	17B	160	212
GE-19	1"	17B	160	212

BUILDING NO.	TABLE "A" CONT. DWG. NO.	PG-368 SIZE	TABLE "B" CONT. DWG. NO.	PE-84 SIZE	TABLE "C" CONT. DWG. NO.	PG-215 SIZE	TABLE "D" CONT. DWG. NO.	TABLE "D" CELL NO.	TABLE "D" LINE GE-2 NO. REQ.	TABLE "D" LINE GE-2 SIZE	TABLE "E" LINE GE- SIZE
K-301-5	-	-	301-1-M-00-AA-5	2"	301-5-M-00-AA-1	4"	301-5-M-00-AA-1	#8	1	4"	6"
K-301-1 TO 4	-	-	301-1-M-00-AA-5	2"	301-1-M-00-AA-8	4"	-	-	-	-	6"
K-302-1	-	-	302-2-M-00-AA-1	2"	302-1-M-00-AA-3	4"	302-1-M-00-AA-3	#1	2	4"	6"
K-302-2 TO 4	-	-	302-2-M-00-AA-1	2"	302-2-M-00-AA-2	4"	-	-	-	-	6"
K-302-5	302-5-M-00-AA-2	1½"	302-2-M-00-AA-1	2"	302-5-M-00-AA-1	4"	302-5-M-00-AA-1	#8	4	4"	6"
K-303-1	-	-	303-1-M-00-AA-4	2"	303-1-M-00-AA-3	4"	303-1-M-00-AA-3	#1	2	4"	6"
K-303-2 TO 9	-	-	303-1-M-00-AA-4	2"	303-2-M-00-AA-2	4"	-	-	-	-	6"
K-303-10	303-10-M-00-AA-2	2"	303-1-M-00-AA-4	2"	303-10-M-00-AA-1	4"	303-10-M-00-AA-1	#8	4	4"	6"
K-304-1	-	-	304-1-M-00-AA-4	1½"	304-1-M-00-AA-3	3"	304-1-M-00-AA-3	#1	2	3"	4"
K-304-2 TO 4	-	-	304-1-M-00-AA-4	1½"	304-2-M-00-AA-1	3"	-	-	-	-	4"
K-304-5	-	-	304-1-M-00-AA-4	1½"	304-5-M-00-AA-1	3"	304-5-M-00-AA-1	#8	1	3"	4"
K-305-1	-	-	305-1-M-00-AA-4	1½"	305-1-M-00-AA-2	3"	305-1-M-00-AA-2	#1	2	3"	4"
K-305-2 TO 11	-	-	305-1-M-00-AA-4	1½"	305-2-M-00-AA-1	3"	-	-	-	-	4"
K-305-12	-	-	305-1-M-00-AA-4	1½"	305-12-M-00-AA-1	3"	305-12-M-00-AA-1	#8	1	3"	4"
K-306-1	-	-	306-1-M-00-AA-5	1"	306-1-M-00-AA-2	3"	306-1-M-00-AA-2	#1	2	3"	4"
K-306-2 TO 6	-	-	306-1-M-00-AA-5	1"	306-2-M-00-AA-1	3"	-	-	-	-	4"
K-306-7	-	-	306-1-M-00-AA-5	1"	306-7-M-00-AA-1	3"	-	-	-	-	4"
K-309-1 & 2	-	-	309-1-M-00-AA-4	2"	309-1-M-00-AA-3	4"	-	-	-	-	6"
K-309-3	-	-	309-1-M-00-AA-4	2"	309-3-M-00-AA-1	4"	309-3-M-00-AA-1	#1 & 2	2"	4"	6"
K-310-1	-	-	310-1-M-00-AA-3	1½"	310-1-M-00-AA-2	4"	310-1-M-00-AA-2	#8	1"	4"	6"
K-310-2 & 3	-	-	310-1-M-00-AA-3	1½"	310-2-M-00-AA-1	4"	-	-	-	-	6"
K-311-1	-	-	311-1-M-00-AA-4	1½"	311-1-M-00-AA-2	3"	311-1-M-00-AA-2	#1	1	3"	4"
K-312-1-2 & 3			312-1-M-00-AA-2	1"	312-1-M-00-AA-1	3"	312-1-M-00-AA-1	#1	3	3"	4"

FIG. 43

NO.	DESCRIPTION	DATE	BY	CHECKED
3	ADDED LINE GE-4 OR DETAILS FOR GE-5	2-5-46	D.B.S.	D.S.
2	ADDED LINE GE-19, INSTR. PI & PBM, LINES GE-4 & GE-18	1-12-46	D.B.S.	D.S.
1	ADDED LINE PG 03-12	12-26-44	D.B.S.	J.T.S.

REVISIONS

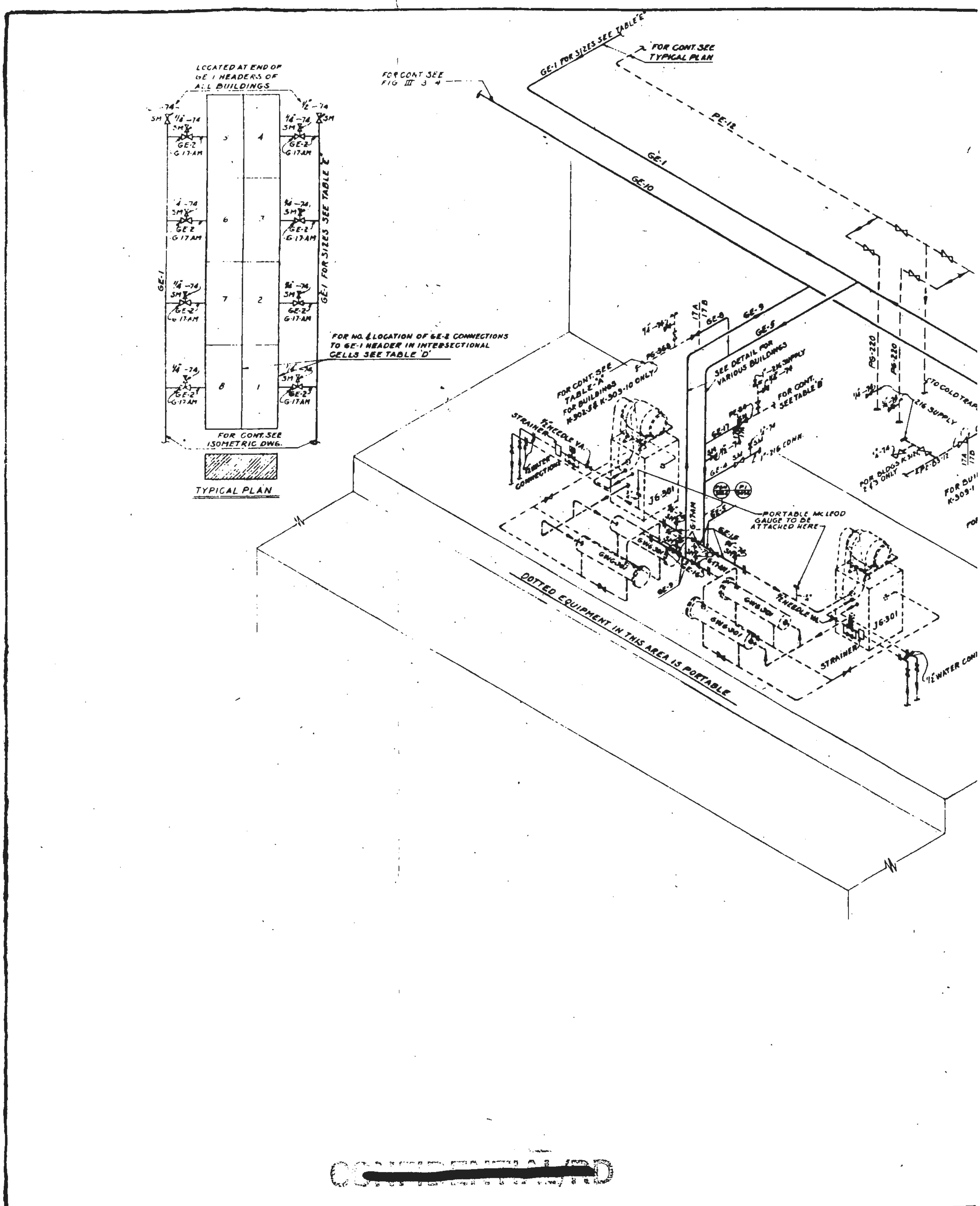
FOR ENGINEERING FLOW DIAGRAM
216 EVACUATION LINES

DRAWN L. J. COX TRACER — SCALE — DATE 8-9-44
CHECKED [signature]
APPROVED [signature]
No. 301-1-M-00-AA-7

[redacted]

~~CONFIDENTIAL/RD~~

~~SECRET~~



~~CONFIDENTIAL/RD~~

supplies the buffer zones of the differential transmitters and the process control valves of the cell. These buffer zones afford process protection against air inleakage in case of failure of a diaphragm or bellows. A capillary choke flow element indicates any radical change in the condition of flow in the buffer zone line. Normally there will be no flow since the nitrogen is dead-ended in the instruments. Occurence of flow indicates a break either to process or to atmosphere.

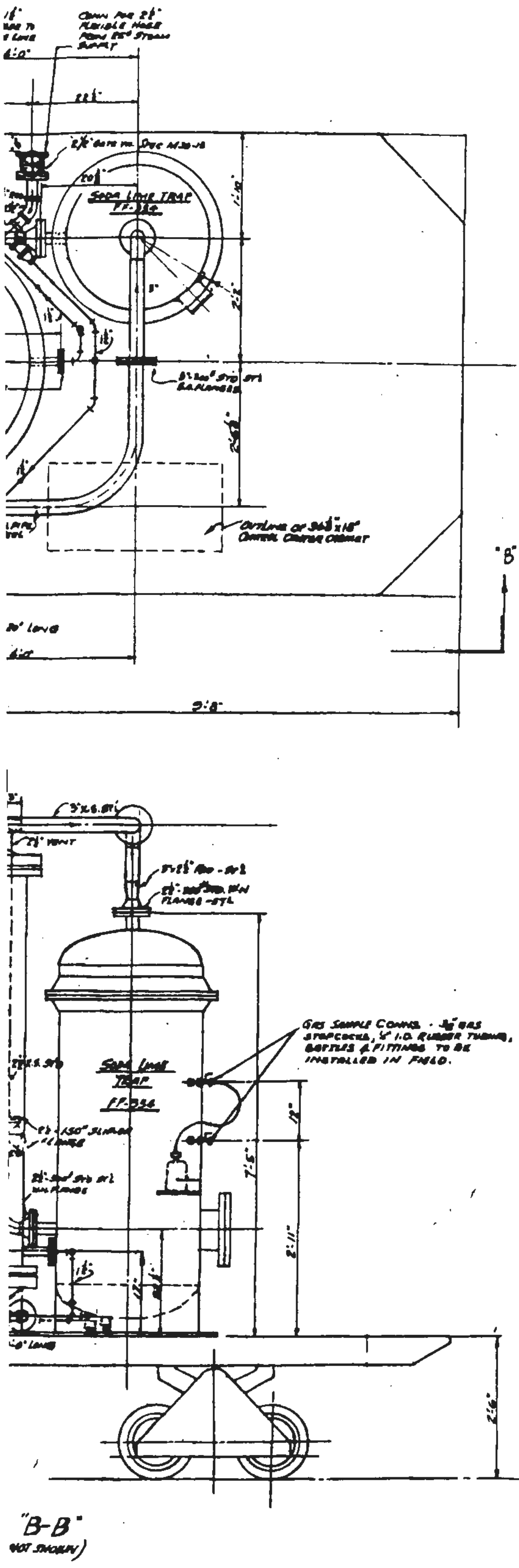
(6) Building and Cell Datum System. - The cell datum system (Par. 8-12b(4)) is arranged so that it can be normally connected to a constant pressure building datum header, or, if desired, to a system which varies the datum as the process pressure varies. Further information is contained in Volume III of the Kellex Operating Manuals.

10-8. Mobile Service Units. - Various portable units have been designed to serve miscellaneous temporary purposes at any desired point in the cascade. Many of the operating principles, designs, and functions are analogous to those of equipment described in Section 8. Mobile units used at K-25 are briefly discussed below; extensive descriptions are available in Volume IV of the Kellex Operating Manuals.

a. High Vacuum Pumping Units. - These units are used in leak detection work. The pumping equipment is described in Volume 2, Paragraph 5-10; the leak detection equipment in Volume 2, Paragraph 6-4.

b. C-716 Supply, Purging, and Disposal Units.

(1) Purpose. - It was planned to test the performance of all items of process equipment, prior to placing in service with uranium hexafluoride, by preliminary operation on n-perfluoroheptane



REFERENCE DRAWINGS
STOKES VACUUM PUMP ---- SK 212 E 10
MIST FILTER - WESTINGHOUSE DWG - 18A - 2742
TRAILER - PHILLIPS M & M. S. Co. DWG TP-440816-1

CF-351 - PRIMARY SALT REACTOR - 1400C-80-AA
FF-354 - SODA LIME TRAP ----- 1400F-75-6B
DRAIN TANK ------------ 1400M-09-AG
4" CONNECTOR STUB ------- 300M-18-AG

NOTES & SPECIFICATIONS:-
VALVES, FITTINGS & PIPE TO CONFORM TO THE FOLLOWING KELLEX SPECIFICATIONS, UNLESS OTHERWISE NOTED

GAS LINES ----------- M30-3A
FILTER OIL RETURN LINES ------ M30-3A
WATER & DRAIN LINES ------ M30-15
STEAM & CONDENSATE LINES -- M30-13

ALL FLANGED JOINTS IN GAS LINES TO BE PROVIDED WITH 1/16" THICK, DOUBLE JACKETED FLAT COPPER ASBESTOS GASKETS, UNLESS OTHERWISE NOTED. NO ALLOWANCE IN DIMENSIONS HAVE BEEN MADE FOR GASKETS.

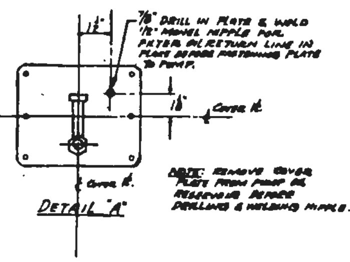


FIG. 44

THE KELLEX CORPORATION

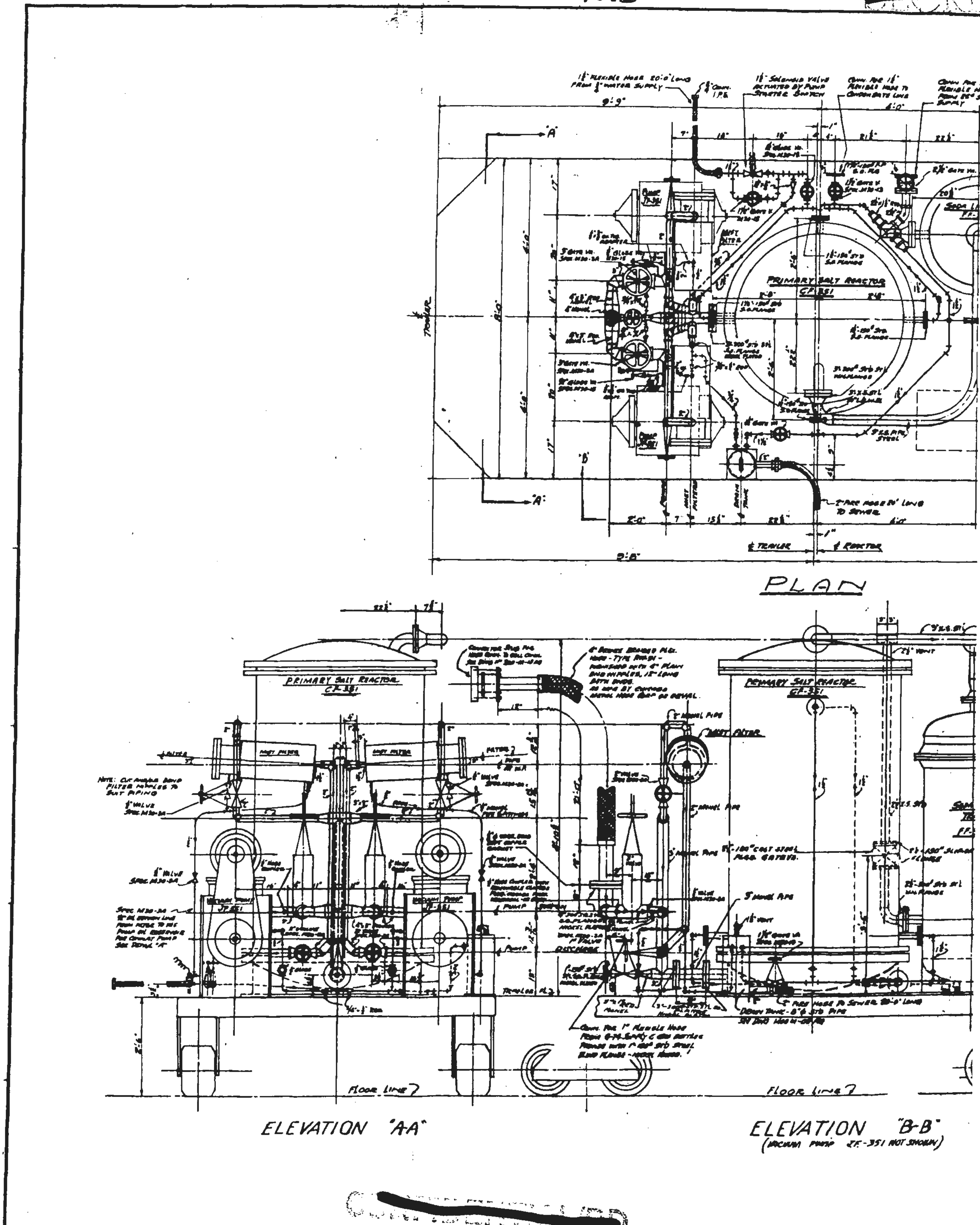
ASSEMBLY - TEMPORARY MOBILE DISPOSAL UNIT

NO.	DESCRIPTION	DATE	BY	CHECKED
1	ADDED SAMPLE CONNS & GAS VALVE IN VENT LINE - ADDED ℄ OF PRIMARY REACTOR	11-29-44	J.K.H.	[illegible]

REVISIONS

DRAWN I. PRUMBST TRACED ___ SCALE 3/4" = 1'-0" DATE [illegible]
CHECKED KARST
APPROVED [illegible] NO. 1400M-09-GA

[redacted] [redacted]



[redacted]

(code name: C-716) as a process gas. This work is described in Volume 5. Mobile service units were accordingly provided to serve the following purposes:

1. To charge C_7F_{16} into the cells.
2. To evacuate cells containing C_7F_{16} at operating pressure.
3. To evacuate cells containing mixtures of air and C_7F_{16} at atmospheric pressure.
4. To purge air and nitrogen continuously from equipment operating on C_7F_{16} by withdrawing a mixture of air, nitrogen, and C_7F_{16}, condensing and separating the C_7F_{16}, vaporizing it, and returning it to the operating equipment.

(2) Design. - The C_7F_{16} supply, purging, and disposal equipment is mounted on a trailer. Approximate overall dimensions are: height 12 feet, length 16 feet, and width 8 feet. Condensers, receivers, and pumps are pyramided in the central portion of the trailer, arranged for maximum use of gravity flow, and held in position by structural steel supports.

(a) Cell-Charging Equipment. - When C_7F_{16} is to be fed to a cell, it flows from a storage receiver to a vaporizer, from which it is piped to the cell. The vaporizer is made of silicon bronze, and has an external electrical strip heater. The receiver is a 58 gallon drum, also of silicon bronze.

(b) Removal and Purging Equipment. - A vacuum pump and vapor condenser are used to remove gaseous C_7F_{16} from a cell and liquefy it. C_7F_{16} is separated from air or nitrogen by conden-

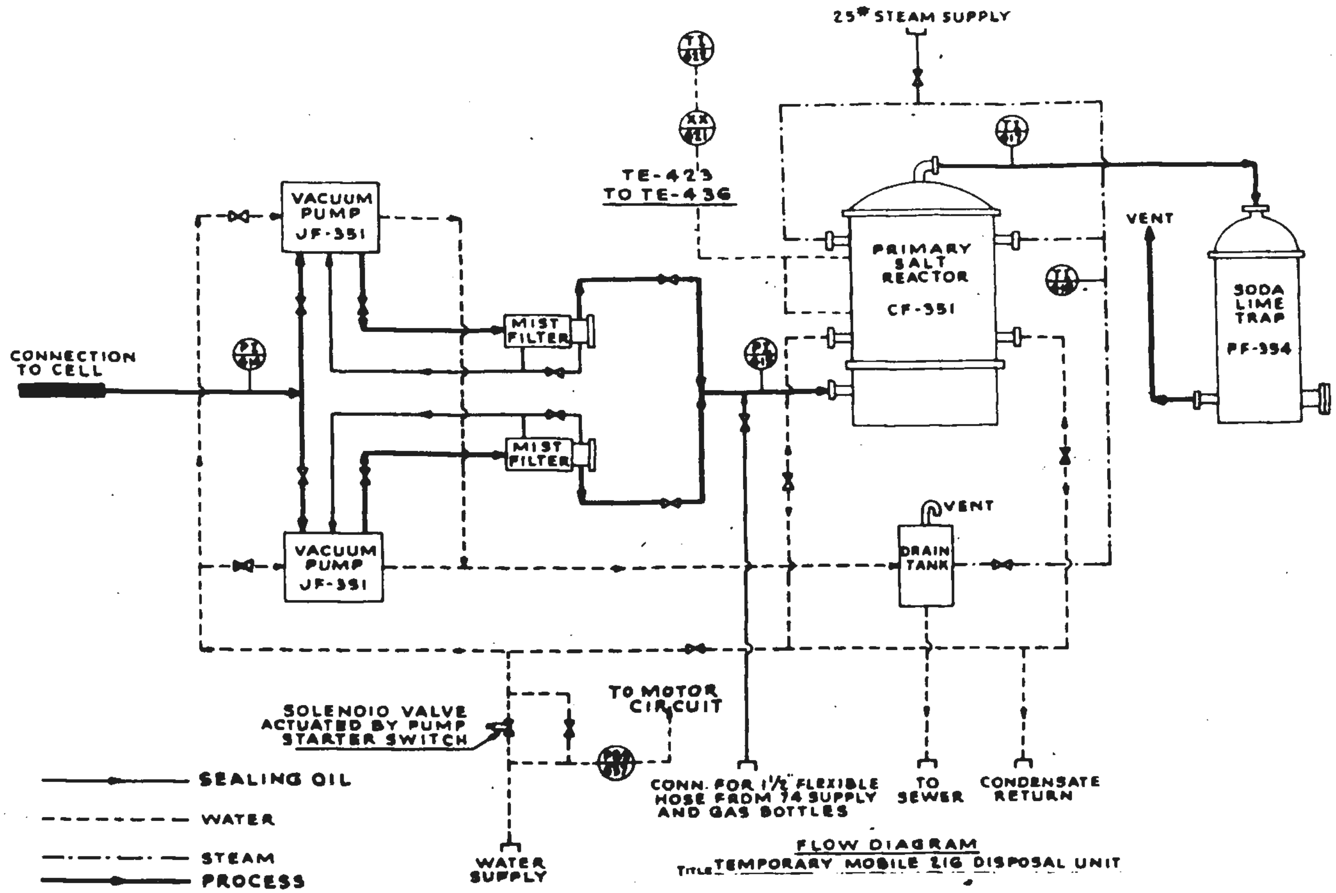

25# STEAM SUPPLY
TE-423
TO TE-436
VACUUM PUMP JF-351
VACUUM PUMP JF-351
MIST FILTER
MIST FILTER
CONNECTION TO CELL
PRIMARY SALT REACTOR CF-351
VENT
SODA LIME TRAP PF-354
VENT
DRAIN TANK
SOLENOID VALVE ACTUATED BY PUMP STARTER SWITCH
TO MOTOR CIRCUIT
CONN. FOR 1½" FLEXIBLE HOSE FROM 74 SUPPLY AND GAS BOTTLES
TO SEWER
CONDENSATE RETURN
WATER SUPPLY
SEALING OIL
WATER
STEAM
PROCESS
FLOW DIAGRAM
TITLE TEMPORARY MOBILE ZIG DISPOSAL UNIT

FIG. 45

sation when a cell containing dilute C_7F_{16} is purged. Condensation is achieved by means of an auxiliary two-stage Freon-22 refrigeration system. The C_7F_{16} condenser is made up of a bronze shell and finned copper tubes.

c. C-216 Supply Units.

(1) Purpose. - The C-216 mobile supply units are designed to supply fluorine (code name; C-216) to the cells for the purpose of conditioning cell piping after assembly.

(2) Design. - The fluorine is supplied to the process area in cylinders at either of two concentrations. Pure fluorine is furnished when a circulating conditioning procedure is to be used, and a 20 mol per cent mixture of fluorine in nitrogen when the static conditioning method is to be used. The cylinders are filled to a pressure not exceeding 40 p.s.i. at Section 1300 (Par. 11-4), and mounted on a dolly for ease of transportation within the process buildings. The dolly and drum are transported between process buildings, and between the process area and Section 1300, by means of a special truck. The drum is connected to the fluorine inlet connection of the cell to be conditioned by means of a special section of pipe and flexible metal base. The holding drum is a 1/4 inch thick monel cylinder of 49 cubic feet capacity, 5-1/2 feet in length.

d. C-216 Disposal Units.

(1) Purpose. - The C-216 disposal system was designed to exhaust fluorine-nitrogen mixture from equipment and piping, and transport it by pipeline to the fluorine disposal plant, K-1405 (Par. 11-5). This disposal plant was not scheduled for completion during the early stages of K-25 operation; one portable disposal unit

SCHEMATIC DIAGRAM ABSORPTION UF_6 UNIT

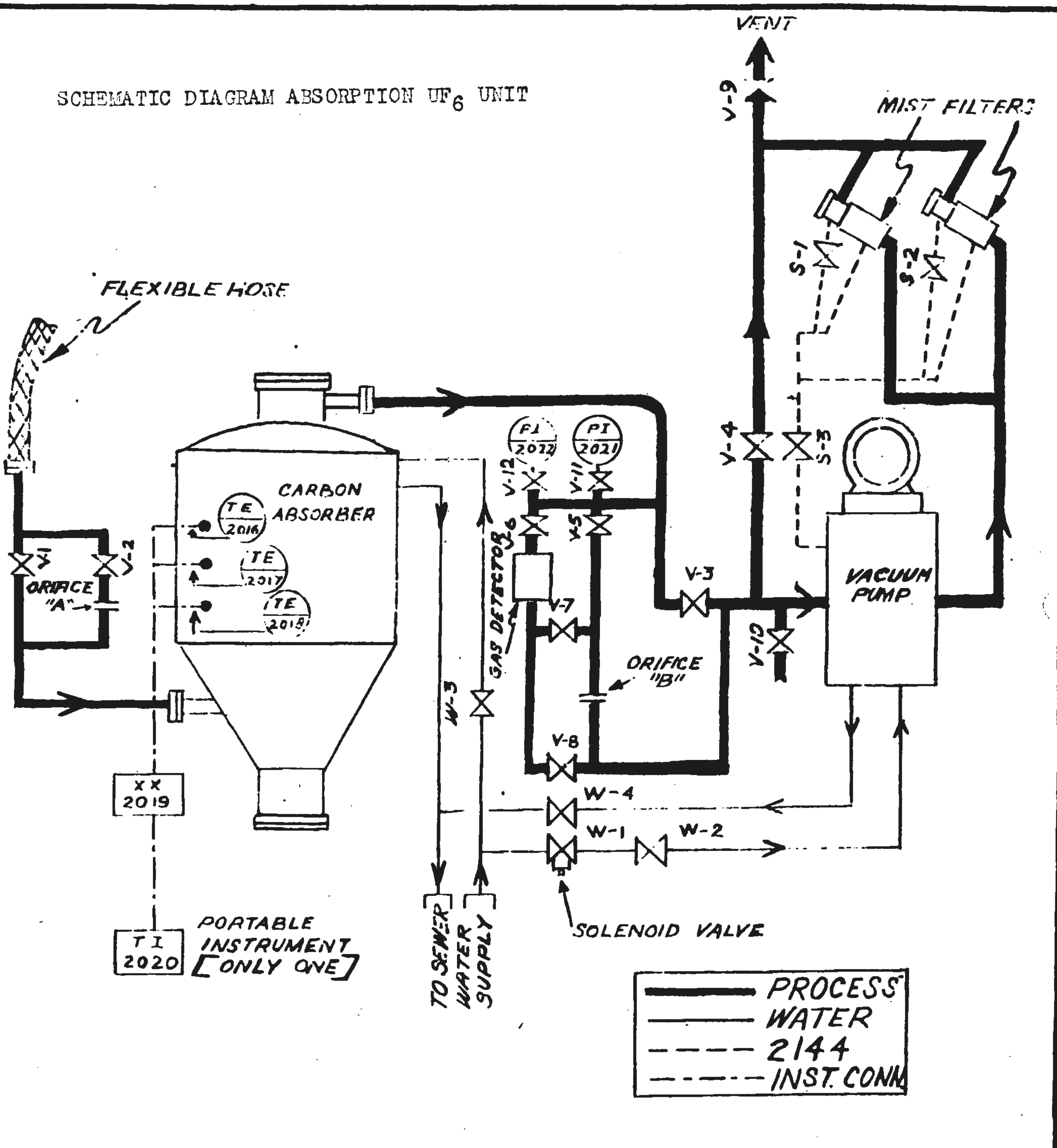


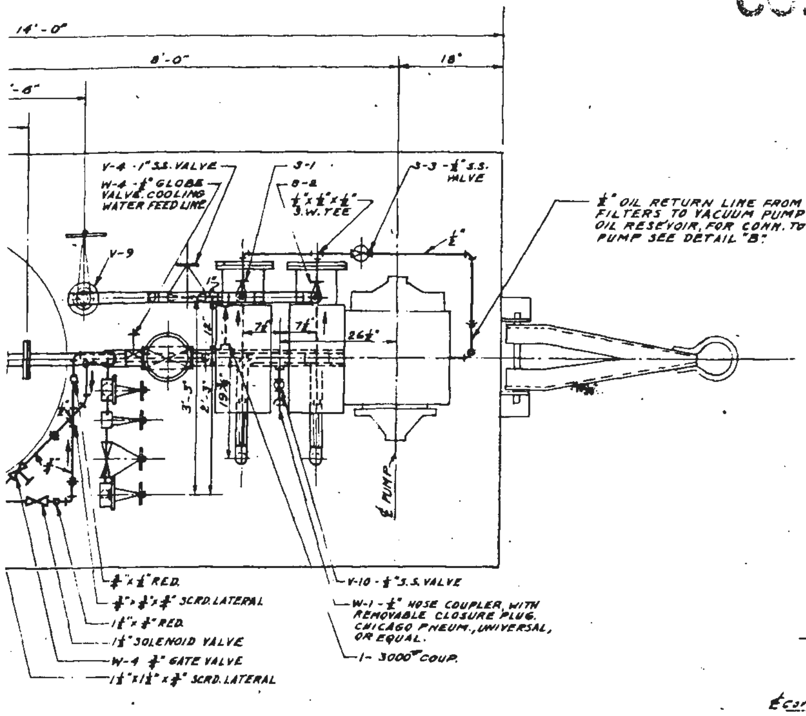
FIG. 46

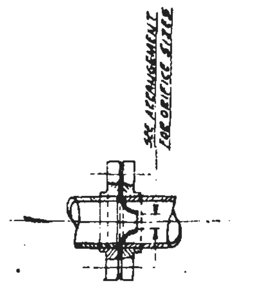
was therefore designed to serve as a temporary means for removing fluorine from cells after conditioning.

(2) Design.

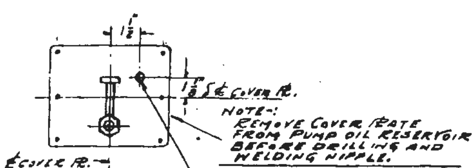
(a) Permanent System. - The permanent fluorine disposal unit consists of a system of fixed piping with portable vacuum pumps. Fluorine-nitrogen mixture is withdrawn from the cells or other pieces of equipment to building headers. At the front of each building, these gases pass through portable vacuum pumps which are used singly or in pairs, depending on the size of the equipment being evacuated. The gases discharged from the vacuum pumps pass through mist filters, where entrained pump oil is removed, and then enter a collecting header which skirts the process area, and carries the gas to the disposal tower at Building K-1405. Stokes vacuum pumps are used as described in Paragraph 5-9 of Volume 2. A typical portion of the permanent piping system, and the portable pumping facilities, are shown in Figure 43 (facing p. 10.19).

(b) Temporary Unit. - Equipment for the temporary unit is mounted on a trailer, and can be moved to the required location by means of a truck. The temporary C-216 disposal wagon is shown in plan and elevation by Figure 44 (facing p. 10.20). A schematic diagram is shown in Figure 45 (facing p. 10.21). Fluorine-nitrogen mixture is exhausted from the equipment, after conditioning, by means of two vacuum pumps connected in parallel. The pumps discharge through mist filters, where entrained pump oil is removed, and then to a salt reactor where the fluorine is absorbed, and chlorine gas is released. This vessel is water-cooled to dissipate the heat of the reaction. The

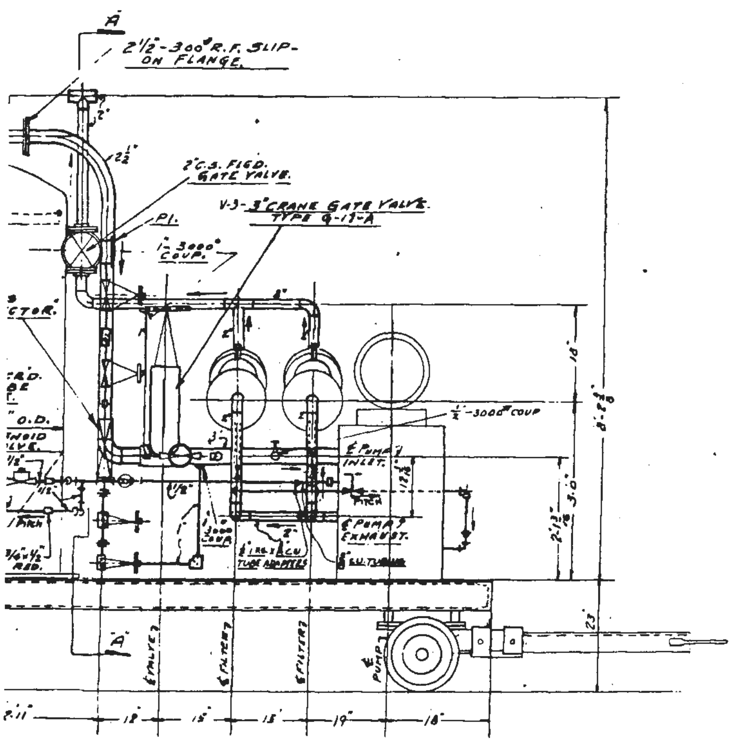




TYPICAL SECTION THRU "IDENL" ORIFICE.



DETAIL "B"



NOTES & SPECIFICATIONS

VALVES, FITTINGS & PIPE TO CONFORM TO THE FOLLOWING KELLEX SPECIFICATIONS UNLESS OTHERWISE NOTED

GAS LINES	
FROM CONNECTOR STUB TO ABSORBER INLET	M 30-3A
FROM ABSORBER OUTLET TO VENT	M 30-3
FILTER OIL RETURN LINES	M 30-3
WATER & DRAIN LINES	M 30-15

ALL FLANGED JOINTS IN GAS LINES TO BE PROVIDED WITH 1/8" THICK DOUBLE JACKETED FLAT COPPER ASBESTOS RING GASKETS UNLESS OTHERWISE NOTED

REFERENCE DRAWINGS

#300-F-75-EA — Portable Carbon Absorber Drum
TP-4408(1)-Trailer Assembly - Parkell Engr. Co.
#18-A-2748 - MIST FILTERS - WESTINGHOUSE.
SK. 212-E-10 - VACUUM PUMP - F. J. STOKES MACH. CO.

NOTES

DWG. NO. 300-Q-CA WAS ORIGINALLY ASSIGNED FOR THIS DRAWING BUT NOT USED.

NO. REQD. - 2 UNITS COMPLETE AS SHOWN.

FIG. 47

NO.	DESCRIPTION	DATE	BY	CHECKED
2	GENERAL REVISIONS.	11/11/44	[illegible]	J.E.K.
1	COUP. FOR P.I. WAS 3/4" NO. REQD. WAS 3.		J.K.H.	[illegible]
	REVISIONS			

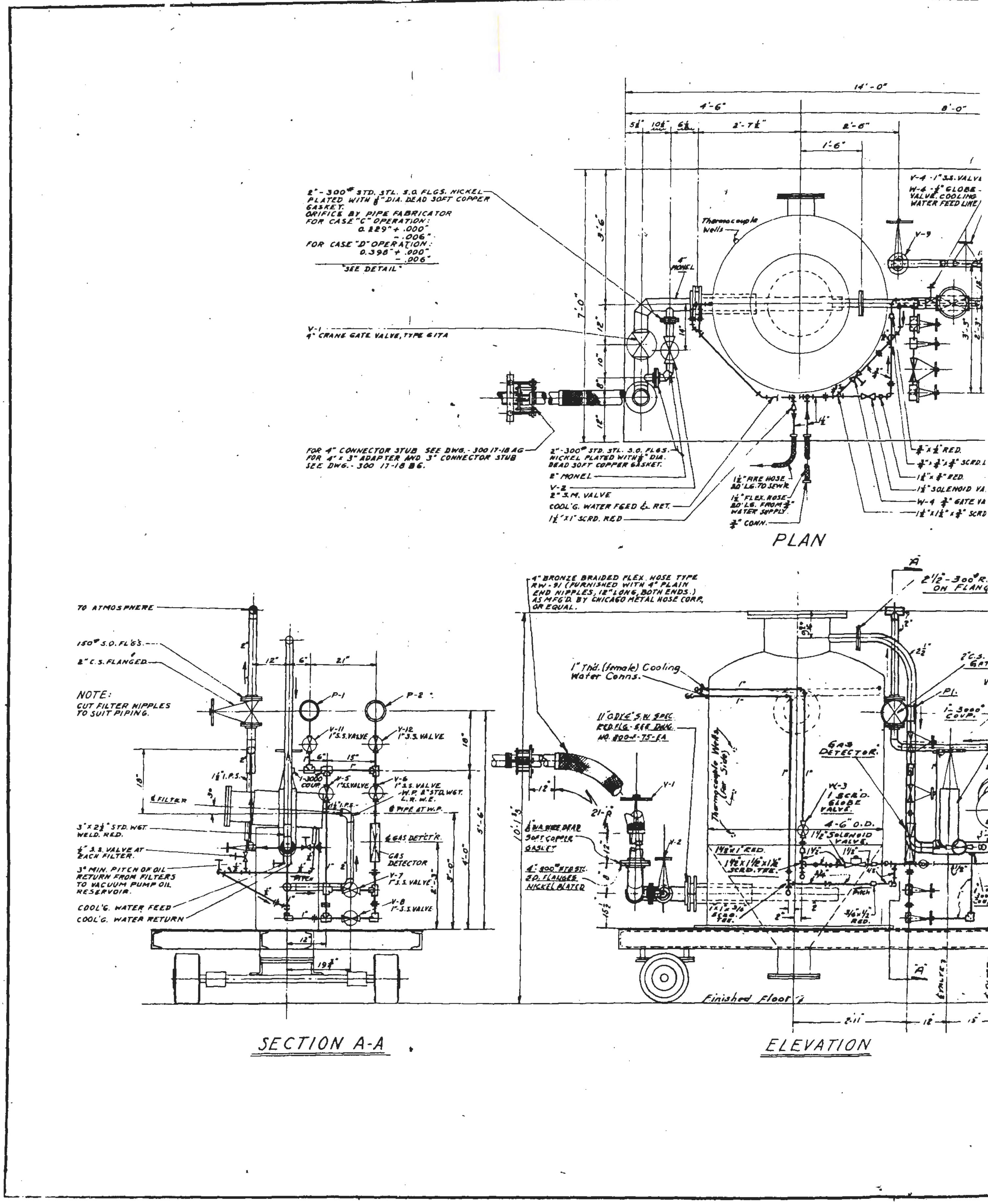
THE KELLEX CORPORATION

FOR ASSEMBLY OF MOBILE DISPOSAL UNIT.

DRAWN J. HOWE... TRACED ... SCALE 3/4" = 1'-0" DATE ...
CHECKED ...
APPROVED ...

No. 300M-18-AA

[redacted]



[redacted]

[redacted]

effluent gas mixture, consisting of chlorine, nitrogen, and some fluorine, leaves the reactor and flows through a soda lime trap where the concentrations of fluorine and chlorine are reduced to a safe value before the gas is vented to the atmosphere.

e. C-616 Absorption Units. - Two mobile units were constructed to serve as a means for evacuating and disposing of uranium hexafluoride (code name: C-616) from Case I cells before the process gas recovery system was brought into operation. The mobile UF_6 disposal unit, shown in the flow diagram, Figure 46 (facing p. 10.22), is mounted on a trailer so that it may be easily moved by an electric tractor. It consists, essentially, of a flexible hose connection to the cell to be evacuated, a carbon trap, a vacuum pump, and two mist filters. Gas containing from 10 to 100 per cent UF_6 is passed through a valve and throttling orifice, whereas mixtures containing less than 10 per cent UF_6 are fed to the carbon trap without throttling. The gases flow through a bed of mixed activated carbon and alumina where, at temperatures below 450°F, UF_6 is removed from the gas stream by surface adsorption. At higher temperatures, UF_6 reacts with the carbon to form non-volatile uranium compounds and volatile carbon fluorides. Flow must be stopped if the temperature, as indicated by thermocouples in the carbon bed, rises above 450°F. The units were designed to absorb 233 pounds of UF_6. An assembly drawing of the unit is shown in Figure 47.

SECTION 11 - CONDITIONING AREA DESIGN

11-1. Introduction. - In addition to the conditioning area proper (designated Section 1400), this section treats of Sections 1300 and 1500, also physically located in the northeast region of the K-25 site which is spoken of more broadly as the "conditioning area" in order to distinguish facilities in this location from those of the process, power and administration areas. Locations of structures mentioned below are shown in Appendix A4 of Volume 1, and Appendix D16 of Volume 5. The following discussion of conditioning area design may be supplemented by reference to Volume I of the Kellex Operating Manuals, Book IX of the Kellex Engineering Descriptions, and Sections III,(1) and III, (5) of the Kellex Completion Report. Conditioning area operations are covered in Volume 5.

11-2. Conditioning Building (K-1401).

a. Purpose. - The conditioning building was designed to house equipment and facilities serving a variety of purposes:

1. Conditioning of the following classes of equipment:

   a. Converters.

   b. Process pumps.

   c. Miscellaneous sub-assemblies.

2. Testing of equipment:

   a. Porosity and separation efficiency of converters.

   b. Vacuum testing.

3. Cleaning of equipment.

4. Repair of equipment.

5. Storage of spare equipment and parts.

6. Pipe fabrication.

The conditioning building was thus designed basically as an extensive and specialized maintenance plant where equipment could be prepared for service in the process area.

b. Preliminary Engineering. - It was necessary that the facilities listed above be available before any process equipment could be installed in the main process buildings. The conditioning building and accessories were therefore scheduled for early construction, and had to be engineered in the shortest possible time. The building (exclusive of special equipment and systems) was designed, under contract W-7407-eng-19, by Ford, Bacon, and Davis, Inc., who also managed the construction work. Decisions affecting layout of the building and the amount of equipment to be installed were primarily influenced by two considerations:

1. The installation would have to be large enough to handle an enormous volume of equipment during the construction stages of the K-25 program without becoming a bottleneck.

2. Oversizing was to be avoided, since it was planned that eventually the building would be used for maintenance purposes only.

The problem was complicated by the uncertain status of the cleaning and conditioning development programs. Analysis of the cleaning, conditioning, and maintenance activities planned established the fact that a building 400 feet wide and 1000 feet long would be required. The building would have to be conveniently located with respect to railway sidings to facilitate reception of equipment arriving from the manufacturers' plants. It was also important that access be available to main highways leading into the process area. Fortunately, a steel framework was found, of suitable size and design, and partly fabricated for use by another project. A considerable amount of time was saved by procuring this steel; the framework was rapidly adapted by Ford, Bacon, and Davis to meet specific K-25 requirements.

c. Original Design. - The conditioning building, situated 300 feet east of the cascade "U", is a 400 by 1000 foot, one-story building of steel frame and brick wall construction. It is 25 feet high, and contains a partial basement of 72,000 square feet area. Overhead cranes serve operating floor space. Floor area was originally allocated as follows:

Conditioning furnace room	64,000 square feet
Running test stands	24,000
Pipe assembly shop	41,600
Cleaning area	25,600
Vacuum testing area	12,800
Unit assembly	28,800
Unit storage	32,000
Storage - parts	28,800
Maintenance and repair shop	52,800
Instrument shop	6,400
Transfer lanes	67,200

Cafeteria	4,800
Offices, laboratories, etc.	11,200
Basement	68,000
	468,000

(1) Converter Conditioning Stands. - The converter conditioning stands were designed to provide a means for pre-treating the diffusion stage converters by circulating fluorine-nitrogen mixtures, leak testing the entire assembly before treating, and checking the porosity of the barrier tubes before and after conditioning. It was necessary to release detailed drawings and specifications to equipment manufacturers before adequate laboratory data were available. For example, it was not known whether conditioning for a few hours at 300°F would be preferable to conditioning for longer times at lower temperatures; whether static or circulating treatment would be required; and whether dilute or concentrated fluorine gas concentrations would be most efficient. There was also uncertainty as to whether the presence of an oxide film would interfere with the formation of a protective fluoride coating and whether means could be found for removal of objectionable organic impurities during barrier manufacture. It was possible that a hydrogen treatment and/or degassing might be required to prepare the barrier for conditioning. In order to provide for all contingencies, the converter conditioning stands were originally designed to permit:

1. Hydrogen treatment at temperatures up to 600°F.
2. Degassing under high vacuum.
3. Conditioning with or without circulation at tempera-

[redacted]

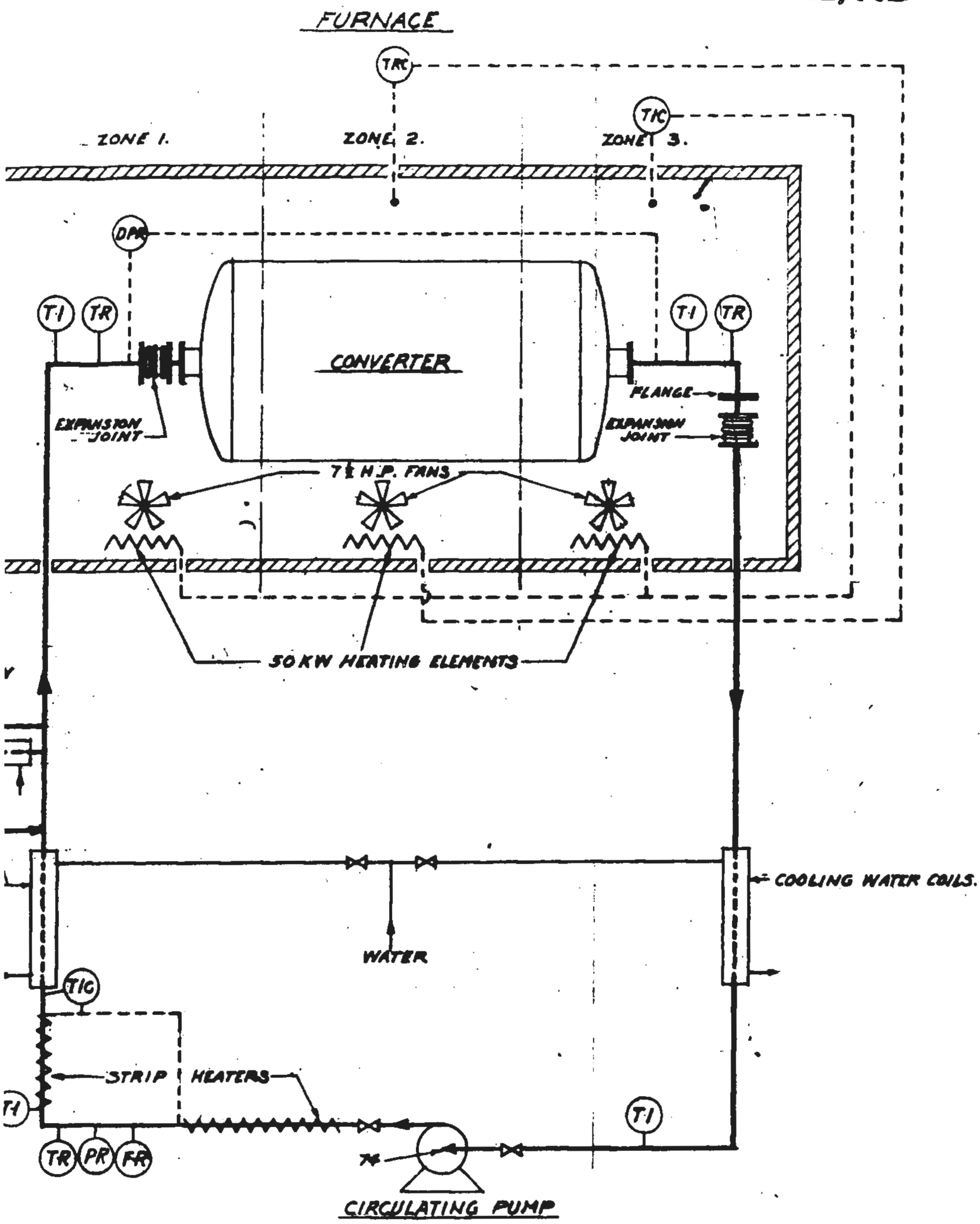
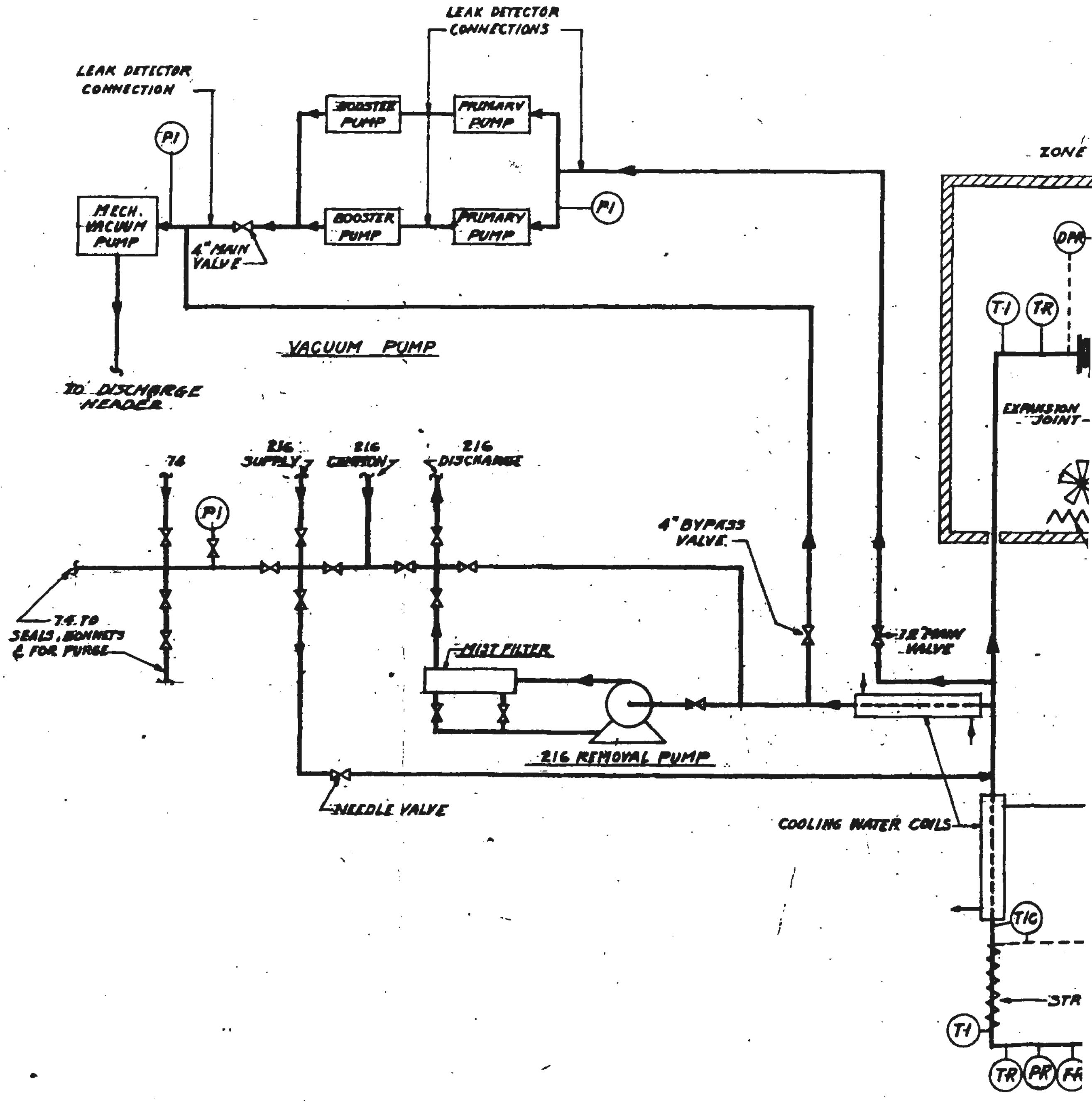


FIG. 48

PROCESS FLOW DIAGRAM	
LARGE FURNACE STAND.	
DRAWN J.E.A. TRACED SCALE DATE	
CHECKED APPROVED	No. 391-O.D. B

[redacted]

[redacted]



[redacted]

tures up to 300°F for as long as 24 hours.

Provision of converter conditioning facilities was based on the following anticipated daily production of converters at the Chrysler plant:

Size 1	2 units per day
2	7
3	7
4	4
	20

The required number of stands was set at 18 large size units (for Size 1 and 2 converters) and 18 small size units (for Size 3 and 4 process converters, and purge converters). Several months after the orders had been placed for the converter and pump conditioning stand equipment, and at a time when the engineering of the conditioning area was well under way, conclusive laboratory data became available. Optimum conditioning called for a five hour circulation cycle in dilute fluorine at 300°F. Hydrogen treatment and degassing were found to be unnecessary. Hydrogen treating facilities were therefore eliminated, and slight design modifications were made in order to adapt the stands for best operation at 300°F.

(a) Furnaces. - The furnaces proper (located on the main floor) are of the electrically heated, horizontal bell type, fitted with removable heads to permit setting the converters in place. The furnaces and electrical control equipment were furnished by the General Electric Company. Each large furnace (Fig. 48) is 7'-11-1/2" in diameter by 16'-0" in length, and is provided with a gas-tight welded steel casing with 5 inches of insulation on the sides, and a refractory brick floor. Heating elements with a total capacity of 150 KW extend below the supports along the longitudinal axis of the furnace. They are divided into three separately controlled groups of 50 KW capacity each. The heating elements are fitted with steel casings which are connected to the suction of three centrifugal fans, each of which is driven by a 7-1/2 horsepower motor. The fans circulate heated air through the heaters and around the converter in such manner as to provide efficient heat transfer. The upper portion is a semi-cylindrical, removable head. A skirt on the edge of the hood fits into a trough around the edge of the lower portion of the furnace, and provides for a water seal to keep the heated air from escaping through the joint between the two sections. The lower portion of the casing is provided with a limit switch which is open when the hood is removed; while in this position it prevents the closing of fan motor and heater circuits, and affords protection of operators working on the furnace. Three 4 inch vent valves are placed along one side of the furnace, and additional valves, of 3 inch size, are located on the upper portion of the hood. These are used for admitting air to, and discharging air from, the furnace in order to assist in cooling the furnace and the converter at the end of the conditioning period. The small furnaces are 5'-3-1/2" x 12'-5-1/4", and similar in design.

(b) Alignment Device. - The lower portion of the furnace is fitted with an alignment device for locating converters in the proper position. This device consists of two rollers with axes parallel to the longitudinal axis of the furnace, and serves as the support for the convertor. The rollers rest upon mountings at either end which permit the assembly to be shifted laterally by means of jack screws. The rollers themselves may be moved toward or away from each other at each end. Such movements shift the points of support so as to raise or lower the converter, at either or both ends, in order to bring the flanged nozzles to the proper elevation for alignment with the piping. A dog, with a turnbuckle attached to the framework at one end of the furnace, supplies the means for shifting a converter longitudinally along the rollers. Adjustment is thus provided in three directions. Spacer pieces to be mounted upon the rollers are provided for the support of the Size 2 converter so as to bring the elevation of its center line to the same height as that of the Size 1 converter when setting it in place for conditioning.

(c) Piping. - Monel circulating piping for conditioning gas is traced with cooling coils and strip heaters. It passes through the floor, and connects with the circulating pumps, vacuum pumps, and fluorine removal pumps located in the basement. Also installed in the basement are the furnace instrument panels, gas feed lines, and exhaust lines. This arrangement reduces the required base area, and serves to separate the operating crews from the handling crews (App. E9).

(d) Pumps. - The circulating pumps (Vol. 2, Par. 5-6) are driven by 7-1/2 horsepower motors, and are designed to circulate gases at the rate of 350 CFM. The fluorine removal pumps (Vol. 2, Par. 5-9) are rotary type vacuum pumps of 50 CFM capacity, capable of reducing the pressure in the assembly to 1 mm. of mercury.

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CONFIDENTIAL/RD

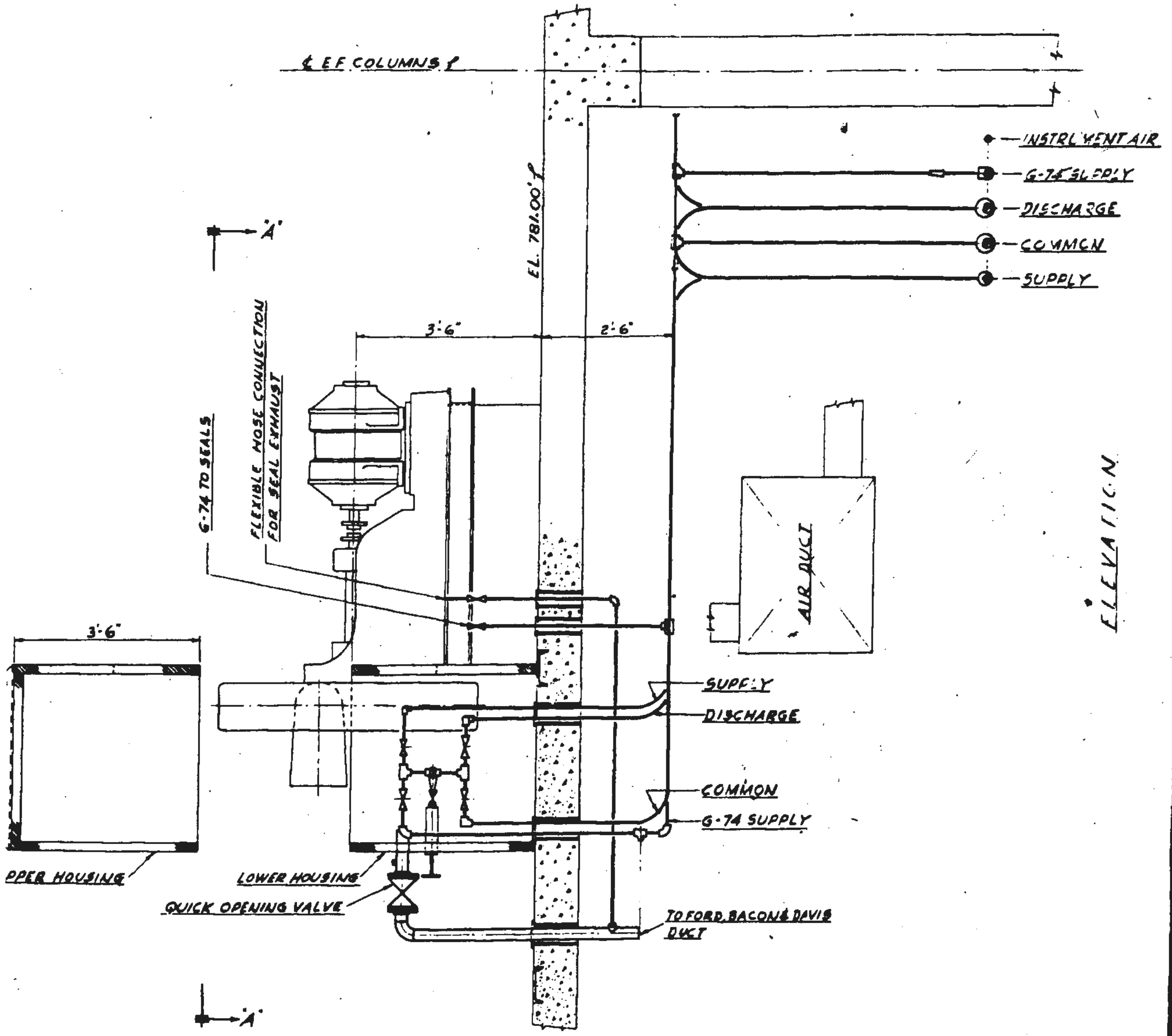


FIG. 49

CONDITIONING BUILDING - FURNACE ROOM
LARGE PUMP CONDITIONING STAND

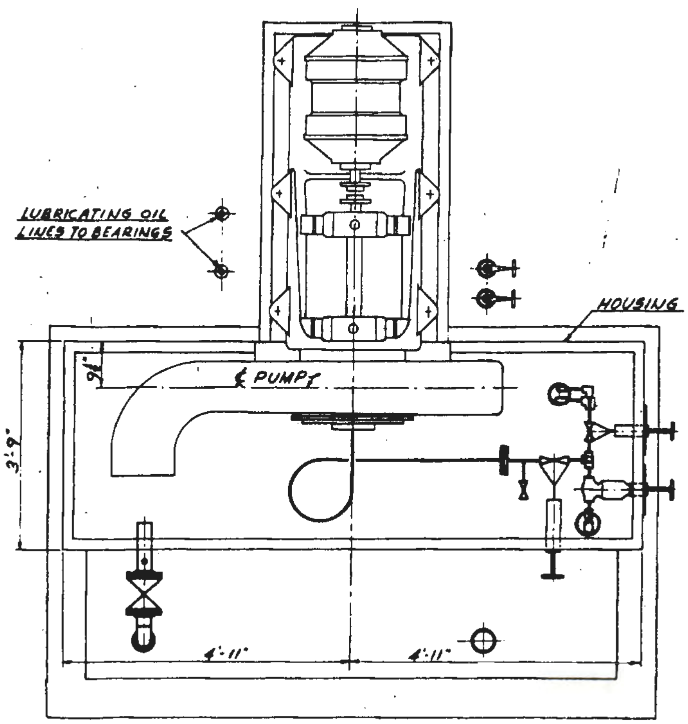
DRAWN D.M. PACE
CHECKED KARST
APPROVED D. K. Dean
No. SK-1400M-04-A8

CONFIDENTIAL/RD

SECRET

A B C D E F

7 6 5 4 3 2 1



PLAN "A-A"

A B C D E F

They take suction from the circulating piping between the discharge side of the circulating pump and the furnace. The fluorine vacuum pumps are lubricated with special fluorocarbon oil, and provided with a mist filter in the discharge line, which leads into one of two fluorine disposal headers. A high vacuum pump (Vol. 2, Par. 5-10) is connected to the "A" end of the converter, and is used for evacuating the unit prior to treatment. In conjunction with a leak detector (Vol. 2, Par. 6-4), it is also used for leak testing of the entire assembly before a run. Each small stand is equipped with a 2000 CFM vacuum pump, and each large stand with a 4000 CFM pump. Appendix E9 shows a photographic view of converter test stand furnace piping and pumps. A detailed description of converter conditioning equipment may be found in Volume XXIII, Part I of the Kellex Operating Manuals.

(2) <u>Pump Conditioning Stands.</u> - Twenty conditioning stands were provided to facilitate fluorination of process pumps. Each consists principally of a control panel, a pump sub-base, and a hood for enclosing the pump casing during processing (Fig. 49). The hood is made in two sections, the lower section being fastened to the floor, and containing a manifold of five bellows-sealed valves. Four of these valves control nitrogen, fluorine, common, and disposal headers. The fifth is located at the common junction of the other four. All have extension handles for operating from outside the hood. A flexible tube runs from the last-named valve to the intake flange on the pump, and a pressure measurement tap is provided in this line. Sixteen 500 watt strip heaters are located in the lower hood. A limit switch on the heaters (open when the hood is off) is installed for safety purposes.

The interior of the hood can be ventilated by means of the same exhaust system which evacuates the pump seals. Each pump stand hood is connected into this system through a quick-opening valve. Suitable auxiliary systems are installed for the supply, respectively, of fluorine, nitrogen, lubricating oil, instrument air, and electrical power, and for fluorine disposal, seal and hood exhaust, and instrumentation. A full description may be found in Volume XXIII, Part II of the Kellex Operating Manuals.

(3) <u>Running Test Stands.</u>

(a) <u>Preliminary Engineering.</u> - When it was uncertain what decline in barrier porosity would be normal during converter conditioning, and whether or not the conditioning operation would be carried out under static or circulating conditions, it was originally proposed that each unit (or a large majority of the total) should be tested after conditioning to determine its porosity and separation performance under conditions which closely simulated actual operation. For this purpose, the "running test stand" was developed, and the converter test area was originally designed to accommodate nineteen stands.

(b) <u>Purpose.</u> - Specifically, the contemplated function of the running test stands was three-fold:

1. To provide a performance test in order to demonstrate that converters (and process pumps) would operate at pressure levels, friction drops, and flow rates in conformity with plant design.

2. To measure the porosity of units as a final acceptance

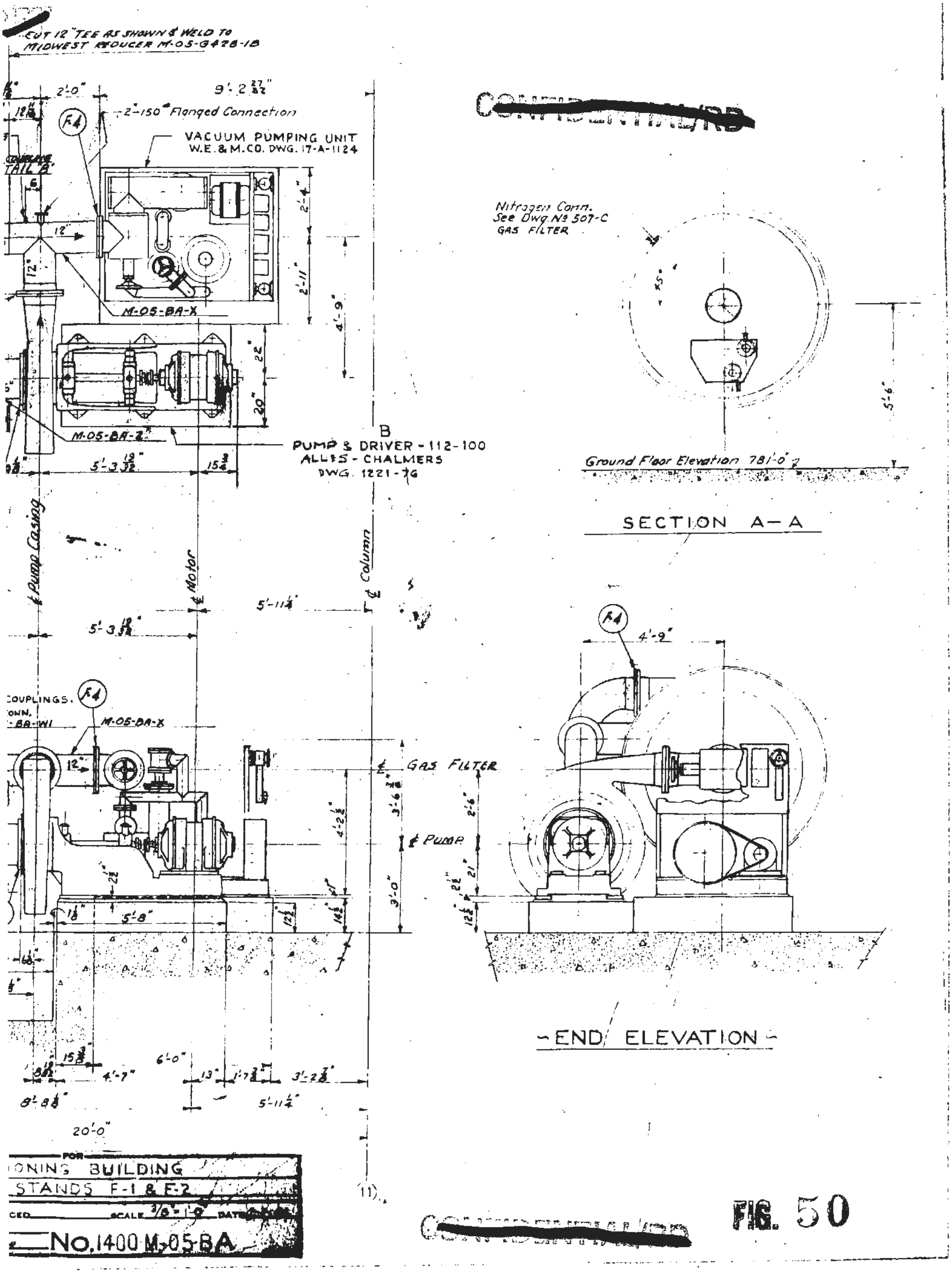
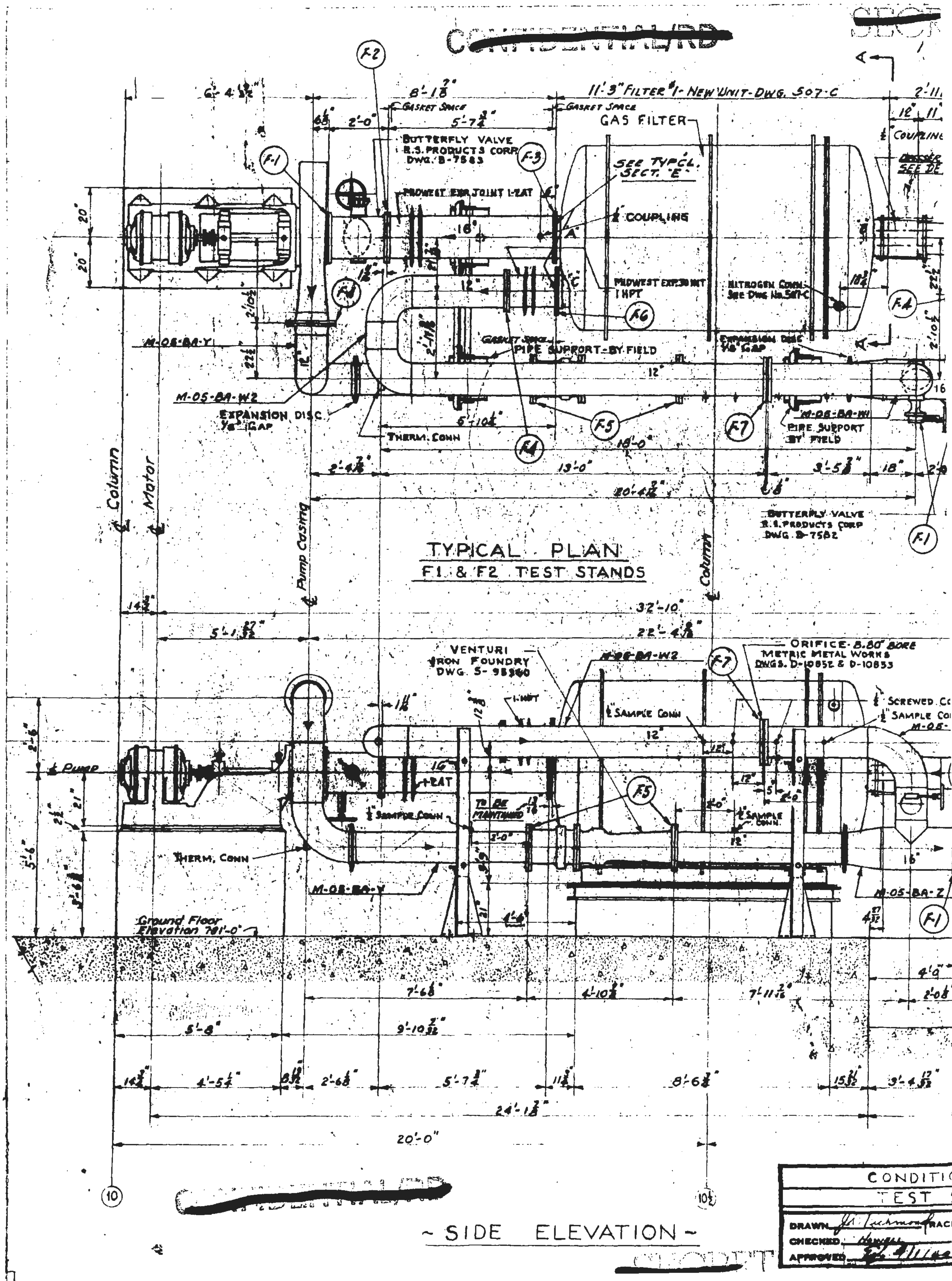

CUT 12" TEE AS SHOWN & WELD TO MIDWEST REDUCER M-05-G428-1B
2"-150# Flanged Connection
VACUUM PUMPING UNIT W.E. & M.CO. DWG. 17-A-1124
M-05-BA-X
M-05-BA-Z
B
PUMP & DRIVER - 112-100 ALLIS - CHALMERS DWG. 1221-76
Nitrogen Conn. See Dwg. No 507-C
GAS FILTER
Ground Floor Elevation 781'-0"
SECTION A-A
℄ Pump Casing
℄ Motor
℄ Column
COUPLINGS.
℄ GAS FILTER
℄ Pump
END ELEVATION
ONING BUILDING
STANDS F-1 & F-2
SCALE 3/8" = 1'-0"
NO. 1400 M-05-BA
(11)

FIG. 50

2



TYPICAL PLAN
F1 & F2 TEST STANDS

~ SIDE ELEVATION ~

test in this respect.

3. To measure the separation performance of converters.

(c) <u>Further Development.</u> - Work with a prototype running stand at Chrysler, however, corroborated the basic permeability transformation theory developed, and the approximate correctness of the calculated friction drops inside the unit; it followed, therefore, that measurements of permeability made on the conditioning stand with nitrogen at atmospheric pressure and low pressure drops could be safely translated theoretically to permeability of process gas under operating conditions. At the same time, the leak flow theory showed that damage to the barrier could be more sensitively detected by low-pressure-drop flow measurements, than by measurements of decline in separation efficiency. It also developed, subsequently, that conditioning of converters by circulating dilute fluorine-nitrogen mixtures would be preferable to static treatment. Flow measurements at the conditioning stand would therefore be available, and the running test consequently became unnecessary as a final acceptance test. This was fortunate, since experience had proved that the running tests were time-consuming, and very troublesome, mechanically.

(d) <u>Test Stands Installed.</u> - Four running test stands (Fig. 50) were finally installed for the purpose of testing separation efficiency of converters of each of the four standard sizes. In addition, one was provided for testing the "A" pump Venturi meters (Par. 7-5b), and two were constructed to serve as "breaking in" stands to determine the most desirable type of instrumentation for running tests. The test stands are arranged in a row along a trench in which are located C_7F_{16} supply and return mains, nitrogen supply and exhaust mains, and water, instrument air, and lubricating oil lines. The trench leads to a service pit containing equipment for supply and removal of C_7F_{16} and C_8F_{16}. The service pit is 25 x 25 x 10 feet deep. It is provided with access ladders and with a ventilation system capable of handling 5000 CFM of air. The converter assembly for the four standard size running test stands includes a base for receiving the converter. An "A" pump and a "B" pump of sizes corresponding to the converter size are permanently installed on concrete sub-bases at each end of the converter base.

(e) <u>C_7F_{16} Supply System.</u> - n-perfluoroheptane (C_7F_{16}) is used as a test fluid. The utilities for the supply of C_7F_{16} are located in the service pit from which test fluid is furnished to the several test stands and removed from the converters on test in these stands through pipe mains in the distribution trench. C_7F_{16} is introduced from shipping drums into a drier, which is mounted over, and drains into, a horizontal charging tank. From the charging tank, the circuit leads to the C_7F_{16} fluid heater. This apparatus consists of seven double-pipe elements, and serves to preheat the test fluid with steam. From the preheater, C_7F_{16} is delivered to a reboiler. The vapor generated in the reboiler is delivered to the trench distribution system.

(f) <u>C_8F_{16} Supply System.</u> - Process coolant (C_8F_{16}) is supplied to the coolers of converters under test. The C_8F_{16} system is designed to furnish a continuous supply of coolant, at controlled temperature, to any single test stand, or to any number of test stands operating simultaneously. The system includes a storage tank, coolant cooler, coolant pump, and spare pump.

(g) Pump Seal System. - Procedures for the testing of converters on the running test stands call for the circulation of nitrogen, C_7F_{16}, and mixtures of the two gases. Nitrogen is used principally as a circulating medium for warming the system. During this step, the mechanical work of the circulating pump is converted into heat, and warms the converter and piping. During this stage, nitrogen must be used for sealing of the pumps. While testing with C_7F_{16} or mixtures of C_7F_{16} and nitrogen, it was important that there would be no dilution or change in dilution of C_7F_{16}. The seals accordingly had to be supplied with C_7F_{16} vapor. Thus requirements called for a seal gas supply from two sources. Nitrogen is delivered to each stand from a main under a reduced pressure of 5 p.s.i.g. C_7F_{16} is taken from the main vapor line in the trench in which the vapor pressure is 5 p.s.i.g. Since C_7F_{16} will condense at atmospheric temperatures when under pressures above 1.5 p.s.i.a., the main is steam traced as are also the branches leading to the seals of the pumps. At each pump, the nitrogen supply passes through a gas filter, and branches alongside the pump base. One branch leads directly to the pump atmospheric seal; the other joins the C_7F_{16} supply line. The common line connects to the inner seal of the pump. The vacuum chamber of the seal is connected to a vacuum header serving all of the test stands. Two 15 CFM Stokes vacuum pumps maintain the seal vacuum header under vacuum at all times during operation.

(h) Instrumentation. - Primarily, instrumentation is provided for the purpose of measuring the gas flow rate and pressure losses through the barrier tubes of a converter under test, together with the corresponding rates of flow and pressure losses under established pressure and temperature conditions. Separation factor tests require sampling and analysis to establish the percentages of nitrogen in C_7F_{16}- nitrogen mixtures at the inlet and outlet points of the converter.

(i) High Vacuum Pump. - A 2000 CFM Westinghouse high vacuum diffusion pump connected to the inlet at the "B" end of the converter assembly produces the vacuum necessary for leak testing.

(j) Lubricating System. - Lubricating oil for the pump bearings is piped through branches from the supply and return headers connecting with the central lubricating system (which also supplies the pumps under treatment in the converter conditioning stands).

(4) Pipe Assembly Shop. - This area was used by the Midwest Piping and Supply Company for assembling of process piping (Vol. 4).

(5) Cleaning Area. - Cleaning facilities include a degreaser capable of handling any unit dis-assembly, five small auxiliary reservoir tanks for cleaning solutions, a set of turning rolls for cleaning large cylindrical vessels, water filters, and four drying units. Steam and acid fumes are exhausted by means of five 50,000 CFM fans (Par. 11-3b). The cleaning operations are carried out in twelve tanks each approximately 34 feet long, 5 feet wide, and 4 feet deep. Five are rubber-lined, and three are lined with acid resisting brick. Three contain steam heating coils, and six are equipped

for forced circulation. All overflow to a trench system depressed in the floor. The trenches are lined with acid-proof brick, and conduct waste cleaning acids to Building K-1407 for neutralization (Par. 11-6). The cleaning shop can handle equipment ranging from small valves to large pipe assemblies, and is equipped for solvent degreasing, alkaline cleaning, water rinsing, acid pickling, scratch brushing, and surface passivation.

(6) Vacuum Testing Area. - The vacuum testing area adjoins the cleaning area. It contains six portable vacuum stands for testing pipe assemblies. Vacuum testing of equipment to be newly installed in the process plant, or re-installed after repair and/or reconditioning, is carried out in this area. In addition, mobile equipment is used for vacuum testing at various locations throughout the building. Vacuum testing equipment is discussed in Volume 2, Paragraphs 5-10 and 6-4.

(7) Unit Assembly and Storage Area. - This space was used for the assembly of process piping. After original K-25 construction and equipment installation was finished and conditioning of the process piping was begun, this area was converted for use in disassembly of units before cleaning.

(8) Maintenance and Repair Shop. - Six divisions were originally included in this space; machine shop, tool room, heat exchanger shop, pipe and welding shop, sheet metal shop, and electrical shop. These facilities were capable of making general and specific repairs to all classes of process equipment.

d. Present Design. - After completion of the initial

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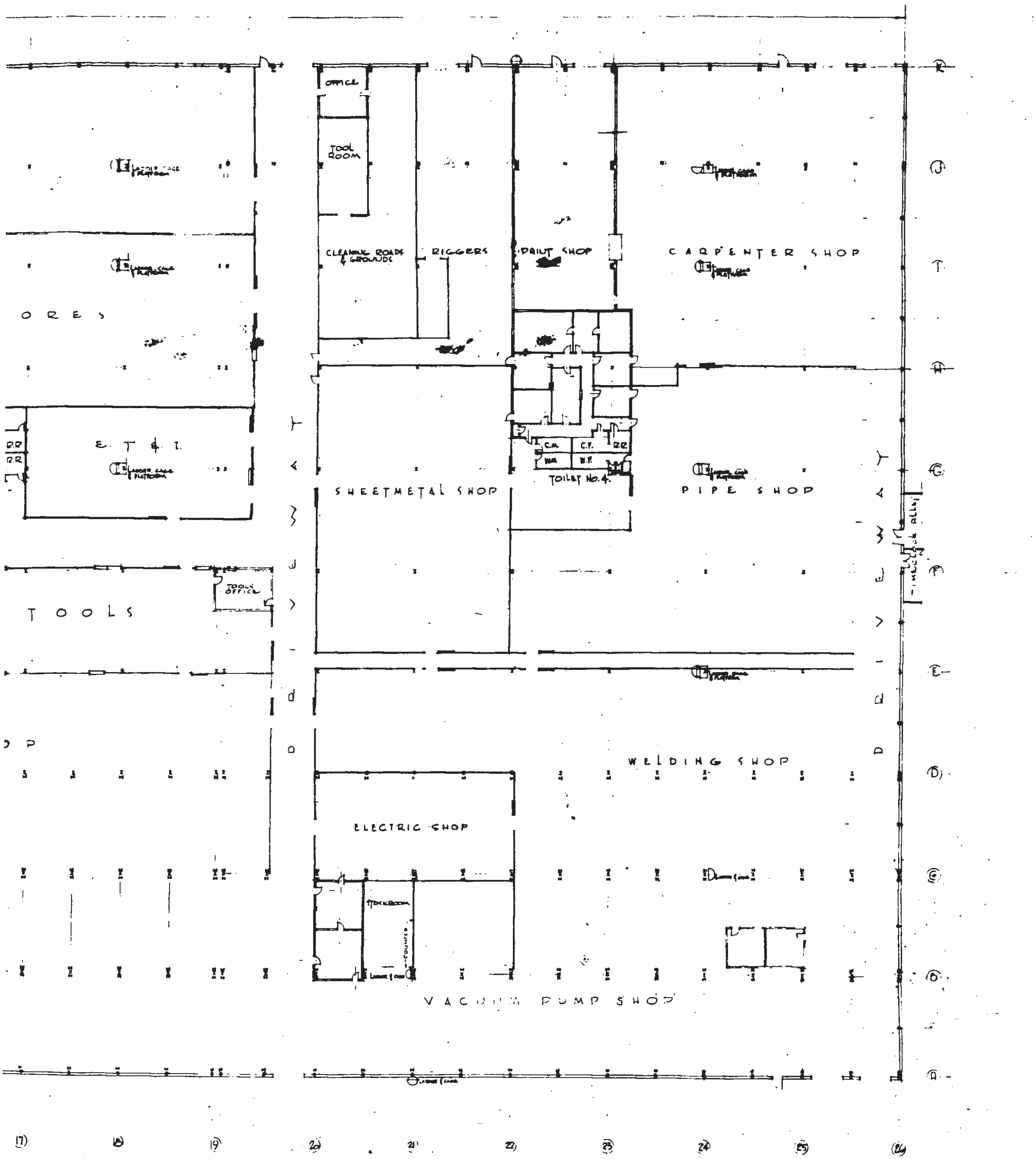

D FLOOR PLAN - BUILDING K-1401 - 25 JULY 1946

FIG. 51

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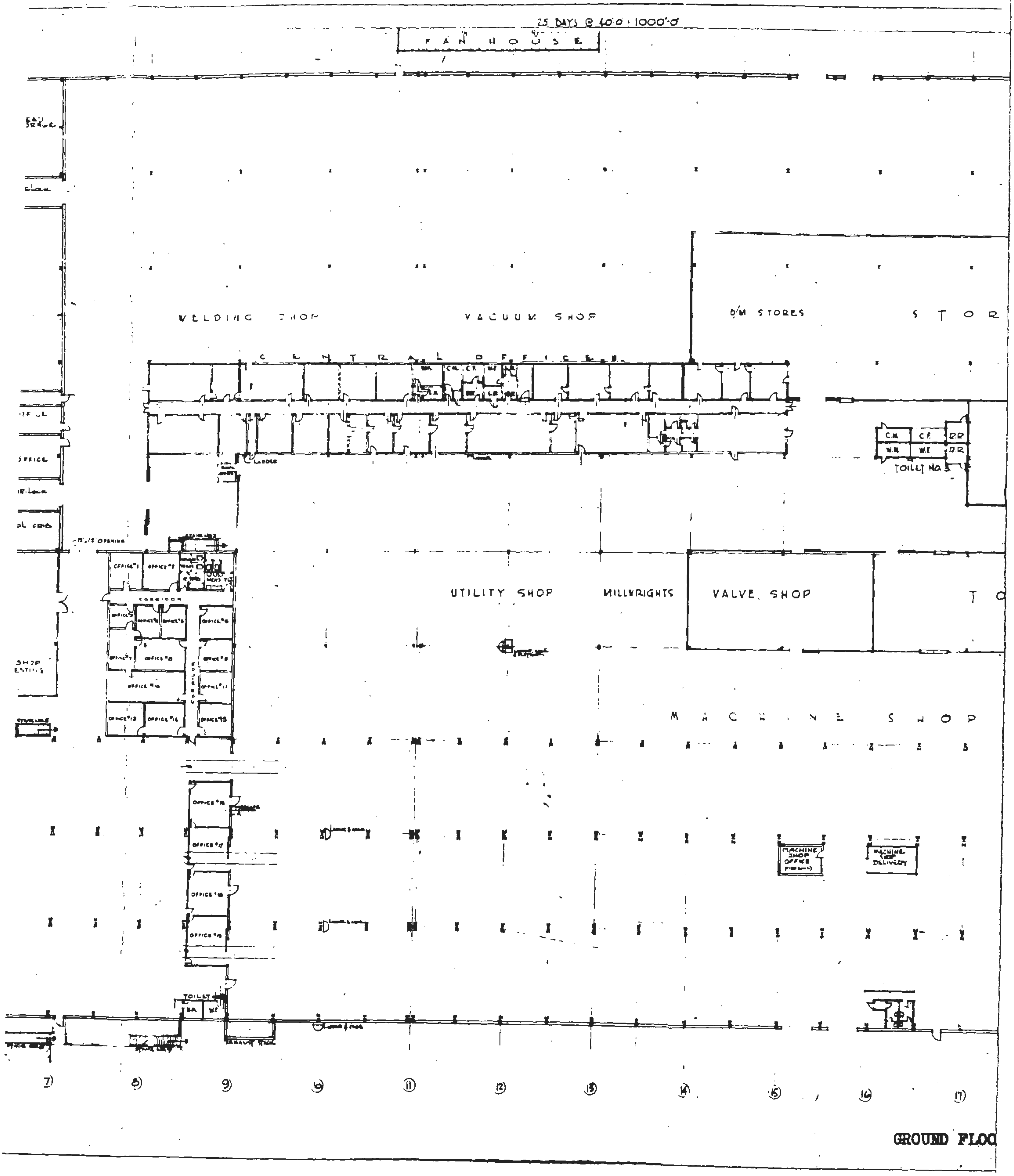
[redacted] SECRET 2



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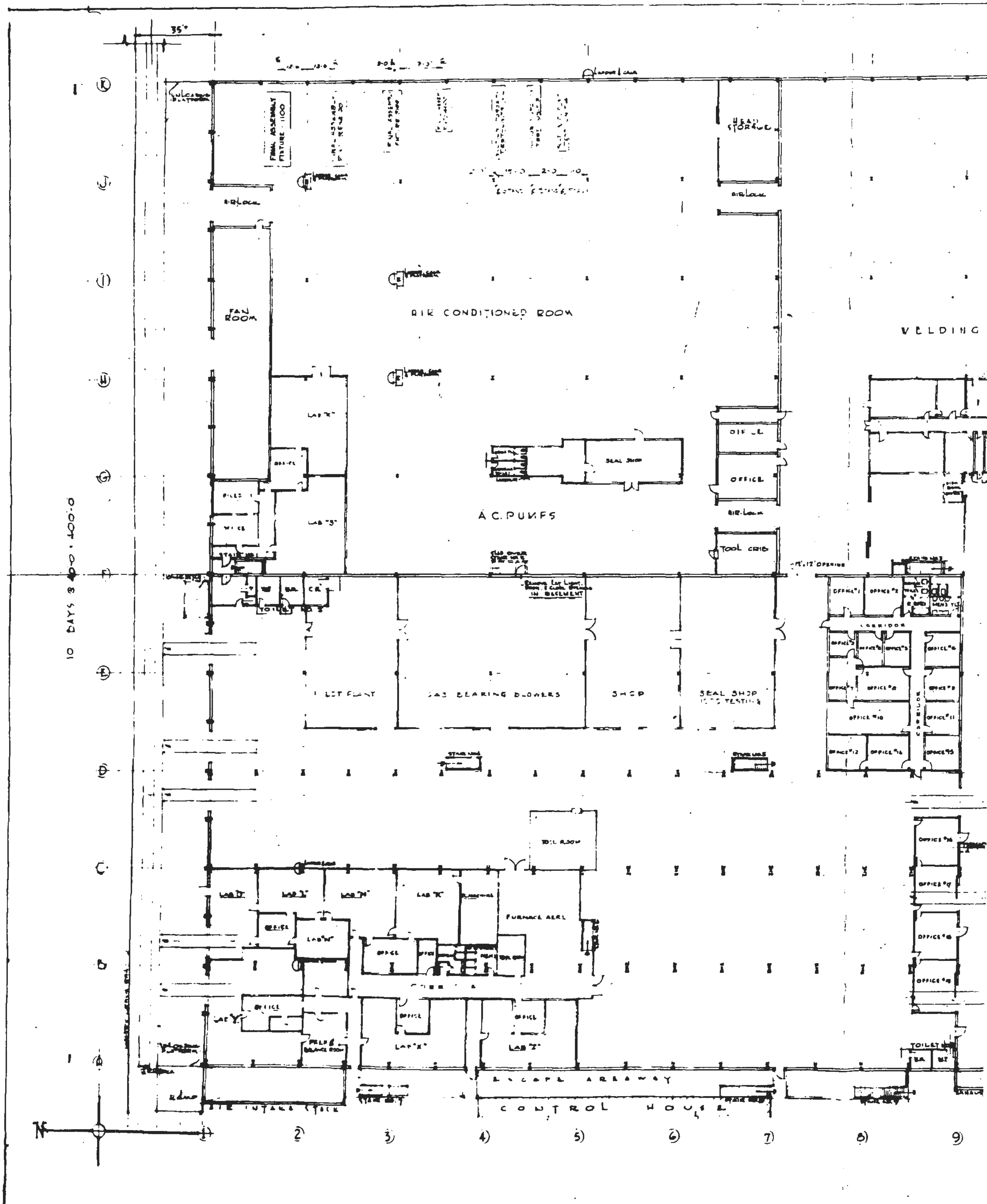

[redacted]

activities involved in cleaning, conditioning, assembling, and preparing for installation the large quantities of process equipment and piping required by the diffusion cascade, a number of internal design and arrangement changes were made in Building K-1401, in order to make most effective use of the facility. The present layout is shown in Figure 51. Facilities currently installed may be broadly classified under the following headings:

(1) <u>Conditioning Stands.</u> - Six converter stands and eight pump stands have been removed in order to make room for development work now being carried out in this area (see below).

(2) <u>Running Test Stands.</u> - These units are being maintained in standby condition.

(3) <u>Cleaning and Vacuum Testing Facilities.</u> - These areas have not undergone important changes since their initial construction.

(4) <u>Maintenance Facilities.</u> - Maintenance facilities have been greatly expanded, and at present occupy the greater part of the entire building. Since the start of plant operations, the amount and types of maintenance work done in the conditioning building has increased steadily, with much of the repair work previously done in temporary shops set up at various points in the process area being transferred to Building K-1401, which now includes the following shops:

1. Carpenter shop
2. Paint Shop
3. Pipe Shop

4. Insulation shop

5. Welding shop

6. Vacuum pump shop

7. Electrical shop

8. Machine shop

9. Equipment test and inspection shop

10. Building and grounds shop

11. Valve repair shop

12. Sheet metal shop

(5) Re-tubing Area. - A converter re-tubing and testing area has been set up in the northern third of the building. Equipment shipped from the Chrysler Lynch Road plant has been installed for this work. This includes apparatus for assembling and re-tubing converters, test equipment, and the air conditioning system formerly used at the Chrysler plant. A process pump and seal shop is also located within this area.

(6) Barrier Testing Laboratory. - A new barrier test laboratory is being set up in the northwest corner of the building. Construction of the laboratory was started in October 1946, and is now about 95 per cent complete. The department consists of fifteen offices and individual laboratories containing barrier manufacturing and testing equipment, which was shipped to K-25 from the SAM Laboratories (Vol. 2), and the Houdaille-Hershey plant. The following equipment has been installed:

1. DELETED DELETED

DOE b(3)

2. Two centrifuges.

3. DELETED DELETED

4. DELETED DELETED

DOE b(3)

DOE b(3)

5. Electric ovens.

6. Electrophoretic equipment.

7.

8. DELETED DELETED

9.

DOE b(3)

10. A large group of flow and pressure recording instruments for testing efficiency of barriers.

11-3. Accessory Conditioning Structures. - The following small buildings are located adjacent to the conditioning building, and serve accessory purposes:

a. Control House (K-1402). - The control house is a one-story and basement structure adjacent to the west wall and near the north end of Building K-1401. It houses electrical and control equipment for apparatus in the K-1401 furnace room.

b. Fan House (K-1403). - The fan house, a one-story concrete and hollow tile structure, is located just east of the conditioning building cleaning area, and houses five 50,000 CFM motor-driven fans which exhaust the acid fumes from cleaning operations. To eliminate any possible recirculation of fumes, the air and vapors are discharged 60 feet above the ground through a special stack.

c. <u>Acid Storage House (K-1404).</u> - A storage system was constructed along the east side of the conditioning building for handling and storing hydrochloric and sulfuric acids. Two 10,000 gallon tanks are located adjacent to a railroad siding. Pumps and valves are enclosed in a pump house for unloading acid, and for transferring it to the cleaning tanks.

11-4. <u>Fluorine Generating Plant (Section 1300).</u>

a. <u>Purpose.</u> - The K-25 fluorine plant was designed to manufacture, handle, and store the large quantities of elemental fluorine gas required by the Project for conditioning purposes.

b. <u>Preliminary Engineering.</u> - Research and development on methods of producing fluorine are discussed in Book VII. This work was coordinated by the Kellex Corporation, and involved studies and investigations at a number of industrial and university laboratories. The decision was made to provide manufacturing facilities at the site because of first, the importance of an uninterrupted supply of this special chemical, and, second, the desirability of avoiding the physical dangers involved in attempting to transport large quantities of the substance over long distances. The general design of the fluorine plant was worked out by the Hooker Electrochemical Company, who also carried out initial operations, under contract W-7405-eng-258 (Vol. 5). Detailed designs and construction drawings were prepared by Ford, Bacon, and Davis, Inc., who also managed the construction under contract W-7407-eng-19 (Vol. 4). A number of design features of the fluorine plant (e.g., instrumentation, safety devices, and HF removal system) were developed jointly by Hooker, Kellex, and Carbide.

c. Capacity. - The intermittent and variable nature of conditioning operations planned, made fluorine gas requirements difficult to predict. Best estimates prepared by Kellex, indicated that a supply of 150 pounds per day would be necessary. Seven fluorine production cells were installed in Building K-1301, with space for seven more. Each can produce more than 50 pounds of fluorine per day. Because of the importance of avoiding contamination of equipment being conditioned, particularly the barrier surfaces of converters, the following fluorine gas product specifications were laid down:

Oxygen	less than 1 per cent
Hydrogen fluoride	less than 1 per cent
Mist	less than 70 parts per million
Fluorine	greater than 95 per cent

Section 1300, with a maximum storage capacity of 540 pounds, includes one of the largest fluorine-under-pressure installations in the country.

d. Design. - Except for a single pilot plant installation (Book VII), no industrial utilization of fluorine had ever been undertaken prior to the K-25 Project. Fluorine is the most reactive of all elements. Because of its extraordinarily agressive chemical nature, special designs and precautions were necessary throughout the proposed installation. The fluorine plant, as constructed, consists of three buildings of steel frame and brick wall construction, located several hundred feet north of the conditioning building. Certain of the equipment is enclosed by brick barricades, special ventilation is provided, and an elaborate alarm system is installed to warn of equipment failures or other emergencies. The plant is briefly described below, and a flow

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52 - 11A

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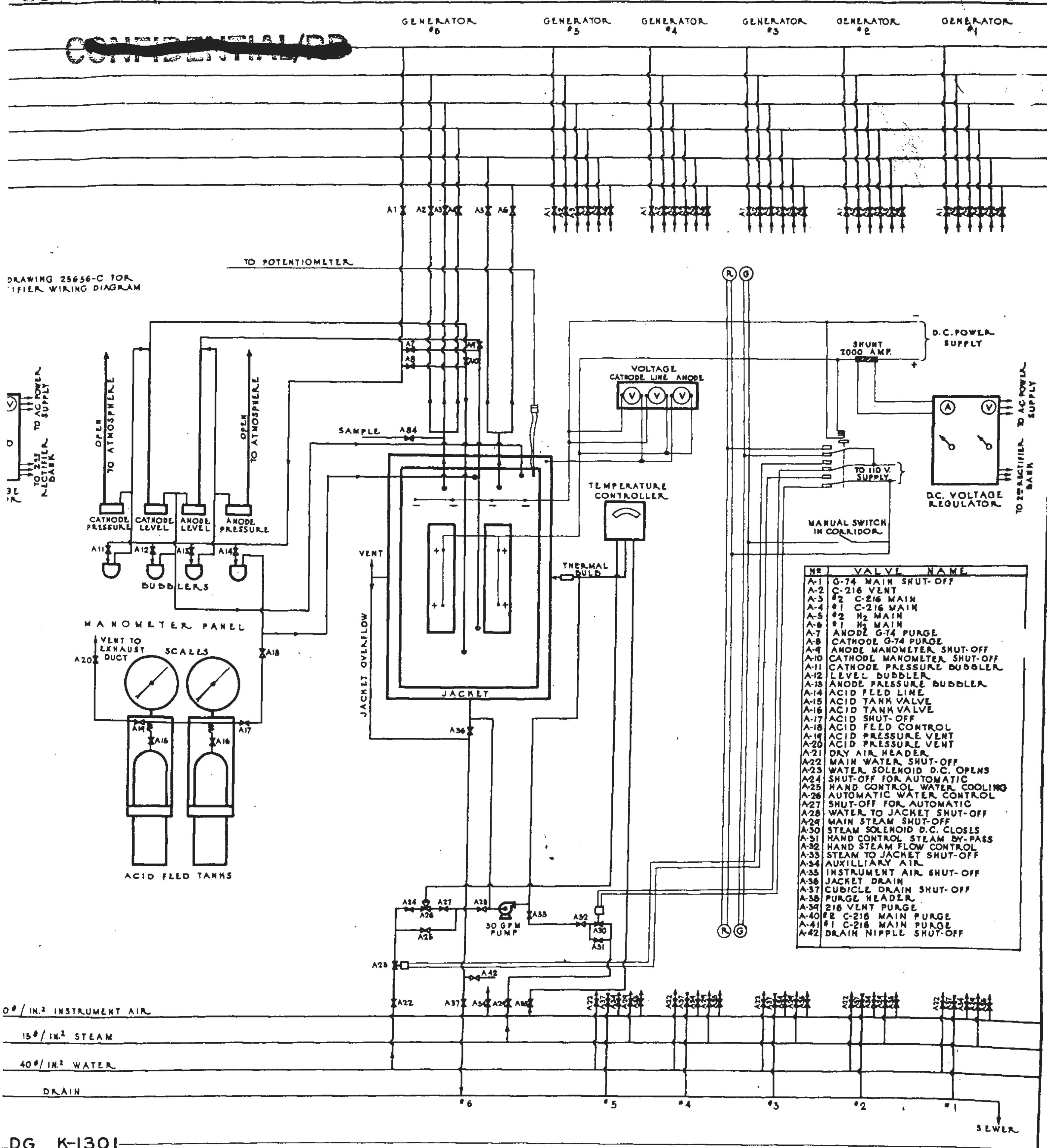

Nº	VALVE NAME
A-1	G-74 MAIN SHUT-OFF
A-2	C-216 VENT
A-3	#2 C-216 MAIN
A-4	#1 C-216 MAIN
A-5	#2 H_2 MAIN
A-6	#1 H_2 MAIN
A-7	ANODE G-74 PURGE
A-8	CATHODE G-74 PURGE
A-9	ANODE MANOMETER SHUT-OFF
A-10	CATHODE MANOMETER SHUT-OFF
A-11	CATHODE PRESSURE BUBBLER
A-12	LEVEL BUBBLER
A-13	ANODE PRESSURE BUBBLER
A-14	ACID FEED LINE
A-15	ACID TANK VALVE
A-16	ACID TANK VALVE
A-17	ACID SHUT-OFF
A-18	ACID FEED CONTROL
A-19	ACID PRESSURE VENT
A-20	ACID PRESSURE VENT
A-21	DRY AIR HEADER
A-22	MAIN WATER SHUT-OFF
A-23	WATER SOLENOID D.C. OPENS
A-24	SHUT-OFF FOR AUTOMATIC
A-25	HAND CONTROL WATER COOLING
A-26	AUTOMATIC WATER CONTROL
A-27	SHUT-OFF FOR AUTOMATIC
A-28	WATER TO JACKET SHUT-OFF
A-29	MAIN STEAM SHUT-OFF
A-30	STEAM SOLENOID D.C. CLOSES
A-31	HAND CONTROL STEAM BY-PASS
A-32	HAND STEAM FLOW CONTROL
A-33	STEAM TO JACKET SHUT-OFF
A-34	AUXILLIARY AIR
A-35	INSTRUMENT AIR SHUT-OFF
A-36	JACKET DRAIN
A-37	CUBICLE DRAIN SHUT-OFF
A-38	PURGE HEADER
A-39	216 VENT PURGE
A-40	#2 C-216 MAIN PURGE
A-41	#1 C-216 MAIN PURGE
A-42	DRAIN NIPPLE SHUT-OFF

BLDG. K-1301

FIG. 52

HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N.Y.

CHG. No.
W. O. No.
CP.

MADE BY: H.R.S.E. SCALE
TRACED BY: DATE
CHECKED BY: APPROVAL

DWG. 25474-C

FLOW DIAGRAM BLDGS. K-1301, 2 & 3 — PART A

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52-2A

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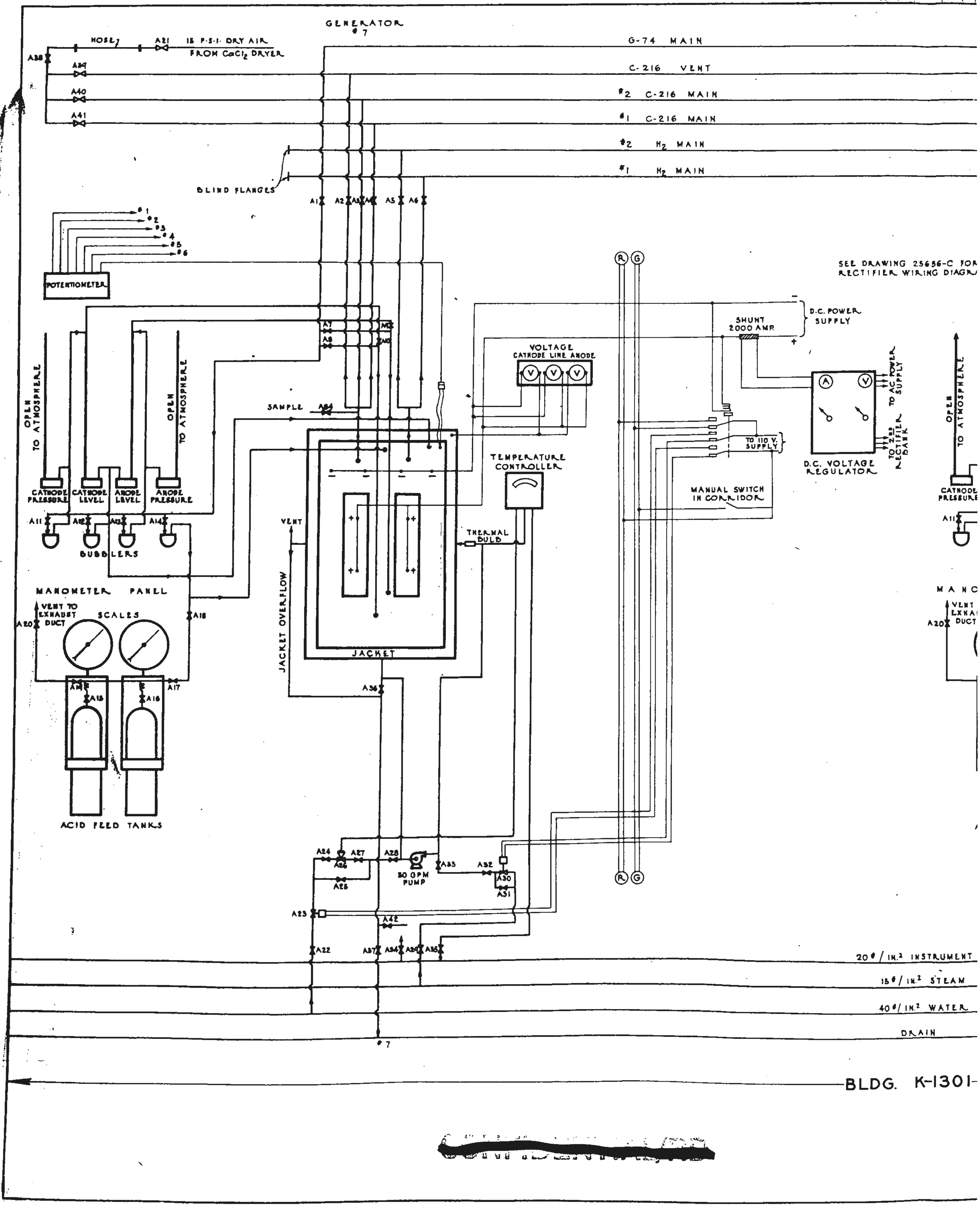

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52-1B

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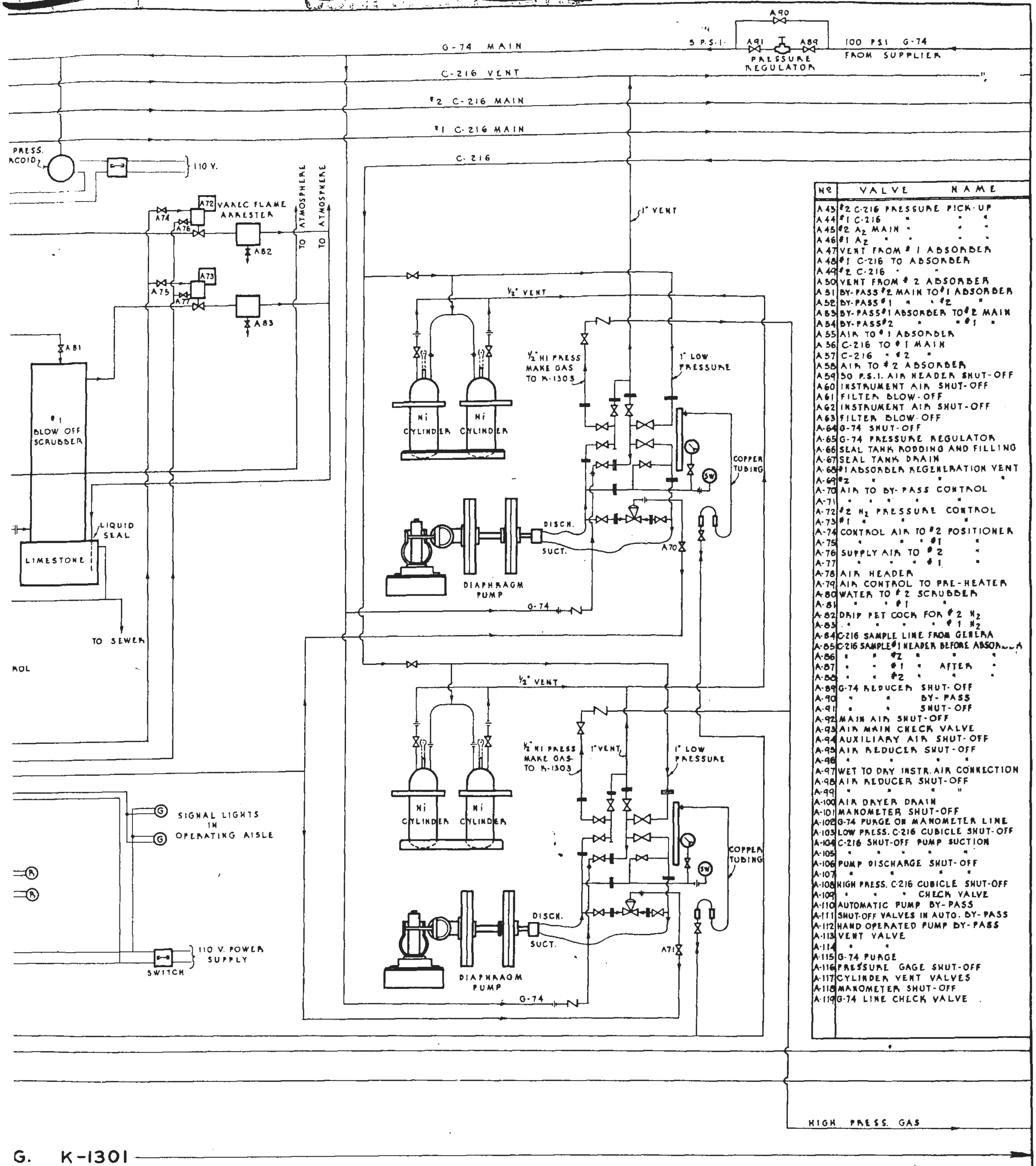


Nº	VALVE NAME
A 43	#2 C-216 PRESSURE PICK-UP
A 44	#1 C-216 " " "
A 45	#2 A_2 MAIN " " "
A 46	#1 A_2 " " " "
A 47	VENT FROM #1 ABSORBER
A 48	#1 C-216 TO ABSORBER
A 49	#2 C-216 " "
A 50	VENT FROM #2 ABSORBER
A 51	BY-PASS #2 MAIN TO #1 ABSORBER
A 52	BY-PASS #1 " " #2 "
A 53	BY-PASS #1 ABSORBER TO #2 MAIN
A 54	BY-PASS #2 " " #1 "
A 55	AIR TO #1 ABSORBER
A 56	C-216 TO #1 MAIN
A 57	C-216 " #2 "
A 58	AIR TO #2 ABSORBER
A 59	30 P.S.I. AIR HEADER SHUT-OFF
A 60	INSTRUMENT AIR SHUT-OFF
A 61	FILTER BLOW-OFF
A 62	INSTRUMENT AIR SHUT-OFF
A 63	FILTER BLOW-OFF
A-64	G-74 SHUT-OFF
A-65	G-74 PRESSURE REGULATOR
A-66	SEAL TANK RODDING AND FILLING
A-67	SEAL TANK DRAIN
A-68	#1 ABSORBER REGENERATION VENT
A-69	#2 " " "
A-70	AIR TO BY-PASS CONTROL
A-71	" " " " "
A-72	#2 H_2 PRESSURE CONTROL
A-73	#1 " " "
A-74	CONTROL AIR TO #2 POSITIONER
A-75	" " " #1 "
A-76	SUPPLY AIR TO #2 "
A-77	" " " #1 "
A-78	AIR HEADER
A-79	AIR CONTROL TO PRE-HEATER
A-80	WATER TO #2 SCRUBBER
A-81	" " #1 "
A-82	DRIP PET COCK FOR #2 H_2
A-83	" " " " #1 H_2
A-84	C-216 SAMPLE LINE FROM GENERA
A-85	C-216 SAMPLE #1 HEADER BEFORE ABSORBER
A-86	" " #2 " " "
A-87	" " #1 " AFTER "
A-88	" " #2 " " "
A-89	G-74 REDUCER SHUT-OFF
A-90	" " BY-PASS
A-91	" " SHUT-OFF
A-92	MAIN AIR SHUT-OFF
A-93	AIR MAIN CHECK VALVE
A-94	AUXILIARY AIR SHUT-OFF
A-95	AIR REDUCER SHUT-OFF
A-96	" " " "
A-97	WET TO DRY INSTR. AIR CONNECTION
A-98	AIR REDUCER SHUT-OFF
A-99	" " " "
A-100	AIR DRYER DRAIN
A-101	MANOMETER SHUT-OFF
A-102	G-74 PURGE ON MANOMETER LINE
A-103	LOW PRESS. C-216 CUBICLE SHUT-OFF
A-104	C-216 SHUT-OFF PUMP SUCTION
A-105	" " " " "
A-106	PUMP DISCHARGE SHUT-OFF
A-107	" " " "
A-108	HIGH PRESS. C-216 CUBICLE SHUT-OFF
A-109	" " " CHECK VALVE
A-110	AUTOMATIC PUMP BY-PASS
A-111	SHUT-OFF VALVES IN AUTO. BY-PASS
A-112	HAND OPERATED PUMP BY-PASS
A-113	VENT VALVE
A-114	" "
A-115	G-74 PURGE
A-116	PRESSURE GAGE SHUT-OFF
A-117	CYLINDER VENT VALVES
A-118	MANOMETER SHUT-OFF
A-119	G-74 LINE CHECK VALVE

FIG. 52

NO.	REVISIONS	DATE	NO.	REVISIONS	DATE
1			7		
2			8		
3			9		
4			10		
5			11		
6			12		

HOOKER ELECTROCHEMICAL
NIAGARA FALLS, N. Y.

CHG. No.
W. O. No.
CP.

MADE BY C. R. L. SCALE
TRACED BY MCR DATE 1-15-44
CHECKED BY [illegible] APPROVED

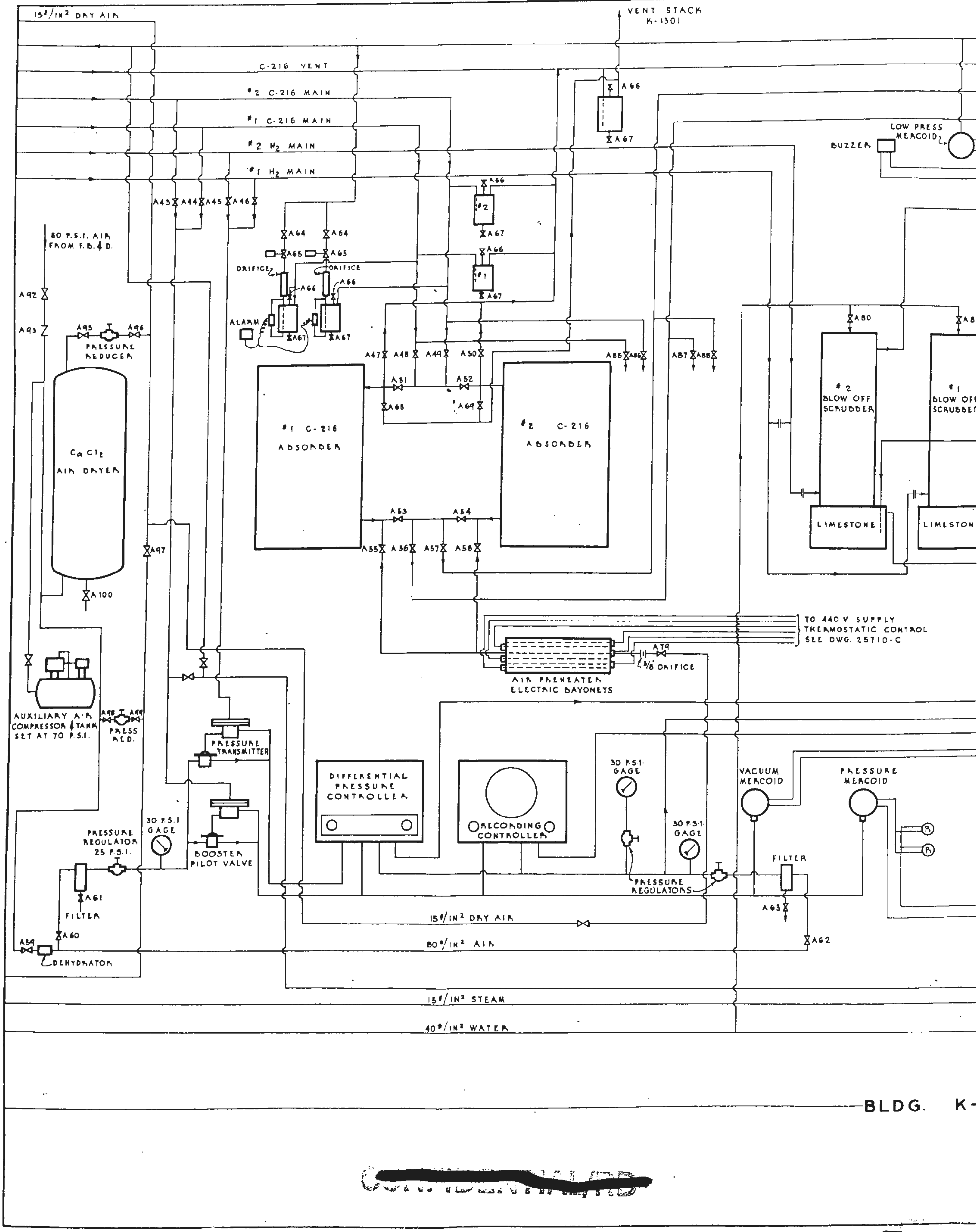
DWG. 25475-C

FLOW DIAGRAM BLDGS. K-1301 2 & 3 PART B

[redacted]

52-2B

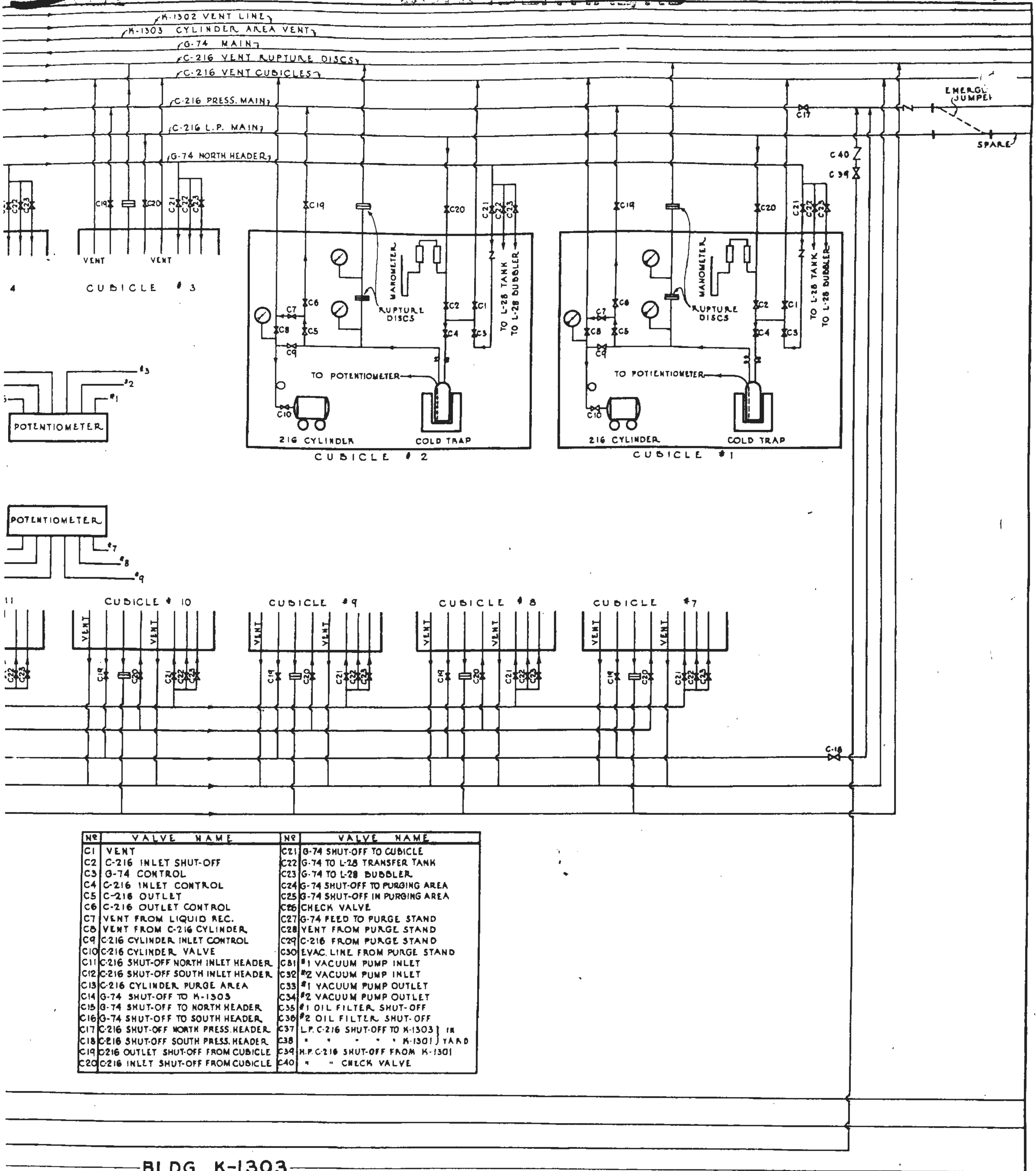
[redacted]



[redacted]

[redacted]

#52-1C



Nº	VALVE NAME	Nº	VALVE NAME
C1	VENT	C21	G-74 SHUT-OFF TO CUBICLE
C2	C-216 INLET SHUT-OFF	C22	G-74 TO L-28 TRANSFER TANK
C3	G-74 CONTROL	C23	G-74 TO L-28 BUBBLER
C4	C-216 INLET CONTROL	C24	G-74 SHUT-OFF TO PURGING AREA
C5	C-216 OUTLET	C25	G-74 SHUT-OFF IN PURGING AREA
C6	C-216 OUTLET CONTROL	C26	CHECK VALVE
C7	VENT FROM LIQUID REC.	C27	G-74 FEED TO PURGE STAND
C8	VENT FROM C-216 CYLINDER	C28	VENT FROM PURGE STAND
C9	C-216 CYLINDER INLET CONTROL	C29	C-216 FROM PURGE STAND
C10	C-216 CYLINDER VALVE	C30	EVAC. LINE FROM PURGE STAND
C11	C-216 SHUT-OFF NORTH INLET HEADER	C31	#1 VACUUM PUMP INLET
C12	C-216 SHUT-OFF SOUTH INLET HEADER	C32	#2 VACUUM PUMP INLET
C13	C-216 CYLINDER PURGE AREA	C33	#1 VACUUM PUMP OUTLET
C14	G-74 SHUT-OFF TO K-1303	C34	#2 VACUUM PUMP OUTLET
C15	G-74 SHUT-OFF TO NORTH HEADER	C35	#1 OIL FILTER SHUT-OFF
C16	G-74 SHUT-OFF TO SOUTH HEADER	C36	#2 OIL FILTER SHUT-OFF
C17	C-216 SHUT-OFF NORTH PRESS. HEADER	C37	L.P. C-216 SHUT-OFF TO K-1303 } IN YARD
C18	C-216 SHUT-OFF SOUTH PRESS. HEADER	C38	" " " " " K-1301 } IN YARD
C19	C-216 OUTLET SHUT-OFF FROM CUBICLE	C39	H.P. C-216 SHUT-OFF FROM K-1301
C20	C-216 INLET SHUT-OFF FROM CUBICLE	C40	" " CHECK VALVE

FIG. 52

NO.	REVISIONS	DATE	NO.	REVISIONS	DATE
1			7		
2			8		
3			9		
4			10		
5			11		
6			12		

HOOKER ELECTROCHEMICAL CO
NIAGARA FALLS, N.Y.

CHG. NO.
W.O. NO.
CP.

MADE BY McRae SCALE
TRACED BY DATE
CHECKED BY APPROVED

DWG. 25476-C

FLOW DIAGRAM BLDGS. K-1301, 2 & 3 PART C

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52-2C

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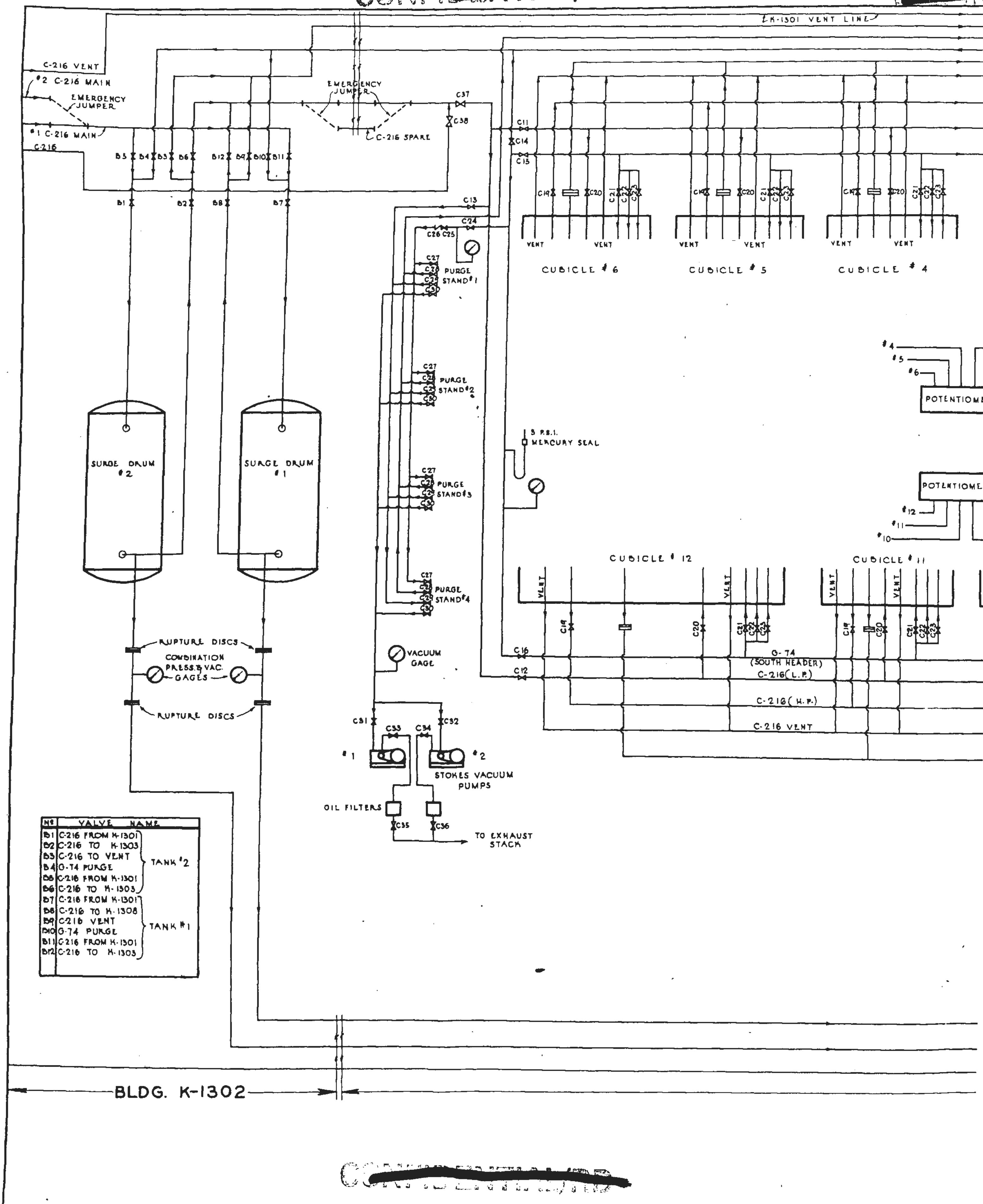

No	VALVE NAME	
B1	C-216 FROM K-1301	TANK #2
B2	C-216 TO K-1303	
B3	C-216 TO VENT	
B4	G-74 PURGE	
B5	C-216 FROM K-1301	
B6	C-216 TO K-1303	
B7	C-216 FROM K-1301	TANK #1
B8	C-216 TO K-1308	
B9	C-216 VENT	
B10	G-74 PURGE	
B11	C-216 FROM K-1301	
B12	C-216 TO K-1303	

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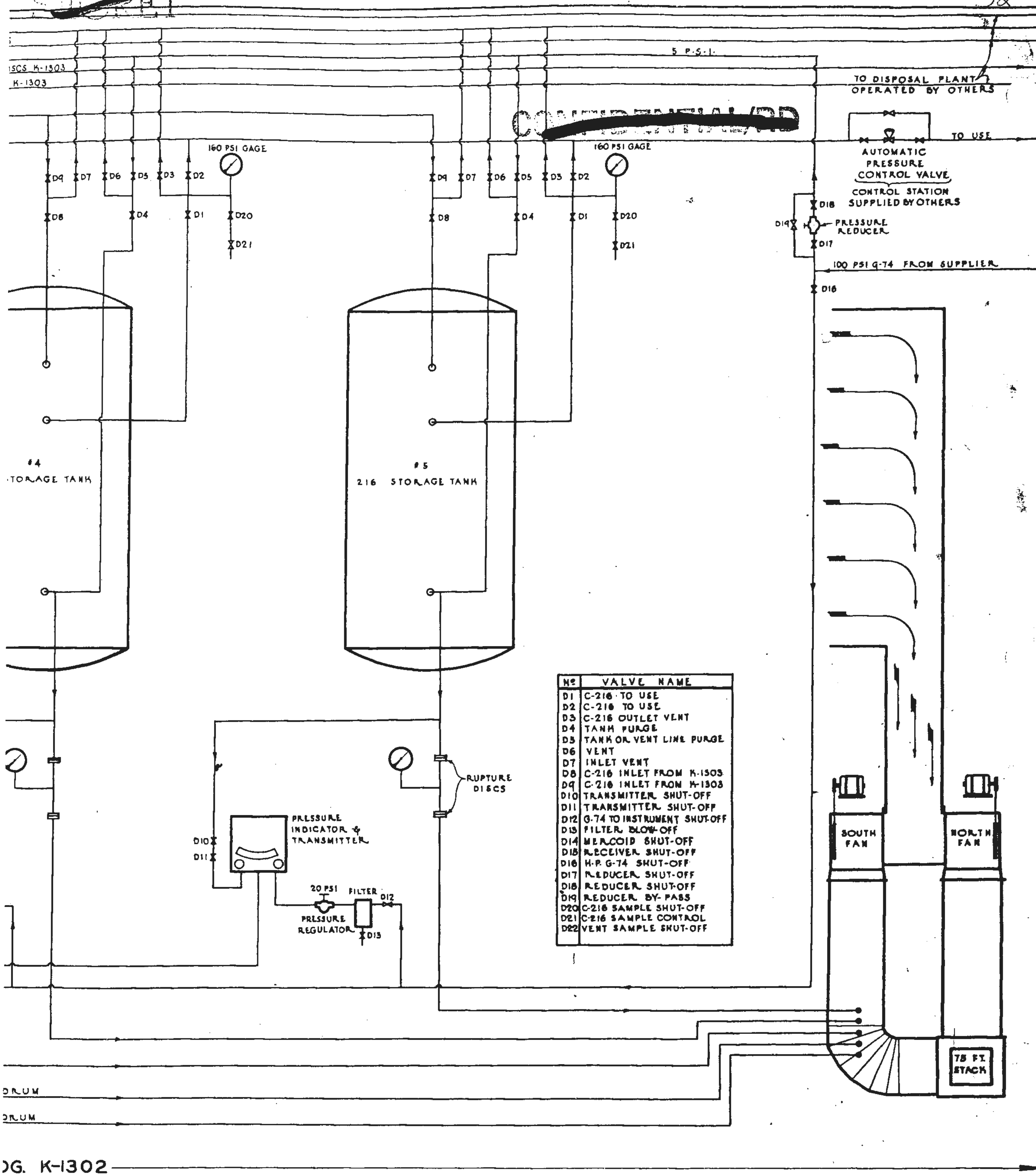
[redacted]



Nº	VALVE NAME
D1	C-216 TO USE
D2	C-216 TO USE
D3	C-216 OUTLET VENT
D4	TANK PURGE
D5	TANK OR VENT LINE PURGE
D6	VENT
D7	INLET VENT
D8	C-216 INLET FROM K-1303
D9	C-216 INLET FROM K-1303
D10	TRANSMITTER SHUT-OFF
D11	TRANSMITTER SHUT-OFF
D12	G-74 TO INSTRUMENT SHUT-OFF
D13	FILTER BLOW-OFF
D14	MERCOID SHUT-OFF
D15	RECEIVER SHUT-OFF
D16	H.P. G-74 SHUT-OFF
D17	REDUCER SHUT-OFF
D18	REDUCER SHUT-OFF
D19	REDUCER BY-PASS
D20	C-216 SAMPLE SHUT-OFF
D21	C-216 SAMPLE CONTROL
D22	VENT SAMPLE SHUT-OFF

FIG. 52

HOOKER ELECTROCHEMICAL CO.
NIAGARA FALLS, N. Y.

CHG. No.
W.O. No.
CP.

MADE BY M.T.L.S.S. SCALE
TRACED BY DATE
CHECKED BY APPROVED

DWG. 25477-C

FLOW DIAGRAM BLDGS. K-1301, 2 & 3 PART D

[redacted]

52-2D

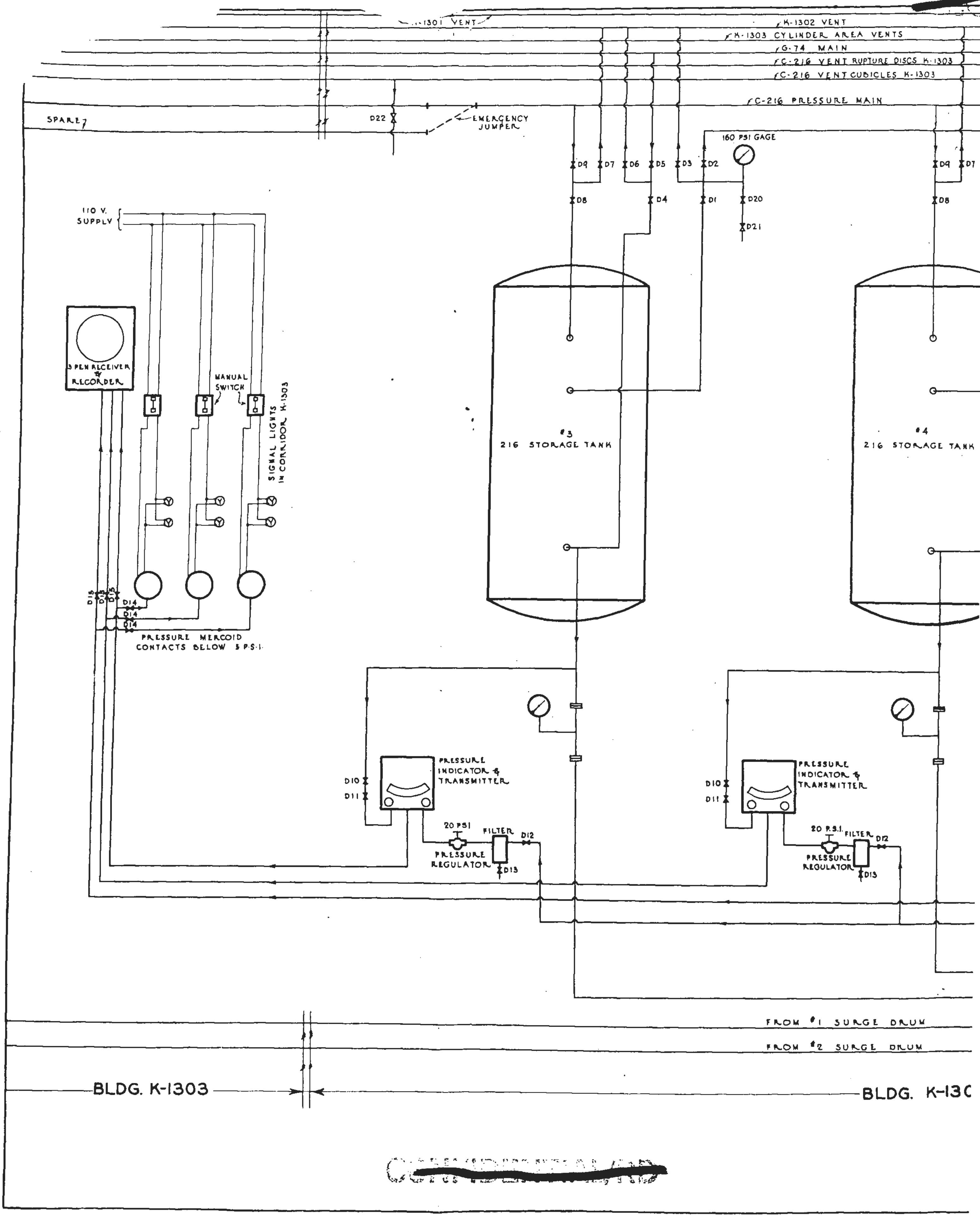

K-1301 VENT
K-1302 VENT
K-1303 CYLINDER AREA VENTS
G-74 MAIN
C-216 VENT RUPTURE DISCS K-1303
C-216 VENT CUBICLES K-1303
C-216 PRESSURE MAIN
SPARE
D22
EMERGENCY JUMPER
160 PSI GAGE
D9
D7
D6
D5
D3
D2
D8
D4
D1
D20
D21
110 V. SUPPLY
3 PEN RECEIVER & RECORDER
MANUAL SWITCH
SIGNAL LIGHTS IN CORRIDOR K-1303
D15
D14
PRESSURE MERCOID CONTACTS BELOW 3 P.S.I.
#3 216 STORAGE TANK
#4 216 STORAGE TANK
PRESSURE INDICATOR & TRANSMITTER
D10
D11
20 PSI
PRESSURE REGULATOR
FILTER
D12
D13
FROM #1 SURGE DRUM
FROM #2 SURGE DRUM
BLDG. K-1303
BLDG. K-130

diagram for Section 1300 is shown by Figure 52, in four parts; further discussion is provided in the Kellex Completion Report, Section III, (1) E.

(1) <u>Generating Building (K-1301).</u> - Building K-1301 houses fluorine generating and auxiliary equipment, mechanical compressors, an office, and a laboratory.

(a) <u>Electrolytic Cells.</u> - Fluorine is generated by electrolysis at 100°C of a solution of potassium fluoride (KF) in hydrogen fluoride (HF), the composition corresponding approximately to 1.8 mols of HF to 1 mol of KF. The HF is decomposed into hydrogen (H_2) which forms at the cathode, and fluorine (F_2), which forms at the anode. Each cell requires a maximum current of 2000 amperes. Direct current power at 9.5 volts is supplied from eight copper oxide rectifiers per cell. The anode assembly consists of 28 carbon blades (1-1/2 x 6-1/4 x 18 inches) bolted to a copper bar. A steel screen diaphragm surrounds the anodes, and two steel cathodes are placed outside the screen. Two per cent lithium fluoride is added to the electrolyte to retard anode polarization. The cells are equipped with warm water cooling coils which can be used as steam coils at time of shutdown to keep the electrolyte molten. The cells operate with continuous HF feed, and can run for long periods of time without replacement.

(b) <u>HF Absorbers.</u> - The crude generated fluorine is contaminated with HF. It is purified by passage through sodium fluoride (NaF) tray absorbers, which reduce the HF content to a value below 1 per cent. HF is removed from these absorbers periodically by regenerating with hot air; regeneration off-gas is piped to the disposal system at Building K-1405 (Par. 11-5). The HF-free fluorine gas flows at a pressure of several inches of water to a surge tank in Building K-1302 as described below. The hydrogen gas waste product is sent to a water scrubber to remove HF, and is then vented to the atmosphere.

(c) Pressure Control. - All cells discharge fluorine into a single header, which is interconnected with the hydrogen header by means of a differential pressure control system. In this way, when the pressure varies in the fluorine main, the hydrogen pressure is adjusted to an equal value by throttling, so that the electrolyte will be maintained at the same level in both the anode and cathode compartments of the cells. If this were not done, the hydrogen would find its way into the fluorine chamber, [redacted], with a resulting explosion that might break the cell. If the pressure in the fluorine main rises above a pre-determined level, (e.g.,4 inches of water), the fluorine line is vented into the disposal line. Conversely, if a vacuum develops in the fluorine lines, the automatic control system bleeds nitrogen into the fluorine header to break the vacuum, thereby preventing the possibility of moisture inleakage into the system. (Moisture reacts violently with fluorine.) A signal light system affords warning when fluorine begins to empty into the vent line, or when nitrogen begins to bleed into the fluorine line.

(d) Compressors. - A process design change was effected in the methods of handling fluorine, when suitable compressors became available. These were installed in Building K-1301, and are discussed below.

(2) Storage Building (K-1302).

(a) Surge Tanks. - Surge tanks in Building K-1302 provide damping of pressure variations in the fluorine lines, so as to minimize the load on the automatic control system. Two tanks are provided, one of which normally operates floating on the line, the other acting as a spare. They are of nickel-clad steel, 4 feet in diameter, and 12 feet long; gage pressure is normally several inches of water. The gas flows from the surge tanks to the liquefaction cubicles (or compressors).

(b) Storage Tanks. - Three additional nickel-clad tanks, each 6 feet in diameter and 20 feet long, provide storage for about 1-1/2 days' fluorine production. The original design was based on the assumption that the tanks would be operated batch-wise, one tank being filled while the other discharges to the conditioning building, the third being a spare. However, should it become desirable, they can be operated floating on the line. The tanks are designed for a working pressure of 100 p.s.i.g. and fitted with 60 p.s.i.g. rupture discs. They are equipped with nitrogen lines for purging into the disposal plant, K-1405, and can be evacuated from that point if necessary.

(c) Pressure Control. - Converters to be conditioned cannot be subjected to pressures greater than 5 p.s.i.g., and, as a safety precaution, conditioning building fluorine line pressure was limited to about 1 p.s.i.g. Since storage pressure was to be in the range of 20-30 p.s.i.g., an air-operated, monel "S" type valve (Par. 8-11c) was developed to maintain the pressure below 2 p.s.i.g.

As a double precaution, in case of failure of this valve, a second valve was provided, designed to shut off automatically in case the pressure should tend to rise above 5 p.s.i.g. To allow for sweeping fluorine from the lines in the event of fires, or before opening them for maintenance, it was initially intended to run cross connections from the fluorine pipes to nitrogen supply. Instead, however, at the request of Carbide and Carbon Chemicals Corporation, a high pressure nitrogen cylinder, separated from the line by a rupture disc, was placed at the end of each line. With the development of vacuum pumps to handle fluorine, adequate means for quickly evacuating the piping became available.

(3) <u>Liquefaction and Bottling Building (K-1303)</u>. - After various means of handling the fluorine were considered, pressuring by liquefaction was selected as the best available method. Other alternatives studied were mechanical compression, pressuring with nitrogen, operation of vessels and lines under partial vacuum, and pressuring by refrigeration and heating. The choice of the liquefaction method was based upon considerations of flexibility of operation, and minimum operating hazards. However, provision was also made for subsequent conversion to mechanical compression in the event of successful development of a suitable compressor.

(a) <u>Liquefaction Cubicles</u>. - There are 12 cubicles in Building K-1303, each one of which is capable of liquefying gas and re-vaporizing it either into the storage tanks at K-1302, or into portable cylinders which can be placed inside the cubicle. Cubicles were operated batch-wise, with one always followed by another in such manner that the flow of gas to and from the building was continuous. The gas was admitted into an all-nickel bomb immersed in a larger vessel containing liquid nitrogen. Condensation of the gas created a vacuum in the bomb. When approximately 10 pounds of fluorine had been admitted, as indicated by the scale from which the bomb was suspended, the admission of fluorine was stopped, and the liquid nitrogen bath lowered away. The subsequent warming up of the bomb vaporized the liquid fluorine; when the pressure reached 30 p.s.i.g., the gas was allowed to flow into the storage tanks at K-1302. When a portable cylinder was to be filled with fluorine, it was brought into the cubicle on a buggy, and filled in the same manner as a storage tank. Space is provided at the west end of Building K-1303 for cylinder maintenance, as required, and for cylinder purging. Vacuum pumping facilities are also available for evacuation of the cylinders.

(b) <u>Conversion to Mechanical Compression.</u> - By August 1944 Hooker, aided by Kellex, developed a satisfactory diaphragm-type pump, which was fabricated by the Wilson Pulsa-feeder Company. At the direction of Kellex, Hooker then made an engineering analysis which indicated that, from the standpoint of operating economy, it would be very desirable to change from liquefaction to mechanical compression. Accordingly, the installation was designed, cooperatively, by Hooker, Carbide, and Kellex. Two compressors, with related control equipment, were installed in Building K-1301. According to the revised method of operation, which was begun in February 1945, generated fluorine is compressed and delivered to the storage tanks in a straightforward pumping operation. The liquefaction installation in Building K-1303 is now in standby status. The pump consists of two diaphragm heads spaced some distance apart and hydraulically connected. The power side diaphragm is connected to a reciprocating oil piston running at a speed of 90 strokes per minute; the impulses are transmitted to a monel pump diaphragm through a two-inch monel pipe filled with fluorolube MFL. The pump diaphragm transmits the impulses to the fluorine through a suction and discharge valve head. The pumps are located in a special section of Building K-1301, and take suction from the surge tanks in K-1302. Fluorine is delivered under pressure to the storage tanks at K-1302, or to portable tanks at K-1303.

(4) <u>Fluorine Distribution System.</u>

(a) <u>Distribution to Conditioning Building.</u> - Since the fluorine generating plant could be located adjacent to the conditioning building, and only one portion of that building required fluorine, a permanent piping system was chosen for this service. To insure reliability, and to exclude the possibility of contamination by dust, mist, or air (which would be intolerable, for example, in gas to be used for conditioning of barrier surfaces), a welded, all-monel system was designed.

(b) <u>Distribution to Process Area.</u> - Fluorine was to be used at hundreds of widely scattered, and frequently varying, points in Section 300, and was to be required in intermittent and extremely variable amounts. These considerations led to the choice of mobile cylinders for distribution to this area, instead of a permanent piping system (Par. 10-8c).

11-5. Fluorine Disposal Plant (K-1405).

a. Purpose. - The fluorine disposal plant was designed to absorb the toxic and corrosive fluorine and hydrogen fluoride components of various waste gases before venting to the atmosphere. These gases arise from the following sources:

1. Manifold vents and cylinder maintenance in Building K-1303.
2. Dehydration, cell purging, and HF absorber regeneration in Building K-1303.
3. Tank evacuation and purging in Building K-1302.
4. Vent lines from Buildings K-1302, K-1303, and K-1401, and pressure relief of the fluorine feed line from Building K-1302 to Building K-1401.
5. Discharge from vacuum pumps in Building K-1405.
6. Eight inch spent conditioning gas return line from Section 300.

b. Preliminary Engineering. - Research and development work on methods of disposing of waste fluorine was done by Johns-Hopkins University, Princeton University, and the Chrysler Corporation. The studies were coordinated by Kellex; consultation services were rendered by Carbide. A discussion of this work and of alternate methods considered is presented in Section III, (1) E of the Kellex Completion Report. This paragraph describes the K-25 fluorine disposal installation as constructed; further details may be found in Volume XXIII, Part III of the Kellex Operating Manuals.

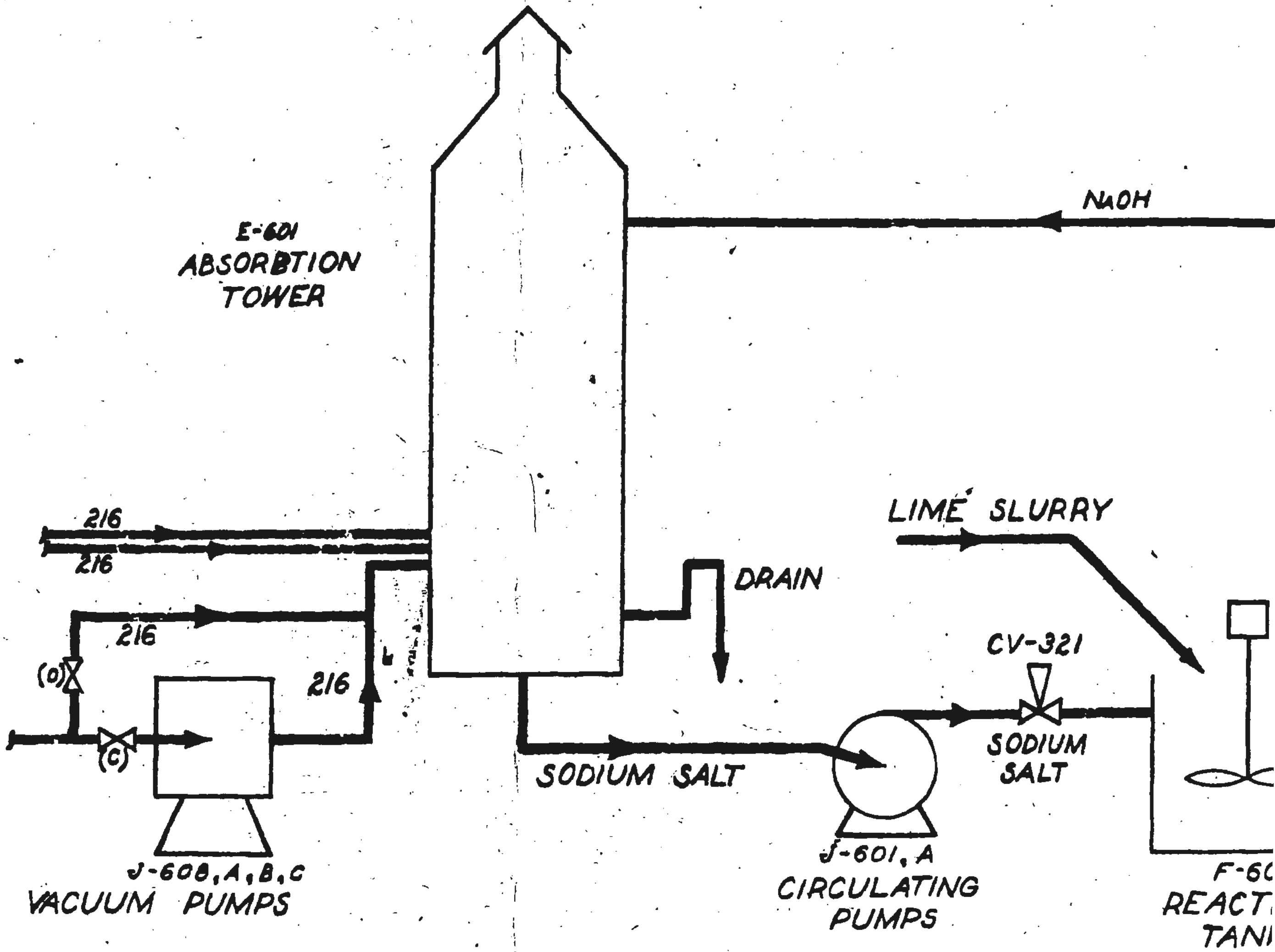
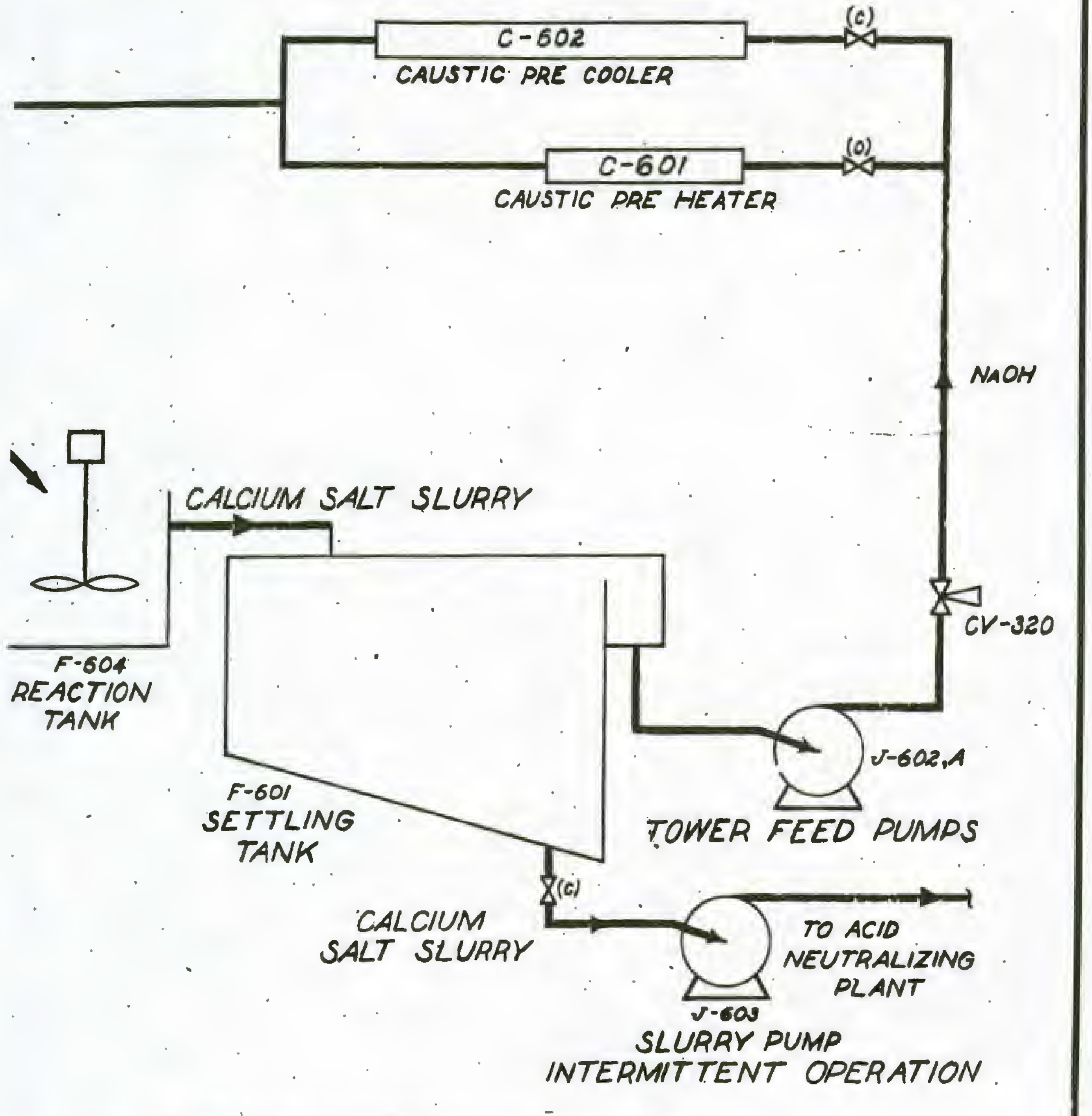

E-601
ABSORBTION
TOWER
NaOH
216
216
216
216
(O)
(C)
DRAIN
LIME SLURRY
CV-321
SODIUM
SALT
SODIUM SALT
J-608, A, B, C
VACUUM PUMPS
J-601, A
CIRCULATING
PUMPS
F-60
REACT
TAN

FIG. 53



SCHEMATIC PROCESS FLOW SHEET 216

TITLE DISPOSAL PLANT BUILDING K-1405

DESCRIPTION	DATE	CHECKED	THE KELLEX CORP.	SCALE ___ DATE ___ AP. ___ DR. ___ TR. ___ CKD. ___ No. 557 O.D.-III
REVISIONS				

c. Capacity. - The disposal plant was designed to handle all fluorine generated in Section 1300, but is sufficiently flexible so as to be capable of operating at much lower rates. The disposal tower can handle 78 CFM of gas containing up to 20 per cent fluorine and 10 per cent hydrogen fluoride. Maximum fluorine content of vented gas was specified at 6 parts per million.

d. Design. - The fluorine disposal plant (Fig. 58) is located in Section 1400, northeast of the conditioning building. Building K-1405 contains a caustic regeneration tank, vacuum pumps, lime storage space, an office, and a control laboratory. Outside the building are located the disposal tower, caustic storage tanks, decantation tank and settling tank.

(1) Disposal Tower. - The fluorine absorption tower is an alkaline scrubber of 800 cubic foot volume, lined with carbon bricks, and packed with carbon Raschig rings*. Gas flow is maintained countercurrently to a descending stream of 5-10 per cent caustic solution flowing at a rate of 50-100 GPM. Contact time is at least one minute. Gas enters the tower at three points in its base. Sulfuric acid seal pots prevent moisture from diffusing back into the line. To avoid spontaneous combustion of the gas feed piping with the fluorine, these lines are constructed of monel. This also minimizes the possibility of corrosion by liquid fluoride solutions formed in case of back diffusion of water into these lines. Spent conditioning gases from the conditioning and process buildings are sent to the tower by means of pumps in these buildings, but four 100 CFM vacuum pumps are installed at K-1405 to serve as emergency standby equipment.

(2) Emergency Stack. - An emergency stack was provided to dispose of the waste gases when the absorption tower is out of service for repair or cleaning. The stack was constructed of 4 inch monel pipe, and extends 70 feet above the surrounding grade.

(3) Reaction Tank. - Effluent liquor from the tower is pumped to a 2250 gallon reaction tank where the dissolved sodium fluoride is converted to insoluble calcium fluoride by means of lime slurry pumped from a 90 gallon lime slaker. The neutralization requires 20 minutes of vigorous agitation. This reaction also regenerates the caustic, which can then be recycled.

(4) Settling Tank. - Reaction liquor flows by gravity to a 22,000 gallon settling tank from which clear liquor overflows a weir and is pumped back to the tower. The tank is equipped both with a preheater and a precooler so that the temperature may be adjusted in either direction.

(5) Caustic Storage Tanks. - Two 26,500 gallon steam heated cylindrical tanks are provided for storage of 20-25 per cent caustic solution, with pumping facilities for unloading 50 per cent caustic from tank cars. Piping is arranged to permit the required dilution in the storage tanks. Required make-up caustic is pumped from the storage tanks to the settling tank.

(6) Control Laboratory. - A chemical laboratory was installed so that a continual check on operations could be maintained.

e. Presence of UF_6 in Waste Fluorine. - It has sometimes been necessary to vent gases containing both process gas and fluorine to the disposal plant. This introduced technical problems which were studied by Kellex with a view toward prevention of accumulation of enriched material and special attendant hazards. The Kellex Completion Report, Section III, (1) E, discusses methods developed for prevention of precipitation of process gas in the disposal solution, and for selective removal of UF_6 from UF_6-F_2 mixtures. In September 1945, Kellex recommended temporary avoidance of hazards by means of a portable alumina trap for UF_6 removal from waste gases to be sent to the fluorine absorption system. Subsequently, for permanent solution of the problem, Carbide proposed that in order to minimize new construction, they would prefer to allow UF_6-contaminated fluorine waste gases to enter the cascade and be removed in the purge system. Kellex studied the method and found it advantageous. This necessitated the substitution of alumina for some of the carbon in the carbon traps near the top of the plant (Par. 11-8).

f. Fluorine Disposal Piping. - On the basis of considerations similar to those which argued against the distribution of fluorine conditioning gas to the process area by means of a permanent piping system, it was at first thought best to exhaust and absorb the waste gas from conditioning operations by means of mobile apparatus, and it was planned to proceed with design and construction of twenty such units. These, however, necessarily developed into large, bulky sets of apparatus. Carbide therefore requested that the use of this type of fluorine disposal equipment be reconsidered. After a thorough review of the problem, it was decided to abandon the mobile fluorine disposal units; one was retained for emergency use. A permanent piping system was then installed to collect spent conditioning gases from both Sections 300, and 1400, and channel them back to the K-1405 disposal system. Standard seamless steel pipe was applicable for this service, and the system was set up for use in conjunction with mobile fluorine evacuation pumps (Par. 10-8d).

g. Revision of Disposal System. - In March 1946, use of the caustic disposal tower was discontinued, and the fluorine disposal system simplified by arranging for the continuous venting of all conditioning gases directly to the atmosphere through the emergency stack. In the process area, off gases from a reconditioned cell are bled into the process cascade for ultimate removal in the purge system (Section 312). This eliminates the problem of uranium loss in waste conditioning gases. These procedures are made possible because of the small quantity of spent conditioning gases handled in present operations. In order to handle fluorine gas which may arise from the rupture of a pressure control disc in Building K-1302, a brick chimney, equipped with a blower at its base, has been constructed to dispose of waste gas from this source. When the disposal tower was shut down, the sludge content of the settling tank (containing small amounts of uranium compounds) was transferred to an underground concrete pit pending ultimate disposal.

11-6. Acid Neutralizing Plant (K-1407).

a. Purpose. - This facility was designed by the Kellex Corporation for the purpose of disposing of the acid wastes from cleaning operations in the conditioning building.

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CONFIDENTIAL/RD

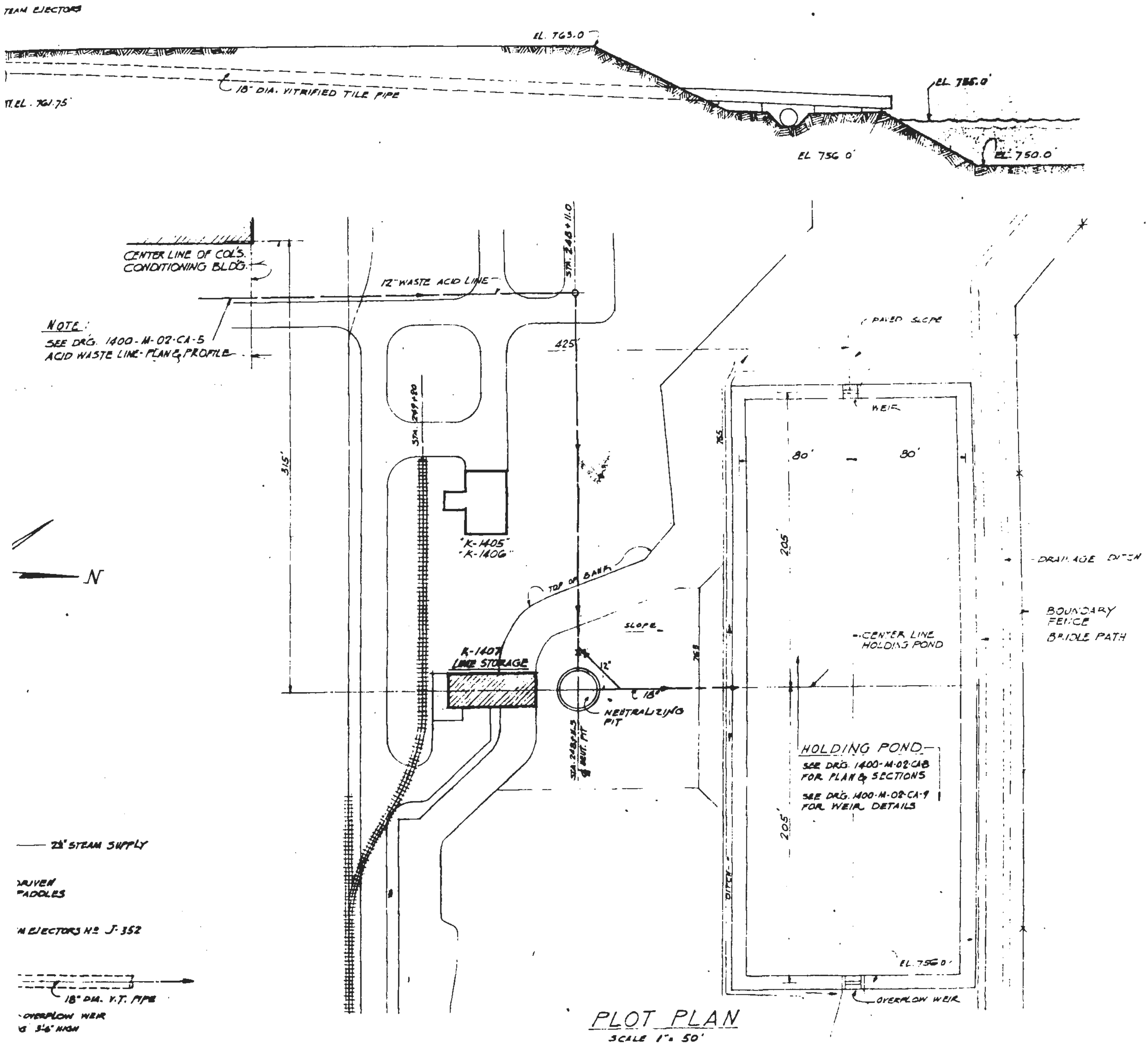

FIG. 54

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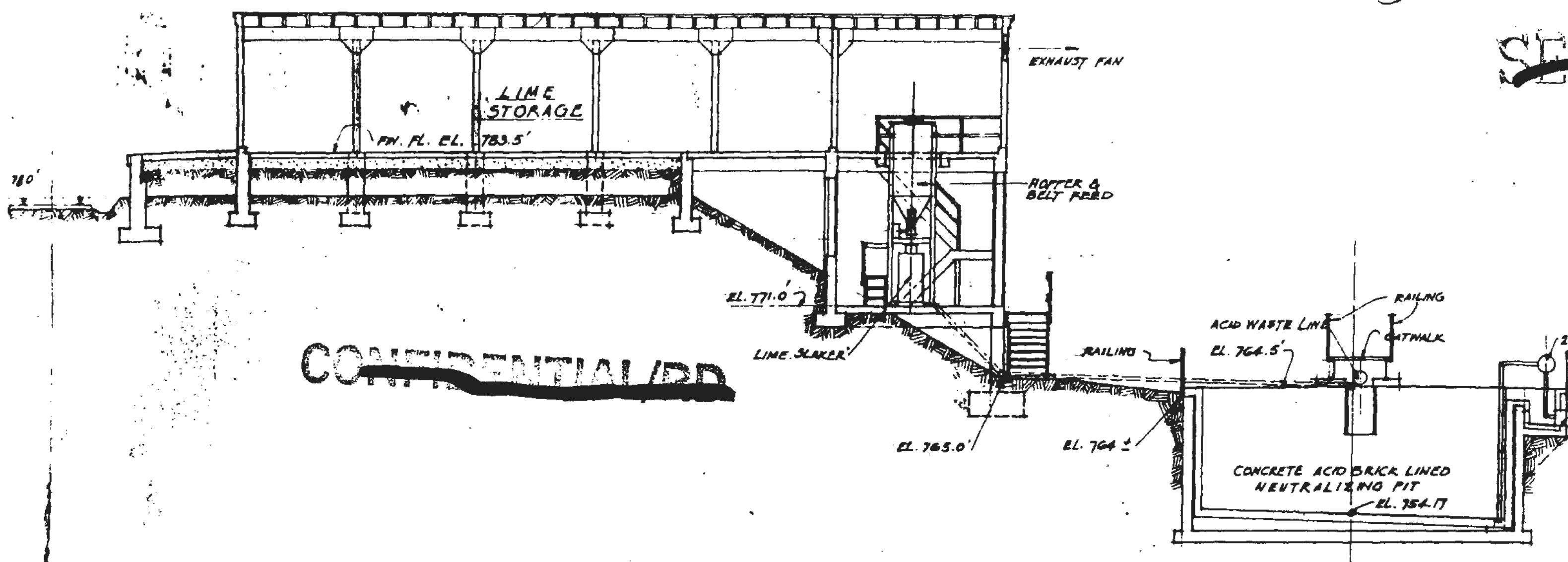

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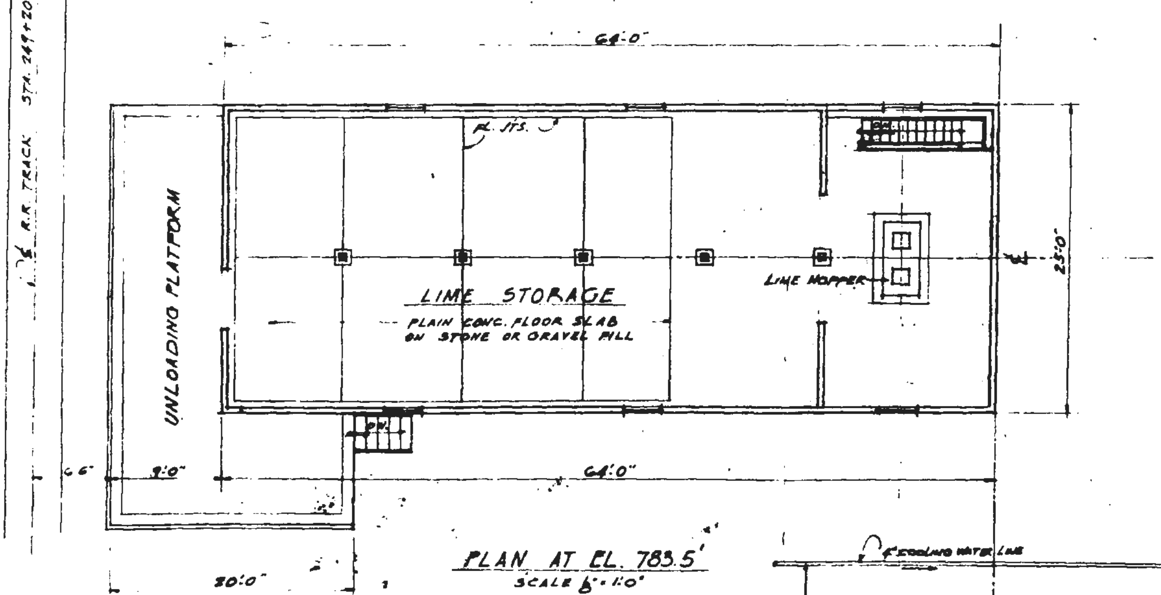
SECTION

SCALE 1/8" = 1'-0"



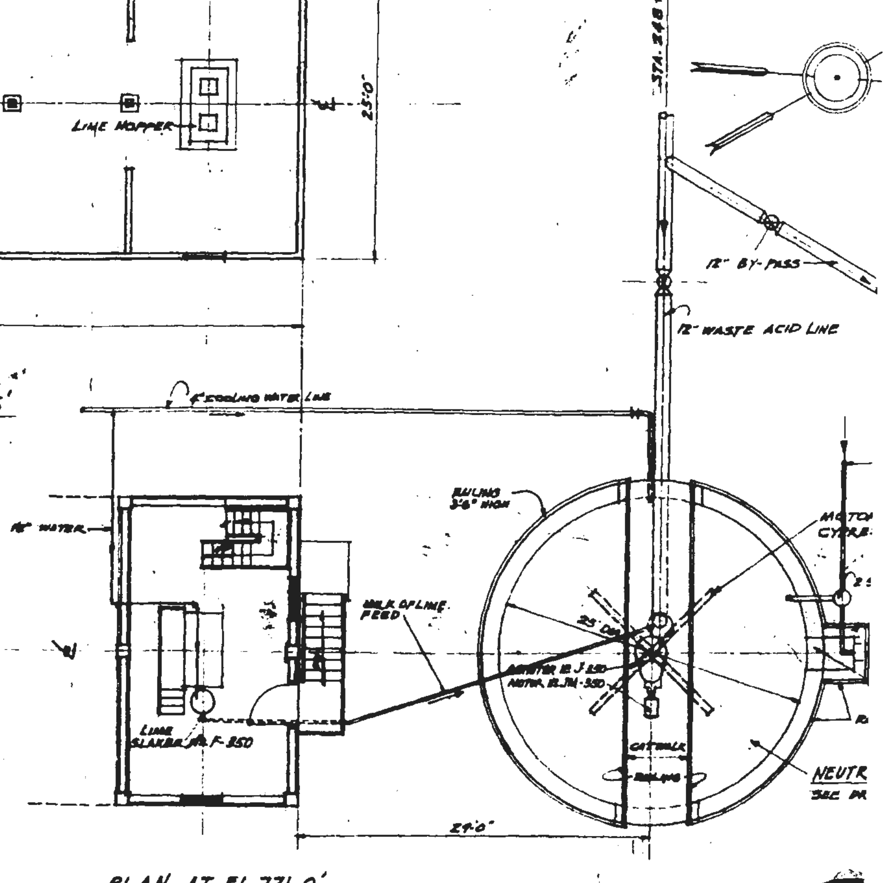
PLAN AT EL. 783.5'

SCALE 1/8" = 1'-0"

NOTE:

FOR ARCHITECTURAL PLANS, ELEVS. & SECTS. SEE DRG. NO 1407-K-30-AA

FOR ARCHITECTURAL DETAILS SEE DRG. NO 1407-K-30-BA



PLAN AT EL. 771.0'

SCALE 1/8" = 1'-0"

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b. <u>Design.</u> - The acid neutralization plant (Fig. 54) is contained in a 25 x 64 foot building located northeast of Building K-1401. Adjacent to the building is a concrete neutralizing pit which leads to a holding pond 410 feet long, 160 feet wide, and 5 feet deep. Lime is unloaded from railroad cars, and stored within the building. It passes through a hopper and feeder to a slaker tank equipped with a high speed agitator. The slaked lime slurry thus formed flows by gravity to a 25 foot diameter, 10 foot deep neutralization pit which is lined with acid-proof brick. At this point, it is mixed with waste acids having the following approximate maximum analysis:

Sulfuric acid	30 per cent by weight
Hydrochloric acid	15
Nitric Acid	5
Sodium dichromate	1/2 pound per gallon

The acid runs through a 12 inch line to the pit where lime neutralization is effected by means of agitation with a heavy duty paddle type mixer. The neutralized solution is discharged from the pit to the holding pond by means of two 200 GPM steam ejectors. Suspended solids are settled out, and clear effluent overflows to Poplar Creek. The rate of run-off from the pond is set by adjustment of weir gates at each end.

11-7. <u>Nitrogen Plant (K-1408).</u>

a. <u>Purpose.</u> - The nitrogen plant was designed for the purpose of supplying Project requirements for moisture-free gaseous nitrogen (code name: G-74) and liquid nitrogen (code name: L-28). The

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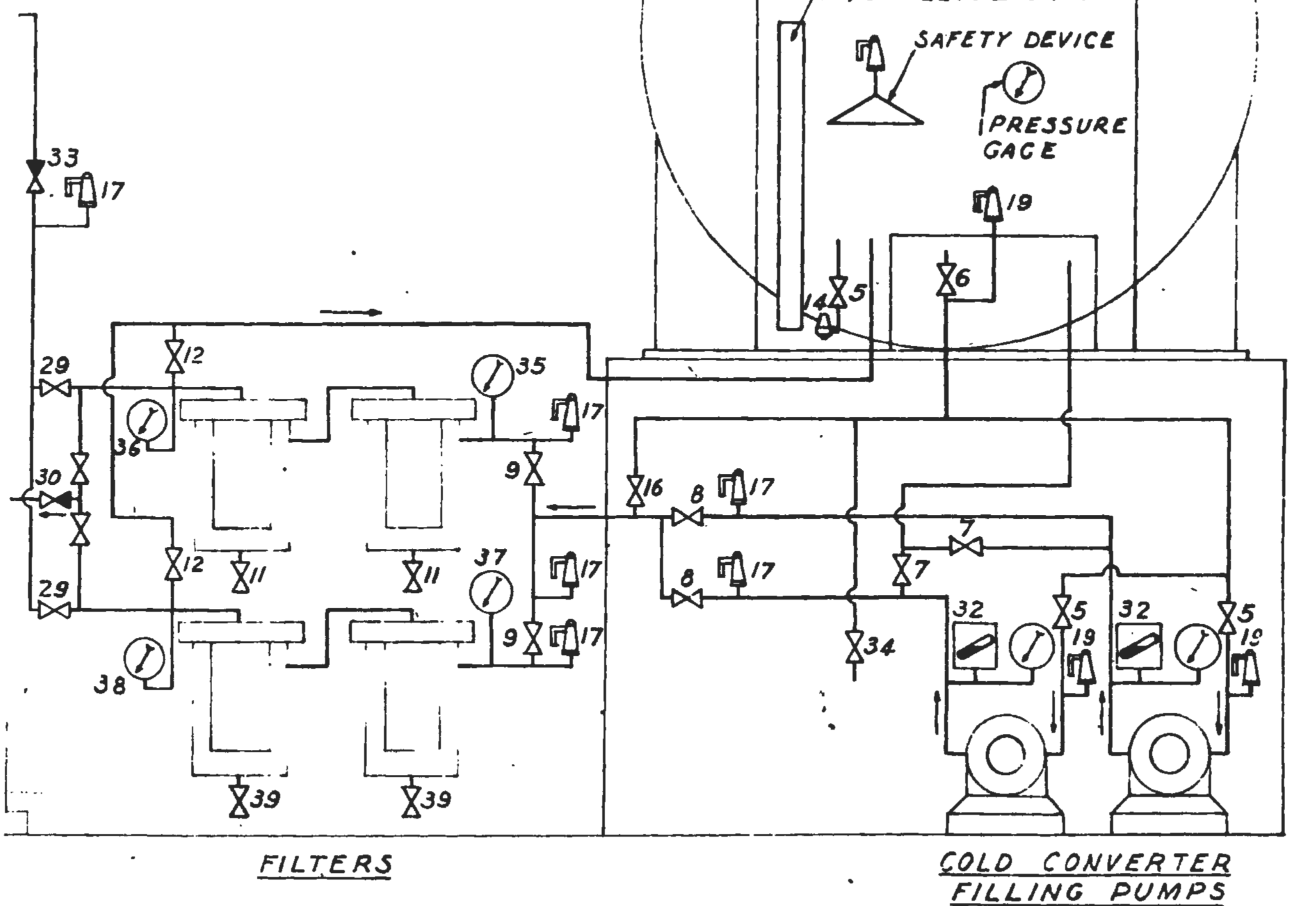
.wal Valve
.ers Inlet Pressure Gage
.ers Outlet Pressure Gage
.ters Inlet Pressure Gage
.ters Outlet Pressure Gage
.ter Assembly Drain Valve
.-Off Valve
.ator By-Pass Valve
.t Shut-Off Valve
.ator Inlet Valve
.ator Outlet Valve
.et Shut-Off Valve



LABORATORY OF THE LINDE AIR PRODUCTS CO.
TONAWANDA, N.Y.

TITLE FLOW SHEET
K-25 INSTALLATION

CH'K'D.	DRAWN B.M.B. 6-5-44	SCALE
TRACED	APP'VD.	A-158223

FIG. 55

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LEGEND

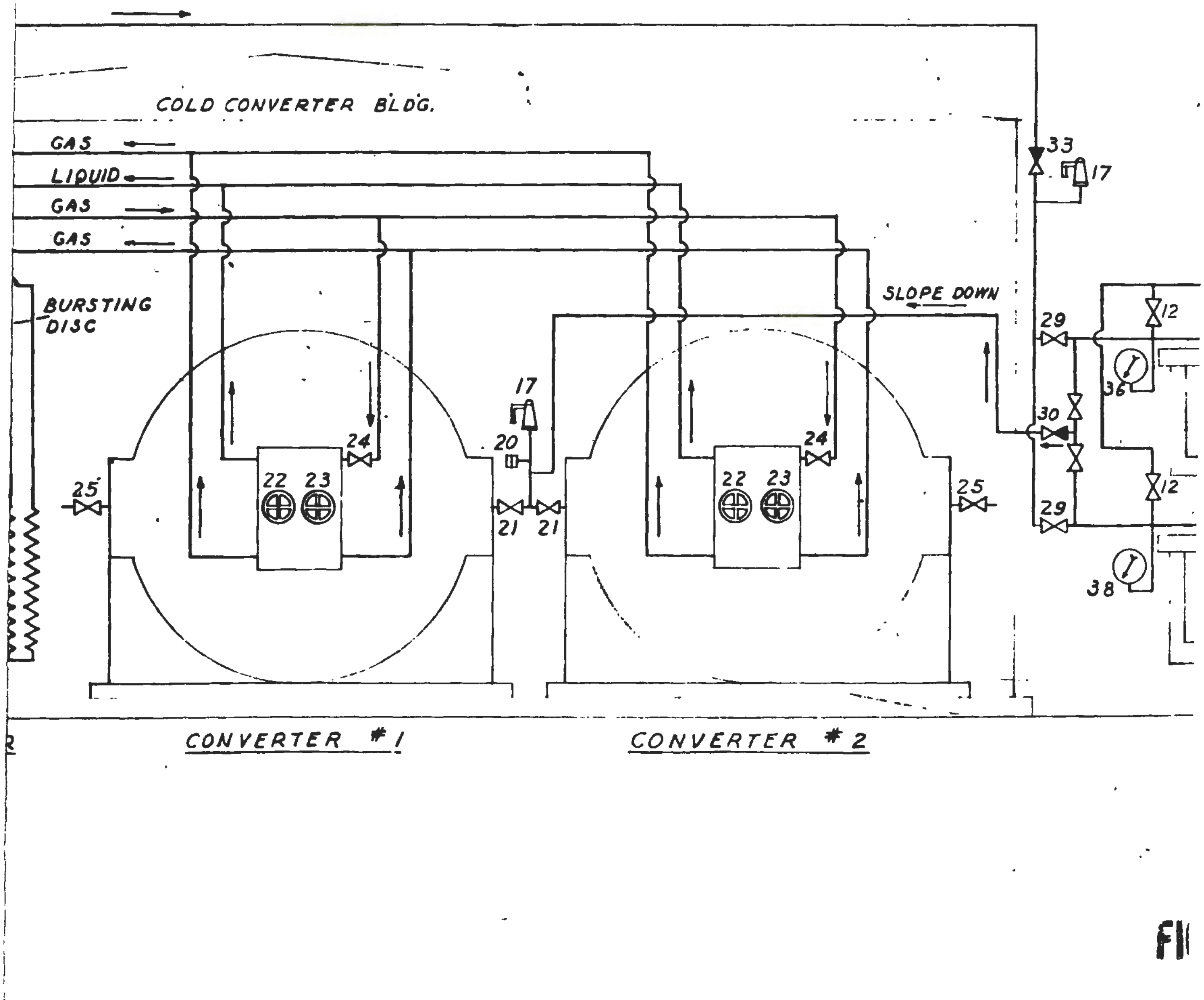
rawal Shut-Off Valve

ve
lve
Drain Valve
alve
e Valve
ut-Off Valve

.S.I.
S.I.

20 Bursting Disc Set at 385 P.S.I.
21 Cold Converter Filling Valve
22 Cold Converter Withdrawal Valve "Gas"
23 Cold Converter Withdrawal Valve "Liquid"
24 Inlet to Cold Converter Jacket Heater "Heater"
25 Cold Converter Blowdown Valve
26 Master Regulators
27 Back Pressure Valve
28 Regulator
29 Filter Thawout Valve
30 Filter Discharge Check Valve
32 Mercoid Control Set at 290 P.S.I.
33 Filter Thawout Line Check Valve

34 Liquid Withdrawal Valve
35 Left Hand Filters Inlet Pressure
36 Left Hand Filters Outlet Pressur
37 Right Hand Filters Inlet Pressur
38 Right Hand Filters Outlet Pressu
39 Right Hand Filter Assembly Drain
40 Pipe Line Shut-Off Valve
41 Receiver Regulator By-Pass Valve
42 Regulator Inlet Shut-Off Valve
43 Receiver Regulator Inlet Valve
44 Receiver Regulator Outlet Valve
45 Regulator Outlet Shut-Off Valve



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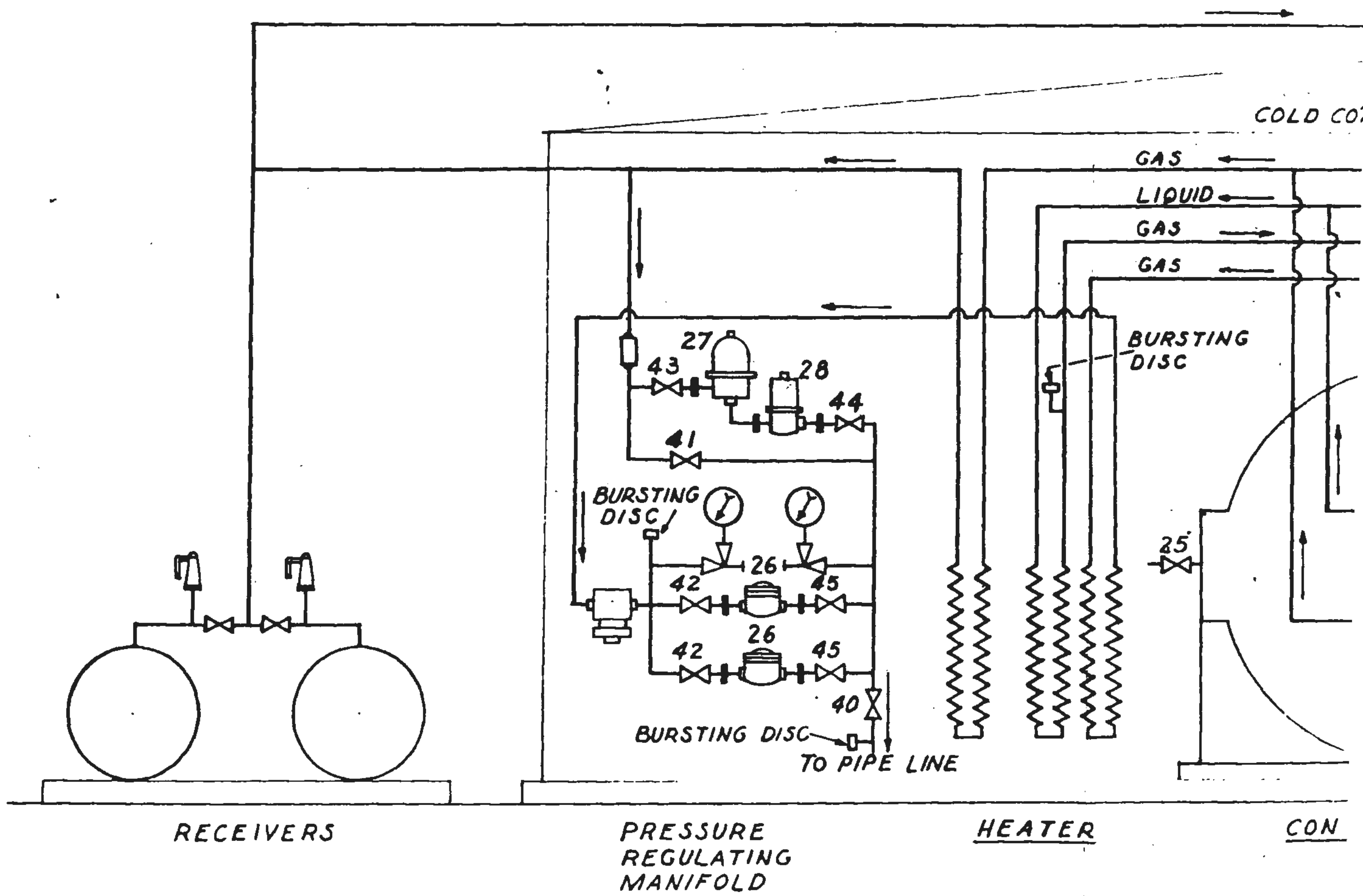
5 Pump Suction Valve
6 Storage Tank Liquid Withdrawal Shut-Off Valve
7 Pump Priming Valve
8 Pump Discharge Valve
9 Filter Assembly Inlet Valve
10 Filter Assembly Outlet Valve
11 Left Hand Filter Assembly Drain Valve
12 Filter Assembly Priming Valve
14 Storage Tank Back Pressure Valve
15 Storage Tank Gas Phase Shut-Off Valve
16 Filter Liquid Inlet Valve
17 Safety Valve Set at 350 P.S.I.
19 Safety Valve Set at 30 P.S.I.



[redacted]

nitrogen distribution system described in Paragraph 10-7 is supplied from this source.

b. Preliminary Engineering. - K-25 nitrogen gas requirements were estimated at 2,000,000 cubic feet per day. Kellex recommended that a plant be erected at the site to produce nitrogen by liquefaction and subsequent fractional distillation of air, but the District decided against such an installation because of the shortage of construction personnel. Construction of a plant to produce nitrogen by removal of oxygen from air using hydrocarbon combustion was also considered, but ruled out, because loss of combustion control over even limited periods would result in the formation of carbon monoxide. This was considered a possible source of barrier plugging. There was also evidence indicating that carbon monoxide could react with fluorine to form a highly toxic compound analogous to phosgene. The final decision involved the selection of a liquid nitrogen vaporization system. Process and equipment design was supplied by the Linde Air Products Company; building design and construction management were handled by Ford, Bacon, and Davis; the work was coordinated by Kellex.

c. Capacity. - The vaporization plant has an approximate design capacity of 1500 standard cubic feet of gas per minute at a dew point of -100°F.

d. Design. - The installation (Fig. 55) consists of equipment for receiving, storing, and filtering liquid nitrogen, vaporizing the liquid, and supplying gas by pipeline at constant pressure to the process and conditioning areas as required. It is housed within a 20 x 31 foot, one-story frame building, north of the conditioning building, and east of the fluorine generating building.

(1) Storage Tanks.- Two vacuum-insulated storage tanks are filled with liquid nitrogen from tank cars by means of transfer pumps.

(2) Pumps and Filters. - A twin pump assembly removes liquid nitrogen from the storage tank, and forces it through a battery of filters to a pair of converters.

(3) Converters and Vaporizers. - The "converters" provide temporary storage, and are maintained under slightly higher pressure than pipeline requirements. Liquid flows from a cold converter through a vaporizer, and through a pressure regulator to the line. Two small receivers are provided for accumulation of the normal evaporation from the converters. The rate of gas production is controlled automatically by a line pressure control valve. A drop in line pressure opens a valve in the steam line, evaporating liquid nitrogen to maintain the desired pressure. Outside the building, two four inch headers branch from the main nitrogen gas supply header. These supply Sections 300 and 1400 respectively.

11-8. Carbon Mixing Plant (K-1410). - In a large number of carbon traps throughout the plant, the carbon charge must be diluted by alumina pellets in order to avoid caking of the carbon in the event of a flow of concentrated UF . When carbon and alumina pellets are simultaneously poured into a vessel, or when a uniform mixture of carbon and alumina is poured into a vessel in such a way as to allow a conical pile to build up at the center, a natural segregation of the carbon occurs around the outside. Considerable care is, therefore, required when mixing the carbon and alumina pellets, and when charging a carbon trap with the mixture, to avoid this segregation.

a. Purpose. - It is the function of facilities in Building K-1410 to provide an adequate inventory of properly mixed carbon and alumina for charging the carbon traps of Sections 100, 300, 600 and the mobile disposal units. The specific services provided are:

1. Volume mixing of carbon and alumina pellets into storage drums.
2. Storage in drums and barrels of carbon, alumina and mixed carbon-alumina blends.

Three kinds of carbon alumina mixtures are prepared:

1. Two volumes of 2-4 mesh alumina to one volume of 2-4 mesh carbon; used in Sections 100 and 600.
2. One and one-half volumes of 2-4 mesh alumina to one volume of 6-8 mesh carbon; used in all process buildings from K-311-1 through K-302-5.
3. One and one-half volumes of 2-4 mesh alumina coated with 2 per cent cadmium by weight to one volume of 6-8 mesh carbon; used in all process buildings from K-303-1 through K-312-3, including temporary purge system at K-310-10 and, after Case II operation, in the purge system at K-302-5.

56-1

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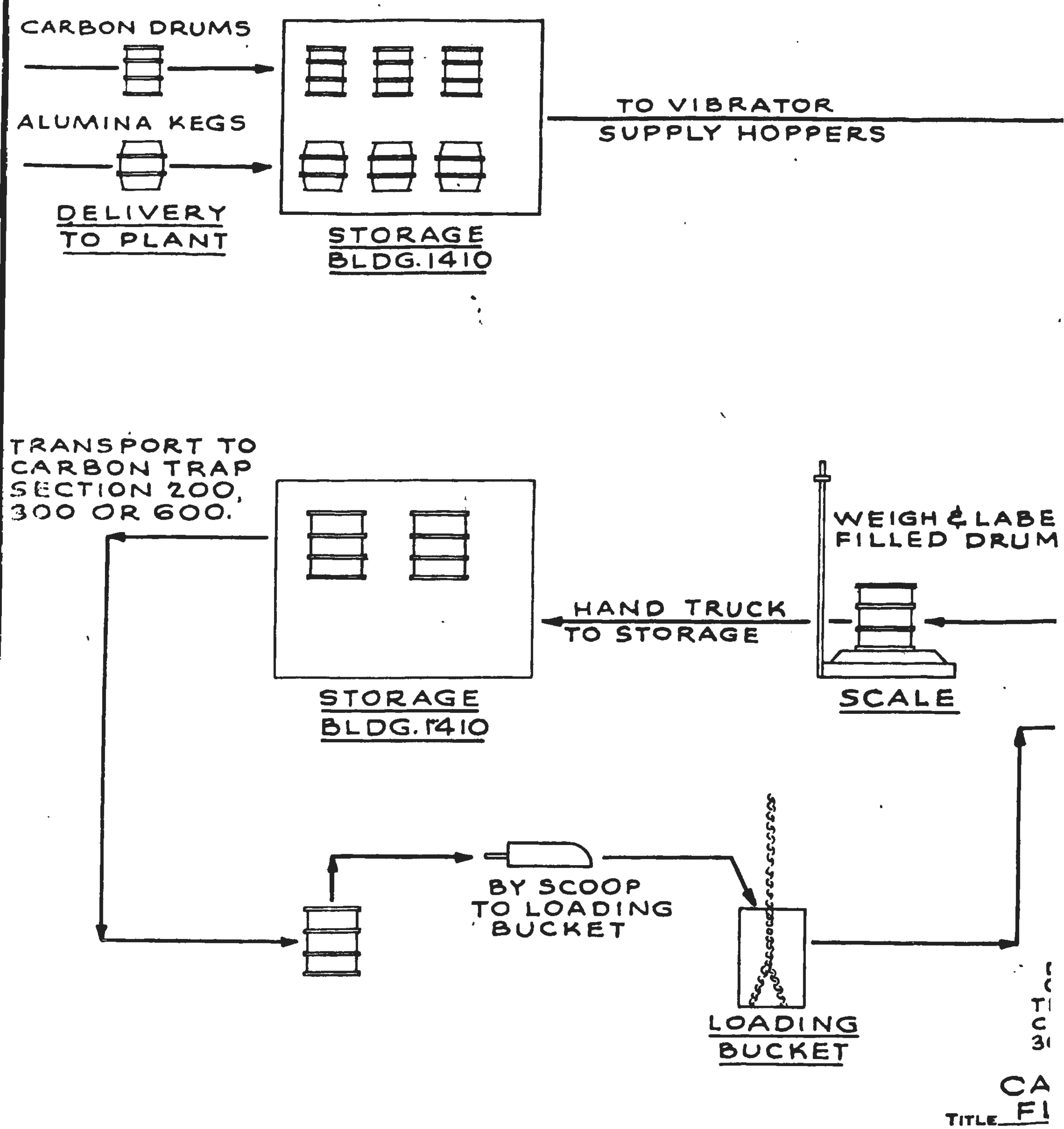

TITLE

FIG. 56

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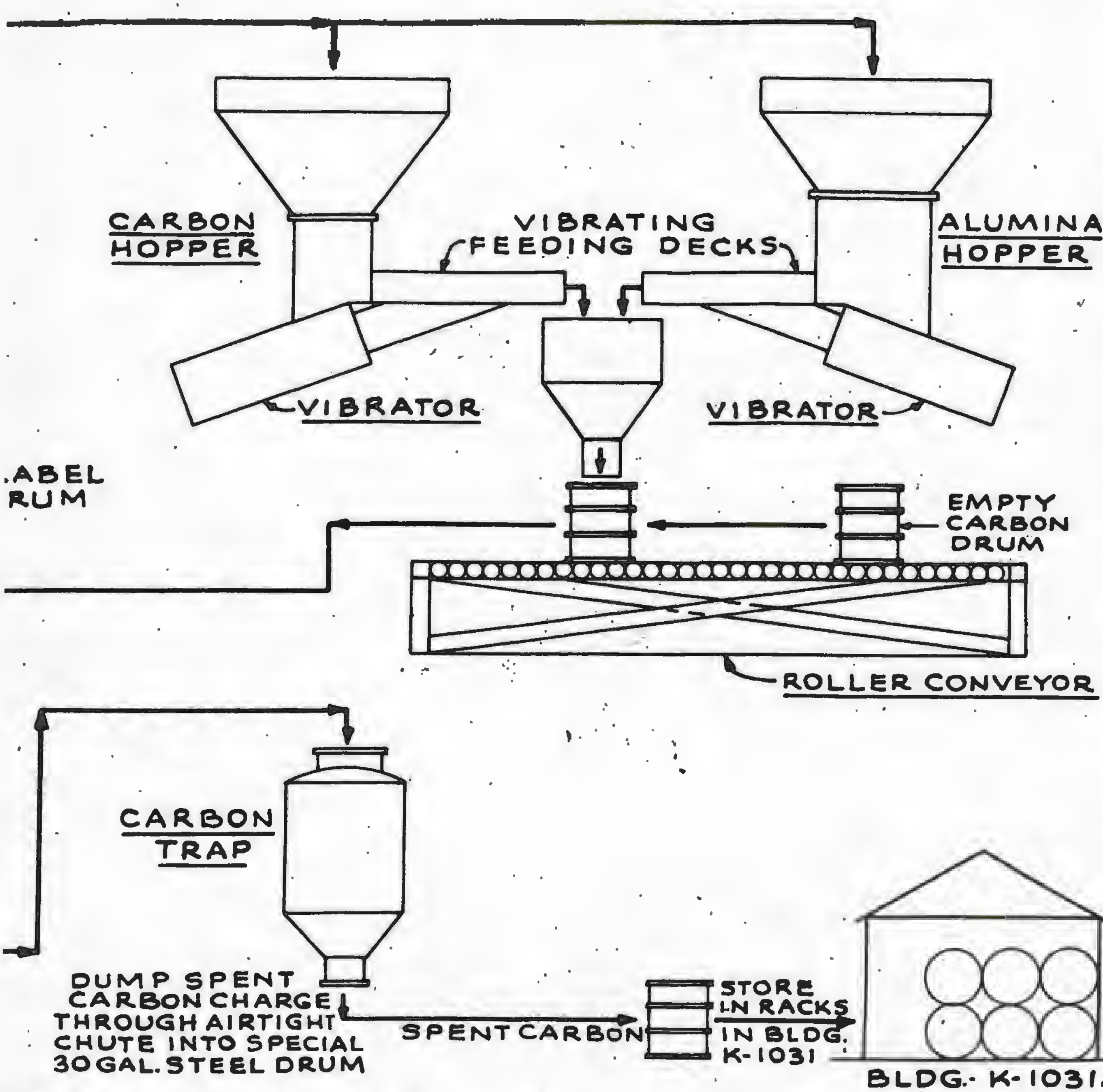

CARBON MIXING, MATERIALS
E FLOW SHEET.

			THE KELLEX CORP.	SCALE ___ DATE ___ AP. ___
...CRIPTION	DATE	CHECKED		DR. ___ TR. ___
REVISIONS				CKD ___ No. 400-O.D.

b. Design. - Building K-1410 is a single story 68 x 122 foot building. It is not located within the conditioning area, but is approximately due west of process building K-306-7. Drums of carbon and barrels of alumina are received for storage at the loading platform. When required for charge make-up, each drum is trucked to the mixing equipment (Fig. 56) under a trolley and electric hoist. One feed hopper is provided for carbon, and one for alumina. From these hoppers, the two materials drop to respective vibrating feeder decks, which deliver to a common blending hopper. The mixture is charged to drums through a flexible sock. The drum is manipulated by hand during filling so as to prevent coning, which would cause segregation of the carbon. Each drum is filled tightly to minimize joggling of the contents during later handling. A more extensive description may be found in Volume XXIV of the Kellex Operating Manuals.

11-9. Auxiliary Steam Plant (Section 1500).

a. Purpose. - The auxiliary steam plant furnishes steam for building and process heating purposes to the process, conditioning, and administration areas.

b. Capacity. - The original capacity of the steam plant (K-1501) was 120,000 pounds per hour at a pressure of 175 p.s.i. With the addition of the K-1531 annex, present total capacity is 270,000 pounds per hour.

c. Design. - The heating plant is located several hundred yards east of the north end of the conditioning building. The original facility contained three 40,000 pound per hour boilers, one 175 foot chimney, and equipment for water treatment and miscellaneous auxiliary

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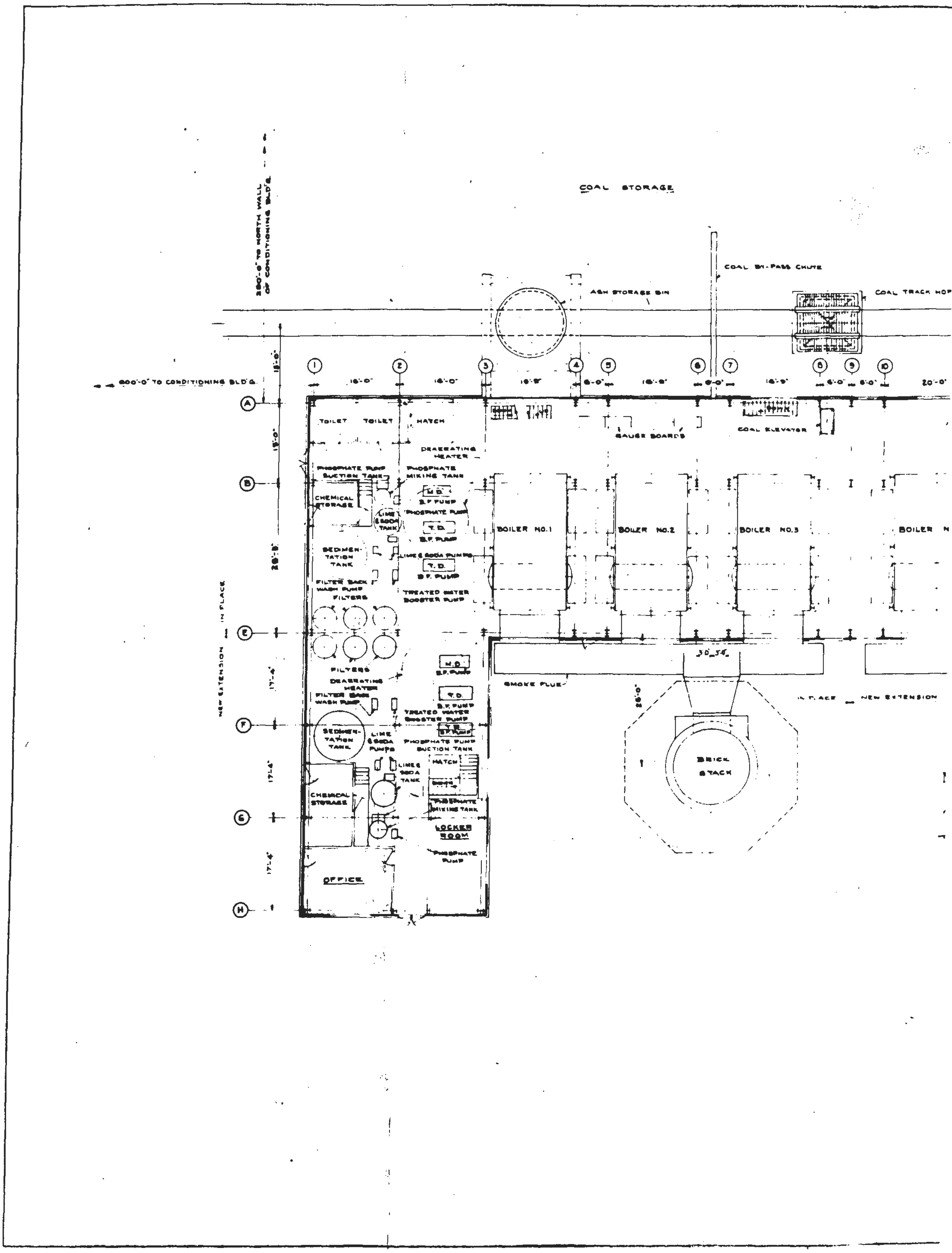

57-2

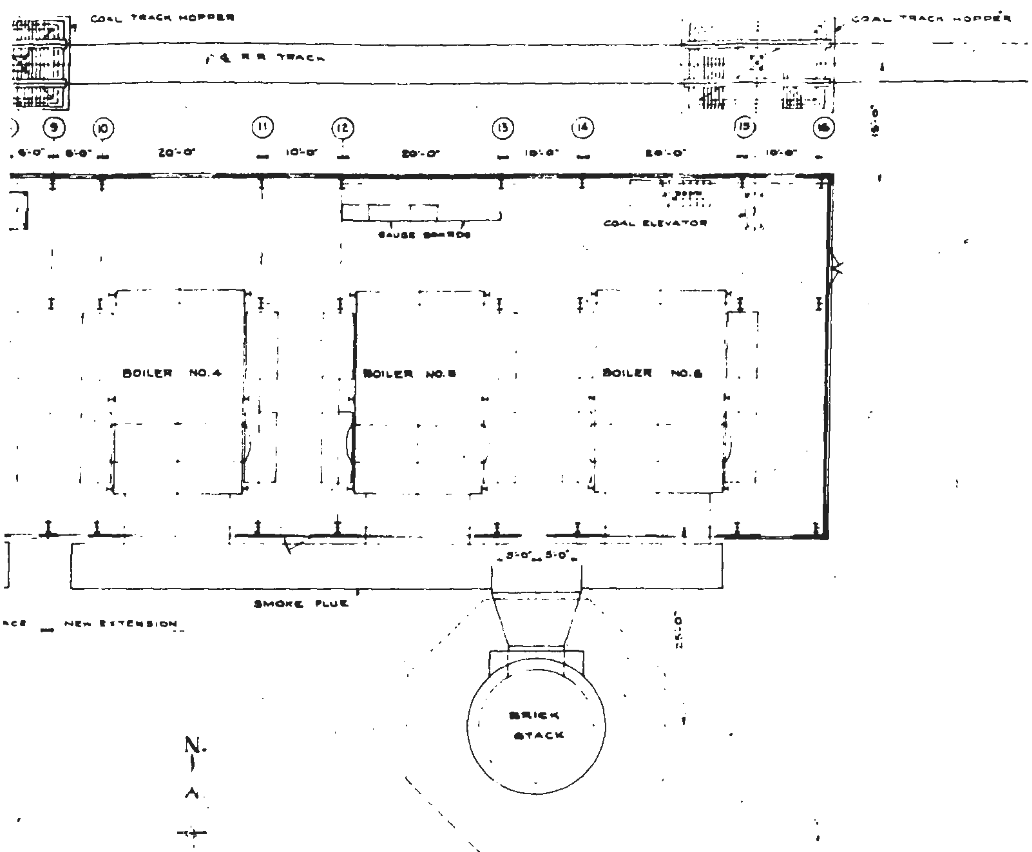

FIG. 57

GENERAL ARRANGEMENT PLAN

HEATING PLANT EXTENSION

SARGENT & LUNDY ENGINEERS CHICAGO, ILLINOIS

JOB NO 1405-7

M-316

services. When the K-27 plant was constructed, it became necessary to expand the steam generating facilities by installing three additional 50,000 pound per hour boilers (which were housed in a structure formed by extending the existing building eastward), and by construction of a second chimney. Additional auxiliary equipment was housed in a structure formed by extending the western portion of K-1501 in a southerly direction. The final layout is shown in Figure 57. The final overall structure is 197 feet long and 43 feet wide, and contains a 32 x 52 foot wing. The steam plant was designed by Sargent and Lundy, and built by the J. A. Jones Construction Company, under Kellex supervision.

(1) <u>Coal Handling Equipment.</u> - Coal delivered to the plant by rail or truck is dumped into one of two track hoppers. Conveyors located in the basement accept coal from the hoppers and deliver it to crushers. The crushed coal is then picked up by the elevators which in turn dump it onto scraper conveyors located on the roof. These dump the coal either into the boiler bunkers, or through a discharge chute leading to the ground, where bulldozers move it to the storage area. The coal handling equipment is composed of two 30 ton units, making a total capacity of 60 tons per hour.

(2) <u>Stokers.</u> - Each of the three stokers located on the main floor receives coal from the bunkers through a coal distributor which feeds coal to the grate through feeders on the front of each stoker. The 40,000 pound per hour boilers have 70 ton bunkers and three feeders per boiler. The 50,000 pound per hour boilers have 85 ton bunkers and four feeders per boiler.

(3) <u>Ash Handling Equipment.</u> - The ash is collected in

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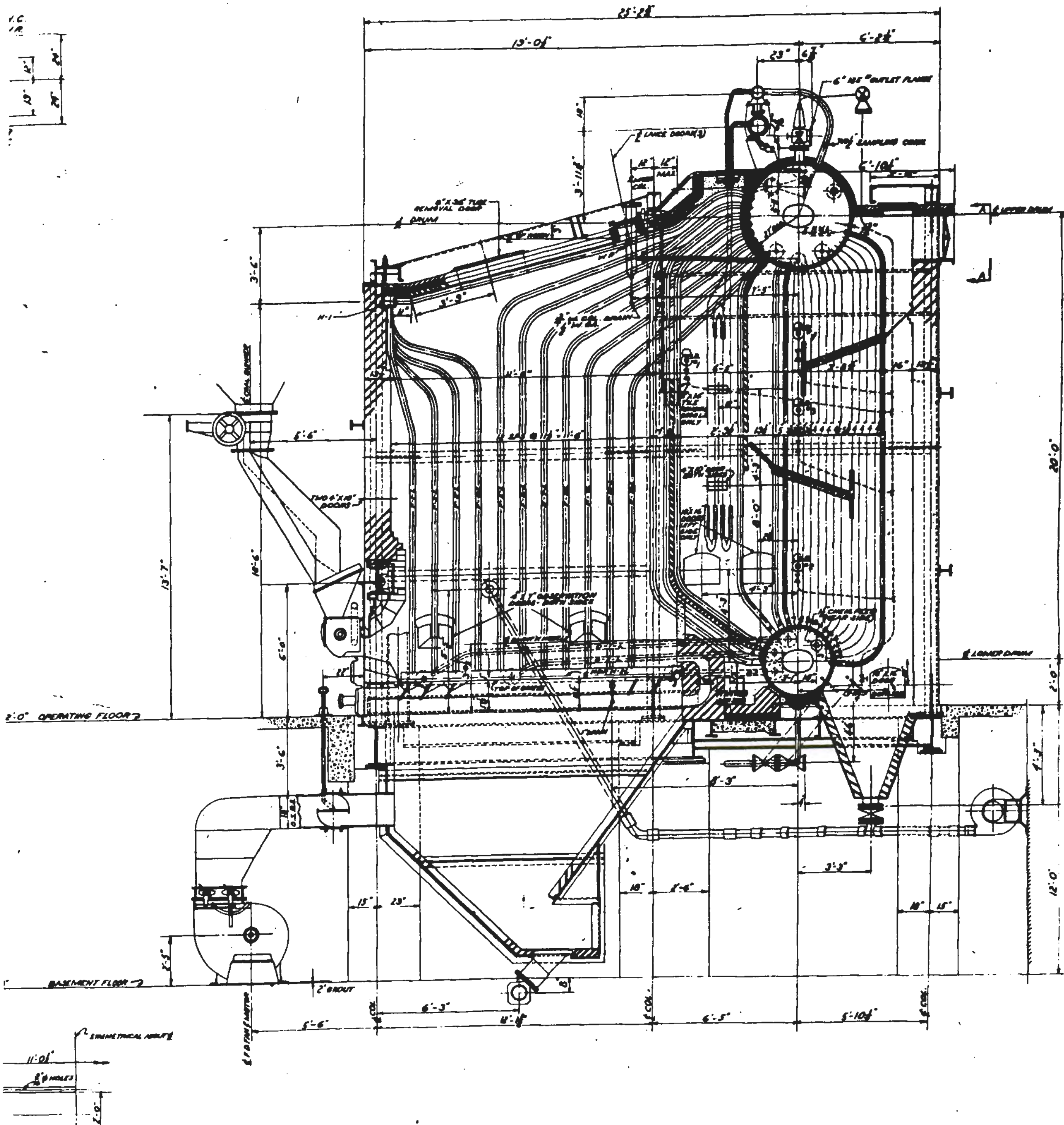

TYPICAL BOILER, K-1501

(40,000 pounds per hour)

FIG. 58

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58-2

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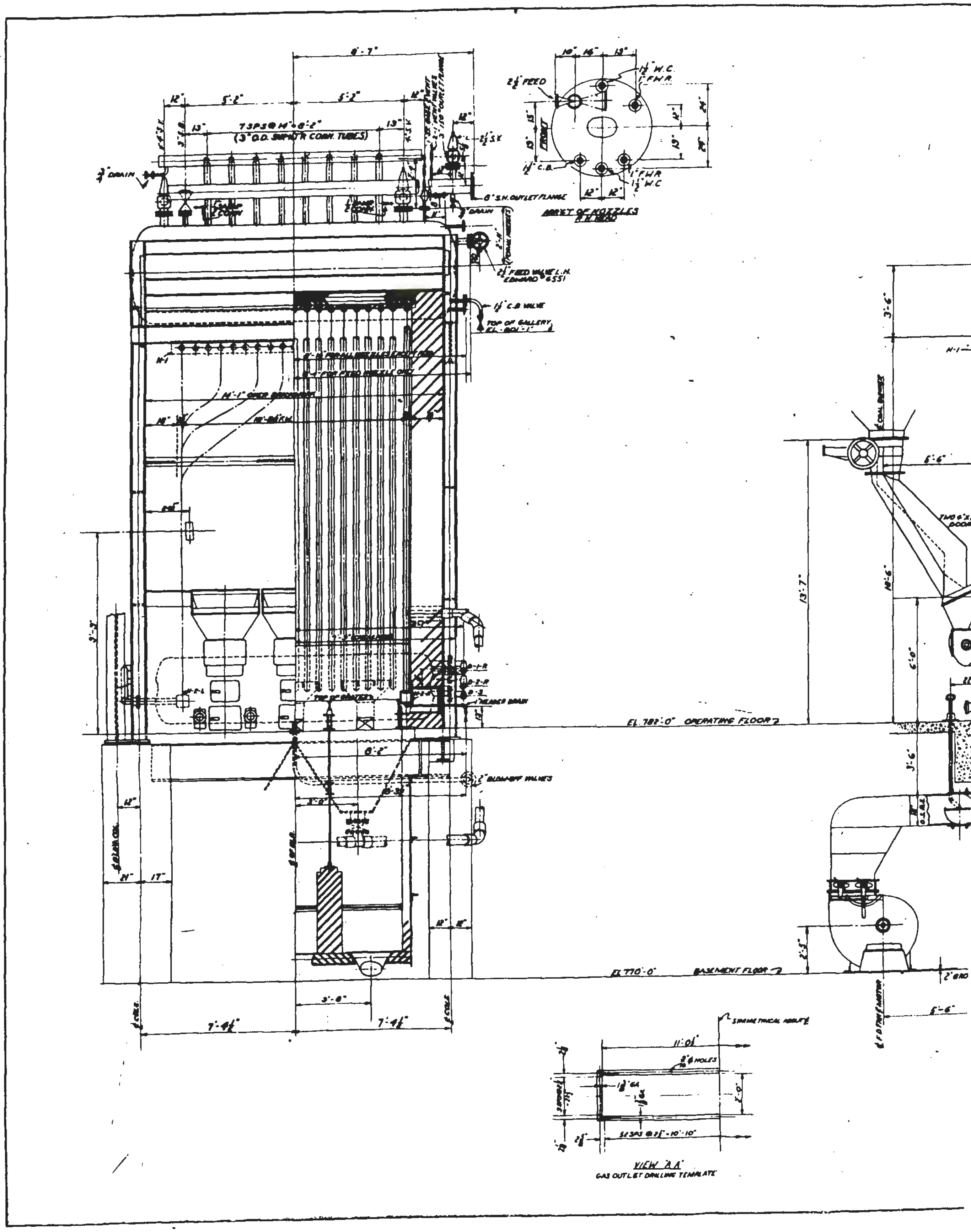


[redacted]

a hopper located in the basement under the stokers. A vacuum system removes the ash to an outside storage bin which discharges into railroad cars or trucks. The vacuum is created by a steam nozzle which discharges to the boiler breeching of either stack. Ash handling capacity is 7-1/2 tons per hour.

(4) Boilers. - The six boilers (Fig. 58), manufactured by Combustion Engineering Company, Inc., are of the two-drum, bent-tube, water-wall type. They are fed with $212^{\circ}F$ feed water, and operate at a steam pressure of 175 p.s.i., and a superheater outlet temperature of $477^{\circ}F$. The three smaller boilers (each of 40,000 pounds per hour capacity) are 24'-4-1/3" long by 14'-9" wide, and are spaced on 22'-9" centers. The three large boilers (each of 50,000 pounds per hour capacity) are 24'-4-3/4" long by 17'-6" wide, and are spaced on 30'-0" centers.

(5) Chimneys. - The two chimneys rise 175 feet above the main floor level. They are of radial brick construction supported on a reinforced concrete foundation. They have a diameter of approximately 17 feet at the base, and 9 feet at the top.

(6) Combustion Control. - Necessary control equipment is provided so that the boilers may be operated either automatically or manually. The methods are analogous to those used in the power plant, Section 700 (Par. 12-5e).

(7) Water Treatment Equipment. - The water treating equipment consists of two complete and similar systems, each composed of a softener, three filters, a deaerating heater, lime-soda feeder, phosphate feeder, flash tank, and heat exchanger. The make-up supply is

taken from the recirculating cooling water system, Section 800. Further details may be found in Volume V, Part I of the Kellex Operating Manuals, and Book X of the Kellex Engineering Descriptions.

SECTION 12 - POWER PLANT DESIGN

12-1. <u>General.</u> - The power plant area (designated Section 700) is one of the largest installations at the site, covers approximately 160 acres, and is located on the east bank of the Clinch River, about 8800 feet southwest of the main process area. Power generation facilities are designed to supply electrical power of extremely high dependability factor at frequencies varying from 45 to 130 cycles. Total design capacity is 238,000 KW. An additional 110,000 KW at the fixed frequency of 60 cycles, has been made available by connection with the Tennessee Valley Authority system.

12-2. <u>Design Bases.</u> - As soon as the main features of the diffusion cascade and its auxiliaries had been fairly well established, initial estimates of K-25 electrical power requirements were made.

a. <u>Load Requirements.</u> - It was originally calculated that the total electrical load would be approximately 193,000 KW, of which 2000 KW was to be 240 cycle variable frequency, 4000 KW was to be 120 cycle variable frequency, 110,000 KW was to be 60 cycle variable frequency, and 77,000 KW was to be 60 cycle constant frequency. It was considered that 27,000 KW (of the constant frequency load) could be of normal industrial dependability; all of the remainder would have to have an extremely high reliability factor. When plans for the construction of Section 5 of the diffusion cascade were cancelled in March 1945, the 240 cycle power block was eliminated. Originally estimated power requirements (App. F12), final design estimates, and actual installed capacity, are tabulated in Appendix D1. The 60 cycle band variable frequency load was to be distributed among seven different frequencies varying from 45 to 65 cycles. The 120 cycle band load was to be distributed between two different frequencies, each of which might have any value from 90 to 130 cycles. It was necessary to be able to change the frequency of each, and to maintain any desired frequency which might be found most suitable, in order to operate process pumps at most efficient speeds.

b. Selection of Power Source. - Careful studies were made to determine the best source of power. Consideration was given to procuring power from the Tennessee Valley Authority, and to constructing a steam power plant at the site. The decision was made to obtain power for the small, non-vital, fixed frequency load by means of a tie-in with the T.V.A. system (App. F17), but to build a power plant within the K-25 area to carry the vital and major portion of the load. Reasons for this decision, as opposed to drawing all power from Tennessee Valley Authority, were as follows:

1. An interruption of power supply to the K-25 process for more than the smallest fraction of a second would have a severely disruptive effect upon plant productivity.
2. Protection of the power station is simplest for an on-site power plant, and supply from an outside source involves the possibility of transmission line interruption resulting from sabotage or other factors.
3. Satisfactory operation of the gaseous diffusion plant demands a wide range of variable frequency power.
4. Acceptance of standard 60 cycle power from an off-site

source to supply the total K-25 load would necessitate conversion of this power to various and variable frequencies in large quantities, and would require a large amount of complicated rotating electrical machinery and control equipment. Such an arrangement would possess disadvantages as discussed below.

5. The availability of power from existing T.V.A. facilities was limited because other war-time activities within the Clinton Engineer Works area and adjacent regions had previously absorbed large blocks of power from this source.

c. Mode of Power Generation. - After the decision was made to construct a power plant at the site, it was necessary to choose between generation at the various required frequencies, and use of frequency-changing apparatus.

(1) Consideration of Rotating Frequency Changers. - It was not felt that this method would present the dependability demanded, since considerable new development work would be required in order to work out equipment designs capable of producing large quantities of power at frequencies which could be varied at will. Furthermore, the equipment would be highly complex, and would involve considerable attendant hazard to service.

(2) Consideration of Electronic Frequency Changers. - All of the larger manufacturers with experience in this field were consulted. The consensus was that an unduly long period of experimentation, design, and development would be necessary. Construction schedules therefore made this method unacceptable.

(5) Selection of Steam-driven Turbo-generators. Direct production at frequencies required was decided upon, since this method provides the most reliable power source, and the simplest source of variable frequency current. Equipment required would involve standard designs, and would therefore be most quickly obtainable, most easily operable, and have highest salvage value. It would also displace less war-essential equipment in industrial manufacturers' shops than any other type. Moreover, a fully equipped boiler plant, suitable for the major portion of the proposed installation was available, and plant foundation and piping drawings were essentially complete. The cost of the on-site variable frequency power generation method ultimately selected was not unduly greater than that of other methods.

d. Transmission to Process Area.

(1) Selection of Underground System. - Various possible methods of power transmission were considered. The dependability requirement ruled out overhead transmission because of the expected probability of occasional outages resulting from lightning and other weather contingencies.

(2) Choice of Cable Type. - Consideration was given to the use of oil-filled cables, cables carried in oil-filled pipes, gas-filled cables, and three-conductor, paper-insulated, lead-covered cables. The first two (oil-filled) types showed a larger overall cost, and presented operating disadvantages. The gas-filled cable is theoretically attractive for this service, but previous usage had been limited; it was rejected because of its experimental nature. The simplicity of installation and operation of the three-conductor, paper-insulated,

lead-covered cable, plus its reliability (proven by extensive prior industrial experience) led to its adoption for power transmission from the K-25 power plant to the process area (Par. 12-10c).

(3) Choice of Transmission Voltage. - Most of the power was to be generated at 13,800 volts. It was decided to transmit it at the same voltage level in order to avoid the necessity for both step-up transformer facilities at the power house, and high voltage switching in the process area. Furthermore, total reactance between generator and load is less at a 13,800 transmission voltage than at higher levels. In the case of the 120 cycle power, transmission was to be at the generation level of 4,160 volts.

e. Steam Rate Requirements. - Approximately 1,500,000 pounds of steam per hour were required for normal operation of the turbo-generator plant. It was decided to install three 750,000 pound per hour steam generating units, two of which would be required for normal operation, the third acting as a spare.

12-5. Procurement.

a. Steam Generating Units. - Two boilers of the desired type and capacity had been ordered by the Commonwealth Edison Company for its Fisk Station in Chicago, but this order had been cancelled at the request of the War Production Board. A great deal of work had been completed on these units, however, and, as their size fitted K-25 requirements very nicely, it was decided (and approved by War Production Board) to procure these boilers, thereby making available a large amount of previously completed design work, and greatly accelerating the progress of power plant construction. A third unit was ordered and constructed, identical in design with the first two.

b. Turbo-generators. - Ten turbo-generators were installed to carry the 60 cycle load (constant plus variable frequency). Most of the machines used had been ordered by prospective purchasers, and were in various stages of fabrication. By direction of the War Production Board they were re-routed to the K-25 Project. Four additional turbo-generators were obtained from the Allis-Chalmers Manufacturing Company in order to carry the 120 cycle load.

c. Auxiliary Equipment. - Specific items of power generation and distribution equipment are discussed in the remainder of this section. Procurement contracts, with summarized information pertaining to effective date, cost, scope of work, etc., may be found in Appendix A. Design and engineering for the power plant were handled by Sargent and Lundy (contract W-7412-eng-13) under the general supervision and direction of the architect-engineer, The Kellex Corporation. A schematic contract chart illustrating procurement channels for power plant equipment is shown in Appendix C5.

12-4. Coal Handling System. - An extensive system of coal handling equipment, furnished by Robins Conveyors, Inc., is designed to perform any of four functions:

1. Convey mine run coal from the railroad track hoppers to the coal breaker, and raw crushed coal to the boiler room bunkers.
2. Convey mine run coal from the railroad track hoppers to a screen, from which the fines are conveyed to the boiler room bunkers, and the larger sizes are conveyed

to a storage pile.

3. Convey mine run coal from railroad track hoppers to the storage pile without processing.

4. Convey coal reclaimed from storage to the breaker, and the boiler room bunkers.

Provision has also been made in the area design for a conveyor to be installed for unloading river barges. Capacity of the coal handling system is 350 tons per hour.

a. Track Scale (K-708E). - A railroad track scale with a capacity of 150 tons, is provided for weighing in coal received.

b. Coal Track Hoppers (K-708A). - Coal is received by rail over two duplex track hoppers with a combined capacity of 400 tons. Each hopper delivers to a duplex shaking feeder under the hopper pit which feeds coal to conveyor No. 1.

c. Coal Transfer House (K-708B). - Conveyor No. 1 transports and elevates the coal to a junction point, where the coal is delivered through a chute to conveyor No. 2. A scale is installed at the foot of this conveyor with a load indicator in the boiler house.

d. Breaker House (K-708C). - The coal is discharged by conveyor No. 2 to a hammermill breaker, which reduces the coal to a size which will pass through a 1-1/2 inch screen, and rejects foreign material through a discharge chute. The breaker consists of a drum, 12 feet in diameter and 22 feet long, driven by a 150 horsepower motor. The paddles are driven by a 50 horsepower motor. Conveyor No. 3 (fitted with a magnetic pulley and sampler) accepts the crushed coal, and transfers it to conveyor No. 4, which, in turn, transports and elevates

TABLE 5. - CONVEYOR DATA

NO.	LENGTH (feet)	BELT WIDTH (inches)	SPEED (ft./min.)	LIFT (feet)	DRIVE (h.p.)
1	157	42	250	46	40
2	322	42	250	55	40
3	26	48	250	level	10
4	173	36	350	56	40
5	330	36	350	53	40
6	25	42	275	22	15
7	1255	42	250	level	75
8	98	42	250	level	10
Hopper Feeder	7	42	40	level	7½
Stacker Booms (2)	33	42	300	10	7½

it to a junction point with conveyor No. 5. The latter conveyor carries the coal up and into the boiler house where a 36 inch, motor-driven, travelling tripper discharges it into bunkers.

e. <u>Screen House (K-706D).</u> - Coal intended for storage is received from conveyor No. 1 (at the junction point with conveyor No. 2) through a chute into conveyor No. 6 which delivers to a screen. Fines are discharged to conveyor No. 8 which transfers them to conveyor No. 2, the latter delivering to the boiler house bunkers. Screened lump coal is discharged through a hinged chute onto the reversing stacking-and-reclaiming conveyor No. 7.

f. <u>Stock Pile.</u> - Conveyor No. 7 is equipped with a motor-driven travelling stacker with two boom conveyors which form initial piles on either side. The storage piles are then formed by bulldozers. Coal is reclaimed from storage into a motor-driven reclaiming hopper located behind the stacker. This hopper is fitted with a belt feeder for regulating the flow on to conveyor No. 7, which, in reclaiming, is operated in reverse direction, and sends the coal to the boiler house bunkers by way of conveyors Nos. 8 and 2. The exterior storage pile is approximately 1100 feet long by 300 feet wide, with a conveyor running longitudinally through the center. The storage area is thus divided into two stock piles, each with a capacity in excess of 125,000 tons; yard storage capacity exceeds $1,000,000 worth of coal.

g. <u>Summary of Conveyor Data.</u> - Table 5 summarizes the characteristics of the coal handling system conveyors. A typical conveyor is shown in Appendix B13.

12-5. Combustion System.

a. Pulverizer Feeders. - Each boiler is served by a 1000 ton capacity bunker. Raw crushed coal is delivered from the bunkers, through automatic coal scales, to feeders which deliver coal at a controlled rate to the pulverizers.

b. Pulverizers. - Each boiler is supplied with pulverized coal by three bowl mills, manufactured by the Raymond Pulverizer Division, Combustion Engineering Company, Inc. Coal fed to a mill falls to the center of the revolving bowl, where it is thrown by centrifugal force between the rolls and the grinding ring. Primary air enters over the top of the bowl, picking up fines and carrying them through deflector openings to a classifier which recycles oversize particles.

c. Burners. - Pulverized coal is carried out of the classifier in the primary air stream, by suction from the exhauster (App. E14) through a 30 inch pipe. It is discharged tangentially through twelve burners, three at each corner of the furnace. The primary and secondary air is supplied to each boiler by two 96,000 CFM forced draft fans which draw warm air from the top of the boiler room, discharging it through the air heaters.

(1) Conversion to Oil Service. - In order to provide for emergency operation in case of coal shortage, one of the boilers was adapted for oil service in the spring of 1946 by suitable modification of burner facilities, and four 25,000 gallon fuel oil day tanks were moved in from the adjacent S-60 area, now in shutdown status (Book VI). The 6,000,000 gallon fuel oil tank farm, also available in the S-60 area, is in use for storage purposes.

d. Gas Handling Equipment. - Some of the gases may be by-passed around the superheater to prevent too high superheater temperature. All the gases pass through an economiser, air heater, and fly ash precipitator. The two induced draft fans of 167,000 CFM capacity for each boiler discharge to a twelve foot diameter steel stack. The three stacks extend 102 feet above the roof, which in turn is 135 feet above the basement floor.

e. Combustion Control.

(1) Methods. - The combustion control system is designed to permit operation by any of the three methods named below. The choice is independent for each of the three boilers.

(a) Automatic Control. - Pressure impulses from the main steam header cause regulators to function which proportion fuel feed, air and boiler feedwater flow, so that constant steam pressure is maintained. With automatic control, the operator must make observations and final adjustments for precise combustion conditions.

(b) Boiler Manual Control. - In this method, the boilers are regulated manually and individually from controllers on their respective control boards. The operator must make continuous observations and adjustments for precise control of combustion conditions and steam pressure.

(c) Hand Control. - The individual regulators are operated separately (either directly or through the boiler control boards). The operator must make observations, regulate steam pressure, regulate each controller separately in proper sequence, and make adjustments for desired combustion conditions.

(2) Variables.

(a) Fuel and Air Feed. - Fuel feed is controlled through regulators on the mill feeders, and primary air by regulators operating exhauster inlet dampers. Total air flow is controlled by regulators which position control vanes on the induced-draft fans.

(b) Furnace Draft. - Furnace draft is controlled automatically by regulators which control the forced-draft fan suction vanes. These regulators are actuated by impulses from the furnace pressure. They may also be controlled manually from the boiler boards.

(c) Feedwater Level. - Control is accomplished by two-element feedwater level regulators, which position the feedwater regulating valve in response to variations in drum level and steam flow. Each feed-water regulator may be remotely controlled from its particular boiler board.

(d) Steam Temperature. - Proper steam temperature is maintained by proportioning the gas flow through the superheater by means of a damper. This damper is positioned by three oil-operated regulators which are positioned from one hand wheel on the boiler gauge board.

f. Boiler Motor Interlocks. - The motors driving fans, coal pulverizing, and feeding equipment are electrically interlocked to prevent the occurrence of dangerous or undesirable furnace conditions as a result of improper operation, and to prevent damage to these motors and their connected equipment.

g. Electrical Precipitators. - Ash content of the coal is about 15 per cent. The gases passing through the boiler, carry half of this ash, about 85 per cent of which will pass through a 325 mesh screen. The CO_2 in the flue gases varies from 10 to 15 per cent, and the unburned carbon loss is about one-half of one per cent. An electrical precipitator type of dust collector is installed in the gas duct between the air heater outlet and the induced draft fan inlets of each boiler. The dust collector is used in order to minimize the amount of ash passing through the induced draft fans causing abrasion and wear, and to prevent a local nuisance resulting from large amounts of fly ash being discharged from the stack. Precipitation equipment (supplied by the Research Corporation) consists of the following for each boiler:

1. A main gas-tight chamber, containing four precipitator sections.
2. An upper gas-tight chamber containing the high tension bus beams which are connected, by means of jumpers through insulator bushings, to the high tension terminals mounted in housings on the precipitator roof.
3. Eight hopper bottoms below each precipitator. (There are also four hoppers below the inlet duct and four below the outlet duct.)
4. Electrically controlled, air-operated, collecting electrode vibrating systems.
5. High tension leads from the precipitator sub-station to the housings on the precipitator roof. Each lead is provided with an oil reservoir connected to the terminal located at the precipitator.
6. A remotely located precipitator sub-station where 440

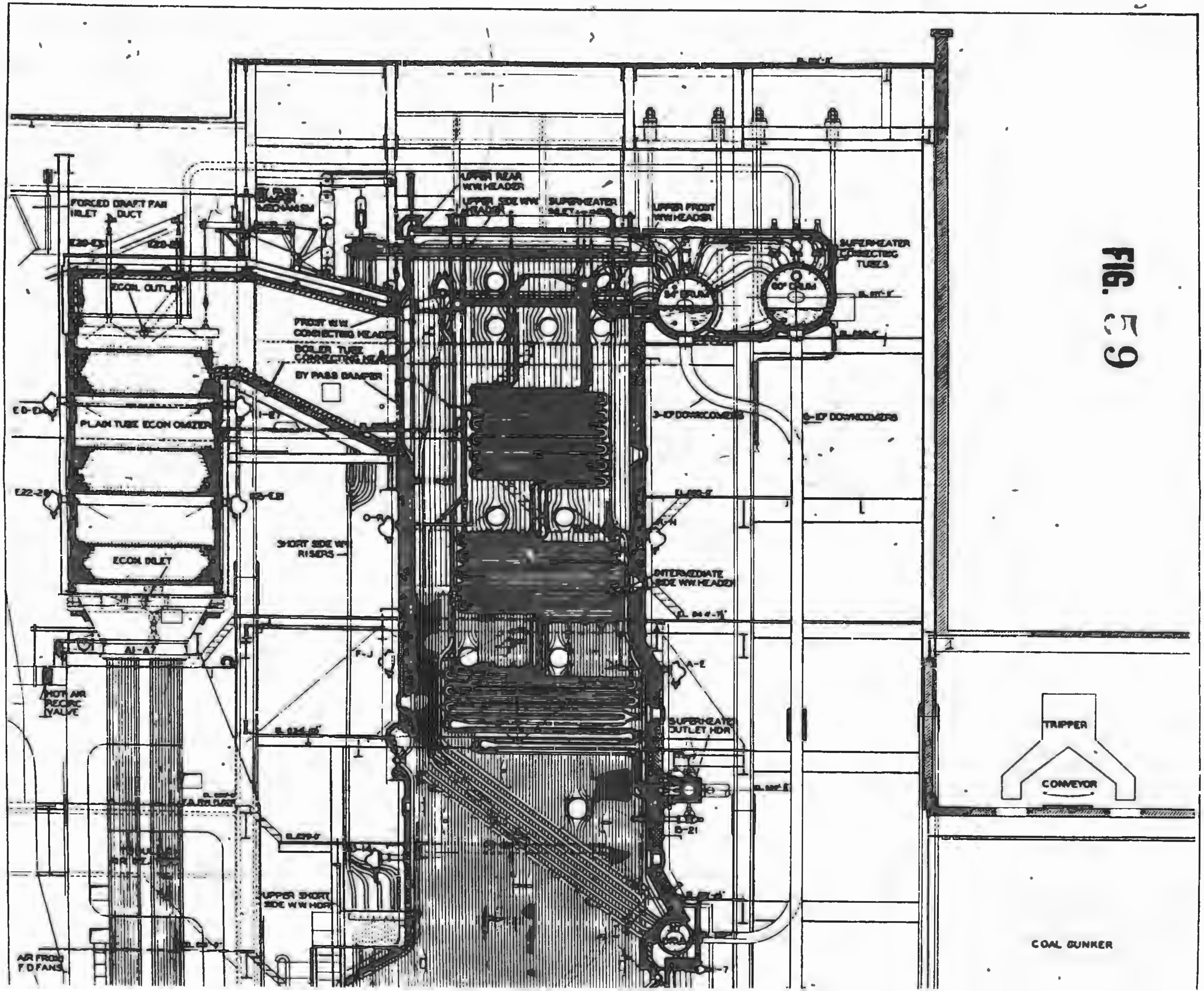
volt alternating current is converted to unidirectional current in the range of 65,000 to 75,000 volts, for use in the precipitator sections.

h. Fly Ash Disposal System. - Fly ash from the hoppers under the precipitators, and from hoppers under the precipitator inlet and outlet connections, is transported through a system of piping by a vacuum produced with two ejectors operating on service water. The water passes through a ring of small nozzles set in the ejector bodies, and converges in the Venturi throats. The air and dust drawn through the system mixes with the water, and is discharged into a splash pan in an air separator tank, where the air is liberated and released through a top vent connection. The mixture of dust and water is discharged from this tank by gravity to a point of disposal at a low region in the area approximately 800 feet from the building.

i. Ash Handling System. - Furnace slag runs continuously through two water-cooled slag holes in the furnace floor to water-filled tanks. The slag disintegrates, upon falling into the water, into small granular pieces. The tanks are emptied periodically into a pit at the south end of the boiler room basement. From the pit, the slag is pumped through an underground pipe running from the ash collecting tank to the same disposal area as the fly ash.

12-6. Steam Generation System.

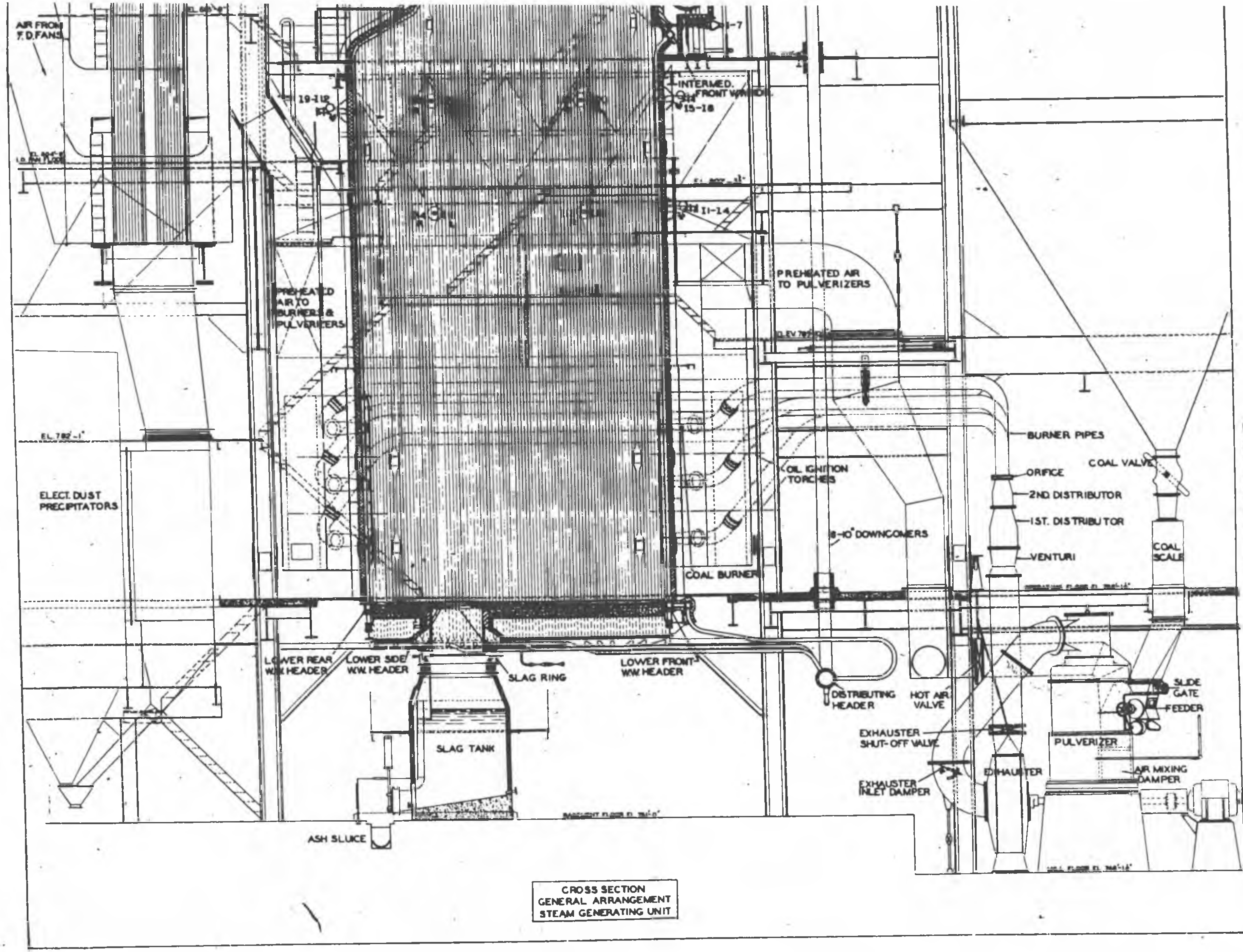
a. Steam Generating Units. - The boiler house (K-701) houses three Combustion Engineering Company tangentially fired steam generating units, each designed to produce 750,000 pounds per hour of superheated steam at 1325 p.s.i. and 935°F. Each unit consists of a



FORCED DRAFT FAN INLET DUCT
ECON. OUTLET
PLAIN TUBE ECONOMIZER
ECON. INLET
FRONT W.W. CONNECTING HEADER
BOILER TUBE CONNECTING HEADER
BY PASS DAMPER
UPPER REAR W.W. HEADER
UPPER SIDE W.W. HEADER
SUPERHEATER INLET HEADER
UPPER FRONT W.W. HEADER
SUPERHEATER CONNECTING TUBES
60" DRUM
3-10" DOWNCOMERS
SHORT SIDE W.W. RISERS
INTERMEDIATE SIDE W.W. HEADER
SUPERHEATER OUTLET HDR
HOT AIR RECIRC. VALVE
UPPER SHORT SIDE W.W. HDR
AIR FROM F.D. FANS
TRIPPER
CONVEYOR
COAL BUNKER

FIG. 59

1-67



CROSS SECTION
GENERAL ARRANGEMENT
STEAM GENERATING UNIT

39-2

three-drum, bent-tube boiler equipped with water-cooled furnace walls, a superheater with by-pass control, an economizer, and a tubular air heater (Fig. 59). The approximate distance from the basement floor to the center line of the upper drums is 120 feet.

(1) Boiler. - The main boiler tube bank consists of four staggered rows of 3 inch tubes.

(a) Lower Drum. - Leaving the lower 30 inch drum, these tubes are bent upward and toward the rear of the unit, where they are combined to form two vertical rows in the same plane. At the top of the unit the tubes are expanded into a round header.

(b) Separating Drum. - This header is connected to a 54 inch separating drum by means of 3-1/2 inch finned tubes which form the roof of the boiler. The 30 inch drum is connected to the separating drum by two rows of 3-1/2 inch uptake tubes at the front of the unit through a round header and its connecting tubes. The outside tubes are finned, and form the boiler front wall. The separating and lower drums are also connected by two 10 inch downcomer pipes.

(c) Offtake Drum. - A 60 inch offtake drum is located in front of the separating drum and 9 inches above it. These drums are connected by means of five rows of 3-1/2 inch water circulators. The 60 inch drum is also connected to the 30 inch drum by one 10 inch downcomer pipe.

(2) Furnace. - Furnace volume is 47,600 cubic feet. The front, rear, and side walls are water-cooled with three-inch bare tubes on close centers. These tubes are of bifurcated construction; that is, two wall tubes are forged together at top and bottom into one

nipple, which is expanded into the headers. The furnace bottom/ is water-cooled by three-inch tubes with cast iron block covering.

(a) Distributing Header. - At the lower front of the unit, there is a large round distributing header which is fed by six 10 inch downcomer pipes, four from the 54 inch drum, and two from the 60 inch drum. A system of 3-1/2 inch tubes from this header feeds the wall and floor tubes.

(b) Front Wall Tubes. - The front wall tubes connect through an intermediate header below the 60 inch drum to 3-1/2 inch riser tubes which pass through and above the main boiler bank. They are arranged in symmetrically staggered relation to the boiler tubes. These risers enter a square header at the top of the unit which is connected to the 54 inch drum by 3-1/2 inch tubes located immediately above the roof tubes.

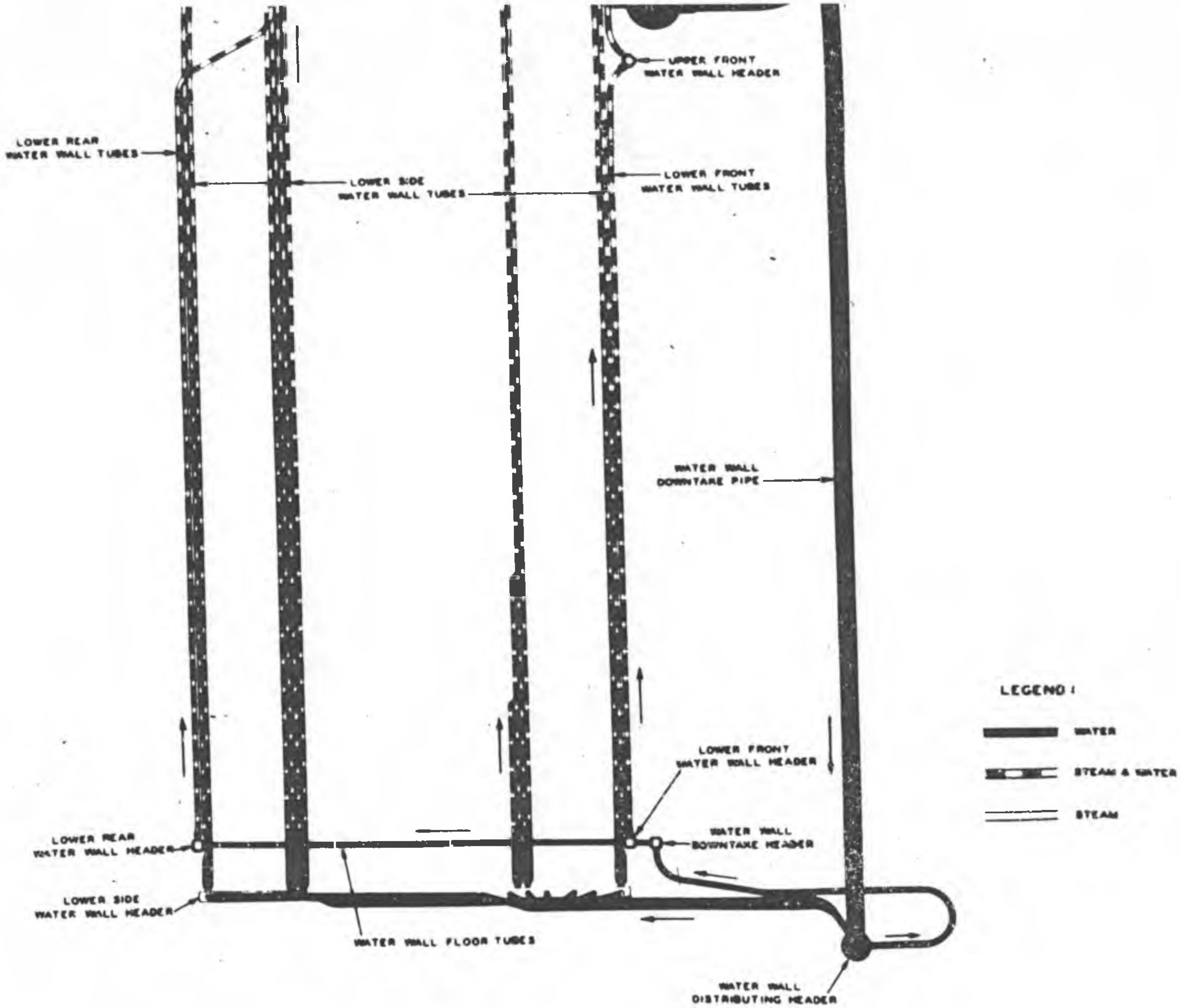
(c) Rear Wall Tubes. - The rear wall tubes are fed by the floor tubes, and connect through an intermediate header with the upper rear, or riser, tubes to a square header at the top of the unit. The outer tubes are finned and form the rear boiler wall. The top header is connected to the 54 inch drum by 3-1/2 inch tubes which form the top of the boiler.

(d) Side Wall Tubes. - The short side wall tubes at the rear of the furnace connect with 3-1/2 inch outside risers through an intermediate header, and the long side wall tubes connect with the upper side wall risers, also through an intermediate header. These risers are 3 inch finned tubes and form the boiler side walls. All side wall risers discharge into headers at the top of the unit which are connected by 5-1/2 inch tubes to the 54 inch drum. The water walls are suspended from the steel girt just below the level of the 30 inch drum, so that the furnace tubes can expand downward and upward uniformly from the point of support. The front and rear walls are tied through the floor tubes. The side walls are held in position against the floor tubes by means of tie rods and springs.

(3) <u>Superheater.</u> - The superheater is of the continuous loop type with 2-1/8 inch tubes. Saturated steam from the offtake drum enters the saturated header through 5-1/2 inch connecting tubes, and flows downward, counter to the gas flow. The steam leaves the superheater through a single 12 inch connection on the outlet header. The superheater is divided into three sections, the top and intermediate sections somewhat shorter than the lower section. This arrangement is made to provide a by-pass for the gases away from the upper sections for the regulation of the superheat. A vertical sliding damper is located at the boiler outlet, and is arranged so that, as it opens the by-pass connection, it also closes the normal gas outlet. This damper is divided into three sections with an operating cylinder for each section. The cylinders are actuated by a master control on the panel board.

(4) <u>Economizer.</u> - A continuous loop type economizer is located at the rear of the unit. It is arranged in two sections with separate inlet and outlet headers. The water enters at the bottom and flows upward, counter to the gas flow.

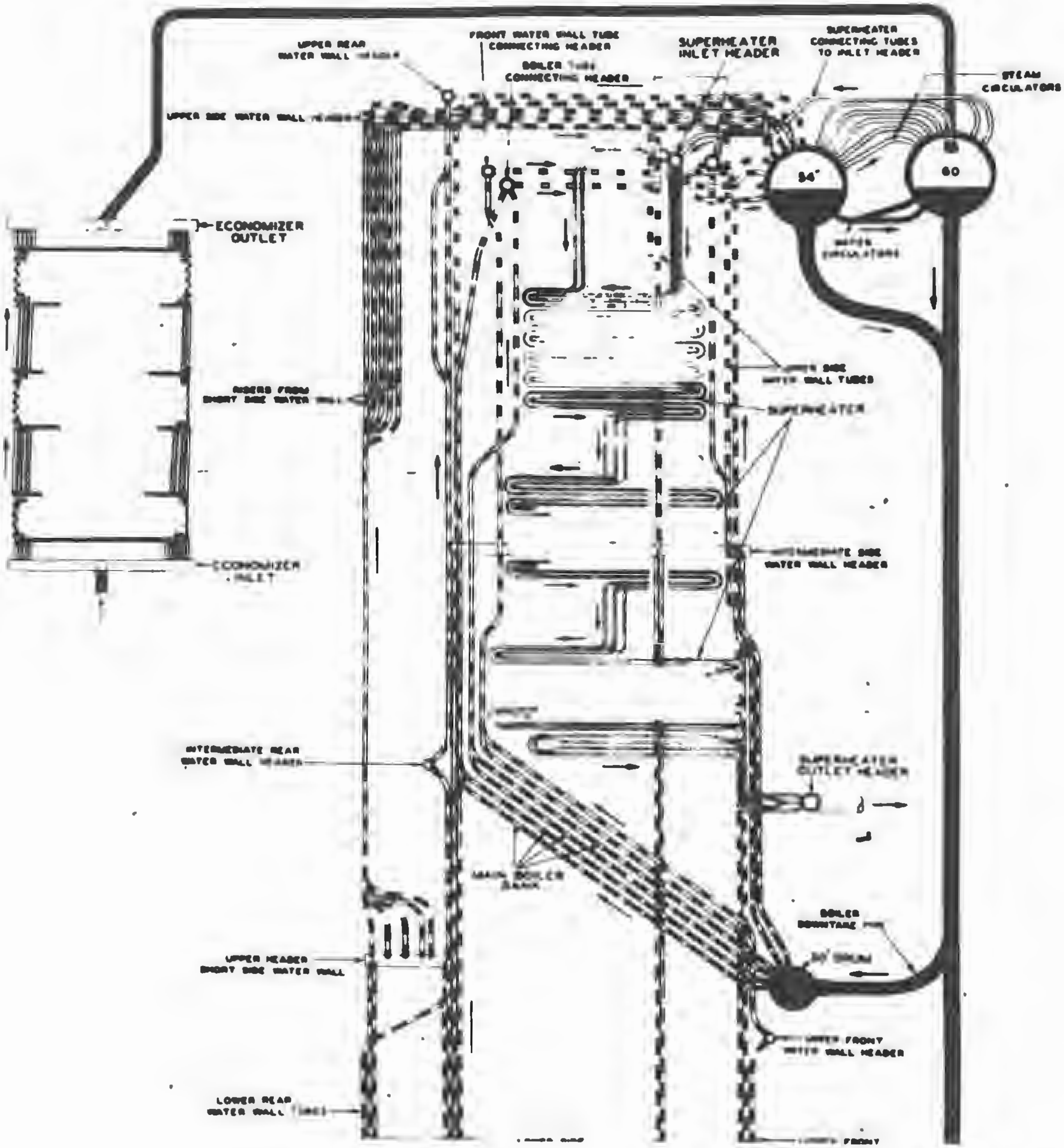
(5) <u>Air Heater.</u> - A tubular air heater is located at the rear of the unit under the economizer. Gas flows straight through



STEAM & WATER CIRCULATION DIAGRAM

FIG. 60

60-2



UPPER REAR WATER WALL HEADER
FRONT WATER WALL TUBE CONNECTING HEADER
BOILER TUBE CONNECTING HEADER
SUPERHEATER INLET HEADER
SUPERHEATER CONNECTING TUBES TO INLET HEADER
STEAM CIRCULATORS
UPPER SIDE WATER WALL HEADER
34"
60
ECONOMIZER OUTLET
WATER CIRCULATORS
UPPER SIDE WATER WALL TUBES
RISERS FROM SHORT SIDE WATER WALL
SUPERHEATER
INTERMEDIATE SIDE WATER WALL HEADER
ECONOMIZER INLET
INTERMEDIATE REAR WATER WALL HEADER
SUPERHEATER OUTLET HEADER
MAIN BOILER BANK
BOILER DOWNTAKE
30" DRUM
UPPER HEADER SHORT SIDE WATER WALL
UPPER FRONT WATER WALL HEADER
LOWER REAR WATER WALL TUBES
LOWER FRONT

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TABLE 6. - TURBO-GENE

UNIT NO.	MANU-FACTURER	IMPULSE STAGES	REACTION STAGES	STEAM PRESSURE P.S.I.	STEAM TEMP. °F	EXHAUST PRESSURE INCHES	OIL CAPACITY GAL.	CC
1	AC	1	33	1250	925	29	3200	Hydr
2	AC	0	51	1250	925	29	3200	Hydr
3	GE	19	0	1250	925	28.5	2400	Hydr
4	GE	19	0	1250	925	28.5	2400	Hydr
5	W	1	29	1250	925	29	2400	Hydr
6	GE	19	0	1250	925	28.5	2400	Hydr
7	W	1	46	1250	925	29	2400	Hydr
8	W	1	46	1250	925	29	2400	Hydr
9	GE	14	0	1250	925	28.5	1000	Ai
10	GE	14	0	1250	925	28.5	1000	Ai
11	AC	1	29	600	750	29	330	Ai
12	AC	1	30	600	725	29	330	Ai
13	AC	1	30	600	725	29	330	Ai
14	AC	1	30	600	725	29	330	Ai

NOTE: AC - denotes Allis-Chalmers Manufacturing Company
GE - denotes General Electric Company
W - denotes Westinghouse Electric and Manufacturing Comp

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ABLE 6. - TURBO-GENERATORS

UST SURE ES	OIL CAPACITY GAL.	COOLED BY	OUTPUT KW	P.F.	KVA	VOLTS	PHASES	CYCLES	RP
)	3200	Hydrogen	35,000	0.8	43,750	13,800	3	45-65	36
)	3200	Hydrogen	25,000	.8	31,250	13,800	3	45-65	36
.5	2400	Hydrogen	25,000	.7	35,714	13,800	3	45-65	36
.5	2400	Hydrogen	25,000	.8	31,250	13,800	3	45-65	36
)	2400	Hydrogen	20,000	.7	28,570	13,800	3	45-65	36
.5	2400	Hydrogen	25,000	.8	31,250	13,800	3	45-65	36
	2400	Hydrogen	25,000	.8	31,250	13,800	3	45-65	36
	2400	Hydrogen	25,000	.8	31,250	13,800	3	45-65	36
.5	1000	Air	12,500	.8	15,625	13,800	3	45-65	36
.5	1000	Air	10,000	.8	12,500	13,800	3	45-65	36
	330	Air	1,500	.7	2,143	4,160	3	90-130	36
	330	Air	3,000	.7	4,286	4,160	3	90-130	36
	330	Air	3,000	.7	4,286	4,160	3	90-130	36
	330	Air	3,000	.7	4,286	4,160	3	90-130	36
			238,000						

ring Company

d Manufacturing Company

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from top to bottom, counter to the direction of air flow. Air enters at the bottom side, and makes three passes across the tubes, leaving at the top.

(6) Cleaning Equipment. - Special care has been taken in the boiler design to prevent the boiler bank, superheater, and water wall surfaces from being fouled by slag and dust, and a complete system of mechanical soot blower units has been provided.

b. Boiler Feed Pumps. - There are 6 eight-inch, six-stage Worthington centrifugal pumps located on the main floor of the boiler room (App. E15). The capacity of each pump is 600,000 pounds per hour against a head of 1600 p.s.i. Two are driven by 1540 horse-power Westinghouse impulse type turbines; the others are motor-driven.

c. Pressure Reducing and Desuperheating Station. - Turbo-generator units Nos. 11, 12, 13, and 14 (and a turbine-driven exciter) use steam at 600 p.s.i. This steam is taken from the high pressure header through a pressure reducing and desuperheating station, which will pass a maximum of 100,000 pounds of steam per hour. The desuper-heater admits high pressure feed water to the steam, thus reducing its temperature to 750°F. The water flow through the nozzle is controlled automatically, through a bellows-operated valve, by a thermal element located in the piping approximately 25 feet downstream.

d. Condensate Pumps. - There are a total of twenty-four Allis-Chalmers condensate pumps, ranging in capacity from 40 to 600 GPM, and with discharge heads ranging from 840 to 900 feet.

e. Water and Steam Circuit.

(1) Boilers. - Water enters each boiler (Fig. 60)

through the economiser, where its temperature is increased by the heat remaining in the flue gases. The heated water then enters the offtake drum. Water from the bottom of this drum flows through the water wall downtake pipe into the lower distributing header, then rises through the furnace water wall. The mixture of steam and water enters the separating drum from which it circulates through the boiler tubes. After passing through the moisture eliminators in the separating drum, the dry steam is conducted through the three sections of the superheater to the outlet header, and then to the main steam header, from which it is distributed to the individual turbines, flow being regulated by the respective turbine governor control valves.

(2) Turbines. - Units 1 to 10 have extraction steam openings for three-stage feed water heating and evaporator makeup. Turbines 11 to 14 each have one extraction opening each for feedwater heaters.

(3) Condensers. - The exhaust steam from each turbine discharges directly into a condenser, and condensed steam is received by a deaerating hot well. From four outside storage tanks, the condenser hot wells also receive the required make-up water, which enters the system at this point.

(4) Condensate Pumps. - Condensate pumps take suction from the condenser hot wells, and discharge to the feed-water heaters. These pumps also return any excess water in the system back to the storage tanks.

(5) Feedwater Heaters. - The cold side receives condensed turbine exhaust, which, after being heated, flows through

the boiler feed pump suction header. The hot side receives extraction steam from the turbines. After condensing, it is either pumped back to the condensate system, or flashed back to the condensers.

(6) Boiler Feed Pumps. - The six boiler feed pumps take suction from the boiler feed header, and discharge into a common header supplying the boilers, through the economizers.

(7) Evaporators. - Three 25,000 pound per hour evaporators are installed for furnishing the necessary make-up water to the system.

(a) Hot Side. - For heating, either extraction steam from the main turbines is used, or exhaust steam from the boiler feed pump turbines. This steam, after condensing in the evaporator coils, is pumped back to the boiler feed pump suction header.

(b) Cold Side. - Make-up water from the Clinch River passes through a deaerating heater, and is pumped to the evaporators. The resulting vapor is condensed in the intermediate pressure feedwater heaters, and then pumped back to the condensate header, or flashed back to the condensers.

(8) Water Treatment Plant. - A Permutit Company 75,000 pound per hour cold carbonaceous process water treating plant was installed in order to overcome difficulties encountered with raw water sludging in the deaerating heater and evaporator feed pumps. This treating plant takes filtered and chlorinated water from the reservation domestic water supply. The water passes through Zeokarb* tanks and a degasifier, thence to a concrete storage tank, from which it is supplied to the deaerating heater.

12-7. Turbo-generators. - There are fourteen turbo-generators (App. E16) installed in the turbine room (K-702). Characteristics of these machines are summarized in Table 6. All are provided with separate motor-generator set exciters, and with suitable lubrication and governing facilities. A spare steam-driven exciter is also provided to serve any turbo-generator in time of emergency. The turbine condensers operate at vacuums of 28 to 29 inches of mercury, and have a total heat transfer area of 224,870 square feet. Total condensing capacity is 1,737,840 pounds per hour, using 254,000 gallons per minute of cooling water.

12-8. Cooling Water System.

a. Crib House (K-705). - Clinch River water is drawn in from a fifty-foot forebay, protected by a steel grill which screens out driftwood and debris, and passes through the crib house which contains four travelling screens.

b. Pump House (K-706). - Water flows from the crib house, through an intake tunnel, stop logs, and sluice gates, into wet wells under the pump house. Cooling water is pumped to the turbine condensers by means of three Worthington vertical shaft, propeller pumps (App. E10), each pump with a capacity of 82,500 GPM and discharge head of 30 feet. The pumps are driven by 700 horsepower 2300 volt motors. An electrically operated rubber-seated butterfly valve is located in the discharge line of each pump. Five service water pumps, and two ash sluice supply pumps, are also installed in this building. The circulating pumps discharge into a 78 inch header through their respective 54 inch discharge lines. The pump discharge header feeds a 66 inch condenser supply header in the turbine room. When the S-50 plant was in operation, its process cooling water was supplied from this pumphouse (Par. 12-9).

c. Discharge Flume (K-702A). - Water leaving the condensers is discharged into ten wells connected to a 10 x 10 foot reinforced concrete discharge tunnel 1006 feet long, which connects with a 2200 foot stone-lined flume 25 feet deep. The flume connects with a second 10 x 10 foot reinforced concrete tunnel discharging into Poplar Creek.

12-9. Steam and Condensate System for S-50. - The construction of the K-25 power plant was completed well before its full generating capacity was needed for operation of the process plant and auxiliaries (Vol. 4). In order to advance the overall Manhattan District program by utilizing the available K-25 steam-generating facilities, the Liquid Thermal Diffusion (S-50) plant was constructed adjacent to the K-25 power house in the latter part of 1944 (Book VI). The bulk of that plant's requirements for process steam, cooling water, and electrical power was then supplied by the K-25 power plant (Vol. 5) for approximately one year, until its full capacity was required for K-25 operations. In order to adapt the power plant to this service, which was not originally contemplated, it became necessary to design and install equipment for sending 1,500,000 pounds per hour of 1250 p.s.i. steam at 925°F to the S-50 Plant, and for handling the same amount of 1000 p.s.i. hot water return at 545°F.

a. Section 750. - Two heat exchangers to cool the hot water to 350°F, and two pressure reducing valves to reduce the pressure to 250-300 p.s.i. were installed. The cooling medium in the heat exchangers was condensate from the turbine condenser hot wells. The cooled water was passed through a pressure reducing valve, and then combined with this condensate. This stream was fed to the boiler feed pump suction header. Excess hot water that could not be cooled by the available condensate was diverted to flash tanks located outside the east turbine room wall. The hot water was flashed to atmospheric pressure, and resulting steam and condensate sent into the main condensers. A relief valve, leading back to the flash tanks, was installed on the boiler feed pump suction header for the protection of the condensate system in case the pressure valves should be accidentally opened. Relief valves were also installed on the flash tanks to protect the main condensers from overpressure.

b. Section 760. - To supplement the equipment of Section 750, additional evaporator and condensate handling equipment was installed and identified as "Section 760".

12-10. Electrical Distribution System. - The power supply to the process area is divided into two general systems: the first supplies constant frequency 60 cycle power; the second is further divided into nine different sub-systems, seven of which may operate at any frequency between 45 and 65 cycles, and two of which may operate at any frequency between 90 and 130 cycles. Utilization voltages are 2400, 480, 208, and 115, the latter two levels serving principally for lighting, heating, and miscellaneous small motors. The remainder of this paragraph presents a brief description of the K-25 electrical system. Further details may be found in Volume V, Part II of the Kellex Operating Manuals, and in Book XI of the Kellex Engineering Descriptions.

a. Main Switch House (K-704). - The main switch house is a three-story brick building, 635 feet long by 46 feet wide, located approximately 150 feet from the turbine house. All electrical power used within the K-25 plant (exclusive of K-27), either generated in Section 700, or received from T.V.A., passes (via underground cables) through K-704, which forms the control center for the transmission system to the plant area. A master control station, and the required 13,800 volt switchgear are installed on the top floor. The ground floor is used for bus connections, potential transformers, dis-connect and pothead enclosures, and miscellaneous auxiliary equipment. The basement is a conduit and cable room (App. E17).

(1) Auxiliary Switch House (K-707). - A four-story brick building, 200 feet long by 30 feet wide, and located behind the boiler house, contains electrical switch gear and controls for the regulation of power supplied to the power house area itself.

b. Outdoor Switchyard (K-709). - Connection with the T.V.A. system is made through a switchyard northeast of the main switch house. Power received is stepped down from 154,000 volts to 13,800 volts by means of three 40,000 KVA power transformers, each of which is equipped with an accessory regulating transformer to permit changing the voltage ratio under load. The low voltage sides of these transformers are tied to the 60 cycle constant frequency bus in the main switch house. There are three incoming 154,000 volt lines to K-709: one direct feed line from the T.V.A. hydroelectric plant at Fort Loudon, one tie-line from the No. 2 Elza Sub-station, and one tie-line from the K-27 switchyard (K-732). The K-27 electrical system is supplied entirely from T.V.A. sources, and is described in Paragraph

14-5. Further details of the general C.E.W. electrical system, and T.V.A. supply connections, are presented in Book I, Volume 12.

c. Main Transmission Lines. - All power is carried from the main switch house to the utilization area by means of underground cables, enclosed within fibre ducts, and encased in concrete. The ducts are grouped in banks of six, and provided with manholes 500 feet apart. Thirteen duct-banks (including spares) are installed between the switch house and the junction manholes near the process area. From the junction manhole area, seven duct banks are carried along the east side of the process area buildings, and seven ducts along the west side. At a point just south of the end of the main process buildings, one bank branches off to the right, and continues north within the cascade court. From the junction manhole area, one run also branches off to supply the administration and conditioning areas. The generation and transmission voltage on the constant frequency system, and on the variable frequency system in the 45 to 65 cycle band, is nominally 13,800 volts at 60 cycles, and proportional at other frequencies. The cables which carry this power to the utilization area (14 for the constant frequency system and 36 for the 45-65 cycle frequency system) are of the 3-conductor, lead-covered type, insulated with 1/4 inch of impregnated paper. The nominal voltage on the 90 to 130 cycle band of the variable frequency system is 4160 volts. The 8 cables which carry this power to the utilization area are of the 3-conductor, lead-covered type, insulated with 3/16 inch of varnished cambric. Shielding is provided on all cables in order to equalize the voltage stress on the insulation, and to assure that most faults will be phase to ground faults. Cable sizes

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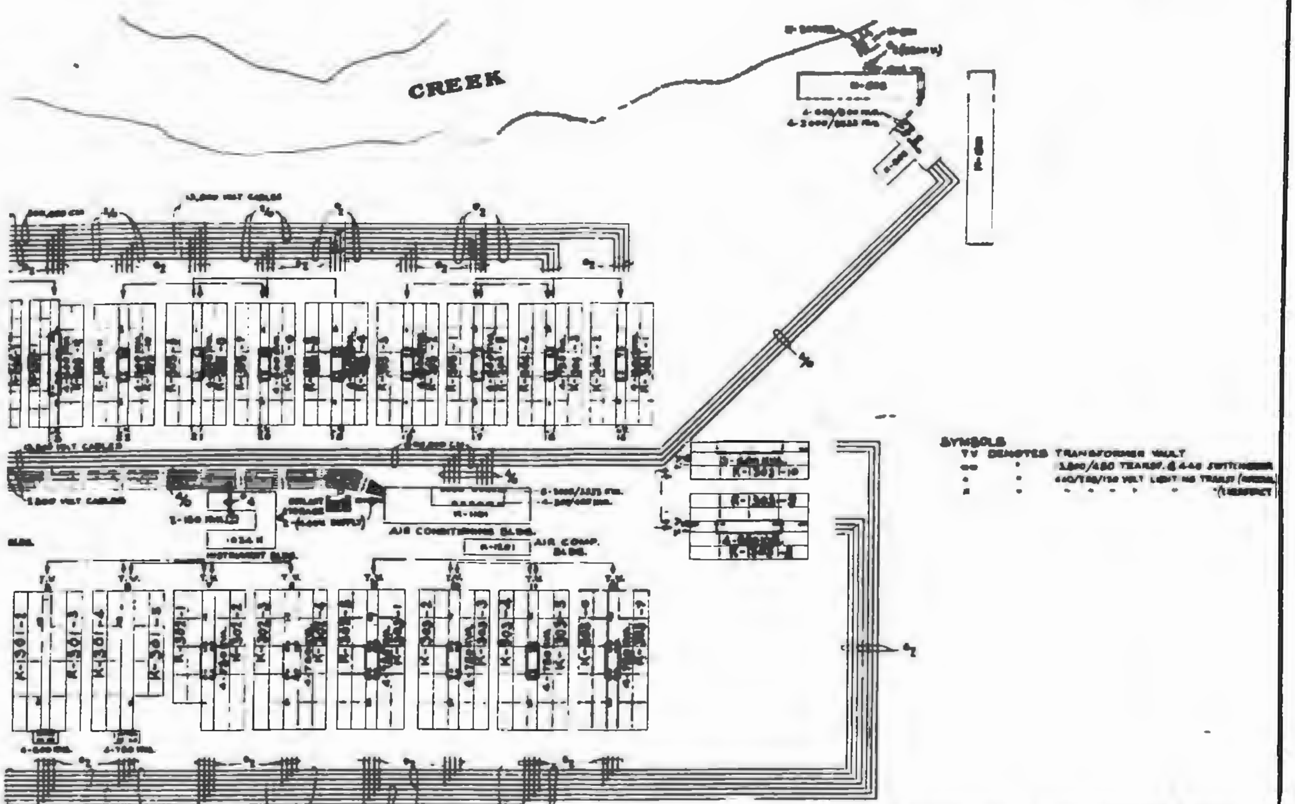

CONSTANT FREQUENCY SYSTEM

FIG. 1

THE KELLEX CORPORATION

SYSTEM CABLE DIAGRAM · CONSTANT FREQUENCY
POWER HOUSE AND PROCESS AREA

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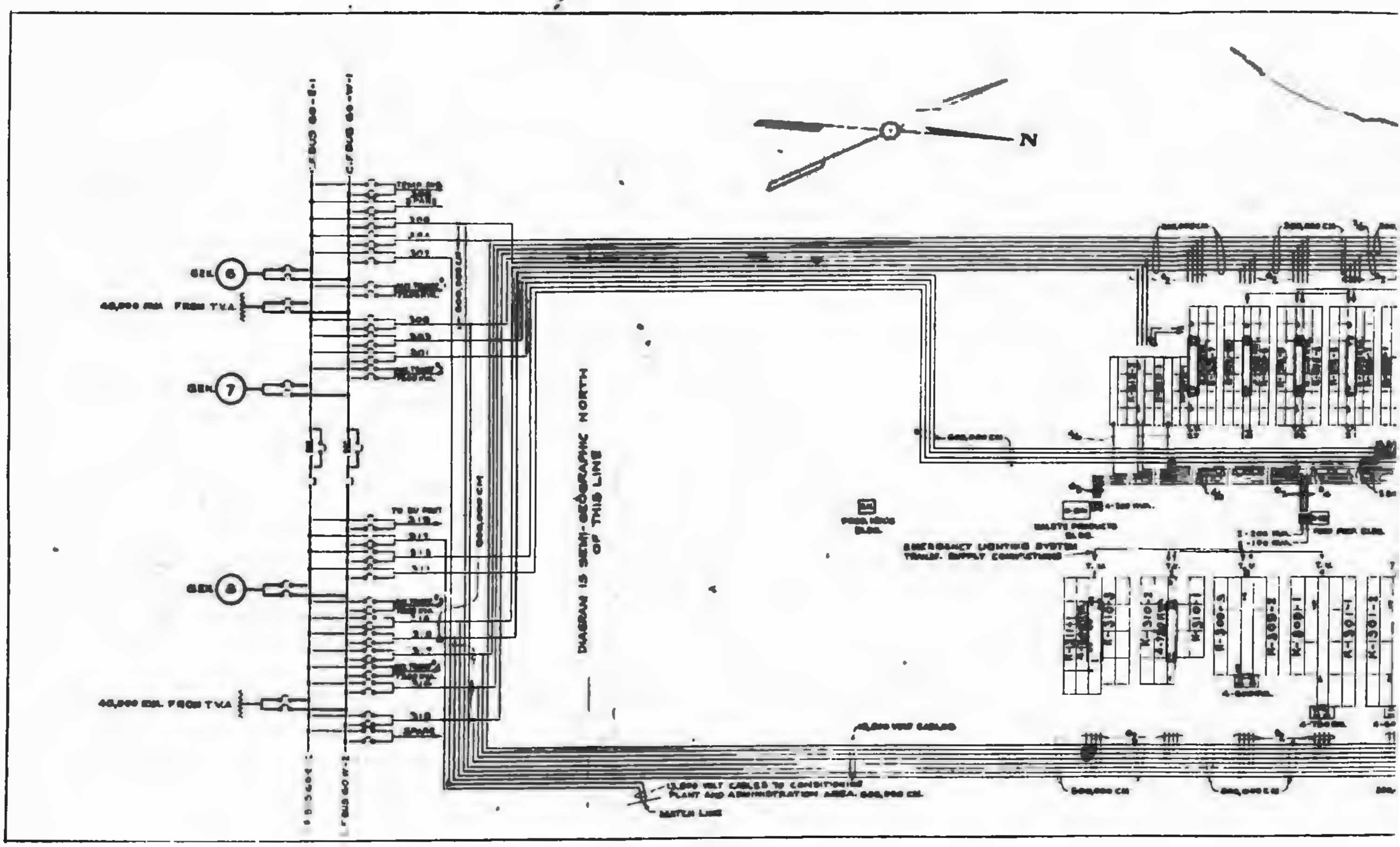

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and layout are shown schematically in Figures 61 and 62.

d. Constant Frequency System. - The constant frequency system (Fig. 61) is supplied from a double bus in the main switch house. Each feeder cable leading to the process area is provided with two breakers so that, in case there is any failure of equipment on either of the two bus sections, the other will remain in service and continue to supply the load. Each of the two bus sections is subdivided into two smaller portions by a 9 per cent 35,000 KVA bus tie reactor which acts to limit the flow of current in the event of a short circuit.

(1) Power Source. - The constant frequency bus is normally supplied with power from three turbo-generators, one acting as a running reserve. In addition, as described above, a connection is made through the switchyard to the incoming T.V.A. supply lines. A 25,000 KVA synchronous condenser is installed in the switch house for use in improving power factor and controlling voltage at times when all constant frequency power is being drawn from the 154,000 volt T.V.A. system.

(2) Intra-Area Distribution. - Throughout the utilization area, a network distribution system is used. Four transformers, each supplied from a different cable, are paralleled on their secondary sides to form a 480 or 2400 volt bus. Each 13,800 volt cable and its associated transformer normally feed one group of switches, but four switch groups are connected together by means of low voltage bus ties, and function as a unit. Transformers and cables sizes are so selected that, with one transformer or its primary feeder out of service, the remaining three can carry the full bus load.

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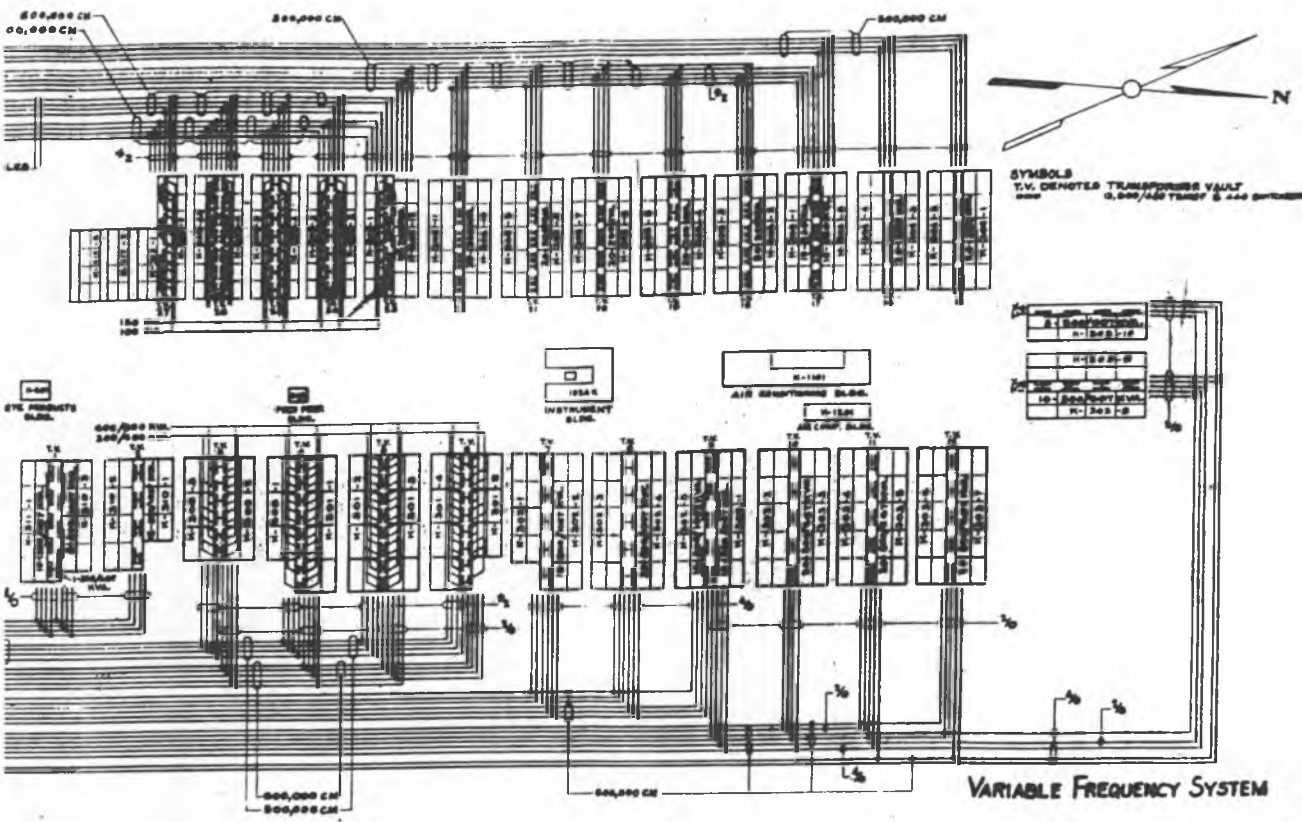

FIG. 62

THE KELLEX CORPORATION

SYSTEM CABLE DIAGRAM-VARIABLE FREQUENCY
POWER HOUSE AND PROCESS AREA

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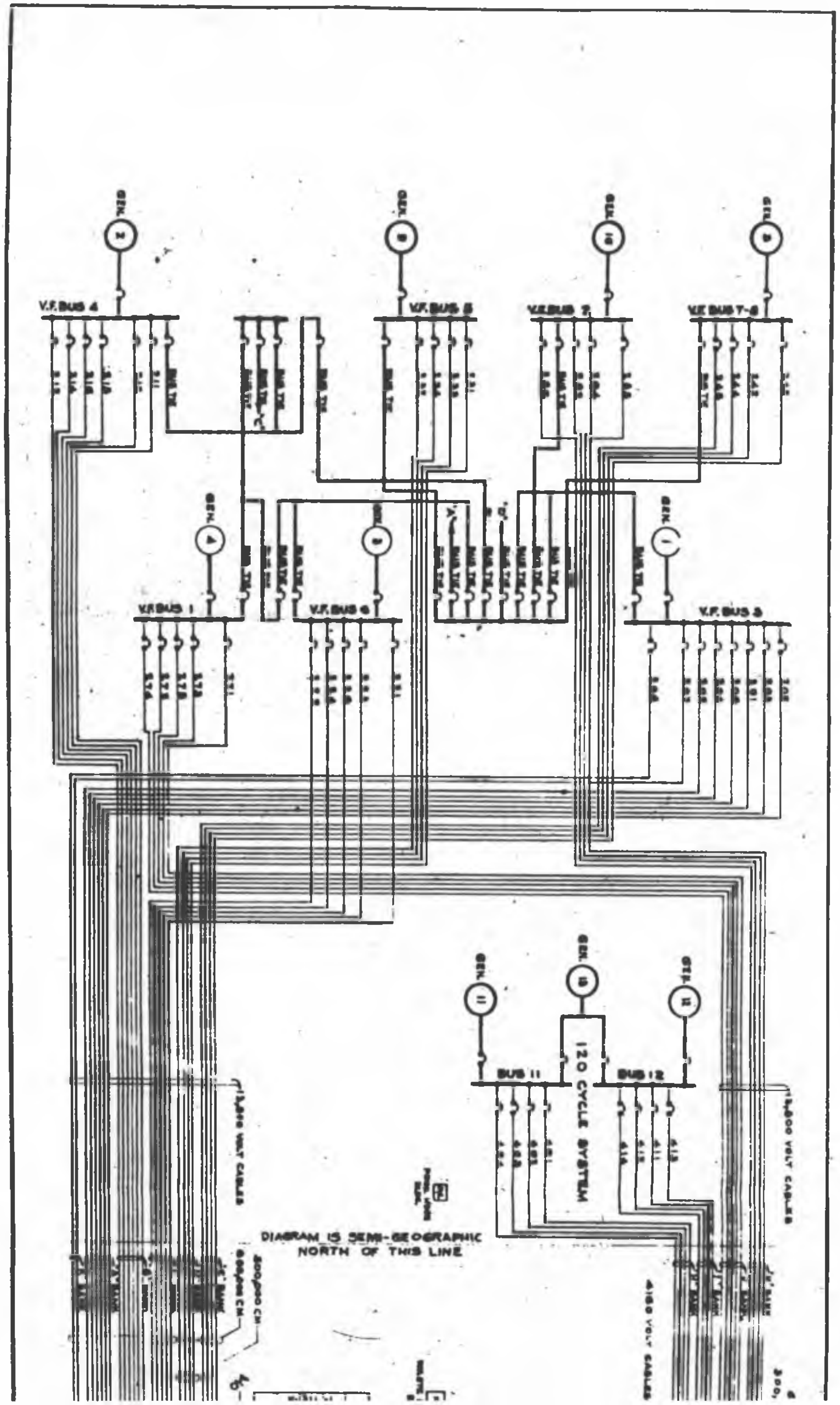

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e. Variable Frequency System. - Each of nine different variable and adjustable frequencies is supplied from a separate bus in the switch house (Fig. 62). These buses are equipped with one breaker per generator and one breaker per feeder.

(1) Power Source. - Each bus in the variable frequency system is normally supplied with power from a particular turbo-generator which is assigned to that bus and to that frequency. A spare turbo-generator is kept available so that it can pick up the load on any of the buses in 45 - 65 cycle band, should the generator normally supplying that bus be out of service. Two spares are provided to serve either of the buses in the 90 - 130 cycle system.

(2) Intra-Area Distribution. - Variable frequency power is used at 480 volts. Transformers and switchgear are located in the process building basement vaults.

(a) 60 Cycle Band. - Two cables and transformers feed one bank of switches, and two of these switch banks are connected together by means of low voltage bus tie cables. When necessary, three of the four cables and transformers in any particular group can carry the total load for that group.

(b) 120 Cycle Band. - In Section 4 of the diffusion cascade the "A" and "B" motors are run at different speeds, and are supplied by different buses. The circuit breakers which supply the "A" and "B" motors for a particular cell are interlocked so that they are both closed and opened at the same time. In case either breaker is tripped automatically by relays, both breakers will open. In Section 4 the transformers are operated in groups of two, instead of in groups of four as in other sections. Each transformer supplies one bank of switches, and two of these switch banks have their low voltage buses connected together. Each switch bank supplies "A" and "B" motors for two cells, each cell being supplied through a separate circuit breaker. Normally, both transformers will be in service, but in an emergency one of the two transformers of a group can supply the entire load.

f. Equipment.

(1) Transformers. - The step-down power transformers are practically all of the non-liquid filled, air-cooled type. Primary voltage in the 120 cycle band variable frequency system is 4,160 volts. In the 60 cycle constant and variable frequency systems, it is 13,800 volts. Secondary voltage is 480 volts in all cases, except for a number of constant frequency units, which deliver power at 2400 volts. Transformer sizes are shown in Figures 61 and 62. The two KVA values are the self-cooled and fan-cooled ratings. In general, the self-cooled rating is adequate for normal requirements, but the fan-cooled rating allows three transformers to carry the entire bus load normally distributed among four. Transformers in the constant frequency system were supplied by Allis-Chalmers; those in the variable frequency system by Westinghouse.

(2) Switchgear. - All of the switching equipment is of the metal-enclosed, air circuit breaker type with removable circuit breakers. In Section 300, the transformers and switching equipment are located in long vaults between the process buildings. In the pump house, air conditioning building, and other miscellaneous buildings,

TABLE 7. - PROCESS PUMP MOTORS

CASCADE SECTION NUMBER	TYPE PUMP	MOTOR RATING (h.p.)	NUMBER OF MOTORS
-3	A	25	45
		30	9
-3	B	50	64
-3	I	50	2
-2	A	50	126
-2	B	100	126
-1	A	60	90
-1	B	100	90
-1	I	60	2
1	A	60	222
1	B	100	222
2a	A	50	276
2a	B	100	276
2a	I	100	2
2b	A	30	552
2b	B	60	552
2b	I	60	2
3a	A	15	288
3a	B	30	288
3a	I	15	2
3b	A	10	708
3b	B	20	708
3b	I	25	2
4	A	7.5	576
4	B	7.5	576
4	I	7.5	2
			5798

NOTE: I denotes intersectional cell pump.

the transformers and switching equipment are located in special rooms provided for that purpose.

(3) <u>Motors.</u> - The variable frequency load consists of power drawn by induction motors driving the diffusion stage process pumps. The 2892 stages of the main cascade, each with its "A" and "B" pumps, require a total of 5784 stage pump motors. The size and distribution of these motors, together with those installed in inter-sectional cells, are shown in Table 7.

SECTION 13 - THE ADMINISTRATION AREA

13-1. General. - The designation, "Section 1000", is applied to ~~include~~ buildings provided at K-25 for administrative and miscellaneous purposes. All of these structures (except as noted in Par. 13-2) are of a temporary low-cost type. Most are located within the administration area, which lies southeast of the main process area.

13-2. Laboratories. - Four laboratory buildings are provided: K-1004-A, -B, -C, and -D. The first three are permanent two-story concrete block structures, and are connected by a corridor. Their combined floor space is 50,000 square feet. The fourth is a one-story wood frame building with a plan area at about 15,000 square feet. All are air-conditioned. Activities and equipment in these laboratories are described in Volume 5.

13-3. Administration Building (K-1001). - The administration building is a two-story, four-wing building containing over two acres of floor space. It is the main office building for the gaseous diffusion plant.

13-4. Industrial Relations Building (K-1032). - As a supplement to the administration building, building K-1032 was constructed on an adjacent plot of ground to house offices having to do with industrial relations and similar matters.

13-5. Field Office Buildings (K-1029, K-1034). - Two two-story field office buildings are located just south of the cascade "U". These were designed and built for the purpose of providing office facilities for a portion of the administrative personnel of the J. A. Jones Construction Company, The Kellex Corporation, and the Manhattan District. They are now used by Carbide to provide office space for the Instrument, Equipment Test and Inspection, and General Engineering Departments.

13-6. Personnel Facilities. - The following personnel facilities are provided:

K-1002	Cafeteria
K-1003	Dispensary
K-1005	Payroll and Safety
K-1015	Laundry
K-1026	Bus Terminal
K-1027	Bus Repair Shop

13-7. Miscellaneous Buildings. - Numerous warehouses, change houses, pay stations, first aid stations, guard houses, and garages are located throughout the K-25 area.

SECTION 14 - THE K-27 AREA

14-1. General. - The K-27 plant is a structurally separate annex to the main cascade of the gaseous diffusion plant. It can be operated as a separate unit, but is normally operated in conjunction with the main K-25 plant, the two process areas being interconnected so as to form a "cascade of cascades" (Vol. 5). The decision to construct the K-27 plant is discussed in Paragraph 7-2. An extensive description of K-27 is available in Volume V of the Kellex Completion Report.

a. Contractual Arrangements. - In practically all cases, specific portions of the K-27 work were performed by the same contractors (App. A) who had handled corresponding phases of the originally designed K-25 plant. For example, overall responsibility for design, engineering, and procurement was vested in the Kellex Corporation under Modification No. 2 of contract W-7405-eng-23.

b. K-27 Plant Site. - The K-27 plant is located within the K-25 Area. Site selection was governed by consideration of the following factors:

1. Minimum disturbance to existing structures and services.
2. Proximity to existing utility supply facilities such as electric feeder cables, sanitary water, fire water, etc.
3. Ease of drainage.
4. Proximity to the K-25 plant.
5. Availability of cooling water make-up supply.
6. Proximity to existing administrative and construction facilities.

7. Ease of grading and soil preparation.

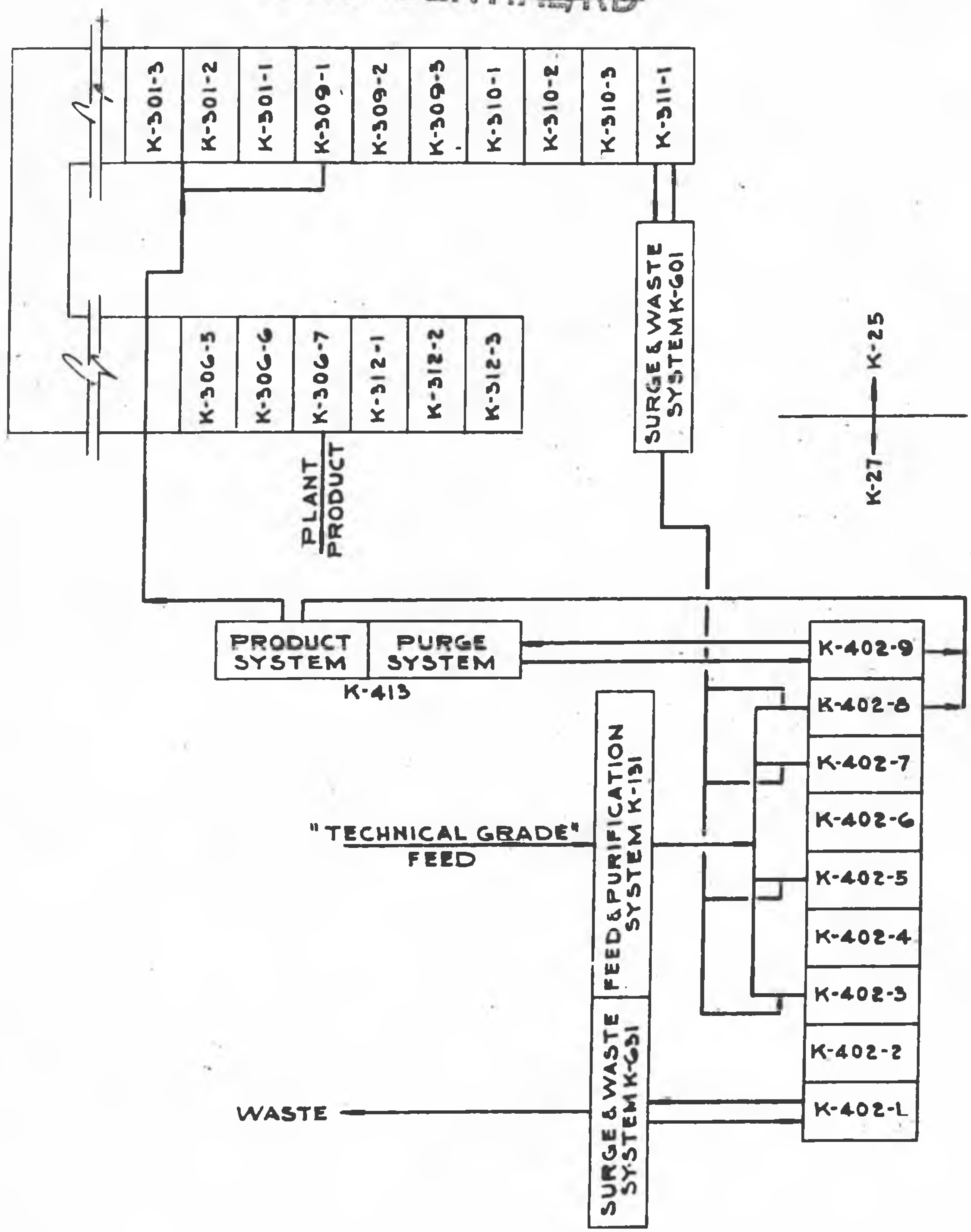
8. Accessibility from other parts of the area.

K-27 buildings occupy a sixty-acre plot of land just southwest of the main cascade "U". Thus, the K-27 cascade is situated within a deep bend of Poplar Creek, and is bordered on three sides by that stream. Plot plans of the K-27 area, and of the overall gaseous diffusion plant area, including K-27, are presented in Volume 1, Appendices A3 and A5. Photographic views are shown in Volume 5, Appendices D16 and D17.

c. Design Principles. - Design principles of the K-27 plant are identical with those of the main K-25 plant. In order to expedite the speed of construction, and since K-25 plant operation had proved successful, the general policy was followed of extending the diffusion plant process facilities by constructing duplicates of one of the main cascade process buildings (Vol. XXI of Kellex Operating Manuals). Only those changes were made which were absolutely necessary, or by means of which significant improvement could be effected without delaying the progress of construction. Accordingly, discussion of K-27 design, as presentedbelow, follows an outline similar to that used for the main K-25 plant; emphasis is placed upon points of difference between K-27 and the previously designed K-25.

d. Capacity. - In effect, K-27 operation produces an enriched feed for the K-25 cascade, and thereby increases its daily production of U-235. It was contemplated that the K-27 extension would result in a 35 to 60 per cent increase in total U-235 production.

14-2. Process Design. - The K-27 cascade consists of 540 diffusion stages. As in K-25, six stages are grouped to form a cell. The cascade



TITLE SCHEMATIC DIAGRAM SHOWING COMBINED OPERATION OF K-25 & K-27 PLANTS

FIG. 63

is housed in nine contiguous process buildings (designated Section 400), each containing ten cells. The process equipment essentially duplicates that of Section 2a of the main cascade. Figure 63 depicts the method of process interconnection between the two cascades.

a. Feed and Purification System (Section 130). - The K-27 feed and purification system (Vol. XI of the Kellex Operating Manuals) differs in several important respects from that originally designed for service with the main K-25 cascade. Feed to K-27 is obtained from two sources:

1. Fresh, normal concentration, UF_6 supplied by the Harshaw Chemical Company.
2. Partially processed uranium hexafluoride recycled from the bottom of the K-25 cascade.

Experience with the main cascade feed purification program had shown that it would be unnecessary to provide purifying facilities for the fresh feed stock received from Harshaw. Accordingly, no equipment corresponding to the UF_6 distillation towers of Section 100 was provided. It was decided, on the other hand, to provide purification facilities for the recycled stream from K-25. The K-27 feed and purification plant, as finally designed, is subdivided into three distinct systems which are discussed below.

(1) Fresh Feed Vaporization System. - Fresh feed stock is vaporized directly by immersion of drums in hot water baths, and the vapors are sent through feed filters to the K-27 cascade. This is essentially similar to the method used in the feed system for the main cascade. Four hot water baths are provided, each serving a bank of four

cylinders. Total vaporizing capacity is on the order of 32,000 pounds of UF_6 per day.

(2) Batch Still Purification System. - This installation, housed in a separate room of Building K-131, contains principally a packed tower and re-boiler, a still pot, condenser, and reflux drum, together with process material containing drums, and water bath vaporizers for feeding purified UF_6 to Section 400. The system removes such impurities picked up during processing in the main cascade as coolant and light diluents, and was designed to reduce C_8F_{16} concentration to a specified 2.14 per cent by weight. An extraction and separation unit is provided for removing traces of UF_6 from the C_8F_{16} coolant recovered in the purification operation. Process piping in Section 130 differs from that of Section 100 (which is traced with calrod heaters) in that it is encased within electrically heated air conditioned enclosures, which confine leaking process material, and permit of purging the leaking area. Also, whereas the feed to the Section 100 purification system is vaporized by electrical heating jackets, in Section 130 the feed to the batch still is vaporized by hot water coils clamped around the shipping containers.

(3) UF_6 Disposal System. - The disposal system (housed in Building K-132) removes UF_6 from vent gases, purge gases, and relief valve discharges by absorption in water. The resultant solution is returned to Building K-131, and agitated in a tank with a 10 per cent caustic solution which precipitates the uranium as sodium uranate, $Na_2U_2O_7$. The precipitate is filtered in a plate and frame press, washed, and charged to barrels for storage. The filtrate and washings are transported

by tank truck to the conditioning area for disposal.

b. Surge and Waste System (Section 630).

(1) Surge System. - Similar in design and purpose to Section 600 of K-25, the K-27 surge system includes a bank of twelve large drums capable of absorbing an inventory fluctuation of 3900 pounds, which is equivalent to 15 per cent of the K-27 cascade inventory.

(2) Waste System. - The waste system, with a design capacity of 9300 pounds of process material per day, withdraws process gas from the "B" line serving the surge system, and compresses it to 33-50 p.s.i.a. by means of two special pumps (Par. 14-3d(1)) connected in series. The stream is then liquefied by heat exchange with process coolant, and collected in one of two waste accumulators from which it is drained to shipping cylinders for storage. The K-27 surge and waste system is completely spared (Vol. XXXIX of the Kellex Operating Manuals).

(3) Ventilation System. - A carefully engineered ventilation system has been provided in Building K-631 to furnish the following services:

1. Protection of personnel against toxic gases.
2. Limit and control surfaces requiring decontamination in case of a leak.
3. Dissipate heat.

The ventilation system is unique in that certain areas of the building where process gas is handled at super-atmospheric pressures are maintained at pressures below atmospheric so that leakage of process gas to the atmosphere will not contaminate other parts of the building. In those parts of the building where process gas pressures are below atmospheric, the pressures are held slightly above the normal barometric level in order to minimize further the flow of contaminated atmosphere into such areas.

c. Purging System. - Design of K-27 purging facilities was considerably simplified because of K-25 operating experience, and because of the fact that the process stream at the top of K-27 is not very highly enriched in light isotope concentration.

(1) Alternatives Considered. - Two methods were considered. The first involved a design similar to that used in the temporary purge and product systems at the top of Sections 2a and 2b of the K-25 cascade. This method would possess the advantage of simplifying K-27 product removal, but would necessitate relatively complicated plant purging operations. The second alternative was based upon the use of normal cascade cells to produce light diluent of high purity (about 1 mol per cent UF_6). This would permit separation of the product withdrawal system from the purging system.

(2) Final Design. - The latter method was chosen because of its simplicity. It also made possible the sparing of purge system cold traps by recovery system cold traps. The highest on-stream cell of the K-27 cascade normally operates on direct recycle, and light diluent is concentrated in the top 2-5 cells to 99 or more mol per cent. A purge stream is taken from the "A" stream of the uppermost stage and compressed to atmospheric pressure by means of a Beach-Russ vacuum pump of the type used in the process gas recovery system. The stream passes through a cold trap system housed in Building K-413, and is refrigerated with liquid CO_2 at minus $55^{\circ}F$. It is then run through a carbon absorber and exhausted to the atmosphere. A control valve in the vacuum-pump suction line regulates

the flow of purge gas so that the UF_6:N_2 ratio in the process stream at one of the stages near the top of the cascade remains constant. Refrigeration is supplied from the CO_2 refrigerating plant in Building K-402-9 which also serves the K-27 process recovery system. For stand-by purposes liquid CO_2 for refrigeration can also be supplied from cylinders. The design capacity of the purge system is 2400 standard cubic feet of nitrogen per day.

d. Process Gas Recovery System. - The process gas recovery system of K-27 differs from that of K-25 (which was equipped with recovery stations scattered throughout the main process buildings) in that a single central station is provided. This design was chosen after study and discussion between Kellex and Carbide. Three two-pump vacuum pumping stands, placed at equal intervals along the cascade, exhaust the process gas from the process equipment when necessary, and discharge it through mist filters into a header which runs along the front of the process buildings, and leads to the central station at the front of Building K-402-8. At this point three cold traps are provided, together with auxiliary carbon traps and controls. Recovered process material is stored in five liquid storage drums and returned as needed to the cascade by way of a return header which runs parallel to the evacuation header. Operation of the K-25 cascade has shown that the Allis-Chalmers stage pumps can operate at lower pressures and smaller suction volumes than were originally anticipated. This information was utilized by employing these pumps to evacuate the contents of a cell, and transfer the process material to another cell, or to the main cascade stream. In this way, a cell can be evacuated to less than 10 per cent of normal shutdown pressure, the remainder of the evacuation being taken care of by the recovery system, which thereby carries a greatly reduced load. In the K-25 recovery rooms, a storage drum, after being filled, had to be disconnected from the piping, moved, and replaced by another storage drum. In K-27, storage in the cold trap room is provided for by stationary drums which collectively can hold the contents of one building. These drums are manifolded and encased in an electrically heated box designed so that the UF_6 can be held in the drums either as a liquid or as a vapor. Extra storage capacity can be obtained by vaporizing the UF_6 from the recovery storage drums and sending it to the product room in Building K-413 through a piping connection provided for this purpose, and condensing it into portable product drums. The piping arrangement also makes it possible to use the K-27 cascade recovery system for evacuation of equipment in the surge and waste system, or as a spare purging system when the normal purge system is shut down. The K-27 process gas recovery system and purge and product system is described in Volume XXXVIII of the Kellex Operating Manuals.

e. Product Withdrawal System. - The K-27 product system serves to transfer K-27 product to K-25 at a metered rate, and provides a means for operating either the K-25 or K-27 cascade when the other is out of service. The principal difference from the K-25 product system, where the product rate is relatively low, is that the K-27 design product withdrawal rate is 4400 pounds per day. Final design of the product withdrawal system was fixed after consultation with Carbide. Product is withdrawn from a cell near the top of the K-27 cascade where the light diluent concentration approximates three mol per cent. Product may be withdrawn through any of a number of connections installed between the converter outlet and stage control valve in the sixth stage of the third, fourth, fifth, sixth, and seventh cells from the top of Building K-402-9.

Similar connections are made in Building K-402-8 for use in the event that Building K-402-9 may be taken off stream. Product is normally transferred to K-25 in the vapor phase by means of interconnecting piping between the two plants, which run through purge and product building K-413 (Fig. 63), where the flow rate is continuously metered. The product system is housed in Building K-413 along with the purge system, the two systems being separated by a partition wall. On account of the process pressure differential between K-25 and K-27, no booster pump mechanism is required. The product header discharges into any of a number of feed-points in the K-25 cascade.

(1) Alternate System. - Facilities are also available for liquefying the process material, and transporting it to K-25 in tared drums. When this method is used, (e.g., when the K-25 cascade is shut down) a stream is drawn from the product header, and compressed by means of two special pumps (Par. 14-3d (1)) connected in series. The compressed gas passes through a condenser where it is liquefied by heat exchange against C_8F_{16}, the liquid flowing by gravity into run-down drums, from which it is drained into tared shipping drums. These drums have a combined storage capacity of 15 tons of UF_6, and provide a stockpile for supplying the K-25 cascade for a considerable period, in the event that normal flow of K-27 product is interrupted.

14-3. Equipment Design.

a. Barrier. -

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b. Converters. - The converters of the K-27 stages are identical with the Size 2 converters of the K-25 cascade (Table 3, facing p. 8.10). The use of a higher quality barrier makes possible a higher operating pressure in K-27 (Section 400) than is possible in K-25 (Section 300). A typical K-27 cascade "B" stream pressure would be on the order of 3.2 p.s.i.a.; a maximum pressure of 4.0 p.s.i.a. is possible. This maximum pressure fixed design cooler duties, electrical power requirements, and some of the instrument ranges. A typical "A" stream flow rate through K-27 barrier is 637,000 pounds per day, as against 490,000 pounds per day in Section 2a of the K-25 plant.

c. Process Pumps. - Because of the relatively high pressures and increased interstage flow at which the K-27 stages were to be operated, the stage-pump motors had to be capable of a higher power output than was necessary in Section 2a. The "A" pump motors are rated for continuous operation at 75 horsepower, and the "B" pump motors at 150 horsepower.

d. Service Pumps. - The various special pumps developed (Vol. 2, Section 5) for K-25 service were used for corresponding applications in K-27.

(1) Waste and Product Pumps. - It was necessary to design one new pump for the K-27 plant. The K-27 waste system required a positive displacement pump to compress UF_6 to 33-55 p.s.i.a. prior to liquefaction; the K-27 product system involved a similar pumping service. A Beach-Russ pump (Vol. 5, Par. 8) was tested at the Kellex Jersey City Test Floor, and later at the plant site. A number of design modifications were made, and a two-stage unit was developed with increased cylinder clearance and an improved lubrication system.

e. Process Gas Coolers. - The stage coolers are identical with those used in K-25. K-27 contains no intercell coolers, however, the need for these being eliminated by the use of MFP-10 plastic valve seats, which are capable of withstanding higher operating temperatures than the "C" rubber seats originally installed in the main cascade.

f. Process Piping. - K-27 process pipe is identical with that used in K-25, with the exception that the three and four inch sizes (as well as the larger diameters) are of nickel-plated steel instead of monel. By the time that the K-27 plant was constructed, Bart Laboratories had extended their plating techniques to permit of handling these smaller sizes.

g. Process Block Valves. - The G-17 block valves in K-27 are equipped with MFP-10 seat rings instead of the "C" rubber seating material originally used in K-25.

h. Instrumentation. - Instrumentation changes were made primarily in cases where it was found possible to effect simplification or improvement without delaying the program. Specific details are described in Section S-III (10) of the Kellex Completion Report.

i. Stage Control Valves. - As in the K-25 plant, butterfly control valves are used to regulate stage pressures in the K-27 plant. Since complete closure of a control valve would result in process disturbances which would overload the pump motors, it was decided to provide special means for preventing the valves from closing beyond a pre-determined amount. This was accomplished by controlling the air supply for the diaphragm motors of the valves to that pressure which would permit the valves to close to a specified position. The valves have also been fitted with stops to limit the degree of closure. The relays used in K-25 were supplied with two degrees of "reset"; this has proven unnecessary, and the relays used in K-27 are designed without the reset feature.

j. Cold Traps. - The cold traps used in the K-27 purging system were salvaged from cancelled recovery rooms in Sections 3a and 3b of the K-25 cascade. Those used in the K-27 process gas recovery system, however, were specially designed for the K-27 plant. Representing a modification of the radial fin type trap, they are larger and somewhat simpler in design than any type used in the K-25 plant, containing no inner refrigerant shell. A feature of these traps is a nickel wool filter installed at the outlet to remove entrained UF_6.

k. Carbon Traps. - K-27 carbon traps are similar in design to those of K-25, but generally somewhat larger in size.

14-4. Process Service Installations.

a. Process Coolant System. - The C_8F_{16} coolant system for K-27 (Vol. XXXV of the Kellex Operating Manuals) differs from that for K-25 primarily in the following ways:

1. As mentioned above, intercell coolers are not required.
2. An undesirable upward thrust obtained in Section 300 coolant circulating pumps is eliminated by drilling the impellers of pumps in Section 400.
3. In order to reduce coolant loss, the inert gas blanket pressure on the coolant system was reduced to ½ inch of water column gage, instead of the 3-5 p.s.i.g. originally specified in the K-25 coolant system.
4. A pulsation damper has been placed in the coolant circulating

pipe discharge pressure gage line in order to minimize the effect of pump vibration on the gage reading.

5. The entire temperature level of the coolant system (except for the inlet cooling water temperature) is higher than in the K-25 plant, because of the higher specified process temperatures.

b. Recirculating Cooling Water System (Section 830). - Some consideration was given to enlarging the K-25 system so that it would be able to supply the cooling requirements of the K-27 plant. However, it was soon found that this would require major revisions of the existing plant, and would require the interruption of process operations. The scheme was therefore abandoned. A separate cooling tower (H-832) is provided for K-27 service. It is a 14 cell induced draft installation. The recirculating system is similar in principle to that of K-25. Design capacity is 55,000 GPM, and indicated load is approximately 34,000 GPM. It was originally expected that the K-27 system would require its own make-up water supply facilities. However, operating results at K-25 showed that the make-up requirements for that plant were running less than estimated, so that it was possible to feed K-27 from the K-25 system, and a tie-in was made between the supply main of K-25 and the return main of K-27 to carry make-up feed to the latter system. Late in the design of the new plant, and at Carbide's suggestion, facilities were added so that make-up water can be fed to both plants from the sanitary water system. This provides a stand-by source which can be used during periods of low water, and when the raw river water is exceptionally dirty. Because of the higher process gas circulating rates and pressures in the cascade of the K-27 plant, the quantity of heat to be carried away per building is greater than for a similar ten-cell building in Section 2a of the K-25 cascade. It was therefore necessary to increase the differential pressure between the supply header and the return header so that each building would receive the required supply of cooling water. As a result, the recirculating pump discharge pressure is higher in the K-27 plant, and the sizes of the supply and return mains, and of the building headers are proportionately larger. Further details are available in Volume XXXVII of the Kellex Operating Manuals.

c. Dry Air System. - The dry air system of K-27 serves a function similar to that of K-25. It was designed to operate as a dead-end system, since experience in the main K-25 plant had shown that system to be preferable to continuous circulation. It was originally intended that a dehumidification plant should be set up in Building K-1131 for producing the dry air needed in K-27, but it was later calculated that the existing K-25 dehumidifying installation (Section 1100) would be able to supply the needs of both process areas, with both operating on the dead-end system. A connecting supply line was therefore installed to supply the K-27 plant with dry air from Section 1100. Construction of Building K-1131 was discontinued, and later resumed after the bulk of the more urgent construction work had been completed. The building is now used for miscellaneous storage and maintenance purposes.

(1) Instrument Air. - The K-27 instrument air system differs from that of K-25 in that there is only one system per building. All air-actuated instruments and controls are supplied with minus 70°F dew point air, whether located inside or outside the dehumidified equip-

ment enclosure system. The air is drawn from the main K-27 dry air distribution header, and compressed to 10-55 p.s.i.g. by means of four compressors in Building K-1231, and then sent to the process building distribution system. At the front of each process building, the system is connected to the plant compressed air header in order to make available a source of emergency supply. A full description of the K-27 air distribution systems may be found in Volume XXXII of the Kellex Operating Manuals.

d. Compressed Air System. - The "plant air" for K-27 is fed from the K-25 system (Section 1200) by means of a connecting supply line. No additional compressors were required; existing facilities were capable of carrying the added K-27 load.

e. Lubricating Oil System. - The K-27 process pump lubricating oil system is similar in all important respects to that of K-25, though minor changes were made in the method of feeding and venting the main building supply headers, duplex filters were installed at each stage pump instead of single filters, and the size of the main feed header was increased in order to provide a greater emergency supply of oil (Vol. XXXIII of the Kellex Operating Manuals).

f. Dry Nitrogen Supply System. - The sizes of some of the stage pump sealing systems were increased in order to facilitate vacuum testing of these systems, trace indicators in the seal exhaust headers were eliminated, and the method of controlling seal exhaust pressures was changed so that they are regulated differentially from the seal feed pressures. Further details are available in Volume XXXVI of the Kellex Operating Manuals.

14-5. <u>Power Supply and Distribution (Section 730)</u>. - The K-27 plant was designed to run entirely on constant frequency 60 cycle power. This made it possible to draw all power directly from the T.V.A. system. Accordingly, the entire K-27 electrical supply system is considerably less complicated than the K-25 installation.

a. <u>K-27 Switchyard (K-732)</u>. - The 154,000 volt line between the T.V.A. Watts Bar generating station and the Elza No. 1 substation was looped through the K-27 switchyard, thus providing, in effect, two sources of power supply. A third source was arranged by means of a 154,000 volt line from the K-25 switchyard (K-709). Any two of these three sources can supply the entire K-27 load. Power is stepped down to 13,800 volts by means of five transformers in the K-27 switchyard. It is then transmitted to the K-27 switch house by means of underground cables.

b. <u>K-27 Switch House (K-731)</u>. - The switch house is a steel and concrete structure, about 400 feet long, 50 feet wide, and 40 feet high, located adjacent to the switchyard, and south of the K-27 process buildings. The switching equipment installed in the K-27 switch house is similar to that used in K-25. It is of metal enclosed design with the phases well isolated.

c. <u>Design Load</u>. - In order to provide for possible future expansion of the K-27 plant by construction of three additional process buildings, all 154,000 volt transmission line facilities, switchyard facilities, power transformers, and 13,800 volt switchgear have been designed for a maximum load of 150,000 KW. From this point on, the K-27 electrical distribution system is designed for a total load of 100,000 KW, which was the estimated load for full operation of the nine K-27 process buildings and auxiliaries. The bulk of the power is utilized at 480 volts.

d. Distribution System. - The 13,800 volt cables from the switch house to the process buildings, the low voltage switchgear, and the low voltage cables are all designed to take the full load rating of the motors, and are rated for a stream efficiency of 100 per cent. This rating was based upon experience at K-25 which showed that the estimated stream efficiency of 87 per cent assumed in that area was decidedly conservative. The 13,800 volt bus in the K-27 switch house is divided into two sections. A radial distribution system with four cables to each vault is provided, all four of these cables being supplied from one bus section. Each cable has two breakers, one from the main bus, and one from the reserve bus. Adjacent vaults are fed from alternate bus sections. The two bus sections are not tied together either at the switch house or in the process area. The stage pump transformers and the auxiliary transformers in a given vault are fed from the same cables. Any three of a group of four 13,800 volt cables can carry the full load in emergencies. Furthermore, stage pump transformer sizes have been so selected that any three transformers of a group of four can carry the full load when necessary. Cables and conduits carrying power from the K-27 switch house to Section 400 are of the same types as used in K-25.

14-6. Conditioning and Administrative Facilities. - The K-27 plant is served by Sections 1300 and 1400 in the same way as the main K-25 cascade.

a. Steam Plant (K-1531). - The addition (K-1531) made to the original K-25 process steam plant (K-1501) in order to supply K-27 requirements is discussed in Paragraph 11-9. K-27 is supplied with steam through a separate line which connects with the main steam header supplying the K-25 plant at a point near the southeast corner of the conditioning building. This steam line crosses the K-25 area and extends overhead to K-27. Branches connect with the various auxiliary buildings, and to a header which distributes steam to the nine process buildings. Condensate is pumped back to the heating steam plant through an independent condensate line.

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SECTION 15 - ASSISTANCE FROM BRITISH SOURCES

15-1. Introduction. - A number of design calculations and preliminary investigations of the gaseous diffusion process were made by British scientists. Various conferences were held with this group relative to most practical policies, methods, and procedures. Contacts with the British group developing diffusional separation processes may be grouped into the following four periods:

- Period 1. Preliminary discussions, February-April 1942.
- Period 2. Review of gaseous diffusion plant design, September 1943-January 1944 (App. F14).
- Period 3. Assistance with theoretical problems, February-May 1944.
- Period 4. Development of scraper cold trap, July-October 1944.

British work on the development of "C" rubber valve seats has been mentioned in Paragraph 8-11b, ~~and is further discussed in Sect. VII.~~

15-2. Preliminary Discussions. - The main topics discussed during the first visit of the British group to this country were principles of diffusional separation and alternative types of plant structure. ~~(Vol. 2, Par. 5-3)~~. The discussions on theoretical principles were helpful to American workers in disclosing the major design problems and suggesting design methods. The views of the British group on plant structure, however, were too divergent from the American plan to be of much practical value and were, therefore, rejected for reasons indicated in the following paragraph.

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15-3. Review of Gaseous Diffusion Plant Design. - At the suggestion of The Kellex Corporation, the British group was invited to criticize the design of the gaseous diffusion plant. A series of conferences was held at which the following subjects were discussed:

a. Barrier Materials. - The British investigators reviewed the relative merits of barrier materials under consideration, and aided in the selection of the DA barrier.

b. Stage Recycle Principle. - In December 1943, the British investigators proposed that an investigation be made of the "rabbit principle", a stage recycle method. In this plant, converter diffusate from only the first pass is advanced to the next higher stage; diffused gas from the remaining passes is recycled back to the same stage. The merit of the method lay in the reduction of required number of stages to obtain a specified product concentration, but, at the same time, total barrier area requirements were increased. A change over to this method at the current status of process development would have seriously delayed the completion of the plant because of increased complexity of converter design and stage operation. The method was carefully reviewed by Kellex engineers, and it was decided that process advantages which might be obtained could not justify its acceptance. The British group later concurred with this decision.

c. Cascade of Cascades Principle. - At the suggestion of the British investigators, some consideration was given to designing the gaseous diffusion plant as a "cascade of cascades". In such a design, the plant is not laid out as a simple, long cascade, but, rather, is compartmentalized, and consists of a number of smaller groups of stages, each in itself set up as a simple cascade, and each connected with its neighbors in a manner analogous to the interconnection of individual stages. Thus, there is associated with each unit cascade a feed, waste, and product stream which correspond, respectively, to the "B" inlet stream, "B" outlet stream, and "A" stream of an individual stage. Each unit cascade is fed with a mixture of "product" from the unit cascade below, and "waste" from the unit cascade above. The waste from the unit cascade under consideration is fed to the unit below, and the product is fed to the unit cascade above. Such an arrangement would facilitate purging at a number of intermediate points in the cascade, and opportunity would exist for independent operation of the unit cascades, and for localisation of operating disturbances within these units. The disadvantages involved increased complexity of the process piping system, and less efficient utilisation of diffusional equipment. Discussions on the advantages of this type of plant structure were helpful in suggesting means for controlling operating disturbances and in devising alternative purging methods, but the plant was not converted to the cascade of cascades principle since the American plan appeared to be satisfactory and design was progressing on schedule. The method of sectionalising the simple cascade, which was finally chosen, permitted sufficiently rapid isolation of process disturbances, and avoided the complexity of the cascade of cascades layout.

d. Purge Cascade. - The British group made a valuable analysis of possible difficulties with the purge cascade system. They pointed out that if the compressors of the purge cascade failed to work, the plant as then designed would be without means for purging light gases. They suggested that the control of the purge cascade might present special difficulties, and offered to undertake a detailed analysis of this problem. Although it was later found that control of the purge cascade was relatively simple, the discussions instigated by the British were helpful in understanding the problems connected with it.

e. Pressure Control. - The British group criticized the method proposed for control of stage pressures and recommended the use of laminar resistance in place of automatic pressure control valves. Although the British suggestion was not adopted, the criticisms raised concerning the use of automatic valves were valuable in eliminating potential difficulties with this type of equipment.

f. Flat Plate Diffusers. -

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Although construction of the British diffusers appeared perfectly feasible, it was not adopted because the American design was well under way, was on schedule, and its performance was considered satisfactory.

g. Cold Traps. - The British investigators made a number of valuable suggestions concerning the design of cold traps. In particular, they suggested that trouble might be encountered in the Kellex type of trap from low heat transfer coefficients and process gas fume losses. Both of these criticisms were subsequently proved valid by experimental tests, and the cold traps were modified to include the installation of mist filters.

15-4. <u>Assistance with Theoretical Problems.</u> - During the period from March to June 1944, certain members of the British group, Messrs. C. F. Kearton, R. Peierls, K. Fuchs and R. Skyrme, were stationed in New York, and, on request from Kellex, and with the approval of the War Department, undertook analysis of the following theoretical problems:

1. Cascade of cascades flow sheets.
2. Exact calculation of equilibrium time.
3. Loss of separation due to surges.
4. Control of main cascade (e.g., frequency of use of automatic control valves).
5. Control of purge cascades.

Reports of these theoretical studies were summarized in a series of reports ~~(App. [illegible])~~, and have been helpful in anticipating problems of plant design. (The MSN Series) ~~of Reports~~)

15-5. <u>Development of Scraper Cold Traps.</u> - The British investigators had advocated the use of a scraper cold trap in an alternative method for process stream purging in case the diffusion purge cascade should prove inoperable. In this type of trap, solidified material is continually removed by scraping, thereby maintaining high overall heat transfer coefficients. To investigate the usefulness of the scraper cold trap, the British workers invited The Kellex Corporation to send representatives to Billingham, England, to observe there the operation of an experimental model. Dr. W. I. Thompson and Mr. E. A. Johnson remained in England from July to October 1944 for this purpose. Upon their return to this country, The Kellex Corporation, with the aid of the National Research Corporation, was able to complete the engineering design of a scraper cold trap (App. F25). However, it was later decided not to use this trap because of the difficulties anticipated in controlling its process gas inventory.

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SECTION 16 - SAFETY AND SECURITY

16-1. Safety Program.

a. Organization.

(1) New York Safety Committee.

(a) Functions. - The New York Safety Committee was organised in December 1943, at the request of the New York Area Engineer, to serve in a consultant and advisory capacity on safety problems involved in handling fluorine, uranium hexafluoride, and other hazardous chemicals used in K-25 work.

(b) Composition. - The Committee was composed of members of the Kellex staff representing process, engineering, and research, a liaison officer from the Medical Section of the Manhattan District, and a member of the SAM Laboratories staff.

(c) Activities. - In the performance of its duties, representatives of the Committee visited all laboratories and other organisations of the K-25 group working with hazardous materials, including those under contract to the Madison Square Area for development and production of special chemicals (Book VII).

(2) Transfer of Responsibility. - By the end of February 1945, the bulk of the safety work had been completed. The Manhattan District Engineer's office was so informed, and the recommendation made that the responsibility for continuing these activities be transferred to the Carbide and Carbon Chemicals Corporation at the plant site. In letter dated 28 March 1945 (App. F26), the New York Area Engineer was informed that instructions had been issued to effect

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the transfer of responsibility for Safety Committee activities to Carbide and Carbon Chemicals Corporation. Actual transfer was completed early in April 1945.

b. Safety Measures. - In the course of its activities, the Safety Committee prepared for the New York Area Engineer a total of fourteen safety bulletins, revisions, and supplements (App. I1) describing the hazards entailed in dealing with these dangerous special materials, and prescribing regulations for their safe handling.

16-2. Security Program.

a. Organization.

(1) District Organization. - A full account of the evolution of the District Security organization and its activities is presented in Book I, Volume 14. In March 1943 a security officer was assigned to the New York Area office. With the development of the Manhattan District intelligence and security system, the functions of the Area Security Office changed; from June 1943 until May 1944, this position mainly required liaison between contractor, area, and District Intelligence and Security Sections. As sub-areas were created, under the jurisdiction of the New York Area Engineer, it became necessary to assign security officers to the Decatur, Milwaukee, and Detroit Areas. Each of these sub-area security officers was directly responsible to the respective sub-area engineer and also, as in the New York Area, to the local District Intelligence Officer. After the District Intelligence Section was reorganized as the Intelligence and Security Division, an officer from the local Branch Intelligence and Security Office was substituted for the Area Security Officer. Each of these area security

representatives then became responsible for all security and intelligence matters pertaining to his area, and to contractors therein. They reported both to the respective Area Engineers, and to the local Branch Intelligence and Security Offices. In the case of the New York Area, this system took effect in May 1944.

(2) Contractor Organization.

(a) The Kellex Corporation. - In December 1942, with the signing of the Kellogg contract, the Personnel Director of The M. W. Kellogg Company was appointed Security Agent for that company. His duties consisted largely of initiating clearance of personnel, and of setting up the security requirements to be followed by the contractor in accordance with District instructions. In February 1943, the Personnel Director of The Kellex Corporation took over these functions for Kellex, and a few days thereafter a full time Security Agent was appointed by Kellex to assume for the corporation responsibility for security of all operations of Kellex and its subcontractors. At this time, the Kellex Security Agent reported directly to the New York Area Security Officer. This system continued in effect thereafter, with some variations as the District Security organization was developed. During the latter period, the contractor security agent reported both to the Area Security Officer, and to the local District Intelligence Officer.

(b) Other Contractors. - In May 1943, Kellex was relieved of the responsibility for security over prime contracts which had been written at their instance, but over which sub-areas had been created. In November 1943, Kellex was relieved of the responsibility for security involving other prime contracts even though not administered by a sub-area. This jurisdiction was assumed directly by the Security Officer of the Area Engineer. Kellex then retained responsibility only for its own organization, and for its subcontractors and vendors. However, security agents were appointed by all prime contractors and all important subcontractors. In general, these agents were the personnel directors of the respective organizations, and operated on a part-time basis with respect to security. They reported directly to the responsible Area Engineer and to the local Intelligence Officer.

b. Security Measures. - A complete security program was established for those facilities and sub-areas where a great amount of classified information was located, or where production was of paramount importance. The Carbide and Carbon Chemicals Corporation, General Electric, Westinghouse, Crane Company, Bakelite, Metals Disintegrating, and a number of other contractors were then governed by the security regulations described below (App. I2). Prime contractors of lesser importance either from the standpoint of production, or of possession of classified information, were subject to this security program with varying degrees of modification. The complete program called for the establishment of procedures for personnel clearance and visitor control, educational programs, plant protection, and designating of certain restricted areas.

(1) Personnel Clearance. - Clearance by investigation, of all military and contractor personnel who were granted access to either classified information or restricted areas, was handled by

the District Intelligence and Security Division. The degree of investigation was dependent upon the facts revealed in the personnel clearance forms, and upon the position to which the individual was being assigned. In order to expedite Project activities, a system of interim clearance was worked out by which personnel clearance forms were screened immediately upon submission, the the individual either granted or denied clearance on this basis. The complete investigation which followed determined either the continuance of the individual in his position, or in the event of derogatory information, his termination or reassignment.

(2) Designation of Restricted Areas. - Restricted areas were designated in which either important classified documents and information were located, or work of great importance was being carried on. Admission to these areas was granted only to those who were specifically designated and had received proper clearance.

(3) Visitor Control. - A system of visitor control was established which called for the issuance, by the Area Security Officer, of Manhattan District passes to those who, for approved specific purposes, wished to visit a restricted area or a company which had received a contract with a classification of higher than "Restricted".

(4) Educational Program. - An educational program was established to insure that all personnel were aware of the importance, and the means of handling, of classified information. This program was carried out with the assistance of the various area security officers. The media of education were motion pictures, lectures,

literature, posters, and regular contacts with personnel where necessary. The program included specific instruction as to the proper classification of correspondence and its safeguarding and handling. Spot-checks were conducted at regular intervals by the security officer and by the security agents of the contractors.

(5) Plant Safeguards. - Plant protection measures were adopted at various installations, from the standpoint of safeguarding military information, and for the protection of research and production activities. These measures included establishment and instruction of guard forces, fencing of areas, pass and badge control, and fire protection.

SECTION 17 - COSTS

17-1. Introduction. - An overall compilation of costs attributable to the K-25 Project is given in Volume 1, Section 7, together with an explanation of the principles involved in the method of cost presentation used. Costs incurred under the special chemicals development and procurement program are treated in Book VII. This section presents total costs chargeable to all other phases of the K-25 design, engineering, and procurement activities.

17-2. Cost Breakdown. - A detailed breakdown according to prime contracts is shown in Appendix A, which also presents original and modified contract estimates.

17-3. Cost Summary. - Total cost figures for K-25 design, engineering, and procurement, effective as of the end of the fiscal year 1946 are as follows:

Contract Payments to Date	$245,598,661	
Fixed Fee Payments to Date	9,039,913	
Material Furnished by Government to Date	966,401	(credit)
Total Contract Costs to Date	253,672,173	
Estimated Total Costs for Completed Contracts	275,449,699	

SECTION 18 - ORGANIZATION AND PERSONNEL

18-1. <u>District Organization.</u>

a. <u>Overall Organization.</u> - The large number of contractors involved, and their wide geographical dispersion, posed a difficult administrative problem which was solved by the creation of a number of Manhattan District Areas, so located as to permit close association with all contractors. This organization served to administer contracts and expedite the solution of procurement problems arising within a particular Area.

b. <u>Line of Authority.</u> - The New York Area Engineer was responsible for the supervision of all Kellex design, engineering, and procurement activities. To facilitate the enormous task assigned the New York Area, additional areas (actually "sub-areas") were established, to handle administrative details, in Milwaukee, Wisconsin; Decatur, Illinois; and Detroit, Michigan. Where major pieces of equipment were being fabricated, responsibility for technical and procurement activities and decisions was retained by the New York Area. In certain instances, other Manhattan District Areas not primarily concerned with the Diffusion Project rendered supplementary services. Chief among these is the Madison Square Area, whose role is described in Book VII. Appendix C20 shows the District organization for administration of design, engineering, and procurement activities connected with the K-25 Project. Solid lines show the direct line of authority as it applies to the New York Area activities. Dashed lines indicate the relationship of other areas and Manhattan District offices which are only partly concerned with the diffusion plant. Contractors supervised by the Milwaukee, Decatur, and Detroit Areas are shown in Appendices C1, 2, 3, and 4.

18-2. <u>New York Area.</u>

a. <u>Organization.</u> - On 7 January 1943, Lt. Colonel J. C. Stowers was designated both as Unit Chief of the K-25 Project, and as Area Engineer, New York Area. One of his first assignments as Area Engineer was to organize a New York Area Office to administer The M. W. Kellogg Company contract, which had become effective on 14 December 1942. By 31 May 1943, the New York Area Office staff had increased to four officers and fifteen civilians. Two of these officers were assigned to the Decatur and Detroit "projects" as distinguished from other Kellogg-Kellex activities. Separate Decatur, Detroit, and Milwaukee Areas were later created to relieve the New York Area Engineer of administrative duties connected with Houdaille-Hershey Corporation, Chrysler Corporation and Allis-Chalmers Manufacturing Company operations. The first published organization chart of the New York Area, dated 31 May 1943, is shown in Appendix C6. As of 31 March 1945, the New York Area office consisted of 12 officers, 4 enlisted personnel, and 51 civilians. The increased scope of activity required a more complex organization, which is shown in Appendix C7. The New York Area was dissolved as of 23 August 1946.

b. <u>Personnel.</u> - Lt. Colonel J. C. Stowers served as New York Area Engineer from 7 January 1943 until 28 February 1946. Thereafter, the position was held by Major W. C. Campbell. Additional information concerning key personnel of the New York Area is given in Appendix J1.

18-3. Milwaukee Area.

a. Organization. - The Allis-Chalmers Manufacturing Company was engaged on 8 February 1943 to manufacture pumps for the K-25 Project. In order to administer the manufacturing plant construction program, a project office was opened in West Allis, Wisconsin, and Lt. Colonel R. C. Gregory was assigned as Project Engineer on 23 February 1943. A staff of one additional officer and nine civilians was assembled. The Area organization as of 1 June 1943 is shown in Appendix C8. On 31 March 1945, the area staff consisted of four military and twelve civilian members (App. C9).

b. Personnel. - Lt. Colonel R. C. Gregory was succeeded on 15 July 1943 by Captain R. C. Hill who assumed the position of Area Engineer. He was in turn succeeded on 6 August 1944 by Major J. L. McCormick, Jr. who served as Area Engineer until 14 November 1945. Thereafter the position was held by Captain J. D. Anderson until the area was dissolved on 30 June 1946. A list of key military and civilian personnel attached to the Milwaukee Area is presented in Appendix J2.

18-4. Decatur Area.

a. Organization. - On 19 April 1943 the Houdaille-Hershey Corporation agreed to set up a pilot plant at its Decatur plant for the purpose of developing the production of the electrofaced nickel barrier. After several months, sufficient progress had been made to warrant the construction of a production plant. Captain J. H. Brannan was assigned as Project Engineer on 24 May 1943 for the purpose of assembling sufficient personnel in a project office to supervise plant construction. This project office functioned under the direct supervision of the New York Area Engineer, inasmuch as The Kellex Corporation was assisting in the design of this plant and its equipment. In order to facilitate progress on this project, Decatur was designated as an Area of the Manhattan Engineer District on 20 July 1943 for administrative purposes only. The Kellex Corporation was directly concerned with barrier research, development and manufacture. Plant construction was completed in July 1944. At that time the Area office staff consisted of two officers and ten civilians. An area organization chart dated 5 September 1943 is provided in Appendix C10. The functions of the Area office increased continually, so that by 31 March 1945 the Area force consisted of six military and twenty-two civilian members (App. C11). The Decatur Area was dissolved as of 1 July 1946.

b. <u>Personnel.</u> - The position of Decatur Area Engineer was held successively by Captain J. H. Braman, Major C. E. Choate, Major J. J. Moran, and Captain R. L. Crawford, as tabulated in Appendix J3. This appendix presents additional information regarding other Area personnel.

18-5. <u>Detroit Area.</u>

a. <u>Organization.</u> - The original Detroit Office was opened by Major (then Captain) Norman R. Archer in May 1943, with a force of two civilians. On 21 July 1943, the Detroit Area was established, with Lt. Colonel (then Major) A. Tammaro as Area Engineer, and Captain

R. G. Seider as Executive Officer. The civilian strength grew to fourteen by 15 July 1943, and was increased slightly over that figure in succeeding months. The principal functions of this area were administration of the Chrysler Corporation contracts W-7405-eng-127 (for the production of K-25 process converters) W-7405-eng-56 (for design and development), and numerous other construction and procurement prime contracts and subcontracts in connection with the work and facilities for the prosecution of the work. The Area organization as of 16 August 1943 is shown in Appendix C12. As of March 1945, the Detroit Area was headed by Major F. H. Belcher, Area Engineer. The staff included four other officers, one enlisted man and 22 civilians. The area activities by this time were confined principally to production under contract W-7405-eng-127. A consolidated organization chart as of 31 March 1945 is attached (App. C13).

b. Personnel. - The position of Detroit Area Engineer was held successively by Lt. Colonel A. Tammaro, Major F. H. Belcher, and Captain J. D. McCormick, as tabulated in Appendix J4, which also presents information regarding other key personnel.

18-6. The Kellex Corporation.

a. Organization. - In view of the magnitude of the undertaking contracted for in W-7405-eng-23, The M. W. Kellogg Company preferred, for accounting and security purposes, to separate completely its Manhattan District commitments from its other activities. The Kellex Corporation, a wholly-owned Kellogg subsidiary, was accordingly organized in January 1943. From then on, all work under the contract was prosecuted by, and in the name of, The Kellex Corporation. This arrangement proved to be most satisfactory from both the Government's and the contractor's viewpoints. Many key personnel of the Kellogg Company were transferred to The Kellex Corporation, together with a considerable portion of other personnel in the various grades. Because of the complexity of the work, highly trained specialists were borrowed from other industrial companies and organizations under various financial agreements. Some departure was made from a normal channelized organization. The work was broken down into conventional sections, and top caliber engineers with industrial experience were placed in charge of each section. The Kellex Corporation was set up as a complete self-sustaining firm with engineering, research, expediting, accounting, and service groups of various types. Appendix C14 presents a typical early Kellex organization chart. Appendix C15 shows a later chart typifying the organization as applied to K-27 activities.

b. Employment Statistics.

(1) Total Employees. - The total personnel of The Kellex Corporation amounted to 1,676 persons as of 31 March 1945, of whom 364 were stationed in the field, the remainder operating in or out of the New York office. A breakdown by categories is provided in Appendix D2.

(2) Employment Growth. - A graph showing the variation by months of Kellex personnel strength is included as Appendix C16. The peak employment was reached during the summer months of 1944. Appendix D3 tabulates estimates of the maximum number of individuals engaged in design and engineering activities at facili-

ties of subcontractors of The Kellex Corporation. The nature of the work and the products being manufactured likewise are listed in these appendices.

c. Personnel. - A list of key Kellex personnel and their chief duties is attached (App. J5). This list is divided into three sections showing (1) the corporate officers of The Kellex Corporation, (2) top engineering and administrative personnel of the corporation, and (3) a supplemental alphabetical list of other division and section heads. Individuals who made fundamental scientific research studies are listed also in Volume 2. Individuals engaged by principal subcontractors of The Kellex Corporation who made significant development contributions are listed in Appendix J6.

18-7. Allis-Chalmers Manufacturing Company.

a. Employment Statistics. - A peak employment of 625 employees was reached by Allis-Chalmers Manufacturing Company on 1 April 1943. This company manufactured equipment for the diffusion plant. Appendix C17 illustrates the variation of personnel strength, and Appendix D4 shows the number of design and engineering personnel at peak activity.

b. Personnel. - A list of key design and engineering personnel of the Allis-Chalmers Manufacturing Company, together with their contributions to the diffusion Project is provided in Appendix J7.

18-8. Houdaille-Hershey Corporation.

a. Employment Statistics. - A total of 4,070 persons was employed by the Houdaille-Hershey Corporation in its Garfield Plant on 31 March 1945; office duties required 573 people, 2,515 were engaged in plant operations, 627 in plant maintenance, 234 in laboratory and research work and 121 were employed as guards. Appendix D4 contains the estimated number of design and engineering personnel at peak activity. A graph showing month-by-month variation of total Garfield Division employees is attached as Appendix C18.

b. Personnel. - A list of key design and engineering personnel of the Houdaille-Hershey Corporation, together with their contributions to the gaseous diffusion project, is appended (App. J7).

18-9. The Chrysler Corporation.

a. Employment Statistics. - The personnel strength of the Chrysler Corporation at its Lynch Road Plant reached a peak of 2,605 persons on 1 May 1945, of whom 132 were engaged in engineering and laboratory activities, 1,567 in production, 285 in plant maintenance work, and 621 in other categories. Appendix D4 gives the estimated number of design and engineering personnel at peak activity. A graph showing month-by-month variation of total Lynch Road employees is provided as Appendix C19.

b. Personnel. - A list of key design and engineering personnel of the Chrysler Corporation, together with their contributions to the gaseous diffusion project is included in Appendix J7.

18-10. Other Contractors.

a. Employment Statistics. - Estimated total design and engineering personnel employed at the peak of their activity by other contractors supplying diffusion plant requirements are listed in Appendix D4, together with the type of product manufactured.

b. Personnel. - A list of key design and engineering personnel at other contractor installations, not specifically mentioned in preceding paragraphs, together with their contributions to the diffusion project, is presented in Appendix J7.

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "A"

CONTRACTS

The following list represents a tabulation of design, engineering, and procurement prime contracts attributable to the K-25 Project with the exclusion only of contracts pertaining to the special chemicals program; the latter contracts are treated in Book VII. The list is complete as of the end of the fiscal year 1946, and cost figures are effective as of this date.

Contract type is tabulated in the first column and denoted by a numerical code, the key for which is as follows:

(1) Unit price supply.
(2) Fixed fee architect-engineer-construction-management.
(3) Design and development, reimbursement for expenditures.
(4) Unit price supply with periodic adjustment of price.
(5) Reimbursement for cost plus a fixed fee.
(6) Lump sum construction.
(7) Lump sum supply.
(8) Lump sum design and development.
(10) Construction and operation, reimbursement for expenditures.
(11) Lump sum architect-engineer services.
(12) Design and drafting, reimbursement based on man-hour rate.
(13) Unit price service.
(14) Unit price construction.
(15) Storage.
(16) Rental.
(17) Lease.

Method of letting is tabulated in the second column and denoted by a numerical code, the key for which is as follows:

(1) Negotiated by New York Area.
(2) Negotiated by Detroit Area.
(3) Negotiated by Milwaukee Area.
(4) Negotiated by Decatur Area.
(5) Negotiated by District Engineer.
(6) Negotiated by District Office.
(7) Negotiated by Madison Square Area.
(8) Negotiated by Boston Area.
(9) Negotiated by St. Louis Area.

The contract table is arranged in numerical order by contract number; the following index list facilitates use of the table in cases where contractor's name is known, but the contract number is not.

Alco Products Division (American Locomotive Company)	W-7415-eng-38
Allis-Chalmers Manufacturing Company	W-7405-eng-54
	W-7405-eng-61
	W-7405-eng-62
	W-7405-eng-63
	W-7405-eng-261
	W-26-021-eng-70
American Bridge Company	W-22-075-eng-92
American Steel Band Company	W-42-069-eng-90
Bakelite Corporation	W-7405-eng-283
Bart Laboratories	W-7409-eng-19
	W-7415-eng-39
	W-26-021-eng-57
Beach-Russ Company	W-7415-eng-34
Bethlehem Steel Company	W-7405-eng-57
	W-7405-eng-69
Birmingham Construction Company	W-7405-eng-189
Buffalo Forge Company	W-26-021-eng-61
Burke Company, O. W.	W-7405-eng-132
Carbide and Carbon Chemicals Corporation	W-7415-eng-44
Carrier Corporation	W-7425-eng-28
Campbell Company, Inc., A. S.	W-7418-eng-64
Chrysler Corporation	W-7405-eng-56
	W-7405-eng-127
	W-22-075-eng-133
Combustion Engineering Company, Inc.	W-7405-eng-58
	W-7405-eng-285
	W-26-021-eng-59
	W-26-021-eng-60
Commercial Solvents Corporation	W-35-058-eng-63
	W-35-058-eng-64
Commonwealth-Edison Company	W-7405-eng-60
Connelly Iron Sponge and Governor Company	W-26-021-eng-55
Crane Company	W-7418-eng-17
	W-7418-eng-18
Decatur, City of	W-7405-eng-178
Elliott Company	W-7421-eng-14
Farrar and Trefts, Inc.	W-7415-eng-33
Federal Deposit Insurance Corporation	W-26-021-eng-68
Fidelity Moving and Storage Company	W-7415-eng-31
Fisher Governor Company	W-7421-eng-13
Foster Wheeler Corporation	W-7401-eng-95
Fuller Company, George A.	W-7405-eng-131
General Cable Corporation	W-7412-eng-34

General Electric Company	W-7401-eng-50
	W-7401-eng-79
	W-7405-eng-64
	W-7405-eng-68
	W-7405-eng-70
	W-7405-eng-130
	W-7405-eng-138
	W-7405-eng-271
	W-7415-eng-40
	W-7418-eng-53
	W-7418-eng-54
Girdler Corporation	W-7423-eng-12
Glans and Killian Company	W-7405-eng-190
Hall Engineering Company	W-7405-eng-195
Hennes Trucking Company, John	W-14-108-eng-47
Herron-Zimmers Moulding Company	W-7415-eng-41
	W-26-021-eng-52
Houdaille-Hershey Corporation	W-7405-eng-55
	W-7405-eng-149
Illinois Power Company	W-7405-eng-176
	W-7405-eng-177
	W-7405-eng-181
	W-7405-eng-183
Industrial Plants Corporation	W-7409-eng-32
International Nickel Company	W-7407-eng-41
	W-7407-eng-48
Jelliff Manufacturing Corporation, C. O.	W-7415-eng-42
Kahn, Inc., Albert	W-7405-eng-65
	W-7405-eng-129
Kellogg Company, M.W.; Kellex Corporation	W-7405-eng-23
Kerby-Saunders, Inc.	W-7415-eng-32
Klug and Smith	W-7425-eng-51
Kopperman and Sons, Joseph	W-7415-eng-36
Korfund Company, Inc.	W-26-021-eng-47
Linde Air Products Company	W-7401-eng-14
	W-7401-eng-90
	W-26-021-eng-46
	W-26-021-eng-51
	W-28-094-eng-29
Lerne Plumbing and Heating Company	W-7405-eng-191
Lukens Steel Company	W-7405-eng-67
Mahon Company, R. C.	W-7405-eng-66
Maloney Electric Company	W-7405-eng-262
Manning, Maxwell, and Moore, Inc.	W-42-060-eng-69
Marley Company	W-7409-eng-17
	W-26-021-eng-58
McGean Chemical Company	W-7409-eng-22
Metals Disintegrating Company, Inc.,	W-7405-eng-139
	W-7415-eng-37
Metzcar and Son, R. H.	W-7405-eng-231
Midwest Piping and Supply Company, Inc.	W-7421-eng-12

National Research Corporation	W-7415-eng-60
National Tube Company	W-7401-eng-66
Office Supply and Equipment Company	W-7407-eng-65
Okonite-Callender Cable Company	W-7412-eng-33
Otis Elevator Company	W-7418-eng-57
Pacific Pumps, Inc.	W-7401-eng-65
Patterson-Kelley Company, Inc.	W-7418-eng-62
Pennsylvania Engineering Company	W-14-108-eng-68
Phelps-Dodge Copper Products Corporation	W-7405-eng-274
Pratt Company, Henry	W-7405-eng-59
Pritchard and Company, J. F.	W-7407-eng-50
Procter and Gamble Company	W-7405-eng-230
Reconstruction Finance Corporation	W-31-109-eng-42
Republic Flow Meter Company	W-7418-eng-52
Research Corporation	W-7405-eng-126
Roberts Construction Company, Inc., W. T.	W-22-075-eng-91
Robins Conveyors, Inc.	W-7412-eng-29
Rogers Company, Ralph	W-7418-eng-66
Salem Engineering Company	W-7421-eng-15
Sargent and Lundy	W-7418-eng-13
Schock-Gusmer and Company, Inc.	W-7415-eng-43
Singmaster and Breyer	W-7405-eng-318
Smith Corporation, A. O.	W-7415-eng-38
Stokes Machine Company, F. J.	W-7415-eng-21
Struthers-Wells Corporation	W-28-094-eng-31
Taylor Instrument Companies	W-7418-eng-14
Tennessee Valley Authority	W-31-109-eng-33
Transit Mix Concrete Corporation	W-7418-eng-4
Tull Metal and Supply Company, Inc., J. M.	W-7418-eng-56
Valley Iron Works Company	W-7407-eng-49
Vierling Steel Works	W-7412-eng-32
Wagner Electric Corporation	W-7418-eng-42
Walsh-Spencer Company	W-22-075-eng-93
Westinghouse Electric and Manufacturing Company	W-7407-eng-47
	W-7407-eng-55
	W-7415-eng-45
	W-7415-eng-61
	W-7418-eng-11
	W-7418-eng-15
	W-7418-eng-18
	W-7418-eng-19
	W-7418-eng-40
	W-7418-eng-63
	W-26-021-eng-64
Whitehead Metal Products Company, Inc.	W-7423-eng-11
Whiting Corporation	W-7412-eng-30
Whitlock Manufacturing Company	W-7415-eng-25
Worthington Pump and Machinery Corporation	W-7418-eng-12
	W-7418-eng-30
York Corporation	W-7418-eng-50

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7401-eng-14 (5)	Linde Air Products Company 7 April 1944 (1)	New York, N. Y.	Designs, engineering, and oper of plant to produce 640 tons nickel oxide and 12,500 pounds MFP-10
W-7401-eng-60 (1)	General Electric Company 23 April 1943 (1)	New York, N. Y.	Furnish and deliver eight turb generator sets, 1500 KW to 25,
W-7401-eng-79 (7)	General Electric Company 2 October 1943 (1)	New York, N. Y.	Furnish and deliver 36 electri rectangular bell type furnaces equipment.
W-7401-eng-85 (1)	Pacific Pumps, Inc. 18 October 1943 (1)	Huntington Park, Calif.	Furnish and deliver 605 specia vertical circulating pump unit
W-7401-eng-86 (1)	National Tube Company 22 November 1943 (1)	Pittsburgh, Pa.	Furnish and deliver 247,900 fe seamless black pipe.
W-7401-eng-90 (1)	Linde Air Products Company 28 January 1944 (1)	New York, N. Y.	Supply liquid nitrogen to K-25 Estimated 300,000 gallons
W-7401-eng-96 (4)	Foster Wheeler Corporation 1 March 1944 (1)	New York, N. Y.	Furnish and deliver 200 specia and 60 special steel expansion
W-7405-eng-23 (2)	M. W. Kellogg Company Kellex Corporation 14 December 1942 (1)	Jersey City, N.J. New York, N. Y.	Research, development, procure architectural, engineering, su and consultant services in con with design of the K-25 Plant.
W-7405-eng-34 (2)	Allis-Chalmers Manufacturing Company 8 February 1943 (1)	West Allis, Wisc.	Design, development, and const of plant; procurement and inst of equipment and facilities th production of pumps and driver
W-7405-eng-55 (3)	Houdaille-Hershey Corporation 23 April 1943 (1)	Detroit, Mich.	Research and development of "A and pilot plant operation.

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SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED FE PAYMEN TO DAT
Designs, engineering, and operation of plant to produce 640 tons of nickel oxide and 12,500 pounds of MFP-10	$ 1,738,400	$ 1,738,400	$ 2,606,063	$ 51,00
Furnish and deliver eight turbine generator sets, 1500 KW to 25,000 KW.	2,288,240	2,287,610	2,045,410	-
Furnish and deliver 38 electric rectangular bell type furnaces and equipment.	692,800	692,800	692,800	-
Furnish and deliver 605 special vertical circulating pump units.	610,595	752,129	934,729	-
Furnish and deliver 247,900 feet of seamless black pipe.	277,115	298,827	294,108	-
Supply liquid nitrogen to K-25 Plant. Estimated 300,000 gallons.	300,000 (per year)	300,000 (per year)	681,146	-
Furnish and deliver 200 special monel and 60 special steel expansion joints.	125,000	125,000	114,396	-
Research, development, procurement, architectural, engineering, supervisory, and consultant services in connection with design of the K-25 Plant.	254,568,698 (Includes work supervised by Kellex but done under other prime contracts.)	331,101,898	29,474,568	2,837,069
Design, development, and construction of plant; procurement and installation of equipment and facilities therein for production of pumps and drivers.	4,412,000	5,400,000	5,029,702	177,200
Research and development of "A" barrier and pilot plant operation.	1,000,000	1,600,000	1,531,880	-

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8,400	$ 1,738,400	$ 2,606,063	$ 51,000	$ 157,052	$ 2,814,115	$ 3,160,000
8,240	2,287,610	2,045,410	-	-	2,045,410	2,045,410
2,800	692,800	692,800	-	-	692,800	692,800
0,596	752,129	934,729	-	-	934,729	950,000
7,115	298,827	294,108	-	-	294,108	294,108
0,000 (r year)	300,000 (per year)	681,146	-	-	681,146	702,000
5,000	125,000	114,396	-	-	114,396	114,396
9,698	331,101,898	29,474,568	2,837,069	176,183 (Credit)	32,135,454	33,022,000
ludes work supervised Kellex but done under er prime contracts.)						
2,000	5,400,000	5,029,702	177,200	461,291	5,668,193	5,730,000
0,000	1,600,000	1,531,880	-	8,028	1,539,908	1,555,000

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-56 (3)	Chrysler Corporation 15 April 1943 (1)	Highland Park, Mich.	Develop methods, procedur facilities for manufactur units in volume.
W-7405-eng-57 (1)	Bethlehem Steel Company 27 April 1943 (1)	New York, N. Y.	Furnish and deliver struc steelwork.
W-7405-eng-58 (7)	Combustion Engineering Company, Inc. 28 April 1943 (1)	New York, N. Y.	Furnish and deliver 3 ste generating units.
W-7405-eng-59 (7)	Henry Pratt Company 28 April 1943 (1)	Chicago, Ill.	Furnish and deliver 3 ste flues and ducts, complete generating units.
W-7405-eng-60 (1)	Commonwealth Edison Company 27 April 1943 (1)	Chicago, Ill.	Furnish and deliver vario regulators, valves, gages, electrical equipment.
W-7405-eng-61 (1)	Allis-Chalmers Manufacturing Company 27 April 1943 (1)	West Allis, Wis.	Furnish and deliver 1-22, 3-3000; 1-1,800 KW genera 4-22,500; 1-30,000, 3-12, 1-1350 square feet cond
W-7405-eng-62 (3)	Allis-Chalmers Manufacturing Company 8 February 1943 (1)	West Allis, Wis.	Design, develop, manufact 22 pumps and drivers.
W-7405-eng-63 (4)	Allis-Chalmers Manufacturing Company 1 March 1943 (1)	West Allis, Wis.	Furnish and deliver 3068 HP motors; 3068 also 12 and 22 oil systems.
W-7405-eng-64 (1)	General Electric Company 22 May 1943 (1)	New York, N. Y.	Furnish and develop 22 mo 1750 HP, and various 440 control equipment.

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SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLU[DING] FEE)
Develop methods, procedures and facilities for manufacturing diffusion units in volume.	$ 250,000	$ 1,600,000	$ 1,566,[illegible]
Furnish and deliver structural steelwork.	245,640	245,640	329,4[illegible]
Furnish and deliver 3 complete steam generating units.	2,577,700	2,577,700	2,577,7[illegible]
Furnish and deliver 3 steel stacks, flues and ducts, complete for 3 steam generating units.	186,[illegible]	186,081	186,[illegible]
Furnish and deliver various controllers, regulators, valves, gages, and other electrical equipment.	295,257	282,672	282,[illegible]
Furnish and deliver 1-25,000; 1-25,000; 3-3000; 1-1,500 KW generating units and 4-22,500; 1-30,600; 3-12,000; 3-3,640; 1-1850 square feet condensers.	2,088,427	2,225,243	2,246,[illegible]
Design, develop, manufacture and deliver 22 pumps and drivers.	700,000	700,000	498,[illegible]
Furnish and deliver 5632 [illegible] to [illegible] HP motors; 6068 size 12 to [illegible] pumps, and 53 oil systems.	37,715,800	26,374,780	27,069,[illegible]
Furnish and develop 28 motors, 350 to 1750 HP, and various 440 volt motor control[illegible] equipment.	279,408	291,587	276,[illegible]

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...INAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED FEE PAYMENTS TO DATE	MATERIAL FURNISHED BY GOVERNMENT, TO DATE	TOTAL CONTRACT COSTS TO DATE	ESTIMATED TOTAL CONTRACT COSTS WHEN COMPLETED
250,000	$ 1,600,000	$ 1,566,613	-	-	$ 1,566,613	$ 1,567,000
245,640	245,640	329,492	-	-	329,492	329,492
2,577,700	2,577,700	2,577,779	-	-	2,577,779	2,577,779
186,868	186,081	186,081	-	-	186,081	186,081
295,287	282,672	282,868	-	-	282,868	282,868
2,035,427	2,226,245	2,246,868	-	-	2,246,868	2,247,000
700,000	700,000	488,866	-	$ 8,472 (Credit)	480,394	700,000
7,715,800	26,374,790	27,089,733	-	5,214	27,094,947	27,150,000
279,402	291,587	274,205	-	-	274,205	274,205

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-65 (11)	Albert Kahn, Inc. 27 May 1943 (2)	Detroit, Mich.	Furnish the necessary arc engineering services need construction of a manufac building.
W-7405-eng-66 (1)	R. C. Mahon Company 27 May 1943 (2)	Detroit, Mich.	Furnish and deliver appro 5750 tons of fabricated s steel and erect approxima tons of this steel at the Road Plant.
W-7405-eng-67 (4)	Lukens Steel Company 9 June 1943 (1)	Coatesville, Pa.	Install equipment furnish Government and manufactur and deliver nickel-clad p bars, heads, cylinders, s etc.
W-7405-eng-68 (1)	General Electric Company 14 June 1943 (1)	New York, N. Y.	Furnish and deliver vario cable.
W-7405-eng-69 (1)	Bethlehem Steel Company 15 June 1943 (1)	New York, N. Y.	Furnish and deliver struc steelwork.
W-7405-eng-70 (3)	General Electric Company 1 July 1943 (1)	New York, N. Y.	Conduct studies and resea nection with the measurem control of liquids and ga develop designs of electr electronic instruments fo analysis and process purp
W-7405-eng-126 (7)	Research Corporation 28 June 1943 (1)	New York, N. Y.	Furnish and install 3 dus with electric equipment, with appurtenances.
W-7405-eng-127 (5)	Chrysler Corporation 23 July 1943 (1)	Highland Park, Mich.	Remove and relocate machi renovate plant; procure a production machinery and and operate plant so as t diffuser units.

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CP	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTR PAY TO (NOT ING
ch.	Furnish the necessary architectural-engineering services needed for the construction of a manufacturing building.	$ 5,832	$ 5,832	$
ch.	Furnish and deliver approximately 5750 tons of fabricated structural steel and erect approximately 750 tons of this steel at the Mound Road Plant.	750,432	756,231	
, Pa.	Install equipment furnished by Government and manufacture, clean and deliver nickel-clad plates, circles, bars, heads, cylinders, reducer pipe, etc.	2,532,906	4,300,768	5,
. Y.	Furnish and deliver various electrical cable.	67,202	762,159	1,
. Y.	Furnish and deliver structural steelwork.	129,630	129,630	
. Y.	Conduct studies and research in connection with the measurement and control of liquids and gases and develop designs of electrical and electronic instruments for testing analysis and process purposes.	100,000	100,000	
. Y.	Furnish and install 3 dust precipitators with electric equipment, each complete with appurtenances.	225,370	215,370	
rk,	Remove and relocate machinery and renovate plant; procure and install production machinery and equipment and operate plant so as to produce diffuser units.	56,539,396	61,953,185	34,

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5,832	$ 5,832	$ 5,832	-	-	$ 5,832	$ 5,832
50,432	756,231	756,231	-	-	756,231	756,231
32,906	4,300,768	5,699,831	-	$ 609	5,700,440	5,800,000
67,202	762,159	1,047,717	-	-	1,047,717	1,100,000
129,630	129,630	124,648	-	-	124,648	124,648
100,000	100,000	40,714	-	-	40,714	62,000
225,370	215,370	215,370	-	-	215,370	215,370
539,398	61,953,185	34,624,924	$ 4,00[illegible]	1,202,756 (Credit)	37,425,613	43,854,000

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-129 (11)	Albert Kahn, Inc. 13 July 1943 (2)	Detroit, Mich.	Furnish the necessary ar[...] engineering services need[...] construction and supervis[...] construction at Mound Roa[...]
W-7405-eng-130 (1)	General Electric Company 17 July 1943 (1)	New York, N. Y.	Furnish and deliver misc[...] switchgear equipment cons[...] variable and constant fr[...] equipment, control panels[...] etc.
W-7405-eng-131 (2)	George A. Fuller Company 21 July 1943 (1)	Chicago, Ill.	Architect-Engineer-Manage[...] for design and constructi[...] facturing plant, power h[...] treating plant, hydrogen[...] carbon dioxide generating [...] necessary utilities, serv[...] appurtenances. Construct [...] Laboratory and dehydratio[...] operate certain parts of [...] Hershey Plant.
W-7405-eng-132 (6)	C. W. Burke Company 24 July 1943 (2)	Detroit, Mich.	Furnish equipment and mat[...] construct a New Military [...] Servicing and Finishing P[...] Mound Road, Macomb County[...]
W-7405-eng-138 (1)	General Electric Company 17 July 1943 (1)	New York, N. Y.	Furnish and deliver 3 oi[...] self and air pressure [...] put regulating and 1-7500 [...] transformer and all neces[...] materials, including wood [...] switches, miscellaneous [...] oil circuit breakers.
W-7405-eng-139 (4-10)	Metals Disintegrating Company, Inc. 24 February 1944 (1)	Elizabeth, N. J.	Design and construct a bu[...] addition to contractor's building at Verona, N. J. [...] procure, install necessar[...] and produce nickel powder [...]

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F	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED F[illegible] PAYME[illegible] TO DA[illegible]
	Furnish the necessary architectural engineering services needed for construction and supervision of construction at Mound Road Plant.	$ 56,400	$ 61,082	$ 61,082	-
F.	Furnish and deliver miscellaneous switchgear equipment consisting of variable and constant frequency equipment, control panels, assemblies, etc.	2,841,217	3,283,896	3,778,278	-
	Architect-Engineer-Manager Services for design and construction of manufacturing plant, power house, water treating plant, hydrogen, nitrogen and carbon dioxide generating plant, and necessary utilities, services and appurtenances. Construct "C" Area Laboratory and dehydration plant and operate certain parts of the Houdaille-Hershey Plant.	2,882,946	7,694,118	9,378,848	[illegible]
.	Furnish equipment and materials and construct a New Military Vehicle Servicing and Finishing Plant on Mound Road, Macomb County, Mich.	520,457	872,975	872,975	-
I.	Furnish and deliver 3 oil cooled, 2 self and air pressure cooled, 1 output regulating and 1-7500 KV power transformer and all necessary materials, including wood structures, switches, miscellaneous devices and oil circuit breakers.	318,072	806,041	1,456,373	-
J.	Design and construct a building addition to contractor's present building at Verona, N. J. and design, procure, install necessary equipment and produce nickel powder.	2,000,000	1,618,078	1,331,281	-

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56,400	$ 61,022	$ 61,022	-	-	$ 61,022	$ 61,022
41,917	3,863,996	3,778,278	-	-	3,778,278	4,204,000
62,944	7,684,118	9,378,848	156,124	328,540 (Credit)	9,206,432	10,000,000
29,457	872,978	972,975	-	-	972,975	972,975
19,072	506,061	1,456,373	-	-	1,456,373	1,477,000
00,000	1,618,678	1,331,281	-	64,832 (Credit)	1,266,450	1,266,450

CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-149 (5)	Houdaille-Hershey Corporation 10 June 1943 (1)	Detroit, Mich.	Design and procurement of supervision of installati equipment; preparation fo operation of a manufactur to produce 6,500,000 "DA" tubes.
W-7405-eng-176 (1)	Illinois Power Company 14 March 1944 (4)	Decatur, Ill.	Acquire and construct all equipment, materials, and way needed for supplying service to a barrier plan
W-7405-eng-177 (13)	Illinois Power Company 15 March 1944 (4)	Decatur, Ill.	Gas service.
W-7405-eng-178 (1)	City of Decatur 1 May 1944 (4)	Decatur, Ill.	Construct facilities to f to Decatur plant, and fur unit price per cubic foot
W-7405-eng-181 (6)	Illinois Power Company 15 March 1944 (4)	Decatur, Ill.	Installation of 21,251 li 8" high pressure gas main
W-7405-eng-183 (13)	Illinois Power Company 1 July 1944 (4)	Decatur, Ill.	Supply commercially clean
W-7405-eng-189 (6)	Birmingham Construction Company 4 August 1943 (2)	Birmingham, Mich.	Furnish labor and materia construct trunk line sewe Road Plant, Macomb County
W-7405-eng-190 (6)	Glanz and Killian Company 6 August 1943 (2)	Detroit, Mich.	Provide labor and materia all work for the plumbing protection system require Road Plant.
W-7405-eng-191 (6)	Lorne Plumbing and Heating Company 6 August 1943 (2)	Detroit, Mich.	Furnish labor and materia all heating and ventilati for construction of the M

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F	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRAC PAYME TO DA (NOT IN ING FE
:e	Design and procurement of equipment; supervision of installation of equipment; preparation for, and operation of a manufacturing plant to produce 6,500,000 "DA" barrier tubes.	$ 23,412,420	$ 16,536,000	$ 28,71
	Acquire and construct all necessary equipment, materials, and rights of way needed for supplying electric service to a barrier plant.	18,171	18,171	71
	Gas service.	900	900	6
	Construct facilities to furnish water to Decatur plant, and furnish water at unit price per cubic foot.	2,049	2,049	3
	Installation of 21,251 linear feet of 8" high pressure gas main.	65,074	65,074	6
	Supply commercially clean and dry gas.	41,500 per month	41,500 per month	3
ich.	Furnish labor and materials and construct trunk line sewer at Mound Road Plant, Macomb County, Michigan.	21,660	21,660	2
.	Provide labor and material and perform all work for the plumbing and fire protection system required at the Mound Road Plant.	134,100	138,493	13
.	Furnish labor and material and perform all heating and ventilating work required for construction of the Mound Road Plant.	79,252	77,979	7

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12,420	$ 16,536,000	$ 28,711,692	$ 1,305,000	$ 246,086	$ 30,262,778	$ 33,972,000
18,171	18,171	719,975	-	-	719,975	720,000
900	900	63,354	-	-	63,354	63,354
2,049	2,049	36,110	-	-	36,110	36,000
35,074	65,074	65,074	-	-	65,074	65,074
11,500 r month	41,500 per month	337,267	-	-	337,267	340,000
21,660	21,660	21,660	-	-	21,660	21,660
34,100	138,498	138,498	-	-	138,498	138,498
79,252	77,979	77,979	-	-	77,979	77,979

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-195 (6)	Hall Engineering Company, 10 August 1943 (2)	Detroit, Mich.	Provide labor and materia[l] installation of electrica[l] connection with the const[r] the Mound Road Plant.
W-7405-eng-230 (7)	Procter and Gamble Company 24 August 1943 (1)	Cincinnati, O.	Purchase of used boiler h[o]
W-7405-eng-231 (6)	R. H. Metzcar and Son 16 September 1943 (2)	Cincinnati, O.	Dismantling, loading, shi[p] erecting of used boilers a
W-7405-eng-261 (1)	Allis-Chalmers Manufacturing Company 25 October 1943 (1)	West Allis, Wis.	Furnish and deliver 142 - KVA air-cooled transforme[rs]
W-7405-eng-262 (1)	Maloney Electric Company 25 October 1943 (1)	New York, N. Y.	Furnish and deliver 61 - 57 - 50 KVA air-cooled tr[ansformers]
W-7405-eng-271 (1)	General Electric Company 14 December 1943 (1)	New York, N. Y.	Furnish and deliver compl[ete] corders or component parts
W-7405-eng-274 (1)	Phelps-Dodge Copper Products Corporation 30 December 1943 (1)	New York, N. Y.	Furnish and deliver 50,000 AWG and 10,000 feet #4/0 c

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W-7405-eng-285 (1)	Combustion Engineering Company 16 February 1944 (1)	New York, N. Y.	Furnish and deliver 3 stea[m] units and auxiliary equip[ment]

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OF	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXE PA TO
h.	Provide labor and material for the installation of electrical work in connection with the construction of the Mound Road Plant.	$ 80,362	$ 84,234	$ 84,234	
O.	Purchase of used boiler house equipment.	43,000	43,000	43,000	
O.	Dismantling, loading, shipping and re-erecting of used boilers and stokers.	39,585	41,831	41,831	
Wis.	Furnish and deliver 142 - 300 to 2000 KVA air-cooled transformers.	241,400	690,469	857,141	
Y.	Furnish and deliver 61 - 150 KVA and 57 - 50 KVA air-cooled transformers.	124,225	78,751	78,751	
Y.	Furnish and deliver complete line recorders or component parts.	2,342,337	2,342,337	2,376,215	
Y.	Furnish and deliver 50,000 feet #2 AWG and 10,000 feet #4/0 cable.	51,190	51,190	52,648	
DELETED	DELETED			DELETED	
Y.	Furnish and deliver 3 steam generating units and auxiliary equipment.	89,587	91,422	92,906	

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...0,362	$ 84,234	$ 84,234	-	-	$ 84,234	$ 84,234
...15,000	43,000	43,000	-	-	43,000	43,000
...59,585	41,831	41,831	-	-	41,831	41,831
...41,400	690,489	857,141	-	-	857,141	857,141
...34,225	78,751	78,751	-	-	78,751	78,751
...42,337	2,342,337	2,376,215	-	-	2,376,215	2,376,000
...51,190	51,190	52,648	-	-	52,648	52,648
DELETED			DELETED		DELETED	
...19,587	91,422	92,906	-	-	92,906	92,906

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7405-eng-316 (2)	Singmaster and Breyer 1 September 1944 (1)	New York, N. Y.	Architect-Engineer and proc service for installation of ment and utilities in an ex building at Buffalo, New Yo a new addition to plant at New York.
DELETED	DELETED		DELETED
W-7407-eng-47 (1)	Westinghouse Electric and Manufacturing Company 15 June 1943 (1)	New York, N. Y.	Furnish and deliver 23 vert diaphragm electric motors; volt, 7½ KVA motors, 5 - 25 squirrel cage motors; 2 con frequency changer sets, etc
DELETED	DELETED		DELETED
W-7407-eng-49 (4)	Valley Iron Works Company 9 February 1944 (1)	Appleton, Wis.	Furnish and deliver 140 bel reciprocating piston pumps plates for the pumps.
W-7407-eng-50 (7)	J. F. Pritchard and Company 10 February 1944 (1)	Kansas City, Mo.	Furnish and deliver 3 dual activated alumina hydryer u
W-7407-eng-55 (1)	Westinghouse Electric and Manufacturing Company 18 February 1944 (1)	New York, N. Y.	Furnish and deliver 477 - 2 and 1400 nofuse circuit bre 3 metal enclosed switchgear sets.
W-7407-eng-65 (1)	Office Supply and Equipment Company 18 August 1944 (6)	Knoxville, Tenn.	Furnish and deliver 400 cab

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OF	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUD-ING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUD-ING FEE)	CONTR PAY TO (NOT ING
Y.	Architect-Engineer and procurement service for installation of equipment and utilities in an existing building at Buffalo, New York, and in a new addition to plant at Tonawanda, New York.	$ 1,027,000	$ 2,027,000	$
	DELETED	DELETED	DELETED	
Y.	Furnish and deliver 23 vertical diaphragm electric motors; 42-440 volt, 7½ KVA motors, 5 - 25 HP squirrel cage motors; 2 complete frequency changer sets, etc.	128,956	238,552	1
	DELETED	DELETED	DELETED	
.	Furnish and deliver 140 bellows sealed reciprocating piston pumps and base plates for the pumps.	1,400,000	1,408,295	1,1
o.	Furnish and deliver 3 dual adsorber activated alumina hydryer units.	97,240	333,300	3
.	Furnish and deliver 477 - 225 ampere and 1400 nofuse circuit breakers and 3 metal enclosed switchgear equipment sets.	174,281	392,903	4
1.	Furnish and deliver 400 cabinets	21,340	21,340	:

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7,000	$ 2,027,000	$ 841,111	$ 22,544	$ 79	$ 863,734	$ 864,000
DELETED			DELETED			DELETED
1,956	256,552	266,924	-	-	266,924	266,924
DELETED			DELETED			DELETED
0,000	1,408,295	1,548,780	-	3,611	1,552,391	1,600,000
7,240	333,300	355,850	-	-	355,850	355,850
1,281	392,903	481,624	-	-	481,624	481,624
1,340	21,340	21,340	-	-	21,340	21,340

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7409-eng-17 (7)	Marley Company, Inc. 15 October 1943 (1)	Kansas City, Kansas	Furnish and deliver 1-#1[illegible] 1 #14-244 Marley wood fill[illegible] induced draft double flow [illegible] cooling towers, less water [illegible]
W-7408-eng-19 (4)	Hart Laboratories 22 November 1943 (1)	Belleville, N.J.	Clean and electroplate appr[illegible] 290,450 linear feet of sea[illegible] steel pipe.
W-7409-eng-22 (1)	McGean Chemical Company 27 April 1944 (1)	Cleveland, Ohio	Design and Construct a buil[illegible] its plant for the manufact[illegible] special nickel carbonate a[illegible] and install necessary equi[illegible] manufacture approximately [illegible] pounds of such special nick[illegible] carbonate.
W-7409-eng-32 (1)	Industrial Plants Corporation 15 August 1944 (7)	Long Island City, N. Y.	Purchase of certain stock [illegible] equipment
W-7412-eng-29 (7)	Robins Conveyors, Inc. 22 May 1943 (1)	Passaic, N. J.	Furnish and deliver 1 comp[illegible] for handling, crushing and [illegible] run-of-mine coal at a [illegible] of 350 tons per hour and 1 [illegible] system for stocking and re[illegible] run-of-mine coal, includ[illegible] prescreening equipment, tr[illegible] stackers, reclaiming hoppe[illegible]
W-7412-eng-30 (1)	Whiting Corporation 4 June 1943 (1)	New York, N. Y.	Furnish and deliver 1 - 4 [illegible] 1 - 3 motor and 1 - 1 moto[illegible] cranes.
W-7412-eng-32 (1)	Vierling Steel Works 18 June 1943 (1)	Chicago, Ill.	Furnish and deliver approx[illegible] 1,757,000 pounds of miscel[illegible] iron and steel for boiler [illegible] turbine room, boiler feed [illegible] elevator enclosure and pum[illegible]

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y.	Furnish and deliver 1-#12-24A and 1 #14-24A Marley wood filled wood induced draft double flow type cooling towers, less water basins.	$ 193,830	$ 193,830	$
, N.J.	Clean and electroplate approximately 290,450 linear feet of seamless steel pipe.	529,000	1,500,000	1,
Ohio	Design and Construct a building at its plant for the manufacture of special nickel carbonate and procure and install necessary equipment and manufacture approximately 300,000 pounds of such special nickel carbonate.	200,000	200,457	
d Y.	Purchase of certain stock supplies and equipment	485,370	485,370	
. J.	Furnish and deliver 1 complete system for handling, crushing and conveying run-of-mine coal at a nominal capacity of 350 tons per hour and 1 complete system for stocking and reclaiming run-of-mine coal, including conveyors, prescreening equipment, travelling stackers, reclaiming hopper, etc.	330,964	330,039	
N. Y.	Furnish and deliver 1 - 4 motor, 1 - 3 motor and 1 - 1 motor overhead cranes.	56,240	56,240	
ll.	Furnish and deliver approximately 1,757,000 pounds of miscellaneous iron and steel for boiler house, turbine room, boiler feed pump bay, elevator enclosure and pump house.	162,171	162,171	

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...3,830	$ 193,830	$ 193,830	-	-	$ 193,830	$ 193,830
...9,000	1,500,000	1,825,290		9,282	1,834,572	1,834,572
...0,000	200,457	213,634	-	-	213,634	213,634
5,370	485,370	166,672	-	-	166,672	166,672
...0,964	330,039	330,039	-	-	330,039	330,039
...6,240	56,240	56,709	-	-	56,709	56,709
...2,171	162,171	128,525	-	-	128,525	128,525

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7412-eng-33 (1)	Okonite-Callender Cable Company 28 June 1943 (1)	Passaic, N.J.	Furnish and deliver various electric cable.
W-7412-eng-34 (1)	General Cable Corporation 28 June 1943 (1)	New York, N. Y.	Furnish and deliver various 3, 4, 5, 7, and 9 conductor
W-7415-eng-21 (1)	F. J. Stokes Machine Company 3 December 1943 (1)	Philadelphia, Pa.	Furnish and deliver 30 - 10[illegible] 44 - 50 CFM vacuum pumps and spare parts for same.
W-7415-eng-28 (1)	Whitlock Manufacturing Company 16 December 1943 (1)	New York, N. Y.	Furnish and deliver coolant as following: 120 - 1306 sq[illegible] feet; 92 - 720 square feet; [illegible] 493 square feet; 48 - 980 sq[illegible] feet; 118 - 643 square feet; [illegible] 197 square feet.
W-7415-eng-31 (13)	Fidelity Moving and Storage Company 20 August 1943 (1)	Bayonne, N. J.	Storage of nickel powder.
W-7415-eng-32 (7)	Kerby-Saunders, Inc. 22 March 1944 (1)	New York, N. Y.	Furnish and deliver 10 refr[illegible] units complete, last stage nitrous oxide stage.
W-7415-eng-33 (1)	Farrar and Trefts, Inc. 15 May 1944 (1)	Buffalo, N. Y.	Furnish and deliver 52 nick[illegible] tanks in sizes ranging from [illegible] OD- 8'0" OD.
W-7415-eng-34 (4)	Beach-Russ Company 13 March 1944 (1)	Brooklyn, N. Y.	Furnish and deliver 159 - 5[illegible] vacuum pumps.
W-7415-eng-35 (4)	A. O. Smith Corporation 22 April 1944 (1)	New York, N. Y.	Furnish and deliver 688 ext[illegible] coolers and 17 spare tube b[illegible] consisting of fin tubes bra[illegible] tube sheets.

)F	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUD- ING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUD- ING FEE)	CONTRAC PAYMENT TO DA (NOT IN ING FE
J.	Furnish and deliver various electric cable.	$ 719,808	$ 1,189,072	$ 1,28
Y.	Furnish and deliver various 2, 3, 4, 5, 7, and 9 conductor cable.	447,933	527,892	52
7a.	Furnish and deliver 30 - 100 CFM and 44 - 50 CFM vacuum pumps and various spare parts for same.	108,425	159,740	18
Y.	Furnish and deliver coolant coolers as following: 120 - 1306 square feet; 92 - 720 square feet; 15 - 493 square feet; 48 - 980 square feet; 118 - 643 square feet; 97 - 197 square feet.	911,157	935,814	1,351
,	Storage of nickel powder.	17.55 per month	42.45 per month	
'.	Furnish and deliver 10 refrigerator units complete, last stage being a nitrous oxide stage.	250,000	250,000	18
	Furnish and deliver 52 nickel-clad tanks in sizes ranging from 2'0" OD- 8'0" OD.	93,796	114,815	130
.	Furnish and deliver 159 - 50 CFM vacuum pumps.	275,000	458,984	708,
.	Furnish and deliver 688 external coolers and 17 spare tube bundles consisting of fin tubes brazed into tube sheets.	1,319,141	791,360	902,

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19,808	$ 1,189,072	$ 1,286,877	-	-	$ 1,286,877	$ 1,287,000
17,933	527,892	529,487	-	-	529,487	529,487
8,425	159,740	184,822	-	-	184,822	185,000
1,157	935,614	1,352,397	-	28,001	1,380,398	1,390,000
55 onth	42.45 per month	817	-	-	817	817
0,000	250,000	18,837	-	-	18,837	18,837
5,796	114,815	130,703	-	-	130,706	130,706
,000	458,984	708,902	-	50	708,952	715,000
,141	791,860	902,849	-	369	903,218	903,218

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7415-eng-36 (7)	Joseph Kopperman and Sons 2 May 1944 (1)	Philadelphia, Pa.	Furnish and deliver 1 experi cold-trap and various parts materials for cold-traps.
W-7415-eng-37 (4-10)	Metals Disintegrating Company, Inc. 25 April 1944 (1)	Elizabeth, N. J.	Convert present building for manufacture of Elgin powder design and construct a build and procure and install equi to process Virginia powder a manufacture Elgin powder and brighten B powder at Elizabe N. J.
W-7415-eng-38 (1)	Alco Products Division (American Locomotive Company) 11 May 1944 (1)	New York, N.Y.	Furnish sixteen soda lime tr ten surge drums, 119 carbon three absorber drums.
W-7415-eng-39 (1)	Bart Laboratories 12 January 1944 (1)	Belleville, N. J.	Clean and electroplate appro 1511.57 square feet of vario to 16" pipe.
W-7415-eng-40 (1)	General Electric Company 1 February 1944 (1)	New York, N. Y.	Furnish and deliver 485 diff pressure panels and 6,318 di ential pressure transmitters
W-7415-eng-41 (1)	Herron-Zimmers Moulding Company 31 May 1944 (1)	Detroit, Mich.	Furnish and deliver 79,100 h backing strips.

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SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED F PAYME TO DA
1. Furnish and deliver 1 experimental cold-trap and various parts and materials for cold-traps.	$ 769,000	$ 124,684	$ 124,684	-
Convert present building for the manufacture of Elgin powder and design and construct a building and procure and install equipment to process Virginia powder and manufacture Elgin powder and brighten B powder at Elizabeth, N. J.	2,125,000	2,222,500	1,827,022	-
Furnish sixteen soda lime traps, ten surge drums, 119 carbon traps, three absorber drums.	72,150	137,349	146,487	-
Clean and electroplate approximately 1511.57 square feet of various 6" to 16" pipe.	6,590	6,590	6,791	-
Furnish and deliver 485 differential pressure panels and 6,318 differential pressure transmitters.	1,094,036	1,094,036	1,181,489	-
Furnish and deliver 79,100 half backing strips.	67,500	95,875	112,911	-
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000	$ 124,684	$ 124,684	-	-	$ 124,684	$ 124,684
000	2,222,500	1,827,022	-	14,873 (Credit)	1,812,149	2,223,000
130	137,349	146,487	-	-	146,487	146,487
590	6,590	6,791	-	-	6,791	6,791
036	1,094,036	1,121,489	-	-	1,121,489	1,140,000
500	96,875	112,911	-	-	112,911	112,911

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7415-eng-43 (4)	Schock-Gusmer and Company, Inc. 9 June 1944 (1)	Hoboken, N. J.	Furnish and deliver cold tr as follows: 47 - 9½" O.D. 6'8" long; 7 - 10" IPS x 10 long and 20 - 4½" O.D. x 8' long.
W-7415-eng-44 (1)	Carbide and Carbon Chemicals Corporation 14 June 1944 (1)	New York, N. Y.	Furnish and deliver 16 mobi C-216 disposal units and 3 absorber units.
W-7415-eng-45 (7)	Westinghouse Electric and Manufacturing Company 27 June 1944 (1)	New York, N. Y.	Furnish and deliver various variable frequency and cont equipment.
W-7415-eng-60 (3)	National Research Corporation 14 September 1944 (1)	Boston, Mass.	Research to design, develop, manufacture and deliver 3 - pounds/hour scraper cold tr systems, including condense ejectors and re-evaporators.
W-7415-eng-61 (8)	Westinghouse Electric and Manufacturing Company 16 September 1944 (1)	New York, N. Y.	Renovate premises, install machinery and manufacture, furnish and deliver 1,650 m
W-7418-eng-4 (1)	Transit Mix Concrete Corporation 7 January 1943 (6)	New York, N. Y.	Furnish ready-mix concrete.
W-7418-eng-11 (1)	Westinghouse Electric and Manufacturing Company 3 April 1943 (1)	New York, N. Y.	Furnish and deliver 2 - 25, and 1 - 20,000 KW turbo-gen units and 2 sets automatic selector equipment.
W-7418-eng-12 (7)	Worthington Pump and Machinery Corporation 6 May 1943 (1)	New York, N. Y.	Furnish and deliver 6 boile pumps and 1 complete rotati for each pump.

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OF	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRAC PAYME TO DA (NOT I ING F
J.	Furnish and deliver cold traps as follows: 47 - 9½" O.D. x 6'8" long; 7 - 10" IPS x 10'6" long and 20 - 4½" O.D. x 8'4½" long.	$ 240,000	$ 340,000	$ 3
Y.	Furnish and deliver 16 mobile C-216 disposal units and 3 spare absorber units.	113,555	113,555	(
Y.	Furnish and deliver various variable frequency and control equipment.	78,500	84,425	6
.	Research to design, develop, manufacture and deliver 3 - 647 pounds/hour scraper cold trap systems, including condensers, ejectors and re-evaporators.	300,000	300,000	
Y.	Renovate premises, install machinery and manufacture, furnish and deliver 1,660 motors.	3,500,000	3,500,000	(
Y.	Furnish ready-mix concrete.	2,415,000	3,289,171	8
Y.	Furnish and deliver 2 - 25,000 KW and 1 - 20,000 KW turbo-generator units and 2 sets automatic frequency selector equipment.	1,494,030	1,494,030	1,3
Y.	Furnish and deliver 6 boiler feed pumps and 1 complete rotating element for each pump.	134,696	152,426	1

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240,000	$ 340,000	$ 310,210	-	-	$ 310,210	$ 310,210
113,555	113,555	50,022	-	-	50,022	50,022
75,500	84,425	653,874	-	-	653,874	660,000
300,000	300,000	5,790	-	-	5,790	5,790
500,000	3,500,000	89,760	-	-	89,760	89,760
415,000	3,289,171	877,067	-	-	877,067	877,067
494,030	1,494,030	1,389,711	-	-	1,389,711	1,389,711
134,696	152,426	158,254	-	-	158,254	158,254

CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7418-eng-13 (12)	Sargent and Lundy 20 April 1943 (1)	Chicago, Ill.	Design, drafting and estimat work in connection with a st turbine power plant of appr mately 235,000 KW turbine ge capacity.
W-7418-eng-14 (4)	Taylor Instrument Companies 12 May 1943 (1)	Rochester, N. Y.	Furnish engineering, procure consultant and advisory serv connection with instruments by the Contractor or Governm Contractor shall furnish and relays and transmitters spec floor instruments and standa special instruments.
W-7418-eng-15 (1)	Westinghouse Electric and Manufacturing Company 15 May 1943 (1)	New York, N. Y.	Furnish and deliver 3 - 22,6 square feet surface condense 3 circulating water single s priming ejectors.
W-7418-eng-16 (7)	Westinghouse Electric and Manufacturing Company 24 May 1943 (1)	New York, N. Y.	Furnish and deliver various house switch gear equipment exciter sets for turbine gen
W-7418-eng-17 (1)	Crane Company 15 June 1943 (1)	Long Island City, N. Y.	Furnish and deliver 30 gate 3" to 12"
W-7418-eng-18 (4)	Crane Company 25 June 1943 (1)	Chicago, Ill.	Alter building as necessary out work under contract. Fu and deliver gate valves and floor valves and plate with or other plating material pi fittings furnished by the Go
W-7418-eng-19 (7)	Westinghouse Electric and Manufacturing Company 17 July 1943 (1)	New York, N. Y.	Furnish and deliver 569 Type transformers and various part automatic air blast equipment

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OF	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRAC PAYM TO DA (NOT I ING F
.	Design, drafting and estimating work in connection with a steam turbine power plant of approximately 238,000 KW turbine generating capacity.	$ 600,000	$ 750,000	$ 7
. Y.	Furnish engineering, procurement, consultant and advisory services in connection with instruments furnished by the Contractor or Government. Contractor shall furnish and deliver relays and transmitters special test floor instruments and standard and special instruments.	1,700,000	3,762,571	5,1
Y.	Furnish and deliver 3 - 22,600 square feet surface condensers and 3 circulating water single stage priming ejectors.	197,820	197,820	1
Y.	Furnish and deliver various power house switch gear equipment and exciter sets for turbine generators.	2,329,461	2,565,793	3,6
City.	Furnish and deliver 30 gate valves 3" to 12"	64,534	62,849	6
.	Alter building as necessary to carry out work under contract. Furnish and deliver gate valves and test floor valves and plate with nickel or other plating material pipe fittings furnished by the Government.	5,916,355	10,928,491	14,2
Y.	Furnish and deliver 569 Type ASL transformers and various parts and automatic air blast equipment.	2,164,920	1,992,563	2,6

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500,000	$ 750,000	$ 734,555	-	-	$ 734,555	$ 734,555
700,000	3,762,571	5,139,880	-	76	5,139,956	5,139,000
197,820	197,820	198,889	-	-	198,889	198,889
329,461	2,565,793	3,686,164	-	-	3,686,164	3,732,000
64,634	62,849	61,163	-	-	61, 163	61,163
916,355	10,928,491	14,241,983	-	- 118 (Credit)	14,241,865	14,265,000
164,920	1,992,565	2,664,829	-	-	2,664,829	2,664,829

CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7418-eng-40 (7)	Westinghouse Electric and Manufacturing Company 23 October 1943 (1)	New York, N. Y.	Furnish and deliver 188 - 200 and 4000 CFM vacuum pump set various bellows assemblies a spare parts.
W-7418-eng-42 (1)	Wagner Electric Company 8 December 1943 (1)	St. Louis, Mo.	Furnish and deliver 608 - 1 HP coolant pump motors.
W-7418-eng-50 (1)	York Corporation 28 March 1944 (1)	New York, N. Y.	Furnish and deliver 12 compl mobile refrigeration plants removal, recovery and conden sation of special gases and complete equipment for the ai conditioning of Laboratory Buildings A, B, C, and D.
W-7418-eng-52 (4)	Republic Flow Meter Company 17 April 1944 (1)	Chicago, Ill.	Furnish and deliver 684 - 4" magnetically operated butter control valves.
W-7418-eng-53 (1)	General Electric Company 20 April 1944 (1)	New York, N. Y.	Furnish and deliver 324 leak detectors, 30 mass spectro-meters, 40 sets operating sp shelf spares, acoustic gas analyzers, etc.
W-7418-eng-54 (4)	General Electric Company 5 May 1944 (1)	New York, N. Y.	Furnish and deliver 175 speci air bearing, 3 ph. induction motors, 7200 RPM, approximate 6 HP.
W-7418-eng-56 (1)	J. M. Tull Metal and Supply Company, Inc. 3 July 1944 (1)	Atlanta, Ga.	Furnish and deliver 104,500 l feet of 1/4" to 2" standard l monel pipe.
W-7418-eng-57 (7)	Otis Elevator Company 26 July 1944 (1)	New York, N. Y.	Furnish, deliver and install Blair, Tennessee 7 electric automatic freight elevators, wide x 6'10" front.

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#	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRAC PAYME TO DA (NOT IN ING FE
Y.	Furnish and deliver 186 - 2000 and 4000 CFM vacuum pump sets and various bellows assemblies and spare parts.	$ 982,466	$ 1,221,057	$ 1,24
.	Furnish and deliver 608 - 1 to 50 HP coolant pump motors.	86,848	118,966	15
Y.	Furnish and deliver 12 complete mobile refrigeration plants for removal, recovery and condensation of special gases and complete equipment for the air conditioning of Laboratory Buildings A, B, C, and D.	293,143	293,143	36
	Furnish and deliver 684 - 4" magnetically operated butterfly control valves.	408,557	278,278	30
Y.	Furnish and deliver 324 leak detectors, 30 mass spectrometers, 40 sets operating spares, shelf spares, acoustic gas analyzers, etc.	1,648,636	1,648,636	1,51
Y.	Furnish and deliver 175 special air bearing, 3 ph. induction motors, 7200 RPM, approximately 6 HP.	437,500	437,500	6
	Furnish and deliver 104,500 linear feet of 1/4" to 2" standard IPS monel pipe.	120,319	149,687	30
Y.	Furnish, deliver and install at Blair, Tennessee 7 electric automatic freight elevators, 6'4" wide x 6'10" front.	53,767	53,767	6

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L ACT ATED T CLUD- E)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED FEE PAYMENTS TO DATE	MATERIAL FURNISHED BY GOVERNMENT TO DATE	TOTAL CONTRACT COSTS TO DATE	ESTIMATED TOTAL CONTRACT COSTS WHEN COMPLETED
2,466	$ 1,221,057	$ 1,249,575	-	-	$ 1,249,575	$ 1,250,000
6,848	118,966	154,404	-	-	154,404	155,000
3,143	293,143	368,008	-	-	368,008	368,008
8,557	278,278	301,877	-	16	301,893	302,000
8,636	1,648,636	1,518,861	-	176,015 (Credit)	1,342,846	1,910,000
7,500	437,500	64,485	-	-	64,485	64,485
0,319	149,687	303,772	-	-	303,772	303,772
3,767	53,767	61,448	-	-	61,448	61,448

CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7418-eng-60 (7)	Worthington Pump and Machinery Corporation 29 July 1944 (1)	New York, N. Y.	Furnish and deliver 10 refri units; the last stage of the being a nitrous oxide stage, furnish and deliver various parts and 63 globe valves.
W-7418-eng-62 (1)	Patterson Kelly Company, Inc. 1 September 1944 (1)	East Stroudsburg Pa.	Furnish and deliver 58 cold
W-7418-eng-63 (4)	Westinghouse Electric and Manufacturing Company 14 June 1944 (1)	New York, N. Y.	Furnish and deliver 263 nick plated mist filters complete inlet and outlet connections equipped with electric heate
W-7418-eng-64 (3)	A. S. Campbell Company, Inc. 13 September 1944 (1)	East Boston, Mass.	Develop production methods a technical and design equipme for production of special tu
W-7418-eng-66 (14)	Ralph Rogers Company 27 December 1943 (8)	Nashville, Tenn.	Quarry, crush, screen, other process, as specified, hand haul, and load crushed stone.
W-7421-eng-12 (5)	Midwest Piping and Supply Company, Inc. 20 December 1943 (1)	St. Louis, Mo.	Furnish and deliver approxim 6,200 tons of fabricated unit the complete coolant and coo storage systems and process for the complete waste and process, production handling, purification systems and rel instrument piping systems re for the process plant.
W-7421-eng-13 (4)	Fisher Governor Company 21 December 1943 (1)	Marshalltown, Iowa	Furnish and deliver 2788 - 4" 12" steel or monel body butt control valves and 652 bellow assemblies for valves.
W-7421-eng-14 (7)	Elliott Company 8 January 1944 (1)	Jeannette, Pa.	Furnish and deliver 44 pumps complete and 20 complete sets replacement parts.

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OF I	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUD-ING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUD-ING FEE)	CONTRA PAYM TO D (NOT I ING F
Y.	Furnish and deliver 10 refrigeration units; the last stage of the units being a nitrous oxide stage. Also furnish and deliver various spare parts and 63 globe valves.	$ 526,868	$ 537,268	$ 5
burg	Furnish and deliver 58 cold traps.	353,000	166,719	1
Y.	Furnish and deliver 263 nickel plated mist filters complete with inlet and outlet connections and equipped with electric heaters.	197,250	197,250	20
Mass.	Develop production methods and technical and design equipment for production of special tubing.	50,000	50,000	20
nn.	Quarry, crush, screen, otherwise process, as specified, handle, haul, and load crushed stone.	462,250	1,201,950	
.	Furnish and deliver approximately 6,200 tons of fabricated units for the complete coolant and cooling storage systems and process pipe for the complete waste and surge, process, production handling, feed purification systems and related instrument piping systems required for the process plant.	4,565,000	6,145,410	7,22
	Furnish and deliver 2788 - 4" to 12" steel or monel body butterfly control valves and 652 bellows assemblies for valves.	1,466,062	1,098,412	1,433
	Furnish and deliver 44 pumps assembled complete and 20 complete sets of seal replacement parts.	79,200	82,000	184,

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528,868	$ 537,288	$ 587,167	-	-	$ 587,167	$ 595,000
363,000	166,719	170,633	-	2,711 (Credit)	167,922	167,922
197,250	197,250	206,926	-	-	206,926	206,926
50,000	50,000	20,520	-	- 15	20,535	20,535
462,250	1,201,950	2,157	-	-	2,157	2,157
565,000	6,146,410	7,221,849	65,000	1,202 (Credit)	7,285,647	10,800,000
[illegible]466,062	1,098,412	1,433,244	-	183	1,433,427	1,434,000
79,200	82,000	184,267	-	-	184,267	184,000

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-7421-eng-15 (1)	Salem Engineering Company 21 February 1944 (1)	Salem, Ohio	Furnish and deliver 261 vario Type A, B, C, D, and E specia alloy muffles, 144 sets of ol and 377 grills.
W-7423-eng-11 (4)	Whitehead Metal Products Company, Inc. 3 February 1944 (1)	New York, N. Y.	Furnish and deliver 180 flat gas filters.
W-7423-eng-12 (1)	Girdler Corporation 5 February 1944 (1)	Louisville, Ky.	Furnish and deliver material equipment for the constructio 1 hydrogen manufacturing and purification plant having cap to produce 1500 standard cubi meters of hydrogen per hour.
W-7425-eng-28 (1)	Carrier Corporation 12 January 1944 (1)	New York, N. Y.	Furnish and deliver 14 centri air compressors, together wit increasing gears and motors.
W-7425-eng-51 (13)	Klug and Smith 14 January 1944 (1-3)	Milwaukee, Wis.	Unload, move, stack, cover, m coils.
W-14-108-eng-47 (13)	John Mennes Trucking Company 20 June 1944 (3)	Milwaukee, Wis.	Truck transportation of pumps West Allis, Wisconsin to Blai Tennessee.
W-14-108-eng-68 (1)	Pennsylvania Engineering Company 18 June 1945 (6)	Philadelphia, Pa.	Supply of freon gas and cylin
W-22-075-eng-01 (1)	W. T. Roberts Construction Company, Inc. 24 April 1945 (8)	Cambridge, Mass.	Supply of cement asbestos for buildings.

?	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED F PAYMEI TO DAT
	Furnish and deliver 261 various Type A, B, C, D, and E special alloy muffles, 144 sets of clamps and 377 grills.	$ 868,316	$ 2,246,032	$ 2,255,786	-
f.	Furnish and deliver 180 flat plate gas filters.	500,000	246,990	328,839	-
r.	Furnish and deliver material and equipment for the construction of 1 hydrogen manufacturing and purification plant having capacity to produce 1500 standard cubic meters of hydrogen per hour.	541,806	514,741	514,741	-
l.	Furnish and deliver 14 centrifugal air compressors, together with speed increasing gears and motors.	66,406	200,068	201,448	-
l.	Unload, move, stack, cover, metal coils.	8,269	7,087	14,140	-
l.	Truck transportation of pumps from West Allis, Wisconsin to Blair, Tennessee.	12,210	12,210	12,210	-
Pa.	Supply of freon gas and cylinders	10,328	8,991	9,051	-
a.	Supply of cement asbestos for certain buildings.	13,456	13,456	5,962	-

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168,315	$ 2,248,032	$ 2,255,786	-	-	$ 2,255,786	$ 2,255,786
500,000	246,990	328,839	-	13,060 (Credit)	315,779	315,779
41,505	514,741	514,741	-	-	514,741	514,741
56,408	200,068	201,448	-	-	201,448	201,448
8,269	7,087	14,140	-	-	14,140	14,140
12,210	12,210	12,210	-	-	12,210	12,210
10,328	8,991	9,051	-	-	9,051	10,000
13,456	13,456	5,952	-	-	5,952	5,952

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-22-075-eng-92 (7)	American Bridge Company 30 April 1945 (8)	Boston, Mass	Supplies delivered to Oak Rid and Blair, Tennessee.
W-22-075-eng-93 (1)	Walsh-Spencer Company 15 May 1945 (8)	Boston, Mass.	Furnish certain types of over doors.
W-22-075-eng-133 (7)	Chrysler Corporation 15 August 1945 (6)	Highland Park, Mich.	Furnish steam, water, electri and inspection services. DOE b(3)
DELETED	DELETED		DELETED
W-26-021-eng-47 (1)	Korfund Company, Inc. 20 October 1944 (1)	Long Island City N. Y.	Furnish and deliver Korfund i lators, vibro-isolators.
W-26-021-eng-51 (7)	Linde Air Products Company 15 December 1944 (1)	New York, N. Y.	Furnish liquid nitrogen as re for the operation of 2 Govern plants operated by the Contra
W-26-021-eng-52 (1)	Herron-Zimmers Moulding Company 14 February 1945 (1)	Detroit, Mich	Furnish and deliver 426,000 h backing strips.
W-26-021-eng-55 (1)	Connelly Iron Sponge and Governor Company 3 March 1945 (1)	Chicago, Ill.	Furnish and deliver 682 - 3" cast iron relief valves.
W-26-021-eng-57 (1)	Bart Laboratories 6 April 1945 (1)	Belleville, N. J.	Electroplate approximately 80, linear feet of 3 to 16 inch ni plated pipe.

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SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUDING FEE)	FIXED [illegible] PAYM[illegible] TO D[illegible]
Supplies delivered to Oak Ridge and Blair, Tennessee.	$ 100,239	$ 100,239	$ 52,366	-
Furnish certain types of overhead doors.	4,099	4,099	1,850	-
Furnish steam, water, electricity, and inspection services.	5,352 (per year)	5,352 (per year)	5,189	-
DELETED	DELETED		DELETED	
y Furnish and deliver Korfund isolators, vibro-isolators.	53,528	63,840	74,004	-
Furnish liquid nitrogen as required for the operation of 2 Government plants operated by the Contractor.	300,000	300,000	227,684	-
Furnish and deliver 426,000 half backing strips.	536,760	536,760	760	-
Furnish and deliver 682 - 3" to 12" cast iron relief valves.	214,245	214,245	190,412	-
f. Electroplate approximately 80,000 linear feet of 3 to 16 inch nickel-plated pipe.	385,914	463,033	384,425	-

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CT TED LUD-)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUD- ING FEE)	CONTRACT PAYMENTS TO DATE (NOT INCLUD- ING FEE)	FIXED FEE PAYMENTS TO DATE	MATERIAL FURNISHED BY GOVERN- MENT TO DATE	TOTAL CON- TRACT COSTS TO DATE	ESTIMATED TOTAL CON- TRACT COSTS WHEN COMPLETED
,239	$ 100,239	$ 52,366	-	-	$ 52,366	$ 52,000
,099	4,099	1,850	-	-	1,850	2,000
,352 year)	5,352 (per year)	5,189	-	-	5,189	12,500
DELETED			DELETED			DELETED
,528	63,840	74,004	-	-	74,004	74,004
),000	300,000	227,684	-	418	228,102	300,000
760	536,760	760	-	-	760	760
245	214,245	190,412	-	-	190,412	190,412
914	463,033	384,425	-	-	384,425	442,000

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-26-021-eng-58 (7)	Marley Company, Inc. 14 April 1945 (1)	Kansas City, Kansas	One double flow type cooli tower.
W-26-021-eng-59 (7)	Combustion Engineering Company, Inc. 17 April 1945 (1)	New York, N. Y.	Furnish and deliver three pound per hour steam gener units.
W-26-021-eng-60 (1)	Combustion Engineering Company, Inc. 24 April 1945 (1)	New York, N. Y.	Furnish and deliver twelve 30 foot 10 per cent nickel drums.
W-26-021-eng-61 (1)	Buffalo Forge Company 27 April 1945 (1)	New York, N. Y.	Furnish and deliver 150 ve fans.
W-26-021-eng-64 (7)	Westinghouse Electric and Manufacturing Company 10 May 1945 (1)	New York, N. Y.	Furnish and deliver two 25 synchronous condensers.
W-26-021-eng-68 (15)	Federal Deposit Insurance Corporation 26 September 1945 (1)	Jersey City, N. J.	Storage of a quantity of p
W-26-021-eng-70 (1)	Allis-Chalmers Manufacturing Company 28 April 1945 (1)	West Allis, Wis.	Furnish and deliver 550 - power motors and 550 - 150 motors.
W-28-094-eng-29 (1)	Linde Air Products Company 1 August 1945 (5)	New York, N. Y.	Contractor agrees to sell and Government agrees to p contractor products L-28 a

OF R	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRA PAY TO (NOT I ING I
,	One double flow type cooling tower.	$ 102,390	$ 104,574	$ 1
. Y.	Furnish and deliver three 50,000 pound per hour steam generating units.	113,404	113,404	1
. Y.	Furnish and deliver twelve 10" by 30 foot 10 per cent nickel clad drums.	71,520	71,520	
. Y.	Furnish and deliver 150 ventilating fans.	83,568	93,794	
. Y.	Furnish and deliver two 25,000 KVA synchronous condensers.	273,775	273,775	1
, N. J.	Storage of a quantity of powder.	150 (per month)	150 (Per month)	
Wis.	Furnish and deliver 550 - 75 horsepower motors and 550 - 150 horsepower motors.	706,238	754,529	7
. Y.	Contractor agrees to sell to Government, and Government agrees to purchase from contractor products L-28 and L-28-B	342,500	4,300,000	3

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102,390	$ 104,574	$ 104,897	-	-	$ 104,897	$
113,404	113,404	108,538	-	143	108,681	
71,520	71,520	67,944	-	-	67,944	
83,565	93,794	84,868	-	-	84,868	
273,775	273,775	222,486	-	-	222,486	
150 (er month)	150 (Per month)	300	-	-	300	
706,238	754,529	759,592	-	-	759,592	
42,500	4,300,000	350,739	-	-	350,739	

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CONTRACT NO. TYPE	NAME OF CONTRACTOR EFFECTIVE DATE METHOD OF LETTING	HOME OFFICE OF CONTRACTOR	SCOPE OF WORK
W-28-094-eng-31 (13)	Struthers Wells Corporation 1 October 1945 (2)	Warren, Pa.	Perform all services neces the handling, storage, pre packing and delivery of co property.
W-31-109-eng-33 (16)	Tennessee Valley Authority 1 March 1945 (6)	Knoxville, Tenn.	Rental of towboat and barg
W-31-109-eng-42 (17)	Reconstruction Finance Corporation 7 August 1945 (9)	Washington, D. C.	Lease of aluminum foundry
W-35-058-eng-63 (1)	Commercial Solvents Corporation 22 May 1945 (4)	New York, N. Y.	Furnish 75,600 gallons of
W-35-058-eng-64 (1)	Commercial Solvents Corporation 2 July 1945 (4)	New York, N. Y.	Supply of 190 proof ethyl
W-42-069-eng-89 (1)	Manning, Maxwell, and Moore, Inc. 26 April 1945 (5)	Muskegon, Mich.	Supplies.
W-42-069-eng-90 (7)	American Steel Band Company 8 May 1945 (6)	Pittsburg, Pa.	Furnish protective steel r certain buildings.

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OF	SCOPE OF WORK	ORIGINAL CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	MODIFIED CONTRACT ESTIMATED AMOUNT (NOT INCLUDING FEE)	CONTRA PAYM TO D (NOT I ING F
	Perform all services necessary for the handling, storage, preservation, packing and delivery of certain property.	$ 1,458	$ 1,458	$
enn.	Rental of towboat and barge.	10 and 15 per day	10 and 15 per day	
). C.	Lease of aluminum foundry building.	1 (per year)	1 (per year)	
Y.	Furnish 75,600 gallons of ethyl alcohol.	43,092	43,092	4
Y.	Supply of 190 proof ethyl alcohol.	30,780	30,780	3
h.	Supplies.	23,932	23,932	2
i.	Furnish protective steel roofing for certain buildings.	29,995	29,995	20
			TOTALS:	$245,59

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1,458	$ 1,458	$ 1,458	-	-	$ 1,458	$ 2,000
...d 15 ...ay	10 and 15 per day	5,721	-	-	5,721	3,000
1 ...er year)	1 (per year)	4,133	-	-	4,133	4,133
...3,092	43,092	42,517	-	-	42,517	42,517
...0,780	30,780	30,780	-	1,420 (Credit)	29,360	29,360
...3,932	23,932	23,932	-	-	23, 932	23,932
...9,995	29,995	20,799	-	-	20,799	21,000
TOTALS:		$245,598,661	$ 9,039,913	$ 966,401 (Credit)	$253,672,173	$275,449,699

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "B"

PLAN DRAWINGS

No.	Title
1.	Plan of K-25 Cascade Buildings showing Arrangement of Sections, Buildings, and Cells, and showing Type of Barrier Installed in each Cell.
2.	Overall Process Material Flow Diagram showing the Path of the Process Stream throughout the Main Cascade.

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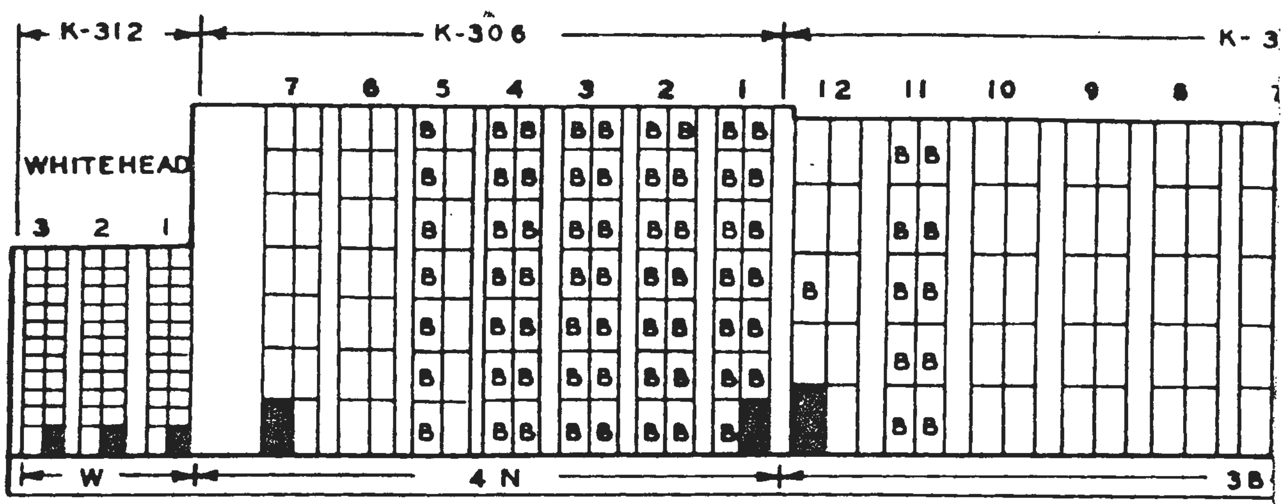

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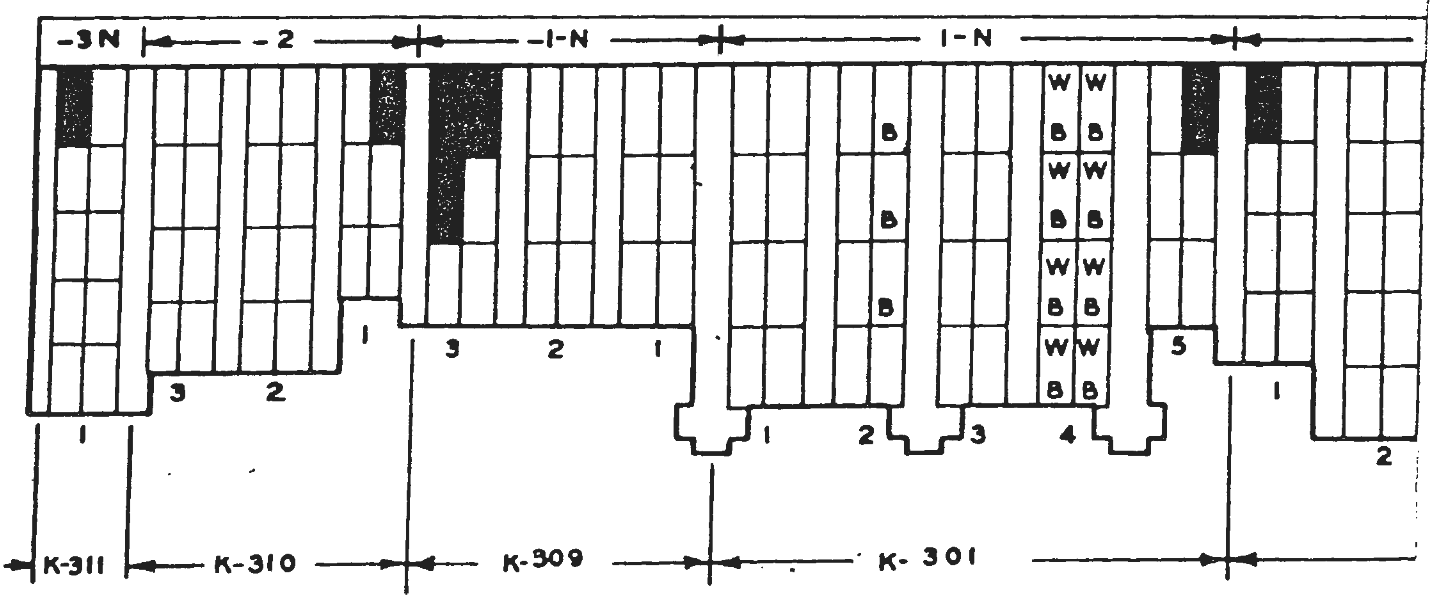

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B 1-2

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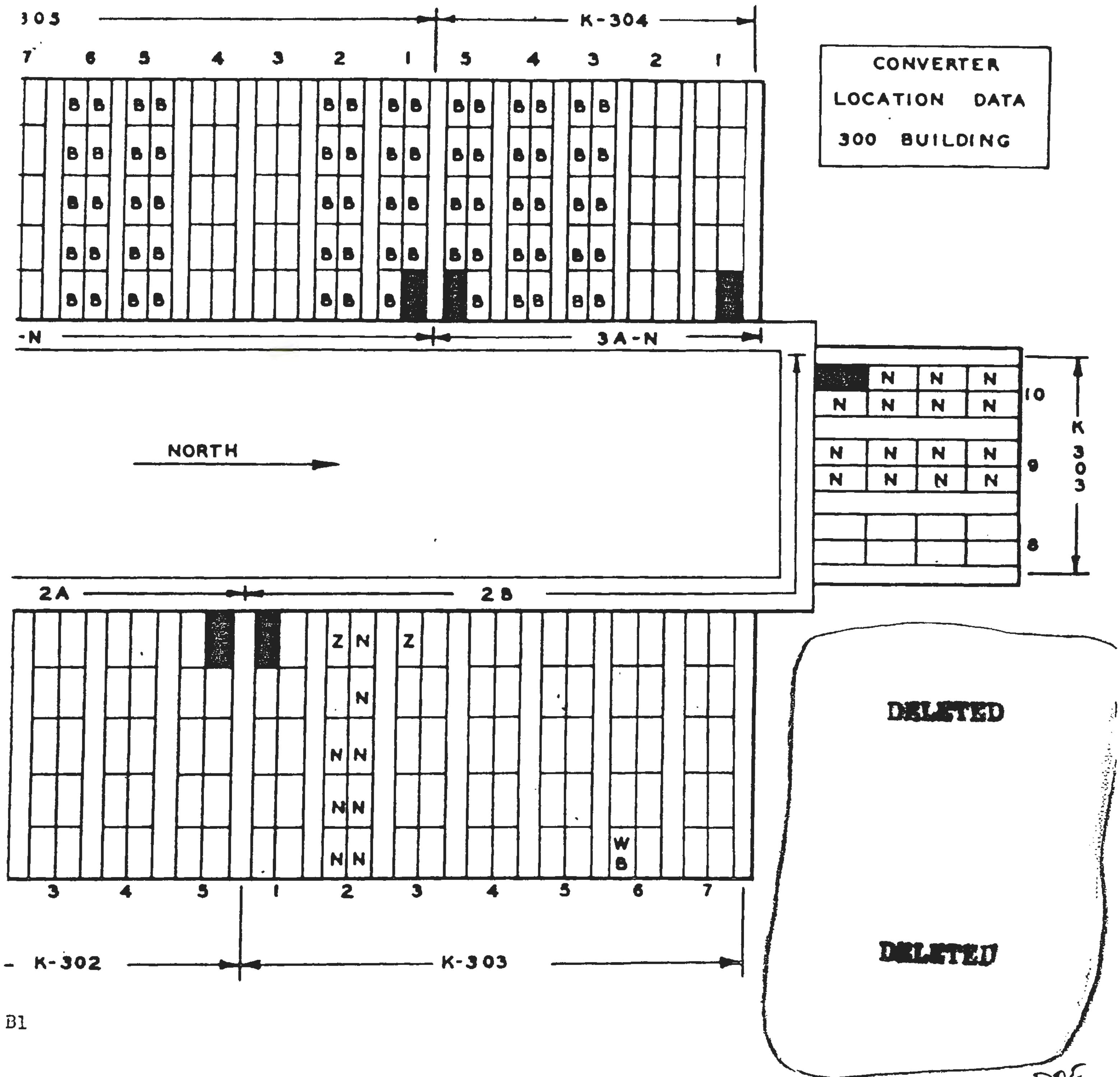

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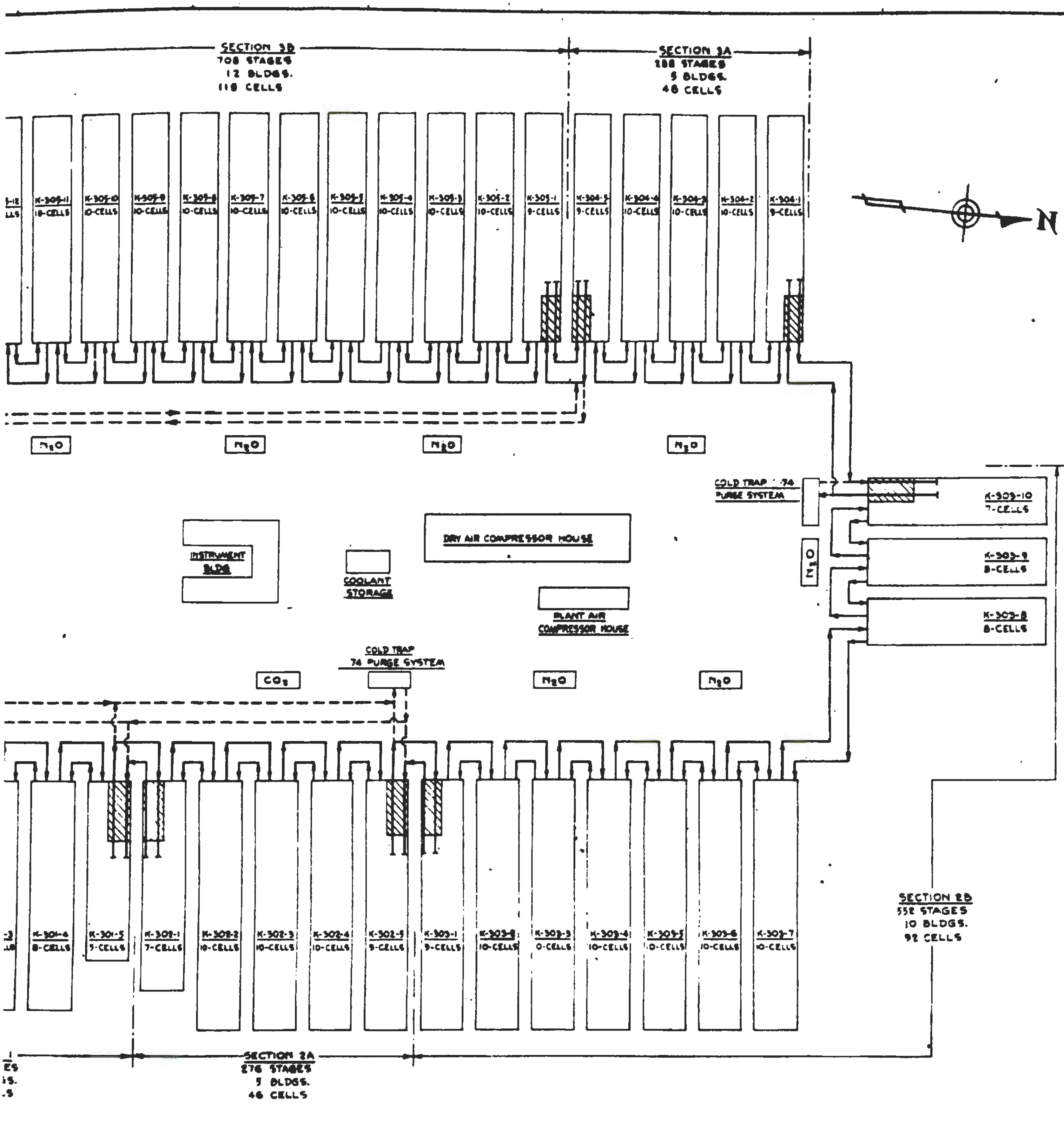
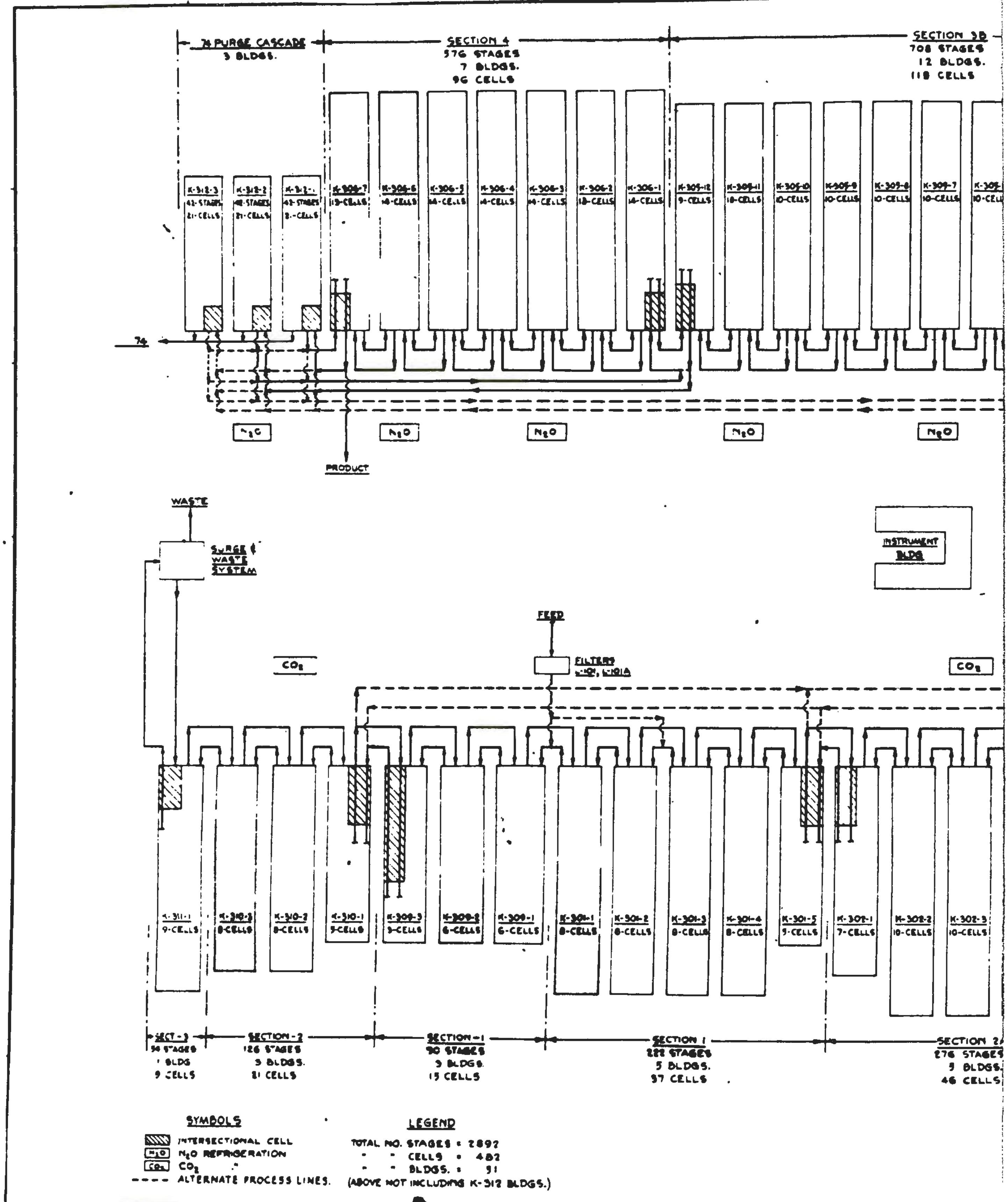


K-25 FLOW DIAGRAM

B2-2



74 PURGE CASCADE
3 BLDGS.
SECTION 4
576 STAGES
7 BLDGS.
96 CELLS
SECTION 3B
708 STAGES
12 BLDGS.
118 CELLS
K-312-3 42-STAGES 21-CELLS
K-312-2 42-STAGES 21-CELLS
K-312-1 42-STAGES 21-CELLS
K-306-7 13-CELLS
K-306-6 14-CELLS
K-306-5 14-CELLS
K-306-4 14-CELLS
K-306-3 14-CELLS
K-306-2 13-CELLS
K-306-1 14-CELLS
K-305-12 9-CELLS
K-305-11 10-CELLS
K-305-10 10-CELLS
K-305-9 10-CELLS
K-305-8 10-CELLS
K-305-7 10-CELLS
74
PRODUCT
WASTE
SURGE & WASTE SYSTEM
INSTRUMENT BLDG
FEED
FILTERS
CO_2
N_2O
K-311-1 9-CELLS
K-310-3 8-CELLS
K-310-2 8-CELLS
K-310-1 5-CELLS
K-309-3 5-CELLS
K-309-2 6-CELLS
K-309-1 6-CELLS
K-301-1 8-CELLS
K-301-2 8-CELLS
K-301-3 8-CELLS
K-301-4 8-CELLS
K-301-5 5-CELLS
K-302-1 7-CELLS
K-302-2 10-CELLS
K-302-3 10-CELLS
SECT-3 54 STAGES 1 BLDG 9 CELLS
SECTION-2 126 STAGES 3 BLDGS. 21 CELLS
SECTION-1 90 STAGES 3 BLDGS. 15 CELLS
SECTION 1 222 STAGES 5 BLDGS. 37 CELLS
SECTION 2A 276 STAGES 5 BLDGS. 46 CELLS
SYMBOLS
INTERSECTIONAL CELL
N_2O REFRIGERATION
CO_2 "
ALTERNATE PROCESS LINES.
LEGEND
TOTAL NO. STAGES = 2892
" " CELLS = 482
" " BLDGS. = 51
(ABOVE NOT INCLUDING K-312 BLDGS.)

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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "C"

CHARTS AND GRAPHS

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Procurement of Gas Diffusion Plant Process Equipment (Principal Contracts only)

Area Engineer
New York Area

Architect-Engineer
The M.W.Kellogg Co.
The Kellex Corp.

Pumps & Drivers
Allis-Chalmers Mfg. Company
W-7405-Eng-53 *

Barrier Tubes
Houdaille-Hershey
W-7405-Eng-140 *

Gas Diffusers
Chrysler Corp.
W-7405-Eng-127 *

Steel Pipe
National Tube Co.
W-7401-Eng-86

Nickel Plating
Bart Laboratories
W-7409-Eng-19

Process Piping
Midwest Piping and Supply Company
W-7401-Eng-12

High Vacuum Pump	Beach-Russ Company	W-7415-Eng-34
Special Process Valves	Crane Company	W-7418-Eng-18
Butterfly Control Valves	Fisher Governor Co.	W-7421-Eng-13
Differential Pressure Panels and Transmitters	General Electric Co.	W-7415-Eng-40
Mass Spectrometers and Leak Detectors	General Electric Co.	W-7418-Eng-53
Recording Gas Analysers	General Electric Co.	W-7405-Eng-271
Cold Trap Parts	Joseph Kopperman & Sons	W-7415-Eng-36
Cooling Towers	The Marley Co., Inc.	W-7409-Eng-17
Coolant Circulating Pumps	Pacific Pump Works	W-7401-Eng-65
Assembly of Cold Traps	Patterson Kelley Co.	W-7418-Eng-62
Magnetically Operated Control Valves	Republic Flow Meters Co.	W-7418-Eng-52
Cold Traps	Schock, Gusmer Co.	W-7418-Eng-43
Process Gas Coolers	A.O. Smith Corporation	W-7415-Eng-35
Plant Instruments	Taylor Instrument Co's.	W-7418-Eng-14
Nitrogen Purge Pumps	Valley Iron Works Co.	W-7407-Eng-49
Vacuum Pumps	Westinghouse El.& Mfg.Co.	W-7418-Eng-40
Coolant Coolers	The Whitlock Mfg. Co.	W-7415-Eng-25
Refrigeration Units	Worthington Pump and Machinery Corp.	W-7418-Eng-60
Transformers	Allis-Chalmers Mfg.Co.	W-7405-Eng-261
Transformers	Westinghouse El.& Mfg.Co.	W-7418-Eng-19

Main Process Plant,
Oak Ridge, Tenn.

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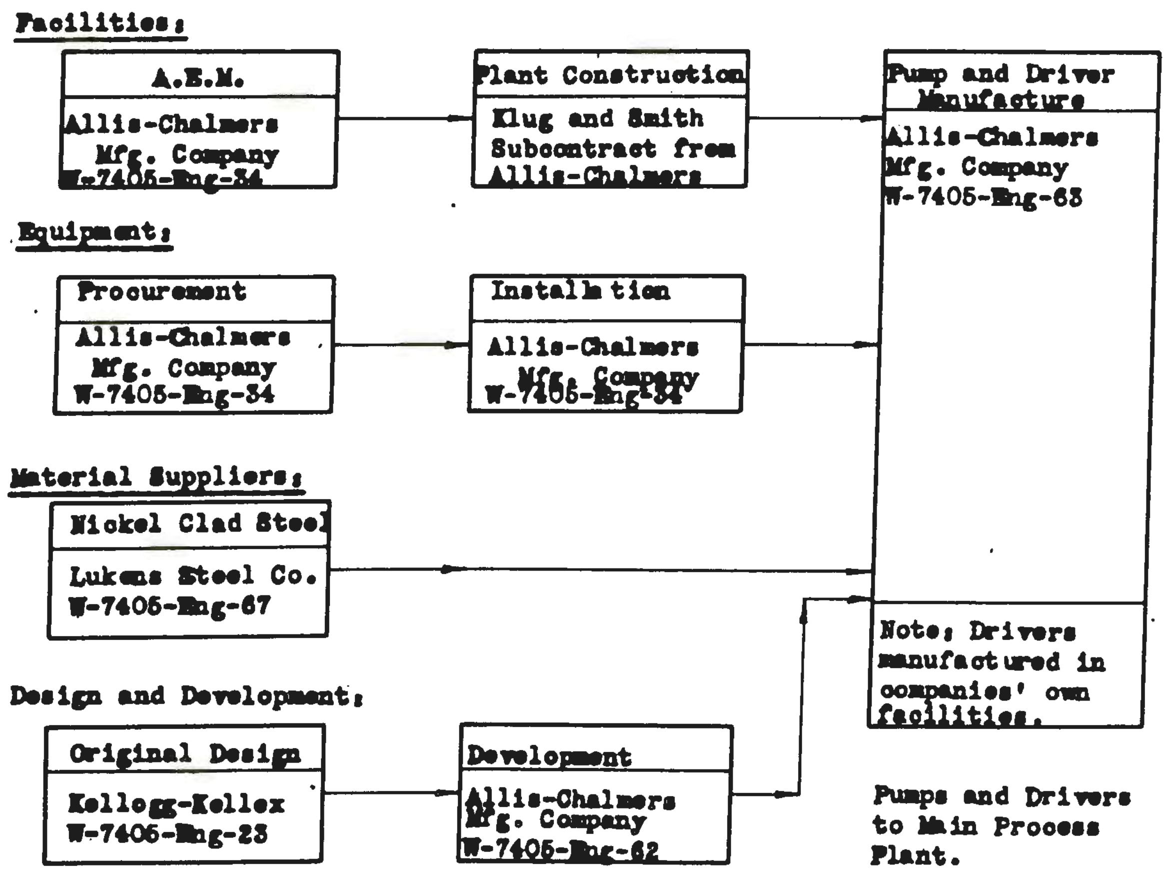
PROCESS GAS PUMPS AND DRIVERS
Milwaukee, Wisconsin



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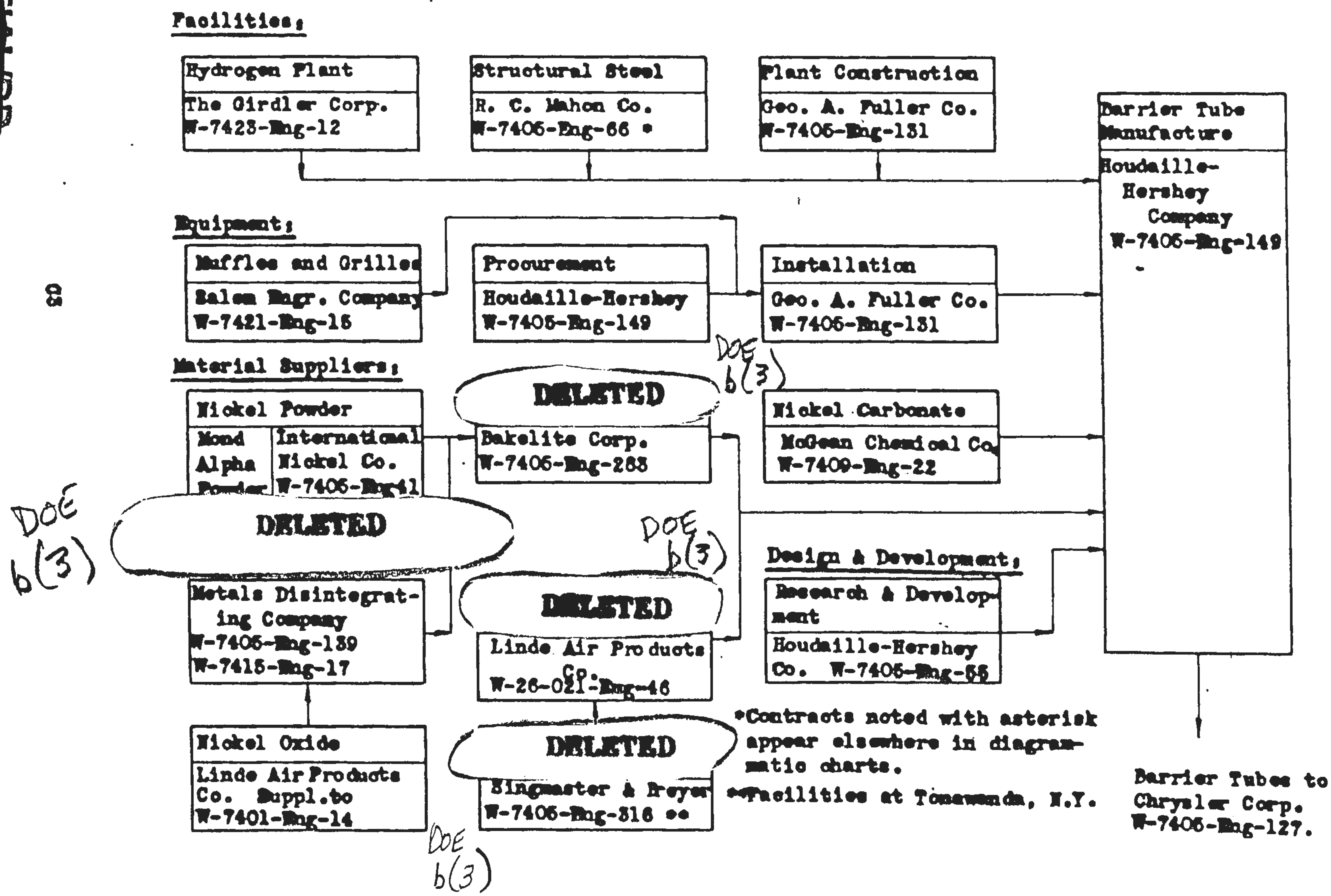
BARRIER TUBE PRODUCTION
Decatur, Illinois.



*Contracts noted with asterisk appear elsewhere in diagrammatic charts.

**Facilities at Tonawanda, N.Y.

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GAS DIFFUSER PRODUCTION
Detroit, Michigan

Facilities:
Originally contemplated - cancelled later.

Architect-Engineer	Structural Steel	Plant Construction	Original Facility
Albert Kahn, Inc. W-7405-Eng-65	R. C. Mahon Co.** W-7405-Eng-66 *	No contract let	Not built

Mound Road Facility - To accommodate activities removed from Lynch Road Plant.

Architect - Engineer Albert Kahn, Inc. W-7405-Eng-129	**Structural Steel** R. C. Mahon Co. * W-7405-Eng-66	**Plant Construction** C. W. Burke Co. W-7405-Eng-132	**Mound Road Facility** Government owned. Chrysler occupied & on Chrysler property for duration of Contract. W-7405-Eng-127.
Sewer Birmingham Cont. Co. W-7405-Eng-189	**Plumbing** Glens & Killian Co. W-7405-Eng-190	**Electrical** Hall Engr. Company W-7405-Eng-195	
Heating & Ventilating Lorne Plumbing & Htg. W-7405-Eng-191	**Boilers - Purchase** Proctor & Gamble Co. W-7405-Eng-230	**Boilers - Dismantling Re-erecting** R. H. Metzgar & Son W-7405-Eng-231	

*Contracts noted with asterisk appear elsewhere in diagrammatic charts.

**Structural Steel ordered for original facility used for Mound Rd. facility, Decatur, Ill. facility & Conditioning Bldg. at Oak Ridge, Tennessee.

Lynch Road Facility

Removal of Existing Operations Chrysler Corp. W-7405-Eng-127	**Renovation** Chrysler Corp. W-7405-Eng-127	**Equipping** Chrysler Corp. W-7405-Eng-127	**Gas Diffuser Manufacture** Chrysler Corp. W-7405-Eng-127

Material Suppliers:

Barrier Tubes Houdaille-Hershey Co. W-7405-Eng-149

Design and Development:

Original Design [illegible] W-7405-Eng-23	**Development** Chrysler Corporation W-7405-Eng-56

Gas Diffusers to Main Process Plant.

PROCUREMENT OF POWER PLANT EQUIPMENT
(Principal Contracts Only)

Area Engineer
New York Area

Architect-Engineer
The Kellex Corp.
The M.W.Kellogg Co.
W-7405-Eng-23

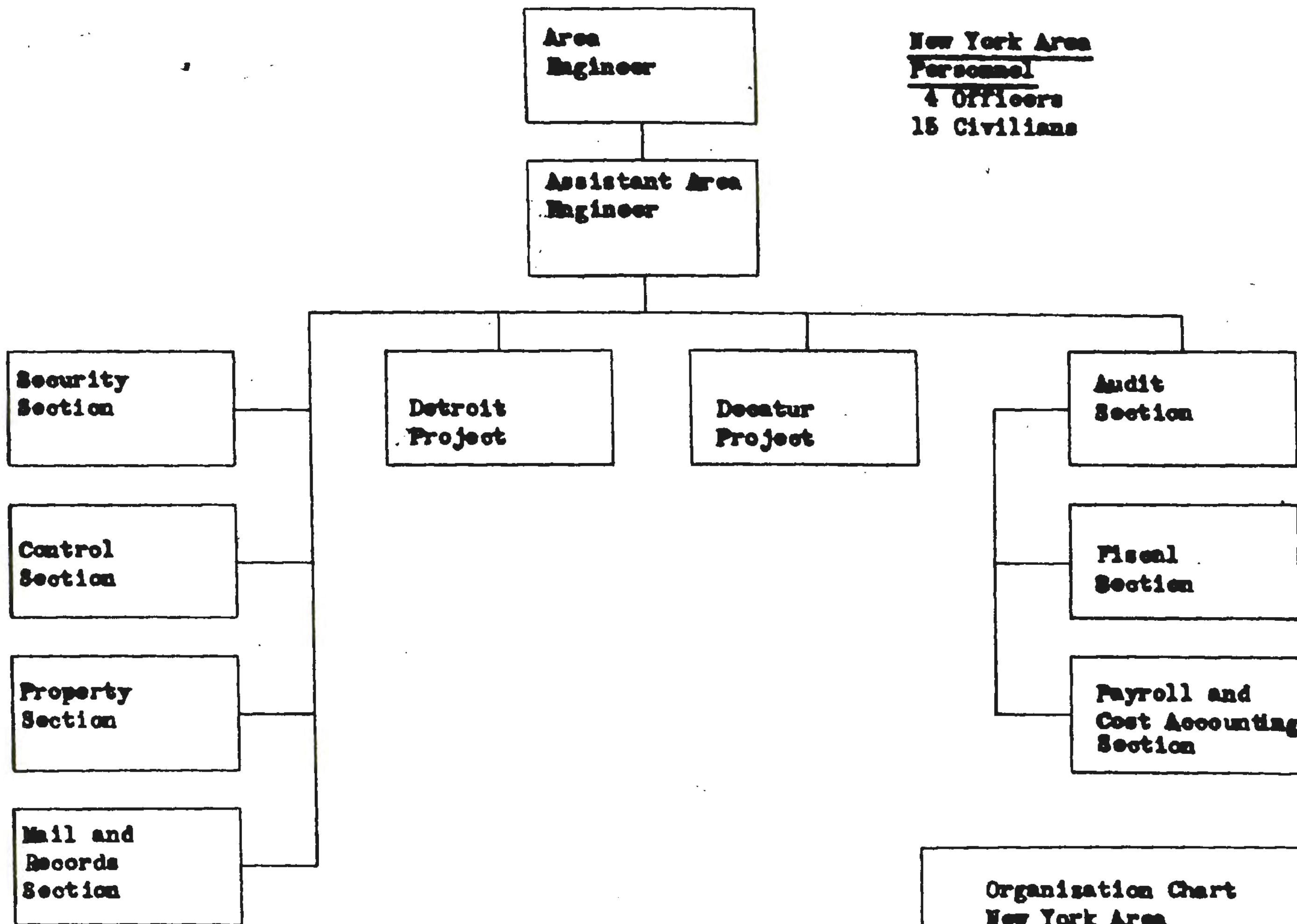
Design and Engineer'g

Sargent & Lundy
W-7418-Eng-13

Turbines and Condensers	Allis-Chalmers Mfg. Co.	W-7405-Eng-61
Turbines	General Electric Co.	W-7401-Eng-50
Turbines	Westinghouse El.& Mfg.Co.	W-7418-Eng-11
Transmission Line Towers	American Bridge Co.	W-7418-Eng-61
Structural Steel	Bethlehem Steel Co.	W-7405-Eng-57 W-7405-Eng-69
Boilers	Combustion Engineer'g Co.	W-7405-Eng-58 W-7405-Eng-285
Electrical Controllers	Commonwealth Edison Co.	W-7405-Eng-60
Cable	Phelps Dodge Copper Prod.Co.	W-7405-Eng-274
Cable	General Cable Corp.	W-7412-Eng-34
Cable	General Electric Co.	W-7405-Eng-68
Cable	Okonite Callender Co.	W-7412-Eng-33
Switchgear	General Electric Co.	W-7405-Eng-130
Switchgear	Westinghouse El.& Mfg.Co.	W-7418-Eng-16
Transformer	General Electric Co.	W-7405-Eng-138
Steel Stacks	Henry Pratt Company	W-7405-Eng-59
Coal Conveyors	Robins Conveyors, Inc.	W-7412-Eng-29
Condensers	Westinghouse El.& Mfg.Co.	W-7418-Eng-15
Pumps	Worthington Pump & Machinery Corp.	W-7418-Eng-12

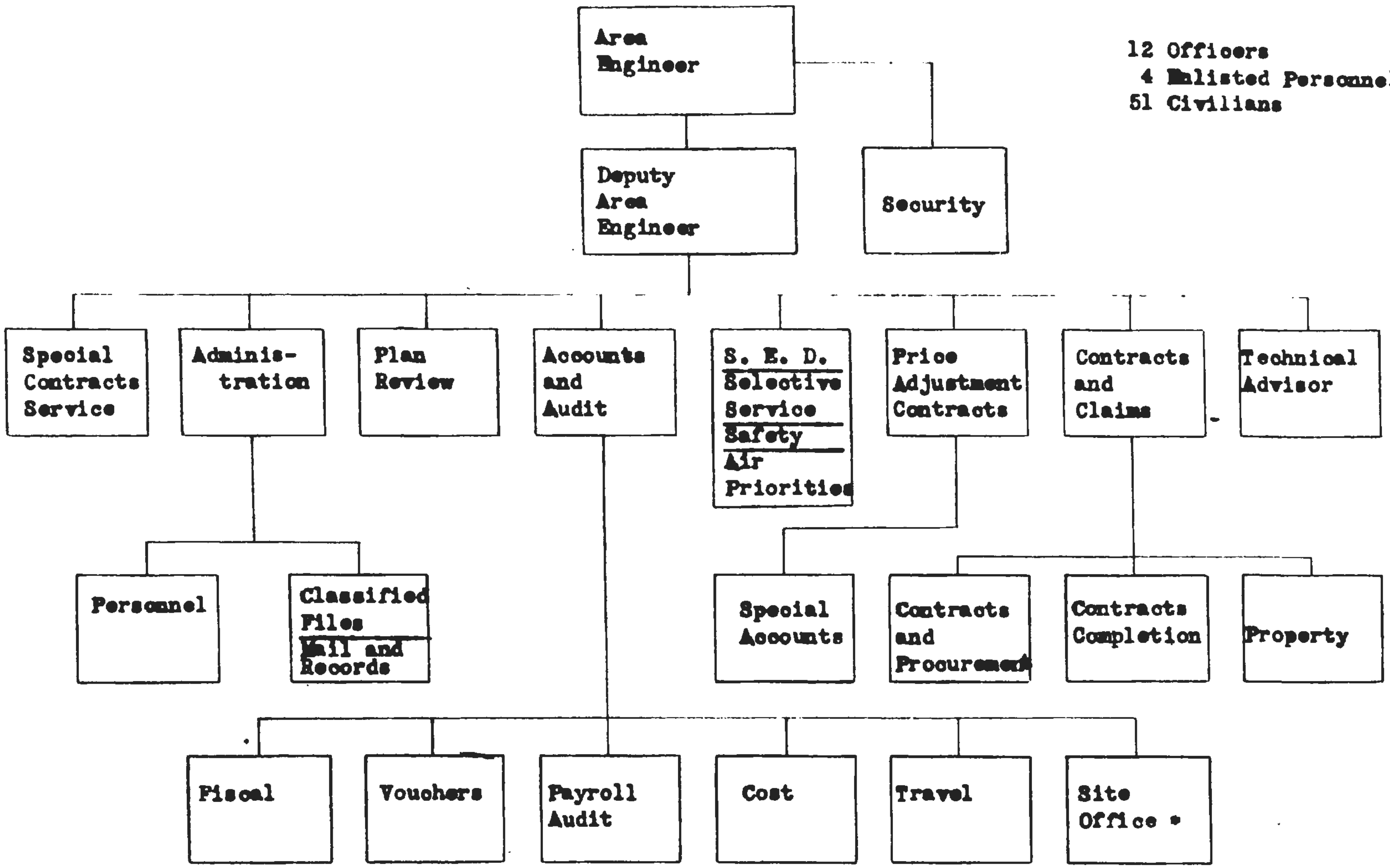
K-25 Power House
Oak Ridge, Tennessee.

New York Area Personnel
4 Officers
15 Civilians



Organization Chart
New York Area
31 May 1943

C6



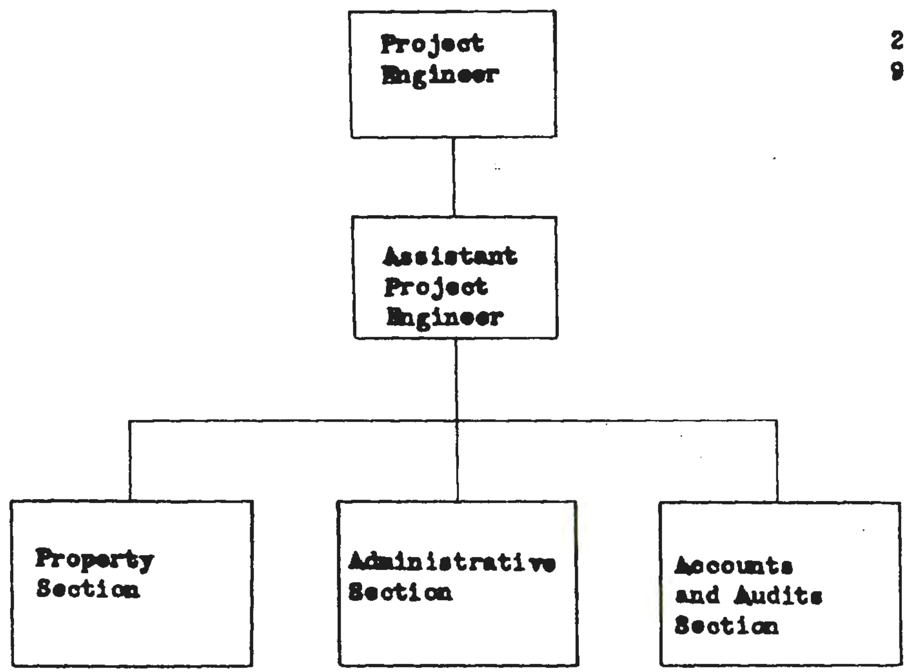
12 Officers
4 Enlisted Personnel
51 Civilians

* Not carried on New York Area Time Roll

Organization Chart
New York Area
31 March 1945

C7

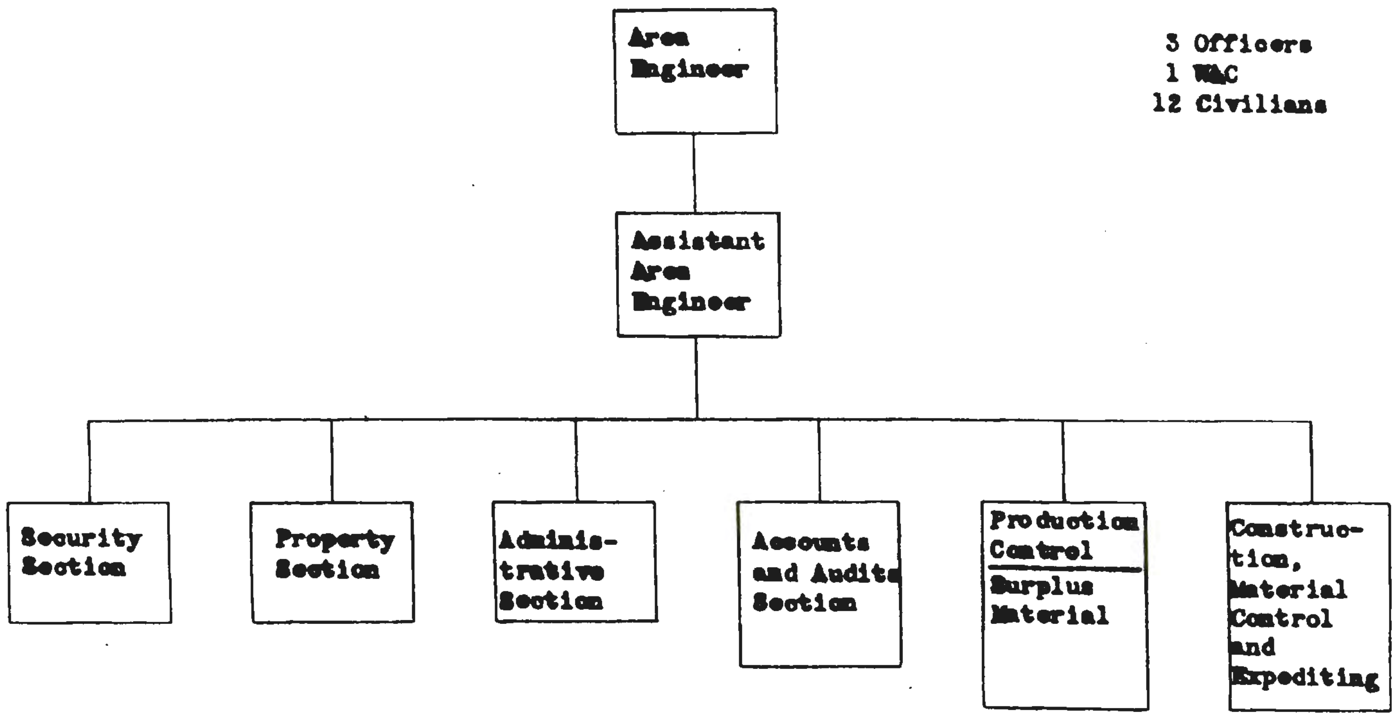
C8



2 Officers
9 Civilians

Organization Chart
Milwaukee Area
1 June 1943

3 Officers
1 WAC
12 Civilians



Organization Chart
Milwaukee Area
31 March 1945

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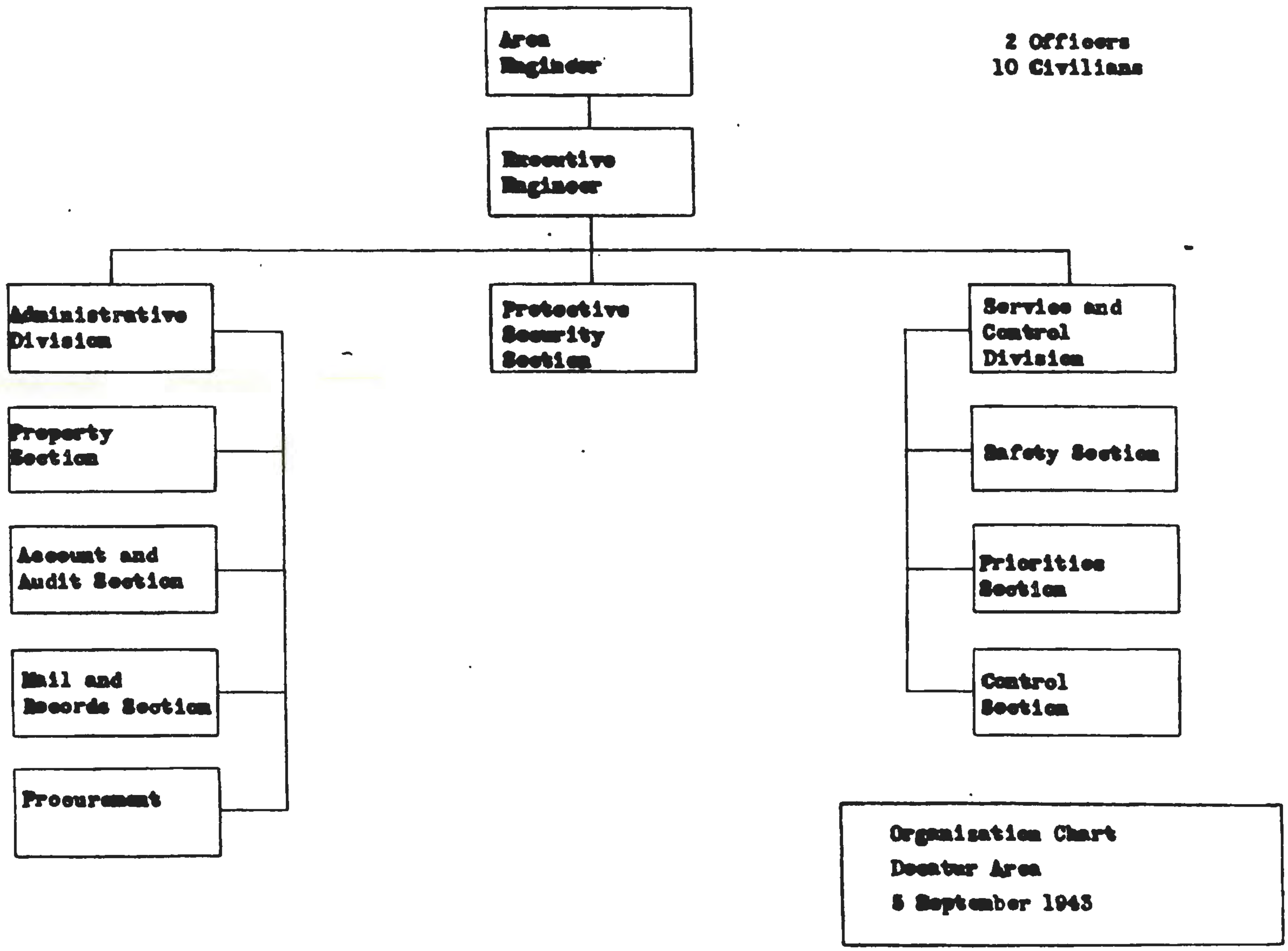

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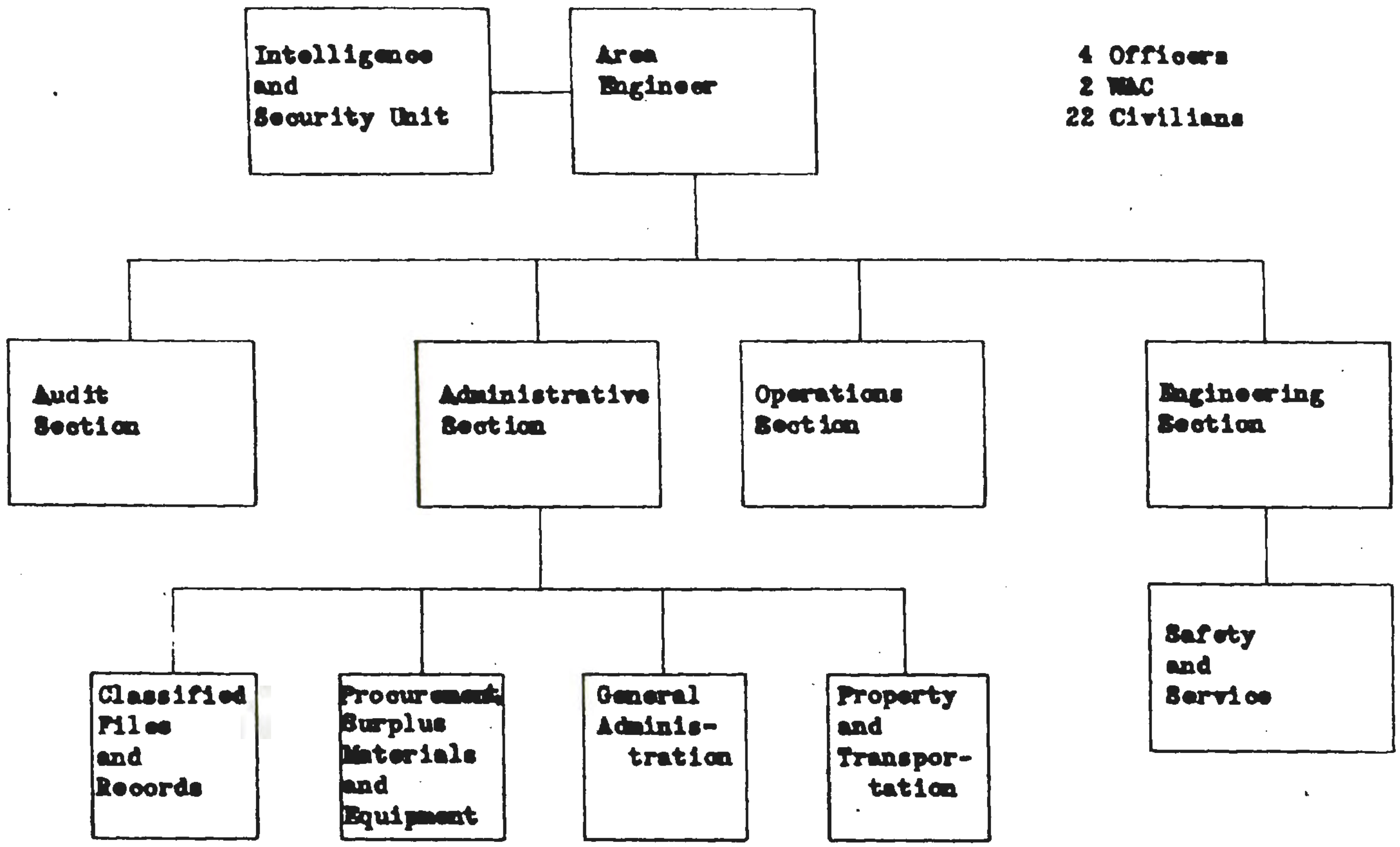
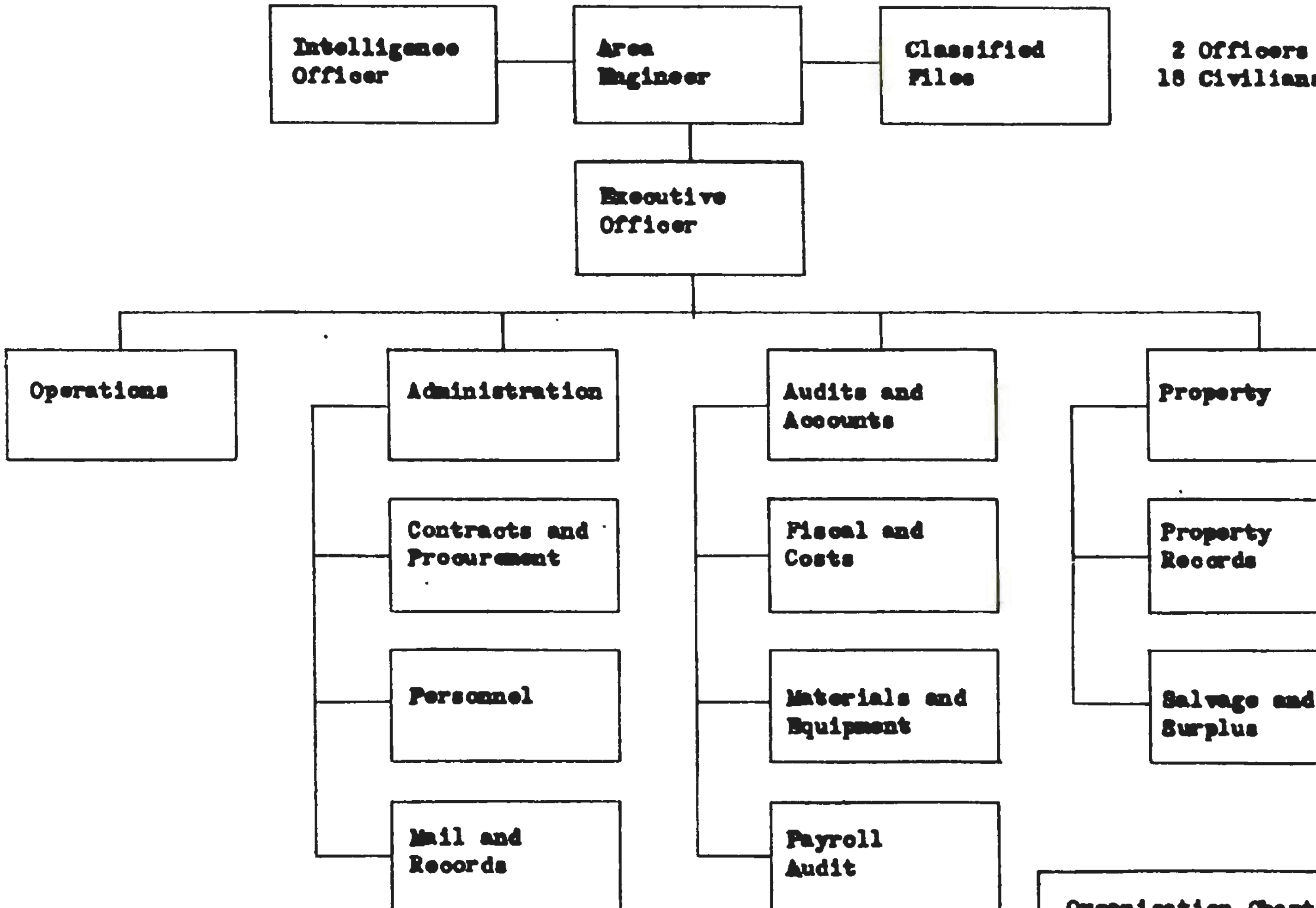


4 Officers
2 WAC
22 Civilians

Organization Chart
Decatur Area
31 March 1945



Organization Chart
Detroit Area
16 August 1943

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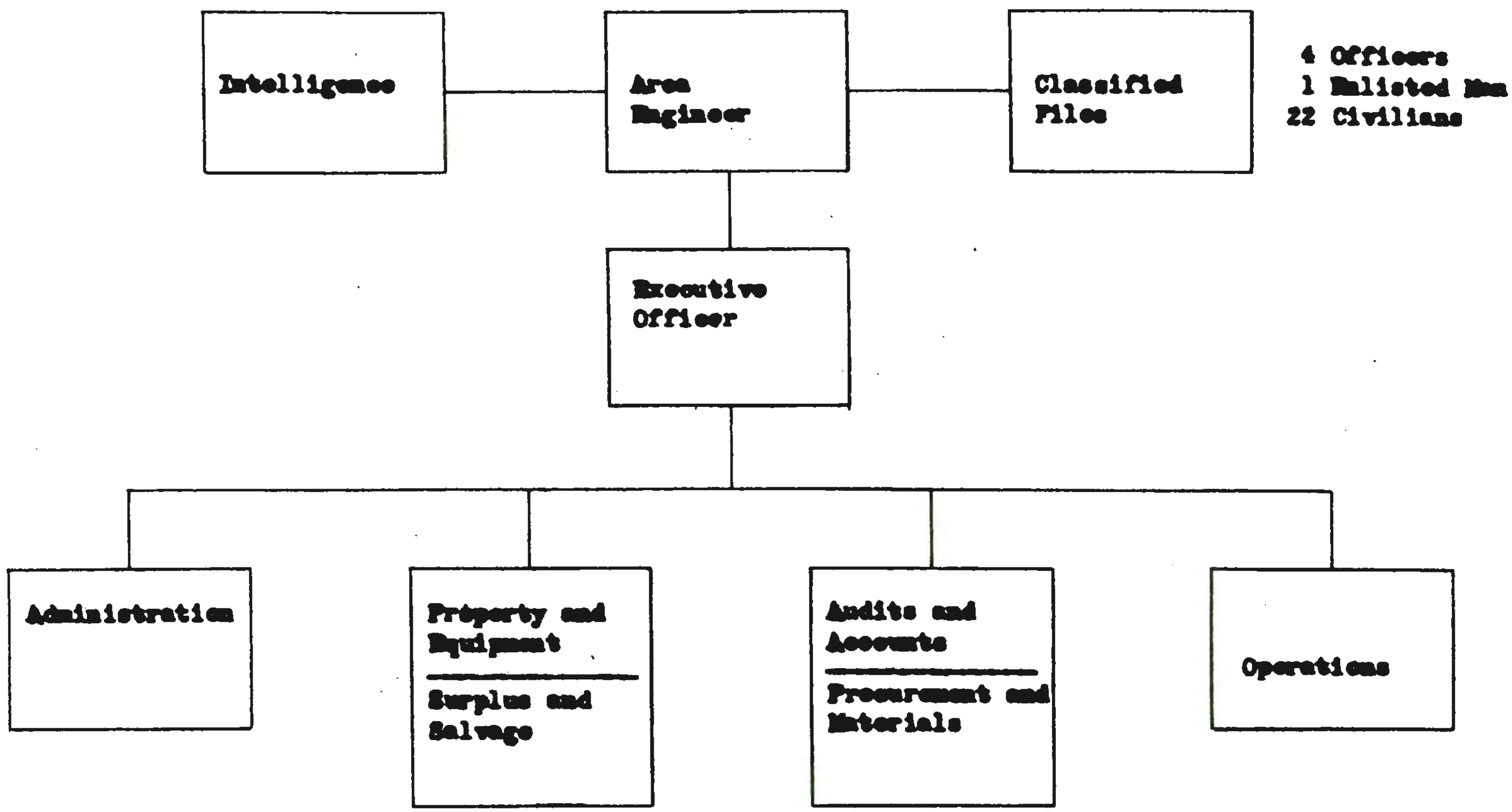

Organization Chart
Detroit Area
31 March 1946

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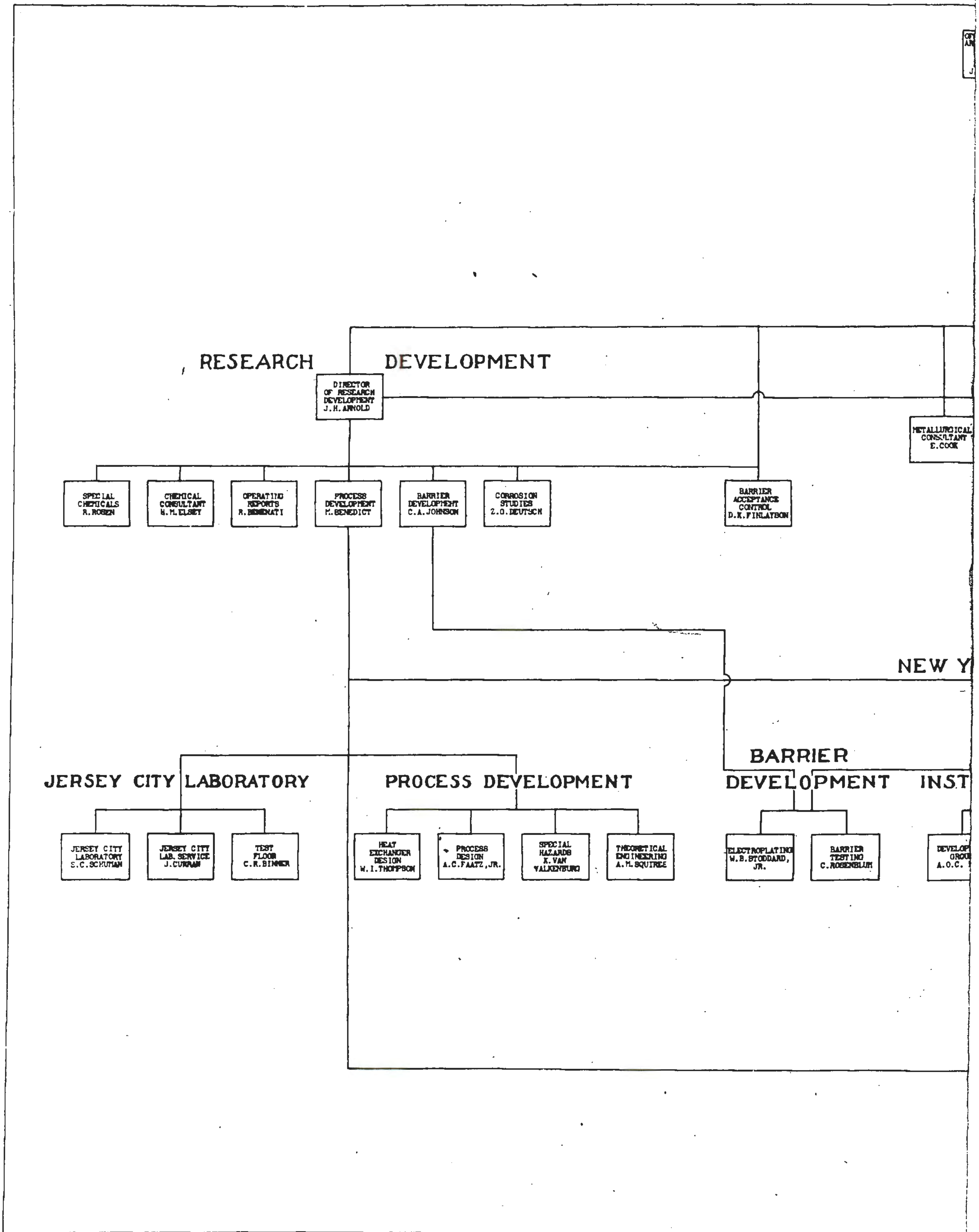

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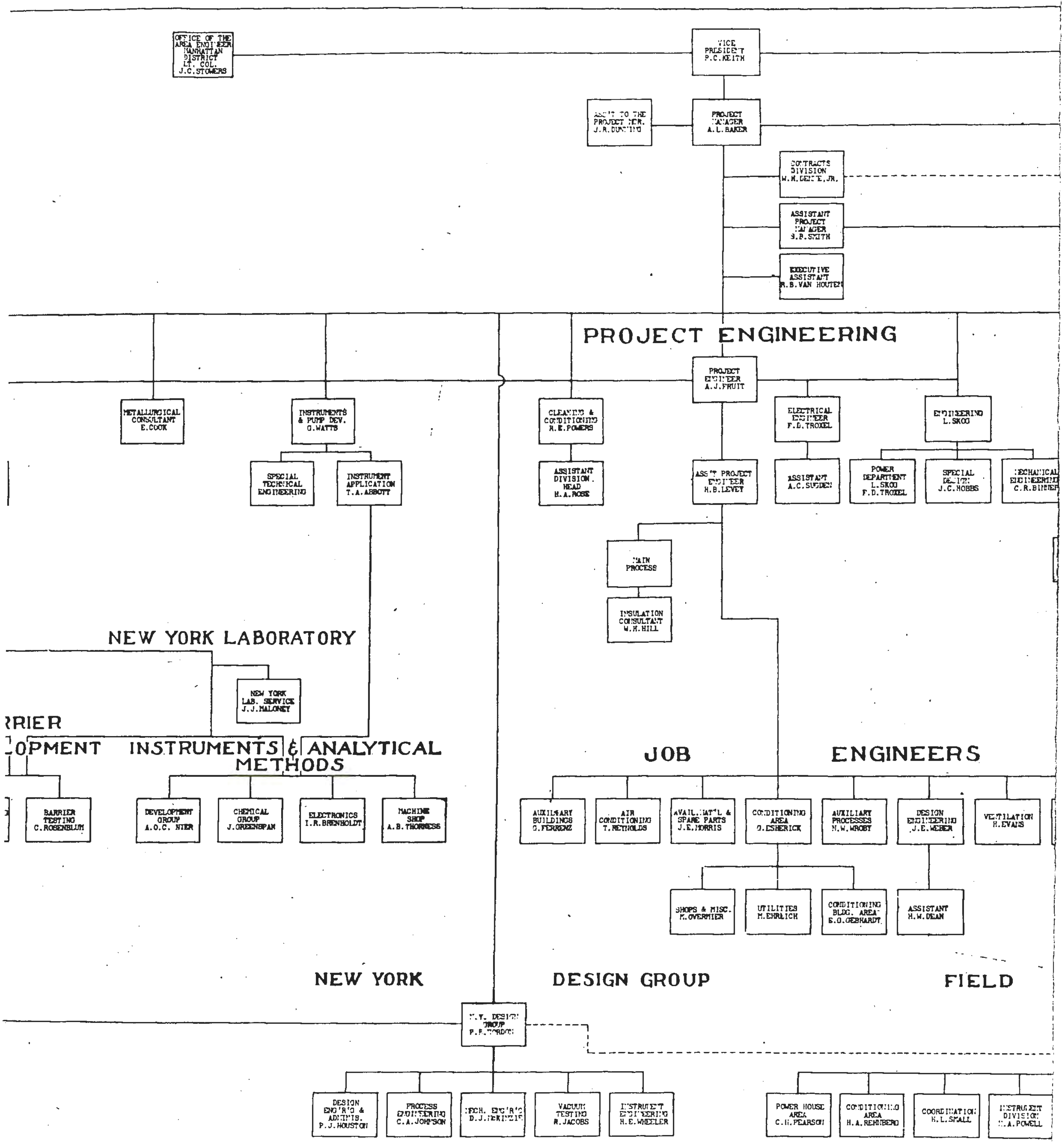

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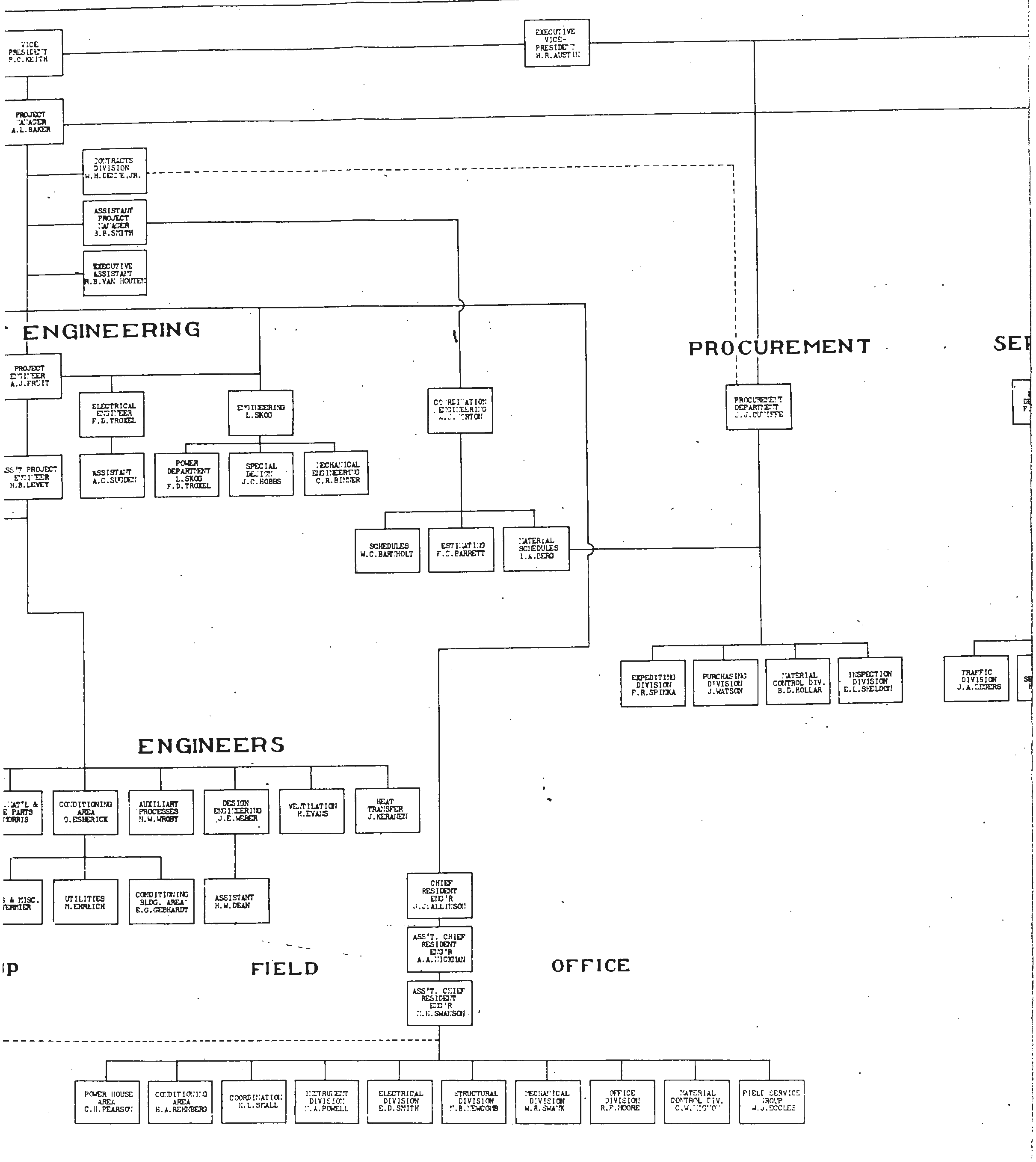

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C14-4

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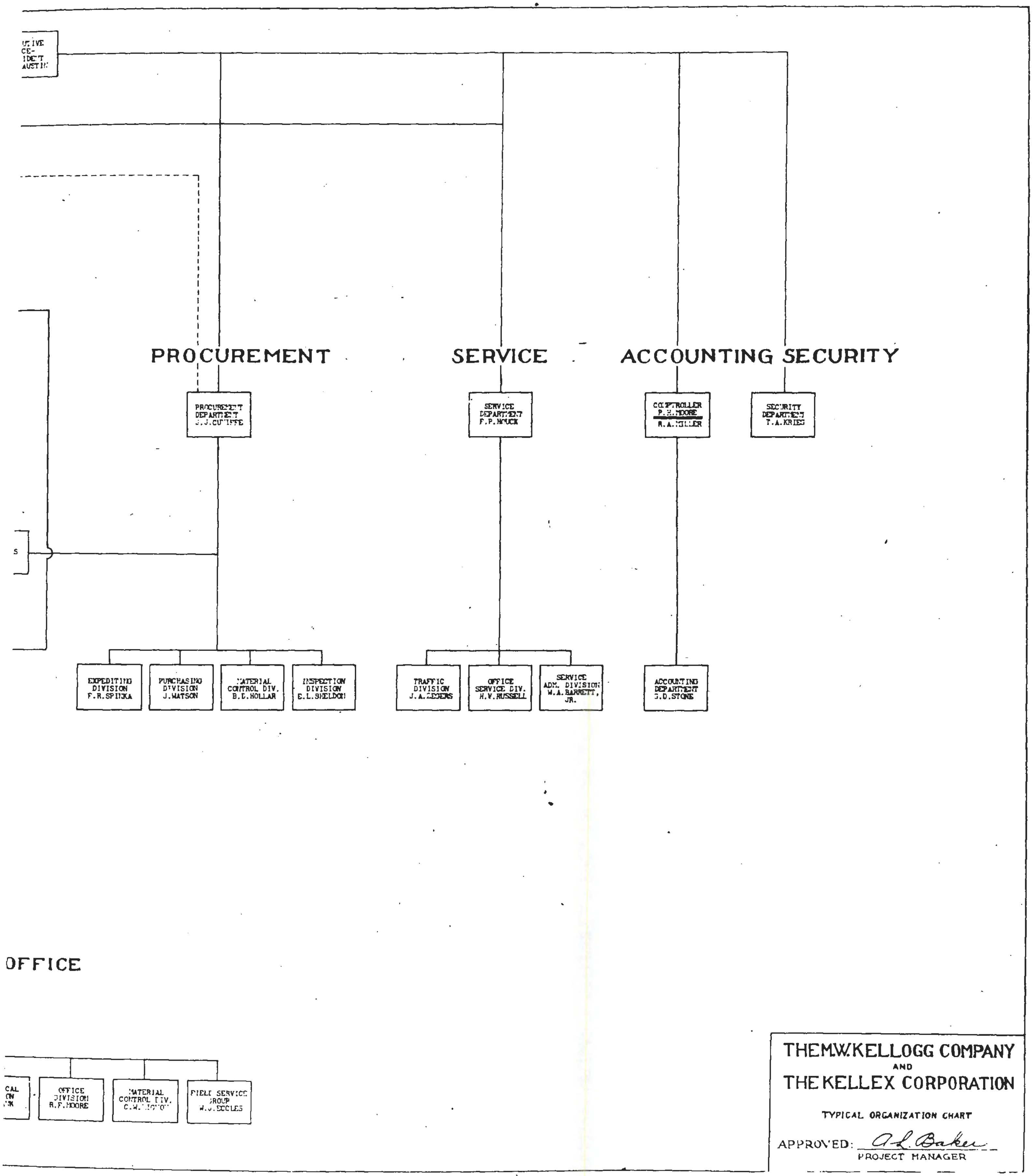

THE M.W.KELLOGG COMPANY
AND
THE KELLEX CORPORATION

TYPICAL ORGANIZATION CHART

APPROVED: A.L. Baker
PROJECT MANAGER

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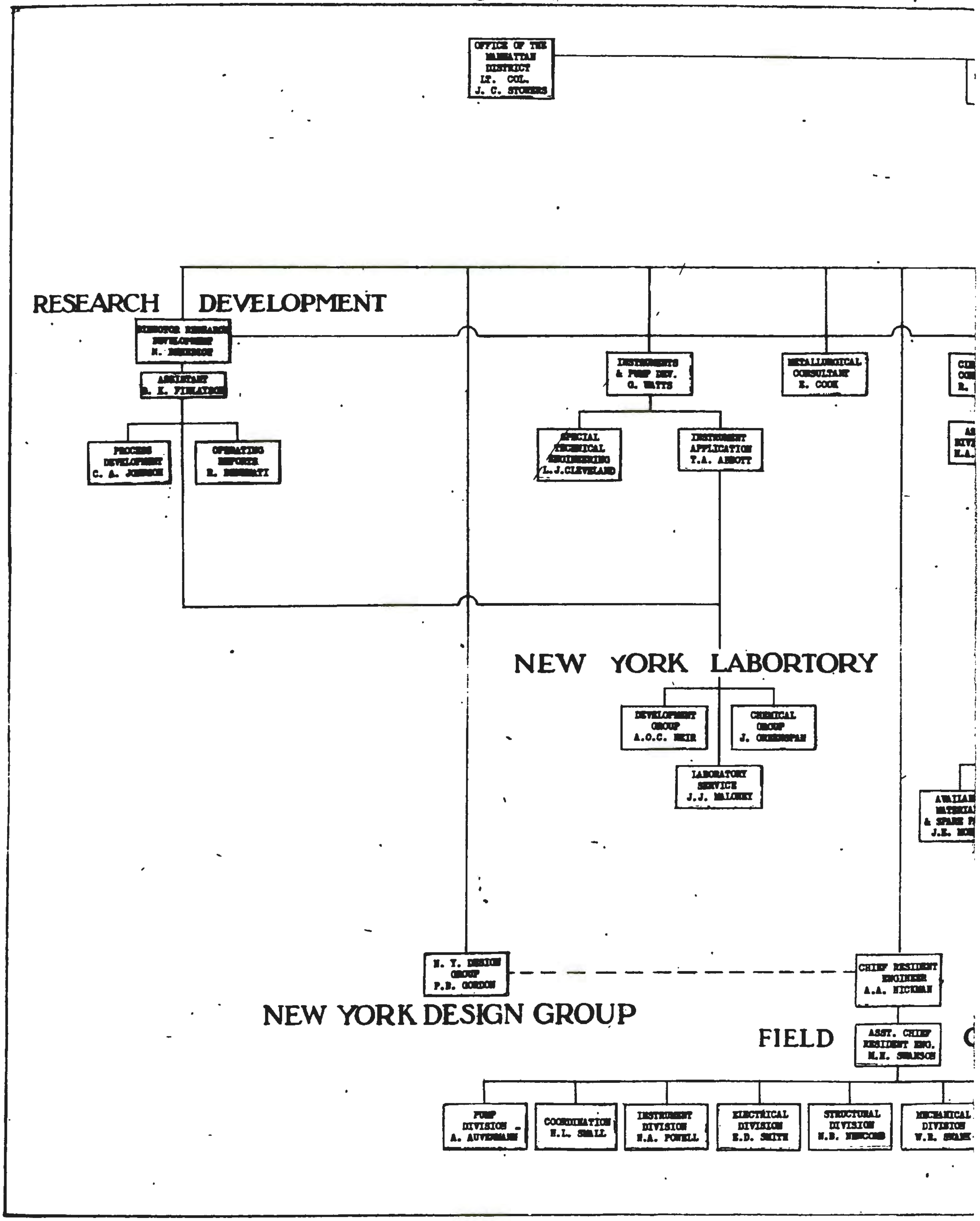
C15-1


OFFICE OF THE
MANHATTAN
DISTRICT
LT. COL.
J. C. STOWERS
RESEARCH
DEVELOPMENT
ASSISTANT
PROCESS
DEVELOPMENT
OPERATING
REPORTS
INSTRUMENTS
& PUMP DEV.
G. WATTS
METALLURGICAL
CONSULTANT
E. COOK
SPECIAL
TECHNICAL
ENGINEERING
L. J. CLEVELAND
INSTRUMENT
APPLICATION
T.A. ABBOTT
NEW YORK LABORTORY
DEVELOPMENT
GROUP
CHEMICAL
GROUP
LABORATORY
SERVICE
J.J. MALONEY
N. Y. DESIGN
GROUP
P.B. GORDON
NEW YORK DESIGN GROUP
CHIEF RESIDENT
ENGINEER
A.A. HICKMAN
FIELD
ASST. CHIEF
RESIDENT ENG.
M.E. SWANSON
PUMP
DIVISION
COORDINATION
E.L. SMALL
INSTRUMENT
DIVISION
N.A. POWELL
ELECTRICAL
DIVISION
E.D. SMITH
STRUCTURAL
DIVISION
MECHANICAL
DIVISION

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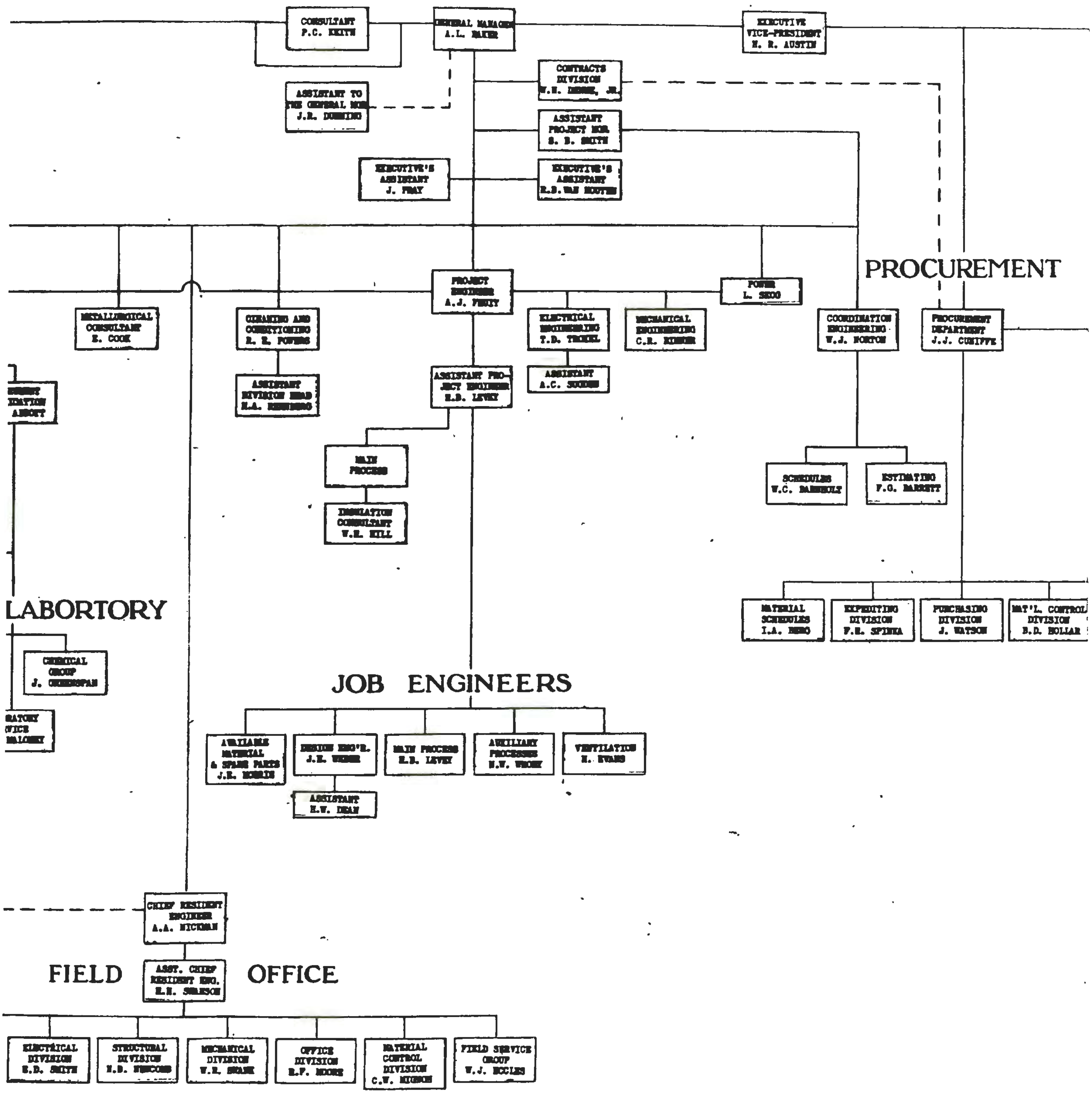

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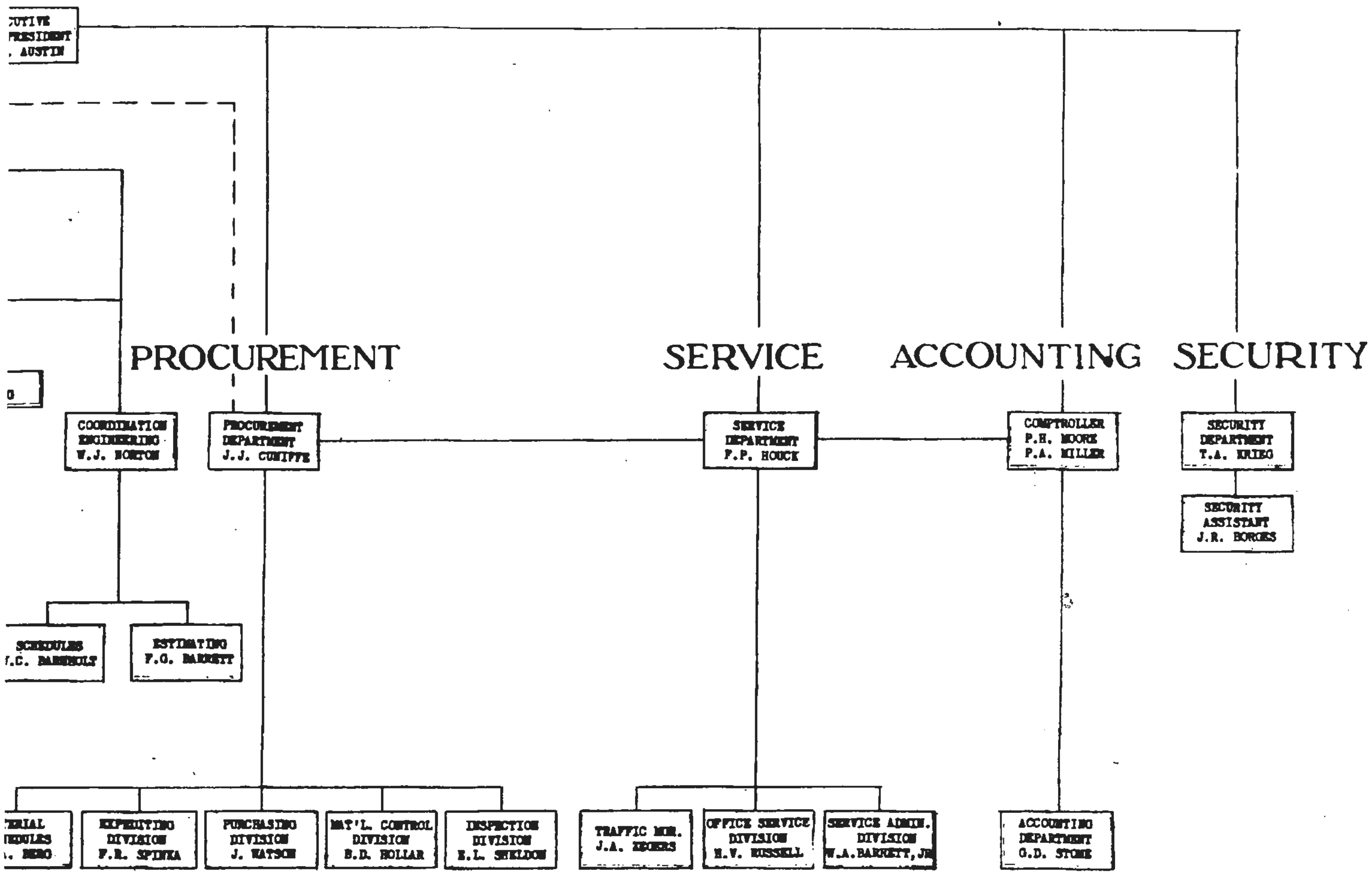

THE M.W. KELLOGG COMPANY
AND
THE KELLEX CORPORATION

TYPICAL ORGANIZATION CHART
K-27 PROJECT

APPROVED. A.L. Baker
GENERAL MANAGER

[redacted]

C16-1

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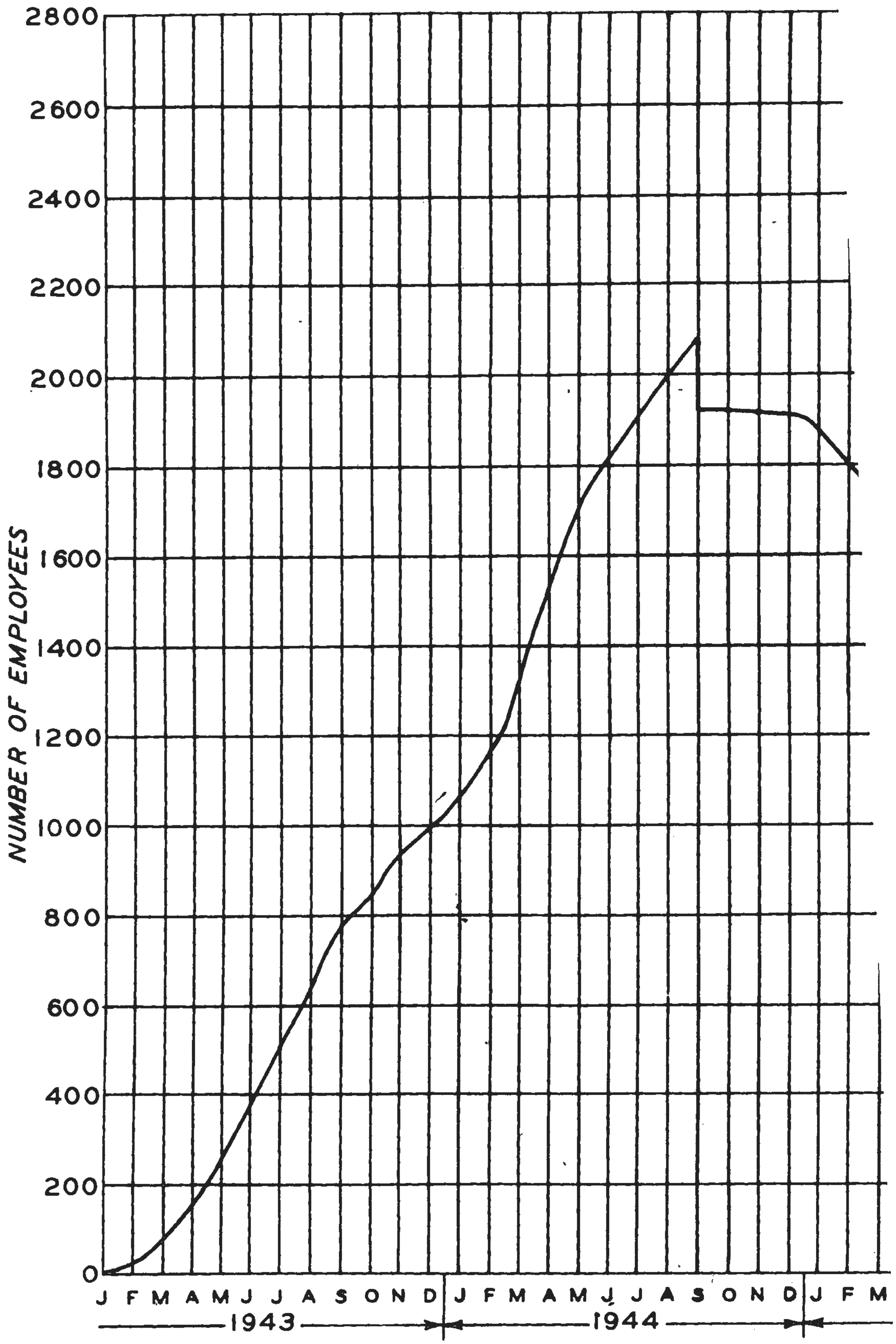
TOTAL CONTRACTING P

KELLEX



C16

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C16-2

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TOTAL CONTRACTING PERSONNEL

KELLEX

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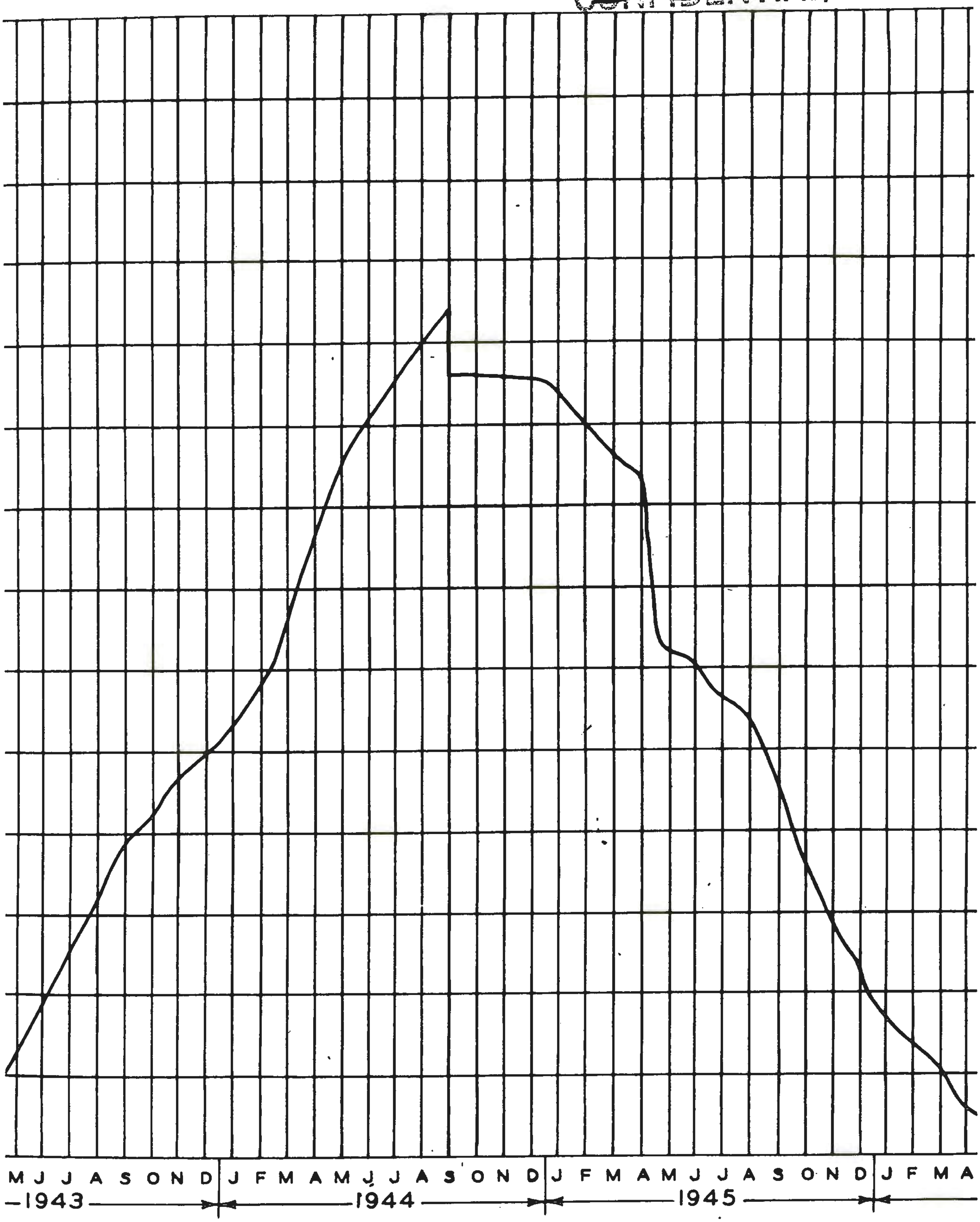

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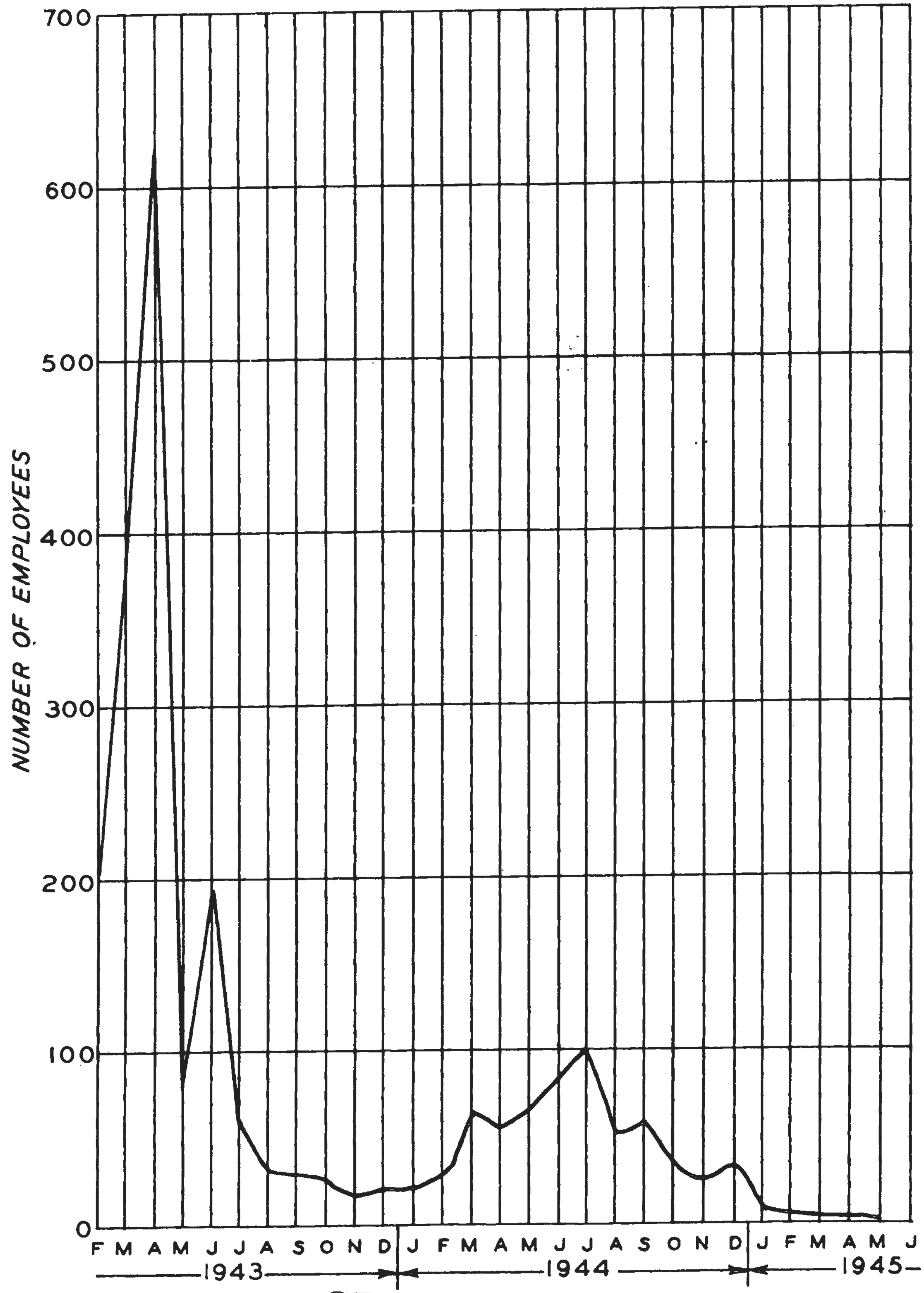
TOTAL CONTRACTING PERSONNEL
ALLIS CHALMERS



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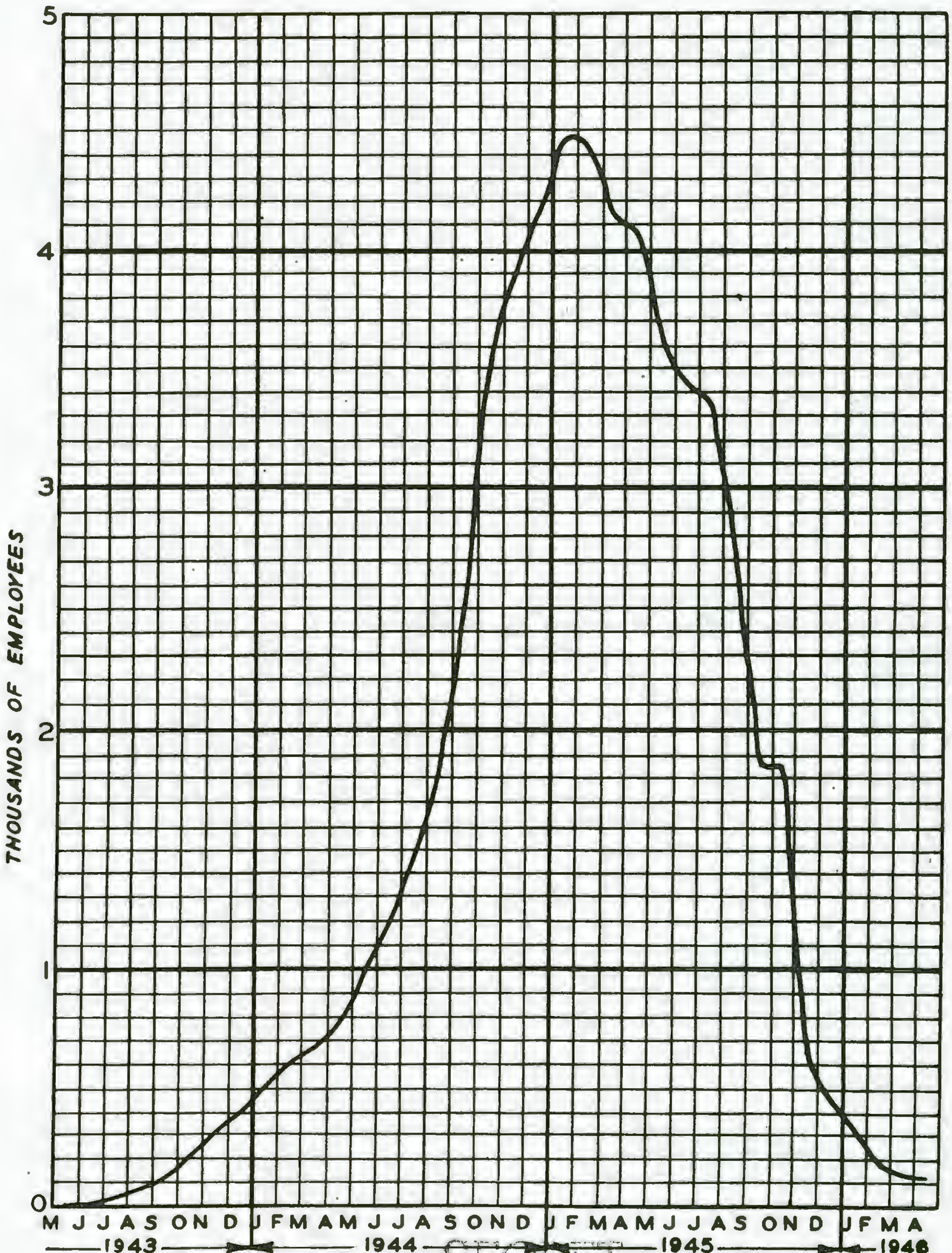
TOTAL CONTRACTING PERSONNEL
HOUDAILLE HERSHEY



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CMO

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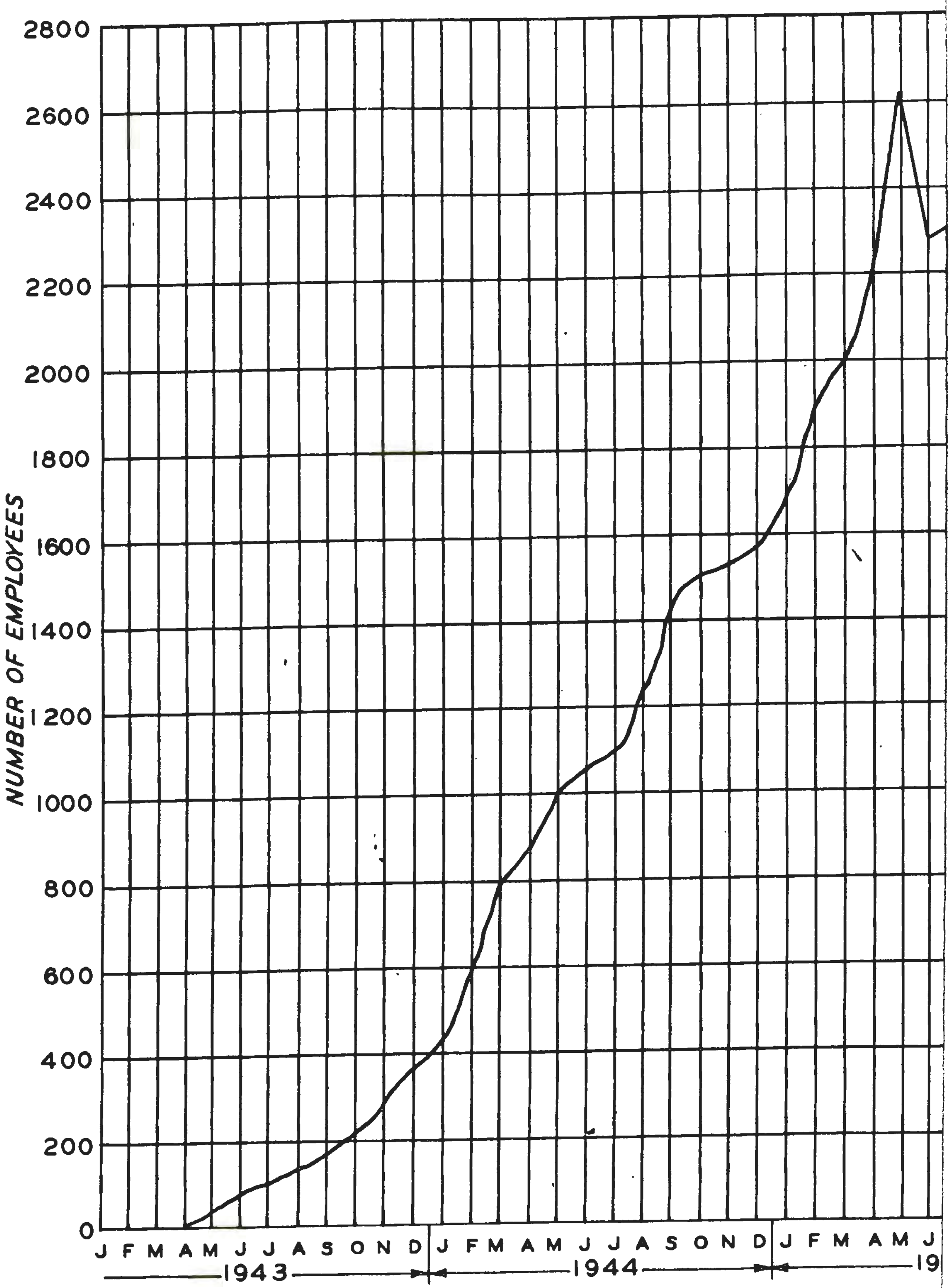
TOTAL CONTRACTING PERSONNE

CHRYSLER



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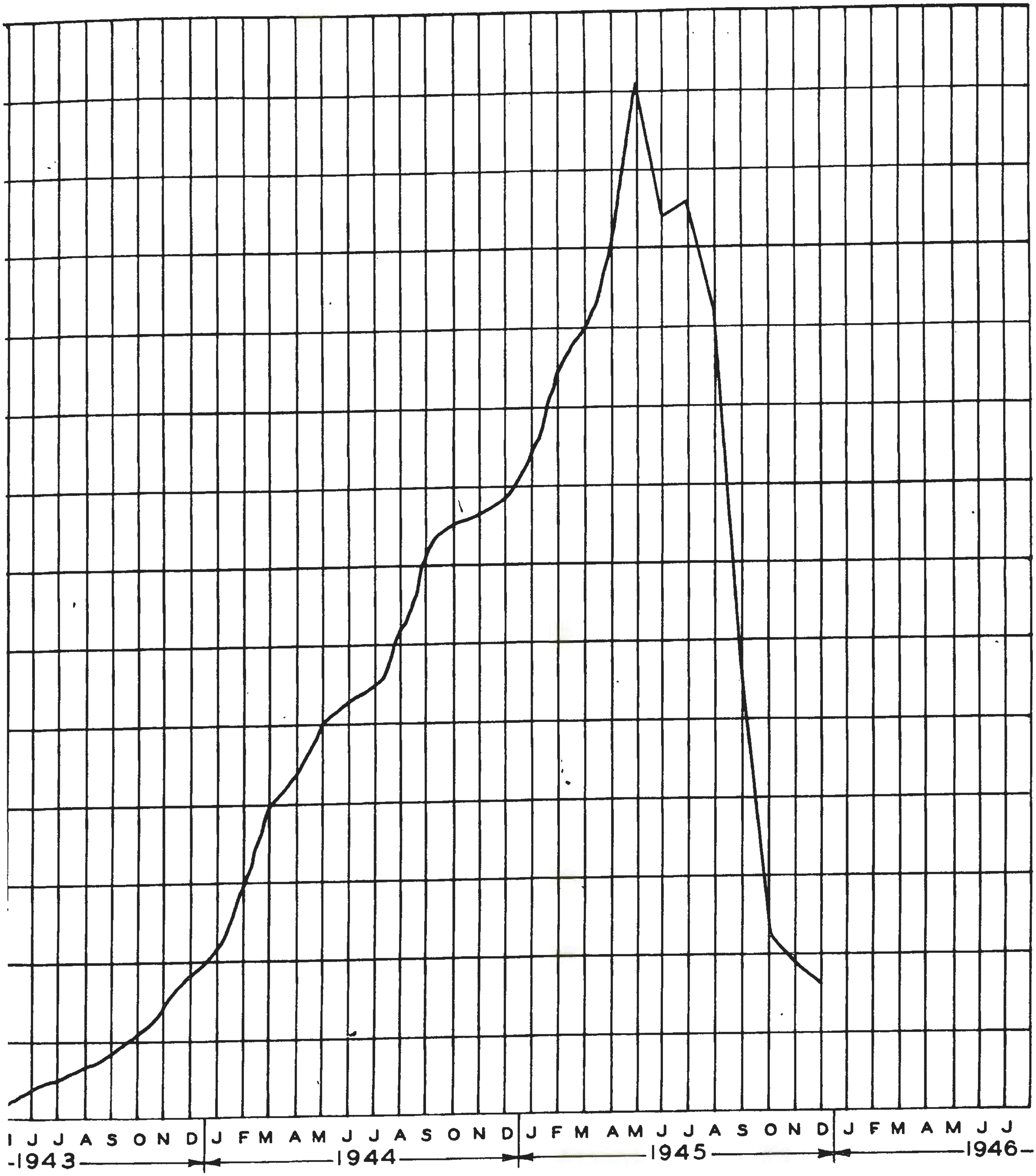
C19-2

TOTAL CONTRACTING PERSONNEL

CHRYSLER

CONFIDENTIAL/RD



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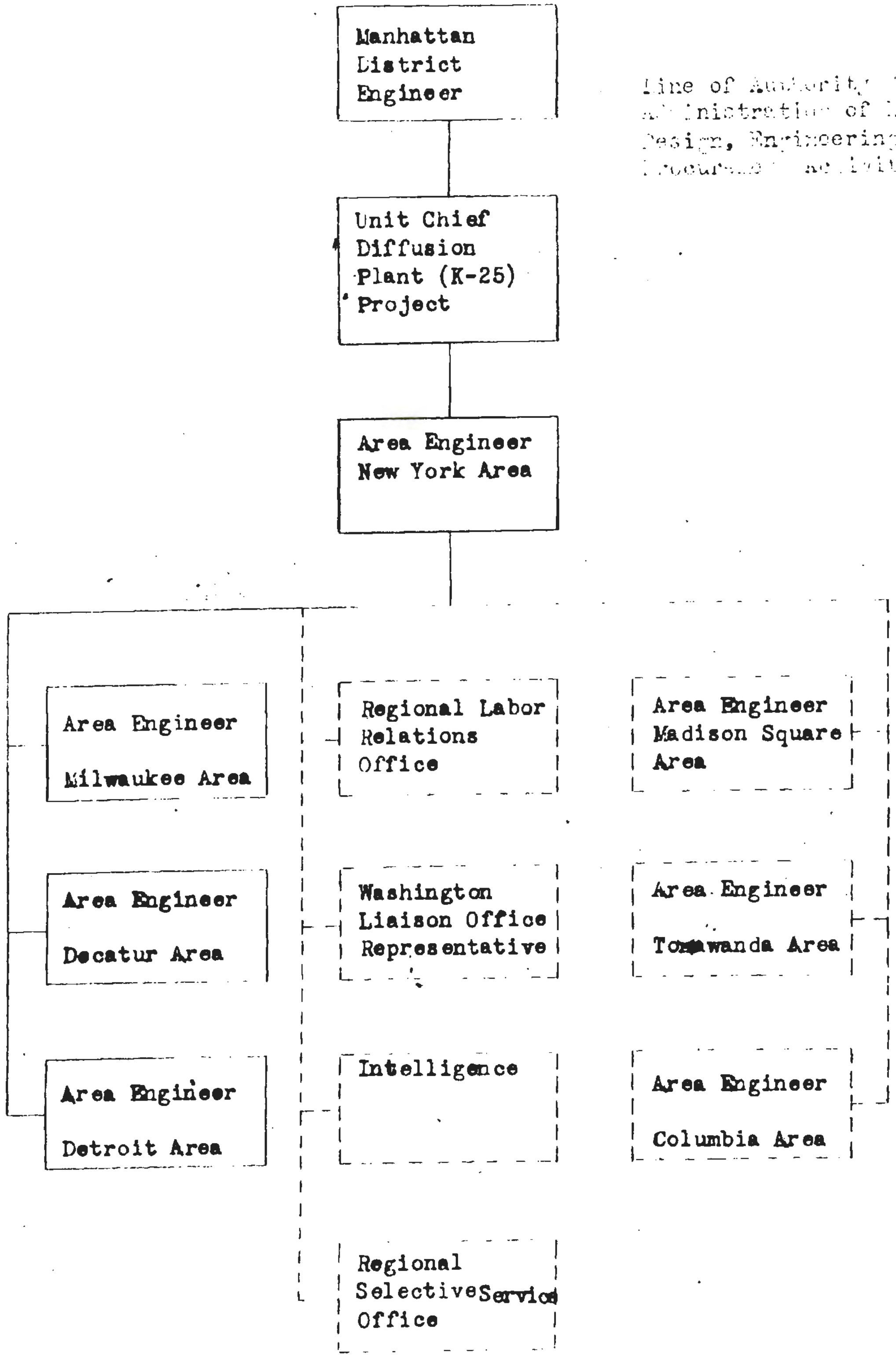
CMD

Line of Authority for administration of K-25 Design, Engineering and Procurement activities



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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "D"

TABULATIONS

No.	Title
1.	Power Requirements for the K-25 Plant as originally, and as finally designed.
2.	Total Personnel Figures as of 31 March 1945 for The Kellex Corporation.
3.	Design and Engineering Personnel of Kellex Subcontractors on K-25 Development Work.
4.	Design and Engineering Personnel of K-25 Contractors other than The Kellex Corporation.
5.	Kellex Engineering Descriptions.

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K-25 POWER REQUIREMENTS

	ORIGINAL DESIGN		FINAL DESIGN	
	Estimated Amount	To be Installed	Estimated Amount	Actual Installed
Variable Frequency.				
60 Cycle - Operating between 45 & 65 cycles	109,430	7- 152,500	109,420	7- 152,500
Running Reserve		1- 25,000		1- 25,000
120 Cycles - Operating between 90 & 130 cycles	4,015	2- 4,500	5,850	3- 7,500
Running Reserve		1- 3,000		1- 3,000
240 Cycles - Operating between 180 & 240 cycles	2,715	2- 4,000	(not installed - Section V cancelled March 1945)	
Running Reserve		1- 2,000		
Constant Frequency.				
60 Cycle - for Auxiliary purposes	77,220		77,220	
From Power House (From T.V.A. System)		2- 50,000 (27,000)		2- 50,000 (110,000)
Total	193,380	16- 241,000	192,490	14- 238,000
Rounded Estimate	193,000	241,000	193,000	238,000
From T.V.A. System		27,000		110,000
Total Connected Capacity		268,000		348,000

NOTE: Figures followed by dashes indicate number of turbo-generators.

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~~CONFIDENTIAL/RD~~ ~~SECRET~~

THE KELLEX CORPORATION - TOTAL PERSONNEL FIGURES AS OF 31 MARCH 1945

Total Employees	1,649
Borrowed Personnel	27
Total Personnel	1,676

__Tabulation by Class of Work__

	New York	Field	Total
Technical	635	188	823
Administrative	24	2	26
Clerical	539	143	672
Maintenance	134	21	155
Totals	1,332	354	1,676

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DESIGN AND ENGINEERING PERSONNEL OF
KELLEX SUBCONTRACTORS ON
K-25 DEVELOPMENT WORK

Subcontractors	Nature of Work	Estimated Personnel at Peak
Elliott Company	Seal development	14
Westinghouse Electric and Manufacturing Company	Motor development	16
Trent Tube Manufacturing Company	Barrier tube machine	3
Metal Forming Corporation	Welding development	7
Sam Tour, Inc.	Metal studies	7
Hanson, Van Winkle and Munning Company	Plating machine	1
United States Testing Company	Rubber tests	1
Firestone Tire and Rubber Company	Rubber development	8
General Electric Company	Welding and motor development	9
International Nickel Company	Furnace development	12
Harshaw Chemical Company	Chemicals development	6
Hammel-Dahl Company	Valve design	9
Electroloy Company, Inc.	Welding development	1
Kerby Saunders, Inc.	Refrigeration	4

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DESIGN AND ENGINEERING PERSONNEL OF K-25 CONTRACTORS OTHER THAN THE KELLEX CORPORATION

DOE b(3)

Contractor	Product	Estimated Peak
Allis-Chalmers Manufacturing Company	Process Pumps	34
American Locomotive Company	Drums	8
A. O. Smith Company	Coolers	32
Bakelite Corporation	DELETED	20
Bart Laboratories, Inc.	Pipe plating	5
Beach-Russ Company	Pumps	3
Chrysler Corporation	Diffusers	132
Crane Company	Process valves	9
Farrar and Trefts, Inc.	Nickel clad drums	4
Fisher Governor Company	Butterfly valves	3
F. J. Stokes Company	Pumps	3
General Electric Company	Instrumentation	35
General Electric Company	Motor development	28
General Electric Company	Conditioning furnaces	14
Henry Pratt Company	Butterfly valves	3
Herron-Zimmers Moulding Company	Back strip holders	3
Houdaille-Hershey Corporation	Barrier	234
Midwest Piping and Supply Company	Pipe fabrication	12
National Research Corporation	Scraper cold trap	4
Pacific Pumps, Inc.	Coolant pumps	7
Patterson Kelley Company	Cold traps	4

Contractor	Product	Estimated Peak
Republic Flow Meters Company	Magnetic valves	8
Schock-Gusmer Company	Cold traps	1
Taylor Instrument Companies, Inc.	Instrumentation	32
Valley Iron Works	Purge pumps	6
Westinghouse Electric Corporation	Diffusion pumps	8
Whitehead Metal Products, Inc.	Purge Diffusers	6
Whitlock Manufacturing Company	Coolant coolers	12
Worthington Pump and Machinery Corporation	Refrigeration systems	10
York Corporation	Refrigeration	9

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KELLEX ENGINEERING DESCRIITIONS

Book	Title
II	Section 100 - Feed Purification System
III	Section 600 - Cascade Surge and Waste System
IV	Section 700 - Power Plant
V	Section 800 - Recirculating Water System
VI	Section 1100 - Air Conditioning System
VII	Section 1200 - Plant Air System
VIII	Section 1300 - C-216 Generation, Compression, Storage
IX	Section 1400 - Conditioning Plant
X	Section 1500 - Heating Plant
XI	K-25 Electrical System

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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "E"

PHOTOGRAPHS

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No.	Title
15.	Motor-driven Boiler Feed Pumps, and Pulveriser Coal Hoppers in Turbine Room, Building K-702.
~~16.~~	~~Turbo-generators Nos. 4, 3, 2, and 1 in Turbine Room, K-702.~~
17.	Cable Room below Main Switch House, K-704.
18.	View of the Houdaille-Hershey Plant, Decatur, Illinois.
19.	View of the Allis-Chalmers Plant, Milwaukee, Wisconsin.

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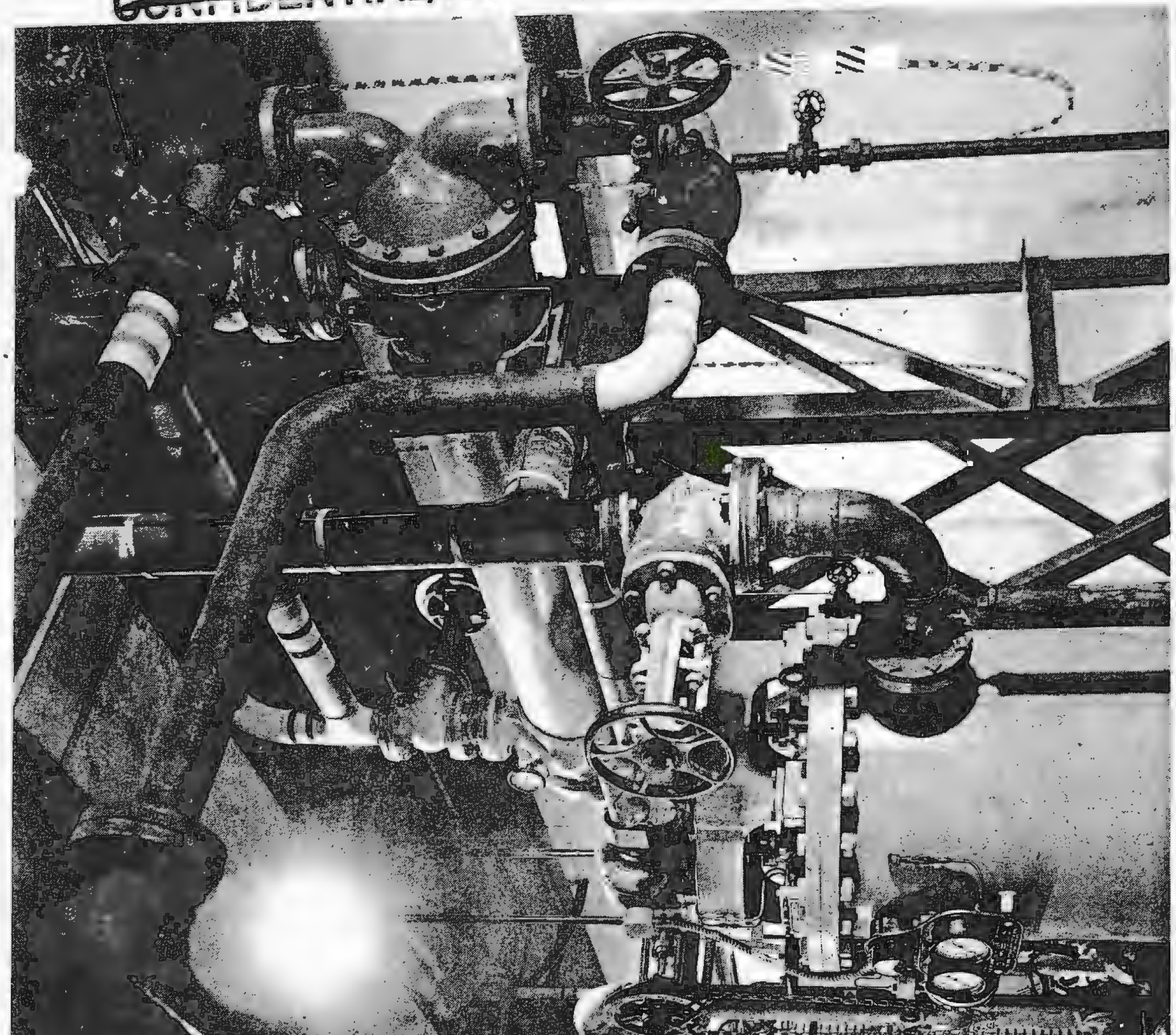
~~CONFIDENTIAL/RD~~

E1 Typical Process Lubricating Oil System showing Lubricant Filter, Cooler and Drain Drum.

~~CONFIDENTIAL/RD~~

~~SECRET~~

CONFIDENTIAL/RD SECRET



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E-1

E2 Typical Process Coolant Cooler and Coolant Drain Drum.

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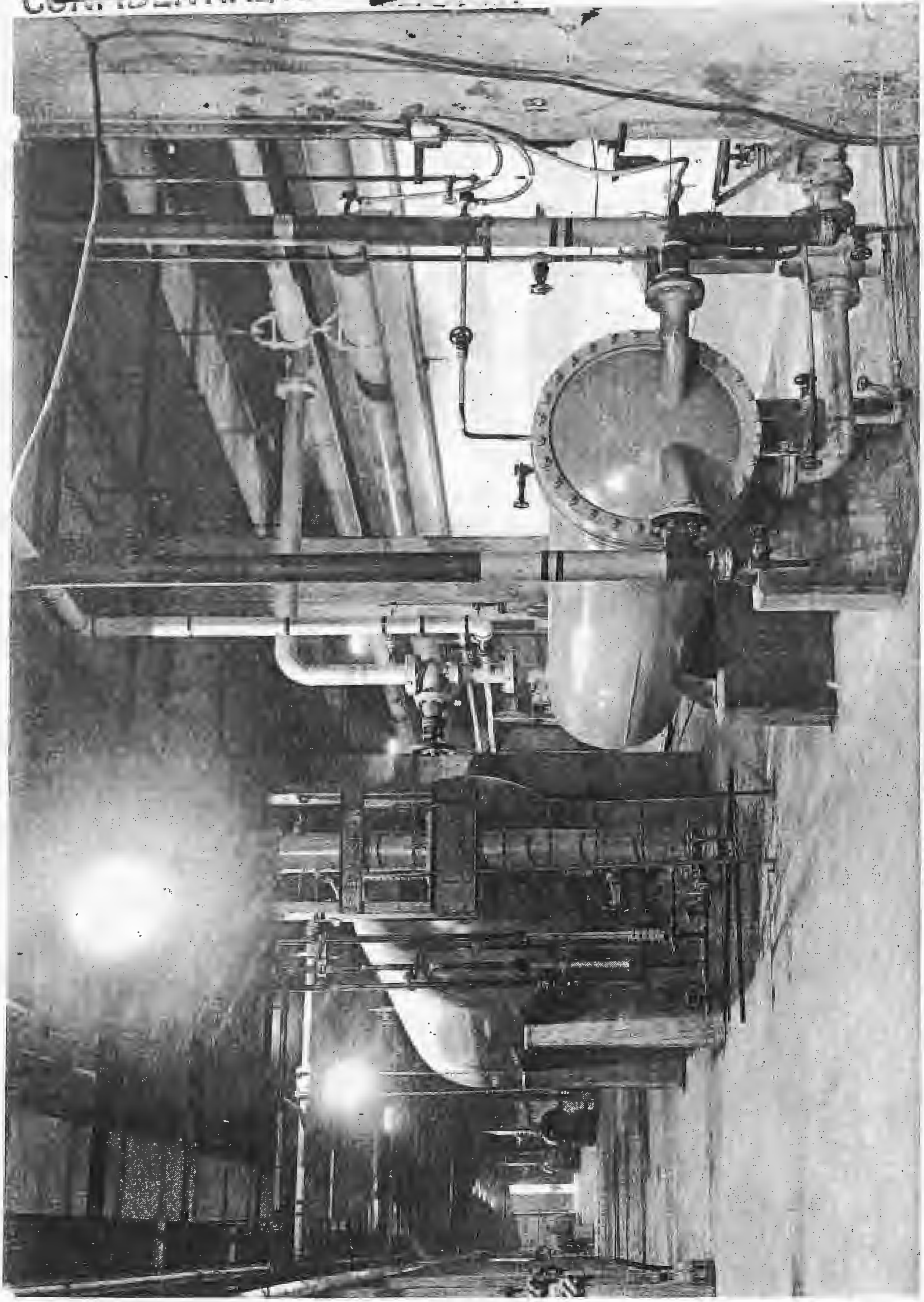

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~~CONFIDENTIAL/RD~~

E3 Cold Trap Installation in Temporary Purge and Product Room, Building K-303-10, before application of insulation. The funnel shaped item at the right is part of a vacuum dust removal system.

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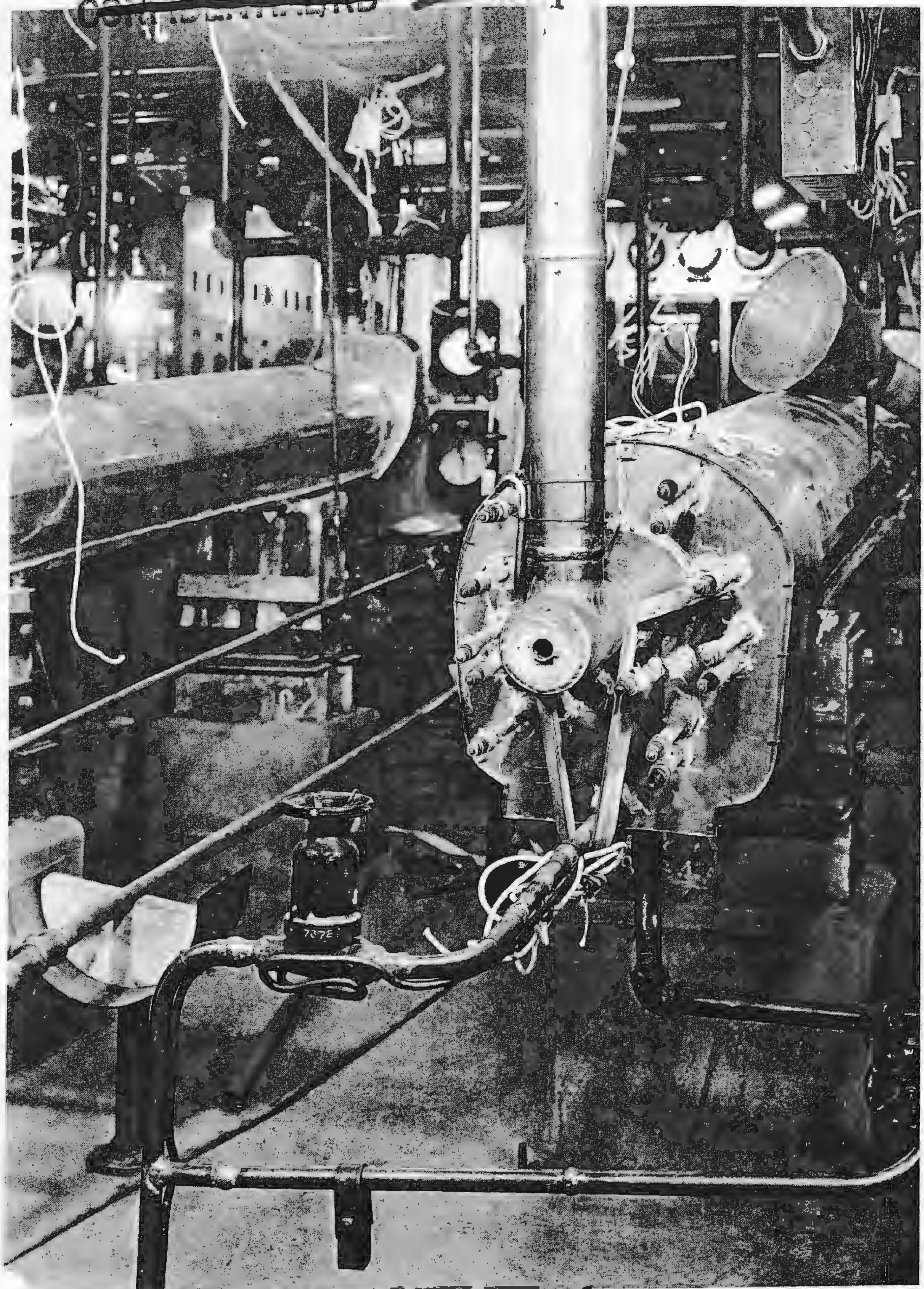

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E-3

E4 General View of a Typical Process Gas Recovery Room showing Cold Traps, Pumps, Process Material Container Jackets, and Scales.

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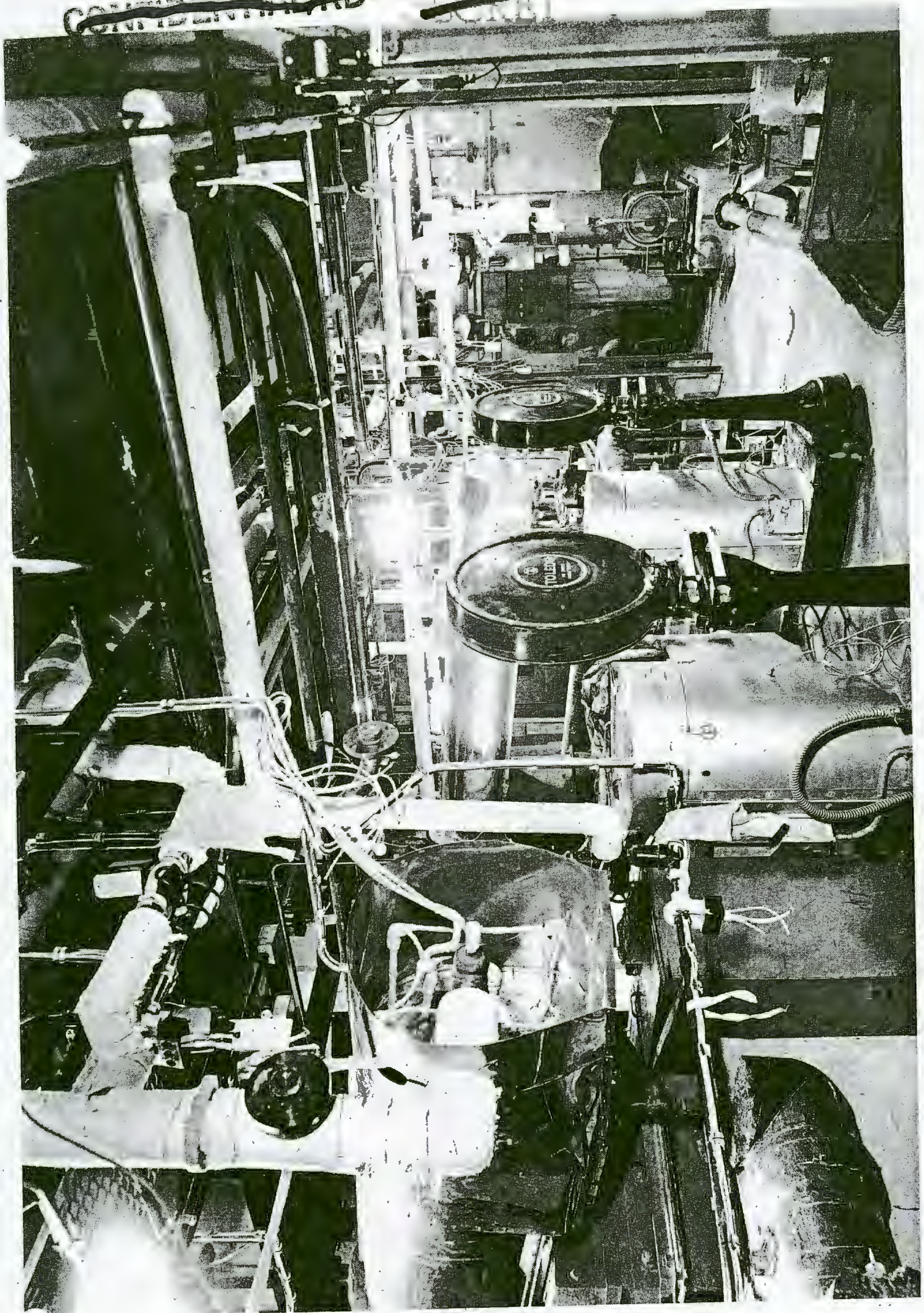

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E5 Typical Process Building Ventilating Fans and Ductwork.

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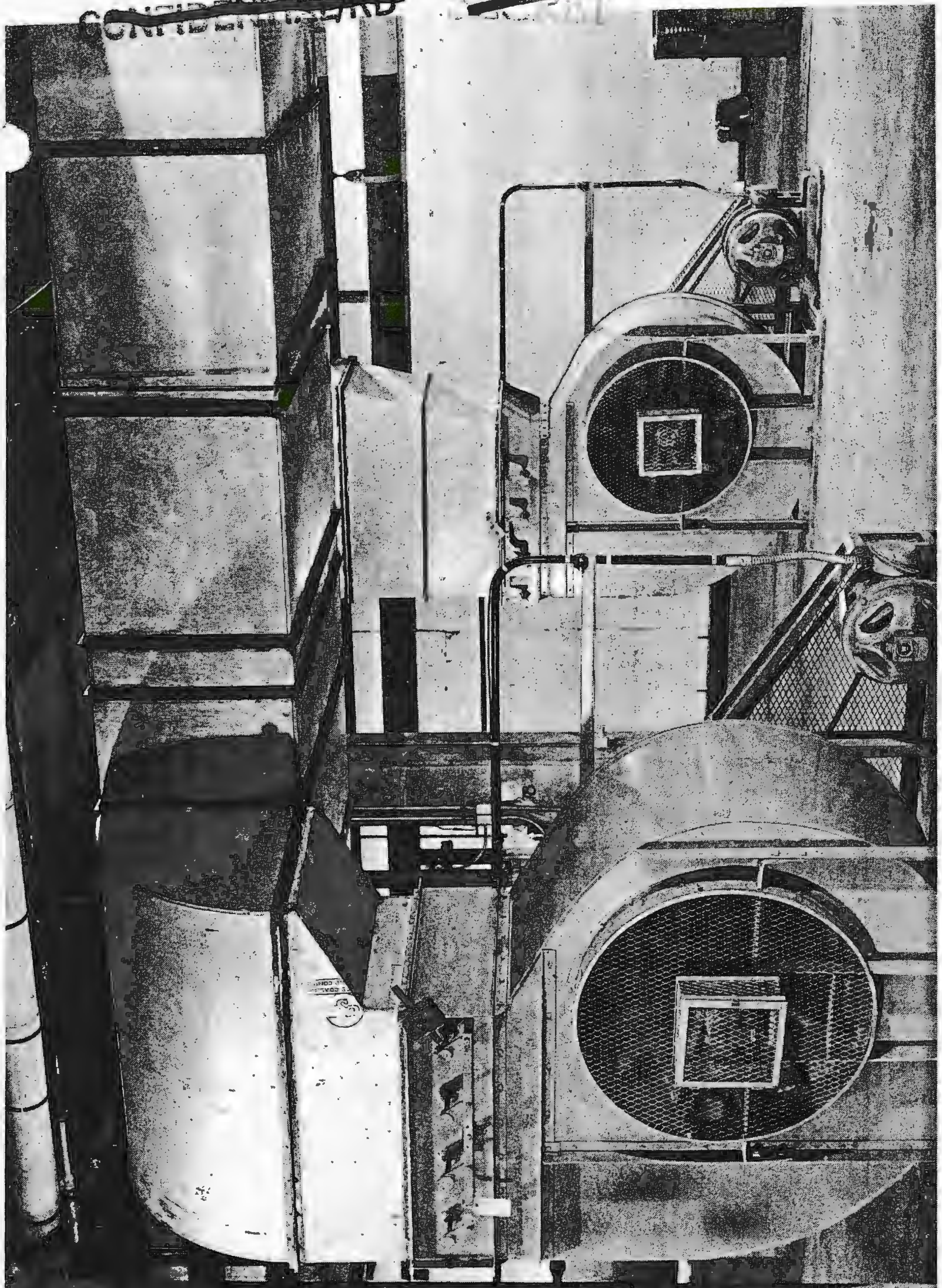

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E6 Typical Process Building Transformer Vault.

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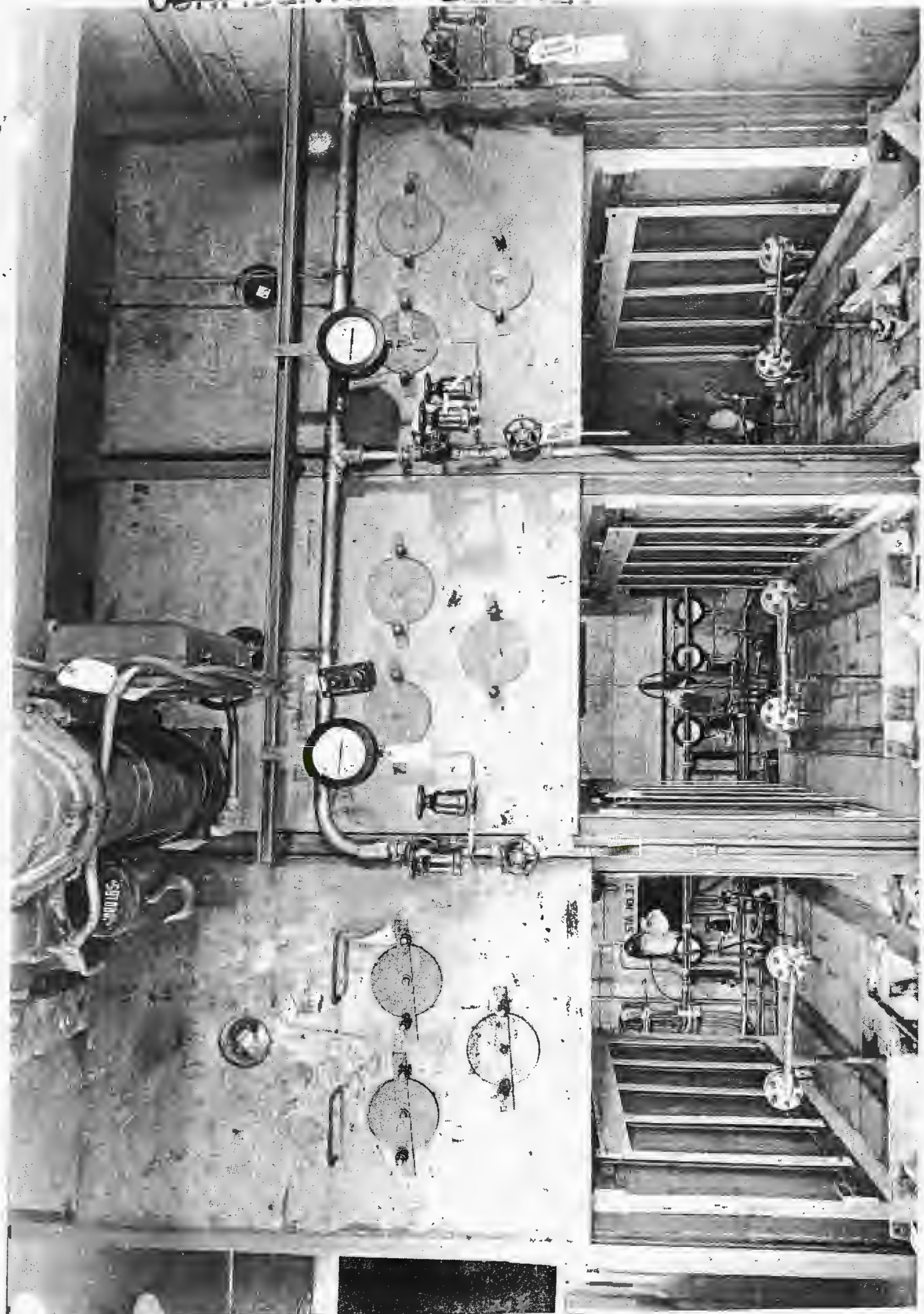
F-6

E7 View of Furnace Room in Feed Purification Building K-101.



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E-7

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E8 View of Surge Pumps and Instrumentation in Surge and Waste Building K-601.

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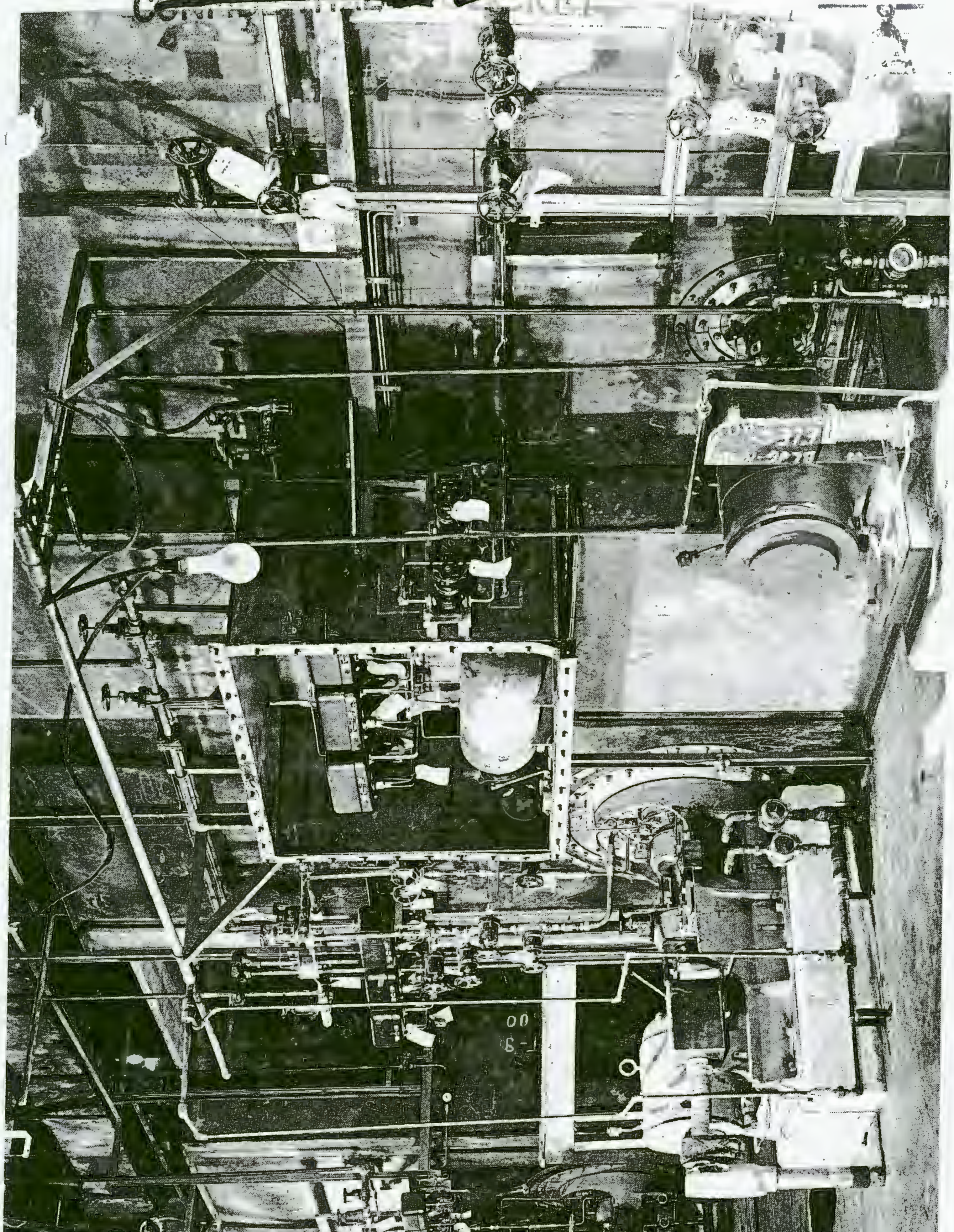

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E-8

E9 Basement of Conditioning Building K-1401, showing Furnace Piping, and in foreground from left to right, Elliott Conditioning Pump, Stokes Fluorine Removal Pump, and Westinghouse High Vacuum Pump.

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E-9

SECRET

CONFIDENTIAL/RD

E10 Circulating Cooling Water Pumps in Pump House,

Building K-706, for Turbine Condensers.

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F-10

E11 Air Compressors in Compressor House, Building K-1201.

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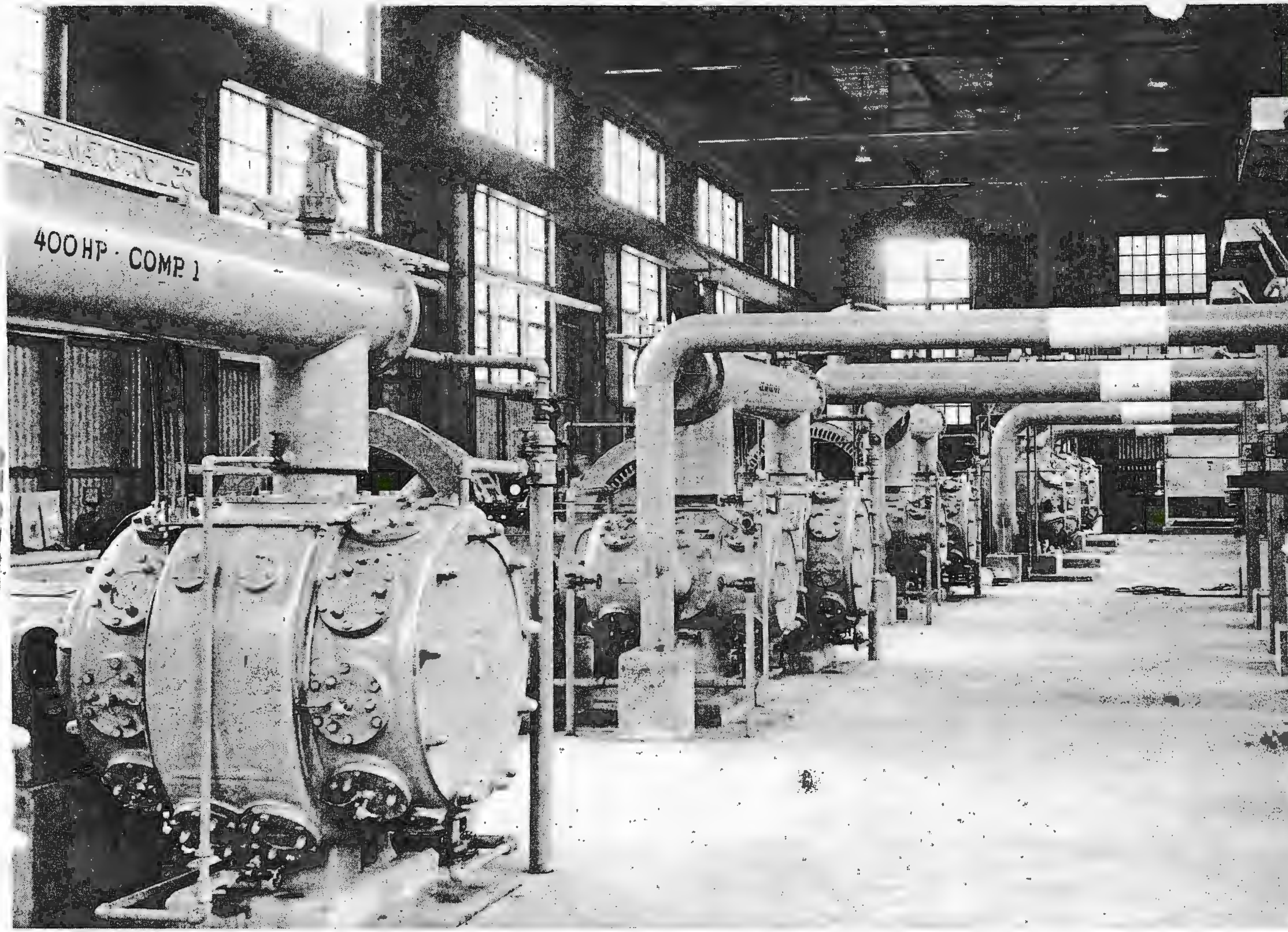

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F-11

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E12 Ammonia Compressors (center) and Brine Circulating Pumps (right) in Dry Air Plant, Building K-1101.

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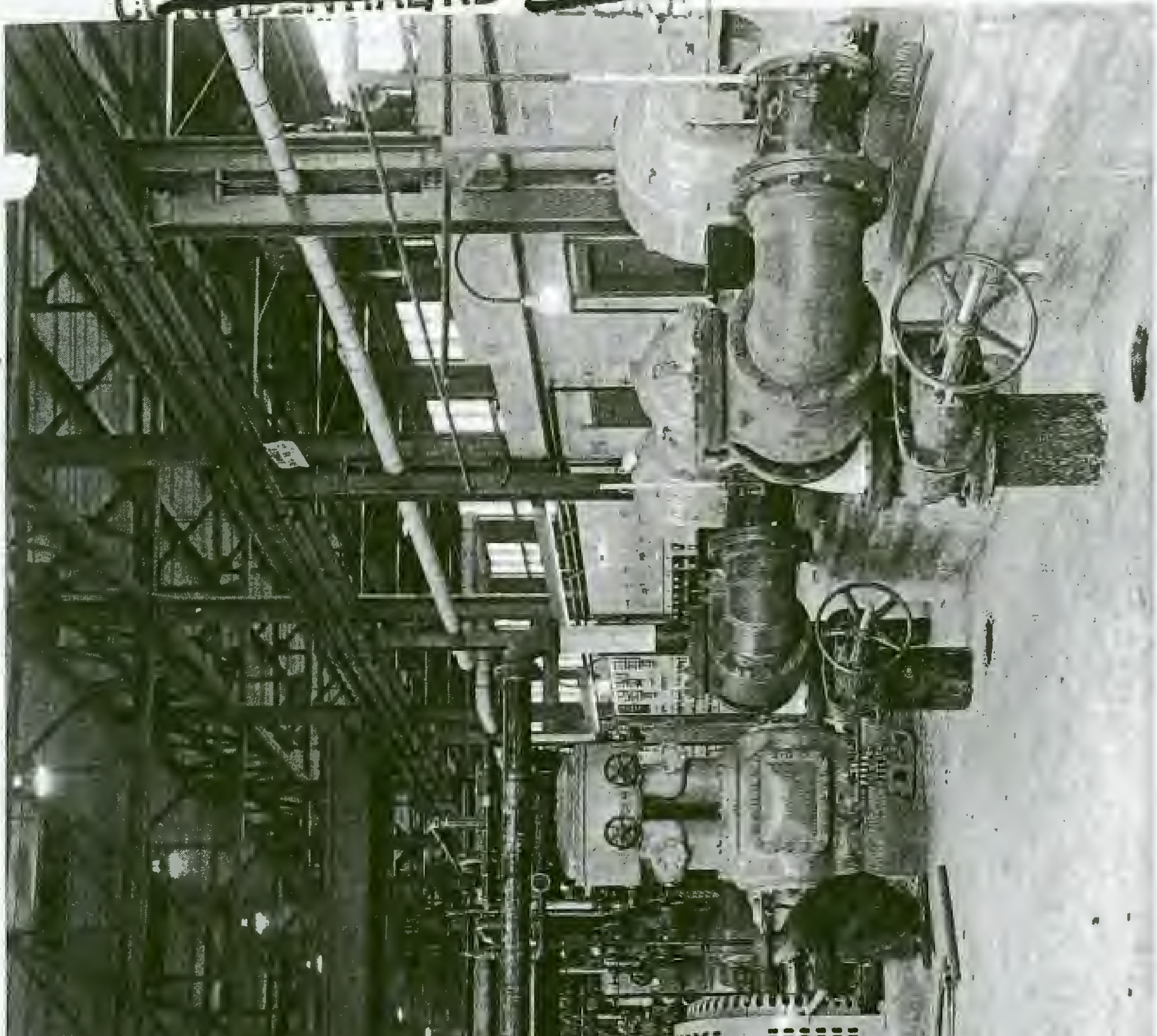

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E-12

E13 Typical Coal Conveyor in Power House Area.

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E14 Pulverizers and Exhausters in Boiler House,
Building K-701.

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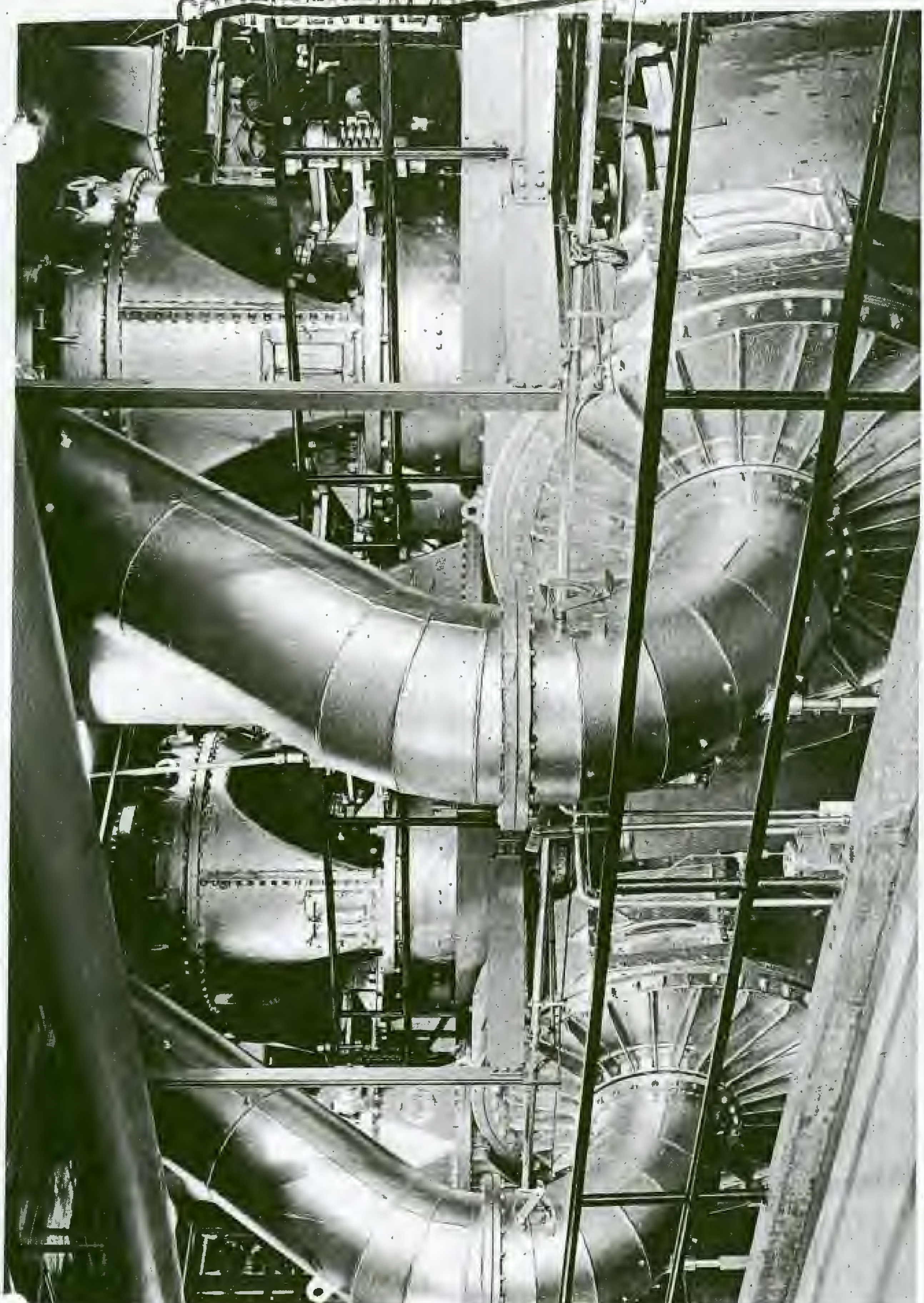

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F-14

E15 Motor-driven Boiler Feed Pumps, and Pulverizer

Coal Hoppers in Turbine Room, Building K-702.

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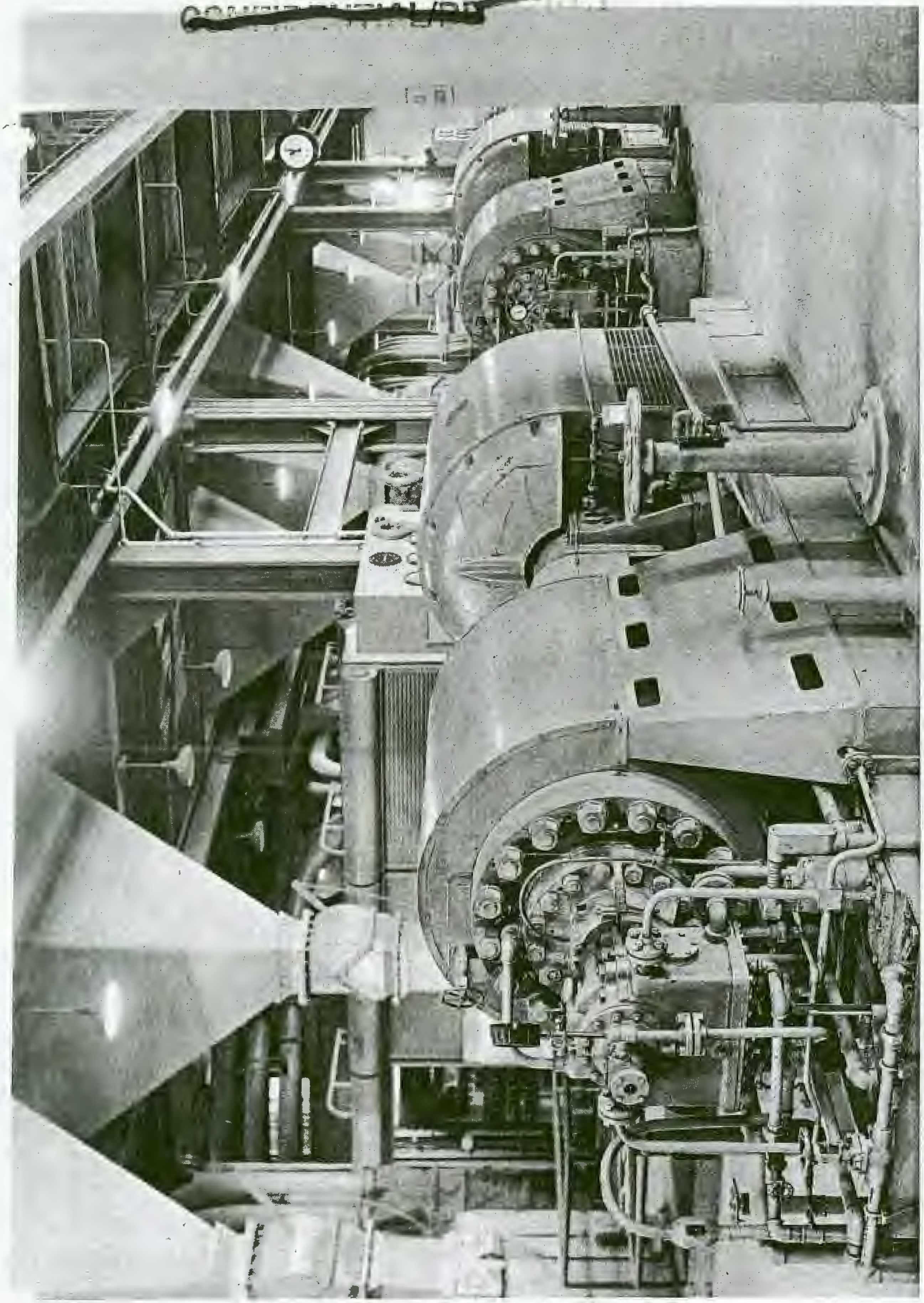

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E16 Turbo-generators Nos. 4, 3, 2, and 1 in Turbine Room K-702.

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F-16

E17 Cable Room below Main Switch House, K-704.

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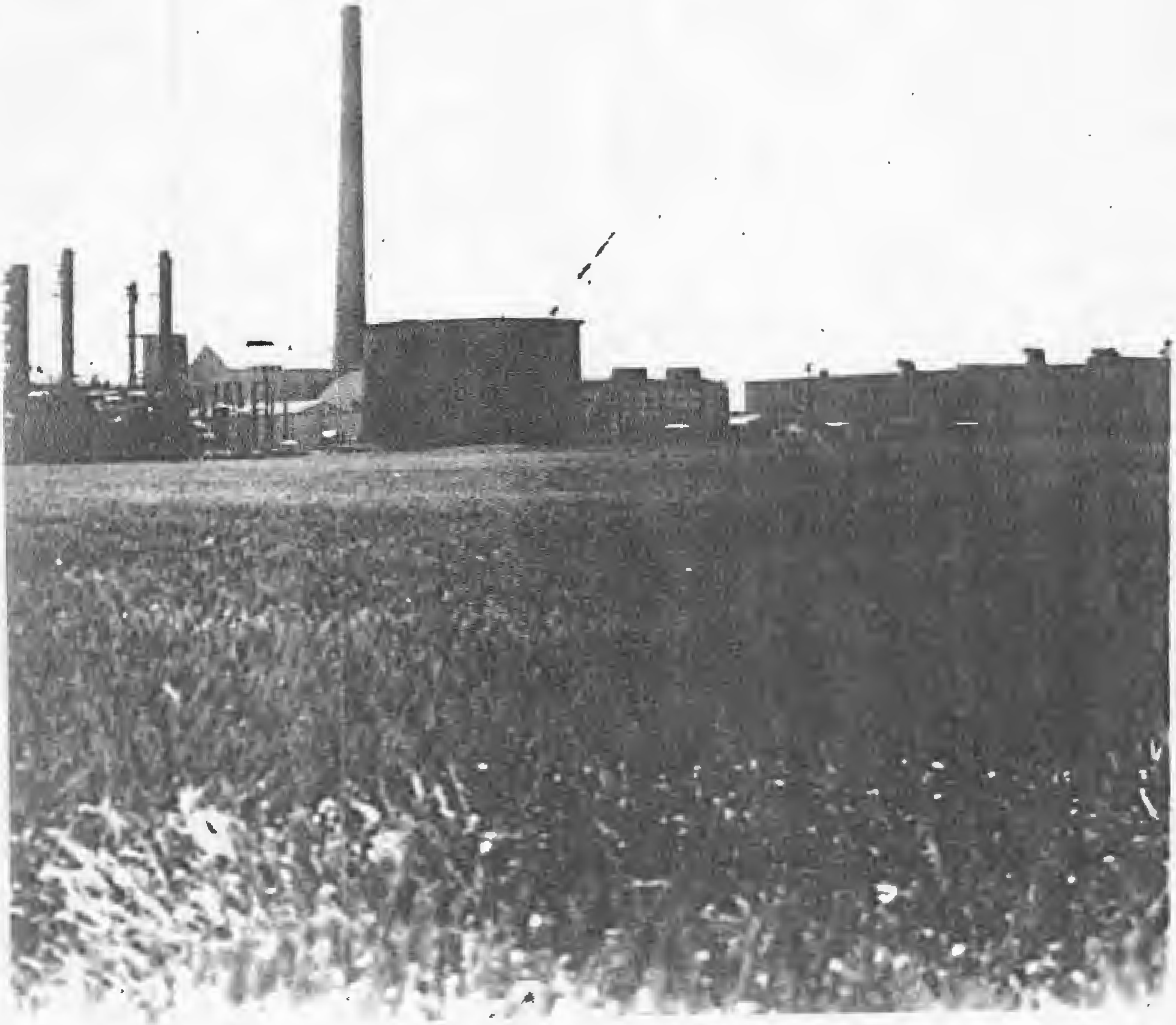

E18

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E19 View of the Allis-Chalmers Plant, Milwaukee, Wisconsin, Constructed for the Manufacture of Process Pumps.

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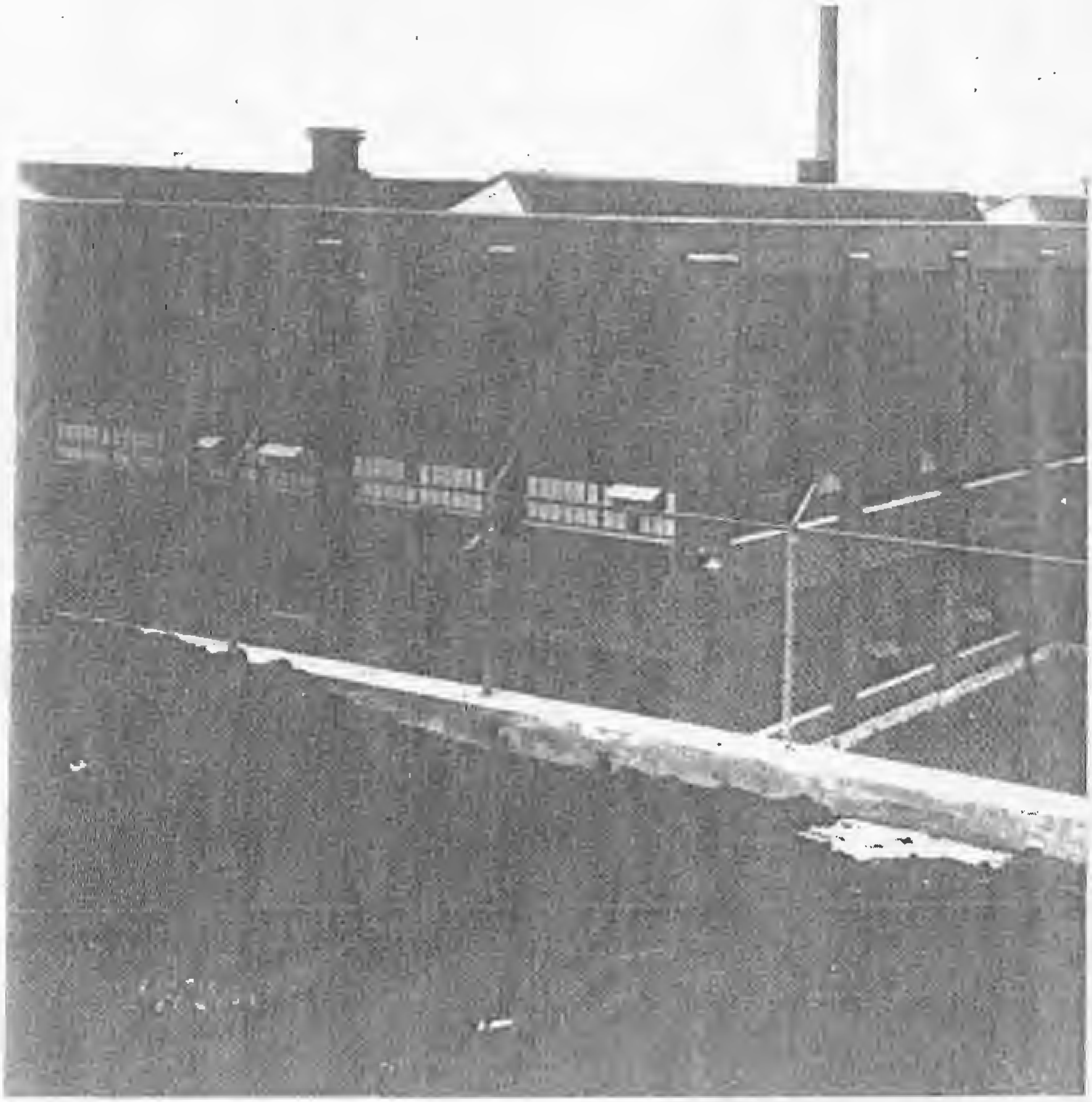

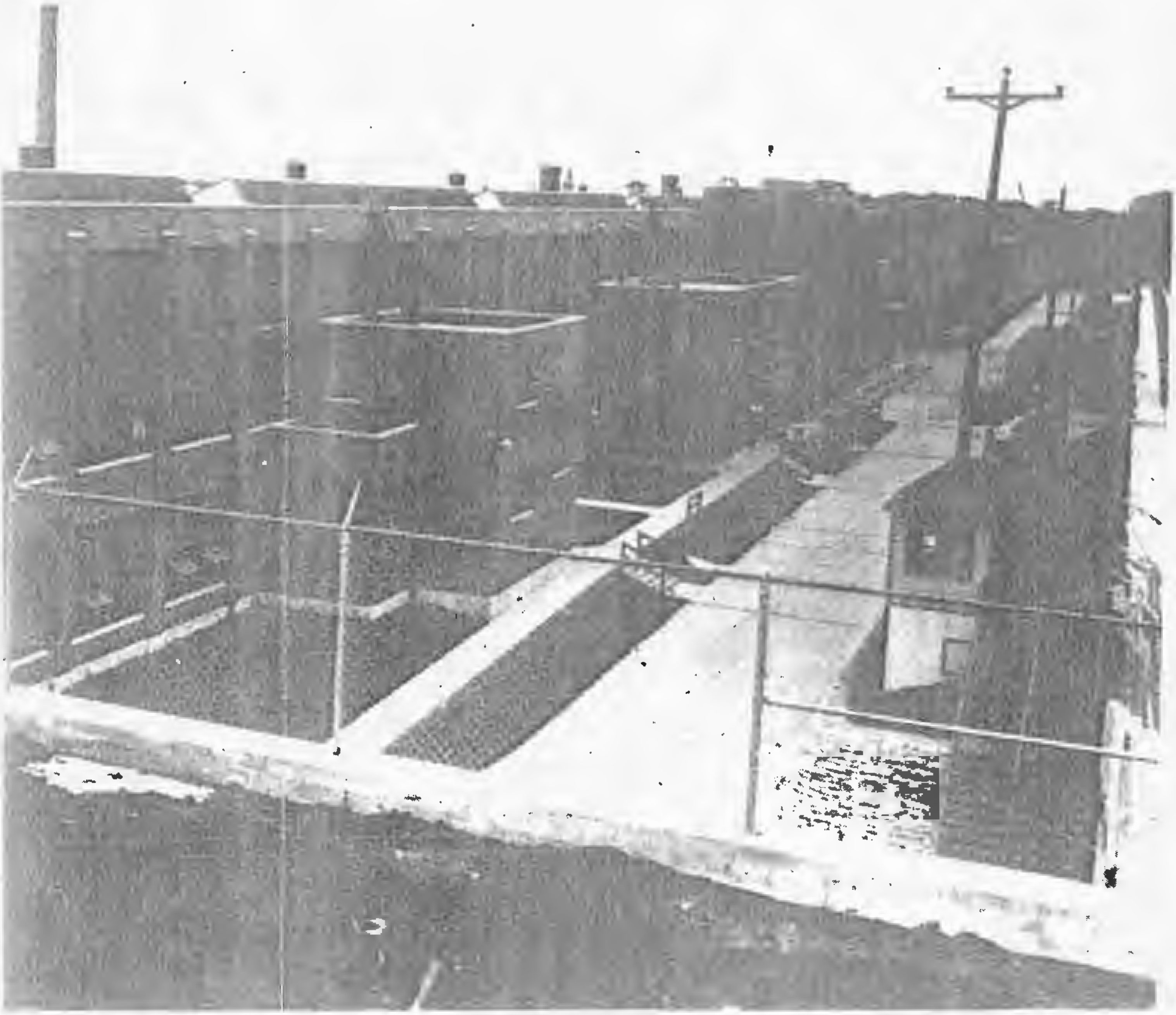

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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "F"

FILE REFERENCES

No.	Title
1.	Contract OEMsr-406 between the Office of Scientific Research and Development and The M. W. Kellogg Company. Manhattan District Classified Contract Files.
2.	"The Diffusion Plant - First Progress Report" dated 29 March 1943. Manhattan Classified Files, File No. A-625.
3.	Letter Contract W-7405-eng-23 and formal Contract W-7405-eng-23. Manhattan District Classified Contract Files.
4.	Minutes of Military Policy Committee, Classified Files, Major General L. R. Groves, Washington, D. C.
5.	Minutes of the Meeting of OSRD S-1 Executive Committee, 14 November 1942. Classified Files, Major General L. R. Groves, Washington, D. C.
6.	Recommendations of Reassessment and Reviewing Committee, 4 December 1942. Classified Files, Major General L. R. Groves, Washington, D. C.
7.	Letter dated 14 December 1942 from the Manhattan District to the M. W. Kellogg Company. Classified Files, Major General L. R. Groves, Washington, D. C.
8.	Memorandum dated 24 February 1944, from Major General L. R. Groves to the Under Secretary of War, and notation of approval thereon by the Under Secretary of War. Classified Files, Major General L. R. Groves, Washington, D. C.
9.	British MSN Reports. Manhattan District Technical Report Files, MSN Series.
10.	Operational Reports, Jersey City Pilot Plant, Nos. 1 - 10 dated 2 May 1944 to 1 December 1944. Kellex Retired Files, K-25 Division Office, Cabinet J-13.

No.	Title
11.	"Gas Diffusion Plant Site Selection." New York Area Classified Files, File No. NY 600.03.
12.	Letter dated 25 March 1943, from Mr. P. C. Keith to Lt. Col. J. C. Stowers, "Power Supply and Requirements - K-25 Project." New York Area Classified Files, File No. NY 675 (Power Plant).
13.	"Minutes of Meeting", by Mr. A. L. Baker (Kellex Corporation) dated 18 August 1943. New York Area Classified Files, File No. NY 337 (Kellex).
14.	Report on Subjects Discussed with British Representatives, dated 16-29 September 1943, by Karl Cohen. Manhattan District Technical Report Files, File No. A-1211.
	Minutes of Meeting held at The Kellex Corporation's Offices, 17 September 1943. Manhattan District Technical Report Files, File No. M-167.
15.	Code Letter to Contract No. W-7405-eng-23 dated 14 December 1942. New York Area Top Secret Files.
16.	"Minutes of Conference on Project Status", dated 11 August 1943, by Mr. A. L. Baker. New York Area Classified Files, File No. NY 337 (Kellex).
17.	Contract W-7418-eng-5 with the Tennessee Valley Authority for the design and construction of a 13.8 KV transmission line from sub-station at Clinton Laboratories to K-25 sub-station; also
	Contract W-7418-eng-6 for the design and construction of a 161 KV transmission line from Elza sub-station; also
	Contract W-7418-eng-163 for the design and construction of a 154 KV transmission line from Fort Loudon Dam to K-25 sub-station. Manhattan District Classified Contract Files.
18.	Minutes of Meeting held 16 January 1944 at Decatur, Illinois, forwarded by Captain J. H. Brannan. Manhattan District Classified Files, File No. M337 (General), Case No. 3501.
19.	Subcontract S-12128 under OSRD. Contract OEMsr-412 with Columbia University (See Appendix A - Volume 2).
20.	Letter from Col. K. D. Nichols to The Kellex Corporation. Manhattan District Classified Files, MD 400.41, Case No. 17245.

No.	Title
21. ✓	Letter from Lt. Col. J. C. Stowers to The Kellex Corporation New York Area Classified Files, File No. NY 400.41.
22. ✓	Letter from Col. K. D. Nichols to The Kellex Corporation. Manhattan District Classified Files, File No. MD 400.41, Case No. 20484 A.
23.	Contract W-7405-eng-26 ~~from~~ for the operation of the gas diffusion plant; also provides for consultant services and research and development work pertaining to design, engineering, construction and operation (See Vol. 5).
24. ✓	Letter Supplement to Contract W-7405-eng-23 dated 31 March 1945. Manhattan District Classified Contract Files.
25.	Letter Contract W-7415-eng-60 dated 14 September 1944, with National Research Corporation, terminated 8 December 1944. Manhattan District Classified Contract Files.
26.	Letter dated 28 March 1945, from Lt. Col. Williams to Lt. Col. Stowers. New York Area Classified Files, Case No. 9496.
27. ✓	Memorandum dated 25 January 1943 from A. L. Baker to P. C. Keith, Subject, Inspection Trip of 1/18/1943. Manhattan District Classified Files, File No. MD 333.
28. ✓	Letter dated April 1943 from Major General L. R. Groves to A. L. Baker, Subject, Location of Gas Diffusion Project. Manhattan District Classified Files, File No. MD 600.03.
29. ✓	Minutes of Meeting held 3 May 1943 between the District, Kellex, and Carbide. New York Area Classified Files, File No. NY 337.

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MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "G"

DOCUMENTARY EXHIBITS

No.	Title
1.	Estimated cost as taken from record of negotiations for Contract W-7405-eng-23 with The M. W. Kellogg Company and The Kellex Corporation.

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ESTIMATED COST AS SHOWN IN RECORD OF NEGOTIATIONS

CONTRACT W-7405-eng-23

Estimated Cost - Excluding Contractor's Fixed Fee:

Material	$183,571,782
Freight and Warehouse	1,864,240
Construction Equipment	1,569,682
Labor (Field)	50,605,151
Compensation and Public Liability Insurance on Field Labor	4,123,500
Process Development	3,520,000
Process Engineering	512,000
Mechanical Engineering	3,267,000
Field Supervision	1,784,000
Procurement	840,000
Home Office	1,835,000
Compensation and Public Liability Insurance (All Other Labor)	653,883
Laboratory Work	614,680
Total	$254,560,698

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MANHATTAN DISTRICT HISTORY

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VOLUME 3 - DESIGN

APPENDIX "H"

GLOSSARY

Term	Definition
Duriron -	trade name for a high silicon (about 14.5 per cent) iron alloy resistant to most acids other than hydrofluoric.
Florite -	trade name for a hard, granular desiccating agent and adsorbent made from bauxite aluminum ore by special processes of activation and mechanical adaptation.
Raschig rings -	gas absorption tower packing used to obtain both high unrestricted volume for flow of fluids, and high surface area per unit bed volume.
Zeokarb -	a synthetic carbonaceous zeolite formed by the sulfonation of powdered coal, and capable of regeneration with either salt or acid. It can therefore produce a softened water containing either sodium or hydrogen ions (or a mixture of the two) in place of the original calcium and magnesium ions; consequently, acidity of the effluent may be adjusted to the desired value.

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "I"

SAFETY AND SECURITY BULLETINS

No.	Title
1.	New York Area Safety Committee Bulletins
2.	Security Publications

NEW YORK AREA SAFETY COMMITTEE BULLETINS

Bulletin No.	Title
SM1.	Safety Committee Regulations for handling C-616 in laboratories and for small scale operations.
SM1, Rev. 1	Safety Committee Regulations for handling C-616 in laboratories and for small scale operations.
SM1, Sup. 1	Medical Considerations of work with C-616.
SM2	Safety Committee Regulations for handling C-216.
SM2, Rev. 1	Safety Committee Regulations for handling C-216.
SM2, Rev. 2	Safety Committee Regulations for handling C-216.
SM2, Rev. 3	Safety Committee Regulations for handling C-216.
SM3	Safety Committee Regulations for handling hydrofluoric acid in laboratories and for small scale operations.
SM4	Safety Committee Regulations for the handling of materials used in cleaning operations.
SM4, Sup. 1	Methods of detection of trichloroethylene and carbon tetrachloride in the atmosphere.
SM4, Sup. 2	General remarks on operation of trichloroethylene degreasers.
SM5	Safety Committee Regulations for the handling of materials used in electroplating.
SM5, Sup. 1	Method of detection of trichloroethylene and carbon tetrachloride in the atmosphere.
SM5, Sup. 2	General remarks on operation of trichloroethylene degreasers.

SECURITY PUBLICATIONS

Protective Security Manual dated 1 February 1943.

Security and Intelligence Manual dated December 1943.

Intelligence Bulletin No. 4 dated 22 October 1943.

Intelligence Bulletin No. 5 dated 27 November 1943.

Intelligence Bulletin No. 6 dated 29 November 1943.

Intelligence Bulletin No. 7 dated 28 June 1944.

MANHATTAN DISTRICT HISTORY

BOOK II - GASEOUS DIFFUSION (K-25) PROJECT

VOLUME 3 - DESIGN

APPENDIX "J"

KEY PERSONNEL

KEY PERSONNEL, NEW YORK AREA

Stowers, Lt. Col. J. C. - Officer-in-Charge, K-25 Project from 7 January 1943 to 17 January 1945. New York Area Engineer, from 7 January 1943 to 28 February 1946. Supervised and coordinated design, engineering, and procurement activities. Maintained liaison between the District and contractors for purposes of consultation, guidance, production control and expediting procurement of equipment.

Archer, Major H. R. - Executive Officer from 27 July 1943 to 29 December 1944.

Campbell, Major W. C. - Deputy Area Engineer from 6 March 1944 to 28 May 1945. New York Area Engineer from 1 March 1946 to 23 August 1946.

Christensen, Major J. G. - Supervised special contracts. On duty in the New York Area from 20 August 1944 to 29 August 1945.

Greenstein, Major Harold. - Legal Advisor and supervised contracts termination. Reported to New York Area 1 November 1944.

Moran, Major J. J. - Technical advisor from 1 June 1943 to 1 March 1944.

Morris, Major D. H. - Administered special price adjustment contracts, including coordination of production of such contracts. Reported to the New York Area 30 August 1945.

Beckwith, Captain M. M. - As technical advisor from 1 February 1944 to 2 November 1944, supervised research and development contracts and coordinated special chemicals requirements.

Carothers, Captain H. T. - Supervised special production contracts, coordinating schedules and expediting production. Reported to the New York Area 15 May 1944.

Duley, Captain L. A. - Special contracts and expediting from 16 October 1943 to 26 June 1945.

Fredenburgh, Captain E. H. - Reported to the New York Area on 28 July 1943.

Maloney, Captain J. H. - Special contracts and expediting. Reported to New York Area 8 March 1944.

Quayle, Captain F. J. - Reported to the New York Area on 15 December 1943. As Contracts and Procurement Officer, prepared, distributed, reviewed, and recorded all contractual instruments, and attended all conferences on contract negotiations. Authorised representative of the Contracting Officer. Reviewed purchase orders on CPFF contractors for compliance with procurement regulations, and approved same. Issued preference rating certificates as required. Certified payrolls and reimbursement vouchers for all New York Area contractors.

Rosenblum, Captain Charles - On loan to The Kellex Corporation from 12 January 1944 to 1 December 1944. Headed Kellex Corporation Barrier Testing Section and Barrier Production Section successively. Technical advisor to the Area Engineer.

Alpert, 1st Lt. H. R. - Assistant Property Officer from 26 October 1944 to 23 August 1945.

McMullen, 2nd Lt. W. E. - As Security Officer, formulated and enforced security policies and made security investigations. Reported to New York Area 30 May 1944.

Stebbins, S/Sgt. Mary - In charge of Classified Files Section. Reported to New York Area on 18 November 1944.

Griffin, R. N. - Chief administrative assistant to the Area Engineer from 1 June 1943 to 28 July 1945.

Levine, Aaron - Responsible for plan review and acted as general engineering advisor to the Area Engineer. Joined the Area staff on 1 August 1943.

McKee, J. F. - Head of the Audit Branch since 16 April 1943.

Sailsbery, Miss Frances - Confidential Secretary and Administrative Assistant to the Area Engineer since 16 January 1943, immediately after the creation of the New York Area.

Schenk, H. A. - Head of the Administrative Branch. Joined the Area Staff on 26 April 1943.

KEY PERSONNEL, MILWAUKEE AREA

Gregory, Lt. Col. R. C. - Project Engineer from 23 February 1943 to 15 July 1943. In charge of construction of Allis-Chalmers pump manufacturing plant.

McCormick, Major J. L., Jr. - Area Engineer from 6 August 1944 to 14 November 1945. Administered all District contracts in the area; responsible for work progress and expediting; set area policies; coordinated work between Contractors and the Architect-Engineer.

Anderson, Captain Jon D. - Property Officer. Assisted with Production Control; responsible for surplus materials, records and disposal. Milwaukee Area Engineer from 15 November 1945 to 30 July 1946.

Fugard, Captain John R., Jr. - Assistant Area Engineer. Served as Cryptographic and Salvage Officer, and assisted with production control. In charge of construction and critical materials control and expediting.

Hill, Captain R. C. - Area Engineer from 15 July 1943 to 5 August 1944. Handled all District production contracts in the Area.

Fitzgerald, Edmund A. - Head of Accounts and Audit Section.

Landon, Edward F. - Security Agent.

Schultz, Eleanora H. - Chief of Administrative Section.

Steck, Hazel F. - Chief of Property Section.

KEY PERSONNEL, DECATUR AREA

Choate, Major Carlisle E. - Area Engineer from 10 October 1944 to 8 December 1944.

Moran, Major John J. - Area Engineer from 12 December 1944 to 14 December 1945.

Beckwith, Captain Merton M. - Assistant, Technical from November 1943 to January 1944.

Brannan, Captain John H. - Area Engineer from 20 July 1943 to 9 October 1944.

Crawford, Captain Robert L. - Assistant, Engineering and Maintenance. Area Engineer from 15 December 1945 to 1 July 1946.

Bemsen, Captain George W. - Intelligence and Security Officer from 24 August 1944 to 27 January 1945.

Schneider, Captain Henry W.- Assigned 3 January 1945 as Acting Area Engineer.

Walker, 1st Lt. Homer D. - Operations Division from 1 September 1943 to 5 January 1945.

Cooley, 2nd Lt. Larry E. - Assigned 28 January 1945 as Security Officer.

Bihl, Edward J., Jr. - Assigned 1 August 1943 as Administrative Assistant (Property)

Chasteen, Roger H. - Assigned 1 September 1943 as Administrative Assistant (Procurement and Surplus)

Comstock, Elbridge G. - Engineer (Mechanical) from 16 December 1943 to 31 August 1944.

Dondero, Louis E. - Assigned 3 December 1943 as Chief of Administration Section.

Dwyer, Thomas W. - Assigned 12 December 1944 as Engineer (Safety)

Labovitz, Saul I. - Project Auditor from 1 November 1943 to 25 November 1945.

Haven, Alexander - Assigned 22 January 1944 as Chief Administrative Assistant.

<u>Moyer, Curtis R.</u> - Chief Project Auditor from 16 January 1944 to 31 July 1944.

<u>Olsen, Gail R.</u> - Chief Engineering Aide from 2 August 1943 to 15 January 1945.

<u>Oppenheimer, Leo F.</u> - Administrative Assistant (Labor Relations) from 23 August 1944 to 7 December 1944.

<u>Pippin, Raymond E.</u> - Principal Administrative Assistant from 9 July 1943 to 7 March 1944.

<u>Rich, Roy H.</u> - Associate Engineer (Civil) from 6 December 1943 to 20 January 1945.

<u>Vesler, Harold W.</u> - Assigned 25 January 1944 as Chief Project Auditor.

KEY PERSONNEL, DETROIT AREA

Tammaro, Lt. Col. A. - Area Engineer, 21 July 1943 to 15 November 1944. Supervised the initiation and the execution of the major portion of the construction and early operations under this Area.

Archer, Major Norman R. - Resident Engineer in preliminary organization of the work from May 1943 to July 1943.

Belcher, Major F. H. - Area Engineer, 16 November 1944 to 31 January 1946.

Shepherd, Major R. E. - Executive Officer, 30 November 1944 to 4 April 1945. In direct supervision of Area Operations, also served as Acting Area Engineer.

Brannan, Captain J. H. - Assistant to the Area Engineer and Accountable Property Officer, 15 January 1945 to 13 April 1945.

Howie, Captain A. L. D. - 27 November 1944 to 23 January 1945, Assistant Area Engineer and Accountable Property Officer.

McCormick, Captain J. D. - Appointed on 16 February 1945 as Assistant Area Engineer and Accountable Property Officer. Area Engineer from 1 February 1946 to present.

Seider, Captain R. G. - Executive Officer, September 1943 to January 1944.

Crowley, Lt. J. T. - 23 November 1943, assigned as Security and Military Intelligence Officer.

McElwreath, Sgt. W. J. - Assistant Security and Military Intelligence Officer, assigned 13 January 1944.

Burling, H. D. - Assigned 21 June 1943 as Chief of Property Section.

Loupe, Mrs. E. L. - Assigned 15 January 1944 as Administrative Assistant and Secretary to Area Engineer and Executive Officer.

Pruner, J. W. - Assigned 16 September 1943 as Chief Project Auditor.

Watkins, C. O. - Assigned as Office Engineer from September 1943 to June 1945.

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KEY PERSONNEL, THE KELLEX CORPORATION

CORPORATE OFFICERS

Kellogg, M. W.	President
Johnson, F. E.	First Vice-President
Austin, H. R.	Executive Vice-President and General Manager
Harvison, L. H.	Second Vice-President
Keith, P. C.	Third Vice-President
Gidley, E. L.	Secretary
Wadell, Ethel M.	Assistant Secretary
Moore, P. H.	Treasurer and Comptroller

TOP ENGINEERING AND ADMINISTRATIVE PERSONNEL

Abbott, T. A. - Division Engineer, Instrument Department. Responsible for the design and development and production of process instruments.

Allinson, J. J. - Chief Field Resident Engineer. In charge of administration of field forces for supervision and coordination of construction.

Arnold, J. H. - Director of Research and Development. Supervised and coordinated all research, process development pilot plant operations, and specification of special chemicals and materials.

Baker, A. L. - Project Manager. In charge of organization and administration of all engineering; scheduling; process equipment procurement; expediting and inspection; and supervision of construction. Was responsible for securing the services of many key scientific and technical personnel.

Benedict, Dr. M. - Engineer in charge of Process Design. Planned much of the experimental work on barriers, corrosion, pilot plant, cold traps, vacuum pumps and coolers under O.S.R.D. and Manhattan District contracts. Carried out all the fundamental mathematical studies of the diffusion process and established the basic principles upon which the design of the plant is founded. Also developed the process design for the entire plant and auxiliaries excepting utilities.

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Cook, Dr. E. - Metallurgical Consultant. Advised on special metallurgical problems. Contributed to barrier manufacturing design.

Denns, W. H., Jr. - Head of Contracts Division. In charge of the negotiations, preparation and administration of all contracts for the procurement of materials, equipment, apparatus, machinery, supplies and services for the project.

Dunning, Dr. J. R. - Assistant to Project Manager. Technical Coordinator. Consultant to Vice-President, Project Manager and Process Engineering Department on fundamental requirements of the plant.

Fruit, A. J. - Project Engineer. Responsible for the design of the plant and all auxiliaries. Assisted in forming engineering policies.

Gordon, P. B. - Head of the New York Design Group (Field). Assisted in the engineering and construction of the barrier manufacturing plant.

Houck, F. P. - Service Manager. In charge of all service functions for The Kellex Corporation.

Johnson, Dr. C. A. - Research Engineer. Developed barrier used in the plant. Supervised laboratory work on corrosion studies, pilot plant operation, cold traps and other special equipment. Assisted in correlation of main plant operating studies.

Keith, P. C. - Vice-President and Executive in Charge of Project. Formerly member of Planning Board of OSRD Project SSRC-17. Personally directed early research and development work under OSRD contract and later directed all phases of research and development as well as all other technical work under Manhattan District contract.

Levey, H. B. - Assistant Project Engineer. Assisted the Project Engineer in design of the main plant.

Nickman, A. A. - Assistant Chief Resident Engineer. Supervised engineering and construction in the field. In early stages was Resident Engineer for construction of power plant.

Nier, Dr. A. O. - Physicist. Did early work on mass spectrometer at University of Minnesota. Continued work at Kellex under Manhattan District. Responsible for mass spectrometers used for leak detection analysis of contaminants in plant process stream and isotopic analysis as well as for a variety of other applications. Also developed numerous other analytical machines and tools.

Norton, W. J. - Head of Coordination Engineering. Responsible for scheduling, reports, estimating and schedule engineers.

Powers, R. E. - Division Engineer, Cleaning and Conditioning Department. Devised and perfected techniques for cleaning, conditioning, plating and vacuum testing. Responsible for vacuum tightness of the plant.

Skog, L. - Division Engineer, Mechanical Engineering Department. Supervised the development of diffusers and other special process equipment. Responsible for design of power generating plant. Engineered special power and distribution system for main plant.

Smith, S. B. - Assistant Project Manager. Coordinated operation of various departments with emphasis on design and construction scheduling.

Squires, A. M. - Process Engineer. Aided in the mathematical studies on the fundamentals of the diffusion process and on the productivity, equilibrium time and preferred modes of operation of the large diffusion plant. Also aided in the development of the process design of the main plant equipment.

Watts, G. W. - Division Engineer, Pump and Instrument Department. Supervised the development and manufacture of special process pumps and instruments.

SUPPLEMENTAL ALPHABETICAL LIST

Armistead, Dr. F. C. - Field Engineer. Vacuum testing specialist for various manufactured components of the main plant.

Barnholt, W. C. - Schedule Engineer. Prepared construction schedules, cost estimates and special reports.

Barrett, F. G. - Head of Estimating Department.

Barrett, W. A. - Assistant Service Manager.

Benenati, R. F. - Engineer. Supervised the writing of the operating manuals.

Berg, I. A. - Schedule Engineer. Responsible for schedule engineering of Power Plant and coordinating work of Schedule Engineering Division.

Binner, C. R. - Assistant Division Engineer, Mechanical Engineering. Supervised design and construction of test floor and Jersey City Laboratory. Later was Chief Mechanical Engineer, supervising design of process valves, cold traps, and preparation of mechanical and erection specifications.

<u>Brewster, O. C.</u> - Development Engineer, Pump Department. Supervised the development and production of the special purge cascade pumps.

<u>Buschow, H. P.</u> - Job Engineer. Designer of diffusers, special filters and cold traps.

<u>Cuniffe, J. J.</u> - Director of Procurement. Responsible for Kellex procurement, expediting and inspection.

<u>Dean, D. K.</u> - Job Engineer. Mechanical Engineer for Conditioning Department.

<u>Dean, H. W.</u> - Division Engineer, Design Section. Responsible for structural design of main plant.

<u>Deanesly, R. M.</u> - Engineer. Fundamental work on barrier performance. Directed technical work for barrier testing.

<u>Deutsch, Z. G.</u> - Division Engineer, Barrier Development Group.

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<u>Dwyer, P. F.</u> - Engineer. Preparation of basic specification for valves and piping materials.

<u>Elsey, Dr. H. M.</u> - Consultant Chemist. Critically reviewed essentially all phases of the research and development work - aided in setting of specifications and procedures for large scale manufacture of special materials and continually inspected and constructively criticised chemical aspects of such manufacturing units and of the large diffusion plant.

<u>Esherick, G. E.</u> - Engineer, Cleaning and Conditioning Department. Design and layout of equipment in the conditioning and maintenance buildings.

<u>Evans, H. W.</u> - Job Engineer. Supervised design of ventilating systems.

<u>Fantz, A. C., Jr.</u> - Process Engineer. General assistant to head of process engineering department.

<u>Ferrens, G.</u> - Job Engineer. Supervised design of site laboratories and other auxiliary buildings.

<u>Finlayson, D. K.</u> - Engineer. In charge of Barrier Acceptance Group; set manufacturing specifications, responsible for acceptance and scheduling of barrier.

Greenspan, Dr. J. - Engineer. Assisted in the design and development of special instruments.

Hill, W. H. - Insulation Consultant. Advised on special insulation problems.

Hobbs, J. C. - Mechanical Design Consultant. Developed special process valves. Consultant on mechanical piping arrangements and layouts.

Hogerton, J. F. - Engineer. Correlated material for completion report.

Hollar, B. D. - Supervisor of Material Control Board (New York).

Hopkins, W. A. - Plating Specialist. Supervised development and application of cleaning and plating methods.

Jacobs, Dr. R. B. - Division Engineer, Vacuum Testing. Developed vacuum testing techniques and special vacuum testing equipment. Supervised vacuum testing at site.

Krieg, T. A. - Security Agent. Responsible for security of Kellex operations.

LaBarr, H. C. - Field Division Engineer, Electrical Division. Responsible for electrical installations.

Landau, Dr. Ralph - Chemical Engineer. Carried out process development work on nitrogen generating and fluorine disposal plants.

Lowenstein, H. H. - Assistant Division Engineer. Head of boiler design and procurement on steam power and heating plants.

McKinzie, D. J. - Engineer. In charge of preparing erection and mechanical specifications in the field. Supervised Test Floor construction.

Morris, J. E. - Job Engineer. Supervised transfer of Government equipment to project and coordinated spare parts procurement.

Newcomb, N. B. - Field Division Engineer, Structural Division. Responsible for structural installations.

Powell, N. A. - Field Division Engineer, Instrument Division. Responsible for instrument installations.

Pray, J. A. - Schedule Engineer, Barrier Production. Coordinated deliveries of critical components required in barrier manufacturing.

Rehnberg, H. A. - Field Division Engineer, Conditioning Building. Supervised construction and operation of Conditioning Building.

Reynolds, T. G. - Job Engineer. Supervised design of conditioned air plant for main process.

Rose, H. A. - Assistant Division Engineer, Cleaning, and Conditioning Department. Assisted in developing of special vacuum pumps for process service and supervisor of vacuum testing of manufactured equipment.

Rosen, Dr. R. - Chemist in charge of special chemicals. Devised inspection methods and compiled specifications for all special chemicals developed for the large plant. Also carried out a variety of chemical investigations including the bulk of the work on valve seats.

Rosenblum, Dr. C. - Research Chemist. Devised methods of evaluating barrier quality and organized production control laboratory. Also consulted on overall barrier development program.

Russell, H. V. - Personnel Manager.

Schuman, Dr. S. C. - Chemist. In charge of Jersey City Laboratory. Studied special chemicals stability and ran test floor.

Sheldon, E. L. - Head of Inspection Department. Administrative head of all Kellex inspection personnel at vendors' plants.

Small, H. L. - Field Division Engineer, Coordination. In charge of coordination of construction.

Spinka, F. E. - Chief Expediter.

Stoddard, W. B., Jr. - Chemist. DELETED
DELETED studied production methods.

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Stone, G. D. - Head of Accounting Department. In charge of the accounting section.

Sugden, A. C. - Assistant Division Engineer, Electrical Department. Made studies of power requirements and distribution.

Swank, W. R. - Field Division Engineer. Responsible for mechanical installation.

Swanson, W. H. - Resident Engineer. In charge of Kellex operations at Allis-Chalmers (Hawley Plant), and later Field Resident Engineer.

Swearingen, Dr. J. S. - Development Engineer. Developed process pump seals and made studies on fundamental pump designs.

Thompson, Dr. W. I. - Development Engineer, Process Department. Assisted in development of cold traps and related process equipment.

Troxel, F. D. - Division Engineer, Electrical Department. Coordinated and responsible for all electrical power distribution and consumption problems.

Van Houten, R. B. - Assistant to the Project Manager. Liaison for engineering and service activities. Assisted in technical personnel procurement.

Van Valkenburg, K. - Engineer, Process Department. Coordinator for special hazards problems, process department.

Watson, J. - Assistant Director of Procurement. In charge of purchasing department.

Weber, J. E. - Chief Design Engineer. Chief of Design Section and Drafting Rooms.

Wheeler, H. E. - Development Engineer. Responsible for instrument applications.

Wosby, N. W. - Job Engineer. In charge of auxiliary process systems.

Zegers, J. A. - Traffic Manager. Responsible for all personnel and equipment transportation problems.

KEY PERSONNEL OF PRINCIPAL KELLEX SUBCONTRACTORS ON DESIGN AND ENGINEERING DEVELOPMENT

ELLIOTT COMPANY

Crawford, D. B. - Job Engineer. Supervised design and development testing.

Lapp, R. H. - Seal Engineer. Special seal studies and development.

Sheets, H. E. - Engineer. Conducted research studies on gas flow in pumps.

Smith, R. B. - Chief Engineer. Coordinated development and engineering of special seals and pumping equipment.

FIRESTONE TIRE AND RUBBER COMPANY

Daugherty, W. J.
Dillon, J. H.
Ebert, H. L.
Kelsey, R. H. - Development studies and tests on special rubber for valve seats.

GENERAL ELECTRIC COMPANY

(See Appendix J2)

HARSHAW CHEMICAL COMPANY

Cromer, H. W. - Conducted research on recovery of uranium hexafluoride from spent carbon trap residues.

Filipic, H. F. - Special studies on nickel carbonate slurries for plating.

Harshaw, William J. - President. Coordinated development and specification of nickel carbonate slurries for plating.

Juredine, G. M. - Conducted research on the preparation and properties of nickel carbonate.

Lang, K. E. - DELETED DELETED

Pine, P. R. - DELETED DELETED

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Shadduck, Dr. H. A. - DELETED

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Swinehart, Dr. C. A. - Conducted research on recovery of uranium hexafluoride from carbon trap residues.

INTERNATIONAL NICKEL COMPANY

Bieber, C. L. - Head of Works Laboratory. Supervised testing and specifications of nickel products.

Carey, J. W. - Engineer. Supervised specifications for all nickel products.

Flocke, F. G. - Welding Specialist. Developed welding techniques and procedures used by many equipment manufacturers.

Kline, E. H. - Plant Manager. Supervised melting and forming procedures at Huntington, West Virginia.

Merica, P. D. - Technical Director. Coordinated technical development of nickel powder for barrier and nickel products used in equipment development.

SAM TOUR, INC.

Davidoff, Charles - Engineer. Performed barrier studies and tests.

Tour, Sam - Technical Director. Coordinated metallurgical studies and development of welding apparatus.

TRENT TUBE MANUFACTURING COMPANY

Elge, F. E. - President. DELETED DELETED DOE b(3)

Hamm, W. - Mechanical Engineer. Supervised design and engineering.

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

(See Appendix J7.)

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KEY PERSONNEL OF PRIME CONTRACTORS ENGAGED IN K-25
DESIGN AND ENGINEERING DEVELOPMENT

ALLIS-CHALMERS MANUFACTURING COMPANY

Avery, John - Manager. Blower and Compressor Department. Over-all coordinator of development and production of process pumps.

Codrington, C. F. - Assistant Manager. Blower and Compressor Department. Assisted in coordinating Hawley Plant Work.

Layman, D. - Seal Specialist Engineer. Supervised seal production and testing at the Hawley Plant and pump installation at the K-25 plant site.

Nagler, Forest - Chief Mechanical Engineer. Responsible for mechanical design and testing.

Neubauer, E. T. - Chief Engineer. Hawley Plant. Supervised design and development during period of production and testing.

Shaw, M. C. - Chief Engineer. Blower and Compressor Department. Supervised early stages of design and development on blowers.

AMERICAN LOCOMOTIVE COMPANY, ALCO PRODUCTS DIVISION

Ettington, M. - Chief Engineer. Coordinated design engineering on special drums and tanks.

Gantvoort, J. M. - Engineer. Supervised engineering and testing.

A. O. SMITH CORPORATION

Chyle, J. - General Superintendent. Also in charge of welding development and procedures.

Lindsay, E. H. - Job Engineer. Coordinated design and manufacture of special coolers.

Scudder, C. - Assistant Chief Engineer. Supervised design engineering.

Kepler, W. - Designs and Metallurgical studies.
Lembe, C.
Megow, L.
Scheil, M.

BAKELITE CORPORATION

Groff, Frasier - Development Engineer.

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Merrill, L. K. - General Superintendent. Headed up a joint Kellex-Carbide organization on all phases of barrier production particularly those activities carried on at Houdaille-Hershey plant.

BART LABORATORIES, INC.

Bart, S. G. - Vice President. Coordinated development of process and production of internally plated steel pipe.

Loucks, M. - Engineer. Supervised techniques and testing.

BEACH-RUSS COMPANY

Beach, E. J. - Vice President. Directed development and testing of special vacuum pump.

CHRYSLER CORPORATION

Beebe, A. H. - Director of Research. Headed laboratory work in research and development.

Foot, D. F. - Charge of design group.

Hartgering, J. M. - Assistant Operating Manager. Supervised production and coordinated engineering.

Heinen, C. - Chief Chemical Engineer. Responsible for conditioning and barrier tests.

Heisner, C. - Designed plating facilities and worked out techniques and procedures.

Loofbourrow, A. - Chief Engineer. Supervised preparation of all shop drawings and details from basic Kellex design.

Maloney, A. - Charge of Mechanical Testing Laboratory.

Wells, H. S. - Operating Manager. Coordinated design and manufacturing.

CRANE COMPANY

Houser, A. M., Jr. - Design Engineer. Responsible for development, shop details, and standardization of special process valves.

Giaque, C. A. - Design engineers. Also assisted in working out special
Grubbe, A. C. production and testing techniques.
Hansen, A. H.
Hedberg, R.
Kittredge, H. H.
McInery, J.
Rech, H. F.
Wendt, H. S.

FARRAR AND TREFTS, INC.

Lyall, R. G. - Design Engineer. Supervised design and testing procedures.

Trefts, J. A., Jr. - Vice President. Coordinated design engineering on nickel clad tanks.

FISHER GOVERNOR COMPANY

Burris, T. B. - Special development studies. Later on loaned to The Kellex Corporation for special instrumentation studies.

Engel, R. A. - Chief Engineer. Coordinated engineering work on special butterfly valves.

Hunt, Verle J. - Design Engineer. Responsible for bellows and bellows seal designs.

F. J. STOKES COMPANY

Hull, L. W. - Chief Engineer. Supervised design engineering of special vacuum pumps.

GENERAL ELECTRIC COMPANY

Anderson, Marshall - Job Engineer. Directed development and engineering on sealed air bearing motors.

Bousman, H. W. - Design and development of electronic components for
Foust, C. M. mass spectrometers and space recorders (ionization chambers).

Brucker, G. W. - Design of manifold systems for line recorders and
Remscheid, E. J. space recorders.

Cochran, D. - Design of acoustic analysers.
Mikelson, W.

Gardner, G. F. - Design of differential pressure transmitters and
Rich, T. A. experimental development programs.

Hansen, C. A., Jr. - Design of acoustic analyzers and thermal conductivity instruments.

Haskell, O. S. - Heating Engineer. Supervised development and engineering on special furnaces for conditioning of process equipment.

Kaestle, F. L. - Design and application engineering relative to all instrument programs.

Killam, K. A. - Development Engineer. Directed special air bearing development.

LaPierre, Cramer W. - Assistant Engineer. General Engineering Laboratory. Supervised and coordinated all research and development studies for the Manhattan District by the Electro-Mechanical Division on the Acoustic Gas Analyzer.

Lee, Everett S. - Engineer, General Electric Laboratory. New and special instruments required by the Manhattan District were developed in the General Engineering Laboratory.

Middel, H. D. - Design of line recorders, differential pressure transmitters, acoustic analyzers, and experimental development programs.

Newell, J. K. - Development Engineer. Supervised motor development.

Rader, L. T. - Design of magnetic butterfly valve.

Safford, M. M. - Research Engineer. Research on insulations and metal properties of motors.

Smith, Dr. James J. - Assistant Engineer, General Engineering Laboratory. Supervised and coordinated technical and administrative engineering for the General Engineering Laboratory on the mass spectrometer type leak detector.

Stack, S. S. - Design of dew point recorder.

Steenstrup, C. - Refrigeration Specialist. Special development of high speed rotary seal for air bearing motor.

Williams, W. D. - Engineer. Development on magnetic thrust bearing.

Winne, Harry A. - Vice President, in charge of Engineering Apparatus Department. New and special instruments required by the Manhattan District were developed in the General Engineering Laboratory, a division of the Apparatus Department.

Worcester, W. G. - Design of assay machine or large isotope spectrometer.

HENRY PRATT COMPANY

Cottingham, E. B. - Mechanical Engineer. Supervised design and production.

Smith, S. B. - Vice President. Coordinator of design engineering and production of special butterfly valve.

HERRON-ZIMMERS MOULDING COMPANY

Crowe, O. J. - General Manager. Coordinated development and design of barrier holding pack.

Hall, W. J. - Chief Engineer. Supervised design engineering and testing.

HOUDAILLE-HERSHEY CORPORATION

Borchert, Leslie C. - Assisted in the management and coordination in the development work and in the technical direction of production operations involved in the manufacture of all DA barrier used on the Manhattan District Project, also conducted liaison between the Garfield Division and other coordinated laboratories and plants.

Conley, Charles C. - Assisted in the management and coordination in the development work and in the technical direction of production operations involved in the manufacture of all DA barrier used on the Manhattan District Project.

Girardi, Dr. Daniel J. - DELETED DELETED DELETED DOE b(3)

Graham, Dr. A. K. - Head of laboratory and pilot plant development on barrier.

Jenks, William E. - DELETED DELETED DELETED DOE b(3)

Kinnaman, R. B. -

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Pinner, W. L. - Technical Director. In charge of laboratory, and responsible for translating laboratory techniques to barrier production. Also, supervised quality control.

MIDWEST PIPING AND SUPPLY COMPANY

Downing, J. R. O. - Development Engineer. Development of vacuum equipment and procedures.

Fantz, F. C. - Vice President. Design and development of special welding equipment and methods for the St. Louis fabrication shop and the field shop.

Leonard, B. H. - Welding Specialist. Developed and adapted welding equipment.

Morse, R. J. - President. Coordinated development on vacuum equipment and techniques and the design of a scraped cold trap system.

Wilms, H. - Design Engineer. Designed special fabricating equipment.

PACIFIC PUMPS, INC.

Cleveland, L. J. - Chief Engineer. Supervised design engineering of coolant pumps.

Weis, A. R. - President. Coordinated of engineering and production.

PATTERSON KELLEY COMPANY

Greiner, G. R. - Engineer. Designed special dies and welding fixtures.

Monaco, J. - Job Engineer. Coordinated design, development and testing of special cold trap.

REPUBLIC FLOW METER COMPANY

McMahon, J. B. - Over-all coordinator of design and development of magnetically operated butterfly valve. On loan to Kellex Corporation instrument department.

Rosenberger, A. J. - Chief Engineer. Supervised design and mechanical testing.

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SCHOCK GUSMER COMPANY

Striberny, A. - Superintendent. Developed designs and manufacturing techniques for production of special cold traps.

SHARPLES CORPORATION

Moore, Dr. Walter J. - Supervised the installation and development of testing methods used in the evaluation of barriers.

Nix, Dr. Foster C. - Supervised and coordinated all research and development studies conducted for the Manhattan District at The Sharples Corporation, Research Laboratories.

TAYLOR INSTRUMENT COMPANIES, INC.

Hanna, E. J. - Coordinator of procurement and manufacture of instruments made by Taylor and those procured from 35 subcontracting sources.

Hubbard, K. H. - Chief Engineer. Supervised development and design activities.

Olsen, R. E. - Managing Engineer. In charge of all development, engineering, design and production. Outstanding contribution rendered in over-all instrumentation program and as a member of the Kellex Process Instrumentation Committee.

Howard, G. E.
Heamer, Ronald
Stoll, H. W.
Yate, K. L.
Ziegler, J. G.
\- Development engineers. Responsible for various phases of design, production and installation of pneumatic instruments.

VALLEY IRON WORKS

Kolb, W. K. - Works Manager. Coordinated design and development of reciprocating pumps.

Wells, J. D. - Chief Engineer. Supervised design layout and testing.

WESTINGHOUSE ELECTRIC CORPORATION

Dralle, H. E. - Manager of Petroleum and Chemical Engineering Division. Coordinated development and engineering work on gas bearing motors.

Hagg, A. C. - Research Engineer. Research Laboratory, East Pittsburgh, Pa. Made studies of gas lubricated bearings for high speed motors.

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<u>Heller, P. R.</u> - Mechanical Engineer, A/C Generator Engineering Department. Mechanical design and studies on gas bearing motors.

<u>Kilgore, L. A.</u> - Manager, Motor Section. Supervised design and engineering on gas bearing motors.

<u>Robinson, R. C.</u> - Electrical Engineer, A/C Generator Department. Electrical design for gas bearing motors.

WHITEHEAD METAL PRODUCTS, INC.

<u>Crocker, C. G.</u> - Plant Manager. Coordinator of design and development work on special process diffuser for purge use.

<u>Mehlin, R.</u> - Plant Engineer. Supervised design and testing.

WHITLOCK MANUFACTURING COMPANY

<u>Proudy, R. B.</u> - Job Engineer. Supervised design and coordinated engineering.

<u>Smith, S. A.</u> - Chief Engineer. Supervised production adaptation and testing of special cooler.

WORTHINGTON PUMP AND MACHINERY CORPORATION

<u>Magee, W. H.</u> - Chief Engineer. Supervised development and design of H_2O refrigeration systems.

<u>Quinlan, F.</u> - Engineer. In charge of design engineering group.

YORK CORPORATION

<u>Cordrey, A. J.</u> - Engineer. Coordinated design and engineering of special air conditioning systems for site laboratories and for portable C-716 units.

<u>Olsen, T.</u> - Refrigeration Engineer. Supervised design of laboratory air conditioning systems.

<u>Russell, G.</u> - Mechanical Engineer. Supervised design of portable C-716 refrigeration equipment.

METALS DISINTEGRATING COMPANY

<u>Dunlap, Gordon E.</u> - Supervised and coordinated all research, development and construction. Developed Fine Nickel Grinding Process.

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