AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 3

CONFIDENTIAL
2-3-81 and 2-8-74
Date

SAVANNAH RIVER PLANT

DPE--974-De/Ver.

SR/H-- 742

ENGINEERING AND DESIGN

By Authority of

VOLUME V

#400 AREA

1.

2.

Name

Title

Date

Name

Title

Date

ENGINEERING DEPARTMENT

E. I. DU PONT DE NEMOURS & CO. (INC.)

Wilmington, Delaware

Prime Contractor

For

UNITED STATES ATOMIC ENERGY COMMISSION

U. S. CONTRACT NO. AT(07-2)-1

DU PONT PROJECT 8980

JANUARY, 1957

DPE-974

Deleted version

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

Reviewing
Official

Date

J. Banick, AED Class Officer
9/11/89

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DPE 974
Vol IV

3

SAVANNAH RIVER PLANT

PROJECT 8980

ENGINEERING AND DESIGN HISTORY

VOLUMES AND TITLES

VOLUME I - ADMINISTRATION

VOLUME II - #100 AREAS

VOLUME III - #200 AREAS

**VOLUME IV - #300/700 AREAS AND GENERAL SERVICE
FACILITIES**

VOLUME V - #400 AREA

**VOLUME VI - POWER AND ELECTRICAL FACILITIES
(ALL AREAS)**

SAVANNAH RIVER PLANT - PROJECT 8980
ENGINEERING AND DESIGN HISTORY
OF
#400 AREA

VOLUME V

CONTENTS

	Page
SECTION I - DESCRIPTION AND DEVELOPMENT	13
SECTION II - SELECTION AND DESCRIPTION OF PROCESS	17
SECTION III - SPECIALIZED DESIGN PROBLEMS	29
SECTION IV - DESIGN	45
PROCESS BUILDINGS	59
ADMINISTRATIVE, PERSONNEL AND SERVICE FACILITIES	247
ELECTRICAL FACILITIES	268
STEAM FACILITIES	268
WATER FACILITIES	269
GENERAL FACILITIES	270

400 ARFA

PLOT PLAN - 400-D AREA

SAVANNAH RIVER PLANT

PROJECT 8880

ENGINEERING AND DESIGN HISTORY

OF

THE #400-D AREA

SAVANNAH RIVER PLANT

I - DESCRIPTION AND DEVELOPMENT

The #400-D Area is that section of the Savannah River Plant containing facilities for the production of high purity heavy water for use as a moderator and coolant in the #100 Areas. Deuterium gas also is produced here for use at another site. The Area further includes auxiliary process facilities for; (1) producing H_2S and inert gas used, respectively, as a heavy water process component and for purging process equipment, (2) flaring normally vented or emergency discharges of H_2S gas to the atmosphere and (3) storing (Tank Farm) raw material and products of (1) above, and storing in limited amounts, gas from the heavy water process.

With the exception of a river water supply and an area waste water outfall, the #400-D Area is self-sufficient as to utilities, containing the source of the necessary steam, electric power, compressed air and well water, together with river water treatment plants, sanitary facilities, drainage lines and ditches, and alarm systems. The area is fenced and provided with gate houses, walks and parking facilities. Area telephone equipment, standard gauge trackage and roads connect with plant-wide communication and transportation systems. While the #400-D Area itself does not extend to the Savannah River, the Water Pump House, Building #681-5G, located at the river bank, serves the #400-D Area exclusively. Drainage ditches from the area empty into a swamp which drains into the river. The electric power generating facilities, referred to above, also supply other areas of the Savannah River Plant.

Service buildings and facilities for the area include:

1. Gate houses and patrol headquarters;
2. Area supervision offices and first aid;
3. Control laboratory and supervisor's office;
4. General monitoring building for sampling and analyzing the atmosphere for radioactive gases;
5. Change houses;
6. Miscellaneous shops and maintenance shelters; and
7. Steel, pipe and miscellaneous materials stores.

The #400-D Area is located in the west central part of the Savannah River Plant approximately one mile east of the Savannah River, the western boundary of the plant. When, during the fall of 1950, the layout for the Savannah River Plant was being developed, no facilities for the production of heavy water on that site were contemplated. However, this layout did anticipate the AEC's expansion program of late 1950 by assigning space for three additional #100 Areas. During January, 1951, authorization was given to du Pont's proposal that the additional heavy water production facilities, made necessary by the expanded reactor program, should be located on the Savannah River Plant. By this time sites had been chosen for the principal manufacturing areas. The remaining space was not ideally suited for facilities using quantities of toxic gas, but the #400 Area site was finally selected because it satisfied or contributed to the following major requirements.

1. A satisfactory distance from the #100 Areas.
2. Approximately one mile from the town of Ellenton, South Carolina. Though located within the plant boundaries, the disposition of this town was not certain at that time.
3. A prevailing westerly wind extends some measure of protection from gas to off-plant property located approximately one mile west.
4. Early start-up. This requirement was made necessary by the reactor start-up schedule. The choice of location for the #400-D Area contributed to its earlier operation because of the proximity of existing railroad lines and the Savannah River. The importance of this to the schedule for early start-up is indicated by the fact that the Pump House, Building #681-5G, was designed to supply only the #400-D Area. The quantity of water furnished is small when compared with the designed capacity of the pump houses serving other areas of the plant, thus making possible more rapid installation of pumping facilities for this one area.
5. Sufficient suitable space to permit future 100 per cent expansion of production facilities.

Prevailing winds and the presence of large quantities of a toxic gas (H_2S) played a more important part in determining the layout within the #400-D Area than in the choosing of the site for that area. Processes utilizing H_2S are located downwind from the service and administration buildings. In addition, separation of the hazardous (with respect to H_2S) from

the non-hazardous buildings is effected to an extent which results in the plant layout covering more area than would be expected for normal du Pont commercial work. For example, the Supervisor's Office and First Aid, Building #704-D, is located approximately one-half mile from the "GS" Process, Building #411-D, and the distance from the Power House, Building #484-D, to the "GS" Process is almost as great. The Control Laboratory, Building #772-D, and the "Intermediate" and "Finishing" heavy water processes, Buildings #420-D and #421-D, are situated approximately 1000 feet west of the hazardous processes.

However, it was not feasible to place all service facilities in such remote locations. The Shops, Stores and Change House, Building #717, is more convenient to the operating areas, yet is located west and upwind from those facilities utilizing H_2S . To facilitate on-the-job repair work, it was necessary also to locate certain maintenance shops and shelters within the "GS" Process Buildings, #411-D, #412-D and #413-D, these being essentially open structures. These shops and shelters, though located within the process buildings, are service buildings and are therefore discussed separately in this volume, as distinguished from the Control Rooms, Secondary Substations, etc., which are considered part of the process buildings.

SECTION II-

SELECTION AND DESCRIPTION OF PROCESS

Page

PROCESS SELECTION	19
GENERAL	19
BACKGROUND OF PROCESS	19
USE OF WORLD WAR II FACILITIES	20
NEED FOR PRODUCT IN REACTOR PROGRAM	20
SELECTION OF SITE FOR INITIAL PRODUCTION	21
DU PONT CONTRACT	21
NECESSITY FOR THE #400-D AREA	22
PROCESS DESCRIPTION	22
GENERAL	22
"GS" PROCESS	23
"DW" PROCESS	24
"E" PROCESS	25
H ₂ S PROCESS	25
INERT GAS PROCESS	26
WATER TREATMENT PLANT	26

II - SELECTION AND DESCRIPTION OF PROCESS

PROCESS SELECTION

GENERAL

To understand the reasons for the installation of the heavy water production process at the Savannah River Plant, it is desirable to review very briefly some of the events that led to the prior selection of much the same process for use at the Dana Plant. Although the two plants correspond very closely, the Savannah River Plant profited by limited operating experience at Dana and, as well, reflects altered operating conditions and requirements.

BACKGROUND OF PROCESS

In October 1942, the Manhattan District of the United States Army Corps of Engineers requested the du Pont Company to present its recommendations on the feasibility of designing and constructing a large-scale plant for the production of certain fissionable materials. Among other recommendations, du Pont at that time advised the construction of plants for the production of heavy water to be used as an alternative to graphite as a moderator. This recommendation was accepted and, in December 1942, du Pont was commissioned to design, construct and operate such plants in accordance with its recommended process. Of the three processes then known it appeared that the most attractive, from the standpoint of simplicity, knowledge of similar operations, and particularly with respect to construction time, was the fractional distillation of water. Therefore, plants employing this process and having a combined capacity of 2.4 tons of heavy water per month, were erected at the Wabash River, Alabama, and Morgantown Ordnance Works and were identified as the "P-9" Facilities. An electrolysis unit for final concentration and purification was erected at Morgantown to serve all three distillation plants.

While design and construction of these facilities proceeded, du Pont continued to study the other two processes, the Dual-Temperature and the Hydrogen Distillation processes. The latter presented many problems, and available time for research and design was so short that it was soon abandoned. On the other hand the Dual-Temperature process, consisting of the countercurrent contacting of water and hydrogen sulphide in two towers at two different temperatures, was thought worthy of further consideration. This 1942 observation is of interest because this process, somewhat modified and identified as the "GS" process, became one of those selected for use at both the Dana and the Savannah River Plants.

Following World War II, the distillation plants at Morgantown and Alabama were dismantled, and the cells, rectifier, and other equipment from the Morgantown electrolytic unit were shipped to the Wabash plant to be stored.

Between 1942 and 1948 several improvements in the Dual-Temperature process were developed by outside interests and brought to the attention of the Atomic Energy Commission. By modification in design and by additional methods of saving steam, it was estimated that operating costs could be reduced substantially from those anticipated when the Manhattan District was considering the process. These improvements made the development of the Dual-Temperature process more attractive.

USE OF WORLD WAR II FACILITIES

In December 1949, a review was begun by the Girdler Corporation for the NYOO of the feasibility of converting the AEC-owned "P-9" distillation plant at the Wabash River Ordnance Works to a low pressure "GS" production plant. The greatest disadvantage in the use of the existing facilities was that, having been designed for vacuum operation, they could not be used for a high pressure system. However, it was thought possible to produce 2-1/2 tons of heavy water per month in the converted plant at lower pressures.

At the request of the AEC, the Girdler Corporation made a review of the Dual-Temperature process and a study of the "P-9" facilities, with the conclusion that, although the existing distillation plant could be converted to an inefficient "GS" plant, a new and efficient high pressure plant capable of the same production as the converted plant could be built for the same capital investment and in approximately the same time.

By May of 1950 the AEC had reached the conclusion that a "GS" plant was necessary to the national defense and security, and undertook negotiations for the design and construction of a pilot plant and the design of a production plant. Girdler was selected to do this work and the capacity of the production plant was set at about 40 tons of heavy water per year.

NEED FOR PRODUCT IN REACTOR PROGRAM

On June 8, 1950, the President of the United States approved a program jointly recommended by the Atomic Energy Commission and the Department of Defense for the quantity production of materials needed for thermonuclear weapons. Soon thereafter the du Pont Company was requested to review the technical aspects of a new production center as a preliminary to contract considerations with the Commission for all phases of the work.

As then defined, the directives of the President could be met by the construction of two heavy water moderated reactors. The du Pont Company undertook to (1) estimate heavy water requirements and the reactor time schedule, (2) evaluate the technical feasibility, engineering development and economical relationships of the process available for the production of heavy water, and (3) correlate reactor program requirements with heavy water plant construction schedules.

SELECTION OF SITE FOR INITIAL PRODUCTION

The results of these studies indicated that 300 tons of heavy water would be required for the two reactors. A survey showed that the available utilities at the Wabash River site were sufficient, above the requirements of a totally reactivated Ordnance Plant, to accommodate six "GS" units. The accumulated production of these units, having a nominal design capacity of 240 tons per year would be enough to permit the two reactors authorized for the new Savannah River Plant to be charged and placed in operation as soon as they were completed.

During September and October, 1950, Girdler was authorized by the Atomic Energy Commission to proceed with the Dana Plant. Substantially in accordance with du Pont recommendations, the main production facilities were to consist of six "GS" units, each with a nominal capacity of 40 tons per year, a distillation train known as the "DW" plant, and an electrolytic finishing process or "E" plant.

DU PONT CONTRACT

On October 11, 1950, du Pont, by Letter Contract, assumed complete responsibility for the design, construction and operation of the new Savannah River Plant and the heavy water production facilities at Dana. On October 31, 1950, the Girdler Corporation's contract for the construction and operation of the Dana Pilot Plant and the design of production units was terminated and, effective November 1, Girdler entered into a subcontract with du Pont to continue construction of the plant.

During the period between the receipt of the Letter of Intent on August 1, 1950, from the AEC and the execution of the Letter Contract, the du Pont Company, though having no legal responsibilities in the atomic energy program, contributed to its progress by assuming the position of technical advisor in matters pertaining to the production of heavy water. In that capacity it investigated equipment and materials of construction, and furnished expediting and inspection services to the Girdler Corporation.

NECESSITY FOR THE #400-D AREA

Subsequent to the determination that six "GS" units would serve two reactors adequately, the scope of the Savannah River project was increased to a total of five reactors. The construction and operating schedules for this expanded program made it evident that additional heavy water production capacity was necessary. In addition, as a result of a du Pont study, the original estimate of 150 tons of heavy water required per reactor was raised to 200 tons, and early results of pilot plant operation at Dana indicated that the production expectancy of each heavy water unit might be as low as 30 tons per year instead of the originally designed capacity of 40 tons per year.

It was thus established that, in addition to the six units under construction at Dana, six other units of equal capacity were required to meet revised schedules. Since the utilities at Wabash were insufficient to handle the additional capacity, it was decided to locate the new facilities at the Savannah River site. The units at either plant could supply normal operating make-up but those at Savannah, because of their location, were planned to be the long-term operating facilities. This also coincided with the fact that, in the original planning, the operation of the Dana Plant was to be discontinued upon the fulfillment of initial AEC heavy water requirements. In some instances, therefore, that plant was constructed of less costly and less durable materials than was the case at Savannah.

A more complete discussion of the background of the #400-D Area product and of the du Pont Company's contribution to the development of the process, will be found in the Dana History - Section II - "Background of Product and Preliminary Developments Leading to Contract".

PROCESS DESCRIPTION

GENERAL

The heavy water process employed at the Savannah River Plant consists of three distinct steps by which deuterium oxide is produced from its natural concentration in water: (1) the "GS" process, which utilizes the isotopic exchange reaction between hydrogen and deuterium in water with H_2S acting as the exchange medium; (2) the "DW" process, which effects the separation of light and heavy water by fractional distillation; and (3) the "E" process, which concentrates deuterium oxide by electrolysis.

To supply the large quantities of hydrogen sulfide gas required by the "GS" process, an H₂S generating plant was installed at Savannah. This plant generates approximately 15 tons of H₂S per day by a process based upon the reaction of sodium hydrosulfide and sulfuric acid.

A mixture of air and H₂S can produce an explosive gas, creating a safety hazard within the "GS" area. In order to minimize this danger, inert gas is used to purge air from all pipe lines and vessels into which H₂S is to be injected. It is also used as a substitute for H₂S when making dummy runs or tests on "GS" equipment, and to purge H₂S from equipment that is being shut down for maintenance work. This inert gas, essentially free of oxygen, is produced at the plant site in a process involving the combustion of propane gas.

The #400-D Area required large quantities of water, chiefly for the "GS" process and the power house. These two users require water differing in degree of treatment from little or none for cooling purposes to high quality for process and boiler make-up.

To satisfy the diverse requirements, extensive water treatment facilities were provided within the area. These include not only the conditioning facilities but also adequate storage capacity for water of the several qualities required.

"GS" PROCESS

Deuterium, an isotope of hydrogen, is present in both H₂S and water in extremely small proportions. In natural water the ratio is one part deuterium in 7000. The "GS" process is based upon the isotopic exchange between deuterium and hydrogen ions, and utilizes the deuterium exchange between H₂S and water.

In the process, a continuous flow of process water passes countercurrent to a flow of hydrogen sulfide gas in bubble-cap tray towers - first in a "cold" tower at a relatively low temperature (86°F. to 104°F.), and then in a "hot" tower at a comparatively high temperature (266°F.). Heat exchangers heat or cool the liquid and gas flowing from tower to tower. Since equilibrium conditions favor concentration of deuterium in the water phase at the lower temperature, deuterium present in the previously enriched H₂S is absorbed by the water in the cold tower, and the water is stripped of deuterium by H₂S in the hot tower. (The amount of deuterium from stripped water is lower than that from make-up water). By a succession of

such operations - alternate absorption and stripping and the replacement of the stripped water - an increase in heavy water concentration occurs in the liquid phase at the base of the cold tower.

Water enters the top of the towers and passes to the bottom from which it is drained, while the gas enters the bottom of the towers and passes to the top where it is discharged. This process continues through two "stages", the second stage producing a higher concentration of heavy water. The flows are such that the second stage obtains approximately one-third of the enriched liquid and gas streams leaving the cold and hot towers, respectively, of the first stage. Approximately an equal amount of water and gas which has been stripped in the second stage is returned to the first stage. Consequently, the size of the towers in the second stage is established so that the volume of the towers is reduced by approximately 65 per cent.

The process operates continuously until the heavy water concentration in the second stage has become approximately 10 per cent, at which time a certain amount of enriched water is withdrawn as product. This withdrawal takes place for only a few minutes each day since it is not desirable to deplete the system entirely of the enriched water.

In addition to bubble-cap tray towers and heat exchangers, this process requires a system of centrifugal pumps and blowers, stripper towers, condensate drums, connecting piping, valves, and related instrumentation. A detailed analysis of the process and the equipment involved will be found under "Building #411-D, "GS" Process".

"DW" PROCESS

The "DW" process is the second step in the concentration of heavy water. This process takes advantage of the difference in volatility between hydrogen oxide and deuterium oxide to effect the separation of the latter by fractional distillation.

This process also utilizes bubble-cap tray towers, and is divided into five stages. Liquor from the second stage of the "GS" process, having a concentration of approximately 10 per cent heavy water, is piped to the first "DW" stage - two towers connected in series, referred to as the "top" tower and the "bottom" tower.

Here the initial distillation takes place. The liquid which collects at the bottom of the "bottom" tower, having become further enriched, is passed on to the second stage tower where it again is distilled. This procedure is repeated until the feed from the "GS" process has been

distilled five times. The liquor drawn from the fifth and final stage is approximately 98 per cent deuterium oxide.

Vacuum operation is used to reduce the number of plates and quantity of steam required, and to enhance the relative volatility. Each stage is complete with calandrias, vacuum jets, condensers and pumps. Refrigeration of inerts going to the vacuum jets is necessary to reduce D_2O losses.

A detailed account of the "DW" process and the equipment involved, will be found under "Building #420-D Concentrator (DW Process)".

"E" PROCESS

The "E" process is the final purification step in the production of heavy water. This process utilizes the principles of electrolysis to raise the concentration of the deuterium oxide solution received from the "DW" plant from 98 per cent to 99.8 per cent minimum D_2O concentration.

Since impurities in the process fluid seriously affect the efficiency of this process, the first step is the removal of any impurities. This is accomplished by the addition of potassium permanganate followed by distillation of the D_2O . An electrolyte, potassium carbonate, is then added after which the fluid is fed to a series of cells where electrolysis is effected by passing a current of 1000 amperes through each cell.

The separation of D_2O from H_2O is accomplished by operating groups of cells batch-wise in stages handling fluid of various D_2O content. The prepared feed is introduced to the next to the bottom step of a series of seven electrolytic operations. At each step the combined hydrogen and oxygen evolved are burned, condensed and returned to cells operating at a weaker concentration, except a cut from the condensate from electrolysis of the weakest liquid which is returned to the "DW" Plant.

Heavy water of approximately 99.8 per cent D_2O content is drawn as residue from the high concentration stage. Following a final evaporation process to remove the electrolyte, the heavy water is stored in aluminum drums.

A detailed account of the "E" process and the equipment involved, will be found under "Building #421-D - Finishing Building ("E" Process)".

H_2S PROCESS

Hydrogen sulfide is generated at Savannah by a continuous reaction of sulfuric acid with sodium hydrosulfide.

Sodium hydrosulfide solution and 60°Be sulfuric acid are metered into a glass-lined reactor, together with process water. The resulting reaction produces sodium sulfate, discharged as waste, and H_2S gas. The gas is passed through a wash tower where water removes traces of acid and other impurities. The gas then flows to two-stage H_2S compressors. Following the final stage of compression, the H_2S gas is liquefied in a water-cooled condenser from which it flows into storage tanks.

Gas may either be supplied to the "GS" towers directly from the compressors, or liquefied for storage purposes only. As additional gas is required, the liquefied H_2S is vaporized and piped to the "GS" area.

In addition to producing gas for the "GS" units, the H_2S plant also liquefies gas pumped down from the "GS" plant during shut-downs for maintenance and repair operations.

A more detailed account of this process and the equipment involved will be found under "Building #401-D - H_2S Production Plant".

INERT GAS PROCESS

The inert gas generating plant utilizes equipment which burns propane gas and compresses and stores the resulting gas, a product almost completely free of oxygen. The plant has a nominal generating capacity of 10,000 s.c.f.h., and can operate at as low a level as 3000 s.c.f.h.

Since inert gas is used for several purposes and under different operating conditions, compressors are provided for these varying demands. A small compressor will deliver the minimum output of the generator for either purging or storage purposes at 85 p.s.i.g. A larger compressor will deliver from the generator or from storage the equivalent of 600 s.c.f.h. at 350 p.s.i.g. If large quantities of gas at high pressure are needed quickly, the H_2S compressors can be used and will supply the maximum output of the inert gas generator at 300 p.s.i.g.

A more detailed account of this process and the equipment involved will be found under "Building #401-D - H_2S Production Plant".

WATER TREATMENT PLANT

Six primary requirements for water exist within the #400-D Area: (1) power house condensers, (2) process cooling, (3) fire and miscellaneous, (4) boiler feed, (5) process feed, and (6) domestic service. The quality of water required differs for each of these services. Since the total

flow of approximately 70,000 g.p.m. (design capacity) must be treated by several different methods the conditioning and storage facilities are rather extensive. These are described briefly, according to the services they supply. A more complete discussion will be found in Vol. VI - Power Facilities.

Chlorinated water is supplied to the #400-D Area from a River Pump House. The supply line terminates at an elevated concrete reservoir consisting of an inlet chamber, mixing chamber and raw water storage basin having a capacity of 30 minutes retention time at average pumping rates. Approximately 23,000 g.p.m. is taken from the inlet or mixing chamber for use in the power house condensers. No treatment is required for this service. Provision is made for returning most of this condenser water to the mixing chamber if that is desired. However, it is normally a once-through operation.

The balance of the water enters the storage basin where some sedimentation takes place. From the basin approximately 34,000 g.p.m. is withdrawn for process cooling. Strained water is provided by self-cleaning strainers installed in the booster pump discharge lines.

The remaining stream, approximately 10,000 g.p.m., passes through chemical treatment, flocculation and separation, and thence through a gravity sand filter to a clear well.

The clear well supplies: (1) fire lines and several relatively small requirements such as cooling tower make-up, backwashing and miscellaneous power house use; (2) boiler feed make-up; and (3) process make-up. Water for the fire lines and the miscellaneous uses requires no further treatment.

Boiler feed make-up water must be practically free of silica and hardness. To provide water of this quality, filtered water from the clear well passes through hydrogen zeolite softeners followed by degasifiers and silica absorbers. From this point it flows as make-up water from the absorbers to the power house at a design rate of 1300 g.p.m. Floating on this line is a 100,000-gallon elevated soft water storage tank.

The requirements for process make-up water are zero alkalinity, freedom from inert gas and minimum acidity. These conditions are obtained by pumping the filtered water from the clear well through facilities for the addition of sulphuric acid, thence through vacuum deaerators and a caustic feed unit for pH adjustment, to a 200,000 gallon storage tank. From this tank, pumps with a combined capacity of 6600 g.p.m. supply the water to the process area through a 20-inch overhead line.

Domestic water for the #400-D Area is supplied directly from wells. The only treatment given this water is chlorination. A 100,000 gallon elevated storage tank floats on the supply line.

Well water is also pumped to the process buildings where certain cooling operations demand water at a temperature lower than the river water. This cooling well water is taken from separate wells for each service and not from the domestic water system.

SECTION III
SPECIALIZED DESIGN PROBLEMS

	Page
EXPERIMENTAL AND DEVELOPMENT WORK	31
METALLURGY	32
GENERAL	32
NATURE OF THE PROBLEM	32
GENERAL CORROSION	33
BLISTERING	35
CRACKING	36
INHIBITORS	36
SAFETY	37
GENERAL	37
H₂S HAZARD	38
SOURCE OF H₂S HAZARD	39
REDUCTION OF HAZARD	39
Personnel Protection	40
Design Considerations	41
Medical Facilities	43

III - SPECIALIZED DESIGN PROBLEMS

EXPERIMENTAL AND DEVELOPMENT WORK

The design of the #400-D Area of the Savannah River Plant was based largely on the design of the Dana Plant plus a limited amount of Dana operating experience - limited because Savannah construction schedules were such that design for much of the #400-D Area had to be frozen before the Dana counter-parts were operable.

The development of the Dana process involved considerable research and experimental work, particularly with respect to the "GS" process phase. A paucity of information on the processing of large volumes of hydrogen sulphide left unanswered many questions concerning metallurgy, operating methods, and safety. Therefore, an extensive research program was undertaken to provide data otherwise unobtainable except through operating experience. Information developed thereby provided the basis for the design of critical process equipment and for the formulation of methods of procedure.

For Dana, there were instances where, in order not to delay start-up, design proceeded without waiting for the results of experimental work; or subsequent research proved that earlier accepted data were incorrect. This was particularly true in the determination of suitable materials of construction, and resulted in the replacement of approximately 240,000 heat exchanger tubes after start-up. This was only one of numerous changes made in the Dana design.

Since research and development work continued throughout the Dana construction period and the Savannah #400-D Area design periods, the Savannah design not only benefited from early Dana operating experience but also could be based upon more complete and conclusive research results because of its later completion schedule. This accounts for many of the differences in similar facilities at the two plants.

The research work was conducted largely by groups outside the Design Division, under the general direction of the Atomic Energy Division. Other du Pont organizations engaged in the research program were the Engineering Service Division of the Engineering Department, the Chemical Department, the Explosives Department (AED), and the Chambers Works of the Organic Chemicals Department. The Engineering Research Laboratory of the Development Engineering Division made important contributions to many phases of this program.

Research also was instituted by the Girdler Corporation at the time it held the prime contract for the Dana Plant. This was continued at Girdler's Louisville laboratories under du Pont direction and a pilot plant at Dana became an integral component of the over-all research facilities employed for the benefit of both plants.

Reference should be made to Section VII of the Dana history for a brief discussion of the significant development projects undertaken. It will be noted that for a more detailed description, further reference is made to the subsections devoted to those phases of the plant design to which the several development projects contributed; i.e. metallurgy, safety, and process. The reader pursuing such detail should refer to the designated section in both the Dana and Savannah histories; the former to obtain the details incident to the original design which are only summarized in the Savannah history, and the latter to learn of the significant changes, if any, made for the Savannah River Plant.

METALLURGY

GENERAL

The processes at Dana and the Savannah River #400-D Area being the same, the problem of choosing suitable materials of construction for the two plants was identical. Work for Dana furnished most of the information since design of that plant was started first. However, research continued beyond the Dana design stage resulting in some changes in materials for that plant and more suitable initial installations for Savannah.

The subject of metallurgy, treated in some detail in Section VII of the Dana history, is summarized below.

NATURE OF THE PROBLEM

The "GS" Process for the concentration of heavy water involves the handling of wet hydrogen sulfide gas and H_2S saturated water at temperatures up to approximately $150^{\circ}C$. and pressures up to about 300 p.s.i.g. Industrial experience with these conditions was limited largely to the oil refinery industry but it was known that difficulties had been encountered with general corrosion, sulfide-stress cracking, and blistering of carbon steel equipment. Corrosion studies were therefore started at the Girdler Corporation's laboratories in August, 1950, to develop general information as a basis for the specification of materials of construction. When the magnitude of the problem became apparent, du Pont instigated

an intensive corrosion study. This work was undertaken by the Development Engineering Division of the du Pont Engineering Department.

The experimental work undertaken by du Pont can be divided into four principle categories as follows:

1. Development of general information,
2. Search for effective inhibitors of the corrosion of carbon steel by H_2S -water mixtures,
3. Investigation of blistering, and
4. Miscellaneous - metallographic examination, physical testing, check analysis, etc., of specimens and equipment parts from the Girdler autoclaves and from test installations in the Pilot Plant.

Work under this program was more or less continuous, but results of individual tests were evaluated from time to time so that information as developed could be used in the design.

GENERAL CORROSION

The reaction between H_2S -water mixtures and carbon steel and some other metals and alloys results in the formation of a film or heavy coating of generally insoluble iron sulfides. Investigation of this corrosive effect on the potentially applicable principal materials of construction resulted in the following conclusions.

1. Carbon steel is a practical material of construction for "GS" process equipment where limited life and periodic replacement are permissible or where metal thickness is sufficient to allow a corrosion allowance in design. Corrosion starts at a very high rate (several hundred mils per year) but under stagnant or relatively low velocity conditions decreases with time to 10 mils per year or less because of the build-up of the coating of the iron sulfides. Greater corrosion occurs under conditions of direct impingement or turbulence in which this coating is continually removed, because the iron sulfides do not corrode as rapidly as the base steel.

The relatively high general corrosion rate of carbon steel is objectionable for two reasons other than direct thinning of the equipment in service: (a) continued hydrogen generation favors blister formation, and (b) the quantity of sulfide sludge produced is sufficient to create a definite operating problem.

2. Stainless steel is a good material of construction where longer life or less frequent replacement are basic requirements. It has a low rate of corrosion, pitting only slightly. The high cost and relative scarcity of this material limit its use.
3. Bronze is unacceptable because it builds up heavy coatings of corrosion products which slough off in layers.
4. Stellite is an acceptable material of construction as it essentially resists corrosion under "GS" process conditions. It also resists abrasion and galling. Its use is limited, however, to small parts in small quantities because of the high cost and because this metal is available only as a weldable hard surface deposit.
5. Aluminum is unacceptable because of the high rate of galvanic corrosion which results from its contact with H_2S -water mixtures and other metals.
6. Inconel, nickel, monel, titanium, and platinum are acceptable but have little applicability due to their scarcity and high cost. Copper, tin bronzes, and aluminum bronzes corrode rapidly and therefore are unacceptable.

The following components of the "GS" plant, because of their exposure to the H_2S -water mixtures, were thought to be particularly subject to corrosion: towers, tower trays and bubble caps, heat exchangers, process piping, valves, blowers, and pumps. However, in evaluating materials of construction for fabrication of the mass of equipment, it was found difficult to justify any materials other than plain carbon steel. While other materials exhibited lower over-all corrosion rates, they are considerably more expensive and involve problems of procurement and delivery.

It has been noted that the use of carbon steel under conditions of direct impingement (where the corrosion products would be removed as formed) would result in an extremely high rate of corrosion. One of the most critical parts of the plant in this respect was the "GS" Process piping. Laboratory tests indicated that the rate of erosion-corrosion within the pipe varied directly with the fluid velocity, and even at velocities that would ordinarily be considered normal for industrial process fluids, the rate would be excessive. Accordingly, the "GS" Process pipe lines were sized to obtain an unusually low fluid velocity.

The materials chosen for a particular service or piece of equipment at Savannah and the reasons for a change, if any, from that used at Dana for the same facility will be found by referring to the chapter in this history devoted to the building concerned.

BLISTERING

Blistering of the surface of carbon steels subject to H_2S -water mixtures is due to the absorption of atomic hydrogen and its collection and recombination to form molecular hydrogen in confined laminations, artificial or accidental voids, non-metallic inclusions - in brief, at any point of discontinuity in the metal. Over a period of months, or years, extremely high internal pressures are generated which eventually rupture the metal. This presented a potentially serious problem.

The probability of blistering diminishes as the number of imperfections in the steel is reduced. Therefore, it was decided early in the Dana program to specify silicon killed steel throughout for all carbon steel equipment exposed to process conditions. There was a possibility that more uniform steel could be secured by reducing the yield from ingots from the usual 60 per cent to approximately 30 per cent. Because this would cost two or three times as much as the steel specified and cause considerable delay, and because mills were not receptive to such specifications, the idea was abandoned. However, with the reduction of potential blister sites to a minimum as the objective, search was instituted for the most practical method of non-destructive plate inspection in order to identify and mark for rejection all plates with gross voids or laminations. This research resulted in the decision to use the ultrasonic reflectoscope for the inspection of all plate material designated for process equipment.

The pressure build-up causing blistering can be stopped by drilling a small hole to the vulnerable spot in the metal, thus venting the void to the atmosphere. This procedure was followed with shell plates, welding at nozzles and flanges, and other points where voids might occur. In the case of shell plates, obviously, venting was employed only where adequate thickness of plate remained and when laminations or inclusions appeared to be of a minor character.

Other means considered to reduce the blistering hazard at Dana were:

1. A carbon steel liner for the towers. This was thought to be feasible but not practical. The additional cost would have been approximately \$60,000 per tower, and the program delayed from seven to nine months.

2. A 10 per cent cladding of towers and other equipment with Type 316 stainless steel. This would have added approximately \$40,000 to the cost of each tower and delayed start-up from six to eight months.
3. The use of coating - such as Herosite, Amercoat, concrete, rubber, and furnace rosins. These were found to hold no promise of eliminating hydrogen blistering and were not considered further.

Any plan that delayed Dana's start-up more than six months would not be accepted, and it was decided, therefore, even though there was an acknowledged risk, that Design should continue on the basis of using carbon steel for towers, pipelines, and heat exchangers. The Savannah River schedules, however, did permit time to obtain stainless steel, and the advantages of using this metal were such that extensive use was made of it, particularly in those buildings of the "GS" plant which are considered permanent.

CRACKING

Tests on stressed specimens in contact with H_2S -water mixtures indicated that low or medium carbon steels in the soft condition do not crack at stresses below the yield point. It was found that high carbon steels and high strength alloy steels are much more subject to cracking, and when fully hardened and highly stressed will crack readily. Accordingly, mild carbon steel was specified wherever carbon steel was to be used throughout the system, and stress relief of all welds, including field welds, was specified as a fabrication and construction procedure. Where high strength alloy steels were used, as bolting for example, it became necessary to exercise great care to prevent excessive stressing.

INHIBITORS

The search for an effective corrosion inhibitor for carbon steel was particularly extensive and continued throughout the design period of both plants. The price differential between carbon steel and stainless steel would have been sufficient justification for the search, but for the Dana plant the factors of early procurement and volume purchases were too pressing. Large quantities of carbon steel were to be used in pipelines, towers and tanks, and since tests indicated a square foot of exposed surface might produce up to a pound of scale per year, there was speculation as to whether the plant would be operable over a considerable period of time without plugging or without loss of safe pressure operation conditions.

Hundreds of inhibitors were tested for their value in reducing corrosion. In general, the highest degree of inhibition under test conditions was shown by certain complex amines and proprietary materials. However, little advantage was gained by additions of less than 50 p.p.m. and preliminary work indicated that inhibitor concentrations in excess of 20 p.p.m. would result in serious disposal problems.

In view of the foregoing objections, ammonia became the most potentially attractive inhibitor candidate. Tests indicated that it would give a satisfactory reduction in the corrosion rate of carbon steel; that it was cheap, plentiful, and recoverable in a stripping process; and that it would not constitute a pollution problem in the plant effluent. However, subsequent data developed by pilot plant operations and E.R.L. experiments indicated that a steam capacity, greater by 50 per cent or more, would be required to strip ammonia from the system and reduce the H_2S content of the "GS" plant effluent to a satisfactory level. This additional steam capacity was not available at Dana and it was not desirable to make it available at Savannah. Also, evidence developed in these tests seemed conclusive that the presence of ammonia tended to loosen all iron sulfide scale.

The du Pont Chemical Department then developed an ion-exchange recovery method for the complex amines re-arousing interest in these types of inhibitors. The lowest corrosion rate obtained, 0.4 mil/hr. on carbon steel at 120°C. and 250 lb./sq. in., was obtained in subsequent tests employing tetraethylenepentamine (TEPA), and the Lummus Company was requested to make a design study for a TEPA inhibitor system.

During evaluation of inhibitors, continuing corrosion tests in uninhibited media showed that, although rates were initially high, the rates decreased with time because of the formation of a protective iron sulfide scale. As long as this protective scale was present the long-term corrosion rate was reduced to as low or lower than the inhibited rate.

Although no suitable inhibitive was discovered, it was possible to circumvent the overall corrosion problem in many cases by preventing sloughing or erosion of the protective scale, reducing the need for inhibitors considerably. With justification so reduced, the program of inhibitor addition to the "GS" Process was dropped.

SAFETY

GENERAL

There exists at the Savannah River #400 Area one serious and unusual safety problem which arises from the manufacture,

storage and use of very large quantities of hydrogen sulfide as a process component. The volume of this gas handled is so great that the release of only a small percentage could cause large areas of the plant and surrounding countryside to be unsafe for human occupancy. Until the time of design and operation of Dana plant the magnitude of the problem had been beyond the scope of industrial experience.

In as much as the safety problem, and the measures taken to reduce the hazard, were essentially the same at both Savannah and Dana, the reader should refer to the Dana history for a complete discussion of the subject. A brief summary of the problem is given below.

H₂S HAZARD

The hazard arising from the use of H₂S is twofold: (1) the direct injurious effect on human beings and (2) its corrosive effect on various materials of construction. The latter has been discussed in the preceding section under the title "Metallurgy".

H₂S is an extremely toxic, inflammable gas which forms explosive mixtures with air. Its odor, similar to that of rotten eggs, is readily perceptible from even very low concentrations of the gas in air, ranging from detectable at approximately one-tenth p.p.m. to very strong from approximately 30 p.p.m. Concentrations of from 150 to 200 p.p.m. can be tolerated without serious consequences for short periods of time. However, concentrations above 300 p.p.m. are extremely dangerous, and from 600 p.p.m. up may prove fatal even with very brief exposure.

The insidious property of the gas is the fact that exposure to 100-150 p.p.m. for a period of a few minutes results in the loss of smell. Consequently, a person may be in the presence of a lethal concentration of H₂S and not be able to detect an odor.

The explosive limits of H₂S gas is between 4.3 per cent and 46 per cent by volume. The ignition temperature is 260°C. H₂S burns in air to form sulphur dioxide and water.

Sulphur dioxide is almost as toxic as H₂S but not as insidious. SO₂ is so much more of an irritant that it is next to impossible to breathe even low concentrations, and the olfactory nerves remain sensitive over greater concentrations. Because of the extreme toxicity of H₂S, it was evident that the formulation of emergency lifesaving and personnel evacuation procedures was necessary. For sound planning, it was necessary also to have a knowledge of H₂S concentrations downwind from the plant under possible

emergency conditions and to establish a program to enable the individual in charge of emergency procedures to be continually aware of existing and forecasted weather conditions. Studies were made by the du Pont Engineering Service Division, using established formulas for calculating the turbulent dispersion of gas and tests were conducted involving the controlled discharge of H_2S from the pilot plant. Considerations, other than toxicity, were the possible rates and elevations of discharge, wind speed and direction.

SOURCE OF H_2S HAZARD

Within the Savannah River #400-D Area, H_2S is present as a gas at the H_2S plant where it is manufactured, as a liquid at the tank farm where it is stored, and as a gas and water-saturated solution at the "GS" units. In each of these areas it exists in such quantities that, in the event of a major release, a lethal atmosphere would be created quickly and might continue for hours or even days. The magnitude of the hazard is appreciable since approximately 100 tons of gas are in process or storage within a 25 acre area.

The circumstances that might create a dangerous H_2S condition are:

1. The direct release of the gas to the atmosphere because of (a) leakage or failure of facilities, (b) deliberate release due to an operating emergency, and (c) the continuous escape of small quantities of gas from waste water streams and from inert gas purges.
2. The release of water containing H_2S to an open ditch or flowing stream causing: (a) initial H_2S flash to the air due to sudden pressure decrease, (b) H_2S evolution from the stream of water initially saturated with H_2S , or (c) river pollution caused by insufficient loss of H_2S from the stream.
3. The release of liquid H_2S resulting from storage tank leakage or failure.

REDUCTION OF HAZARD

The design problem involved in reducing the H_2S hazard was determined to be one of anticipating the nature of the emergencies, providing means of controlling the required release of gas to a minimum and, in all cases of intentional H_2S release, providing as safe a disposal system as possible. The following outlines the program set up to promote maximum safety.

Personnel Protection

This involved the use of gas detecting devices to measure the concentration of gas in the atmosphere and waste streams, the use of an alarm system to warn of impending danger, and the provision of masks for those who might be trapped in a dangerous area or whose duties require them to remain in such an area.

Protection of personnel by regulation of conduct and the establishment of emergency procedures was a function of the Operating Department (A.E.D.) and not the Design Division.

The Consolidated Engineering Company's "Titrilog" was found to be satisfactory, and the best commercially available device, for detecting and measuring the concentration of H_2S in the atmosphere. It was necessary, however, for the E.R.L. to develop an instrument to perform similar functions for waste streams. E.R.L. also developed an automatic remote sampling system for both types of instruments so that a single analyzer could serve as monitor for a number of locations. Both single station and multi-station sampling installations were made at Dana.

The Dana history describes the atmosphere and water analyzers and the provisions for remote sampling. However, at Savannah, identification of contamination is accomplished by manual rather than automatic sequential control of the supply lines feeding the multi-station analyzer. The automatic equipment was considered too costly and complex for the infrequent service to which it is subjected.

In general, the areas, lines and streams monitored at Dana are also sampled at Savannah. However, the difference in plant layout obviously results in some variation in arrangement.

Eight "Titrilog" and alarm units and three gas-in-water analyzers and alarms were installed at Savannah. One "Titrilog" is located in the control room of each "GS" building to monitor the ventilating air, with one additional unit in the control rooms for Buildings #411-D and #413-D which, by means of sampling stations, monitor the areas on the west and east side of the "GS" plant, respectively. One "Titrilog" is located in the control room of the H_2S Plant and monitors the H_2S area and Tank Farm, Buildings #401-D and #402-D. Similarly, a "Titrilog" in the Control Laboratory, Building #772-D, monitors that building, the shops area, Building #717-D to the east, and the process areas, Buildings #420-D and #421-D, to the south. The eighth "Titrilog" is located in the Patrol Headquarters, Building #701-1D, and monitors only the interior of that building. The three gas-in-water analyzers are located in the "GS" Analyzer House (part of Bldg. #411-D), one unit

unit monitoring the waste cooling water from the "GS" Area, and the third unit monitoring the combined waste cooling water streams from the "GS" and H₂S Areas.

Air masks are located strategically throughout the plant so that they are readily available in the event of an accident. The Scott Air-Pak masks are equipped with a portable cylinder of compressed air and are available with cylinders of various capacities - seven and one-half, fifteen and thirty minutes.

For maintenance work, hose-type masks are provided. Air for these masks is supplied by an air distribution system consisting of a number of cylinder stations in the operating area where water-pumped compressed air is stored and the proper piping provided for hose connections. Controlled building ventilation is employed for the control rooms in the "GS" and H₂S areas where operators must remain during an emergency to effect shutdown of units and issue warnings and instructions to other operating areas. The operation of this ventilating system is generally as described in the Dana history except that the intake dampers at Savannah are opened manually. The service and administrative areas of the #400 Area can be evacuated in cases of emergency.

Numerous alarms and warning devices were installed as aids to safety. Since a knowledge of wind direction is of prime importance in evacuating hazardous areas in the event of a gas line break, a number of wind socks, illuminated at night, were installed at strategic locations to indicate the direction of escape. Wind direction and velocity indicators and recorders were installed in control rooms and at guard headquarters to assist in issuing warnings and planning operations during an emergency.

Design Considerations

This phase of the program centered on the inclusion of safety measures in plant design. The effort to accomplish this took two forms: (1) the furnishing of auxiliary equipment which would not have been installed were it not for existence of poisonous gas, and (2) the designing of process equipment and facilities with a consideration for the hazard in case of their failure. The second of the forms given above, equipment design, was concerned chiefly with the choice of satisfactory materials of construction, the use of a corrosion allowance where carbon steel was specified, stress relieving, etc. In this metallurgical field the Savannah River plant was able to take advantage of experience gained at Dana and of more conclusive results of E.R.L. studies. Equipment design also included such special considerations as the use of minimum thickness holes for detecting excessive corrosion, sealing of rotating parts to reduce leakage, the venting of gasket joints and lagging to reduce the fire hazard

from trapped gas. As further effort in this field stringent pressure tests were conducted on equipment and process lines after erection. Both hydrostatic and halide tests were made on as large a section of the facilities at one time as was practical.

The auxiliary equipment consists of those facilities furnished in an effort to anticipate and reduce every known unsafe condition resulting from the use of H_2S . With one exception, auxiliary facilities serve the same purpose at Savannah as those installed at Dana. These consist of: (a) flare and vents, (b) equipment isolation, (c) emergency power supply, (d) drain and run-down tanks, (e) inert gas supply, and (f) gas strippers. The contribution that each of these makes to the safety effort is described in the Dana history. The design development of these facilities, to the extent that they differ from those furnished at Dana, is described in the Savannah history under the section devoted to the process or utility of which they are a part.

The exception referred to above concerns the retention basins. These basins were constructed in the waste streams at Dana to provide a holdup for waste water excessively contaminated with H_2S or H_2SO_4 . From the basins, such water can be released at a controlled rate thus preventing damage to the country between the plant and the Wabash River and possible pollution of the river beyond the allowed limit.

All water streams leaving the Savannah #400-D Area flow in part through pipelines and then are combined in an open ditch, flowing to the swamp and then to the river. Waste water from the operating area is mixed in a pipeline with about five to six times its volume of cooling water. The large effluent stream from the power house joins this mixture in the open ditch. The time duration of flow through the open ditch is approximately one hour; the time of flow through the swamp has not been estimated. The waste stream on its way to the Savannah River does not pass through an off-plant area as was the case in Dana, so the evolution of minor amounts of gas throughout its length or damage along its banks are not of major concern.

Because of the more favorable conditions for handling the possibly contaminated process area waste water stream at Savannah, retention basins were not provided. However, production area discharge water piping was designed so that, if required at a later date, basins could be installed with a minimum of piping rearrangement and a minimum investment.

The list of auxiliary facilities mentioned above includes one, (c), emergency power supply, which, while provided for both plants, differs entirely in the means of accomplishment.

At Dana, a gasoline engine-driven generator was installed in the process area. This generator supplies the minimum power requirements for control and orderly shutdown in the event of a purchased power failure. At Savannah, however, the #400-D Area power requirements are generated within the area and distributed directly to the several substations serving the process buildings. In the "GS" area there are six substations one for each building wing. The "emergency" bus sections of these substations are cross connected in such a manner that upon the failure of the direct supply to one of the two for each building the other will automatically be connected to supply sufficient power to permit an orderly shutdown. Complete details of this emergency system will be found in Vol. VI - "Electrical Facilities".

Medical Facilities

Special apparatus, both for field and hospital use, was specified through the joint effort of the Operating Department and the Medical Division. The Design Division rendered assistance in procurement and in providing general accommodations for this equipment. Items ranging from inhalators and stretchers to a completely mobile first aid station were included in this equipment.

SECTION IV**DESIGN**

	Page
PROCESS BUILDINGS	59
BUILDING #401-D - HYDROGEN SULFIDE PLANT	59
FUNCTION	59
PRINCIPAL COMPONENTS	60
BUILDING FLOOR SPACE	60
BUILDING DETAILS	60
CONSTRUCTION DETAILS	61
EQUIPMENT	62
H ₂ S Equipment	62
Inert Gas Equipment	66
Miscellaneous Facilities	67
Process Piping	67
Control Facilities	68
Electrical Facilities	68
Instrumentation	68
PROCESS	69
Description	69
H ₂ S Production	69
Inert Gas Production	70
Development	71
H ₂ S Production	71
Inert Gas Production	73
DEVELOPMENT OF DESIGN	74
Building	74
Equipment	74
H ₂ S Equipment	74
Inert Gas Equipment	79
Materials of Construction	79
Safety	80
DRAWINGS	80

BUILDING #402-D - TANK FARM	80
FUNCTION	80
PRINCIPAL COMPONENTS	81
BUILDING FLOOR SPACE	81
BUILDING DETAILS	81
CONSTRUCTION DETAILS	81
EQUIPMENT	81
DEVELOPMENT OF DESIGN	82
Equipment	82
H ₂ SO ₄ Charge Pumps	82
NaHS Storage Tank	82
H ₂ S Storage and Rundown Tanks	83
Vaporizers	83
Process Vents	83
Car Spots	83
Metallurgy	84
Safety	84
DRAWINGS	84
 BUILDING #411-D - "GS" PROCESS	 84
FUNCTION	84
PRINCIPAL COMPONENTS	85
BUILDING FLOOR SPACE	85
BUILDING DETAILS	86
CONSTRUCTION DETAILS	86
EQUIPMENT	88
General	88
Production Towers	88
Heat Exchangers	88

Gas Blowers	89
Process Pumps	89
Condensate Drums and Separators	90
Waste Water Stripping Facilities	90
Product Stripping Facilities	90
Rundown and Drain Facilities	91
Gas Purging, Feed Water and Control Facilities	91
Liquid Weighing and Transfer Facilities	91
Emergency Shutdown Facilities	91
Electrical	91
Power Supply	92
Emergency Power Supply	94
Power Control	94
Lighting	95
Communications	96
Miscellaneous	97
Instrumentation	97
Basis of Design	97
Design Considerations	99
Control Room Facilities	102
Piping	103
Safety	103
PROCESS	103
Description	103
General	104
Main Process	104
Auxiliary Processes	111
Development	114
General	114
Metallurgy	120
Safety Considerations	121
Additions to Process	121

DEVELOPMENT OF DESIGN	122
Buildings	122
Superstructure	122
Foundations	123
Safety	124
Equipment	124
General	124
Towers	126
Heat Exchangers	138
Separators	154
Blowers	157
Process Pumps	166
Product Analysis and Sampling	169
Rundown Facilities	170
Product Handling	171
Insulation and Steam Tracing	173
Process Lines	174
DRAWINGS	176
BUILDING #411-5D - SHELTER AND SHOP	179
FUNCTION	179
PRINCIPAL COMPONENTS	179
BUILDING FLOOR SPACE	179
BUILDING DETAILS	179
CONSTRUCTION DETAILS	179
DRAWINGS	180
BUILDING #412-D - "GS" PROCESS	176
FUNCTION	176
BUILDING	176
EQUIPMENT	176
Production Towers	177

Heat Exchangers	177
Condensate Drums and Separators	177
Waste Water Stripping Facilities	178
Product Stripping Facilities	178
Gas Purging, Feed Water and Control Facilities	178
PROCESS	178
DEVELOPMENT OF DESIGN	178
DRAWINGS	178
BUILDING #412-4D - MASK MAINTENANCE BUILDING	180
FUNCTION	180
PRINCIPAL COMPONENTS	180
BUILDING FLOOR SPACE	180
BUILDING DETAILS	180
CONSTRUCTION DETAILS	181
DRAWINGS	181
BUILDING #412-5D - SHELTER AND SHOP	181
FUNCTION	181
PRINCIPAL COMPONENTS	181
BUILDING FLOOR SPACE	181
BUILDING DETAILS	182
CONSTRUCTION DETAILS	182

DEVELOPMENT OF DESIGN	183
DRAWINGS	183
BUILDING #413-D - "GS" PROCESS	176
BUILDING #413-4D - SHELTER AND SHOP	183
BUILDING #419-D - FLARE	183
FUNCTION	183
PRINCIPAL COMPONENTS	184
BUILDING FLOOR SPACE	184
BUILDING DETAILS	184
CONSTRUCTION DETAILS	184
EQUIPMENT	184
Stacks	184
Instruments	185
Piping	185
Safety	185
PROCESS	185
Development	185
DEVELOPMENT OF DESIGN	186
Equipment	186
Tower	187
Stacks	187
Pilot Burners	189
Flare Headers	190
Safety	190
DRAWINGS	192
BUILDING #420-D - CONCENTRATOR ("DW" PROCESS)	192
FUNCTION	192

PRINCIPAL COMPONENTS	192
BUILDING FLOOR SPACE	192
BUILDING DETAILS	192
CONSTRUCTION DETAILS	193
EQUIPMENT	193
Towers	194
Tanks	195
Calandrias	195
Reflux Condensers	195
Vent Coolers	196
Vent Chillers	196
Pumps	196
Vacuum Jets	196
Refrigeration Units	196
Process Piping	197
Instrumentation	197
Electrical	197
PROCESS	198
Description	198
Development	200
DEVELOPMENT OF DESIGN	200
Building	200
Equipment	200
Towers	201
Calandrias	201
Condensers	202
Coolers and Chillers	202
Safety	203
Metallurgy	203

DRAWINGS	203
BUILDING #421-D - FINISHING BUILDING ("E" PROCESS)	203
FUNCTION	203
PRINCIPAL COMPONENTS	203
BUILDING FLOOR SPACE	204
BUILDING DETAILS	204
CONSTRUCTION DETAILS	204
EQUIPMENT	205
Process Equipment	205
Receiving Scale Tank	205
Crude Feed Pump	205
Crude Head Tank	205
Potassium Permanganate Mix Tank	205
Treating Kettle	205
Treating Kettle Condenser	205
Scale	206
Treated Feed Hold Tank	206
Electrolyte Mix Tanks	206
Electrolytic Cells	206
Cell Rectifier and Switchgear	207
Cell Residue Tanks	207
Cooler Condenser and Vent Condensers	207
Gas Burners	207
Drainage Tank	208
Drainage Tank	208
Drainage Pump	208
Condensate Receivers	208
Final Residue Tank	208
Cell Residue Pump	208
Final Evaporator Feed Tank	208
Final Evaporator	208
Final Condenser	209
Heads Tank	209
Product Receivers	209
Finished Product Scale	209
Cylinder Loading Feed Tank	209
Sump Tank	209
Ammonia System	210
Oxygen and Helium Cylinder Station	210
Electrical Equipment	210
Instrumentation	212

Piping	213
PROCESS	213
Description	213
Development	216
DEVELOPMENT OF DESIGN	218
Building	218
Equipment	219
Pumps	220
Cells	220
Burners	221
Process Lines	221
Seals	221
Flash-backs	222
Cooling Water	222
Electrolyte	222
Electrical Facilities	223
Oxygen and Helium Cylinder Station	224
Materials of Construction	224
Miscellaneous Changes	224
SAFETY	225
Fire and Explosion	225
Electrical	226
Other Hazards	226
DRAWINGS	227
BUILDING #421-1D - "E" PROCESS - CYLINDER LOADING	227
FUNCTION	227
PRINCIPAL COMPONENTS	227
BUILDING FLOOR SPACE	228
BUILDING DETAILS	228
CONSTRUCTION DETAILS	229
EQUIPMENT	230

Gas Production	230
Feed Tanks	230
Electrolytic Cell Bank and Rectifier	230
Oxygen Cooler	230
Oxygen Condensate Pot	230
Oxygen Mist Separator	230
Oxygen Relief Seal Pot	231
Oxygen Chillers	231
Deuterium Seal Pot	231
Deuterium Cooler	231
Deuterium Mist Separator	231
Deuterium Condensate Pot	231
Deuterium Holder	231
Holder Outlet Seal Pot	232
Cylinder Loading	232
De-Oxidizer	232
De-Oxidizer Aftercooler	232
Deuterium Compressor	232
Compressor Aftercooler	232
Condensate Pot	232
Oil Extractor	232
Product Manifolds	233
Vacuum Pump	233
Oil Collection Pot	233
Refrigeration System	233
Refrigeration Unit	233
Expansion Pots	234
Oil Separator	234
Process Piping	234
Purging	234
Instrumentation	234
PROCESS	236
Description	236
Development	238
DEVELOPMENT OF DESIGN	239
Building	239
Equipment	239
Electrolytic Cell Bank and Rectifier	240
Seals and Vents	240
Deuterium Compressor	241
Refrigeration System	241
Electric Power	242

Procurement	244
Safety	245
DRAWINGS	246
BUILDING #805-D - PROCESS LINES	246
FUNCTION	246
PRINCIPAL COMPONENTS	246
DEVELOPMENT OF DESIGN	246
DRAWINGS	247
ADMINISTRATIVE, PERSONNEL AND SERVICE FACILITIES	247
BUILDING #701-1D - AREA GATEHOUSE AND PATROL HEADQUARTERS	247
FUNCTION	247
PRINCIPAL COMPONENTS	248
BUILDING FLOOR SPACE	248
BUILDING DETAILS	248
CONSTRUCTION DETAILS	249
EQUIPMENT	249
DEVELOPMENT	250
DRAWINGS	250
BUILDING #701-2D - GATE HOUSE	251
FUNCTION	251
PRINCIPAL COMPONENTS	251
BUILDING DETAILS	251
CONSTRUCTION DETAILS	251
EQUIPMENT	251
DRAWING	251

BUILDING #701-3D - GATE HOUSE	251
FUNCTION	251
PRINCIPAL COMPONENTS	252
BUILDING DETAILS	252
CONSTRUCTION DETAILS	252
EQUIPMENT	252
DRAWING	252
 BUILDING #704-D - SUPERVISOR'S OFFICE AND FIRST AID	252
FUNCTION	252
PRINCIPAL COMPONENTS	253
BUILDING FLOOR SPACE	253
BUILDING DETAILS	253
CONSTRUCTION DETAILS	253
DEVELOPMENT OF DESIGN	254
EQUIPMENT	254
Offices	254
Medical	255
Mechanical Utility Room	255
Air Exhaust	255
DRAWINGS	255
 BUILDING #707-D - CHANGE HOUSE	256
FUNCTION	256
PRINCIPAL COMPONENTS	256
BUILDING FLOOR SPACE	256
BUILDING DETAILS	256
CONSTRUCTION DETAILS	256

EQUIPMENT	257
DEVELOPMENT OF DESIGN	257
DRAWING	257
 BUILDING #711-D - STEEL AND PIPE STORAGE	 257
FUNCTION	257
PRINCIPAL COMPONENTS	258
BUILDING FLOOR SPACE	258
BUILDING DETAILS	258
CONSTRUCTION DETAILS	258
EQUIPMENT	258
DEVELOPMENT OF DESIGN	258
DRAWING	259
 BUILDING #717-D - SHOPS, STORES, AND CHANGE HOUSES	 259
FUNCTION	259
PRINCIPAL COMPONENTS	259
BUILDING FLOOR SPACE	260
BUILDING DETAILS	260
CONSTRUCTION DETAILS	260
EQUIPMENT	261
Offices	261
Utilities Room	261
Heating and Ventilating	261
Change Room	262
Shops and Tool Crib	262
DEVELOPMENT	262
DRAWING	263

BUILDING #772-D - CONTROL LABORATORY AND SUPERVISOR'S OFFICE	263
FUNCTION	263
PRINCIPAL COMPONENTS	263
BUILDING FLOOR SPACE	263
BUILDING DETAILS	264
CONSTRUCTION DETAILS	264
EQUIPMENT	265
Laboratory Area	265
Offices	266
Change Rooms	266
Cafeteria	266
Utility Room	266
Heating and Ventilating	267
Gas Cylinder Storage	267
DEVELOPMENT OF DESIGN	267
DRAWINGS	268
ELECTRICAL FACILITIES	268
STEAM FACILITIES	268
WATER FACILITIES	269
GENERAL FACILITIES	270

IV - DESIGN

PROCESS BUILDINGS

BUILDING #401-D - HYDROGEN SULPHIDE PLANT

- #401-1D - Control Building
- #401-2D - Breathing Air Cylinder Shed
- #401-3D - East Platform - Working
- #401-4D - West Platform - Working

FUNCTION

The function of Building #401-D is to provide:

1. Facilities to produce an initial charge of approximately 750 tons of hydrogen sulphide for the "GS" units, to make up process losses and to liquefy gas removed from those units when they are to be shut down.
2. A manufacturing plant to supply the #400-D Process Area with inert gas for purging, blanketing and testing equipment, and for use during "dummy" runs.

NOTE:

Much of the equipment discussed in this section for (1) above is physically located in the Tank Farm, Building #402-D, adjacent to the H₂S Plant. Such equipment is described here in the interest of a complete presentation since, regardless of its location, it is an integral part of the H₂S production and storage facilities. Items constituting this category are: (a) unloading and transfer pumps, (b) reactant and product storage tanks, (c) gas rundown tanks, and (d) vaporizers.

PRINCIPAL COMPONENTS

1. A compressor and control house which encloses both the H_2S and inert gas compressors and which includes an electrical control room, instrument control room, supervisor's office and toilet facilities.
2. A shed enclosing the inert gas generator.
3. Outside storage tanks.
4. Process equipment supports of standard outside construction.

BUILDING FLOOR SPACE

	<u>Approx. Square Feet</u>
Compressor shelter	1350
Electrical control room	175
Instrument control room	200
Supervisor's office	40
Toilet	50
Inert gas generator shed	300
Breathing air station	85

BUILDING DETAILS

Class - III (a & b) below, Class IV (c) below.

Size - (a) Compressor and control house - 30' x 60'.
Area - 1930 square feet.
Volume - 32,500 cubic feet.

(b) Inert gas generator shed - 15' x 20'.
Area - 300 square feet.
Volume - 3875 cubic feet.

(c) Breathing air station - 7' x 12'.
Volume - 756 cubic feet.

CONSTRUCTION DETAILS

Compressor and Control House

Foundations - Reinforced concrete with spread footings.

Superstructure - Structural steel frame.

Exterior walls - Corrugated cement asbestos board. No walls to 8' above floor on three sides of compressor shelter; corrugated asbestos above 8': fourth wall is control house wall.

Interior partitions - Corrugated asbestos with 3/8" sheet rock plus 1/2" insulation board; wood studs.

Interior of exterior walls - 3/8" sheet rock plus 1/2" insulation board; wood studs. No interior finish in compressor area.

Ceiling - Wood furring with 1/2" insulation board with 3/8" sheet rock plus 2" fiberglass insulation. No ceiling in electrical control room or compressor area.

Floor - Concrete, on grade, No. 1 finish.

Doors - Hollow metal.

Sash - None.

Roofing - Corrugated asbestos.

Heating - Forced air through heaters and ductwork for instrument control room. Air from this room is bled into the toilet room and electrical control room.

Ventilation - A slight positive pressure is maintained in the instrument control room and the electrical control room by means of mechanical blowers. The compressor area has gravity roof ventilators.

Breathing Air Station

Foundations - Reinforced concrete.

Superstructure - Wood frame.

Exterior Walls - Two sides and one end open. One end 3/8" flat transite.

Lining - None.

Ceiling - None.

Floor - Concrete on grade.

Roofing - Corrugated asbestos - overhang 2'-9" on sides and 12" at ends.

Doors - None.

Sash - None.

Contents - Six air cylinders (Building #401-2D only) and two hose racks. Incandescent lighting.

EQUIPMENT

H₂S Equipment

The equipment installed for the production and storage of H₂S is listed below in approximately the order in which it is used in the process, regardless of its physical location. All equipment is located within the H₂S Plant except as noted.

H₂SO₄ Unloading Pump

One model 1-1/2" CG-1 Worthington single stage centrifugal pump, 100 g.p.m., 50 ft. head, all liquid-wetted parts or corrosion resistant materials, complete with flexible

coupling and 5 h.p., 1750 r.p.m. drive. (Located at Tank Farm.)

H_2SO_4 Storage Tank

Two 10'-0" I.D. x 48'-0" long horizontal carbon steel tanks, 1/4" corrosion allowance, capacity 30,000 gal., design pressure 30 p.s.i.g., operating pressure atmospheric, stress relieved. (Located at Tank Farm.)

H_2SO_4 Charge Pump

Two type 1" DDB Lawrence vertical centrifugal submerged pumps, 6 g.p.m., 82 ft. head, shaft-type 316 S/S, impeller - Carpenter #20 S/S, casing - cast iron, column - steel, complete with 5 h.p., 1750 r.p.m. drive. (Located at Tank Farm.)

NaHS Solution Unloading Pump

One model 1-1/2" CRVN Ingersoll-Rand single stage centrifugal pump, 150 g.p.m. with 5 h.p., 3450 r.p.m. drive, (Located at Tank Farm.)

NaHS Solution Storage Tank

One 35'-0" O.D. x 36'-0" high, carbon steel tank, 1/8" corrosion allowance, capacity 250,000 gal., design pressure atmospheric, operating pressure atmospheric, steam coil - 200 ft. of 2" pipe, 150 lb. flanged nozzles, 20" manhole in roof, concrete dike. (Located at Tank Farm.)

NaHS Solution Charge Pump

One model 1" CRVN Ingersoll-Rand single stage centrifugal pump, 15 g.p.m., 115 ft. head, all iron construction, complete with 3 h.p., 3450 r.p.m. drive. (Located at Tank Farm.)

Reactor

One 20 ft. U-bend, consisting of two 10 ft. runs of 2" glass-lined steel pipe with 2" inlet mixing tee. Design pressure 100 p.s.i.g., operating pressure 25 p.s.i.g.

Reactor Separator

One 18" O.D. x 0.44" nom. wall x 3'-5" high separator, carbon steel with all interior surfaces lined with rubber. Design pressure 100 p.s.i.g., operating pressure 25 p.s.i.g.

H₂S Stripping Tower

One 22" dia. x 17'-0" high lead-lined steel tower - 1/4" steel, 1/8" lead, all internal components constructed of Hastelloy. Maximum working pressure of 185 p.s.i.g. at 275°F. Complete with 12 ft. of 1-1/2" Raschig ceramic rings, packing supports, distributor, and steam sparger.

Water Wash Tower

One 24" O.D. x 15'-0" high steel tower, 9/16" wall thickness, maximum allowable pressure 280 p.s.i.g., operating pressure 24 p.s.i.g. Includes distributor, packing supports and 10 ft. of 1-1/2" Raschig ceramic rings.

Water Wash Pump

One model 1" L-SVC Pacific single stage centrifugal pump, 40 g.p.m., 58 ft. head, casing-cast steel, impeller - stainless steel; complete with 3 h.p., 1750 r.p.m. drive.

Water Wash Cooler

One 12" O.D. steel shell, floating head, vertical heat exchanger, 3/4" O.D. x 17 ga. (minimum) Type 304 S/S tubes 20' long, effective surface 262 sq. ft. Corrosion allowance - Shell side 1/4", tube side 1/8". Design pressure - 150 p.s.i.g. both shell and tubes.

Knockout Drum

One 30" I.D. x 7'-0" high x 3/4" wall carbon steel drum. Corrosion allowance 1/4", design pressure 330 p.s.i.g., operating pressure 22 to 300 p.s.i.g.

Entrainment Separator

One 16" O.D. x 2'-6" high x 1/2" wall carbon steel vessel. Corrosion allowance 1/8", design pressure 330 p.s.i.g., operating pressure 22 to 300 p.s.i.g.

Compressors

Two Ingersoll-Rand 7-1/4" and 4-3/4" x 13", Class ES-2 heavy duty, double acting, horizontal gas compressors with type #43K valves in both first and second stage, suction pressure 5 or 250 p.s.i.g., discharge pressure 435 p.s.i.g.

Materials of Construction:

Cylinder liners - Ni-Resist
Pistons and rings - Cast iron

Cylinders and heads --Cast iron
 Piston rods - Type 410 S/S
 Packing - Babbitt (France Packing Co. type)
 Springs - Monel
 Gaskets - Monel-asbestos
 Packing case - Type 410 S/S
 Combination gland and soft packing box - Cast iron
 Valve seat - Type 410 S/S
 Valve plate and springs - Inconel
 Valve stop plate - Type 303 S/S
 Studs, nuts and cotter pins - Type 416 S/S

Texrope V-belt drive, 150 h.p., 440 V., 900 r.p.m.
 standard splash-proof induction motor. Compressor speed
 250 r.p.m.

Intercoolers

Two 22" O.D. steel shell, floating head, vertical heat
 exchangers, 3/4" O.D. x 17 ga. (minimum), Type 304 S/S tubes
 10' long, effective surface 410 sq. ft. Corrosion allowance -
 Shell side 1/4", tube side 1/8". Design pressure - Shell
 525 p.s.i.g., tubes 150 p.s.i.g.

Interstage Knockout Drum

Two 12-3/4" O.D. x 18" x 1/2" wall, carbon steel drums.
 Corrosion allowance 0.118". Design pressure 525 p.s.i.g.,
 operating pressure 100 p.s.i.g.

H₂S Condensers

Three 28" O.D. steel shell, floating head, vertical
 heat exchangers, 3/4" O.D. x 17 ga. (minimum), Type 304 S/S
 tubes 20' long, effective surface 1630 sq. ft. per unit.
 Corrosion allowance - shell side 1/4", tube side 1/8".
 Design pressure - shell 600 p.s.i.g., tubes 150 p.s.i.g.
 (Located at Tank Farm.)

Vent Condenser

One 12" O.D. steel shell, floating head, vertical heat
 exchanger, 3/4" O.D. x 17 ga. (minimum), Type 304 S/S tubes
 10' long, effective surface 131 sq. ft. Corrosion allowance -
 shell 0.22", tubes 1/8". Design pressure-shell 600 p.s.i.g.,
 tubes 150 p.s.i.g. (Located at Tank Farm.)

Liquid H₂S Storage

Two 11'-0" I.D. x 48'-0" long x 2-3/4" wall, carbon
 steel tanks, 1/4" corrosion allowance, capacity 36,750 gal.
 each, design pressure 600 p.s.i.g., operating pressure

435 p.s.i.g. Includes concrete dike and fire wall. (Located at Tank Farm.)

H₂S Rundown Tanks

Two 6'-0" I.D. x 36'-0" long x 1-5/8" wall, carbon steel tanks, 1/4" corrosion allowance, capacity 7700 gal. each, design pressure 600 p.s.i.g., operating pressure 435 p.s.i.g. Includes concrete dike and fire wall. (Located at Tank Farm.)

H₂S Rundown Tank

One 11'-0" I.D. x 42'-0" long x 2-3/4" wall, carbon steel tank, 1/4" corrosion allowance, capacity 33,500 gal., design pressure 600 p.s.i.g., operating pressure 435 p.s.i.g. Includes concrete dike and fire wall. (Located at Tank Farm.)

H₂S Vaporizers

Five 12-3/4" O.D. steel shell, floating head, vertical heat exchangers, 3/4" O.D. x 17 ga. (minimum), Type 304 S/S tubes 5' long, effective surface 56 sq. ft. each. Corrosion allowance - shell side 1/8", tube side 3/16". Design pressure - shell 150 p.s.i.g., tubes 480 p.s.i.g. Outlet head is extended to approximately 3 ft. above the tube sheet, forming a 12-3/4" O.D. x 3 ft. disengaging chamber. (One vaporizer located on each H₂S Storage and Rundown Tank in Tank Farm.)

Drain Pots

Five 24" I.D. x 3'-0" long, Type 304 S/S vessels for attachment to bottom head of vaporizers. (Located at Tank Farm.)

Inert Gas Equipment

Propane Storage Tank

One 5'-6" dia. x 20' long carbon steel tank, 3680 gal. capacity. Complete with unloading facilities for tank trucks.

Inert Gas Generator

One Gas Atmosphere, Inc., model XH1000-A Exothermic Gas Generator to produce 10,000 s.c.f.h. of essentially oxygen-free inert gas and capable of providing specification gas when operating at as low a rate as 3000 s.c.f.h. Generator consists of a firebrick-lined combustion chamber, shell and tube cooler, and automatic controls, all constructed for outdoor operation.

Inert Gas Compressor and Aftercooler (Low Pressure)

One Clark 6" x 7" SLR reciprocating double-acting single stage compressor having capacity of 3000 s.c.f.h. at intake pressure of 0 p.s.i.g. and discharge pressure of 85 p.s.i.g. Complete with 15 h.p. gear-head motor drive and one model SAF-6, 1-1/2" size aftercooler including moisture separator and automatic dump trap.

Inert Gas Compressor (High Pressure)

One Clark 3" x 5" SLS single stage, double-acting horizontal straight line, water cooled compressor, complete with 15 h.p. V-belt drive. Compressor has capacity of 600 s.c.f.h. at intake pressure of 85 p.s.i.g. and discharge pressure of 350 p.s.i.g.

Inert Gas Storage Tank

One 10'-0" dia. x 50' long carbon steel tank, capacity 4000 cu. ft., stores compressed gas at 75 p.s.i.g.

Miscellaneous Facilities

Process Piping

The problems confronted in designing process lines were, in general, the same as those encountered in the "GS" Area. Reference should be made to the history of Building #411-D for a complete discussion of process lines, because it is within the "GS" Area that similar process components are handled to the greatest extent and under the most difficult conditions. The materials of construction and methods of fabrication of the process piping were much the same as for that area, having been selected to give the safest, yet most economical system possible. In general, all process lines are of seamless steel pipe, with those lines carrying H_2SO_4 , H_2S , and H_2S -water mixtures, being of heavier wall thickness to provide an additional corrosion allowance. Welded or socket welded joints were specified; screwed joints were kept to a minimum. Since the H_2S compressors produce a pulsating flow in the pipe lines, considerable time was devoted to developing a piping system which would have a minimum of vibration during compressor operation.

Wherever hydrate formation might be expected in any of the H_2S -water piping, steam tracing was specified. Stress relieving and minimum thickness holes (discussed in Section VII of the Dana history under "Safety") were also provided. Dana operating experience contributed to the choice of materials for, and types of, valves, plug cocks, and other accessories.

Control Facilities

Instrumentation was provided as required for the measurement and control of process variables. Included in the system were certain audible and visible alarms to warn of deviations from normal operations. A central control panel was provided in the control room. This panel contains Building #402-D, Tank Farm, instruments as well as those for Building #401-D. The control room also includes an instrument for monitoring the #401-402 area atmosphere for H_2S .

Electrical Facilities

These buildings required only average continuity of electrical service, since no hazardous conditions are generated by loss of process power, and no loss of process time results from power interruption beyond the period of the power outage itself. Therefore, power service was provided from the common area power feeder, which also supplies other miscellaneous process and service buildings. A substation for transformation of the distribution voltage (13.8 KV) to the utilization voltage (480 volt) was located near the Control Building and only this lower voltage supplied to the building. Lighting is supplied through dry-type, step-down transformers from the power (480 volt) system voltage.

The communication and signal facilities provided for the H_2S Plant and Tank Farm consist of Bell System telephones and two soundpowered telephone systems, one serving Buildings #401-D and #402-D, and the other interconnected with all the process control rooms in the #400-D Area. In addition, these buildings (#401-D and #402-D) are connected to an area-wide safety alarm and loud speaker system through which they can originate evacuation signals and emergency announcements, as well as receive evacuation, air raid and all clear signals, and announcements.

Instrumentation

The problem of controlling the H_2S manufacturing process is principally one of controlling the flow of process materials. The method of exercising this control in the #400-D Area is essentially the same as employed at Dana Plant. By referring to the section of the Dana history devoted to the H_2S Plant, the reader will find examples of the extent of process control and control points. These examples are subject to some variation in their application to the Savannah River Plant because of experience gained at Dana and the fact that at the latter plant the generating facilities were designed to operate at lower pressures.

The instruments and control systems used in Building #401-D are generally of the same type as used in the "GS" Area, Building #411-D, and reference should be made to the history of Building #411-D for this information. It will be found that, in most cases, pneumatically operated commercial instruments are used.

PROCESS

Description

H₂S Production

The hydrogen sulphide plant was designed to produce H₂S at a rate of approximately 15 tons per 24-hour day from the reaction between sodium hydrosulfide and sulfuric acid.

The raw materials required, 60° Be. H₂SO₄ and 40% NaHS, are received in tank cars and are stored for use. The two are metered into a glass-lined pipe, which functions as a reactor. The reaction occurs instantly and violently to produce H₂S gas and sodium sulfate. Prior to entering the reactor, the acid stream is diluted with treated process water, enough water being added to maintain the sodium sulfate in solution.

The mixture of gas and liquid discharges from the reactor into a rubber-lined cyclone separator. Here the mixture is separated, the gas stream passing on to the water wash column, and the sulfate solution, plus entrained gas, discharging to the waste water stripper.

In the water wash column, the gas stream is scrubbed of any solid matter and/or excess acid. The wash water is cooled and recycled, except for a small continuous purge. From the wash column, the gas stream passes through two cyclone-type separators in series, the knockout drum and separator, and continuing, enters one of the two-stage H₂S compressors.

The liquid streams from the separator following the reactor, from the water wash column, and from the knockout drum and separator, are stripped of H₂S in the waste water stripper. This is a packed column using 40 p.s.i.g. steam as a stripping agent. Off-gas from the stripping column joins the gas stream entering the water wash column and continues through the process as described above. The waste liquid from the stripping column, having had its H₂S content reduced to a tolerable amount, is discharged to a process sewer, thence to the river. Flow controllers maintain a pressure not over 25 p.s.i.g. in the stripper column and a minimum pressure valve at the compressors bypasses gas

around the compressor to maintain a pressure above atmospheric at the compressor suction.

The H_2S compressors receive the gas normally at about 22 p.s.i.g. compressing it to 435 p.s.i.g. Each of the two compressors is equipped with an inter-cooler and an inter-stage cyclone type separator. The compressed gas is cooled and condensed in shell-and-tube type condensers, and stored as a liquid.

Three main condensers and a vent condenser are provided with piping so arranged that one or more condensers may be cut out of operation for the removal of hydrate.

It is not necessary to liquefy gas except for storage. Gas is delivered to the "GS" units directly from the compressors. The H_2S storage tanks are equipped with vaporizers in order to supply H_2S in a gaseous state to the "GS" units.

In addition to producing gas, the H_2S Plant is used to pump down the "GS" units, i.e., to liquefy H_2S from "GS" units when inspection or maintenance work must be done. Due to the desirability of relatively rapid evacuation of the towers, and the resultant greater quantities of gas to be handled, it was the pump-down service which fixed the capacity of much of the H_2S Plant. Thus, if pressure is maintained in the "GS" towers by pumping in water, a pair of first stage towers can be emptied in about two hours providing simultaneous use is made of both H_2S compressors and all three liquefaction condensers.

The gas from the "GS" area during pump-down is brought to the separator following the H_2S water wash column, the gas from the hot towers first being cooled by the secondary condenser in the "GS" unit being pumped down. The path of the gas from this point is as described above for newly produced gas, except that only the first stage of the compressors is used and three separate storage tanks and vaporizers are provided for the liquid rundown H_2S . These storage tanks, with a combined capacity of 43,900 gallons, are sufficient for the H_2S pump-down from four of the 24 "GS" units.

Inert Gas Production

The inert gas generating plant was designed to produce essentially oxygen-free gas at a maximum rate of 10,000 s.c.f.h. by burning propane gas. The gas generator, a "package" unit, receives propane from the propane storage tank, air from the surrounding atmosphere, and discharges the product to the suction side of a low pressure compressor. This compressor will deliver 3000 s.c.f.h. of gas, at 85 p.s.i.g. which may be stored in the gas storage tank or used for purging

and blanketing various pieces of equipment in the #400-D Area.

If relatively small quantities of higher pressure gas are required to test piping or equipment, the low pressure gas can be fed to the suction side of a high pressure IG compressor which will deliver 3000 s.c.f.h. at 300 p.s.i.g.

Since a dummy run of a "GS" unit requires a large volume of high pressure inert gas, the piping in the compressor area is so arranged that gas from the generator can be fed directly to either one or both of the two H_2S compressors. Thus, the full generating capacity of 10,000 s.c.f.h. can be compressed to 435 p.s.i.g. and piped to the "GS" Area.

Development

H_2S Production

Hydrogen sulphide gas is used as a process component in the extraction of heavy water. It was estimated that an initial charge of 750 tons of H_2S would be required by the "GS" units and in addition there would be processing losses to replenish. These estimates and the "GS" construction schedule dictated the rate at which gas had to be accumulated on the plant.

The decision to manufacture H_2S on the plant rather than purchase the gas, and the choice of the process to be used, were made when the Dana Plant was designed. The purchase of gas at the required rate of delivery raised seemingly insurmountable transportation problems. As for a means of generating the gas, the reaction of $NaHS$ and H_2SO_4 was thought to produce H_2S of high quality and with a simple by-product disposal problem.

Other possibilities given consideration for H_2S production, and their principal disadvantages include:

1. Reaction of sulfur and a hydrocarbon - the mixture of gases which would result would require a more complicated purification train than the product from the $NaHS$ process.
2. Reaction of metallic sulfides and acid - the impurities of the sulfides would, here too, demand considerable gas purification.
3. Reaction of sulfur and caustic - the by-product thiosulfate formed would constitute a disposal problem.

A more detailed discussion of the reasons for not purchasing H_2S gas and the choice of a process for its generation is found in the Dana history.

The decisions made for Dana were the basis for design of the H_2S production facilities at Savannah River. The original Dana design made by the Girdler Corporation, while utilizing $NaHS - H_2SO_4$ process, specified a relatively large batch-operated generator. At du Pont's request, the design was changed to provide a small generator (glass-lined pipe) operating continuously at atmospheric pressure. This generator was developed by du Pont and tested at its Chambers Works.

With a few exceptions, process and equipment for Savannah River are patterned after the Dana installation. The principal difference is the operation of Savannah generating facilities at approximately 25 p.s.i.g. instead of essentially atmospheric, as at Dana. There were two reasons for this change, (a) to obtain comparable dryness of H_2S with the higher scrubbing water temperature at the Savannah site, and (b) to permit the use of only one of the two compressors during the normal production of gas. Two 125 c.f.m. compressors were purchased, as at Dana, so that a pair of "GS" towers could be emptied of H_2S in less than two hours. However, being able to dispense with one compressor during the production of gas should result in lower maintenance costs. Condensers were installed to liquefy gas at the pump-down rate (27,700 lb/hr.) which is greatly in excess of that required for gas generating purposes.

The second difference between the two installations is related to the first. While H_2S production facilities were made the same size as at Dana,² due to the increased pressure at Savannah the capacity is about 10% higher, even though only one compressor is being used.

Other differences between the two plants concern the use of gas-producing and storage facilities for "GS" gas pump-down. At Dana, gas from the hot towers is cooled in the H_2S water-wash before being compressed and liquefied. At Savannah, gas from the hot towers is cooled in the secondary condensers of the unit being pumped down. This gas is then introduced into the H_2S Plant at the separator following the water wash tower.

The pump-down facilities at Savannah River also differ from those at Dana because, at the former location, only H_2S gas is returned to the H_2S area for storage - the liquid from the towers being stored within the "GS" Area. At Dana, both run-down liquid and gas are stored in the Tank Farm.

At Dana, no separate storage capacity (rundown tanks) was provided for pumping down first stage "GS" towers because of the very large quantity of relatively low value material involved. The gas from these towers is returned, after liquefaction, to the 30,000 gallon storage tanks used to store newly produced H_2S . The first stage liquid is considered expendable. However, the Savannah "GS" units being much smaller (approximately one-fourth the capacity of a Dana unit) it was considered desirable to provide rundown tanks for gas from the entire unit. To provide for the possibility of more than one unit being shut down, storage capacity equal to the H_2S content of four "GS" units was installed at the Savannah River Plant.

Inert Gas Production

The process chosen for the manufacture of inert gas at Savannah River is the same as that used at Dana. Propane was considered a desirable fuel for the production of inert gas because it is readily available, will burn uniformly to provide a gas almost completely free from oxygen, and can be used for the pilot light of the flare.

Since the manufacture of inert gas and H_2S present some similar unit operations, these two processes were combined in one building, achieving minimum operator attendance. As a result, Building #401-D was designated to include the equipment required to manufacture inert gas.

The principal differences between the inert gas generating facilities at Savannah River and Dana are their capacities and compressor discharge pressures. The generator at Dana and the unit originally ordered for Savannah has a capacity of 3000 s.c.f.h. This was considered adequate to supply #400-D Area process units with gas for minor testing and blanketing purposes. However, experience gained at Dana Plant indicated that an inert atmosphere was desirable in the "GS" units during a dummy run. Therefore, the order for the 3000 s.c.f.h. generator for Savannah was cancelled and replaced with one of 10,000 s.c.f.h. capacity. Since the higher capacity would be required only during a dummy run of a "GS" unit, the new generator was designed to permit operation at rates as low as 3000 s.c.f.h.

While no change was made in the storage pressure of inert gas at Savannah, the need for higher pressures for test purposes resulted in the purchase of a second compressor which, when operated in series with the low pressure compressor, will deliver 300 s.c.f.h. at 300 p.s.i.g., an adequate volume for minor testing.

For a dummy run, the maximum capacity of the inert gas generator is required, and a high pressure. As this service is demanded infrequently, the piping is arranged so that either or both of the two H₂S compressors can be utilized.

DEVELOPMENT OF DESIGN

Building

The H₂S process presented the usual problems associated with handling a toxic, flammable, and highly corrosive gas under relatively high pressure. It was therefore desirable to have all process equipment out-of-doors or in roofed shelters, only minimum protection being given to that equipment not suitable for direct exposure to the weather.

The building portion of Building #401-D is of Class III design and basically duplicates similar elements at the Dana Plant. It provides complete shelter for the electrical control facilities, instrument control room, offices and toilet facilities, partial shelter for compressors and gas generators, and support for other equipment installed out-of-doors. A slight positive air pressure is maintained in the control rooms and office to prevent the entrance of H₂S.

Generally speaking, the design of the building provides an economical structure, simple in detail, yet resulting in a permanent facility. This conforms to the Area policy of providing adequate, minimum buildings with the least expenditure of money. The type of structure, Class III, was selected by agreement between the Atomic Energy Division and the Atomic Energy Commission. A description of Class III construction and reasons for its selection for the #400-D Area will be found in the section of this history devoted to Building #411-D, subsection "Development of Design".

In addition to the operating buildings described above, one of the seven identical breathing air stations supplied to the #400-D Area, is located within the H₂S Plant. This is described in a previous section. The six remaining air breathing stations are located within the "GS" Area. Serving only as a place to keep the emergency air cylinders and hose masks out of the weather in a section of the plant where much of the process equipment is out-of-doors, no unusual design problems were encountered.

Equipment

H₂S Equipment

The principal factors affecting the design of equipment for the Savannah River H₂S Plant were, as was the case for the

Dana Plant, the toxic and corrosive properties of the process materials. Also, at temperatures under approximately 90°F., solid hydrates are formed with detrimental effect on pipe lines, valves and other equipment.

Since it had been decided that the Savannah generating facilities would utilize the same process, and have the same design capacity as the Dana Plant, Dana equipment design became the pattern for Savannah. The development of this equipment is discussed in some detail in the Dana history.

However, aside from minor changes such as storage capacities, separator sizes, etc., dictated by new conditions or experience from the Dana installation, several major differences exist with regard to some pieces of equipment. These main items are discussed below; references should be made to the Dana history for that development which is applicable to both plants.

Many of the differences in design of the two plants are due to the higher temperature of the cooling water available at Savannah River. Use of such water in a plant of the Dana design would lower the drying efficiency of the process. The problem was resolved by increasing the pressure at the water wash tower to 25 p.s.i.g. to obtain comparable dryness of H_2S with the higher scrubbing water temperature. This change also permitted the use of only one of the two compressors during the production of gas, since the capacity of the compressors is multiplied roughly in proportion to the increase of absolute suction pressure. The change, if any, resulting from the increase in operating pressure on the process equipment is given below along with other comments.

Reactor

The "U" shaped, 2" glass-lined pipe reactor which had been chosen for Dana was duplicated at Savannah. The idea was advanced that greater rigidity might be had from a single straight length. However, by the time of the Dana review which prompted this suggestion, it was too late to change the Savannah reactor from its "U" shaped design.

H_2S Stripping Tower

This tower is a conventional packed column and presented no design problems other than materials of construction. Because the process material being handled is both corrosive and toxic, adequate protection against equipment failure is imperative.

For the low pressure at Dana, the column is made of Haveg. The Savannah H_2S process, being at a higher pressure, requires a stronger construction material. A survey, considering the economical aspects, led to the selection of lead-lined steel for the shell and Type 316 S/S for internal components. Later, experience at Dana indicated that it was impractical to operate the stripper with the effluent at less than 1% acidity, against which Type 316 S/S has very poor corrosion resistance. Even lead covered steel was considered inadequate for the packing supports because of the considerable washing that takes place. Hastelloy "C" was found to be satisfactory for the internal components and was specified for the replacement of the grid bar and distributor pan assemblies.

Water Wash Tower and Cooler

At Dana, the function of the water wash tower and the cooler was two-fold; first, to remove entrained acid and cool the gas from the reactor before compressing, and second, to cool the rundown gas from the hot "GS" towers before compressing. This second service dictated the size and operating characteristics, the rundown rate of the flow being many times the generating capacity and the "GS" gas pressure being 300 p.s.i.g. compared with a reactor pressure of approximately 5 p.s.i.g.

Originally, it was expected that the function of this equipment at Savannah would be the same as at Dana. Therefore, the only differences in design basis would be due to the smaller size of the "GS" units at Savannah and a change in the "GS" gas storage requirements. Later, when the decision was made to cool the rundown gas in the "GS" condensers instead of at the H_2S plant, it was realized that both the wash tower and its cooler could be reduced in size. However, no change was made because a redesign would have delayed construction and start-up of the H_2S producing facilities.

Heat Exchangers

It should be noted that at Savannah River all coolers, condensers, etc., have Type 304 S/S tubes. The design of Savannah, considered to be the more permanent of the two plants, took into account every experience gained at Dana, to increase plant operating life.

Compressors and Intercoolers

This equipment is similar to that installed at Dana. However, the increase in gas generating pressure to approximately 25 p.s.i.g. (compressor suction), resulted in changed operating characteristics. For example, as noted above,

one compressor suffices to handle plant design capacity.

H₂S Condensers

As at Dana, the three Savannah condensers are sized to handle "GS" rundown. Thus, while generating gas, any one unit may be taken out of service for the removal of hydrate or for repairs. During a "GS" pump-down, all three condensers will be used in parallel.

At Savannah, a single condenser serves the function of permitting venting of inert or non-condensable gases of the H₂S condensers with a minimum loss of H₂S. The unit was sized to justify its economic installation on the basis of process gas saved per operating year.

Vaporizers

At first the vaporizers installed in Building #402-D were of essentially the same design as those at Dana; that is, they included the liquid disengaging section above the top tube sheet as provided in the revised Dana design. This section was provided with a liquid by-pass line back to the inlet of the vaporizer, to prevent the return of entrained liquid to the tank.

After installation of these units at Savannah, but prior to start-up, Dana experienced difficulty from the excessive collection of water as a separate phase in the bottom of the vaporizers and in the liquid lines, thus preventing them from operating. It was found that this condition could be alleviated by periodic blowdown, and that became the practice at Dana.

For the Savannah installation, however, a more satisfactory solution to the problem was desired. This took the form of a separating chamber consisting of a stainless steel pot added to the bottom head of each vaporizer. The initial vaporizer installations having been completed, the addition of the drain pots necessitated extensive changes to the concrete dike floors and process piping.

Process Vents

Vents were provided for the Savannah H₂S Plant generally as at the Dana Plant, with two exceptions. The first, a change, resulted from increasing the low pressure generating system pressure beyond the practical range of a water seal. While flow controllers are set to maintain a pressure not over 25 p.s.i.g. in the stripper column, emergency relief is afforded by rupture

discs which vent to the high pressure flare.

The second exception was an addition to the vent system and was dictated by Dana operating experience. Specifically, it provides for the ventilation of the H_2S compressor's distance piece, and venting the packing leak-offs on each compressor. Ventilation is accomplished by semi-enclosing the distance pieces to permit viewing and access through one side only. Sweep air is sucked through this opening and exhausted through a port on the closed side of each distance piece. A single blower and suitable duct work are provided to exhaust the sweep air through a stack located as far from the control room ventilation intake as is practical. The three packing leak-offs on each compressor are vented through a separate manifold connected to the low pressure flare line.

H_2S Dryer

At the time a process was being developed for the generation of H_2S , the problem of obtaining a dry gas before liquefaction, or perhaps even before compressing, resulted in a considerable amount of study. In selecting the compressors for Dana, an extensive survey of commercial installations was made by du Pont to determine the industry's experience with compressing wet H_2S . As a result, it was not considered necessary to install gas drying equipment ahead of the compressors, if suitable materials of construction were used in fabricating those compressors.

Following further investigation and conferences on the subject, it was thought that with the aid of separators all entrained water could be removed between the compression stages. It was, therefore, decided to eliminate the gas dryers from further consideration.

Interest in H_2S drying equipment was unexpectedly renewed during October, 1951, when pitting of the carbon steel plates in the Dana pilot plant H_2S storage tank was noticed. It was believed that the pitting was due to the water phase in the liquid H_2S which lies at the bottom of the tank. Concern was expressed for the Tank Farm H_2S storage tanks which were designed with the same plate corrosion allowance as was used for the pilot plant equipment since allowance would not provide adequate protection against pitting.

Before a decision was reached on a drying system, another possible cause for the pitting of the tank bottom was advanced and the choice of a drying system was postponed. Investigation continued, however, but by mid-summer of 1952,

it had been decided that H₂S drying equipment would not be installed at either Dana or Savannah River Plants.

The subject of H₂S drying is discussed in considerable detail, including the relative merits of the several drying systems considered, and with the expected cost of the most favored method, in the section of the Dana history entitled "H₂S Plant - Building #101".

Inert Gas Equipment

General

No development of equipment was necessary for Savannah River. The facilities are of the same type as those at Dana, the only difference being an increase in equipment capacity made necessary by new uses for the gas.

With the decision to expand the use of inert gas at Savannah River to include minor testing and "GS" dummy runs, it was necessary to add a second compressor to furnish the relatively small quantity required for testing at the higher test pressure (300 p.s.i.g.). It was also necessary to increase the capacity of the generator from 3000 s.c.f.h. to 10,000 s.c.f.h. because of the large quantity required for a dummy run. Additional compressor capacity was not added because of the infrequent demand for this service. However, the piping is arranged so that the H₂S compressors can be utilized when the entire inert gas generating capacity is required at high pressure.

Providing these additions to the inert gas service necessitated relatively minor changes in existing foundations and some revision in piping at the H₂S compressors.

Materials of Construction

The metallurgical and related safety aspects of handling H₂S have been summarized under "Specialized Design Problems". It is evident from the summary that, because of the corrosive action of the process materials found in Building #401-D, namely H₂S and H₂S-water mixtures, materials used in equipment design had to be selected with great care. This was equally true of the "GS" Production Area. Because of the far greater complexity of the process and the vastly larger quantities of process materials handled in the "GS" Area, the discussion of material choices is included in the history section devoted to that area.

Reference should, therefore, be made to the chapter concerning Building #411-D because, in general, the materials of

construction used for a given service in the H₂S Plant were the same as those chosen for the "GS" Area.

Safety

The safety problem at the H₂S Plant is essentially the same as that in the "GS" Area. Likewise, the effort in Design to reduce the safety hazards to a minimum also followed principles incorporated into the "GS" Area design. The contribution to safety included venting of equipment to the Flare, monitoring the area to detect and measure atmospheric contamination, the furnishing of gas masks, use of minimum thickness holes, and the choice of materials of construction least subject to attack by the process streams and/or the use of a corrosion allowance in calculating metal thickness. Also contributing to the safety effort was the experience gained in operating similar equipment at Dana Plant.

Further information concerning the nature of the H₂S hazard and the effort to reduce it to a minimum will be found in this history under "Specialized Design Problems", and in the section devoted to the description of Building #411-D.

The only major safety problem associated with inert gas facilities was the location of the propane storage tank. This tank serves both the Flare, Building #419-D, and the inert gas generators. It is located out-of-doors, adjacent to the road so that the propane supplier may readily make tank truck deliveries. No insulation or protection from the weather was considered necessary. However, the tank was painted with a reflective paint to cut down absorption of solar heat.

DRAWINGS

- W-140315 - Plot Plan and General Arrangement
- W-140240 - Process Flow Diagram
- W-140241 - Piping and Instrument Diagram
- W-140325 - Piping and Instrument Diagram
- W-140943 - Design Drawings - Index
- W-140839 - Breathing Air Station

BUILDING #402-D - TANK FARM

FUNCTION

To provide:

1. Equipment for the handling and storage of raw materials and finished product for the H₂S Plant, Building #401-D (H₂S production only).

2. Storage for H_2S removed from the "GS" Area, Buildings #411-12-13-D.
3. Equipment for vaporizing the liquid H_2S for delivery to the "GS" Area.

Note: The Tank Farm is adjacent to the H_2S Plant and many of the facilities which make up the Tank Farm actually function as a part of the H_2S generating process and have, therefore, been described in the previous section - Building #401-D, H_2S Plant. Also, H_2S condensing facilities, not considered a part of the Tank Farm, though physically located within its boundaries, have been described in the previous section. Problems relating to the storage and handling of materials and related facilities will be discussed in this section.

PRINCIPAL COMPONENTS

1. Unloading and storing facilities for reactants.
2. H_2S storage tanks and vaporizers.
3. H_2S rundown tanks and vaporizers.

BUILDING FLOOR SPACE

There are no enclosed structures in the Tank Farm. All equipment is installed out-of-doors with typical ladders and platforms for access to tanks.

BUILDING DETAILS

Class III Construction

CONSTRUCTION DETAILS

Foundations - Reinforced concrete with spread footings.

Superstructure - Structural steel framing for stairways and access platforms.

Walls - Reinforced concrete dike walls around the $NaHS$ and H_2S tanks and reinforced concrete fire walls around the H_2S tanks.

Floors - Concrete on grade inside dike walls.

EQUIPMENT

1 - H_2SO_4 Unloading Pump

Described with H_2S Plant

2 - H ₂ SO ₄ Storage Tanks	—	Described with H ₂ S Plant			
2 - H ₂ SO ₄ Charge Pumps		"	"	"	"
1 - NaHS Solution Unloading Pump		"	"	"	"
1 - NaHS Solution Storage Tank		"	"	"	"
1 - NaHS Solution Charge Pump		"	"	"	"
4 - H ₂ S Condensers		"	"	"	"
2 - Liquid H ₂ S Storage Tanks		"	"	"	"
3 - H ₂ S Rundown Tanks		"	"	"	"
5 - H ₂ S Vaporizers with Drain Pots		"	"	"	"
2 - Car Spots - one for unloading NaHS and one for unloading H ₂ SO ₄					
Piping		"	"	"	"
Instrumentation		"	"	"	"
Electrical		"	"	"	"

DEVELOPMENT OF DESIGN

Equipment

With the exception of the propane and inert gas storage tanks, generally the same facilities have been included in the Savannah River Tank Farm as installed in the Dana Tank Farm. At Savannah, all facilities associated with the generation of inert gas are considered a part of the H₂S Plant and have been discussed in that section.

H₂SO₄ Charge Pumps

A pump is installed in each of the acid storage tanks. Vertical, centrifugal, submerged pumps are used in order to insure positive priming and to eliminate stuffing box problems.

NaHS Storage Tank

This is a 250,000 gallon capacity carbon steel tank welded on the site. To prevent stratification of its contents, the piping at the tank permits recirculation of the contents through the unloading pump. Freezing of the NaHS solution is prevented by the use of an internal steam coil. Since the coil is subject to caustic embrittlement, all welds have been stress relieved.

NaHS presents the usual safety problems of a typical caustic. While a tank rupture is a remote possibility, it was considered desirable to enclose the tank in a concrete dike. In addition to offering operator protection from the caustic, the dike permits controlled disposal of the NaHS. If the tank contents ran out on the ground, the sandy soil would absorb large quantities of the material and would have to be removed since any subsequent spillage of acid would evolve H₂S, making the area temporarily uninhabitable.

H₂S Storage and Rundown Tanks —

The usual safety practices for handling liquified toxic, corrosive materials were observed, including adequate corrosion allowance, elimination of screwed joints in connecting piping, and complete stress relieving and X-raying of the vessels.

As in the case of the NaHS tank, these five tanks are enclosed in a concrete dike, each having its own compartment within the dike. For additional safety, the concrete partition walls between the tanks were extended upward to serve as fire walls. Thus, in the event of a tank rupture and subsequent fire, the disturbance would be confined to a single tank.

While designing H₂S storage tanks for Dana Plant, much thought was given to means for rapid disposal of the liquid H₂S following a major tank leak and resulting flash vaporization. In the event of small leaks the contents of the faulty tank could be transferred by means of the drain lines. However, in the case of a major break, vaporization of the liquid remaining within the diked area might continue for several days, rendering much of the plant uninhabitable during that time.

No satisfactory plan was devised for quickly reducing this hazard although a number of schemes were studied. However, every reasonable precaution was taken in the tank design and it was decided that no further provisions should be made for removing spillage at Dana. No additional provisions were made for Savannah River. A more complete discussion of this subject will be found in this volume in the section on "Specialized Design Problems", subsection "Safety", and in the Dana history.

Vaporizers

See H₂S Plant.

Process Vents

See H₂S Plant.

Car Spots

The basic data from which the two structural steel car spot platforms were designed indicated that cars with dome platforms were expected when receiving sulphuric acid and NaHS. Accordingly, a simple counterweighted platform providing safe access to the tank car platform was designed.

A survey of car spot designs in use in Du Pont commercial plants resulted in selection of a design giving access to cars with or without dome platforms. Platforms fabricated from this design replaced those originally installed.

See H₂S Plant.

See H₂S Plant.

W-140315 - Plot Plan & Gen. Arrangement
W-140240 - Process Flow Diagram
W-140241 - Piping & Instrument Diagram
W-140325 - Piping & Instrument Diagram
W-140943 - Design Drawings - Index

Building #411-1D Production Unit No. 1 - Open Type
Structure with Two Wings
Building #411-2D Substations A & B.
Building #411-3D Control House
Building #411-4D Analyzer House

The heavy water production facilities at the Savannah River Plant employ three distinct process steps for the concentration of deuterium oxide from natural water: (1) the "GS" process, which is based upon an isotopic exchange between deuterium and hydrogen ions and utilizes the deuterium exchange reaction between H_2S and water (previously called the Dual-Temperature process but renamed for security purposes); (2) the "DW" process which effects the separation of light and heavy water by fractional distillation; and (3) the "E" process which further concentrates deuterium oxide by electrolysis.

The "GS" process is the initial concentrating step in the production of 240 tons per year of deuterium oxide (D_2O , heavy water). It increases the concentration of D_2O from its "natural abundance" concentration in water of 0.015% by weight (0.014 Mol %) to 11% (10 Mol %). Product from the "GS" process is pumped to Building #420-D (the "DW" process) for further concentration.

The "GS" facilities consist of three essentially identical "Buildings", (#411-D, #412-D and #413-D). Building #411-D, the first of these structures, is characterized by having facilities which are considered temporary, i.e., having approximately the same designed life expectancy as the Dana Plant.

PRINCIPAL COMPONENTS

1. One control house containing a central instrument control room, mass spectrometer room, laboratory, offices, scale tank room and toilet facilities.
2. Two electrical substations, one for each wing of the "GS" process structure.
3. Two "wings", each containing four "GS" process units and their auxiliaries.
4. One analyzer house containing the instruments with which the waste water streams from all three "GS" Buildings and the H_2S plant are analyzed for H_2S content.

BUILDING FLOOR SPACE

Approx.

Analyzer House 350 sq. ft.

Control Building

Instrument control room	2025 sq. ft.
Mass spectrometer room	1140 sq. ft.
Laboratory	470 sq. ft.
Offices	280 sq. ft.
Scale tank room	735 sq. ft.
Toilets	200 sq. ft.

Electrical Substations

Basement	1200 sq. ft., each
First floor	1200 sq. ft.

Building Wings ("GS" Process Structures)

Ground floor	17,550 sq. ft., each
--------------	----------------------

BUILDING DETAILS

Class - IIISize -

Total Area - 10,552 sq. ft.

Total Volume - 170,600 cu. ft.

CONSTRUCTION DETAILS

Analyzer HouseFoundations - Reinforced concreteSuperstructure - Wood frameExterior walls - Corrugated asbestos siding
on 1/2" asphalt-coated sheathing.Interior of exterior walls - 1/4" asbestos
wall board with 2" Rockwool batts between
the studs.Ceiling - 1/4" asbestos board with 2" Rockwool
batts between ceiling beams.

Doors - Wood

Sash - None

Roofing - Corrugated cement asbestos board.Floors - ConcreteHeating - Unit heater.Ventilation - Wood louver and 20" gravity type roof
ventilator.Lighting - Vapor-tight incandescent.Control RoomFoundations - Reinforced concrete with spread footings.Superstructure - Structural steel frame

Exterior walls - Corrugated cement asbestos board.

Interior partitions - Sheet rock on wood studs.

Interior of exterior walls - No finish in scale
tank room. All other areas have insulation
board and sheet rock finished surfaces.Ceiling - None in scale tank room. All other
areas have wood furring with insulation board
and sheet rock finished surfaces. Fiberglas
insulation.

Doors - Hollow metal

Sash - None

Roofing - Corrugated cement asbestos board.Floors - ConcreteFloor Covering - Asphalt tile except in scale tank
room.Heating - Unit heaters in scale tank room. Forced
air through heaters in conjunction with air-
conditioning system in all other areas.Air Exhaust - Two exhaust fans in the laboratory,
one in each of the toilets.

Lighting - General purpose fluorescent.

Electrical Substations

Foundations - Reinforced concrete with spread footings.

Superstructure - Structural steel frame.

Exterior walls - Corrugated cement asbestos board.

Interior of exterior walls - No finish.

Ceiling - None

Doors - Hollow metal

Sash - None

Roofing - Corrugated cement asbestos board.

Floors - Concrete

Heating - Unit heaters.

Ventilation - Gravity type roof ventilators.

Lighting - Vapor-tight incandescent.

Building Wings (GS Process Structures)

Foundations - Reinforced concrete cellular construction.

Superstructure - Structural steel frame with pre-cast concrete stair treads and walkways.

Lighting - Incandescent, vapor-tight with prismatic refractors.

The purpose of the structures outlined above is evident from their names, with the possible exception of the building "wings". There are two "wings" in each "GS" process building consisting of a continuous four-floor, open air, steel structure approximately 54 ft. high, 445 ft. long, and 29 ft. wide at the fourth floor and 39 ft. wide at the lower floors. This structure encloses all the process equipment for four units except the towers.

The general arrangement by floors is:

1st floor - Pumps, blowers.

2nd floor - Separator tanks, control stations.

3rd, 4th floors - Heat exchangers.

Catwalks provide access to the top and mid-elevations of the towers. A stairway at one end of the wing extends to the top tower catwalk; the other end of the wing is provided with a combination of a 50 ft. high stairway and ladders. Later permanent stairways extending from grade to the 54 ft. elevation (fourth floor) were added to units #2 and #7 of each "GS" building, thus providing each building wing with a stairway at approximately the mid-point of its 445 ft. length.

The foundation for the wing consists of a continuous concrete cellular structure approximately 450 ft. long, 62 ft. wide, and extending at greatest depth to 14 ft. below finished grade.

In addition to the structures described above, each "GS" Building has two breathing air stations, each station containing twelve air cylinders and two air hose racks. The breathing air stations in the "GS" Area are not specifically identified by a building number. For a description of a breathing air station see "Building #401-D - Construction Details".

EQUIPMENT

General

Building #411-D contains eight two-stage "GS" units, designated as units #1 to #8 inclusive. The equipment for each of the two stages of a unit, while similar, differs in size and capacity and includes some items not required for both stages. The eight units, however, are identical, except for some slight deviation in materials of construction. The unit will, therefore, be made the basis of "GS" equipment description.

Each unit comprises two systems (one for each stage) of bubble cap tray towers, heat exchangers, pumps, blowers, condensate drums, stripper tower, instrumentation, and the necessary interconnecting pipe, valves and fittings. The following is a brief resume of the equipment required per unit.

Production Towers

These are bubble cap tray towers with carbon steel shells and stainless steel internal parts.

- 1 1st Stage Cold Tower 11'-0" I.D. x 116'-0" high.
- 1 1st Stage Hot Tower 12'-0" I.D. x 116'-0" high.
- 2 2nd Stage Cold Towers 6'-6" I.D. x 114'-0" high.
- 2 2nd Stage Hot Towers 6'-6" I.D. x 114'-0" high.

Heat Exchangers

Except as noted in the tabulation which follows, all exchangers have carbon steel shells with 1/4 in. corrosion allowance, carbon steel tube sheets, 3/4 in. O.D. by 17 ga. Type 304 stainless steel tubes, and Type 304 stainless steel baffles and supports.

- 4 1st Stage Primary Condensers - 45" diam., Type 304 stainless steel tube sheets and 20'-0" lg. tubes.
- 2 1st Stage Secondary Condensers - 38" diam., 20'-0" lg. tubes.
- 1 2nd Stage Primary Condenser - 36" diam., Type 304 stainless steel tube sheets and 24'-0" lg. tubes.
- 1 2nd Stage Secondary Condenser - 32" diam., 24'-0" lg. tubes.

- 4 1st Stage Liquid Heaters - 24" diam., 24'-0" lg. tubes.
- 4 2nd Stage Liquid Heaters - 14" diam., 24'-0" lg. tubes.
- 3 1st Stage Stripper Exchangers - 24" diam., 24'-0" lg. tubes.
- 1 2nd Stage By-pass Cooler - 10" diam., 12'-0" lg. tubes.
- 1 2nd Stage Compressor Aftercooler - 28" diam., 12'-0" lg. tubes.
- 2 2nd Stage Steam Heaters - one 3" Sch. 40 Type 316 S/S tube 24'-0" lg; shell consists of 4" Sch. 40 steel pipe.

Gas Blowers

Carbon steel casings, aluminum impellers.

- 1 1st Stage Gas Booster - I-R 20" x 20" Type CVS-20 with 1000 h.p., 4160 v., 3 phase, 60 cycle drive. Capacity - 87,800 s.c.f.m.
 - 1 2nd Stage Gas Booster - I-R 10" x 8" Type CVS-8 with 600 h.p., 4160 v., 3 phase, 60 cycle drive. Capacity - 26,400 s.c.f.m.
- (Note: One each of above blowers was purchased as a warehouse spare for the entire "GS" Area. Seal oil system described under "Development of Design - Blowers".)

Materials of Construction

Casing: Cast steel ASTM A-27 Gr. 70-36
 Shaft: Carbon steel
 Impeller: Cast aluminum 355-T6
 Shaft seals: Carbon to stellite. (Cameron double seals)

Process Pumps

- 1 1st Stage Cold Tower Pump - 260 g.p.m., 252 ft. head, 30 h.p., 3550 r.p.m. motor.
- 1 1st Stage Condensate Pump - 60 g.p.m., 253 ft. head, 15 h.p., 3550 r.p.m. motor.
- 1 1st Stage Make-up Pump - 100 g.p.m., 250 ft. head, 15 h.p., 3550 r.p.m. motor.
- 1 1st Stage Humidifier Pump - 1100 g.p.m., 118 ft. head, 50 h.p., 1750 r.p.m. motor.
- 1 1st Stage Hot Tower Pump - 355 g.p.m., 152 ft. head, 25 h.p., 3550 r.p.m. motor.
- 2 2nd Stage Cold Tower Pumps - 85 g.p.m., 198 ft. and 145 ft. head, 15 h.p. and 10 h.p., 3550 r.p.m. motors.
- 1 2nd Stage Condensate Pump - 30 g.p.m., 262 ft. head, 10 h.p., 3550 r.p.m. motor.

- 2 2nd Stage Hot Tower Pumpa - 105 g.p.m., 216 ft. and 219 ft. head, 15 h.p., 3550 r.p.m. motors.
- 1 2nd Stage By-pass pump - 15 g.p.m., 162 ft. head, 5 h.p., 3550 r.p.m. motor.

Materials of Construction

Casing: 304 S/S
 Impellers: 304 S/S
 Shafts: SAE 4140 Steel
 Shaft Sleeves: 316 S/S
 Seals: Rotating face: 304 S/S faced with #6 stellite.
 Stationary face: Carbon. (Duraseal Double seals)

Condensate Drums and Separators, carbon steel

- 6 1st Stage Separators - 4'-0" I.D. x 4'-6" lg.
- 2 2nd Stage Separators - 3'-0" I.D. x 4'-6" lg.
- 1 1st Stage Hot Tower Drum - 6'-0" I.D. x 14'-0" lg.
- 1 1st Stage Condensate Drum - 6'-0" I.D. x 3'-0" lg.
- 1 2nd Stage Condensate Drum - 3'-0" I.D. x 6'-0" lg.
- 1 2nd Stage Cold Tower Drum - 2'-6" I.D. x 5'-6" lg.

Waste Water Stripping Facilities

- 1 Waste Water Stripper - 5'-0" I.D. x 28'-0" high.
 This is a bubble cap tray tower with carbon steel shell and S/S internal parts. (Type 410 S/S trays, Type 304 caps).

In addition to the equipment listed above, which is required for each of the eight units, other facilities are provided which serve all eight units. The following are the more important of these facilities.

Product Stripping Facilities

- 1 Product Stripper (Tower) - 12-3/4" O.D. x 24'-1-3/4" high, shell and internals of Type 316 S/S, contains 16'-0" of Raschig ring packing.
- 1 Product Cooler - Shell, 14" diam., carbon steel; tubes, 3/4" x 17 ga. x 12' lg., Type 304 S/S.
- 1 Product Stripper Reboiler - Shell, 12" diam., carbon steel; tubes, 3/4" x 17 ga. 12' lg., Type 304 S/S.
- 1 Stripper Condenser - Shell, 10" diam., carbon steel; tubes, 3/4" x 17 ga. x 8' lg., Type 304 S/S.
- 6 Stripper Preheaters - Arrangement - shells in parallel; tubes in series. Shell, 3" Sch. 40 carbon steel pipe, tube, one 2" Type 316 S/S Sch. 40 pipe 24' lg.
- 1 Stripper Feed Pump - 25 g.p.m., 152 ft. head, materials same as for pump list above.

- 1 Pipette Tank - 24" I.D. x 5'-6" lg., carbon steel.
- 1 Unstripped Product Storage - 6'-0" I.D. x 12'-0" lg., carbon steel (weigh tank - 2500 gal. capacity).

Rundown and Drain Facilities

- 1 Weak Liquor Rundown Tank - 6'-6" I.D. x 40'-0" lg., carbon steel.
- 1 Rich Liquor Rundown Tank - 6'-6" I.D. x 40'-0" lg., carbon steel.
- 1 1st Stage Drain Tank - 4'-6" I.D. x 9'-0" lg., carbon steel.
- 1 Drain Tank Pump - 25 g.p.m., 92 ft. head, materials same as for pump list above.

(Note: H₂S rundown tanks for the "GS" Process are located in the Tank Farm. See Building #402-D for description.)

Gas Purging, Feed Water and Control Facilities

- 1 Purge Tower (Packed) This is a two-section tower. The lower or primary section is made up of a 5'-0" I.D. x 21'-0" high, and the upper or secondary section, approximately 11-3/4" diam. x 18'-0" high, is made up of carbon steel shells.
- 1 Purge Tower Pump - 740 g.p.m., 208 ft. head.
- 1 Process Feed Heater - Shell, 40" diam., carbon steel; tubes, 3/4" x 17 ga. x 24' lg., Type 304 S/S.
- 2 Recirculating Water Pumps - 2450 g.p.m., 117 ft. head.

Liquid Weighing and Transfer Facilities

- 2 Weigh Tanks (1-Product and 1-Return solution) - 4'-6" I.D. x 9'-0" lg., carbon steel shells.
- 1 Product Pump - 25 g.p.m., 118 ft. head.
- 2 Return Pumps (one spare) - 4 to 40 g.p.m.

Emergency Shutdown Facilities

To prevent the release of large volumes of H₂S in the event of a disaster, means are provided for shutting down a unit, or an entire building by throwing a crash shut-down switch in the control room. This actuates motor-driven valves which, within any unit, will isolate each of the first stage towers, the second stage as a stage, and stop all pumps and blowers.

Electrical

Electrical work in the "GS" Area includes power and lighting equipment, distribution wiring, control inter-

connections, grounding, instruments and communications equipment. The following description is equally applicable to each of Buildings #411-D, #412-D and #413-D, although some facilities are common to all three buildings.

Power Supply

Each "GS" Building is supplied with electricity by two 13.8 kv., 3-phase, 3-conductor underground feeders, one serving the west wing substation and one the east. These feeders emanate from different buses in the generating station. In addition, a common 13.8 kv. stand-by feeder is provided to supply any one or all six substations in the three "GS" Buildings in the event of outage of a normal feeder.

The disposal of the twenty-four production units in six process wings of four units each made it most desirable to maintain the principal electrical distribution scheme on a "wing" basis also, for the following reasons:

1. The electrical loading of one four-unit wing was nearly the maximum that could be supplied from the power house through one cable circuit of practical size.
2. While the production units are largely independent of one another, four units of each wing are supplied by a common group of auxiliary equipment, such as raw water, seal oil and the like.

To match this process arrangement, the electrical system was designed for:

1. Individual grouping of all the pumps of each stage (207 h.p.).
2. Individual supply to each gas blower (1000 h.p. and 600 H.P.).
3. Individual supply to the group of motors serving the auxiliary functions to all four units and control room (162 h.p. plus 19 kw.).
4. Individual supply with standby source for all valves in all four units (approximately 200 h.p. total).
5. Normal lighting supplied from one main circuit per unit with an additional main circuit for auxiliary areas.
6. Emergency lighting and instrument equipment supplied from the valve power source (with standby), through one main panel per unit with additional main panels for control equipment and blackout lighting.

The electrical "unit" then, is a wing or one-half of a process building. It supplies four process units and the associated auxiliaries. There are six such electrical "units" serving the three process buildings #411-D, #412-D, and #413-D, with the following development description applying to any one of the six electrical units except where otherwise stated.

The secondary terminals of the transformer are connected through a 2" (i.p.s.) bus in a metal housing to a set of switchgear and motor starters within the substation building. One main circuit breaker, two branch circuit breakers and eight motor starters are included in the switchgear. One branch circuit breaker supplies 4160 volts to the main lighting transformer; the other, 4160 volts to the 480 volt power transformer supplying pumps, valves and medium-power equipment. The eight motor starters are for the gas blowers, one 1000 h.p. and one 600 h.p. per unit, four units per wing. Contactor type starters are employed because of their complete suitability for the service and their low cost compared with circuit breaker units. High reliability of power supply to the gas blowers is provided by having each independently served from the 4160-volt bus. Control power for the eight gas blower motor starters is supplied from a single large control transformer through separately fused circuits to each motor starter. Original equipment did not include the separate fuses; these were added after delivery to remove any dependence of one starter on another.

Motors of 100 h.p. and smaller are supplied at the nominal potential of 480 volts. This voltage is obtained by means of a dry type 4160/480-volt step-down transformer, supplied from the 4160-volt bus through one of the branch circuit breakers. The transformer is located in the substation house, adjacent to its low voltage switchgear with which it forms a coordinated low-voltage power center.

To provide maximum isolation between individual process units and thereby maximum unit service reliability, four starter groups are installed for the motors of the four process units of each wing. By this means, it is possible to shut down the complete service to any one process unit and de-energize its starter group without affecting the other process units. Likewise, trouble in the electrical system of one unit is much less likely to affect the electrical systems of other units, contributing to higher productivity and reduced hazard. Each starter group is connected through a separate power circuit breaker to the wing 480-volt bus.

Distribution of power from the starter location to the motors in the process units is through underground fibre duct runs to the manhole associated with the process unit,

thence by individual steel conduit underground to the motor or to a riser support and in conduit above to the motor or other elements above grade. In the fibre ducts, several cables are drawn into each duct, while in the steel conduit one smaller conduit is used for each cable. Fibre duct is less costly than steel conduit, so maximum use has been made of it. The motor-operated valves and the single, seal-oil air-compressor are so important to safety that dual power supply has been provided.

Emergency Power Supply

A 480-volt emergency tie feeder is provided between the two substations serving each "GS" Building. The switchgear is arranged to transfer automatically the emergency lighting load (a small portion of the total lighting), the instrument supply, the motor-operated valves and the communication system to the emergency tie feeder upon failure of the normal supply. This feature permits safe shutdown and closing of the isolation valves upon failure of the electrical supply. Flare valves and the flare ignition system are also operable from the emergency feeder.

Attention is called to the difference in the manner of providing emergency power for the "GS" units at Savannah and Dana plants. Emergency power at Savannah is supplied from the same generating station, Building #484-D, as the normal power by utilizing 480 v. emergency tie feeders between individually served substations. The reliability of these emergency feeders is enhanced by the existence of the common 13.8 kv. stand-by substation feeder and the tying of Building #484-D with power houses in other plant areas and with a source of purchased power.

At Dana the sole normal supply is purchased power on which the adjacent ordnance works has priority. It was necessary, therefore, to furnish a gasoline engine-driven generator as an independent source of emergency power.

Power Control

In general, all process motors, including motor-operated valves, may be fully controlled from the instrument boards in the control rooms and at stations in the field, except that blower motors can be started only in the field. Indicating lights on the boards show whether or not motors are running and whether motor-operated valves are open or closed.

A "crash" switch is provided on the instrument board for each of the production units and for the pumps associated with the purge and products systems. These switches activate rapid emergency shutdown equipment under their control. Operation of any "crash" switch causes immediate stoppage of all

pumps and blowers in the area controlled and, in the case of a production unit, closure of all motor-operated isolation valves except in the line from the Waste Water Stripper to the sewer. The latter valve is under manual and low level control only. An emergency ventilation shutdown switch is provided in the control house. Operation of this switch shuts down all ventilation in the control house to prevent entry of contaminated air.

The motor-operated flare valves are not included in the "crash" system. These are under manual control by means of switches on the instrument board.

The ignition system for the flare tower is controlled by means of push buttons at the base of the tower and on the instrument boards of the three "GS" buildings. Each ignition control station contains a pilot gas selector switch and a momentary contact push button to energize the spark and glow ignitors. The switch permits the operator to discharge a continuous pilot gas flow through the flare tower or a flow only while ignition devices are on.

Lighting

Lighting is provided in the working areas at the following approximate intensities:

Analyzer house	20 foot-candles
Control room	20 foot-candles
Laboratory	30 foot-candles
Electrical building	8 foot-candles
Pump area	15 foot-candles
Tower platforms, etc.	Sufficient for operational safety.

The lighting main circuit breaker is electrically operated by the blackout control so that all normal lighting is extinguished upon operation of the area-wide blackout circuit. Lighting in outdoor locations provides adequate intensity for the operation of equipment and safety of personnel, and in a manner similar to that employed in modern du Pont outdoor process areas. Where possible, fixtures are suspended from overhead steel. Standard walkway, upright pipe standards have been used where no overhead supports were available. Because of the height and width of the structures and vessels, lighting fixtures have been placed throughout the area, instead of using only a few "floodlight" fixtures. By this method light can be better distributed throughout the area and structures.

Control house lighting fixtures are fluorescent; all others both indoors and outdoors are vaportight incandescent.

Special blackout fixtures are also included. Gas mask cabinets and breathing air stations are specially lighted for ready identification.

Communications

The "GS" plant is provided with a comprehensive communication system to originate and receive alarm signals, emergency and local announcements, and to page personnel in the process areas. The signals are broadcast throughout each building area by means of loudspeakers fed from amplifiers in each building wing. The three "GS" Buildings are interconnected by a "bridging" line, by means of which emergency announcements and evacuation alarms may be transmitted from building to building. The "bridging" line also is connected to other process areas in the #400-D Area and to a number of non-process buildings. Signals originating elsewhere, such as air-raid alarm and evacuation alarm, can thus be broadcast throughout the "GS" plant.

A control cabinet on the operator's desk in the instrument room of each "GS" building is equipped with the following devices:

Microphone - Used for local paging in the "GS" wings and for area-wide emergency announcements.

Master Talk Switch - Makes area-wide announcements possible.

Evacuation Switch - Turns on evacuation alarm, which is heard throughout the #400-D Area.

Sound-powered Telephone - Used for local conversation in each wing.

Relays are provided to establish the following precedence of signals:

1. Evacuation Alarm
2. Master Talk (to entire #400-D Area).
3. Local Talk (within that wing).

The sound-powered telephone system is independent of the amplifier system, however, an amplifier and speaker are provided so that personnel in the process area can speak to the operator. When the operator lifts the phone from its hook, the amplifier and speaker are cut out and the operator then converses with the remote station directly via sound-powered phone. This is to avoid feedback from the speaker to the phone transmitter.

As the audible intensity requirement of the loudspeaker system is inescapably geared to the intensity of noise in the process area to be served, an estimate of this process noise was required during the design phase. Sound intensities obtained at the Dana plant blowers appeared most applicable, so these were used for areas adjacent to the large blowers; normally anticipated sound decrement data were applied to estimate the noise levels to be anticipated at various distances from the blowers. After start-up of the process, however, it was found that these estimates were entirely too low; while the noise intensity near the blowers was reasonably close to that estimated, the noise intensity at locations away from the blowers did not diminish as normally expected, probably due to sound transmission through the piping and steel structures. To provide adequate coverage, it was found necessary to increase the total speech system power to nearly ten times the originally estimated value.

At the same time that this deficiency in coverage was discovered, tests showed that the performance of the speaker and speaker transformer equipment was far short of the manufacturer's own specification. When this condition was brought to the manufacturer's attention, he replaced the faulty components with equipment which met performance specifications.

A second sound-powered telephone system permits communication among the process areas comprising the #400-D Area. This system features coded ringing by means of hand-cranked magnetos and howlers. Bell telephone and fire alarm connections were also provided in the "GS" Area.

Miscellaneous

Strip heaters and thermostats are installed in the insulated housings enclosing all instruments in which hydrates would form if a minimum temperature of 86°F. were not maintained. Heaters and thermostats are also installed for the flow meters in the blower seal oil lines to maintain constant viscosity.

All steel structures, towers and electrical equipment are grounded through a network of buried cable which is, in turn, grounded through artificial ground electrodes or through water pipe connections.

Instrumentation

Basis of Design

Control Requirements

Since the "GS" process is based upon the principle of increasing the D_2O concentration by the continuous counter

current contacting of H_2S and water at high pressures (300#) under controlled temperature conditions, the system requires complete temperature, pressure and flow control systems for the various stages. Also, because of the toxic nature of the materials and the relatively high pressures used, isolation of various components of the process, for example the towers and exchangers, is effected by numerous motor-operated stop valves. These valves were designed for operation by remote control, either singly or as a unit, from the central control room board.

Type of Control

The plant, in general is instrumented for control of all major operating variables from a remote central control room. Many points of measurement less critical for operation are not so instrumented. For example, general pressure gauges, test wells for temperature indication, thermometers and slight flow indicators are mounted locally. Blind transmitters, where used, are equipped with process gauges located in the air transmission lines for local indication as well as remote recording indication or controlling features.

With the exception of the motor-operated isolation and flare valves and several solenoid valves, all controls are of the pneumatic type. While electronic systems of control are now available, at the time of the plant design such a system was not readily obtainable at a reasonable price and with the necessary degree of flexibility.

Instrument manufacturers were contacted by du Pont at the beginning of design, and price agreements were executed for most standard designs of instruments contemplated for use. For flow control and measurement of H_2S gas and liquids containing H_2S , the special Taylor "Diaplex" flow transmitter was specified by du Pont after careful consideration of serviceability. Since the size of the plant required hundreds of instruments, consideration of economy in control room size and general operation of the plant made it almost mandatory to choose the miniature size case instruments for recording and controlling. Since such instruments were not available for temperature measurement by thermocouples, standard size instruments were used in these instances.

Control Systems

All major control is centralized in a main control room with local sensing instruments of the pneumatic transmission type. The air from these transmitters is connected to either miniature panel board mounted recorders or recorder-controllers. In the case of controllers, the air is also connected to blind controllers located behind the panel board where temperature and level service with slow response is adequate

or to field mounted blind controllers where flow and pressure service with fast response is required. The blind controllers for temperature service were also specified with derivative action to secure better control. These controllers are connected directly to diaphragm motor-operated control valves located in the process streams. In some cases, the controllers are connected in cascade to other controllers where the process variables are inter-dependent. Level control, where critical, is connected as indicated above, using the level instrument for pneumatic transmission of the signal. Where not critical, the level instruments are connected directly to control valves and also indicated on the control panel. Many less critical variables are indicated on the control panel by pneumatic transmission from locally mounted transmitters. As noted above, flow transmitters for services on H_2S bearing material are of special diaphragm sealed design developed by Taylor Instrument Company and known as "Diaplex" transmitters.

Design Considerations

General

Instruments for measurement and control of variables were chosen of standard design except as described below. They are of the construction generally specified by the instrument industry for a high order of accuracy. Control instruments were specified with proportional response, automatic reset, and derivative action, separately or in series as required by application in engineering and design for stability of control.

Pressure

Pressure instruments for Savannah were specified for full range operation. Suppressed range instruments, while theoretically capable of giving a closer control point operation, are limited to the specific suppressed range employed and therefore lack flexibility and interchangeability.

Temperature

Important temperature points are measured by thermocouples or filled bulb type temperature transmitters. For checking purposes, numerous locally mounted thermometers are installed, and thermowells only were specified for all inlets and outlets of exchangers and other points which were considered necessary for test runs. These thermowells are of standard design for the insertion of thermocouples. When operations began, permanent industrial thermometers were requested instead of thermocouples in 30 per cent of

the locations. It was then necessary to procure these thermometers with special bulb sizes to fit the previously installed thermowells.

Flow

Flow is measured by using differential pressure transmitters connected to orifice plates as the primary element. Because of sediment and hydrate formation, segmental type plates were specified for H_2S service. These specially designed plates were purchased from Taylor Instrument Company, which also furnished the calculations and specified the segmental height from flow conditions furnished by the Lummus Company. Plates for sizes 2 inches and less are of the eccentric type. Plates for steam, water, air, and other normal services are of the conventional concentric type.

Special Instruments

1. Instruments of special design are installed for measuring the H_2S content in the discard water. These were developed by du Pont Engineering and operate by measuring the turbidity developed in the sample by precipitation of sulphur with copper nitrate. Since many gallons of water are discarded from the plant, these instruments are required to monitor any over-contamination in the effluent streams from the area. Sampling points are located in the units and at distant points in the drainage ditches. Water samples are pumped from these points for continuous analysis at the centrally located instruments.

2. Anemometers were purchased and are installed at special locations on tower structures and in control rooms for direct recording of wind direction and velocity. This is a safety precaution for movement of personnel in case of leakage of H_2S from process equipment.

3. Special instruments are installed in the control area for continuous analysis of air at strategic points in the plant. This analysis is made with instruments known as "Titrilogs" rented from the Consolidated Engineering Corporation. These are designed to actuate an alarm to alert the operating personnel in case of undue concentrations of H_2S in the air.

4. Pressure instruments for measurements at points containing H_2S either in solution or as a gas are of the chemical type with a special stainless steel diaphragm for connection to the pressure point. The instrument is filled with a non-compressible fluid (water solution of glycerine) from the diaphragm to the measuring element or Bourdon tube. A similar arrangement is used by Taylor Instrument Company in the design of their "Diaplex" differential pressure transmitters. Each of the two connections is protected by diaphragm seals.

5. Due to the large size of lines and the small allowable pressure drop, the butterfly-type control valves for regulation of H_2S gas from the circulating compressors were specified. These were designed specially by Continental Equipment Company, are lined with stainless steel, and have a stainless steel flapper. They are heavy duty design, wafer-type valves with outboard bearings at either end of the flapper shafts.

Major Equipment Instrumentation

Towers The towers are, in general, counterflow liquid and gas absorption vessels or stripping towers for separation of gas and liquid. The instrumentation is of conventional type. Automatic control of flow of liquid and gas feed, of pressure by the addition of high pressure gas, temperature of feed, and bottom level by withdrawal or addition of liquid, are accomplished by standard methods. Critical points are connected to alarms for alerting operating personnel. Specific instruments used for this and subsequent pieces of equipment are completely covered in the instrument list for the entire job.

Blowers The blowers are circulating gas compressors, motor driven, with gas flow regulated by flow controllers to the suction of the compressors through the butterfly valves described above.

Exchangers Where control is necessary on exchangers, the temperature signal from a transmitter is used to control the flow of cooling water on steam to the opposite side of the exchanger by control valve regulation through pneumatic controllers.

Pumps The pumps are motor driven, the bearings and gland being cooled and sealed by special high pressure sealing liquid. No instrumentation.

Tanks The level in tanks is maintained by conventional liquid level controllers, and special alarm switches are installed for high and low levels where this condition is critical.

Utilities Flow instruments are installed for control and recording of steam to the various units. Since the steam supply pressure is not constant, a special regulating station is installed for maintaining constant pressure to the units. Special tempering units are installed for regulating the temperature of the process water used in the units. Regulators and filters are installed for air used for instrument actuation.

Control Room Facilities

Each building is provided with a control room containing an instrument panel for remotely and automatically indicating, recording or controlling the critical points in the operation. As previously noted, each building consists of eight parallel and duplicate two-stage sections divided into two wings. In addition, each wing of the unit includes one auxiliary unit. The control room for each building was divided to agree geographically with the above layout.

The instrument panel consists of twenty-eight sections of identical size divided into two U-shaped parts of fourteen sections each, one for each wing. The first three sections and the second three sections contain the instruments for the first and second production units respectively. The next two sections contain auxiliary unit instruments as well as the common pyrometer indicator. The following six sections contain the instruments for the third and fourth production units. The second half of the panel duplicates the above arrangement. The auxiliary units, however, are not duplicates but consist of two separate and distinct groups of facilities for the entire unit.

The instruments for each section of the production unit located on three panels are arranged with alarms in the top row, indicators in the second row, and recorders and controllers in three lower rows. Electrical push buttons are located below these on each of the side panels, with the two large case potentiometer recorders on the central panel.

Stop valves for process isolation are arranged with motor operators. These can be operated with push button stations located on the board. Also, start and stop push buttons are located on the board for motor operated pumps. Control valves for adjusting process variables are arranged for air operation, either automatically from control stations located on the board, or manually during start-ups or emergencies by adjustments from the control cases.

Critical control points are connected to alarms and, where these control points entail elements of danger because of deviation from the set points, interlocks are provided for automatically closing valves or releasing pressure at the time the alarms are sounded.

A complete system for inter-plant telephone communication is installed so that personnel can be contacted from any of numerous locations throughout the plant including the central control buildings.

Piping

In addition to the process and service piping within each "GS" unit, outside overhead and underground lines supply each building and connect it with the other "GS" buildings and other facilities in the #400 Area. Included in these outside lines are process lines such as product transfer lines, gas supply and flare lines, and service lines such as steam, air, water, process and storm and sanitary sewers.

The various piping systems will be discussed in subsequent sections.

Safety

Because of the hazardous nature of H_2S , the following safety features have been incorporated in the design of the building:

1. Waste water effluent is stripped of H_2S , automatically analyzed for H_2S content, and discharged through a sewer and canal system to the Savannah River.
2. A breathing air system consisting of air masks and air supply headers is provided. This permits several hours of operation or maintenance in a toxic atmosphere, or emergency egress from the area.
3. A system of valves, which may be remotely operated from the control room, isolates various portions of each unit in the event of an emergency.
4. A continuous atmospheric sampling system automatically actuates an alarm when the gas content exceeds a predetermined safe level.
5. Wind direction and velocity at the top of the towers are indicated and recorded in the control room.

The facilities listed above are discussed in some detail in the section devoted to safety of the entire #400 Area. The efforts to build safety into individual pieces of equipment are described either in that safety section (Specialized Design Problems), or in the section devoted to the development of process equipment.

PROCESS

Description

General

The "GS" facilities consist of three essentially identical "buildings", each containing eight parallel concentrating "units", plus a control house and common "auxiliary" equipment. Each building is divided into two wings of four process and one auxiliary unit each. An electrical substation is provided at each wing.

In addition to the "GS" process facilities, a single analyzer house has been provided to serve all three "GS" buildings. This house is physically located within the area of Building #411-D.

The nominal capacity of the entire "GS" area (three buildings) is 240 tons of deuterium oxide per year after credits for weak liquor returned from the "DW" plant. This rated capacity is based on 8000 hours of operation per year for each unit, at temperature levels of 104°F. in the cold towers and 266°F. in the hot towers, and at a nominal system pressure of 300 p.s.i.g.

Design was based upon recovering 15 per cent of the D₂O in the process feed water as a 10 Mol % solution for further processing in the "DW" area. That area returns a 3% solution for reworking.

Main Process

[The "GS" process utilizes the hydrogen-deuterium isotopic exchange reaction between hydrogen sulfide and water,

The equilibrium constant for this reaction varies with temperature and favors the concentration of deuterium in the water phase, with greater concentration occurring at the lower temperature. [The basic process makes use of two bubble cap towers operating at different temperatures, designated as the "cold tower" and the "hot tower". The cold tower acts as the concentrating medium while the hot tower functions as a stripper.

[When streams of H₂S gas and water flow countercurrently in a cold and hot tower connected in series, deuterium present in H₂S is absorbed by the water in the cold tower, and "stripped" from the effluent by the H₂S in the hot tower. Thus, the product tends to concentrate at the center of the system, or stage. By removing a portion of the concentrated material and replacing it with material of lower concentration, it is possible to ditch water containing less deuterium than enters with the feed.] The

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

2

of

3

concentrated liquid could be drawn off as product from a single stage, but due to the low concentration of the feed water, the tower size required to effect a reasonably concentrated product would be prohibitive. Therefore, the concentration is carried out in two stages, which permits the use of smaller columns in the second stage.

The bulk of the water feed entering the first stage towers traverses that system in a single pass, while a charge of H_2S gas is continuously recirculated countercurrent to the liquid flow. A portion of the liquid stream flowing between the cold and hot towers is sent to the second stage cold tower. The liquid leaving the second stage hot tower is returned to the first stage at the top of that hot tower. Product is drawn off as a liquid from the condenser in the gas stream between the second stage hot tower and cold tower. H_2S is removed from the product and from the process waste in the stripping columns and recycled.

Large quantities of heat are necessary to raise the temperature of the gas leaving the cold tower prior to its introduction into the hot tower, and also to add the moisture necessary to saturate the gas at this high temperature. Conversely, large quantities of heat must be removed in cooling the gas leaving the hot tower, condensing its high moisture content. It is possible to accomplish this partially by means of indirect heat transfer between the two.

Similarly, feed water entering the cold towers at low temperatures requires heating before introduction into the hot tower. After leaving the hot tower, this waste water requires preheating to reduce steam consumption in the waste water stripper. Part of the heat in the stripper overflow water is recovered by countercurrent heat exchange to preheat the feed to the stripper in the stripper exchangers. Additional heat is recovered for preheating the liquid feed to the hot tower.

Suitable heat exchangers are provided to heat or cool these liquid and gas streams flowing from tower to tower.

The crude material for the "GS" process is natural water which contains approximately 0.000143 Mol D_2O in H_2O . This water is pumped from the Savannah River and treated before being fed to the process. (For a description of the water treatment and the facilities required, refer to the Chapter entitled "Building #483-D - Water Filtration and Treatment Plant").

Process cooling water is untreated except that it receives anti-algae chlorine treatment at the river pumping station.

After the initial H_2S charge has been made to a unit, additional gas is required only to make up for leakage, loss in waste, and consumption by chemical corrosion or decomposition. H_2S gas is delivered by pipe line from the H_2S production area where it is stored as a liquid. (Descriptions of the H_2S manufacturing and storage facilities may be found in the Chapters entitled "Building #401-D - Hydrogen Sulfide Plant", and "Building #402-D - Tank Farm".)

A second source of supply to the "GS" process is the return of 3 Mol % D_2O recycling solution from the "DW" process where it is produced as a residue. This solution is pumped directly to the three "GS" building control rooms, each of which is equipped with a scale tank to receive the recycled material. The "DW" plant was "designed" to make three pumpings a day of approximately 800 gal. each, and for each of the three "GS" buildings to receive one batch. From the "GS" control room the recycled material is pumped back to the process through one of the second stage cold towers. Provision has been made to permit the selection of any single unit of the eight comprising a process building to receive this material.

The basic heat balances for a "GS" unit are illustrated by Fig. GS-1, Page 107. While only the first stage is shown on this flow diagram, the two stages are basically the same. Major operational differences, such as the non-existence of a humidifier and waste stripper in the second stage, are explained in the following process description.

Treated water at $86-104^\circ F.$ is fed to a first stage cold tower and exposed countercurrently to cold H_2S gas ($86-104^\circ F.$) which has been previously enriched in the first stage hot tower. This results in enrichment of the water flowing down the cold tower to about four times its initial deuterium content.

Water from the base of the cold tower is divided into two streams, one, containing approximately 33% of the liquid flow, is sent to the top of the second stage cold tower. The remainder is mixed with the condensate from the first stage primary and secondary condensers, heated to $266^\circ F.$ in the liquid heaters, mixed with water returning from the second stage hot tower, and exposed countercurrently with H_2S gas in the first stage hot tower. In this tower the water is "stripped" of all the valuable constituent absorbed in the cold tower plus a part of that which entered in the process feed.

The spent water from the hot tower is preheated to $384^\circ F.$ in the stripper heat exchanger and pumped to the top of the waste water stripper. Within this stripper, the introduction of live steam raises the water temperature to $422^\circ F.$ resulting

in an effluent containing less than 1 p.p.m. of H_2S . The gas from the stripper is returned to the bottom of the hot tower. The stripped waste water is sent to the stripper heat exchanger where it preheats the stripper feed. It is then piped to the liquid heater where it heats the cold tower effluent to the hot tower operating temperature. Finally, this waste water is discharged to the sewer.

H_2S from the top of the cold tower is sent to the base of the hot tower. This tower is divided into two sections, the bottom ten (10) trays being designated as the humidifier and the balance of the tower being known as the exchange section. Process gas passes through both sections, but process liquid is withdrawn only from the base of the exchange section. Cool gas enters the base of the humidifier section where it is heated to a temperature as near the $266^\circ F$. operating temperature of the hot tower as is practicable, by direct contact with hot effluent water from the primary condensers.

This humidifier water stream is a recirculating system and under ideal conditions would require only the addition of sufficient water to make up the loss due to evaporation. However, in this service, recirculation would result in an increasing concentration of solids within the stream. To offset this condition, a purge equal to the evaporation is taken from the system and sent to the waste water stripper. The balance of the water from the base of the humidifier section, plus make-up, is returned to the primary condensers where it picks up heat to repeat the cycle.

Gas, partially heated in the humidifier, then enters the bottom of the exchange section of the hot tower where it is further heated and humidified to saturation at $266^\circ F$. by the injection of live steam from the top of the waste water stripper. The hot gas rises through the hot tower where it "strips" deuterium from the process liquid. The overhead gas stream from the hot tower is then divided, 33% being sent to the base of the second stage hot tower, and the remaining 67% routed through the primary and secondary condensers. Here it is cooled and dehumidified to saturation conditions at $104^\circ F$. Condensate joins the stream entering the liquid heater as described above. The exit gas from the secondary condenser is mixed with the gas returning from the top of the second stage cold tower and then enters the bottom of the first stage cold tower in which it gives up its enriched deuterium content to the process feed water and returns to its original composition, thus completing the cycle.

The inter-tower flow of the liquid and gas streams of the second stage is analogous to that of the first stage. It has been explained that the second stage receives approximately 33% of the liquid and gas streams leaving the first

stage cold and hot towers, respectively, and returns approximately the same quantity of liquid and gas to the first stage hot and cold towers respectively. That is to say, the second stage receives a portion of the enriched liquid and gas produced by the first stage, and returns to the first stage, streams having concentrations equal to first stage conditions.

The equipment in each stage is similar in performance characteristics. The second stage differs in that it receives approximately one-third of the amount of feed and its size and capacity has therefore been reduced. The second stage differs further in that the hot and cold towers each consist of two columns in series, for structural reasons. Also, the second stage does not include a humidification section in the hot tower, and no waste water stripping facilities.

The gas passing from the first to the second stage bypasses the first stage primary and secondary condensers and enters the second stage hot tower saturated at 266°F. There is, therefore, no necessity for a humidifier. The process water from the second stage hot tower is returned to the first stage hot tower.

The second stage water cycle may be summarized as follows, and again reference should be made to Fig. GS-1. Approximately 33% of the water from the base of the first stage cold tower, having by-passed the first stage liquid heater, constitutes the feed to the second stage. This water passes through the second stage cold tower, liquid heater and hot tower, just as the main stream passes through the first stage. The water from the base of the second stage hot tower is then returned to the main stream of water entering the top of the first stage hot tower. All water condensed in the second stage is returned to the second stage hot tower except for a small portion withdrawn intermittently as product. This last condition represents a deviation from first stage practice and is not indicated on the flow diagram. The diagram indicates that the product is taken from the stream emerging from the base of the cold tower. Actually, this could be the procedure in the second stage as well as in the first. However, by drawing from the condensed vapor stream, a product very low in dissolved solids can be obtained.

A second operational difference from first stage practice is likewise not indicated on the flow diagram. In order to obtain a more favorable liquid-gas ratio in the more concentrated region of the second stage, a side stream of water is withdrawn from the hot tower, cooled and returned to the side of the cold tower. Also, the 3% D₂O recycle solution returned from the "DW" process re-enters the "GS" process at this point.

The second stage gas cycle may be considered as a by-pass around the first stage condensers. Approximately 33% of the hot gas from the first stage is delivered to the base of the

second stage hot tower. This gas passes through the hot tower, condensers, and cold tower, just as the main stream of gas passes through the first stage. The cold gas leaving the second stage cold tower rejoins the stream from the first stage condenser entering the first stage cold tower.

Auxiliary Processes

The foregoing portion of the process description discusses only the facilities provided for each unit. There are, however, other facilities serving the eight units in a building that need not be duplicated in each unit. They are located in the auxiliary bays of each wing.

Such facilities, with one exception, are supplied to each of the three "Buildings" and are so arranged that they can serve each of the eight units as required. Included in this classification is equipment for product handling, gas purging, process feed preheating, cooling water tempering, and the storage of run-down materials.

The one exception is the analyzer house located at Building #411-D and serving the entire "GS" Area. The analyzer house contains equipment for detecting the presence of unsafe quantities of H_2S in the waste water streams at designated points throughout the #400-D Process area. This equipment is described in the chapter entitled "Safety".

After the first and second stages have been operating for a period of time, the condensate at the second stage primary and secondary condensers will reach the 10% concentration desired. The total condensate will be many times the amount which can be withdrawn as product without depleting the system, so most of it is returned to the second stage hot towers via the liquid heaters.

Product draw-off is intermittent. For a few minutes each day condensate is withdrawn from each of the eight units through a pipette tank to a stripper feed tank which is installed at each "Building". When sufficient material has accumulated in the feed tank, it is pumped through the product stripper and cooler to an atmospheric weigh tank for delivery to the "DW" process. Facilities were designed for this batch pumping to "DW" to occur on an average of once a day.

A purge column is provided at each "Building" for the removal of any inerts which may build up in the cycling H_2S . The operation consists of scrubbing a portion of the gas with process make-up water. The water diverted for this purpose, having absorbed the H_2S , is sent to the four units on one side of a building or to all eight units, so that at

least four units are being purged simultaneously. The non-condensable gases are piped to the flare stacks.

Run-down tanks are provided to hold process liquid and gas for temporary periods when it is desired either to partially or completely empty process equipment. Even under emergency conditions, the provision for isolating major components makes possible the recovery of much process material. The amount of such recovery depends on the nature of the emergency and the time during which any release of gas can be tolerated.

The greater part of the hold-up liquid is contained within the first stage. However, this fluid is of such comparatively low value that it was considered uneconomical to provide the storage capacity it would require. There are two methods of disposing of this first stage process fluid: 1) through the waste water stripper and thence to the waste stream, or 2) careful dumping directly into the effluent from the remaining twenty-three units with care to keep the concentration of H_2S in the waste stream below a dangerous level.

The value of the second stage liquid dictates its maximum recovery. For a scheduled shutdown, this is accomplished by withdrawing condensate from the primary and secondary condensers. Since the amount of second stage condensate is many times that normally drawn off as product, the major part of the hold-up in a unit can be removed in a short time. About 2500 gal. of condensate may be stored in the product stripper feed tank. Further withdrawal from the system is taken to two liquid rundown tanks, each of which is sized to hold the contents of two second stage towers. Arrangement is such that one tank will receive the contents of the two high concentration towers, and the other tank the contents of the lower concentration towers.

Two second stage run-down tanks have been provided for each "Building". Since provision has been made for by-passing the regular gas inlets for start-ups without removing drain-down liquid, the probability of having to drain more than a single unit at a time was considered remote. However, sufficient process gas storage tankage is provided for each "Building" to accommodate the entire gas contents of four units - about 160 tons of H_2S stored as a liquid. Segregation of process gas in storage was not considered necessary. The gas run-down tanks are located at the Tank Farm, Building #402-D, in order to utilize the H_2S manufacturing area compressors, condensers, and other equipment.

A 4'-6" I.D. x 9'-0" long first stage drain tank is installed below grade at each of the three "GS" buildings. The purpose of these tanks is to receive the relatively small amounts of process fluid that occasionally must be drained from parts of a unit for reasons of maintenance or efficient

operation. Examples of the diversified need for a drain tank include: 1) draining a blower casing of water entrained in the gas suction line, and 2) draining the bottom head of a tower where the normal bottoms outlet is in the shell. A steam sparger in each drain tank provides means for stripping H_2S from the fluid collected, after which the remaining liquid is pumped to the sewer. Drain tanks are inadequate in size to serve as first stage liquid run-down tanks and are not intended for that purpose.

Approximately 6300 g.p.m. of treated water is required for process liquid make-up for the "GS" process (three buildings). This stream is received from the Water Filtration and Treatment Plant, Building #483-D, at approximately river water temperature, and split three ways, each branch terminating in the west wing of a "GS" building. Here the make-up water for the eight units is preheated to at least $86^{\circ}F.$, the minimum temperature desirable for the introduction of water into the first stage cold towers. Although there is only one preheater in a building, it is an integral part of the heat recovery system for all eight units. The heating medium, used to the greatest practical extent, is the combined process waste water stream from the stripper exchangers and liquid heaters in the "GS" building. Thus the preheater serves to extract the remaining useful heat from the process waste water. At times, especially during the winter when the river water temperature is at its lowest, there may be insufficient heat in the waste stream to adequately preheat the process feed. Steam is then introduced through a sparger into the waste stream ahead of the preheater.

Originally, control of a preheater was by a temperature controller with the transmitter in the process feed line utilizing the standard range of instrument air pressure to operate a three-way valve controlling the relative amounts of waste water by-passing and entering the exchanger. Failure to obtain the desired feed temperature, when the entire waste stream was entering the preheater, necessitated the manual operation of a steam valve to furnish additional heat to the waste stream. This method of control was not sufficiently flexible and was soon changed. The transmitter continues to operate over the same range of instrument air pressure but the flow control valve now operates within only the lower half of the former range with full flow through the preheater at the top of its new range. Pressures transmitted in the upper half of the former range actuate a steam valve and at the same time hold the waste water valve at the point of maximum opening to the preheater.

Large quantities (approximately 28,000 g.p.m.) of virtually untreated river water are used in the "GS" process

area as the cooling medium for the secondary condensers and miscellaneous coolers, and then are returned to the river. In all such pieces of equipment, where the process fluid being cooled contains H_2S , care is taken not to lower the temperature below approximately $86^\circ F$. because of possible hydrate formation. To eliminate this possibility when the river water temperature is low, pumps are provided to recirculate a portion of the spent cooling water, thus tempering the stream entering the condensers.

One recirculating water pump is provided at each building "Wing". Its operation is completely automatic, the amount of recirculation being determined by the inlet cooling water temperature. Provision also is made for the introduction of steam if recirculation fails to sufficiently temper the cooling water stream.

One other auxiliary process, the seal oil system, is not discussed here because its use primarily is with operation of the H_2S blowers rather than the production of heavy water. (A description of the seal oil system may be found under "Development of Design - Equipment - Blowers".)

Development

General

At the time du Pont began working with the Girdler Corporation in an advisory capacity and before du Pont assumed prime responsibility for the Dana Plant, the Dual Temperature, or "GS", Process had been relatively well established by the AEC. As design progressed, a number of significant changes were made in the general process, the most important of which are reviewed in the following pages.

The Girdler Corporation's contract with the AEC for new facilities at WROW, provided first for the design and erection of a pilot plant and second, the design of a seven-stage production unit, including such research and development as required to establish the design.

During early considerations of this process it had been decided to concentrate the deuterium oxide only to 2% and thereafter further increase the concentration by electrolytic methods. Experimental work had indicated that the 2% concentration could be accomplished in four stages. Although experimental concentration had not been attempted beyond the 2% range, there was no reason to believe that this process could not produce a considerably more concentrated product, and the cost of additional stages would be small due to the reduction in size of each succeeding stage.

This, then, was the basis for the decision to erect a seven-stage production unit, although the concentration that might be expected in the seventh stage was not accurately known.

While the possibility of utilizing the "GS" Process to concentrate heavy water to the desired degree of 99.8% was to be investigated, it was anticipated that if the end product of the "GS" Process contained less than 99.8% deuterium oxide, this concentration could be achieved by means of the electrolytic process formerly used at Morgantown. Girdler's contract included, as well, the design of the electrolytic unit. Determination of the economic concentration limits of the process and the solution to various operational problems, such as the suitability of certain materials and types of equipment and control problems, was to be accomplished through "GS" pilot plant operations. Therefore, design and erection of a pilot plant took precedence in the Girdler scope of work in order that design of the production unit might benefit by pilot plant operating experience.

It was anticipated that the desired information could be obtained from the pilot plant in sufficient time to incorporate the findings in the production plant design and thus eliminate, or at least reduce, the need for further pilot plant operation. Accordingly, the pilot plant was designed to become the 4th, 5th, 6th, and 7th stages of the production plant.

On October 5, 1950, Girdler was authorized to design and construct six production units at Dana Plant, previously referred to as WROW. Prime responsibility for this work was assumed by du Pont on November 1, 1950. By this time it had become evident that there would be a continuing need for a pilot plant. As full production from the six units would be required to meet the schedule requested by the AEC, the pilot plant was no longer considered a section of a production unit but rather as a unit in itself.

As studies and design progressed, it became evident that process and equipment complexities would make it advisable to limit the concentration of heavy water in the "GS" units to a maximum of 15-18%. Therefore, it was recommended that a water distillation process ("DW" Process) be used to increase the heavy water concentration to 98%, with final concentration to 99.8% being achieved by a batch electrolysis process ("E" Process). As both the "DW" and "E" processes had been used previously, it was believed that the required purity of product could be readily and dependably obtained without the risk visualized in the operation of the "GS" Process at concentrations of D_2O above 15-18%.

The recommendation to utilize three processes to achieve the desired end product concentration was adopted and the design for Dana proceeded on that basis. The number of stages per unit was reduced from seven to five based on the judgment that this would be sufficient to produce the desired 15-18% concentration.

It should be noted here that the calculations and estimates indicating the amount of concentration possible for each "GS" stage were based on an assumed tower plate efficiency of 50%. This assumption was first made by the AEC New York Operations Office and adopted by Girdler in its study of the process. As design and procurement proceeded without benefit of pilot plant experience, it was considered necessary to anticipate changes in plant design should a lower tower plate efficiency be experienced. The most practical method of redesigning without serious delay, should that become necessary, was to retain the existing specifications for the first stage, which constitutes the major part of the equipment, and compensate for the reduced efficiency by increasing the number and size of subsequent stages. Calculations were thereby made on a basis of 25% plate efficiency. These led to a tentative decision to design the "DW" process to receive heavy water having a concentration of 3.7% instead of 18%, should a plate efficiency of 25% develop. However, these design changes were not necessary since, ultimately, 50% plate efficiency was realized.

Factors vitally influencing the extraction and production of heavy water in the "GS" process were the pressures and temperatures at which the units were to operate. These operating characteristics were fairly well established by the AEC from their studies, and by their consultants. The conditions selected by the AEC seemed satisfactory to Girdler and to du Pont and became the basis of Dana Plant design. The subject is briefly discussed here in the interest of completeness. Further details may be found in AEC reports and the Girdler history of the Dana Plant.

The basic Dual Temperature, or "GS", Process involves a continuous flow of process water passing countercurrently to a flow of hydrogen sulphide gas in two towers operated at different temperatures, wherein the cold tower acts as the concentrating tower and the hot tower functions as a stripper. It was found that the distribution coefficient, which is the ratio of deuterium in the gas phase to the deuterium in the liquid phase, decreased with an increase in pressure at any given temperature. The decrease in the coefficient with pressure was much greater at high temperature than at low temperatures. The effect of pressure, therefore, was to bring the hot and cold tower equilibrium lines closer together thereby reducing the percentage of recovery of deuterium in the feed water. However, an increase

in pressure permitted a greater mass throughput of both liquid and gas in a given tower size resulting in a greater overall recovery in terms of pounds of heavy water extracted from the feed. In addition, the use of higher pressure decreased the steam requirements per pound of product due to the lower partial pressure of the water vapor required in the gas at the hot tower temperature. In general, high pressures tended to benefit the "GS" Process both from a production and an economic viewpoint.

Temperature was also an important factor in the operation of the "GS" Process since the distribution coefficient changes quite rapidly with temperature. The distribution coefficient increased with increasing temperature and the rate of increase was more pronounced at low temperatures. For this reason it was desirable to operate the cold tower at a relatively low temperature. However, the cold tower temperature was limited to a minimum of approximately 85°F. since at elevated pressures the hydrogen sulfide gas formed a solid hydrate with water at this temperature. Therefore, a temperature of 86°F. was selected as the design operating temperature for the cold towers at Dana.

From the viewpoint of heavy water extraction it was advantageous to operate the hot and cold towers with as large a temperature differential as possible. Since the cold tower temperature had been selected, the problem was to determine the maximum practicable hot tower temperature. Although the extraction of heavy water increased with an increase in the hot tower temperature, the steam requirements of the process increased very rapidly with temperature due to the large vapor pressure variation of water with temperature. In addition, the use of high temperatures increased the corrosion problem associated with the H_2S - H_2O system, as well as the problem of thermal decomposition of H_2S . An evaluation of these factors led to the selection of 248°F. as the design operating temperature for the Dana hot towers.

The use of 86°F. for the Dana cold tower design temperature limited the allowable operating pressure to 375 p.s.i.g. since at this pressure and temperature the H_2S gas would liquefy. In order to use the existing boilers to maximum advantage, it was decided to design for a maximum pressure of 300 p.s.i.g. and an operating pressure of 265 p.s.i.g. This also permitted the use of 300 lb. class of piping, fittings, and flanges.

During the early part of 1951, design calculations were made for the "GS" units at Savannah River. At that plant, because of the higher river water temperature during the summer, the Dana cold tower design temperature would

not be economically attainable. -For this reason, the temperature levels for Savannah were raised 10°C., to 40°C. (105°F.) in the cold tower and to 130°C. (266°F.) in the hot tower, thus maintaining the same temperature differential between towers as at Dana.

A second factor entered into the determination of optimum flow ratios. The decision was made early in Savannah design to line the major vessels in two-thirds of the units with stainless steel. A combined shell and liner thickness was to permit operation at a pressure about 40 p.s.i. higher than in the Dana and Savannah unlined towers, excluding from consideration the extra 1/4-inch of metal thickness provided as corrosion allowance in these towers. Further, it was recognized that at Savannah, the Dana temperature conditions could be maintained during the winter, and that until appreciable loss of metal by corrosion had occurred, all towers at both sites could be operated at the higher pressure level.

Accordingly, calculations were made to show the effect of variations of pressure and temperatures within these limits. The results of these calculations indicated that operation at the higher pressure level, for either set of temperatures, favored increased production, both through greater feed rate and higher percentage recovery.

Thus optimum temperatures and pressure were established. Increasing the pressure at Dana, with much of its equipment on order, was thought to present a difficult problem. The vendors of the various types of equipment involved were asked, therefore, to review their designs on the basis of an increase in tower operating pressure to 300 p.s.i.g., and 320 p.s.i.g., at the base of the waste water stripper.

The replies to these inquiries indicated that many changes would be required and that there would be a reduction in safety provisions for even the 300 p.s.i.g. condition. The conditions resulting from the application of 320 p.s.i.g. pressure would make a change to such pressure even less attractive. Accordingly, it was decided not to alter the operating pressure at Dana. For Savannah, however, with design and procurement at a much earlier stage, and higher steam pressure available, the increased general operating pressure (300 p.s.i.g.) could be, and was, adopted.

Later, new calculations were made for Dana and the conclusion was reached that the pressure could be raised to approximately 300 p.s.i.g. without the necessity of most of the changes previously indicated. Furthermore, the increase could be made safely, until corrosion reduced the metal thickness to one-half of the corrosion allowance incorporated

into the design. The pressure was increased on that basis, resulting in an increase in capacity of approximately four per cent.

As design and construction of the Dana Plant progressed it became increasingly evident that complications were to be expected in the operation of the four pairs of first stage hot and cold towers in parallel. This parallel arrangement, and to a lesser degree the multiplicity of stages, introduced major problems in control which it was desired to avoid at Savannah.

The anticipated difficulties consisted chiefly in maintaining the equilibrium of the process flow through each tower where differences in pressure drop through the several towers might cause differences in liquid level in the base of the towers. Also, it was expected that the concentration level in these towers must drop when a pair of towers was put back in operation following shut-down. It was believed that the operation of a hot and cold tower as an independent pair would be a great improvement.

A study made by AED to determine a more operable process led to the conclusion that the "GS" Process at Savannah River would consist of two stages compared with the five at Dana. One pair of towers constitute a first stage and two pairs of smaller towers a second stage. It was believed that the improved control with attendant increased productivity, made possible by the elimination of parallel flow, and the improved continuity of operation to be expected from the less complicated unit would more than justify the somewhat higher cost and greater operating hold-up of the Savannah design.

In addition, a second advantage is obtained by the change. Having the "GS" Process at Dana operating as six units meant that a unit shutdown would reduce capacity approximately 17 per cent. The two-stage units at Savannah meant that additional units would be required in order to maintain the desired production capacity. As a result, twenty-four individual process units are equally divided between Buildings #411-D, #412-D and #413-D. The shutdown of any one of these units will cause only a 4 per cent reduction in capacity.

Such a low production loss can be tolerated for sufficient time to satisfy maintenance requirements. Therefore, in general, no spare equipment was furnished for the Savannah "GS" Buildings. However, early in 1952, at the request of AED, the Design Division made evaluations and estimates, together with design, for the procurement and installation of the necessary spare equipment to maintain

continuity of operation in case it was desired to change the original decision to operate without spares.

Metallurgy

During the early studies on the dual temperature process made during World War II, one of the greatest uncertainties regarding the process was the corrosion of equipment by the H_2S -water mixtures. Materials of construction such as stainless steel, which at that time was believed necessary, were costly and difficult to obtain. Although experimental results indicated that the addition of a corrosion inhibitor to the feedwater or the use of a protective coating would solve this problem and reduce the need for stainless steel, no adequate long-term test had been made. Later, when the AEC began an investigation of companies experienced in handling hydrogen sulfide, for the purpose of locating possible future contractors, the subject of materials of plant construction was discussed with each firm. It was the general opinion that under the conditions of operations, carbon steel could be used for almost all of the equipment. The severe corrosive effects which had been attributed to hydrogen sulfide seemed to be due instead to carbon dioxide or oxygen impurities accompanying the hydrogen sulfide.

Girdler's contract with the AEC to design and construct a "GS" Process pilot plant and a single production unit of Dana, also provided for the construction of corrosion testing equipment and the initiation of a thorough testing program. Girdler's experience in the handling of hydrogen sulfide solutions indicated that mild carbon steel would resist corrosion sufficiently well to permit its use in the towers, exchangers and piping. However, as a precaution, it was planned to include a corrosion inhibitor in the liquid stream. It was assumed from the start that stainless steel would be required in the stripper and the stripper heat exchanger, because of the high temperatures to which they are subjected. It had also been assumed that the tower plates and bubble caps should be of stainless steel construction, due to their high liquid and gas flow rates. It was believed that with carbon steel the corrosion rate would be greatly increased under such operating conditions.

Early results of the corrosion tests indicated the problem to be much more critical than had been anticipated. Du Pont then instituted corrosion studies to find suitable materials of construction, and conducted an extensive search for an effective inhibitor. These efforts continued throughout the entire period during which the Dana and Savannah River Plants were being designed. This work is summarized in another section of the history. Because of the urgency of the project it was not possible to await results of corrosion tests before ordering equipment. As a result many changes were made as experience was gained. The steps taken to minimize

corrosion are outlined in the sections relating to specific equipment.

References above to changes in materials of construction are more applicable to Dana than to the Savannah River Plant. While design for Savannah was begun before Dana could be placed in operation, Savannah design was able to take advantage of corrosion test results that were not available at the time initial Dana orders were placed.

The proof that severe corrosion conditions exist in the "GS" Process, and a difference in the intent of the two plants, resulted in one major dissimilarity in the choice of materials.

After the initial requirements for heavy water have been produced by the Dana Plant and the #400-D Area, limited permanent production facilities will be needed to supply heavy water make-up requirements. Buildings #412-D and #413-D at Savannah were chosen as the permanent facilities and, because of the severe corrosion conditions, were designed with stainless steel in contact with the process fluids. Since the entire production capacity of the #400-D Area is not required to make up product losses, the process equipment in Building #411-D has carbon steel in contact with the process fluids. Since carbon steel was more readily available than stainless steel, this factor also permitted an improvement in the start-up scheduled for the #400-D Area.

Although hundreds of chemicals were investigated, a suitable inhibitor had not yet been found at the time design of both plants was completed. Therefore, no provision for the use of an inhibitor was included.

The subject of metallurgy is discussed in more detail in that section of this history entitled "Specialized Design Problems".

Safety Considerations

The primary hazard of the "GS" Process results from the use of hydrogen sulfide as a process component. This subject is treated in some detail in the chapter entitled "Specialized Design Problems", which contains sections explaining the nature of the hazard, factors contributing to unsafe conditions and the facilities provided for their reduction. Features incorporated in design in the interest of safety are discussed in the sections devoted to the development of design of the various types of equipment.

Additions to Process

As design of the Dana "GS" Process progressed, it was

found necessary to add auxiliary equipment not contemplated originally. These additional facilities were included primarily to effect more satisfactory operation of the process, but in some instances were added in the interest of safety. The principal additions at Dana were:

1. Purge towers
2. Run-down system
3. Isolation facilities
4. Water purification
5. Flare system
6. Retention basins
7. Emergency generator facilities
8. H₂S plant
9. Inert gas generation facilities

A description of these facilities and the reasons why they were, or were not, required at Savannah will be found in the applicable sections discussing a specific process or type of equipment. All were provided at Savannah except the retention basins and the emergency generator.

DEVELOPMENT OF DESIGN

Buildings

Superstructure

Early in the design phase for the Savannah River #400-D Area, the AED specified that Class III construction should be used for process buildings, though slight deviations were later authorized for the "E" Process buildings. Class III may be characterized as "conventional" construction, having good fire resistant characteristics but avoiding the use of brick, or sheet metal material, thereby producing a minimum missile hazard in case of disintegration from a blast.

Class III construction was chosen because of the substantial savings in construction cost that could be effected by its adoption instead of utilizing solid reinforced concrete Class I construction. A further consideration favoring such a choice was that because of the existence of similar facilities elsewhere, the loss of the #400-D Area process buildings would not seriously impair the continuity of the Savannah River Plant production for a prolonged period of time.

Subsequently, as the necessity for additional operating buildings within the #400-D Area became apparent, consideration was given to the use of "Temporary Construction" (TC) buildings which, toward the end of the construction period, were no longer needed for that service. The savings to be effected by relocating such buildings, and altering them as required, were attractive. However, many of these "TC" buildings,

while otherwise acceptable, failed to satisfy Class III construction requirements because of the missile hazard resulting from the use of sheet metal siding and roofing. The construction of other "TC" buildings was even less conformable because of the use of wood framing and siding. The former type was readily convertible to Class III construction by replacing the sheet metal with corrugated asbestos, but the major part of the desired savings could be realized only if the original building components were re-used.

In mid-1953, the AEC approved a Class IV type of building construction. This type may be described as "conventional" construction with no limitations on materials of construction. Thus provision was made for the use of "TC" buildings. A number of such structures were authorized for the Savannah River Plant. One, the Shelter and Shops, Building #412-5D, is in the "GS" Process area. This is a small service structure and does not present any considerable missile hazard. Building #412-5D and other former "TC" buildings within the #400-D Area are described in their respective sections of the history.

The subject of Class IV construction is discussed in this section devoted to the development of "GS" Process buildings in order to outline in a single section all of the reasons which prompted the choice of building construction for #400-D process areas, and because Building #412-5D, while not considered a part of the "GS" Process, is located within the area designated as Building #412-D.

Foundations

While the Class III construction specified for the Savannah #400-D Area was essentially the same as employed at the Dana Plant, the foundations for the "GS" units at Savannah (specifically, the foundations for the "wings" of Buildings #411-D, #412-D and #413-D) presented a very different and serious problem. While satisfactory for ordinary structural requirements, soil conditions at the site were found to be such that the ordinary type of foundation would be inadequate to meet the unusually close tolerances permitted for uneven settlement of the "GS" towers.

A thorough study of the problem was instigated and involved du Pont, the Lummus Company, the U.S. Corps of Engineers and their soils consultants, and the firm of Moran, Proctor, Freeman and Meuser, consulting engineers, engaged by du Pont to assist in foundation design.

The first steps in the solution of the problem, following physical and analytical investigations, were conferences with the U. S. Corps of Engineers' Soils Board during which the extent of soil upheaval without load was calculated.

From this beginning, suggested procedures included: 1) the use of a raft-type foundation, 2) preloading of the area, and 3) use of cellular foundations.

The use of a raft-type foundation was originally advocated by du Pont because of a considerable cost advantage, but the suggestion had to be rejected, due to the flexibility of such a foundation under existing soil conditions.

The idea of preloading the area with mounds of earth to prepare the soil for subsequent raft-type foundations was advanced by the Corps of Engineers. This plan was discarded primarily because of its time element. It was expected that adequate settling would require the area to remain under load for six months, which was not compatible with start-up schedules.

The cellular-type foundation suggested by Moran, Proctor, Freeman and Meuser was adopted. The increased depth of this type of foundation results in greater stability. It was not the most economical, but was the only type which would assure an adequate foundation for the deflection limitations established by the superstructure design.

Safety

The provisions for the safety of personnel who must remain in the "GS" control rooms during hazardous atmospheric conditions were given serious consideration. As at the Dana Plant, a slight air pressure is maintained in the "GS" control rooms to prevent gas leakage into the building. Titrilogs were provided to monitor the air intake from the stacks and, at the first sign of danger, this supply is cut-off and the intake sealed. Hose masks are available for those who must remain, and tank masks for those who may vacate the area. In rooms that are air conditioned, the air is recirculated to give some measure of comfort. Emergency power, however, is not used to continue air conditioning or recirculation. The safe period of time that men can remain in the building depends entirely upon the nature and extent of the emergency. An orderly shut down of the process is most desirable, if the emergency conditions permit.

Equipment

General

The urgent need for these facilities and those of the Dana Plant resulted in the establishment of completion schedules that tended for some time to force design along at an abnormal pace. This was particularly true with respect to Dana and was imposed by the necessity of designing without benefit of pilot plant experience or the completion of research

and development work, which was carried on simultaneously with design. This procedure resulted in many changes in design, frequently after fabrication was well advanced.

In the case of Savannah, it was possible to take some advantage of Dana design and construction experience. However, this experience was far from complete and for some time included little or no operating experience. As a result, the Savannah design was also subject to numerous changes.

Many of the design problems peculiar to this process resulted from the use of H_2S . The handling of this gas in such large quantities, and at relatively high temperatures and pressures, was without precedent. The potential hazard of the #400-D Area to animal life and vegetation was tremendous. Because of this, considerable effort was expended in providing a safe plant.

The value of the process water and the toxic nature of the H_2S gas are such that leakage from the system must be held to an absolute minimum. The sealing of shafts on rotary pumps and blowers was a particularly difficult problem.

Other major factors affecting design and posed by the use of H_2S included extensive steam tracing of equipment, piping and instruments to avoid the formation of the H_2S -water hydrate. Also, corrosion control was a major consideration. Materials of construction were selected on the basis of plant life, ease of part replacement, availability, cost, and conservation of scarce materials. In many cases, little or no information was available on similar applications and frequently design had to be changed because of new results obtained during corrosion tests.

A major factor in the design of the Dana Plant was the need for an unusually high degree of operating dependability in order to eliminate loss of materials due to shutdowns. This problem was of somewhat less importance at Savannah due to the use at that plant of twenty-four small units instead of the six relatively large units as installed at Dana. The loss due to a unit shutdown at Savannah is thereby reduced to approximately 25 per cent of that experienced at Dana.

The sections which follow endeavor to explain the design development of specific types of equipment used in the "GS" Process and, where applicable, the design problems outlined above are discussed in greater detail. For a general discussion of the metallurgical and safety aspects of the design, the reader should refer to the section of this history entitled - "Specialized Design Problems".

Towers

Exchange Towers

Since the exchange towers and trays were the most expensive items in the production units, it was only logical that they would be the limiting feature in the plant design. The general layout, design, size and number of towers were first determined and the remainder of the plant was designed around these to allow utilization of maximum tower capacity.

The process tower shells installed at Savannah are of essentially the same design as those of the same sizes used at the Dana Plant. For Building #411-D no change was made in the specified material of construction. Thus, the development of design for Savannah was identical to that for Dana.

At the time design was initiated on the Dana Plant, it was anticipated that pilot plant operations would develop the required data regarding the relative efficiency of packed versus bubble-tray columns. However, as related in the du Pont Company report on the engineering and design of the Dana Plant, it was necessary to select the tower design for that plant without the benefit of experience. The relative advantages of each type of tower were compared at that time, and the features of the bubble-tray column appeared more desirable for this service. The Atomic Energy Division, therefore, approved the selection of tray-towers for Dana and, on the basis of this authorization, design for the Savannah River Plant also specified bubble-tray towers.

As experienced during design of the Dana Plant, transportation limitations affected the diameter and height of the columns for the Savannah River Plant. Maximum diameter was again limited to 12 feet, including the projection of all nozzles, lugs and other external tower components. Similarly, the weight of the columns again required the use of the scarce heavy-duty type cars for shipment, and in some cases the use of special trains which could move only during daylight hours. As an example of this transportation difficulty, one tower vendor, located in Birmingham, Alabama, could obtain a shipping clearway to the site only by routing through Chicago and Philadelphia.

Fabrication of the Dana process towers in the field was considered one means of obtaining larger diameter towers. However, the towers would have required field stress relieving necessitating the erection of a large stress relieving furnace at the site. The time involved in the construction of such a furnace, its cost, and the problem of disposal after tower fabrication was complete made this scheme appear uneconomical.

Radiographing of the welded seams would also have been a serious handicap with field fabricated vessels. Therefore, it was considered more feasible to have the vessels shipped to the site completely fabricated. Field fabrication, thus discarded for Dana, was not considered for the Savannah Plant.

Since the hot towers required a greater volumetric capacity, it was decided to use the 12-foot diameter towers as the first stage hot towers at Dana. On this basis it was determined that 11-foot diameter towers would be adequate for the first stage cold towers. Later, these diameters were chosen for the first stage at Savannah. Tray spacing for the Dana towers was selected on the basis of gas throughput and height of tower. Calculations indicated that approximately 70 trays per tower would be required for the desired separation. Obviously, for a given number of trays the height of the tower will vary directly with the tray spacing, and it is also true that the allowable gas velocity increases with tray spacing, and at a faster rate than does the tower height. A tray spacing of 18 inches, requiring a tower 116 feet high, tangent to tangent, was chosen as the most desirable and practicable for Dana. The same tray spacing and number of trays were used in the first stage towers at Savannah. With the addition of a 6-foot skirt, the over-all tower length became 122 feet.

Establishment of the 122-foot length (including skirt) and the 12-foot maximum diameter of the shell did not mean that complete 11-foot and 12-foot tower shells for either plant could be shipped in one piece. In some instances the length was excessive, but in all cases the base ring diameter exceeded the 12 feet and was therefore removed for shipment. When length was a determining factor, a portion of the skirt was detached from the vessel and welded to the remaining section after arrival in the field. In all cases, the part of the skirt in contact with the shell was welded to the shell and stress relieved at the fabricator's shop so that no additional heat treatment was necessary after the lower section was welded on at the site.

While designing towers for Dana, consideration was given to the use of an inside projecting base ring which would have allowed the vessel to be completely fabricated by the vendor. However, the difficulties which would have been involved in tower erection were far more serious than the necessity of welding the base ring to the vessel in the field. This type of base ring was not considered for Savannah towers.

At Dana, the second stage towers were sized to have 25 per cent of the first stage tower volume, because that proportion of the first stage process gas and water flow was advanced to the second stage. The 25 per cent split had been

accepted by both the Girdler Corporation and du Pont from the design by J. S. Spevack for the AEC.

At Savannah, however, that ratio (25%) was not maintained. The desire to save time and design expense resulted in the duplication of the 6-foot 6-inch diameter Dana third stage tower shells for the Savannah second stage towers. Having made this choice, the tower internals, pumps and blowers were arranged and/or sized to obtain the optimum performance for towers of this size operating in the second and final stage. The result was approximately a one-third split of the first stage process flow.

Considerations of tower internals, the liquid-gas ratio, vapor velocity and other process conditions, dictated specification of the following features for the 6-foot 6-inch diameter towers. Tray spacing of 18 inches for the hot towers and 15 inches for the cold towers was determined. Since the column diameter for the cold towers is slightly greater than required for the proposed operating velocity, the tray spacing could be reduced. Also, the hot towers required 140 trays and the cold towers 168 trays. For structural reasons, this last condition was met by using two 70-tray and two 84-tray columns, each pair in series, for the hot and cold towers, respectively. Because of the 15-inch tray spacing in the cold towers, all four towers are the same height.

The severe corrosion of carbon steel equipment in this service made the use of stainless steel-lined or stainless-clad vessels desirable. However, the cost of such lining, the delay which would have resulted in the completion of the vessel, and the fabrication problems which would have had to be worked out in the short time available made the use of stainless-lined vessels at Dana prohibitive. Also, in the interest of speed, and because Building #411-D contains the temporary "GS" production facilities, stainless-lined towers were not used in that portion of Savannah River Plant.

The decision was made to use silicon killed carbon steel vessels, with a 1/4-inch corrosion allowance on all integral parts exposed to the process conditions. All shell plates, heads and vessel nozzles were examined for laminations by reflectoscopy. Any part which contained severe laminations was rejected, and all minor laminations were vented to atmosphere by drilling holes through the plate to the depth of the laminations. All the vessels were completely radiographed and stress relieved after all fabrication was complete. No welding was allowed on the vessels after they had been stress relieved. The rigidity of specifications resulted in a large percentage of rejections in the first batches of steel rolled. In fact, it became necessary to relax the specifications for the use of killed steel for nozzles and flanges for the first

"GS" unit at Dana to avoid delay in equipment delivery. The desired materials were available for Building #411-D at Savannah since those facilities were not ordered until a later date.

The tray support rings in the towers of both stages of the eight units in Building #411-D are of carbon steel. When designing towers for Dana, consideration was given to the use of stainless steel rings as an alternative to the heavy carbon steel construction required to obtain full corrosion allowance on all exposed sides. This idea was discarded because of the undesirability of welding stainless steel to the carbon steel shell.

The tower vendors were permitted to choose one of several methods of fabrication that would prevent the formation of confined artificial laminations between the tray ring and the tower shell. These included full penetration welding, the method most generally used, and the use of a ring with a grooved edge against the shell - the ring being drilled to vent the groove.

For Dana, lining of the vessels with Gunitite was considered. However, this type of lining was rejected because of the fabrication problems involved and the uncertainty as to the degree of protection that would be obtained.

The towers, and all other process vessels for both "GS" plants, were constructed according to the 1950 ASME Code for unfired pressure vessels. A wind load equivalent to a velocity of 100 m.p.h. was allowed. With few exceptions, all nozzles were constructed of long welding neck forgings, and were reinforced to withstand the maximum allowable pressure of the vessel shell in the uncorroded condition. The minimum nozzle size of the process towers was 2 inches. There were no threaded connections in contact with the process materials. The manway gaskets were 1/16-inch compressed asbestos Buna S bonded.

As explained under "Process-Development-Metallurgy", Building #411-D at the Savannah River Plant was designated as a "temporary" facility. The Building's life expectancy being the same as that of Dana Plant, the same materials of construction for tower shells were specified and identical requirements regarding selection and inspection of materials were maintained.

Buildings #412-D and #413-D were designed as the permanent part of the "GS" Plant. The hot and cold towers in these two buildings differ from those in Building #411-D only in the materials from which they were fabricated. It has been explained that the use of stainless steel was

desirable but the prohibitive cost and intolerable delay resulting from the substitution of this metal for carbon steel prevented its use for towers at the Dana Plant and Building #411-D at Savannah. However, when applied to the permanent facilities, these reasons lost much of their validity and failed to offset the indicated advantages from the use of stainless steel. Accordingly, the specifications for Buildings #412-D and #413-D called for either stainless steel-lined or stainless-clad process towers.

For the lined or clad towers, the same over-all shell thickness was specified as for the comparable all-carbon steel towers in Building #411-D. The thickness of the stainless steel was fixed at 7/64-inch for all towers, resulting in a corrosion allowance for the carbon steel portion of the shells of approximately 1/8-inch. This carbon steel was of the same quality and was subjected to the same rigid inspection as that for the towers in Building #411-D. The stainless steel parts of the tower shells in Buildings #412-D and #413-D are Type 316.

Several schemes for tower erection at Savannah were considered. The method used at Dana, involving the use of ginpoles and the rail cars on which towers were shipped, was chosen for that plant because it appeared to be the most rapid. However, it necessitated erection in a very definite sequence. This required receipt of the towers at the site in the established sequence so they could be erected as they arrived and the rail cars released as soon as possible.

This sequence requirement resulted in a most complex schedule of tower fabrication, shipment and erection. The arrangement at Savannah, having only a single row of towers on either side of a building, simplified the problem somewhat. In view of this different layout it was decided to obtain a 200-ton stiff leg derrick so that the towers could be erected in any sequence and without the use of the rail cars. Thus the towers could be stockpiled on the ground and the cars released promptly. However, procurement difficulties regarding the derrick made it necessary to erect the first three Savannah towers by the Dana method. Anticipating this possibility, two ginpoles had been sent from Dana to Savannah and the first towers delivered had been ordered with lifting lugs for both the derrick and poles, so erection schedules were not delayed.

All of the process towers at Savannah are conventional columns built in one section with manholes in the side of the shell for access to the tower and for bubble tray installation. The trays in these towers all have manways removable from either the top or bottom of the tray so that trays may be inspected or repaired without removing them from the towers.

A characteristic of the Savannah "GS" Plant is the use of modular production units. Building #411-D comprises eight such units. The numerous small units, as compared with Dana, make this possible. Thus, one set of unit drawings was sufficient and the degree of equipment interchangeability attained between units was a decided improvement over that at Dana.

In an effort to promote interchangeability in the design of the 6-foot 6-inch ID towers within a unit, and thus further facilitate erection, identical fittings were placed on both second stage hot towers and both second stage cold towers. However, sample connections and drawoff and inlet connections were not required by process conditions for both towers in each pair.

Several design features are common to some or all of the process towers. Among these are drain and bypass facilities, impingement plates, dip pipes and lifting devices. These provide increased tower life and improved flexibility of operation, and facilitate erection and maintenance. However, operating conditions induced numerous variations in tower design. For example, a considerable liquid holdup is provided for in the bottom of the first stage cold towers. However, the first stage hot towers are not provided with any appreciable holdup volume since the base of the column serves as the humidifier section. Consequently the process liquid draw-off from the eleventh tray is connected by a pipe line to a hot tower drum. This drum provides for the base control of the hot tower. To reduce the possibility of tray damage, should some abnormal occurrence cause backing up of liquid from the drum into the tower above the eleventh tray, provision is made for overflow into the humidifier section where the danger of tray failure is thought to be less likely.

The holdup in the cold tower bottom and in the hot tower drum constitutes the only normal storage capacity provided for first stage process liquid. The relatively low value of this liquid does not justify the cost of rundown facilities. The method of disposing of the holdup in the event a tower must be emptied, is given under "Process - Description".

In the second stage, the value of the process liquid has been increased considerably, while the quantity in process has been greatly reduced. It was, therefore, desirable to provide adequate holdup in case of a shutdown and that limited rundown facilities be furnished to store the liquid in the event it is necessary to empty a tower. The rundown facilities are discussed in a subsequent section.

When a unit is shut down, the second stage hold-up is normally stored within the towers. Since the drain-down liquid level will rise above the regular gas inlets, necessitating removal of the liquid before restarting, provision is made for introducing gas at higher elevations until normal operation is possible. An exception to this storage procedure is the lower (processwise) of the two second stage cold towers. Because of the high value of the liquid at the bottom of this tower, the highest to be found in any tower of the unit, it is considered unwise to risk loss by allowing this liquid to collect in the tower bottom. A cold tower drum with a feed from the tower bottom is used as an external tower base section. The actual tower bottom is run "dry".

Uniform distribution of the liquid is especially important in the split-flow type trays in the humidifier section of the first stage hot towers to prevent all, or a major portion, of the liquid from being handled on one side of the tray, thus allowing a relatively free bypass for gas on the other side of the tray. This uniform distribution was obtained by the use of special internal feed pipes. Also, partial baffle plates were installed in and above the center weirs to minimize gas bypassing across the trays. Partial baffles only are used to prevent the build-up of unequal pressure areas in the tower.

Since the corrosion rate within a unit was expected to be high with a relatively high solids content resulting in the liquid, the drawoff from most of the towers is taken from the side of the base rather than through the bottom head. This minimizes the possibility of introducing scale into the process pumps. Dip tubes are provided in these liquid outlet nozzles, extending down into the bottom head of the tower. Drain connections in the bottom head permit blowdown of scale deposits as required.

However, the lower (processwise) of the two second stage cold towers does not utilize this design; because of the value of the liquid the tower bottom is run "dry".

Dip pipes are also employed in all towers to distribute liquid feed to the proper location on the trays. The designs vary in complexity from the distributors used in the waste water strippers and in the hot tower humidifier sections, to a simple turned-down elbow fitting in the second stage cold towers.

Impingement plates are installed in all towers in both stages to prevent erosion of the tower shell by the gas entering at the base. In general these impingement plates are located against the shell wall opposite the nozzle, but in special cases, such as at the stripper overhead stream feed point in the first stage hot towers, the plates are installed

at the nozzle to prevent damage to tower internals. All impingement plates are made of stainless steel and are designed in sections to be removable through the tower manholes.

Waste Water Stripping Towers

The waste water stripper is 5 ft. ID x 28 ft. high and has a total of 12 split-flow bubble cap trays, except Unit #7 in Building #412-D. (See next section - "Bubble Cap Trays".) This tower serves to remove H_2S from waste process water by direct steam stripping. Overhead gas from the stripper is returned to the bottom of the hot tower exchange section.

The initial concept of this tower for Dana was a packed tower. Later, concern was expressed over the liquid distribution in such a tower and design was changed to the use of bubble cap trays. Bubble cap trays were the only type of installation considered for Savannah River until late in the construction phase when AED, wishing to evaluate slat-type trays in this service, chose unit #7 in Building #412-D for the study.

Stripper tower operating pressure and temperature were set by the minimum required to introduce the overhead gas to the hot towers, (approximately 300 p.s.i.g. and 408°F.). The provisions for feed distribution and for flow and pressure equalization, which are made in the humidifier section of the hot tower, were also included in the design of this tower.

The eight waste water stripping towers in Building #411-D, like the other process towers in this building, have carbon steel shells and tray support rings. The shell plates were subject to the same specifications and inspection. Similarly, the waste water stripping towers in Buildings #412-D and #413-D like the other process tower shells in those buildings, are designed for a longer life by utilizing stainless steel. The discussion on the use of stainless steel for the hot and cold towers in Buildings #412-D and #413-D, given earlier in this section, applies as well to the waste water strippers, except that the latter are all fabricated from Type 316 stainless-clad plate.

Of primary importance in stripper tower design were the efforts to prevent the discharge of waste water containing dangerous concentrations of H_2S . Means of detecting such a condition were developed and are discussed in another section of this history.

Many of those phases of Savannah River tower design that were actually developed for Dana, have been outlined above in a condensed form. A more detailed discussion of that

development may be found by referring to the Engineering and Design History of Dana Plant.

Trays

The bubble cap trays in the seven towers constituting a single process unit are, in general, of standard design - a slotted cap and riser held to the tray proper by a bolted strong-back assembly. The tray, which is made in sections to permit installation or withdrawal through a tower manhole, is supported transversely in the tower in light channel purlins which, in turn, are supported by clamping to the tray bars welded on the inside circumference of the tower shell. Manways are provided in each tray to facilitate access in the towers.

Liquid flow across the tray is controlled by weirs attached to the tray, and liquid seal height on the tray is controlled by the adjustable exit weir. The setting on the exit weir fixes the minimum liquid depth (the distance from the tray to the top of the weir plus the height of the liquid crest during flow) and the maximum liquid depth at the fixed inlet weir is then dependent upon the hydraulic gradient across the tray. The liquid is conducted from one tray to the next lower tray by downcomers attached to the trays.

To obtain high liquid flow rates on the tray and yet keep the pressure drop of the gas flow through the caps to a reasonable value, and to provide stability of operation, two types of bubble caps were specified. The bubble caps close to the inlet weir are higher than those on the exit weir side of the tray to compensate for the hydraulic gradient and to provide an essentially uniform depth of liquid over the entire tray area for the gas to pass through.

Two types of trays, cross flow and split flow, are used generally at Savannah River. Cross flow trays, where liquid flows from one side of the tray to the other, are used throughout the process with two exceptions. Split flow trays, where the liquid flows from both sides toward the center or from the center toward both sides, are used in the humidifier section of the first stage hot tower and in the waste water stripper.

A third type, a tray of special design, is used for the dry plate (tray No. 70) in the first stage cold tower. This tray has no weirs and two of the slots in each cap are cut through the skirt so that there will be minimum liquid retention on the tray and thus increase the plate efficiency as a mist eliminator.

Special considerations in tray design were made as overall design progressed, due to suggested improvements or because

of unsatisfactory test or operating experience at Dana. Modification of the bottom tray seal pans on the split flow trays was required to prevent impingement of the inlet gas stream on the liquid cascading from the middle of the tray down into the liquid pool in the tower base. As originally conceived, this liquid wall would, in effect, baffle off one side of the tower and upset gas flow distribution. This condition was corrected by building up the sides of the seal pan and cutting down the end sections, causing the liquid to flow over the ends of the pan and leaving the center section of the tower base free for gas passage.

An alternative bubble cap assembly design was submitted by the tray vendor, Gilbert & Barker, to utilize wedges instead of bolting for holding the cap-riser assembly to the tray, thus reducing cost of the tower internals. Although the design was considered feasible by du Pont, the timing of the suggestion and the delivery requirements of trays were such that use of the wedge-type cap assembly was not significantly attractive and, consequently, the original bolted design was retained. However, to develop information for possible use in the future, 500 Type 304 stainless steel wedge-type caps were purchased and installed at random for evaluation in a production unit.

Early in 1952, after approximately three weeks of operation of the first Dana "GS" unit, a large percentage of the trays in the hot tower were found to be dislodged. Minor damage was also found in one cold tower and the stripper. The exact cause of this damage could not be established and subsequent start-up of this and successive units failed to reproduce the conditions which caused the damage.

As a result of these difficulties the design of trays, tray supports, etc., was reviewed. Certain inadequacies were found and corrected at Dana and the design for the Savannah trays was modified to include these changes. The principal improvements consisted of (1) providing additional supports to the downcomer plates on the cross flow trays by attaching the bottom edge of the downcomer plate to the weir beam on the tray below, and (2) reinforcing the trays in the stripper towers. The former was considered necessary to hold the plate in position and to prevent its being blown tightly against the inlet weir, blocking off the downcomer and restricting liquid flow down the tower. The latter was thought desirable because the direct steam stripping action was considered to be more violent than the gas-liquid contacting in the other towers. Although further strengthening of trays in the hot and cold towers was considered, and comprehensive tests and analyses were performed by du Pont at Dana and at the vendor's shops, costs were shown to be high and benefits relatively small, so the program was curtailed.

The initial design of trays for Savannah did not provide drain holes. It was reasoned that after a shutdown the unit could be brought on stream and to equilibrium much more rapidly if it were not necessary to load the trays each time. After the tray collapse at Dana it was decided to provide drain holes in an attempt to minimize conditions where liquid could build up on the trays and possibly cause their collapse.

Somewhat related to the drain hole phase of design, was the problem of tray leakage. To keep leakage to a minimum, original specifications provided for the packing of tray purlins at the tray bar joints, and the gasketing of tray sections around their periphery and at the joints between riser and tray. In addition, relatively strict leakage tests and inspection procedures were specified, both at the vendor's shops and by du Pont in the field, to assure that workmanship in the fabrication and installation of the tray components was of high caliber. The delivery of trays was often delayed because of these specifications.

Subsequent developments at both Dana and Savannah River, however, demonstrated that the amount of leakage normally obtained with ungasketed metal to metal joints was not as severe as thought initially. The use of listing tape and other gasket materials was discontinued and leakage tests were relaxed. However, locations where the trays showed poor fit-up or overly large openings were still gasketed or packed to avoid excessive spill-by, especially if near the inlet weirs. The relaxation of the original specification concerning tray leakage materially improved tray procurement difficulties.

Another significant modification resulting from the initial Dana operating difficulties was the revision to the eleventh tray total drawoff arrangement in the first stage hot tower. This is discussed in the preceding section of this history.

Late in 1952, a new physical phenomenon of H_2S -water systems was discovered at Dana which resulted in modification of the bubble caps in waste water stripper towers and in a development program for a new tray design. Operating experience revealed that iron sulfide is soluble in H_2S -saturated water to a greater degree than in the stripped waste water resulting, in the production plant, in an accretion of iron sulfide solids on the upper stripper trays which either partially or completely blocked slots in the bubble caps. Tests made by the Engineering Research Laboratory confirmed the opinion that the trouble was caused by precipitation of iron sulfide compounds as hydrogen sulfide was stripped from the process liquid waste. This difficulty was estimated to be only one-fourth to one-sixth as severe at Savannah as at Dana. The difference is probably attributable

to the fact that the bubble caps at Dana are Type 410 stainless steel while those at Savannah are Type 304 stainless steel, the latter having less tendency to corrode in H₂S-water service.

At Savannah River, action was taken to prevent blocking of the trays by cutting out the lower two-thirds of alternate ligaments of bubble caps in the top six trays in the stripping towers. This increased the free area and still retained the bubble forming features in the caps. In addition, an open slat type tray design was developed, shown by test to be dynamically stable. Accordingly, a set of prototype trays was fabricated and installed in place of the top six bubble cap trays in unit #7 of Building #412-D. The purpose of this installation was evaluation, in case further corrective measures become necessary at either Dana or Savannah. The slat-type tray consists essentially of 4-inch light stainless steel channels laid, flange down, on 6-inch centers across the tower. Three layers of such slats are installed for each of the six bubble cap trays replaced.

All "GS" bubble tray components at the Dana Plant were made of Type 410 stainless steel which, at the time the trays were ordered, appeared to be a suitable material. Subsequent metallurgical studies indicated that Type 304 stainless steel is somewhat more resistant to corrosion in this particular type of service. Prior to this investigation, the orders for the Savannah bubble trays also had specified Type 410 stainless steel. However, it was not possible to change the entire order to Type 304 since the vendor had already received certain quantities of Type 410 stainless steel and a national shortage of all types of stainless steel existed at the time.

The following is a tabulation of the various types of materials furnished for the bubble trays in the eight "GS" units which constitute Building #411-D. The internal parts of all tray towers in Buildings #412-D and #413-D are Type 304 stainless steel.

Units 1 to 8	Type 304 SS Caps and Strongbacks
Units 1 and 2	Type 410 SS Strongback bolts and nuts
Units 3 to 8	Type 304 SS Strongback bolts and nuts
Units 1 to 8	Type 410 SS Trays, Purlins, Risers and Hardware.

Purge Towers

Purge towers, or scrubbers, are provided to permit purging undesirable gases from the recirculated H₂S with a minimum loss of H₂S. Process feed water is used to scrub the H₂S from the purge and return the H₂S to the process while less soluble CO₂, N₂, H₂ and O₂ are vented.

The scrubbing equipment selected is similar to that used at the Dana Plant, consisting of a primary and a secondary packed tower. The latter is mounted on the top of the primary tower to form a single purge unit. At Dana a purge tower was erected at each "GS" unit, and the operation consisted of scrubbing a continuously bled portion of the circulating gas. At Savannah, however, a single purge unit was supplied to each "GS" Building (eight units) to simplify the facilities. Arrangement is such that simultaneous purging of either the four units of one wing or the eight units of one building is possible. Attention must be given to proper distribution of the feed water, which is used to absorb the H_2S , in order to guard against upsets in the pressure levels of the various units.

The three Savannah River purge towers are sized approximately as follows: the primary tower 5-foot I.D. by 21-foot tangential height with 12 feet of ceramic Raschig rings; the secondary tower fabricated from 12-inch extra heavy pipe 18 feet long, flange to flange, with 15 feet of Raschig rings. With the use of a 17-foot high skirt and a 5-foot diameter by 12-inch diameter transition head 2 feet 2 inches long, the combined over-all height is 58 feet 2 inches. The purge tower for Building #411-D was fabricated from silicon killed carbon steel. However, the primary tower shells for the permanent "GS" buildings, Buildings #412-D and #413-D, were rolled from Type 316 stainless steel clad plate, and the secondary towers were fabricated from Type 316 stainless steel, schedule 40, 12-inch pipe.

Heat Exchangers

General

Heat exchangers are provided throughout the system to conserve heat, and to introduce or remove heat energy where necessary. These exchangers are installed vertically, except as noted, on the third and fourth floors of the open steel structure adjacent to the towers.

Since each unit of the eight comprising Building #411-D is essentially identical, only the heat exchangers in the two stages of one unit are described here. However, the exchangers used in connection with product stripping and cooling, and feed water heating (facilities serving all eight units) are also included. It should be noted that the humidifier section (bottom ten trays) of the first stage hot towers is a part of the heat exchange system. The functions of the various heat exchangers are summarized below:

<u>Equipment</u>	<u>Function</u>	<u>Medium</u>
a. Liquid heaters	Heat liquid from cold tower to hot tower temperature.	Stripped process waste water leaving the stripper exchangers.
b. Steam heaters	Heat liquid leaving 2nd stage liquid heaters to hot tower temperature.	Steam
c. Primary condensers	Cool gas leaving the hot tower*	Recirculated humidifier water
d. Secondary condensers	Cool hot tower gas from primary condensers* to cold tower temperature	Cooling water
e. Stripper exchanger (waste water)	Heat hot tower process liquid effluent to stripper temperature	Stripped process waste water leaving the stripper.
f. After cooler	Cool gas from 2nd stage gas blowers to cold tower temperature	Cooling water
g. By-pass cooler	Cool hot tower liquid to cold tower temperature	Cooling water
h. Humidifier section of hot tower (first stage)	Heat entering gas toward hot tower temperature	Recirculated humidifier water
i. Water preheater	Heat feed water to cold tower temperature	Stripped process waste water leaving the process
j. Product stripper preheater and stripper re-boiler	Heat product to stripping temperature	Steam
* A part of condensate from 2nd stage primary and secondary condensers is withdrawn as product and sent to product stripper.		

<u>Equipment</u>	<u>Function</u>	<u>Medium</u>
k. Product stripper	Cool gas from stripper	Cooling water
l. Product cooler	Cool product to near cooling water temperature	Cooling water

The heat exchangers are arranged for interchange of heat between both hot and cold gas streams and hot and cold liquid streams. The gas heat exchange load is about 2.4 times the liquid heat exchange load in order to condense water vapor in the gas stream. The latent heat of condensation of steam in the hot gas accounts for over 60 per cent of the gas heat exchange load, and the total exchange of gas sensible heat is only slightly less than the total exchange of liquid sensible heat.

Because of the heat dominance of the water vapor portion of the gas stream, the heating phase is termed humidification and the cooling phase termed condensation. Gas-to-liquid exchange was employed to economize on heat exchange surface and simplify the humidification operation. Thus, the humidifier comprises the bottom ten plates of the first stage hot tower through which the cold tower gas flows up counter to the recirculated humidification water, which absorbs heat from the gas and steam leaving the hot tower. The simultaneous heating and humidification of the gas are effective because of the intimate contact between gas and liquid. Water to make up for that evaporated from the humidifier liquid stream and that removed in the purge stream is taken from the warm waste water stream leaving the process. Since gas leaves the humidifier somewhat below hot tower temperatures, the heat deficiency is made up with direct steam injection.

The hot gas leaving the hot towers must be cooled to cold tower temperature. This is partially accomplished by the cooled water from the bottom of the humidifier section. Of the total cooling required, 70 per cent is accomplished in the primary condensers, the heat removed from the gas being recirculated to the humidifier. The remaining 30 per cent of the heat removed is adsorbed by cooling water in the secondary condensers and is heat lost from the system.

The exchange of heat between the liquid stream in the liquid heaters is accomplished by using the hot tower liquid to heat the cold tower liquid. The hot tower effluent (waste water) passes through the stripper exchangers where it is heated to near stripper operating temperature. This effluent then passes through the stripper where H_2S is removed by contact with steam. It then flows back through the stripper

exchanger to heat the liquid entering the stripper. As much of this waste water as is needed is used to heat the liquid leaving the first stage cold tower to hot tower temperatures. The remainder of the waste water performs the same function in the second stage where any heat deficiency is made up by heating the liquid with steam.

Cooling water at a minimum of 30°C. (86°F.), saturated steam at 345 p.s.i.a., and heat exchanger approaches no closer than 10°C. (18°F.) to cooling water temperature constituted the basis for design of this equipment.

The design of the heat recovery system of the two-stage "GS" plant at Savannah River utilized the basic arrangement employed at Dana modified, in general, only to accommodate the flow sheet revisions necessary to reduce the process from a five-stage to a two-stage operation. The humidifier-condenser heat recovery cycle and the waste water heat recovery system are identical in concept at both plant locations. Details of the Savannah River design are discussed below.

Choice of Type

In general, the "GS" heat exchangers are similar to standard units used throughout the chemical and petrochemical industries. Within the production unit, all exchangers are of shell and tube construction, with the exception of the steam heater which is a jacketed pipe unit. In the main, all the exchangers are single pass units, both on the shell and on the tube side. The bypass cooler constitutes the only exception, having six passes on the process or tube side.

Initially, the Lummus Company proposed the use of horizontal units with unique applications of the mediums in the exchangers. This idea was abandoned early in the design and all units were altered to a vertical design with relatively standard flow arrangements as used at Dana.

There is one major difference between units in the two plants. At Dana, the process stream in the primary and secondary condensers is in the shell. For Savannah River, however, it was determined that better heat transfer rates could be obtained by reversing the mediums in these condensers. Although the mediums were reversed, this rate advantage was not utilized at Savannah River by reducing the physical size of the exchanger itself. The design did, however, result in an eventual saving in heat exchange investment since it was not necessary to line with stainless steel the 48 secondary condenser shells in Building #412-D and #413-D to make their operating life compatible with other

equipment exposed to process fluids.

Other advantages gained by changing the mediums included:

- (1) minimizing the number of pieces subject to corrosion, and
- (2) reducing cost by eliminating the corrosion allowance on shells, baffles, etc.

The adoption of this change for Savannah introduced a separation problem not experienced at Dana. Where H_2S -steam mixtures had been flowing on the shell side, condensate could be drawn off from the bottom of the shell. Changing the gas flow to the tube side necessitated the use of separators after the condensers. The subject of "Separators" is treated in another section of this chapter.

Slip Tubes

All heat exchanger units have a floating tube sheet to accommodate tube expansion. The floating head closure is inside the shell cover and necessitates the use of an outside packed joint on the piping connection to the floating head cover where the pipe passes through the shell cover.

This slip tube joint consists of a du Pont Standard stuffing box using soft packing and a lantern ring. Adjustment and take-up of the packing is accomplished by an adjustable bolted gland accessible from the outside of the unit.

Since the slip tubes are of carbon steel, it was anticipated that contact with the process materials, or even water, would result in deterioration of the tube surface, thereby destroying its effectiveness as a slip joint. Stainless steel sleeves were used to offset this disadvantage. Installation of the sleeves was effected in three ways for the Savannah River exchangers: (1) welding on a thin plate, (2) depositing an overlay, or (3) actually fabricating a section of stainless steel pipe as part of the slip tube, i.e., making the slip tube of both carbon and stainless steel. This last method, although providing for adequate functioning of the slip joint, resulted in an extremely severe metallurgical-mechanical condition. The first two methods were used with complete success.

Another feature of the slip tube in the single pass exchangers is the piping and connection. With this type of exchanger the shell cover must be completely removed to permit removal of the floating head cover and, therefore, the piping end connection on the slip tube must be designed to pass the shell cover. This problem is normally handled, with exchangers of this design, by utilizing a screwed end connection. Such a connection would not meet the rigid requirement

that for this service all process piping connections were to be flanged and welded. A special end connection was designed which satisfied both equipment disassembly and process piping requirements. The pipe end was threaded with a standard straight thread and faced off so that when a standard, screwed, raised face flange was installed the end connection was equivalent to a small male faced flange connection. This design utilizes a gasketed joint, permits the ready removal of the flange to facilitate disassembly of the floating head of the exchanger, and provides a standard end connection to match the process piping.

A unique feature of the design of the slip tube is the inclusion of the lantern ring in the stuffing box, although the packing is not to be lubricated. The purpose was to provide for continuity of operation in the event of a serious leak. It was anticipated that when such a leak occurred, high pressure water could be connected to the lantern connection in the stuffing box and the escape of H_2S or H_2S -saturated water prevented by "pressurizing" the packing and causing preferential leakage of the "sealing" water. This feature may be of value in preventing hazardous leaks in the liquid heaters and in the stripper exchanger, all of which carry some H_2S -bearing water in the shells, but it is of more particular importance in the primary condensers where there is H_2S -saturated water on the shell side.

As originally installed, the slip joint employed an asbestos rope packing, with graphite and mineral oil lubricant. In the summer of 1952, however, it was demonstrated at the Dana Plant that this packing was not suitable because of the relatively rapid leaching of the lubricants in process service. As a result "Teflon" impregnated asbestos rope packing was purchased and installed. Although more expensive, the "Teflon" impregnated packing permits desired stuffing box operation and the leaching and general disintegration of the packing is not a problem.

Miscellaneous Connections

Many essentially standard features are included in the basic exchanger design including drains, vents, thermowell connections, sampling, pressure measurement and pressure relief connections. The sampling and pressure measurement connections, however, are not a part of the exchanger itself but are located in the piping immediately adjacent to the exchangers. This was done to reduce the cost of the exchangers by eliminating as many special connections as possible. Since flange connections are required in process piping, the exchanger nozzles would have been extremely clumsy and difficult to fabricate. Process requirements necessitated the use of many sampling connections and it was decided that these

could serve also as pressure measurement connections. Pressure indication at exchangers is not a normal operating requirement.

Special piping connections and relief valves were provided in most of the exchangers to prevent overpressure on either the shell or tube side. This overpressure relief protection is required to minimize the damage to equipment and personnel which would occur if pressure were to build up in the exchanger to a point where the unit would rupture. For example, if the valves in both the outlet and inlet water lines to the aftercooler were inadvertently closed, the liquid trapped on the shell side would expand due to the considerably higher gas temperature on the tube side. The shell pressure would increase rapidly and rupture would result unless external relief was provided.

Overpressure because of thermal expansion is possible on the shell side of the primary and secondary condensers, the aftercoolers, the bypass cooler, and on the tube side of liquid heaters, stripper exchangers, and steam heaters. With units having cooling water on the shell side, such as the secondary condensers, relief valves were installed on water piping inside the exchanger block valves.

With units having process materials in the tube or shell side, the use of relief valves was not considered desirable because of the possible release of H_2S into the atmosphere and because of the process imbalance which would result from failure of any of the valves. This problem was solved by installing valve bypasses around specific exchanger block valves so that if the main valve were closed, the increase in volume would dissipate itself through the bypass line and into an adjacent tank or tower. The bypass line valves are normally to be locked open but can be closed to effect a tight shutoff when so desired.

Since all exchangers are mounted vertically, vent connections are provided on the channel cover and in the fixed tube sheet. In general these vent connections are blanked off and are intended to be used only periodically. The liquid heaters and the stripper exchangers are exceptions to this and are covered separately below. The venting of the shell in most instances is accomplished by drilling the fixed tube sheet radially and then drilling up from the under side of the sheet to intersect the radial drill hole. The exterior connection is made by reaming out the tube sheet hole and welding in a standard flanged nozzle. This fixed tube sheet vent nozzle is blanked off in all cases since shell venting is not a continuous procedure.

The installation of the fixed tube sheet vent nozzle resulted in some apparently insurmountable fabrication difficulties

in many of the exchangers. Since all welding of carbon steel requires stress relief, some vendors thought that the installation of the shell vent could best be accomplished by placing it in the top shell flange. This was considered desirable in that it would eliminate the machining step on the fixed tube sheet caused by the vent nozzle (the tube sheet gasket surfaces usually required machining after the welding and stress relieving operation on the nozzle). The use of the shell vent connection on the top shell flange (by drilling radially into the flange to intersect a drill hole made down at an angle from the inside face of the flange) is a satisfactory way to remove accumulated vapors from the shell and the connection can be heat treated with the shell with no additional trouble.

The welding problem involving the fixed tube sheet of the stainless exchanger units in Buildings #412-D and #413-D was overcome by permitting the fabricator to use a screwed and seal-welded stainless steel vent connection in the tube sheet. Since stainless steel screwed connections are not particularly objectionable, and since seal welding provides a leak-proof joint without overheating and distortion, the installation of the vent could be made after final tube sheet machining. The installation of the shell vent in the top shell flange, as described above for the carbon steel shells, would have been impractical, if not impossible, in the stainless steel lined shells.

A major modification of the design of the liquid heaters and stripper exchangers was required to minimize possibility of gas binding on the tube side of the exchangers. As the hot tower or stripper feeds are heated in the units, gas is evolved from solution. As originally designed, the flow through the various exchangers in series was both up and down. It was thought that under downflow conditions the gas binding would be severe and that the channel heads would require continual venting with possible loss in exchanger performance. As a result, the piping configuration was modified to make the gas-liquid pass upward through the tubes in all bundles in series. This, it was reasoned, would allow the liquid to sweep the gas along with it and minimize, if not eliminate, difficulties and efficiency loss because of gas binding. Vent connections are provided on the channel covers of the exchangers and are piped to the down stream side of each group. However, initial operation indicated these vents were not necessary.

In addition to the change in flow through the bundles, it was necessary to supplement this modification by adding a baffle plate just opposite the inlet pipe and inside the floating head cover. This was required to prevent the flow from being channeled through the central tubes only, with a

fair chance, because of the gassing conditions, of the outer tubes acting as downspouts.

Drain connections are provided in the shell covers of all exchangers. In units carrying cooling water on the shell side, the drains are half couplings. In other units carrying process liquid or stripped process liquids, drains are flanged nozzles. In the stainless steel lined primary condensers, lined nozzles are utilized. All shell drain connections are either blanked or plugged since draining is only to be done intermittently or on shutdown. No drain connections are required on the tube side of the exchangers, except the bypass cooler, since all are single pass units. The complete draining of the floating head cover on the bypass cooler was considered desirable but a practical solution to the problem could not be developed. It was decided that the major portion of the liquid could be blown out of the tubes with compressed inert gas and that the small amount of liquid which would probably be left in the head would not be critical in the small exchanger. The hydration of this liquid during a prolonged shutdown is to be prevented by circulating tempered cooling water in the shell.

Seal Strips or Dummy Tubes

A required modification as design progressed provided for the installation of seal strips or dummy tubes in some exchanger tube bundles. These are required to provide a better seal at the shell on the periphery of the tube bundle and consequently minimize bypassing of liquid around the tubes. The justification for seal strips differs basically from the reason for having a tight baffle-shell fit; the latter tends to prevent bypassing of the heat exchange surface down the length of the shell, while the former are employed to minimize bypassing of the surface across the width of the shell.

At the time seal strips were added to the design, it was all but impossible for all exchanger vendors to obtain sufficient stainless steel bar stock. It was also impractical for vendors to install the strips. As a result, only those units in which a high transfer efficiency was desired, such as the the primary and secondary condensers were equipped with seal strips. As an alternative to seal strips, and in order to reduce the cost and possible equipment delivery delay, dummy tubes were added to the bundles. These tubes were installed through the crossflow baffles on the standard tube spacing pattern but could be placed closer to the shell since they were cut off short of each tube sheet. The dummy tubes were crimp-closed on both ends to prevent bypassing of liquid through them. All voids of any significance in the tube pattern periphery were thus sealed off.

Interchangeability

During the design period, specific exchanger designs were modified to provide as much interchangeability as feasible among units. This was desirable mainly to facilitate field erection and to permit the use of a modular process unit so that only one design was necessary for all twenty-four "GS" production units. Agreement was reached between the vendors of the first stage liquid heaters and the stripper exchangers on all key external dimensions so as to make both types outwardly identical. It was not possible to have all components of both units made alike because the two vendors involved employed their own tube bundle design. The external details, however, were the critical points and agreement on these resulted in expediting field schedules since it then became immaterial whether a stripper exchanger or a liquid heater unit was available. In fact, some of the "GS" process units at Savannah River have no liquid heaters, but are equipped with seven stripper exchangers.

Interchangeability made a significant contribution to the use of modular process units. The first stage primary condensers were fabricated by two vendors, one supplying the 32 bundles for Building #411-D and the other supplying the 64 bundles for Building #412-D and #413-D. Because of the difference in materials of construction between Building #411-D and the other two buildings, all 96 bundles could not be interchanged during construction. However, the critical nozzle dimensions of all 96 bundles are identical, permitting the use of only one set of piping and other design drawings for all three buildings.

An effort was made to standardize tube sizes, an ideal not entirely realized at Dana. The result was the use of 3/4-inch O.D. by 17 BWG tubing in all exchangers except the steam heaters and the product stripper preheaters, where both the tubes and shells are fabricated from schedule 40 pipe.

Exchanger Handling

Facilities had to be provided for the removal and replacement of tube bundles or of an entire exchanger. Several alternatives were originally considered including the use of bridge cranes, traveling hoists and gantry cranes. The most practical and economically attractive method appeared to be the use of a manually tracked electric hoist, but no action was taken other than to purchase trolleys to accommodate the hoist if required.

In the initial design, the structural steel building not only provided exchanger supports and platforms but was framed above the exchangers at a sufficient elevation to permit removal of the largest and longest exchanger. This steel superstructure was located immediately over the large condenser units and was provided with a continuous crane rail running directly over the center of the exchangers and approximately fifty feet above them. A second crane rail was cantilevered off the side of the main superstructure columns to service the liquid heaters, stripper exchangers, and smaller units. Because structural steel orders had to be placed as quickly as possible there was no time to solve the bundle handling problem.

In the fall of 1951 the use of the area maintenance crane was proposed. A study indicated that this new alternative plan for handling heat exchangers was entirely feasible and the plan was accepted. As a result of this decision, the superstructure steel over the exchangers became superfluous and was removed. Some small expenditure was required to modify the design of the remainder of the building structure and also to remove those sections of the superstructure which had been erected, however, a total savings of about 750 tons of steel was effected. Much of this now superfluous structural steel had been delivered, but not all had been erected. Credit toward other use was obtained from fabricators in whose shops the balance of this steel was held.

This stock pile of steel was used most advantageously to alleviate shortages resulting from frequent delays in the delivery of steel intended for other use.

One additional feature was provided to facilitate maintenance and handling of components of the heat exchangers. By virtue of their arrangement in the unit, some of the exchanger bottom heads are not readily accessible to maintenance personnel from the building walkways. To minimize difficulty in maintaining the exchangers by eliminating scaffolding, unnecessary framing, etc., a portable platform of tubular metal construction provides a convenient safe, and readily available working platform. One of these portable platforms was assigned to each building wing.

Gasketing

Gasket specifications for the Savannah River heat exchangers called for thin ($1/32"$) compressed asbestos material. Since TEMA requires the use of a metal jacketed asbestos gasket, most of the fabricators were unfamiliar with the straight compressed asbestos gasket and, as a result, were not sure of its successful application.

At Dana, spiral-wound or metal-clad gaskets were investigated for use in this service. However, as the early metallurgical studies progressed, it became evident that the metal jacketed gasket in H₂S-water service would not be satisfactory because of the anticipated rapid attack on the highly stressed metal in an assembled joint. Consequently, use of the straight compressed asbestos gasket was made mandatory and was eventually shown to be practical. It was necessary, however, for du Pont engineers to visit some of the vendors' shops and show shop personnel how to assemble the exchangers correctly.

With the decision to use the compressed gasket at Dana, the generally standard 1/8-inch or 1/16-inch thickness was first chosen. However, experience gained in testing the erected heat exchangers demonstrated that after a gasket is compressed in the assembled joint it "relaxes", i.e., exhibits a physical property tending to decrease its base thickness. For example, with a 1/8-inch gasket bolted to an equivalent stress of 100 pound-feet, the joint pressure decreases with time by "relaxation" of the gasket and within a day's time the equivalent bolting load may drop to 70 pound-feet. Obviously, if the initial loading imposed on bolting in any joint is equal to that required to maintain a tight closure, "relaxation" because of gasket "shrinkage" will result in a leaking joint.

This property of a gasket to "relax" diminishes in magnitude as the base thickness of the gasket diminishes. The Savannah River exchanger closures were finally gasketed with 1/32-inch stock and exhibited very little tendency to develop leakage in operation.

Bolting

Early in 1952, the du Pont metallurgical studies showed that high stresses in alloy steel bolting were definitely not compatible with exposure to H₂S-water service and, in fact, showed that maximum limiting stresses should be only about one-half of the ASTM allowable tensile strength. When alloy bolting material had been tested in bar stock form earlier in the program, the failure stress under tension and other process service conditions was about 100,000 p.s.i. Later tests, using commercial studs, showed that a high incidence of failure could be anticipated if stresses in process service exceeded approximately 65,000 p.s.i.

As a result, specifications were modified and vendors were advised that bolting stresses were to be limited to 40,000 p.s.i. and that all joints were to be made up in accordance with a strict stepwise procedure, using a torque wrench to stay within the 40,000 p.s.i. stress limitation. The 25,000 p.s.i. safety factor was employed since it was

known at that time that the limits of accuracy of a torque wrench were only approximately plus or minus 20 per cent. In the case of the primary condensers, where floating head bolting is continually exposed to process fluids, and where leakage or failure will result in loss of valuable products and create a hazardous condition, the specifications were revised to restrict combined stresses in bolting to 20,000 p.s.i. maximum.

During this time an extensive exchanger testing program was being carried on by the du Pont Construction Division to evaluate gasket "relaxation". Since many exchangers not assembled by controlled bolting methods had already been shipped to the site, the field expanded its testing program to include the evaluation of bolting stresses. This proved the use of torque wrenches to be of very doubtful value. Where the anticipated stress in each bolt was found to be in the range of 32,000 to 48,000 p.s.i. in a torque wrench method test, the stress determination by the more positive elongation method showed actual levels in the range from 10,000 to 90,000 p.s.i. On the basis of this information, the use of the torque wrench was discontinued and the bolting program began to utilize the elongation method of stress determination.

The erratic and therefore unsatisfactory behavior of the torque wrench is believed due to the fact that individual studs and nuts are not alike. A varying part of the energy indicated on the wrench dial may be dissipated in overcoming a bad thread condition, dirt, or poor lubrication. The torque wrench, although suitable for general service, is not a very satisfactory control device for accurate work.

Materials of Construction

The selection of suitable materials of construction for the "GS" heat exchangers proved to be one of the major problems in the design of these units.

The earliest ground work on the selection of materials of construction was done on the basis of a report compiled in 1950. This report, compiled by the Design Division, covered observations made at the du Pont Chambers Works of equipment which had been exposed to hydrogen sulfide. While this report could not include conditions duplicating those anticipated for Dana operations, it did provide some background on the effects of H_2S on various metals. It also gave sufficient information to enable Design to determine that high quality, low carbon steel could safely be used for most of the fabrication.

This report became starting point for design work but continuing metallurgical experimentation was necessary before

all facets of the problem could be considered solved. The Du Pont Engineering Research Laboratory took over the problem and worked on two aspects; (a) corrosion processes and (b) tests on candidate materials. The Engineering Research Laboratory Group made use of the Chambers Works data, some previous observations on similar problems made by firms in the oil industry, and some limited data from early tests conducted by the Girdler Corporation.

A detailed discussion of the metallurgical problems involved in designing "GS" facilities will be found in the chapters entitled "Metallurgy" and "Safety". These discussions explain the several mechanisms by which corrosion of metals by H_2S can occur, and the results of tests on numerous candidate materials including carbon and stainless steels and many non-ferrous metals and alloys.

Because of critical completion schedules for the Dana Plant simultaneous design and testing work was necessary. These completion schedules were further complicated by the need for large quantities of the materials of construction and, therefore, some of the materials had to be ordered before all tests were completed by the Engineering Research Laboratory. These two factors, the stringent delivery dates and large material quantities, led to the decision that silicon killed steel would be used for most of the equipment. As it developed, the Engineering Research Laboratory's test data largely confirmed this selection.

For some services it was necessary to use stainless steel in spite of the relatively short anticipated life for Dana. This applied primarily to exchangers which handle liquids that are particularly corrosive because of concentrations of H_2S , temperature ranges, etc. Where carbon steel was used a 1/8-inch to 1/4-inch corrosion allowance was provided in the heat exchangers.

Carbon steel was chosen for the shells and tubes for many of the Dana exchangers. However, as the tests by ERL progressed, both in the laboratory and in the Pilot Plant, it became evident that for some services the corrosion rate was greatly in excess of that anticipated. This was particularly true of the tubes, and eventually provision was made to replace all tube bundles with stainless steel tubes. Even for those exchangers where the indicated corrosion rate was considered acceptable for the limited life of the plant, spare stainless steel bundles were eventually provided when the expected life of the plant was later increased.

At one stage in the search for a tube material more satisfactory than carbon steel, both aluminum and aluminum-clad tubes were considered.

Later considerations indicated that Alclad tubing would offer no advantages and that aluminum tubing would be a possible candidate for all primary and secondary condensers. A sprayed zinc lining was to be used with this scheme on the carbon steel shells and tube sheets to prevent galvanic action.

Since the primary condensers operate under the most severely corrosive conditions, it had previously been decided to use stainless steel lined or clad shells for these pieces of equipment in the "permanent" Buildings #412-D and #413-D. Lining of primary condenser shells with zinc would be required, therefore, only in Building #411-D.

At the same time that aluminum tubes were being considered for the primary and secondary condensers serious doubts were expressed concerning the suitability of that material for this service. Experience at Dana later confirmed these doubts and it was then decided to use stainless steel tubes instead of aluminum tubes. Later stainless steel tubes were specified for all the heat exchangers in the "BS" units of all three buildings at Savannah.

At this point, the plan was to use Type 304 stainless steel for the tubes. However, as corrosion studies progressed, it was found that Type 316 was more resistant to surface pitting than Type 304. As a result, Type 316 stainless steel tubes were furnished for the primary condensers in Buildings #412-D and #413-D. As has been pointed out, these condensers are exposed to the most severe service in all three buildings. However, Type 304 was considered to be adequate for Building #411-D since this building was not a part of the "permanent" facilities. Type 304 stainless steel was also chosen for tube sheets, both fixed and floating, in all primary condensers.

Miscellaneous Design and Procurement Problems

The design problems during fabrication and installation of the Savannah River "GS" heat exchangers were many and varied. The urgency of the procurement program was such that purchase orders were placed when specifications were not fully completed. Throughout the fabrication phase, revisions resulting from initial omissions, design requirements, and newly acquired information were found necessary to provide a satisfactory specification. Although the problems were somewhat similar to those encountered at Dana, conditions in the early procurement stages precluded full use of Dana experience.

The vendors receiving orders for exchangers had, by and large, quoted on the basis of their standard fabrication techniques and in general conformation to TEMA, the Tubular Exchanger Manufacturers' Association. There were, however, many specific items omitted or not covered sufficiently by the

TEMA's standards which were considered desirable and, consequently, it was necessary to amplify and make more stringent a good many parts of the specifications. Among these were specific tolerances and assembly dimensions, fabricating techniques, materials selection and restriction, and testing procedures. These special conditions, particularly the close tolerances specified, caused much consternation on the part of the exchanger vendors during fabrication.

Tolerances Although dimensions and tolerances given by TEMA were generally satisfactory for the petroleum industry, the problems involved in containing such a hazardous material as H_2S were considered to be unique and to require special treatment. Further, experience had shown some of the requirements of TEMA to be entirely inadequate. Specific examples of the special requirements are those on shell out-of-roundness, tolerances on tube hole drilling in baffles, baffle spacing, tube hole-tube sheet tolerances, gasket dimensions and joint closure details, especially that of the floating head joint.

As an example of the close tolerances specified, very precise drilling of tube sheet holes was essential. There are approximately 1300 tube holes on a first stage primary condenser sheet, each drilled to a tolerance of plus or minus $1/64$ -inch between holes. The tube holes were drilled to a minimum permissible dimension to limit the amount of expansion to 0.012" maximum when the tubes were rolled in. Joint tolerances, such as ring depth, etc., were specified with tolerances as small as plus 0.000" and minus 0.005" to assure accurate fit-up and to reduce the chance of equipment failure.

Material Selection Material selection and restrictions imposed tight controls during fabrication. All carbon steel components other than relatively complicated shapes, such as a channel forging, were reflectoscoped to insure a material free of faults. As in the case of "GS" towers, defects determined by the reflectoscope were either repaired by chipping and welding or the material was rejected.

Fabrication The special fabrication techniques that were required also imposed more than normal care on the assembly of exchangers. As with the towers, all carbon steel welding required stress relief and close inspection of welding details and methods to make certain that as much resistance to stress corrosion and hydrogen blister was maintained as possible. Although TEMA also specified stress relief after all carbon steel welding was completed, the ASME Code and general TEMA requirements permitted some repairs or additions without subsequent stress relief. This provision was not acceptable for the Savannah River exchangers. Tube

rolling procedures were also controlled rigidly and controlled-torque rolling was required.

Testing Testing requirements of the fabricated exchanger components and the assembled exchangers were revised after purchase orders were placed to include tests other than the standard hydrostatic test. Specifically, a series of halide tests and a final air test were added in an attempt to be absolutely certain that the exchangers were suitable for use in H₂S service. Any leaks discovered in a test were repaired and the test repeated. If a unit had to be disassembled to correct a fault, all tests had to be repeated.

Although there was some resistance to the extensive testing required, the results were not particularly detrimental to cost or delivery. For example, one vendor of a large number of units experienced less than 1 per cent rejection of tubes because of the added halide and air tests.

Procurement Procurement of the exchangers was complicated to some extent by the security requirements of the "GS" process. Inasmuch as security also applied to other equipment in the #400 Area and to other areas, it is discussed in another chapter. As in the case of all of the major equipment in the "GS" units, the urgency of the program resulted in an all out effort by all concerned to obtain delivery of the heat exchangers.

Heat exchangers were purchased from ten different vendors located throughout the country. Schedules of fabrication and delivery were critical. Aside from the fact that the geographical distribution of the vendors would complicate fabrication and shipping schedules, the large amount of tubing required presented an extremely complex problem. Approximately six million lineal feet of tubing, all 3/4-inch 17 BWG, was required for the heat exchangers.

Perhaps the most significant step in obtaining an earlier exchanger delivery was the decision to purchase all tubing separately and independently of the exchangers, and to allocate it to the exchanger fabricators on a supply and demand basis. Since the amount required represented a major portion of the nation's existing tube mill production, it was necessary to discover and develop new sources of supply. With tubing controlled and being shipped, as it became available, to the point where it was needed, the continuity of vendors' fabrication schedules was improved. Had each individual vendor purchased and controlled tubing for his own specific use, the exchanger procurement program would have been seriously jeopardized.

Separators

Eight vapor-liquid separators are installed in the process

lines of each "GS" unit to remove the liquid condensed from the hot tower overhead gas.

The six first stage separators are 4'-0" I.D. by 4'-6" long, and the two second stage separators are 3'-0" I.D. by 4'-6" long, each having a tangential inlet nozzle, a dip-type outlet gas nozzle and a drain or liquid outlet nozzle.

Use of this equipment in the "GS" process is peculiar to the Savannah River Plant. In the Dana "GS" units, the primary and secondary condensers are designed for a process gas flow through the shell side of the exchangers and condensate flowing down the shell is removed through a nozzle in the shell cover. Separators, as such, are not required because the condensers themselves serve the purpose. For Savannah River, however, it was determined that heat balances could be improved if the mediums in the condensers were reversed. Consequently, it was necessary to provide some means for removing the condensate from the exchangers. An initial proposal to install a pipe tee in the outlet line from each condenser did not appear to be reasonable and centrifugal separators were adopted.

This decision was made at a time when structural steel was being received at the site and sometime after exchanger orders had been placed. As a result, the separator design is based upon a modification of a du Pont standard separator. Although the diameter of the units corresponds to the standard, the configuration of the inlet nozzle and the length of the body had to be shortened to fit the process arrangement. A single dip pipe was utilized and a cross type baffle installed in the bottom head of each separator to reduce re-entrainment of liquid in the exit gas stream and to minimize vortex effect of the liquid outlet flow.

The design of these separators proved to be one of the most troublesome items in the over-all "GS" process design. A few months prior to start-up of the Savannah River "GS" Plant, the question of separator collection efficiency was raised by the AED and was subsequently reviewed in the field by the Design Division. It was found that re-entrainment of liquid in the exit gas stream of the separator could introduce an undesirable amount of liquid into the second stage blower, but the other separators were considered satisfactory in this first evaluation. It was assumed that condensate flowing down the outer wall of the dip pipe was falling into the high gas velocity area at the entrance to this pipe. At that time a short, concentric, cylindrical collar was installed on the end of the exit dip pipe in the separator under the second stage secondary condenser to divert the flow of the liquid outside the area of high gas velocity and thus reduce

re-entrainment in the gas outlet stream.

At start-up of the first unit in Building #411-D, serious vibration of the separators, particularly those serving the first stage secondary condensers, was observed. In the first analysis, it was thought that this instability was caused by process surges associated with start-up. However, as the operation and control of the unit improved, the vibrations continued. Further study indicated that the liquid in the base of the separators was being severely vortexed by the circular pattern of the gas flow resulting in non-uniform loading and attendant swaying of the units. It appeared that the distance between the bottom of the gas exit pipe and the normal operating level of liquid in the bottom of the equipment was insufficient and that the vortex breaker originally provided was inadequate.

Consequently, the two separators under the first stage secondary condensers were braced to the building structural steel to reduce the strain in the piping and associated equipment. Although bracing did not halt the vortexing and swirling in the equipment itself, the apparent movement of the two separators was reduced.

Coincident with the vibration problem, the question of separator efficiencies was again raised by the AED. As an adjunct to the question of efficiency there also arose the problem of corrosion-erosion because of the relatively high gas inlet velocities in the separators, especially since the gas carried entrained liquid. An evaluation showed that, although absolute efficiency could not be predicted, separation would be improved by altering the exit dip pipe design. It was decided to modify the dip pipes in all separators in the "GS" Area. The original modification to the separator dip pipe under the secondary condenser was not considered adequate and was voided. The new design, however, was based on the same theoretical principle.

In connection with the corrosion-erosion problem, it was shown that inlet velocities had to be retained at high values to effect as good a separation as possible. Since the high inlet velocities were not compatible with the carbon steel construction of the separators, it was decided to provide all stainless steel lined or clad separators.

Separators were purchased initially on the predetermined pattern of one-third carbon steel and two-thirds stainless steel clad or lined carbon steel construction. When the decision was made to have all separators constructed of stainless steel lined or clad carbon steel, half of Building #411-D (West Wing) was in operation and the other half (#411-D East Wing) about to go on stream. However, the carbon steel

separators in Building #411-D East were removed and replaced with stainless steel lined units from Building #413-D East. The units removed from Building #411-D East were then lined off the site with stainless steel and re-installed in Building #413-D East.

As more operating units were placed in service, it became evident that the problems connected with separator vibration were not materially reduced by bracing. As an alternative measure, a new baffle design was developed by the AED and the Design Division. This consisted of a system of radial and horizontal baffles set in the bottom head. In effect, a false bottom was formed so that gas did not swirl and vortex liquid in the bottom head. The new baffles were built in sections to permit installation through the separator manhole.

All separators in one unit (No. 5) of Building #411-D (East Wing) were modified to include the new baffles and dip tubes and when the unit was placed in operation no vibration was observed. After the successful trial of this installation in No. 5 Unit all units except those in Building #411-D West were modified.

Before the success of the baffle experiment in Unit No. 5 was known, a second evaluation of structural bracing was made. Since the initial bracing of the separators under the secondary condensers was of some value in reducing vibration, the scheme was extended to include all eight separators in a single unit. In start-up, however, this was shown to be of no advantage. In fact, the over-all problem was increased because the entire unit began to vibrate. Bracing of separators was discontinued immediately since it was obvious that bracing merely transferred the effects of the dynamic forces within the separators through the building steel to the entire unit.

After lining the 32 separators removed from Building #411-D East and modifying all separators not in operation to incorporate the new baffle and dip tube design, all separators with the exception of those in Building #411-D West Wing, were considered acceptable. Since the life of these carbon steel units would probably be short, about one year, replacement separators were ordered. These 32 new separators, carbon steel with 20 per cent stainless steel cladding and with the new dip pipes and baffles, have since been installed.

Blowers

Each "GS" production unit at Savannah River is provided with an Ingersoll-Rand, single stage, centrifugal-type, vertical discharge gas blower in both first and second stages.

The first stage gas blower takes suction from the cold tower overhead and discharges into the humidifier section of the hot tower. The second stage gas blower takes suction from the overhead stream from the hot tower, downstream of the primary and secondary condensers, and discharges through the aftercooler into the base of the cold tower. Both blowers serve the single purpose of boosting the system gas flow sufficient to provide circulation at design rates.

Both of the gas blowers are the result of an extensive survey originally made by du Pont to determine a satisfactory means of gas circulation for use at the Dana Plant. The first stage gas blower at Savannah is identical in design, and essentially identical in construction to blowers furnished by the same vendor for first stage use at Dana. However, the smaller second stage gas blower at Savannah has no counterpart at Dana. The basis of its design and mechanical operation is premised on the larger unit.

The search conducted by du Pont for a satisfactory gas blower, although immediately concerned with the Dana installation, covered a rather wide scope, including visits to installations employing similar operations, close review with manufacturers of potentially applicable units, and a survey of known industrial information pertaining to gas handling. One, if not the major problem, was that of providing effective sealing of the shaft where it passes through the rear of the casing. A mechanical seal was selected as the most satisfactory solution and, with this as a basis, the Dana design was evolved.

As noted above, the first stage blower at Savannah River is identical in design to the Dana first stage, Ingersoll-Rand blower. The Savannah River blower was, in fact, sized on the basis of the performance tests of the Dana blower at the fabricator's shop. The second stage blower at Savannah River had no prototype and was sized on the same general design basis as the larger units. The two Savannah blowers are identical in design, however, except for physical dimensions. The shaft size is identical on both units to provide as much interchangeability as possible. The second stage blower was constructed, assembled, and tested for satisfactory attainment of design specifications prior to trimming the impeller and making other necessary adjustments.

The Savannah blowers are both sized on the basis of handling 20 to 21 per cent over design flows. Both units are driven by 3600 r.p.m., 4000 volt electric motors; the first stage blower is provided with a 1000 h.p. drive while the second stage blower is provided with a 600 h.p. drive. The choice of the 4000 volt motor was based upon the results of an economic evaluation of electrical supply to the large drives and matched standard available transformer sizes.

Materials of Construction

The materials of construction of the two sizes of Savannah "GS" blowers are identical and, with the exception of a few minor differences, are the same as used at Dana.

Investigations made with the cooperation of companies handling hydrogen sulfide on a large scale played an important part in establishing requirements. It was learned that wet H_2S gas is extremely corrosive and that the gas in this condition should be avoided if at all possible. This greatly influenced the selection of materials for the blowers. Every effort was made to remove entrainment so that the process gas would be as dry as possible as it passed through the blowers. In this way the use of the more expensive corrosion-resistant metals could be avoided. In addition to being an economic factor, this also allowed Design to take advantage of more readily available types of metal and thus improve delivery dates.

In spite of this effort to avoid the use of scarce, expensive materials, it was thought necessary to employ them in fabricating vital parts of the blowers. In general, the large parts of the units such as casings, impellers and shafts, were made from carbon steel or aluminum. Some smaller components in the blowers are either faced with, or fabricated from, stainless steel.

The casings supplied on the "GS" process blowers are of cast steel. Early in the course of blower construction some difficulty was experienced by the vendors with shrinkage of the castings. This resulted in a considerable amount of repair welding. However, as soon as more casting experience was gained with the materials being used, techniques were improved and less repair was needed.

The Dana impellers are of normal design for the required services. They are cast from aluminum, as this was judged to be the most suitable metal in the light of process conditions and materials handled.

The impellers are keyed onto spuds in the impeller shaft so that electrolytic action might be circumvented. The shafts are carbon steel overlaid with Type 316 stainless steel. There was, at one time, some discussion on heat treating the Dana impellers after they were formed. However, this was not done since the impellers were cast over and permanently attached to the shafts, and the differences in the coefficient of expansion between the two metals would have affected alignment. Heat treating the Savannah impellers was not considered.

The Savannah River impellers have a stainless steel hub. It was thought that impellers with this stronger hub material were less likely to fracture than were the solid aluminum impellers used at Dana.

Seal Oil System

Probably the most significant design consideration given the entire blower problem was the development and provision of satisfactory seals on the blower drive shaft. The main requirements were that the sealing device be as leak-proof as possible, and that it be dependable and relatively maintenance-free. The major portion of development of the double mechanical seal finally adopted was done for the Dana Plant gas blowers. By the time it was necessary to procure blowers for Savannah River the seal design had become firm.

The search for suitable seals, like some other aspects of Dana development, was aided materially by a thorough investigation of du Pont facilities using gas blowers and of installations in the petroleum industry where similar problems were encountered.

Three major types of seals were considered for use in the blowers:

1. Labyrinth-type seals using 300 lb./sq. in. of steam and seal fluid.
2. Conventional stuffing boxes utilizing water as seal fluid.
3. Double mechanical seals using oil as sealing fluid.

Of these three alternatives, the last seemed to offer the most advantages.

The first type was dropped because of inherent corrosion, erosion and thermal distortion problems and because of some instances of poor performance on other installations in the past.

The conventional stuffing boxes presented an unreliable aspect in that the amount of leakage would be dependent on the skill of the worker installing the packing and the time available for repacking. It was hoped that a seal method less subject to the human element might be found.

The third alternative, the double mechanical seals with oil seal fluid, appeared, after complete investigation, to be the most suitable. This consists of a flat rotating face against a flat fixed face at each end of the seal housing.

Du Pont installations using double mechanical seals were inspected with the aim of collecting design information. However, these installations did not operate at comparable speeds or pressures. Seals were found within the petroleum industry operating at either the proper speed or pressure but none could be found which embraced both requirements.

Following numerous conferences with two blower vendors, both submitted seals which could provide satisfactory operation. The Elliott Company used a "Duraseal" manufactured by the Durametallic Corporation and Ingersoll-Rand adopted a "Cameron" seal of their own manufacture that fitted the requirements.

Early operating experience showed that the "Cameron" seals were the most satisfactory from both the operating and maintenance standpoints. Therefore, as the "Duraseals" failed, they were replaced by "Cameron" seals, the design of the two types being such that the units as a whole were interchangeable. In order to develop an alternate source of seal supply, Elliott later agreed to supply a modified design of their "Duraseals" and parts for this modified "Duraseal" were essentially interchangeable with the "Cameron" seal components.

Even as development work was proceeding on seals, there was some fear that the oil sealing fluid would leak into the blowers and contaminate the gas. Testing of completed seal assemblies showed that this type of leakage was so slight that it was negligible.

The seal employed in the Savannah River gas blowers is the "Cameron" type, double seal with a bland fluid surrounding the running parts at a pressure of approximately 40 p.s.i.g. in excess of the blower operating pressure. All rotating parts of the seals except the set screws and springs are made of Type 316 stainless steel. The set screws are nickel plated alloy steel; the springs are carbon steel. The rotating seal faces are overlaid with stellite and the stationary seal faces are of carbon, press-fitted into a steel housing.

The seal oil supply consists of an independent 330 p.s.i.g. (approximately) circulating oil header system for each building wing with each blower seal housing in the wing connected to the header. The blower housing is essentially a dead-end connection which draws oil from the header only to the extent that there is leakage between the seal faces. A cross tie line connects the two independent wing systems within the building, but is used only when major repairs are necessary to one of the wing systems.

The circulating source for each seal oil system (one wing) is a constant volume vane-type pump. The correct pressure is maintained by the use of a control valve on the return oil header to the seal oil pump sump. In addition, an oil reservoir tank is provided to minimize surging and other pressure fluctuations in the system and to afford an extra oil supply. This seal oil tank floats on the oil supply header and the level of oil in the tank is controlled by an air compressor through sequential switching and by the system pressure which is dictated by the seal oil pump.

The air compressor is provided with built-in pressure switches which cut on and off at 320 p.s.i.g. and 330 p.s.i.g., respectively. This control feature permits operation of the seal oil system upon failure of the seal oil pump, since the air compressor will maintain adequate pressure in the seal housings during this time.

Each seal system is provided with alarms to indicate the predetermined high and low levels in the oil storage tank, and to warn of either oil pump or air compressor failure indirectly, through the tank controls.

Important steps in the seal oil system are the filter and metering operations. Filtering is necessary since the oil must be clean and free from any particles that might cause scoring or otherwise damage the seal faces. The metering operation is included to give a quantitative indication of seal performance since this is determined on the basis of oil lost through the seals. At Dana considerable difficulty was encountered in obtaining a suitable filter and oil metering instrument for a satisfactory service. The Savannah River installation benefited from this experience.

The flow meter consists of a very small orifice plate and an amplifying balanced beam which is connected through a pneumatic transmission system to a flow alarm. The flow meter indicates in the field only and alarms in the central control room.

Because the oil rate through the individual meters is so small, flow is in the "stream-line" or laminar range with the result that the pressure differential across the orifice is directly proportional to the viscosity of the oil and hence to the temperature of the oil passing through the instrument.

In order to avoid wide inconsistencies in flow measurement it was necessary to provide a means of maintaining the oil at a relatively constant temperature, at least in the instrument. This was accomplished by coiling a section of the oil supply line immediately upstream of the instrument and placing both the coil and the entire instrument inside of an insulated and heated housing. The remainder of the feed

line from the header to the seal housing is insulated only. Although the temperature within the heated housing does fluctuate to some extent, the range of temperatures, and hence viscosities, is not sufficient to materially affect the flow indication.

Reversal of Rotation

Early in the design phase of the Savannah River units, it became apparent that some means must be provided to prevent the blowers from reversing rotation in the event of a blower motor failure. Such reversals would be caused by backflow of gas through the blower from the pressurized system. It was expected that this reversed gas flow could carry the speed of rotation to a point where destruction of the impeller, motor, and probably the casing, would result. Furthermore, this destructively high speed was calculated to develop within a relatively short span of time.

Consequently, a Morse Formsprag non-reversing clutch was purchased for each blower motor for attachment on the far end of the motor shaft. Double shaft motors were procured to accommodate this non-reversing device. Operation of the clutch is such that, while the motor is driving the blower normally, the motor shaft in the clutch rotates freely. When, however, the motor shaft attempts to reverse, a series of cogs in the clutch are engaged and prevent this rotation.

At Dana, the use of this non-reversing mechanism could not be widely applied because many of the blower drives had been delivered and were provided with only a single-ended shaft. The methods considered at Dana to prevent reverse spinning included the installation of solenoid actuated brakes and one-way clutches over the motor-blower coupling, and the use of isolation valves tied into the electrical supply which could shut off pressure from both sides of the blower in the event of a power failure. Of these methods, the use of isolation valves was the one ultimately selected.

As an additional precaution for the Savannah River installation, the non-reversing devices were supplemented by a system of isolation valves similar to the Dana installation, thus providing relatively rapid automatic closing of the flow control valve (suction butterfly valve) in each blower gas line and closing of the motor operated blower suction and discharge block valves. Later, the operation of the non-reversing clutches was shown to be troublesome and their use, with the isolation valve system, unnecessary. They were, therefore, removed from the blowers.

Venting, Purging, Draining and Testing

Additional significant design items on the gas blowers

were features provided to facilitate maintenance and general operation of the unit. Since relatively high maintenance was anticipated, based on Dana experience, facilities for venting, purging, and draining of the blowers were added. These took the form of valve connections for purging and venting and of valve piping systems for draining and blow-down. Also, valve connections were provided above the suction and discharge block valves for water sealing the valves. It was not expected that the large gate valves would close tightly against 300 p.s.i.g. gas and therefore the addition of water above the valves would be required to insure a tight seal to protect personnel working on the blowers.

The piped blow-down system was provided to keep the blowers as free of water as practicable and to permit blow-down during operation. In addition to connections on the blower casings, the first-stage blower suction line is arranged to provide intermittent blow-down and thus minimize the problems resulting from water getting into the blowers. These blow-downs are all connected to an underground process drain header and into a process drain tank in the building west auxiliary unit.

Also, from experience gained at the Dana plant, a high pressure inert gas header system is provided through the units to facilitate testing. Although the scope of this compressed inert gas system is not limited to use with the blowers, the installation of the facilities was found desirable when it was realized that testing of the blowers at Dana after repairs and before re-starting was being carried out using hydrogen sulfide. Since this was considered to be an undesirable procedure for Savannah River, the compressed inert gas facilities were installed. See description of facilities in Building #401-D.

Design Changes

Following the installation of the blowers at the Savannah River Plant, operational difficulties were encountered which necessitated a number of design changes. Some of these problems were first met at Dana while others were due to the different conditions or arrangement at Savannah. A list of the more important design changes is given below. When completed, they successfully concluded a rather difficult period of effort to obtain satisfactory blower operation.

1. Seal Oil Pumps - Changed from the Dana design to constant volume, variable pressure type to make pump operation compatible with the circulating system control which had been redesigned for Savannah.

2. Seal System Air Compressors - Placed control of these compressors on wing emergency power circuits to insure continuity of seal oil pressure on the blowers in the event of a

primary service failure.

3. Tracing Oil Circulating System - Initial concept that tracing of lagged oil lines was unnecessary proved to be incorrect. The temperature-viscosity effects resulted in low pressure in last units on the oil lines. The design change specified Type "C" tracing to keep the oil from getting too warm.

4. Filters - Several cases of unit shut-down were experienced due to failure of the oil filter head bolts. This difficulty was found to be due to the vendor's error in materials of construction used and failure to adhere to the indicated bolting specifications. The heads on all filters were found to be cast aluminum instead of high tensile strength carbon steel and all failures occurred with single bolt heads. The vendor replaced the order with similar filters of stainless steel and of four bolt design. The filter specifications were altered to include this change in design.

5. Blower Insulation - The contour tracing and lagging used on the Dana blowers made access for maintenance relatively difficult. Efforts to improve this condition at Savannah led to consideration of rigid housing such as panels fabricated from sheet metal with the inside face insulated. The use of sheet metal was rejected because of the anticipated high maintenance from frequent assembly and disassembly. Housing fabricated from panels of Marinite was suggested. This material was found to possess satisfactory thermal efficiency and ruggedness and was therefore accepted. A further contribution to rapid and adequate access for blower repairs was the use of easily installed groups of coils as tracing.

6. Facilitating of Field Operation - For reasons of convenience and safety, the blower controls were moved to form a group with the blower starter in the field - the only place that blowers can be started. Included in this change were the pushbuttons for the suction and discharge valves and the several instrument indicating gages.

7. Piping Assembly - Experience at Dana indicated that distortion of the blower casings occurred at the time the piping was fitted. Since the mechanical seals on the blowers operate at very close tolerances, such distortion is very undesirable. At Savannah, "dutchmen" were used in the suction and discharge lines to facilitate piping fit-up. By altering the "dutchmen", no strain is placed on the casing. Special support plates were used to prevent lateral movement of the discharge piping. Also, a jackscrew arrangement was provided to break the connections to the blower casing.

8. Controls and Safeguards - The original design provided for a single crash circuit for the four "GS" units in a wing. A mishap, needlessly shutting down four units, resulted in the installation of a separate panel board, served from the main instrument panel, with an individual crash control for each "GS" unit.

Originally, both the suction and discharge motorized valves closed when the blowers were stopped. This made it impossible to start the blowers so these valves were removed from the interlocking control system and arranged so that they are under the full control of the operator, except that they remain under the control of the crash switch. The suction butterfly valve at each blower remained a part of the interlocking control system, continuing automatic protection against reversal of flow by closing the line when a blower is stopped and opening it when the blower is started.

As discussed previously, non-reversing clutches were provided as an extra precaution against damage resulting from reversal of blower rotation in case of power failure. These were removed from the system because of unreliable operation.

Process Pumps

The pumps utilized in the "GS" Process may be divided into three categories as to service:

1. Transfer of H_2S water mixtures from tower to tower or stage to stage,
2. Supplying water for process feed and cooling, emptying sumps, etc., where the water contains little or no H_2S , and,
3. Seal oil pumps.

It is category (1), the pumping of highly corrosive and dangerously toxic gas-water mixtures, with which this section of the history is primarily concerned.

The initial work in selecting a suitable pump for handling H_2S water mixtures at Savannah River was performed in connection with the design of the Dana Plant. Wherever possible, pump components of standard design were used. However, in a number of instances, these had to be supplemented to adapt the pumps for the peculiarities of the process. Since the Savannah pumps are based primarily on the Dana design, reference should be made to the Dana history for a discussion of these adaptations.

At the outset of design for the Savannah "GS" Plant, pumps of identical design to Dana were selected. However,

differences occurred in the quantity and sizing and in the extent of sparing, due to the use of twenty-four small process units instead of six large "GS" units, as at Dana. Also, and of greater importance, operating experience at Dana began to indicate the desirability of changes in the materials of construction. Later, packing was substituted for mechanical seals on some pumps and the difference in design between the two plants increased. The following sections deal with the important differences and serve to supplement insofar as the Savannah design is concerned, similar information in the Dana history.

Materials of Construction

The process pumps handling H_2S -water mixtures for the #400-D Area were originally ordered with carbon steel casings the same as furnished for Dana. However, operating experience at Dana indicated that severe erosion-corrosion conditions existed within the casings. The specifications were therefore changed to provide Type 304 stainless steel casing.

For similar reasons the Savannah pump impellers were also changed to Type 304 stainless steel. Excessive erosion-corrosion had been anticipated in designing the Dana pumps because of the high liquid velocities expected. Accordingly, design velocities were reduced by increasing the size of the pump discharge lines. However, this measure did not sufficiently retard erosion-corrosion to allow the use of carbon steel pumps at Savannah. The metallurgical aspects of handling H_2S -water mixtures are discussed in detail in an early section of this history.

Seals

The reasons for selecting mechanical seals for certain process pumps and the necessity for developing special seals are discussed in the Dana history. The same type of seal, manufactured according to du Pont specification by the Dura-metallic Corporation, was furnished for the Savannah River "GS" Process pumps.

Before completion of the three "GS" Process Buildings, the AED reopened earlier discussions on an alternative means of preventing loss of process material around the impeller shaft. The use of mechanical seals imposed operating difficulties and correspondingly high maintenance cost. Also, the rigid restriction on leakage of mechanical seals required very smooth and flat carbon and stellite faces to provide a running fit capable of holding a 300 lb. pressure across the face and operating at approximately a 40 lb. face loading pressure maintained by a spring load. Great care and cleanliness were required to insure their proper alignment in operation.

As there were some indications that packing glands could be satisfactorily used and at lower cost, AED requested the Design Division to furnish packing gland assemblies for four production units (one-half building). Accordingly, forty-four assemblies of varied sizes were provided for the Operating Department to replace mechanical seals as difficulties with the seals developed, such installations to be on an experimental basis.

The provision for flushing the Savannah River process pump seals was changed from the original design. Flushing serves to (1) lubricate the seal surfaces with solids-free liquid, and (2) prevent the loss of process material to the atmosphere. The original design provided for flushing the first stage pump seals with make-up water and, to minimize the dilution of the process liquid, flushing the second stage pump seals with liquid obtained from pump discharge. Experience at Dana indicated that the operation of mechanical seals was improved with the use of clean fresh water. Provision was therefore made for flushing the second stage seals with make-up water but the facilities for using discharge water were retained for use, when steady operation of these seals was achieved. All seal flushing systems were provided with filters and rotometers to aid in proper operation.

To reduce loss further, distance pieces were enclosed on some pumps and any leakage or spillage from pumps handling high concentration material was collected in drip pans.

Sparing of Pumps

All "GS" Process pumps at the Dana Plant subject to continuous operation are supplied with complete spares. However, such an arrangement was not originally believed necessary at Savannah River. It was reasoned that the comparatively small units at the latter plant (approximately one fourth the capacity of a Dana unit) could be put on and off the line with small effect on area production. As pump difficulties were experienced at Dana, concern increased about maintaining continuity of operation at Savannah.

Studies and evaluations were prepared for a number of schemes ranging from sparing practically all pumps of both stages to sparing a selected few critical pumps, either individually or with a common spare for more than one pump. The scheme chosen, and on which detailed design work was authorized, provided for: (1) no spares on first stage pumps; (2) a common spare for the second stage top (figuratively, as applied to flow of process water) hot and cold tower pumps; and (3) individual spares for the second stage bottom hot tower pump, the second stage bottom cold tower pump and the second stage condensate pump.

Detailed design drawings for concrete, steel, electrical, underground piping, line schedules and piping arrangement were completed but not issued to the field. Requisitions were issued and prices obtained but no orders were placed.

Decision to proceed with the pump sparing program was withheld pending the results of operating experience. The cost of the installed program was estimated as \$77,000 per unit.

Design Changes

Initial operation of the second stage bypass pump resulted in vapor binding. Operation of this pump is particularly important since without it the designed concentration of the units cannot be attained. It became necessary to utilize a vent pot to minimize the vapor entrainment, venting the pot back into the tower.

The problem of obtaining the desired capacity from the second stage cold tower pumps was recognized at Dana and resulted in larger impellers being provided for the bottom cold tower pumps at Savannah. This often caused a shut-down due to overload from only slightly abnormal flows. Accordingly, the impeller was trimmed to give satisfactory pump performance.

It was found advisable to install filters on the product pump discharge line to reduce the possibility of solids being transferred to the "DW" Plant. The estimated rate at which scale would build up within the production units indicated the possibility of iron sulphide solid impurities in the product. The filters installed are capable of passing 25 g.p.m. and removing particles from 1/2 to 10 microns in size.

Product Analysis and Sampling

Frequent, rapid and precise analysis of process water at various stages of each unit is required for successful operation of the "GS" Process in order to determine the degree of heavy water concentration attained within the unit.

This is accomplished in the Savannah "GS" building by the same methods employed at Dana.

No effort was made at Savannah to provide automatic sampling. Such an installation in one unit at Dana had proved costly and this was the primary reason for not extending its application, although the elimination of the

time lag in taking samples from scattered locations was a desirable feature. The justification for an automatic sampling installation at Dana was based on the anticipated savings in operating labor under conditions expected to demand the frequent and rapid delivery of many samples taken from locations covering a wide area. However, experience showed that frequent and fast sampling was not as critical as first thought and the operating labor for this service could, therefore, be reduced to a minimum for each building. Consequently the sampling procedure at Savannah became a manual operation whereby the operator draws the process fluid at various sampling points and conveys it in sample bottles or bombs for analysis.

The analyzers used are the specialized Consolidated Engineering Corporation Model 21-330 Mass Spectrometers. These are duplicates of those used at Dana - in fact, they were ordered for Dana in January, 1951, when, because of the long delivery time required, forty were ordered before exact requirements could be firmed. Later, twenty were transferred to Savannah. The addition of pressure compensators, with which it was possible to relax the sample pressure tolerance from 2-1/2% to 15% plus or minus, and of helium type leak detectors completed the requirements for analyzers. The Mass Spectrometers are installed in the Control Room of each "GS" Building and in the laboratory of Building #772-D, Control Laboratory and Supervisor's Office.

Information concerning the search for a suitable analyzer and the method of making sample connections for manual operation may be found in the Dana history. References in that history to sample points are, obviously, not applicable to the Savannah River Plant.

Rundown Facilities

Storage tanks are provided at Savannah River to hold "GS" process liquid and gas when it is desired to empty process equipment partially or completely. Because the gas storage tanks are located in the Tank Farm, Building #402-D, and some of the gas rundown equipment is common with equipment provided in the H₂S Plant, Building #401-D (adjacent to Building #402-D) the history of the H₂S Plant includes the discussion of these facilities. A summary of that discussion is given here together with comments on liquid storage because, regardless of their location, the rundown facilities constitute a phase of the "GS" Process.

H₂S gas withdrawn from the "GS" Process is cooled from the hot towers, relieved of entrained water, compressed and condensed for storage as a liquid. Since equipment performing these functions was also required for the production and storage of new H₂S, common facilities were installed for both

operations. However, cooling if required, is effected by the "GS" secondary condensers, and three additional storage tanks and vaporizers were provided for gas rundown and located in the Tank Farm. The common equipment was sized to accommodate the rundown gas which, at times, must be handled at a much greater rate than the H_2S generating capacity.

The "GS" Buildings and the Tank Farm are some distance apart at the Savannah Plant, in contrast with the Dana Plant where the two areas are adjacent and where both liquid and gas are stored in the Tank Farm. The use of common equipment makes it worthwhile to pipe the gas this greater distance but there is no such advantage in the case of liquid rundown. Accordingly two 6'-6" I.D. x 40'-0" high tanks are provided at each of the three "GS" buildings. These tanks are fabricated from carbon steel plate since they are intended only for intermittent use.

At the Dana Plant, no separate storage tanks were provided for a first stage rundown because of the large quantities of relatively low-value material involved. The H_2S is pumped, after liquefaction, to the 30,000 gal. H_2S storage tanks and the process liquid is sent to the retention basins. However, in the case of the smaller two stage "GS" units at Savannah (the first stage capacity is only approximately 25% of a Dana first stage) it was considered desirable to provide rundown tanks for gas rundown from the entire unit. Because of the possibility of more than one unit being shut down, storage capacity equal to the H_2S content of four of the twenty-four "GS" units was installed. No arrangement for the segregation of process gas in storage was considered necessary.

No tanks for storage of first stage liquid are furnished at Savannah as this liquid is considered expendable. The liquid rundown tanks described above are sized so that each will hold the liquid contents of two second stage towers. They are installed in pairs so that high concentration and low concentration liquids can be segregated. Thus, liquid rundown capacity was furnished for the second stage of one unit per building.

Product Handling

Product Stripper

The product stripper was designed to remove H_2S from the product before sending the liquid to the "DW" Plant for further concentration. Condensate from the second stage primary and secondary condensers is used as feed to the stripper. The gas removed is re-introduced into the process gas line. Steam in a reboiler is used for stripping to prevent product dilution.

The Savannah product strippers are similar to those installed at each Dana "GS" unit. However, the much smaller Savannah units produce, at the average rate, only about 4 g.p.h. as compared to approximately 16 g.p.h. from a Dana unit. At this low rate of production a single unit would require an inordinately small stripper. Therefore, it was decided to combine the product from eight units (one building) and perform the stripping operation on the composite stream. This required only three strippers for the entire "GS" area. Each stripper was designed to be fed about 800 gallons of product per day (100 gallons from each unit) bled from the second stage condensate drum.

Because of high temperature and turbulence conditions in the strippers, both characteristics contributing to rapid corrosion and contamination of product, stainless steel was chosen as the material of construction. The vessels were fabricated from 12-inch diameter (3/8" wall) Type 316 S/S pipe and are approximately 24 feet long. To effect the required stripping, 16 feet of ceramic Raschig ring packing was required.

Heat Exchangers and Storage Facilities

Auxiliary equipment required for each building for product handling in connection with the stripper includes:

1. A pressure volumetric tank (pipette tank) of approximately 100-gallon capacity for measuring the product withdrawn from the process. Each of these tanks, used only intermittently and not for storage, is fabricated from carbon steel with 1/4-inch corrosion allowance.

2. A pressure scale tank of 250-gallon capacity to receive the product increments from the pipette tank and to feed the stripper. The tank in Building #411-D was fabricated from carbon steel plate even though it is in constant use but Buildings #412-D and #413-D are provided with stainless clad tanks.

3. Four heat exchangers; stripper preheater, stripper reboiler, stripper condenser (for stripped H_2S), and product cooler. The stripped product cooler is necessary to prevent flashing of the product when the pressure is reduced to atmospheric for storage. The above exchangers are of the same construction in all three buildings, carbon steel shells and stainless steel tubes.

4. An atmospheric 1000-gallon hold-up scale tank for stripped product. This normal hold-up of about one day's production from eight units represents one third of the daily supply to the "D/V" area. This tank, operating at low temperature and atmospheric pressure and containing liquid

free from H_2S , is fabricated from carbon steel.

Insulation and Steam Tracing

The need for insulation and steam tracing of process lines, valves and equipment in the Savannah "GS" buildings was dictated by a two-fold requirement; (1) the prevention of solid hydrate formation from H_2S -water mixtures by keeping such mixtures at temperatures above $86^\circ F.$, and (2) the addition and/or retention of heat to prevent freezing during the winter in a plant largely unhoued.

The above requirements are identical to those for the Dana Plant and to a considerable extent were met in the same manner. The steam tracing problem at Dana was made particularly difficult by lack of design experience with the conditions stated in (1) above. It became necessary to design concurrently with early construction phases. As construction of Dana neared completion the steam tracing requirements became firmer and methods more clearly defined. Specifications could, therefore, be written with some certainty for the remainder of the plant. In general, these specifications were adopted for use at Savannah.

Generally, standard thermal insulation was used throughout Buildings #411-D, #412-D, and #413-D. However, the fire hazard, caused by possible leakage of H_2S gas, prevented the use of the customary insulation finishes where such a condition might exist. For application in these places, a fire resistant finish called Insul-Mastic No. 35 was originally selected. The finish was first used at Dana Plant where, after about a year of exposure to the elements, the compound showed signs of severe cracking and general disintegration. All the Insul-Mastic finish was removed and a newly developed finish known as Benjamin Foster Compound No. 60-60 was applied.

At the time of the decision to replace the insulation finish at Dana, less than one-half of the Insul-Mastic installation had been made at Savannah River. While the Savannah specifications were immediately changed to call for the Benjamin Foster compound, none of the previously installed finish was removed. At Savannah, the Insul-Mastic had been reinforced with a wire mesh on several towers which seems to have prevented the serious disintegration experienced at Dana: other towers have Insul-Mastic applied without reinforcement and disintegration has been very severe.

A departure from ordinary pipe line insulating practice at the Savannah Plant resulted because of an incident which occurred when Dana started operating. H_2S , leaking at a flanged joint, started a fire in the insulation. To

reduce the fire hazard by eliminating the trapping of gas, all flanged joints 4 inches and larger are not insulated. For the same reason, vents were placed through the insulation wherever minimum thickness holes were drilled.

For a detailed account of the problems involved in the design of insulation and steam tracing for pipe lines and equipment handling H_2S -water mixtures, reference is directed to the corresponding section of the Dana history. That report is applicable also to the insulation and steam tracing design problems presented by the #400 Area at the Savannah River Plant, except the Specifications, which are for Dana Plant only, and the methods of application to certain pieces of equipment. Specifications No. 3017 and No. 3018 provide the details for the Savannah River Plant insulation and steam tracing, respectively.

The equipment exceptions referred to concern pumps, blowers, valves and other pieces of equipment which for maintenance reasons must be dismantled at more or less frequent intervals. At such times, some or all of the insulation and steam tracing must be removed to gain access to the equipment. At Dana, the general practice was to use contour tracing and lagging, the removal and replacement of which added materially to the equipment maintenance cost.

Efforts to improve this condition at Savannah led to consideration of rigid housing such as panels fabricated from sheet metal with the inside face insulated. These materials were rejected because of the anticipated high maintenance cost from frequent assembly and disassembly. However, a housing fabricated from panels of "Marinite" was developed and found to possess satisfactory thermal efficiency and ruggedness. A further contribution to rapid and adequate access for equipment repairs was the use of easily installed groups of flat coils as tracing instead of container coils.

Process Lines

Part of du Pont Specification 3018 covers all "GS" and H_2S unit pipe, valves and fittings for the Savannah River #400-D Area. This specification is the product of many changes made as the result of corrosion studies, tests in the pilot plant at Dana and operating experience at the Dana Plant.

The design for most of the Savannah process lines is based on 350 p.s.i.g. maximum pressure and 300°F. maximum temperature, but otherwise the specification differs little from that prepared for use at Dana. The design of some valves was altered for materials of construction and/or certain operating characteristics to meet the special conditions imposed by H_2S service. Such changes were worked out

by du Pont and the valve manufacturers on the basis of Dana experience. For the most part, any difference in specification for the two plants reflects a change that would have been made at Dana had its advantages been known in time to specify without causing start-up delay.

Generally, the same special requirements for fabrication, erection, testing, safety, etc., were applicable to both Savannah and Dana process lines. A brief outline of these requirements follows.

1. Provision for some corrosion allowance on carbon steel components.
2. Stress relieving of all welds - including field welds.
3. Elimination of screwed joints wherever possible.
4. Provision in design for extremely low stresses in piping and bolting. Bolting of flanged joints to specifically recommended torque.
5. Provision for suitable supports and anchorage of line to prevent undue movement caused either by expansion or vibration.
6. Safety provisions; minimum thickness holes, halide testing of erected piping in addition to normal hydrostatic test, unlagged flanged joints.
7. Protection; insulation and steam tracing as protection against hydrate formation and normal freezing.
8. Strainers and filters installed as required to insure against damage to pumps, compressors, control valves and other critical equipment.
9. Provision for block valves in header piping to allow isolation of uncompleted portions of the plant from those in operation during the construction period. This was a problem applicable only to Savannah and was dictated by the physical arrangement of the units and the start-up schedule.

A more complete discussion of the special requirements as well as the early development work on process lines is given in the Dana history.

It should be noted that at the Dana Plant some of the special requirements listed above, notably the stress relieving of field welds and the drilling of minimum thickness

holes, were very costly and time consuming operations because of the necessity for using trial and error methods. These requirements were more expeditiously met at Savannah River.

DRAWINGS (Buildings #411-D, #412-D, and #413-D)

W-140314	Plot Plans				
W-140221	" "				
W-140447	" "				
W-140291	Process Flow Diagram				
W-140323	Process Piping & Instrument Diagram				
W-140324	" " " "				
W-140475	" " " "				
W-140476	" " " "				
W-140482	" " " "				

BUILDING #412-D "GS" PROCESS BUILDING #413-D "GS" PROCESS

Building #412-1D Production Unit No. 2 - Open Type
Structure With Two Wings
#412-2D Substations A & B
#412-3D Control House
(#413-1D, 2D, & 3D - Same as corresponding
Building #412)

FUNCTION

Buildings #412-D and #413-D are the second and third of the three essentially identical "GS" Process "Buildings", but are characterized by being the two installations in this group containing facilities which are considered permanent. These facilities were designed to operate indefinitely to produce heavy water make-up after the initial requirements were satisfied. The design capacity of each of these buildings is the same as that for Building #411-D.

BUILDING

Buildings #412-D and #413-D are essentially identical to Building #411-D with respect to "Principal Components", "Building Floor Space" and "Construction Details". However, the analyzer house is omitted, since one such house is able to serve all three "GS" buildings.

EQUIPMENT

The equipment in Buildings #412-D and #413-D is identical to that installed in Building #411-D except that, as previously explained, stainless steel is more widely used in

fabricating their components. Also, there were instances where a certain stainless steel was specified for a particular service in Building #411-D, but subsequent laboratory tests or Dana operating experience found a different grade of stainless steel to be more suitable. Advantage could be taken of such findings for Buildings #412-D and #413-D whereas the delay resulting from changing the specifications for Building #411-D could not be tolerated. Nor was longer equipment life necessarily an advantage in this latter building. Critical factors always carefully evaluated when determining the advisability of a change in metal specification to provide longer equipment life, were the scarcity of the metals being considered, the improvement in life expectancy of the fabricated parts, the time required for procurement, and the major difference between the "GS" buildings. Building #411-D, a temporary facility, was scheduled for early production; Buildings #412-D and #413-D, permanent facilities, were scheduled for later start-up dates.

In the following list of major types of equipment found in Buildings #412-D and #413-D, only those components are mentioned which deviate from the specifications as written for Building #411-D. A complete list of equipment for each of Buildings #412-D and #413-D can be obtained from the list given under "Building #411-D - Equipment", when corrected as indicated here. A single exception, which involves a difference existing between Building #412-D and Building #413-D, will be noted below. While referring to the list of equipment for Building #411-D it should be noted that the list is in two parts, one giving the equipment for each of the eight units in the building, the other part indicating facilities in which a single installation serves all eight units.

Production Towers

The carbon steel shells are either lined or clad with Type 316 stainless steel, and all internal parts are of Type 304 stainless steel.

Heat Exchangers

The first and second stage primary condensers have carbon steel shells with either lining or cladding of Type 304 stainless steel.

The first and second stage primary condensers have Type 316 stainless steel tubes.

Condensate Drums and Separators

The first stage separators have Type 316 stainless steel lining. The second stage separator shells are either clad

or lined with Type 316 stainless steel.

The first and second stage condensate drums have Type 316 stainless steel clad shells.

The second stage cold tower drum shell is lined with Type 316 stainless steel.

The shells for all the above vessels are of carbon steel lined or clad as noted.

Waste Water Stripping Facilities

The waste water stripper shell is of carbon steel clad with Type 316 stainless steel and all internal parts are of Type 304 stainless steel.

Note: A variation in tray construction exists in the waste water stripper for unit #7 of Building #412-D. A stainless steel slat-type tray consisting of three layers of 4-inch channels, laid flange down on 6-inch centers across the tower, was substituted for each of the top six bubble cap trays in this one vessel.

Product Stripping Facilities

The unstripped product storage tank shell is fabricated from carbon steel plate having Type 316 stainless steel cladding.

Gas Purging, Feed Water and Control Facilities

The purge tower lower section is rolled from Type 316 stainless clad carbon steel plate and the upper section is fabricated from Type 316 stainless steel pipe.

PROCESS

Same as Building #411-D.

DEVELOPMENT OF DESIGN

For the sake of subject completeness and to avoid a considerable amount of repetition or reference, this section under "Building #411-D" was written to be applicable to all three "GS" buildings and to explain the differences in the equipment listed above.

DRAWINGS

See drawing list under "Building #411-D".

BUILDING #411-5D - SHELTER AND SHOP

FUNCTION

This building provides a shelter for maintenance personnel while performing on-the-job work.

PRINCIPAL COMPONENTS

The structure is a roofed-over concrete slab having one end and portions of sides permanently enclosed. Canvas drop curtains are provided for the balance of the building.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Working Area

312

BUILDING DETAILS

Size Ground area - 14'-0" x 24'-6"
 Area - 343 sq. ft.
 Volume - 3775 cu. ft.

CONSTRUCTION DETAILS

Foundation - Reinforced concrete grade beams.

Superstructure - Wood frame.

Exterior walls - a) One end and 8' along each side - corrugated asbestos.

b) Canvas drop curtains for balance of building.

Interior of exterior walls - No finish.

Ceiling - None.

Insulation - None.

Floor - Concrete slab on grade.

Doors - None.

Sash - None.

Roofing - Corrugated cement asbestos.

Heating - None.

Ventilation - None.

Lighting - Fluorescent.

Electrical

Electricity is provided for the fluorescent lighting,

receptacles and welding receptacles.

Location

This Shelter and Shop is located within the area designated as Building #411-D, and in approximately the center of the space between the "Wings" of that Building.

DRAWINGS

W-141299 - Architectural, Plans and Details.
W-141301 - Electrical.

BUILDING #412-4D MASK MAINTENANCE BUILDING

FUNCTION

To provide storage, servicing, and dispensing facilities for the gas masks and air masks used by personnel in the #400-D Area. The servicing consists of routine repairs, sterilizing, replacement of cannisters or charging of air cylinders.

PRINCIPAL COMPONENTS

1. An enclosed area for performing the required dispensing and servicing of gas masks and air masks, including storage of parts.

2. An adjacent, sheltered area for the storage of compressed air cylinders.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Servicing area	360
Storage area	225

BUILDING DETAILS

Class III

<u>Size</u>	a. Servicing area - 24' x 15'
	Area - 360 sq. ft.
	Volume - 4200 cu. ft.
	b. Storage area - 15' x 15'
	Area - 225 sq. ft.
	Volume - 2625 cu. ft.

CONSTRUCTION DETAILS

Foundation - Reinforced concrete grade beams.

Superstructure - Wood frame.

Exterior walls - Corrugated cement asbestos board.

Interior of exterior walls - No finish.

Ceiling - None.

Insulation - None.

Floor - Concrete, on grade, No. 1 finish.

Doors - Wood with glass.

Sash - Wood, double hung.

Roofing - Corrugated asbestos.

Heating - Direct radiation.

Ventilation - None.

Lighting - Interior - fluorescent; exterior - incandescent.

Location

The Mask Maintenance Building is located within the area designated as Building #412-D and between the Electrical Substation for the east "Wing" and the Control Building.

DRAWING

W-141297 - Architectural, Electrical, Plumbing

BUILDING #412-5D - SHELTER AND SHOP

FUNCTION

To provide a maintenance work shelter and space for work benches, tools, and supplies used frequently in on-the-job repairs. The building also provides sanitary facilities for field personnel.

PRINCIPAL COMPONENTS

A single structure housing an instrument shop, electrical shop, general maintenance shop, and toilet room.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

(a) Instrument shop -

240

(b)	Electrical shop	240
(c)	General shop	480
(d)	Toilet room	240

BUILDING DETAILS

Class - IV

Size - Working area - 20' x 60'-4"
 Area - 1220 sq. ft.
 Volume - 15,600 cu. ft.

CONSTRUCTION DETAILS

Foundation - Reinforced concrete grade beams.

Superstructure - Steel frame.

Exterior walls - Corrugated galvanized steel.

Interior of exterior walls - No finish except in toilet room where 1/4" flat cement asbestos board is used.

Ceiling - None except in toilet room which has 1/4" flat cement asbestos board on wood nailers.

Insulation - None.

Partitions - Partial 1/4" flat cement asbestos board partition between Instrument and Electrical Shops. Toilet room partitioned off from shops areas with 1/4" flat cement asbestos board. All partitions on one side of studs only.

Floor - Concrete slab on grade.

Doors - Hollow steel.

Sash - Metal, pivoted type.

Roofing - Corrugated galvanized steel.

Heating - None.

Ventilation - Fans in eaves at ends of building.

Gravity roof ventilator for toilet room segregates ventilation of toilet room from remainder of building system.

Lighting - Fluorescent in shops areas, incandescent in toilet room.

Electrical

Electricity provided for lighting, fan motors, receptacles, and welding receptacles. The 440 v. power supply is provided with sufficient capacity for limited heating if required.

Services

Plant air and domestic water supplied to shops areas and toilet room.

Location

This Shelter and Shop is located within the area designated as Building #412-D, and in approximately the center of the space between the "Wings" of that buildings.

DEVELOPMENT OF DESIGN

Building #412-5D is a relocated "Temporary Construction" building reduced in width by retaining only the 20 ft. center bay throughout the length of the structure. It is of Class IV construction, the principal deviation from Class III requirements being the re-use of sheet metal siding and roofing. All interior work is new to suit the permanent function of the building.

Class IV construction was established, with the approval of the AEC, to permit the use, in specific cases, of available "TC" buildings as permanent operating structures. Most "TC" buildings would be unacceptable by the Class III standards previously required for the #400-D Area. The subject of Class IV construction and the re-use of "TC" buildings is discussed in greater detail in that section of this history entitled, "Building #411-D", sub-section "Development - Buildings".

DRAWINGS

W-160560 - Architectural, Concrete, Steel, and Plumbing.
W-141301 - Electrical.
D-122758 - Yard Piping.

BUILDING #413-4D - SHELTER AND SHOP

This Shelter and Shop is a duplicate of Building #411-5D and occupies a similar position relative to the operating units, except that it is located within the Building #413-D area.

BUILDING #419-D - FLARE

FUNCTION

The flare provides a means of disposing of routine leakage and the emergency discharge of large quantities of H₂S gas from Buildings #401, #402, #411, #412 and #413-D.

PRINCIPAL COMPONENTS

A structural steel framework, 50 feet square at the base and 375 feet high, encloses a 20-inch diameter, high pressure flare stack and a 6-inch diameter, low pressure flare stack.

BUILDING FLOOR SPACE

There is no building as such. The only structure consists of the high steel tower which occupies a ground area of 2500 square feet.

BUILDING DETAILS

Class - III.

CONSTRUCTION DETAILS

Foundations - Reinforced concrete with spread footings.

Superstructure - Structural steel, including ladder to top of tower and grating platforms. All structural steel is galvanized to reduce maintenance to a minimum.

EQUIPMENT

Stacks

The high pressure flare stack consists of a base section 4 feet in diameter and 18 feet high and 359 feet of 20-inch carbon steel pipe topped with 18 feet of 20-inch stainless steel pipe. The base section contains water and acts as a flame arrestor for the gas line which discharges 10 feet below the normal water level.

The low pressure flare stack consists of 6-inch diameter stainless steel pipe extending 398 feet above grade. Two flame arrestors are placed in the process lines supplying this low pressure flare and are installed just ahead of the stack.

Two large propane gas burners are placed at the top of the high pressure stack. These are ignited by electrically heated glow-wire igniter pilots. Both the H₂S igniting pilots and the burners use propane gas piped from Building #401-D.

Instrumentation

Instrumentation is provided to control the water level in the base of the 20-inch stack, and to regulate the propane gas used in the burners.

Piping

Since the flare serves the tank farm and the "GS" and H_2S processes, much of the piping and many of the valves used for venting to the flare belong to those several areas. However, the headers supplying the flare are considered a part of this installation. This subject will be treated in greater detail in a later section under the heading "Development of Design".

Safety

Safety equipment consists of air masks and air supply headers extending to the top of the tower with outlets at each platform elevation, approximately every 20 to 25 feet.

PROCESS

Development

The flare is one of the several auxiliary facilities added to the #400-D Area purely for reasons of safety. Its primary need stems from the production and use of large quantities of an extremely toxic gas, H_2S , as a process component.

The nature of the H_2S hazard, and the effort made to reduce it to a minimum, has been discussed in detail in the Dana history, and summarized in this report in the section "Specialized Design Problems", under "Safety". Only a brief statement of pertinent facts is presented here.

The release of H_2S to the atmosphere and the consequent creation of a hazard to operating personnel can result from (1) the normal venting and leakage of process equipment, (2) the purging of equipment before and after shutdown, and (3) emergencies resulting from such possible malfunctions as a line break, a seal failure, an explosion or fire, an operating error or subversive action. Items (1) and (2) result in a continuous release of a relatively small quantity of gas at known locations from which it can be removed by vent lines.

Source (3), however, could cause the rapid release of a very large volume of H_2S from almost any part of the plant where this gas is either stored or in process. Obviously it

is impractical to enclose these areas or to vent all facilities. The problem was resolved by endeavoring to design, test and erect facilities in such a way that possibilities of an emergency would be minimized and by providing a sizable header which, with a system of remotely operated motorized valves, makes possible the isolation of critical sections of the facilities and the removal of much of the gas from these sections.

Studies made during design of the Dana Plant indicated the desirability of flaring these discharged gases rather than attempting any method of recovery. The routine leakage, termed the low pressure discharge, is insufficient to warrant recovery and the intolerable emergency release, or high pressure discharge, occurs infrequently but in such quantity that rapid disposal is the paramount objective. By discharging at a high altitude, approximately 400 feet above grade, during normal atmospheric conditions, the gas becomes diluted to a non-toxic concentration by the time it settles to the ground. Under unusual and extreme conditions, such as a temperature inversion, dangerous concentrations may still be expected at ground level.

H₂S in very low concentrations evidences itself by its characteristic odor, that of rotten eggs. In higher concentrations it reacts on the olfactory nerves, deadening them completely so that one is not aware that he is in a toxic or perhaps a lethal atmosphere. However, H₂S can be burned in air, producing sulphur dioxide (SO₂). While this gas is also very toxic and has a distinctive pungent odor, it does not deaden the sense of smell and therefore, is noticeable in all concentrations. As a safety measure, an ignition system is provided at the top of the flare stack which makes it possible to burn the H₂S discharge, converting it to SO₂. As with H₂S, the SO₂ should be adequately diluted by the time it reaches grade.

DEVELOPMENT OF DESIGN

Equipment

To provide a basis for the design of disposal facilities, data had to be compiled on the quantity of gas that must be vented, dispersion of H₂S under various atmospheric conditions, prevailing atmospheric and wind conditions at the site, allowable concentration limits, and radius of detectability from the flare. All this information entered into considerations which determined stack heights, diameters, and other pertinent design data.

The design data being essentially the same for the two plants, the Savannah River flare is generally the same as that

installed at Dana. However, a few changes were made in the SRP design based on Dana operating experience, notably with reference to the burner and ignition system, and to the gas headers and their supports. These and other changes are discussed in subsequent sections. The location of the flare with respect to the process areas at Savannah River depended upon local prevailing wind conditions rather than upon Dana design or experience. It is obviously desirable to have as many of the operating personnel to the windward of the flare as much of the time as possible.

Tower

The tower supporting the two flare lines (stacks), like the one at the Dana plant, is fabricated of galvanized structural steel and is similar to a wide-base antenna tower without guy wires. The tower itself is 50 feet square at the base and 375 feet high, the two stacks extending above the top platform to a height of 398 feet above grade.

Galvanized steel was specified in an attempt to minimize maintenance costs by eliminating the need for protective painting. Because the Savannah River Plant is located in a restricted zone, no aircraft warning painting was required by the CAA. Aircraft warning lights were also eliminated for the same reason. Since the Dana plant is near several major air lanes, lighting, but not painting, was required at that site.

Stacks

The flare stacks at Savannah River are essentially the same as those at Dana, having the same diameters and approximately the same height. Both the high pressure and low pressure stacks, as well as the headers, are separate lines to minimize corrosion in the larger line (high pressure) which is used infrequently.

The materials used in fabricating the stacks were chosen on the basis of an evaluation between carbon steel, Type 304 stainless steel and Type 317 stainless steel. The 6-inch low pressure stack, handling the leakage from all relief valves as well as the discharge from purging process vessels and lines, is essentially in continuous use and is therefore made of Type 304 stainless steel pipe having a wall thickness of 1/4-inch. The 20-inch high pressure stack, operating infrequently, is fabricated from carbon steel with protective painting on the outside surface, except that the top 18 feet is 25-20 stainless steel in order to reduce corrosion of the top while burning the H_2S . Since replacement of the top section is a costly procedure, the installation of stainless steel was readily justified.

To ignite the H_2S from the high pressure stack two burners are located at the top of the stack but no provision is made for igniting the gas from the low pressure stack as dispersion of the relatively small volume of H_2S involved can be tolerated.

At low gas flow rates it was considered possible for the flame to flash back down the stack and into the headers so two flame arrestors were installed in the low pressure header just ahead of the stack. Since the flow in the high pressure stack is normally low, a flame arrestor, consisting of a water seal, is provided by having the header supplying the stack discharge below 10 feet of water in the base of the stack. Instrumentation is installed to maintain the proper liquid level.

In addition to acting as a flame arrestor, the water in the base also causes the diversion of small quantities of gas to the low pressure stack. While there are actually two systems, high and low pressure, the two are interconnected near the flare tower. Since the pressure drop through the water seal is greater than that of the low pressure system, small flows of gas in the high pressure header are diverted to the low pressure equipment. A discharge of large quantities of high pressure gas blows the liquid seal clear, permitting the gas to escape freely. The liquid seal is automatically replaced upon a drop in gas flow.

Protection to the stacks is provided as follows:

1. High pressure stack. Steam and inert gas are supplied to the base section, the steam being used to melt any hydrate in the stack and to purge large quantities of gas, while a small amount of inert gas is bled into the stack continuously to maintain an inert atmosphere in the stack, minimizing corrosion and extending stack life. Also, the 18-foot base section and its water piping is steam traced and insulated to prevent freezing.

2. Low pressure stack. To prevent any hydrate or natural ice formation inside the stack, this line is steam traced and insulated. Since the insulation at the top would be exposed to the flame from this stack or from the adjacent high pressure stack, the top 20 feet of insulation is protected by a stainless steel sheath.

Early in 1952, operating experience at Dana indicated that during steam-out of solid hydrate, the flare stacks would become sufficiently heated to cause an expansion of approximately 9 inches. This displaced portions of the stack from its guides, damaged insulation, and broke small connecting lines. Review of this difficulty resulted in a number of changes in the Savannah River design. These changes included the addition of a 6-inch diameter cleanout at the base of the

low pressure stack, an increase in the height of the stack dowl guides, and the provision of sections of flexible electrical conduit and flexible hose in the propane fuel line. It was also necessary to install insulation on the low pressure stack in a manner that would allow expansion.

Pilot Burners

Dissatisfaction with the H_2S ignition system installed at the Dana Plant prompted a new design and operating procedure for Savannah River. The Dana H_2S ignition system consists of two propane-fed pilot burners, set 180° apart inside the stack top, which are ignited by heavy duty airplane-type spark plugs. Initial tests were quite unsatisfactory but after further study and some changes involving propane feed points and jets, the successful ignition incident rate was raised to about 90% for a single burner. With two burners installed, it was believed that this rate would suffice.

At the time difficulties were being experienced at Dana, the Savannah River flare program was still in the design stage. The desire to furnish Savannah with a more reliable device than that developed at Dana resulted in a revision of the ignition system. This system consists of two large pilot burners, each ignited independently by electrical glow-wire pilot igniters. The glow wire igniters can be actuated by electrical controls at the base of the flare, or in any of the three "GS" control rooms.

In a further effort to furnish Savannah River with an improved ignition system, the idea was advanced by the AED that continuous pilot operation would be desirable. The chief objection to this was based on instructions by the AEC to make the flare as obscure as possible, including careful shielding of any pilot light required at the tip of the stack. Since effective shielding was considered improbable, the continuous operation of a pilot flame could not conform to AEC instructions. However, the advantages of a continuous pilot seemed so great that the AEC was asked to grant permission for that method of operation; it was stressed that the pilot flame could be extinguished at any time to satisfy blackout requirements. Permission to make this change was given by the AEC.

The Savannah River flare is located some distance from the H_2S Plant, Building #401-D, which contains the propane storage tank. For this reason, the design for intermittent pilot burner operation contemplated supplying propane from cylinders placed at the bottom of the flare tower. For continuous operation, however, the rate of fuel consumption dictated supplying the flare by pipe line direct from the storage tank.

Flare Headers

From the inception of the Dana design, concern was expressed as to the effect on the high pressure headers of the release of one or more "GS" towers under emergency conditions. As soon as it was possible, tests were conducted under what was considered the worst possible conditions. A number of improvements were found necessary in the header design.

The high pressure headers at Dana are hung from pipe supports but the headers at Savannah River are held up by beam cuts resting on the pipe supports. Early in 1952, AED requested the Design Division to review the revised Dana design for controlled and restrained movement of the headers and include the improvements in the Savannah design if applicable. Because of the basic difference in the method of supporting the headers, it did not seem necessary to appreciably modify the design of Savannah. The beam cuts supporting the Savannah lines were well guided and anchored to prevent line "whipping" similar to that experienced in the initial Dana tests.

However, because of the critical nature of the function which these flare lines serve, it was decided to investigate and test the effect of arbitrarily chosen emergency conditions including water slugs. As a result of the test program minor changes were made in design, including the addition of more pipe guides, the elimination of sharp turns and the stiffening of bents, guides, and beam cuts.

Another request by the AED asked the Design Division to recommend a tighter sealing valve for Savannah River than the gate valves used at Dana for flaring the "GS" towers. An engineering review of this situation resulted in the installation of connections for water-sealing the valves when closed.

Safety

The primary purpose of the flare is to dispose of normal and emergency releases of H_2S in such a manner that the hazard to operating personnel will be reduced to a minimum. It is of interest to examine the extent of this reduction that can be anticipated at Savannah River.

The Engineering Service Division of du Pont's Engineering Department has compiled the table given below which indicates the downwind ground level concentrations of gases expected to be encountered from a 400-foot flare stack under various conditions.

<u>Emission Rate</u> H ₂ S (lb./hr.)	<u>Wind Vel.</u> (mph)	<u>Ave. Max. Conc.</u> H ₂ S (or SO ₂ If H ₂ S Is Burned) (ppm by Vol.)	<u>Momentary</u> <u>Peak Conc.</u> (ppm by Vol.)
1000	1	1.52	15.2
1000	5	0.30	3.0
1000	10	0.15	1.5
1000	15	0.10	1.0
5000	1	7.60	76.0
5000	5	1.50	15.0
5000	10	0.75	7.5
5000	15	0.50	5.0
10000	1	15.20	152.0
10000	5	3.00	30.0
10000	10	1.50	15.0
10000	15	1.00	10.0
15000	1	22.80	228.0
15000	5	4.56	45.6
15000	10	2.28	22.8
15000	15	1.52	15.2

The point of maximum concentration will occur anywhere from 2000 feet to about 2 miles downwind from the flare stack depending upon whether moderate or low turbulence conditions exist in the atmosphere.

It should be noted that of the higher concentrations indicated above, all the average maximum concentrations can be tolerated during a prolonged exposure, and the highest momentary peak concentration is within the range that can be inhaled for approximately one hour without serious consequences. Further, it is unlikely that the higher concentrations for any given condition of wind velocity and gas release covered by the table will occur within the operating area. These statements are not to be construed as meaning that operating personnel are unprotected where such concentrations of gas exist. Much lower concentrations actuate alarms and cause evacuation or use of masks, depending upon the duties of the personnel concerned.

Attention is also called to the fact that the concentrations referred to above as probably tolerable are the result of gas emission of only 15,000 pounds per hour, the approximate capacity of the low pressure flare. The capacity of the high pressure flare is approximately 100,000 pounds per hour. Thus it would seem that any emergency release requiring even partial use of the high pressure flare would result in dangerous conditions at ground level, except under the most favorable atmospheric conditions.

It was realized that, while use of the flare will greatly improve conditions, a major gas release can still create a serious hazard within the operating area and for a considerable distance downwind of that area. All efforts to design against failure of H₂S containing facilities were employed.

DRAWINGS

W-140200 - Plot Plan
W-140541 - Process Piping & Instrument Diagram
W-140945 - Design Drawing Index

BUILDING #420-D - CONCENTRATOR ("DW" PROCESS)

FUNCTION

The "DW" process is the second, or intermediate, step in the concentration of heavy water and provides an increase in concentration of D₂O from 11 per cent, as received from the "GS" process, to 98 per cent by weight.

PRINCIPAL COMPONENTS

The building consists of a single-story structure divided into an Instrument Control Room, Pump Room, Electrical Control Room, and a Compressor Area. A superstructure above the first floor supports various condensers, coolers and jets. All tanks, except weigh-tanks, and all process towers are in two rows outdoors, one on each side of the building and supported independently.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Instrument control room	715
Pump room	4462
Electrical control room	252
Compressor area	532

BUILDING DETAILS

Class - III.

Size -

Area - 6030 square feet.
Volume - 121,300 cubic feet (enclosed).
222,000 total cubic feet.

CONSTRUCTION DETAILS

Foundations - Reinforced concrete with spread footings.

Superstructure - Structural steel frame.

Exterior walls - Corrugated asbestos board; compressor room open to 8' above the floor. No interior finish except in instrument room which has 1/4" insulation board, finished with 3/8" sheet rock.

Interior partitions - Instrument room has 1/2" insulation board and 3/8" sheet rock on finished side, corrugated asbestos on pump room side.

Ceiling - Instrument room only; wood furring, 1/2" insulation board, 3/8" sheet rock and 2" fiberglass.

Doors - Hollow metal.

Sash - None.

Floors - Concrete.

Roofing - Corrugated asbestos, except roof over pump room is a concrete slab forming the floor of the condenser area.

Heating - Unit heaters in the pump room and electrical control room; air conditioning unit in the instrument room; none in compressor area.

Air Conditioning - A package unit is provided in the instrument control room.

Air Exhaust - The pump room has gravity roof ventilators and wall louvers; the electrical room has mechanical blowers. No ventilation facilities are provided in the compressor area.

Lighting - Fluorescent in the instrument control room; vapor-proof, incandescent in all other locations.

EQUIPMENT

Building #420-D contains two vacuum distillation trains of five stages each, each stage made up of six distillation towers. The first stage is theoretically a single tower but, because of fabrication and erection considerations, is actually two towers connected in series. Each succeeding stage consists of one tower only.

Facilities provided for each stage of each distillation train consist of the following principal items:

Sectional tower, bubble cap trays.
Calandria.
Reflux pump (first stage only - other stages operate on gravity reflux).
Reflux condenser.
Vent cooler.
Twin vent chillers.
Transfer pump.
Vacuum jet.
Distillate receiver.
Rundown tank.

Facilities common to both distillation trains consist of the following:

Scale tank and storage tank - Receipt of material from "GS".

Scale tank and storage tank - Return of material to "GS".

Transfer pump - "GS" return.

Transfer pump - Product to "E".

Transfer pump - First stage distillate to "GS" return tank.

A NH₃ refrigeration unit and auxiliary equipment, 17.3-ton maximum capacity, to supply coolant for vent cooler and twin chillers.

With the exception of the scale tanks, all tanks are located out of doors on concrete pedestals or extended concrete saddles. Insulation only is provided to prevent the contents from freezing as it is expected that these vessels will be used for short durations, since they are used only during shutdowns.

Without exception, all pumps are installed within the building and each process pump is provided with an installed spare. Towers, condensers, coolers and chillers are all outdoors. Steam traced or heated housings are provided for instrumentation; outdoor liquid lines are traced.

The following is a brief resume' of the major equipment required for Building #420-D.

Towers

These are fabricated in flanged sections about 6' long, with bubble cap trays installed at the factory. Trays are supported on pedestals which carry the tray weight to the base of the tower.

2 - 6'-0" I.D. x 92'-0" high steel towers - 84 trays - first stage.

2 - 7'-6" I.D. x 81'-0" high steel towers - 72 trays - first stage.

- 2 - 5'-0" I.D. x 81'-0" high steel towers - 72 trays - second stage.
- 6 - 4'-0" I.D. x 77'-0" high steel towers - 72 trays - third, fourth, and fifth stage.

Tanks (Process)

- 3 - Steel vertical scale tanks 5'-0" I.D. x 9'-0" high - liquid from "GS".
- 1 - Steel horizontal storage tank - 6'-6" I.D. x 12'-0" long - liquid from "GS".
- 3 - Steel vertical scale tanks 5'-0" I.D. x 9'-0" high - liquid to "GS".
- 1 - Steel horizontal storage tank 6'-6" I.D. x 12'-0" long - liquid to "GS".
- 2 - Steel vertical storage tanks 10'-0" I.D. x 18'-0" high - rundown - first stage.
- 1 - Steel horizontal storage tank 6'-6" I.D. x 12'-0" long - rundown - second stage.
- 3 - Steel horizontal storage tanks 4'-6" I.D. x 12'-0" long - rundown - third, fourth and fifth stage.
- 4 - Steel horizontal storage tanks 18" I.D. x 2'-0" long - Surge.
- 2 - Steel vertical scale tanks 3'-0" I.D. x 5'-0" high - product weigh.

Calandrias

These are shell and tube carbon steel exchangers with process liquid on the tube side and 40# steam on the shell side. All have 1" diameter by 8' long, 14 gauge tubes:

- 2 - 24" diameter shell - 200 tubes - 358 sq. ft. - first stage.
- 2 - 18" diameter shell - 87 tubes - 160 sq. ft. - second stage.
- 6 - 16" diameter shell - 60 tubes - 110 sq. ft. - third, fourth and fifth stages.

Reflux Condensers

These are shell and tube, falling-film type exchangers with the process fluid on the shell side and river water on the tube side. All of carbon steel tubes, 2" diameter by 16' long, 12 gauge:

- 2 - 66" diameter shell - 559 tubes - 4500 sq. ft. - first stage.
- 2 - 46" diameter shell - 253 tubes - 2040 sq. ft. - second stage.
- 6 - 36" diameter shell - 151 tubes - 1210 sq. ft. - third, fourth and fifth stages.

Vent Coolers

All ten units have essentially the same condensing load and are identical in size, except that the two on the common vent system of the distillation trains are identical in construction to the vent chillers described below. Each unit consists of a double coil inside a 6" pipe shell. The process medium passes through the coils with 35°-40°F. ammonia in the shell:

- 10 - 6" diameter shell, 2-1/2" 18-gauge seamless tube - 11.7 sq. ft.
- 2 - 6" diameter shell, 1-3" Sch. 40 seamless pipe - 18.0 sq. ft.

Vent Chillers

Two in parallel constitute a unit. All units are identical and are constructed of 3" Sch. 40 seamless pipe, jacketed with 6" pipe. Effective length 20'. Cooling medium - 20°F. Ammonia.

- 20 - 6" diameter shell, 1-3" Sch. 40 seamless pipe - 18.0 sq. ft. Chillers are connected in pairs - one being used while the other is being thawed by passing hot ammonia gas directly from the compressor through the shell.

Pumps

- 39 - 1-1/2" x 1-1/4" Allis Chalmers SS-DHB single stage centrifugal pumps complete with Durametallic single mechanical seals, Falk couplings, cast steel casings and cast iron impellers. Direct driven by 5 h.p., 3600 r.p.m. motors.

Vacuum Jets

The desired pressure of 100 mm. Hg. abs. at the top of each column is developed by:

- 10 - Croll Reynolds No. 200-N two-stage, noncondensing evactors, rated at 10 lb. air per hour at 88mm. using 100 p.s.i.g. steam with a maximum back pressure of 1 p.s.i.g.

Refrigeration Units

- 3 - 5" x 5" - 282 r.p.m., vertical, belt drive, York compressors with 15 h.p. motor and all auxiliary equipment. Rating at 40°F. inlet temperature - 14 tons; at -20°F. - 3 tons. Refrigeration for the

vent coolers and chillers is supplied from these units. Since there are two temperature levels required, one unit normally operates at 40°F., another at -20°F., while the third is a standby unit for either service.

Process Piping

All process piping is carbon steel, with carbon steel valves. Wherever possible, joints are either welded or socket welded. Valves are generally flanged, with some of the smaller sizes socket welded. All outdoor liquid lines are steam traced to prevent freezing. Since all of the equipment and piping is carbon steel, some corrosion products are to be expected. To prevent transferring these products to the "E" process, filters are installed at the transfer pump of the fifth stage tower. By recirculating the heavy water through the filters, most scale is removed.

Instrumentation

Instruments are provided as required for the measurement and control of process and utility variables. A central instrument control panel is located in the instrument control room.

Control of the process feed, column bottoms draw-off, and overheads draw-off are manual through valves and rotometers, level indicators being used instead of level controllers. Since the entire train is essentially an extension of the stripping section of the first stage, it was feared that automatic level correction in one stage might cause trouble in another. Boil-up in each stage is controlled by steam flow controllers.

Absolute pressure recorders are provided to record the pressure in each stage. An indication of an increase in pressure tells the operator that the vent chiller in use is plugging with ice and that a switch to the other unit is required. Vacuum is controlled by automatic air bleeds on each steam jet.

Electrical

Equipment and processes of this building presented no extraordinary electrical problems, either from the process hazard or extreme reliability standpoints. Power was, therefore, supplied from the common area miscellaneous feeder, through an outdoor substation located just south of the building. The main building supply is at 480 volts, with lighting voltages obtained through dry-type step-down transformers.

Safety alarm components and emergency lights are supplied from a connection to the common area emergency (480 volt) circuit.

PROCESS

Description

The "DW" facilities consist of two parallel, identical, continuous, vacuum distillation trains, each consisting of five stages. Some equipment, principally storage tanks, weigh tanks and run-down tanks, are common to both trains. The description of the process which follows traces the path of the process materials through a single train and the jointly used facilities.

The first stage consists of two bubble cap towers piped in series, having a total of 156 plates. Since the feed solution to this stage may have a varying concentration, while the desired concentration of product remains constant, means have been provided for feeding the solution on the 24th or 48th plate of the first tower, or the 23rd, 43rd, 63rd, or 84th tray of the second tower. This feed amounts to a nominal 386 lbs./hr. of 11 per cent material, plus a small amount of 6 per cent solution returned from the "E" process.

The liquid flows down through the column, contacting the rising vapors, and is transferred from the base of the first column to the top of the second column by pumping. From the base of the second tower, 5000 lbs./hr. of a 20 per cent mixture is pumped forward to the top of the second stage tower. Slightly less than 5000 lbs./hr. of 20 per cent solution is returned to the bottom of the first stage as condensate from the second stage.

The bottom of the first stage is equipped with a reboiler, or calandria, that provides a boil-up rate of 11,000 lbs./hr. at 20 per cent concentration. Forty p.s.i.g. steam is used on the shell side of the exchanger as a source of heat. The vapors rise through the bubble trays, contacting the down flowing liquid, and pass on to the base of the first tower in the first stage. Here they again rise through the tower and discharge to the condenser and recovery system. Since H_2O is more volatile than D_2O , these vapors are now rich in H_2O , containing only about 3 per cent D_2O .

The condenser receives 11,000 lbs./hr. of 3 per cent gas and condenses essentially all of the gas at 104°F. using water as a cooling medium. The uncondensed gases pass on to an ammonia-cooled vent cooler where additional liquid is recovered at 50°F. and combined with the condenser stream. The

remaining gas enters one of two parallel vent chillers where the bulk of the residual water vapor is removed from the stream by freezing at -13°F . It is estimated that 0.03 lbs./hr. of water continues and is lost through the vacuum system.

The first stage reflux is returned by pumping at the rate of about 11,000 lbs./hr. of 3 per cent stock. A small cut of the first stage condensate, 355 lbs./hr., is made, weighed, and stored for periodic return to the "GS" process. During start-up the first stage towers, and all others, are operated on total reflux until equilibrium is reached.

The second stage of the distillation chain continues the stripping of H_2O from D_2O . The 5000 lbs./hr. of 20 per cent feed from the first stage enters the top of the second stage tower, flowing down to the reboiler at the base of the tower. The reboiler provides a boil-up rate of 5000 lbs./hr. of a solution now at 40 per cent concentration.

Three thousand lbs./hr. of this mixture are pumped forward to the third stage as feed, and 31 lbs./hr. less of 40 per cent condensate is returned from the third stage.

Vapors off the top of the second stage have a concentration of 20 per cent and a 5000 lbs./hr. rate. As in the first stage, they pass through their condenser, vent cooler and vent chiller, and then to the vacuum system. Temperatures are the same as in the first stage. All second stage condensate, except during start-up, is returned to the first stage.

The third, fourth and fifth stages continue enriching the D_2O content in the same manner. Three thousand lbs./hr. of 68 per cent and 90 per cent are withdrawn from the bases of the third and fourth stages and forwarded to the next stage. Thirty-one pounds per hour less of 40 per cent, 68 per cent and 90 per cent condensate from the third, fourth and fifth stages respectively are returned to the preceding stage.

In the fifth and last stage, 31 lbs./hr. of approximately 98 per cent product are continuously withdrawn and pumped to storage in a scale tank. This material is pumped forward on a convenient schedule to the "E" process for final concentration.

Run-down tanks are provided for the six columns in each train. In the event it becomes necessary to shut down a train, or parts of a train, the liquid in the system is collected in these tanks. Upon start-up, this liquid is returned to its proper tower.

Development

The process involved in this building is an established commercial operation and was utilized in the P-9 plants during World War II as the primary step in the concentration of heavy water.

At the Dana Plant, where the newly developed "GS" process was first used as the initial concentration step, the distillation ("DW") process served as the intermediate step in the extraction of heavy water. Thus, for the Savannah River installation, no process development on this step was required.

More favorable equilibrium relationships between D_2O and H_2O at reduced pressure dictated the use of vacuum distillation equipment. While this method of operation at Savannah represents no departure from the procedure at Dana, or the P-9 Plants, it was thought desirable to record in this section the reason for such an installation.

DEVELOPMENT OF DESIGN

Building

The selection of Class III construction for the Building #420-D structure was made by the Atomic Energy Division and the Atomic Energy Commission. The process involved, being of an established commercial nature and involving no hazardous materials, the design of the structure presented no special problems.

Equipment

The major factors affecting design of the Savannah River "DW" Plant were prevalent in the Dana design, and therefore did not present new problems. These major factors were: 1) provision of adequate design capacity to be capable of accepting feed of varying concentration and yet deliver sufficient product of 98% concentration, and 2) prevention of loss of high value product through leakage or as vapor with the vented inerts from condensers.

During the summer of 1951 it was proposed that perhaps a saving could be obtained by utilizing some of the P-9 towers available at Dana. A study which took into consideration dismantling, shipping, reactivation, and the necessary modification to Savannah design, indicated a saving of about \$40,000. However, balanced against the anticipated high cancellation charges on equipment already ordered for Savannah, the probable delay in completion and the poor operating history of the P-9 towers, the apparent savings did not justify their use and the original Savannah design was retained.

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

3

of

3

Proposed operating characteristics of the Savannah River #400-D Area prompted a major change in "DW" plant design from that erected at Dana. At the latter plant, capacity production is anticipated throughout the life of the plant. At Savannah, however, it was expected that after the initial requirements of heavy water are satisfied, the demand for that product will not exceed two-thirds of the design capacity. Thus, at some future date, the process flow through the "DW" plant would be greatly reduced, being supplied only by the permanent "GS" units, Buildings #412-D and #413-D. Under this anticipated condition, improved control, flexibility and continuity of operation, and reduced hold-up dictated the use of two parallel distillation trains having a combined capacity equal to the single train at Dana.

Since the "DW" process had been used in previous installations, no unusual problems of equipment design were encountered in providing these facilities for Savannah River. However, some of the items requiring consideration are noted below.

Towers

These are bubble cap tray towers made up of conventional sectional units. The prevention of liquid leaks from the trays and of bypassing of vapor was important. The trays were given a flanged lip that is higher than the normal liquid level. This eliminated the need for sealing the trays against leaks. Rigid clearance tolerances between the tray lip and the tower wall resulted in the trays being "press fitted" into the shell. This reduced bypassing of vapors to a minimum. Each tower section is insulated between the flanges, the flanges being left bare since their heat loss would not justify the cost of insulation.

Calandrias

As originally designed, the calandrias were located some distance from the towers. During the course of a design review, it was noted that the pipe runs involved would produce excessive pressure drop and that the desired 90 per cent recirculation could not be achieved. Accordingly, the calandrias were relocated as close to the towers as possible.

To reduce the possibility of product loss or contamination, the calandrias have fixed double tube sheets, top and bottom. The tubes are welded into the outer sheets and rolled into the inner ones. The space between the two sheets is vented to the atmosphere. In this manner, leakage through either sheet may be checked.

Condensers

Each stage is provided with a relatively large condenser to give the heavy reflux required. In operation, the condensers receive the vapors from the top of the towers, condensing most of them. During start-up, the piping is so arranged that each stage may be run on total reflux until equilibrium is reached. Normally, the condensate is returned to the previous stage through the transfer pumps.

In November 1951, a review of the design revealed that it was questionable whether the condensers were located high enough to overcome pressure drop in the return piping to the towers. A detailed analysis revealed that the exchangers should be elevated an additional 10 feet in order to achieve satisfactory operation.

At the time of this design change, the structural steel for the building had been erected but no equipment installed. The additional structural steel required to raise the upper floors was obtained on the site by using a portion of the excess steel from the original heat exchanger craneway on the "GS" units (See Buildings #411-D, #412-D and #413-D for a discussion of this excess steel.) The actual installation of the steel was therefore readily accomplished with no significant delay in the construction schedule.

The condensers are all shell and tube, falling-film type units with river water on the tube side. The top and bottom tube sheets are exposed, the water falling into a collection pan. After the units were placed in operation it was found necessary to install splash shields around the pan to confine wind-blown spray.

Like the calandrias, the condensers are provided with double, fixed tube sheets at the top and a single bottom sheet with welded-in tubes. Double sheets were provided at the top since the top ends of the tubes are submerged in water and any in-leakage would dilute the process stream. At the bottom sheet, the tube ends are exposed to the atmosphere and any leaks around the tubes only pass air that, in small quantities, do not adversely affect the process.

Coolers and Chillers

These pieces of equipment are necessary because the non-condensed vapors leaving the condensers are saturated with $\text{H}_2\text{O}-\text{D}_2\text{O}$. To retain this valuable material in the process, these vapors pass to vent coolers and thence to chillers for further condensing, using ammonia as the coolant.

Safety

The "DW" Process does not present any peculiar safety problems as no hazardous materials are handled. However, to protect operating personnel from atmospheric contamination by H_2S which could be carried downwind from the H_2S or "GS" areas, an atmospheric sampling station is located in the "DW" area and connected to the H_2S detector in Building #772-D. In addition, air masks are provided in the "DW" control room to insure continuous operation.

Metallurgy

Before leaving the "GS" area, the "DW" feed is subjected to a final stripping of any remaining H_2S . Since the feed is free of the corrosive gas-water mixtures, and since there is no need at this stage for extreme cleanliness of product, the material of construction generally used throughout the "DW" plant is carbon steel.

DRAWINGS

- W-140813 - Plot Plan
- W-140862 - Plot Plan
- W-140250 - Process Flow Diagram
- W-140251 - Process Flow Diagram
- W-140258 to W-140264 Incl. - Process Piping & Instrument Diagram
- W-140946 - Design Drawings Index

BUILDING #421-D - FINISHING BUILDING ("E" PROCESS)

FUNCTION

The "E" Process is the third and final step in the production of heavy water and is designed to increase the concentration of D_2O from 98%, as received from the "DW" Plant, to 99.8% or better. However, the facilities are so designed that the desired 99.8% can be obtained even though the concentration of the feed received from the "DW" Plant is as low as 90.0%.

PRINCIPAL COMPONENTS

A single structure houses all the facilities. This structure is divided into the following rooms or areas: electrical control room, locker room, cylinder storage, auxiliary room, office and toilet room, cell and pit room, and process areas.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Electrical control room	1100
Locker room	435
Cell and pit room	2765
Cylinder storage	535
Auxiliary room	1300
Office and toilet	200
Second floor	1340
Third floor	1340
Fourth floor	625
Fifth floor	625

BUILDING DETAILS

Class - III.Size - Area - Total Floor Area - 9960 sq. ft.

Ground Area - 6332 sq. ft.

Volume - 172,000 cu. ft.

CONSTRUCTION DETAILS

Foundations - Reinforced concrete with spread footings.Superstructure - Structural steel framing.

Concrete roof slab over office.

Exterior walls - Corrugated asbestos; pit walls below grade are poured concrete.

Partitions - Concrete block where vapor barrier required. Woven wire at locker room.

Ceiling - None.

Doors - Metal, wood, both panel and flush type.

Sash - Pivoted steel.

Roofing - Corrugated asbestos.Floors - Concrete.Floor Covering - Asphalt tile in office.Heating - Steam unit heaters, except for radiator in toilet room.Air Conditioning - None.Air Exhaust - Roof exhaust fans provide forced ventilation in the electrical control room and the cell room; gravity roof ventilators serve balance of building except office which has a window.

Lighting - Incandescent, vapor-tight.

EQUIPMENT

Process Equipment

In general, the following equipment description lists the major pieces of process equipment as they would normally occur in the process flow.

Receiving Scale Tank

One, 650-gallon cylindrical steel tank mounted on tank scale having a 10,000# capacity. This tank receives and inventories the heavy water pumped from the "DW" Plant.

Crude Feed Pump

One 25 g.p.m., 0-50 foot head, steel centrifugal pump for transferring feed from the receiving tank to the crude head tank.

Crude Head Tank

One 400-gallon vertical steel tank fitted with a helium sparger pipe for mixing. This tank serves as a storage tank for the process feed.

Potassium Permanganate Mix Tank

One 250-gallon vertical steel tank fitted with a portable agitator. Feed to this tank is by the crude feed pump described above.

Treating Kettle

One 450-gallon steel Dopp-type kettle with steam jacket and scraper-agitator and fitted with a wetted-wall column. This kettle is used for treating the process feed with KMnO_4 under total reflux conditions. It is supplied primarily by gravity from the crude head tank.

Treating Kettle Condenser

One helical oil condenser, consisting of a helical coil of 2" O.D. stainless steel tubing immersed in a steel cooling box, and equipped with a vapor-liquid separator. Total cooling surface is approximately 45 sq. ft. This equipment condenses the D_2O - H_2O vapors from the KMnO_4 treatment.

Scale

One 500# platform scale - used for weighing potassium permanganate and/or potassium carbonate.

Treated Feed Hold Tank

One 1000-gallon vertical steel tank. This tank receives the condensate from the KMnO_4 purification step and delivers it to either of the two electrolyte mix tanks.

Electrolyte Mix Tanks

Two vertical steel tanks, each fitted with a propeller agitator and a perforated stainless steel leaching basket. One tank of 1000 and the other of 250-gallon capacity. Potassium carbonate is weighed into the leaching basket and $\text{D}_2\text{O}-\text{H}_2\text{O}$ is added from the treated feed hold tank to yield a 7.5% K_2CO_3 solution for cell feed by gravity.

Electrolytic Cells

The 150 cells are arranged in six rows of 25 cells each. Each cell has a capacity of 17 gallons and is constructed from a 12" diameter by 5' steel shell (cathode) jacketed with a 16" steel pipe. A 10" diameter, 2' long, steel pipe is inserted at the bottom to provide additional cooling and cathode surface.

A solid nickel anode, 11.26" I.D. by 21" high, is suspended from, and insulated from, a flat steel cover and hangs in the annulus between the two cathode sections. Polythene spacers are used to prevent contact between the anode and cathode. Electrical terminals are provided at the top cover for anode and cathode connections. Each cell is mounted on porcelain insulators, which in turn are mounted on a steel framework.

Normal operation utilizes four rows (100 cells) on the third and strongest stage, one row (25 cells) on the second stage, and one row of twelve cells on the first or weak stage. One row of cells is headered in two groups of twelve and thirteen cells each to provide additional operating flexibility.

Each cell is filled and drained through a single connection. Suitable filling and drain headers, fitted with isolation valves, are installed. Liquid lines are connected to each cell through sections of neoprene hose to prevent grounding. Gas connections are taken from the top of each cell, through plastic tubing, to a pipe header on each cell row. From these headers the cell gases pass through separators and cooler condensers enroute to the burners.

Cell Rectifier and Switch Gear

This equipment is described in the "Electrical Equipment" section below.

Cell Residue Tanks

Two vertical steel tanks of 100 and 300-gallon capacities, each fitted with helium sparger lines. These tanks receive the cell residue from the first and second stage electrolytic operations, respectively.

Cooler Condensers and Vent Condensers

Nine identical units, each constructed from a 6" x 6' long steel pipe shell through which H_2O - D_2O vapors pass. Cooling is provided in each unit by two internal helical pipe coils filled with liquid ammonia at plus 40°F. Coil surface is approximately 14 square feet. Liquid spray and H_2O - D_2O vapors contained in the cell gases are condensed in six of the units, serving as cooler condensers, and returned to process. Of the three vent condensers, two recover D_2O from outward breathing of the various tanks and vents in the process, while the third is connected in series with these two and serves to condense light water vapor from the air breathing inward to the tank system.

Gas Burners

Six identical gas burner condensers, each having a shell made of vertical stainless steel pipe, jacketed with an outer steel pipe. Cooling water flows through the jacket to condense the D_2O mixture formed from the combustion of the cell gases.

One burner-condenser serves each cell row. Since one cell row is divided in two parts, and each part is connected to a separate gas header, cross piping is provided to permit feeding of the gas from one-half of this cell row to any one of the six burners. With these cross connections, various operating combinations are possible. The gases enter the top of each burner through one or more of three orifices. A hot wire igniter starts and maintains combustion as the gases issue from the orifices. Complete combustion is insured by the addition of a slight excess of oxygen. The condensate passes through a pipe separator and flows to the condensate receivers. Sight glass ports are provided so that the burning can be observed. Provision is made for the addition of helium to each burner at normal shutdowns to minimize the flame travel back to the cell equipment.

Drainage Tank

One 300-gallon vertical steel tank fabricated to withstand a pressure of 150 p.s.i.g., which might result from a flash-back of the burner gases. This tank receives the H_2O - D_2O condensate from the cooler condensers.

Drainage Tank

One 400-gallon horizontal steel receiver. This tank receives the contents of the 300-gallon drainage tank described above, which is drained intermittently by gravity, and also receives the weaker cell residues from the intermediate electrolytic steps.

Drainage Pump

One centrifugal pump, 25 g.p.m., 0-50 ft. head. This pump transfers the cell residues from the 400-gallon drainage tank to tanks at higher elevations.

Condensate Receivers

Three 400-gallon and five 150-gallon vertical stainless steel cut tanks, each fitted with a removable sparger pipe through which helium gas can be passed to mix the tank contents. These tanks receive condensate of varying D_2O strengths discharged from the burner-condensers. They drain by gravity to the electrolyte mix tanks. The weakest cuts can be drained to drums for return to the "DW" Process.

Final Residue Tank

One 750-gallon horizontal steel receiver. This tank receives strong cell residues drained from the cells on completion of the final electrolytic step.

Cell Residue Pump

One 25 g.p.m., 0-50 ft. head, vertical centrifugal pump. This pump transfers the process fluid from the final residue tank to the final evaporator feed tank.

Final Evaporator Feed Tank

One 1000-gallon vertical steel storage tank, fitted with sparger pipe for helium. This tank provides storage and feed by gravity to the final evaporator.

Final Evaporator

One 450-gallon vertical dished bottom Dopp-type kettle with steam jacket and scraper-agitator. This vessel, a duplicate

of the treating kettle previously described, is used for evaporation of the final cell residues to free them from the potassium carbonate electrolyte.

A slurry of K_2CO_3 is recovered for re-use. The vapors from the kettle are passed through a vertical 3" stainless steel pipe about 20' long, fitted with an internal spiral, which acts as a wetted wall column equivalent to four or five transfer units.

Final Condenser

One 2-1/2" helical stainless steel pipe coil installed in a stainless enclosure. Cooling water passes through the coil, which has a surface of about 50 sq. ft., to condense the D_2O-H_2O vapor from the final evaporator. Hot condensate from this condenser is sub-cooled by passage through an aftercooler consisting of a helix of 1" stainless steel tubing immersed in a cooling tank and providing a cooling surface of about 10 sq. ft.

Heads Tank

One 300-gallon vertical steel tank. This tank receives product cuts of off-grade material from the final evaporator.

Product Receivers

Two 400-gallon vertical stainless steel tanks, each fitted with a gas sparger for mixing. These tanks receive specification-grade product, and drain by gravity to drums through a stainless steel product filter packed with cotton batting.

Finished Product Scale

One 1000-pound dial type "Print-Weigh" platform scale set at floor level. This scale is used for weighing drums of product.

Cylinder Loading Feed Tank

One 2500 lb. capacity carbon steel weigh-tank. This tank receives and weighs specification-grade product and drains by gravity to feed tanks in Buildings #421-1D and #421-2D. Note: This feed tank was installed at the time of erecting Building #421-2D (1954).

Sump Tank

One 100-gallon vertical stainless steel tank. This tank collects the drainage and spillage from the operating

room and the cell room. A 15 g.p.m. sump pump transfers this collected drainage to drums for recovery, if it contains D_2O . Light water is pumped to the sewer.

Ammonia System

Two one-ton ammonia refrigeration units, one an installed standby, including compressors, condensers, ammonia receiver, and surge tank. Non-condensables, which accumulate in the ammonia system, can be vented through an ammonia purger. These units are installed to provide a supply of liquid ammonia at $+40^{\circ}F$. for the cooler-condensers and vent condensers.

Oxygen and Helium Cylinder Station

Two cylinder manifolds, one for each gas, with appropriate high pressure connections, reducing valves, and pressure relief valves.

Electrical Equipment

The electrical work in Building #421-D consists of a.c.-d.c. rectifying equipment and connections for the electrolytic cells, power for motor-driven equipment, burner igniters, electrically-operated instruments, a communication system other than telephone and fire alarm, lighting, and grounding. The entire building, except for the electrical control room and the office, is considered a Class I, Division 2, hazardous location.

Electrical services to the building consist of a 13.8 kv. 3 phase overhead feeder for the rectifier, a 480 volt, 3 phase, feeder for general power, auxiliary and lighting services, and a 480 volt, two-wire single phase feeder, which is tied in with the over-all area emergency lighting system.

The main portion of the electrical work within the building concerned the design of the cell feeders and controls and safe maintenance of the cell circuits. The d.c. electrical requirement for the cell room amounts to 1000 amperes at a maximum of 525 volts. To accommodate operations with new cells or with fewer cells in the circuit, the d.c. supply is capable of stepless adjustment between 22 and 525 volts. On shutdown, the cell circuit can be grounded to discharge any residual electrical potential.

The a.c. feed at 13,800 volts passes through a regulating auto-transformer to provide a constant voltage supply. Ten taps on the low voltage side of this transformer permit a choice of output from 13,800 to 2960 volts.

The output of the auto-transformer feeds a rectifier transformer which steps the voltage down from 13,800 to 525, or to correspondingly lower voltages if the input is cut below 13,800 volts. (Minimum output is 110 volts.)

The reduced a.c. voltage is rectified to d.c. in six Westinghouse Ignitron rectifier tubes. The Ignitron output voltage is further reducible by employing a motor-driven mechanical phase-shifter unit, which changes the phase angle of the voltage supply to the ignitors with respect to the cell anode supply.

Originally, the phase shifter was designed to reduce the d.c. output voltage by only 15 per cent, but this was found at Dana to give insufficient operating flexibility.

The d.c. output from the rectifiers is fed through tubular copper busses to the cell rows. The d.c. switch gear and bus connections divide the cells into eight groups electrically. Two cell rows are each divided into two half rows, which can be energized independently of each other. The remaining four cell rows can be switched on and off as single groups of 25 cells each. Further operating flexibility can be obtained by the use of jumper connections. All operating cells are connected in series, electrically, to utilize the maximum possible potential at the rectifier. This results in higher rectifier efficiencies.

Current to the cells can be switched on only in the electrical control room. However, it can be cut off either, from the cell room, at the second floor operating panel, at the fifth floor burner panel, by "crash" buttons, or at main switches in the electrical control room.

Operations at Dana showed that grounding of the cells or cell connections was a continual operating problem. To assist in the location of such troubles, ground detection equipment was installed at Savannah to demonstrate the magnitude of electrical grounds in the cell system. When the resistance between the cell circuit and the ground drops below normal, an alarm is sounded to warn operating personnel.

Failure of the d.c. supply to the cells is signaled to the second floor operating area and to the burner operator on the fifth floor. Ignitor and burner failures are signaled to the burner operator. Abnormal rates of current leakage to ground are signaled to the second floor area. In addition to these alarms, the panel on the fifth floor carries the various electrical controls associated with the operation of the burners and ignitors.

Communication with the other area buildings is provided by Bell Telephone and by a voice-powered phone operating between the several area control rooms. A speaker system permits receipt of alarms and emergency announcements originated in other buildings. Room to room communication in Building #421-D is provided by another voice-powered phone circuit, and by an inter-communication system operating between the office, electrical control room, second floor panel, and fifth floor burner area.

Instrumentation

Instrumentation is largely of a conventional nature. Controls on operations performed in the treating kettle and final evaporator are grouped on an instrument panel installed on the second floor. These include indicating instruments for tank levels, steam flow rate, reflux and overhead rates, and temperatures. The conductivity recorder provides a continuous record of the conductivity of the final product.

High temperature alarms are provided to signal cooling water failure on the treating kettle condenser and the final condenser, and on the gas burners. High-level alarms are included on the treating kettle, the final evaporator, the two electrolyte mix tanks, and the sump tank. The finished product scale is equipped with an alarm actuated by the weight of a nearly-filled drum.

Additional alarms signaling power supply failure, burner failures, or abnormal current leakage rates are described in the section on "Electrical Equipment".

With the advent in 1953 of cylinder loading facilities adjacent to the "E" Plant, and because the "E" plant was given supervision over these new cylinder loading facilities (Building #421-1D), it was thought advisable to arrange instrumentation to permit control from either site. This was accomplished by installing full control equipment in Building #421-1D and parallel essential control panels in Building #421-D. The extent of this control may be found by referring to "Building #421-1D - Equipment - Instrumentation".

When, in 1954, Building #421-2D was erected to house additional cylinder loading facilities, it was decided to make this new building the control center for both cylinder loading buildings. The parallel controls for Building #421-1D which had been installed in Building #421-D, were moved to Building #421-2D. At the same time, a feed tank for both Buildings #421-1D and #421-2D was installed in Building #421-D and equipped with an alarm unit assembly. Thus, the addition of this alarm unit constituted the net change in "E" Plant instrumentation as the result of cylinder loading operations.

Piping

Piping for heavy water is of carbon steel, except where cleanliness of vapor or liquid demands that stainless steel be employed. Generally, all pipe lines conducting the product after it leaves the cells are stainless steel. Screwed connections are avoided wherever possible. Where used, they are back-welded. In the smaller pipe sizes, bends and socket weld fittings including socket well valves are used. Larger fittings are welded except at flanged valves. Gaskets are Code G-201, compressed blue African asbestos, except on final product lines where "Teflon"-covered asbestos is used. Stainless steel valves are packed with "Teflon".

The only feature which might be termed unusual, regarding pipe lines in the "E" Process, is the sizing and arrangement of the lines to reduce the amount of process fluid hold-up to a minimum. The value of the material in process is such that it costs about \$75 to fill one foot of standard 2" pipe. Where possible, process lines are sloped to drain completely. Any unavoidable pockets on liquid lines are fitted with drain valves. Also, because of the value of the material being handled, and the frequent handling of process liquids of varied concentrations, special attention was given to the accessibility of all valves and controls to preclude mistakes and inaccuracies in the transfer of materials.

Neoprene hose connections are used on the cooling water inlets and process drains at each cell to provide electrical insulation. The gas off-take at each cell is connected to the cell header through a piece of plastic tubing to provide electrical insulation and visibility.

PROCESS

Description

The feed to the "E" Process is a concentrated product of the "DW" Process. Periodically, this feed is pumped from a "DW" scale tank to a 650-gallon scale tank in the "E" Building at a normal feed rate of 62 lbs. per hour of 98% D₂O.

The first step in feed treatment is one of purification. This is accomplished by the addition of potassium permanganate, which results in oxidation of the organic impurities and a precipitate of MnO₂ which is removed periodically. The process feed is pumped from the scale tank to a 400-gallon head tank for temporary storage. A portion of this feed is pumped directly to a 250-gallon agitated mix tank where potassium permanganate is added, to produce about a 5% solution in D₂O-H₂O. A single batch of about 300 gallons is fed to a

steam-jacketed treating kettle along with about 3.5 lbs. KMnO_4 per 100 lbs. of $\text{D}_2\text{O}-\text{H}_2\text{O}$. This mixture is boiled under total reflux to effect complete oxidation of organic impurities. The resulting CO_2 is vented to the atmosphere. It should be noted that this and all similar vents on the "E" Process are passed through refrigerated (40°F .) vent condensers to minimize the loss of D_2O .

On completion of the oxidation step, the batch is distilled overhead from the treating kettle, condensed, and run to storage. Vapors from the treating kettle pass at a rate of 300 lbs. per hour through a 3-inch stainless steel falling-film column and are condensed in a stainless steel helical coil immersed in a steel tank supplied with well water at 68°F . as a cooling medium. A portion of the condensate is returned to the column as reflux during the distillation step.

The treating kettle is fitted with a scraper agitator which removes slurry residues of the purification operation. These are discharged through a bottom waste connection, after they have been leached with light water for the maximum recovery of D_2O .

The purified heavy water feed is collected in a 1000-gallon hold tank and pumped from there to a 1100-gallon agitated electrolyte mix tank. Solid potassium carbonate is weighed into a leaching basket in the mix tank and the mixer is operated to make an 825-gallon batch of 7.5% K_2CO_3 in $\text{D}_2\text{O}-\text{H}_2\text{O}$. The resulting solution is run by gravity to some 80 or more electrolytic cells.

About 25 per cent of the charge is electrolyzed, leaving a residue richer in D_2O than the feed. The mixed gases from the cells, containing H_2 , D_2 , and O_2 , are passed through a separator and refrigerated chiller to reduce their D_2O content and then are burned to H_2O and D_2O vapor inside a water-jacketed stainless steel burner-condenser. Noncondensable gases are vented from this unit to the atmosphere. Normally, the principal noncondensable is a slight excess of oxygen added to the system to assure complete oxidation of D_2 and H_2 .

The burner condensate is weaker in D_2O than the cell feed. It is collected in any one of eight stainless steel cut tanks (150 to 400 gallons each), dependent on its D_2O content, and is recycled for a further electrolysis. The K_2CO_3 electrolyte is added to the smaller, weaker cuts in a second electrolyte mix tank of 250 gallons volume.

The "E" Process theoretically requires the use of seven batch electrolytic steps to increase the D_2O concentration of the cell liquor from 98% to 99.8%. At Savannah River, by

a combination of cell residues and cell overheads of comparable strengths, the number of these steps is reduced in practice from seven to three. The weakest overhead cut contains about 5% D_2O . Since its volume is small, it is periodically collected in 55-gallon aluminum drums, analyzed, weighed, and returned to the "DW" Process for reworking.

About 125 electrolytic cells are normally in operation out of 150 installed. The operating cells are divided into three or more groups of varying numbers in each, to accommodate the different volumes of feeds at their several concentrations. Electrically, all operating cells are connected in series, which permits an economic rectifier voltage in the order of 300 to 500 volts at 1000 amperes.

To prevent condensation, the gas leaving the liquid separator of each cell gas header is piped through a heated line, into an ammonia-cooled condenser. The condensate is run to the drainage system and the gas flows into the burner.

Considerable care must be taken in the operation of the burners to insure satisfactory combustion without flash-backs or a loss of flame. In fact, the possibility of flash-backs greatly influenced the design of these facilities. For example, two continuously energized ignition systems serve the nozzles in each burner, and sight-glass ports are provided for observation purposes. Also, the main flow of condensate from each burner-condenser header is drained through a catch pot, which is provided with an 18-inch liquid seal. The shallow seal would release vapors from a flash-back if one were to occur. Changes made in design to alleviate the flash-back difficulty are discussed below in the section "Development of Equipment".

The concentrated cell residues from the final electrolytic step, amounting to some 600 gallons, are drained by gravity to a 750-gallon steel residue tank. A steel centrifugal pump transfers this material to a 1000-gallon steel evaporator feed tank.

Final purification and the removal of the electrolyte are accomplished in the final evaporator which is a steam-jacketed 450-gallon kettle fitted with a scraper agitator, a duplicate of the treating kettle used for permanganate treatment.

A 300-gallon batch is fed by gravity from the feed tank to the evaporator and the kettle contents are heated to boiling. Vapors pass through a 3-inch stainless steel wetted-wall column, similar to that used on the treating kettle, and are condensed in a stainless steel return condenser consisting of a helical pipe coil and a tank annulus with cooling water in the coil. Sub-cooling of the condensate is

provided by a stainless steel aftercooler, consisting of a helical pipe coil immersed in a cooling tank.

Rotameters control the reflux and overhead from the evaporator. The initial operation is a total reflux to remove soluble gases such as ND_3 and CO_2 which are vented. The first product cut is boiled off at 75 lbs. per hour and collected separately in a 100-gallon head tank until the distillate meets specifications. A pure product is characterized by high resistivity to the flow of electricity. Therefore, a conductivity cell in the condensate line permits a continual check on the product purity. The head cut is added to the next evaporator batch.

The final product cut at 200 lbs. per hour is collected in either of two 400-gallon stainless steel product receivers. Helium gas is used to mix the contents.

A K_2CO_3 slurry is recovered from the evaporator kettle and re-used as electrolyte in subsequent batches.

The product is drained by gravity from the receivers through a cotton batting filter to 55-gallon aluminum drums. Before filling, each drum is carefully washed and dried and flushed with helium to displace air containing light water vapor. A floor scale is provided for weighing each drum as it is filled. The filled drums are mounted on wooden pallets for transfer by truck to storage in Building #122-R. Average production is 60 lbs. per hour, or an annual total of 240 tons.

A branch connection provided a gravity flow of condensed specification-grade material to Building #421-1D when, in 1953, cylinder loading facilities were added to the #400-D area. The flow rate was indicated by the forward flow rotameter on the line which normally fed the product receivers. Inventory of this transfer was made in Building #421-1D.

When, in 1954, additional and considerably more extensive cylinder loading facilities (Building #421-2D) were added, a weigh tank of 2500 lb. capacity was inserted in the branch line in Building #421-D and connected to serve both cylinder loading buildings. Thus, weight accountability for the process material supplied to Buildings #421-1D and #421-2D takes place at the source of that material, Building #421-D.

Development

Design of the "E" Process for the Savannah River Plant followed very closely that developed for the Dana Plant.

At Savannah, as at Dana, the "E" Process receives as feed the product of the "DW" plant containing about 98% D_2O and concentrates it to 99.8% minimum D_2O content. The normal capacity of the plant is 240 tons per year, based on 333 days of 24 hours each. The plant in addition to meeting this normal requirement was built to economically process initial feed with concentrations as low as 90% D_2O concentrate, and to recycle product that has a final concentration less than the required minimum 99.8%.

The exchange and distillation processes employed in concentrating heavy water from its natural abundance to the higher percentage strengths are well adapted to handle the large volumes of water involved. However, in concentrations above 90%, the low relative volatility in distillation and the small driving force in the isotopic exchange process would require a large number of plates to effect separation. The large relative volatility and the suitability of the electrolytic process to handle small volumes of concentrate make it attractive for the finishing stages. The large power requirement per unit volume of water processed is not a serious problem in handling the small volumes of higher strength product.

The process is designed for batch operation. More specifically, the electrolytic cells are operated in groups batch-wise. In so doing, the cells are used in the manner required at each stage, with fewer cells being utilized on the weak liquor where the quantities are small than on the strong liquor where they are large. The number of cells used in each step is such that at the point in each cycle where the volume is a maximum, the charge to each cell is 100 pounds. During electrolysis, the volume of liquid is run down by at least 25 per cent and the residue is used in the succeeding step.

Consideration of the possibility of continuous operation led to the conclusion that the number of cells required would be at least three times as great as in batch-wise operation. At "total reflux", the minimum number of steps would be five, and with an infinite number of steps, the volume of "reflux" would require 33 cells in one step. Semi-continuous or intermittent operation to keep the cells essentially full, and the current density, therefore, at a continued maximum, did not seem to offer advantages in proportion to the difficulties involved. Batch-wise operation is flexible, convenient and relatively fool-proof.

Since the "E" Process had been successfully operated at the Morgantown plant during World War II, the experience gained at that plant became the basis of design when du Pont was commissioned to provide similar facilities at the Dana

plant. Much of the equipment from this operation at Morgantown was in storage at the Wabash River Ordnance Works (Dana). Only a few phases of design required further development. These were concerned, primarily with factors related to the expansion of plant size or capacity, and some refinement of process and equipment.

Because of the start-up date scheduled for the Savannah River Plant, it was necessary to start design for the #400-D Area finishing plant while the facilities at Dana were still under construction. As the Dana design represented a very recent and concerted effort to include every improvement, and since these facilities at the two plants were to have the same design capacity, the decision was made to utilize generally the same design. Minor differences arose from the use of some second-hand tankage, electrolytic cells, refrigeration equipment, and rectifier equipment at Dana, whereas all units were purchased new for Savannah.

Not being confronted with the problem of using existing equipment, the Savannah design was free to specify facilities that would improve the handling of process fluids and the control of the process. This accounted for some of the variations in pipe and vessel sizing, and in materials of construction, between the two plants. The major changes made for the Savannah installation are described in the section which discusses development of equipment.

DEVELOPMENT OF DESIGN

Building

Building #421-D is essentially a duplicate of the "E" Process building at Dana, Building #301. Class III construction was chosen for both of these buildings. However, because of the possible presence of hydrogen (deuterium) - oxygen mixtures in a room with necessarily exposed power feeders and connectors, concrete block partition walls were used to isolate the cell room from the electrical room and other operating areas. Louvers near grade admit ventilation air to the building, while fans in the roof of the electrical room and the cell room provide forced ventilation for these areas. In the operating area, roof ventilators provide a natural draft.

Also, because of this gas hazard, and because of the presence of an ammonia refrigeration system in the building, both inside and outside stairs are furnished to provide two operator exits on each floor.

After the erection of this building at Savannah, it developed that a portion of the allotted space would not be

utilized for the electrical installation. At the request of AED, the unused portion of the room was partitioned off and converted into a locker room.

Equipment

The basis for the design of the Savannah River "E" Process equipment was the du Pont experience in designing and operating a similar but smaller unit at Morgantown Ordnance Works during World War II, and in designing and operating a unit almost identical to that for Savannah at the Dana Plant.

While the design for Savannah is generally the same as for Dana, an effort was made to incorporate into the Savannah design the benefit of Dana operating experience. However, the Savannah "E" Process design and construction were well advanced before the Dana "E" facilities were placed in operation. Further, Savannah construction schedules were such that changes could not be made in design if they would involve alterations to the design of the building structure or major changes in the design of equipment.

A guiding philosophy in design was the high value of the product. Equally important was the requirement of an extremely high level of purity for the product.

Accordingly, every precaution was taken to reduce process holdups and to make the piping and equipment tight to reduce leakage to a minimum. Means for the recovery of all spillage and process drainage were provided. The frequent handling of process liquids of varied concentrations necessitated very careful equipment layout to decrease the possibility of accidental cross-contamination. Effort was also made to remove, insofar as possible, all occasions for contamination of the product by foreign matter.

In an effort to discover possible faults and shortcomings in the Dana design so that they might be avoided at Savannah, a group made up of representatives of AED and the Design Division made a careful inspection of the Dana Finishing Plant following its initial operation. Recommendations were made, generally aimed at significantly improving the efficiency, precision, and reliability of operation.

Construction schedules permitted the adoption of a number of the recommendations made by the inspection group, as well as other changes that were found to be desirable as Savannah construction progressed. Effecting these changes necessitated, in some instances, altering facilities that had been erected. Changes in existing piping, for example, were extensive and very costly.

Thus, except for designed capacity, many differences exist between the facilities used at Morgantown and Dana, and those finally furnished at Savannah. The following sections contain a brief description of the more important changes and the reasons for making them; also, the reasoning which influenced some phases of design development.

Pumps

Wherever convenient, liquid transfers at SRP are made by gravity flow. Where pumps are necessary, the centrifugal units selected have a long vertical shaft with a stuffing box above the liquid level in the supply tanks, thereby eliminating stuffing box leakage.

Cells

The cells installed at Savannah are a modification of those made by Stuart Oxygen Company and used by Consolidated Smelting and Refining Company at Trail, British Columbia, and by du Pont at the Morgantown Ordnance Works.

A solid nickel anode, 11.26" I.D. by 4'6", is suspended and insulated from a flat steel cover and hangs in the annulus between the two cathode sections. Nickel-plated anodes were used in the cells at Morgantown, but flaking of the nickel caused short-circuiting between anode and cathode. Solid nickel anodes were therefore provided for both the Dana and Savannah plants.

The cells, as originally installed at Morgantown, had anodes that were almost the full depth of the cell. These had slots cut in them in order to equalize gas pressure on both sides of the anode. However, these anodes were distorted by pressures built up during flash-backs and would short out.

Before the Savannah River unit was placed in operation, Dana developed a modified anode in which the effective height was reduced to 21" and any remaining slots filled in. This change improved operation of the cells appreciably and, at the request of AED, the change was incorporated into the Savannah design.

While this change was being made, an additional modification to the anode was developed by du Pont in an effort to eliminate short circuiting around the head of the anode structure. Twelve of these units were installed at Savannah on an experimental basis with results to be evaluated by the Operating Department.

Burners

The Savannah River gas burner design is essentially the same as for those originally installed by du Pont at the Morgantown Ordnance Works and later at Dana.

At Morgantown, the burner condensate was periodically neutralized by the addition of small quantities of K_2CO_3 dissolved in D_2O . This was done to avoid corrosion of carbon steel equipment by nitric acid resulting from nitrogen fixation in the burners. At Savannah, helium gas is used in the cell headers to exclude air (N_2) and, in addition, stainless steel receivers and piping are substituted for their carbon steel counterparts of the earlier installation.

Process Lines (Cell Gas and Burner Condensate)

The original Savannah River design specified the use of carbon steel pipe on all cell gas lines. Operating experience at Dana disclosed that pipe scale plugged the burner orifices and resulted in frequent flash-backs. To minimize this trouble, with the accompanying loss of production time, du Pont decided to change all this piping to stainless steel, even though the carbon steel pipe had already been installed.

The gas off-take at each cell was originally connected to the cell header through a piece of pyrex glass tubing which provided electrical insulation and visibility. These were replaced with plastic tubing to eliminate breakage.

Steam tracing is used on the cell gas lines between the separators and the cooler-condensers. This is done to prevent condensation of liquid in these headers, which in turn would result in irregular gas flow and, possibly, interruption in burner operation.

Seals

Mercury manometers were originally provided to indicate the pressures in the cell gas headers, and mercury seals were included to relieve excessive pressures. The gases released through the seal pots discharged inside the building, which was considered undesirable. The possibility of mercury contamination of the product made it additionally advisable to replace seals and manometers. Indicating pressure gauges were substituted for the manometers and the seals were replaced by 1/8-inch neoprene rupture discs, installed between standard 1-inch pipe flanges. The discharge from the rupture discs was piped outside the building.

The liquid condensate from the gas burners flows to a pipe separator and thence through an 18-inch loop seal, to isolate the receivers from the burner conditions. Original Savannah design specified 5-inch seals, but Dana experience displayed the need for a deeper seal. A seal bottle replaced an earlier design of a 6-foot loop seal on each off-gas line to relieve excess burner pressure to the atmosphere by way of the vent condensers. This seal blows at about 6-inch water pressure, well below the pressure required to blow the 18-inch loop seals.

Flash-backs

Flash-backs, due either to operating difficulties or to normal cell shutdowns, cause a pressure rise to a possible maximum of a 150 p.s.i.g. in the equipment handling the cell gases. When this was determined, all such equipment was designed for 150 p.s.i.g. service.

Morgantown and Dana experience showed that oxide scale, a.c. voltage surges, mercury globules, water droplets, and particles of solid electrolyte were possible causes of flash-backs at the burners. The substitution of stainless steel for carbon steel gas piping, the elimination of mercury manometers and seals, and the use of cooler-condensers and separators represent improvements made in the Savannah design to lessen the possibility of such flash-backs.

Cooling Water

In order to maintain the maximum separation factor between D_2O and H_2O at the cells, it is necessary to cool these cells with water limited to a maximum temperature of 65°-70°F. This was easily accomplished at Dana, as the water supply for the entire plant came from wells. However, at the Savannah plant, where the main source of water is the Savannah River, these temperature conditions could not be met during the summer. In the early stages of design, a refrigerated river water system was contemplated to provide adequate summer cooling. Later, it was found that sufficient well water could be obtained at the desired temperature. This eliminated any need for a chilled water supply.

Electrolyte

Potassium carbonate is used as an electrolyte instead of potassium hydroxide, which is commonly employed in the electrolysis of water and was initially used in the "E" Process at Morgantown. K_2CO_3 is readily obtainable as a pure material, as compared to KOH, which normally contains appreciable amounts of undesirable impurities, as well as several percent of water of hydration. In operation, KOH is additionally undesirable

since it tends to foam on evaporation, resulting in appreciable solids carry-over. The holdup of D_2 as a part of the KOD molecule is also an undesirable feature.

Electrical Facilities

The electrical drawings for the Dana building were reproduced for use at the Savannah River Plant with only minor changes to take advantage of improvements found desirable at Dana. This re-use was facilitated by the fact that the Lummus Company, designers of the process buildings of the #400-D Area at Savannah River Plant, had also designed the Dana equivalent of the #421-D Building. Changes found necessary at Dana, therefore, were made on the SRP designs in time to be effective for the original #400-D Area installation.

The only major electrical change found necessary was that of increasing the range of continuous adjustment of the main rectifier voltage. The available continuous adjustment in the original rectifier equipment was only 15 per cent, or just adequate to cover the range between the coarse adjustment steps. Early tests carried out at Dana during the latter part of 1951 indicated a need for a much wider range of continuous adjustment to permit start-up of a particular group of cells at very low current, thence, increasing smoothly to the maximum current of the system. It was found that this required a voltage adjustment slightly in excess of 50 per cent in place of the original 15 per cent. Representatives of Dana, AED and Wilmington Design then met with the rectifier manufacturer in Pittsburgh and explained the problem and the requirements to the manufacturer's engineers. They were able to provide an auxiliary component which, when connected to the control circuits of the original rectifier, increased the continuous control range to over 65 per cent. This change was simultaneously incorporated into the SRP design.

Extreme reliability of power supply was not a requirement of this building, so its services were connected to the general area feeder (designated feeder #7). The low voltages were supplied from the substation just south of Building #420-D, over aerial lines east of the building, while the rectifier was connected directly to the 13.8 kv feeder #7 by an aerial connection at the north end of the building.

This process unit is served by the plant's dial telephone system, the process inter-building voice-powered telephone system, the safety alarm system which receives only area-wide signals, the area-wide blackout control system and the area-wide emergency electric power system.

Oxygen and Helium Cylinder Station

Space for the storage of high pressure oxygen and helium cylinders is provided in Building #421-D. Two cylinder manifolds are installed, one for each gas, with appropriate high pressure connections, reducing valves and pressure relief valves.

It was originally specified by AED that argon would be used as the inert gas. Further investigation showed that helium would be cheaper and more readily available, and the substitution was accepted.

In addition to providing for complete combustion in the gas burners, a supply of CO_2 for the evaporator feed tank and the product receiver was originally specified. It was intended to carbonate the electrolyte solution in the evaporator feed tank as was done at Morgantown when potassium hydroxide was used as an electrolyte. In the product receiver, CO_2 was to be bubbled through the product for pH adjustment. Experience at Dana showed that neither service was required, and the supply of CO_2 for these two vessels is omitted at Savannah.

Materials of Construction

Corrosion is not severe in this process. Low carbon steel is utilized for various receiving, storage, and mix tanks and for electrolytic cell construction with the exception of the nickel cell anode. The burner condensers and the storage tanks which collect the burner condensate are of stainless steel, to resist attack by small amounts of nitric acid formed in the burners from nitrogen in the burner gases. The vapor and liquid lines, condensers, and receivers which handle the final product are also of stainless steel, to prevent product contamination.

Miscellaneous Changes

The following items are examples of additional changes made in Savannah design in an effort to avoid difficulties encountered in the initial operation of the Dana plant.

1. The arrangement and/or resizing of some vessels, pipe lines, and valve groups, to accomplish at least one of the following objectives: reduce hold-up, increase flexibility of batch handling, reduce the possibility of mixing process fluids of different concentrations, or to minimize loss through mishandling.
2. The use of additional cooler-condensers in a further effort to extract from vent lines the last trace of process vapor that might be lost.

3. A greater centralization of control equipment to permit simplification of operations.

4. Miscellaneous additions to the alarm system.

SAFETY

The safety hazards in the "E" Process are largely comparable to those encountered in normal chemical plant practice, with the exception of the dangers associated with the handling of hydrogen (deuterium) - oxygen mixtures, and the electrical hazards in the cell room. Safety aspects of the cell room operation are comparable to du Pont operating experience in the Electrochemicals Department. Construction of these facilities at Savannah River is in accordance with good cell room practice.

Much that was done at Savannah River in the interest of safety has been reviewed in discussing the development of building and equipment design. Any repetition here is in the interest of presenting, in one section, a complete picture of the safety problem.

Fire and Explosion

Building #421-D is housed in a steel-framed asbestos-covered building with concrete floors. Concrete block partition walls isolate the cell from the electrical room and the other operating areas. Louvers near grade admit ventilating air to the building. Fans in the roof of the electrical room and the cell room provide forced ventilation. In the operating area, roof ventilators provide a natural draft.

All equipment containing the H_2 , D_2 - O_2 mixtures is designed for 150 p.s.i.g. service, which is the maximum pressure expected as a result of flash-backs from the gas burners. Neoprene rupture discs are installed on each cell gas header to relieve excessive pressures, and the gases so vented are piped outside the building. Loop seals and seal bottles isolate the cell gas system to protect other equipment from the effects of flash-backs.

With the exception of the electrical room, in which open equipment is used, the rest of the building is considered a Class I, Division II, location from the standpoint of explosion hazard. All electric motors are totally enclosed with nonsparking fans. Switch gear in the operating rooms is oil-immersed, and lighting fixtures are vapor-tight. Certain electrical controls for the burner ignitors are open equipment. To avoid a sparking hazard,

they are mounted in an outdoor enclosure at the fifth floor level.

Electrical

The principal electrical hazards to the operators are in the cell room. Direct current voltages may be as high as 525 v. on the bus bars, at 1000 ampere current. Wooden walkways and railings are provided between the cell rows. Trip switches on the d.c. current are available in the cell room. A depolarizing breaker is included to eliminate the potential remaining on the cells after the current is shut off.

It was originally specified that limited operator access would be permitted during cell operation. In practice, all doors leading to the cell room are kept locked. Normal access to the building is through the office area. The cell room is chained off during a run, and operator access is forbidden.

Adequate alarm and intercommunication systems are provided to warn of dangerous operating conditions within this building and of hazards originating in other areas.

Other Hazards

An ammonia refrigeration system is installed in the building. To facilitate escape in the event of ammonia leakage, interior stairs and an outdoor stair tower provide two operator exits on each floor.

Two safety showers are available for emergency use, one in the cell room and the other on the third floor where K_2CO_3 is handled.

Protection from H_2S gas in the atmosphere is provided the occupants of the "E" Process building as follows:

1. The atmosphere around Building #421-D is sampled by an air analyzer unit located at Building #772-D. The detection of a hazardous concentration of H_2S will result in the operation of an alarm system.
2. Self-contained portable air mask bottle sets are provided at the #421-D Building for use for emergency egress in the event of hazardous contamination of the atmosphere.
3. Wind direction and velocity indicators, located elsewhere, serve to warn operators if the "E" Process areas are on the downwind side of a contaminated area.

For complete description of the H_2S hazard, refer to that section of the history devoted to "Specialized Design Problems - Safety".

DRAWINGS

W-140306 - Plot Plan
 W-140307 - Plot Plan
 W-140308 - Plot Plan
 W-140356 - Plot Plan
 W-140283 - Process Flow Diagram
 W-140277 to W-140281 Incl. - Process Piping & Instrument Diagram
 W-140947 - Design Drawing Index

Note:

The additional facilities for the production of deuterium gas and cylinder loading, referred to in the preceding pages as Building #421-2D, were erected during 1954 on another project. A description of those facilities and the history of their design, therefore, are not included here.

BUILDING #421-1D "E" PROCESS - CYLINDER LOADING

FUNCTION

Deuterium gas of [REDACTED] D_2 content is produced by the electrolysis of a portion of the specification quality heavy water from the "E" Process, Building #421-D. The design capacity of the facilities provided for this purpose is [REDACTED] c.f.h. The product is loaded into standard gas cylinders at [REDACTED].

PRINCIPAL COMPONENTS

A single structure houses all facilities except a gas storage tank which is located outdoors. The structure is west of, and immediately adjacent to, the "E" Process Building and is connected to Building #421-D by a covered walkway.

The operating facilities may be described as including two production and one auxiliary process sections as follows:

1. Gas production including gas holder (low pressure system).

2. Cylinder loading (high pressure system).
3. Refrigeration system used in connection with Section 1 above.

Note: Originally, a second auxiliary process was installed in Building #421-1D. This process provided for the recovery of D_2 from off-quality product, a step made necessary by the high cost of the process material. With the subsequent decision to greatly increase the cylinder loading facilities (Building #421-2D), it was determined that the D_2 recovery equipment would be adequate to serve both buildings, and this could be done more advantageously if located in the larger of the two buildings. Accordingly, this equipment was moved to Building #421-2D, and the description of the process included in the history of that building. For identical reasons, equipment for the recovery of D_2O from D_2O -oil mixtures was moved from the first to the second cylinder loading building and described in the history of the latter building.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Cell Room	290
Rectifier Room	165
Corridor	95
Compressor Area	480
Loading Area	530
Mezzanine	270
Covered Walk	170
Roofed Loading Shed	50

BUILDING DETAILS

The building is of Class III construction except that concrete block walls are used on three sides of the rectifier room. These block walls serve as a fire wall and vapor barrier to segregate electrical equipment from the process areas.

Size - The structure is essentially single-storied, approximately 24 ft. wide by 62 ft. long, but has two roof elevations and three finished floor elevations, including a mezzanine floor. Excluding the mezzanine the building is approximately 27 ft. high over a 25 ft. by 22 ft. area in the south end of the building, 21 ft. high over a 25 ft. by 18 ft. area in the central portion of the building and 18 ft. high over a 25 ft. by 22 ft. area in the north end of the building. Approximate heights are taken from the top of finished floor slabs to top of finished flat roofs.

Area - 1550 sq. feet ground floor.
 270 sq. feet mezzanines.
 1820 sq. feet - total.

Volume - 34,480 cubic feet - building proper.

CONSTRUCTION DETAILS

Foundations - Reinforced concrete; grade beam construction with spread footings at column piers.

Superstructure - Structural steel frame with insulated flat concrete roof on purlins and steeltex.

Exterior walls are of corrugated asbestos on girts.
 No interior finish on exterior walls.
 Concrete block walls around rectifier room.
 Doors - Hollow metal.

Roofing - Built-up.

Insulation - One-inch Foamglas between 2-inch concrete roof slab and built-up roof finish. Walls not insulated.

Floors - Concrete, No. 1 finish. Mezzanine floor is part concrete, part grating.

Heating - Unit heaters - forced draft.

Air Conditioning - None.

Ventilation - Unit heater fans provide ventilation through louvers at the bottom and along the top of side walls.

Lighting - Vapor-tight incandescent fixtures throughout.

Access -

1. A paved area for trucks is provided at the north end of the building.
2. A covered walkway, approximately 42 feet long, connects Buildings #421-D and #421-1D.
3. A concrete walkway extends from the covered walkway at the south end of the building to the three doors on the west side - a distance of approximately 60 feet.

EQUIPMENT

Gas Production

In general, the following description lists the major pieces of process equipment as they would normally occur in process flow.

Feed Tanks

Two 120-gallon cylindrical carbon steel tanks with gauge glasses and covers. Design pressure - atmospheric; temperature - 100°F.

Electrolytic Cell Bank and Rectifier

One electrolytic cell bank (9 cells) suitable for producing 250 s.c.f.h. of 99.5% minimum purity deuterium gas. Cells arranged for manual filling by gravity flow from the feed tanks, with provision to keep feed material from contact with air and for determining liquid level in each cell. Cells are mounted in a suitable supporting frame and have pipe manifolds for separately collecting deuterium and oxygen. Cells are electrically insulated from both frames and manifolds.

One rectifier to deliver direct current at 24 volts, 2000 amperes, ungrounded. Equipment to include air-cooled transformer to step down 440 volt, 3 phase building supply voltage to that required by the rectifier. Control equipment and safety devices with instruments and indicating lights insure the safety of equipment and personnel. All of these were purchased as a "packaged" unit from the Electric Heating Equipment Company.

Oxygen Cooler

One fintube hairpin exchanger to condense 1.8 lbs. per hour of water vapor from a mixture consisting of 2.0 lbs. per hour of water vapor and 10.6 lbs. per hour of oxygen. Inlet temperature 150°F., outlet 80°F. Cooling water - 193 lbs. per hr., inlet temperature 67°F., outlet temperature 80°F. Design pressure 150 p.s.i.g. on each side. Materials are Types 304 and 316 stainless steel.

Oxygen Condensate Pot

One 18-inch by 16-inch from flat bottom head to flat top head, Type 304 stainless steel pot with calibrated gauge glass.

Oxygen Mist Separator

One 1-1/2 inch pipe line separator with cast steel body -

300 lbs. s.w.p. at 750°F.

Oxygen Relief Seal Pot

One Type 304 stainless steel pot - 8-5/8 inch o.d. by 15 inch high with shell fabricated from 8 inch Schedule 10S pipe and top and bottom from 3/16 inch plate.

Oxygen Chillers

Two fintube hairpin exchangers to condense 0.21 lbs. per hour of water vapor from a mixture consisting of 0.21 lbs. per hour of water vapor and 10.6 lbs. per hour of oxygen. Inlet temperature is 80°F., with outlet temperature -15°F. Refrigerant is 8.4 lbs. per hour of Freon with inlet and outlet temperatures at -20°F. Design pressures are 200 p.s.i.g., refrigerant side, and 150 p.s.i.g. on the process side. Materials are Types 304 and 316 stainless steel. Chillers are designed for parallel installation - only one being in service at a time while the other is thawing.

Deuterium Seal Pot

One Type 304 stainless steel pot, 8-5/8 inch o.d. by 11 inch high with shell fabricated of 8 inch Schedule 10S pipe and top and bottom of 3/16 inch plate.

Deuterium Cooler

One fintube hairpin exchanger to condense 3.6 lbs. per hour of water vapor from a mixture consisting of 4 lbs. per hour water vapor and 1.3 lbs. per hour of gas. Inlet temperature is 150°F., outlet temperature is 80°F. Cooling water 385 lbs. per hour, 67°F. inlet, 80°F. outlet. Design pressure is 150 p.s.i.g. on each side. Materials are Types 304 and 316 stainless steel.

Deuterium Mist Separator

One 1-1/2 inch pipe line separator having cast steel body - 300 lbs. SWP at 750°F.

Deuterium Condensate Pot

One Type 304 stainless steel pot 18 inch o.d. by 16 in. from flat bottom head to flat top head with calibrated gauge glass.

Deuterium Holder

One 1000 cubic foot capacity Wiggins' Type dry seal gas holder. Working pressure 3.55 inches of water. Holder

of carbon steel construction with neoprene impregnated nylon diaphragm.

Holder Outlet Seal Pot

One 6 inch diameter by 14 inch high carbon steel pot.

Cylinder Loading

De-Oxidizer

One 750 s.c.f.h. catalytic deoxidizer as manufactured by the Pure Gas Equipment Company.

De-Oxidizer After-Cooler

One fintube hairpin exchanger to cool 1.3 lbs. per hour of gas containing 0.55 lbs. per hour of water. Inlet temperature of wet gas is 300°F., outlet temperature is 80°F. Cooling water 191 lbs. per hour - inlet temperature 67°F., outlet 80°F. Design pressure 150 p.s.i.g. on each side. Materials are Type 304 and 316 stainless steel.

Deuterium Compressor

One 5 inch by 3-1/4 inch by 1-5/16 inch by 5 inch Ingersoll-Rand Type ER-3, horizontal, reciprocating, water cooled, belt-driven compressor, complete with drive, separator, intercoolers, and 7-1/2 h.p., 1200 r.p.m. explosion-proof induction motor. To deliver 8-c.f.m. of gas at 2000 p.s.i.g. with inlet pressure of zero p.s.i.g. and 80°F. Parts in contact with the process material are of alloy steel.

Compressor Aftercooler

One heat exchanger consisting of a pipe coil fabricated from 25 lineal feet of 9/16 inch o.d. by 5/16 inch i.d. stainless steel pipe, placed in a carbon steel drum having well water circulating on the shell side.

Condensate Pot

One 4-1/2 inch o.d. by 14 inch high carbon steel tank.

Oil Extractor

One high pressure dual pre-filter, 4-1/2 inch o.d. by 30 inch long, operating at 2000 p.s.i.g. with an inlet temperature of 90°F. Equipment for continuously removing oil from the hydrogen compressor discharge line. Unit is piped and valved to permit replacement of extractor charge without interruption to the flow of process gas.

Product Manifolds

Two 4-cylinder manifolds complete, including pipe, pigtails, miscellaneous valves, flanges, fittings, specialties and cylinder valve connections. Manifolds arranged to operate in parallel at 2000 p.s.i.g. All materials stainless steel.

Vacuum Pump

One Beach-Russ Type 2-9-SSVD-CP rotary single stage, motor-driven, high vacuum pump, complete with separator and lubricator, stainless steel and Monel packing, motor and V-belt drive, bypass piping from the suction side to the discharge side of pump. Pump for evacuating a hydrogen gas bottle (222 cubic feet volume) from 14.7 to 1 p.s.i.a., which requires pumping approximately 770 cubic feet of evacuated gas. Pump has a capacity of 7 c.f.m. or more and therefore the time required to evacuate the bottle from 14.7 to 1 p.s.i.a. is slightly less than two hours.

Oil Collection Pot

One 12-3/4 inch o.d. by 2 ft. high carbon steel tank equipped with calibrated gauge glass and constructed for pressure of 150 p.s.i.g. This pot is the collecting point for condensed D₂O and D₂O-oil mixtures from the deoxidizer aftercooler, the compressor separator, intercoolers and aftercooler condensate pot, the compressor coil and packing leakoffs and from the oil extractor.

Refrigeration System

The following items constitute the major pieces of equipment for the auxiliary refrigeration unit designed to serve the oxygen chillers in the gas producing process.

Refrigeration Unit

One 1/4 ton "package" refrigeration unit consisting of motor-driven compressor, double tube condenser and piping within the unit.

Operating conditions: refrigerant - Freon 12, suction pressure 15 p.s.i.a. cooling water temperature - 86°F., cooling water pressure - 150 p.s.i.g. (designed).

Freon Receivers - One low pressure Freon receiver approximately 13 inch o.d. by 24 inch high, weld line to weld line. Design conditions: pressure - 300 p.s.i.g., corrosion allowance - 1/16 inch. Materials of construction: carbon steel.

One high pressure Freon receiver - 18 inch o.d. by 2 ft. high from weld line to weld line. Design conditions and material of construction - same as low pressure receiver.

Both receivers equipped with gauge glass.

Expansion Pots

Two 8-5/8 inch o.d. by 12 inch high, weld line to weld line, carbon steel, vertical expansion chambers. Design pressure - 300 p.s.i.g.

Oil Separator

One 4-1/2 inch o.d. by 14 inch high carbon steel tank. The drain line from the separator returns the oil to the compressor crank case.

Process Piping

Piping and valves carrying process materials are of stainless steel because of the requirements for purity of product and because this construction also minimizes the possibility of scale formation plugging the small orifices.

Purging

Fittings for the introduction of a purging medium into the system were included in the process design.

Instrumentation

Instrumentation is provided to control pressures, temperatures and flow rates and to give audible warning should irregularities or hazardous conditions occur. In general, the instrumentation is of standard type that might be found with any similar commercial process. Examples of this type, and probably the most important, are as follows:

- (a) A limit switch to prevent operation of the cells when valve in product line to holder is closed, thus preventing pressure build-up in cells.
- (b) A limit switch to prevent operation of compressor when valve in holder discharge line is closed, thus preventing pulling a vacuum in the compressor.
- (c) A remotely and manually controlled valve to regulate the by-pass around the compressor.
- (d) A pressure recorder and controller, with valve in the high pressure gas line ahead of the loading manifold.

- (e) A pressure recorder and alarm actuated by the cylinder manifold pressure.

In addition to the instrumentation listed above, two special controls were required. The first of these is a departure from the usual method of equalizing pressure on the oxygen and hydrogen sides of the cell diaphragms by using weir boxes with the water level adjusted to cause the desired back pressure.

While standard cells can be used, contact between the process material and natural water obviously cannot be tolerated, so a special means of control was devised. This took the form of a pneumatically operated pressure differential recorder controller system with which the liquid level on the deuterium and oxygen sides of the cell diaphragms is regulated by controlling the back pressure in the oxygen off-gas line.

The second special control system was desirable because of the necessary strict accountability of the process materials. It consists of a pneumatic position recorder attached to the gas holder. Besides giving a continuous record of the holder elevation, it activates a sequential switch which will give an alarm and/or cut out either the cell bank, when the holder is at high level, or the compressor, when the holder is at low level. In addition, this instrument is supported by limit switches on the holder, set to perform the same duties. This installation makes doubly sure that loss of gas through emergency venting of the holder will not be necessary, and that the compressor will not pull a vacuum due to lack of gas in the suction line.

Because supervision of the cylinder loading process was originally housed in the main "E" Plant it was desired that a minimum of instrumentation be supplied in that building. Therefore, critical records and indications were kept on parallel control panels in Buildings #421-D and #421-1D. In addition, the by-pass around the gas compressor could be controlled from Building #421-D, and both buildings were provided with "crash" switches for emergency shutdown of Building #421-1D. Audible signals in Building #421-D operated through an existing buzzer system.

Later, when the considerably larger facilities for cylinder loading (Building #421-2D) were erected, it was decided that the new building should be the control center for both buildings. All control equipment described above as being located in Building #421-D was therefore moved to Building #421-2D.

The above discussion describes the instrumentation as specified by the Design Division and actually installed. After completion of the building, and its acceptance by the Operating Department, the AED made a change involving items (c) and (d) above. With the original installation, the manually operated by-pass valve would be set from Buildings #421-D or #421-1D to maintain the proper pressure with normal compressor speed and cylinder filling rate. Should the discharge pressure increase and the by-pass valve not be manually reset accordingly, the pressure would continue to increase to the critical point where a switch would cut off the compressor.

The change introduced a solenoid operated valve at the by-pass valve. Under normal conditions, settings were made from Buildings #421-D (later from #421-2D) or #421-1D as before. However, as the discharge pressure increases above the point of control, the back pressure control is automatically transferred to the by-pass valve by a switch activating the solenoid valve.

This change, while not the responsibility of the Design Division, is discussed here so that the reader might have knowledge of the latest development in the control of this process.

PROCESS

Description

The final product of Building #421-1D must meet the following specifications:

Nitrogen
Oxygen
Moisture
Deuterium

Feed to Building #421-1D consists of specification quality heavy water (99.75% minimum D_2O) received from the "E" Plant, Building #421-D, by pipe line to two feed tanks. Weight accountability of the material entering this process was maintained by the use of calibrated gauge glasses on the feed tanks. Later, when Building #421-2D was erected, a weigh tank was installed in the "E" Plant to serve both cylinder loading buildings. Thus weight accountability was transferred to the source of the process material.

Electrolysis is accomplished in diaphragm-type electrolytic cells operating at essentially atmospheric pressure. These cells are charged initially with a 7.5% solution of potassium carbonate in D_2O prepared in the "E" Plant. The cells operate continuously, the proper operating level being

maintained by manual addition of pure D_2O makeup from the feed tanks.

Oxygen and deuterium are evolved by the electrolytic action and are collected in separate headers. The oxygen is cooled, first in a water cooled exchanger and then in a refrigerated condenser, the condensate separated for return to the cells and the dry gas vented to the atmosphere. The deuterium gas is directed through a water cooled heat exchanger and a separator to remove entrained liquid and is then stored in a one-thousand cubic foot gas holder at atmospheric pressure. As in the oxygen line, condensate is recovered in a collection pot for return to the cells.

From the gas holder the deuterium gas is heated to approximately 100 degrees centigrade and passed through a catalytic de-oxidizer where any remaining oxygen will be combined with some of the deuterium to form water vapor. Most of this water vapor is removed in the de-oxidizer aftercooler, the last step in the process before compressing.

An Ingersoll-Rand 3-stage compressor discharges the gas at about 2000 p.s.i.g. The remaining water vapor in the gas, now at high pressure, is extracted by the compressor separators, intercoolers and aftercooler. Since the compressor is oil-lubricated, an oil extractor has been inserted in the gas discharge line. From the oil extractor, the gas goes to the cylinder loading facilities which consists of two 4-cylinder manifolds and connections for serving gas cylinder trailers. A vacuum pump is connected to the manifold system so that the gas cylinders can be evacuated to about 50 millimeters of mercury absolute pressure before initial loading.

The condensed water vapor and oil water mixture removed from the system in the compressor separator and coolers and in the oil extractor are collected in a single oil collection pot from which it is taken to a de-emulsifier in Building #421-2D where the D_2O is separated from the oil mixture and recovered. The de-emulsifier was originally located in Building #421-1D.

Every effort is made throughout the process to prevent the loss of either D_2 or D_2O . In the gas producing section of the process, a reverse in flow and consequent loss of gas from the cells is prevented by the installation of seal pots and loop seals. All vents to the atmosphere, except the oxygen discharge, are through Drierite tubes. Further, a seal pot is provided at the gas holder outlet to prevent loss from the holder in the event that any subsequent equipment must be shut down for repairs. The compressor high-

pressure relief is a rupture disc and pipe assembly connected to the disc with the collection pot. Means for collecting leakage at the compressor packing or from the cooling coils is also provided. Throughout the entire process, all such vessels as feed tanks, condensate pots, seal pots, and the oil collection pot are equipped with gauge glasses in the interest of strict accountability of the process material.

An auxiliary process consisting of a refrigeration system is provided in Building #421-1D to serve the parallel oxygen chillers by alternately supplying Freon at -20°F . and at 90°F . The high temperature defrosts one of the exchangers while the other is in service at the lower temperature. This is a "flooded" system and consists essentially of a compressor and condenser, a high pressure Freon receiver, a low pressure Freon receiver, expansion pot for each of the two lines serving the chillers and an oil separator in the compressor discharge line.

Development

There was practically no process development, as such, in connection with Building #421-1D. The scope of work prepared by the AED specified the electrolytic process for producing deuterium gas from D_2O , stringent specifications for the product (see "Process -2-Description"), and that the gas be loaded into cylinders at 2000 p.s.i.g., at the design rate of 250 s.c.f.h. There were however, certain operating conditions which necessitated the addition of some equipment that might not be found in similar commercial processes. The required purity of product and the high cost of the process material, necessitating strict accountability of this material, were major factors affecting the design of the process.

Purity of product being essential, oxygen removal by deoxidation, and oil removal by adsorption were adopted. Well water, rather than river water, was used in product coolers to reduce water in the product to as low a value as possible. The necessity for strict accountability of product resulted in provision of additional collection pots, the off-quality recovery system (burner), a refrigeration system, and an oil- D_2O separation system to facilitate all possible recovery of D_2 and D_2O .

Originally, drying equipment to reduce the heavy water in the final product was considered. The dryer was eliminated, however, since compression of the gas to 2000 p.s.i.g. and cooling to 80°F ., resulted in a product with a satisfactory water content.

DEVELOPMENT OF DESIGN

Building

A site west of and adjacent to, the existing "E" Plant, Building #421-D, was chosen for the cylinder loading facilities, Building #421-1D, as these were to be operated in conjunction with the heavy water finishing process.

Since Building #421-1D was to be designed for long-term operation, the same type of construction (Class III) was employed as used for Building #421-D. Due to the similarity of operating conditions, heating, ventilation, safety considerations, and provision for recovery of spillage are comparable to Building #421-D.

Sufficient sanitary facilities, lockers and office space for operating personnel are available in Building #421-D and samples are taken elsewhere for laboratory analysis so that the floor space of the new building could be reduced to that required for production equipment and cylinder storage and handling. Equipment is arranged in the same manner in the cylinder loading building as in the "E" Process building, the cell equipment being housed in a separate area isolated from the electrical control and rectifying equipment.

Equipment

The AED requested that the equipment for Building #421-1D be kept simplified and that similar types of equipment in use at commercial hydrogen plants be specified. It was also suggested that consideration be given to the use of some available equipment from the Morgantown P-9 Plant and Dana Plant.

The first request was followed - except that the high purity specified for the product required the use of stainless steel for much of these facilities. Also the extreme importance of process material conservation necessitated some duplication in controls to minimize deuterium venting, and the use of more equipment for condensing and condensate collection than might be found in a commercial installation.

The available Morgantown and Dana equipment consisted of an insufficient number of electrolytic cells, an ignition rectifier and a burner for the off-grade recovery system. None of this equipment was used. The reasons for buying new cells and rectifier will be found in subsequent sections. The burner was not used because an improved burner had been developed for Building #421-D.

Electrolytic Cell Bank and Rectifier

The choice of new cells and a new rectifier for use in this building rather than the utilization of available equipment from Morgantown and Dana Plants was largely dictated by electric power economics. This phase of the problem is discussed in a later section entitled "Electric Power".

Contributing to the price disadvantage and poorer delivery prospects of the Morgantown cells was the modification necessary for this service, namely, the conversion to diaphragm cells. Even with the new cells, a pressure equalizer had to be included to balance the pressure on both sides of the diaphragm and thus eliminate the possibility of deuterium loss to the oxygen side. This equalization was accomplished by instrumentation rather than by the means usually employed in the hydrogen separation process. This has been explained in the section entitled "Instrumentation".

It having been decided not to utilize the Morgantown cells, the necessity for speed in completing Building #421-1D dictated the use of standard equipment wherever possible. Essentially standard cells with polystyrene insulators and spacers were chosen. Time did permit, however, the incorporation of certain improvements in cell construction to prevent loss of the extremely valuable process material. The pressure equalizer mentioned above was one such improvement. Another was the placing of mantles over the normally open fill cups to prevent loss from splashing, contamination and evaporation.

In a further effort to prevent loss of valuable process materials, the vent connection on top of each cell feed is tied into a vent manifold which is vented to the atmosphere through a Drierite Tube. Also the drain plug in each cell was replaced with a nipple and plugged screwed valve to facilitate draining of the cells for periods of extended shutdown.

Seals and Vents

The necessity for strict accountability of process materials, because of their high value, resulted in the use of an extensive system of sealing, venting, condensate collection and recovery, etc. In some instances, dual devices are employed to prevent operating conditions that would result in venting and loss. Other examples of the effort to prevent loss are: 1) the use of Drierite tubes for gas release in the low pressure part of the process and 2) the substitution of a high pressure relief valve and rupture disc blowing to air, for a rupture disc blowing to the holder, thereby preventing overpressurizing of the gas holder by back feed from cylinders.

Deuterium Compressor

At the time of starting design of the cylinder loading facilities it appeared that the criteria regarding purity, lack of leakage and high yield might make the choice of a hydrogen compressor a very difficult problem. However, it was later believed that a standard water lubricated, or even an oil lubricated compressor, could be used by including with the machine special provisions for recovering packing leakage, plus the use of adequate coolers, separators and D₂O recovery facilities following the compressor. An oil lubricated compressor was installed and, in addition to those special provisions mentioned above, an oil collection pot and a de-emulsifier were added to the system.

The process dummy run disclosed that the compressor third stage relief valve would start to leak at 1800 p.s.i.g. and would return nearly half of the gas to the suction line. Several valves were tried with the same results. Therefore, the valve was removed and a rupture disc and assembly, set at 2400 p.s.i.g., was installed.

Besides the usual controls furnished with the compressor, special precautions were taken to protect the system and to prevent loss of process materials. These controls are discussed in the section entitled "Instruments" earlier in this chapter.

Perhaps the most difficult phase of the compressor problem was its procurement. This is discussed in the section entitled "Procurement" below.

Refrigeration System

To furnish the oxygen coolers with a cooling medium at -20° F., a "flooded" refrigeration system was designed. This system, utilizing Freon 12 as the refrigerant also provides for the intermittent hot gas defrosting of the two parallel oxygen chillers.

After design and procurement on this system had reached an advanced stage, the AED suggested that these facilities might be more complex and costly than a "package" direct expansion unit. It was suggested also that defrosting by either electric power or low pressure steam would simplify the system.

The Design Division's reasons for favoring retention of the system as designed included:

1. Float control valve of "flooded" system more trouble-free than expansion valve of direct expansion system.

2. Direct expansion system was developed to adjust to variable loads. The application under discussion is essentially a constant load.

3. The installation requires vertical orientation of the finned tubes to permit defrosting. With the direct expansion system oil would accumulate in the traps formed by the coil return bends, starving the compressor of lubrication and reducing the active heat transfer surface area. Evaluation disclosed no more desirable method of defrosting.

4. Even if a change to direct expansion were desirable, the expense of repeating design and procurement would be greater than the small (if any) savings made possible by the change.

5. Consultation with a representative of the Carrier Corp., revealed their approval of the design, and that they knew of no "package" unit available for such a specialized application without considerable modification.

6. The instrumentation is admittedly more comprehensive in coverage, superior in quality and therefore higher in cost than that usually furnished with "package" equipment. However, the quality and scope of instrumentation is consistent with that furnished for similar services at Savannah River Plant.

The AED accepted the original design with only one major revision. A dual installation of compressor and condenser had been contemplated - one of each serving as a spare. The AED first requested that the spare equipment be kept in the "Extra Machinery" account (not installed), and later decided that no spare equipment should be provided. The purchase orders for the second compressor and condenser were therefore cancelled.

Electric Power

When designing the electric power supply for Building #421-1D, it was logical to consider the possibility that there might already be sufficient capacity available in Building #421-D, because of the proximity of the two buildings. Building #421-D is served by a 13.8 kv. line for cell operation, and a 440 v. line for all other "E" Process services, totaling approximately 100 kv.-a. The 440 v. line originates at substation Building #452-4D (south of Building #420-D) and is of considerable length due to skirting to the east of the area reserved for the future expansion of the "DW" and "E" Processes. This line also serves a well, located east of the Finishing Area and requiring approximately 50 kv.-a. Thus the total load on this line from substation Building #452-4D was 150 kv.-a.

The installation of the electrolytic cell bank and the other miscellaneous electrical requirements in Building #421-1D would add a load of approximately 80 kv.-a. to the "E" Process Area. Of this, 50 kv.-a. is required for the electrolytic operation. Since there was insufficient rectifier capacity in Building #421-D to supply this new load in series with the maximum "E" Plant requirements, consideration was given to using the 1000 amp. ignitron rectifier then available at the Dana Plant. The cost of such an installation was compared with that of a new 2000 ampere, 25-volt, dry disc type rectifier. The comparison favored the new rectifier, principally because it could be purchased for use on the available 440 v. line. The Dana rectifier would require 2300 v. service and would require the construction of a new substation.

When design was started for this building it was suggested that electrolytic cells from the Morgantown P-9 plant might be used. These were 1000-ampere cells that would require some modification to make them suitable for the new service. Further, there was an insufficient number of these old cells. Quotations were obtained for (a) rehabilitation and use of the 1000-ampere cells from Morgantown, plus additional new 1000-ampere cells to provide the total desired capacity, and (b) the purchase of nine new 2000-ampere cells. The quotations indicated the cost of using the old equipment to be about \$3000 more than providing new 2000-ampere cells. In addition, delivery would be less satisfactory for the old equipment.

Thus it was decided to install new 2000-ampere cells and a new 2000-ampere, 25 volt, dry disc rectifier. It later developed that the Electric Heating Equipment Company, vendors for the nine new cells, quoted above the low bidder for the rectifying equipment by approximately \$3000. It was decided to pay this premium to obtain the advantages of a "package" unit, i.e., having the entire job under the sole responsibility of a vendor with extensive experience in this field. For this rush program it was expected by this means to obtain a well coordinated design in a minimum of time.

The addition of the 80 kv.-a. load in Building #421-1D to the loads then served from substation Building #452-4D would have overloaded that substation. Also, the additional current in the existing power distribution line from the substation to Buildings #421-D and #421-1D would result in an excessive voltage drop in the lines with resultant unsatisfactory service at these buildings.

These two problems were resolved by:

1. Transferring the 50 hp. well pump from the "E" group distribution system to the shops distribution system,

by running a line south from substation Building #452-1D to the well; and

2. Installing additional lines on existing poles along the road just west of substation Building #452-4D and leading directly to the new Building #421-1D.

The other miscellaneous electrical facilities installed consist of normal lighting, emergency lighting, signal and communication systems, power for compressors, etc. The emergency, signal, and communication systems are similar to, and in some cases operate from, those in Building #421-D. Safety precautions pertaining to cell installation and operation largely duplicate those in effect in the "E" Process cell room.

Procurement

Design for Building #421-1D which was begun early in March, 1953, was faced with serious procurement difficulties since the AEC had requested a start-up date of July, 1953. It was anticipated that the cells and rectifier, gas holder and deuterium compressor would constitute the limiting pieces of equipment. While firm orders were placed during March, 1953, the first estimated delivery for the compressor was January, 1954, and for other items as late as September, 1953. Also, it was believed that certain items of stainless steel instruments and piping could not be made available by July, 1953.

The difficulty concerning the compressor was eased by the acquisition of a used machine for use as an alternative. The compressor problem is discussed in greater detail below.

Later, the promised delivery dates on the cells, rectifier and gas holder were improved and these items were removed from the critical list. However, it became evident that the feed tanks, certain collecting, expansion and seal pots, and the two Freon receivers would not be received from their vendors in time. This problem was resolved by having the Construction Division fabricate these items in the field and by cancelling the original orders. Ten vessels were obtained by this means.

The receipt of other pieces of equipment was expedited by accepting quotations on the basis of delivery rather than lowest price. Items treated in this manner included the rectifying equipment and the burner. The specification for the various heat exchangers was changed to allow the use of a higher priced stainless steel alloy because it was immediately available and the equipment concerned was on the critical list.

By the end of April 1953, the AED expressed a willingness to test and start-up the building in two sections - the gas production facilities including the holder on the scheduled date and the compressing and loading facilities two weeks later. It developed that this arrangement made it possible to have all the necessary equipment installed in time for testing. Those facilities not yet received affected only the efficiency of the process, not the production, and were installed later.

With the promised delivery date for the cells considerably improved, the requirement for early operation of this building was more dependent for fulfillment on the procurement of the deuterium compressor than on any other piece of equipment. The purchasing phase was therefore concentrated on searching for both a new compressor and a used compressor.

The Ingersoll-Rand Co. quoted the lowest price and earliest delivery (26 weeks) for a suitable new compressor. This delivery was not satisfactory but the order was placed and efforts made to improve the shipping date. In the meantime a ten year old, rebuilt, five-stage Norwalk compressor was found to be available at the Du Pont Experimental Station. It was in good operating condition and suitable for interim service. Contacts with dealers in used equipment failed to produce anything more attractive.

When it became evident that no improvement could be made in the I-R shipping date, the Norwalk compressor was purchased and shipped to the plant. Foundations that would require a minimum of change to accommodate the I-R compressor were installed. Piping and electrical drawings for both machines were issued and changes were made in the Norwalk unit to make it suitable for this exacting service. Spare parts were ordered to assure continuity of service.

Subsequently, Ingersoll-Rand found it possible to cut its manufacturing time nearly in half. This did not quite meet the required date but since the vendor was working a three shift, seven day week no further improvement could be made. The AED decision to conduct their start-up tests in two sections made it possible to wait for the new compressor. The Norwalk compressor was finally transferred to the "Excess Material" account for disposal.

Safety

The major safety hazards on this building are the same as those in Building #421-D, in that the equipment is similar. The dangers are associated with the handling of deuterium-oxygen mixtures. The efforts made to minimize these hazards,

by design and arrangement of equipment and by operating procedure, are explained in the chapter of this history devoted to Building #421-D ("E" Process).

For that portion of Building #421-1D having a dissimilar process from Building #421-D (compressing and loading), adequate warning and precautions against dangerously high pressure are provided by alarms and relief facilities.

By virtue of its proximity to Building #421-D, Building #421-1D is located within an atmospheric air monitored area. A dangerous concentration of H_2S will actuate alarms over the circuits that serve the Finishing Building.

DRAWINGS

W-140111 - Plot Plan and General Arrangement

W-140991 - Process - Piping and Instrument Flow Diagram

Note:

The additional facilities for the production of deuterium gas and cylinder loading, referred to in the preceding pages as Building #421-2D, were erected during 1954 on plant project, S8-1003. A description of these facilities and the history of their design, therefore, are not included here.

BUILDING #805-D - PROCESS LINES

FUNCTION

The process lines provide the piping necessary to transfer the various concentrations of process water to and from Buildings #411-D, #412-D and #413-D and Building #420-D and then to Building #421-D.

PRINCIPAL COMPONENTS

These lines consist of approximately 3300 feet of 1-1/2 inch diameter overhead steel pipe line, steam chased and lagged.

DEVELOPMENT OF DESIGN

The value of the process water carried in outside lines is exceedingly high. Further, the quantity of water to be transferred between buildings is quite small and the distance between

buildings relatively great, specifically the distance between the "GS" and the "DW" Areas. For these reasons it was desirable to use small size pipe to minimize the line capacity. Also, the line was carefully sloped to permit maximum drainage to reduce the holdup between batch transfers.

Aside from the above possible exceptions, the methods of construction of the outside process lines and the materials used in these lines are generally the same as found for overhead water lines on Du Pont's commercial plants: 1) welded steel pipe and fittings; 2) flanged joints at valves; and 3) steam chased and lagged to prevent freezing. The combination of small size and careful sloping made it necessary to hang the process lines from larger service lines rather than attempt to span the distance between the pipe supports provided for the larger lines.

DRAWINGS

- Map 3313, Sheet No. 725 - Outside Lines Overhead Piping Plans.
- Map 3313, Sheet No. 726 - Outside Lines Overhead Piping Lines.

ADMINISTRATIVE, PERSONNEL AND SERVICE FACILITIES

BUILDING #701-1D - AREA GATEHOUSE AND PATROL HEADQUARTERS

FUNCTION

This building, situated beside a two-lane vehicular entrance to the area, houses the central headquarters for the area patrolmen, together with the normal and emergency control equipment, including fire alarm recording, blackout, and public address systems, and radio and telephone communications facilities. Primarily, it is the control point for personnel and vehicular traffic in and out of the area. For one phase of this operation, facilities also are provided for processing and issuing personnel health meters.

One section of the building, a Class I structure, is designed for emergency use in order to assure the continued operation of vital communication facilities during disaster control and also to provide protection against gamma rays. The remainder of the building is for normal use and is Class III construction.

Building operation is on a three shift basis.

PRINCIPAL COMPONENTS

Two offices, a mustering area, locker and toilet room facilities for approximately 80 men, and two personnel control lanes with an intervening badge counter are provided for handling a peak of 320 men per shift in the Class III portion of the structure.

Emergency control, and communications equipment and facilities are housed in the Class I wing. It contains a satellite telephone exchange designed to handle calls within the area and on the project. Operation is fully automatic. The basic equipment and a set of controls for radio communications, and blackout and public address systems are located in the Class I section of the building. A dual set of controls for normal use and the fire alarm recorder are installed in the Class III portion of the building.

Adjoining the Class I structure is a small Class I shelter housing an electric generator for emergency light and power supply.

BUILDING FLOOR SPACE

<u>Class I</u>	<u>Approx. Sq. Ft.</u>
Telephone exchange	350
Emergency control center	180
Utilities room	160
 <u>Class III</u>	
Badge alley	540
Three offices	530
Health meter laboratory	200
Two toilets	200
Utilities room	170
Lunch room and assembly area	295
Locker room	635

BUILDING DETAILS

This is a single story building composed of a Class I wing approximately 23 ft. by 51 ft. by 11 ft. from the floor to the top of the flat roof slab, with an adjoining Class I unit approximately 7 ft. by 8 ft. by 8 ft. high housing a generator, and a Class III portion approximately 46 ft. by 61 ft. by 11 ft. high from floor to top of the roof slab. The total area is 4033 square feet and the total volume is 67,970 cubic feet.

CONSTRUCTION DETAILS

The building has a reinforced concrete foundation with spread footings and concrete floor. The Class I wing has reinforced concrete walls, roof and interior partitions of concrete baffle construction. The ceiling is formed by the exposed underside of the roof structure. Doors in this area are of hollow metal and there are no exterior windows. Roofing is built-up.

The Class III section has a structural steel frame with web roof joists and a concrete roof slab on riblath. Exterior walls of this portion of the building are corrugated asbestos board. Interior partitions and the interior of exterior walls are of flat cement asbestos board on steel studs. Toilet room walls are concrete to a height of 4 ft. with flat cement asbestos board above this level. The suspended ceiling is finished with the same material. Doors are hollow metal and window sash is steel, double-hung. Roofing is built-up.

Exterior walls and roof in the telephone section have asbestos board finish over wall insulation and the same treatment to a height of 6 ft. in other parts of the Class I section and on interior walls of the health meter laboratory. The concrete floor is covered with asphalt tile in all offices and corridors, and in the health meter laboratory of the Class III section and the telephone exchange of the Class I section.

Heating in the Class I wing is supplied by forced air through ducts in conjunction with the air conditioning system. The same means is provided in the health instruments laboratory. Unit heaters are installed in the badge alley. All other areas in the Class III section are heated by forced air through ducts. The steam source for these heating services is the area power house. The Class I section and the health meter laboratory are air conditioned by self contained units. Fans on the roof maintain an air exhaust through ducts from the Class I area, the locker room, toilets, and the Class III area corridor. Fluorescent lighting is installed in the offices, badge alley, health meter laboratory and the emergency control center. All remaining areas have incandescent lighting.

EQUIPMENT

Radio receiving and sending equipment, 30 watt capacity.
Fire alarm recorder, blackout and public address system
and controls.

Telephone exchange, 100 lines capacity.

3.5 kw. 120 v. diesel-driven electric power generator.
 One self-contained air conditioned unit, 5-ton capacity.
 Air supply and exhaust fans, air heating units, ductwork.
 Conventional office furniture.
 Guns and cabinets.
 78 Lockers with benches.
 Lunch eating facilities.
 Badge counter.
 Gas masks for emergency use in the Class I Section.

DEVELOPMENT

A separate facility, designated Building #702, to house the area telephone exchange equipment and an emergency control center was included in the preliminary scope of design for the Savannah River Plant. On August 31, 1951, it was decided to delete this building and to incorporate its facilities in a wing to be added to the Gatehouse and Patrol Headquarters Building. This revision first applied to those facilities in the #100 Areas but was later extended to include the same buildings in the F, H, and D Areas. The combination was effected at the Savannah River Plant as a result of a study made of the separate facilities provided for these two operations at Hanford. It was decided that the emergency control centers should be more readily accessible to the radio control operators, who normally are located in the patrol and security buildings, in the event disaster control operations should become necessary.

This juxtaposition of security facilities and the telephone exchange and emergency control equipment in one building presented design problems of a particular nature. Design criteria required that the housing of the telephone exchange and emergency control center be of Class I construction since these facilities had to be located in a permanent structure which would be habitable during disaster control. Class III construction, however, was suitable for the normal security and patrol functions. The obvious solution was the specification of a Class I wing for the communications operations attached to a Class III structure for the operational security facilities. In addition to meeting these two basic requirements, Class I construction provided a bomb shelter and protection against gamma ray contamination for building personnel.

DRAWINGS

W-155479 - Floor Plan.
 W-155480 - Elevations.

BUILDING #701-2D - GATE HOUSE**FUNCTION**

This structure serves as a shelter for two guards, based elsewhere, engaged in control of railroad traffic to the area.

PRINCIPAL COMPONENTS

The facility consists of a one room gate house equipped with a telephone.

BUILDING DETAILS

It is a single-story, Class III structure with over-all dimensions approximately 10 ft. by 10 ft. by 9 ft.-5 in. from the floor to the top of the roof sheathing. The area is 100 square feet and the volume, 950 cubic feet.

CONSTRUCTION DETAILS

The wood frame building is supported on reinforced concrete foundations. The roof is wood on wood joists, treated for fire resistance, with built-up roofing. Exterior walls are sheathed with corrugated asbestos board and the interior of exterior walls is of gypsum wall board. There are no interior partitions. The ceiling is gypsum board applied to the underside of the roof joists. Insulation is placed in the walls and above the ceiling. There is no covering on the concrete floors. Electric heating is installed and lighting is incandescent.

EQUIPMENT

Table and two chairs, costumer, 3-kw. electric heater.

DRAWING

W-155731 - Plan and Elevations.

BUILDING #701-3D - GATE HOUSE**FUNCTION**

This facility provides a control point for personnel and vehicular traffic to and from the "GS" section of the area.

PRINCIPAL COMPONENTS

The one room structure is located between a two-lane vehicle entrance and has a single personnel control lane within the building.

BUILDING DETAILS

A single-story, Class III structure, approximately 13 ft. by 15 ft. by 9 ft.-5 in. from the floor to the top of the roof sheathing, the building has an area of approximately 202 square feet and a volume of 1900 cubic feet.

CONSTRUCTION DETAILS

The building foundations are of reinforced concrete and the frame is wood. The roof is wood framing on wood joists, treated for fire resistance, with built-up roofing. Exterior walls are sheathed with corrugated cement asbestos on wood studs and the interior of exterior walls is of gypsum wall board. There are no interior partitions. The ceiling is of gypsum wall board. Insulation is installed in walls and above the ceiling. There is no covering on the concrete floor. The building is heated by an electric heater and lighting is fluorescent.

EQUIPMENT

Badge counter and rack, 7.5 kw. electric heater, table, two chairs and two stools.

DRAWING

W-155429 - Plan and Elevations.

BUILDING #704-D - SUPERVISOR'S OFFICE AND FIRST AID

FUNCTION

Administrative offices, training quarters, and first aid facilities for the #400-D Area are provided in this building. Headquarters for the Operating Department during the early stages of construction were located here until other area buildings became available.

PRINCIPAL COMPONENTS

Administrative operations are accommodated in twenty-three offices, a lobby, a conference room, and a vault. Toilet and rest room facilities for male and female employees are provided. The medical section includes an office, laboratory, X-ray and dark rooms, a cardiograph room, cot rooms, and reception and toilet facilities. A mechanical utilities room houses the air conditioning equipment and other service apparatus.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Twenty-three offices	3650
Lobby	330
Vault, outside of 8" walls	190
Conference room	515
Toilets	485
Medical section, except corridor	2040
Mechanical utilities room	440

BUILDING DETAILS

Of single-story, T-shaped, Class III construction, one section is 40 ft. 11-1/2 in. by 180 ft. 7-1/4 in., and the other is 40 ft. 11-1/4 in. by 62 ft. 5-3/4" out to out of foundation walls. Each section is 18 ft. 9 in. high from floor to peak of the double-pitched roof and 8 ft. 5-1/2 in. high from floor to ceiling. There is an oxygen bottle room and vestibule 12 ft. 2 in. by 10 ft. 1 in. by 8 ft. 7 in. to the top of the flat roof. At the front there is a roofed over entrance 6 ft. 6 in. by 20 ft. by 8 ft. 4 in. to the top of the roof. The total building area is 10,087 square feet, that of the entrance area is 130 square feet, and the total volume is 162,000 cubic feet.

CONSTRUCTION DETAILS

The building foundations are of reinforced concrete with spread footings. The structural steel, prefabricated frame of rigid design has the exterior walls insulated and sheathed with corrugated cement asbestos board. Interior partitions and the interior of exterior walls are gypsum wall board on wood studs. Toilet room walls are concrete to a height of 4 ft., with gypsum board above. Ceilings are suspended and finished with gypsum wall board except in the vault, the oxygen bottle room and the utility room which are exposed. They are acoustically treated throughout except in the utility room, the dark room, the toilets and small

service rooms. Doors are wood and window sash is steel, double-hung. Roofing is corrugated cement asbestos board with insulation installed above the ceilings. The concrete floors are covered with asphalt tile. Heating is furnished by fintube radiators with steam supplied from the area power house. The conference room and the medical section are air conditioned.

Air exhaust is provided from toilet and corridors. Lighting is fluorescent in offices, conference room, first aid section and laboratory, and in the physiotherapy and X-ray rooms. Other areas have incandescent lighting.

DEVELOPMENT OF DESIGN

This building was designed originally as an H-shaped structure with two wings, each 40' wide by 180' long, and a connecting wing 40' wide by 60' long. The availability of the Ellenton school building for project use by February 1952 made possible the elimination of the west wing on which construction was stopped July 9, 1951. Erection of the other long wing continued as planned. The former connecting wing was redesigned to accommodate the vault and the sanitary facilities. The deletion of one wing freed a substantial quantity of structural steel for reallocation to other buildings on the plant.

Occupancy of this building was desired by the Operating Department by January 15, 1952. Air conditioning equipment, however, was not scheduled for completion until March 15, 1952. Temporary heating was required and electric heating was recommended as the most economical. On December 14, 1951 a temporary heating system was selected for installation. This included ten 3000 watt electric heaters, a transformer, and an electric cable in the attic over the outside walls of the Medical section. On February 22, 1952 additional changes were authorized to provide facilities for an Operations Employment Center in this building until the completion of the Medical and Employment Building in the #700 Area.

In July of 1951 canopies over the main entrance to the Medical section at the south end of the main wing were added for protection during storm periods, and a dressing room was located between the female cot room and the X-ray room.

EQUIPMENT

Offices

Conventional office furniture.

Conference room facilities for 50 people.

Folding partition to divide conference room into two parts.

Medical

Conventional office furniture.
 Rest room equipment including cots, mattresses, etc.
 Diathermy machine.
 X-Ray equipment.
 Resuscitator.
 Oxygen manifold.
 Cardiograph.
 Urinalysis equipment.
 Centrifuge.
 Microscope.
 Hemocytometer.
 Hemoglobimeter.
 Stethoscope.
 Ophthalmoscope.
 Refrigerator.
 Miscellaneous minor equipment.
 Cabinets.
 Shelving, etc.

Mechanical Utility Room

Refrigerant compressor, 20-ton capacity.
 Evaporative condenser, 247,000 B.t.u./hr.
 Chiller, 240,000 B.t.u./hr.
 Reheat coil, 87,000 B.t.u./hr.
 Hot water converter 50,000 B.t.u./hr.
 Fan, 1200 c.f.m., and reheat coil, dehumidifying coil.
 Self-contained air conditioning unit, 5-ton cap.
 Motor controls.
 Air compressor, 2 c.f.m.

Air Exhaust

In addition to the equipment located in the Mechanical Utility Room the following air exhaust equipment is located in the attic:

- 2 Exhaust fans (8700 c.f.m. each) and duct work.
- 3 Exhaust fans - (2) at 1350 c.f.m. and (1) at 7850 c.f.m. with duct work.

DRAWINGS

W-155295 - Floor Plan
 W-155297 - Elevations.

BUILDING #707-D - CHANGE HOUSE

FUNCTION

This structure provides change house facilities for personnel employed in the "GS" section of the #400 Area.

PRINCIPAL COMPONENTS

The plan of this building provides separate locker rooms and shower and toilet facilities for operators and janitors, with separate entrance vestibules for each group. Change house facilities are also provided for the Works Engineering Department personnel. Both sections of the building have utility room facilities.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Operators change room	1100
Janitors change room	220
Mechanical utility room	190
Works Engineering change room	1680

BUILDING DETAILS

The Change House is a single story, Class III structure, approximately 82 ft. long by 41 ft. wide out to out of foundation walls by 18 ft. from the floor to the peak of the double-pitched roof and 8 ft. from floor to ceiling. The building area is 3345 square feet and the volume, 54,770 cubic feet.

CONSTRUCTION DETAILS

Constructed on a reinforced concrete foundation slab with wall footings, this building has a prefabricated, rigid frame with a pitched roof. The bulk of this structural steel came from the surplus resulting from the cancellation of a portion of Building #704-D. Floors in all rooms are hard-finished concrete. Exterior walls and roof are covered with corrugated cement asbestos. Interior partitions and the interior of exterior walls are of flat cement asbestos board on wood studs. Toilet room walls are concrete to a height of 4 ft. with cement asbestos board above. Except in the utility room all ceilings are suspended and finished with flat cement asbestos board. Insulation is installed on exterior walls and on top of suspended ceilings. Doors are wood and window sash is steel, double-hung.

Hot air heating is provided from a unit heater through a system of ducts with anemostats. Mechanical ventilation changes the air through exhaust ducts from each toilet room. Incandescent lighting is installed throughout the building.

EQUIPMENT

145 Lockers.
Refrigerator, hot plate and table.
Hot water tank.
Unit heater, 164,000 B.t.u., and duct work.
Exhaust fan 1630 c.f.m. and duct work.

DEVELOPMENT OF DESIGN

Since continuity of process operations would not be interrupted by the loss of this facility, a permanent structure was not required. Therefore, Class III construction was permitted, imposing on design only those factors pertaining to expendability - fire resistance and the missile effect of construction materials in the event of a bomb blast.

It was decided in September, 1953, to increase the facilities of this gate house by adding an extension approximately 41 ft. by 41 ft., to the west side of the existing structure. The additional space provides a locker and change room equipped to serve 175 Works Engineering Department personnel (on the basis of a maximum of 75 per shift) toilets and shower room, and a utility room. All facilities and services including furniture and fixtures, lighting, heating and ventilating are the same as those supplied in the original structure. Construction details are essentially identical to those of the parent building. This Class III extension has an area of approximately 1680 square feet and a volume of 27,385 cubic feet.

DRAWINGS

W-156129 - Floor Plan and Elevations. (First Section)
W-159548 - Floor Plan and Elevations (Extension)

BUILDING #711-D - STEEL AND PIPE STORAGE

FUNCTION

This facility provides a sheltered storage space for pipe, large valves, steel bars, small shapes, and sheet metal. It is located near the area maintenance shop, Building #717-D.

PRINCIPAL COMPONENTS

The plan comprises a roofed-over area, open on two sides, for the storage of steel stock and pipe, and two areas enclosed on three sides - one for sheet metal and one for large valves.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Steel stock and pipe storage	440
Sheet metal storage	50
Valve storage	140
Insulation storage	240
Paint and lubrication storage	240

BUILDING DETAILS

Of single story, class III construction, approximately 20 ft. by 34 ft., the building is 10 ft. 8 in. high from the floor to the top of the flat roof which extends to form a 4 ft. overhang on two sides and one end. The total area is 1160 square feet and the total volume is 13,560 cubic feet.

CONSTRUCTION DETAILS

With foundation walls of reinforced concrete, the structure is of wood frame treated for fire resistance. Exterior walls and interior partitions are of corrugated cement asbestos board on wood studs left exposed on the interior of exterior walls and on one side of interior partitions. The ceiling is formed by the exposed underside of the roof sheathing. Roofing is built-up and the floor is a concrete slab. Lighting is incandescent. There are no doors or windows.

EQUIPMENT

Storage racks for steel stock, pipe, etc. and sheet metal.

DEVELOPMENT OF DESIGN

The development of the design for this structure was governed only by its classification as expendable and by its function as a storage facility.

It was decided on October 10, 1953 to increase the size of this building by the addition of an extension 24 ft. long

by 20 ft. wide by approximately 11 ft. high in order to provide space for storage of insulation materials in a section 12 ft. wide by 20 ft. long and a similar area for paint and lubrication materials storage. This enclosed area is of the same construction as the original building.

DRAWING

W-155761 - Plan, Elevations & Details

BUILDING #717-D - SHOPS, STORES, AND CHANGE HOUSE

FUNCTION

A central location for routine maintenance and inspection work involving shop facilities is provided by this building. Major overhaul, rebuilding and new fabrication work are carried out in the Maintenance Central Shops, Building #717-A. Building #717-D contains offices for supervisory and maintenance personnel, change room facilities, and a combination tool and stores room. The stores room is the receiving and distribution point for maintenance material from the Central Stores, Building #713-A, and for items awaiting repair. Gasoline and tire service are available at an island service station in the road leading to the shops section of the area.

PRINCIPAL COMPONENTS

Administration

Seven offices, a conference room for 25 employees, women's toilet and rest room, and a utilities room are located in this section of the building.

Change Room

Two locker rooms, each with toilet and shower facilities, are provided for approximately 120 employees.

Shops

The shops include machine, millwright, welding, pipe and valve, electrical and instrument shops, and an electronic testing room. There are three offices for shop supervisors and a tool crib and storage area.

BUILDING FLOOR SPACE

<u>Administrative</u>	<u>Approx. Sq. Ft.</u>
Offices Six - 14 ft. by 10 ft.	
One - 13 ft. 6 in. by 20 ft.	1110
Conference room	400
Toilet and rest rooms	210
<u>Utility Room</u>	385
<u>Locker, toilet and shower rooms</u>	1350
<u>Shops</u>	
Instrument shop	1650
Electronic testing and repair	150
Electric shop and office	1250
Tool crib and storage	2400
Machine shop and office	4200
Pipe and valve shop and office	1860
Welding shop	1250
Gas cylinder storage shed (roofed over)	64

BUILDING DETAILS

This is a Class III, single-story building approximately 101 ft. wide by 182-ft. long by 13 ft. from the floor to the bottom chord of the truss and 30 ft. high from the floor to peak of the gable-ended pitched roof. The total building area is 18,365 square feet and the volume is 415,167 cubic feet, based on the average height.

CONSTRUCTION DETAILS

This building has reinforced concrete foundations with spread footings, a structural steel frame, and a trussed roof. The exterior walls are corrugated cement asbestos board on steel girts. Interior of exterior walls are flat cement asbestos board or gypsum wall board, depending on the service, on wood studs. Shop walls have a 3/8 inch plywood wainscot, above a concrete base, to a height of 8 ft. above the floor. Interior partitions are plywood on wood studs in the shops, and gypsum wall board or flat cement asbestos board elsewhere, depending on the service performed in those areas. Toilet room walls are concrete to a height of 4 ft., with cement asbestos board above this level. Shower room walls are concrete faced with ceramic tile to a height of 7 ft. Ceilings are suspended, except in the shops,

and finished with flat gypsum wall board. The ceilings in the offices and the conference room are acoustically treated. Doors are wood and sash is steel double-hung in offices and projected in shops areas. The roofing material is corrugated cement asbestos board. The exterior walls of the offices, toilets and rest rooms are insulated. The concrete floors are covered with asphalt tile in the offices, conference room, and women's rest rooms and toilet, with quarry tile being used in the showers. The shops and the tool crib are heated by unit heaters. The offices and office corridor have fin-tube type radiation. Forced air through ducts, in conjunction with an air conditioning system, furnishes heat to the conference room, and the locker rooms are heated by forced air through ducts. The steam source for these services is the area power house. Air exhaust is maintained from the office corridor, the locker and toilet rooms, the utility room, and the welding shops by fans and duct systems through the roof and by fan ventilators from the shops and the tool crib area.

Lighting is fluorescent in the offices, shops, and conference room and incandescent in other areas.

EQUIPMENT

Offices

Conventional office furniture.

Utilities Room

Self-contained air conditioning unit, 10-ton capacity, with duct work for conference room.

Hot water storage tank, 865 gal.

Heating and Ventilating

In addition to the equipment in the utilities room, the following is installed for change rooms heating and exhaust, and exhaust from toilet rooms, utilities room, and shops areas:

- 1 Heating and ventilating unit, 2325 c.f.m., 158,700 B.t.u./hr.
- 3 Exhaust fans; 810, 2125 and 2710 c.f.m.
- 7 Roof ventilators, 4220 c.f.m. each.
- Duct work for the above.
- 31 Unit heaters, 58,400 B.t.u. each, for shops.

Change Room

120 lockers with benches.

Shops and Tool Crib

Monorail system, 2-ton capacity.
 Lathe, 16 inch x 102 inch.
 Milling machine, #2A.
 Radial drill, 3 ft.
 2 Metal cutting saws.
 Gas cutting and welding equipment.
 Pipe and conduit bending and threading machines.
 Air compressor.
 Wood and steel work benches.
 Welding booths.
 Electric testing equipment.
 Miscellaneous small equipment, hand and machine tools.
 Fume exhaust system in welding area 200 c.f.m. fan and ductwork.
 2 Jib cranes, 2-ton.
 Tool makers lathe, 10 inch.
 Shaper, 16 in.
 Hydraulic press, 50-ton.
 Grinders, drill presses.
 Portable arc welders.
 Welding and cutting tables.
 Steel bins, cabinets and shelving.
 3 Transformers, 10, 25 and 37-1/2 kw.
 Conventional shop office equipment.
 Gasoline storage tank (5000 gal.) and pump.

DEVELOPMENT

A permanent structure was not required for this facility, therefore its possible expendability imposed on design only those considerations contingent upon the fire resistance and missile effect of materials of construction. A pertinent factor in planning was the possible limitation of the shop space in this building since major overhaul, rebuilding, and new fabrication work are accomplished in the Maintenance Central Shops, Building #717-A.

It was decided on January 16, 1953 to construct a Lapmaster room in one corner of the existing machine shop of this building. This made it necessary to install a blower and to relocate light fixtures in this area to provide proper ventilation and lighting necessary for the correct operation of the Lapmaster machine.

DRAWINGS

W-155318 - Floor Plan.
W-155319 - Elevations.

BUILDING #772-D - CONTROL LABORATORY AND SUPERVISOR'S OFFICE**FUNCTION**

This building contains laboratory facilities for the control of the #400-D Area processes. Also provided are office facilities for plant supervision and a cafeteria for area personnel. Operation is on a three-shift basis.

PRINCIPAL COMPONENTS

The laboratory section for area processes includes a Mass Spectrometer Room with temperature controlled between 70° and 80°F. and dew point maintained below 62°F.; a Density Analysis Room with rigid control of temperature and relative humidity at $77 \pm 1/2^\circ\text{F.}$ and $50\% \pm 5\%$, respectively; and a General Chemical Analysis room for sample distillations with temperature maintained between 70° and 80°F. and relative humidity maintained at $50\% \pm 5\%$. Also included are laboratory offices and a Store Room and Incoming Samples Room for glass washing, sample preparation and glass blowing, where the same atmospheric control is required as for the Chemical Analysis Room.

Four small offices, three group offices, a conference room and a file room are provided in the supervisory section with toilet and change room facilities for 100 male and female employees.

The cafeteria is divided into two sections, an operator's lunch room with a seating capacity of 84 and a janitor's section with a seating capacity of 18. This design provides for service to approximately 200 employees per shift, with hot food being prepared at the Main Cafeteria, Building #708-A, and delivered to this cafeteria in "Aervoid" carriers.

Air conditioning and other mechanical equipment is contained in a Utility Room. A roofed-over area adjacent to the laboratory is used for the storage of bottled gases used in laboratory operations.

BUILDING FLOOR SPACE**Administrative****Offices****Approx. Sq. Ft.****1830**

tile except in the toilets, locker rooms and utility room.

Heating is furnished by fin-tube radiators except in the laboratory wing, the cafeteria and the locker rooms. The cafeteria, laboratory area and conference room are heated by forced air in conjunction with the air conditioning system and the locker rooms are heated by forced air through heaters and duct work. Steam for heating purposes is supplied from the area power house.

The lunch room, conference room, laboratories and laboratory offices are air conditioned. Air exhaust is maintained by fans through ducts from corridors in the office area, toilets and locker rooms and from the laboratory area by hoods in the laboratories and the cafeteria.

Lighting is fluorescent in laboratories, offices, and conference and lunch rooms. Other lighting in the building is incandescent.

EQUIPMENT

Laboratory Area

Mass Spectrometer Room

- 6 Mass spectrometers.
- 6 Laboratory benches, 3 with chemstone top.
- 1 Laboratory hood.
- 1 Distillation rack.
- 1 Alberene stone top bench with sink.
- 1 Titrilog and vacuum pump.

Complement of laboratory instruments, utensils, glassware, etc.

Density Room

- 1 10 ft. Chemstone top laboratory bench.
- 10 4 ft. Chemstone top laboratory benches.
- 3 Cupboards.

Complement of laboratory instruments, utensils, glassware, etc.

General Chemical Analysis

- 2 Laboratory hoods, double, 8 ft. long.
- 16 Laboratory benches, 4 ft., stone top.
- 2 Laboratory sinks, stone top.
- 4 Laboratory benches, 2 ft., with stone tops.

Conference room	260
Toilets, locker and rest rooms	930
Utility room	635

Laboratory Wing

Laboratories	2400
Laboratory Offices	645
Lunch Rooms and Serving Area	2200

BUILDING DETAILS

This one and one-half story facility is of Class III construction. It is a tee-shaped building with one wing approximately 52 ft. x 77 ft. x 26 ft. high from the floor to the top of the double-pitched roof and 12 ft. high from the ground floor to the floor of the loft. The cross bar of the tee housing the cafeteria and offices is 38 ft. x 202 ft. x 18 ft. from the floor to the peak of the double-pitched roof. The total building area is about 11,500 square feet and the volume, 211,000 cubic feet.

The gas cylinder storage shed is a roofed area approximately 6 ft. by 12 ft. x 8 ft. average height. Its area is approximately 80 square feet and the volume is in excess of 600 cubic feet.

CONSTRUCTION DETAILS

The building foundations, of reinforced concrete with spread footings, support a rigid structural steel frame with steel rafters and roof purlins. The quipment room floor over the laboratory wing is of reinforced concrete over a steel frame, while the floor over the office and cafeteria wing is of wood on wood joists supported on wood bearing partitions. Exterior walls are of corrugated cement asbestos board and interior partitions are gypsum wall board or flat cement asbestos board on wood studs. The interiors of exterior walls are gypsum board on wood studs. Toilet room walls are of concrete to a height of 4 ft., with cement asbestos board above this level. Ceilings are finished with gypsum board and are suspended in the lunch room area, applied directly to overhead framing in the office section, and against insulation below the loft floor slab in the laboratory wing. Acoustical ceiling treatment is provided in the offices and the conference room.

Doors are wood and window sash is double-hung steel. Corrugated asbestos board is used for roofing. Exterior walls, the walls of toilets and rest rooms and all ceiling areas are insulated. The concrete floor slab is covered with asphalt

- 2 Cupboards.
- 1 Steel bench.

Complement of laboratory instruments, utensils, glassware, etc.

Storage and Sample Room

- 10 Cabinets, 3 ft. and 4 ft. in length.
- 1 3 ft. steel electric drying cabinet.
- 1 5 ft. glass blowing table - cement asbestos top.
- 1 10 ft. set of sink and drains with hood above.
- 1 9 ft. 9 in. fume hood for samples.
- 1 S.S. laboratory truck.
- Shelving.

Offices

Conventional office furniture.
Conference room - facilities for 20 people.

Change Rooms

- 2 Women's locker rooms - 66 lockers total.
- 1 Men's locker room - 35 lockers.

Cafeteria

Dining tables with swing type stools attached, 7 for 16 and 3 for 6 people.

Serving counter with auxiliary equipment.
Drinking water station.
Soiled dish cart.
Dishes and tableware.
Electric toaster and griddle.
Ice cream box.
Dishwashing equipment.
Electric refrigerator.
Urns.
Ice bin and ice cube maker.
Food container truck.

Utility Room

- 1 750-gal. hot water tank.
- 2 Compressors, each 81-ton capacity, 100 h.p. motor.
- 4 Condensers, 275 g.p.m. circulating water capacity.
- 2 Chillers, 155 g.p.m. and pumps.
- Heat Exchangers.
- 1 Condenser receiver.
- Auxiliary equipment for above refrigeration equipment.

Heating and Ventilating

In addition to the equipment in the Utility Room the following is located in the attic.

- 1 Self-contained air conditioning unit for the conference room, 1500 c.f.m., 5-ton capacity.
- 1 Unit of filters, heating coils, sprays, dehumidifying and cooling coils, fan, etc. for conditioning the laboratory 12,200 c.f.m.
- 1 Air conditioning blower unit, 3600 c.f.m. with cooling and heating coils for cafeteria.
- 2 Propeller fans for attic exhaust, 12,000 and 16,400 c.f.m.
- 1 Unit of 1600 c.f.m. for forced hot air heating of toilet, shower, and rest rooms.
- 10 Exhaust fans varying from 1260 c.f.m. to 4460 c.f.m. for exhaust from toilet and shower rooms, cafeteria, laboratory, laboratory hoods, conference room, utility room.

Necessary ductwork, controls, etc. for the above.

Gas Cylinder Storage

Oxygen, propane and nitrogen gas manifolds.

DEVELOPMENT OF DESIGN

The design of this facility was affected largely by the requirement for close control over atmospheric conditions in the laboratory section of the building. A minimum economical life of five years and the missile effect of materials of construction in the event of a bomb blast, since the structure is considered expendable, were also taken into consideration.

It was decided on October 29, 1953, to rearrange the equipment and partitions in the cafeteria section of this building to provide the additional space necessary to serve properly the necessary number of people. This revision affected the food serving area, and a separate small dining area and some toilet space were eliminated. The increased operational facilities and liberated space were utilized to expedite food handling operations and promote more efficient services.

DRAWINGS

- W-155500 - Floor Plan.
- W-155501 - Elevations.

ELECTRICAL FACILITIES

The #400-D Area power house contains facilities having a total electric power generating capacity of 62,500 kilowatts. These consist of three 7500-kw. high-pressure non-condensing turbine generators and four 10,000-kw. low-pressure automatic extraction condensing units. The high-pressure units take steam at full boiler pressure, 900 p.s.i. and exhaust at 385 p.s.i. The 385 p.s.i. steam extracted from the high-pressure turbines services the four low-pressure turbines which discharge to condensers.

The prime function of these facilities is to furnish the electric power required by the #400 Area and its river pump house, Building #681-5G. But in addition, electric power is furnished to the other areas through the Plant high voltage transmission system.

The following electrical facilities are discussed in detail in Volume VI of this history.

- Bldg. #451-D - Primary Substation
- Bldg. #452-D - Secondary Substation
- Bldg. #501-D - Fence & Road Lighting
- Bldg. #503-D - Distribution Lines
- Bldg. #505-D - Fire Alarm Systems
- Bldg. #506-D - Telephone Cable & Instruments
- Bldg. #507-D - Safety Alarm System

STEAM FACILITIES

The #400-D Area power house, the largest of nine installed at the Savannah River Plant, contains four 330,000 lbs. per hr., 900 p.s.i., 900°F. pulverized coal-fired steam generating units. Coal is unloaded from an adjacent railroad siding, on which four car pullers are installed, to a storage area having a 243,000 ton capacity. The stokers are fed by a belt-conveyor system having a capacity in excess of 350 tons per hour.

Furnace ash and fly ash are collected in hoppers and sluiced through overhead ash sluicing lines by a hydraulic jet pump system. These sluicing lines discharge into two

earth dike basins, separated by a common dike, having a combined storage capacity of approximately 7-1/2 years of accumulated ash.

The following steam facilities are discussed in Volume VI of this history.

Bldg. #484-D - Power House
Bldg. #488-D - Ash Disposal Basin
Bldg. #801-D - Pipe Supports
Bldg. #802-D - Steam Lines
Bldg. #809-D - Ash Sluicing Lines

WATER FACILITIES

The #400-D Area is supplied water from the Savannah River by a river pump house, Building #681-5G, serving this area only, and having a designed pumping capacity of 75,000 g.p.m. Six pumps are installed in this building, each having a rated capacity of 12,500 g.p.m. against a head of 105 feet. A 60-inch reinforced concrete line from the pump house conveys water at a maximum rate of 70,000 g.p.m. to the area reservoir where it is conditioned as required and distributed throughout the area for various uses. A series of pumps discharge raw river cooling water from the reservoir to the turbo-generator condensers in the #400-D Area power house at a maximum rate of 23,000 g.p.m. Process water, also untreated, is pumped from this reservoir through strainers to the "GS" units at a maximum rate of 34,000 g.p.m.

Precipitator and filter units adjoining the reservoir condition a portion of the river water for distribution as process make-up water, cooling tower make-up, boiler feed make-up, and various miscellaneous uses. Other facilities, including softener units, a degassifier, deaerators and an acid mix tank, further condition the filtered boiler feed and process feed make-up water.

Domestic water for the area is supplied from deep wells. Elevated storage consisting of two 10,000 gallon tanks, located one above the other, provides an emergency supply of domestic and boiler feed make-up water. The domestic water tank is supplied by two deep wells in the area, while the other tank is supplied from the boiler feed make-up line from the water treatment plant.

Two of the turbo-generator condensers installed in the #400-D Area power house are cooled by circulating water from an 18,500 g.p.m. capacity cooling tower.

Three chemical feed buildings provide facilities for treating the well water and the water in the basin of the cooling tower.

The following water facilities are discussed in detail in Volume VI of this history.

Bldgs. #480-1,2,3D - Chemical Feed Buildings
Bldg. #483-D - Water Filtration and Treatment Plant
Bldg. #485-D - Cooling Tower
Bldg. #487-D - Elevated Water Storage Tank
Bldg. #683-D - Chlorine Unloading and Storage Facilities
Bldg. #806-D - Water Lines
Bldg. #901-D - Water Lines
Bldg. #902-D - Fire Lines
Bldg. #905-D - Wells and Pumps

GENERAL FACILITIES

A discussion of the general services and facilities of similar use over the entire plant, such as roads, walks, parking areas, telephone and alarm systems, and other general services, is contained in a separate volume of this report.

There, by a record of the over-all problems and specific solutions, it is possible to present a picture of their general characteristics and scope.

The following general services are discussed in detail in Volume IV of this history.

Bldg. #601-D - Standard Gauge Track
Bldg. #603-D - Roads (Inc. Bridges & Culverts)
Bldg. #604-D - Walks
Bldg. #605-D - Fences
Bldg. #607-D - Septic Tanks
Bldg. #613-D - Parking Areas
Bldg. #614-1D - General Monitoring Building
Bldg. #614-2D - Wind Indicators
Bldg. #697-D - Site Work and General Grading
Bldg. #698-D - Landscaping
Bldg. #709-D - Fire House
Bldg. #732-D - Furniture & Fixtures
Bldg. #903-D - Sanitary Sewers
Bldg. #904-D - Process Sewers
Bldg. #907-D - Storm Sewers

DATE

FILMED

8 / 1 / 94

END