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SANITIZED VERSION OF A BRIEF DESCRIPTION OF THE GASEOUS DIFFUSION PROCESS (OCTOBER 23, 1959)

(SANITIZED VERSION OF CRD DOCUMENT # KP-1753)

Compiled by
S. G. Thornton
Environmental Management Division
OAK RIDGE K-25 SITE
for the Health Studies Agreement

January 29, 1996

Oak Ridge K-25 Site
Oak Ridge, Tennessee 37831-7314
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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
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A BRIEF DESCRIPTION OF THE GASEOUS DIFFUSION PROCESS

UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION

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Date: October 23, 1959

KP-1753

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A BRIEF DESCRIPTION OF THE GASEOUS DIFFUSION PROCESS

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Thomas W. Selby 9/8/94
ADC or ADD signature (first reviewer) Date
9/8/94
ADD signature (final reviewer) Date

UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION

Operating

- OAK RIDGE GASEOUS DIFFUSION PLANT
- OAK RIDGE Y-12 PLANT
- OAK RIDGE NATIONAL LABORATORY
- PADUCAH GASEOUS DIFFUSION PLANT

for the Atomic Energy Commission

Under U. S. Government Contract W7405 eng 2

UNION CARBIDE

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INTRODUCTION

The problems of material control and inspection of a gaseous diffusion plant are complicated by the enormous size of the plants and the amounts of uranium materials handled. It is required that millions of kilograms of uranium materials per month be accounted for in a continuous process in equipment unique to the gaseous diffusion process and consuming electrical power produced from some of the largest generating stations in the world. Such a large operation requires many smaller auxiliary facilities, which, under usual industrial standards, are appreciable in size.

The following presentation is designed to show the size, general physical appearance and complexity of the gaseous diffusion plant and equipment, using the plant at Oak Ridge as an example.

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FIGURE 1

Uranium Production Cycle

The gaseous diffusion plant is the basic unit in the production of enriched uranium. Almost the entire supply of uranium feed materials flows through the gaseous diffusion system. The chart shows the major uranium flows to and from the plants. In addition to the streams shown are the material flows to licensees which are becoming appreciable in size.

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FIGURE 1

URANIUM PRODUCTION CYCLE

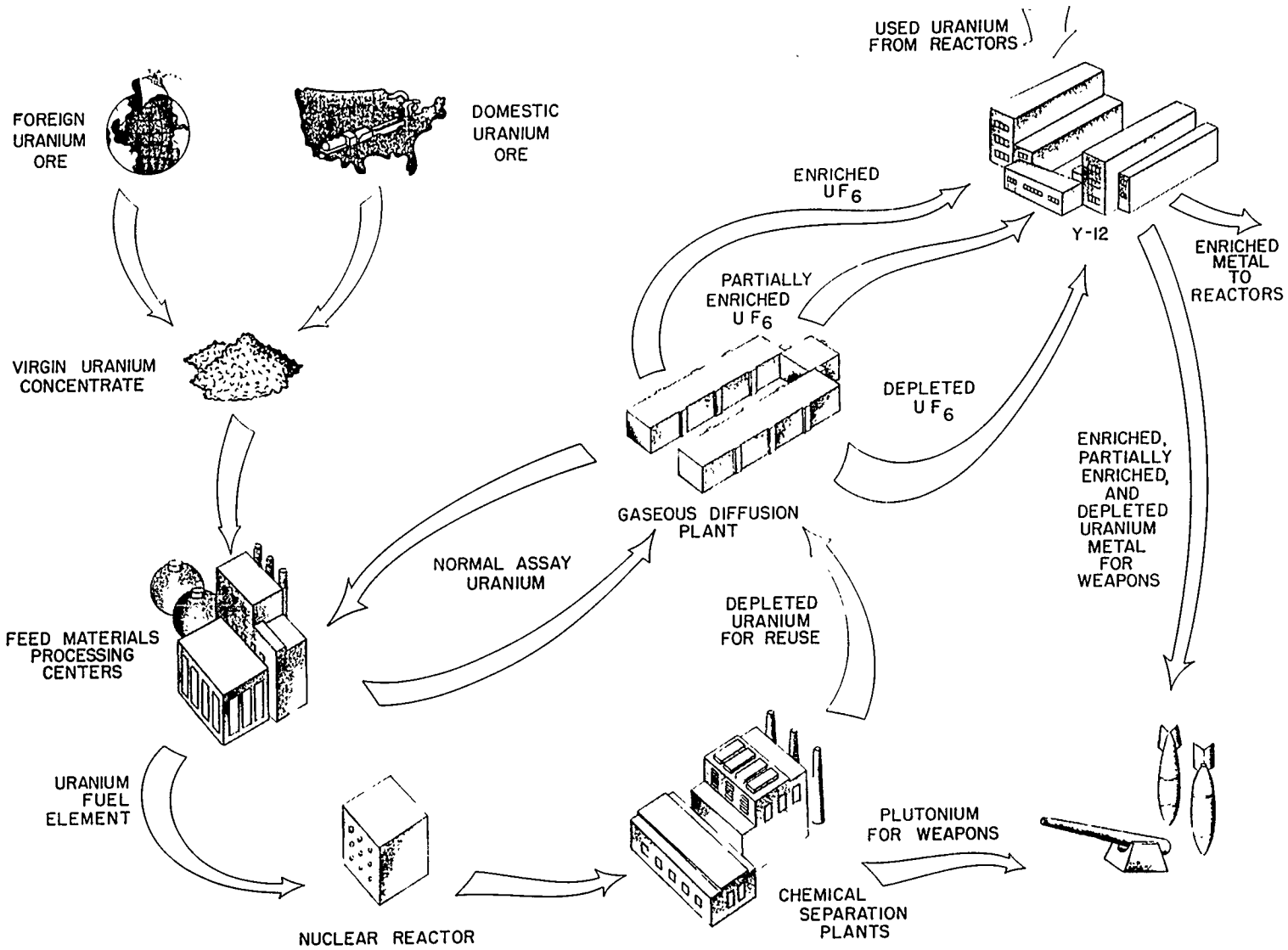

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FIGURE 2

The American Gaseous Diffusion Complex

The American gaseous diffusion complex consists of three diffusion plants operating in an overlap configuration. The Oak Ridge and Portsmouth plants produce high assay product material while the Paducah plant serves as a stripping plant for the other two plants.

The size of the operation is indicated by the fact that the three plants consume close to 10% of the nation's total generation of electrical power.

FIGURE 2

GASEOUS DIFFUSION COMPLEX

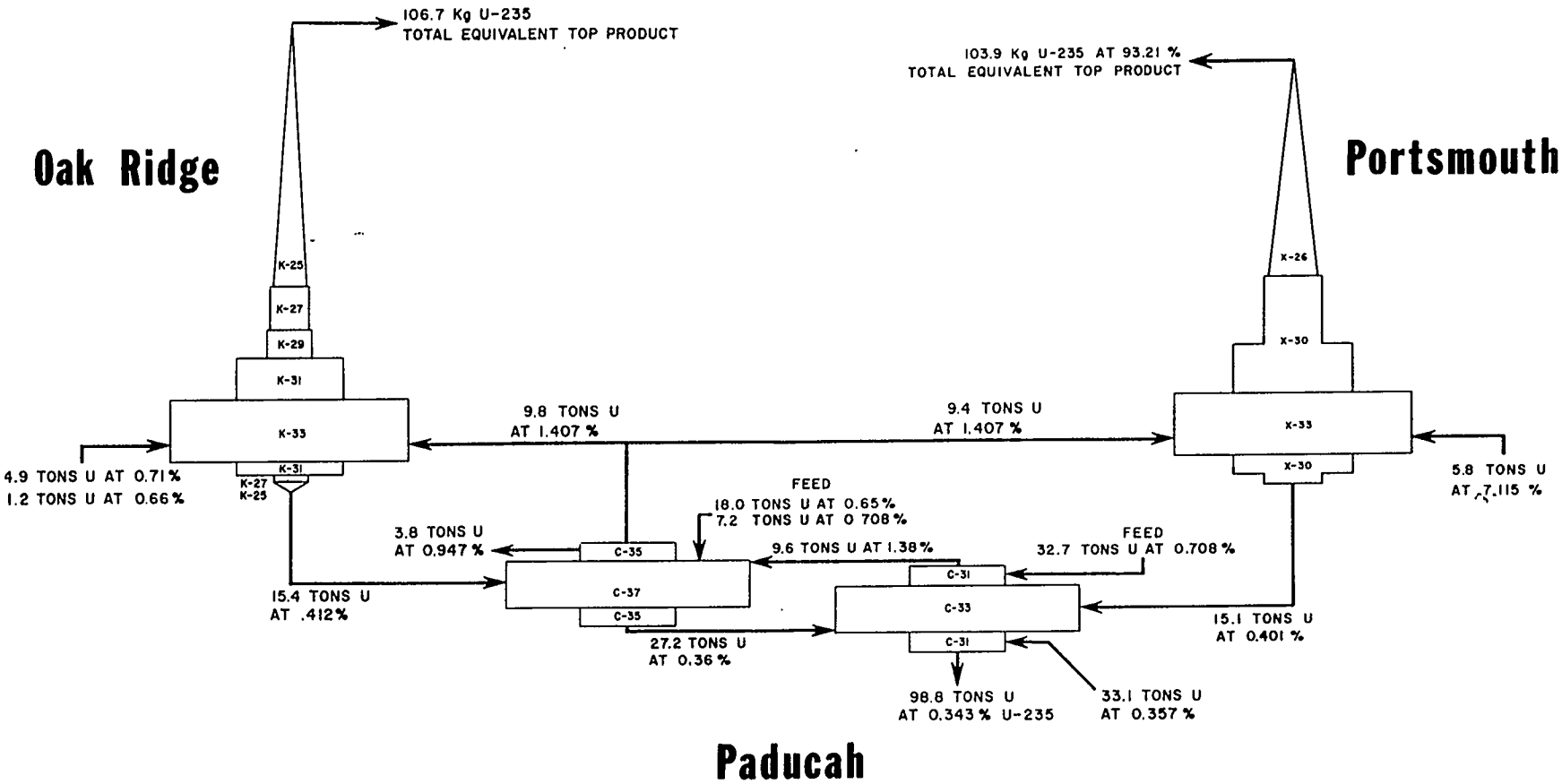

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FIGURE 3

Aerial View of the Oak Ridge Gaseous Diffusion Plant

The Oak Ridge plant is shown as a typical gaseous diffusion plant although the Portsmouth plant is quite similar. A short list of pertinent statistics indicates the complexity of the material control and inspection problem.

Process building area	105.5 acres
Number of stages	4,384
Barrier area	
Piping	1,017 miles
Instruments	37,500
Process equipment volume	3,500,000 cubic feet
Internal exposed surface area	
Uranium inventory	
Enriched uranium production	106 kilograms uranium-235/day

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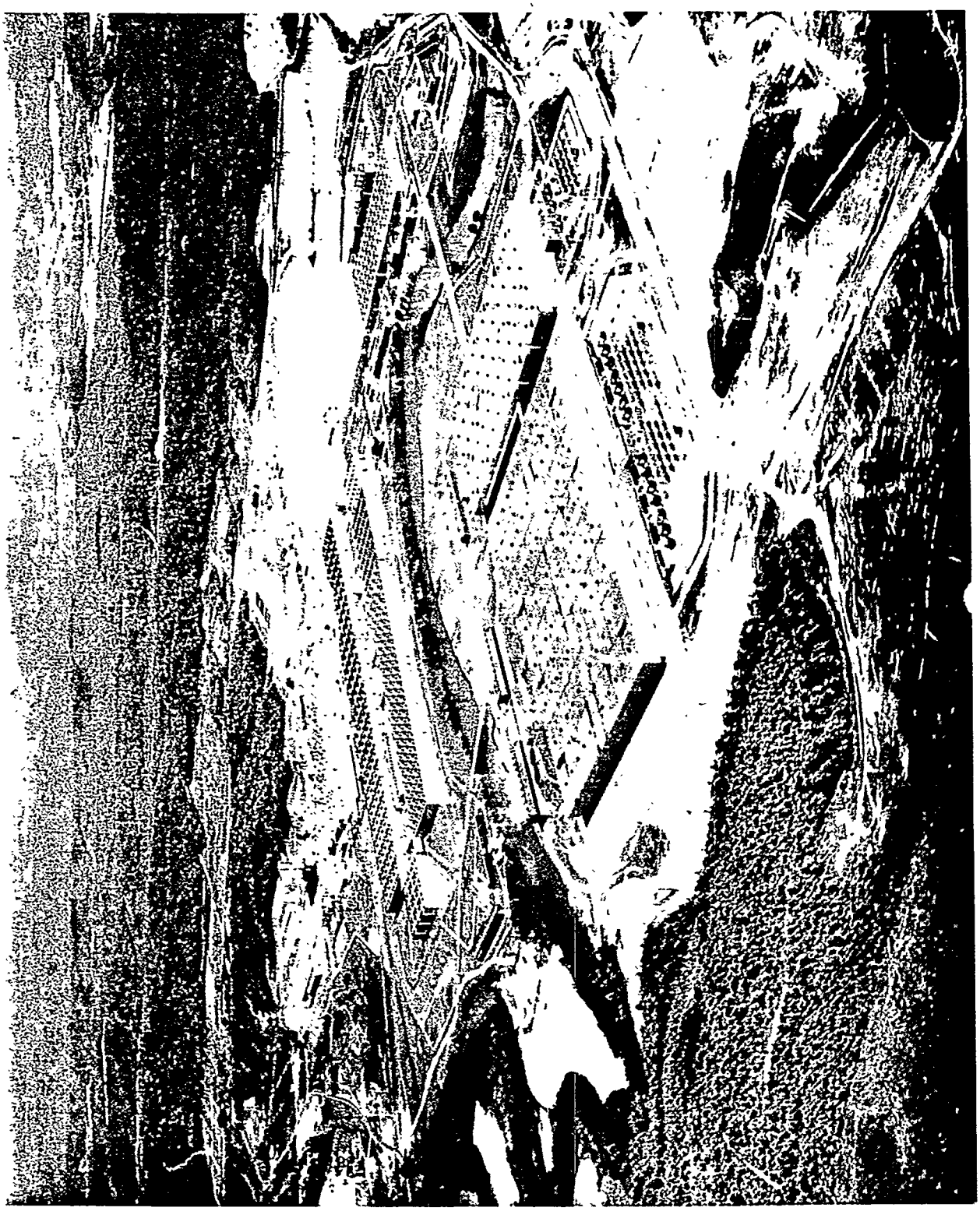

FIGURE 3

AERIAL VIEW OF ORGDP

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FIGURE 4

Pictorial Representation of the Oak Ridge Gaseous Diffusion Plant

Shown here is a pictorial representation of the Oak Ridge plant showing the relationship between the process buildings and the various auxiliary and supplementary buildings.

Building Number	Function
K-27, K-25, K-31, K-33	Process Buildings
K-1401	Maintenance Shops
K-1131	Feed Manufacturing Facility
K-1100, K-1037	Barrier Manufacturing Facility
K-1101, K-1201	Air Compression Facility
K-1004-A, D, L, H, and J	Laboratory Buildings
K-1001	Administration Building
K-631	Tails Withdrawal
K-800 through K-892	Cooling Water Buildings
K-700 through K-792	Electrical Installations
K-1420	Decontamination Building

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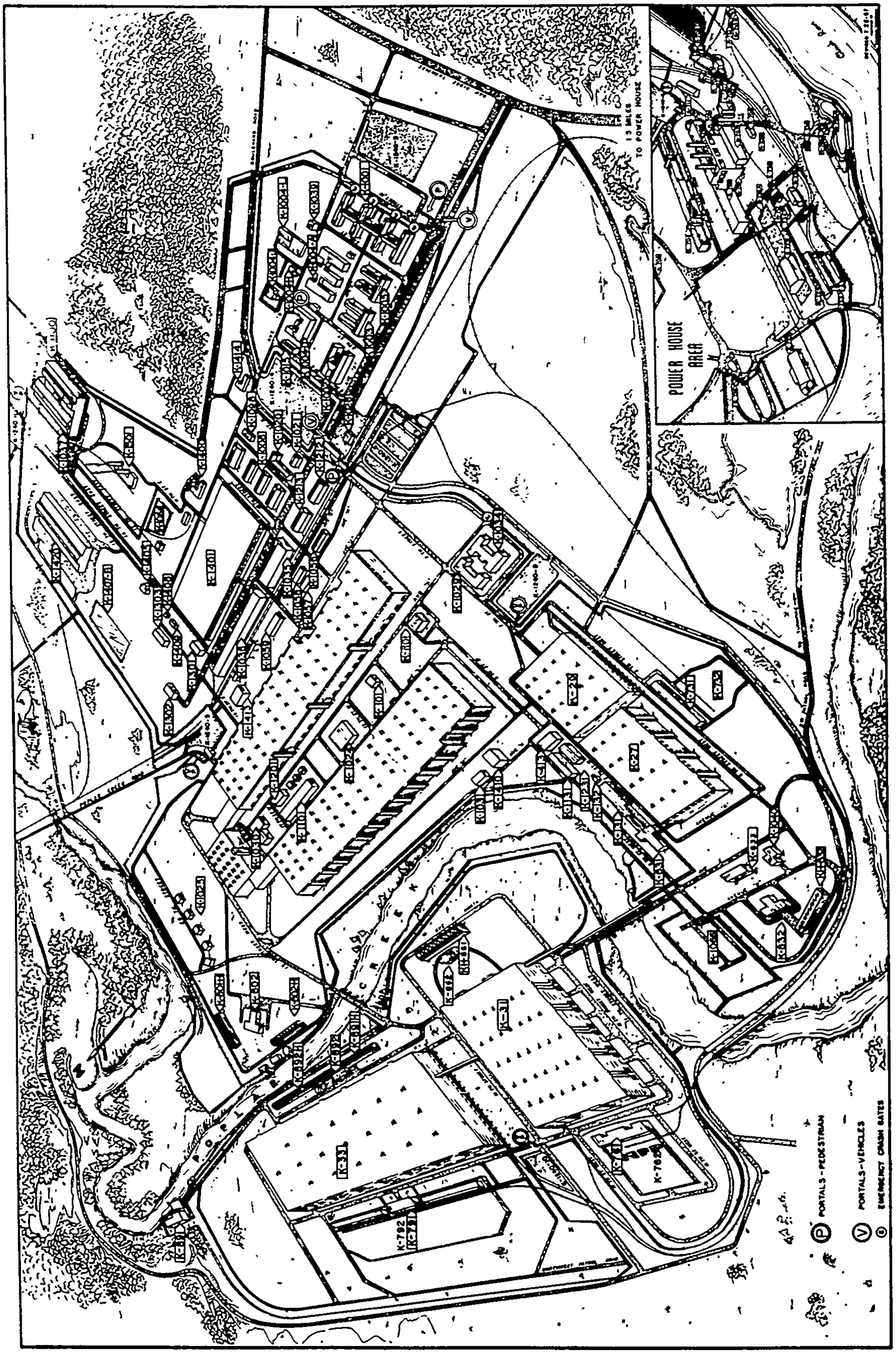

OAK RIDGE GASEOUS DIFFUSION PLANT

FIGURE 4

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FIGURE 5

Compressor and Converter

The basic equipment for the gaseous diffusion separation is the converter, containing the barrier and a gas cooler, and the compressor.

The converter contains the barrier necessary for the separation of the uranium isotopes. The converter also contains a gas cooler to remove the heat of compression generated by the compressors. Nine sizes of converters are used in the gaseous diffusion process as is necessary to match gas flows in the various cascade locations.

The compressor provides the motivation force for the gas stream and provides a pressure differential across the barrier in the converter. The installed compressor capacity at the Oak Ridge plant is 8-1/4 million cubic feet of process gas per second. Two compressor types are used, the axial-flow type as is shown and a centrifugal type. There are 1,540 axial-flow type compressors and approximately 5,600 centrifugal type compressors installed at Oak Ridge. Several sizes of each type compressor are used in the plants.

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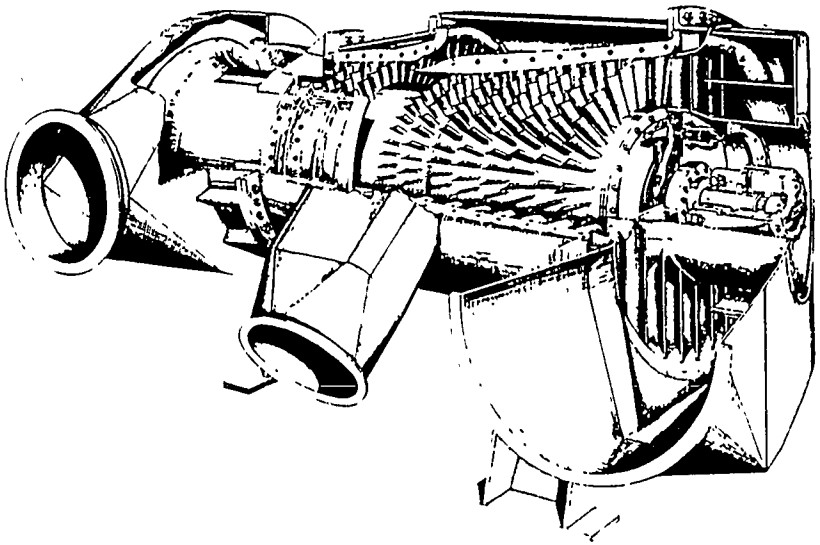
FIGURE 5

COMPRESSOR AND CONVERTER

AXIAL FLOW COMPRESSOR



MODIFIED CONVERTER

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FIGURE 6

Equipment Sizes

Presented here are silhouettes of the various types of compressors and converters used in the gaseous diffusion plants. Sizes 000 through 4 are installed at Oak Ridge with sizes 000, 00, 0, 7, and 8 installed at Portsmouth. The largest equipment sizes are used around the cascade feed points with the equipment becoming smaller as the distance from the feed points increases.

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STAGE SIZES

FIGURE 6

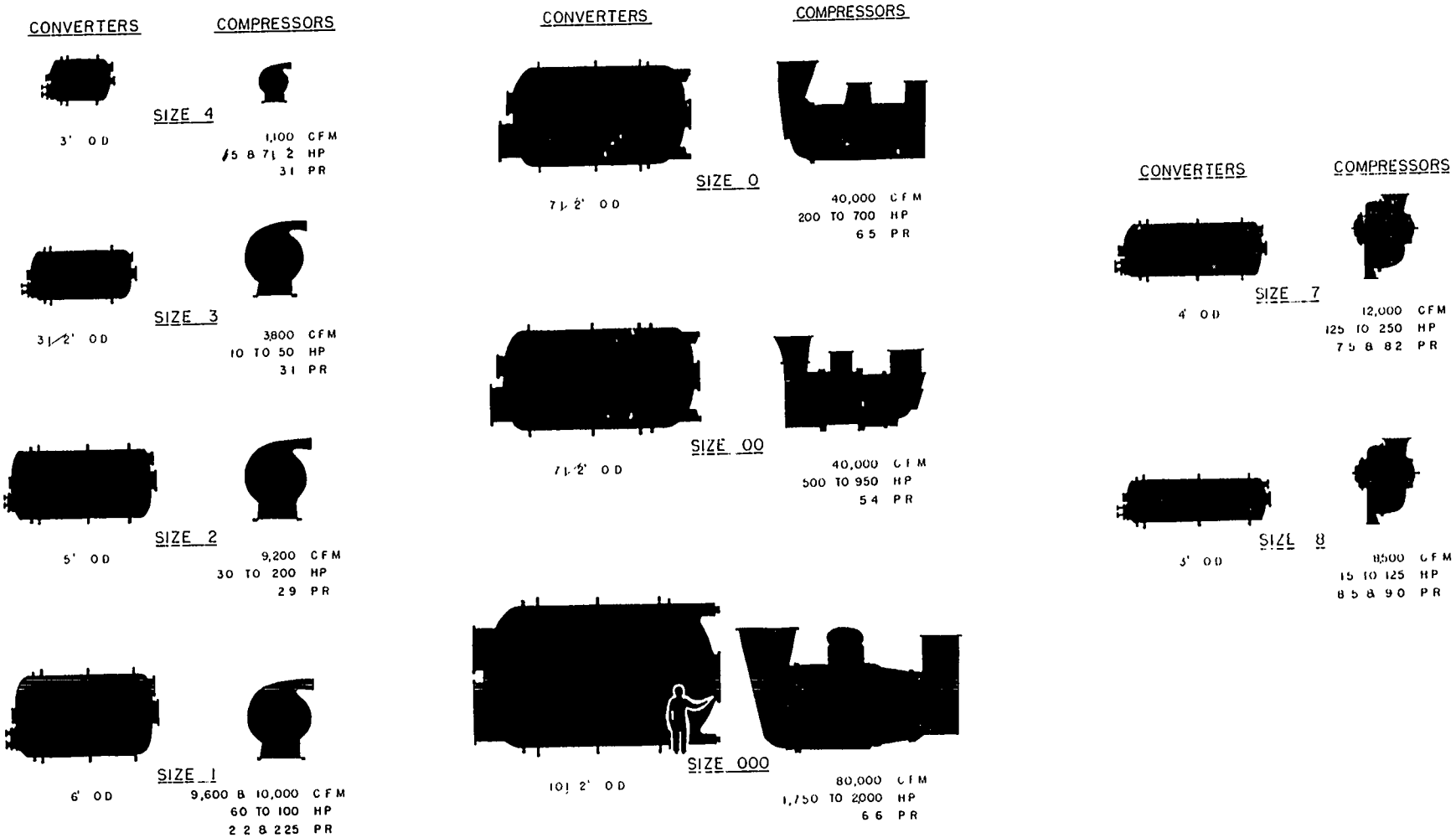

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FIGURE 7

Stages

The fundamental unit of the gaseous diffusion process is the stage. Shown here are the two types of stages used at Oak Ridge. The centrifugal stage is used in the upper portions (higher assay) of the plant and is smaller in size than the axial stage. The diagram shown here of axial-flow equipment shows the arrangement of three stages.

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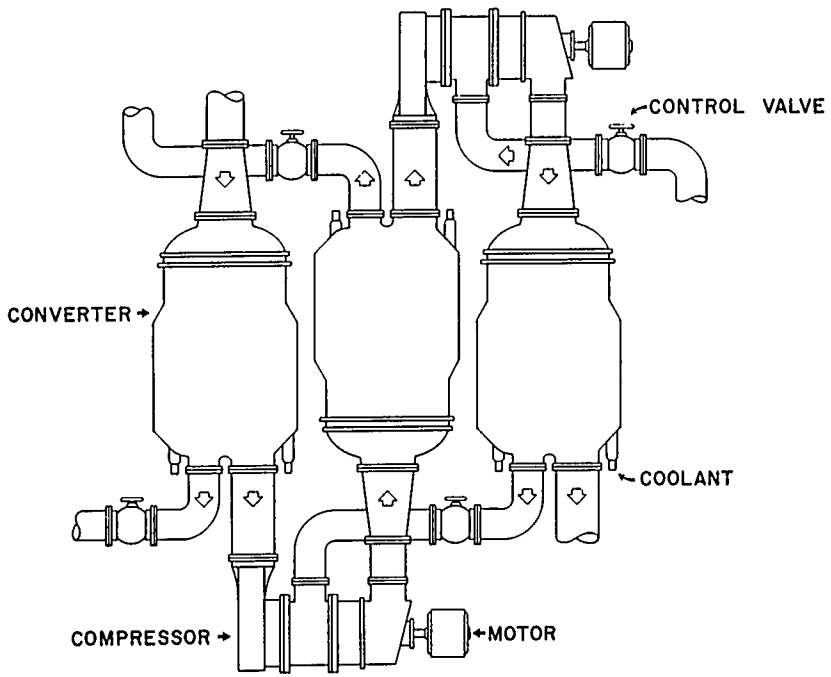
FIGURE 7

BADGER STAGE ARRANGEMENT

AXIAL FLOW COMPRESSORS



SINGLE STAGE CENTRIFUGAL COMPRESSOR

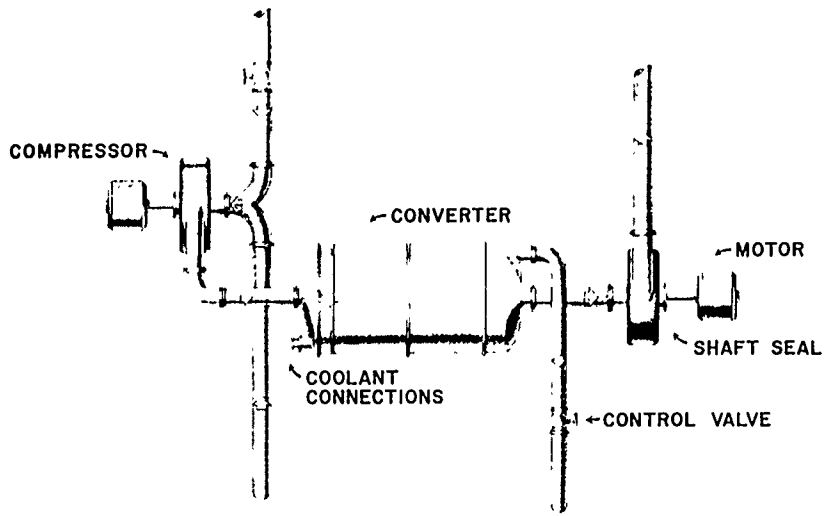


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FIGURE 8

Cell Arrangement

Gaseous diffusion stages are grouped in arrays called cells which can be isolated from the process system for maintenance purposes without affecting the remainder of the process system. Cells at the Oak Ridge plant consist of from 6 to 10 stages depending on the location in the plant. The schematic diagram shown here is a cell arrangement in the K-33 building.

Building	No. of Cells	Stages/Cell	Total Stages
K-33	80	8	640
K-31	60	10	600
K-29	30	10	300
K-27	90	6	540
K-25	384	6	2304
Total	644	-	4384

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CELL ARRANGEMENT
AXIAL FLOW COMPRESSORS

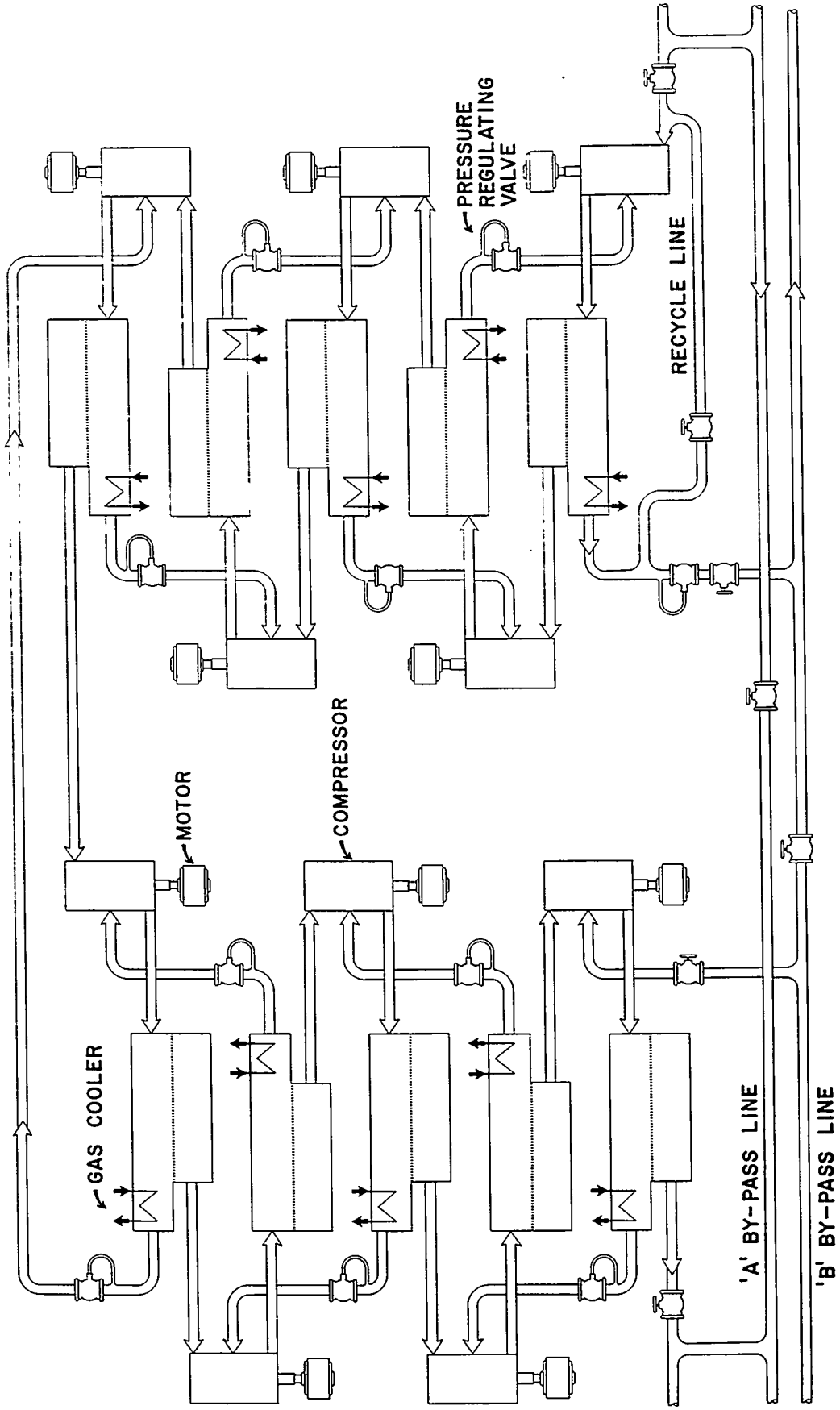

FIGURE 8

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FIGURE 9

Unit Arrangement

Production cells are further grouped into units to permit the isolation of larger segments of the process should operating difficulties arise. A production unit usually consists of ten cells although the number of cells per unit in the original structure at Oak Ridge, the K-25 building, varies from 3 to 10.

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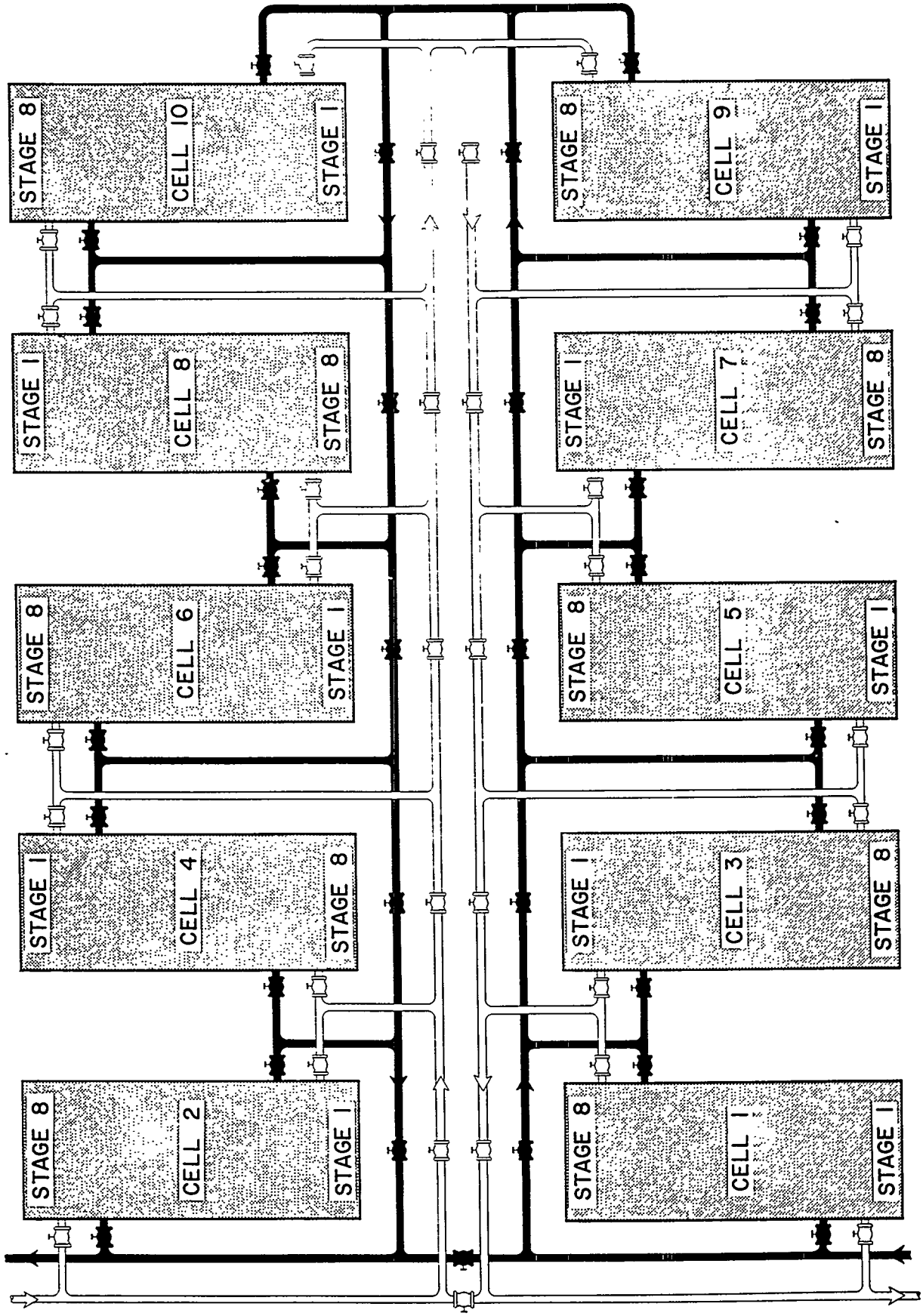

UNIT ARRANGEMENT
SIZE 33 EQUIPMENT

FIGURE 9

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FIGURE 10

Cell Floor - K-29

Shown here is a view of the cell floor in the K-29 building showing the physical arrangement of the process equipment. No housings were installed over this equipment since design operating temperatures and pressures were low enough to make such measures unnecessary. This equipment was the first axial-flow gaseous diffusion equipment to be used and was completed in 1950.

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Refer to page 32 of Pa.17V

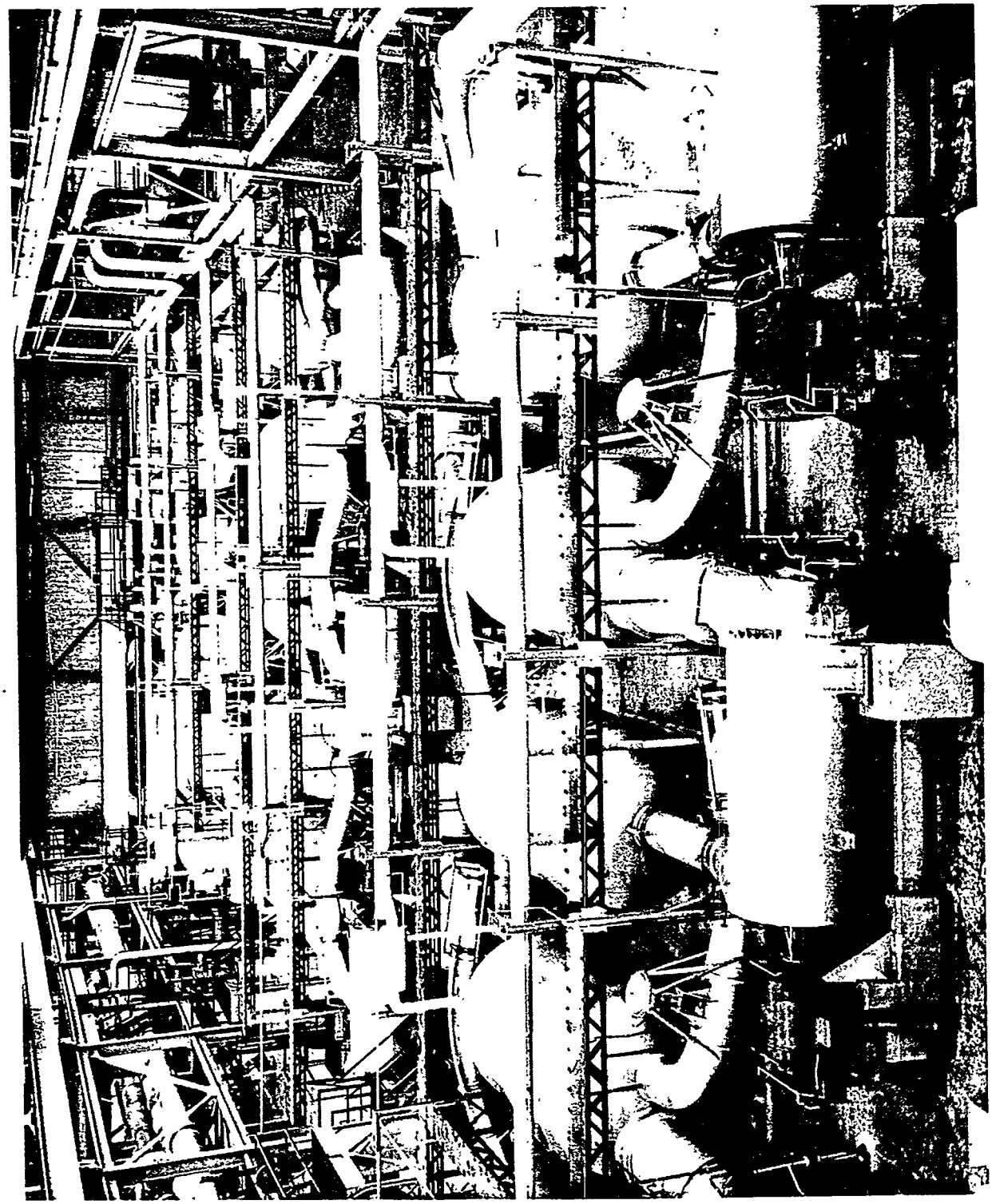

FIGURE 10

CELL FLOOR
NO CELL ENCLOSURE

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FIGURE 11

Cell Floor - K-31

The process equipment installed in the gaseous diffusion complex following the completion of the K-29 building were designed to operate at higher pressures and temperatures, making it necessary to cover process equipment with housing. Shown here is a view of the cell floor of the K-31 building.

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FIGURE 11

SIZE 31 EQUIPMENT

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FIGURE 12

Operating Floor - K-31

The high ambient temperature on the cell floor of the gaseous diffusion plants makes it necessary to operate the equipment remotely. The operating floor, as shown here for the K-31 building, is below the cell floor in all the gaseous diffusion buildings with the exception of the two original buildings, K-25 and K-27, where the operating floor is above the cell floor.

The operating floor shown here contains all the instruments required to regulate the process and to measure the uranium inventory. Also installed on this floor are various auxiliaries such as transformers, ventilating fans, coolant pumps, and oil pumps.

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OPERATING FLOOR - K-31

FIGURE 12

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FIGURE 13

Central Control Room

The Oak Ridge Gaseous Diffusion Plant is operated from a central control room. Slave recorders convey pertinent information to this point, permitting plant supervision to make necessary operating decisions. The data available to Central Control Room personnel include inleakage rates, power loads, the usages of utilities (water, air, etc.), process valve positions, and electrical system arrangements.

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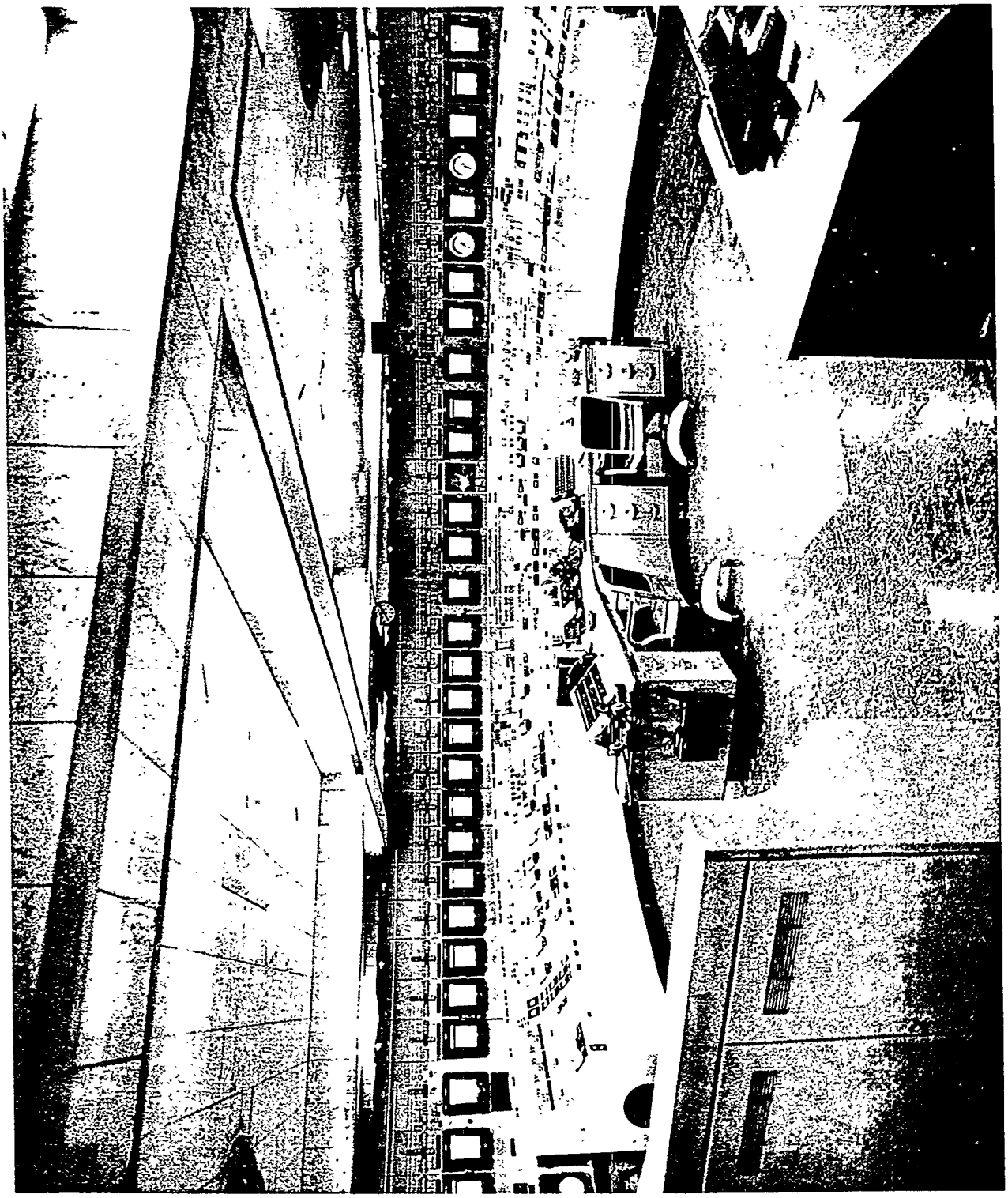

FIGURE 13

CENTRAL CONTROL ROOM

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FIGURE 14

Power Generation and Transmission

The Oak Ridge Gaseous Diffusion Plant was originally designed to generate its own power with the installation of a 250 Mw power station. As the plant was expanded, TVA was called upon to supply the greater portion of the power used. This figure presents the TVA power sources. The main source of TVA power is from the Kingston steam plant, 7 miles from the gaseous diffusion plant. There are eighteen lines over which TVA supplies power to the Oak Ridge area.

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FIGURE 14

POWER

GENERATION and TRANSMISSION

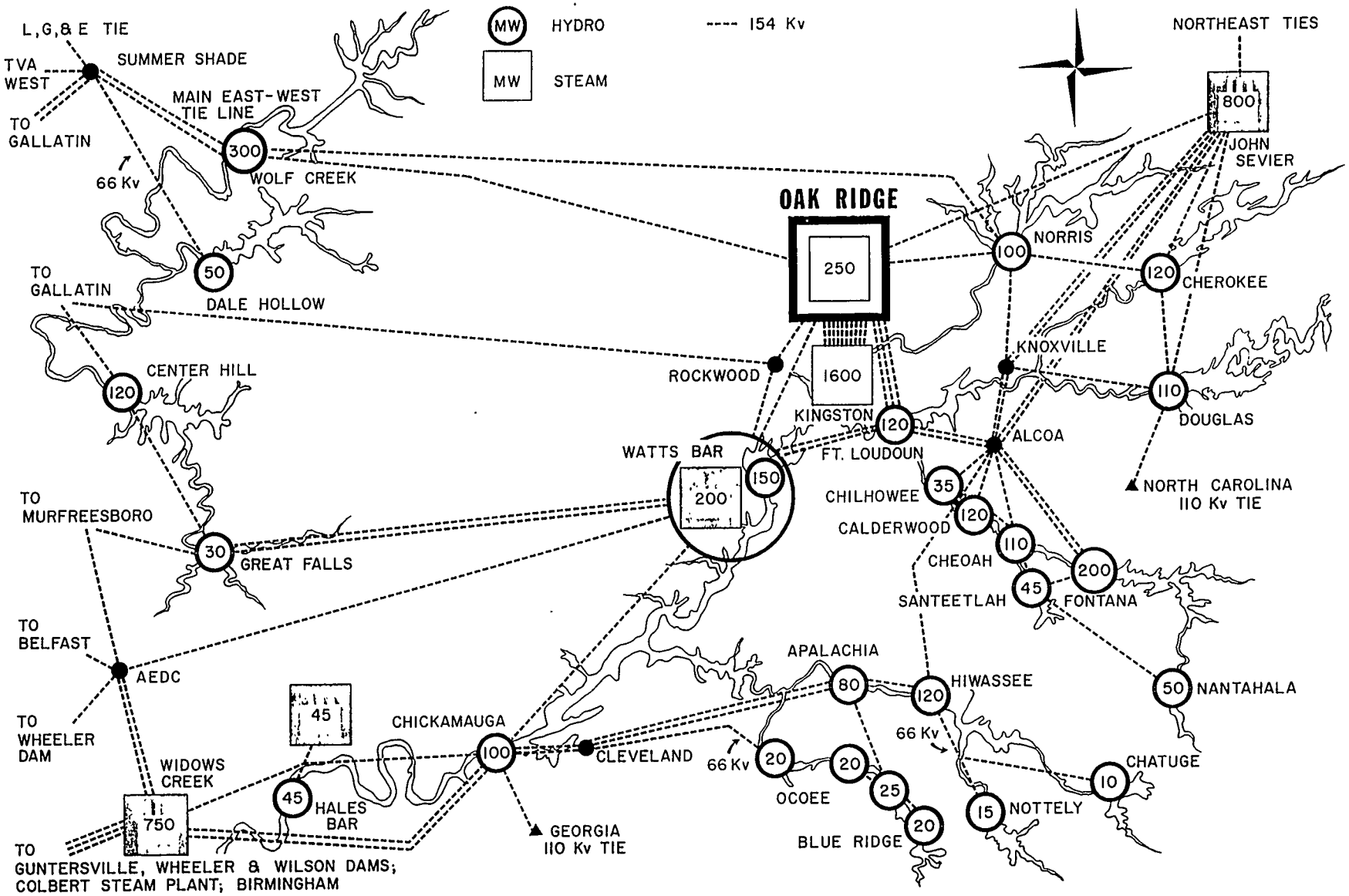

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FIGURE 15

K-33 Switchyard

The power lines to the Oak Ridge Gaseous Diffusion Plant supply power to four switchyards. The switchyard shown here supplies the K-33 building. Some idea of the size of the electrical system can be obtained from the following data:

Number of transformers	939
Number of motors	8,044
Motor sizes	1½, ~~5~~ to 2000 hp
Installed horsepower	2,070,000 hp
Underground feeders	200 miles

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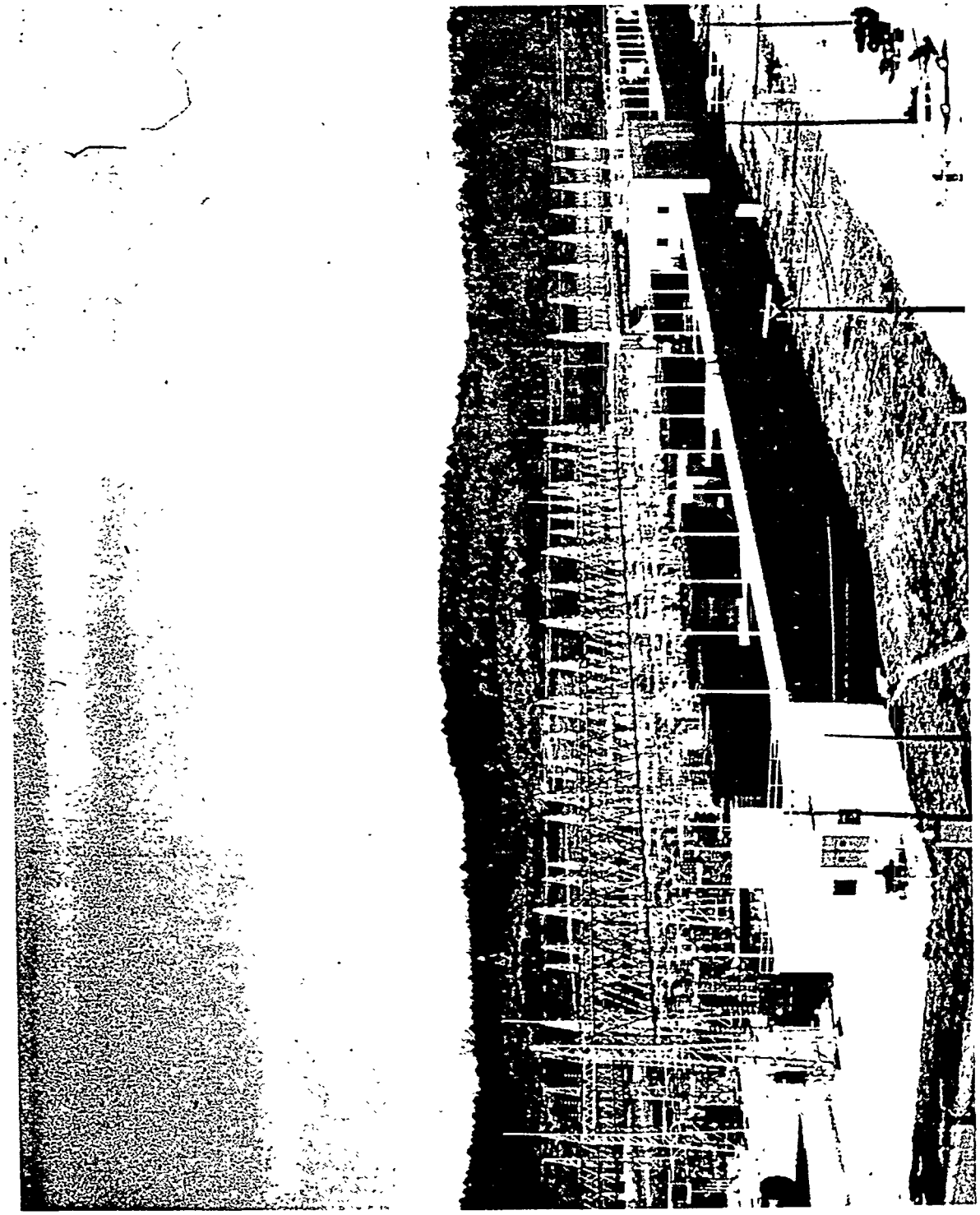

K-33 SWITCHYARD

FIGURE 15

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FIGURE 16

Cooling Towers

A distinguishing mark of the American gaseous diffusion plants is the cooling water towers. These towers remove the heat of compression from the process system through a series of heat exchangers. Heat is removed from the process system by an intermediary coolant, inert to the process gas, which is in turn cooled by water. The water is then cooled in atmospheric cooling towers. The cooling water system at the Oak Ridge plant is capable of circulating 380,000,000 gallons of water per day. Evaporation from the cooling towers requires the addition of 18,000,000 gallons per day to the systems. This water is obtained from the Clinch River and is processed through a water treatment system.

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COOLING TOWERS

FIGURE 16

SECRET

FIGURE 17

Uranium Hexafluoride Manufacture

Many auxiliary operations are required to permit the operation of the gaseous diffusion plants. One such operation is feed manufacturing. Feed manufacturing facilities are installed at all three of the gaseous diffusion plant sites. A fourth plant, not operated in conjunction with a diffusion plant, also supplies feed materials. This schematic drawing shows the steps required to produce uranium hexafluoride from oxides supplied by refining plants.

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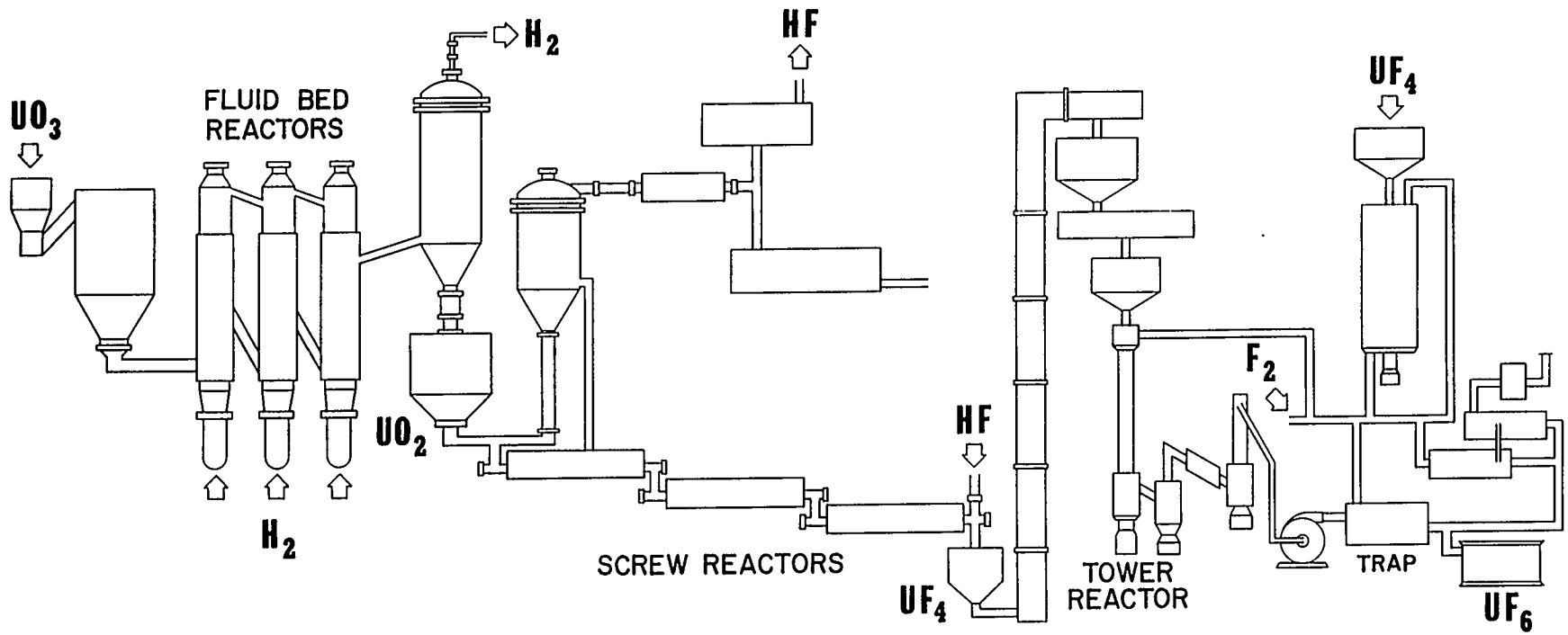
FIGURE 17

UF_6 MANUFACTURE



REDUCTION

$UO_3 + H_2 \rightarrow UO_2 + H_2O$

HYDROFLUORINATION

$UO_2 + 4HF \rightarrow UF_4 + 2H_2O$

FLUORINATION

$UF_4 + F_2 \rightarrow UF_6$

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FIGURE 18

Decontamination Facility

Another auxiliary operation required at a gaseous diffusion plant is the decontamination and uranium recovery systems. Equipment removed from the plant must be decontaminated to remove uranium materials for recovery and to permit maintenance on the equipment. Shown here is the K-1420 decontamination building at the Oak Ridge plant.

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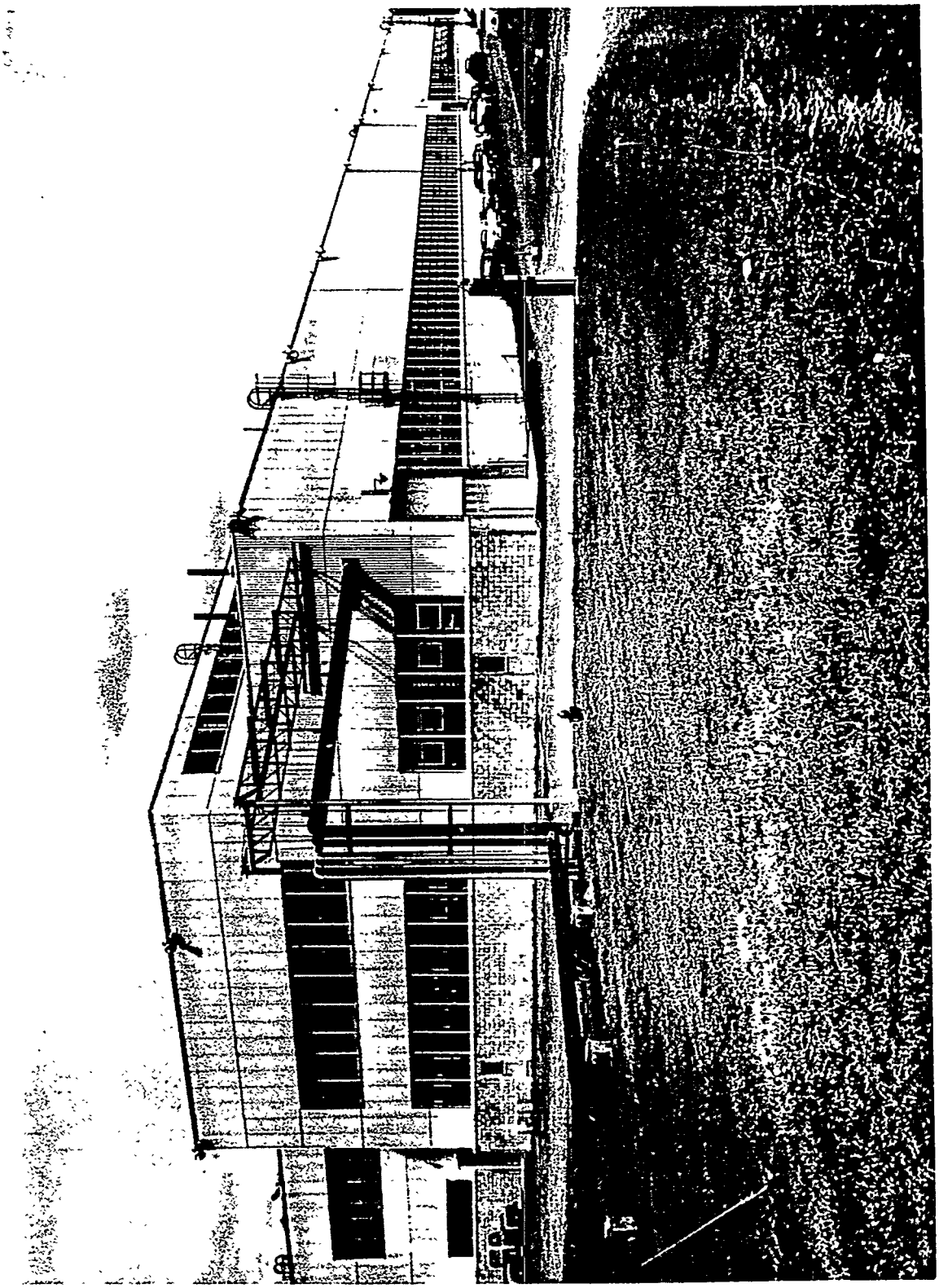

FIGURE 18

DECONTAMINATION FACILITY

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FIGURE 19

Large Equipment Decontamination

Shown here is the large equipment decontamination facility in the K-1420 building. Here equipment is dismantled and moved through a succession of booths in which the equipment is sprayed with acid solutions, rinsed, and dried.

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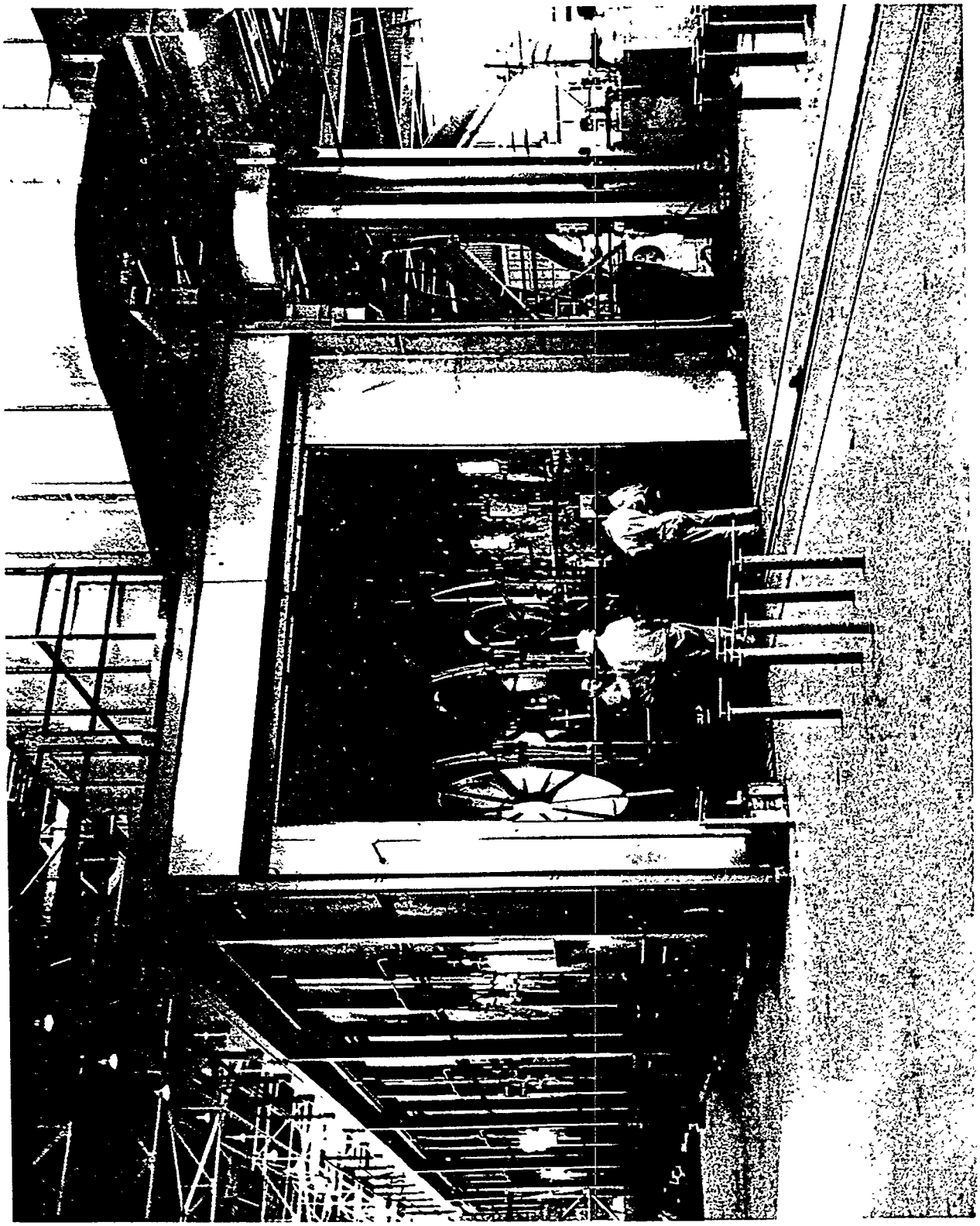

FIGURE 19 LARGE EQUIPMENT DECONTAMINATION

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FIGURE 20

Barrier Arrangement

Shown here is the barrier tube bundle for a K-33 stage. The small bundle fits inside the doughnut-shaped outer bundle.

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BARRIER ARRANGEMENT

FIGURE 20

SECRET

FIGURE 21

Small Equipment Decontamination

Small equipment is decontaminated on tables such as shown here. The solution is collected in geometrically safe storage containers beneath the tables for later uranium recovery.

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FIGURE 21

SMALL EQUIPMENT DECONTAMINATION

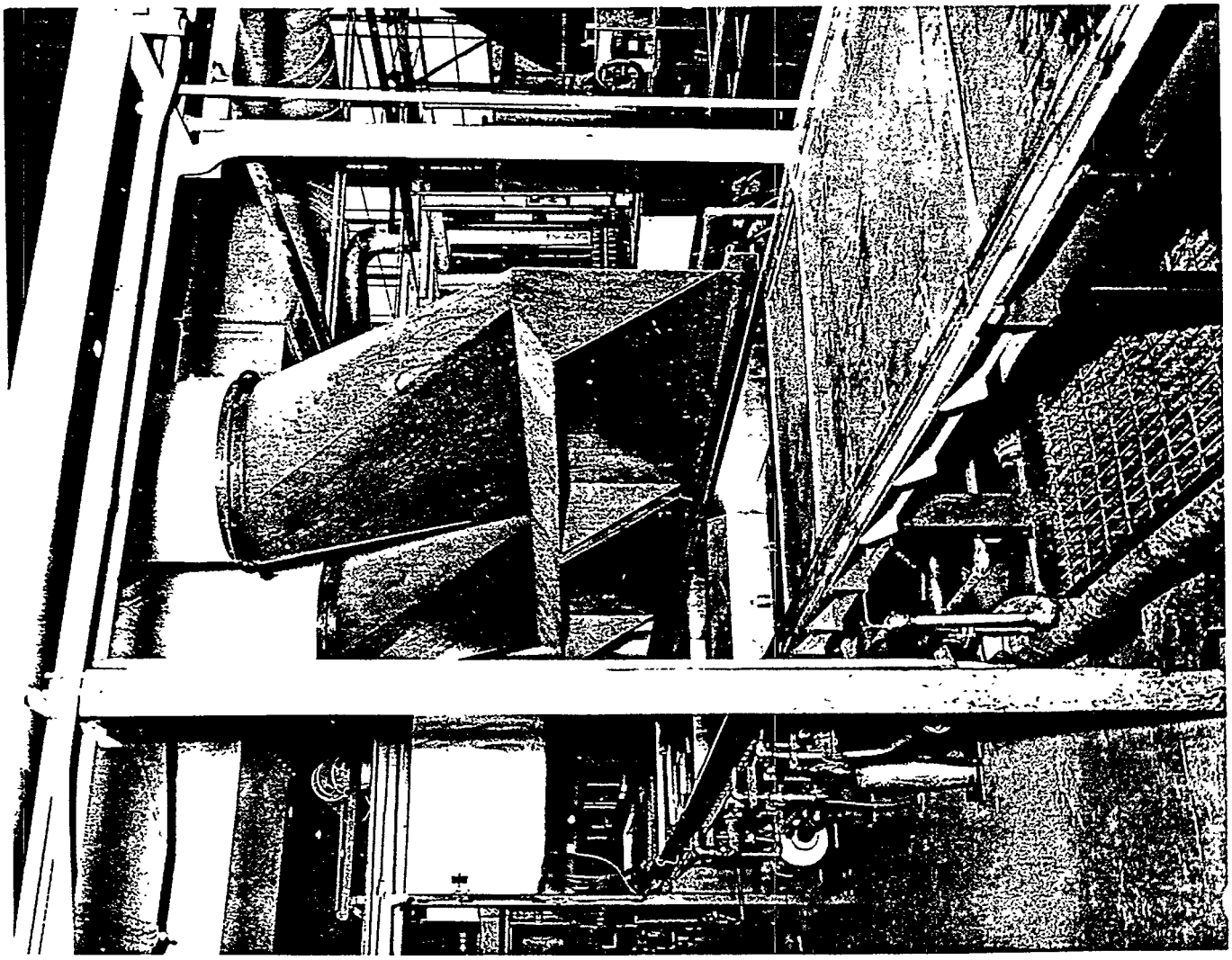

FIGURE 22

Incinerator

Combustible materials are burned in this facility with the ash being collected for later uranium recovery.

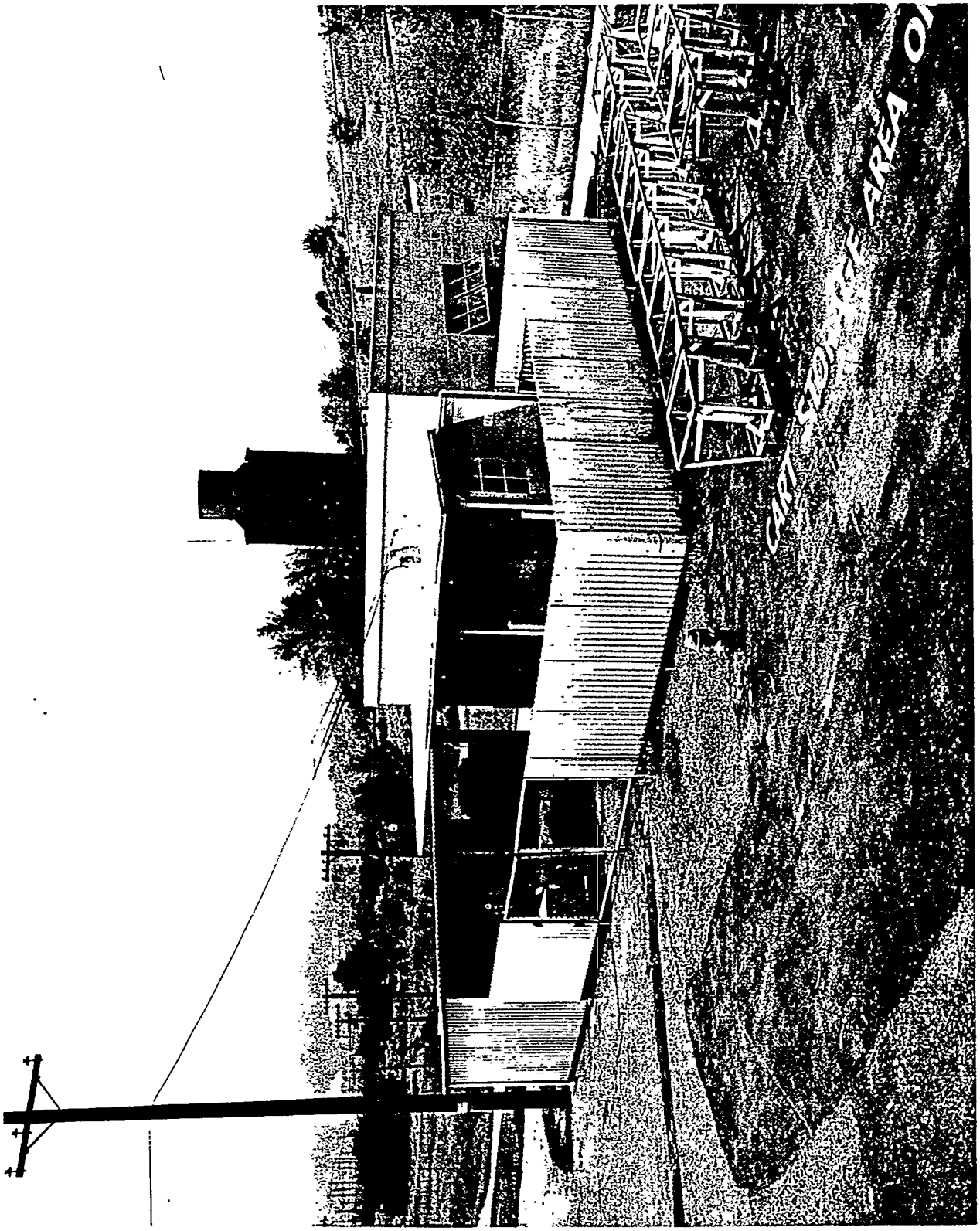

FIGURE 22 INCINERATOR

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FIGURE 23

Maintenance Shops

The operation of the gaseous diffusion plants requires a relatively large maintenance force with facilities to handle the process equipment. Shown here is a view of the K-1401 maintenance shop at the Oak Ridge plant.

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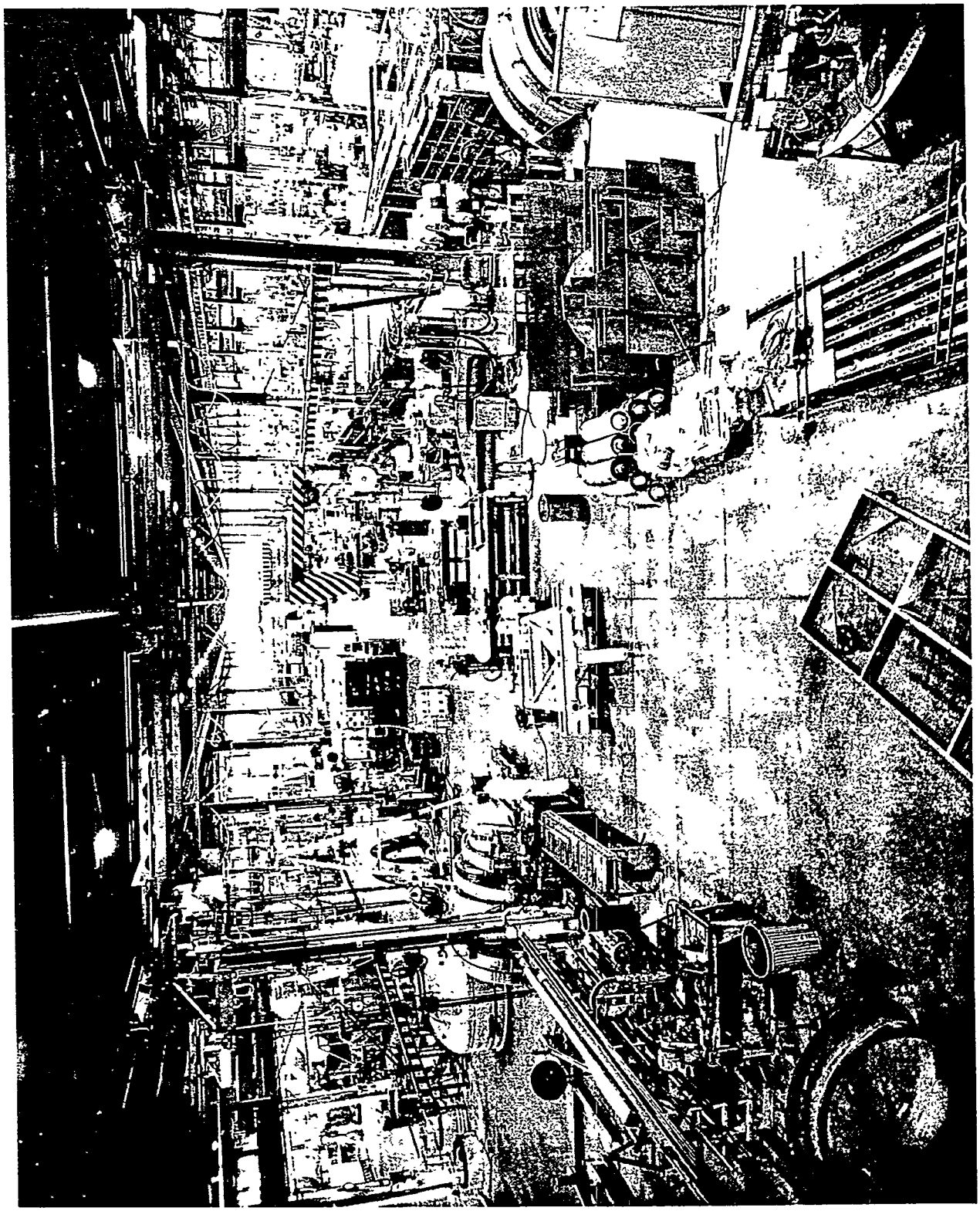

MAINTENANCE SHOPS

FIGURE 23

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FIGURE 24

Schematic of Major Material Inventories and Flows at the Oak Ridge Gaseous Diffusion Plant

The schematic shows the various material flows and inventories necessary for the operation during a typical month.

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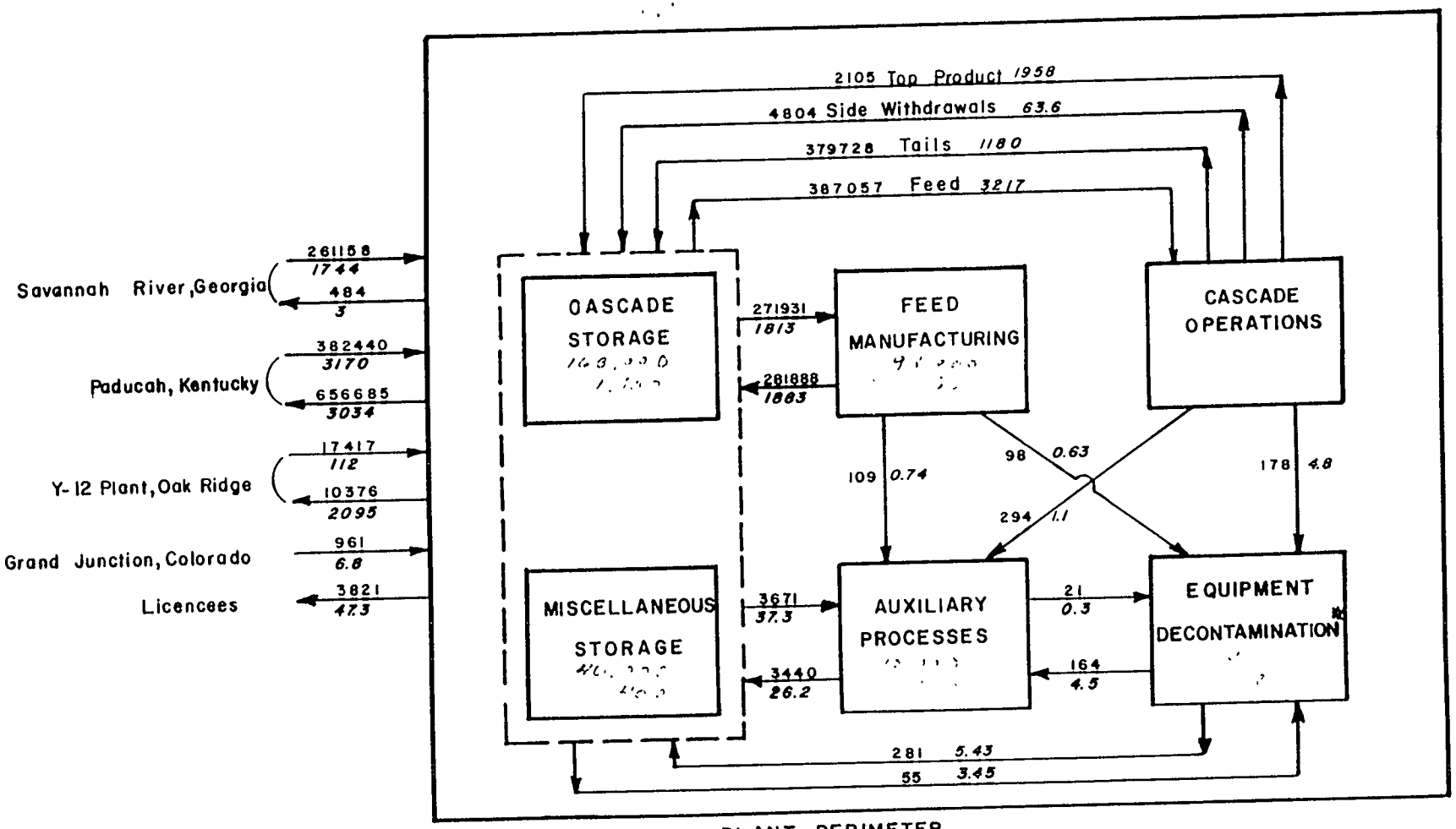
FIGURE 24

SCHEMATIC OF MAJOR MATERIAL INVENTORIES AND FLOWS AT ORGDP



LEGEND
VERTICAL FIGURES=KG.URANIUM
SLANTED FIGURES=KG U-235

*Inputs given are based on material obtained on decotaminating. No independent measure of inputs is practical. Since inputs are not measured, accountability control on de-contamination is not possible, and physical security is required.

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FIGURE 25

Schematic of Major Transfers of Containers

The schematic shows the number of containers handled during a typical month. The containers vary in size from a 20,000-pound capacity to milligram sizes.

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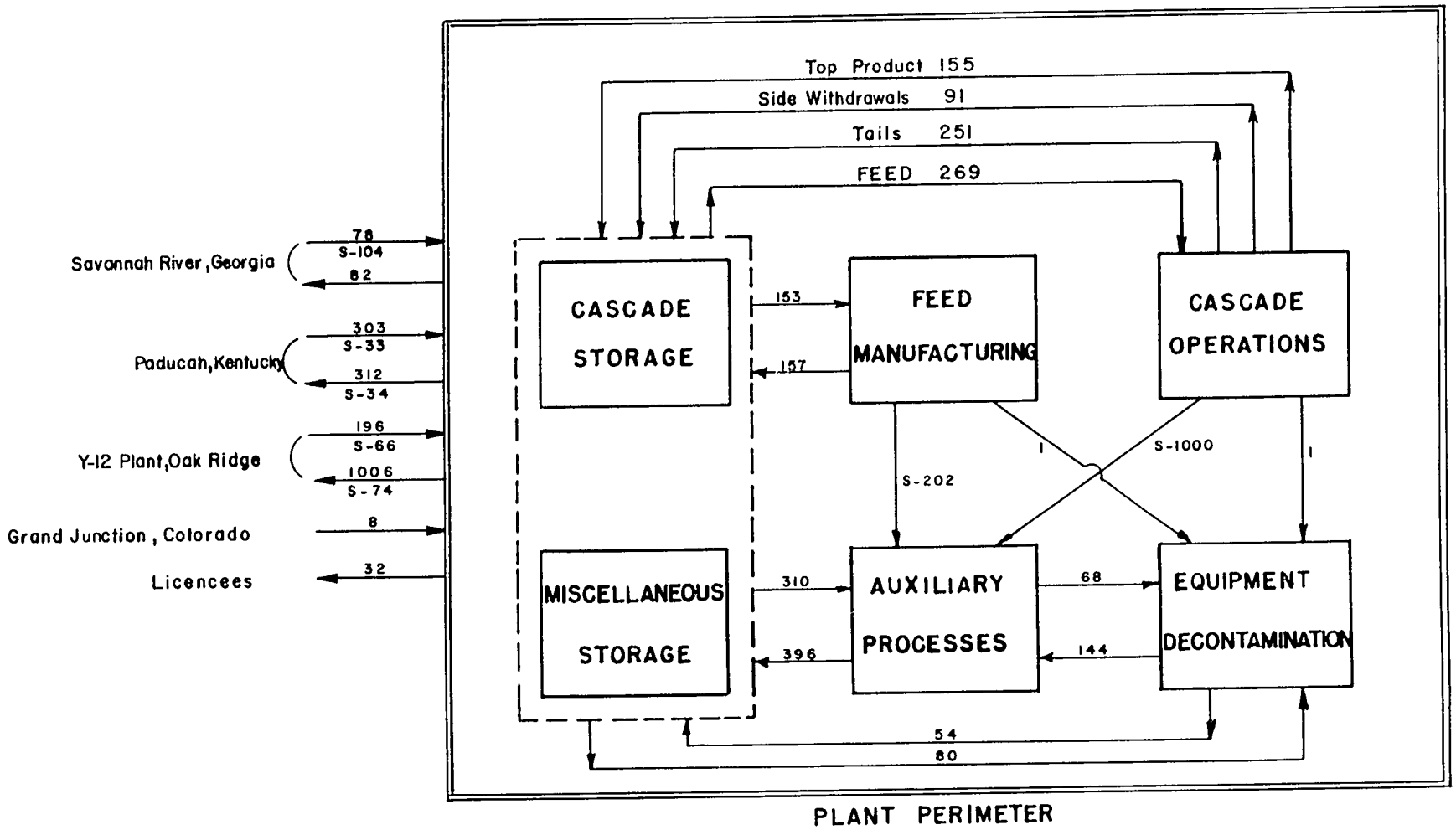
FIGURE 25

SCHEMATIC OF MAJOR TRANSFERS OF CONTAINERS



NOTE:
Numbers preceded by S denote sample containers.

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FIGURE 26

Accountability Experience at the Oak Ridge Gaseous Diffusion Plant

This figure presents a summary of accountability experience at the Oak Ridge Gaseous Diffusion Plant. An explanation of this chart is given below:

(1) The cumulative plant deficiencies for total uranium (U) and U-235 are defined by:

plant receipts less plant shipments,
less plant final inventory.

The plant deficiencies shown are accumulated from the start of operations at Oak Ridge.

(2) The hidden inventories for total uranium (U) and U-235 are the estimated and measured "legitimate losses", including the corrosion of the process gas (UF_6) on plant equipment surfaces.

Estimates of "hidden inventory" are not given until the third quarter of 1949, at which time the consolidation of "hidden inventory" data throughout the plant was finished.

(3) The "accounting efficiencies" for total uranium and U-235 are defined by:

[plant receipts plus "hidden inventory" less plant deficiency]

divided by plant receipts.

The "accounting efficiency" is seen to be the material accounted for as a fraction of the material to be accounted.

Since no "hidden inventory" estimates were available until 1949, the "accounting efficiencies" prior to 1949 do not include the correction for "hidden inventory".

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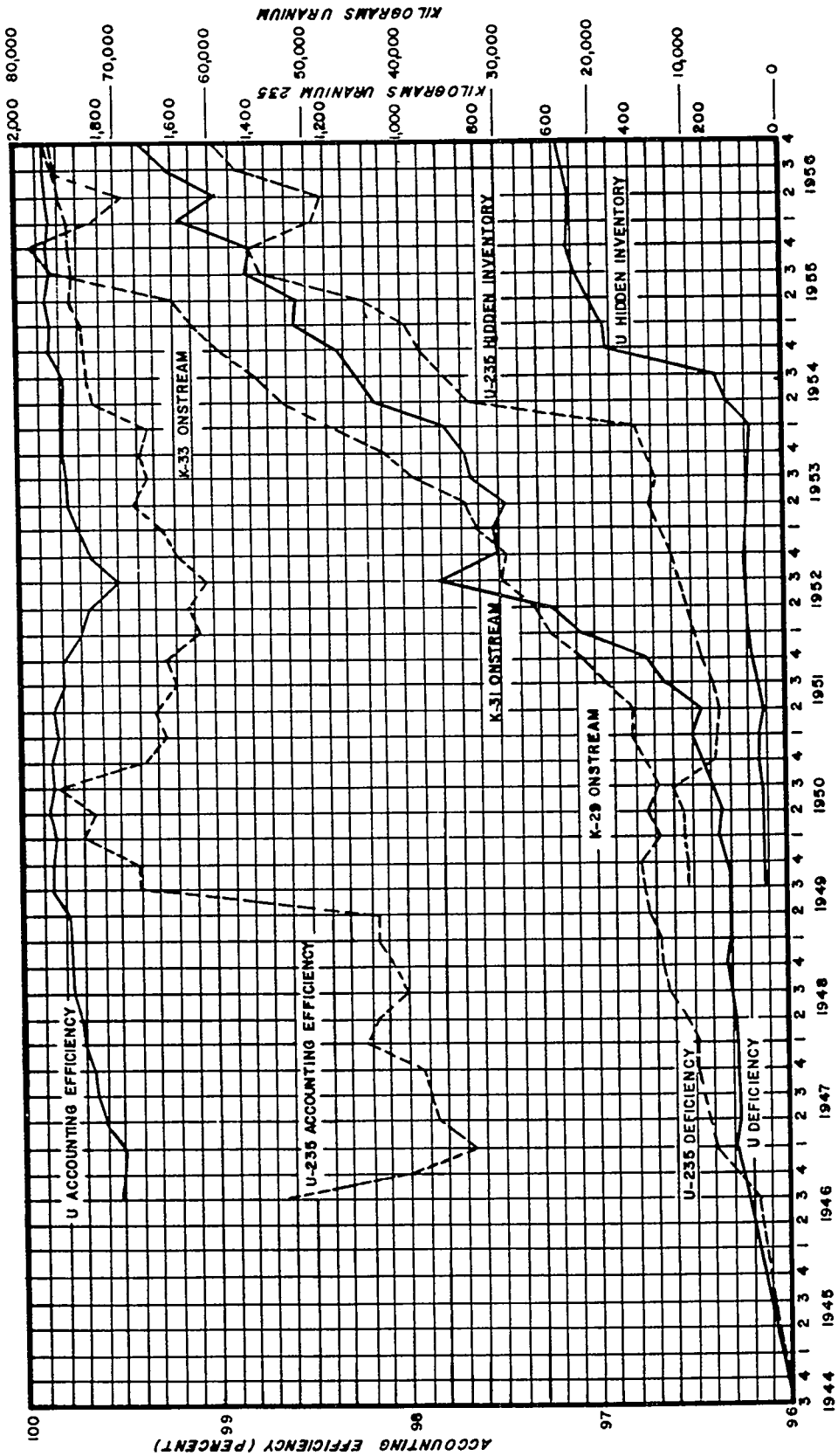
ACCOUNTABILITY EXPERIENCE AT ORGDP

FIGURE 26



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