

**This document was too large to scan
as a single document. It has
been divided into smaller sections.**

Section 4 of 5

Document Information

Document #	HW-18700		
Title	REDOX TECHNICAL MANUAL		
Date	07/10/1951		
Originator	WOODFIELD FW	Originator Co.	GE, HAPO
Recipient		Recipient Co.	
Keywords	MANUALS, NUCLEAR MATERIALS CONTROL & ACCOUNTABILITY, SEPARATION PROCESSES & PROCEDURES, WASTE TREATMENT & DISPOSAL		
Project	REDOX, DECLASS		
Inspected Date	07/13/2005		

DECLASSIFIED

897

B. SILVER REACTOR

1. Function

The gases evolved during slug dissolution contain radioactive iodine as well as some radioactive particulate matter in the form of mists and dusts. These must be removed prior to discharging the off-gas to the atmosphere through the stack.

The iodine is removed by chemical reaction with silver nitrate in the Silver Reactor, this silver nitrate being deposited as a solid on the surfaces of Berl-saddle packing. Three reactors, numbered A-3, B-3, and C-3 are installed in the Dissolver Cells of the Redox Plant. The physical and chemical principles of the Silver Reactor are discussed in Chapter III.

Removal of the particulate matter from the Dissolver off-gas by a Fiberglas filter is discussed in Chapter X.

2. Description

The Silver Reactor(6) shown on Figure XVI-2 consists of a vertical packed column 9 ft. 3 in. long and 24 in. in outside diameter supported on the shell of a vertical gas heater 6 ft. 10-1/2 in. long. The heater has a rectangular cross section with dimensions of 17 in. by 10-1/4 in. Between 50 and 150 cu.ft./min. of off-gas from the Dissolver enters the bottom of the heater through a 4-in. sch. 40 pipe. The gas passes upward through nine duct-type 12-kilowatt Chromalox heater coils which heat the gas to $475 \pm 25^{\circ}\text{F}$. to accelerate the chemical reaction and prevent condensation of moisture in the reactor. The gas continues upward through a 7 ft. 9-3/4 in. length of packed section and leaves the top of the tower through a 4-in. sch. 40 pipe to the Off-Gas Filter.

The column is packed with 1/2-in. ceramic Berl saddles which are coated with silver nitrate. The coating is applied by dipping the saddles in a 20 M solution of silver nitrate, draining, and drying. The column is packed through a hand hole just below the hold-down screen. The hand hole is welded shut after the column is packed. No provision is made for replacing the packing. The hold-down screen consists of a grating covered with 1/2-in. screen. A support screen at the bottom of the packed section is of similar construction.

All metallic elements in contact with the off-gas are Type 317 stainless steel.

3. Performance

The performance and life expectancy of the Silver Reactors is treated in more detail in Chapter III. Based on data obtained from the operation of similar reactors, the unit is expected to remove 99.9 per cent of the radioactive iodine present in the Dissolver off-gas.

DECLASSIFIED

4. Auxiliaries

The temperature controller of the gas entering the Silver Reactor and the temperature recorder of the exit gas are described in Chapter XIX.

Three-phase 440-volt current is supplied to the heaters through two electrical connectors. Two connectors are used because of the large current flow (maximum of approximately 250 amperes), which is carried through a total of 12 pins (6 on each connector).

C. AGITATORS

1. Design Basis

"Hot" agitators are used in Redox Plant to promote chemical reactions, improve mixing, and improve heat transfer coefficients. Redox agitators were designed to provide three types of agitation: mild, medium, and violent. "Mild" mixing is described as the type of agitation which causes no disturbance of the liquid surface other than a swirling effect. "Medium" agitation is that which causes waves in the liquid surface but no break in the continuity of the surface. "Violent" mixing produces waves, seething, and splashing.

2. Description

2.1 General

The 22 "hot" agitators⁽¹²⁾ for the Redox Plant were made by Eastern Industries, Inc. A typical agitator is shown on Figure XVI-3. The agitators are driven by vertically mounted explosion-proof electric motors (Class I, Group D). The agitators are connected through a flexible coupling directly to the motor shaft in the case of small high-speed agitators, and by a flexible coupling to the output shaft of a speed reducer which is directly connected to the motor shaft for the larger and lower-speed agitators. The agitator shaft is divided into two sections for protection from damage during transit. The upper portion of the shaft, referred to as the stub shaft, carries both thrust and radial bearing loads, while the lower portion, which is joined to the upper section with a rigid flange-type coupling, carries the agitator blading. The stub shaft is sealed by two water-flooded rotary mechanical seals at the upper and lower ends of a cylindrical tube welded in the mounting flange. The vertical tube also contains a water-lubricated guide bearing, near its lower end and within the zone confined by the seals, to provide shaft support near the point of load application.

The thrust and radial loading at the upper end of the stub shaft is absorbed by a grease lubricated radial-thrust ball bearing located above the top water-flooded seal.

2.2 Driving motor

All driving motors are 440-v., 3-phase, explosion-proof, Class I,

Group D, vertical, flange-mounted motors. The 1-hp. and 1/3-hp. agitators are driven directly at speeds of 1150 rev./min. and 1725 rev./min. respectively. The 7-1/2 hp. and 5-hp. units are driven through Winfield H. Smith Corp. planetary-type gear reducers at speeds of 97 rev./min. and 121 rev./min. respectively.

2.3 Stub shaft, bearings, and seals

The agitators have stub shafts ranging in diameter from 3/4 to 3 in. which extend from the flexible drive couplings down through the agitator mounting flanges into the vessels being serviced. The stub shaft passes through a tube which acts as seal and bearing housing in the agitator mounting flange.

The weight of the agitator shaft and the thrust produced by the agitator action are absorbed in a deep groove, radial-thrust ball bearing near the top of the stub shaft. The bearing is bolted into a flanged lubrication housing mounted above the agitator mounting flange. Standard Garlock grease seals above and below the bearing retain the lubricant within the housing.

The lower end of the stub shaft is guided by a water-lubricated sleeve bearing located within the seal housing. The sleeve bearing is made of boron carbide (Norbide), and has a diametrical shaft clearance of 0.002 in. per inch of shaft diameter. The bore of the bearing is finished to 10 microinches (root mean square) or better. Two lubrication grooves 3/16 in. wide and 0.025 in. deep run the length of the bearing. The portion of the stub shaft which runs within the bearing is hard-surfaced with 1/16 in. of Stellite No. 6 and finished to 10 microinches (r.m.s.) or better.

The static reservoir of water, contained in the seal and bearing housing for the purpose of lubricating the bearing, is retained by two single rotary Peerless seals, one at each end of the housing. Each seal has spring-loaded boron carbide (Norbide) seal faces which are polished to a flatness of 1 to 2 light bands and a finish of 5 microinches (r.m.s.) or better. The seal faces are retained in Kel-F cups. Teflon chevron packing prevents leakage around the shaft at the rotating seal face.

2.4 Propellers

The agitator shaft and propellers come assembled as a unit to be bolted to the stub shaft by a rigid flanged coupling in the field. This precaution was taken to protect the shaft from being bent in transit.

The 7-1/2 hp. and 5-hp. units have paddle-wheel type propellers, 33 in. and 24 in. in diameter, respectively. Each propeller has 10 blades at a pitch of 15 degrees. The 1-hp. and 1/3-hp. units have standard three-bladed marine propellers 8 in. and 5-3/4 in. in diameter, respectively. All propellers are shrunk fit and welded to the agitator shafts.

2.5 Lubrication

The sleeve bearing on the stub shaft is lubricated by a static reservoir of water contained within the seal and bearing housing. The water is supplied at a head of approximately 25 ft. from a calibrated container in the Operating Gallery. The water is supplied through 1/2-in. i.p.s. pipe which has no traps or pockets and which is sloped to back-vent the air from the seal chamber.

The inboard and outboard motor bearings, a guide bearing in the speed reducer, and the radial-thrust bearing on the stub shaft are greased remotely by a Farval lubrication system. The grease used is Texaco Regal Starfak or equivalent. The gear reducer has an oil reservoir to which a given amount of oil is charged from a station in the Operating Gallery. The 7-1/2 hp. reducers have a capacity of 8 qt., and the 5-hp. units have a capacity of 5-1/4 qt. The oil recommended for use in Socony Vacuum Gargoyle Compound No. 2.

The oil and seal water lubricants utilize two lines of a three-way connector. The dual-line Farval grease system uses two lines of a second three-way connector. The greased bearings and the oil reservoir drain through a Lube Exhaust Adapter to a 20.4 gal. Lube Exhaust Collector on the side of the vessel. The Collector has a design capacity sufficient for one year of operation and may be removed by the crane for replacement.

The Farval system of grease lubrication, the method of supplying oil to the speed reducers, and the Lube Exhaust system are described in Section F of this chapter.

3. Operation

The seal is the critical element of the agitator. Seal water must be provided to the seal chamber at all times during operation. Operation of the seal without water lubrication will result in overheating the seal faces, fusion of the Kel-F seal cups, and rapid seal failure. The rate of seal leakage is measured by observing the change in level of the seal water burette in the Operating Gallery over a measured time interval. Combined in leakage of seal water (agitator or agitator and pump) must not exceed 0.5 gal./day.

D. CENTRIFUGE

1. Function

The Centrifuge, H-2, connected between the Oxidizer, H-4, and the IAF Make-Up Tank, H-1, is used to remove some of the particulate matter originating from insoluble inorganic components in the aluminum can, Al-Si bonding layer, and slugs, released during jacket removal and slug dissolution, and to remove scavenger from the feed stream if a scavenger is used to accomplish partial decontamination by the removal of radioactive zirconium and niobium. (See Chapter III for details of feed preparation.)

2. Description

The Centrifuge, shown in Figure XVI-4, is a Bird 40-in. solid-bowl machine which may be operated at 870 or 1740 rev./min. to give an effective centrifugal force at the inside diameter of the bowl of 430 or 1730 G (430 or 1730 times the force of gravity). The bowl holdup is 60 gal. and may be reduced to 10 gal. by the operation of skimmers. The bowl has three horizontal baffles spaced 5-3/8 in. apart. The baffles have an inside diameter of 27 in. The centrifuge is essentially the same as the machine used in the Bismuth Phosphate Plants⁽¹³⁾ which is described in Section C of the Hanford Works Technical Manual (HW-10475). The Redox centrifuge differs from the centrifuge used in the Bismuth Phosphate Plants by the incorporation of design features, as described below, which are calculated to reduce cell contamination through minimization of the escape of entrained mists or droplets.

Shroud: The centrifuge bowl and case are purged with air during the dissolution of MnO₂ scavenger. A sheet stainless steel shroud encloses the centrifuge spindle and provides a tight case between the motor mounting and the centrifuge case. Purge air is admitted to the side of the shroud through a 1/8-in. i.p.s. pipe. The purge air and evolved gas from dissolution of the MnO₂ are swept out of the case through the 8-in. i.p.s. centrifuge discharge line.

Fume cover: A fume cover is provided between the spindle and the top of the case to prevent the creep of liquid up the spindle and to restrict the open area between the spindle and the cover. Two slinger rings, attached to the shaft are designed to provide a close clearance on either side of the fume cover and act as a baffle-type seal.

Dip legs: Five removable dip legs are provided for transfer of material to and from the bowl and for weight factor measurement. The dip legs are inserted into the centrifuge bowl through nozzles in the case. The top end of the dip tube is provided with a male connector half and a bail which fits within the female half of the mating connector.

Lubrication: A Farval grease metering lubrication system is provided for lubricating the motor and spindle bearings of the centrifuge. The waste grease is collected in a grease collecting can mounted on the side of the centrifuge. The Farval lubricating system is described in Section F of this chapter.

3. Performance

Laboratory and semi-works centrifugation studies have demonstrated that centrifugation without scavengers at a holdup time of 20 minutes of both standard (normal turbidity) and off-standard (abnormal turbidity) dissolver metal solution at 1100 or 1600 G gave improved clarities, although not the maximum clarities which can be obtained with a scavenger⁽¹⁾. Longer holdup times improve the clarity only slightly. The use of bowl speeds which give a centrifugal force approaching 1600 times gravity can be

expected to give clarities up to 10% better than those obtained at lower speeds (1100 times gravity).

Absolute values which define the improvement in clarity of dissolver solution resulting from centrifugation have been found to be a function of the history of the solution, the original clarity, and the density and viscosity of the liquid phase, and undefined characteristics of the solid phase.

The use of scavengers in centrifugation is discussed in Chapter III.

E. PR CAN

1. Function

The PR (plutonium removal) Can is a 15-gal. portable vessel in which the plutonium nitrate solution constituting the final plutonium product of the Redox Plant is transported to the 234-5 Building or 231 Building for further processing. The PR Can and its container jacket are identical with the equipment described as "Vessel F-1"⁽²⁾ and "Product Container" in Section C of the Hanford Works Technical Manual, HW-10475.

2. Description

The PR Can, Container Jacket, and PR Can Stopper are shown in Figure XVI-5.

2.1 PR Can⁽⁸⁾

The PR Can is a dished-bottom flat-top stainless-steel container 18-3/4 inches in outside diameter by 14-5/8 inches high, mounted on four 1-inch diameter legs. Lifting bails are welded to the flat top which is also provided with an approximately 3-in. diam. filling hole with chamfered edges. A spherically ground, 3-1/4 in. diam. lid may be clamped over the hole to form a tight seal. The filling hole is completely surrounded by a partition or wall to prevent spread of spilled solution.

2.2 Jacket

The PR Can is carried in a Container Jacket during transit. The stainless steel jacket is 22-13/16 inches in outside diameter and 27 inches deep. The Jacket is provided with lifting slots on the sides and skids on the bottom. Water inlet and outlet lines of 1/8-in. i.p.s. pipe allow the inside of the Jacket and the outside of the PR Can to be flushed.

2.3 PR Can Stopper⁽⁹⁾

The PR Can Stopper is a rigid assembly used in filling the PR Can. The stopper which fits the opening in the PR Can is mounted 31-1/2 in. above the floor level on the cross arm of an inverted L-shaped pipe

bracket fabricated from 1/2-in. schedule 40 stainless steel pipe. The stopper is tapered and provided with a Teflon gasket which mates against the chamfered hole in the PR Can during filling. Two short dip tubes of 1/2-in. i.p.s. stainless steel pipe extend through the stopper. One dip tube, the vacuum line, extends to a point 6-1/2 inches below the top of the can when the can is in filling position. The other line, the filling line, ends just below the bottom of the stopper.

3. Filling Operation

The PR Can is filled by raising it with a chain hoist until the chamfered hole in the can top seals against the Teflon gasket on the PR Can Stopper. A vacuum is drawn on the Plutonium Transfer Trap, E-21, and the PR Can is partially evacuated through the dip leg of the vacuum line. The contents (about 8 gal.) of the Plutonium Concentrator, E-17, are then transferred to the evacuated PR Can through the filling dip tube. In the event of error which would otherwise result in overflowing the PR Can, the vacuum line dip tube discharges any overage into the Plutonium Transfer Trap. After filling, the PR Can is lowered, the lid is bolted shut, and the can is weighed and placed in the Jacket Container for transfer.

F. AUXILIARIES

1. Gang Valves

Gang valves are used to operate the steam jets in the Redox Plant. They consist of four sequence-controlled air-operated diaphragm valves (steam, purge, shut-off, vent) in the Pipe Gallery(10) operated by means of a remote manual air operator(14) in the Operating Gallery. The air operator has a two-position, "ON"- "OFF" handle. When the handle is in the "ON" position steam enters the jet. When the handle is turned to "OFF" the air operator automatically sets the diaphragm valves in an intermediate "OFF-1" position as described below. After a short period (10 to 90 seconds) the air operator automatically returns the diaphragm valves to the "OFF" position. The position assumed by the four air-operated diaphragm valves corresponding to the manually set positions of the remote air operator are shown below:

	<u>Steam Valve</u> (Normally Closed)	<u>Purge Valve</u> (Normally Closed)	<u>Shut-Off Valve</u> (Normally Closed)	<u>Vent Valve</u> (Normally Open)
OFF	Closed	Closed	Closed	Open
ON	Open	Closed	Open	Closed
OFF-1	Closed	Open	Open	Closed

Figure XVI-6 shows the operation of the system schematically.

In the "OFF" position the steam, purge, and shut-off valves are closed and the valve header is vented to the Jet Vent Header. When the operating handle is turned to "ON", the shut-off valve and steam valve

are opened, the vent valve is closed, and the jet operates. Immediately after the handle is turned to "OFF", the steam valve is closed and the purge valve is opened, admitting air or inert gas to the jet line in order to purge the line of steam and prevent condensation and reverse flow of process solution into the steam line. This "OFF-1" position is automatically held for a period that may be adjusted from 10 seconds to 1-1/2 minutes before all valves return to their normal "OFF" position.

2. Samplers

2.1 Function and types

Remote samplers are employed in the Redox Plant to obtain small quantities of radioactive process materials for analysis. Samples with a volume of 0.5 and 5.0 ml. are collected by means of "bayonet"⁽²⁾ or "trombone"-type samplers, which are described in Section C of the Hanford Works Technical Manual, HW-10475. Where sample quantities of 10 or 100 ml. are required, the Redox Sampler, described below, is employed.

2.2 Description of the Redox Sampler

The essential elements of the Redox Sampler⁽¹⁵⁾, shown in Figure XVI-7, are: (a) the sampler filling box, which houses the mechanism and is shielded with lead or concrete; (b) a sample carrier, containing a polyethylene sample cup in which the sample is collected; (c) an air-operated lift mechanism which raises the sample carrier through a trap door to a mandrel or filling spout; and (d) a nitrogen-operated jet, which reduces the pressure in the sample carrier and allows the stream to be sampled to flow into the carrier.

Three dip tubes form the elements of the sampler which extend into the vessel to be sampled. One dip tube carries the sample to the filling spout or mandrel on the sampler. The second dip tube is the nitrogen jet discharge line which returns the excess process fluid to the vessel when the sample carrier is full. The third dip tube is a nitrogen bleed line which enters the sample line dip tube near the bottom and is used to decrease the apparent density of the contents of the sample line when the elevation of the sampler carrier is above the maximum lift of the jet.

The sampler filling box is supplied with a water flush pipe which has holes drilled along its length. The flush water is drained to a drain header in the Pipe Tunnel. A vacuum on the drain header maintains the Sampler filling box at a reduced pressure. The discharge of the air-operated lift mechanism vents into the sampler filling box.

2.3 Operation

In operation, the sample carrier is placed on the platform of the lift mechanism through a door in the front of the sampler filling box. The lid of the sample carrier is removed remotely and the sample carrier is raised upward through a trap door to the filling spout by means of the pneumatic lift mechanism. When the platform is at the maximum raised

position, the bottom of the filling mandrel forms a tight seal against the polyethylene sample cup. The sample cup is partially evacuated through the suction line of the nitrogen jet. This causes process solution to flow into the cup. When sufficient sample has been obtained (as determined by the pre-set position of the end of the nitrogen jet suction line), excess solution passes through the jet and is discharged back to the vessel. The sample carrier is then lowered by the lift mechanism. As the seal breaks between the sample cup and the mandrel, the sample line drains back to the vessel. The sample carrier is removed from the box by means of a special carrying fork.

Some solutions of high density cannot be raised to the sample cup by the nitrogen jet. This difficulty is circumvented by bleeding nitrogen through a fixed orifice into the sample line in the vessel near the bottom of the dip tube. This decreases the apparent density of the sampled fluid so that it may be lifted by the jet. A nitrogen separator in the sampler filling box, separates the entrained gas from the sample.

3. Strainers

3.1 Design basis

Strainers are used in "cold" solution streams in the tank farm and in aqueous make-up to remove insoluble particles and foreign bodies which enter with the dry chemicals. All continuous "cold" feeds and some batch feeds to the cell tanks are filtered by disc-type strainers which may be cleaned during operation. Other streams are filtered by standard basket screen strainers which are cleaned between operating periods.

The basket-type strainers are designed for pressure drops ranging from 1 to 4 lb./sq.in. at operating flow rates and will remove particles with a mean diameter ranging from 0.25 in. down to 0.008 in. by means of 4 to 125-mesh screens.

The disc-type strainers are designed for pressure drops of 0.5 to 2 lb./sq.in. at operating flow rates, and will remove particles with a mean diameter of 0.008 to 0.02 in.

3.2 Basket-type strainers(18)

In the standard basket-type strainer the stream enters a flanged inlet in the filter, flows downward into the screen basket, through the screen, and out the flanged outlet which is in line with the inlet. The cast stainless steel strainer body has a bolted lid which may be opened to permit the removal of the basket for cleaning.

3.3 Disc-type strainers(16)(17)

The flanged, in-line disc-type strainers, made by the Cuno Engineering Corp., are illustrated in Figure XVI-8. Solution flows downward into the body of the strainer from the flanged inlet. The fluid then passes radially between a stack of circular discs. The discs are separated by

902e
[REDACTED]

spacers which are thinner than the smallest particle to be filtered from the stream. The fluid passes upward through passages in the stack of discs and out the outlet line. The passages are closed at the bottom of the stack.

The stack of discs may be rotated past stationary cleaner blades by a handle outside the filter. The cleaner blades scrape from the edge of the disc the filtered solids which fall to the bottom of the strainer and may be removed through an outlet during inoperative periods.

The larger disc-type strainers have two or three stacks of plates which are all rotated simultaneously through gears by an external handle.

4. Remote Lubricating System

4.1 Remote grease supply system (Farval)

Rotating equipment in "hot" areas of the 202-S Building, such as pumps, agitators, and the centrifuge, have ball bearings which require periodic grease lubrication. A Farval Dualine system is used to satisfy the requirements of remote maintenance. The system is illustrated schematically in Figure XVI-9. The operator, employing a grease gun, forces grease alternately through two giant button head type Alemite grease fittings mounted on the Operating Gallery wall. The grease is fed to the equipment through two lines of a 1/2-in. three-way connector and jumper. From the three-way connector mounted at the equipment the grease is fed through two Type 347 stainless steel 1/4-in. sch. 40 pipes to a Farval Dualine valve⁽¹⁹⁾ mounted rigidly on the equipment. The valve meters 1/20 oz. of grease to each bearing through 3/8-in. Type 347 stainless steel tubing each time one of the dual lines is pressurized. Waste grease is forced out of the bearing through 1/4-in. sch. 40 pipe to a waste lube adapter bracket bolted to the edge of the equipment mounting flange. The grease then flows through a funnel-like adapter into a 1-in. sch. 40 pipe and thence into a waste lube container hung on the side of the vessel. Waste lube containers⁽¹¹⁾ are of two sizes and have a design capacity sufficient for one year of operation. A 1-3/4 gal. container is used where grease only is collected. Where grease plus lubricating oil is collected, a 20.4-gal. container is utilized. The container can be lifted out of the cell by the crane for replacement.

4.2 Remote oil changing system

The 7-1/2 hp. and 5-hp. "hot" Redox agitators have speed reducers which require periodic remote oil changing. This accomplished by supplying oil through a gravity feed line from the Operating Gallery. A portable hand-operated barrel pump is used to pump a measured amount of oil from a 5-gal. container on the pump into a 1/2-in. threaded inlet on the Gallery wall. One line of a 1/2-in. three-way jumper is used to carry the oil to the agitator. Another line of the jumper is used to carry water to the vapor seal as described in Section C of this Chapter. From the three-way connector at the agitator the oil flows to the speed reducer through a 1/2-in. sch. 40 Type 347 stainless steel pipe. The waste

DECLASSIFIED

907

1613

oil overflows through another 1/2-in. pipe to a waste lube adapter bracket and thence to a 20.4-gal. waste lube container as described under Fl.1, above.

DECLASSIFIED

908

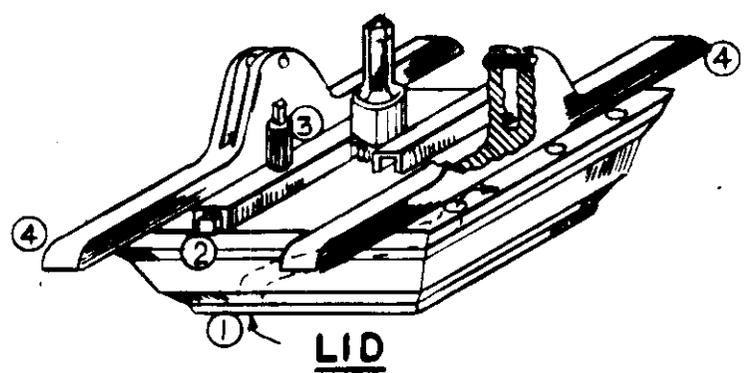
DECLASSIFIED

REFERENCES

- (1) HW-9148 Redox Technical Data Study No. 2, Clarification of Dissolver Metal Solution by Centrifugation. R. B. Richards. 3-8-48.
- (2) HW-10475 H.E.W. Technical Manual, Section C. Author not stated. 5-1-44. Pp. 236, 307, 515-518, 283-284, 730, 526-531.
- (3) W-72486 General Arrangement -- Slug Carrying Cask, Rev. 2, Hanford Works. 9-30-44.
- (4) W-75010 Sections -- Lid-Slug Carrying Cask, Hanford Works. 5-17-44.
- (5) W-74896 Plan and Sections -- Slug Carrying Cask, Hanford Works. 5-17-44.
- (6) H-2-5479 Off-Gas Heater and Absorber -- Assembly and Details. 2-14-51.
- (7) H-2-8045 M.E. -- General Arrangement -- Plans and Sections -- Alteration to Centrifuge. 5-29-50.
- (8) D-64263 Container, Rev. 4, Hanford Works. 8-11-44.
- (9) H-2-8777 M.E. -- Details -- P.R. Can Stopper and Pipe Support, Rev. 1. 10-17-50.
- (10) H-2-9088 Piping -- Nomenclature for Gang Valve Units. 8-17-50.
- (11) H-2-9390 M.E. -- Sub-Assembly and Details -- Lube Exhaust Containers, Rev. 1. 10-27-50.
- (12) BPF-2946 Agitators, Hanford Works.
- (13) BPF-71238 Centrifuge, Hanford Works.
- (14) BPF-2389 Gang Valves, Hanford Works.
- (15) BPF-2750 Redox Sampler, Hanford Works.
- (16) BPF-2497 Plate-Type Strainers, Hanford Works.
- (17) BPF-2344 Plate-type Strainers, Hanford Works.
- (18) BPF-2162 Screen-type Strainers, Hanford Works.
- (19) BPF-74385 Remote Lubricating Equipment, Hanford Works.

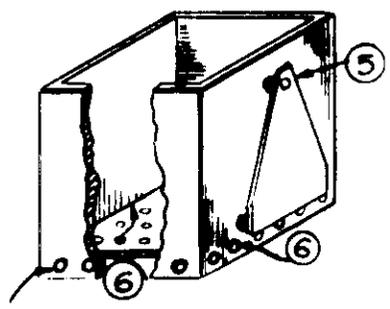
DECLASSIFIED

Figure XV
CASK ASSEMBLY

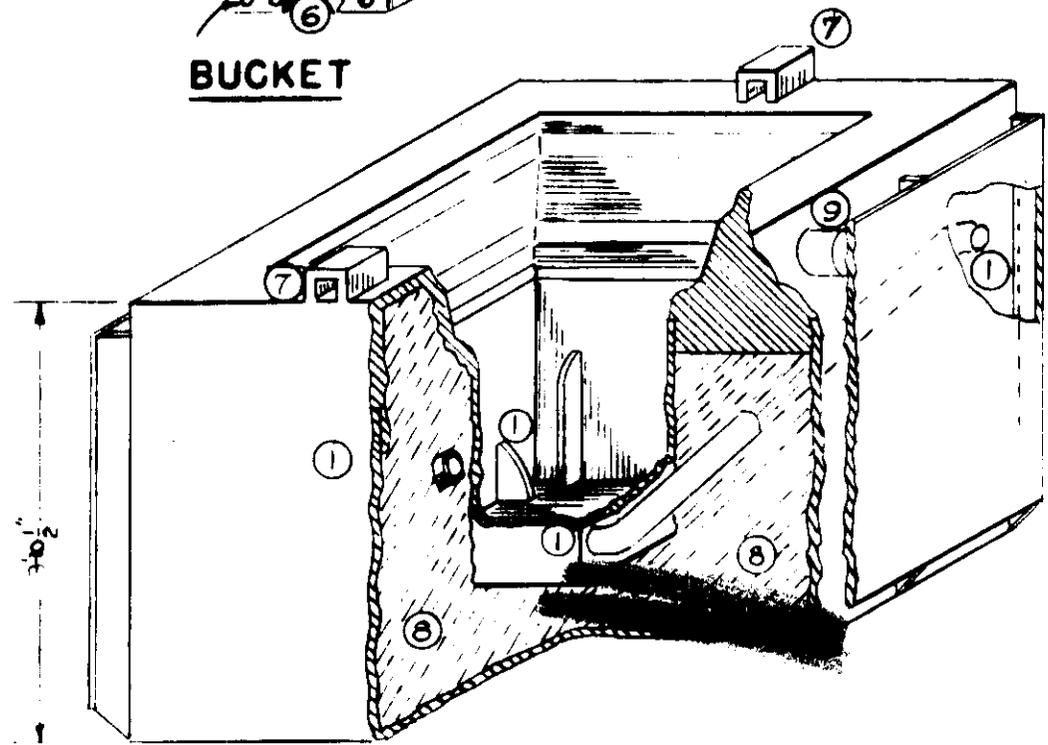


LID

- ① WATER CIRCULATING TUBE
- ② LOCKING BAR
- ③ BALL LOCK
- ④ LID ARMS
- ⑤ LUG FOR LIFTING BUCKET
- ⑥ HOLES FOR WATER CIRCULATION THROUGH BUCKET
- ⑦ CATCHES FOR LOCKING BARS
- ⑧ LEAD FILLED CASK WALLS 12½ THK.
- ⑨ LUG FOR LIFTING CASK



BUCKET



CASK

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

DECLASSIFIED



HW-18700

910

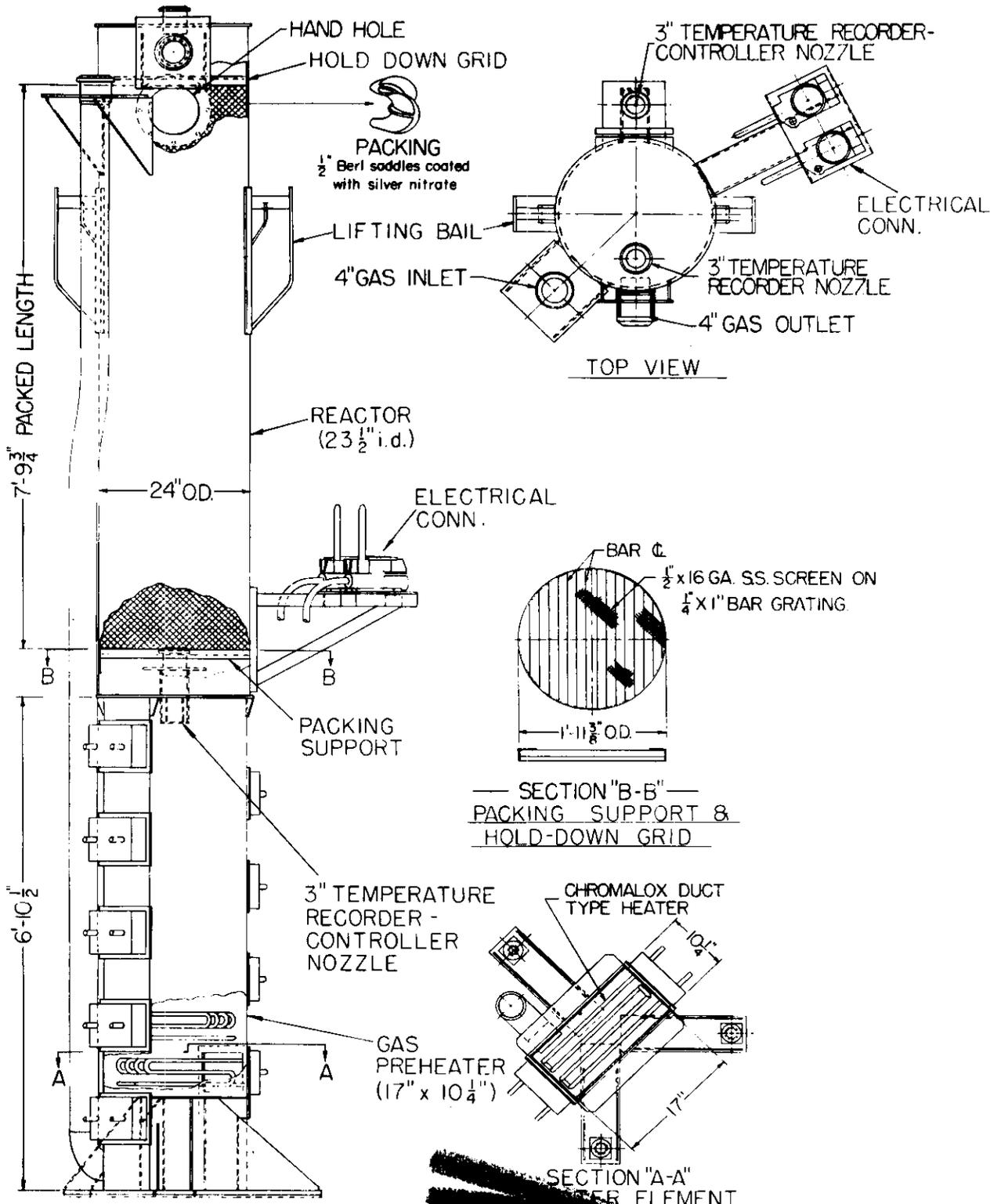
DECLASSIFIED

HW-18700

911

Figure XVI-2

REACTOR



DECLASSIFIED

DRAWING NO. H-2-5479

912

HW-18700



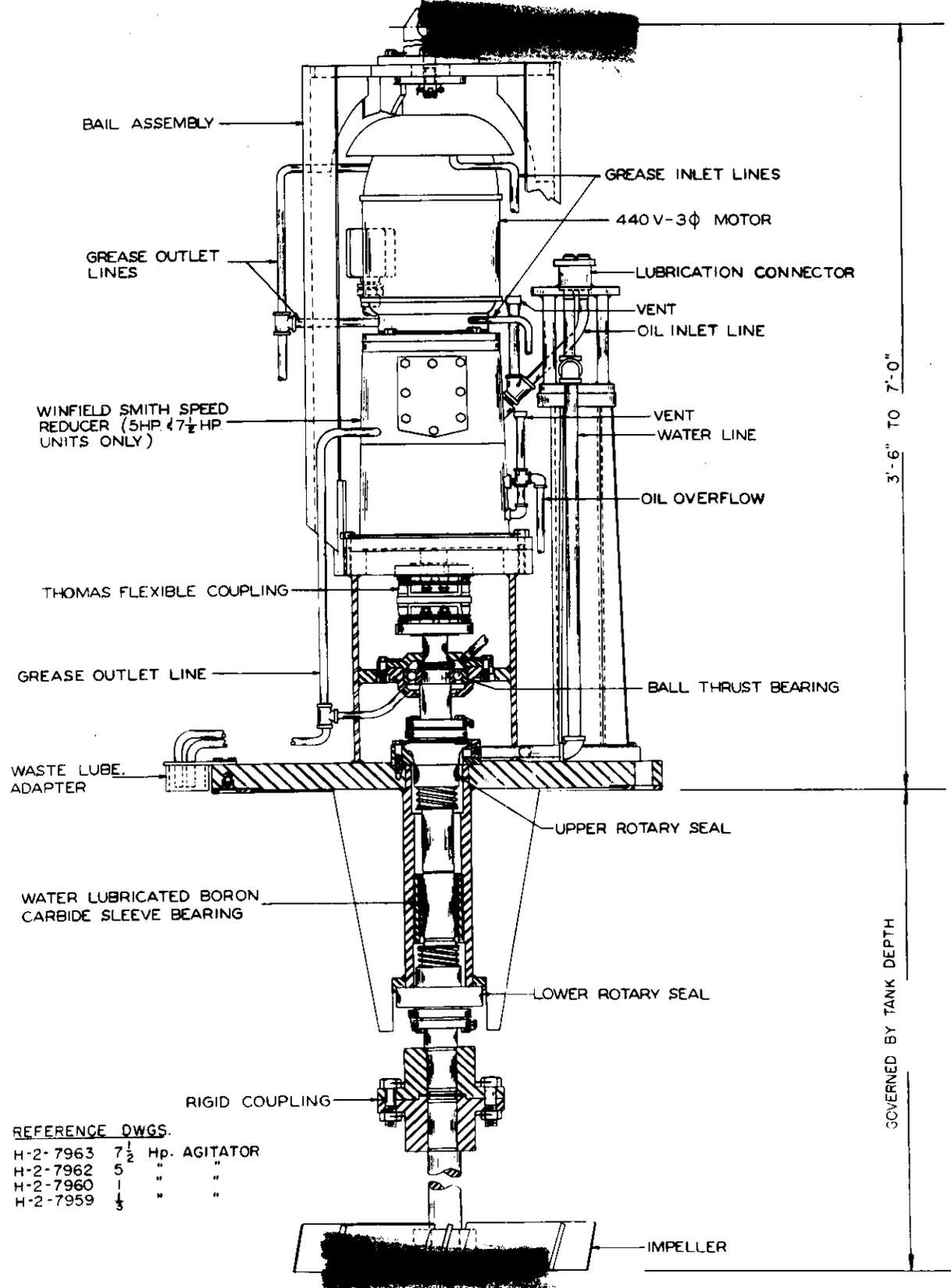
DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**



DECLASSIFIED

Figure XVI-3
TYPICAL AGITATOR



REFERENCE DWGS.

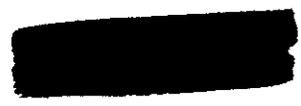
H-2-7963	7 1/2	HP.	AGITATOR
H-2-7962	5	"	"
H-2-7960	1	"	"
H-2-7959	1/3	"	"

GOVERNED BY TANK DEPTH

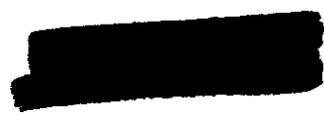
914

HW-18700

DECLASSIFIED



**THIS PAGE
INTENTIONALLY
LEFT BLANK**



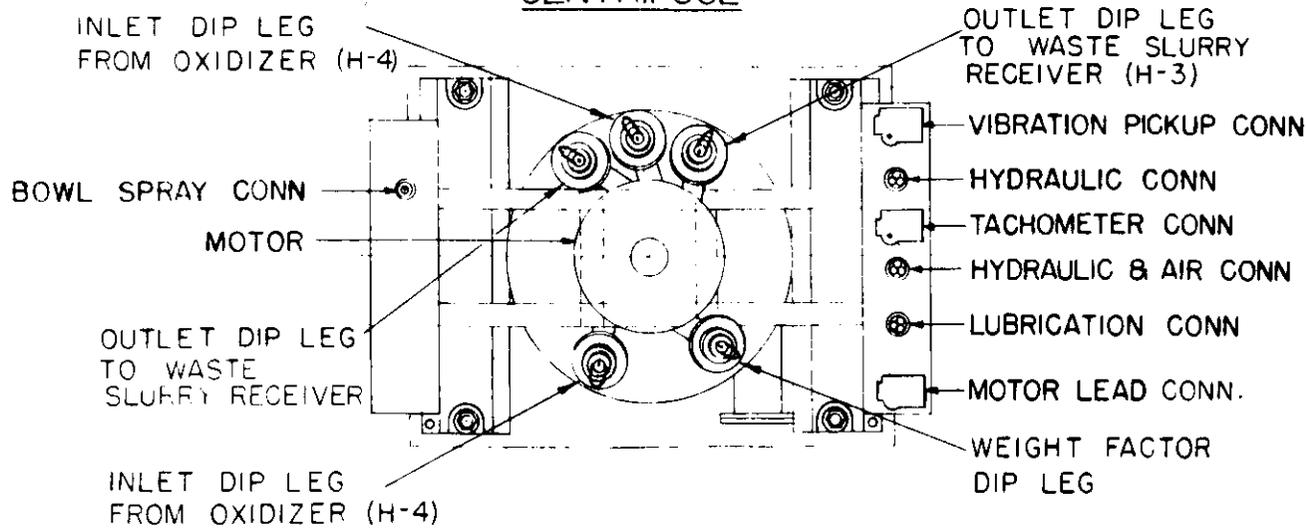
DECLASSIFIED

DECLASSIFIED

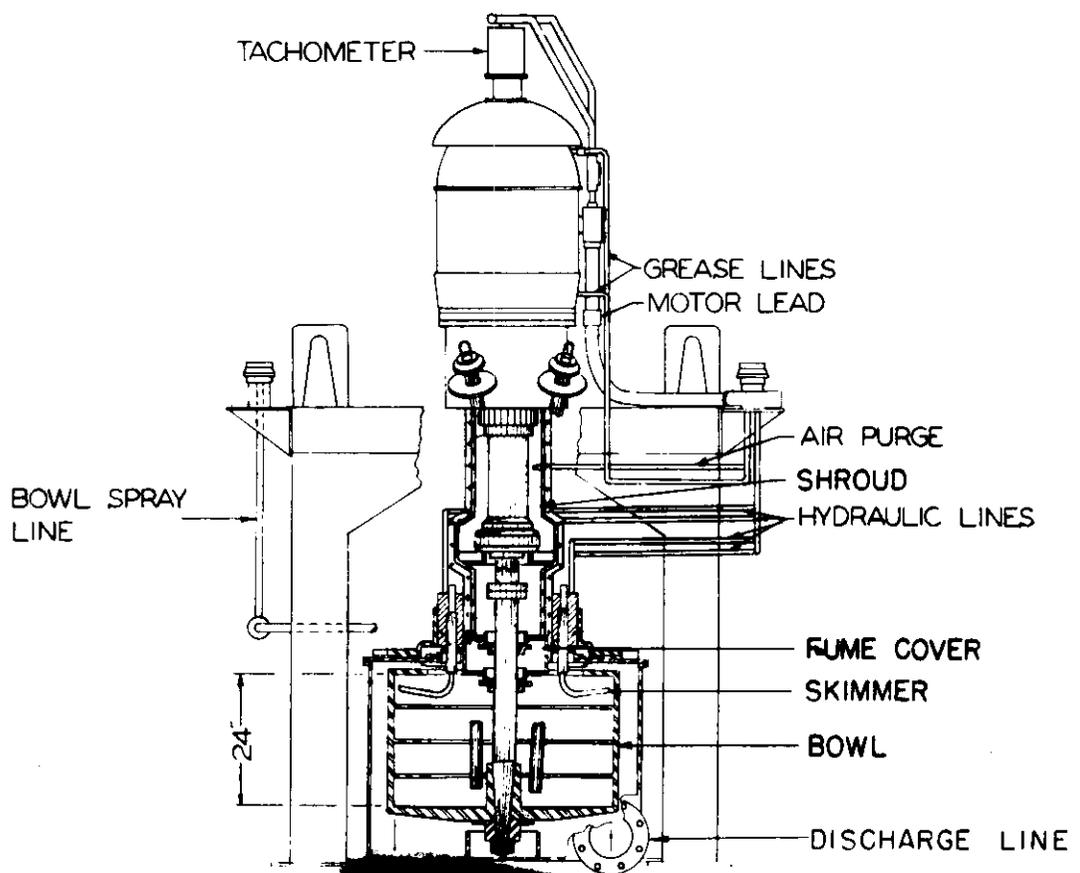
HW-18700

915

H-4
CENTRIFUGE



— PLAN —



DECLASSIFIED

914

HW-18700



DECLASSIFIED

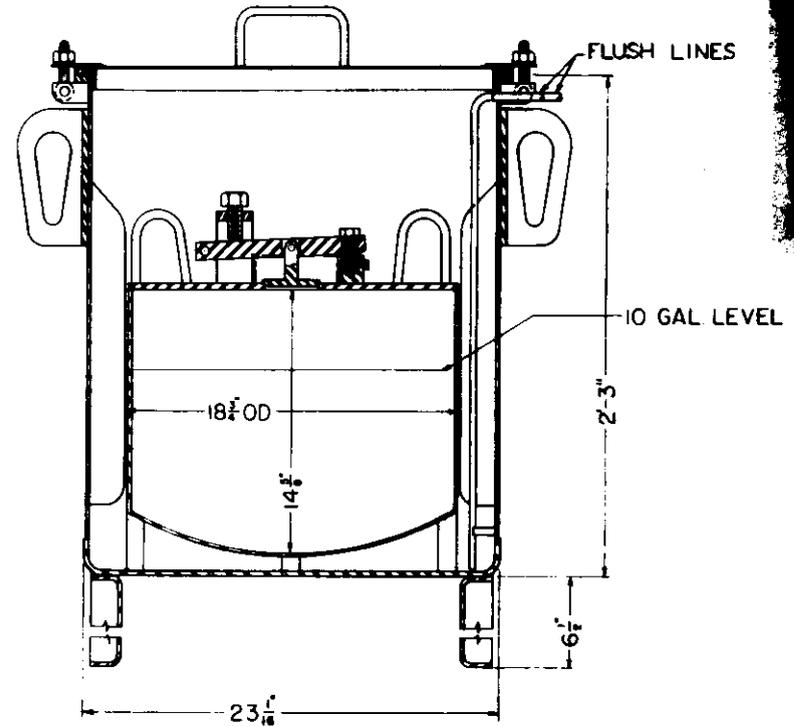
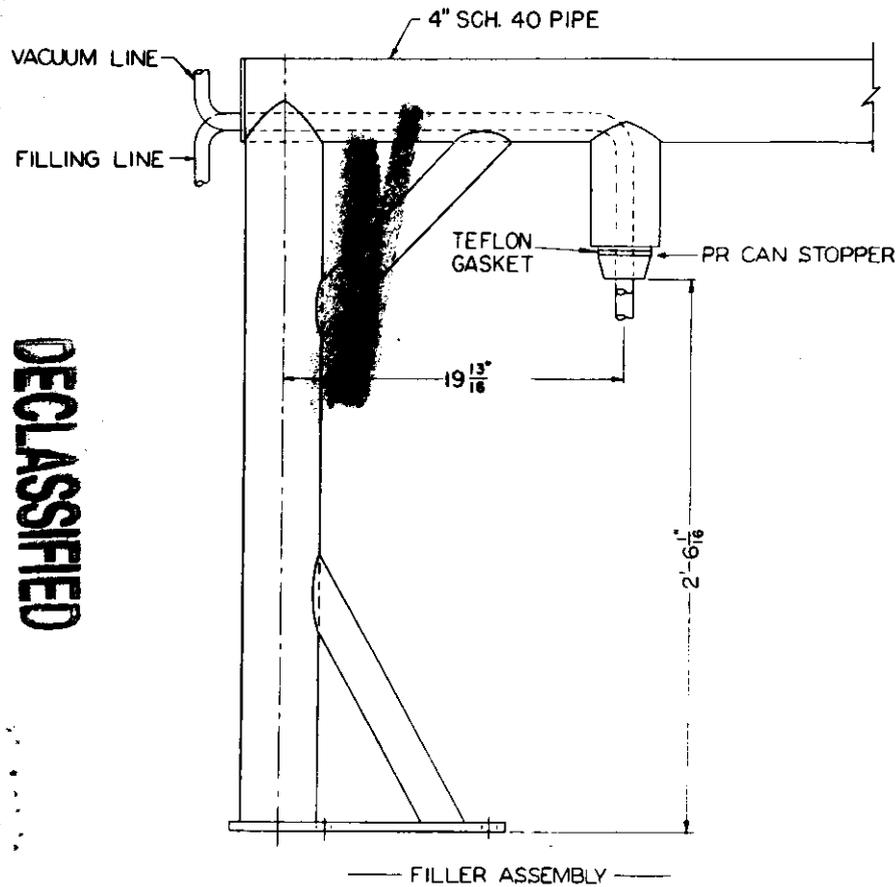
THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

Figure XVI-5

PR CAN, CONTAINER AND FILLER ASSEMBLY



DECLASSIFIED

DECLASSIFIED

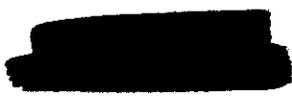
HW-18700
Fig. XVI-5

917

918

DECLASSIFIED

HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

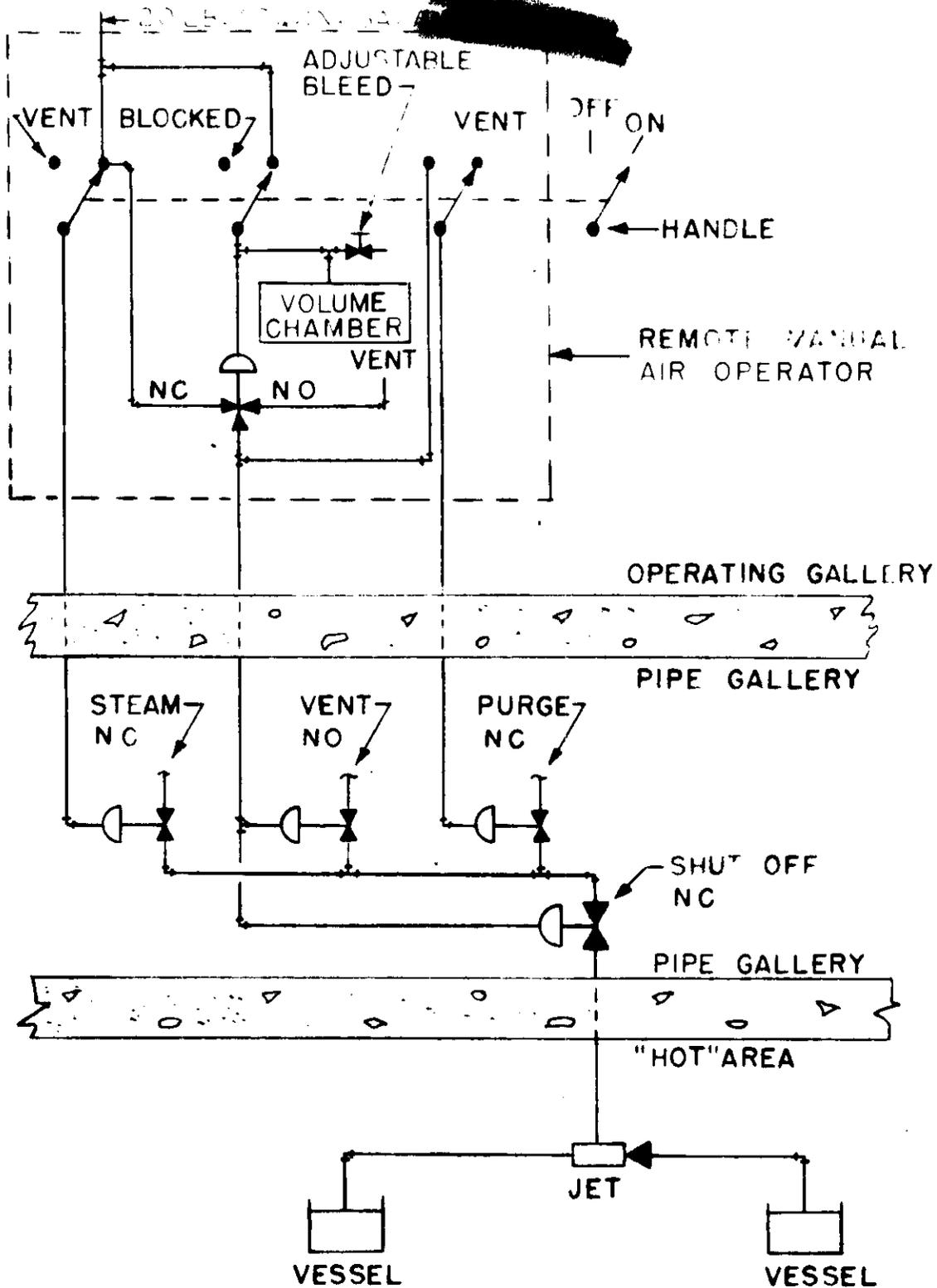


DECLASSIFIED

HW-18700 919

Figure XVI-6

GALVANIC VALVES



NC - NORMALLY CLOSED
 NO - NORMALLY OPEN

DECLASSIFIED

920

HW-18700

DECLASSIFIED



**THIS PAGE
INTENTIONALLY
LEFT BLANK**

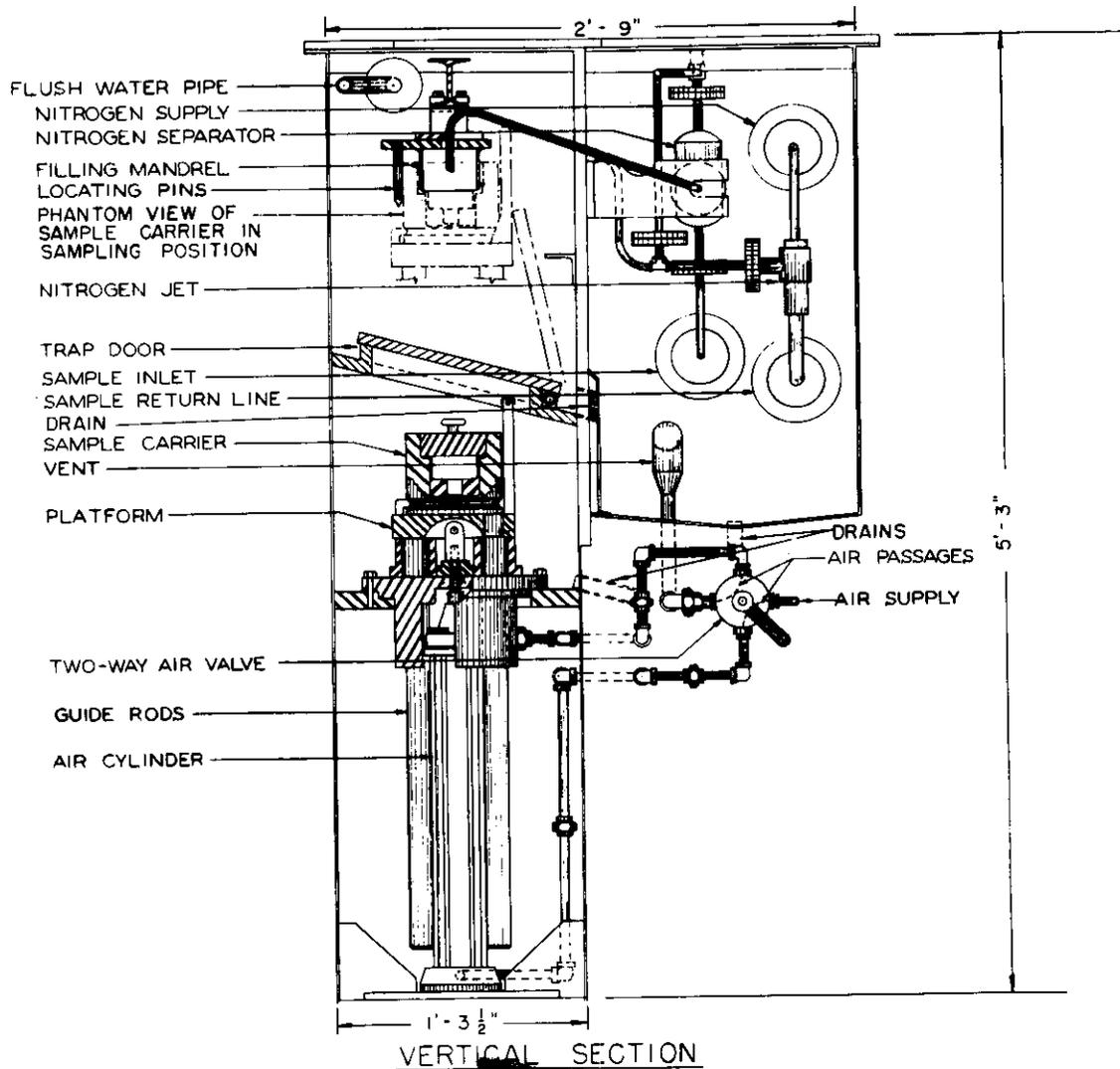
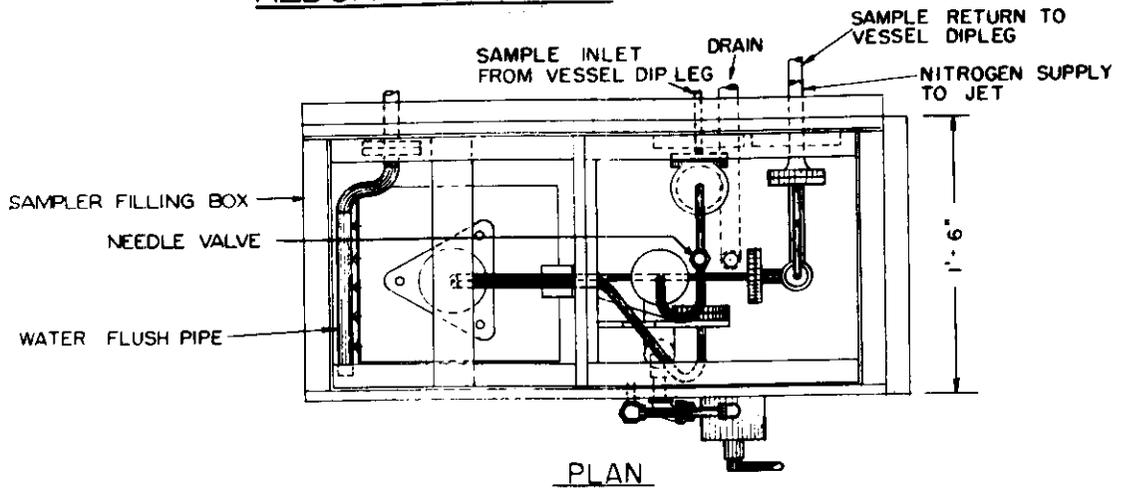


DECLASSIFIED

DECLASSIFIED

921
HW-18700

Figure [REDACTED]
REDOX SAMPLER



DECLASSIFIED

922

SECRET

HW-18700



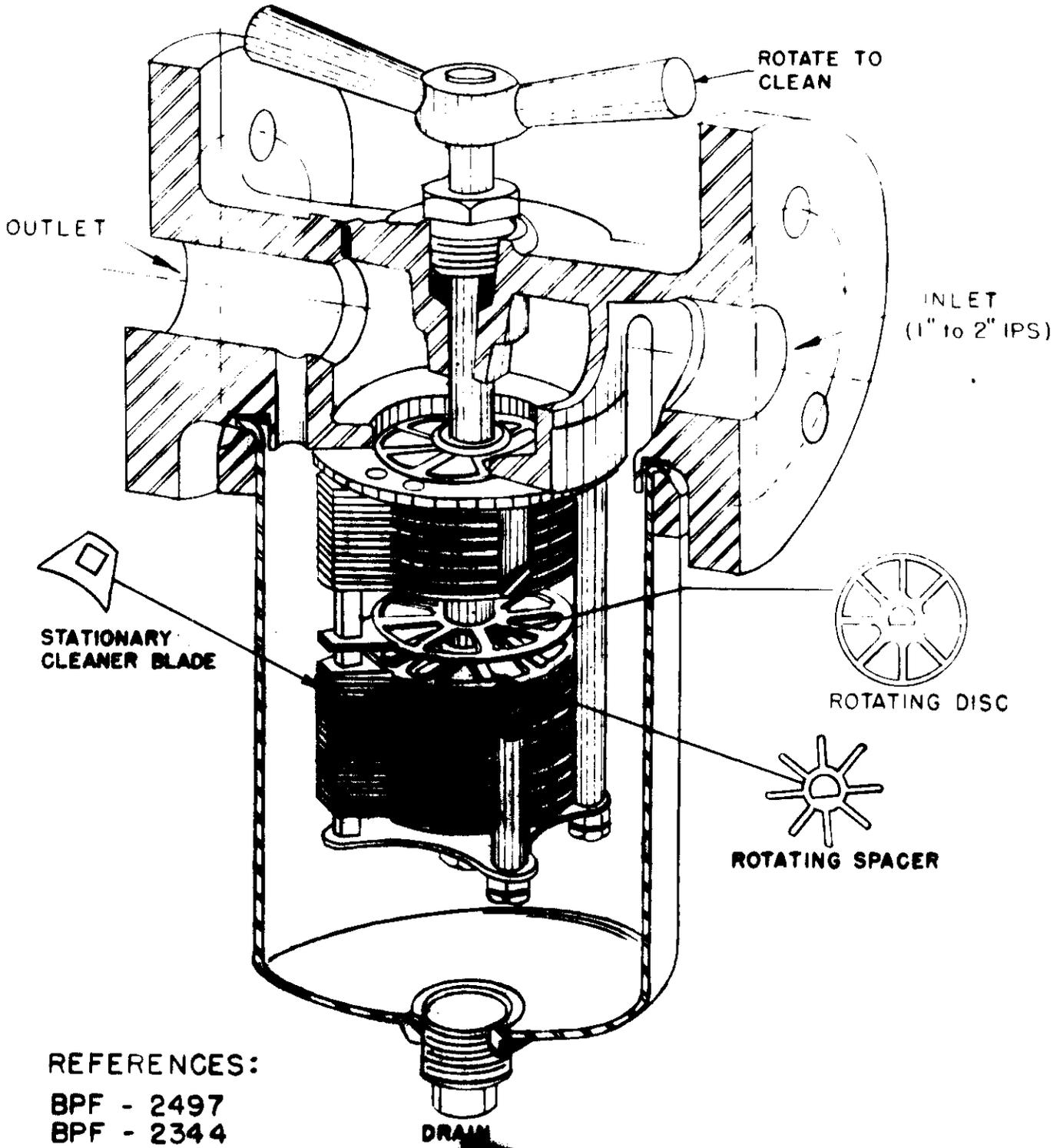
DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

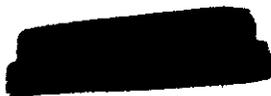
VI 8
DISC-TYPE STRAINER



REFERENCES:
BPF - 2497
BPF - 2344

924

HW-18700



DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**

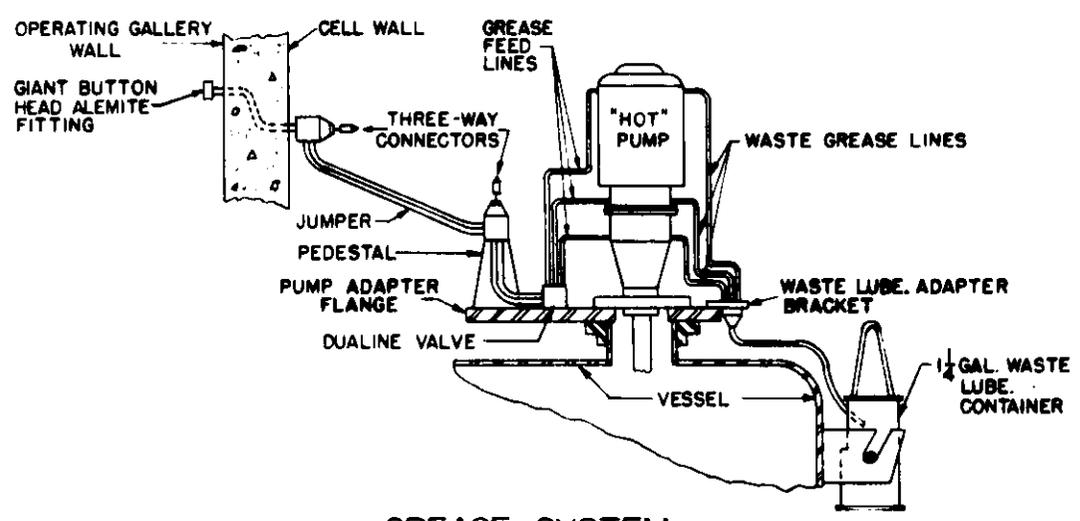


DECLASSIFIED

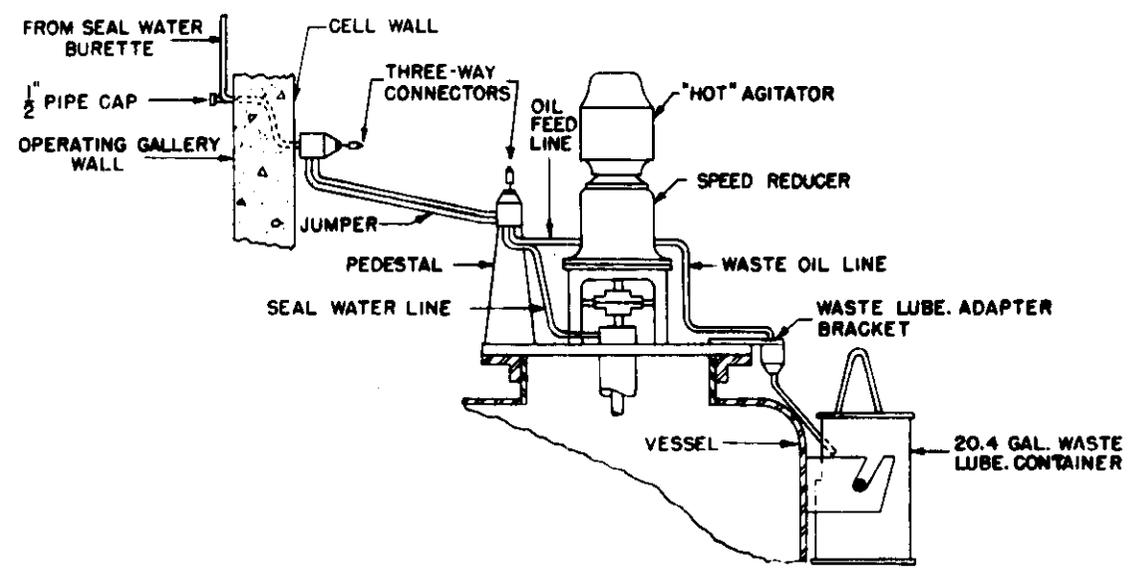
DECLASSIFIED

HW-18700

Figure XVI-9
REMOVAL OF LUBRICATING SYSTEM



GREASE SYSTEM



OIL AND SEAL WATER SYSTEM
DECLASSIFIED

924

DECLASSIFIED

HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

PART II: PLANT AND EQUIPMENT, continued

CHAPTER XVII. PUMPS AND JETS

<u>CONTENTS</u>	<u>Page</u>
A. "HOT" SERVICE PUMPS	1702
1. Basis of Selection and Design	1702
1.1 General requirements	1702
1.2 Metering pumps	1702
1.3 Rotodynamic pumps	1703
2. Regenerative Turbine Pump	1704
2.1 Theory of operation	1704
2.2 Effect of variables on pump performance	1704
2.3 Adaptation of the regenerative turbine pump	1705
3. Process Requirements for "Hot" Service Pumps	1706
4. Description of Production Units	1706
4.1 Pumps	1706
4.2 Torque tube and shaft	1708
4.3 Bearings	1708
4.4 Vapor seal	1710
4.5 Motor and coupling	1711
4.6 Mounting and interchangeability	1711
B. "COLD" SERVICE PUMPS	1712
1. Basis of Selection and Design	1712
2. Single-Stage Pumps	1712
2.1 Requirements	1712
2.2 Description	1712
2.3 Performance and operation	1713
3. Double-Stage Pump	1714
3.1 Requirement	1714
3.2 Description	1714
3.3 Performance and operation	1714
C. JETS	1715
1. Function	1715
2. Types and Performance Characteristics	1715
3. Operation.....	1715
REFERENCES	1716

928 [redacted]

CHAPTER XVII. PUMPS AND JETS

A. "HOT" SERVICE PUMPS

1. Basis of Selection and Design

1.1 General requirements

Equipment which is employed in the handling of "hot" process solutions in the Redox Plant has been designed to conform to a number of special requirements which are intended to minimize the possibility of spreading contamination in the building and facilitate the handling of equipment if replacement becomes necessary. The requirements upon which the selection of "hot" pumps is based are enumerated and discussed below:

- (a) Performance: The pump capacity and head must be sufficient to satisfy the requirements of the process.
- (b) Materials of construction: The materials of construction must resist corrosion by process fluids and vapors.
- (c) Length of service: The pump is expected to operate for at least one year without maintenance and without significant change in performance characteristics.
- (d) Leakage: The pump must either be entirely leak-proof or must be mounted in such a location that leakage of process fluid is contained within the vessel from which the fluid is pumped.
- (e) Size: The pump must be compact and possess a geometry consistent with the requirements of remote handling.
- (f) Strength: The pump must possess sufficient strength to resist the shocks and impacts which occur during remote handling.
- (g) Drainability and flushability: The pump must be drainable. Pockets or traps which retain process fluids and are difficult to flush are undesirable.
- (h) Other restrictions: The lack of bottom outlets on process tanks usually demands that the process pumps be submerged within the tank. An externally mounted pump must be completely leak-proof and possess a suction lift equivalent to the depth of the tank.

1.2 Metering pumps

Many of the "hot" process streams must be pumped at a controlled rate of flow. In the interest of economy of equipment and reduction in the complexity of flow control instrumentation, the most desirable type of "hot" pump for the Redox process would be a metering or volumetric displacement pump which delivers a constant, reproducible flow rate at a given speed. Flow control would be achieved by controlling the speed of the drive motor.

The moving elements of metering pumps may be vanes, gears, pistons, screws, or flexible diaphragms. Constant volumetric delivery depends on the maintenance of critical clearance relationships between moving and stationary parts or upon the leak-free operation of check valves.

An evaluation of the performance and reliability of many conventional metering pumps led to the conclusion that the successful development and application of a metering pump which would meet all the specified requirements for a "hot" process pump was not feasible within the time available for a development program. Thus, the development of flow-generating pumps and associated flow control instrumentation was stressed in preference to metering pumps. The flow control instrumentation employed in conjunction with the flow-generating pump is described in Chapter XIX.

1.3 Rotodynamic pumps (1)

A rotodynamic pump, as distinguished from a metering or positive displacement pump, is characterized by the use of a wheel or rotor whose rotating blades or vanes impart tangential acceleration to a liquid flowing through the pump. The motion is continuous without reversal of direction. Rotodynamic pumps have the following desirable features: (a) proven reliability and long life; (b) rugged construction with a minimum of moving parts; (c) readily fabricated from corrosion-resistant materials; and (d) flexibility in performance.

Centrifugal and regenerative turbine pumps are rotodynamic pumps. A standard centrifugal pump is essentially a "low head" pump; i.e., the maximum head against which the pump will deliver fluid is relatively low. In order to develop a greater head in a centrifugal pump it is necessary either to increase the impeller diameter or to employ multiple pumping stages in series. Either alternative increases the size of the pump.

The regenerative turbine pump has a capacity which is approximately the same as that of a centrifugal pump of similar size; but, because of the design of the impeller and volute channels, the regenerative turbine pump develops a higher discharge head. In the Redox process the flow rates are relatively low and the head requirements are generally higher than the discharge heads produced by a single-stage centrifugal pump of reasonable size. The regenerative turbine pump being ideally suited to such requirements has been selected for use in the Redox process.

Figure XVII-1 illustrates the performance characteristics (i.e., head vs. capacity, horsepower vs. capacity, and efficiency vs. capacity) of a standard centrifugal pump and a regenerative turbine pump having similar impeller diameters and operating at the same speed (1750 rev/min.).⁽²⁾ The maximum head developed by the regenerative turbine pump is several times that developed by the centrifugal pump, while the efficiencies of the two pumps are similar. The turbine pump requires maximum horsepower at maximum head (no flow), while the centrifugal pump requires maximum horsepower at maximum flow. Rotodynamic pumps have no dry suction lift and are not self-priming. Once primed, rotodynamic pumps have a suction lift which is a function of pump design.

930 [REDACTED]

DECLASSIFIED

2. Regenerative Turbine Pump

2.1 Theory of operation

A turbine, or regenerative, pump (sometimes called a peripheral pump) is a rotodynamic pump so designed that it can develop several times the pressure obtained from a centrifugal pump having equal impeller diameter and operating at the same speed. In the turbine pump, liquid flows into the volute channel which surrounds the impeller vanes (or blades) which are located on both sides of the impeller at the periphery. The entering fluid recirculates between the rotating vanes. Consequently, energy supplied to the liquid is the result of a number of impacts, or impulses, imparted by the impeller vanes as the liquid travels the comparatively long distance (nearly one revolution) from the suction to the discharge ports of the pump. A partition (or dam), which separates the suction and discharge ports in the turbine pump, prevents fluid by-passing between the high and low-pressure sides of the pump. Figure XVII-2 is a sectional view of a typical regenerative pump and shows the arrangement of the component elements of the pump.

The impulses given to the liquid by the blades of the turbine impeller are comparable to the multistaging of centrifugal pumps. The number of impulses given to the liquid by the blades of the impeller depends on the fluid flow rate and the speed of rotation. Pressure developed in the volute chamber of the turbine pump is variable, being a maximum at the discharge port and a minimum at the suction port.

2.2 Effect of variables on pump performance⁽³⁾

Two types of variables, i.e., design and operating, affect the performance of turbine pumps. Design variables which affect the pump performance characteristics are impeller diameter and speed. Although other design variables, such as the cross-sectional area of the volute channel and the number and geometry of the impeller teeth, affect pump performance, the relationships existing between the variables are empirical and cannot be expressed concisely in simple form. Operating variables which affect pump performance include fluid density and viscosity.

2.21 Design variables

- (a) Capacity: In general, the capacity of a turbine pump is proportional to the impeller speed and the square of the impeller diameter.
- (b) Discharge head: The discharge head of a turbine pump is proportional to the square of the speed and the cube of the impeller diameter.
- (c) Horsepower: The brake horsepower of a turbine pump is proportional to the cube of the impeller speed.
- (d) Efficiency: The efficiency of a turbine pump cannot be expressed in terms of simple relationships. In general, pump efficiency

[REDACTED]

DECLASSIFIED

is a function of a number of energy losses which include (1) friction in bearings and seals, (2) impeller and shaft hydraulic friction, (3) leakage loss between high and low-pressure areas in the pump, and (4) hydraulic losses due to friction and eddying.

2.22 Operating variables

- (a) Density: At constant impeller speed, the discharge head, in feet of pumped fluid, and the pump capacity are independent of the density of the pumped fluid. The discharge pressure, in lb./sq.in., and the power required to drive the pump are proportional to the density of the pumped fluid, at constant impeller speed.
- (b) Viscosity: No simple relationship between pump performance and the viscosity of the fluid pumped can be expressed. In general, an increase in viscosity decreases the pump efficiency and discharge head, at a given capacity and speed.

2.3 Adaptation of the regenerative turbine pump

The regenerative turbine pump was selected as the "hot" pump for the Redox Plant because of the above-mentioned desirable features and characteristics. In order to meet the special requirements necessitated by the nature of the process, the turbine pump was adapted to submerged operation in the bottom of the vessel from which process fluid is pumped. A typical pump assembly, showing the arrangement of the various elements, is shown in Figure XVII-3. The submerged pump assembly consists of a regenerative turbine pump mounted vertically on the lower end of a vertical extension or torque tube. For any particular vessel in which a submerged pump is required, the length of the torque tube is specified so that the suction inlet of the pump is near the bottom of the vessel when the extension tube is suspended vertically in position on the nozzle of the vessel. The pump is driven by a vertical drive shaft which extends concentrically through the torque tube. The pump impeller is mounted on the lower end of the drive shaft which is supported by means of a ball thrust bearing located above the mounting flange of the assembly. A flexible coupling connects the stub shaft of the vertical, flange-mounted, 1750 rev./min., electric driving motor with the upper end of the drive shaft. All metallic elements of the pump assembly, that are in contact with process fluid, are fabricated from 300-series stainless steel. The drive shaft is guided by means of sleeve bearings located in the pump on either side of the impeller, and by a sleeve bearing at the mid-point of the torque tube for those cases where the shaft length exceeds 5 ft. 10.5 in. The sleeve bearings, consisting of boron carbide bushings and stellite journals, are force-lubricated by process fluid by delivering a portion of the discharge stream from the pump to the bearings through grooves, channels, and holes provided in the pump casing, torque tube, and bearing retainers. The pump discharge line, mounted vertically beside the torque tube, extends upwards through the mounting flange to the male half of a remote connector. A water-lubricated, double, rotary seal is employed to seal the shaft at the point of exit from the top of the torque tube. The seal prevents process vapors within the vessel from contaminating the atmosphere in the cells.

932 [REDACTED]

The pump discharges process solution through a transmitting rotometer which sends an electrical signal proportional to the flow rate to a recorder-controller. The controlling element of the recorder-controller sends an air signal to a Hammel-Dahl throttling valve located in the pump discharge line.

3. Process Requirements for "Hot" Service Pumps

Seventeen "hot" service pumps are required in the Redox process. Sixteen of the pumps handle "hot" process solutions. One pump, G-1, handling neutral hexone, is classified as a "hot" pump because it is located in the canyon area of the 202-S Building. Three of the seventeen pumps, i.e., Pumps P-A3, P-B3, and P-C3 were scheduled to pump 40 per cent NaOH to the Dissolver Off-Gas Scrubbers, A-3, B-3, and C-3. A silver reactor (for details see Chapter III, Feed Preparation, and Chapter XVI, Other Process Equipment) will replace the scrubber for the removal of radioactive iodine. The caustic scrubbers will be held for installation in another location if it becomes necessary to remove oxides of nitrogen.

The "hot" process streams vary in flow rate from less than 1 gal./min. to 50 gal./min. and have a range of head requirements from 16 to 164 feet. (Head, in feet, refers to head, in feet, of pumped fluid. A rotodynamic pump delivers the same head of fluid at constant speed and viscosity, regardless of density. Horsepower is affected by density of the pumped fluid.) This range of head and flow requirements are satisfied with two pump designs. The T-50-428 pumps (fifteen required) have a nominal capacity of 25 gal./min. and the T-50-566 pumps (two required) have a nominal capacity of 50 gal./min. Table XVII-4 lists the important features of the seventeen "hot" pumps. Because of the different shaft lengths resulting from variations in the height of the process vessels, nine spare pumps are required to insure continuity of process operation in the event of a pump failure. In determining the number of spare pumps required, the seventeen pumps are divided into seven groups based on the seven different shaft lengths required. One spare pump is provided for each group. The two pumps with a nominal capacity of 50 gal./min. both fall in the group of five pumps with shaft lengths of 9 feet 8-1/2 inches. Thus, in this group, two spares are provided: one with a nominal capacity of 50 gal./min.; the other with a nominal capacity of 25 gal./min.

4. Description of Production Units⁽⁴⁾

An assembly drawing of a typical Redox pump is shown in Figure XVII-3. The component parts of the assembly are described below. The pumps were built and assembled by the Peerless Pump Division of the Food Machinery Corporation.

4.1 Pumps

4.1.1 Function

The pumps serve to generate a flow of process fluid to a process installation, e.g., a solvent-extraction column. A continuous, controlled flow at the specified operating conditions is necessary for the efficient operation of the process. Two pump sizes are required to cover the range

of head and flow required by the process. The two sizes, nominally rated at 25 gal./min. and 50 gal./min., differ only in the thickness of the impeller blades at the teeth and the cross-sectional area of the liquid channel surrounding the impeller teeth.

4.12 Description

The pump consists of the multivaned impeller together with the suction and discharge heads containing the channel sections and dam. The sectional view of the entire pump assembly, shown in Figure XVII-3, is supplemented by a cutaway view, Figure XVII-2, illustrating the action and functions of the impeller, channels, and dam. Each head is fitted with a bearing and spacer ring. The assembled heads have a maximum diameter of 7.5 in. and are fabricated from cast, Type 347, stainless steel. Liquid enters the pump axially through a 1.5-in. suction pipe, 3 in. long (6 in. in the E-5 and E-6 Pumps), in the bottom of the suction head, and is discharged vertically upward through a 1.25-in. i.p.s. discharge line in the discharge head. Spacer rings of carbon-filled fluorothene-B (60% carbon), furnished by Carbide and Carbon Chemical Company (Graphitar No. 2 in the case of P-A3, B3, C3 and spare, P-H5 and spare, and P-G1 and spare), maintain a clearance of 0.005 in. between the ring faces and the impeller side faces. The rings, pressed and pinned into each pump head, restrict by-passing of fluid. The dam or partition which separates the suction and discharge ports is cast integrally with the pump casing. The clearance between the outer edge of the impeller periphery and the concentric, convex arc of the dam is 3.5 mils. All of the pumps have 5-in. diameter, Type 347, stainless steel impellers. The nominally-rated 25-gal./min. pumps have impellers that are 0.375 in. thick at the blades, and the 50-gal./min. pumps have impellers that are 0.5185 in. thick. The impeller is keyed to the drive shaft and is free to move axially with respect to the shaft. Total axial movement of the impeller is restricted to 0.005 in. by thrust faces on the ends of the impeller hub. These thrust faces act against the ends of the bearings which are shrunk-fit into each pump head. (See paragraph A4.3, this chapter, for bearing details.) The thrust faces are lubricated by solution which is force-fed to the center of each bearing and subsequently discharged across the thrust faces.

4.13 Operation and performance

The performance characteristics (head vs. capacity) of the two pump sizes are shown in Figure XVII-5. The curves were obtained using water as the pumped fluid. Process fluids having different densities and viscosities will affect the performance characteristics of the pump as discussed in paragraph A2.2, this chapter. The Redox regenerative turbine pumps have no dry suction lift and are not self-priming. Inherent design features of the pump require that the pumped fluid be free of solid material. The pump impeller is free to move axially on the drive shaft and has an open web between the hub and teeth to equalize the pressure on the two sides of the impeller. This design allows the impeller to assume a position of hydraulic balance and allows for expansion and contraction of the drive shaft. With a blocked discharge, approximately 3500 B.t.u./hr. are theoretically evolved by the 25-gal./min. pump and 8000 B.t.u./hr. by the 50-gal./min. pump when pumping water (specific gravity of 1). The heat evolved when pumping process solutions is tabulated in Table XVII-4.

934

DECLASSIFIED

4.2 Torque tube and shaft

4.21 Function

The torque tube positions and supports the pumps within the process vessels. The length of the torque tube is governed by the height of the process vessel. The pump drive shaft extends concentrically through the torque tube. Although the torque tube provides adequate rigidity to the pump assembly during normal handling and operation, care must be exercised to prevent undue shock and strains which might destroy the critical alignment of the component elements of the pump assembly.

4.22 Description

The torque tube is fabricated from 2-in. i.p.s., Type 347, stainless steel pipe with a welded flange at either end. The upper end of the torque tube is bolted to the mounting flange and the lower end of the torque tube is bolted to the pump. The length of the torque tube is expressed as "set length" and is the distance from the lower face of the mounting flange to the threaded suction inlet of the pump. The set length varies according to the height of process vessel in which the pump is mounted. Seven lengths are required to accommodate the range of vessel heights. These lengths are 2 ft. 7 in., 3 ft. 6 in., 5 ft. 0.75 in., 5 ft. 10.5 in., 6 ft. 7 in., 9 ft. 8.5 in., and 11 ft. 2.25 in. Shafts which have a length greater than 5 ft. 10.5 in. require a guide bearing at the midpoint of the shaft between the lower bearings in the pump and the upper ball thrust bearing. For the pumps in which the set length is 5 ft. 10.5 in. or less, the torque tube is one-piece construction (no center guide bearing). Three, equally spaced, elongated holes, 1/2 in. by 1-1/2 in., are provided at the top and bottom of the torque tube to equalize pressure within the tube and allow circulation of the inert-gas blanket. For pumps in which the set length is 6 ft. 7 in. and greater, the torque tube is of two-piece construction, flanged in the middle to accommodate the center-guide bearing housing. Elongated holes are provided at the top and bottom of each section of torque tube.

The drive shafts have a nominal diameter of 1 in. and are fabricated from Type 347 stainless steel shafting. The journal portion of the shaft is prepared by relieving the shaft 1/16 in. and applying a Stellite No. 6 hard facing with an inert-gas-shielded electrode. The journals are then ground and polished to a surface finish of 10 microinches (root-mean-square) or better; i.e., so that the root-mean-square average height of protuberances and depth of depressions does not exceed 10 microinches (10×10^{-6} in.).

4.3 Bearings

4.31 Function

Two types of bearings are employed in the "hot" pumps to guide and support the drive shaft. The weight of the shaft is supported on a standard, grease-lubricated, ball thrust bearing, located above the mounting flange and exposed only to cell vapors. The shaft is guided by sleeve

DECLASSIFIED

bearings fabricated from boron carbide and lubricated by force-feeding a portion of the pump discharge fluid to lubrication grooves and holes provided in the bearing bushing. Boron carbide is used as a bearing material because of its extreme hardness (between 9 and 10 on Mohs' scale), chemical resistance, and demonstrated performance as a bearing material.

4.32 Description

- (a) Thrust bearing: The thrust bearing which supports the weight of the shaft is a New Departure No. 3303, single-row, deep-groove, ball bearing. The bearing is bolted into a grease chamber above the mounting flange and is lubricated remotely by means of the Farval remote lubrication system described in Chapter XVI. The recommended lubricating grease is Texaco Regal Starfak No. 2.
- (b) Sleeve bearings: Each pump has sleeve bearings on either side of the pump impeller. These bearings are mounted in the suction and discharge heads of the pump. Each bearing is 1.25 in. long with a nominal inside diameter of 0.75 in. The bearings are designed to operate with a diametrical clearance between the bushing and journal of 1.5 mils. The pump bearings are force-lubricated by feeding a portion of the pumped fluid to one or two radial holes located in the axial center of the bushing wall through a 3/16-in. diameter passageway from the high-pressure side of the pump. For single-groove bearings (see below), one hole in the bushing wall is provided. For double-groove bearings, two holes, 180° apart, are provided. Circumferential slots in the bore of the bushing housing insure a positive supply of lubricant to each hole in the bushing.

The center sleeve bearing (for pumps in which the set length is 6 ft. 7 in. or more) is 1.75 in. long with a nominal inside diameter of 1 in. The bearing is designed to operate with a diametrical clearance between the bushing and journal of 2 mils, and is force-lubricated in a manner similar to that described above for the pump bearings. The 3/16-in. diameter passageway is drilled through a bearing mounting flange from the 1.25-in. diameter discharge line. The discharge line extends vertically upward through the bearing flange and parallel to the torque tube. All sleeve bearings are fabricated from boron carbide, a product of the Norton Company, and are polished on the inside diameter, or bore, to a surface finish of 10 microinches (root-mean-square) or better.

Each center sleeve bearing is provided with two, full-length, axial, lubrication grooves on the inside diameter of the boron carbide. The grooves are located in a plane perpendicular to the plane of applied load and pass across the holes provided in the wall of the bushing. The pump bearings located in pump heads are provided with single, full-length, axial grooves. The groove is located opposite the point of applied load. Pumps E-5, E-6, E-7, and E-8 are provided with pump bearings which have two

lubrication grooves similar to those described for the middle bearing. The cross section of all the bearing grooves is a segment of a circle, 25 mils deep and 3/16 in. wide.

4.33 Operation

Sleeve bearings are designed for operation with a positive supply of process-fluid lubricant. Dry operation can only be tolerated for the short interval of time required to flood the bearings at start-up. Longer periods of dry operation, resulting from operation with a dry suction, will cause rapid bearing overheating, expansion, seizing, and failure.

4.4 Vapor seal

4.41 Function

The vapor seal is located on the mounting flange of the "hot" pumps and seals the annular space between the torque tube and the rotating shaft at the point where the shaft emerges from the process vessel through the mounting flange. The seal serves to contain process mists and vapors within the vessel and prevents excessive dilution of inert gas in the vessels which are blanketed, under reduced pressure, with nitrogen.

4.42 Description

The component elements of the seal and their relationship to each other are shown in Figure XVII-3. Essentially, the seal consists of two stationary seal rings mounted in a housing above the mounting flange, and two rotating seal rings which are mounted in housings that rotate with the shaft. A Type 304 stainless steel coil spring separates the two rotating seal housings, which are free to move axially on the shaft, and exerts a force of approximately 10 pounds against the seal faces. The seal rings are fabricated from boron carbide (Norton Company), and are 5/32-in. wide (0.629 sq. in. area) at the face. The seal faces are lapped to a flatness of 1 to 2 light bands and a surface finish of 5 microinches (root-mean-square) or better. Each seal ring is set into a Kel-F (polymerized monochlorotrifluoroethylene) cup which is in turn pressed into the stainless steel housings. Rotation of the seal ring within the cup and the cup within the housing is prevented by raised ribs molded on the Kel-F cups which fit into slots in the seal rings and housings.

The rotating seal-face housings are provided with two 1/4-in. diameter pins which engage slots in a shaft sleeve surrounding and rotating with the shaft. A tight seal is maintained between the shaft sleeve and the seal housing, which is free to move axially on the sleeve, by means of Teflon, chevron-type rings.

The seal is cooled and lubricated by a static head of water which is introduced into the seal housing between the upper and lower seal faces through a 1/2-in. i.p.s. line entering the housing slightly above the elevation of the upper seal faces. Air trapped in the seal housing is vented through the 1/2-in. line which has a minimum slope of 3/16 in./ft. The seal-water line extends from the pump, through a wall jumper to the

Operating Gallery, and terminates in a calibrated burette which is used to measure seal leakage.

4.43 Operation

The seal is designed for operation with water as a lubricant. Dry operation of the seal for short periods will result in excessive heating at the rotating seal faces, fusion and charring of the Kel-F cups, and ultimate seal failure. The rate of seal leakage is measured by observing the change of liquid level in the calibrated burette which is located in the Operating Gallery. It is assumed that all seal leakage enters the process vessel. The total, tolerable, seal leakage into a process vessel is 1/2 gal./day (80 ml./hr.). A properly operating seal will have a seal leakage rate of less than 10 ml./hr. The seals have a demonstrated leakage, on installation, of less than 15 ml./hr. Excessive seal leakage may be caused by dirt or grit between the seal faces. Starting and stopping the pump several times may remove the dirt and return the seal-leakage rate to an acceptable value. The water-supply burette should be monitored regularly with radiation detection instruments because of the direct connection to the "hot" area of the plant.

4.5 Coupling and motor

4.51 Function

A flexible coupling connects the drive shaft of the pump to the motor shaft. A flexible coupling is employed in order to reduce the possibility of bearing wear resulting from misalignment between the shaft and motor due to shock, impact, or mishandling of the assembly during shipping or installation. The driving motor meets Class 1, Group D, National Bureau of Fire Underwriters specifications for the electric motors operating in hazardous areas. This classification is necessary because of the presence of hexone vapors in the cells.

4.52 Description

- (a) Coupling: The coupling is an all-metal (carbon steel) Thomas flexible coupling and is painted with Amercoat No. 23.
- (b) Motor: The driving motor is a 5-horsepower, 1725 rev./min., 440-volt, 3-phase, flange-mounted, vertical, Class 1, Group D, electric motor painted externally with Amercoat No. 23. The motor ball bearings are externally greased by means of the Farval remote lubrication system described in Chapter XVI. Excess grease is piped from the bearing housings to grease collectors mounted near the pumps. Regal Starfak No. 2 grease is recommended for the motor bearings.

4.6 Mounting and interchangeability

The mounting flange of the pump is bolted and gasketed to an adapter flange which is in turn bolted to the nozzle flange on the process vessel. The adapter flange, or "fried egg", is larger than the pump-mounting flange and holds the various connector halves and accessory equipment. The go-

938 [redacted]

ometry and arrangement of the adapter flange varies from vessel to vessel depending on the cell layout and equipment arrangement. The pumps are designed for as much interchangeability as the various shaft lengths and capacity requirements will allow. Any pump will fit any adapter flange. A typical arrangement of a pump and accessory equipment mounted on an adapter flange is shown in Chapter XVI, Figure XVI-9.

B. "COLD" SERVICE PUMPS (5)

1. Basis of Selection and Design

The "cold" service pumps for the Redox Plant were selected on a functional basis. The essential requirements were that (a) the pumps meet the head and capacity requirements for each intended service, and (b) the materials of construction be chemically resistant to the pumped solutions. The service conditions for each of the nineteen pumps are listed in Table XVII-6. Eighteen of the "cold" service pumps are standard, single-stage, centrifugal units and one pump is a two-stage centrifugal unit.

2. Single-Stage Pumps

2.1 Requirements

Eighteen of the "cold" service pumps are standard, single-stage, centrifugal units. These pumps range in capacity from 10 to 80 gal./min. and deliver fluid against dynamic heads ranging from 20 to 130 ft. In order to cover the wide range of head and flow required by the process, single-stage pumps, equipped with impellers ranging in diameter from 4-13/16 in. to 6-3/8 in. are employed. They are driven at speeds of either 1730 or 3450 rev./min. The speed of operation and the impeller diameters are shown for each pump in Table XVII-6.

2.2 Description

A typical single-stage pump is shown in Figure XVII-7.

2.21 Impeller, shaft, and casing

The pumps are equipped with semishrouded, single-suction impellers ranging in diameter from 4-13/16 to 6-3/8 in. The impeller is keyed and locked with double lock nuts to a one-piece, cantilever shaft. The casing is of two-piece construction, vertically split. The inboard half of the casing contains the volute channel, 1-in. flanged discharge nozzle, and stuffing-box gland. The outboard half of the casing contains the axial-flow suction inlet and 1-1/2 in. flanged suction nozzle.

2.22 Packing gland

The stuffing-box gland is provided with six rings of packing, three on either side of a lantern ring. Water may be supplied to the lantern ring through a fitting in the gland. The types of packing required for each

pump depend on the intended chemical service. The types of packing are listed in Table XVII-6. The gland follower is of the patented "Leak-collector" type which completely encloses the gland. A standard hose connection in the bottom of the follower chamber is provided to remove fluid which has leaked through the gland. The gland follower is split and may be removed without dismantling the pump.

2.23 Bearings

The cantilever shaft is supported by two single-row, deep-groove, ball bearings, which are mounted in either end of a bearing housing between the pump and the driving motor. The outboard bearing in the motor end of the housing is fixed in position and carries thrust as well as radial loads. The inboard bearing in the pump end of the housing is free to move axially in the housing to allow for any difference in expansion between the shaft and housing. The bearing housing contains an oil reservoir for bearing lubrication. The oil level is maintained just below the shaft by means of a constant-level oiler.

2.24 Material of construction

The bearing housing and base plate of each pump are fabricated from cast iron. All other metallic elements of the pumps, except the ball bearings, are made of Ircamet, which is the trade name for a variety of chromium-nickel steels. The specific composition of the Ircamet for each of the pump parts is shown below:

Part	Composition, Weight Per Cent				
	Ni	Cr	C	Cu	Mo
Casing, suction piece, impeller, gland, and seal cage	35	16	0.07	2.25	2.5
Shaft and lock nuts	29	20	--	3.25	2.5
Gland bolts	12	18	--	--	3.0

2.25 Motor and coupling

The pump shaft is driven by the motor through a flexible coupling. The totally enclosed (note exception below), squirrel-cage, induction motors which drive the pumps are energized by 440-volt, 3-phase, 60-cycle current, and have sufficient horsepower for the full capacity range of the pump. The motor speed is 1730 or 3450 rev./min., depending on the pump requirements. The horsepower and speed of each motor are listed in Table XVII-6. The motors which drive the pumps handling organic solutions (Pumps P-804-1 and 804-2,) are the same as described above except that they meet Class 1, Group D, Underwriters specifications.

2.3 Performance and operation

Table XVII-6 lists the actual head developed by each pump at the flow rate specified by the process. In addition, the head developed at no flow (shut-off) is listed. A typical head vs. capacity curve may be constructed

940 [REDACTED]

for each pump from the data given, and the flow rate at any other head readily determined.

The pressure at which the water is supplied to the lantern ring controls the amount of leakage of process fluid through the seal. The recommended water pressure is 10 lb./sq.in. greater than the pump suction pressure.

The recommended oil for use in the bearing housing is a paraffin-base oil with a 360°F. minimum flash point and a viscosity of 150 to 185 Saybolt seconds at 100°F. The oil should be changed after 800 hours of operation.

3. Double-Stage Pumps

3.1 Requirements

Five per cent nitric acid must be delivered from the centrifuge spray tank to the centrifuge nozzles at a flow rate of 10 gal./min. and a head of 230 feet. A two-stage centrifugal pump operating at 3450 rev./min. is required for this service.

3.2 Description

The two-stage centrifugal pump is shown in Figure XVII-7. The pump is essentially the same as the single-stage pumps described in paragraph B2.2 of this chapter with the exceptions which are described below.

3.21 Impeller, shaft, and casing

The two-stage pump has two shrouded impellers keyed back to back on the shaft. The pump casing is of three-piece construction, vertically split. The outboard third, or suction plate, contains the axial-flow, 1-1/2 in. i.p.s., suction nozzle. The center third of the casing surrounds and separates the impellers and contains the two volute channels and the horizontal, 1-in. i.p.s., discharge nozzle. The inboard third of the pump casing serves as a portion of the bearing cradle and contains the stuffing-box gland.

3.22 Packing gland

The packing gland contains four rings of packing and no lantern ring. The recommended packing is listed in Table XVII-6. There are no provisions for water-sealing the gland.

3.23 Motor

The pump is driven through a flexible coupling by means of a 5-horsepower, 3450-rev./min., 440-volt, 3-phase, totally enclosed, electric motor.

3.3 Performance and operation

The performance characteristics, head vs. capacity, horsepower vs. capacity, and efficiency vs. capacity are shown in Figure XVII-8 for the two-stage pump.

DECLASSIFIEDc. JETS (6)1. Function

Steam jets are used in the Redox Plant to transfer and recirculate liquids and to partially evacuate vessels. Steam jets are employed where slight dilution and heating of the fluid handled is not objectionable. Jets have the advantage of simplicity, freedom from moving parts, and compact construction.

2. Types and Performance Characteristics

Four sizes of jets are used in the Redox Plant. They are designated by their nominal liquid capacity of 3, 10, 25, and 75 gal./min. A typical jet is illustrated in Figure XVII-9. One jet, J-E21-1, evacuates 26 cu. ft. of nitrogen in 5 minutes to an absolute pressure of 20 in. Hg in the Plutonium Transfer Trap, E-21. This jet is the same nominal size as the 3 gal./min. jets. All jets are fabricated from Type 347 stainless steel.

The performance characteristics for each jet are shown in Figure XVII-10. The capacity vs. discharge pressure, suction lift, and per cent dilution of jetted fluid are shown by the curves. The steam consumption is tabulated for each jet in the legend. All data are based on a 90-lb./sq.in.ga. steam supply.

3. Operation

Steam jets are operated by 90-lb./sq.in.ga. steam supplied through on-off gang valves (see Chapter XVI for description). The operation of the jet is followed remotely by means of a microphone at the process vessel which transmits sound to a speaker in the Operating Gallery. The character of the transmitted sound is an indication of jet operation.

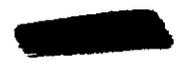
DECLASSIFIED

942



REFERENCES

- (1) Addison, Centrifugal and Other Rotodynamic Pumps, Chapman and Hall, Pp. 272-275, (1948).
- (2) Kristal and Annett, Pumps, McGraw-Hill Book Co., Pp. 116-123, (1940).
- (3) Lock et al, Theoretical Study of High Pressure Dynamic Pressure Type Fuel Pumps for Aviation Gas Turbine Engines, Thompson Products, Inc., Project Report No. NP-1192, 5-15-47.
- (4) BPF 2559, Redox "Hot" Pumps, Hanford Works.
- (5) BPF 2595, Redox "Cold" Pumps, Hanford Works.
- (6) BPF 2377, Redox Jets, Hanford Works.



DECLASSIFIED

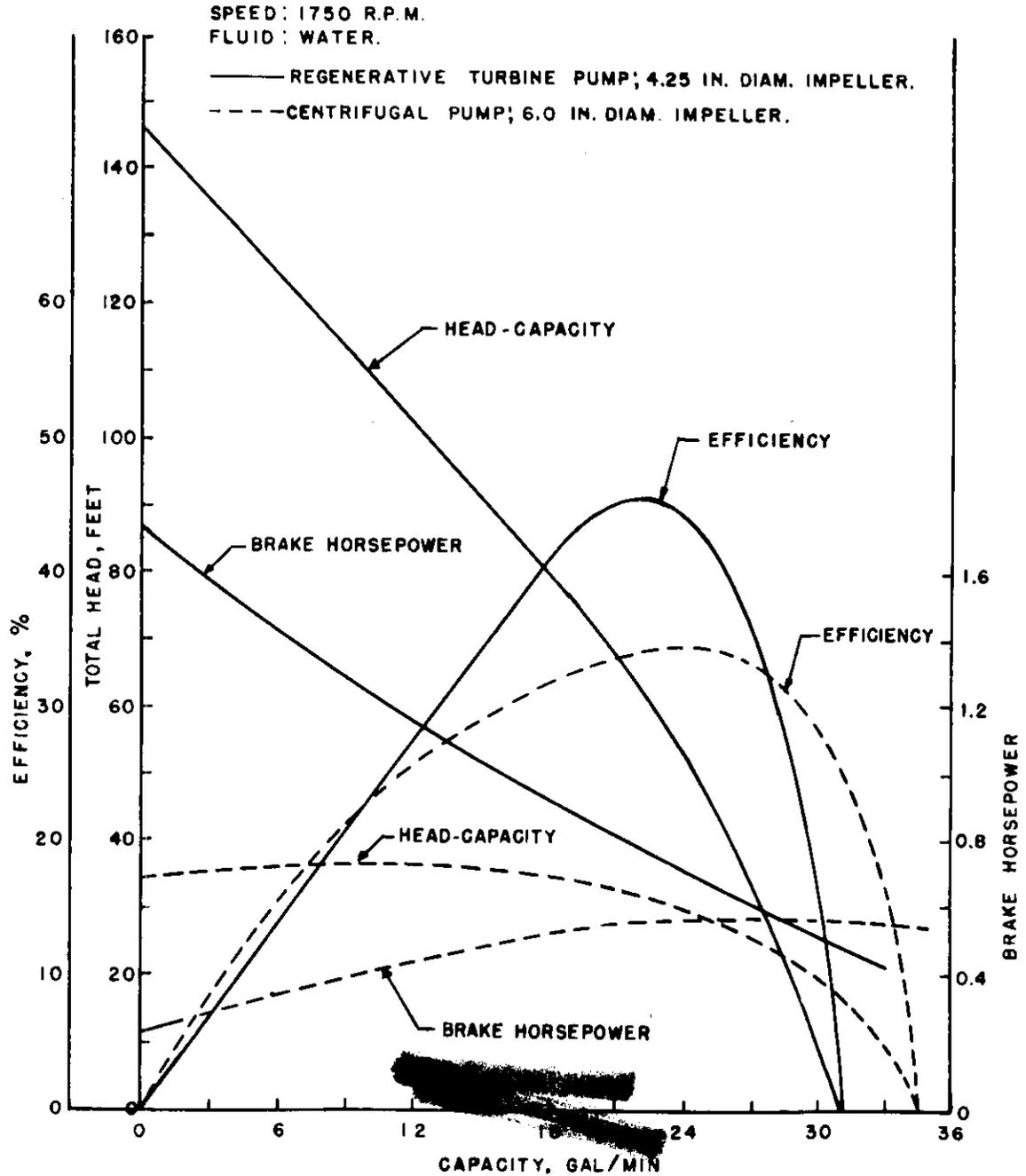
HW-18700

943

XVII-1

CENTRIFUGAL AND TURBINE PUMPS

CHARACTERISTIC CURVES



DECLASSIFIED

9421

SECRET

HW-18700

[REDACTED]

DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK

[REDACTED]

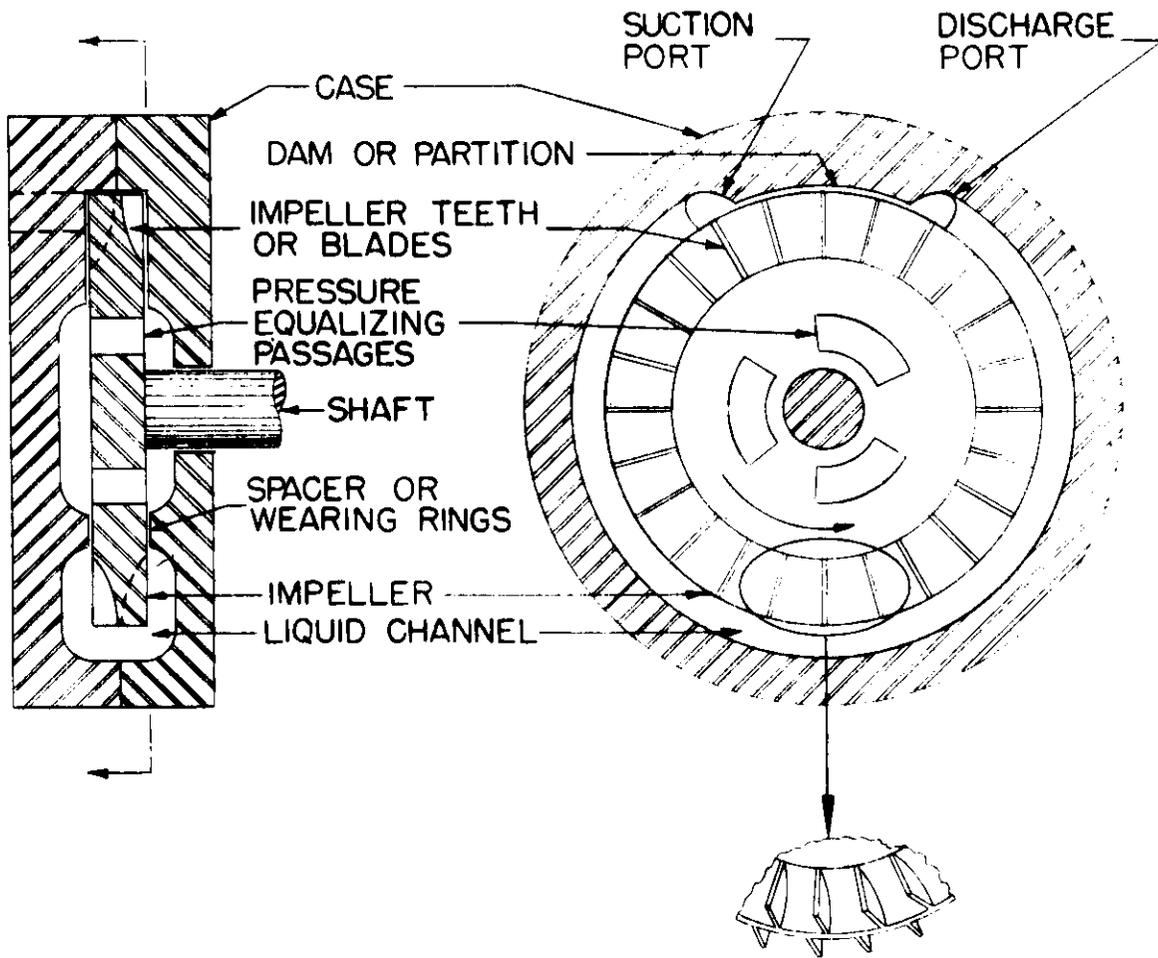
DECLASSIFIED

DECLASSIFIED

HW 1870

945

Figure XVII-2
TYPICAL REGENERATIVE TURBINE PUMP
SECTIONAL VIEW



DECLASSIFIED

946

DECLASSIFIED

HW-18700



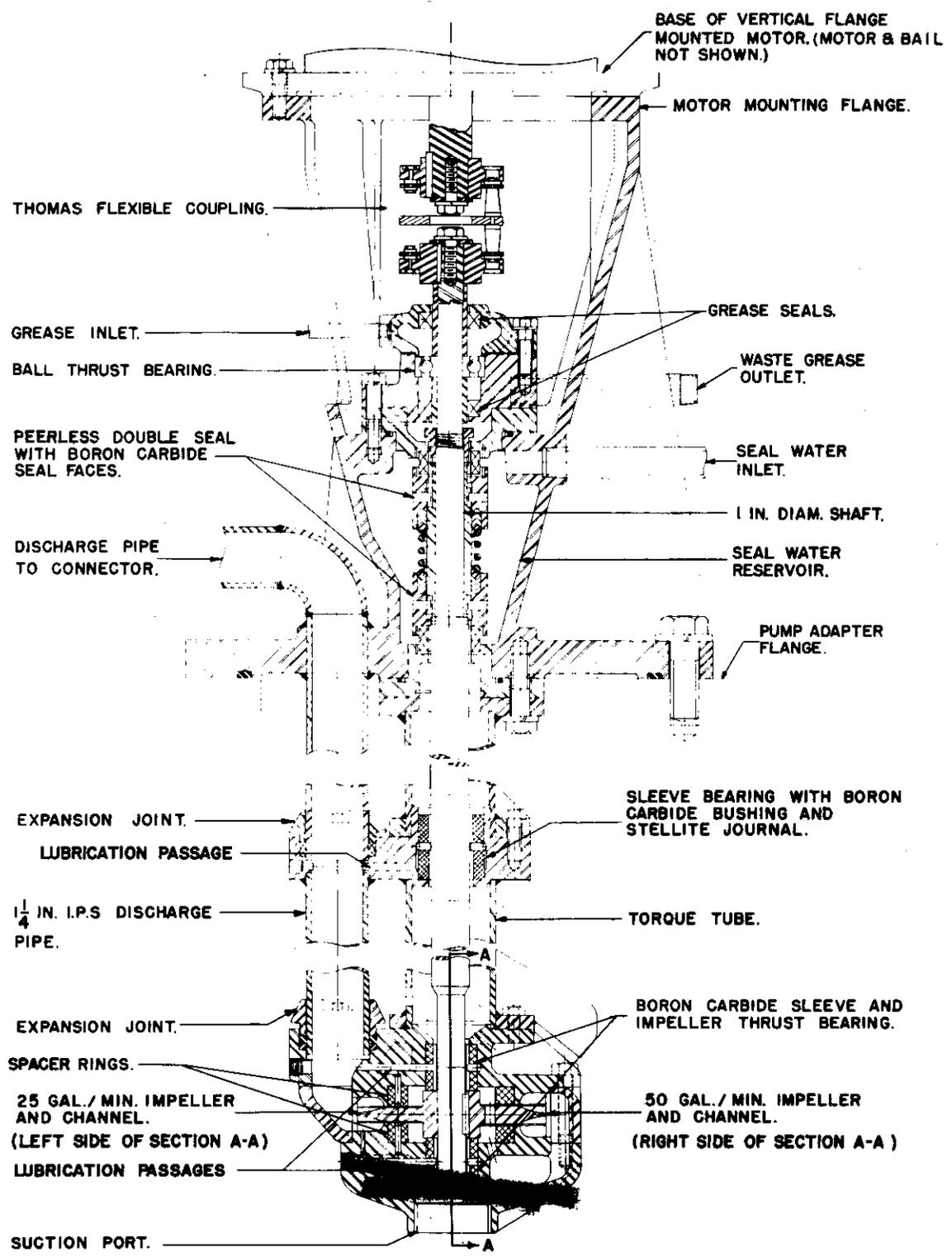
THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

947

FIGURE XVII-3
"HOT SERVICE" PUMPS



948

DECLASSIFIED

HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

TABLE XVII-4
"HOT" SERVICE PUMPS

Oper. No.	Pumps To	Soln.	Service	Mfr's. No.	Set* Length	Middle Guide Bearing	Operating Requirements		Brake Horsepower		Estimated Total Bearing Flow		Estimated Heat Developed	
							Flow Rate Gal./Min.	Head Feet	Closed Discharge	Oper. Flow Rate	Closed Flow Discharge Rate	Oper. Flow Discharge Rate	Closed Flow Discharge Rate	Oper. Flow Discharge Rate
P-A3-A	A-3-A	40% NaOH	Semi-continuous circulating	T-50-428	2'-7"	No	19	50	4.0	2.67	1.2	0.8	5300	2900
P-A3-B	A-3-B	40% NaOH	Semi-continuous circulating	T-50-428	2'-7"	No	19	50	4.0	2.67	1.2	0.8	5300	2900
P-A3-C	A-3-C	40% NaOH	Semi-continuous circulating	T-50-428	2'-7"	No	19	50	4.0	2.57	1.2	0.8	5300	2900
P-D7	F-8	28% Salt Waste	Intermittent transfer	T-50-555	9'-8.5"	Yes	50	55	7.0**	2.40	5.0	2.7	11,400**	2800
P-D13	D-12	ANN	Continuous metered	T-50-428	11'-2.5"	Yes	9.8	53	3.59	2.85	5.5	4.8	4500	3000
P-E1	Column	3AF	Continuous metered	T-50-428	5'-0.75"	No	0.44	135	3.97	3.91	3.1	3.1	5800	
P-E5	Column	2AF	Continuous metered	T-50-428	5'-0.75"	No	0.46	135	4.66	4.62	6.2	6.2	5300	
P-E6	E-7	IBP	Intermittent transfer	T-50-428	5'-0.75"	No	10.0	29	4.07	3.25	6.1	5.3	5700	
P-E7	E-5	2AF	Intermittent transfer	T-50-428	5'-10.5"	No	10.0	16	4.43	3.62	5.2	5.4	6500	
P-E13	F-1	Rework	Intermittent transfer	T-50-428	9'-8.5"	Yes	1.15	75	4.50	4.30	8.7	8.6	5700	
P-F1	Column	2IF	Continuous metered	T-50-428	6'-7"	Yes	1.1	164	3.72	3.57	4.9	4.9	4900	5700
P-F4	Column	3IF	Continuous metered	T-50-428	6'-7"	Yes	1.1	154	4.84	4.74	5.7	5.5	7400	7200
P-F7	Column	1AF	Continuous metered	T-40-428	9'-8.5"	Yes	1.09	164	4.45	4.33	5.5	5.5	6200	6100
P-F8	Column	1SF	Continuous metered	T-50-428	9'-8.5"	Yes	3.5	155	4.03	3.80	5.7	5.3	5400	5100
P-G1	O-1	Hexone	Continuous metered	T-50-428	11'-2.25"	Yes	15.8	45	2.9	1.8	5.7	4.2	3000	1600
P-E1	F-7	Makeup	Intermittent transfer	T-50-555	9'-8.5"	Yes	50	25	8.5**	2.6	6.1	2.3	15,300**	3200
P-E5	H-5	50% NaOH	Semi-continuous circulating	T-50-428	3'-6"	No	30	50	4.7	2.9	0.5	0.2	8000	1900

* Set length measured from underside of mounting flange to face of threaded inlet in pump suction plate. 1 1/2 in. sch. 40 pipe extends 3 in. below boss on all pumps except P-E6 and P-E5 where it extends 5 in. Operating conditions based on a production rate of 3 1/8 tons uranium processed per day.

** Theoretical conditions. The 5 h.p. driving motors of the 50 gal./min. pumps will be overloaded if operated against a closed discharge.

DECLASSIFIED

DECLASSIFIED

9419

950

HW-18700

DECLASSIFIED



**THIS PAGE
INTENTIONALLY
LEFT BLANK**

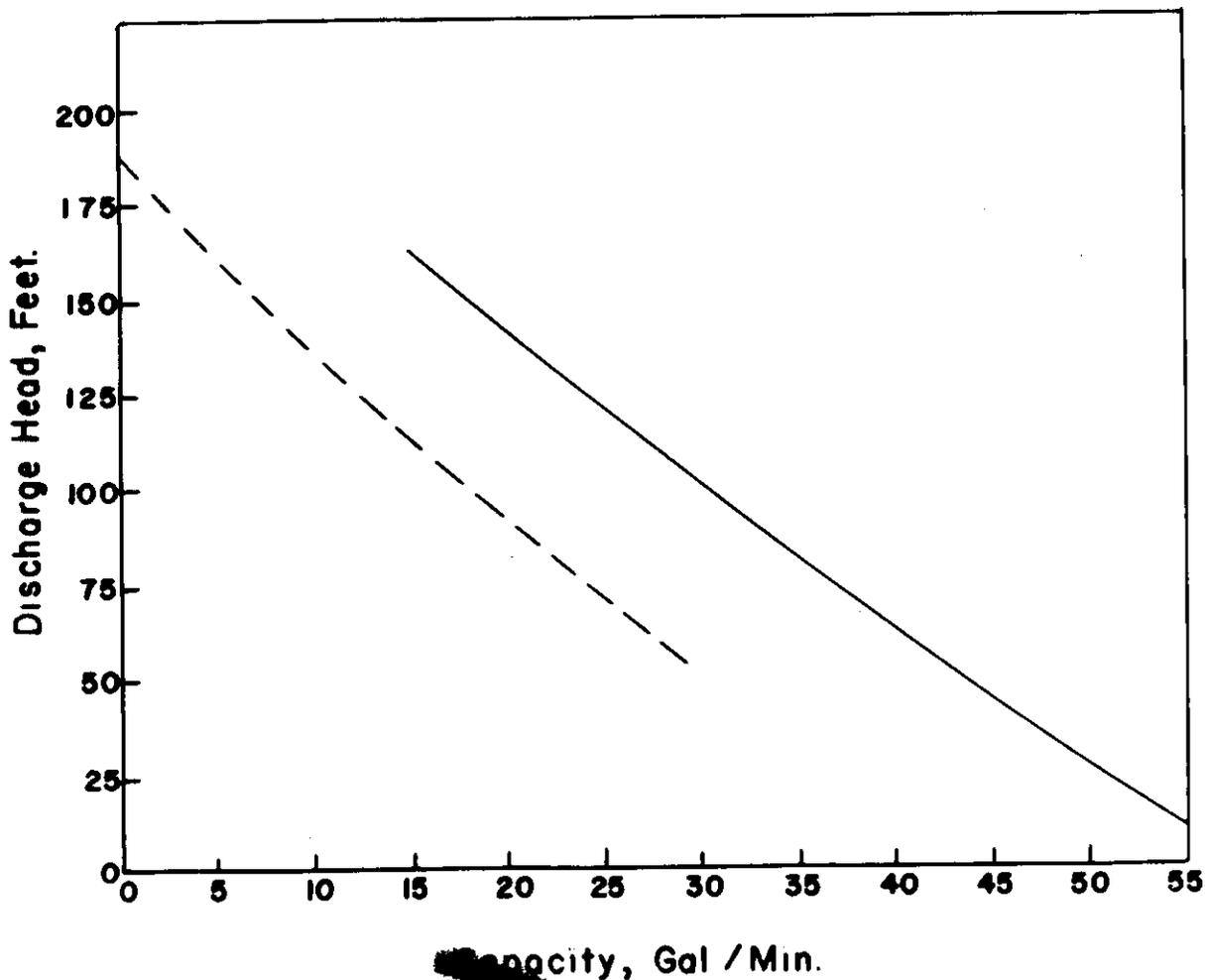


DECLASSIFIED

Figure XVII-5

"HOT" SERVICE PUMPS
PERFORMANCE CHARACTERISTICS

— 50 Gal./Min. (T-50-566) Pumps.
--- 25 Gal./Min. (T-50-428) Pumps.

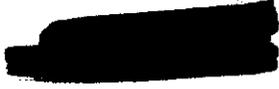


Capacity, Gal / Min.

952

DECLASSIFIED

HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

953

DECLASSIFIED

HW-18770

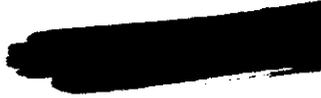
Table XVII - 6
COOLING SERVICE PUMPS

Operating No.	Pump To	Impeller Diameter In.	DESIGN REQUIREMENTS		ACTUAL PERFORMANCE				Motor Horsepower	SPEED Rev./Min	SOLUTION	PACKING
			Minimal Capacity Gal./Min.	Dynamic Head Ft.	Shut Off Head Ft.	Process Head Ft.	Capacity Gal./Min.					
P-602	Header	5	25	80	89	83	25	2	3450	Deminerlized water	Lattice braid cotton impregnated with lubricant and graphite or equal.	
P-603	Gallery Tank	4 13/16	10	80	83	81	10	3	3450	60% HNO ₃	Square plaited braid lubricated blue african asbestos or equal.	
P-507	Header	4 13/16	20	20	72	20	20	3/4	1730	25% NaOH	Square plaited braid, white asbestos lubricated and graphited, or equal.	
P-521	801-O	5 1/2	25	110	126	111	25	3	3450	2% Na ₂ CO ₃	Lattice braid cotton impregnated with lubricant, and graphite or equal.	
P-505	Gallery Tank	5 1/2	25	110	126	111	25	5	3450	60% HNO ₃ or 50% NaOH	Square plaited braid lubricated blue african asbestos or equal.	
P-402	801-S	5 1/2	25	110	126	111	25	5	3450	Na ₂ Cr ₂ O ₇ and water	Square plaited braid, white asbestos lubricated and graphited, or equal.	
P-401	801-A	5 3/4	50	110	131	110	50	5	3450	5% Na ₂ Cr ₂ O ₇ or 61.7% Al(NO ₃) ₃	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-407	801-B	5 1/2	25	110	126	111	25	5	3450	3% Ferric Sulfate or 61.7% Al(NO ₃) ₃ , or 60% HNO ₃	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-406	801-C	5 3/4	50	110	131	110	50	5	3450	5% NaOH or 61.7% Al(NO ₃) ₃ or 3% Ferric Sulfate	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-231	802-C 802-E 803-F	6 3/8	60	130	166	130	60	7 1/2	3450	60% HNO ₃	Square plaited braid lubricated blue african asbestos or equal.	
P-408	802-P 803-B	5 3/8	10	110	113	111	10	3	3450	60% HNO ₃	Square plaited braid lubricated blue african asbestos or equal.	
P-409	802-A	5 1/2	25	110	126	111	25	5	3450	50% Na ₂ Cr ₂ O ₇ or 60% HNO ₃	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-421	803-A	5 1/2	25	110	117	111	25	5	3450	61.7% Al(NO ₃) ₃	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-504	503	4 13/16	10	100	107	100.5	10	5	3450	Ferric Sulfate	Square plaited blue african asbestos, lubricated with mineral oil and graphite or equal.	
P-202	631	6 1/2	80	120	148	121	80	7 1/2	3450	60% HNO ₃ or Al(NO ₃) ₃	Square plaited braid lubricated blue african asbestos or equal.	
P-804-1	Header	4 13/16	20	20	20	20	20	1/2	1730	Organic solution	Chemical #711 or equal with teflon or equal spacers.	
P-804-2	Header	4 13/16	20	20	22	20	20	1/2	1730	Organic solution	Chemical #711 or equal with teflon or equal spacers.	
P-23B	8-3-A	4 13/16	20	20	20	20	20	1/2	1730	5% NaOH	Square plaited braid lubricated blue african asbestos or equal.	
P-H2B*	Centrifuge H-2		10	230	235	230	10	5	3450	5% HNO ₃	Square plaited braid, white asbestos lubricated and graphited or equal.	

* P-H2B is two-stage (ICMRVN) pump.

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



HW-18700

DECLASSIFIED

05/1

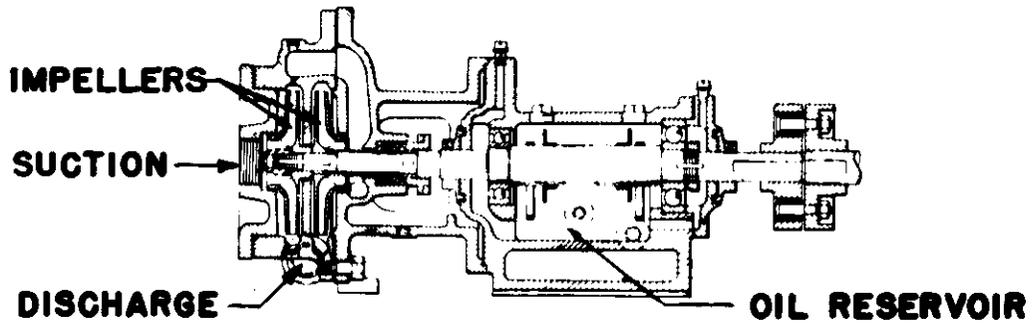
955

HW-18700

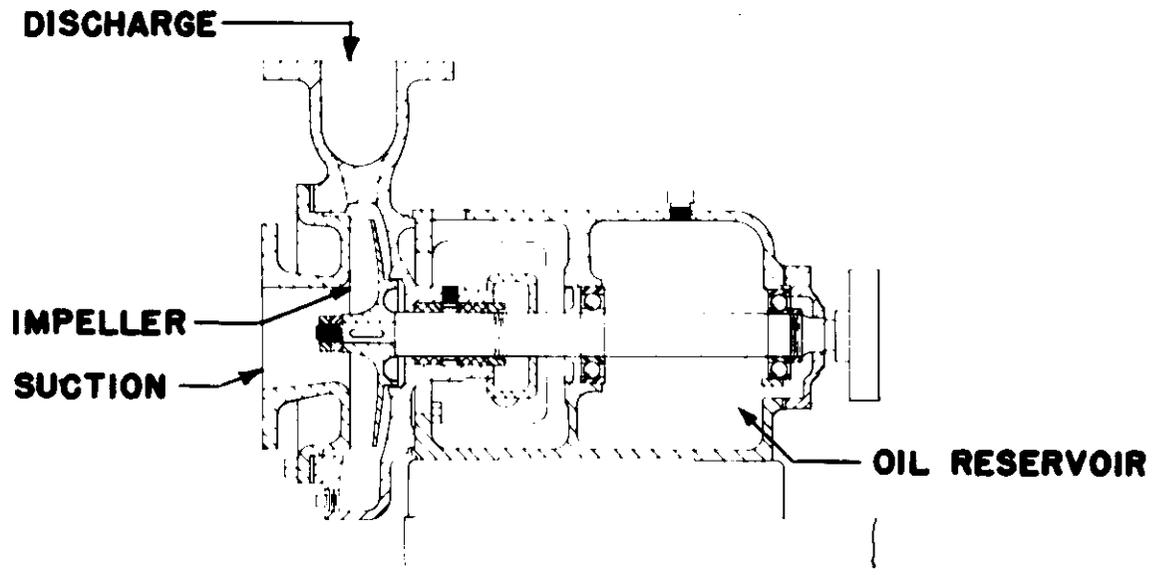
DECLASSIFIED

██████████ VII-7

"COLD" SERVICE PUMPS



TWO - STAGE
CENTRIFUGAL PUMP



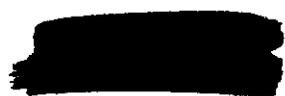
SINGLE - STAGE
CENTRIFUGAL PUMP

DECLASSIFIED

██████████

954

DECLASSIFIED HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

1987/11/10

DECLASSIFIED

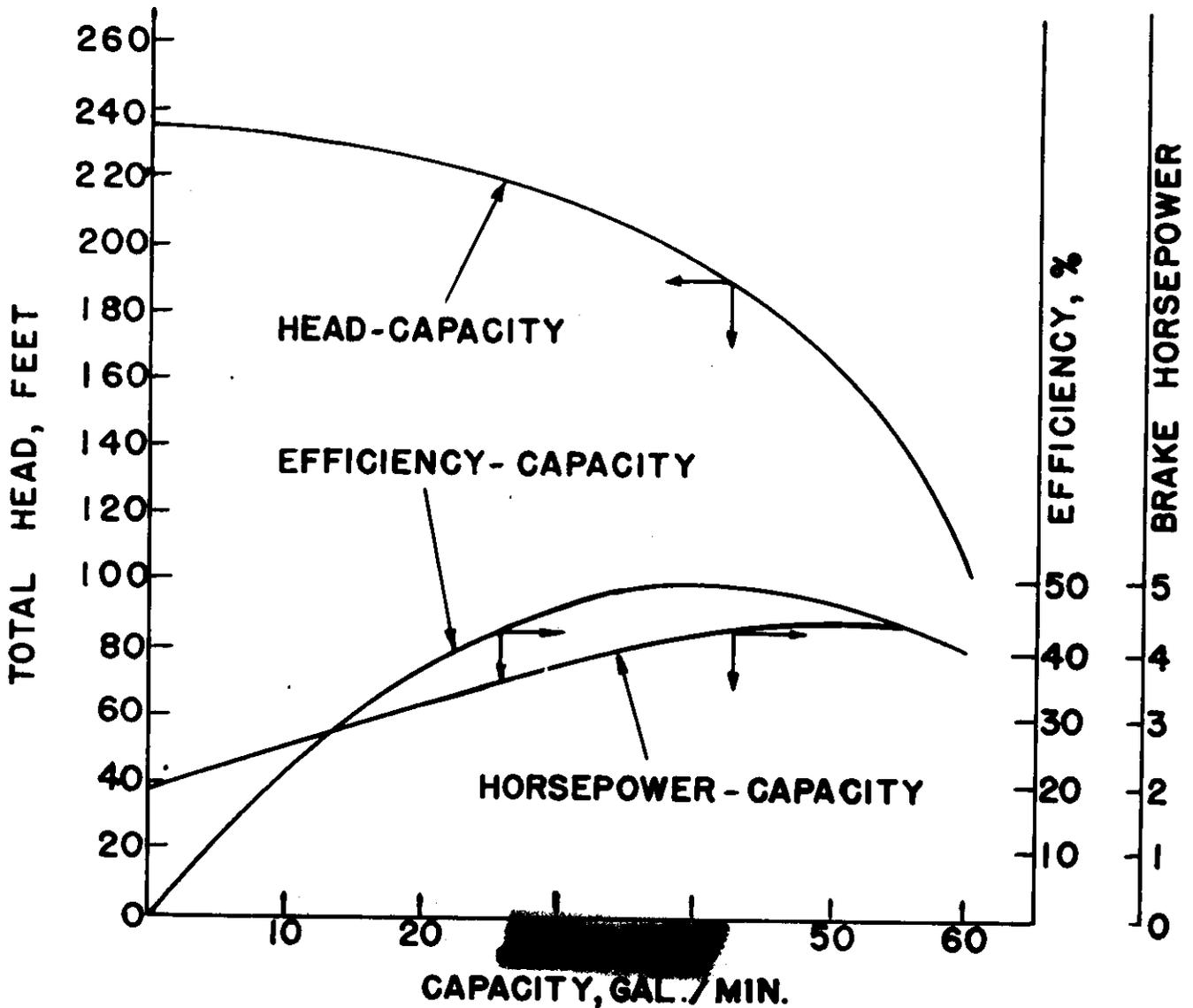
HW - 18700

957

Figure XVII-8

TWO-STAGE "COLD" SERVICE PUMP
PERFORMANCE CHARACTERISTICS

Test Fluid. Water
Speed 3450 RPM



CAPACITY, GAL./MIN.

DECLASSIFIED

DECLASSIFIED

HW-18700

958

[REDACTED]

THIS PAGE
INTENTIONALLY
LEFT BLANK

[REDACTED]

DECLASSIFIED

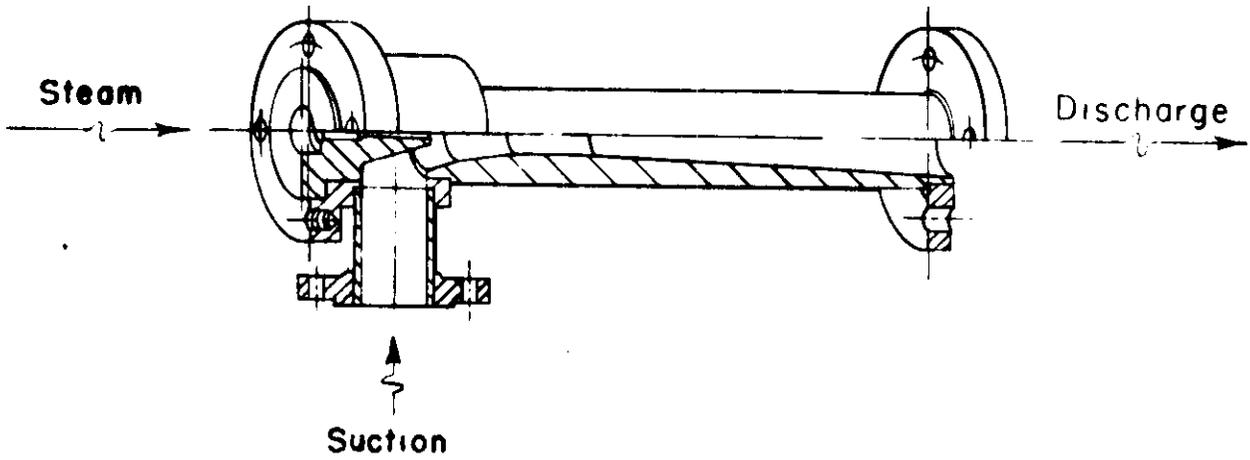
959

DECLASSIFIED

HW-18700

Figure XVII-9

~~SECRET~~



~~SECRET~~

DECLASSIFIED

~~SECRET~~

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

18700-14W-1

960

DECLASSIFIED

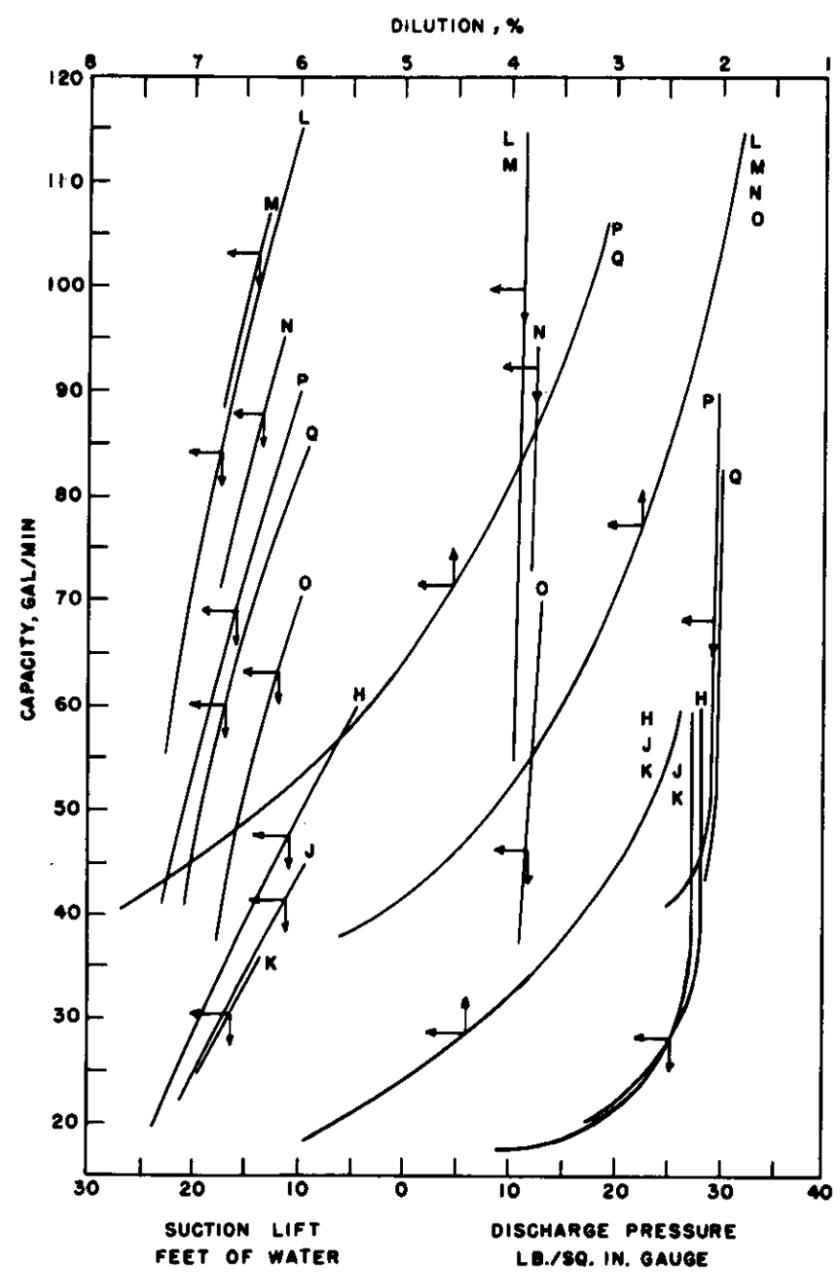
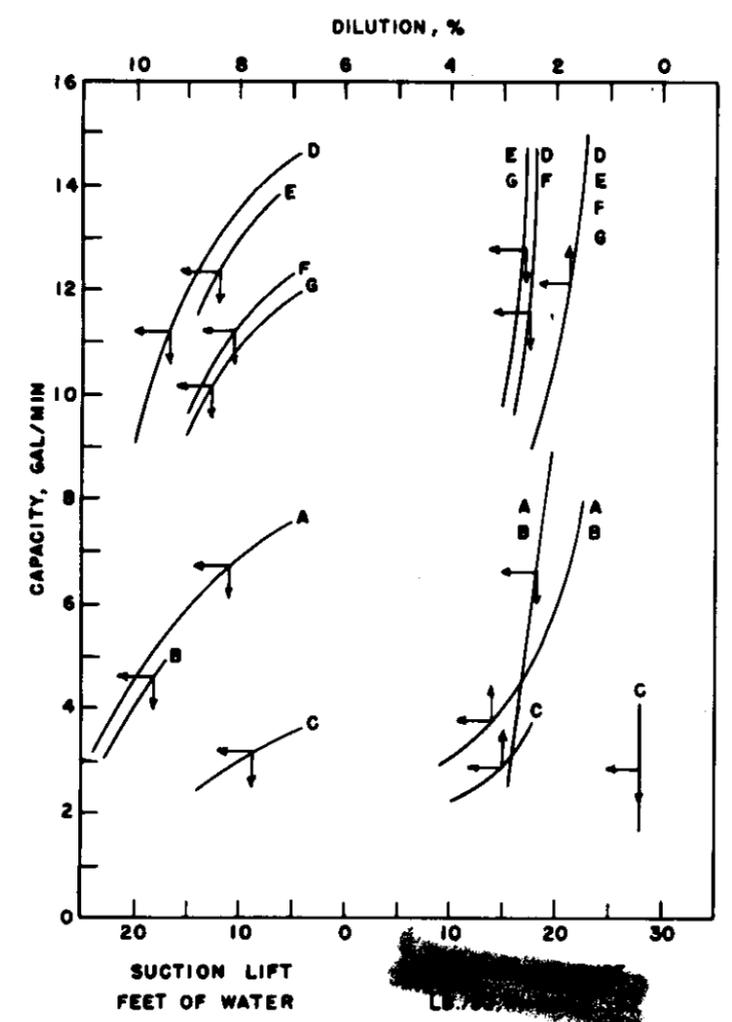
Figure XVII-10

STEAM JETS

PERFORMANCE CHARACTERISTICS

Test Fluid - Water
Steam Pressure - 90 lb./sq.in.ga.

Note: Discharge Pressure-Capacity curves indicate maximum pressure obtainable at constant capacity.



LEGEND

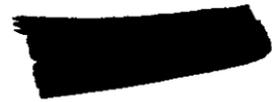
JET	Nominal Capacity Gal./Min.	Steam Consumption Lb./hr/100 gal	Curve
J-A2-1, J-B2-1, J-C2-1, J-A2-3, J-C2-4	75	26.2	Q
J-A2-2, J-B2-2, J-C2-2	25	11.0	H
J-B2-3, J-C2-3	75	17.8	N
J-A3, J-B3, J-C3	10	1.8	E
J-A1, J-B1, J-C1	25	11.0	H
J-H10-1	25	11.0	H
J-H10-2	75	26.2	P
J-H8, J-H9	75	17.8	L
J-H7	75	26.2	P
J-H4-1, J-H4-2	3	1.02	B
J-H5	25	11.0	H
J-H2-1, J-H2-2	25	11.0	H
J-H1-1	75	26.2	P
J-H1-2	75	17.8	L
J-H3-1, J-H3-2	25	11.0	H
J-F7	75	17.8	L
J-F8	75	17.8	L
J-F2	25	11.0	J
J-E13	75	17.8	L
J-F1	25	11.0	H
J-F8	25	11.0	J
J-F4	25	11.0	J
J-E10	25	11.0	J
J-E11	75	17.8	L
J-E12-1	75	26.2	P
J-E12-2	75	17.8	L
J-E6-1	10	1.8	D
J-E6-2	3	0.75	C
J-E4-1	10	1.8	D
J-E4-2	3	0.75	C
J-E7	10	1.8	F
J-E5-1	10	1.8	F
J-E5-2	3	0.75	C
J-E1	10	1.8	D
J-E2-1	10	1.8	D
J-E2-2	3	0.75	C
J-E3-1	3	1.02	A
J-E3-2	10	1.8	D
J-E17	3	0.75	C
J-E21-2, J-E21-3	10	1.8	D
J-D1-1	75	17.8	L
J-D1-2	75	26.2	P
J-J4	10	1.8	D
J-G3-1, J-G3-2	25	11.0	H
J-G4	10	1.8	G
J-G1	75	26.2	P
J-D13	10	1.8	D
J-D12	25	11.0	J
J-D10	75	17.8	M
J-D9-1, J-D9-2	75	17.8	O
J-D8-1	75	26.2	Q
J-D5	25	11.0	H
J-D2-1, J-D2-2	75	17.8	L
J-D7	75	26.2	P
Sump Jet, Canyon	25	11.0	H
Sump Jet, Canyon	25	11.0	H
Sump Jets, Canyon	25	11.0	H
J-E16	3	0.75	C
J-G5	75	26.2	P
Sump Jet, Pu Cage	10	1.8	D
Stack Drain Col. Tank Jet	25	11.0	J
Sump Jet, Stack	25	11.0	J
Centrifuge Rework Jet	25	11.0	H
Remote Shop Sump Jet	25	11.0	H

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

HW-187DD

9/62

PART III: PLANT AND EQUIPMENT, continued

CHAPTER XVIII. REMOTE OPERATION AND MAINTENANCE

<u>CONTENTS</u>	<u>Page</u>
A. PRINCIPLES OF REMOTE OPERATION AND MAINTENANCE.....	1802
B. CRANES.....	1802
1. Canyon Cranes.....	1802
2. Silo Cranes.....	1804
3. Aids to Crane Operation.....	1804
3.1 Illumination.....	1804
3.2 Contrast painting.....	1805
C. REMOTE CONNECTORS.....	1805
1. Pipe Connectors.....	1805
2. Electrical Connectors.....	1805
3. Design Features.....	1806
D. SPECIAL TOOLS.....	1806
1. Impact Wrench.....	1806
2. Grabber.....	1806
E. REMOVAL OF EQUIPMENT FOR MAINTENANCE.....	1807
REFERENCES.....	1807

964

CHAPTER XVIII. REMOTE OPERATION AND MAINTENANCE

A. PRINCIPLES OF REMOTE OPERATION AND MAINTENANCE

The process equipment which is located in the canyon and silo areas of the Redox Plant has been designed to give long, trouble-free service and to require a minimum of maintenance and attention. However, it is recognized that it may become desirable or necessary to remove and replace certain equipment pieces, or to revise process piping. In order to accomplish equipment removal, replacement, or revision, without exposing personnel to radiation hazards, remote handling equipment has been provided for use in the canyon and silo areas of the plant. Railway cranes, with shielded control cabs equipped with optical viewing devices, allow personnel to carry out a variety of operations in the cells and in the silo without danger of exposure to radiation. The cranes are equipped with traveling hoists, remote wrenches, and other specialized handling equipment.

Process piping, electrical conduit, and auxiliary lines leading into each cell terminate in stubs which emerge on the inside of the cell walls at the connector level. The end of each stub is equipped with the male portion of a remote connector. Connection is made to equipment within the cells by means of removable jumpers equipped at each end with the proper half of a remote connector. Process equipment contains connector halves which mate with one end of the jumpers. Each remote connector may be tightened or loosened by rotating a single hexagonal nut with an impact wrench operated from the crane. Each jumper has a lifting bail or eye positioned at the balance point. Thus all intracell piping may be removed remotely by breaking two connections with an impact wrench and lifting the piping from the cell with the crane hooks.

Enlarged nuts, similar to the operating nuts on the remote connectors, operated by the impact wrench, are used to fasten elements of process equipment together so that one element may be removed independently from the other, i.e., pumps and agitators may be removed from process vessels.

Fixed relationships between piping and process equipment are maintained by the use of positioning guides and pins. In addition, piping and process equipment are fabricated to specific dimensions and checked for alignment in a "mock-up" shop (Building 277-S) before attempting installation in the "hot" area. The "mock-up" shop duplicates the process equipment positions in the canyon and silo.

Other factors which promote successful remote handling are illumination, contrast painting, and the skill of the crane operator.

B. CRANES

1. Canyon Cranes

Remote maintenance in the canyon is made possible through the use of

DECLASSIFIED

9205

an electrically driven overhead railway crane⁽²⁾ which operates on tracks running lengthwise and on either side of the canyon. The crane has a 60-ton capacity main hoist for lifting cell covers and heavy equipment, a 10-ton capacity secondary hoist, and two dual auxiliary hoists of 1/2 and 1-ton capacity for use with impact wrenches, grabbers, or other tools. A sketch of the crane appears on the perspective cut-away sketch of the Processing Building (202-S) in Chapter I.

The crane is controlled from a cab shielded with 2-1/4 to 4-1/2 in. of steel. The cab moves behind a concrete wall 2 ft. 2 in. thick at the top and 3 ft. 7 in. thick at the bottom. The cab is ventilated by means of a blower with a rated capacity of 250 cu.ft./min. at 1-in. water pressure. The air entering the cab is filtered through Chemical War Service No. 6 paper filters. The static pressure in the cab is maintained above that of the surrounding area.

The crane operations are observed from the cab by means of two variable power, monocular type periscopes mounted on either side of the crane bridge. Powers of 3/4 (68° vision angle), 2-1/2 (25° vision angle), and 5 (12.5° vision angle) may be selected by the operator. The objective of each periscope may be moved across the canyon and rotated about its axis to permit increased vision.

The crane is powered by a Ward Leonard, variable voltage (0 to 15 volts), variable speed, direct-current drive system, which provides a high torque at low speeds. The electrical equipment located directly over the canyon on the crane trolley is totally enclosed, while that in the cab is standard. The power supply and communication leads to the crane are brought in through open conductor and collector shoes located in the cabway. The maximum lift of the main hook is 60 ft., measured from the cell floor to the hook in maximum lift position. The minimum travel speed of the bridge and trolley (horizontal speed) and hoists (vertical speed) is less than 1 ft./min. The specified maximum travel speeds, expressed in ft./min., are:

<u>Item</u>	<u>Direction of Movement</u>	<u>Speed, Ft./Min.</u>
Bridge	Horizontal (lengthwise of canyon)	140
Main Trolley	Horizontal (crosswise of canyon)	53
60-ton hoist	Vertical	8
10-ton hoist	Vertical	28
Auxiliary hoist trolley	Horizontal (crosswise in canyon)	25
Auxiliary hoists	Vertical	50

The distance across the jaw opening of the main hook on the 60-ton hoist is 8 in., and on the 10-ton hoist hook, 4-1/2 in.

Direct maintenance of the crane hooks and other equipment may be carried out behind a concrete shielding wall at the east end of the canyon. The wall does not extend to the ceiling nor to the north wall of the canyon, thus permitting the crane and hooks to travel behind the wall. A 2-ton capacity, electrically operated crane, mounted on a monorail running crosswise in the canyon over the crane maintenance platform, is used for servicing the main crane.

DECLASSIFIED

96de [REDACTED]

2. Silo Crane

The silo is equipped with an electrically driven, overhead, railway crane, (3), (4) which bridges the short dimension of the silo. The crane has a 10-ton capacity main hoist and two dual auxiliary hoists. The dual auxiliary hoists (1/2 and 1-ton capacity) are equipped with two impact wrenches and a grabber. A spare hoist line is available for future requirements. Like the canyon crane, the silo crane is shown on the perspective cut-away sketch of the Processing Building in Chapter I.

The silo crane may be controlled from the cab, which is shielded with 2 in. of steel, with operation observed through a viewing window of laminated lead glass 4-1/8 in. thick; or the crane may be operated from any of seventeen laminated lead-glass viewing windows located in the silo wall at various levels. The glass laminations are spaced slightly and the voids filled with mineral oil to minimize internal reflections. Jack boxes located near each window, are provided. Portable crane controls, one set for each level, may be connected to the jack boxes.

The maximum height of lift of the silo crane main hoist is 91 ft. 7 in. from the silo floor. The minimum travel speed of the bridge, trolley, and hooks is less than 1 ft./min. The specified maximum travel speeds, expressed in ft./min., are:

<u>Item</u>	<u>Direction of Movement</u>	<u>Speed, Ft./Min.</u>
Bridge	Horizontal (lengthwise of silo)	80
Trolley	Horizontal (crosswise in silo)	25
10-ton hoist	Vertical	25
Auxiliary hoist trolley	Horizontal (crosswise in silo)	25
Auxiliary hoists	Vertical	50

The distance across the jaw opening of the hook on the 10-ton hoist is 4-1/2 in.

The silo-crane electrical system is similar to that of the canyon-crane electrical system, and utilizes a Ward Leonard direct-current drive. The electrical equipment over the silo area is totally enclosed. The cab-ventilation system is the same as that described for the canyon crane cab.

3. Aids to Crane Operation

3.1 Illumination

Good lighting is essential to precise crane operation. In the canyon, an illumination intensity of 5 to 10 foot-candles is maintained at the cover-block level by rows of incandescent light bulbs in the canyon ceiling. This illumination is augmented during operation with the crane by means of sixteen 1000-watt lights on the crane bridge and four 1000-watt lights on the crane trolley. These additional lights increase the intensity to 100 foot-candles at the cover block level. The silo crane is equipped with two floodlights and three searchlights on each side of the trolley. Each

light has a capacity of 500 watts. In addition to the crane lights, 88 light bulbs, 200-watt capacity each, are located in the silo wall in horizontal banks of 9 to 11. The banks may be removed from outside the silo.

3.2 Contrast painting

Contrasting colors and numbers are used to aid the crane operator in handling equipment remotely. In general, all lifting bails, connector nuts, dowel pins, etc., are painted yellow. The cell walls and floors are painted white. The cell cover tops are grey with a yellow band around the edge. Equipment pieces, jumpers, connectors, cell covers, etc., are numbered in black. The numbering system is described in Chapter XII.

C. REMOTE CONNECTORS

The remote connector is a device for connecting process piping, auxiliary lines, or electrical conduits by a single operation performed remotely from the crane cab. The connector is actuated by a single hexagonal operating nut which is turned by an impact wrench. A diagram of a typical pipe connector is shown in Figure XVIII-1, and of an electrical connector in Figure XVIII-2. Pipe connectors are made for 1/2, 1, 2, 3, and 4-in. i.p.s. pipe. The 1/2-in. i.p.s. connectors are made to connect three 1/2-in. lines in a single connector, while the larger sizes are for one line only. Electrical connectors provide multiple contact points (usually seven) within each connector and meet Class 1, Group D requirements.

1. Pipe Connectors (9)(10)

Pipe connectors (Figure XVIII-1) are either vertical or horizontal, corresponding to the position of the stationary portion of the cell piping which is to be connected. Horizontal and vertical connectors are identical except that the horizontal connectors have open guide skirts surrounding the female-connector face to allow vertical movement of the connector over the male portion. In operation, the connectors depend on three hooks or latches, mounted on the female portion of the connector and actuated by rotation of the hexagonal operating nut, which grasp or release the fixed or male portion of the connector. Contact between the two halves of the connector is made at spherically-ground mating surfaces. The surfaces are Type 347 stainless steel faced with No. 6 Stellite approximately 1/16-in. thick, applied by heliarc welding procedure, and ground to a surface finish of 20 micro-inches or better. The female mating surface is provided with a Teflon gasket held in place by a retaining ring.

2. Electrical Connectors (8)

The electrical connectors (Figure XVIII-2) are similar in operation to the pipe connectors. In the electrical connectors the mating faces of the two connector halves are provided with a close fitting labyrinth joint surrounding the spring loaded electrical contact points (normally seven). The labyrinth serves the same function as the labyrinth passage-ways in the shell of a Class 1, Group D, electric motor. One-in.conduit

and No. 10 solid wire is used, except for the centrifuge motor leads, which are No. 4 stranded wire in 2-in conduit.

3. Design Features

The hexagonal operating nuts on all remote connectors are 2 in. across the flat faces of the nuts, so that one impact wrench will fit all connectors. The minimum rated operating torque is 275 ft. lb. for the 3 and 4-in. pipe connectors and 200 ft. lb. for the smaller sizes. The maximum rated operating torque is 550 ft. lb. for the 3 and 4-in connectors and 400 ft. lb. for the smaller sizes. A safety factor of 2-1/2 based on the maximum torque is provided. A 10 to 20-second impact period with the impact wrench is sufficient to make a tight connection.

D. SPECIAL TOOLS

1. Impact Wrench

Electrically driven, reversible impact wrenches are used to make and break the remote connectors and to rotate the remote hold-down nuts on tanks, columns, and other equipment. The wrenches are suspended from auxiliary hoists which are integral with the canyon and silo cranes. A sketch of an impact wrench is shown in Figure XVIII-3. The wrench may be operated either horizontally or vertically by changing the point of suspension. The wrench is lowered to the floor and the suspension device slid along the handle to change position. A positioning device prevents the wrench from turning during operation by engaging with a connector latch or special stops provided for the purpose.

The wrench is driven through a train of gears by a reversible 3/4-horse-power, 3450-r.p.m., 440-volt, 3-phase electric motor. The motor speed is reduced by a planet-gear assembly, which turns the planet-gear frame against the cam balls. Cam surfaces of the hammer are held against the cam balls by the hammer spring. If no resistance to torque is encountered, the hammer lugs remain engaged with the anvil lugs, thus turning the socket or wrench. When the torque necessary to turn the socket exceeds 400 to 500 ft. lb., the resistance is transmitted through the anvil to the hammer, compressing the hammer spring by the action of the cam surfaces and the cam balls. This action disengages the hammer lugs from the anvil lugs and allows the hammer to be rotated and driven forward by the hammer spring. The hammer lugs deliver a sharp blow to the anvil lugs. The force of the blow is transmitted through the anvil and socket to the nut. This hammering action is repeated at a rate of about 900 impacts/min. as long as resistance sufficient to compress the hammer spring is encountered. To loosen a nut, the motor rotation is reversed, and the action is repeated in the opposite direction. Loose nuts, when removed from studs holding equipment in place, are retained in the socket by a snap ring until they can be placed on dummy studs for future use.

2. Grabber(5)

The grabber is a clam-shell bucket device for handling small pieces of equipment that cannot be picked up with the crane hook.

The tool is powered by a reversible fractional-horsepower electric motor that rotates a threaded shaft, which in turn opens or closes the bucket jaws. The lips of the jaws are used to grasp loose nuts and other small items. Pipe may be gripped in horizontal-pipe jaws, which are semi-circular notches cut in the sides of the bucket jaws. A single pair of semi-circular jaws are attached to one side of the bucket for handling vertical pipe.

E. REMOVAL OF EQUIPMENT FOR MAINTENANCE

Tanks, piping, or other equipment may be removed from the canyon or silo for repair, replacement, or revision by means of the remote handling equipment previously described in this chapter. When possible the equipment is partially decontaminated by flushing with decontaminating solutions (See Chapter XXIII) prior to removal. Grossly contaminated items which are to be removed are usually placed in wooden boxes partially filled with sawdust, to absorb and contain leakage. The box is placed on a flatcar and removed via the railway tunnel to the burial grounds.

Equipment which is to be repaired or revised is moved by crane to the remote maintenance shop at the east end of the canyon. Equipment is lowered into the "hot" shop from the canyon through a 12 ft. 9 in. by 27-ft. opening in the canyon deck. This opening is covered with concrete cell cover blocks 4-ft. thick. No other entry to the "hot" shop is provided except through the regulated shop and decontamination room. The remote maintenance shop consists of three sections, (1) a "hot" shop (40 ft. 6 in. x 15 ft. with a height of 26 ft. 3 in.), (2) a decontamination room (40 ft. 6 in. x 24 ft. with a height of 19 ft. 9 in.), and (3) a regulated shop (65 ft. 6 in. x 12 ft. 8 in. with a height of 19 ft. 9 in.). A 1-ton capacity, manually operated monorail crane connects the three sections of the shop. A portion of the "hot" shop is provided with a 12 by 16-foot stainless steel floor equipped with a "hot" drain where contaminated equipment may be flushed and rinsed with decontaminants. Semi-remote or direct maintenance (depending on the degree of contamination) may be performed in this portion of the shop which is equipped with a 1-ton capacity manually operated jib crane. The decontamination room contains two hooded sinks equipped with water, steam, and acid service for additional decontamination of equipment. In the regulated shop, maintenance can be performed under controlled conditions.

Decontamination of equipment that has been in contact with steams of high activity levels (feed and first-cycle waste streams) has generally been impractical, and in most cases has not been attempted.

Direct maintenance, without removal of equipment from the cells, is possible if the radiation and contamination levels in the cell are within tolerances specified by the Health Instrument Division (See Chapter XXI for a discussion of these tolerances).

Special equipment, shown schematically on Figure XVIII-4, (7) has been provided for removing contaminated columns from the silo. After preliminary flushing of the column to be removed and removal of process lines, the column is lowered by crane into the bottom half of a mild steel casing, or cask, mounted on the silo wall. The upper half of the cask is then

970

DECLASSIFIED

lowered over the top of the column, and the two cask sections joined remotely by a liquid-tight flange. The cask containing the column is then lowered to a horizontal position and supported on a dolly consisting of two four-wheeled trucks separated by an E-frame. The dolly and encased column may be withdrawn from the building through the column-carrier outlet on a narrow-gage railway provided for the purpose. The column may be transported by motor crane to the burial grounds for disposal. New columns are brought into the silo and removed from protective casks by a similar procedure. Supporting fins are employed to position and protect the column within the cask.

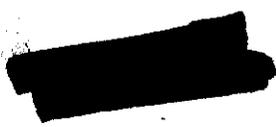
DECLASSIFIED

REFERENCES

- (1) HW-10475-C H.E.W. Technical Manual, Section C. Author not stated. 5-1-44. Pp. 240-245.
- (2) U-26931 and U-26672 Whiting Corporation Drawings, Canyon Crane.
- (3) A-3876 Ederer Engineering Company Drawing, Silo Crane, Assembly Layout.
- (4) B-4476 Ederer Engineering Company Drawing, Silo Crane, Auxiliary Hoists.
- (5) BPF-74629 Grabber.
- (6) H-2-8589 Mechanical Equipment -- Sectional Arrangement -- Impact Wrench.
- (7) H-2-8766 Mechanical Equipment -- General Arrangement. Column Removal Equipment.
- (8) DR-25876 Crane Company Drawing. Mechanical Equipment -- Electrical Connector Assembly, Revision C.
- (9) H-20260 Crane Company Drawing, 2" Three Jaw Type Connector, Horizontal Mounting, Assembly.
- (10) H-30274 Crane Company Drawing, 2" Three Jaw Type 3 Way 1/2" Connector, Vertical Mounting, Assembly.

972

HW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

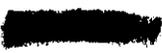
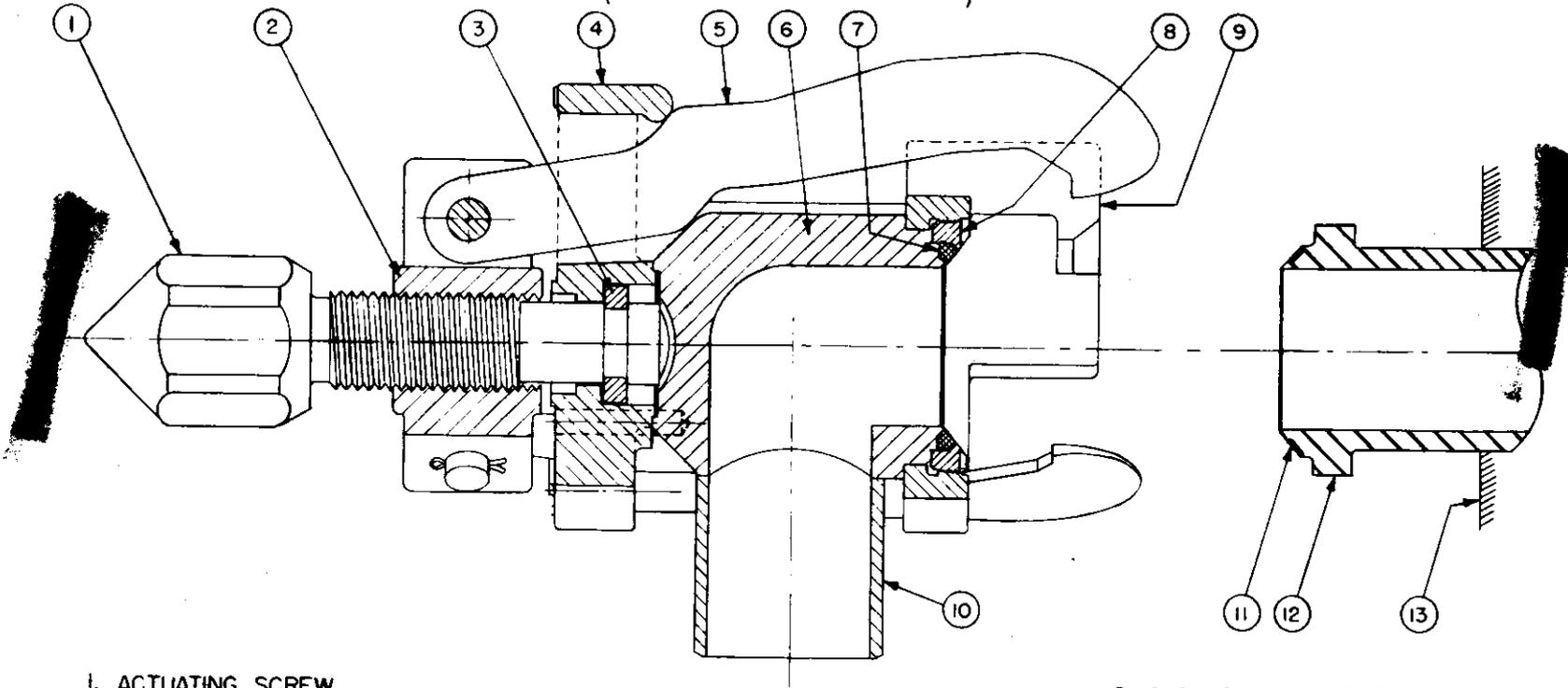


Figure XVIII-1
THREE JAW PIPE CONNECTOR, HORIZONTAL MOUNTING

(FROM CRANE CO. DWG. NO. H-20260)



- 1. ACTUATING SCREW
- 2. LATCH YOKE
- 3. SCREW POSITIONING COLLAR
- 4. LATCH GUIDE
- 5. LATCH
- 6. CONNECTOR BLOCK
- 7. TEFLON GASKET

- 8. GASKET RETAINER RING
- 9. POSITIONING JAW
- 10. PIPE NIPPLE
- 11. STELLITE NO. 6 MATING FACE
- 12. CONNECTOR FLANGE
- 13. KICK PLATE

DECLASSIFIED

DECLASSIFIED

973

974

HVN-18700



DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**



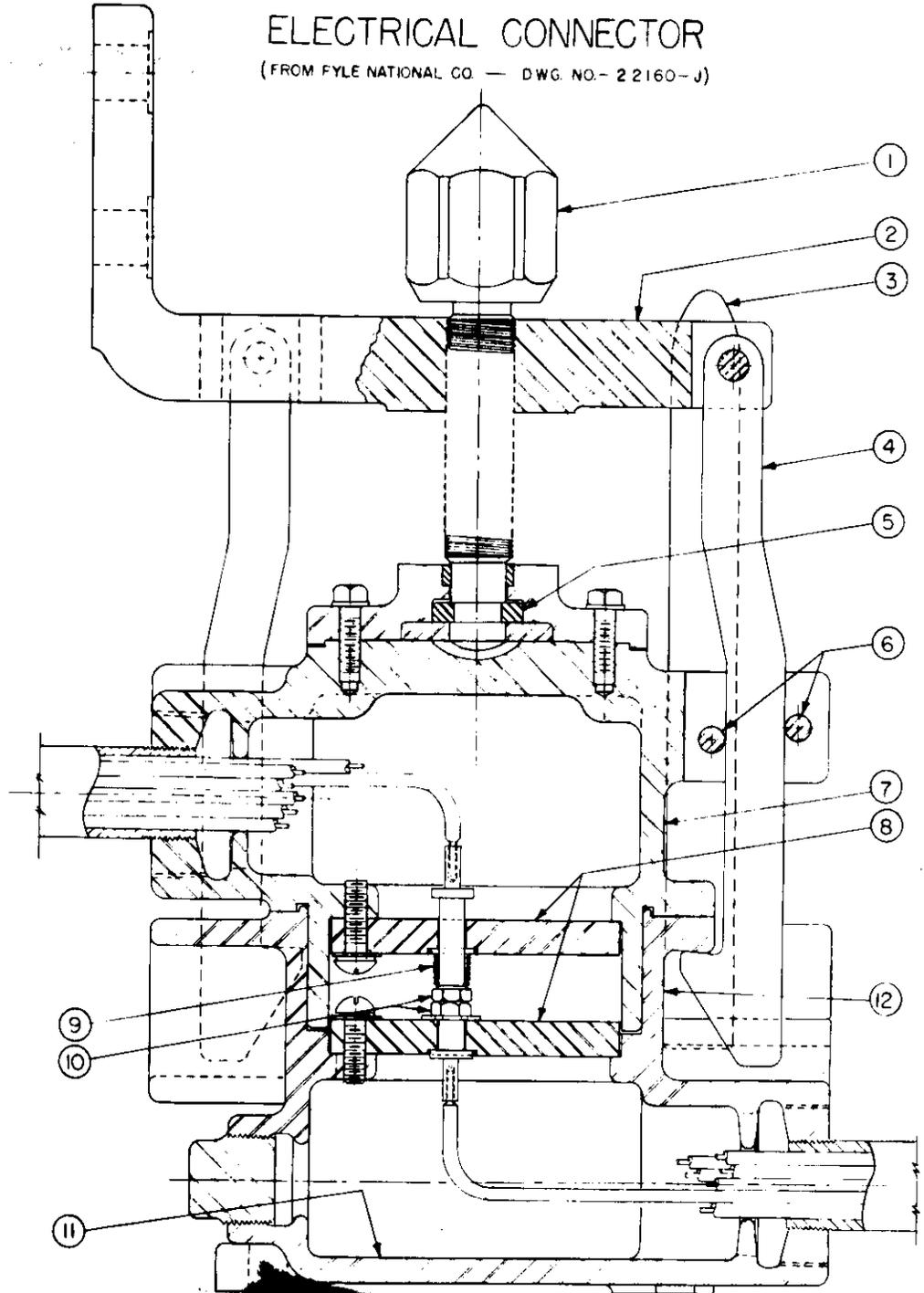
DECLASSIFIED

DECLASSIFIED

Figure XVIII-2

ELECTRICAL CONNECTOR

(FROM FYLE NATIONAL CO. — DWG. NO. — 2 2160—J)



- 1. ACTIVATING SCREW
- 2. YOKE
- 3. GUIDE PIN
- 4. LATCH
- 5. SCREW POSITIONING COLLAR
- 6. LATCH GUIDES

- 7. CONNECTOR HOUSING
- 8. CONTACT INSULATOR
- 9. CONTACT SPRING
- 10. CONTACTS (SEVEN PAIRS)
- 11. CONNECTOR BASE
- 12. LABYRINTH

DECLASSIFIED

0712

HW-187DD

SECRET

[REDACTED]

DECLASSIFIED

TWO PAGE
INITIALLY
LEFT BLANK

[REDACTED]

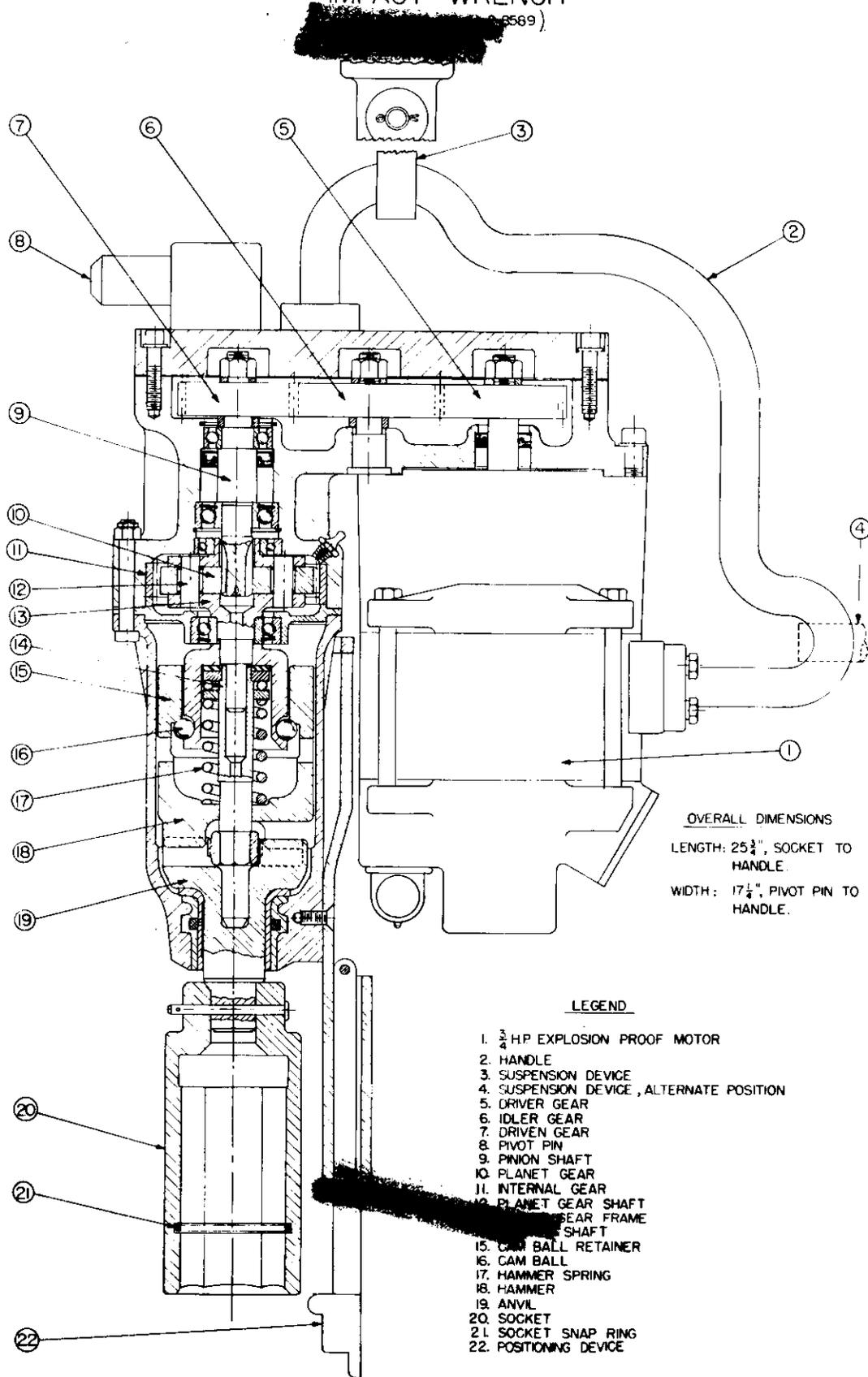
DECLASSIFIED

DECLASSIFIED

HW-18700

977

Figure XVIII-3
IMPACT WRENCH

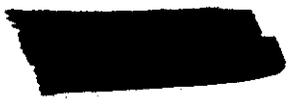


DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

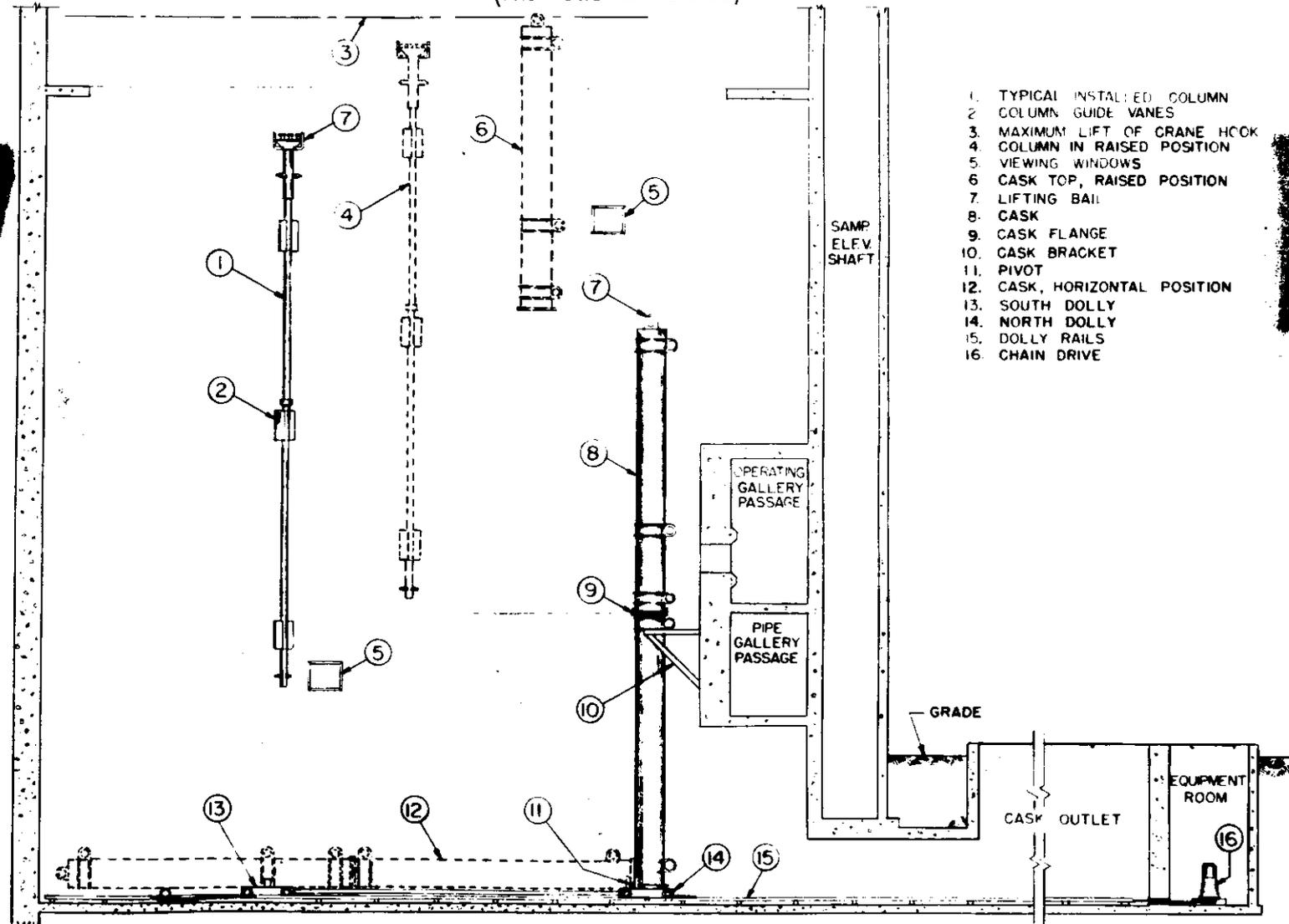


DECLASSIFIED

HW-1870

978

Figure XVIII-4
 COLUMN REMOVAL EQUIPMENT
 (SILO SECTION, TOWER SHAFT, LOOKING WEST)
 (FROM DWG NO. H-2-8766)



- 1. TYPICAL INSTALLED COLUMN
- 2. COLUMN GUIDE VANES
- 3. MAXIMUM LIFT OF CRANE HOOK
- 4. COLUMN IN RAISED POSITION
- 5. VIEWING WINDOWS
- 6. CASK TOP, RAISED POSITION
- 7. LIFTING BALL
- 8. CASK
- 9. CASK FLANGE
- 10. CASK BRACKET
- 11. PIVOT
- 12. CASK, HORIZONTAL POSITION
- 13. SOUTH DOLLY
- 14. NORTH DOLLY
- 15. DOLLY RAILS
- 16. CHAIN DRIVE

DECLASSIFIED

DECLASSIFIED

HW-18700
 Fig. XVIII-4

979



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

HW-18700

980

PART IV: PROCESS CONTROL

CHAPTER XIX. INSTRUMENTATION

<u>CONTENTS</u>	<u>Page</u>
A. INTRODUCTION	1902
B. INSTRUMENT FLOW DIAGRAMS	1902
C. INSTRUMENT PANELS	1903
D. RADIATION INSTRUMENTS	1904
E. VISUAL AND AUDIBLE AIDS	1906
F. FLOW MEASUREMENT AND CONTROL	1906
1. Radioactive Process Streams -- Rotameter System	1906
2. Non-Radioactive Process Streams	1909
2.1 Rotameter system	1910
2.2 Orifice-meter system	1911
2.3 Metering-pump system	1913
2.4 Nitric acid proportioning system	1914
G. PURGE-TYPE PRESSURE INSTRUMENTS	1916
1. Weight Factor Instruments	1916
2. Specific Gravity Instruments	1919
3. Interface Instruments	1921
4. Differential Pressure Instruments -- Solvent-Extraction Columns	1923
5. Miscellaneous Differential Pressure Instruments	1924
H. TEMPERATURE INSTRUMENTS	1925
1. Mercury Thermometers	1925
2. Resistance Thermometers	1925
I. MISCELLANEOUS INSTRUMENTS	1928
1. Ammeters	1928
2. Bourdon-Tube Pressure Gauges	1928
3. Scales	1928
4. Gauge Glasses	1928
5. Vibration Indicator	1928
6. Speed Indicators	1929
7. Manual-Control Stations	1929
8. pH Instrument	1930
9. Conductivity-Type Level Instruments	1930

CHAPTER XIX. INSTRUMENTATION

DECLASSIFIED

A. INTRODUCTION1. General

Industrial instruments fall into two general classes: (a) those which measure and (b) those which measure and control. A measuring instrument may be used by itself, or it may be combined with a control device to form an automatic controller. Recording instruments are utilized as a check on operations and, in the case of flow meters and gravimetric and volumetric measuring devices, are often used for determining energy and material balances.

Continuous processing employed in the Redox Plant requires that automatic instrumentation assume a majority of the control functions over the maintenance and adjustment of flow rates, specific gravities, liquid levels, and temperatures for numerous streams and tanks. In addition to the control functions by automatic instrumentation, there are many operations executed by operating personnel in one section of the plant which will have an effect upon plant performance in other process steps upstream and downstream from the point at which the operation was carried out. The control functions performed by automatic instrumentation, as well as those performed by operating personnel, must be detected by indicating or recording instruments. This record supplied by instrumentation is, in many instances, the only information the operator has available for ascertaining the satisfactory operation of automatic controllers and is used to assist him in the performance of the necessary operations. In addition to the indicating, recording, or controlling instrument functions required by process considerations, instruments are required for numerous non-process applications, such as the determination of radioactivity and abnormal mechanical conditions.

2. Scope of This Chapter

The location and types of instruments, including their auxiliary components, as schematically represented on the instrument flow diagrams, are presented in Section B.

In Section C the arrangement of the receiving (indicating and recording) elements of the instruments on the instrument panel boards is described.

The balance of the chapter briefly describes each type of instrument from a functional viewpoint. General principles, application, component elements, complementary devices (e.g., alarms, valves, and interlocks), range, and accuracy are discussed.

B. INSTRUMENT FLOW DIAGRAMS

The instrument flow diagrams show schematically, for each instrument, (a) the location with respect to process functions and equipment, (b) the variable measured, and (c) the type of instrument, i.e., indicating, re-

DECLASSIFIED

983
DECLASSIFIED

cording, or controlling. It also schematically shows the instrument piping or wiring system and the auxiliary components associated with each instrument. The diagram is essentially a simplified engineering flow diagram emphasizing the instrument system and the primary process system. It illustrates diagrammatically the relationship of the instruments to process control.

The diagram is divided among twenty-two separate sheets (Figures XIX-2 through XIX-23) designed to represent as nearly as possible all closely related process functions on a single sheet. The location of the equipment on the sheets is intended to result in a generalized flow pattern: (a) non-radioactive streams flow from equipment located in the upper portion of the sheet to equipment on the same level or at a lower level; (b) radioactive streams are confined to the lower portion of the sheet, which is schematically indicated to be a radioactive zone by the simulated wall section extending horizontally across the sheet.

Panel boards and panel-board instruments are indicated by a bracketed band inserted on the left-hand margin of the sheet. The property measured by each instrument, i.e., pressure, temperature, flow rate, etc., is indicated by the legend (see Table XIX-1) adjacent to each instrument. Beneath the legend appears the scale division and the range of the instrument.

In general, heavy ruled lines on the sheets denote service lines for either pneumatic or electrical operation of the instruments. Heavy lines are also used to denote the flow path of the primary process streams or continuously added reagent streams.

The remote connectors are indicated by blocks in which the lines terminate. Pipe and connector size is indicated on the lines. Some connectors service two or three lines, as indicated by the continuous rectangle embracing two or three individual blocks. Spare and unused connectors are indicated by open squares within the center of the block. Sampler connectors, which always employ three pipes, are denoted by omission of any separation between the inner blocks of the schematic connectors.

C. INSTRUMENT PANELS

The receiving elements, either indicating or recording, for all instruments whose sensitive elements are located within radioactive zones, as well as other instruments of primary process importance, are mounted on steel panel boards in the operating and sample galleries. The instruments are grouped according to process operations on thirteen individual panel boards as shown in Figures XIX-24, 25, and 26. The process operation corresponding to each panel, or group of panels, is as follows:

DECLASSIFIED

984

<u>Panel</u>	<u>Process Step</u>
A, B, and C	Dissolving
D-1 and D-2	Waste Treatment
E-1	Third Uranium Cycle
E-2	Second and Third Plutonium Cycles
F	First and Second Uranium Cycles
G	Organic Recovery
H	Metal Feed Storage and Feed Pretreatment
J	Off-Gas Filters
K	Solvent-Extraction Columns
L	Plutonium Concentration

Three additional panel boards are provided exclusively for health monitoring radiation instruments. They are: (a) "M", located in the dispatcher's office, (b) "N", located in the SWP Lobby; and (c) "Q", located in the crane cab. Speakers for the sound detection system and clocks are mounted on top of all panel boards, except those devoted exclusively to health monitoring functions. The uppermost zone of each panel board is devoted primarily to pressure-indicating meters and alarm lights. Below these instruments are the C-clamp-type indicating purge-gas rotameters. The most important recording instruments are located below the purge-gas rotameters, approximately at eye level. The lower portion of the panel contains the manual-control stations for remote-operated, controlled-sequence valves and the ammeters for electrical equipment, primarily pump and agitator motors.

The legend accompanying each panel-board instrument is explained in Table XIX-1. The "MK" number shown on the panel-board-mounted instruments denote the number affixed to the instrument data sheet, a source of further detailed information about the instrument.

D. RADIATION INSTRUMENTS

This chapter describes the radiation instruments which are permanently installed in the Redox Processing Building. These instruments are used to monitor radiation for purposes of personnel safety and process control. Chapter XXI of this manual discusses the use and operation of portable survey meters.

General principles: Beta and gamma emissions are detected by measurement of the ionization produced by the passage of negatively charged beta particles (electrons) or the secondary electrons from any electromagnetic (gamma) radiation through a gas-filled chamber containing oppositely charged electrodes. The current flow in the electrode system permits a quantitative measurement of the radiation penetrating the electrode chamber.

Application and purpose: Radiation instruments are employed as a supplement to process control and health protection. They serve as (a) an approximate measurement of decontamination of the plutonium and/or uranium-containing streams and (b) an indication of the level, or extent, of

radiation within the zone "seen" by the instrument.

Sensitive element: The sensitive element of radiation instruments is an ion chamber. This consists of a cylinder containing a gas, an electrically insulated, center, collecting electrode, and a concentric high-voltage electrode. Different types of chambers, as described below, are used for process radiation measurement (primarily gamma detection) and health monitoring applications. Both are manufactured by the General Electric Company.

(a) The steel ion-chamber shell is a cylinder approximately 5 inches in diameter and 27 inches long. The chamber is filled with argon at atmospheric pressure. The chamber is primarily responsive to gamma emission, since the steel walls stop most of the beta emission.

(b) The fiber ion-chamber shell, also known as a Health Monitoring Ion Chamber, is a fiber cylinder approximately 5 inches in diameter and 19 inches long. The chamber is filled with air at atmospheric pressure. The instrument employs a minimum amount of metal in order to obtain a response (similar to that of the human body) to beta and gamma radiation.

Transmitting element: The small current in the ion chamber flows through shielded cables to a Beckman Amplifier located in the operating gallery. The amplifier is a sensitive current-measuring device which gives full-scale deflection of an indicating needle with currents of one microampere to 0.1 microampere, depending on the range selected. By the proper choice of input resistance and developed voltage, any one of six ranges may be used. Voltages up to 0.1, 1.0, or 10 may be impressed across either of two range resistors, rated at 10^{11} and 10^8 ohms. A voltage drop of 0 to 50 mv., caused by flow of the amplified current through a separate fixed resistor, is the variable measured and recorded by the receiving element.

Receiving element: The voltage drop (0 to 50 mv.) across the fixed resistor is recorded by a multiple-point strip-chart recorder (Brown Instrument Company). The recorder is synchronized with the action of a multiple-point switch to record the radiation intensity of several ion chambers separately or, by selection of the multiple-point switch, any one point continuously.

Alarm element: None.

Range: The radiation instrument can detect from 0.03 mr./hr. to 300 r./hr.

Accuracy: The accuracy of the steel ion-chamber instrument, in terms of the measured dose rate, varies with the energy of the incident radiation. If the instrument is calibrated with a 1.0 M.e.v. gamma source, the meter readings (r./hr.) for 0.25 and 3.0 M.e.v. gamma will be approximately 145 and 120 per cent respectively, of the true values.

DECLASSIFIED**E. VISUAL AND AUDIBLE AIDS****1. Visual Aids**

Two monocular-type periscopes are installed in the crane cab and extended along the crane beam to assist the crane operator in manipulation of equipment within the canyon. For either periscope, magnifying power and a corresponding vision angle may be selected from the following three combinations: (a) 3/4 power, 68° vision angle; (b) 2-1/2 power, 25° vision angle; (c) 5 power, 12-1/2° vision angle. The 6-inch diameter, magnesium fluoride-coated objective lens can be translated across the canyon on a rack and pinion drive powered with a 1/4-horsepower electric motor, and rotated about its path of translation by means of a gear system powered with a 1/4-horsepower electric motor. The silo crane operation may be viewed, directly, through 4-1/8 inch thick viewing windows, fabricated from laminated lead glass.

2. Audible Aids

Microphones are employed to transmit sound from operating equipment within the canyon cells through an amplifier and speaker system to the operating gallery. The function of the instrument is entirely qualitative, and experience and practice are required to differentiate abnormal sounds from changes in sound frequency or volume resulting from a normal operation, such as the operation of a jet. The microphone is generally placed on an extended element such as a pipe line. The microphone and speaker system are responsive to sound over the frequency range of 40 to 9000 cycles/second. A single 8-inch permanent-magnetic-type speaker and 15-watt amplifier, together with a multipoint (two to five-point) selector switch and volume control, enables one receiving station (speaker) on each panel board to serve a number of detectors.

F. FLOW MEASUREMENT AND CONTROL**1. Radioactive Process Streams -- Rotameter System**

The flow rate of nine canyon process streams, or radioactive streams commonly referred to as "hot" streams, must be accurately and continuously measured and controlled in order to secure optimum process performance, as explained in Chapter V. The flow-rate measurement and control of these streams is designed around a rotameter-type instrument.

General principle: Rotameters utilize a constant differential head, coupled with a variable-area annular restriction, to measure the flow rate of a fluid. This is accomplished by passing the stream being measured upwards through a vertical, truncated conical tube with the maximum diameter at the top. A rotor, in the form of a modified cylinder, within the tube adjusts its vertical position as required by the flow rate to increase the annular area between the tube and the maximum diameter of the rotor. The general flow equation relating the variables is $Q = CAH^{1/2}$, where Q = flow rate, C = orifice coefficient, A = area (variable), and H = head difference across the annular restriction (constant).

DECLASSIFIED

Application and purpose: Special design, all-stainless-steel rotameters are employed to measure the rates of radioactive streams within the Redox Plant canyon area. By means of appropriate auxiliaries, the measured flow rate is recorded and controlled to the desired value. The flow rate is obtained by inferential methods: i.e., the variable measured through indirect means is the area of the annular constriction, which is directly related to the flow rate. The reliability of the measurement is adequate for process control under the conditions for which the instrument was designed and calibrated. Irregular situations, such as change in the density or viscosity of the measured stream or foreign material in the stream, can result in erroneous measurements. These conditions can be corrected by recalibration or flushing. The operation and component elements of the rotameter flow control are illustrated diagrammatically in Figure XIX-27 and schematically in Figure XIX-28.

Sensitive element: The sensitive element, a special all-stainless-steel rotameter fabricated by the Fischer and Porter Co., consists of three major components. Two of the components, the tapered tube and the rotor, constitute a flow-rate responsive system. The tapered-tube section, integral with the rotameter body, is equipped with rotor stops at the upper and lower ends which restrict the rotor movement to a 50-mm. working length. The upper section of the rotameter body is enlarged to provide increased clearance between the rotor and the rotameter body. This permits the passage of foreign materials, too large to pass through the annular space between the tapered section of the rotameter body and the rotor, by flushing at high flow rates. The lower stop prohibits the rotor from seating against the tapered tube. The resulting small annular restriction permits reversed flow and draining of the rotameter and piping systems.

The rotor, in the approximate shape of two cones joined base to base, is designed to prevent the accumulation of solids on the upper face or gas on the lower face. An extension rod containing a soft iron core is suspended from the lower face. The rotor and extension rod move in a vertical path within the tapered tube, which is flared to a maximum diameter at the top. Thus, as the flow rate increases, the rotor moves higher in the tapered section in order to increase the area of the annular restriction. The vertical position of the rotor, within the working range of the tapered tube, is directly proportional to the flow rate. The third component of the rotameter, a pair of stainless-steel-clad inductance coils positioned concentrically within the stainless steel coil housing, permits the position of the rotor to be detected and registered on the remotely located recorder. Movement of the soft iron armature on the rotor extension rod into the field of one coil and out of the field of the other coil causes a relative change in the inductance of the two coils. The inductance change is detected by the receiving elements.

Transmitting element: The inclusion of the two inductance coils as a part of the null-type, recording and indicating bridge circuit eliminates the need for a separate transmitting element.

Recording and controlling element: The receiving element, a Foxboro Dynalog Recorder manufactured by the Foxboro Instrument Co., employs a

null-type, high-frequency (1000 cycles/second), electrical-bridge circuit to determine the position of the rotor in the rotameter tube by means of the soft iron armature attached to the rotor extension. A change in the position of the armature produces a change in the reactance of both coils. Each coil constitutes one leg of a bridge circuit. The other two legs of the bridge are a fixed and a variable capacitance. The unbalance resulting from a change in the two reactance components causes a small current to flow between the bridge terminals representing the junction points of the reactance and capacitance components. The direction of this current is detected and its magnitude measured by an unbalance voltage amplifier and balance control tube. The output voltage of the balance control tube is fed through a power amplifier to a solenoid motor, which acts to restore the circuit to equilibrium by movement of the plates in a variable capacitor. The movement simultaneously positions the recorder pen, which indicates and records the flow rate.

(a) A manually positioned set pointer is generally employed for setting the desired flow rate. Any deviation of the flow rate, as indicated by movement of the recorder pen away from the set pointer, causes the pneumatic pressure in the control system to increase or decrease as a function of the direction of the pen movement and in proportion to the amount of deviation of the pen away from the set pointer. The changes in pneumatic pressure position the process control valve to bring the flow rate to the proper value as indicated by the set pointer.

The rate of change in adjustment of the pneumatic output pressure can be controlled by auxiliary control elements, proportional band and reset rate. The setting of these devices is empirical and requires the services of the Instrument Division.

(b) Automatically positioned set pointers are provided for setting flow rates on three instruments (FRC-E-1, FRC-F-1, and FRC-F-4). Positioning of the set pointer is accomplished by means of a pneumatic, remotely controlled mechanism (Pneumaticset), which operates in conjunction with a weight factor recorder-controller. The rate of flow from a tank is adjusted to maintain the liquid level in that tank within prescribed limits.

The response of the flow controller can be varied from extreme sensitivity, i.e., a slight change in liquid level will cause an immediate change in flow rate, to zero sensitivity, which results in cancelling out any adjusting action of the weight factor recorder-controller on the flow-rate controller.

Controlled element: The desired flow rate is obtained by varying the position of the valve stem of a pneumatically operated, diaphragm throttling valve made by the Hammel-Dahl Co. The wetted portions of this valve are fabricated from stainless steel. The valve stem is sealed against leakage by a flexible, two-ply, stainless steel bellows. All valves are of the conical plug type, with a maximum stem travel of 0.5 inch, except those controlling the 2BP and 3BP streams. The latter two valves, because of the low flow rates involved, use spline plugs, with a 1.0-inch stem travel. The superstructure of the valves is black iron painted with

Amercoat No. 23. The spring action opposing the pneumatic pressure, applied through a diaphragm assembly, functions to close the valve. The working range of flow rates through the valves for a fixed pressure drop varies from 1 to 50, with movement of the valve plug from minimum to maximum opening.

Alarm: No alarm circuits are actuated by "hot" flow controllers.

Range: The flow ranges of rotameter flow-control systems vary from about 8:1 to 15:1, as indicated in the table below. The exact, actual range of each instrument is determined by individual calibration which is done as part of the process calibration and is reported on the instrument data sheet. The nominal ranges of the instruments are tabulated below:

Nominal Range for "Hot" Rotameters

<u>Operational Marking</u>	<u>Stream</u>	<u>Approximate Flow Rate, Gal./Min.</u>	<u>Approximate Specific Gravity</u>	<u>Approximate Viscosity, Centipoises</u>
FRC-F-7	IAF	0.175 - 1.40	1.68	4.3
FRC-F-8	ISF	0.24 - 3.6	1.38	6.8
FRC-F-1	2DF	0.219 - 1.75	1.65	3.3
FRC-F-4	3DF	0.219 - 1.75	1.64	4.0
FRC-E-6	IBP to Cross-Over Oxidizer	2 - 20	1.21	3.7
FRC-E-5	2AF	0.099 - 0.788	1.22	3.4
FRC-E-1	3AF	0.094 - 0.753	1.21	2.7
FRC-D-13	Feed to Waste Concentrator	1.5 - 15	1.17	2.2
FR-D5-1	Condensate Header to Condensate Stripper Reboiler	2 - 20	1.0	1.0

Accuracy: The delivered flow rate will be within ± 2.0 per cent of the flow rate indicated by the recording pen, provided the flowing stream has the same density and viscosity as the calibrating solution or appropriate correction factors for differences in density and viscosity between the calibrating solution and process solution have been applied to the recorded value. Deviations in density and/or viscosity will require re-calibration or the application of correction factors to the indicated flow rate.

2. Non-Radioactive Process Streams

Flow control of "cold" streams is obtained with three fundamental types of flow-control systems. Rotameters are employed for process chemical streams; orifice meters are employed for service streams, such as water and steam; and metering pumps are employed for the addition of reagent chemical solutions. A fourth type, the nitric acid proportioning system is essentially a combination of rotameter and metering-pump systems.

DECLASSIFIED

2.1 Rotameter system

General principles: The principles of "cold" rotameter operation are identical with "hot" rotameter principles discussed in Subsection 1, above.

Application and purpose: Standard design, glass-tube rotameters are used to measure the flow rate of "cold" process chemical streams. These instruments are identical in all respects to the "hot" rotameters with the exception of the position of the inductance coils, which are above the tapered tube, and the use of glass tubes, which permit visual checks of the rotor position and qualitative observations of the flowing stream. The diagrammatic and schematic illustrations given in Figure XIX-27 and XIX-28, although specific for "hot" rotameters, are applicable to the "cold" system with the exception of minor constructional features.

The flow rate is determined indirectly by the position of the rotor in the tapered, glass metering tube. An extension tube is rigidly attached to the upper face of the rotor. The upper end of the rotor extension contains a soft iron core. Movement of the iron core within the field of two inductance coils attached to the top of the rotameter body changes the relative inductance and permits the receiver to remotely register the per cent of full-scale travel of the rotor, which is proportional to the flow rate.

Sensitive element: The sensitive element is a standard, transmitting-type, glass-tube rotameter manufactured by the Fischer and Porter Co. All metallic elements which are wetted by process solution are fabricated from stainless steels of the Type 300 series. The flow rate is determined by the position of the rotor, which is detected by the effect of an iron armature within a stainless steel extension rod on the reactance values of the two coils mounted above the top of the glass tube assembly. The location of the coils above the rotameter permits the flow to enter at the bottom of the rotameter frame and leave through a port in the top of the frame. No flow occurs in the core space of the coils.

Transmitting element: The inclusion of the two inductance coils as a part of the null-type, recording and indicating bridge circuit eliminates the need of a separate transmitting element.

Receiving and controlling element: The "cold" rotameters employ a Foxboro Dynalog Recorder identical with the units described for the "hot" rotameters in the preceding subsection (1) of this chapter.

Controlled element: The controlled element is a diaphragm-motor, air-operated Hammel-Dahl valve which has been described in the preceding subsection of this chapter.

Alarm: None.

Range: The nominal range of each instrument is summarized in the following table. The actual range of each instrument is determined by process calibration of each individual instrument, which is recorded on the instrument data sheet.

DECLASSIFIED

Nominal Range for "Cold" Rotameters

<u>Operational Marking</u>	<u>Stream</u>	<u>Approx. Flow Rate, Gal./Min.</u>	<u>Approx. Sp. Gr.</u>	<u>Approx. Viscosity, Centipoises</u>
FRC-1A	IAX	0.7 - 5.6	0.81	0.6
FRC-1B	IBS	0.471 - 3.76	0.80	0.6
FRC-1S	ISX	0.25 - 2.5	0.81	0.68
FRC-2D	2DX	0.876 - 7.0	0.81	0.6
FRC-3D	3DX	0.876 - 7.0	0.81	0.6
FRC-2A	2AX	0.188 - 1.51	0.82	0.68
FRC-3A	3AX	0.164 - 1.31	0.82	0.68
FRC-801-S	ISS	0.1 - 0.8	1.21	2.7
FRC-801-A	IAS	0.175 - 1.40	1.29	4.6
FRC-801-B	IBX	0.094 - 0.753	1.22	3.6
FRC-801-C	ICX	0.471 - 3.76	1.00	0.9
FRC-802-D	2DS	0.219 - 1.75	1.30	4.6
FRC-803-D	3DS	0.219 - 1.75	1.30	4.6
FRC-802-E	2EX	0.439 - 3.50	1.00	0.9
FRC-803-E	3EX	0.439 - 3.50	1.00	0.9
FRC-802-B	2BX	0.037 - 0.298	1.00	0.9
FRC-803-B	3BX	0.037 - 0.298	1.00	0.9
FRC-802-A	2AS	0.094 - 0.753	1.22	2.8
FRC-803-A	3AS	0.094 - 0.753	1.21	2.8
FRC-E1 & 2-A	2BP Butt	0.05 - 0.3	1.34	7.7 or 1.8
FRC-801-0	10S	0.169 - 1.35	1.02	1.0
FRC-G3-B	5% NaOH to Organic Distillation Column	0.03 - 0.3	1.09	1.2
FRC-E6 & 7-B	IBP Butt	0.05 - 0.3	1.34	7.7 or 1.8

Accuracy: The delivered flow rate will be within ± 2.0 per cent of the flow rate indicated by the recording pen, provided the flowing stream has the same density and viscosity as the calibrating solution or appropriate correction factors for differences in density and viscosity between the calibrating solution and process solution have been applied to the recorded value.

2.2 Orifice-meter system

General principle: Orifice meters operate on the principle of a constant-area flow restriction with variable differential head. The restriction results in an increase in velocity of the flowing stream and a consequent decrease in the hydrostatic head. The relationship of flow rate and head is expressed in general form by the following equation: $Q = CAH^{1/2}$, where Q = flow rate, C = orifice coefficient, A = area (constant), and H = head difference across the restriction (variable). The difference in hydrostatic head created by the orifice is impressed upon a pneumatic relay system which transmits an output air pressure to a receiving instrument. The receiving instrument records the amplified difference in hydro-

static head. By the above relationships, the reading may be converted to flow rate.

Application and purpose: The orifice-meter system is employed on steam and water streams only, since it has a low rangeability (approximately 1 to 3) and is not drainable or flushable. In this type of service, change in the capacity can be quickly achieved by changing orifice plates. The pneumatic system requires a clean air supply. In time, oil and foreign matter accumulate in the air passages and nozzles and erroneous readings will result. Since the meters are located in an operating area, these troubles can be quickly remedied or prevented by periodic maintenance. Figure XIX-29 illustrates diagrammatically the elements of the orifice flow measurement and control system, and Figure XIX-30 illustrates schematically the components of each element of the system.

Sensitive element: The sensitive element consists of the orifice-plate restriction and the pressure taps. The pressure taps are located within the flanges which retain the orifice plate. The high-pressure tap is upstream from the orifice plate and the low-pressure tap, downstream.

Transmitting element: The pressure taps of the orifice plate are connected by a Foxboro D/P Cell (differential pressure) transmitter. All parts of the cell in contact with solution, including the force-measuring diaphragm, are constructed of stainless steel. A pneumatic transmitter, integral with the diaphragm assembly, converts the pressure differential, which is in the range of 0 to 100 inches of water pressure, to a proportional air output of 3 to 15 lb./sq.in. The output pressure from the D/P Cell actuates a recorder pen to give an indication of the flow rate.

Receiving and controlling element:

(a) Flow indicator. The output air pressure from the Foxboro D/P Cell is received by a Bourdon-tube pressure gage (range, 3 to 15 lb./sq. in.ga.), the dial of which is graduated 0 to 100 on a square-root scale. The dial reading is converted to a flow-rate reading by means of a calibration curve.

(b) Flow recorder. The output air pressure of the D/P Cell is received by a pressure-responsive bellows element which converts the pressure to a pen movement. The pen records on a square-root chart graduated from 0 to 100 and calibrated in flow units of gal./min.

(c) Flow recorder-controller -- manually positioned set pointer. The flow rate of the measured stream is controlled by a pneumatic regulator which transmits an output air pressure to a diaphragm valve. The valve throttles the flow to bring the measured flow rate, as indicated by the recorder pen, into coincidence with the manually positioned controller set pointer. This is accomplished by a system of linkages which increase or decrease the output air pressure in proportion to the direction and deviation of the pen from the set pointer.

(d) Flow recorder-controller -- automatically positioned set pointer. In order to secure the maximum benefit of automatic control, it is desirable in certain applications to make the controller set pointer responsive

to variations in a primary process variable. This is applied to specific gravity control in concentrators and vapor temperature in the Hexone Distillation Column. The deviation of the measured variable, i.e., specific gravity or temperature, from the value indicated by the set pointer causes an adjustment in the stream flow rate tending to correct the deviation. This is accomplished by an indirect action whereby the air output from the controller on the specific gravity or temperature-controlling instrument is transmitted to a pneumatic device (Pneumaticset) which repositions the set pointer in the flow controller and, consequently, adjusts the stream flow rate as required by the primary variable, viz., specific gravity or temperature.

Controlled element: The output air pressure from manual and automatic index positioning controllers is transmitted to a pneumatically operated throttling-type control valve. The flow rate is thereby adjusted to the value indicated by the set pointer.

Alarm: None.

Range: The nominal working range of an orifice-meter system (with an accuracy of $\pm 3\%$ or better) is from 57.5 to 100 per cent of the maximum flow rate. Inasmuch as the throttling valves have a rangeability of approximately 1 to 50, the range of the system is restricted by the orifice plate. By replacement of the orifice plate the range can be readily changed. The nominal range of each orifice-meter system is shown on the instrument flow diagram. The exact range of each instrument is determined by calibration and recorded on the instrument data sheet.

Accuracy: The accuracy of the controlled flow rate is a function of the per cent of maximum flow rate. At 100 per cent of maximum flow rate the flow is controlled to ± 1 per cent of the desired value. At 70 per cent of maximum flow rate the system will deliver a flow rate ± 2 per cent of the desired flow rate; at 57.5 per cent, ± 3 per cent; and at 33 per cent, ± 9 per cent of the desired flow rate.

2.3 Metering-pump system

General principle: Metering pumps utilize a positive displacement system with adjustable stroke and frequency for the continuous, controlled addition of reagent chemical solutions.

Purpose and application: Metering pumps are employed for the continuous addition of 25 per cent sodium hydroxide solution to the ICU and 2EU Concentrators (E-F2-1, E-F5-1) as a means of controlling the acidity of the 2DF and 3DF streams.

Sensitive element: None. The system is manually controlled from an interpretation of the chemical assays of 2DF and 3DF solutions and the observed flow rates of these streams.

Transmitting element: A manually operated pneumatic system located on the panel board transmits an adjustable and variable pressure (0 to 15 lb./sq.in.ga.) to a pneumatically operated positioner on the pump drive system.

Receiving and/or controlling element: The pneumatic pressure from the panel-board-mounted control station is received by a Conoflow pneumatic piston motor which, in turn, positions the speed-regulating lever of a variable-speed transmission.

Controlled element: The controlled element consists of three primary components: (a) a Graham variable-output-speed transmission powered by a constant-speed (1725 rev./min.) electric motor; (b) a Proportioners, Inc., Treet-O-Controller; and (c) a pneumatically powered, single-acting, plunger pump. The Treet-O-Controller converts variable-speed rotary motion from the Graham transmission to variable-frequency reciprocating motion that actuates a slide, or "D", valve in the air supply line to the plunger pump. The stroke length, or displacement per stroke, can be manually adjusted at the pump by inserting or withdrawing the pneumatic-piston stop. The direct-connected stainless steel plunger operates in a Graphitar cylinder liner within the stainless steel reagent head. The plunger is sealed against leakage by a series of Teflon rings within an outside packing gland. In normal operation, adjustment of the addition rate is obtained by frequency control. Stroke adjustment is reserved for compensating for gross changes in flow rate or flowsheet conditions.

Alarm: None.

Range: The discharge rate can be varied from 0 per cent to 250 per cent of the normal flow rate shown on the engineer's flow sketches (see Chapter VI, Section A).

Accuracy: The volumetric delivery will be ± 2.0 per cent of the calibrated delivery rate at all operating rates.

2.4 Nitric acid proportioning system

Provision has been made for the continuous make-up of seven streams of acidified (nitric acid) hexone required as scrub or extractants for the solvent-extraction column battery. This eliminates the storage of acidified hexone, an undesirable practice, and reduces the tankage volume in the silo which would have been required for batch make-up of these streams.

General principle: The system for the continuous blending of nitric acid and hexone is dependent upon two control actions: (a) flow-rate control of the larger-volume stream (water-saturated hexone) and (b) addition of a second stream (nitric acid) at a rate proportional to the flow rate of the larger stream. By means of this system, the acidity and flow rate of the blended stream may be adjusted over a wide range of values.

Application and purpose: Nitric acid proportioning systems are required for seven solvent-extraction columns employing acidified hexone as a scrub or extractant stream (ISX, IAX, IBS, 2DX, 3DX, 2AX, 3AX). The systems supply acidified hexone ranging in nitric acid composition from 0.01 to 0.50 molar, with the same rangeability in flow rate as the other influent streams to the solvent-extraction battery.

The flow rate of the non-acidified hexone stream is the only variable

98
DECLASSIFIED

measured. The composition of the acidified hexone is regulated by a combined automatic and manual adjustment. The former, or automatic, action serves to maintain a fixed ratio between the flow rate of the hexone and the acid streams, irrespective of fluctuation in the hexone flow rate. The latter, or manual, action permits adjustment of the ratio which is directly proportional to the acid molarity of the acidified effluent stream.

The system produces a reagent stream at the desired flow rate, within the limitations of the rotameter system. The acidity of the flowing, blended stream will be maintained within the desired range if the nitric acid reagent is of constant composition. A change in the molarity of the added nitric acid will cause a deviation in the reagent stream which is directly proportional to the change in molarity of the concentrated acid.

A diagrammatic illustration of the elements of the system and their relationship is shown in Figure XIX-31, and a schematic explanation showing the components of each element is presented in Figure XIX-32.

Sensitive element: Although two systems (flow-rate control and proportional-rate control) are combined to accomplish the control objective, they are both flow-rate dependent. The sensing element is a rotameter-transmitter which is identical in operation and construction to the "cold" rotameter described under 2.2, above.

Transmitting element: None, as previously explained in conjunction with "cold" rotameters, under 2.2, above.

Receiving and controlling element: The receiving element, a Foxboro Dynalog Recorder, is identical with the unit employed for "hot" and "cold" streams previously described in Subsection F1.

Two controlling elements, both located in the same instrument case, are employed. One controlling element sends an air signal to a diaphragm control valve in the non-acidified hexone line. This control system is identical to that discussed previously under the controlling rotameter system (Subsection F1). The other controller element transmits a proportional air signal of 3 to 15 lb./sq.in., depending on the flow rate of the hexone stream, to a metering-pump system.

(a) Control valve. The flow of the entering non-acidified hexone stream is throttled by action of a Hammel-Dahl, diaphragm-motor valve described in more detail in Subsection F1.

(b) Nitric acid injection system. The varying-output air pressure from the controller causes the following sequence of events to occur: (1) the air pressure enters a Conoflow piston motor; (2) movement of the piston motor positions the speed-regulating lever of a stepless, variable-output Graham speed reducer (0 to 30 rev./min.); (3) the variable-speed, rotary motion is converted to reciprocating motion by a Proportioneers, Inc., Treet-O-Control unit, which also embodies a sliding-type air valve; (4) the sliding, air-pilot valve controls the cycle of a Proportioneers air-operated piston pump which is directly connected to the plunger of

DECLASSIFIED

the nitric acid metering pump. The change in the volume ratio of acid to hexone is accomplished by manually lengthening or shortening the stroke of the pneumatic power piston and, necessarily, the stroke length of the directly connected plunger delivering acid to the mixing point.

Alarm: Malfunctioning of the proportional addition system, exclusive of the flow-rate control system, is detected by measurement of the temperature rise in the hexone stream resulting from the exothermic reaction between hexone and nitric acid. The temperature difference between the entering hexone stream and the acidified hexone stream for each unit is recorded on Temperature Recorder TR-2A, which has a range of 0 to 10°C. An alarm switch, TAS-2A, actuated by a temperature difference in excess of the set value, energizes a light and bell system.

Range:

(a) Rotameter system. The controlled flow-rate range is nominally 1 to 8.

(b) Nitric acid proportioning system. The rate of nitric acid addition can be varied from 0 to 150 per cent of the established flowsheet rate. The nominal flow range is shown on the instrument flow diagrams.

Accuracy: The accuracy of the delivered flow rate is within ± 2.0 per cent of the flow rate indicated by the recording pen. The accuracy of the composition, or acid concentration of the acidified hexone, is within ± 2.0 per cent of the value calculated from the calibration curves for the metering-pump system.

G. PURGE-TYPE PRESSURE INSTRUMENTS

Purge-type, or dynamic-type, pressure-measuring instruments utilize a flowing stream of either air or inert gas to counterbalance the pressure or hydrostatic head of another fluid into which the purging gas flows through open-ended tubes. This type of instrument is widely used for a variety of applications which are basically dependent upon the measurement of total or differences in hydrostatic pressure. The purge-type instruments are suited to the Redox process because those elements of the instrument located in the radioactive zones are extremely simple. The auxiliary equipment used for transmission, indication, recording, and/or controlling of the primary signal is located in accessible operating areas.

1. Weight Factor Instruments

General principle: The weight factor is determined by measuring the difference in hydrostatic pressure between two points, one of which is in the liquid being measured and the other, in the vapor space directly above the liquid. The pressure at each point is counterbalanced with a gas-filled column flowing into the system. The difference in gas pressure is measured with a manometer, or equivalent device. The measured hydrostatic pressure of the liquid is directly proportional to the weight of the contents of a tank with straight walls, as is apparent from the following relationships:

DECLASSIFIED

997

$W = A \Delta P,$
 where W = weight of tank contents, lb.;
 A = cross-sectional area of tank at horizontal section, sq.ft.;
 ΔP = measured pressure difference, lb./sq.ft.

Application and purpose: Weight factor instruments are employed to determine the contents of tanks in terms of (a) the pounds of a specific component, if the weight percentage composition is known, or (b) the liquid level, or total volume, if the specific gravity is known. Through related control instruments (flow-rate controllers) or controlled elements (motor-operated valves), weight factor instruments are also employed as a sensing element in the regulation of liquid levels. In principle, this type of instrument is limited only by the desired accuracy and the range of the receiving element plus the reliability and precision of the tank calibration relating volume to liquid level. False reading can result from (a) too high a purge-gas flow rate, which introduces line friction, (b) leakage in the instrument lead lines, or (c) restrictions within the instrument lead lines.

A diagrammatic illustration of the components of the weight factor recording and controlling system is shown in Figure XIX-33 and a schematic description of the elements of the component parts is given in Figure XIX-34.

Sensitive element: Two stainless steel 1/2-inch i.p.s. dip tubes, supplied with a regulated flow of gas, constitute the sensitive element.

Transmitting element: The difference in pressure, or head, is transmitted through the gas-filled lines connecting the dip tubes to the receiving element. Gas is supplied to each line at a controlled rate of approximately 0.5 cu.ft./hr. through a Fischer & Porter Co. C-clamp rotameter with a range of 0.1 to 1.0 cu.ft./hr.

Receiving and/or controlling element:

(a) Indicating. The lines from the dip tubes are joined directly to a Trimount Instrument Co. vertical well-type manometer. The high-pressure tap connects to the manometer well and the low-pressure tap, to the manometer tube. The manometer is filled with Red Oil (supplied by Trimount Instrument Co.) which is available with specific gravities of 0.827, 1.00, and 2.95. The height of the indicating fluid is measured by a scale graduated in inches of water pressure and adjustable for zero position.

(b) Recording and controlling. The lines from the dip tubes are connected to high and low-pressure connections of a Taylor Instrument Co., aneroid, bellows-type recorder which converts the measured pressure differential to a linear 0 to 100 scale reading, calibrated in inches of water.

The controller transmits an output pressure of 3 to 15 lb./sq.in.g.a. proportional to the position of the pen from the control set pointer and the relative position of the recording on the chart. The output pressure

DECLASSIFIED

is received by a Foxboro Pneumaticset in a Foxboro flow recording and controlling instrument or transmitted directly to a diaphragm-motor, air-operated throttling valve; in either case, the resultant is an adjustment of the stream flow rate.

Controlled element:

(a) Indirect. The weight factor controller functions by repositioning the control set pointer of a flow recorder-controller through the action of a Foxboro Pneumaticset. The flow recorder-controller maintains the tank liquid level within predetermined limits by adjusting the flow rate from the tank.

(b) Direct. The Organic Surge Tank, G-1, liquid level is directly controlled by transmitting air pressure to a diaphragm-motor air-operated throttling valve which, in turn, adjusts the discharge flow rate. For a description of the valve, see Section D of this chapter and Figure XIX-34.

Alarm: A high liquid-level alarm is installed on certain process vessels and sumps. A pressure-actuated adjustable-range electric switch, made by the Meltron Corp., is operated by the pressure differential across the high and low-pressure weight factor dip tubes. The switch energizes a light and horn, made by the Panalarm Co. The horn has a reset button, but the light continues to indicate until the liquid level returns to normal.

Range: The instrument flow diagrams (Figures XIX-2 to XIX-23) show the nominal range for all instruments. The actual range will be determined by process calibration and the data recorded on the data sheet for each specific instrument. The ranges of individual instruments vary from 0 to 20 inches of water pressure to 0 to 200 inches of water pressure.

Accuracy:

(a) Weight factor indicator. The accuracy of the manometer is determined by the smallest graduation on the scale, either 0.1 or 0.2 inches of water pressure, and by the position of the liquid level with respect to the dip tube. As the interface approaches the end of the dip tube, the accuracy approaches zero.

(b) Weight factor recorder. The weight factor recorder is accurate to ± 1 per cent of full-scale chart reading. The absolute accuracy varies directly with submergence and may be readily calculated for each individual reading.

2. Specific Gravity Instruments

General principle: Specific gravity of a fluid is determined indirectly by measuring the difference in hydrostatic pressure between two points in the fluid, with a known fixed difference in elevation. The pressure at each point is counterbalanced with a column of gas flowing into the fluid. The difference in pressure in the gas-filled lines is measured with a manometer, or equivalent device, from which the specific gravity may be read directly, as is shown in the following equality:

██████████
DECLASSIFIED

1919

999
HW 10700

$$\Delta P = \Delta L \rho,$$
$$\text{or } \rho = \frac{\Delta P}{\Delta L}$$

where ρ = specific gravity (or density); P = measured pressure difference; and ΔL = fixed distance between points. Since ΔL is a constant,

$$\rho = k \Delta P.$$

The units chosen for the proportionality constant "k" will determine whether the value is expressed in density or specific gravity units. The Redox Plant instruments will be calibrated in specific gravity units.

Application and purpose: The indication of specific gravity by indicating and recording instruments is useful in providing an instantaneous partial indication of process performance and for certain applications it is useful as the measured variable employed for process control. For example, in the concentration of ICU and 2EU the specific gravity is measured and compared to a desired value; deviations from the desired value result in adjustment of the evaporation rate by throttling the stream supply to the evaporator. It can be readily appreciated that the measured specific gravity will be at the system temperature and that relationships between specific gravity and temperature must be known to reduce the measured value to a standard reference temperature. The vessel must contain sufficient fluid to submerge both dip tubes or an erroneous reading will result. Operational difficulties, such as (a) too high a purge-gas flow rate, (b) leakage in the instrument lead lines, and (c) restrictions in the instrument lead lines, will result in false readings.

The components of a specific gravity measuring and controlling installation are shown diagrammatically in Figure XIX-35 and schematically, showing the elements of each component, in Figure XIX-36.

Sensitive element: Two stainless steel 1/2-inch i.p.s. dip tubes with a 10-inch difference in vertical height, supplied with a regulated flow of gas, constitute the sensing element.

Transmitting element:

(a) Indicating instruments. The difference in pressure is transmitted through the inert-gas-filled lines connecting the dip tubes and receiving element (indicating manometer). Inert gas is supplied to each line at a controlled rate of approximately 0.5 cu.ft./hr. through a Fischer and Porter C-clamp rotameter with a range of 0.1 to 1.0 cu.ft./hr.

(b) Recording and controlling instruments. The lines from the dip tubes terminate at a Republic Instrument Co. pneumatic differential pressure transmitter which transmits an output air pressure to the receiver proportional to the measured pressure difference. In order to increase the useful range of the recording system, the actual pressure difference is suppressed by a mechanical system within the Republic transmitter. Suppression results in canceling out the pressure difference when the dip

██████████
DECLASSIFIED
██████████

tubes are submerged in water; consequently, the transmitter is operable only for systems with a specific gravity between 1.0 and 2.0. The output air pressure from the Republic transmitter varies directly with the specific gravity and permits a pressure-responsive element in the receiver to be calibrated in specific gravity units.

Receiving and controlling elements:

(a) Indicating instruments. A Trimount Instrument Co. vertical well-type manometer filled with Red Oil (0.827 specific gravity) is employed for indicating the specific gravity. For details, refer to Subsection G1 of this chapter.

(b) Recording instruments. The pressure from the Republic pneumatic transmitter is received by a bellows-type recorder, range 3 to 15 lb./sq.in., made by (1) Brown Instrument Co. for all recorder-controllers and (2) Taylor Instrument Co. for all non-controlling recorders.

(c) Recording and controlling instruments. The recorder is mechanically coupled to a Brown pneumatic controller. This results in regulation of the specific gravity of the concentrate in the Uranium (ICU, 2EU, 3EU) Concentrators and the Waste Concentrator by automatic adjustment of the steam flow to the concentrator coils. Steam flow is adjusted with a pneumatic device (Pneumaticset) within the steam flow controller, which automatically positions the set pointer on that instrument. The Pneumaticset is actuated by a pneumatic pressure from the specific gravity controller.

Controlled element: Control is obtained indirectly through a Pneumaticset receiver in the flow recorder-controller. The Pneumaticset repositions the control set pointer of the flow recording and controlling instrument to increase or decrease the flow rate in order that the specific gravity recorder pen will agree with the specific gravity recorder-controller set pointer.

Alarm: None.

Range:

(a) Indicating instruments. The range is from 0 to 1.7 specific gravity units.

(b) Recording and controlling instruments. The range is from 1.00 to 2.00 specific gravity units.

Accuracy:

(a) Specific gravity indicator. The accuracy of a manometer reading is determined by the smallest graduation on the scale, which is 0.005 of a specific gravity unit.

(b) Specific gravity recorder. The specific gravity recorder is accurate to ± 0.01 of a specific gravity unit.

3. Interface Instruments.

General principle: The position of the interface between organic and aqueous phases is determined by measuring the differential hydrostatic pressure between two points with a known fixed difference in vertical height. The hydrostatic pressure at each point is counterbalanced by a gas pressure within a dip tube. The pressure differential between the dip tubes is detected by a manometer or equivalent device. The measured pressure difference between two dip tubes with a known difference in vertical height represents the summation of the product of the height of each phase multiplied by its specific gravity. The depth of each phase between two fixed points can be calculated and the location of the interface determined if the specific gravity of each phase, the distance between two vertically separated points, and the total difference in pressure are known.

$$\Delta P = H_o \rho_o + H_a \rho_a = (H - H_a) \rho_o + H_a \rho_a = H_a (\rho_a - \rho_o) + H \rho_o$$

$$\text{or } H_a = \frac{\Delta P - H \rho_o}{\rho_a - \rho_o}$$

where ΔP = measured pressure difference; H_o = height of organic phase between dip tubes; H_a = height of aqueous phase between dip tubes; $H = H_o + H_a$ = distance between dip tubes (known); ρ_o = density of organic phase (known); ρ_a = density of aqueous phase (known). Consequently, the interface position for a system with known and constant phase density is directly proportional to the measured pressure difference.

$$H_a = \frac{\Delta P}{\rho_a - \rho_o} - \frac{H \rho_o}{\rho_a - \rho_o} = \frac{\Delta P}{K_1} - K_2$$

Application and purpose: Interface-detecting instruments are employed on the solvent-extraction and solvent-treating columns to indicate the location of the interface and to permit automatic regulation of the interface position by adjustment of the flow rate of the effluent aqueous stream. The instrument is dependent upon the reliability of the two specific gravity measurements and, under normal circumstances, will indicate and control the interface as required for uniform process operation. Certain operational difficulties, such as (a) too high a purge-gas flow rate, (b) leakage in the instrument lead lines, or (c) restrictions within the instrument lead lines, will cause false readings.

A diagrammatic illustration of the components of the interface recording and controlling system is shown in Figure XIX-37 and a schematic description of the elements of the component parts is given in Figure XIX-39.

Sensitive element: Three stainless steel 1/2-inch i.p.s. dip tubes are submerged in the column disengaging section: the first, to a point about 4 inches above the column packing, the second, 25 inches above the first; and the third, 25 inches above the second. The first and second dip tubes are, respectively, the high and low-pressure lines of the interface recording and controlling instrument, and the second and third dip tubes are, respectively, the high and low-pressure lines of the interface-recording

instrument. The flow of inert gas through the dip tubes completes the dynamic sensing system.

Transmitting element: The difference in pressure is transmitted through the inert-gas-filled lines connecting the dip tubes and receiving element. Inert gas is supplied to each line, at a controlled rate of approximately 0.5 cu.ft./hr., through a Fischer and Porter Company C-clamp rotameter with a flow range of 0.1 to 1.0 cu.ft./hr.

Receiving and/or controlling element: A Taylor Instrument Company, aneroid-bellows recorder measures the differential pressure existing across the dip tubes and converts the bellows deflection to a pen movement on a 0 to 100 linear-scale chart. A chart reading of 0 is equivalent to a differential pressure of 20 inches of water and a reading of 100 is equivalent to a differential pressure of 35 inches of water.

The interface-position instruments combine two receiving and recording elements and one controlling element within each instrument case. Normally, the position of the interface is maintained between the lower and intermediate dip tubes, and the intermediate and upper tubes are both immersed in the organic phase. Therefore, the control element is coupled with the pen recording the differential pressure between the lower and intermediate dip tubes. An adjustment permits the other pen to be coupled to the pneumatic controller. Normally, the pressure differential between the upper pair of dip tubes is interpreted in terms of the specific gravity of the organic phase.

The pneumatic controller maintains the desired interface position by regulating the flow rate of the aqueous effluent stream from the column. An output air pressure, which is transmitted from the controller, operates a flow-throttling valve in the effluent stream. The air pressure is proportional to the deviation of the pen from the set pointer and the relative position of the pen on the chart.

Controlled element: The output air pressure from the controller is transmitted to a Hammel-Dahl, diaphragm-motor, air-operated valve installed on the aqueous effluent line from the column. The valve is normally closed by spring action and is pneumatically opened, as required, to restore the interface position to the desired point as indicated by coincidence of the interface-recorder pen with the control set pointer.

Alarm: None.

Range: A differential pressure of 15 inches of water produces full-scale deflection of the instrument pen. The effective range of the instruments is 20 to 35 inches of water pressure, which is the equivalent of a specific gravity range of 0.8 to 1.4. This is accomplished by inserting a 20-inch water head in series with the low-pressure dip-tube line. Since the dip tubes are spaced 25 inches apart, a single liquid phase of 0.8 specific gravity between the tubes results in a pressure difference of zero ($25 \times 0.8 - 20 = 0$); whereas, a single phase of 1.40 specific gravity results in a pressure differential equivalent to 15 inches of water pressure ($25 \times 1.40 - 20 = 15$).

Accuracy: The instrument is fundamentally responsive to changes in pressure differential and can record and control to ± 0.15 inches of water pressure. From this value and a knowledge of the densities of the aqueous and organic phases, the accuracy of the indicated interface position may be estimated. It has been shown that

$$H_a = \frac{\Delta P}{K_1} - K_2,$$

where H_a is the height of the aqueous phase (interface location) in inches, ΔP is the pressure differential in inches of water, and K_1 and K_2 are constants. Also, the constant

$$K_1 = \rho_a - \rho_o,$$

where ρ_a and ρ_o are the densities of the aqueous and organic phases, respectively. Since ΔP is accurate to ± 0.15 inches of water pressure, the accuracy of the interface location (H_a) may be shown, by calculation from the above relationships, to be equal to $0.15 / (\rho_a - \rho_o)$. For example, if values of ρ_a and ρ_o of 1.30 and 0.97, respectively, are assumed, then H_a is accurate to ± 0.45 inches. Thus, when the interface is indicated to be midway between the dip tubes ($H_a = 12.5$ in.) deviation of the actual location from this position may be ± 0.45 inches.

4. Differential Pressure Instruments -- Solvent-Extraction Columns

General principle: Differential pressure is a measure of the difference in hydrostatic head at two points with a known fixed difference in vertical height. The hydrostatic pressure at each point is counterbalanced with a gas pressure. The pressure differential in the gas supply lines is detected by a manometer or equivalent device.

Application and purpose: Differential pressure measuring instruments are used to measure the differential pressure over a portion of the length or the total length of a solvent-extraction column. The measured differential pressure is useful in (a) detecting flood or incipient flood conditions within the column, (b) indirectly indicating waste losses, and (c) indicating deviations from normal column operating conditions.

The applications cited are limited by the accuracy requirements of the differential method. For example, waste losses in the IA Column increase from 0.2 per cent to 2.0 per cent with an increase in the aqueous phase specific gravity of 0.015 at a point approximately 6 feet below the feed point. The accuracy of the sensing and recording systems is 0.005 specific gravity units.

False readings can result from (a) high gas flow rates, (b) restrictions in the instrument lead lines, and (c) leaks in the instrument lead lines.

The components of differential-pressure-type instrumentation are shown diagrammatically in Figure XIX-38 and schematically, showing the elements of each component, in Figure XIX-39. The range and location of

1004

each pressure-differential-type instrument is tabulated in Table XIX-40.

Sensitive element: Two stainless steel 1/2-inch i.p.s. lines, welded to the column shell, are used to detect the pressure within the column. Those applications for detecting a small differential pressure are spaced four feet apart. Installations for measuring the total column differential have the low-pressure tap in the column vent header, and the high-pressure tap approximately one foot above the effluent aqueous-stream outlet.

Transmitting elements: The pressure within the column is transmitted through the gas-filled instrument lead lines to a Republic Instrument Co. pneumatic transmitter. The Republic instrument measures the difference in pressures within the instrument lead lines by means of a force-balancing system and transmits, to the receiving instrument, a variable output pressure (3 to 15 lb./sq.in.ga.) proportional to the measured pressure differential. In order to improve the sensitivity of the pneumatic transmitting unit, an additional fixed pressure drop is introduced into the low-pressure lead line from the column. This decreases the apparent pressure difference between the column taps and improves the response to small changes in differential pressure within the column.

Receiving and/or controlling element: The output pressure from the transmitter is converted by a Taylor Instrument Company bellows-type instrument to pen movement on a linear chart graduated from 0 to 100 and calibrated in inches of water pressure and specific gravity units.

Controlled element: None.

Alarm: None.

Range: The range of the differential-pressure-recording system is 0 to 25 inches of water pressure for the instruments measuring the differential across a four-foot distance within the column and varies according to the column height for instruments measuring total column pressure.

The nominal range in terms of specific gravity and inches of water pressure for each instrument is shown in Table XIX-40. The actual range will be determined by process calibration and recorded on the instrument data sheet.

Accuracy: The accuracy of the measurement is ± 1 per cent of full-scale chart reading and will vary in absolute specific gravity units in accordance with the range of the instrument.

5. Miscellaneous Differential Pressure Instruments

Differential pressure instruments are used to measure pressure differences between (a) tanks and cells, (b) tanks and towers, and (c) cells and operating galleries. Instruments for these purposes are identical in principle to the differential pressure instruments for the solvent-extraction columns. Important differences in detail are as follows:

(a) Transmitting elements (pneumatic transmitters) are not used. The limited ranges necessary for these instruments make this possible.

(b) Manometers (vertical or inclined) are used as receiving elements for all indicating systems. Manometer ranges are shown on the instrument flow diagrams.

(c) Taylor aneroid bellows recorders are used as receiving elements for all recording systems. In general, their nominal ranges are 20 to 40 inches of water, although actual ranges will be determined by process calibration.

(d) The accuracy of the inclined manometers is 0.01 in. Accuracy depends on scale graduation and for vertical manometers is either 0.1 or 0.2 in.

H. TEMPERATURE INSTRUMENTS

1. Mercury Thermometers

Mercury thermometers are used to measure the temperature of fluids. Mercury-type instruments depend on the difference in the coefficient of expansion of mercury and the confining system, usually glass or metal. These instruments are used in the Redox Plant solely for indicating temperatures. The instruments are either mercury-in-glass thermometers, in which mercury expands cubically into an evacuated space in a glass tube, or mercury-in-tubing thermometers, in which the expansion of mercury expands a Bourdon tube. All mercury-type thermometers used in the Redox Plant are calibrated in Centigrade degrees.

2. Resistance Thermometers

General principle: Resistance thermometers depend on the variation of the electrical resistance of a metallic conductor with temperature. A temperature-sensitive resistance coil forms one arm of a Wheatstone-bridge circuit. The other three arms of the bridge contain resistances which have an extremely low temperature coefficient of resistance. In operation, any unbalance of the bridge circuit, due to a variation in the resistance of the temperature-sensitive element, appears as a potential difference. The self-balancing bridge recognizes the condition of unbalance, determines its direction and magnitude, and positions the slide-wire or slide-wire contactor to rebalance the bridge and to indicate the temperature.

Application and purpose: Resistance thermometers are used in the Redox Plant where temperatures must be recorded or where the temperature is the controlling element.

Resistance thermometers are limited by the range for which they were designed and the desired speed of response. The comparatively large mass of the sensitive element decreases the speed of response of the instrument to instantaneous temperature changes.

Conditions which may cause false readings are (a) open connections in the bridge circuit and (b) resistance changes in the temperature-sensitive elements due to corrosion or contamination.

1000e [REDACTED]
DECLASSIFIED

1926

[REDACTED] 18700

Diagrammatic and schematic illustrations of temperature-control installations and their control actions are shown in Figure XIX-41 and XIX-42.

Sensitive element: The sensitive element is the temperature-sensitive resistance of the bridge circuit. The element consists either of a coil of nickel wire wound on a Bakelite spool for low-temperature ranges (0 to 120°C.) or a platinum wire wound on a porcelain insulator for high-temperature ranges (0 to 1000°F.). The elements are sheathed in metal cases which protect them from exposure to corrosive fumes and vapors and prevent damage to the resistance wire during installation. The sheathed element is approximately 3/8 in. diameter and is inserted in a well which protrudes into the media whose temperature is desired.

Transmitting element: The inclusion of the temperature-sensitive resistance as a part of the recording bridge circuit eliminates the need for a separate transmitting element.

Recording and controlling element: The recording element is located at the panel board and contains the other three arms of the Wheatstone-bridge circuit, and the detecting, amplifying, and recording elements of the recorder. A Brown electronic recorder is used for low-temperature service (0 to 120°C.) and a Leeds and Northrup Micromax recorder is used for high-temperature service (0 to 1000°F.). The Brown recorder is composed of four units: a conversion stage; a voltage amplifier; a power amplifier; and a balancing motor. The conversion stage converts the unbalanced direct-current bridge voltage to a proportional alternating-current voltage. The voltage amplifier multiplies the a.c. voltage from the order of microvolts to several volts. The power amplifier delivers power to the balancing motor. Both the phase and the magnitude of this driving power are directly controlled by the amplified a.c. voltage. The balancing motor recognizes the phase of the driving power and accordingly balances the instrument by moving the slide-wire contactor. The slide-wire contactor, pen, and pointer are directly connected to the motor. The Leeds & Northrup recorder also makes use of the Wheatstone-bridge method to determine the resistance change of the platinum element but employs a galvanometer-balancing unit instead of an electronic detector. The balancing unit determines the deflection of the galvanometer and rotates the slide-wire to bring the bridge circuit into balance. Through a mechanical linkage, the pen is moved across a calibrated temperature scale.

Instruments which record only may be multipoint instruments capable of recording on a strip chart, through an automatic selector switch, the temperature detected by two or more sensitive elements. Temperature recording-controlling instruments and certain temperature recording instruments are single-point instruments and continuously record, by means of a pen and circular chart, the temperature detected by one sensitive element.

In the Brown Co. temperature recorder-controller instruments, the temperature desired at the sensitive element is set by manually positioning the controller set pointer. Any deviation of the system temperature away from the desired temperature is indicated by movement of the pen away from the set pointer. The controller senses this deviation and increases or decreases its output air pressure, depending on the direction of the

[REDACTED]
DECLASSIFIED [REDACTED]

pen movement, in proportion to the amount of deviation of the recording pen from the set pointer. The output air pressure acts upon a responsive controlled element to increase or decrease the heat supply to the system.

Controlled element: The output air pressure from the controller unit described above is either used to (a) directly control the steam supply by the action of a pneumatically operated diaphragm throttling valve or to (b) indirectly control the steam or water stream by repositioning the set pointer on a flow recorder-controller.

(a) Pneumatic diaphragm control valve. The controlled air output from the temperature recorder-controller determines the valve opening of a Fisher-Governor throttling valve in a steam line. The amount of steam admitted to the coils of the vessel, in which the temperature is measured, is increased or decreased in accordance with the direction of deviation of the recording pen from the set pointer.

(b) Pneumatic remote index setting system (Pneumaticset). The controlled air output from the temperature recorder-controller repositions the set pointer on a flow recorder-controller which regulates the flow of steam or water to the coils of a vessel whose temperature is measured.

(c) Reactrol system. In the Reactrol system, the power supplied to a set of heaters in the Silver Reactor is controlled by the temperature of the gas passing through the Reactor. Movement of the temperature-recording pen away from the desired temperature on the set pointer in the Leeds and Northrop temperature recorder-controller causes a change in the amount of heat liberated by the resistance heaters by varying the current flowing to the resistance heaters. This is accomplished by changing the direct-current-voltage output of a Thymotrol unit which converts alternating current to direct current. This variable d.c. voltage is applied to the primary windings of a saturable core reactor (transformer) which results in regulation of the current flow and heat input by controlling the alternating-voltage output from the secondary winding of the transformer to 9 heaters, with a total capacity of 12 KW, in the Reactor.

Alarm element: A mercoid switch, located on the slide-wire of the recorders, is used to energize a light and horn to indicate high temperatures.

Range: The temperature-recording and recording-controlling instruments which use a nickel element have a range of 0 to 120 degrees Centigrade. The instruments which use a platinum element have a range of 0 to 1000 degrees Fahrenheit.

Accuracy: The accuracy of the temperature-recording instruments is ± 1 per cent of full-scale reading.

I. MISCELLANEOUS INSTRUMENTS**DECLASSIFIED**1. Ammeters

Indicating ammeters are used to give a visual indication at the panel board of the instantaneous current consumption of electric motors which are used to drive pumps, agitators, and centrifuges. Ammeters are employed to assist in the detection of abnormal operating conditions which may be manifested by changing current consumption. Indicating ammeters are based on the principle that the movement of a pivoted coil in a constant magnetic field is proportional to the electric current passing through the coil. A pointer attached to the rotating coil gives a direct reading on a graduated scale calibrated in amperes. Ammeters are accurate to ± 1 per cent of full-scale reading.

2. Bourdon-Tube Pressure Gauges

Bourdon-tube pressure gauges are used to give a visual indication of the instantaneous pressure exerted by a non-radioactive fluid in a closed vessel, i.e., tank, pipe line, etc. The Bourdon tube is a curved (essentially circular) tube of flat, elliptical cross section, sealed at one end. Pressure applied to the open end tends to straighten the tube. Conversely, vacuum causes the tube to curl up. The movement of the closed, free end of the Bourdon tube is transmitted through a mechanical linkage which, in the conventional pressure gauge, is multiplied by a rack and pinion system to activate a pointer. Pressure gauges are calibrated in lb./sq.in. Bourdon tubes are fabricated from bronze (non-corrosive service) or stainless steel (corrosive service). Pressure gauges are accurate to $\pm 1/2$ per cent of full-scale reading.

3. Scales

Indicating-dial, automatic-balancing, dash-pot dampening, platform-type scales, equipped with self-aligning bearing, manual-locking devices, and dual, reverse-acting, tare beams for loading and unloading the scales, are used to perform basic weighing in the Redox Plant. Scales range from a maximum loading limit of 125 pounds (exclusive of preloading tare) to 10,000 pounds and have an accuracy of ± 0.1 of 1 per cent of full-scale reading.

4. Gauge Glasses

The gauge or sight glasses which are mounted on vessels to give a visual indication of the liquid level are mounted vertically across a 12-inch section near the top of a vessel. A graduated scale, mounted behind the glass, gives the tank liquid level in inches. Valves in the connecting piping at the top and bottom of the gauge glass allow the glass to be isolated from the vessel. The gauge glass is held in place by means of packing glands in the connecting piping.

5. Vibration Indicator

The Centrifuge is equipped with a vibration indicator (wobble meter) which detects unbalance of the Centrifuge bowl during operation. Severe

DECLASSIFIED

wobbling at high speeds, resulting from unequal bowl loading, may damage the bearings or other mechanical parts of the Centrifuge. A magnetic pick-up device, mounted on the Centrifuge shaft, generates a modulated 60-cycle signal with an amplitude of modulation proportional to the shaft displacement. This signal, after amplification, is impressed on the vertical deflection plates of a cathode-ray tube (oscilloscope). The visual result on the oscilloscope is a closed pattern which appears as a straight line, for vibration-free operation, or an ellipse, for unbalanced operation. The wobble of the Centrifuge shaft is proportional to the magnitude of the fluctuation indicated on the oscilloscope.

6. Speed Indicator

An electrical-type tachometer is mounted on the Centrifuge to indicate the speed of rotation. The tachometer is essentially an a.c. generator whose rotor is an extension of the Centrifuge shaft. The output voltage of the generator is proportional to the Centrifuge speed and is indicated at the panel board on a voltmeter calibrated in rev./min. The normal range of the tachometer is 1000 rev./min., but it is overloaded to read a maximum of 1760 rev./min. The accuracy of the tachometer is ± 1 per cent of full-scale reading.

7. Manual-Control Stations

Manual-control stations are multiported, multiposition, manual-setting, pneumatic selector valves located at the panel board and are used to load or unload remotely, according to a pre-set arrangement built into the selector valve, air-actuated diaphragm control valves located in the steam, air, inert-gas, and vent lines of the process. Selector valves either vent the air chamber of a spring-loaded diaphragm control valve or apply air pressure, up to 20 lb./sq.in.gage., to the diaphragm chamber. In some selector valves, the air pressure on the diaphragm chamber is adjusted by means of a pressure-regulating valve located at the panel board. Manual-control stations have the following positions:

Three-position selector. The three-position selector permits the alternate operation of two diaphragm-operated valves. Selector positions are "Off", "One", and "Two". In the "Off" position, both valves are vented. One valve is pneumatically loaded in the "One" position; the other valve is vented. In the "Two" position, the arrangement is reversed.

Two-position selector with time cycle. This selector operates the diaphragm valves in the steam-jet, vent, and purge lines. The various positions and the operation are described in Chapter XVI, Subsection Fl.

Two-position selector with time cycle and adjustable loading. This selector is the same as described above, except that the pneumatic pressure applied to the steam-jet diaphragm valve may be varied by means of a regulator. This selector is used to adjust the flow rate of the feed to the centrifuge.

Three-position selector and adjustable loading. This selector permits the operation of either of two diaphragm valves simultaneously with the operation of a third valve. The schedule of selector positions is shown below:

10110

<u>Position</u>	<u>Valve 1</u>	<u>Valve 2</u>	<u>Valve 3</u>
"Off"	vent	vent	vent
"One"	load	vent	load
"Two"	vent	load	load

The loading at Valve 2 is adjustable.

8. pH Instrument

The term pH is used to denote the concentration of hydrogen ion in a solution. The pH of a solution is determined electrometrically by measuring the difference in potential between an electrode which has a fixed voltage (reference electrode) and an electrode suspended in the solution and in which the voltage varies with the pH. The only pH instruments which were to be employed for process control in the Redox Plant were to control the addition of caustic solution to the Dissolver Off-Gas Scrubbers. A Silver Reactor (for details see Chapter III, Feed Preparation, and Chapter XVI, Other Process Equipment) will replace the scrubber for the removal of radioactive iodine. The caustic scrubbers will be held for installation in another location if it becomes necessary to remove oxides of nitrogen. In the event pH control instruments are used, a schematic arrangement of a pH control system has been included in this chapter and is shown in Figure XIX-43.

9. Conductivity-Type Level Instruments

Conductivity meters operate by passing an electrical current through an aqueous solution containing dissolved inorganic salts. They are employed on underground storage tanks to determine the liquid level of the waste solution. The "conductivity reel" consists of a stainless steel electrode suspended in the tank on a stainless steel tape. This electrode is connected in series with a battery and a galvanometer. As the electrode is lowered into the tank, the liquid level is detected by deflection of the galvanometer needle on completion of the circuit from the probe to ground through the solution. The height of the liquid is determined by reading the tape, graduated in feet and inches, at the point of initial deflection of the galvanometer needle.

TABLE XIX-1
INSTRUMENT LEGEND

<u>Symbol</u>	<u>Instrument or Equipment Piece</u>	<u>Symbol</u>	<u>Instrument or Equipment Piece</u>
AH	Alarm Horn	PR	Pressure Recorder
AI	Ampere Indicator	PS	Pressure Switch
AMP	Amplifier	R	Purge Rotameter
CV	Control Valve	R AMP	Radiation Amplifier
DPI	Differential Pressure Indicator	RE	Radiation Ion Chamber
DPM	Differential Pressure Transmitter	RR	Radiation Recorder
DPR	Differential Pressure Recorder	RS	Reset Button
FE	Orifice Assembly	SGI	Specific Gravity Indicator
FI	Pressure Indicator	SGM	Specific Gravity Transmitter
FM	Rotameter-Transmitter or Orifice Differential Pressure Transmitter	SGR	Specific Gravity Recorder
FR	Pressure Recorder	SGRC	Specific Gravity Recorder-Controller
FRC	Pressure Recorder-Controller	SI	Speed Indicator (Tachometer)
GG	Level Glass	SPKR	Speaker
IR	Interface Recorder	SW	Switch
IRC	Interface Recorder-Controller	TAI	Temperature Alarm Indicator
LC	Level Controller	TAS	Temperature Alarm Switch
M	Motor	TE	Temperature Element
MC	Manual Control Station	TI	Temperature Indicator
MIC or MK	Microphone	TR	Temperature Recorder
P	Pump	TRC	Temperature Recorder-Controller
PAI	Pressure Alarm Indicator	V	Manometer Check Valve
pH AMP	pH Amplifier	VGI	Vacuum Gauge Indicator
pHE	pH Electrodes	VOL	Volume Control
pHR	pH Recorder	WFAI	Weight Factor Alarm Indicator (Light)
pHRC	pH Recorder-Controller	WFAS	Weight Factor Alarm Pressure Switch
PI	Pressure Indicator (Gauge)	WFI	Weight Factor Indicator
		WFR	Weight Factor Recorder
		WFRC	Weight Factor Recorder-Controller
		WI	Weight Indicator (Scales)

DECLASSIFIED

DECLASSIFIED

1012

HW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

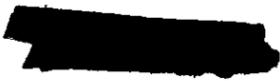


DECLASSIFIED

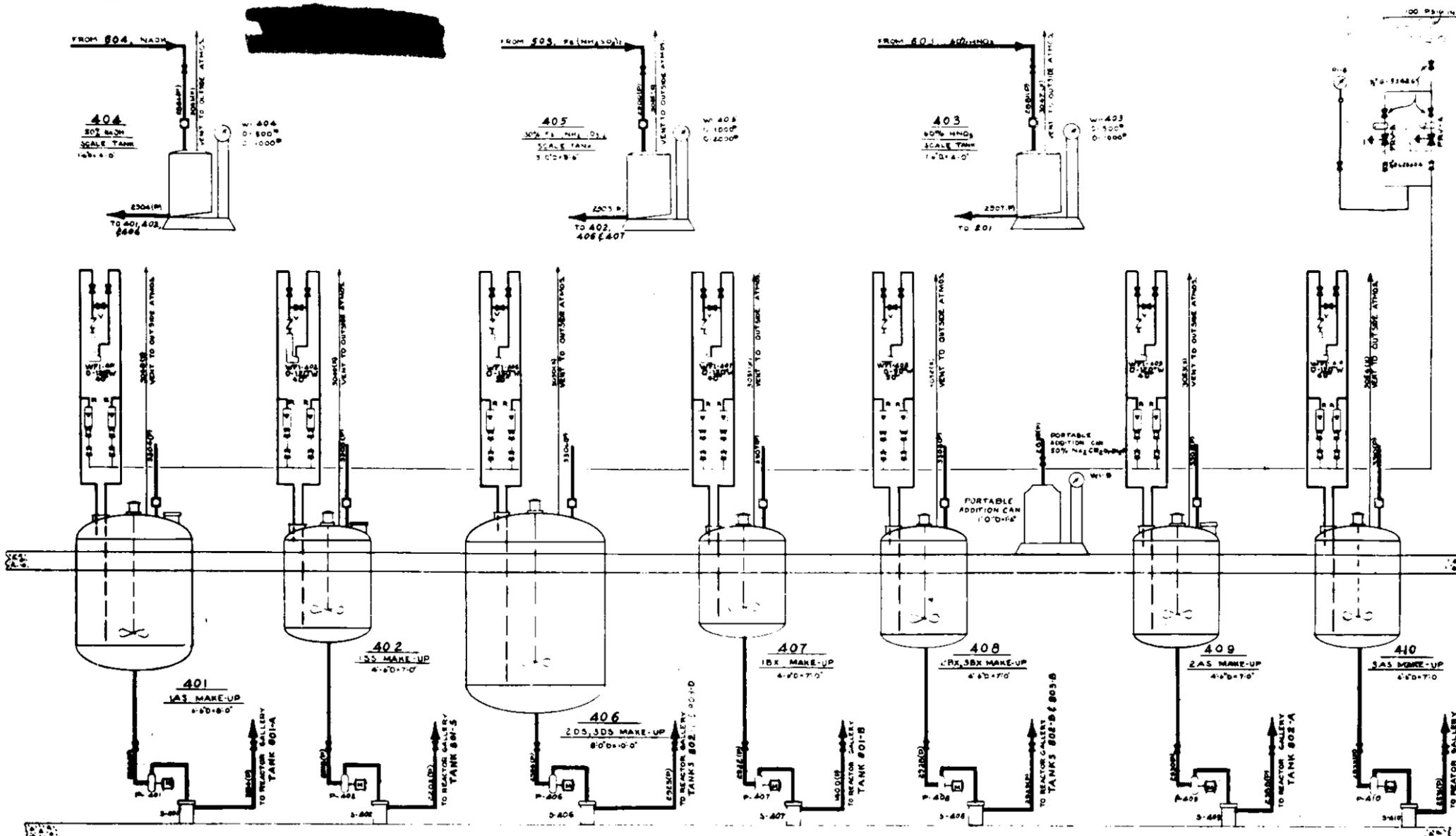


THIS PAGE
INTERNALLY
LEFT BLANK

DECLASSIFIED



HW-1870D



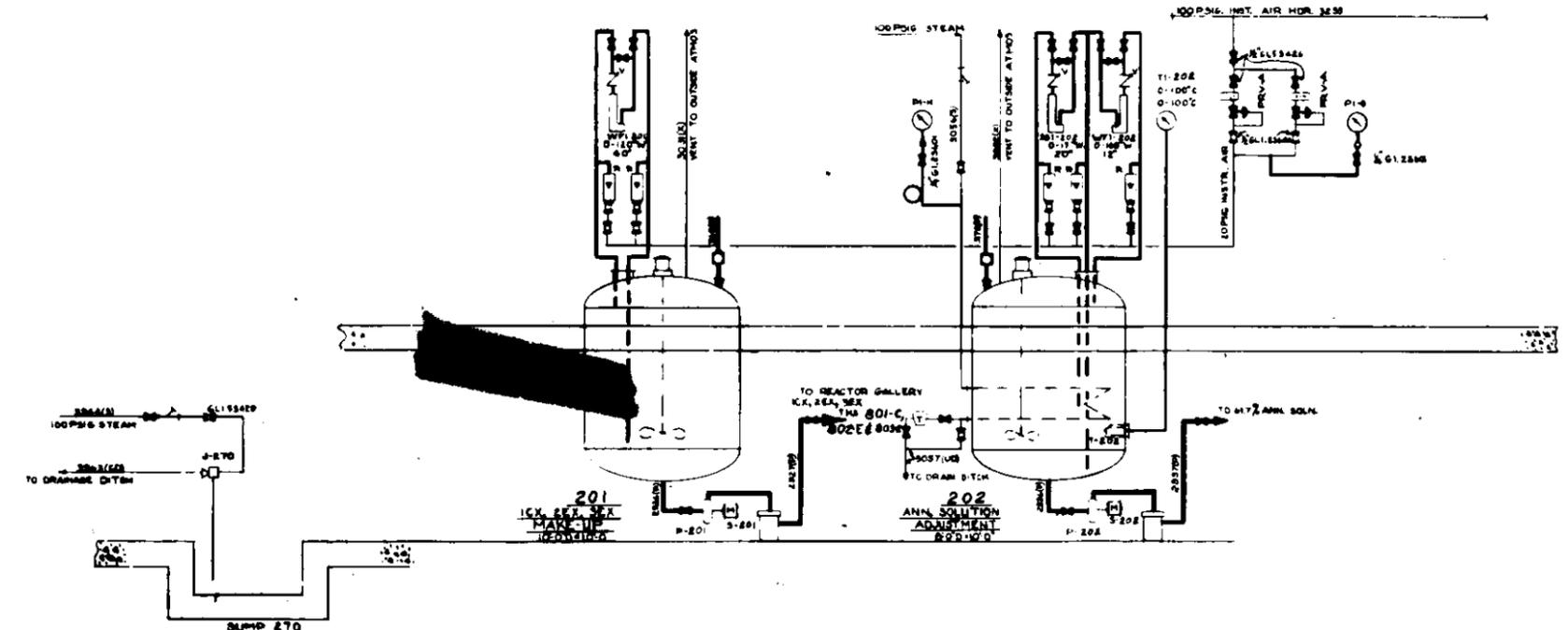
EQUIPMENT SCHEDULE

SYMBOL	SCALE	RANGE	REMARKS
PT	0-300	0-300PSIA	1/2" BPTM CONNECTED
PT	0-200	0-200PSIA	4/2" BOTTOM CONNECTED
V			MANOMETER CHECK VALVE LOCATED AT LOW PRESSURE SIDE
R			PURGE ROTAMETER
PS			PORTABLE SCALE
PSVA			COMBINATION FILTER & REGULATOR

- GENERAL NOTES:
1. FITTINGS & SYMBOIS SHALL BE 1/2" PS UNLESS GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS FITTINGS & SYMBOIS MAY BE 3/8" PS OR 3/4" OD COPPER TUBING WHERE GAUGES ARE MOUNTED REMOTE FROM PRESSURE CONNECTIONS FOR SPECIAL CASES SPECIAL NOTES WILL COVER.
 2. ALL OTHER LINES INCLUDING PNEUMATIC CONTROL LINES AND INSTRUMENT AIR FROM SUB HEADERS TO BE 1/2" OD COPPER TUBING EXCEPT AS OTHERWISE NOTED.
 3. ALL VALVES OFF INSTRUMENT AIR (NITROGEN SUB HEADER TO INSTRUMENTS) PURGE ROTAMETERS TO BE 1/2" OD COPPER TUBING.
 4. INSTRUMENT BY-PASS & BLOCK VALVES ON STEAM & WATER LINES TO BE 1/2" OD 1.2500.
 5. PURGE LINE BLOCK VALVES (BY-PASS AT INSTRUMENT TO BE 1/2" OD 1.2500).
 6. SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR RANGE, A LINE WILL BE IN SPACE NORMALLY OCCUPIED BY SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE AND SIZE. "S" INDICATES SQUARE ROOT SCALE.
 7. INSTRUMENT LINES FROM NITROGEN SUB HEADER TO PURGE ROTAMETER AND FROM PURGE ROTAMETER TO FIRST INSTRUMENT CONNECTION TO BE 1/2" OD COPPER TUBING.
 8. ALL PURGE LINES TO BE 1/2" OD COPPER TUBING FROM INDICATING AND RECORDING INSTRUMENTS TO WALL CONNECTORS ON EQUIPMENT. SUB-PIPES AND BLOCK VALVE PIPING AT INSTRUMENTS TO BE 1/2" I.P.S. CARBON STEEL.
 9. INSTRUMENTS ASSOCIATED WITH EACH TANK ARE TO BE LOCATED NEAR OPERATING VALVE FOR CONVENIENCE OF OPERATION.
 10. INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE AND TERMINATION OF PIPING ARE VISIBLE FROM THE PANEL. RECEIVER INSTRUMENT OR DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 11. FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 12. ALL PRESSURE GAUGES SHALL HAVE 1/2" I.P.S. UNIONS INSERTED BETWEEN TEST CONNECTION AND GAUGE.
 13. INSTRUMENT AIR & L. SUBHEADERS TO BE GALVANIZED IRON, SCHEDULE 40 PIPE-CODE P00HW-4316 REV.1.
 14. INSTRUMENT BY-PASS PIPING SHALL BE 1/2" I.P.S. SCHEDULE 40 CARBON STEEL, CODE P-1E HW-4316 REV.1.
 15. MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTION & CHECK VALVE SHALL BE 1/2" I.P.S. SERIES 300 STAINLESS STEEL.

FIGURE XIX-3
INSTRUMENT FLOW DIAGRAM
AQUEOUS FEED STREAM MAKE-UP

(FROM DWG H-2-7603)



10/14

HW-18700

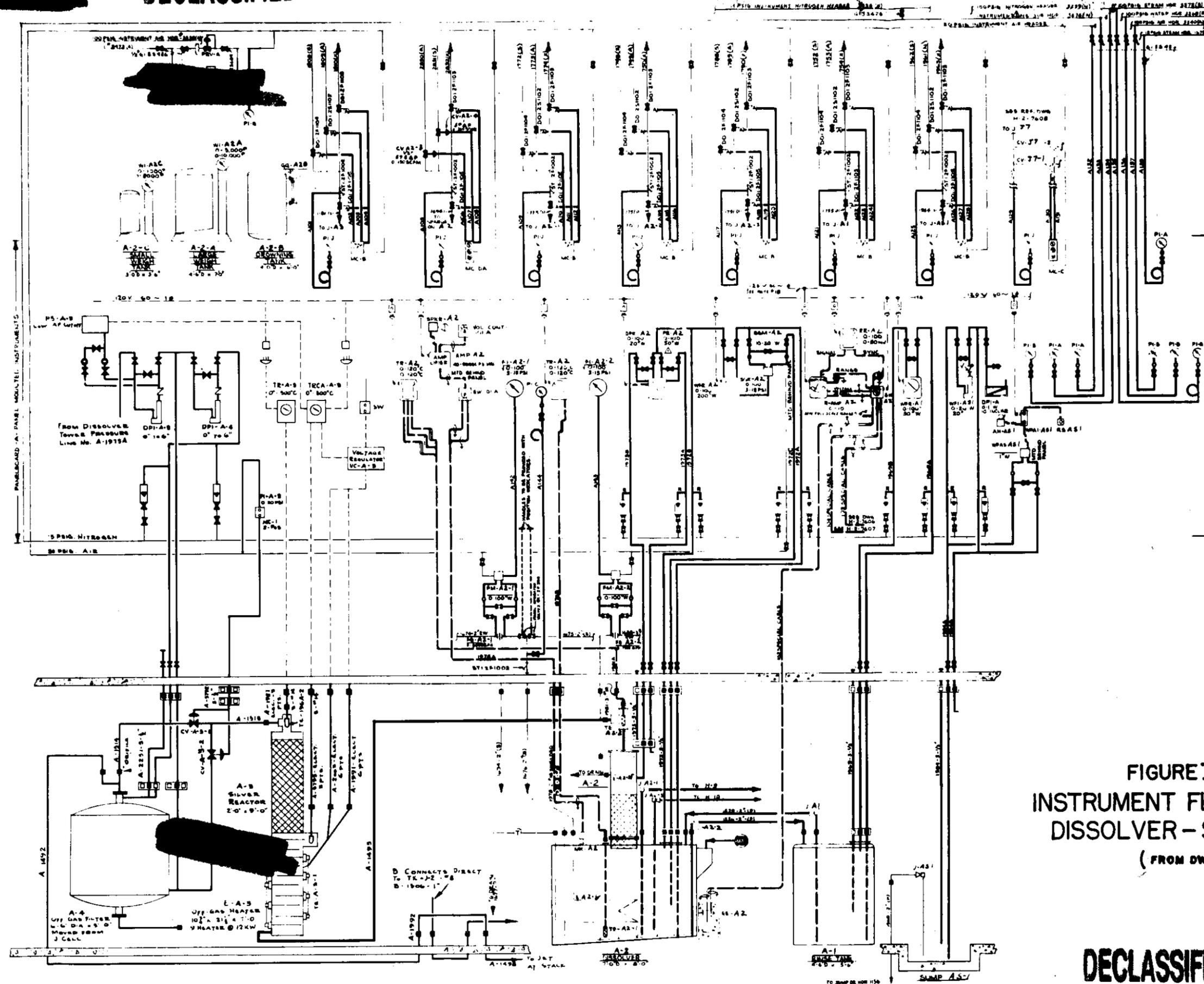


DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED



ITEM	SCALE	RANGE	REMARKS
PI-A	0-100 PSI	0-100	BOARD MOUNTED
PI-B	0-100 PSI	0-100	BOARD MOUNTED
PI-C	0-100 PSI	0-100	BOARD MOUNTED
PI-D	0-100 PSI	0-100	BOARD MOUNTED
PI-E	0-100 PSI	0-100	BOARD MOUNTED
PI-F	0-100 PSI	0-100	BOARD MOUNTED
PI-G	0-100 PSI	0-100	BOARD MOUNTED
PI-H	0-100 PSI	0-100	BOARD MOUNTED
PI-I	0-100 PSI	0-100	BOARD MOUNTED
PI-J	0-100 PSI	0-100	BOARD MOUNTED

- GENERAL NOTES**
- 1- INSTRUMENT LINES FROM INSTRUMENT SUBBASES TO PIPES, EXHAUSTERS AND PRESSURE TRANSMITTERS TO FIRST INSTRUMENT CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
 - 2- ALL PIPING LINES TO BE 1/2" O.D. COPPER TUBING FROM EXHAUSTERS AND INSTRUMENTS TO WALL CONNECTORS OR EQUIPMENT BY PIPES AND BLOCK VALVE PIPES AT INSTRUMENTS TO BE 1/2" O.D. COPPER TUBING.
 - 3- FITTINGS AND BYPASSES SHALL BE 1/2" O.D. COPPER TUBING AND MOUNTED ADJACENT TO PRESSURE CONNECTIONS. FITTINGS AND BYPASSES MAY BE 1/2" O.D. COPPER TUBING WHEN GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS. FOR OTHER CASES SPECIAL NOTES WILL GOVERN.
 - 4- ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES AND INSTRUMENT AIR FROM HEADS TO BE 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
 - 5- ALL VALVES OFF INSTRUMENT AIR & INSTRUMENT SUB-HOUSES AND PURGE EXHAUSTERS TO BE 1/2" O.D. TUBING.
 - 6- SHUT OFF VALVES AT PRESSURE GAUGES AND IN PIPING LINES AT CELL WALL TO BE 1/2" O.D. TUBING.
 - 7- PIPING LINE BLOCK VALVES AND BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. TUBING.
 - 8- INSTRUMENT BY-PASS AND BLOCK VALVES ON STREAM AND WATER LINES TO BE 1/2" O.D. TUBING.
 - 9- ALL ELECTRICAL WIRING IS 1/2" SPEC. NO. HW-6887 EXCEPT AS OTHERWISE NOTED.
 - 10- SCALE AND RANGE IS NOTED IN EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE, A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY THE SCALE OR RANGE. MANUFACTURER'S LITERATURE SHOULD BE REFERRED TO FOR SCALE AND RANGE. PRESSURE GAUGES AND FLOW RANGES ARE LISTED IN THAT ORDER.
 - 11- THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL CONDUCTORS IN THAT LINE.
 - 12- ALL ELECTRICAL CONDUCTORS IN SHIELDED CONDUIT TO WALL CONNECTORS TO BE NO. 10 TYPE TW SOLID. SHIELDED WHEN REQUIRED.
 - 13- INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF CONDUIT AND TERMINATION OF PIPING ARE VISIBLE FROM THE FINAL RECEIVING INSTRUMENT OR DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 - 14- LOADS REFERRED TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 5 TO 10 P.S.I.
 - 15- FOR ALL VALVES NOT IDENTIFIED ABOVE ON SHEET, REFER TO RELATED ENGINEERING DRAWINGS.
 - 16- ALL PRESSURE GAUGES SHALL HAVE 1/2" O.D. UNITS MOUNTED BETWEEN YEST CONNECTION AND GAUGE.
 - 17- ALL CONTROL VALVE SIZES ARE SHOWN IN BODY SIZES.
 - 18- POWER SUPPLY FOR RADIATION AMPLIFIERS TO BE IN ACCORDANCE WITH ELECTRICAL SINGLE-LINE DIAGRAM HW-7888 RECEPTACLE & PLUS SPECIAL TYPES.
 - 19- RADIATION CABLES SHALL BE RUN IN CONDUITS OR SCHEDULE 40 STEEL TUBING EXCEPT WHERE SHOWN OTHERWISE EXCEPT OTHER RADIATION CABLES.
 - 20- INSTRUMENT AIR IS SUBSTANTIALLY TO BE 1/2" GALVANIZED IRON, SCHEDULE 40 PIPE-CODE 40 HW-4314 REV. 1.
 - 21- INSTRUMENT BY-PASS PIPING SHALL BE 1/2" O.D. 304 SS CARBON STEEL, CODE R10 HW-4314 REV. 1.
 - 22- MANHOLES IN PIPING BETWEEN LOW PRESSURE CONNECTIONS & CHECK VALVES SHALL BE 1/2" O.D. 304 SS CARBON STEEL.

FIGURE XIX-4
INSTRUMENT FLOW DIAGRAM
DISSOLVER - SECTION "A"
(FROM DWG. H-2-7608)

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

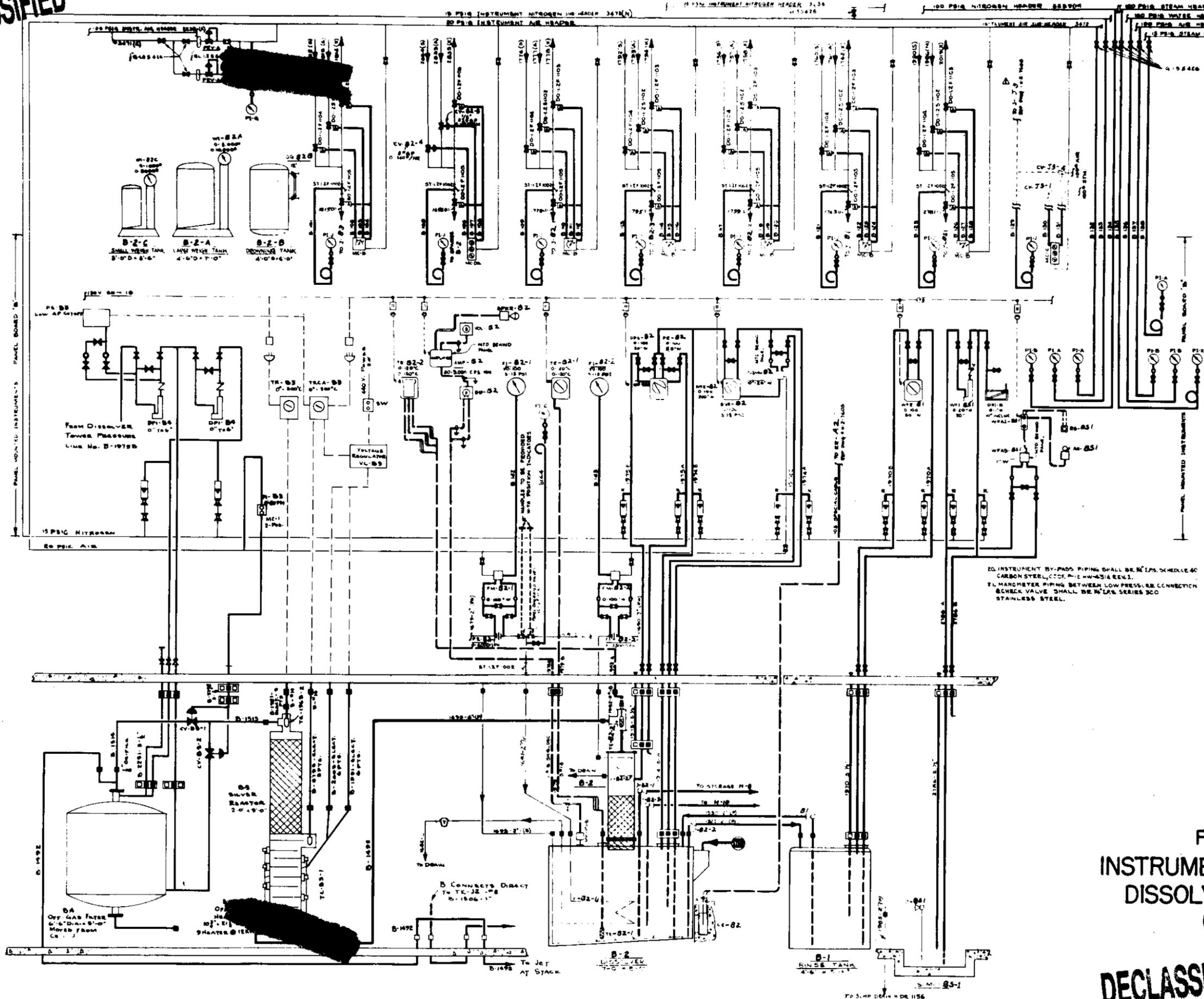


DECLASSIFIED

HM-18700

10/8

DECLASSIFIED



SYMBOL	SCALE	INSTRUMENT	REMARKS
P-1	0-50	PSIG	BOARD MOUNTED
P-2	0-200	PSIG	BOARD MOUNTED
P-3	0-100	PSIG	BOARD MOUNTED
P-4	0-30	PSIG	BOARD MOUNTED
MC-B			3 POS. SW. WITH TIME CYCLE CONTROL
MC-C			3 POS. SW. TO VENT & PROX. LOAD TWO VALVES
MC-BA			3 POS. SW. TO VENT & PROX. LOAD ONE VALVE
V	0-50 PSI		MANOMETER CHECK VALVE
			COMBINATION FILTER & REGULATOR
R			4-1/2" BSPH
PI-1	0-10	PSI	BOARD MOUNTED

- GENERAL NOTES**
- 1- INSTRUMENT LINES FROM NITROGEN SUB-HEADER TO PURGE ROTAMETER AND FROM PURGE ROTAMETER TO FIRST INSTRUMENT CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
 - 2- ALL PURGE LINES TO BE 1/2" O.D. COPPER TUBING FROM INDICATING & RECORDING INSTRUMENTS TO WALL CONNECTORS OF EQUIPMENT. BY-PASSES & BLOCK VALVE PIPING AT INSTRUMENTS TO BE 1/2" IPS CARBON STEEL.
 - 3- FITTINGS & BY-PASSES SHALL BE 1/2" IPS WHERE GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS. FITTINGS & BY-PASSES MAY BE 1/2" IPS OR 3/8" O.D. COPPER TUBING WHERE GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS FOR OTHER CASES SPECIAL NOTES WILL COVER.
 - 4- ALL OTHER LINES INCLUDING PNEUMATIC CONTROL LINES & INSTRUMENT AIR FROM HEADERS TO BE 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
 - 5- ALL VALVES BY INSTRUMENT AIR & NITROGEN SUB-HEADERS & PURGE ROTAMETERS TO BE 1/2" O.D. STEEL.
 - 6- SHUT OFF VALVES AT PRESSURE GAUGES & IN PURGE LINES AT CELL HALL TO BE 1/2" O.D. STEEL.
 - 7- PURGE LINE BLOCK VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. STEEL.
 - 8- INSTRUMENT BY-PASS & BLOCK VALVES ON STEAM & WATER LINES TO BE 1/2" O.D. STEEL.
 - 9- ALL ELECTRICAL WIRING IS 1/4" SPIC. HW-4807 EXCEPT AS OTHERWISE NOTED.
 - 10- SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE, A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY THE SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE & SIZE. "V" INDICATES SQUARE ROOT SCALE. FOR VALVES, THE SIZE, PRESSURE DROP & FLOW RANGE ARE LISTED IN THAT ORDER.
 - 11- THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL THE CONDUCTORS IN THAT LINE.
 - 12- ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BUSHING CONDUIT TO WALL CONNECTORS TO BE NO. 10 TYPE TW SOLID - SHIELDED WHEN REQUIRED.
 - 13- INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE & TERMINATION OF PIPING ARE VISIBLE FROM THE FINAL SPEC-IFIED INSTRUMENT, OR DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 - 14- LEADING PRESSURES TO ALL APPROXIMATELY CONTROLLED VALVES IS TO BE 3 TO 5 PSI.
 - 15- FOR ALL VALVES NOT IDENTIFIED ABOVE OR OTHERWISE, REFER TO RELATED ENGINEERING DRAWINGS.
 - 16- ALL PRESSURE GAUGES SHALL HAVE 1/2" LUGS INSERTED BETWEEN TEST CONNECTION AND GAUGE.
 - 17- ALL CONTROL VALVE STEMS ARE SHOWN AS BODY STEEL.
 - 18- REMOTE CONTROL CABLES SHALL BE PUR IN CONDUIT OR EXCEPT CONTAINING NO ELECTRICAL LINES EXCEPT OTHER MOUNTED CONTROL CABLES.
 - 19- INSTRUMENT AIR & NITROGEN SUB-HEADERS TO BE 1/2" GALVANIZED IRON, SCHEDULE 40 PIPE, CLASS B, 30 HW-4314 REV. 1.

FIGURE XIX-5
INSTRUMENT FLOW DIAGRAM
DISSOLVER - SECTION "B"
(FROM DWG. H-2-7606)

DECLASSIFIED

DECLASSIFIED



THIS PAGE
CONTAINS
NO INFORMATION

DECLASSIFIED

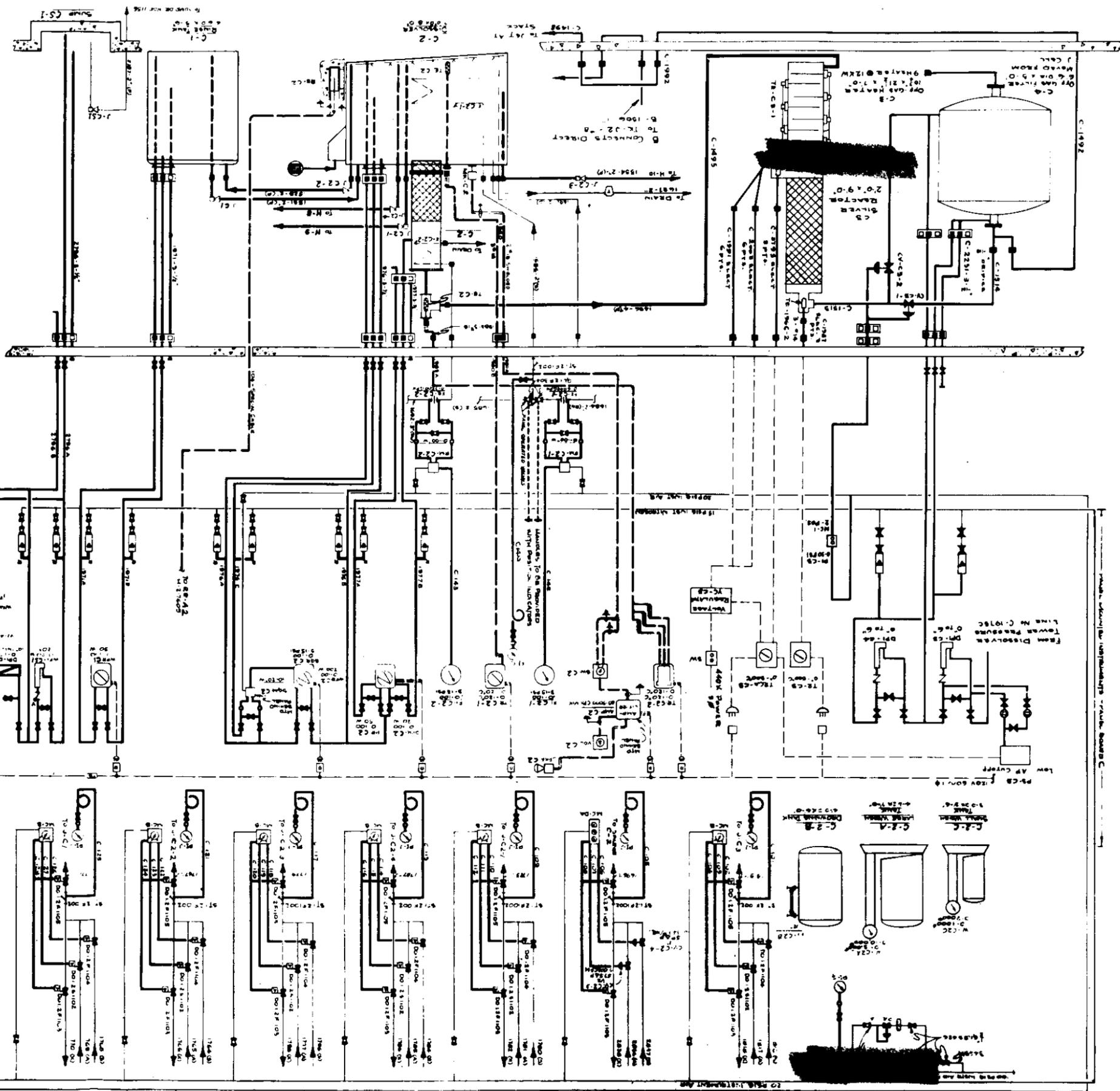


HW-18700

1020

DECLASSIFIED

FIGURE XIX-6
INSTRUMENT FLOW DIAGRAM "C"
DISSOLVER - SECTION "C"
(FROM DWG. H-2-7807)



GENERAL NOTES:

1. INSTRUMENT FLOW DIAGRAMS ARE TO BE USED IN CONNECTION WITH THE INSTRUMENTATION AND PROCESS CONTROL SYSTEMS.
2. ALL INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
3. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
4. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
5. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
6. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
7. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
8. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
9. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
10. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
11. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
12. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
13. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
14. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
15. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
16. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
17. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
18. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
19. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
20. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
21. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
22. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
23. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
24. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.
25. INSTRUMENTS AND PROCESS CONTROL SYSTEMS TO BE INSTALLED SHALL BE IDENTIFIED AS SHOWN ON THIS DIAGRAM.

NO.	DESCRIPTION	DATE	BY	CHECKED
1	ISSUED FOR CONSTRUCTION	10/1/58	J. H. [unclear]	[unclear]
2	REVISION	10/1/58	J. H. [unclear]	[unclear]
3	REVISION	10/1/58	J. H. [unclear]	[unclear]
4	REVISION	10/1/58	J. H. [unclear]	[unclear]
5	REVISION	10/1/58	J. H. [unclear]	[unclear]
6	REVISION	10/1/58	J. H. [unclear]	[unclear]
7	REVISION	10/1/58	J. H. [unclear]	[unclear]
8	REVISION	10/1/58	J. H. [unclear]	[unclear]
9	REVISION	10/1/58	J. H. [unclear]	[unclear]
10	REVISION	10/1/58	J. H. [unclear]	[unclear]

HW 18700
Fig. XIX-6

DECLASSIFIED

10000

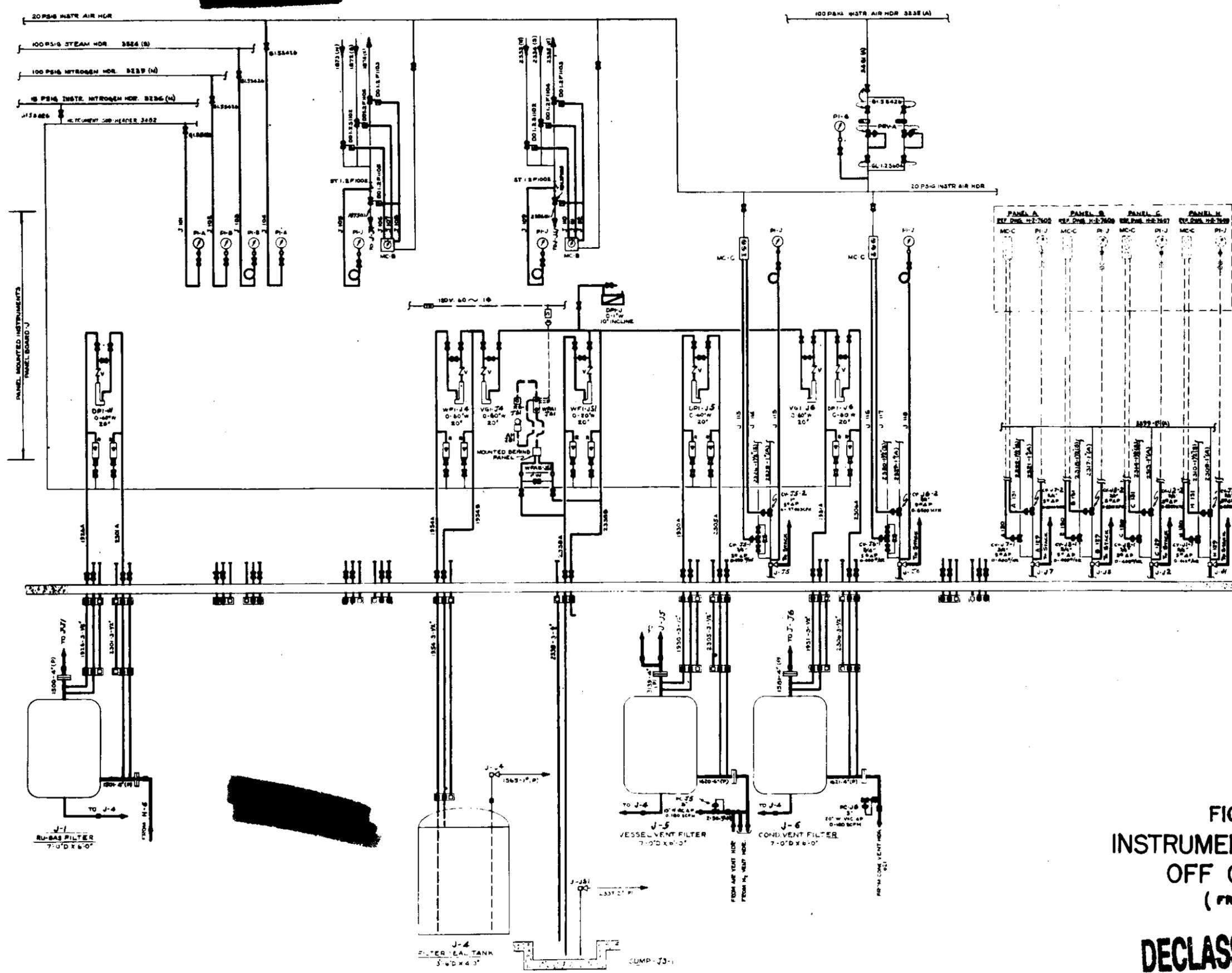
DECLASSIFIED

HM-18700

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED



EQUIPMENT SCHEDULE

SYMBOL	SCALE	RANGE	REMARKS
PI-A	0-30	PSIG	BOARD MOUNTED
PI-B	0-30	PSIG	BOARD MOUNTED
PI-C	0-30	PSIG	BOARD MOUNTED
MC-B			2 POS. SWITCH WITH 7 WE. CYCLE CONTROL
MC-C			2 POS. SWITCH WITH 7 WE. CYCLE CONTROL
PIV-A	0-100	PSIG	2103 SWITCH TO VENT (100% LOAD TO VALVES)
R	0-100	SCPH	COMBINATION FLOW AND ROTAMETER
V			MANOMETER CHECK VALVE

- GENERAL NOTES
- INSTRUMENT LINES FROM NITROGEN SUBHEADER TO PURGE ROTAMETER & FROM PURGE ROTAMETER TO FIRST INSTRUMENT CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
 - ALL PURGE LINES TO BE 1/2" O.D. COPPER TUBING FROM INDICATING & RECORDING INSTRUMENTS TO WALL CONNECTIONS OR EQUIPMENT. BY-PASSES & BLOCK VALVE PIPING AT INSTUMENTS TO BE 1/2" IPS CARBON STEEL.
 - FITTINGS & SYPHONS SHALL BE 1/2" IPS WHERE GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS. FITTINGS & SYPHONS MAY BE 1/2" IPS OR 3/8" O.D. COPPER TUBING WHERE GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS. FOR OTHER CASES SPECIAL NOTES SHALL APPLY.
 - ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES & INSTRUMENT AIR FROM HEADER TO BE 1/2" O.D. TUBING, EXCEPT AS OTHERWISE NOTED.
 - ALL VALVES OF INSTRUMENT AIR & NITROGEN SUBHEADERS & PURGE ROTAMETERS TO BE 1/2" G.I. 1.25604.
 - SHUT OFF VALVES AT PRESSURE GAUGES & IN PURGE LINES AT CELL WALL TO BE 1/2" G.I. 1.25604.
 - PURGE LINE BLOCK VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" G.I. 1.25604.
 - INSTRUMENT BY-PASS & BLOCK VALVES ON STEAM & WATER LINES 1/2" G.I. 1.25604.
 - ALL ELECTRICAL WIRING IS #14 SPEC. HW-2807 EXCEPT AS OTHERWISE NOTED.
 - SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR RANGE, A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE & SIZE. "V" INDICATES AS VARI ROOT SCALE. FOR VALVES, THE SIZE, PRESSURE DROP, & FLOW RANGE ARE LISTED IN THAT ORDER.
 - THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL CONDUCTORS IN THAT LINE.
 - ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BURIED CONDUIT TO WALL CONNECTIONS TO BE #10 TYPE TW SOLID, SHIELDED WHEN REQUIRED.
 - WASTE WENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE & TERMINATION OF PIPING ARE VISIBLE FROM THE FINAL RECEIVER INSTRUMENT, OR DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 - ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE, REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 - ALL PRESSURE GAUGES SHALL HAVE 1/2" UNIONS MOUNTED BETWEEN TEST CONNECTION AND GAUGE.
 - ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZES.
 - INSTRUMENT AIR GA. SUBHEADERS TO BE 1/2" GALVANIZED FLEX. SCHEDULE 40 TYPE 1 CODE 100 HW-484 12X1.
 - INSTRUMENT BY-PASS PIPING SHALL BE 1/2" IPS SCHEDULE 40 CARBON STEEL, CODE 1-12 HW-484 12X1.
 - MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTION & CHECK VALVE SHALL BE 1/2" IPS SERIES 300 STAINLESS STEEL.

FIGURE XIX-7
INSTRUMENT FLOW DIAGRAM
OFF GAS FILTERS
(FROM DWG. H-2-7608)

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

HW-18700

1004

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

DECLASSIFIED



HR-18702

10/2/80

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

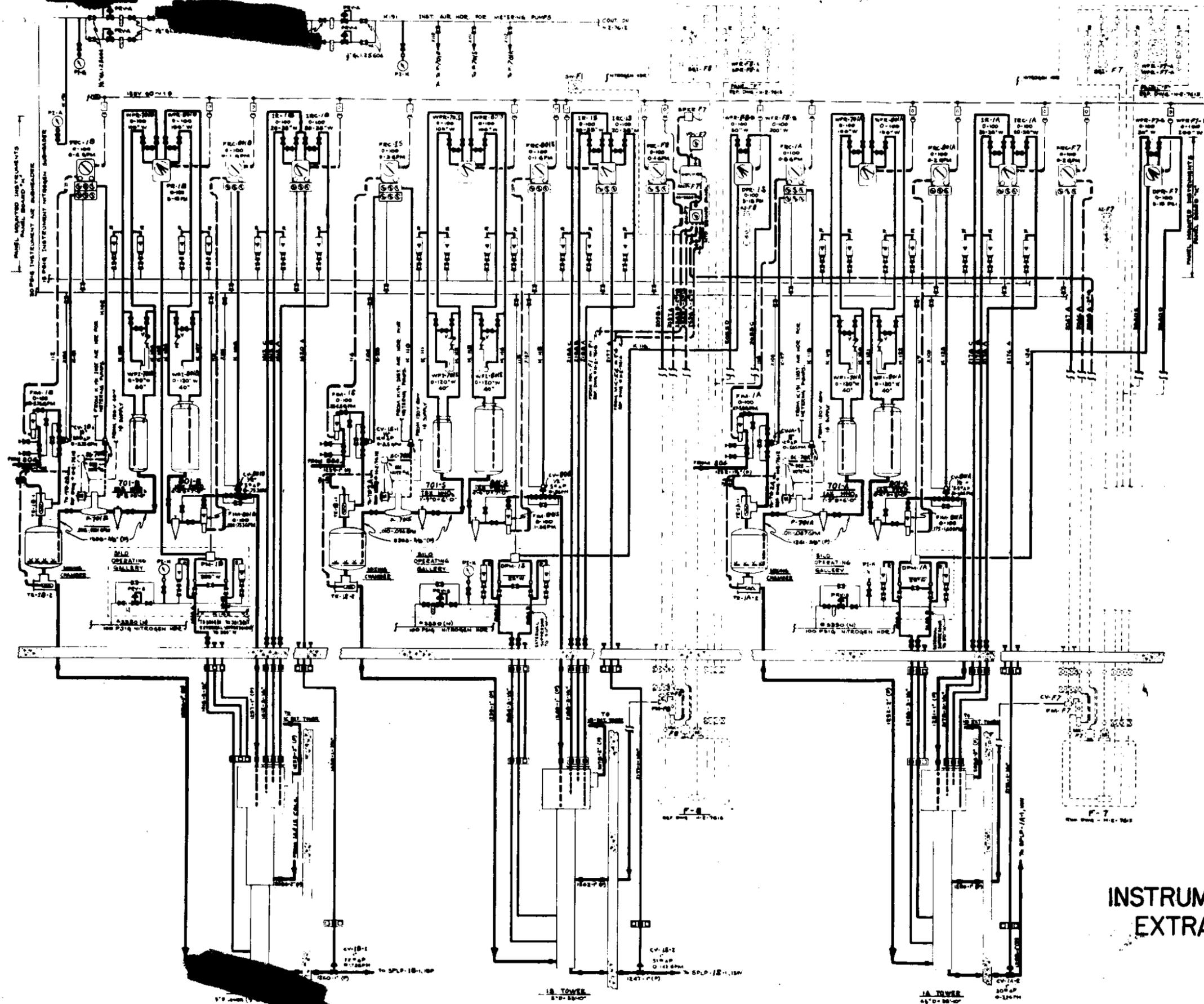


DECLASSIFIED

1038

HW-1870U

HW 18700
Fig. XIX-10



EQUIPMENT SCHEDULE			
SYMBOL	SCALE	RANGE	REMARKS
DI-K	0-60	0-60 PSI	BOTTOM CONNECTED
PIV-A		0-30 PSI	COMBINATION FILTER & REGULATOR
R		0-1-10 SCF	
V			MANOMETER CHECK VALVE
PI-G	0-50	0-30 PSI	BOTTOM CONNECTED
PI-A	0-30	0-30 PSI	BOARD MOUNTED
PIV-B		0-30 PSI	COMBINATION FILTER & REGULATOR

GENERAL NOTES

- INSTRUMENT LINES FROM NITROGEN SUBHEADS TO PUMP ROTAMETERS & FROM PUMP ROTAMETERS TO FIRST INSTRUMENT CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
- ALL PUMP LINES TO BE 1/2" O.D. COPPER TUBING FROM INDICATING & RECORDING INSTRUMENTS TO WALL CONNECTIONS OR EQUIPMENT. BY-PASSES AND BLOCK VALVE BRING AT INSTRUMENTS TO BE 1/2" IPS CARBON STEEL.
- FITTINGS & SYPHONS SHALL BE 1/2" IPS UNLESS GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS. FITTINGS & SYPHONS MAY BE 1/2" IPS OR 3/4" O.D. COPPER TUBING WHERE GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS. FOR OTHER CASES SPECIAL NOTES WILL COVER.
- ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES & INSTRUMENT AIR FROM HEADS TO BE 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
- ALL VALVES ON INSTRUMENT AIR & NITROGEN SUBHEADS AND PUMP ROTAMETERS TO BE 1/2" O.D. 1.25 GAS.
- SHUT OFF VALVES AT PRESSURE GAGES AND IN PUMP LINES AT CELL WALL TO BE 1/2" O.D. 1.25 GAS.
- PUMP LINE BLOCK VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. 1.25 GAS.
- ALL ELECTRICAL WIRING IS #16 SPEC. MW-4507, EXCEPT AS OTHERWISE NOTED.
- SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE NO SCALE OR NO RANGE, A LINE WILL BE IN THE SPACE USUALLY OCCUPIED BY THE SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE & BEEL. " " INDICATES SQUARE ROOT SCALE. FOR CONTROL VALVES, THE SIZE, THE PRESSURE DROP & FLOW RANGE ARE LISTED IN THAT ORDER.
- THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL THE CONDUCTORS IN THAT LINE.
- ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BUNDLED CONDUIT TO WALL CONNECTIONS TO BE #10 TYPE TW SOLID. SHIELDED WHEN REQUIRED.
- INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE & TERMINATION OF PIPING ARE VISIBLE FROM FINAL RECEIVER INSTRUMENT, AND DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
- LOADING PRESSURE TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 20 TO 25 PSI.
- METERING PUMPS MAY BE EITHER VARIABLE SPEED OR STROKE CONTROLLED. SPEED CONTROL METHOD SHOWN IN PHANTOM.
- FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE REFER TO RELATED DIMENSIONAL DRAWINGS.
- ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZES.
- ALL PRESSURE GAGES SHALL HAVE 1/2" IPS UNIONS INSTALLED BETWEEN TEST CONNECTION & GAUGE.
- INSTRUMENT AIR & NITROGEN HEADS TO BE #16 GALVANIZED IRON, SCHEDULE 40 PIPE - CODE PEO HW-4314 REV. 1.
- INSTRUMENT BY-PASS PIPING SHALL BE 1/2" IPS SCHED. 40 CARBON STEEL, CODE PIS, HW-4314 REV. 1.
- MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTIONS & CHECK VALVE SHALL BE 1/2" IPS SERIES 300 STAINLESS STEEL.

FIGURE XIX-10
INSTRUMENT FLOW DIAGRAM
EXTRACTION COLUMNS
IB, IS, IA
(FROM DWG. H-2-7811)

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

HM-18700

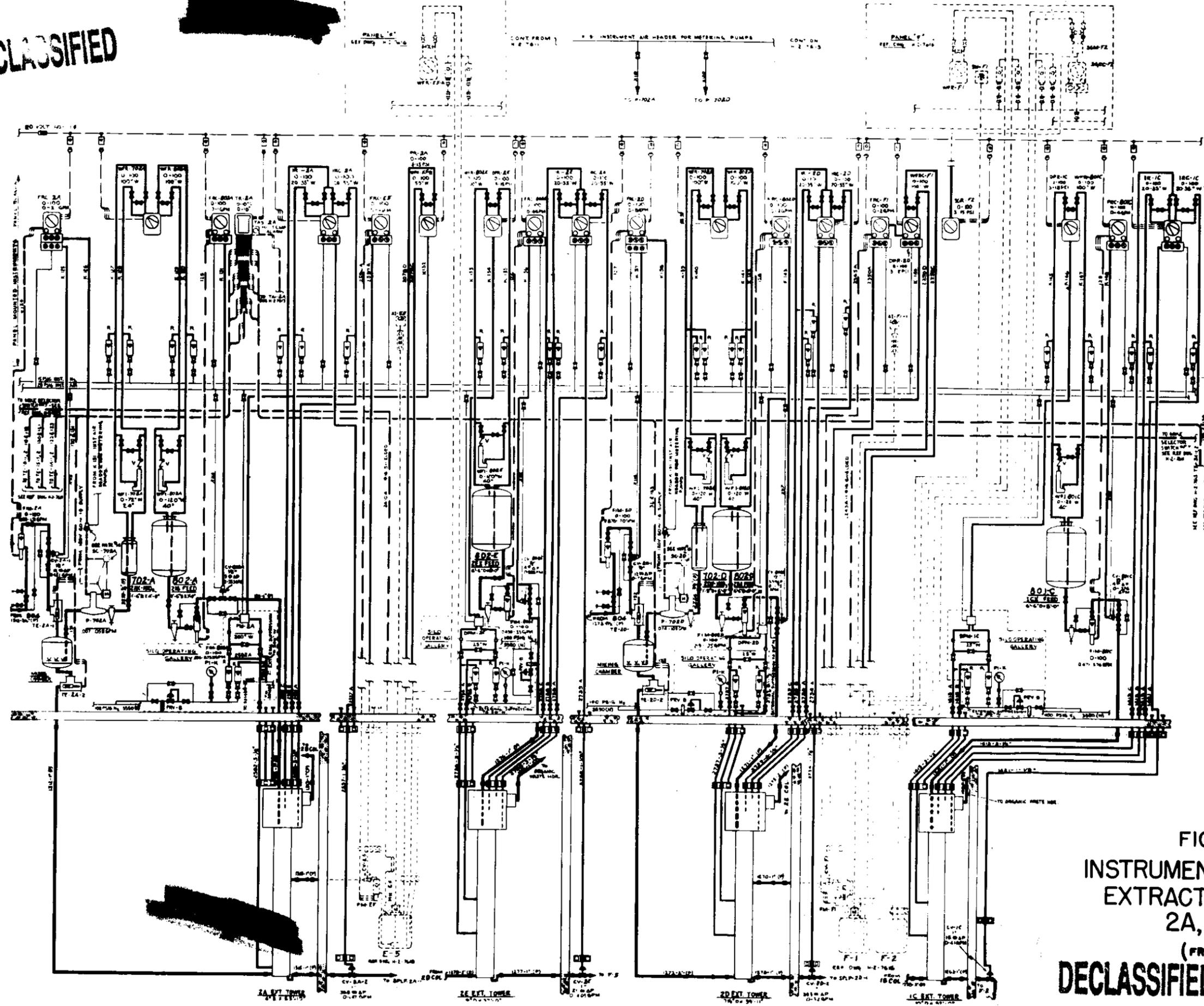


DECLASSIFIED

1030

DECLASSIFIED

EQUIPMENT SCHEDULE			
SYMBOL	SCALE	RANGE	REMARKS
P-E	0-50	0-50 PS	BOTTOM CONNECTED
P-A	0-50	0-50 PS	COMPARISON PUMP AND RECEIVER
R			0-100 PS
V			PARAMETER CHECK VALVE
P-V	0-50	0-50 PS	COMPARISON PUMP & RECEIVER



- GENERAL NOTES**
- INSTRUMENT LINES FROM INSTRUMENT HEADERS TO PUMP, RECEIVER AND FROM PUMP, RECEIVER TO INSTRUMENT HEADERS SHALL BE 1/2" O.D. COPPER TUBING.
 - ALL PUMPS SHALL BE 1/2" O.D. COPPER TUBING FROM HEADINGS AND RECEIVERS INDEPENDENT TO WALL CONNECTIONS AS SHOWN. BY-PASS & BUREAU VALVE PIPING AT INSTRUMENTS TO BE 1/2" O.D. COPPER TUBING.
 - FITTINGS & SPINDLES SHALL BE 1/2" O.D. COPPER TUBING AND RECEIVERS SUBJECT TO PRESSURE CONNECTIONS. FITTINGS & SPINDLES SHALL BE 1/2" O.D. COPPER TUBING, WELDED BARGE AND INSTALLED SEPARATELY FROM PRESSURE CONNECTIONS FOR OTHER LINES. SPECIAL NOTES SHALL APPLY.
 - ALL OTHER LINES, INCLUDING FREIGHTY CONTROL LINES AND INSTRUMENT AIR FROM HEADERS TO BE 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
 - ALL VALVES OF INSTRUMENT AIR AND INSTRUMENT SUBHEADINGS AND PUMP RECEIVERS TO BE 1/2" O.D. BALL VALVES.
 - SHUT-OFF VALVES AT PRESSURE CHANGES AND IN PUMP LINES AT CELL SHALL BE 1/2" O.D. BALL VALVES.
 - PUMP LINE SHUT-OFF VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. BALL VALVES.
 - ALL ELECTRICAL WIRING IS 1/4" O.D. COPPER WIRE, UNLESS OTHERWISE NOTED.
 - SCALE AND RANGE IS NOTED ON EACH INSTRUMENT. IF THERE IS NO SCALE OR RANGE, A LINE WILL BE IN THE SPACE IMMEDIATELY ADJACENT TO THE SCALE OR RANGE. INSTRUMENTS ARE LISTED WITH SCALE AND RANGE. "V" INDICATES SQUARE ROOT SCALE. FOR CONTROL VALVES, THE SIZE, THE PRESSURE DROP, AND FLOW RANGE ARE LISTED IN THAT ORDER.
 - THE NUMBER IN EACH ELECTRICAL LINE APPLIES TO ALL THE INSTRUMENTS IN THAT LINE.
 - ALL INSTRUMENT ELECTRICAL CONNECTIONS TO BE 1/4" O.D. COPPER WIRE, UNLESS OTHERWISE NOTED.
 - INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT SHOWN IF SOURCE AND TERMINATION OF PIPES ARE VISIBLE FROM FINAL RECEIVER AND TRANSMIT, AND DO NOT SHOW ON MORE THAN ONE CONNECTION CHANGE.
 - LOADING PRESSURE TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 1 TO 10 PSI.
 - METERING PUMPS MAY BE EITHER VARIABLE SPEED OR SPINDLE CONTROLLED. SPEED CONTROL METHOD SHOWN IN DRAWING.
 - FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE REFER TO RELATED ENGINEERING DRAWING.
 - ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZES.
 - ALL PRESSURE GAUGES SHALL HAVE 1/2" O.D. HOLES MOUNTED BETWEEN TEST CONNECTION AND GAUGE. FOR CONTROL VALVES, THE SIZE, THE PRESSURE DROP, AND FLOW RANGE ARE LISTED IN THAT ORDER.
 - INSTRUMENT AIR AND SUBHEADINGS TO BE 1/2" GALVANNEED STEEL SCHEDULE 40 PIPE CODE P-12 HW-4314 REV. 1.
 - INSTRUMENT BY-PASS PIPING SHALL BE 1/2" O.D. SCHEDULE 40 CARBON STEEL CODE P-12 HW-4314 REV. 1.
 - MANOMETRIC PIPING BETWEEN LOW PRESSURE CONNECTION & CHECK VALVE SHALL BE 1/2" O.D. SERIES 300 STAINLESS STEEL.

FIGURE XIX-11
INSTRUMENT FLOW DIAGRAM
EXTRACTION COLUMNS
2A, 2E, 2D, 1C
(FROM DWS. H-2-7612)
DECLASSIFIED

1032

DECLASSIFIED

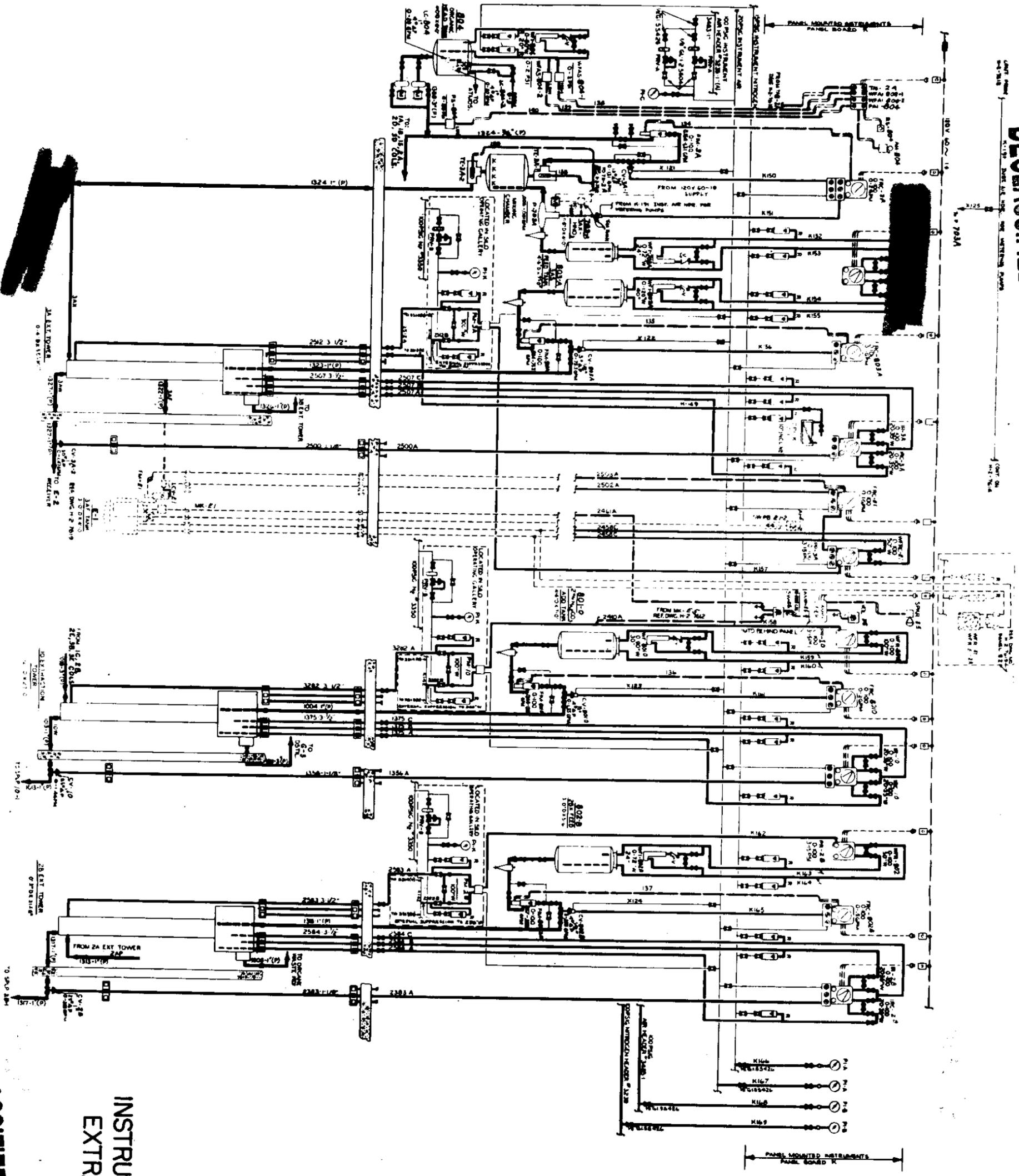
HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED



SYMBOL	SCALE	INSTRUMENT	DESCRIPTION
1.1	0-100	TEMPERATURE	TEMPERATURE
1.2	0-100	TEMPERATURE	TEMPERATURE
1.3	0-100	TEMPERATURE	TEMPERATURE
1.4	0-100	TEMPERATURE	TEMPERATURE
1.5	0-100	TEMPERATURE	TEMPERATURE
1.6	0-100	TEMPERATURE	TEMPERATURE
1.7	0-100	TEMPERATURE	TEMPERATURE
1.8	0-100	TEMPERATURE	TEMPERATURE
1.9	0-100	TEMPERATURE	TEMPERATURE
1.10	0-100	TEMPERATURE	TEMPERATURE
1.11	0-100	TEMPERATURE	TEMPERATURE
1.12	0-100	TEMPERATURE	TEMPERATURE
1.13	0-100	TEMPERATURE	TEMPERATURE
1.14	0-100	TEMPERATURE	TEMPERATURE
1.15	0-100	TEMPERATURE	TEMPERATURE
1.16	0-100	TEMPERATURE	TEMPERATURE
1.17	0-100	TEMPERATURE	TEMPERATURE
1.18	0-100	TEMPERATURE	TEMPERATURE
1.19	0-100	TEMPERATURE	TEMPERATURE
1.20	0-100	TEMPERATURE	TEMPERATURE

- General Notes:**
1. INSTRUMENT LINE SIZES FROM VARIOUS SUBSISTEMS TO BE USED AS INDICATED IN THE INSTRUMENT SCHEDULE TO BE USED.
 2. OLD COPPER TUBING TO BE REPLACED BY 1/2" O.D. COPPER TUBING AND CONNECTIONS TO BE MADE BY BUTT WELDING.
 3. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 4. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 5. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 6. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 7. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 8. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 9. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 10. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 11. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 12. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 13. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 14. ALL INSTRUMENTS TO BE INSTALLED BY PASSE'S AND SHOWN ON DRAWING.
 15. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.
 16. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.
 17. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.
 18. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.
 19. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.
 20. INSTRUMENT SCHEDULE SHALL BE BY PASSE'S AND SHOWN ON DRAWING.

FIGURE XIX-12
INSTRUMENT FLOW DIAGRAM
EXTRACTION COLUMNS
3A, I.O.2B
(FROM DWG. H-E-7813)

1031

HW-18700

DECLASSIFIED

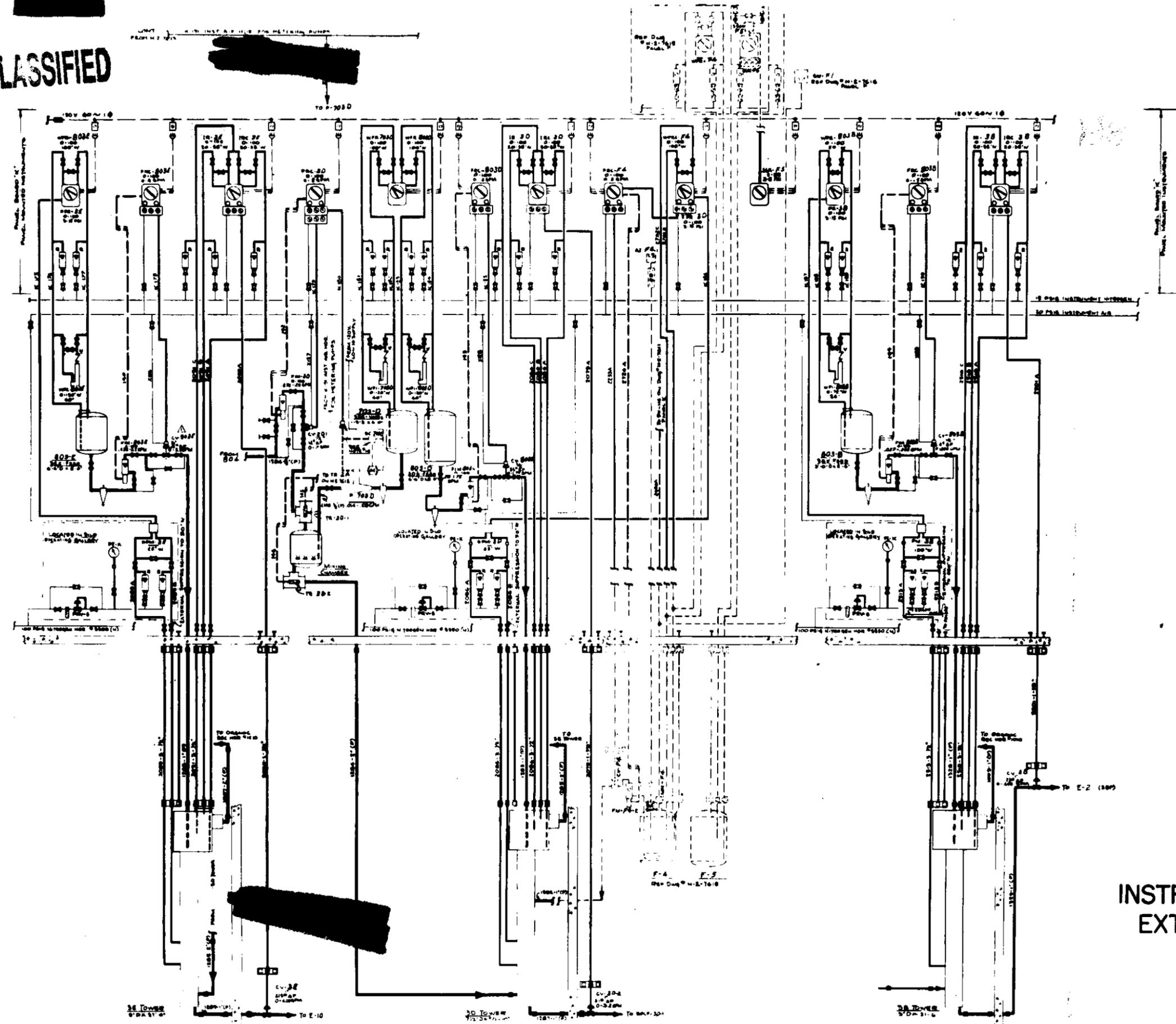


THIS PAGE
INTENTIONALLY
LEFT BLANK

DECLASSIFIED



DECLASSIFIED



EQUIPMENT SCHEDULE			
SYMBOL	SIZE	GRADE	REMARKS
100-1	1/2"	304	Bottom Connection
100-2	1/2"	304	Bottom Connection
100-3	1/2"	304	Bottom Connection
100-4	1/2"	304	Bottom Connection
100-5	1/2"	304	Bottom Connection
100-6	1/2"	304	Bottom Connection
100-7	1/2"	304	Bottom Connection
100-8	1/2"	304	Bottom Connection
100-9	1/2"	304	Bottom Connection
100-10	1/2"	304	Bottom Connection
100-11	1/2"	304	Bottom Connection
100-12	1/2"	304	Bottom Connection
100-13	1/2"	304	Bottom Connection
100-14	1/2"	304	Bottom Connection
100-15	1/2"	304	Bottom Connection
100-16	1/2"	304	Bottom Connection
100-17	1/2"	304	Bottom Connection
100-18	1/2"	304	Bottom Connection
100-19	1/2"	304	Bottom Connection
100-20	1/2"	304	Bottom Connection
100-21	1/2"	304	Bottom Connection
100-22	1/2"	304	Bottom Connection
100-23	1/2"	304	Bottom Connection
100-24	1/2"	304	Bottom Connection
100-25	1/2"	304	Bottom Connection
100-26	1/2"	304	Bottom Connection
100-27	1/2"	304	Bottom Connection
100-28	1/2"	304	Bottom Connection
100-29	1/2"	304	Bottom Connection
100-30	1/2"	304	Bottom Connection
100-31	1/2"	304	Bottom Connection
100-32	1/2"	304	Bottom Connection
100-33	1/2"	304	Bottom Connection
100-34	1/2"	304	Bottom Connection
100-35	1/2"	304	Bottom Connection
100-36	1/2"	304	Bottom Connection
100-37	1/2"	304	Bottom Connection
100-38	1/2"	304	Bottom Connection
100-39	1/2"	304	Bottom Connection
100-40	1/2"	304	Bottom Connection
100-41	1/2"	304	Bottom Connection
100-42	1/2"	304	Bottom Connection
100-43	1/2"	304	Bottom Connection
100-44	1/2"	304	Bottom Connection
100-45	1/2"	304	Bottom Connection
100-46	1/2"	304	Bottom Connection
100-47	1/2"	304	Bottom Connection
100-48	1/2"	304	Bottom Connection
100-49	1/2"	304	Bottom Connection
100-50	1/2"	304	Bottom Connection
100-51	1/2"	304	Bottom Connection
100-52	1/2"	304	Bottom Connection
100-53	1/2"	304	Bottom Connection
100-54	1/2"	304	Bottom Connection
100-55	1/2"	304	Bottom Connection
100-56	1/2"	304	Bottom Connection
100-57	1/2"	304	Bottom Connection
100-58	1/2"	304	Bottom Connection
100-59	1/2"	304	Bottom Connection
100-60	1/2"	304	Bottom Connection
100-61	1/2"	304	Bottom Connection
100-62	1/2"	304	Bottom Connection
100-63	1/2"	304	Bottom Connection
100-64	1/2"	304	Bottom Connection
100-65	1/2"	304	Bottom Connection
100-66	1/2"	304	Bottom Connection
100-67	1/2"	304	Bottom Connection
100-68	1/2"	304	Bottom Connection
100-69	1/2"	304	Bottom Connection
100-70	1/2"	304	Bottom Connection
100-71	1/2"	304	Bottom Connection
100-72	1/2"	304	Bottom Connection
100-73	1/2"	304	Bottom Connection
100-74	1/2"	304	Bottom Connection
100-75	1/2"	304	Bottom Connection
100-76	1/2"	304	Bottom Connection
100-77	1/2"	304	Bottom Connection
100-78	1/2"	304	Bottom Connection
100-79	1/2"	304	Bottom Connection
100-80	1/2"	304	Bottom Connection
100-81	1/2"	304	Bottom Connection
100-82	1/2"	304	Bottom Connection
100-83	1/2"	304	Bottom Connection
100-84	1/2"	304	Bottom Connection
100-85	1/2"	304	Bottom Connection
100-86	1/2"	304	Bottom Connection
100-87	1/2"	304	Bottom Connection
100-88	1/2"	304	Bottom Connection
100-89	1/2"	304	Bottom Connection
100-90	1/2"	304	Bottom Connection
100-91	1/2"	304	Bottom Connection
100-92	1/2"	304	Bottom Connection
100-93	1/2"	304	Bottom Connection
100-94	1/2"	304	Bottom Connection
100-95	1/2"	304	Bottom Connection
100-96	1/2"	304	Bottom Connection
100-97	1/2"	304	Bottom Connection
100-98	1/2"	304	Bottom Connection
100-99	1/2"	304	Bottom Connection
100-100	1/2"	304	Bottom Connection

- GENERAL NOTES:**
1. INSTRUMENT LINES FROM INSTRUMENTS TO FIELD CONTROLS & FROM FIELD CONTROLS TO INSTRUMENTS SHALL BE 1/2" OR LARGER TUBING FROM INSTRUMENTS & REVERSE FOR INSTRUMENTS TO WALL CONNECTIONS OF EQUIPMENT. BY PRESSURE & DIRECTION, VALVE POSITIONS TO BE SHOWN ON DRAWING.
 2. ALL PULSE LINES TO BE 1/2" OR LARGER TUBING FROM INSTRUMENTS & REVERSE FOR INSTRUMENTS TO WALL CONNECTIONS OF EQUIPMENT. BY PRESSURE & DIRECTION, VALVE POSITIONS TO BE SHOWN ON DRAWING.
 3. FITTINGS & SYMBOLS SHALL BE 1/2" OR LARGER SIZES AND NUMBERED ACCORDING TO FIELD CONNECTIONS. FITTINGS & SYMBOLS SHALL BE 1/2" OR LARGER SIZES UNLESS OTHERWISE SPECIFIED. SYMBOLS SHALL BE SHOWN ON DRAWING.
 4. ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES AND INSTRUMENT AIR FROM INLET TO BE 1/2" OR LARGER TUBING EXCEPT AS OTHERWISE NOTED.
 5. ALL VALVES OFF INSTRUMENT AIR & HYDROGEN SULFIDE & PULSE INSTRUMENTS TO BE 1/2" OR LARGER.
 6. SHUT OFF VALVES AT PRESSURE CHANGES & IN PULSE LINES AT CELL WALL TO BE 1/2" OR LARGER.
 7. PULSE LINE SHUT OFF VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" OR LARGER.
 8. ALL ELECTRICAL WIRING IS TO BE SHOWN ON DRAWING EXCEPT AS OTHERWISE NOTED.
 9. SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY THE SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE & SIZE. "I" INDICATES SQUARE BODY SCALE FOR CONTROL VALVES, THE SIZE, THE PRESSURE, DIRECTION & FLOW RANGE ARE LISTED IN THAT ORDER.
 10. THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL THE CONDUCTORS IN THAT LINE.
 11. ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BURIED CONDUIT TO WALL CONNECTIONS TO BE 1/2" TYPE TW BOND, SHOWN WHEN REQUIRED.
 12. INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IN BURIED & REVISIONS OF PIPING ARE VISIBLE FROM FINAL RECEIVED INSTRUMENT, AND DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 13. LEADING PIPING TO ALL CONTROL VALVES IS TO BE 1/2" TO 1/4" IN.
 14. MOVING PIPING MAY BE EITHER VARIABLE SPEED OR SPEED CONTROLLED. SPEED CONTROL METHOD SHOWN IN DRAWING.
 15. FOR ALL VALVES NOT IDENTIFIED ABOVE OR BELOW, REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 16. ALL CONTROL VALVES SIZES ARE SHOWN AS BODY SIZES.
 17. ALL REMOTE CAUSES SHALL HAVE 1/2" OR LARGER SIZES BETWEEN TEST CONNECTION & CAUSE.
 18. INSTRUMENT AIR & ALL PIPING TO BE 1/2" GALVANIZED IRON SCHEDULE 40 PIPE - CODE 312, UNLESS OTHERWISE SPECIFIED.
 19. INSTRUMENT OTHER PIPING SHALL BE 1/2" SCHEDULE 40 CARBON STEEL, CODE 312, UNLESS OTHERWISE SPECIFIED.
 20. MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTIONS SHALL HAVE SMALLER SIZES THAN 1/2" UNLESS OTHERWISE SPECIFIED.

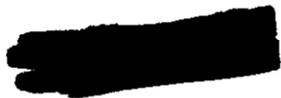
FIGURE XIX-13
INSTRUMENT FLOW DIAGRAM
EXTRACTION COLUMNS
3E, 3D, 3B.
(FROM DWG. N-2-7614)

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



HN-187D

DECLASSIFIED

10324

838
1038

DECLASSIFIED

HM-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

COMPONENT SYMBOLS	
SYMBOL	NAME
W	WATER VALVE
MC-B	MANUAL CONTROL
MC-D	MANUAL CONTROL
MC-E	MANUAL CONTROL
MC-F	MANUAL CONTROL
MC-G	MANUAL CONTROL
MC-H	MANUAL CONTROL
MC-I	MANUAL CONTROL
MC-J	MANUAL CONTROL
MC-K	MANUAL CONTROL
MC-L	MANUAL CONTROL
MC-M	MANUAL CONTROL
MC-N	MANUAL CONTROL
MC-O	MANUAL CONTROL
MC-P	MANUAL CONTROL
MC-Q	MANUAL CONTROL
MC-R	MANUAL CONTROL
MC-S	MANUAL CONTROL
MC-T	MANUAL CONTROL
MC-U	MANUAL CONTROL
MC-V	MANUAL CONTROL
MC-W	MANUAL CONTROL
MC-X	MANUAL CONTROL
MC-Y	MANUAL CONTROL
MC-Z	MANUAL CONTROL

GENERAL NOTES

1. INSTRUMENT LINES FROM A PRESSURE SUB-HEADER TO A PRESSURE VALVE AND FROM A PRESSURE VALVE TO A PRESSURE CONNECTION TO BE IN 1/2" O.D. COPPER TUBING.
2. ALL PUMP LINES TO BE 1/2" O.D. COPPER TUBING FROM HEATING AND RECORDING INSTRUMENTS TO WALL CONNECTORS OR EQUIPMENT BY PIPING BLOCK VALVE FROM INSTRUMENTS TO BE IN 1/2" O.D. CARBON STEEL.
3. FITTINGS & SYMBOLS SHALL BE IN LRS. WHERE CONNECTIONS ARE MADE TO PRESSURE CONNECTIONS, FITTINGS & SYMBOLS MAY BE IN 1/2" O.D. COPPER TUBING. WHERE CONNECTIONS ARE MADE TO PRESSURE CONNECTIONS, FITTINGS & SYMBOLS SHALL BE IN 1/2" O.D. CARBON STEEL. SPECIAL NOTES SHALL COVER.
4. ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES & INSTRUMENT AIR FROM HEADERS, TO BE IN 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
5. ALL VALVES OFF INSTRUMENT AIR & INSTRUMENT SUB-HEADERS AND PRESSURE HEADERS TO BE IN 1/2" O.D. COPPER TUBING.
6. SHUT-OFF VALVES AT PRESSURE VALVES & IN PUMP LINES AT CELL WALL TO BE IN 1/2" O.D. COPPER TUBING.
7. PUMP LINE BLOCK VALVES & BY-PASS AT INSTRUMENTS TO BE IN 1/2" O.D. COPPER TUBING.
8. INSTRUMENT BY-PASS & BLOCK VALVES ON STEAM & WATER LINES TO BE IN 1/2" O.D. COPPER TUBING.
9. ALL ELECTRICAL WIRING IS IN 1/2" O.D. COPPER TUBING EXCEPT AS OTHERWISE NOTED.
10. SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE, A LINE WILL BE IN THE SPACE USUALLY OCCUPIED BY THE SCALE OR RANGE. INSTRUMENTS ARE LISTED WITH SCALE & RANGE. INSTRUMENTS SHALL BE WITH SCALE & RANGE. INSTRUMENTS SHALL BE WITH SCALE & RANGE. INSTRUMENTS SHALL BE WITH SCALE & RANGE.
11. THE NUMBER ON EACH ELECTRICAL LINE APPLIED TO ALL THE CONDUCTORS IN THAT LINE.
12. ALL INSTRUMENT ELECTRICAL CONDUCTORS IN THIS DRAWING TO BE IN 1/2" O.D. COPPER TUBING EXCEPT AS OTHERWISE NOTED.
13. INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IN SOURCE & TERMINATION OF PIPING SHALL BE FROM PANEL MOUNTED INSTRUMENT AND DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
14. LOADS PROVIDED TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 3 TO 12 PSI.
15. PNEUMATIC PUMPS MAY BE EITHER VARIABLE SPEED OR STROKE CONTROLLED. SPEED CONTROL METHOD SHOWN IN DRAWING.
16. FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE REFER TO RELATED ENGINEERING DRAWINGS.
17. ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZE.
18. ALL PRESSURE GAUGES SHALL HAVE 1/2" LRS. UNLESS INDICATED OTHERWISE BY CONNECTIONS AND GAUGE.
19. EXHAUSTION COAXIAL CABLES SHALL BE IN 1/2" O.D. COPPER TUBING CONTAINING 1/2" ELECTRICAL LINES EXCEPT OTHER LOCATION COAXIAL CABLES.
20. INSTRUMENT AIR & SUB-HEADERS TO BE 1/2" O.D. COPPER TUBING, SCHEDULE 40 PIPE, CODE P-20, MW-4000, 1/2" LRS.
21. INSTRUMENT BY-PASS PIPING SHALL BE 1/2" O.D. COPPER TUBING, SCHEDULE 40 PIPE, CODE P-20, MW-4000, 1/2" LRS.
22. HANDMADE PIPING BETWEEN LOW PRESSURE CONNECTIONS AND CHECK VALVES SHALL BE IN 1/2" O.D. COPPER TUBING, SCHEDULE 40 PIPE, CODE P-20, MW-4000, 1/2" LRS.

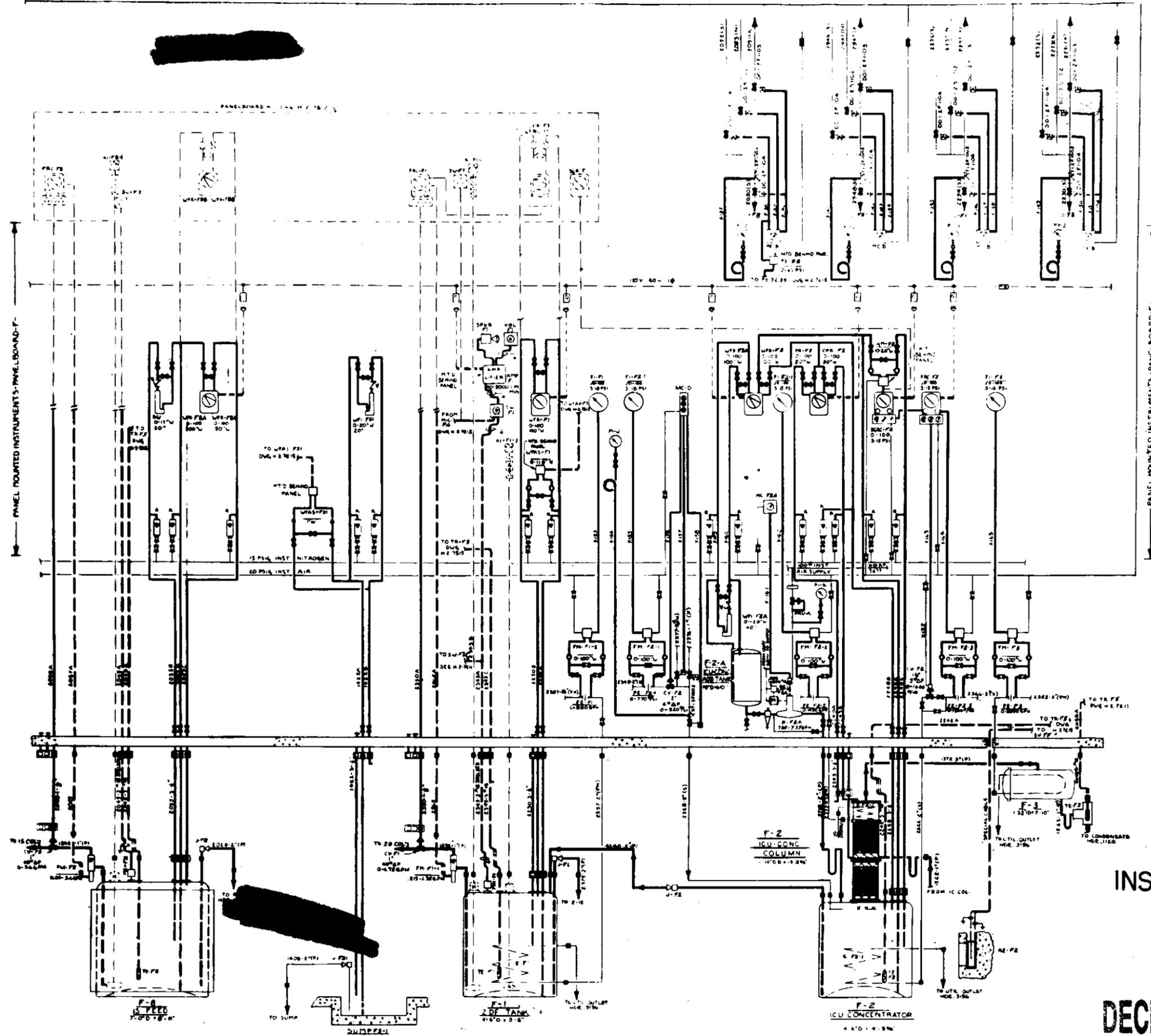
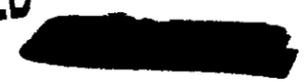


FIGURE XIX-15
INSTRUMENT FLOW DIAGRAM
1ST & 2ND CYCLE
U DECONTAMINATION
(FROM DWG. H-2-7610)

1040

HW 18700

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

10/2

HW-18700

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



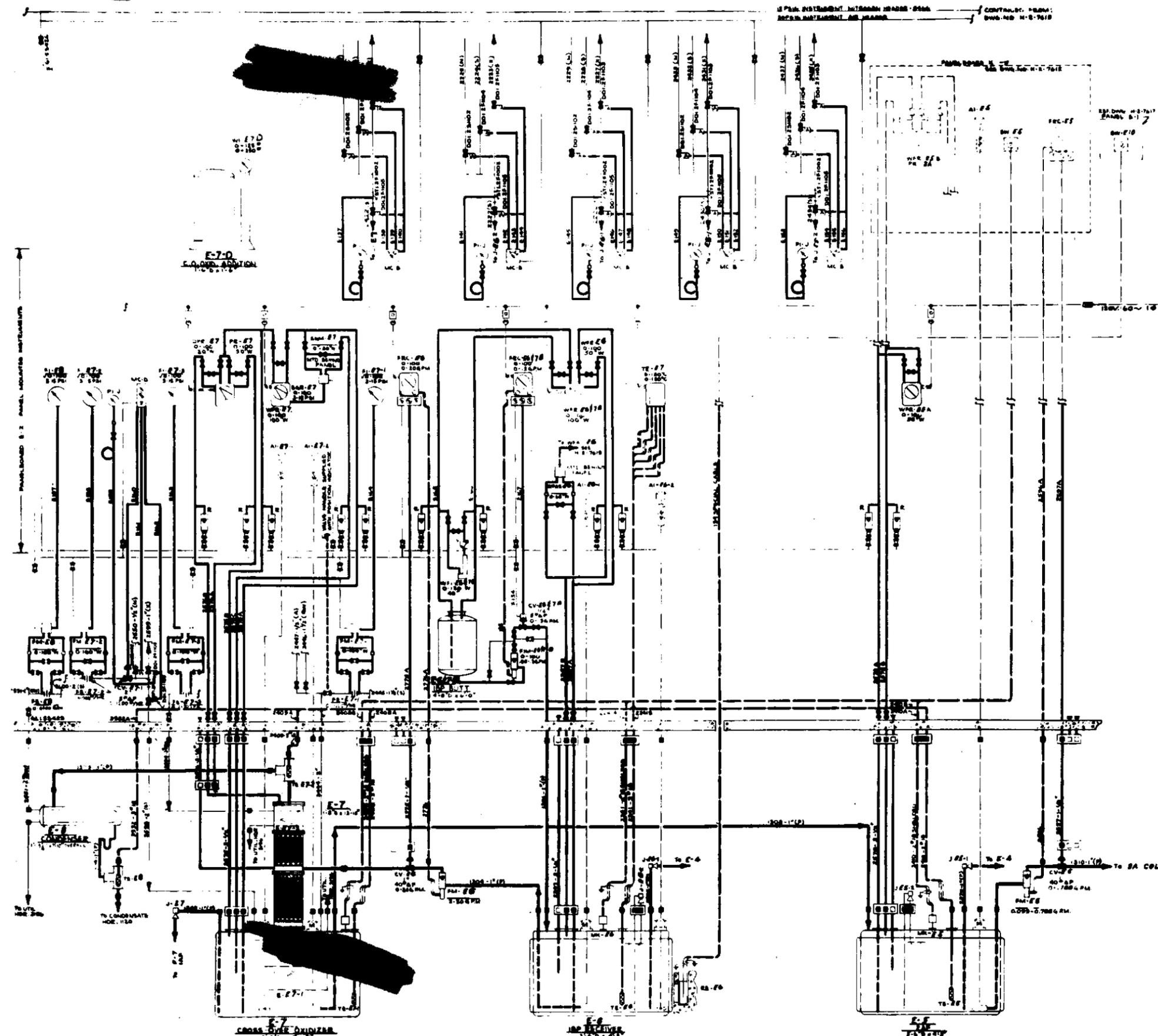
DECLASSIFIED

DECLASSIFIED

1043

HW 18700
Fig. XIX-17

EQUIPMENT	SCALE	REMARKS
MANOMETER CHECK VALVE		
CONTROL		
PIPE 2" TO 1" PRESSURE		
LOAD ON 2" VALVE		



- GENERAL NOTES**
- 1- INSTRUMENT LINE FROM INTERMEDIATE SERVICE TO FROM INSTRUMENTS AND FROM INSTRUMENTS TO CONTROL PANELS SHALL BE 1/2" O.D. COPPER TUBING. ALL OTHER CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
 - 2- ALL PIPING LINES TO BE 1/2" O.D. COPPER TUBING FROM INSTRUMENTS TO CONTROL PANELS AND FROM INSTRUMENTS TO INSTRUMENTS TO BE 1/2" O.D. COPPER TUBING.
 - 3- FITTINGS AND SYSTEMS SHALL BE 1/2" O.D. COPPER TUBING AND SHALL BE INSTALLED IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS. ALL FITTINGS SHALL BE INSTALLED IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS.
 - 4- ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES, INSTRUMENT AIR, AND INSTRUMENT AIR, TO BE 1/2" O.D. COPPER TUBING EXCEPT AS OTHERWISE NOTED.
 - 5- ALL VALVES AND INSTRUMENTS ARE INTERMEDIATE SERVICE AND SHALL BE INSTALLED IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS.
 - 6- SHUT OFF VALVES AT PRESSURE SAGES AND IN PIPING LINES AT CELL WALL TO BE 1/2" O.D. COPPER TUBING.
 - 7- PIPING FOR BLOCK VALVES IS BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. COPPER TUBING.
 - 8- ALL ELECTRICAL WIRING IS TO BE IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS.
 - 9- SCALE RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE RANGE, A LINE WILL BE IN THE SCALE INDICATED BY THE SCALE RANGE INDICATED IN THE INSTRUMENT. IF THE SCALE RANGE INDICATES SQUARE ROOT SCALE, THE SCALE RANGE INDICATES SQUARE ROOT SCALE, AND FLOW SCALE IS LISTED IN VALVE ORDER.
 - 10- THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL THE CONDUCTORS IN THAT LINE.
 - 11- ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BUNDLES SHALL BE WELDED TOGETHER TO BE 1/2" TYPE TO BE WELDED TOGETHER.
 - 12- INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT TO BE INSTALLED IN THE INSTRUMENT ROOM AND TO BE INSTALLED IN THE INSTRUMENT ROOM.
 - 13- LOADING PRESSURE TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 2 TO 4 PSI.
 - 14- INSTRUMENTS BY-PASS BLOCK VALVES ON STEAM & WATER LINES TO BE INSTALLED.
 - 15- FOR ALL VALVES NOT INSTALLED ABOVE OR BELOW THE INSTRUMENTS, THE INSTRUMENTS SHALL BE INSTALLED ABOVE OR BELOW THE INSTRUMENTS.
 - 16- ALL CONTROL VALVE SIZES AND SHOWN AS BODY SIZES.
 - 17- ALL PRESSURE GAUGES SHALL HAVE 1/2" DIA. UNLESS INDICATED OTHERWISE FOR CONNECTION AND GAUGE.
 - 18- INSTRUMENT CONNECTIONS SHALL BE IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS.
 - 19- INSTRUMENT AIR IS TO BE INSTALLED IN ACCORDANCE WITH THE CODES AND STANDARDS APPLICABLE TO THE SYSTEMS.
 - 20- INSTRUMENT WIRING PIPING SHALL BE 1/2" O.D. COPPER TUBING.
 - 21- MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTION & CHECK VALVE SHALL BE 1/2" O.D. COPPER TUBING.

**FIGURE XIX-17
INSTRUMENT FLOW DIAGRAM
2ND & 3RD CYCLE
PU DECONTAMINATION
(FROM DWG. N-2-7619)**

DECLASSIFIED

CLASSIFIED

DECLASSIFIED



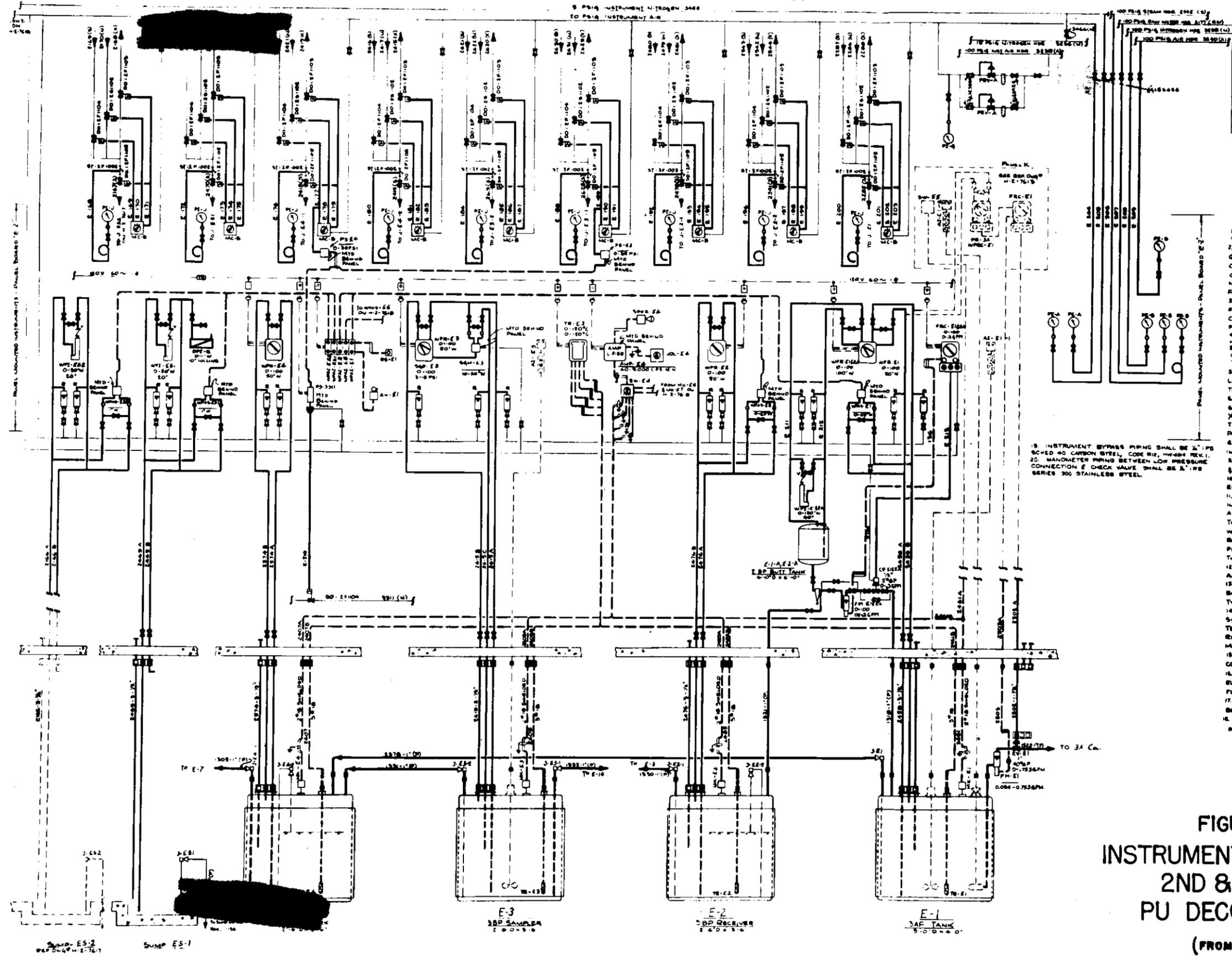
THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

HW-1870D

10/11



INSTRUMENT	SCALE	RANGE	REMARKS
PI-A	0-50	0-50 PSI	BOILER MOUNTED
PI-B	0-50	0-50 PSI	BOILER MOUNTED
PI-C	0-50	0-50 PSI	BOILER MOUNTED
PI-D	0-50	0-50 PSI	SYSTEM COMPRESSOR
PI-E	0-50	0-50 PSI	2 PSI SW. WITH TIME CYCLE CONTROL
PI-F	0-50	0-50 PSI	CONVENTIONAL PRESS. & REGULATED
PI-G	0-50	0-50 PSI	MANOMETER CHECK VALVE

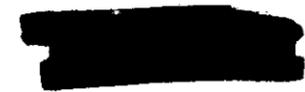
- GENERAL NOTES:**
- INSTRUMENT PIPING IS DESIGNED TO BE GUARANTEED FROM SCHEDULE 40 PIPE - CODE PER HW-484 REV. 1.
 - FITTINGS & SYNDS SHALL BE 1/2" IPS. WHERE GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS FITTINGS & SYNDS MAY BE 1/4" IPS. OR 3/8" OD. COPPER TUBING WHERE GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS. FOR OTHER CASES SPECIAL NOTES WILL COVER.
 - ALL PULSE LINES TO BE 1/4" OD. COPPER TUBING FROM INDICATING & RECORDING INSTRUMENTS TO WALL CONNECTORS OR EQUIPMENT. BY-PASSES & BLOCK VALVE PIPING AT INSTRUMENTS TO BE 1/4" IPS. CARBON STEEL.
 - INSTRUMENT LINES FROM NITROGEN SUB-HEADERS TO PULSE ROTOMETERS & FROM PULSE ROTOMETERS TO PRESS. INSTRUMENT CONNECTIONS TO BE 1/4" OD. COPPER TUBING.
 - ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES & INSTRUMENT AIR FROM HEADERS TO BE 1/2" OD. TUBING EXCEPT AS OTHERWISE NOTED.
 - ALL VALVES OF INSTRUMENT AIR & NITROGEN SUB-HEADERS & PULSE ROTOMETERS TO BE 1/2" G1125604.
 - SHUT OFF VALVES AT PRESSURE GAUGES AND IN PULSE LINES AT CELL WALL TO BE 1/2" G1125604.
 - PULSE LINE BLOCK VALVES & BY-PASSES AT INSTRUMENTS TO BE 1/2" G1125604.
 - INSTRUMENT BY-PASS & BLOCK VALVES ON STEAM & WATER LINES TO BE 1/2" G1125604.
 - ALL ELECTRICAL WIRING IS 1/4" O.D. SPEC. HW-4807 EXCEPT AS OTHERWISE NOTED.
 - SCALE & RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE, A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY THE SCALE OR RANGE. MANOMETERS ARE LISTED WITH SCALE AND SIZE. "S" INDICATES SQUARE BODY SCALES. FOR CONTROL VALVES, THE SIZE, THE PRESSURE DROP AND FLOW RANGE ARE LISTED IN THAT ORDER.
 - THE NUMBER ON EACH ELECTRICAL LINE APPLIED TO ALL THE CONDUCTORS IN THIS LINE.
 - ALL INSTRUMENT ELECTRICAL CONDUCTORS IN BURIED CONDUIT TO WALL CONNECTORS TO BE 1/4" TYPE TW SOLID. SHIELDED WHEN REQUIRED.
 - INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE AND TERMINATION OF PIPING IS VISIBLE FROM FINAL RECEIVER INSTRUMENT, AND DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 - LOADING PRESSURE TO ALL AUTOMATICALLY CONTROLLED VALVES IS TO BE 5 TO 15 PSI.
 - FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 - ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZES.
 - ALL PRESSURE GAUGES SHALL HAVE 1/4" IPS. UNLESS INDICATED BETWEEN TEST CONNECTION AND GAUGE.

FIGURE XIX-18
INSTRUMENT FLOW DIAGRAM
2ND & 3RD CYCLE
PU DECONTAMINATION
(FROM DWG. H-2-7619)

1046

DECLASSIFIED

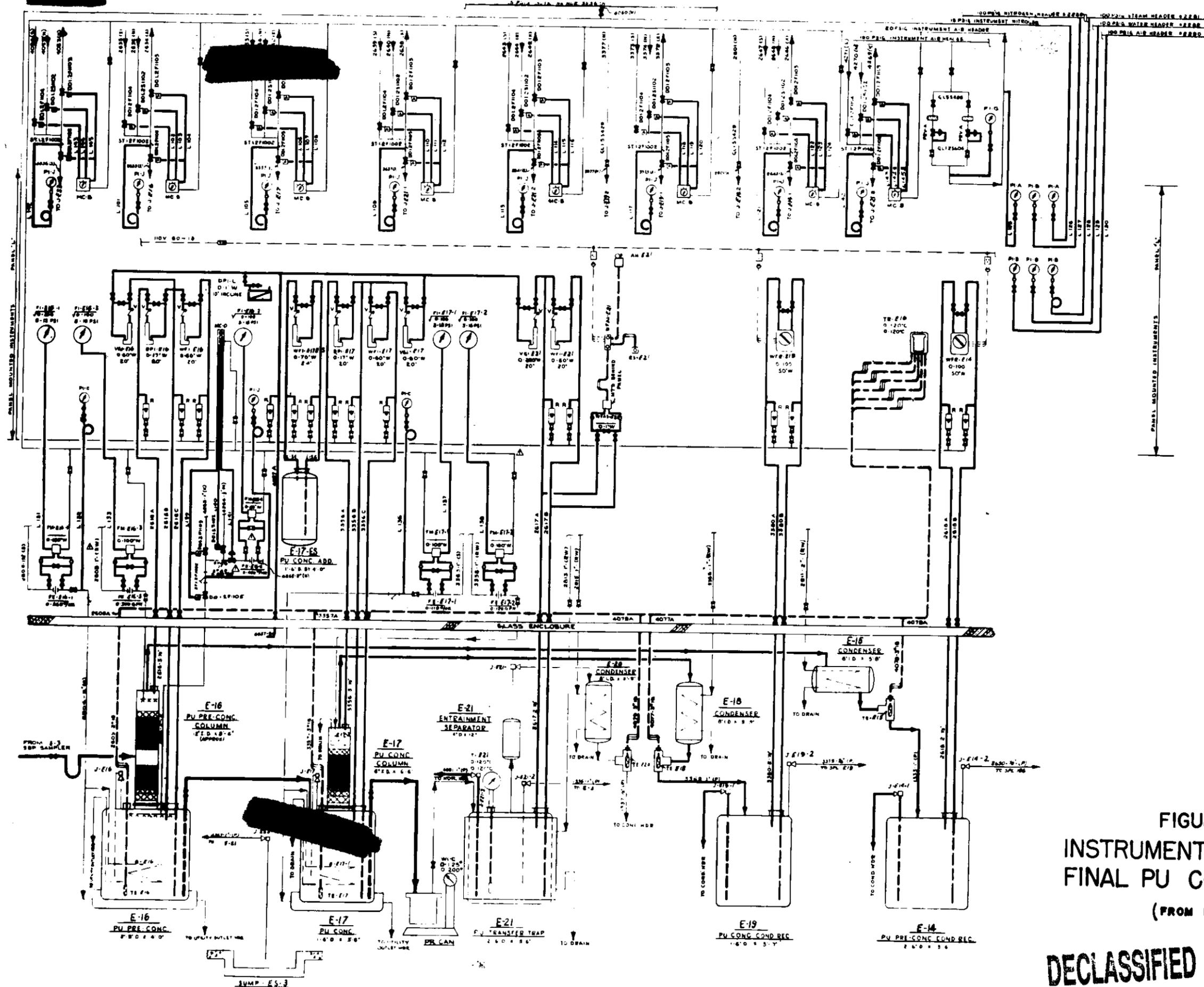
HW-18700



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED



HW 18700
Fig. XIX-19

EQUIPMENT SCHEDULE			
SYMBOL	SCALE	RANGE	REMARKS
PI-A	0-20	0-200 PSI	BOARD MOUNTED
PI-B	0-200	0-2000 PSI	BOARD MOUNTED
PI-C	0-20	0-200 PSI	BOARD MOUNTED
PI-D	0-20	0-200 PSI	BOARD MOUNTED
PI-E	0-20	0-200 PSI	BOARD MOUNTED
PI-F	0-20	0-200 PSI	BOARD MOUNTED
PI-G	0-20	0-200 PSI	BOARD MOUNTED
PI-H	0-20	0-200 PSI	BOARD MOUNTED
PI-I	0-20	0-200 PSI	BOARD MOUNTED
PI-J	0-20	0-200 PSI	BOARD MOUNTED

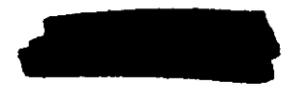
- GENERAL NOTES**
- INSTRUMENT LINES FROM NITROGEN SUBHEADS TO PURGE ROTAMETERS AND FROM PURGE ROTAMETERS TO FIRST INSTRUMENT CONNECTION TO BE WOOD COPPER TUBING
 - ALL PURGE LINES TO BE WOOD COPPER TUBING FROM INDICATOR AND RECORDING INSTRUMENTS TO WALL CONNECTORS OR EQUIPMENT BY-PASSES AND BLOCK VALVE PIPING AT INSTRUMENTS TO BE 1/2" CARBON STEEL
 - FITTINGS & SIPPONS SHALL BE WIPES WHERE GAUGES ARE MOUNTED ADJACENT TO PRESSURE CONNECTIONS. FITTINGS & SIPPONS MAY BE 1/2" PS OR WOOD COPPER TUB WHERE GAUGES ARE MOUNTED REMOTELY FROM PRESSURE CONNECTIONS. FOR OTHER CASES SPECIAL NOTES WILL COVER.
 - ALL OTHER LINES, INCLUDING PNEUMATIC CONTROL LINES AND INSTRUMENT AIR FROM HEADS TO BE WOOD COPPER TUBING EXCEPT AS OTHERWISE NOTED.
 - ALL VALVES OF INSTRUMENT AIR AND NITROGEN SUBHEADS AND PURGE ROTAMETERS TO BE WOOD COPPER
 - SHUT OFF VALVES AT PRESSURE GAUGES AND IN PURGE LINES AT CELL WALL TO BE WOOD COPPER.
 - PURGE LINE BLOCK VALVES AND BY-PASS AT INSTRUMENTS TO BE WOOD COPPER.
 - INSTRUMENT BY-PASS AND BLOCK VALVES ON STEAM AND WATER LINES WOOD COPPER.
 - ALL ELECTRICAL WIRING IS 24 SPEC. HW-4507 EXCEPT AS OTHERWISE NOTED.
 - SCALE AND RANGE IS NOTED ON EACH INSTRUMENT IN THAT ORDER. IF THERE IS NO SCALE OR NO RANGE A LINE WILL BE IN THE SPACE NORMALLY OCCUPIED BY THE SCALE OR RANGE. W/ INDICATES SQUARE ROOT SCALE. FOR VALVES THE SIZE, PRESSURE DROP AND FLOW RANGE ARE LISTED IN THAT ORDER.
 - THE NUMBER ON EACH ELECTRICAL LINE APPLIES TO ALL THE CONDUCTORS IN THAT LINE.
 - FOR ALL VALVES NOT IDENTIFIED ABOVE OR ELSEWHERE, REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 - INSTRUMENT LINES ON LOCAL MOUNTED SYSTEMS ARE NOT NUMBERED IF SOURCE & TERMINATION OF PIPING ARE VISIBLE FROM FINAL RECEIVER INSTRUMENT AND DO NOT SHOW ON MORE THAN ONE CONSTRUCTION DRAWING.
 - ALL PRESSURE GAUGES SHALL HAVE 1/2" UNIONS INSERTED BETWEEN TEST CONNECTION AND GAUGE
 - INSTRUMENT AIR & N. SUBHEADS TO BE 1/2" GALVANIZED IRON, SCHEDULE 40 PIPE - CODE 886, HW-45M REV. 1.
 - INSTRUMENT BY-PASS PIPING SHALL BE 1/2" SCHED. 40 CARBON STEEL, CODE 812, HW-45M REV. 1.
 - MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTION & CHECK VALVE SHALL BE 1/2" 1/8" SERIES 300 STAINLESS STEEL.

FIGURE XIX-19
INSTRUMENT FLOW DIAGRAM
FINAL PU CONCENTRATION
(FROM DWG. H-2-7620)

1048

DECLASSIFIED

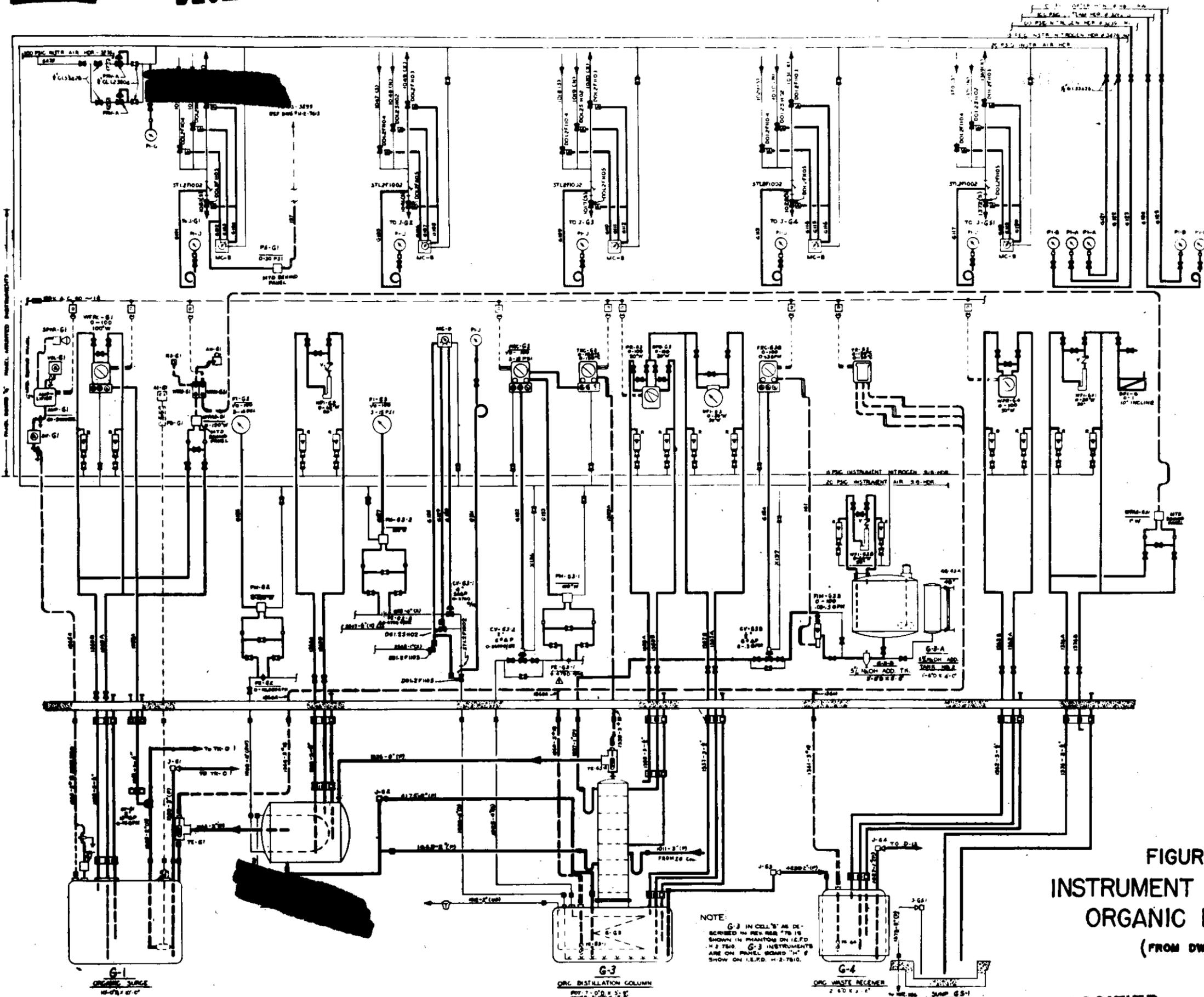
HW-18700



THIS PAGE
INTENTIONAL
LEFT BLANK



DECLASSIFIED



EQUIPMENT SCHEDULE			
SYMBOL	SCALE	RANGE	REMARKS
PI-A	0-30	2.5-25 PSI	WASTE WASTED
PI-B	0-30	2.5-25 PSI	WASTE WASTED
PI-C	0-30	2.5-25 PSI	WASTE WASTED
PI-D	0-30	2.5-25 PSI	WASTE WASTED
PI-E	0-30	2.5-25 PSI	WASTE WASTED
PI-F	0-30	2.5-25 PSI	WASTE WASTED
PI-G	0-30	2.5-25 PSI	WASTE WASTED
PI-H	0-30	2.5-25 PSI	WASTE WASTED
PI-I	0-30	2.5-25 PSI	WASTE WASTED
PI-J	0-30	2.5-25 PSI	WASTE WASTED
PI-K	0-30	2.5-25 PSI	WASTE WASTED
PI-L	0-30	2.5-25 PSI	WASTE WASTED
PI-M	0-30	2.5-25 PSI	WASTE WASTED
PI-N	0-30	2.5-25 PSI	WASTE WASTED
PI-O	0-30	2.5-25 PSI	WASTE WASTED
PI-P	0-30	2.5-25 PSI	WASTE WASTED
PI-Q	0-30	2.5-25 PSI	WASTE WASTED
PI-R	0-30	2.5-25 PSI	WASTE WASTED
PI-S	0-30	2.5-25 PSI	WASTE WASTED
PI-T	0-30	2.5-25 PSI	WASTE WASTED
PI-U	0-30	2.5-25 PSI	WASTE WASTED
PI-V	0-30	2.5-25 PSI	WASTE WASTED
PI-W	0-30	2.5-25 PSI	WASTE WASTED
PI-X	0-30	2.5-25 PSI	WASTE WASTED
PI-Y	0-30	2.5-25 PSI	WASTE WASTED
PI-Z	0-30	2.5-25 PSI	WASTE WASTED

- GENERAL NOTES**
- INSTRUMENT LINES FROM HYDROLYSIS COLUMN TO PURGE ROTAMETER AND FROM PURGE ROTAMETER TO FIRST INSTRUMENT CONNECTIONS TO BE 1/2" O.D. COPPER TUBING.
 - ALL PULSE LINES TO BE 1/2" O.D. COPPER TUBING FROM INDICATING & RECORDING INSTRUMENTS TO WALL CONNECTIONS ON EQUIPMENT BY PIPES. SIGNAL VALVE PIPES AT INSTRUMENTS TO BE 1/2" T.P.S. CARBON STEEL.
 - FITTINGS & SUPPORTS SHALL BE 1/2" LRS WHERE GAUGES ARE MOUNTED SUBJECT TO PREVIOUS CONNECTIONS. FITTINGS & SUPPORTS MAY BE 1/2" IPS OR 1/2" O.D. COPPER TUBING WHERE GAUGES ARE MOUNTED DIRECTLY FROM PROCESS CONNECTIONS FOR OTHER CASES. SPECIAL NOTES WILL COVER.
 - ALL OTHER LINES INCLUDING INSTRUMENTIC CONTROL LINES & INSTRUMENT AIR PIPING TO BE 1/2" O.D. TUBING EXCEPT AS OTHERWISE NOTED.
 - ALL VALVES OFF INSTRUMENT AND FROM INSTRUMENTS AND PURGE ROTAMETERS TO BE 1/2" O.D. TUBING.
 - SHUT OFF VALVES AT FREIGHT BAYERS AND IN PULSE LINES AT CELL WALLS TO BE 1/2" O.D. TUBING.
 - PULSE LINE SIGNAL VALVES & BY-PASS AT INSTRUMENTS TO BE 1/2" O.D. TUBING.
 - INSTRUMENT BY-PASS SIGNAL VALVES ON STEAM AND WATER LINES 1/2" O.D. TUBING.
 - ALL ELECTRICAL WIRING IS TO BE 14 AWG EXCEPT AS OTHERWISE NOTED.
 - SCALE & RANGE IS SET BY EACH INSTRUMENT IN THAT CASE. IF THERE IS NO SCALE OR RANGE LINE WILL BE IN THE RANGE INDICATED BY SCALE OR RANGE. INSTRUMENTS ARE LISTED WITH SCALE & RANGE. INSTRUMENTS WHICH HAVE NO SCALE FOR GIVEN RANGE OR RANGE ARE LISTED WITH RANGE AND LISTING IS TO BE USED.
 - THE NUMBER OF EACH ELECTRICAL LINE APPLIES TO ALL CONNECTIONS IN THAT LINE.
 - ALL INSTRUMENT ELECTRICAL CONNECTIONS IN PIPING CONDUIT TO WALL CONNECTIONS TO BE OF TYPE TO BE SHOWN WHEN REQUIRED.
 - LOWEST PRESSURE TO BE AUTOMATICALLY CONTROLLED VALVES IS TO BE 3 TO 4 PSI.
 - INSTRUMENT LINES ON LOCAL AIR SYSTEMS ARE NOT NUMBERED BY DOUBLE TERMINATION BY PIPING AND VIBRATION FROM PIPING. INSTRUMENTS ARE TO BE SHOWN ON SUCH PIPING AND CONNECTIONS SHOWN.
 - FOR ALL VALVES NOT IDENTIFIED ABOVE SEE ELSEWHERE REFER TO RELATED ENGINEERING FLOW DIAGRAMS.
 - ALL CONTROL VALVE SIZES ARE SHOWN AS BODY SIZES.
 - INSTRUMENT AIR & ALL SUBHEADERS TO BE 1/2" CALIBRATED IRON, SCHEDULE 40 PIPE. CODE P-30 HW-454, REV. 1.
 - INSTRUMENT BY-PASS PIPING SHALL BE 1/2" O.D. COPPER TUBING. USE PI. NUMBER.
 - MANOMETER PIPING BETWEEN LOW PRESSURE CONNECTION & CHANGE VALVE SHALL BE 1/2" SERIES 30 STAINLESS STEEL.

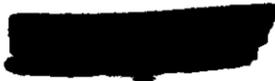
NOTE: G-3 IN CELL 'B' AS DESCRIBED IN REV. 10/76 IS SHOWN IN POSITION ON I.E.P.D. H-2-7610. G-3 INSTRUMENTS ARE ON PANEL BOARD 'M' & SHOW ON I.E.P.D. H-2-7610.

FIGURE XIX-20
INSTRUMENT FLOW DIAGRAM
ORGANIC RECOVERY
(FROM DWS. H-2-7621)

DECLASSIFIED



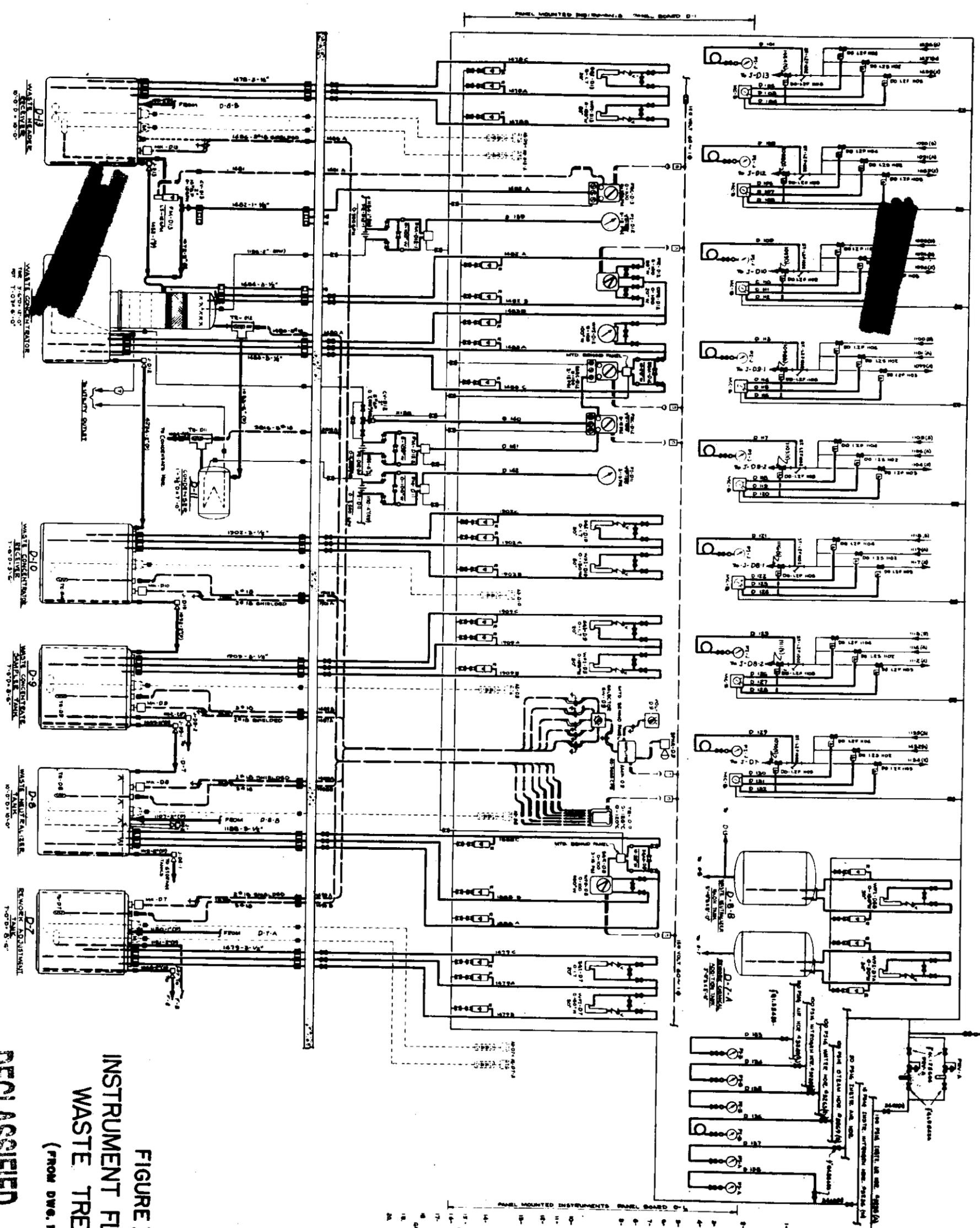
THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

HW-18780

1050



LOGSHEET SUMMARY

NO.	DATE	BY	REVISIONS
1	1-15-54	J. H. [REDACTED]	1-15-54
2	1-15-54	J. H. [REDACTED]	1-15-54
3	1-15-54	J. H. [REDACTED]	1-15-54
4	1-15-54	J. H. [REDACTED]	1-15-54
5	1-15-54	J. H. [REDACTED]	1-15-54
6	1-15-54	J. H. [REDACTED]	1-15-54
7	1-15-54	J. H. [REDACTED]	1-15-54
8	1-15-54	J. H. [REDACTED]	1-15-54
9	1-15-54	J. H. [REDACTED]	1-15-54
10	1-15-54	J. H. [REDACTED]	1-15-54
11	1-15-54	J. H. [REDACTED]	1-15-54
12	1-15-54	J. H. [REDACTED]	1-15-54
13	1-15-54	J. H. [REDACTED]	1-15-54
14	1-15-54	J. H. [REDACTED]	1-15-54
15	1-15-54	J. H. [REDACTED]	1-15-54
16	1-15-54	J. H. [REDACTED]	1-15-54
17	1-15-54	J. H. [REDACTED]	1-15-54
18	1-15-54	J. H. [REDACTED]	1-15-54
19	1-15-54	J. H. [REDACTED]	1-15-54
20	1-15-54	J. H. [REDACTED]	1-15-54
21	1-15-54	J. H. [REDACTED]	1-15-54
22	1-15-54	J. H. [REDACTED]	1-15-54
23	1-15-54	J. H. [REDACTED]	1-15-54
24	1-15-54	J. H. [REDACTED]	1-15-54
25	1-15-54	J. H. [REDACTED]	1-15-54
26	1-15-54	J. H. [REDACTED]	1-15-54
27	1-15-54	J. H. [REDACTED]	1-15-54
28	1-15-54	J. H. [REDACTED]	1-15-54
29	1-15-54	J. H. [REDACTED]	1-15-54
30	1-15-54	J. H. [REDACTED]	1-15-54

- GENERAL NOTES**
- 1- INSTRUMENTS AND GAUGES SHALL BE OF THE TYPE AND MAKE AS SPECIFIED IN THE INSTRUMENT SPECIFICATION SHEET.
 - 2- ALL INSTRUMENTS SHALL BE CALIBRATED AND CHECKED AT THE TIME OF INSTALLATION AND AT REGULAR INTERVALS THEREAFTER.
 - 3- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST VIBRATION AND SHOCK.
 - 4- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST EXCESSIVE TEMPERATURES AND HUMIDITY.
 - 5- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST CORROSION.
 - 6- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST ELECTRICAL INTERFERENCE.
 - 7- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST MECHANICAL DAMAGE.
 - 8- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED ACCESS.
 - 9- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED OPERATION.
 - 10- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED REPAIRS.
 - 11- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED MODIFICATIONS.
 - 12- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED CALIBRATIONS.
 - 13- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED ADJUSTMENTS.
 - 14- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS.
 - 15- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED REPAIRS AND MODIFICATIONS.
 - 16- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED CALIBRATIONS AND ADJUSTMENTS.
 - 17- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS AND REPAIRS.
 - 18- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS AND MODIFICATIONS.
 - 19- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 20- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 21- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 22- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 23- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 24- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 25- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 26- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 27- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 28- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 29- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.
 - 30- ALL INSTRUMENTS SHALL BE PROTECTED AGAINST UNAUTHORIZED RECALIBRATIONS, REPAIRS, MODIFICATIONS AND ADJUSTMENTS.

FIGURE XIX- 21
INSTRUMENT FLOW DIAGRAM
WASTE TREATMENT
(FROM DWG. H-2-7662)

10531

HN-18700

DECLASSIFIED



THIS PAGE
INTENTIONAL
LEFT BLANK

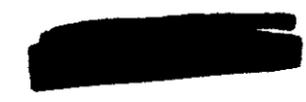


DECLASSIFIED

1054

HW-18700

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

1054

HW-18700

DECLASSIFIED



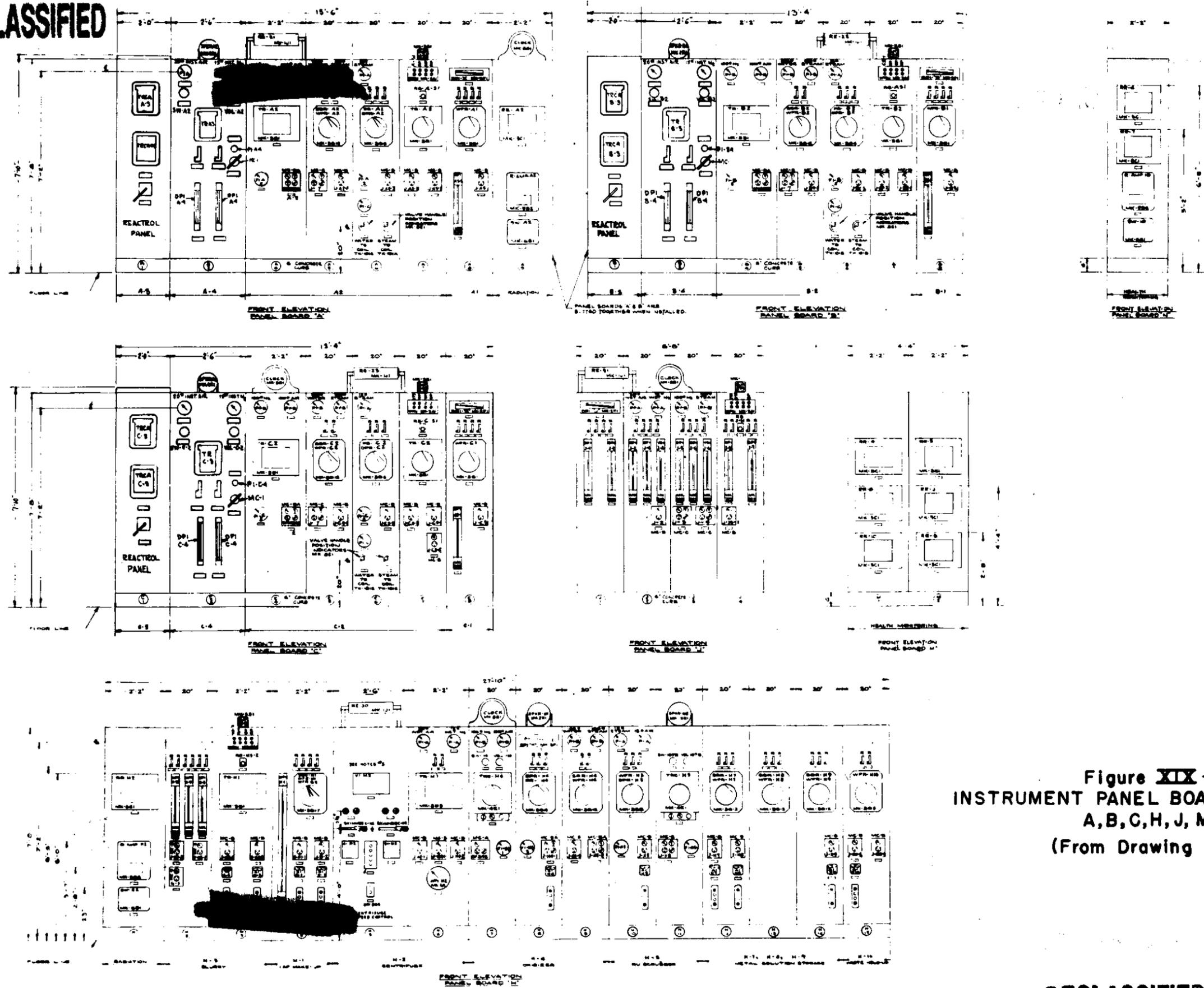
**THIS PAGE
INTENTIONALLY
LEFT BLANK**

DECLASSIFIED



DECLASSIFIED

HW 18700
Fig. XIX-24



APPLICATION NO.	ISSUE NO.
0	000
01-A	000
01-B	000
01-C	000
01-BA	000
01-BB	000
01-CA	000
01-CB	000
01-CC	000
01-CD	000
01-CE	000
01-CF	000
01-CG	000
01-CH	000
01-CI	000
01-CJ	000
01-CK	000
01-CL	000
01-CM	000
01-CN	000
01-CO	000
01-CP	000
01-CQ	000
01-CR	000
01-CS	000
01-CT	000
01-CU	000
01-CV	000
01-CW	000
01-CX	000
01-CY	000
01-CZ	000

- NOTES:**
1. Panel boards to be mounted in accordance with...
 2. All dimensions are to be furnished by customer...
 3. Panel boards are to be mounted in accordance with...
 4. All items shown are to be furnished by customer...
 5. Panel boards are to be furnished by customer...
 6. Panel boards are to be furnished by customer...
 7. For location of panel boards see equipment arrangement drawing H-2-7773 and structural drawing H-2-7774.

REV. NO.	REV. DATE	DESCRIPTION
0-01	0-01	INITIAL DESIGN
0-02	0-02	REVISED TO SHOW...
0-03	0-03	REVISED TO SHOW...
0-04	0-04	REVISED TO SHOW...
0-05	0-05	REVISED TO SHOW...
0-06	0-06	REVISED TO SHOW...
0-07	0-07	REVISED TO SHOW...
0-08	0-08	REVISED TO SHOW...
0-09	0-09	REVISED TO SHOW...
0-10	0-10	REVISED TO SHOW...
0-11	0-11	REVISED TO SHOW...
0-12	0-12	REVISED TO SHOW...
0-13	0-13	REVISED TO SHOW...
0-14	0-14	REVISED TO SHOW...
0-15	0-15	REVISED TO SHOW...
0-16	0-16	REVISED TO SHOW...
0-17	0-17	REVISED TO SHOW...
0-18	0-18	REVISED TO SHOW...
0-19	0-19	REVISED TO SHOW...
0-20	0-20	REVISED TO SHOW...
0-21	0-21	REVISED TO SHOW...
0-22	0-22	REVISED TO SHOW...
0-23	0-23	REVISED TO SHOW...
0-24	0-24	REVISED TO SHOW...
0-25	0-25	REVISED TO SHOW...
0-26	0-26	REVISED TO SHOW...
0-27	0-27	REVISED TO SHOW...
0-28	0-28	REVISED TO SHOW...
0-29	0-29	REVISED TO SHOW...
0-30	0-30	REVISED TO SHOW...
0-31	0-31	REVISED TO SHOW...
0-32	0-32	REVISED TO SHOW...
0-33	0-33	REVISED TO SHOW...
0-34	0-34	REVISED TO SHOW...
0-35	0-35	REVISED TO SHOW...
0-36	0-36	REVISED TO SHOW...
0-37	0-37	REVISED TO SHOW...
0-38	0-38	REVISED TO SHOW...
0-39	0-39	REVISED TO SHOW...
0-40	0-40	REVISED TO SHOW...
0-41	0-41	REVISED TO SHOW...
0-42	0-42	REVISED TO SHOW...
0-43	0-43	REVISED TO SHOW...
0-44	0-44	REVISED TO SHOW...
0-45	0-45	REVISED TO SHOW...
0-46	0-46	REVISED TO SHOW...
0-47	0-47	REVISED TO SHOW...
0-48	0-48	REVISED TO SHOW...
0-49	0-49	REVISED TO SHOW...
0-50	0-50	REVISED TO SHOW...
0-51	0-51	REVISED TO SHOW...
0-52	0-52	REVISED TO SHOW...
0-53	0-53	REVISED TO SHOW...
0-54	0-54	REVISED TO SHOW...
0-55	0-55	REVISED TO SHOW...
0-56	0-56	REVISED TO SHOW...
0-57	0-57	REVISED TO SHOW...
0-58	0-58	REVISED TO SHOW...
0-59	0-59	REVISED TO SHOW...
0-60	0-60	REVISED TO SHOW...
0-61	0-61	REVISED TO SHOW...
0-62	0-62	REVISED TO SHOW...
0-63	0-63	REVISED TO SHOW...
0-64	0-64	REVISED TO SHOW...
0-65	0-65	REVISED TO SHOW...
0-66	0-66	REVISED TO SHOW...
0-67	0-67	REVISED TO SHOW...
0-68	0-68	REVISED TO SHOW...
0-69	0-69	REVISED TO SHOW...
0-70	0-70	REVISED TO SHOW...
0-71	0-71	REVISED TO SHOW...
0-72	0-72	REVISED TO SHOW...
0-73	0-73	REVISED TO SHOW...
0-74	0-74	REVISED TO SHOW...
0-75	0-75	REVISED TO SHOW...
0-76	0-76	REVISED TO SHOW...
0-77	0-77	REVISED TO SHOW...
0-78	0-78	REVISED TO SHOW...
0-79	0-79	REVISED TO SHOW...
0-80	0-80	REVISED TO SHOW...
0-81	0-81	REVISED TO SHOW...
0-82	0-82	REVISED TO SHOW...
0-83	0-83	REVISED TO SHOW...
0-84	0-84	REVISED TO SHOW...
0-85	0-85	REVISED TO SHOW...
0-86	0-86	REVISED TO SHOW...
0-87	0-87	REVISED TO SHOW...
0-88	0-88	REVISED TO SHOW...
0-89	0-89	REVISED TO SHOW...
0-90	0-90	REVISED TO SHOW...
0-91	0-91	REVISED TO SHOW...
0-92	0-92	REVISED TO SHOW...
0-93	0-93	REVISED TO SHOW...
0-94	0-94	REVISED TO SHOW...
0-95	0-95	REVISED TO SHOW...
0-96	0-96	REVISED TO SHOW...
0-97	0-97	REVISED TO SHOW...
0-98	0-98	REVISED TO SHOW...
0-99	0-99	REVISED TO SHOW...
0-100	0-100	REVISED TO SHOW...

Figure XIX-24
INSTRUMENT PANEL BOARD ARRANGEMENT
A, B, C, H, J, M, N
(From Drawing H-2-7773)

DECLASSIFIED

1058

HW-18700

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

0900

DECLASSIFIED

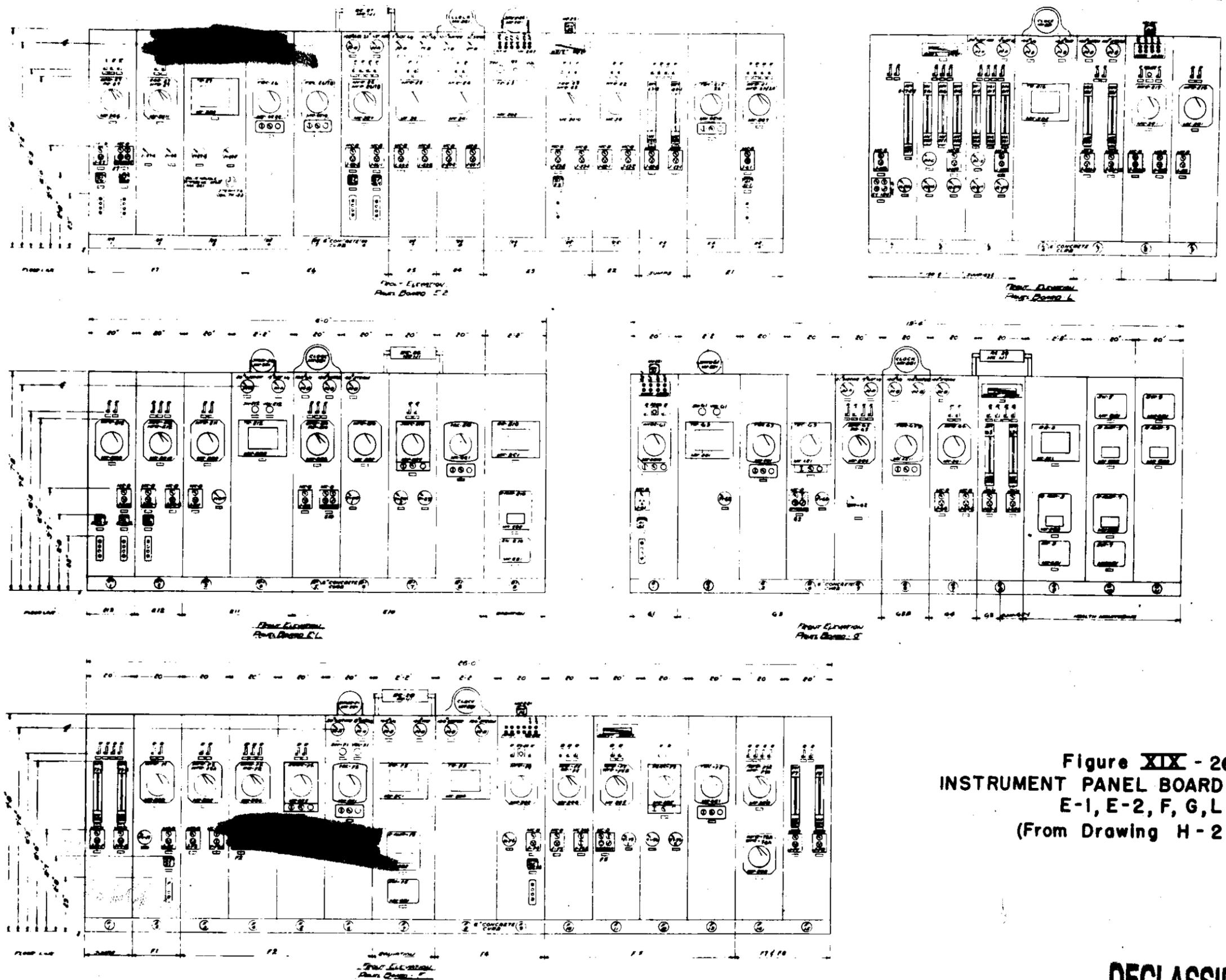


HM-18780

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED



SYMBOLS AND ABBREVIATIONS

SYMBOL	ABBREVIATION
[Symbol]	101
[Symbol]	102
[Symbol]	103
[Symbol]	104
[Symbol]	105
[Symbol]	106
[Symbol]	107
[Symbol]	108
[Symbol]	109
[Symbol]	110

- NOTES
1. PANEL BOARD E-1 TO BE INSTALLED IN INSTRUMENT PANEL CASE WITH INSTRUMENTS INSTALLED AS SHOWN IN THIS DRAWING.
 2. ALL INSTRUMENTS TO BE INSTALLED AS SHOWN IN THIS DRAWING.
 3. ALL INSTRUMENTS TO BE INSTALLED AS SHOWN IN THIS DRAWING.
 4. ALL INSTRUMENTS TO BE INSTALLED AS SHOWN IN THIS DRAWING.
 5. FOR LOCATION OF PANEL BOARD SEE DRAWING H-2-7775.

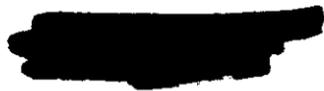
REV.	DATE	BY	CHKD.	TITLE
1	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
2	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
3	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
4	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
5	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
6	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
7	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
8	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
9	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
10	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
11	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
12	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
13	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
14	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
15	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
16	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
17	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
18	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
19	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L
20	11-2-54	[Name]	[Name]	INSTRUMENT PANEL BOARD ARRANGEMENT E-1, E-2, F, G, L

Figure XIX - 26
INSTRUMENT PANEL BOARD ARRANGEMENT
E-1, E-2, F, G, L
(From Drawing H-2-7775)

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

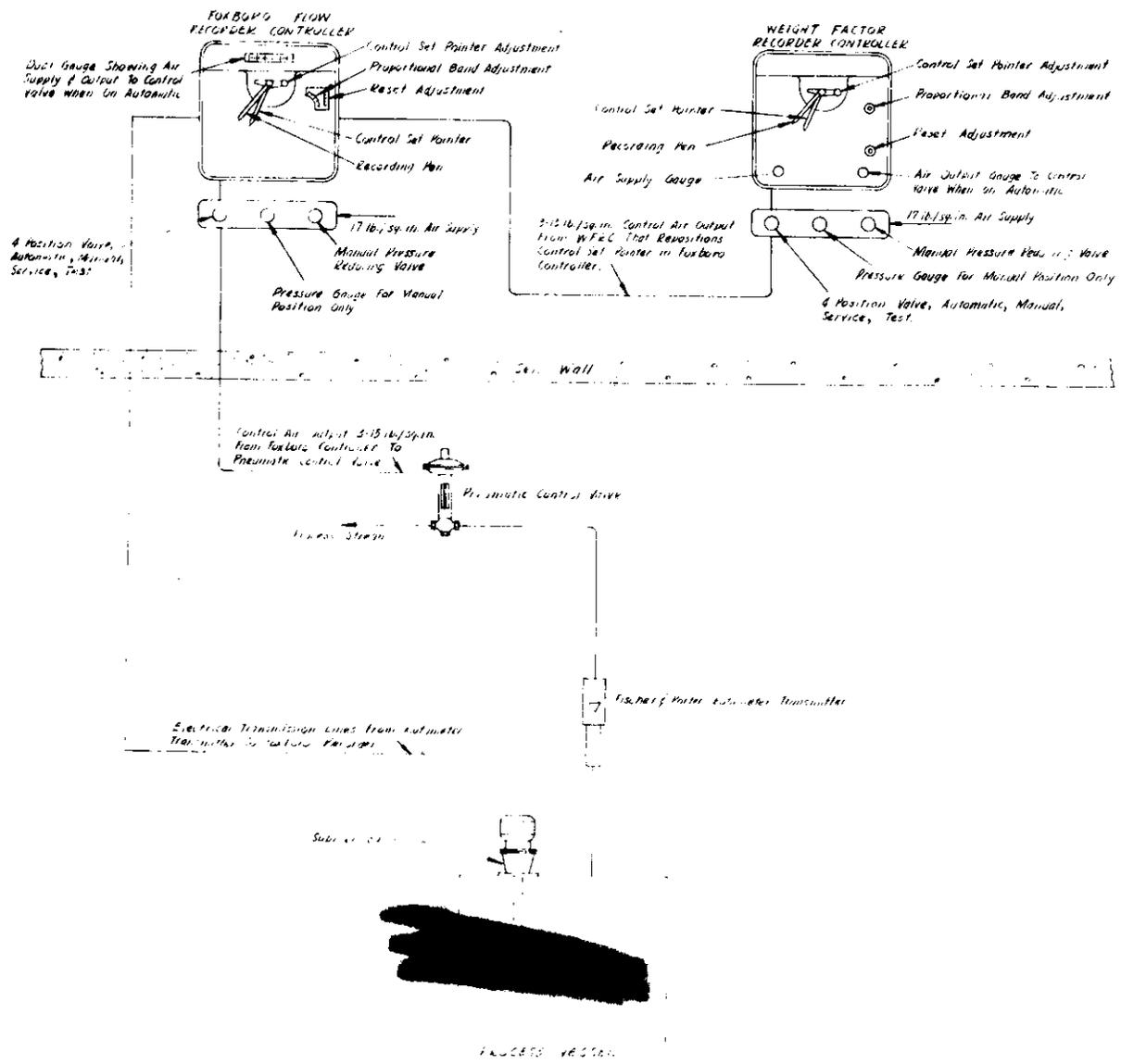
HW-18700

10602

DECLASSIFIED

HW-18700

Figure XIX-27
ROTAMETER CONTROL SYSTEM



DECLASSIFIED

1064

HW-1870D

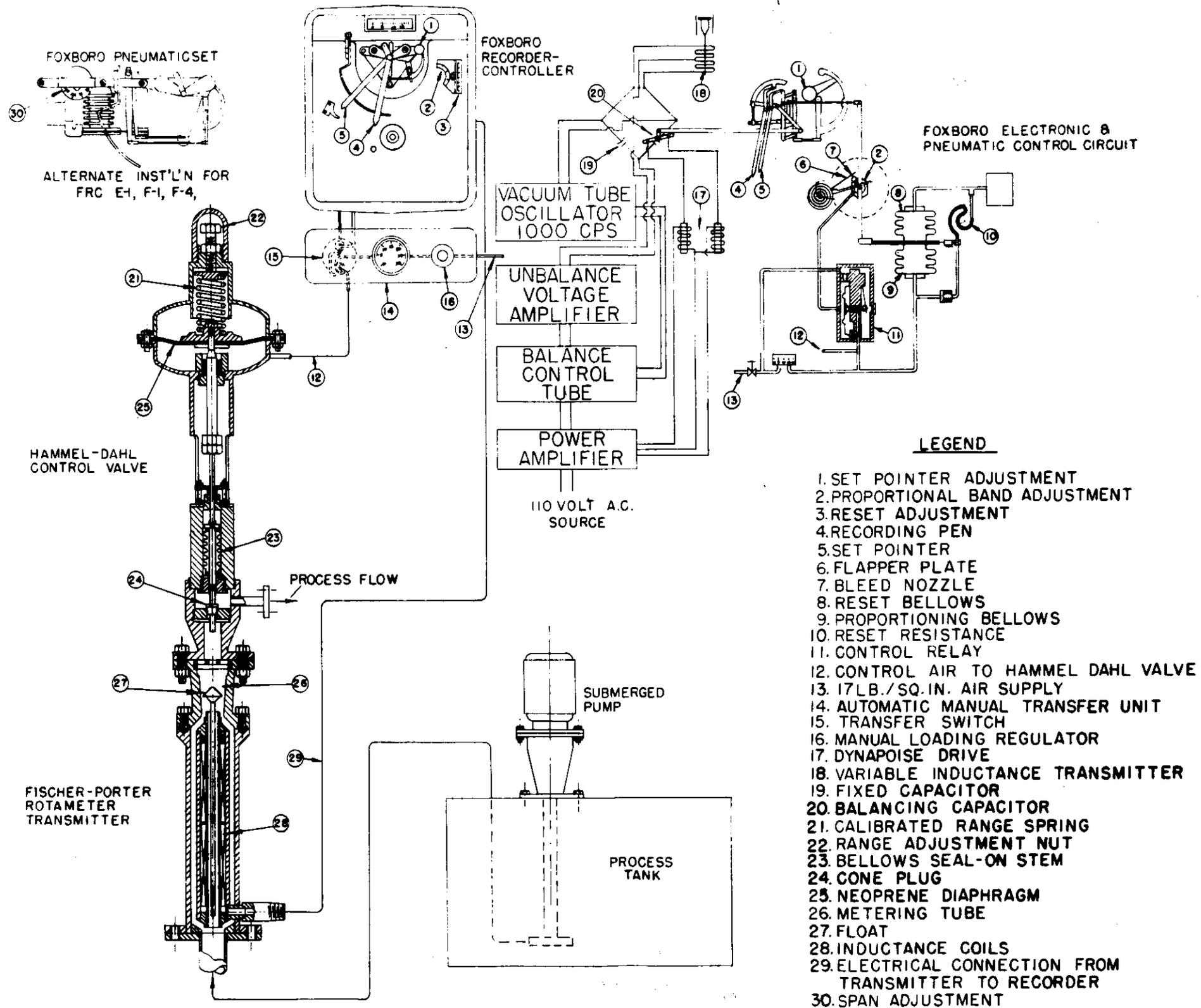
DECLASSIFIED 

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

Figure XIX-28
"HOT" FLOW CONTROL SYSTEM



10/2/62

HMN-18700



DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**



DECLASSIFIED

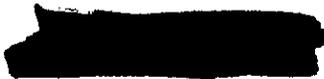
1068

HW-18400

DECLASSIFIED



THIS PAGE
INTERNATIONALLY
LEFT BLANK



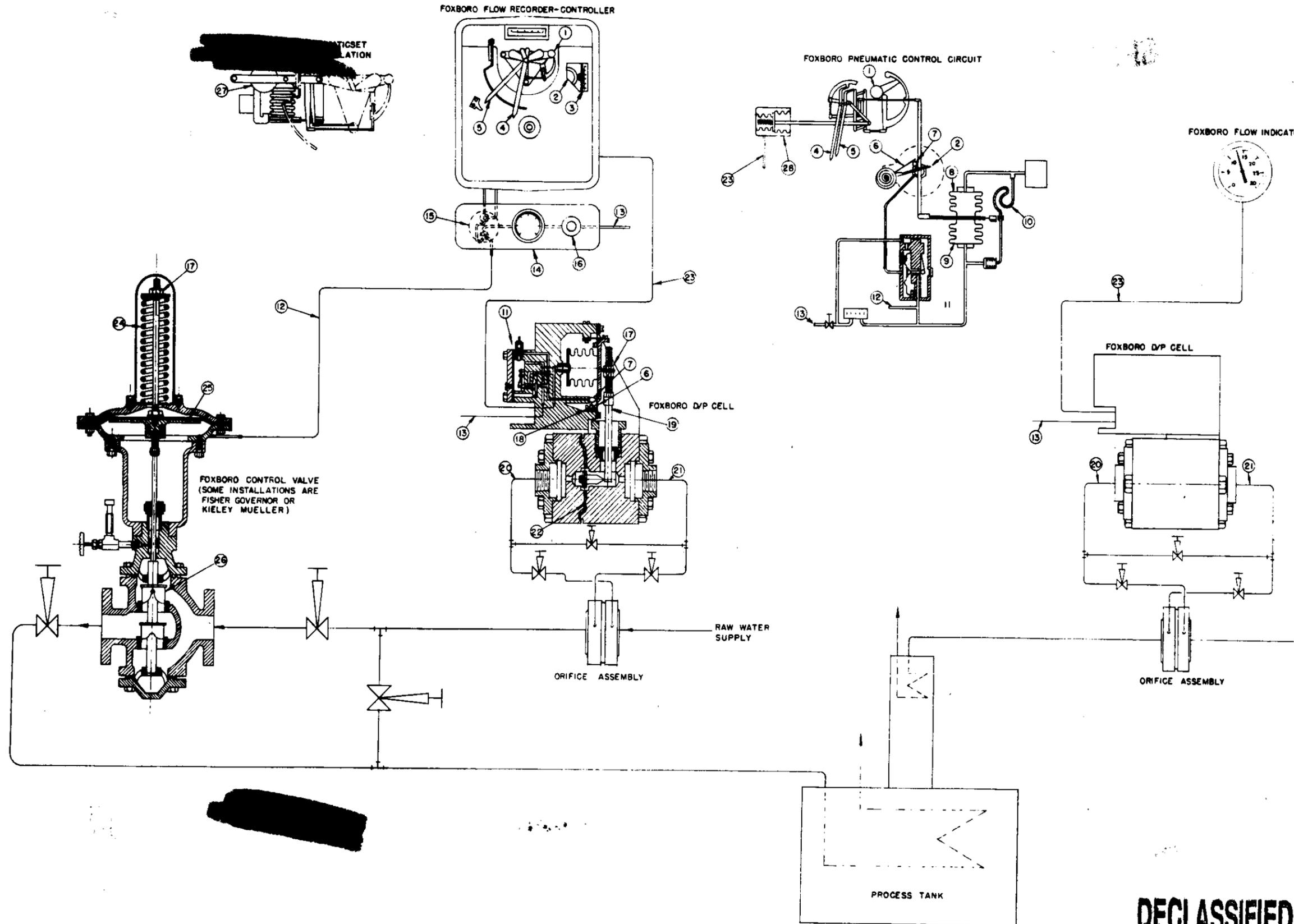
DECLASSIFIED

DECLASSIFIED

1069

Figure XIX-30
"COLD" ORIFICE FLOW SYSTEM

HW-18700
Fig. XIX-30



LEGEND

1. SET POINTER ADJUSTMENT
2. PROPORTIONAL BAND ADJUSTMENT
3. RESET ADJUSTMENT
4. RECORDING PEN
5. SET POINTER
6. FLAPPER PLATE
7. BLEED NOZZLE
8. RESET BELLOWS
9. PROPORTIONING BELLOWS
10. RESET RESISTANCE
11. CONTROL RELAY
12. CONTROL AIR TO FOXBORO VALVE
13. 17 LB./SQ. IN AIR SUPPLY
14. AUTOMATIC MANUAL TRANSFER UNIT
15. TRANSFER SWITCH
16. MANUAL LOADING REGULATOR
17. RANGE ADJUSTMENT NUT
18. ZERO ADJUSTMENT SCREW
19. TORQUE TUBE
20. HIGH PRESSURE CONNECTION
21. LOW PRESSURE CONNECTION
22. 316 STAINLESS STEEL DIAPHRAGM
23. CONTROL AIR TO FOXBORO RECORDER OR INDICATOR
24. CALIBRATED RANGE SPRING
25. NEOPRENE DIAPHRAGM
26. PLUG
27. SPAN ADJUSTMENT
28. PRESSURE RECEIVER

DECLASSIFIED

1107D

DECLASSIFIED HW-18400

[REDACTED]

THIS PAGE
INTENTIONALLY
LEFT BLANK

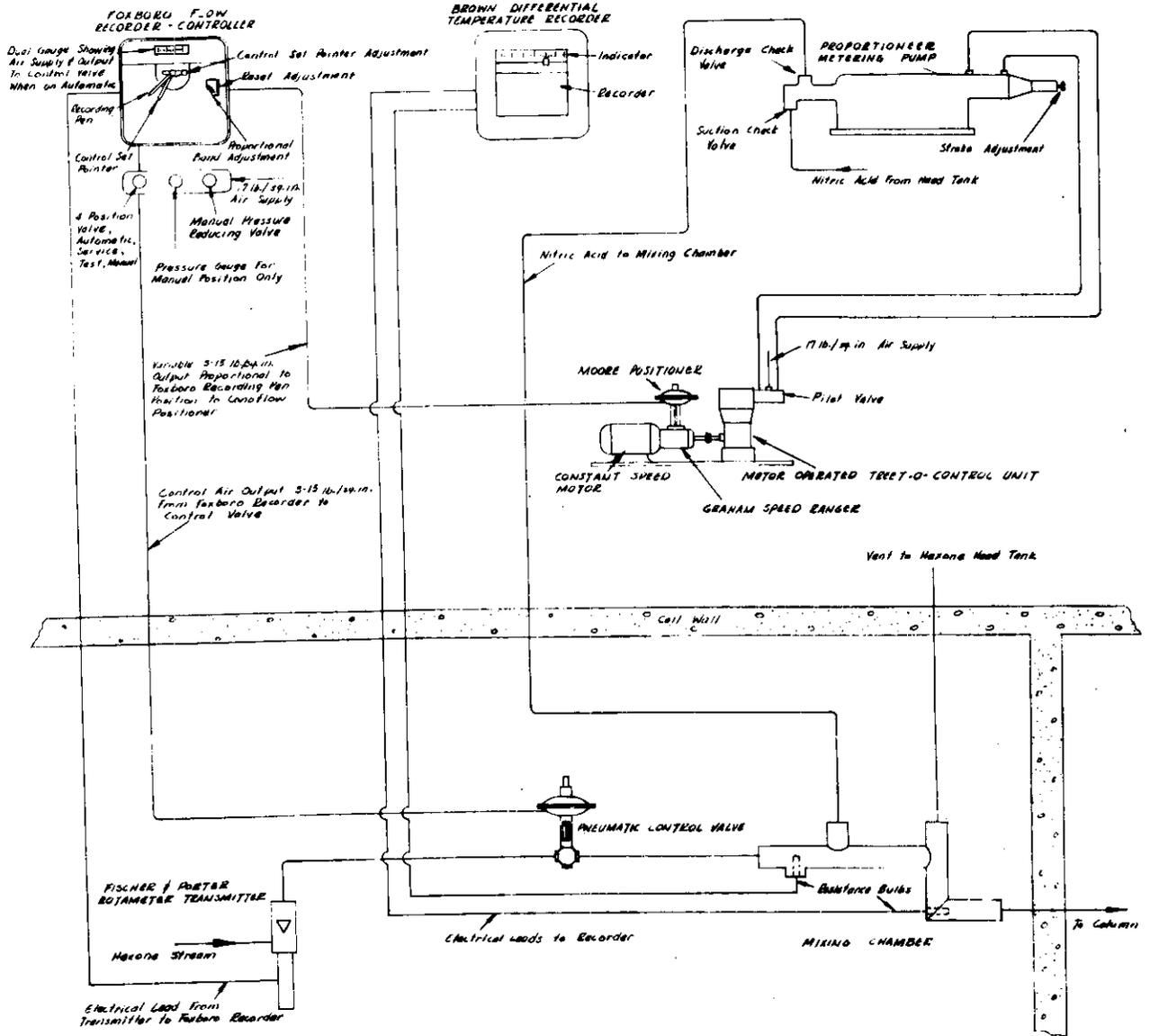
[REDACTED]

DECLASSIFIED

DECLASSIFIED

HW-18700

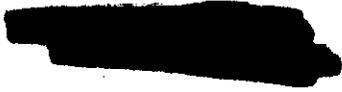
Figure XIX-31
HEXONE & NITRIC ACID BLENDING SYSTEM



DECLASSIFIED

1072

HW-18700



DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**

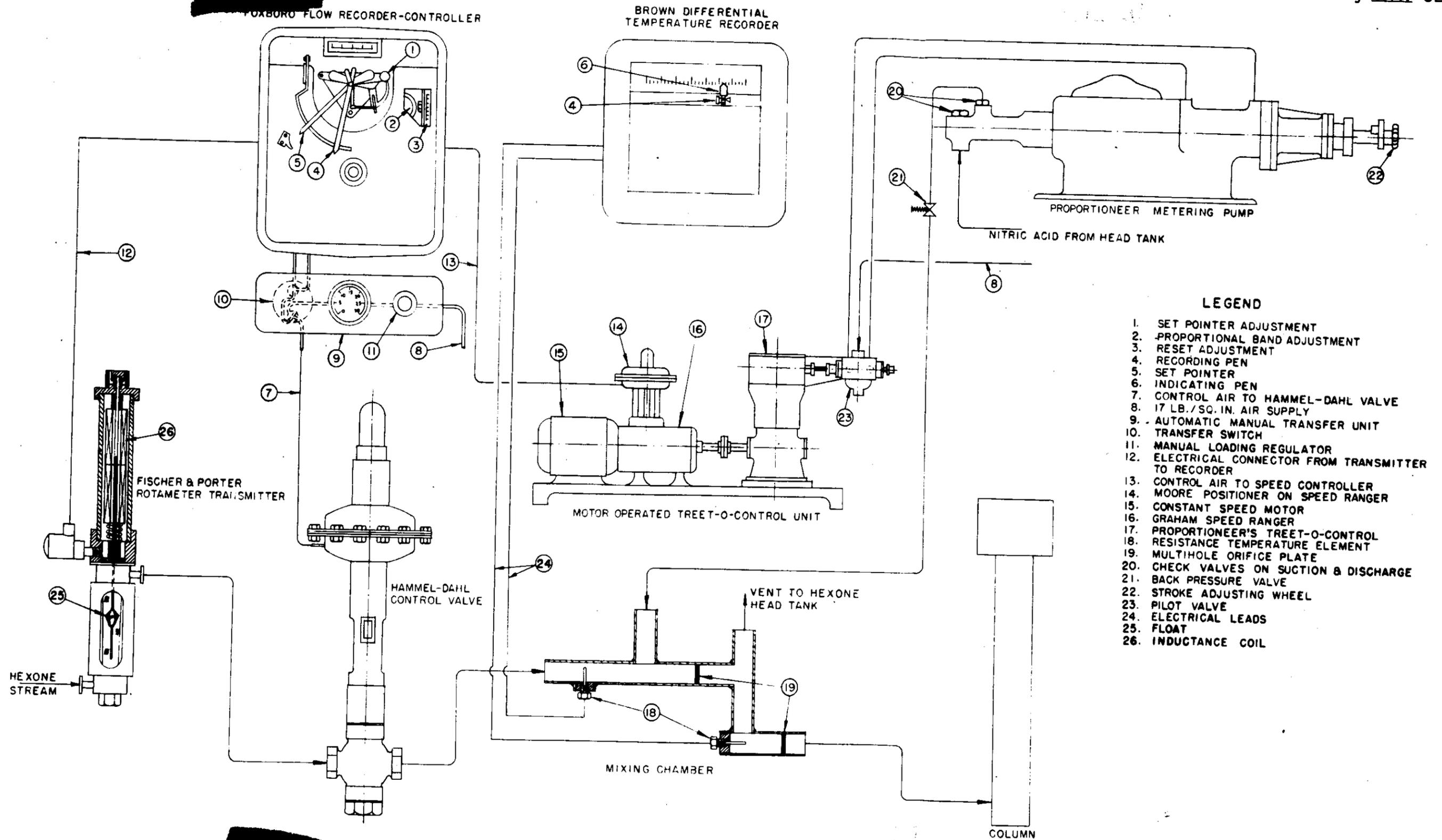


DECLASSIFIED

3

DECLASSIFIED

Figure XIX-32
HEXONE & NITRIC ACID BLENDING SYSTEM



LEGEND

1. SET POINTER ADJUSTMENT
2. PROPORTIONAL BAND ADJUSTMENT
3. RESET ADJUSTMENT
4. RECORDING PEN
5. SET POINTER
6. INDICATING PEN
7. CONTROL AIR TO HAMMEL-DAHL VALVE
8. 17 LB./SQ. IN. AIR SUPPLY
9. AUTOMATIC MANUAL TRANSFER UNIT
10. TRANSFER SWITCH
11. MANUAL LOADING REGULATOR
12. ELECTRICAL CONNECTOR FROM TRANSMITTER TO RECORDER
13. CONTROL AIR TO SPEED CONTROLLER
14. MOORE POSITIONER ON SPEED RANGER
15. CONSTANT SPEED MOTOR
16. GRAHAM SPEED RANGER
17. PROPORTIONEER'S TREET-O-CONTROL
18. RESISTANCE TEMPERATURE ELEMENT
19. MULTIHOLE ORIFICE PLATE
20. CHECK VALVES ON SUCTION & DISCHARGE
21. BACK PRESSURE VALVE
22. STROKE ADJUSTING WHEEL
23. PILOT VALVE
24. ELECTRICAL LEADS
25. FLOAT
26. INDUCTANCE COIL

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

DECLASSIFIED



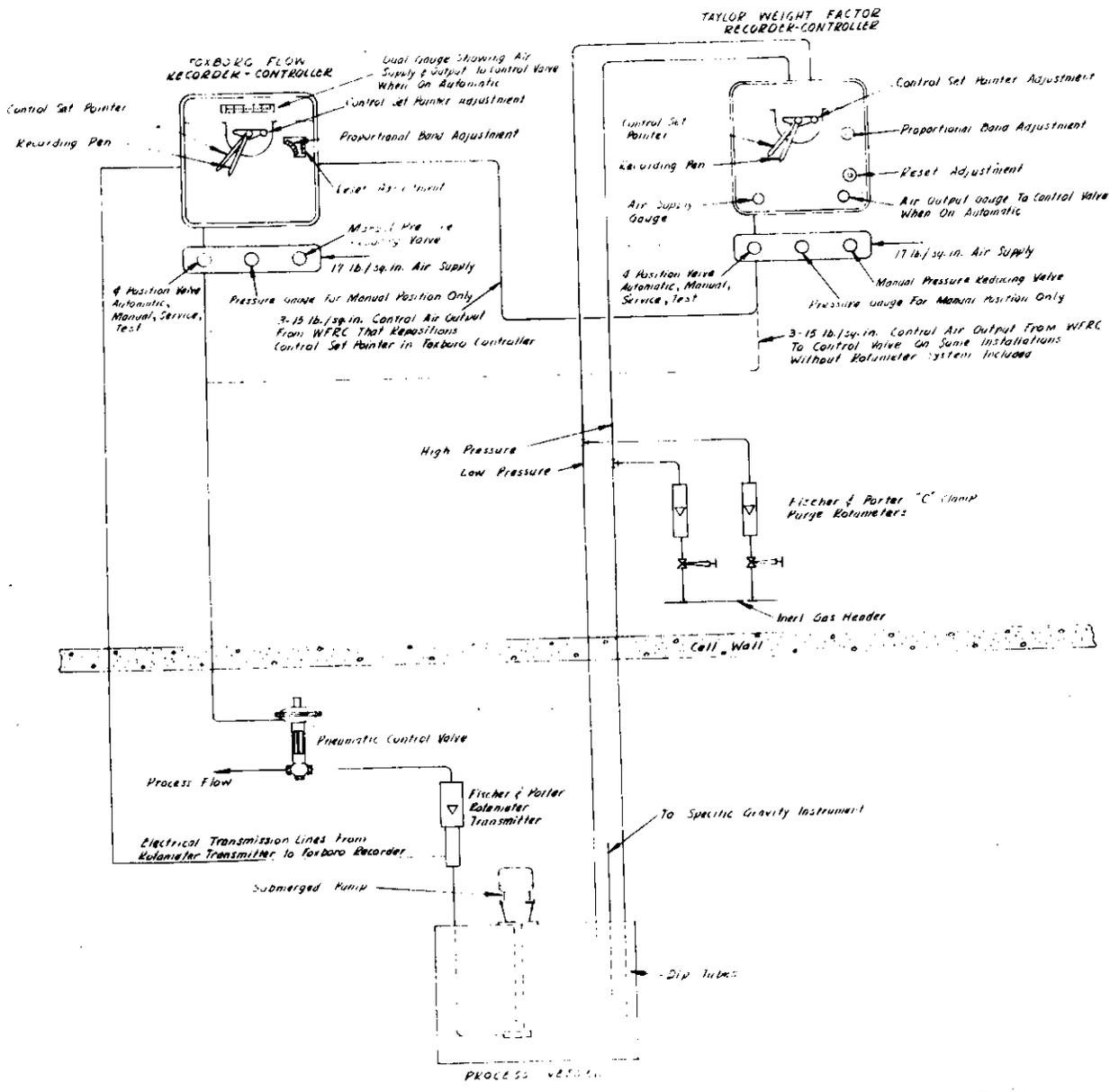
HW-18700

1874

DECLASSIFIED

HW-18700

Figure XIX - 33
WEIGHT FACTOR CONTROL SYSTEM

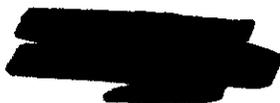


DECLASSIFIED

1076

HRV-18700

DECLASSIFIED

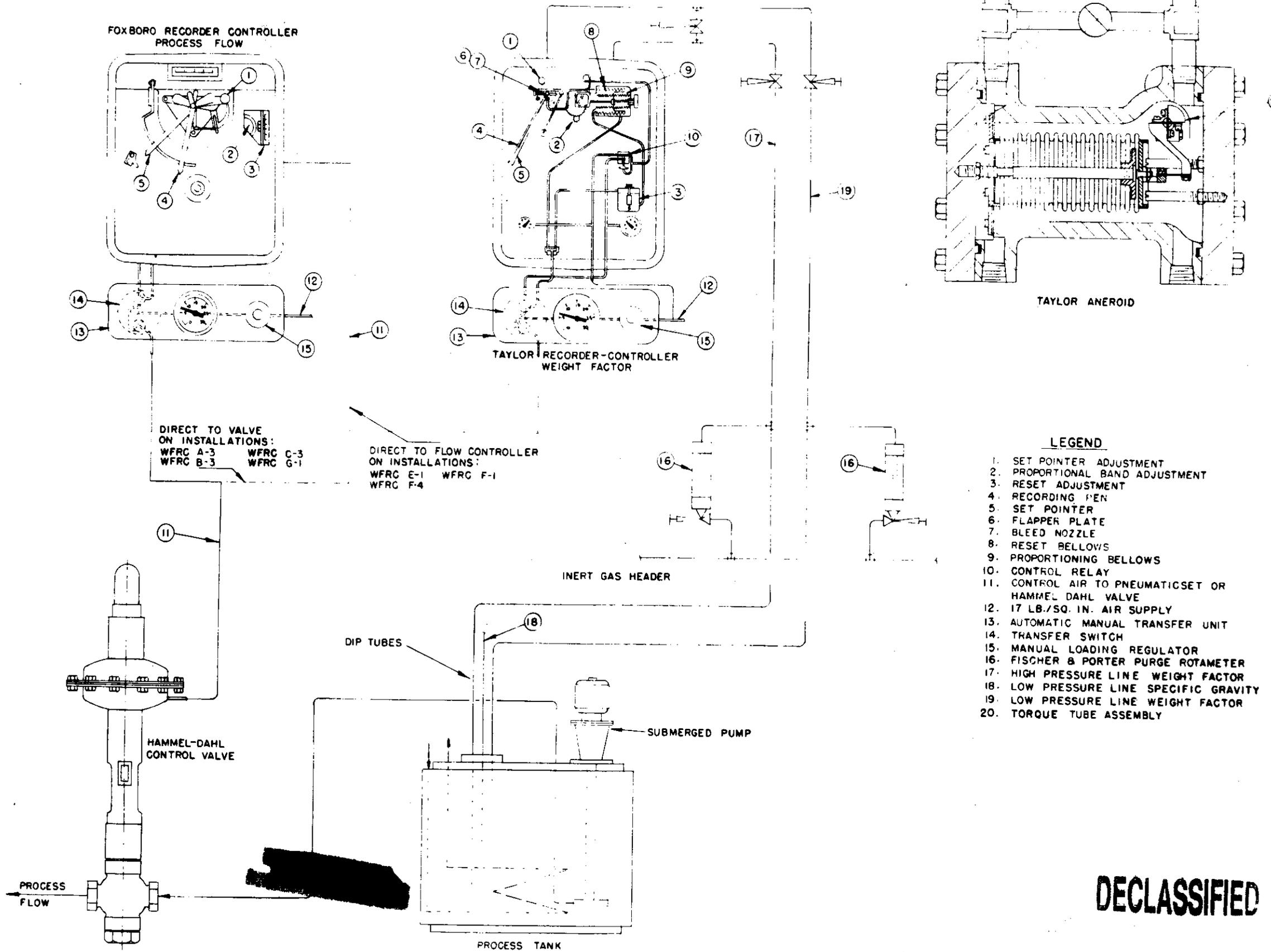


**THIS PAGE
INTENTIONALLY
LEFT BLANK**

DECLASSIFIED



Figure XIX-34
WEIGHT FACTOR CONTROL SYSTEM



1078

HWY-18700

[REDACTED]

DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK

[REDACTED]

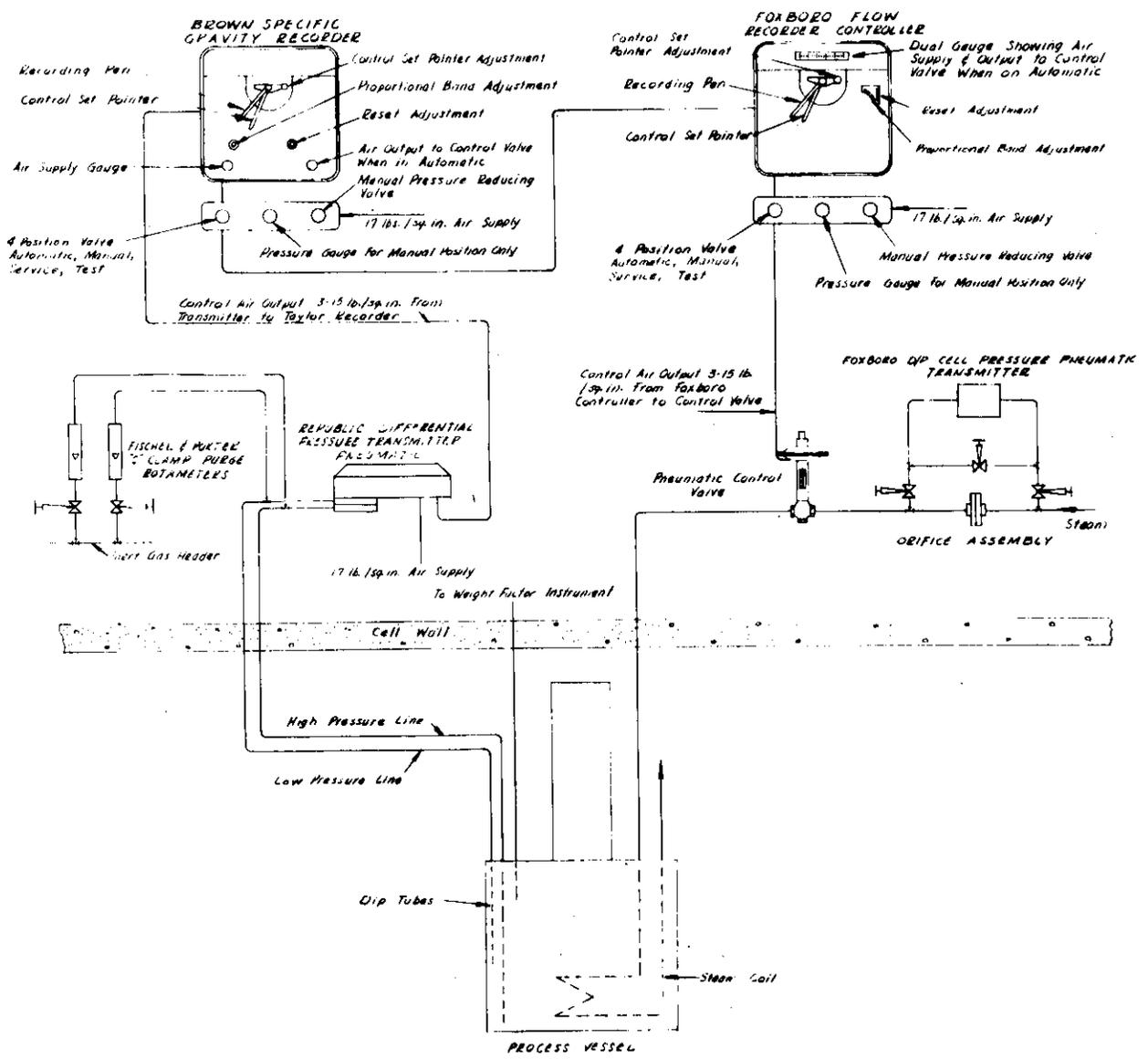
DECLASSIFIED

1078

DECLASSIFIED

HW-18700

Figure XIX-35
SPECIFIC GRAVITY CONTROL SYSTEM



DECLASSIFIED

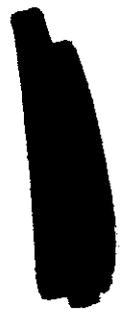
1080

HM-18700



DECLASSIFIED

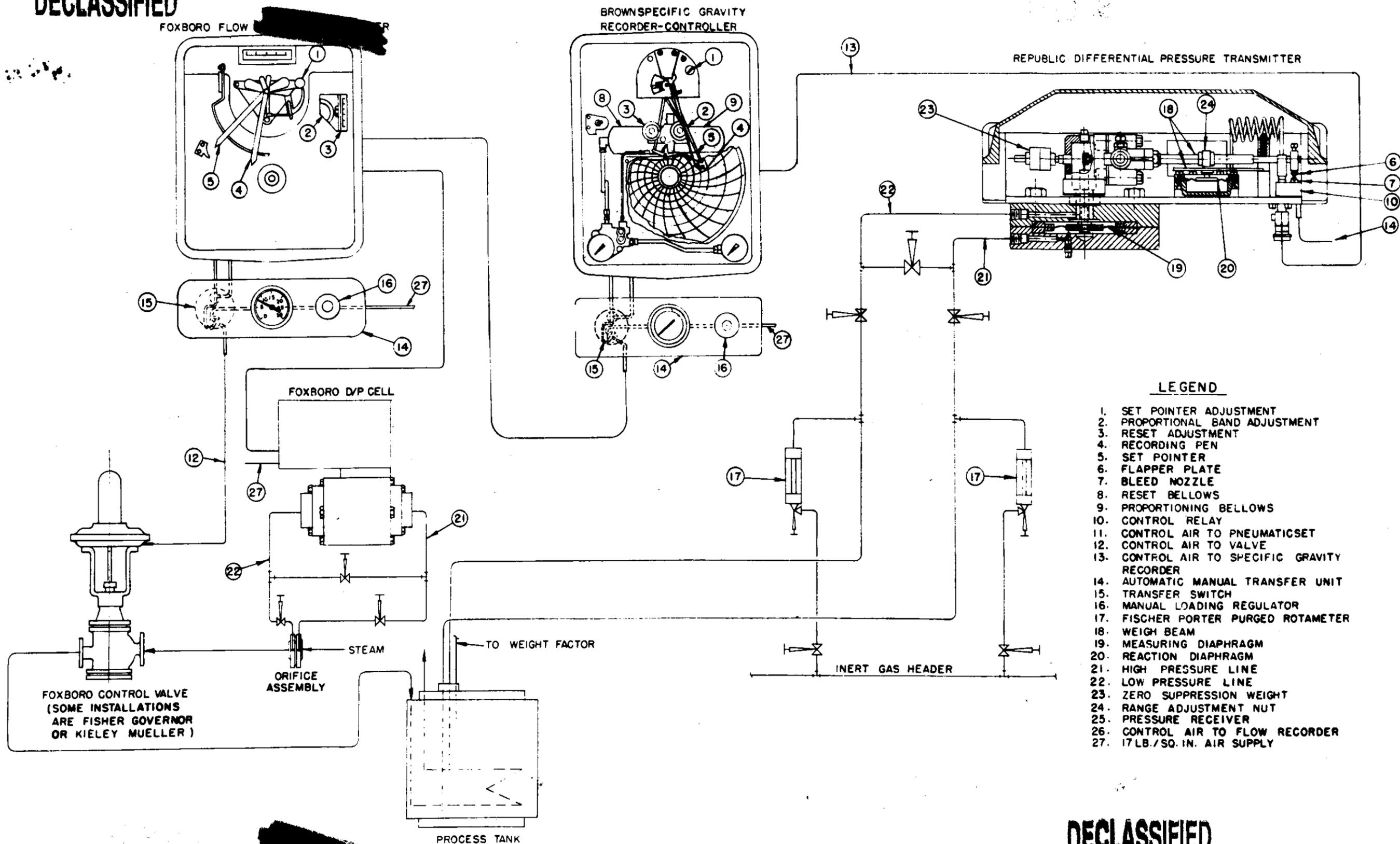
THIS PAGE
IDENTICALLY
LEFT BLANK



DECLASSIFIED

Figure XIX-36
SPECIFIC GRAVITY CONTROL SYSTEM

DECLASSIFIED



LEGEND

- 1. SET POINTER ADJUSTMENT
- 2. PROPORTIONAL BAND ADJUSTMENT
- 3. RESET ADJUSTMENT
- 4. RECORDING PEN
- 5. SET POINTER
- 6. FLAPPER PLATE
- 7. BLEED NOZZLE
- 8. RESET BELLOWS
- 9. PROPORTIONING BELLOWS
- 10. CONTROL RELAY
- 11. CONTROL AIR TO PNEUMATICSET
- 12. CONTROL AIR TO VALVE
- 13. CONTROL AIR TO SPECIFIC GRAVITY RECORDER
- 14. AUTOMATIC MANUAL TRANSFER UNIT
- 15. TRANSFER SWITCH
- 16. MANUAL LOADING REGULATOR
- 17. FISCHER PORTER PURGED ROTAMETER
- 18. WEIGH BEAM
- 19. MEASURING DIAPHRAGM
- 20. REACTION DIAPHRAGM
- 21. HIGH PRESSURE LINE
- 22. LOW PRESSURE LINE
- 23. ZERO SUPPRESSION WEIGHT
- 24. RANGE ADJUSTMENT NUT
- 25. PRESSURE RECEIVER
- 26. CONTROL AIR TO FLOW RECORDER
- 27. 17 LB./SQ. IN. AIR SUPPLY

DECLASSIFIED

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK

DECLASSIFIED



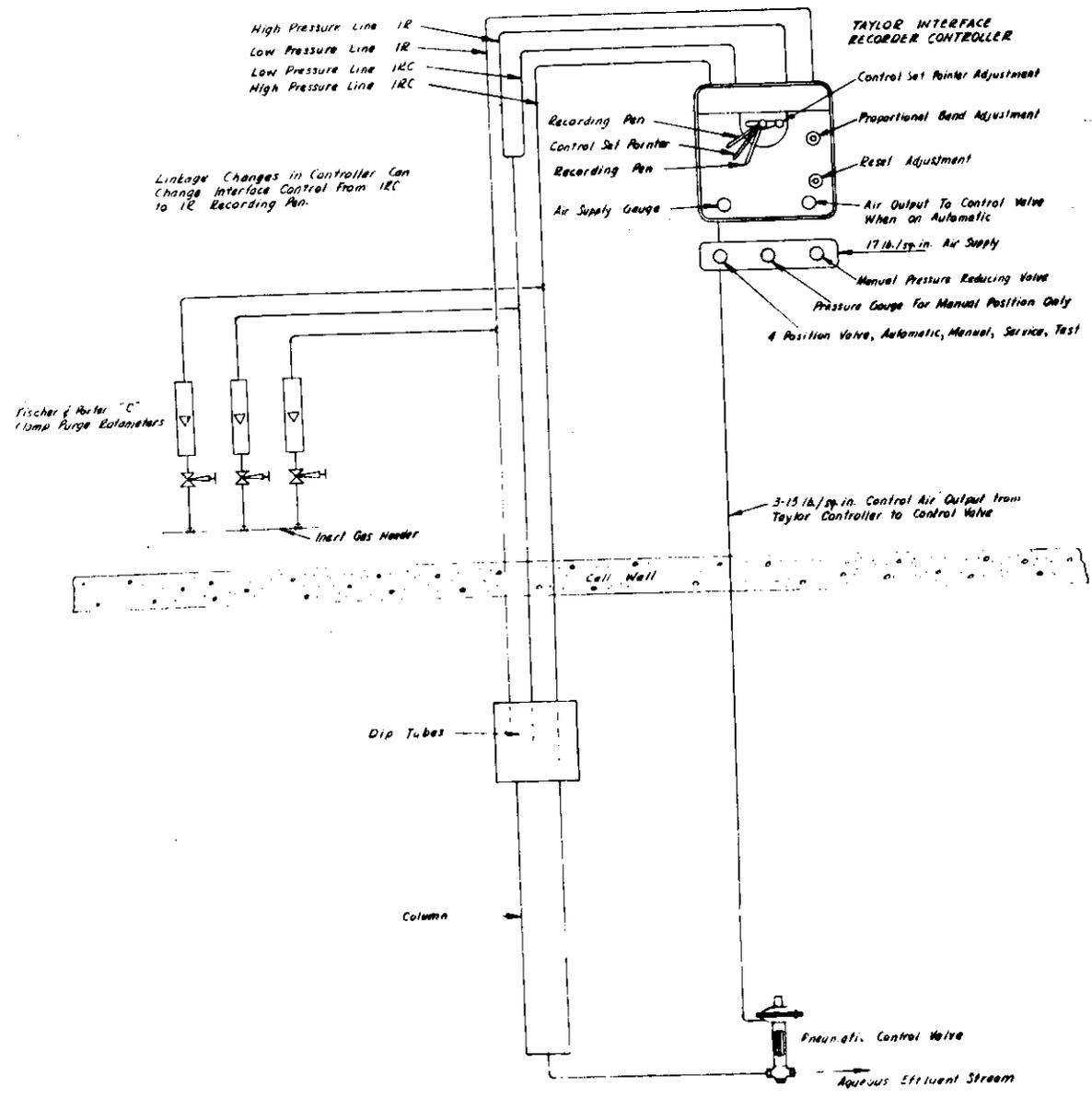
HW-18700

10589

DECLASSIFIED

HW-18700

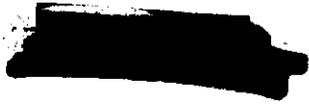
Figure XIX-37
INTERFACE CONTROL SYSTEM



DECLASSIFIED

1084

HW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



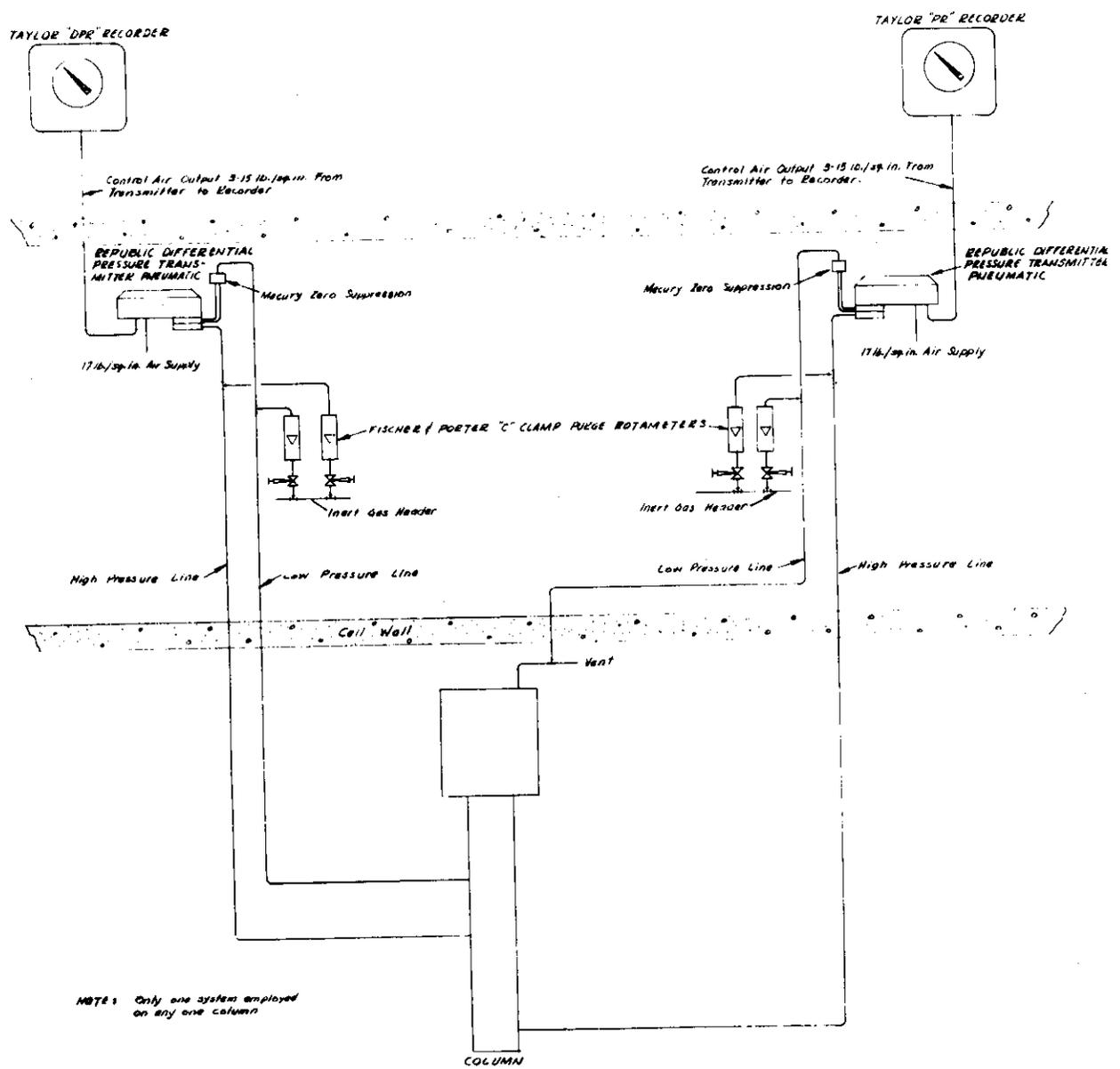
DECLASSIFIED

1085

DECLASSIFIED

HW-18700

Figure XIX-38
DIFFERENTIAL PRESSURE RECORDER SYSTEM



DECLASSIFIED

10/2/82

HW-187100



DECLASSIFIED

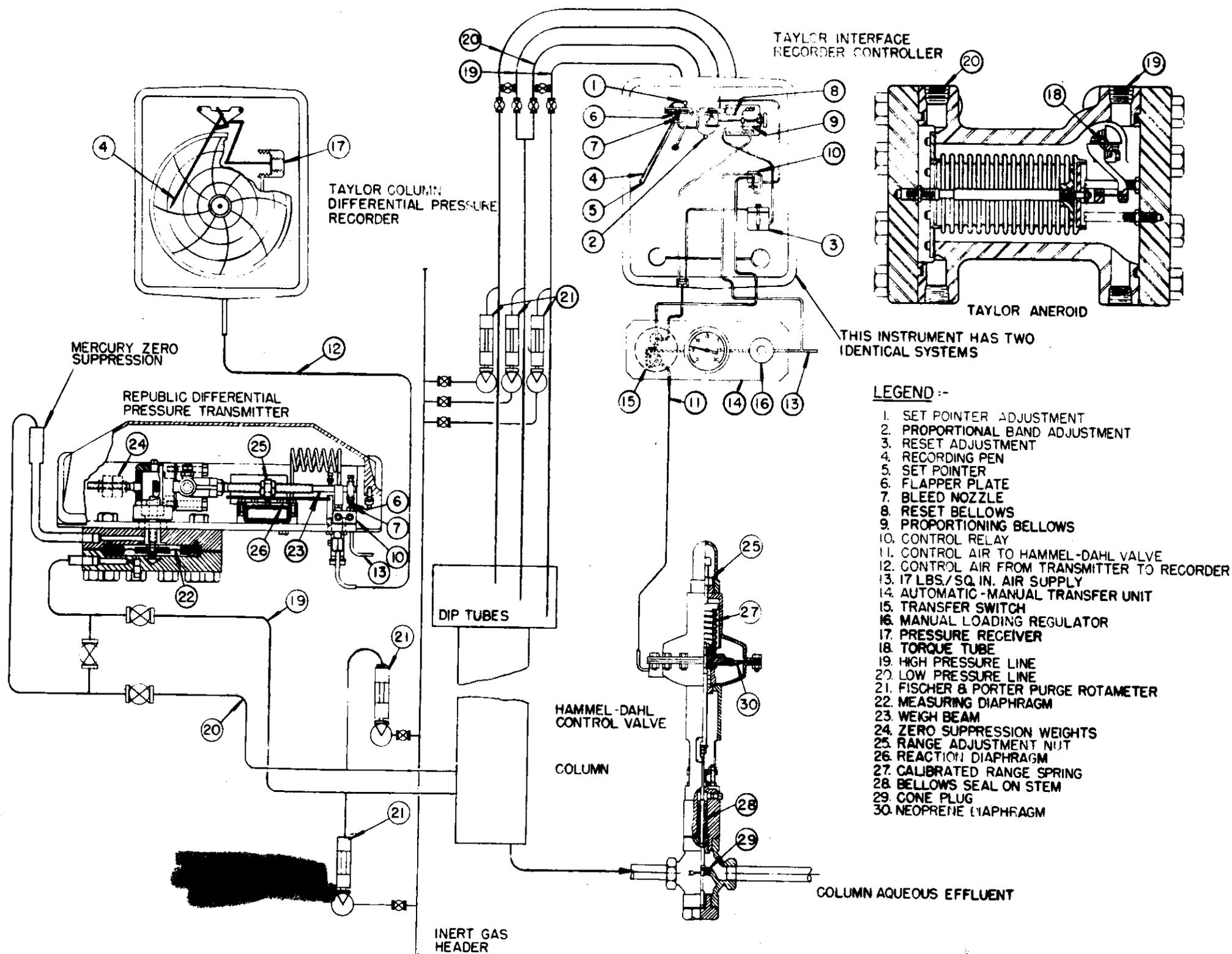
**THIS PAGE
INTENTIONALLY
LEFT BLANK**



DECLASSIFIED

DECLASSIFIED

Figure XIX-39
INTERFACE & COLUMN DIFFERENTIAL PRESSURES



DECLASSIFIED

11088

TW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

TABLE XIX-40

NOMINAL RANGE AND LOCATION OF COLUMN PRESSURE TAPS

Column	Distance from High Pressure Tap to Center of Organic Overflow Line	Distance from Low Pressure Tap to Center of Organic Overflow Line	Distance from High Pressure Tap to Center of Aqueous Effluent Line	Transmitter Range, In. of Water Pressure	External Suppression, In. of Water Pressure	Recorder Range, In. of Water Pressure	Recorder Range, Specific Gravity Units
IA	33'4"	29'4"	22' 3-3/8"	25"	50"	50"-75"	1.04-1.5
IB	45'11"		1'10-3/8"	300"	500"	500"-800"	0.90-1.4
IC	21'6"	17'6"	10'3-3/8"	25"	50"	50"-75"	1.04-1.5
1A	33'4"	29'4"	22'3-3/8"	25"	50"	50"-75"	1.04-1.5
1B	33'4"	29'4"	17'3-1/2"	25"	50"	50"-75"	1.04-1.5
1C	21'6"	17'6"	15'3-3/8"	25"	50"	50"-75"	1.04-1.5
2A	33'4"	29'4"	17'3-1/2"	25"	50"	50"-75"	1.04-1.56
2B	21'6"	17'6"	15'3-3/8"	25"	50"	50"-75"	1.04-1.56
3A	54'3"		1'4-3/8"	300"	500"	500"-800"	0.77-1.23
3B	30'0"		1'3-3/8"	100"	325"	325"-425"	0.90-1.18
3C	54'3"		1'4-3/8"	300"	500"	500"-800"	0.77-1.23
IO	30'0"		1'3-3/8"	100"	325"	325"-425"	0.90-1.18
	20'0"		1'9-3/8"	100"	200"	200"-300"	0.83-1.25

NOTE: The transmitter range, external suppression and recorder range are arbitrary values and may be changed in the field.

DECLASSIFIED

DECLASSIFIED

10910

HW-18700

[REDACTED]

DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK

[REDACTED]

[REDACTED]

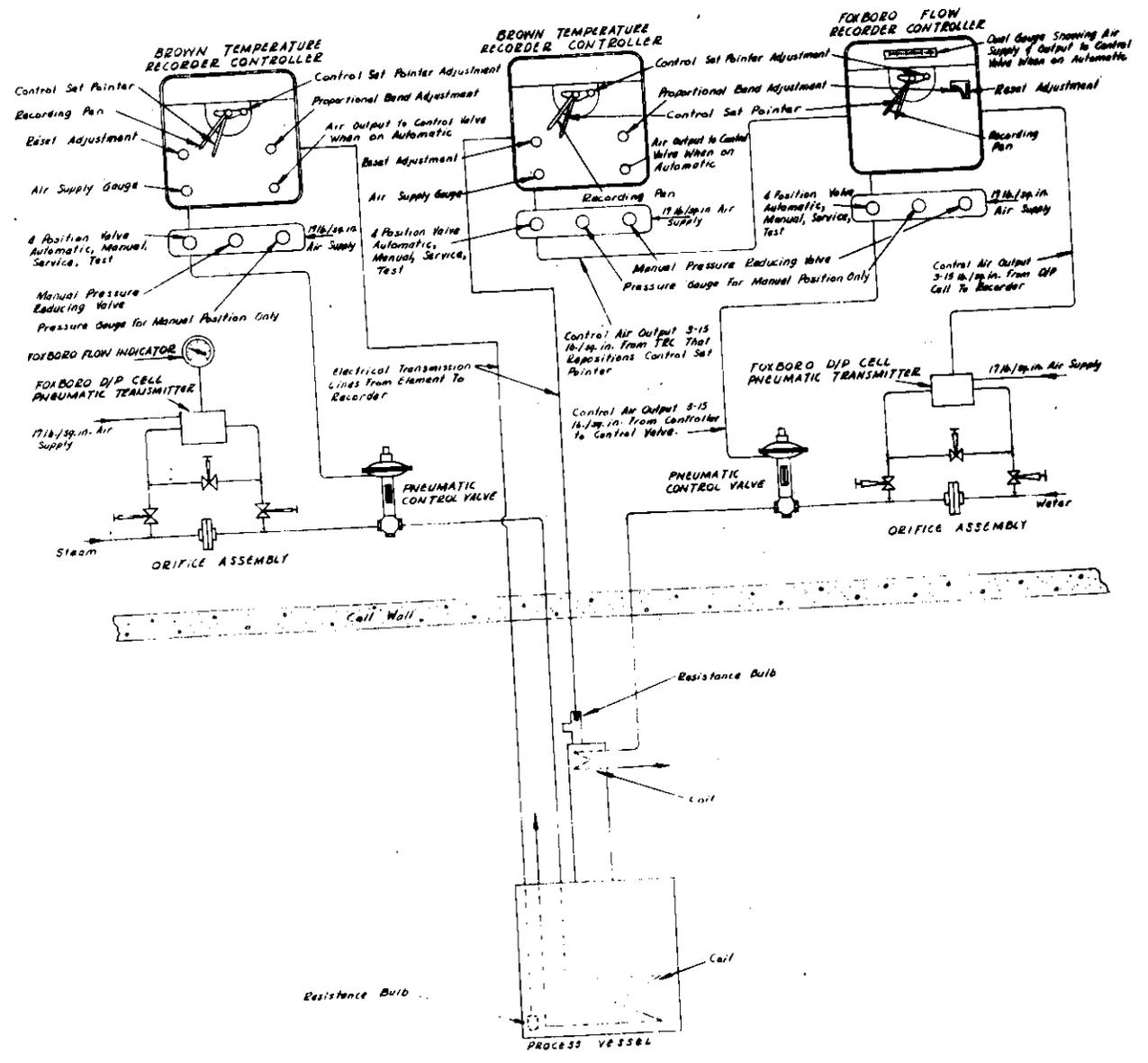
DECLASSIFIED

[REDACTED]

DECLASSIFIED

HW-18700

Figure XIX-41
TEMPERATURE CONTROL SYSTEMS



DECLASSIFIED

1092

HW-18700



DECLASSIFIED

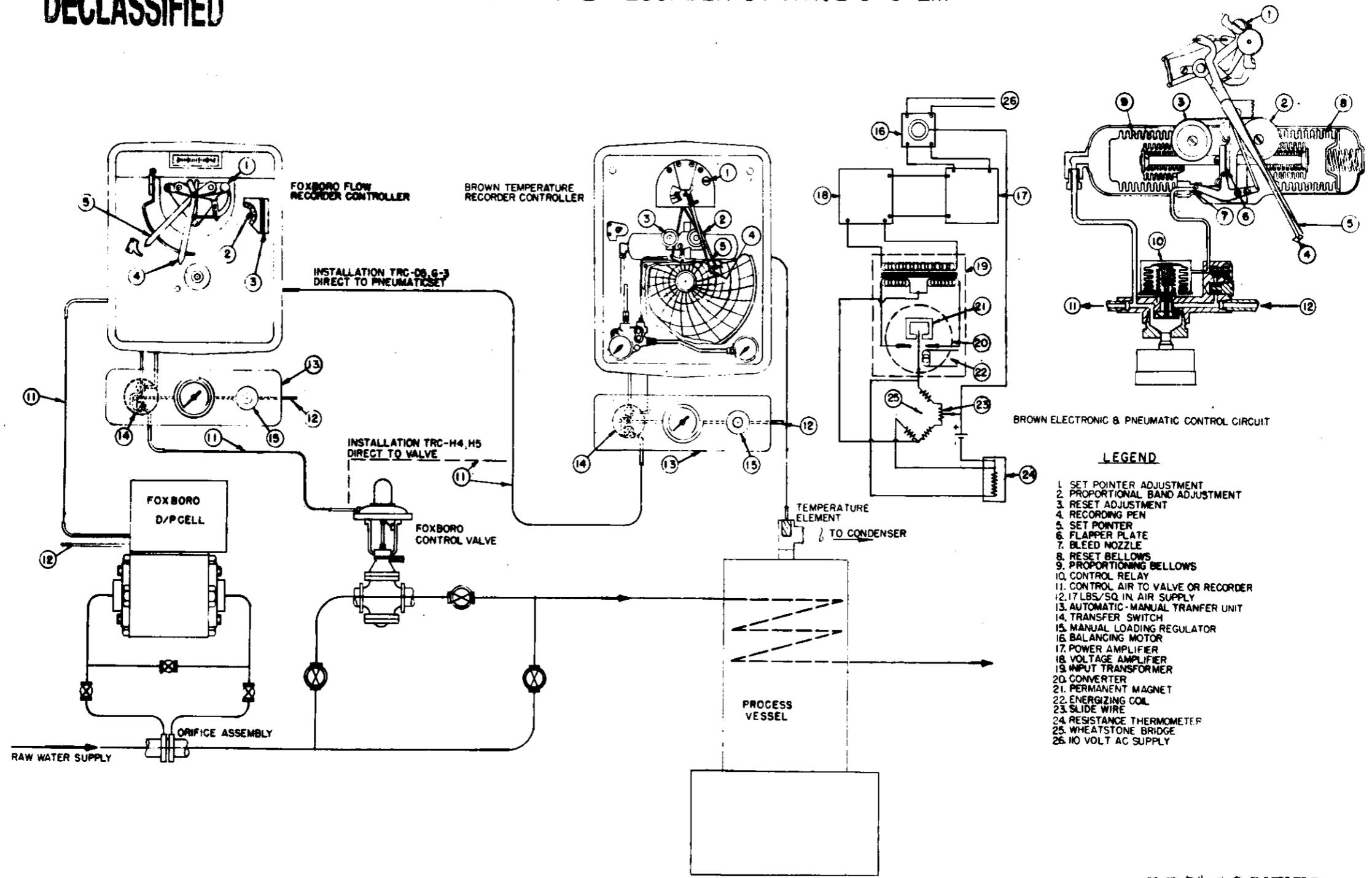
THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

DECLASSIFIED

Figure XIX-42
TEMPERATURE RECORDER CONTROL SYSTEM



DECLASSIFIED

1094

HW-1810D



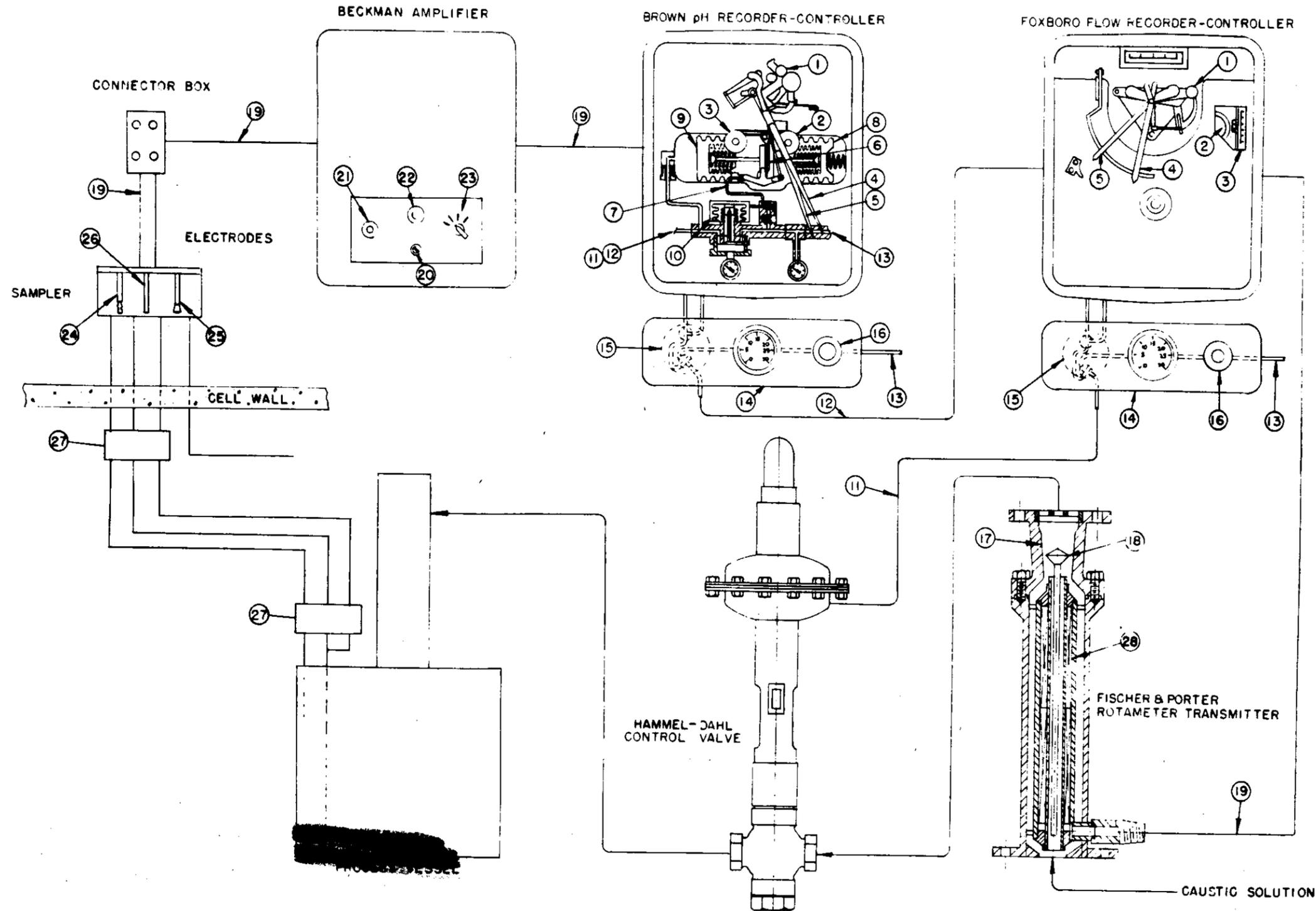
DECLASSIFIED

THIS PAGE
INTERNATIONALLY
LEFT BLANK



DECLASSIFIED

Figure XIX-43
PH RECORDER CONTROL SYSTEM



DECLASSIFIED

LEGEND

1. SET POINTER ADJUSTMENT
2. PROPORTIONAL BAND ADJUSTMENT
3. RESET ADJUSTMENT
4. RECORDING PEN
5. SET POINTER
6. FLAPPER PLATE
7. BLEED NOZZLE
8. RESET BELLOWS
9. PROPORTIONING BELLOWS
10. CONTROL RELAY
11. CONTROL AIR TO HAMMEL-DAHL VALVE
12. CONTROL AIR TO PNEUMATICSET IN RECORDER
13. 17LB./SQ. IN. AIR SUPPLY
14. AUTOMATIC-MANUAL TRANSFER UNIT
15. TRANSFER SWITCH
16. MANUAL LOADING REGULATOR
17. METERING TUBE
18. FLOAT
19. ELECTRICAL LEADS
20. VOLTAGE REGULATOR DIAL 1
21. AMPLIFIER REGULATOR DIAL 2
22. ZERO REGULATOR DIAL 3
23. SELECTOR SWITCH OFF, 1, 2, 3
24. GLASS ELECTRODE
25. CALOMEL REFERENCE ELECTRODE
26. RESISTANCE THERMOMETER TEMPERATURE COMPENSATOR
27. CELL CONNECTOR
28. INDUCTANCE COILS

DECLASSIFIED

10914

HW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

PART IV: PROCESS CONTROL, continued

CHAPTER XX. ANALYTICAL METHODS

<u>CONTENTS</u>	<u>Page</u>
A. INTRODUCTION	2003
1. Definition of Terms	2003
1.1 Time required per determination	2003
1.2 Accuracy (estimated systematic error).....	2003
1.3 Recovery	2003
1.4 Precision	2003
1.5 Sample size	2003
B. PHYSICAL PROPERTIES	2004
1. Specific Gravity by Falling Drop	2004
2. Specific Gravity by Pycnometer	2005
C. CHEMICAL DETERMINATIONS	2005
1. Aluminum Nitrate by Acidimetric Titration	2005
2. Chromium -- Diphenylcarbazide Method	2006
3. Chromium -- Microvolumetric Determination	2006
4. Ferrous Sulfamate -- Volumetric Determination as Ferrous Iron and Sulfamic Acid....	2007
5. Hexone Impurities -- Dinitro Isobutane	2007
6. Hexone Impurities -- Mesityl Oxide	2008
7. Hexone Impurities -- Methyl Isobutyl Carbinol	2008
8. Hexone Impurities -- Methyl Isopropyl Diketone	2009
9. Hexone Impurities -- Organic Acids	2009
10. Hexone Impurities -- Oxidizing Normality	2010
11. Hexone Impurities -- Reducing Normality	2010
12. Nitric Acid by Fluoride Complexing	2010
13. Nitric Acid by Oxalate Complexing	2011
14. Nitric Acid from pH Measurement	2012
15. pH Measurement by One-Drop Electrode	2012
16. Plutonium -- Chemical Assay Method	2013
17. Sodium by the Flame Spectrophotometer	2013
18. Spectrographic Assay of Uranium	2014
19. Sulfamic Acid -- Gasometric Determination	2014
20. Uranium by Chromous Sulfate Titration	2015
21. Uranium by Coulometric Titration	2015
22. Uranium by the Fluorophotometer.....	2016
23. Uranium by the Polarograph	2016
24. Uranium by the X-Ray Photometer	2017

10918



CONTENTS, continued

DECLASSIFIED

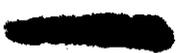
Page

D. RADIOCHEMICAL DETERMINATIONS 2017

1. Americium and Curium 2017
2. Cerium -- Oxalate-Iodate Precipitation Method 2018
3. Cesium -- Chloroplatinic Acid Method 2019
4. Gross Beta by BGO Counter 2019
5. Gross Gamma by Shonka Chamber 2020
6. Iodine - Continuous Extraction Method 2020
7. Neptunium by TTA Extraction 2021
8. Niobium -- Potassium Bromate Method 2021
9. Plutonium -- Adsorbed on Super Filtrol 2022
10. Plutonium -- Direct Evaporation Method 2022
11. Plutonium -- Fluoride Precipitation Method 2023
12. Plutonium -- Lanthanum Hydroxide Sodium Uranate Method .. 2024
13. Plutonium -- Low Level Pu by Fluoride Precipitation 2024
14. Plutonium -- TTA Extraction Method 2025
15. Plutonium -- Zirconium Phenyl Arsonate Method 2025
16. Ruthenium -- Direct Reduction Method 2026
17. Zirconium -- TTA Extraction Method 2026

REFERENCES 2028

DECLASSIFIED



CHAPTER XX. ANALYTICAL METHODSA. INTRODUCTION

This chapter briefly outlines the principal analytical methods available for use in analyzing the various components normally expected in Redox streams. The limitations of each method are presented as an aid to operating personnel so that they can intelligently interpret laboratory results and can request determinations which will produce meaningful data. For each analytical method the precision, accuracy, sample size, time required for analysis, and impurities known to affect the method (if any) have been listed together with a brief description of the method.

As time passes many of the methods described may be improved or replaced with new and better methods. Therefore, if the outline method does not meet a particular process requirement the Analytical Section should be consulted.

1. Definition of Terms

1.1 Time required per determination indicates, unless otherwise noted, the total elapsed analysis time required for a single determination. It includes any method delays such as digestion, cooling or agitation but does not include the time required to get the sample from the operating building to the laboratory.

1.2 Accuracy as presented in this chapter is stated in terms of the percentage disagreement of the average analysis from the absolute or "true" analysis. This disagreement is termed the "systematic error".

1.3 Recovery In radiochemical determinations a portion of the radioactive element concentration being determined is generally lost and not counted. To determine the percentage of the radioactive element lost, a large quantity of an inactive isotope (large in comparison with the radioactive element concentration) is added and its chemical yield (recovery) calculated.

1.4 Precision is an indication of the reproducibility of the method. In this chapter the precision figures represent 99% limits. In other words, in ninety-nine out of one hundred determinations statistical studies have shown the reported value does not vary from the mean value by more than the stated precision.

1.5 Sample size is the volume of sample actually required by the analytical method for a single determination. For most Redox samples duplicate determinations will be made for each requested analysis so the total volume required for a requested analysis will be twice the volume shown on the method tabulations.

For many of the radiochemical methods the sample volume required is dependent upon the precision required of the method and the concentration of the radioactive element. Statistical studies have shown that the following counting precision may be expected from the ASP (Alpha-Simpson-

1100

DECLASSIFIED

Proportional) and BGO (Beta-Gamma-Offner) counters:

<u>Precision (99% Limits)</u>	<u>Total No. of Counts*</u>
±1%	66,000
±2%	18,000
±5%	2,600
±10%	700
± 20%	170

*Note: This is the total number of counts counted for the determination -- irrespective of whether they were counted in a short time for a sample of high radioactivity, or a longer time for a sample of lower radioactivity.

The specific activity for one microgram of plutonium is approximately 1.48×10^5 disintegrations per minute (approximately 74,000 alpha counts per minute on a 50% geometry ASP counter). Therefore, if a five minute count is to be made and one per cent counting precision is desired, the sample aliquot used for a determination should contain approximately 0.2 microgram of Pu. Similarly, for a five minute counting period and 20 per cent counting precision the sample should contain approximately 0.0005 micrograms of Pu. If insufficient sample is available to obtain the counting precision desired during a short counting period the counting precision may be increased by lengthening the counting period.

B. PHYSICAL PROPERTIES

1. Specific Gravity by Falling Drop

Application: Since such a small volume of sample is required the method is ideal for determining the specific gravity of "hot" radioactive aqueous streams such as IAW, IAF, ISW, and Dissolver Solution.

Description: Specific gravity is determined by measuring, at a carefully controlled temperature, the length of time required for a carefully formed small drop of sample to fall (or rise) through a fixed distance in an immiscible liquid. Changes in composition of the immiscible liquid are detected by making periodic determinations with standard samples.

Time required per determination: 20 minutes.

Systematic error: Minus 0.02 to plus 0.02% (i.e., 0.0002 g./ml.).

Precision (99% limits): Better than ±0.1% (±0.001 g./ml.).

Sample size: As little as one drop (0.005 ml.: from a special device which makes small drops) may be used. However, greater precision can be obtained by making several determinations. (3 to 5 drops generally used).

DECLASSIFIED

1101
DECLASSIFIED2. Specific Gravity by Fycnometer

Application: The specific gravity of both hexone and aqueous samples is determined by this method. For samples such as IAF and IAW which contain appreciable amounts of fission products the Falling Drop method should be used.

Description: The weight of a known volume of sample at 25°C. is compared with the weight of an equal volume of water at 4°C.

Time required per determination: 25 minutes.

Systematic error: Minus 0.02 to plus 0.02% (i.e., 0.0002 g./ml.).

Precision (99% limits): ± 0.05% for aqueous samples
(approx. 0.0005 g./ml.),
± 0.1% for hexone samples
(approx. 0.001 g./ml.).

Sample size: "Cold" samples, 5 ml.
Slightly radioactive samples, 2 ml.

C. CHEMICAL DETERMINATIONS1. Aluminum Nitrate by Acidimetric Titration

Application: Aqueous phase concentrations of $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ (ANN) ranging from 1 to 800 g./l. may be determined by this method. The method should not be used for samples with a UNH to ANN ratio exceeding four or a $\text{Fe}(\text{NO}_3)_3$ to ANN ratio greater than one third.

Description: The pH of the sample is carefully adjusted to approximately 10.8 by the addition of sodium hydroxide (or HCl if sample is too basic). At this pH ANN has been converted to sodium aluminate; and uranyl nitrate, ferric nitrate, and sodium dichromate have been converted to sodium diuranate, ferric hydroxide, and sodium chromate. One molar potassium fluoride is then added to the solution, reacting with the sodium aluminate to form K_3AlF_6 and releasing NaOH and KOH which are titrated with standard HCl until the pH before KF addition (approximately 10.8) is again obtained.

Time required per determination: 40 minutes.

Systematic error: Zero to minus 0.1%.

Precision (99% limits): ± 2%.

Sample size: The sample selected should contain from 1 to 8 milligrams of ANN.

DECLASSIFIED

DECLASSIFIED2. Chromium-Diphenylcarbazide Method

Application: This method, like the Microvolumetric Determination, may be used for the determination of Cr(VI) or total chromium concentrations of aqueous Redox solutions greater than 1 g./l. (e.g., IAF, IAS, 2AS). None of the chemicals present in the Redox samples is expected to interfere with the method.

Description: Diphenylcarbazide reacts with dichromate to give a characteristic violet color in dilute acid solutions. The optical density, which is directly related to the dichromate concentration, is determined with a spectrophotometer by passing 540-millimicron light through a fixed depth of the solution.

If total chromium is to be determined, the Cr(III) present in the solution must initially be oxidized by boiling the solution with ammonium persulfate and sulfuric acid in the presence of silver nitrate.

Time required per determination: Cr(VI) - 30 minutes, Cr(Total) - 40 minutes.

Systematic error: Minus 1% to plus 1% (Estimated).

Precision (99% limits): Estimated $\pm 10\%$.

Sample size: Sample chosen should contain from 0.02 to 0.1 milligrams of
 $\text{Cr}_2\text{O}_7 = .$

3. Chromium -- Microvolumetric Determination

Application: Cr(VI) or total chromium concentrations of aqueous Redox solutions greater than 1 g./l. may be determined by this method (e.g., IAF, IAS, 2AS). Ferrous iron interferes with the Cr(VI) determination.

Description: The concentration of Cr(VI) is determined by adding a measured excess of standard ferrous ammonium sulfate to the sample thereby reducing Cr(VI) to Cr(III). The excess ferrous ammonium sulfate is then determined by titrating (oxidizing to Fe(III)) with standard ceric acid sulfate using ferroin indicator.

When the total amount of chromium present in the sample is determined, the procedure outlined above is followed after any Cr(III) has been oxidized to Cr(VI) in caustic solution by hydrogen peroxide. Excess peroxide is destroyed by heating with platinum black catalyst.

Time required per determination: Cr(VI) -- 40 minutes,
Cr(Total) -- 60 minutes.

Systematic error: Approximately plus 1 to 2%.

Precision (99% limits): Approximately $\pm 3\%$.

Sample size: Sample chosen should contain approximately 0.5 milligram of
 $\text{Cr}_2\text{O}_7 = .$

DECLASSIFIED

4. Ferrous Sulfamate -- Volumetric Determination as Ferrous Iron and Sulfamic Acid.

Application: Aqueous ferrous sulfamate concentrations in the range of 10 to 800 g./l. may be determined by this method (Ferrous Sulfamate Makeup, IBX, IBP). For low concentrations of ferrous sulfamate (0.3 to 10 g./l.) greater precision may be obtained using the Gasometric method.

Description: Ferrous iron and sulfamic acid are determined stepwise. The concentration of ferrous iron is first obtained volumetrically by a potentiometric titration with standard potassium permanganate. The permanganate titration is stopped as soon as the potentiometer indicates that the ferrous ion has all been oxidized. The sulfamic acid concentration of the sample is then determined (after heating the sample to 50°C.) by titrating with standard sodium nitrite until the sulfamate ion has been converted to sulfate. Since ferric iron subdues the potentiometric end point of the permanganate titration and completely obscures the nitrite end point, it must be complexed as it is formed by the addition of phosphoric acid to the sample prior to titration.

Time required per determination: 60 minutes (30 minutes for ferrous iron, and an additional 30 minutes for sulfamate).

Systematic error: Ferrous iron -- Approximately minus 10%.
Sulfamic Acid -- Approximately minus 3%.

Precision (99% limits): Ferrous iron -- Better than $\pm 4\%$.
Sulfamic Acid -- Better than $\pm 6\%$.

Sample size: Sample should contain from 5 to 10 milligrams of ferrous sulfamate.

5. Hexone Impurities -- Dinitro Isobutane

Application: Dinitro isobutane concentrations in hexone greater than 0.02 g./l. may be determined by this method. Dinitro isobutane is of interest since it may be formed in recycled hexone as a product of the reaction with nitric acid. Chemical Research Section data (5) indicate that concentrations up to 37 g./l. have little effect on IA Column operation.

Description: Dinitro isobutane is extracted from hexone into 2 M potassium hydroxide. Fixed wavelength ultraviolet light (385 millimicrons) is passed through a fixed depth of solution and the absorption measured by a spectrophotometer. The solution closely follows Beer's Law and the dinitro isobutane concentration is proportional to the absorption.

Time required per determination: 45 minutes.

Systematic error: For samples containing from 0.02 to 0.5 g. dinitro isobutane/l. -- zero to minus 1%.

Precision (99% limits): Better than $\pm 2\%$.

DECLASSIFIED

Sample size: Approximately 5 ml.

6. Hexone Impurities -- Mesityl Oxide

Application: Concentrations less than 0.5 g./l. of mesityl oxide in hexone are determined by this method to ascertain the fitness of hexone for use in the Redox solvent-extraction battery. The mesityl oxide concentration of purchased hexone must be less than 0.3 volume per cent (approximately 2.5 g./l.).⁽¹⁾ Uranyl nitrate and nitric acid interfere and are removed by extraction with water.

Description: The absorption of a specific wavelength (231 millimicrons) of light by a sample containing an unknown amount of mesityl oxide in iso-octane is compared with the absorption of standard solutions containing known amounts of mesityl oxide in iso-octane. To determine the absorption effect of any hexone present in the original sample, a determination is carried out using a pure hexone-iso-octane blank and a suitable correction is made to the result obtained on the unknown.

Time required per determination: 30 minutes.

Systematic error: Minus 1% to plus 1% (estimated).

Precision (99% limits): Estimated $\pm 10\%$.

Sample size: Less than 0.1 ml.

7. Hexone Impurities -- Methyl Isobutyl Carbinol

Application: Concentrations of methyl isobutyl carbinol (MIBC) as low as 0.1 g./l. can be determined by this method. From the determination the suitability of the solvent for use in the Redox extraction batteries is determined. The methyl isobutyl carbinol concentration of purchased hexone must not exceed 0.6 volume per cent (approx. 4.8 g./l.).⁽¹⁾ After pretreatment the concentration should be reduced to 0.03 volume per cent (0.24 g./l.) or less.

Description: The method is based upon the preferential oxidation of primary or secondary alcohols by acid dichromate solution. To a given sample volume acidified by the addition of nitric acid, small titers of potassium dichromate are added until the characteristic potassium dichromate color does not disappear from the hexone phase on standing after vigorous shaking.

Time required per determination: 20 minutes.

Systematic error: Minus 0.1 to plus 0.1 g./l. (estimated).

Precision (99% limits): Better than ± 0.2 g./l. (estimated).

Sample size: 5 ml. or less.

DECLASSIFIED

8. Hexone Impurities -- Methyl Isopropyl Diketone

Application: Methyl isopropyl diketone concentrations in hexone greater than 0.05 g./l. may be determined by this method. This impurity is of interest since it may be formed in recycled hexone as a product of the reaction of hexone with nitric acid. Chemical Research Section data⁽⁵⁾ show that concentrations up to 28 g./l. cause no adverse effects in the IA Column.

Description: The hexone sample is placed directly in a cell and fixed wavelength (432 millimicrons) ultraviolet light is passed through a known depth of sample. The absorption of the sample -- measured by a spectrophotometer -- is dependent upon the methyl isopropyl diketone concentration in the sample.

Time required per determination: 20 minutes.

Systematic error: Minus 5 to plus 5% (estimated).

Precision (99% limits): $\pm 10\%$ (estimated).

Sample size: Approximately 5 ml.

9. Hexone Impurities -- Organic Acids

Application: In hexone solutions containing no nitric acid, weak organic acid concentrations (reported as acetic acid) as low as 0.01 g./l. may be detected by this method. The organic acid concentration of purchased hexone must not exceed 0.05 volume per cent⁽¹⁾ (approx. 0.5 g./l.). If the hexone solution contains an appreciable concentration of nitric acid (i.e., column extractants containing 0.2 to 0.5 M HNO₃) the method may be used to detect organic acid concentrations greater than 1.5 g./l.

Description: The sample is diluted with isopropyl alcohol and the organic acid concentration is determined potentiometrically by titrating with standard potassium hydroxide. Two potentiometric breaks are obtained, one for any strong acids (i.e., nitric acid) present in the sample and one for the organic acid end-point. The volume of NaOH required to titrate between the two end-points is a measure of the organic acid present.

Time required per determination: 45 minutes.

Systematic error: Plus 5%.

Precision (99% limits): Approximately $\pm 5\%$.

Sample size: Sample should contain sufficient organic acid to require 5 to 8 ml. of 0.1 N KOH for the titration (i.e., 5 ml. of sample for a sample containing 1 g./l. organic acid, calculated as acetic acid.)

DECLASSIFIED

1104 [REDACTED]

10. Hexone Impurities -- Oxidizing Normality

Application: The oxidizing normality of Redox hexone may be used to determine the suitability of solvent for reuse in the plant. The oxidizing normality of purchased hexone should not exceed 0.001 N.⁽¹⁾

Description: The moles of ferrous iron oxidized per liter of hexone represents the oxidizing normality of the hexone. Hexone is agitated in contact with a solution containing ferrous ammonium sulfate, nitric acid, and sulfuric acid. The decrease in the aqueous phase ferrous ion concentration is determined colorimetrically. The optical density of the sample is determined by passing light of 508 millimicron wavelength through a fixed depth of aqueous sample to which o-Phenanthroline has been added. (o-Phenanthroline reacts with ferrous iron to form a red complex).

Time required per determination: 30 minutes.

Systematic error: Minus 5 to plus 5% (estimated).

Precision (99% limits): Better than $\pm 20\%$.

Sample size: Approximately 50 ml.

11. Hexone Impurities -- Reducing Normality

Application: The reducing normality of Redox hexone may be determined occasionally since it gives a rough approximation of the suitability of the solvent for reuse in the plant. Specifications limiting the reducing normality of plant hexone are not available. However, since the main contributor to the reducing normality of hexone is methyl isobutyl carbinol the expected range of reducing normality (≤ 0.001) may be calculated from the MIBC specification (≤ 0.03 volume per cent). Since the method is not precise the suitability of the hexone for reuse should be determined by the other impurity methods whenever possible.

Description: The moles of dichromate reduced per liter of hexone represents the reducing normality. A measured excess of standard sodium dichromate is added to the sample, and the excess titrated with standard ferrous ammonium sulfate to the end point of ferrion indicator.

Time required per determination: 30 minutes.

Systematic error: Unknown at time of writing.

Precision (99% limits): Within a factor of two (estimated).

Sample size: Approximately 25 ml.

12. Nitric Acid by Fluoride Complexing

Application: The nitric acid concentration of aqueous and hexone solutions (greater than 5 g./l.) may be obtained by this method. Since the determination has proven satisfactory for small sample volumes, it has been

[REDACTED]

DECLASSIFIED

[REDACTED]

selected for use on "hot" radioactive solutions such as IAW. This method, rather than the potassium oxalate method, is used for solutions containing ferric iron since fluoride forms a "tighter" iron complex than the iron-oxalate complex. The uranium, aluminum, and iron interferences are minimized by the formation of fluoride complexes when potassium fluoride is added to the sample. Chromium (VI) is not complexed. Therefore, its concentration must be determined and a suitable correction applied.

Description: The nitric acid concentration is determined volumetrically by a potentiometric titration with sodium hydroxide. Potassium fluoride is added to the sample solution prior to titration to complex iron, uranium, and aluminum which would interfere with the determination.

Time required per determination: 45 minutes.

Systematic error: Approximately zero to minus 2% (estimated).

Precision (99% limits): Approximately ± 1 g./l.

Sample size: Method is scaled down for micro determinations. Samples as small as 0.010 ml. may be used.

13. Nitric Acid by Oxalate Complexing

Application: Both aqueous and organic samples may be determined by this method. Uranium, aluminum, and chromium ions interfere with the method and must either be removed (Cr removed by precipitation as $PbCrO_4$) or obviated (uranium and aluminum complexed by addition of potassium oxalate). Since ferric iron forms a "tighter" complex with fluoride than with oxalate, samples containing iron should be analyzed by the fluoride method.

Description: The nitric acid concentration is determined by a potentiometric titration with standard sodium hydroxide. If chromium and uranium are present in the sample, potassium oxalate and lead nitrate are added to minimize interference. The chromium concentration must be determined so that a suitable correction may be made for the nitric acid released (and titrated) when chromium is precipitated as lead chromate. Water is added to hexone samples and the potentiometric titration is made on the aqueous phase containing the extracted nitric acid. For "acid deficient" samples a measured amount of standard nitric acid is added to the sample so that the potentiometric end-point may be approached from the acid side.

Time required per determination: Samples containing no interfering ions
-- 30 minutes.
Samples containing interfering ions
-- 45 minutes.

Systematic error: Approximately zero to minus 2%.

Precision (99% limits): Approximately ± 1 g./l.

DECLASSIFIED

1108 [REDACTED]

Sample size: If the radioactivity of the sample permits, sufficient sample should be taken to require approximately 0.005 mole of sodium hydroxide for neutralization. Samples as small as 0.1 ml. may be used with a reduction in the precision attained.

14. Nitric Acid from pH Measurement

Application: This method may be used for the determination of the hydrogen ion concentration for those Redox streams in which only one appreciably hydrolyzed component is present. The concentrations of the hydrolyzed compounds must be accurately known since errors in these concentrations contribute to the total error of the determination. Of the solution components normally expected in Redox streams, only aluminum and uranium are present in sufficient quantities to be appreciably hydrolyzed in neutral or near neutral solutions.

Description: The pH of the sample is measured on a Beckman, Model G, pH meter. Since this method is only sensitive in nearly neutral solutions, samples which are highly acidic or basic are either diluted or neutralized so that the acidity falls within the sensitive pH range. The acid concentration is read from standard calibration curves.

Time required per determination: Approximately 15 minutes for pH determination. However, the aluminum and uranium concentrations must be accurately known. Therefore, the time required to get an answer from the laboratory may be controlled by the time required for an aluminum or uranium analysis.

Precision and systematic error: Since the precision and accuracy would be dependent upon the error in the aluminum and uranium analyses these figures are not given. However, the pH meter may be read to ± 0.05 pH unit.

Sample size: Samples as small as 0.05 ml. may be used.

15. pH Measurement by One-Drop Electrode

Application: The hydrogen ion concentration of small amounts of radioactive aqueous solutions may be determined by the one-drop electrode. From the determination, the completeness of neutralization of wastes to be stored in underground tanks may be determined.

Description: The pH is determined potentiometrically by placing about one drop of sample into the cup-shaped, one-drop electrode of a Model G pH meter.

Time required per determination: 15 minutes.

Systematic error: Dependent upon standards used to calibrate pH meter.

Precision (99% limits): ± 0.05 pH units.

Sample size: One drop (not less than 0.075 ml.).

DECLASSIFIED

1109
DECLASSIFIED
HW-1870016. Plutonium -- Chemical Assay Method

Application: This method is used to determine plutonium concentrations above 10 g./l. such as those present in Pu Concentrate. It may be used to determine the "true" Pu concentration of a sample.

Nitrates and iron interfere with the analysis. Nitrates can be removed by adding sulfuric acid and evaporating. If iron is present, its concentration must be determined and a suitable correction applied.

Description: Plutonium is reduced to the trivalent state with an excess of titanous chloride and then titrated, reoxidized to Pu(IV), with standard ceric sulfate under an inert atmosphere. Because of the lack of suitable color indicators, a potentiometric titration is made using a Ce(IV)-Ce(III) reference electrode and a platinum (indicator) electrode. The first titration break represents complete titration of excess titanous ion while the second indicates completion of the plutonium titration.

Time required per determination: Approximately 45 minutes.

Systematic error: Minus 0.5 to plus 0.5%.

Precision (99% limits): $\pm 2.5\%$.

Sample size: 0.1 ml. for a sample containing 10 to 15 g./l.

17. Sodium Determined by the Flame Spectrophotometer

Application: Aqueous phase sodium concentrations greater than 0.01 g./l. may be determined by this method. The concentration of the solution must be fairly well established (except Na concentration) for the result obtained with the sample is compared with standard solutions of approximately the same overall composition.

Description: An aqueous solution of sodium salt is atomized and then introduced at a carefully controlled rate into a flame where it is ignited giving off the characteristic yellow sodium color. The intensity of light emission at a wavelength of 584 millimicrons is measured with a spectrophotometer and compared with standard sodium solutions measured in the same manner.

Time required per determination: 15 minutes.

Systematic error: Approximately plus 1%.

Precision (99% limits): Approximately $\pm 10\%$.

Sample size: A sample should contain approximately 0.0005 grams of sodium.

DECLASSIFIED

DECLASSIFIED18. Spectrographic Assay of Uranium

Application: The concentrations of trace impurities in concentrated uranium solutions (i.e., Decontaminated UNH Storage of 3EU Concentrate Sampler Tank) may be determined by this method.

Concentrations of impurities in U_3O_8 as low as the following may be detected:

Ag	0.1 p.p.m.	Co	100 p.p.m.	Mg	10 p.p.m.	P	5 p.p.m.
As	5	Cr	10	Mn	5	Pb	5
B	0.2	Cu	20	Mo	20	Sb	2
Be	0.1	K	50	Na	5	Sn	5
Bi	1	Li	5	Ni	10	Zn	100
Cd	1						

Description: The sample is evaporated to dryness, then heated to 700 to 800°C. in the presence of air to convert UNH to U_3O_8 . An aliquot of the U_3O_8 and a small amount of pure gallium oxide (two weight per cent) are placed in a graphite crater electrode and arced using a direct-current source. The spectrum of the gases volatilized by the arc is photographed using a quartz prism spectrograph and the concentrations of impurities are estimated by visual comparison of the spectrum with the spectrum of previously prepared standards. The gallium oxide volatilizes during arcing "flushing" volatile impurities from the U_3O_8 sample.

Time required per determination: Elapsed time -- 8 hours.
Operator time -- 2 hours.

Systematic error: Dependent upon accuracy of the standards and the sensitivity of the photographic plates.

Precision (99% limits): At the lower limits indicated above precision of approximately $\pm 100\%$ may be obtained.

Sample size: For a single spectrographic "shot" (a determination on approximately one third of the spectrum) a minimum of 100 milligrams of U_3O_8 is needed. For a total analysis, duplicate determinations over the entire spectrum, a minimum of 600 milligrams of U_3O_8 is required.

19. Sulfamic Acid -- Gasometric Determination

Application: Aqueous concentrations of sulfamic acid in the range 0.3 to 25 g./l. may be determined by this method. Concentrations greater than 10 g./l. may be determined faster with comparable precision using the potentiometric method. Compounds other than sulfamic acid which contain the amino ($-NH_2$) group interfere with the method (such compounds are not expected in Redox streams).

Description: The sulfamate concentration of the sample is determined gasometrically by measuring the volume of nitrogen evolved when sulfamate is converted to sulfate by the addition of sodium nitrite to a hot acidic sample solution. Nitrogen and oxides of nitrogen are swept from the reaction vessel by pure carbon dioxide. Carbon dioxide, and oxides

DECLASSIFIED

2015

of nitrogen (formed by the reaction of sulfuric acid with any excess of NaNO_2) are absorbed when they are passed through a series of absorbing solutions (liquid bromine, sodium sulfite, and potassium hydroxide).

Time required per determination: Approximately 60 minutes.

Systematic error: Minus 2 to plus 2%.

Precision (99% limits): $\pm 4\%$.

Sample size: Sample should contain approximately 2 milligrams of sulfamic acid.

20. Uranium by Chromous Sulfate Titration

Application: The method may be used for hexone or aqueous phase samples containing more than one gram of UNH per liter (e.g., IAP, IBU, 2DU, 2EU). Nitrates interfere with the method and must be removed by heating with sulfuric and formic acids. If iron and phosphate are both present in a sample the method should not be used. However, the method may be used if either iron or phosphate is present alone.

Description: Uranium is determined volumetrically by titrating to the potentiometric end point with standardized chromous sulfate solution.

Time required per determination: 15 minutes.

Systematic error: Approximately minus 0.5%.

Precision (99% limits): Approximately $\pm 3\%$.

Sample size: The sample size is dependent upon the UNH concentration. Sample sizes should, if possible, be chosen so that the sample contains from 7 to 15 milligrams of UNH.

21. Uranium by Coulometric-Titration

Application: This method may be used for the determination of uranium concentrations as low as 1 g./l. in all Redox streams.

Description: The sample and added iron solution are passed through a lead reductor column to reduce the uranium and iron to the quadrivalent and bivalent states, respectively. The solution is then placed in a coulometer cell and a constant current is passed through the solution until the potentiometer "break" is reached. This break represents the conversion of all the uranium in the solution to U(VI). The length of time the current flows before the break is dependent upon the uranium concentration of the sample. Nitrate ion interferes with the method and must first be removed by boiling the sample in the presence of hydrobromic acid.

Time required per determination: Approximately 45 minutes.

Systematic error: Approximately plus 1%.

Precision (99% limits): Better than $\pm 5\%$.

Sample size: The sample chosen should contain approximately one to ten milligrams of uranium.

22. Uranium by the Fluorophotometer

Application: The fluorophotometer (also called "fluorimeter") may be used to determine low uranium concentrations in both aqueous and organic samples from 0.0001 to 1 g.UNH/l.

Description: Uranium compounds, when fused with sodium fluoride, fluoresce when exposed to ultraviolet light, the amount of fluorescence being proportional to the amount of uranium present. A monochromatic ultraviolet light (365 millimicrons) is directed on a carefully prepared fused sample. The fluorescent light is filtered, and the intensity of the monochromatic fluorescent light (555 millimicrons) passing through the filters is measured. High concentrations of compounds not volatilized during the fusing operation absorb a portion of the fluorescent light. (This effect is known as quenching.) Since a given amount of an interfering compound absorbs a fixed percentage of the uranium fluorescence the quenching effect may be determined by making two determinations, the first on an unspiked portion of the sample and the second on a portion of the sample spiked with a known amount of uranium.

Time required per determination: 45 minutes.

Systematic error: Approximately plus 0.3%.

Precision (99% limits): Better than $\pm 20\%$.

Sample size: The accuracy and precision figures listed above may be obtained if the sample contains from 0.01 to 1 microgram of UNH.

23. Uranium by the Polarograph

Application: The polarograph is an instrument available for the determination of UNH concentrations in aqueous solutions containing from 1 to 20 g.UNH/l. Ordinarily, the fluorimeter is used for the detection of concentrations up to one gram UNH/l. in waste solutions and other methods (X-ray, Chromous Sulfate Titration, and Coulometric Titration methods) are used for the detection of concentrations above 1 g.UNH/l.

Description: An e.m.f. is applied to a sample solution containing hexavalent uranium. This applied e.m.f. is gradually increased, with only a slight increase in the "residual current" flowing through the solution, until the decomposition potential is reached. At the decomposition potential the flow of electrons and the diffusion current quickly increase as the U(VI) is reduced to U(V). The increase in diffusion current is dependent upon the uranium concentration of the sample. For any given sample solution the diffusion current is compared with diffusion currents obtained for standard UNH solutions in the same equipment. Ions such as iron with reduction potentials close to U(VI) interfere and must be reduced chemically or complexed before electrolytic reduction of the uranium.

DECLASSIFIED

Time required per determination: 30 minutes.

Systematic error: Approximately plus 2%.

Precision (99% limits): Better than $\pm 6\%$.

Sample size: Dependent upon UNH concentration. For a solution containing 10 to 100 g.UNH/l., a 1 ml. sample is required. For a sample containing 0.2 to 10 g.UNH/l., 5 ml. are required.

24. Uranium by the X-Ray Photometer

Application: The method is used for either hexone or aqueous solutions (e.g., 2DU, 3DU), containing high UNH concentrations (5 to 1000 g./l.). Since the absorption of X-rays increases very rapidly with increasing atomic number the sample to be analyzed must contain an appreciable concentration of only one element of high atomic number.

Description: X-rays are passed through a fixed depth of sample solution and a portion of the beam, depending upon the concentration of high atomic number elements in the sample, is absorbed. The same X-rays are passed through varying known thicknesses of aluminum which have been calibrated against known standard uranium concentrations until the absorption of the aluminum matches the sample absorption.

Time required per determination: 20 minutes.

Systematic error: Minus 1 to plus 1%.

Precision (99% limits): ± 1 to 2%.

Sample size: The minimum volume required for routine analysis varies with the uranium concentration. Solutions containing more than 100 g.UNH/l. are diluted to provide enough volume of 5 to 100 g.UNH/l. solution to fill a photometer sample cell holding 3 ml. Larger cells may be used if sufficient sample is available.

D. RADIOCHEMICAL DETERMINATIONS

1. Americium and Curium -- Cerium Fluoride Precipitation Method

Application: The method is used for the determination of americium plus curium concentrations in the presence of plutonium in Redox streams containing no amphoteric ions such as aluminum (i.e., IAF solution).

Description: Americium and curium are determined together and no attempt is made to differentiate between them. Any plutonium present in the sample is oxidized to the Pu(VI) state with an excess of ceric sulfate to prevent its precipitation when americium and curium fluorides are carried quantitatively from the solution on cerium fluoride precipitate. The precipitate is then washed, dried, mounted on a platinum disc, and counted by means of a standard alpha counter.

DECLASSIFIED

If plutonium is also to be determined the supernate and wash solutions are collected. The plutonyl and ceric ions are reduced with hydroxylamine hydrochloride and then precipitated as fluorides. The precipitate is then washed, dried, and counted.

Time required per determination: Approximately 40 minutes.

Systematic error: Minus 2 to plus 2%.

Precision (99% limits): $\pm 10\%$.

Sample size: If the radioactivity of the sample permits, to obtain the above stated precision, a sample size should be chosen so that approximately 200 alpha counts/minute are registered on the counter. IAF solution may contain from approximately 8×10^4 to 2×10^5 americium plus curium alpha counts/minute/milliliter (depending upon the pile history and "cooling" record of the uranium used in preparing the IAF solution). Therefore, a 5 microliter sample (the smallest accurately measurable sample volume) provides more than the required 200 counts/minute.

2. Cerium -- Oxalate-Iodate Precipitation Method

Application: All Redox samples.

Description: Cerium activity is separated from other fission product activities by two precipitations. Cerium (including non-radioactive cerium added as a carrier) is first precipitated with oxalic acid. The washed oxalate precipitate is dissolved in nitric acid; cerium oxidized with bromate; and ceric iodate precipitated. The separated iodate is destroyed with oxalic acid and cerium is reprecipitated as the oxalate for mounting and counting. Since the radioactivity of the praseodymium daughter of cerium is measured, the mounted sample must be allowed to stand approximately two hours before counting to permit the cerium-praseodymium transient equilibrium to be reached. The "hard" beta radiation passing through a 355 mg./sq.cm. aluminum absorber is measured on a standard BGO counter. Corrections are made for the carrier recovery which is determined from the weight of the final oxalate precipitate and the weight of cerium carrier originally added.

Time required per determination: 40 minutes operator time,
2-1/2 hour elapsed time.

Systematic error; (500 to 5000 counts/minute) Plus approx. 10%.

Precision (99% limits): For 500 to 5000 counts/minute, $\pm 10\%$.

Sample size: If possible, for the above systematic error and precision, the sample should be chosen so that 500 to 5000 counts/minute are registered on the counter. Since a 0.005 ml. IAF sample (the smallest accurately measured sample volume) contains far more cerium (1×10^7 counts/minute) than required for the analysis, the sample is initially diluted and an aliquot is chosen to give the required 500 to 5000 counts/minute.

1115
DECLASSIFIED3. Cesium - Chloroplatinic Acid Method

Application: Radiocesium in all Redox samples may be determined by this method.

Description: Radiocesium and a carefully measured quantity of inactive cesium "carrier" remain in solution when interfering fission products are removed by scavenging with ferric hydroxide formed in the solution. Cesium in the supernate is then precipitated as the chloroplatinate from acid solution. The cesium chloroplatinate precipitate is then washed, mounted on a weighed brass counting disc, dried, and weighed. From the weight of cesium chloroplatinate the cesium recovery may be calculated. The beta emission of the radiocesium in the precipitate is then determined using a standard BGO counter.

Time required per determination: 45 minutes.

Systematic error: Approximately minus 10% above 1000 counts/minute.

Precision (99% limits): Above 1000 counts per minute, better than $\pm 10\%$.

Sample size: To obtain the systematic error and precision indicated above the sample should contain approximately 1000 to 5000 cesium counts per minute. A 0.005 ml. IAF sample (the smallest accurately measured sample volume) contains far more cesium (5×10^5 counts/minute) than required for the analysis. Therefore, the sample is initially diluted and an aliquot is chosen to give the required 1000 to 5000 counts/minute.

4. Gross Beta by BGO Counter

Application: The BGO (Beta-Gamma-Offner) counter may be used for the determination of total countable beta radiation. Gamma radiation is counted along with beta but the proportion of gamma counts is generally only a small fraction of the total and therefore may be neglected. However, if the gamma counts are a large percentage of the total counts, the gamma count must be determined and beta calculated by difference. The counter may also be used for gross gamma determinations but for most routine gross gamma analyses the Shonka chamber will be used. Only beta radiation (i.e., 0.15 M.e.v. beta or above) capable of passing through a 20 mg./sq.cm. aluminum absorber is counted in the test.

Description: The sample is pipetted onto a watch glass, evaporated to dryness, and counted on a BGO counter, with a 20 mg./sq.cm. aluminum absorber interposed between the sample and the counter.

Time required per determination: 45 minutes.

Precision (99% limits): Approximately ± 4 to 2% for a five minute count of a sample containing 1000 to 5000 counts per minute.

Sample size: If possible, to obtain the above precision, the sample size should be such that 1000 to 5000 counts/minute are received by the counter. (See the discussion at the beginning of this chapter.) One milliliter of

DECLASSIFIED

IAF solution contains approximately 5×10^9 counts/minute. Therefore, to obtain the desired number of counts, a small volume (less than 0.1 ml.) is diluted and an aliquot taken to give the required number of counts. The recovered uranium solution in Decontaminated UNH Storage should contain approximately 20,000 beta counts per minute per gram of uranium.

5. Gross Gamma by Shonka Chamber

Application: Gross gamma may be determined for all Redox samples which contain from 0.02 to 1000 microcuries of gamma activity.

Description: A sample -- gas, liquid, or solid -- is placed in the well of the ionization chamber. The gamma radiation of the sample passes through the inner wall of the chamber into high-pressure argon gas surrounding the chamber producing ionization of the gas. The ionization causes an increase in the current flowing between an electrode in the gas and the ionization chamber wall. The current is measured and recorded using a vibrating-reed electrometer and recording potentiometer and compared with the ionization current produced by standard radium samples.

Time required per determination: Less than 10 minutes.

Systematic error: Dependent upon similarity of gamma radiation of the sample to that of the radium standards. The standard radium samples exhibit 12 different energy radiations ranging from 0.184 to 2.2 M.e.v. The weighted average radiation is approximately 1.2 M.e.v.

Precision (99% limits): Varies with the gamma activity of the sample, from $\pm 0.2\%$ for 100-microcurie samples to approximately 10% for 0.02-microcurie samples.

Sample size: The ionization chamber well will hold any size sample up to approximately 40 ml. However, if possible, the sample size should be selected so that the gamma radiation of the sample is between 0.1 to 100 microcuries. One milliliter of IAF contains approximately 1×10^4 microcuries of gamma radiation. Therefore, an undiluted 5-microliter IAF sample can be measured in a Shonka chamber.

6. Iodine -- Continuous Extraction Method

Application: The concentration of radioiodine may be determined for all Redox samples by this method. If the radioactivity ratio of ruthenium to iodine is high (greater than 100), sufficient ruthenium may be carried along with the iodine to interfere with the method. For such samples inactive ruthenium "holdback" carrier should be added to the sample.

Description: A measured amount of inactive potassium iodide carrier solution and sodium bisulfite solution are added to the sample. Higher oxidation states of iodine are thus reduced to iodide. Nitric acid and sodium nitrite are then added to the solution to oxidize the iodide. The iodine formed is extracted into carbon tetrachloride then back extracted into a sodium bisulfite solution. From the gamma activity and the total iodine content of the sodium bisulfite solution which are determined by counting

in a Shonka chamber and by the Volhard volumetric method respectively, the concentration of radioiodine in the sample may be calculated.

Time required per determination: Approximately 30 minutes.

Systematic error: Approximately minus 7%.

Precision (99% limits): Better than $\pm 10\%$ for a Shonka current representing 0.1 microcuries of gamma activity.

Sample size: The sample size should be chosen so that the current registered by the Shonka counter represents at least 0.1 microcuries of gamma activity. This amount of iodine gamma activity is present in approximately one milliliter of dissolver solution prepared from 90 day-"cooled" slugs.

7. Neptunium by TTA Extraction

Application: This method may be used for the determination of low Np^{237} concentrations in the presence of large quantities of plutonium (IBP) and uranium (Decontaminated UNH).

Description: Neptunium and plutonium are separated from uranium when they are carried on LaF_3 precipitate formed in the solution. The precipitate is washed and dissolved with hydrochloric and boric acid. Plutonium is separated from neptunium by reducing Pu with stannous chloride to the trivalent state which remains in the aqueous phase when neptunium is extracted into 0.5 M TTA (thenoyl trifluoro acetone) in benzene. The neptunium and a small amount of interfering Pu is back extracted into a concentrated HCl solution. A large portion of the already small Pu interference is removed by a second reduction and TTA extraction. A portion of the organic phase containing the neptunium is then mounted on a platinum disc, dried, and counted on a standard alpha counter.

Time required per determination: Approximately 90 minutes.

Systematic error: Approximately minus 20%.

Precision (99% limits): Approximately $\pm 10\%$.

Sample size: To attain counting precision within the above limits the sample should radiate approximately 500 to 5000 neptunium alpha counts per minute during a 5-minute counting period. One milliliter of IAF solution contains approximately 500 neptunium alpha counts/minute.

8. Niobium -- Potassium Bromate Method

Application: The radioniobium (formerly radiocolumbium) concentration of all Redox samples may be determined by this method. The method should not be used for samples containing an appreciable fluoride ion concentration.

Description: Radioniobium and inactive carrier niobium are precipitated as a niobium hydrate from a boiling hydrochloric-oxalic acid solution when

1118

solid potassium bromate is added to the solution to destroy the soluble niobium oxalate complex. Zirconium holdback "carrier" is added prior to precipitation to minimize the interference of "carried" zirconium in the precipitate. The washed niobium hydrate precipitate is dissolved in oxalic acid. The interfering rare earth radioactive elements are then "carried" when lanthanum and thorium oxalates are precipitated. The niobium in the supernate is reprecipitated as potassium bromate is added to the solution. The precipitate is washed with diethyl ether, dried, weighed, and the chemical recovery calculated. The gamma radiation of the dried precipitate is then counted on a BGO counter.

Time required per determination: Approximately 40 minutes.

Recovery: Better than 95%.

Precision (99% limits): $\pm 15\%$.

Sample size: If the radioactivity of the sample permits, for the counting precision stated above, the sample size should be chosen such that a minimum of 300 gamma counts per minute are registered on the BGO counter during a five-minute counting period. Since one milliliter of dissolver solution contains approximately 2×10^6 niobium gamma counts/minute, a 5-microliter sample (the smallest accurately measured sample) would be more than adequate for the determination.

9. Plutonium Adsorbed on Super Filtrol

Application: This method was developed to detect plutonium adsorbed on Super Filtrol scavenger before sending the Super Filtrol to underground waste storage.

Description: Super Filtrol on which Pu has adsorbed is dissolved in concentrated hydrofluoric acid and digested with concentrated sulfuric acid. An aliquot of the sample is then analyzed for Pu using the standard lanthanum hydroxide-sodium uranate method or the LaF_3 method.

Time required per determination: 150 minutes.

Recovery: 97 to 99% dependent upon method used for final Pu analysis.

Sample size and precision: Sample size is dependent upon the plutonium concentration, and the precision required of the determination. For a discussion of these factors refer to the beginning of this chapter. For 1 to 2 per cent counting precision the sample size should be regulated so that during a five-minute counting period 3000 to 15000 counts per minute (approx. 0.04 to 0.2 micrograms of plutonium) are registered on the standard ASP counter. If it is assumed that 0.2% of the plutonium processed in the plant is adsorbed on the Super Filtrol 3000 counts/minute would be present in approximately 0.01 ml. of slurry waste.

10. Plutonium -- Direct Evaporation Method

Application: Plutonium may be determined by this method for these streams,

1119
DECLASSIFIED

both hexone and aqueous, containing little or no uranium (e.g., 2BP, 2BW, 3BP, 3BW, Pu Condensate). The sample should be essentially free of salts (less than 0.25 mg.) which are not volatilized when the sample is evaporated to dryness, for such salts absorb a portion of the plutonium alpha radiation.

Description: The sample is transferred directly to a platinum disc and a small amount of lanthanum fluoride is precipitated on the disc to insure even distribution of the plutonium over the surface of the disc. The precipitate is then evaporated to dryness and the sample is counted on a standard alpha counter.

Time required per determination: 45 minutes.

Recovery: Approximately 100%.

Sample size and precision: Sample size is dependent upon the plutonium concentration and the precision required of the determination. For a discussion of these factors see the beginning of the chapter. For 1 to 2% counting precision the sample chosen should contain sufficient plutonium (0.04 to 0.2 micrograms) to register 3000 to 15000 alpha counts per minute on a standard ASP counter during a 5-minute counting period. A 5-microliter sample of 3BP contains more than 15000 alpha counts/minute.

11. Plutonium -- Fluoride Precipitation Method

Application: This is a radiochemical method which may be used for the determination of high plutonium concentrations (e.g., Dissolver Solution, Pu Conc.). When a hexone phase sample (IAP) is analyzed a small amount of acetone must be added to increase the solubility of hexone in water. The method should not be used for samples (IAW, IBP) containing relatively large concentrations of ions such as aluminum which compete with plutonium for the fluoride.

Description: Pu(III) and Pu(IV) are separated from interfering substances by "carrying" the plutonium on a lanthanum fluoride precipitate formed in the sample solution. The precipitate is centrifuged and washed before counting in a standard alpha counter. If the total amount of Pu is to be determined by this method, the sample must first be treated with a reducing agent ($\text{NH}_2\text{OH}\cdot\text{HCl}$) to convert the Pu(VI) to a lower valence state.

Time required per determination: 90 minutes.

Recovery: 99 to 99.5%.

Sample size and precision: Sample size is dependent upon the plutonium concentration and the precision required of the determination. These factors are discussed at the beginning of the chapter. For 1 to 2 per cent counting precision the sample size should be regulated so that during a 5-minute counting period 3000 to 15000 counts per minute (approximately 0.04 to 0.2 micrograms of plutonium) are registered on the counter. A 5-microliter sample (the smallest accurately measured sample volume) of IAF contains approximately 50,000 plutonium alpha counts/minute.

DECLASSIFIED

12. Plutonium -- Lanthanum Hydroxide-Sodium Uranate Method

Application: This method is used for those streams which contain large concentrations of amphoteric ions such as aluminum which compete with lanthanum during the formation of LaF_3 precipitate. Among the samples which may be analyzed by this method are IAW, ISW, 2DW, 2AW, and other waste solutions containing large concentrations of aluminum nitrate.

Description: Plutonium is separated from amphoteric elements, particularly aluminum, when it is carried from the solution on a precipitate of $\text{La}(\text{OH})_3$ and sodium uranate. The washed precipitate is then dissolved in nitric acid and plutonium is reduced with $\text{NH}_2\text{OH}\cdot\text{HCl}$. This reduced plutonium is carried from the solution on a LaF_3 precipitate. The precipitate is mounted on a platinum disc, dried, and counted in a standard alpha counter. In the presence of large quantities of Cr(III) a portion of the plutonium is not carried during the hydroxide precipitation step. To overcome this effect Cr(III) is oxidized to CrO_4^{2-} using H_2O_2 as the oxidizing agent.

Time required per determination: 150 minutes.

Recovery: Greater than 97%.

Sample size and precision: The sample size is dependent upon the plutonium concentration and the precision required. A brief description of these factors may be found at the beginning of this chapter. Generally, for Redox samples the method will be used for determining low Pu concentrations requiring only fair counting precision. For approximately 20% counting precision the sample chosen should (radioactive level of sample permitting) contain approximately 0.0004 micrograms of Pu. A 5-microliter sample of IAW solution containing 1×10^{-4} g. Pu/liter is required for a determination.

13. Plutonium -- Low-Level Plutonium by Fluoride Precipitation

Application: This method is used for the determination of low plutonium concentrations in the presence of relatively high uranium concentrations (e.g., ICU, 3EU, Decontaminated UNH Storage). The method may be used for analyzing hexone samples if a small amount of acetone is added to the sample to increase its solubility in water.

Description: An initial lanthanum fluoride precipitation is made to separate the plutonium from the bulk of the uranium and other interfering ions. The precipitate, which has "carried" the plutonium and a slight amount of uranium with it, is then metathesized with potassium hydroxide to form lanthanum hydroxide. This $\text{La}(\text{OH})_3$ precipitate (and the "carried" plutonium) is dissolved with concentrated nitric acid and again treated with HF to form a second lanthanum fluoride precipitate. The washed LaF_3 is mounted on a platinum disc, dried, and counted on a standard alpha counter.

Time required per determination: 180 minutes.

Recovery: Approximately 95%.

Sample size and precision: Sample size is dependent upon the plutonium concentration and the precision required of the determination. These factors are discussed at the beginning of this chapter. Generally only fair precision will be required for these low level Pu streams. For approximately 20 per cent counting precision the sample selected should register approximately 40 counts per minute on the standard counter for a 5-minute counting period. A 5-microliter sample of ICU containing 1×10^{-4} g.Pu/liter is required to produce the required 40 Pu alpha counts/minute.

14. Plutonium -- TTA Extraction Method

Application: This method may be used for the detection of the low plutonium concentrations found in Redox waste streams (e.g., IAW, 2AW, 2DU).

Description: Of the three principal valence states of plutonium only Pu(IV) is extracted from aqueous solution by TTA (thenoyl trifluoro acetone). To determine the total amount of plutonium in the sample it is therefore necessary to reduce plutonium (and ferric iron catalyst) to Pu(III) with hydroxylamine hydrochloride, then oxidize to Pu(IV) with sodium nitrite and extract into 0.5 M TTA in xylene. An aliquot of the organic phase is mounted on a platinum disc, dried, and counted on an ASP counter. Since "polymeric" Pu does not extract it must be destroyed by initially adding nitric acid and heating the solution.

Time required per determination: 60 minutes.

Recovery: Greater than 95%.

Precision and sample size: The sample size chosen is dependent upon the precision required, the radioactivity of the sample, and the plutonium concentration. Since this method is to be used for waste streams containing low plutonium concentrations, approximately 10 per cent counting precision may be tolerated. As indicated in the beginning of this chapter this precision represents a counting period of five minutes on a disc containing approximately 0.002 micrograms of Pu.

15. Plutonium -- Zirconium Phenyl Arsonate Method

Application: The method is designed primarily to differentiate between Pu(III) and Pu(IV). The method is applicable when the Pu(III) to Pu(IV) ratio is high but when the ratio falls below 0.4 the accuracy decreases rapidly.

The method may also be used to differentiate between Pu(IV) and Pu(VI). For this differentiation it is assumed that a negligible quantity of Pu(III) exists in a solution containing Pu(IV) and Pu(VI).

Description: Plutonium (IV) is carried from acid solution by a zirconium phenyl arsonate precipitate while Pu(III) remains in solution. The separated precipitate containing the Pu(IV) is dissolved in hydrofluoric acid. Next the Pu(IV) is reduced to Pu(III) by hydroxylamine and carried on a LaF₃ precipitate formed in the solution. This precipitate is then washed,

DECLASSIFIED

mounted on a platinum disc, and counted in a standard alpha counter.

The Pu(III) remaining in the supernate from the zirconium phenyl arsonate precipitation is carried from solution on a LaF₃ precipitate. The precipitate is washed, mounted on a platinum disc, dried, and counted in a standard alpha counter.

If the Pu(VI) and Pu(IV) concentrations are being determined the Pu(VI) remaining in the supernate after zirconium phenyl arsonate precipitation must be reduced to Pu(III) before it is carried on LaF₃.

Time required per determination: 150 minutes.

Recovery: Approximately 95%.

Sample size and precision: Sample size is dependent upon the plutonium concentration, radioactivity, and precision required for the determination. These factors are discussed at the beginning of the chapter.

16. Ruthenium -- Direct Reduction Method

Application: Radioruthenium may be determined in all Redox samples by this method.

Description: A known amount of inactive ruthenium carrier is added to the sample which is subsequently reduced to ruthenium metal with magnesium in a strong hydrochloric acid solution. The metal is filtered, dried, and weighed. The "hard" beta emission passing through a 355 mg./sq. cm. aluminum absorber is measured on a standard BGO counter. The effect of interfering activity of zirconium and cerium is minimized by adding inactive zirconium and cerium "holdback" carriers to the sample so that only a small percentage of the radioactive zirconium and cerium is carried with the ruthenium. From the ruthenium recovery and the beta activity of the ruthenium metal the active ruthenium in the original sample may be calculated.

Time required per determination: 30 minutes.

Recovery: Approximately 101% for high counting rates (1000 to 7000 counts/minute). Approximately 120% for low counting rates (less than 1000 counts/minute).

Precision (99% limits): ± 10%.

Sample size: For the above counting precision the sample should emit approximately 1000 to 7000 ruthenium "hard" beta counts per minute. A 5-microliter sample (the smallest accurately measured sample volume) of Dissolver Solution contains far more radioactivity (1×10^6 Ru beta counts/minute) than required for the determination. Therefore, the sample must be initially diluted and a suitable aliquot taken for analysis.

17. Zirconium -- TTA Extraction Method

Application: The method may be used for the determination of zirconium in all Redox samples. Plutonium interferes with the method and must be re-

DECLASSIFIED

duced to Pu(III) by the addition of $\text{NH}_2\text{OH}\cdot\text{HCl}$ to prevent its extraction into the benzene layer.

Description: After careful adjustment of the nitric acid concentration of the sample, zirconium is quantitatively extracted into a benzene solution of TTA (thenoyl trifluoro acetone). The radioactivity of the benzene layer is then measured in a Shonka counter.

Time required per determination: 35 minutes.

Systematic error: Minus 25 to plus 25% (estimated).

Precision (99% limits): $\pm 25\%$ (estimated).

Sample size: For maximum counting precision the sample size should be selected such that a current representing 300 or more gamma counts per minute is registered on the Shonka counter. The required 300 zirconium gamma counts/minute are contained in a 5-microliter sample of Dissolver Solution.

1124

DECLASSIFIED

REFERENCES

- (1) Richards, R. B. and Smith, R. E., Project C-187-D Purchase Specification -- Methyl Isobutyl Ketone (MIBK), 12-5-50.
 - (2) HW-12867* H. W. Laboratory Manual, 200 Area Section. Author not stated. 7-1-50.
 - (3) HW-14524 Preliminary Analytical Requirements for Redox Production Plant No. 1 (Revised September 20, 1949). R. J. Sloat. 9-23-49.
 - (4) HW-14744 Tentative Analytical Methods and Estimated Sample Sizes for Process Control of Redox Production Plant No. 1. R. J. Sloat and J. W. Hall. 10-19-49.
 - (5) HW-15074 Chemical Research Section Progress Report for October 1949. F. W. Albaugh. 11-15-49.
 - (6) HW-18816 Estimated Analytical Load of Redox Production Plant No. 1 During Routine Operation (18 Months After Cold Startup). R. J. Sloat. 9-15-50.
-

* Principal Reference

DECLASSIFIED

PART V: SAFETY

CHAPTER XXI. HEALTH PROTECTION FROM RADIATION

<u>CONTENTS</u>	<u>Page</u>
A. NATURE OF RADIATIONS	2102
1. Alpha Particles	2102
2. Beta Particles	2102
3. Gamma Rays	2103
B. CURRENT PERMISSIBLE RADIATION EXPOSURE LIMITS	2103
1. Definition of Terms	2103
2. External Radiation Exposure Limits for Hanford Works	2104
2.1 General body exposure	2104
2.2 Exposure of hands and forearms only	2105
3. Permissible Contamination Maxima for Hanford Works	2105
4. Permissible Personnel Contamination Limits	2105
5. Surface Contamination Limits for Hanford Works	2106
5.1 Radiation Danger Zones and regulated areas	2106
5.2 Non-regulated areas	2106
C. METHODS OF MONITORING	2107
1. Monitoring of Operating Areas and Equipment	2107
1.1 Health Monitor (HM) stations	2107
1.2 Portable survey instruments	2108
2. Monitoring of Personnel	2110
2.1 Special Hazard Bulletins	2110
2.2 Personnel exposure monitoring	2110
2.3 Monitoring of personnel leaving a Radiation Danger Zone	2111
3. Ventilation Air Monitoring	2112
4. Stack Gas Monitoring	2113
5. Environs Monitoring	2113
D. EFFECTS OF RADIATION ON THE BODY	2114
1. General Principles Governing Biological Effects	2114
1.1 Effects on tissue	2114
1.2 Radiosensitivity and reversibility	2114
1.3 Total exposure and time factor	2115
1.4 Biological effectiveness of various radiations	2115
2. Effects of External Radiation	2115
3. Effects of Internal Radiation	2116
4. Treatment of Radiation Injuries	2117
REFERENCES	2118

DECLASSIFIED

HW-18700

CHAPTER XXI. HEALTH PROTECTION FROM RADIATIONS

Nuclear radiations are inseparable from the atomic energy program and the production of plutonium. Radiations of the types encountered in the chemical separations plants have been known for over half a century, and their action on living tissue and matter is reasonably well understood. Slowly during the last 50 years, standards of protection were established which regulated the conditions under which work with radioactive materials was performed. Although these standards provided valuable guidance during the first years of the atomic energy development, the radiological problems encountered on this project were many times greater than those ever faced before. Instead of about three pounds of radium under human control, there are now radioactive materials equivalent to millions of pounds of radium. In addition to a few kinds of radiomaterials known previously, we now deal with hundreds of kinds comprising nearly every known element and several new elements. Much effort is being devoted presently to the study of radiations, their hazards and effects, and methods for control of these hazards. The principles followed in the protection of personnel from radiations by shielding are discussed in Chapter XXII. The present chapter deals primarily with the hazards of radiation and personnel protection methods other than shielding.

A. NATURE OF RADIATIONS(9)

Nuclear radiations are invisible and undetectable by the unaided senses. They are of two general types: (a) bits of matter from the nucleus of atoms (neutrons, beta, and alpha particles), and (b) electromagnetic waves called gamma rays or photons. The radiations emitted in the chemical separation processes are alpha, beta, and gamma. Neutrons are emitted only during the pile reaction and, therefore, will not be considered in this chapter.

1. Alpha Particles

As stated in the H.E.W. Technical Manual:(9)

Alpha particles are helium nuclei of mass four and positive charge two. They are ejected spontaneously by the nuclei of uranium and plutonium atoms, but not by fission-product elements. Because of the large mass and charge of the alpha particle, its penetrating power is very low. For example, the alpha particles from uranium are completely stopped by about one inch of air, 0.001 inch of aluminum, or 0.0001 inch of lead. Alpha particles present an important hazard only when the parent substance is taken into the body.

2. Beta Particles

Beta particles, emitted by radioactive nuclei, are fast electrons of very small mass, about 1/8000 that of an alpha particle. They carry a negative charge of one unit and are emitted with energies rarely exceeding 3 M.e.v. (4) Their penetrating power is rather low (2 M.e.v.

DECLASSIFIED

betas are completely stopped by about 23 feet of air or about 1/8 inch of aluminum). The beta radiation hazard assumes importance only when the observer is directly exposed to the source or when the emitter is taken into the body. Under exceptional circumstances the secondary radiation produced upon absorption of beta particles in matter (Bremsstrahlung, or "slowing-down radiation") may also represent a hazard.

3. Gamma Rays

Gamma rays have a wave length roughly one-millionth the wave length of visible light. The most penetrating radiation emitted by the fission products is the 2.1 M.e.v. gamma radiation of lanthanum. Unlike alpha and beta particles, gamma radiation has no definite range in matter but is absorbed exponentially. The intensity of a beam of 2 M.e.v. gamma radiation is reduced ten-fold by passage through 1300 feet of air, 20 inches of water, 8.5 inches of concrete, 8 inches of aluminum, or 1.7 inches of lead. Reduction of the intensity of this radiation by a factor of 100 is obtained by using a shield of 3.4 inches of lead. Although gamma rays are less damaging than alpha or beta radiation, quantity for quantity, they are a major problem because they penetrate so deeply.

B. CURRENT PERMISSIBLE RADIATION EXPOSURE LIMITS

For any systematic program of radiation control, it is necessary to know precisely what quantities and rates of exposure can be permitted. The permissible radiation exposure limit is the quantity of radiation which a human can withstand day after day without perceptible damage to the body. Because of the lack of full, exact knowledge, the permissible exposure limits at Hanford Works are conservatively set and frequently reviewed in light of new information. The safety factors involved are not exactly known. In some cases they may be quite large; in others, just adequate.

1. Definition of Terms

A "roentgen" (r.) is a quantity of gamma or X rays that corresponds to an absorption of 93 ergs per gram of water. (4)

A "rep." (roentgen equivalent physical) is a quantity of any ionizing radiation that will deliver an amount of energy (93 ergs) equivalent to a roentgen to one gram of tissue. (4)

A "rem." (roentgen equivalent man, or mammal) is that dose of any radiation which produces a biological effect equal to that produced by one roentgen of high-voltage X radiation. This is not an absolute definition. A voltage of 400 kilovolts, or more, is considered a high voltage. (4) One rep. of another type of radiation, delivering an equivalent amount of energy, would create more rem. of damage than one rep. of gamma or X rays as follows: (7)

DECLASSIFIED

HW-18700

Gamma or X rays----- 1 r. = 1 rep. = 1 rem.

Beta particles ----- 1 rep. = 1 rem.

Alpha particles ----- 1 rep. = 20 rem.

A curie is a measure of the activity of a radioactive material. The sample is said to have one curie of radioactivity when the number of disintegrations of its atoms per second is equal to 3.7×10^{10} . Since conventional instruments for measuring radioactivity actually count the number of particles (i.e., alpha or beta) emitted per unit of time rather than the number of atoms disintegrating per unit of time, the number and types of particles emitted per disintegration must be known or estimated to convert the radioactivity measurements to curies. This conversion from "counts" to curies is discussed in more detail in Chapter I. The absolute curie defined above should not be confused with the "countable" curie explained in Chapter II.

2. External Radiation Exposure Limits for Hanford Works(5)

2.1 General body exposure

General body exposure limits for radiation are set for certain critical tissues, the selection of which depends on the irradiation pattern. For gamma radiation of quantum energy less than 3 M.e.v., the critical tissues are probably the blood-forming tissues (i.e., the bone marrow) conventionally assumed to lie at a depth of 5 cm. For this radiation, the maximum permissible limit is 0.3 roentgen per week to these blood-forming tissues. For practical reasons, this limit is better expressed in terms of the surface dose per week and on this basis would be 0.5 roentgen per week. This corresponds to 0.3 roentgen per week measured in free air by an instrument such as a C.P. meter. The difference between the 0.5 roentgen/week surface dose and the 0.3 roentgen/week measured in free air is due to back-scattering effects not detected by the C.P. meter.

The critical tissues for high energy beta radiation (up to about 3 M.e.v.) are probably the superficial tissues of the skin, assumed to be the basal layer of the epidermis lying at a depth equivalent to 7 mg./sq.cm. For this radiation the maximum permissible limit is 1.5 rep. per week to the surface of the body*. However, in practice, beta radiation is almost always accompanied by gamma radiation. For such a combination it is difficult to predict which tissues, the skin or the blood-forming organs, become critical. For this reason when both beta and gamma radiation are present, the maximum permissible limit is 0.5 rep. per week to the surface of the body, the gamma and beta components being considered additive. Since surface dosage rates cannot be determined easily for mixed radiations, the maximum permissible limit at Hanford is taken as 0.3 rep. per week measured in free air.

*) This is the proposal of the International Commission on Radiological Protection. The U.S. Committee has not yet decided between 0.5 and 1.5 rep. Hanford will continue to operate on the lower limit until this decision is made.

DECLASSIFIED

1129
DECLASSIFIED2.2 Exposure of hands and forearms only

In the case of exposure of only the hands and forearms, the basal layer of the epidermis (rather than bone marrow) is considered the critical tissue for both beta and gamma radiation. For this reason, the permissible limit in this special case is 1.5 rep. per week, the gamma and beta components being considered additive.

3. Permissible Contamination Maxima for Hanford Works

Permissible concentration levels of radioactive materials taken into the body are based on an allowable exposure of 0.3 rem. per week to the organs significantly affected, except in those cases where a more reliable estimate can be obtained from comparison with radium toxicity. The following table presents the limits for various radioelements (listed in the order of their atomic number) which are of concern in the Redox Plant:(2)

<u>Radioisotope</u>	<u>Retention in Body, Microcuries</u>	<u>Concentration in Air, Microcuries/Cu.Cm.</u>	<u>Concentration in Drinking Water, Microcuries/Cu.Cm.</u>
Kr ⁸⁵	(a)	1.4×10^{-5}	(a)
Sr ⁸⁹	2	approx. 2×10^{-8}	7×10^{-5}
Sr ⁹⁰ (+Y ⁹⁰)	1	approx. 2×10^{-10}	8×10^{-7}
I ¹³¹	0.3	3×10^{-9}	3×10^{-5}
Xe ¹³³	300	5×10^{-6}	4×10^{-3}
Xe ¹³⁵	100	1.7×10^{-6}	1.5×10^{-3}
U (natural)	0.07 (sol.) in bone 0.009 (insol.) in lungs	1.7×10^{-11}	(a)
Pu ²³⁹	0.04 (sol.) 0.008 (insol.) in lungs	2×10^{-12}	1.5×10^{-6}
Fission products (mixed)	(a)	1×10^{-9}	(a)

(a) Limit not determined.

4. Permissible Personnel Contamination Limits(5)

Permissible contamination limits for personnel and clothing are set so that overexposure of personnel and undue spread of contamination are considered impossible. The following table presents these limits:

DECLASSIFIED

1130

DECLASSIFIED

<u>Surface of Skin or Clothing</u>	<u>Types of Contamination</u>	<u>Maximum Permissible Contamination</u>
Skin--general	All	No detectable contamination.*
Skin--hands	Alpha (Pu)	Less than 500 disintegrations/min. total per hand as determined by Four-Fold Alpha Hand Counter.
	Beta	15 registers per 24 seconds with scales of 8, on Four-Fold or Five-Fold Beta Hand Counter.
Shoes (personal)--soles	Alpha (Pu)	Less than 500 disintegrations/min. with Poppy.
	Beta	Fixed on bottom of shoe after cleaning--25 registers per 24 seconds on scale of 8 shoe counter.
Shoes (personal)--surfaces other than soles	All	No detectable contamination.*
Clothing (personal)	All	No detectable contamination.*
Clothing (protective--SWP)	Alpha (Pu)	500 disintegrations/min. per 0.1 square feet.
	Beta	1 mrep./hour surface dosage rate.

* Monitored with Poppy for alpha (low limit of detection = 500 dis./min.) and G.M.-type instrument for beta and gamma (low limit of detection = 100 co./min.)

5. Surface Contamination Limits for Hanford Works(5)

5.1 Radiation danger zones and regulated areas

Control limits are as deemed necessary and practical by the Operating and H.I. Divisions concerned.

5.2 Non-regulated areas

No detectable contamination (as monitored by the Poppy and G.M.-type instruments) is permissible.

DECLASSIFIED

C. METHODS OF MONITORING(5)

Various elaborate provisions in building and equipment design and in equipment operation have been made for the protection of personnel from the hazards of radiation. In addition to these safeguards, it is considered essential that a thorough and constant program of radiation monitoring be maintained so that accidental overexposure of personnel is avoided.

The chief items requiring constant and careful monitoring are included in five categories: (a) operating areas and equipment, (b) personnel, (c) ventilation air, (d) stack gas, and (e) environment. Description of the detailed monitoring procedures and equipment used at Hanford Works for health protection is beyond the scope of this chapter, but the following discussions cover the general features involved in the control of radiation hazards in each of the five categories.

1. Monitoring of Operating Areas and Equipment

Although the equipment and facilities provided are adequate for handling the active process solutions under normal operating conditions, in the event of operational accidents or the need to enter any of the equipment cells or areas for inspection or maintenance, it is necessary that the areas and equipment be surveyed for presence of contamination and radiation. In addition, surveys of all the operating areas of the plant are made on a routine basis in order that contamination can be removed, and radiation confined. The techniques of decontamination are discussed in Chapter XXIII.

1.1 Health Monitor (HM) stations

Fixed monitor stations which measure and record instantaneous radiation levels in the Redox Plant are located as follows:

<u>Location of Chamber</u>	<u>Number</u>	<u>Location of Recorder</u>
Pipe Galleries	6	Dispatcher's office
Canyon Deck	4	Dispatcher's office
Remote Shop	1	Dispatcher's office
Decontamination Room	1	Dispatcher's office
Train Tunnel	1	Dispatcher's office
Crane Maintenance Platform	1	Dispatcher's office
Silo Crane Deck Level	1	Dispatcher's office
Silo Sampling Gallery	1	Silo Operating Gallery
Silo Feed Tank Level	1	Silo Operating Gallery
Silo Operating Gallery	1	Silo Operating Gallery
Operating Gallery	11	Operating Gallery
Sample Galleries	6	SWP Lobby
Canyon Crane Cab	1	Crane Cab

A complete installation consists of an ion chamber, a Beckman RXG amplifier, and a recorder.(5) Fiber ion chambers are used for gamma monitoring;

1132

an acetate window permits it to be used also for beta monitoring. Radiation fields which can be detected reliably are limited by ionization chamber volume, which is standardized, and by the Beckman amplifier, which provides six sensitivities permitting measurement of fields from 0.03 mr./hr. to 300 r./hr. The Operating Division must change the sensitivity on the canyon HM Chamber amplifiers when operations (e.g., charging of a dissolver) in the canyon change the radiation level. The HM instruments are calibrated weekly by the Health Instrument Division.

1.2 Portable survey instruments(5)

The value of any radiation survey is dependent on the judgment of the surveyor in selecting an instrument, making the survey, and interpreting the data. If quantitative measurements are made, survey instruments must be used in substantially the same manner as they were calibrated. Otherwise variable and indeterminate errors are introduced. However, since most survey instruments operate on the same principle (i.e., measurement of the degree of ionization caused by radiation passing through gas in an enclosed chamber) qualitative indications can sometimes be obtained when an instrument is not calibrated for a specific radiation. With regard to alpha measurements, the short range and low penetrating power of the particles require that the instrument be used as close as possible to the area being examined and with no absorber (paper, film of water, etc.) between the source and the sensitive element.

The matter of a time constant must not be overlooked in making any survey with a direct-reading instrument. Every instrument requires a fixed amount of time, usually of the order of seconds, for it to reach a steady reading, or to give any reading at all. It is quite possible to miss radioactive contamination or beams by too rapid survey of the area. For these reasons, considerable skill and experience are required of the surveyor to detect the presence of radiation or to be assured, based on a rapid survey, that radiation is absent. A complicating factor in the use of the instruments is that flames, drafts, or mechanical disturbances of the chambers may affect their readings in some cases.

Six of the most common portable survey instruments are classified below:

<u>Instrument</u>	<u>Function</u>	<u>Radiation</u>	<u>Range(a)</u>	<u>Comments</u>
C.P.(b)	Measurement of radiation field.	Beta Gamma	0-35,000 mrep./hr. 0-5000 mr./hr.	Light weight and very reliable.
Zeuto	Detection of surface contamination.	Alpha Beta	0-50,000 dis./min. 0-200 mrep./hr.	Very satisfactory for general usage.
Juno	Detection of surface contamination and measurement of radiation field.	Alpha Beta Gamma	0-4,000,000dis./min. 0-15,000 mrep./hr. 0-5,000 mr./hr.	Versatile.

<u>Instrument</u>	<u>Function</u>	<u>Radiation</u>	<u>Range(a)</u>	<u>Comments</u>
Poppy	Detection of surface contamination.	Alpha	Greater than 500 dis./min.	Many special probes available. Probes quite fragile.
Portable G.M.	Detection of surface contamination and measurement of radiation field.	Beta Gamma	Detection only 0-80,000 co./min.	Instruments are equipped with probe.
Portable Beckman	Detection and measurement of radiation field.	Beta(>0.5 M.e.v.) Gamma	Detection only 1-2000 mr./hr.	Stable zero. Very short time constant. Heavy.

Notes: (a) Values for alpha and beta are typical values and may vary to some extent from one instrument to another.

(b) This is the complete designation of the instrument. Officially the letters no longer stand for "Cutie Pie".

The description of the Juno below, illustrates the principle used for distinguishing and measuring the dose-rate of an individual radiation in the presence of other radiations. Although the other instruments differ in their physical arrangements and electronic circuits, this principle is the same. The ionization chamber window of the Juno can be covered by a nylon shield and an aluminum shield. Any reading on the microammeter when both shields are in place is caused by gamma rays penetrating to the ionization chamber; the intensity of gamma radiation is obtained from a curve relating scale reading and mr. per hour. For measurement of beta radiation, the aluminum shield is removed, and the microammeter on the instrument is read a second time. The increase in microamperes above the previous reading is caused by the beta radiation and is interpreted on the beta calibration curve. When both the nylon and aluminum shields are removed, the microammeter reading represents the total alpha, beta, and gamma radiation present. Subtraction of the second reading from the third gives a reading which is referred to the alpha calibration curve. Since some soft beta radiation is absorbed by the nylon shield, this latter reading represents small quantities of beta radiation in addition to the alpha; however, this inaccuracy is unimportant.

The portable survey instruments are stored in the S.W.P. Lobby. After the instrument is used, it is returned to the Lobby, surveyed for contamination and cleaned, if necessary, before it is returned to storage.

2. Monitoring of Personnel

DECLASSIFIED

2.1 Special Hazard Bulletins

Procedures issued by the Special Hazards Committee form the basis of the radiation protection policies for personnel in the plant. The following bulletins have been issued to date:

- Bulletin No. 1 --- "Plant Procedure for Work in 'Radiation Danger Zones'."
- Bulletin No. 2 --- "Procedure for Suspected or Known Excessive Radiation Exposure or Contamination."
- Bulletin No. 3 --- "Contaminated Waste Disposal."
- Bulletin No. 4 --- "Procedure for Injury in Contaminated Work Zones."
- Bulletin No. 5 --- "Procedure for Inter-Area and Off-Plant Transfer of Special Process Materials."
- Bulletin No. 6 --- "Investigation and Reporting of Unsafe Practices or Incidents Arising from Special Hazards."
- Bulletin No. 7 --- "Procedure for Release of Equipment from Areas Wherein Contamination is Possible."
- Bulletin No. 8 --- "Procedure for Fire-Fighting in Radiation Danger Zones."

2.2 Personnel exposure monitoring

All persons working in those plant areas in which exposure to radiation is considered possible are required to wear two pocket meters, or "pencils", and a film badge. These instruments are intended to indicate the degree of beta and gamma radiation exposure which each individual experiences.

The pocket meter is essentially an ionization chamber. In use, a predetermined charge is placed on an electrode. The extent to which the charge is dissipated is an indication of the exposure to radiation. The charges on the two meters are read at the end of each shift of use and can indicate gamma dosages from 5 to 280 mr. Since these chambers may be discharged by mechanical shock, dropping them or otherwise subjecting them to sharp blows should be avoided.

The film badge contains two separate films, one more sensitive than the other, which are sensitive to beta and gamma radiation. A silver shield covers approximately three fourths of the film surface so that it is possible to obtain an indication of the relative exposure to beta and gamma radiation. Perforations in the silver shield are used for permanently recording the wearer's payroll number by exposure of the shielded film to a known source of X rays. With each lot of film used,

DECLASSIFIED

DECLASSIFIED

counting instruments (or on both a Poppy and G.M.-type instrument) after each exit from a Radiation Danger Zone, before eating or smoking, and before leaving the process area for the day. However, hand and shoe counting instruments should be considered as a check of prior contamination control methods and not as a means of contamination control in themselves. A high hand or shoe count is unusual and calls for immediate and thorough investigation and decontamination by approved methods.

3. Ventilation Air Monitoring

The methods of air sampling and analysis described in this section apply to particulate radioactivity only. They are of no value in monitoring of radioactive gases such as xenon or krypton, and they pick up only approximately five per cent of the radioiodine. Experience has shown that such coverage is adequate, unless radical changes in dissolving schedules are introduced.

A vacuum air sampling system is installed in the Redox Plant with 101 sampling points located throughout the building. Thirty of these sample points are located in the sample galleries of the canyon and silo. These thirty have six-foot hoses provided which make them semi-portable in that it is possible to move the air sampler to within two feet of process solution sampler boxes. Sixteen sample points are located on the canyon walls, four feet above the deck and staggered on north and south walls. The remainder of the sampling points are distributed throughout the building.

Each sampler has a rated capacity of twenty cubic feet per minute and is equipped with an orifice and manometer for indicating air flow rates. The vacuum is maintained by one of two vacuum pumps, one pump being wired to the emergency electrical system so that continuity of sampling is assured.

The Health Instrument Division has the responsibility for sampling and analyzing the air in the building. Filter papers used for collecting the samples are of two types: (a) Chemical Warfare Service Type 6, an asbestos paper; and (b) Whatman 41 Ashless filter paper. The filter paper, 4-1/4 inches by 8-1/2 inches, is inserted into a brass, perforated, cylindrical head with 70 per cent free area. Air is drawn through the paper until a minimum of 200 cubic feet has been pulled in approximately 10 minutes. (5) However, continuous samples of eight hours or greater duration offer a better indication of the particulate activity that personnel might inhale while working prolonged periods in an area.

Particulate contamination collected on filters is measured by its activity. When the ashless filter paper is used, the paper is digested with acid, and the solution is evaporated to dryness. Counts are made of the solid residue. When the sample is taken on asbestos filter paper, the Horizontal Pig Air Sample Counter or Mica Window counter is used for determining the beta and gamma activity. The optimum time for these readings is within an hour after sampling. If the beta count indicates a high concentration of beta emitters, additional counts are taken to estimate the half-life.

DECLASSIFIED

standards composed of a blank and a series of films exposed to known radiation sources are processed. The exposure experienced by the wearer is determined by comparison of the blackening of the wearer's film with the standards by means of a sensitive densitometer. Over a range of 20 mr. to 20 r. of radiations, good accuracy and reproducibility are obtained. The film badges are generally worn for a two-week period, after which they are monitored and reloaded. If the pocket meters, one as a double-check of the other, indicate that the individual has been exposed to significant radiation, the film badges are processed immediately. The developed film comprises a permanent record of each employee's exposure to beta and gamma radiation. Where radiation exposure of the hands may be significantly higher than to the whole body, hand monitors in the form of rings containing film are worn also.

Routine interim physical rechecks are made on process plant employees so that any systemic radiation effects would be detected. For separations process plant employees, routine thyroid checks for detection of radioiodine are made. Employees routinely give large-volume urine samples which are analyzed for presence of plutonium and/or other radioelements when applicable.

2.3 Monitoring of personnel leaving a Radiation Danger Zone

Personnel working in a Radiation Danger Zone wear protective clothing and equipment prescribed by the supervision of the Health Instrument, Operating, and Servicing Divisions when the Special Work Permit is issued. Protective clothing and equipment of the following kinds are prescribed:

- Body protection -- coveralls, laboratory coats, rubber suits.
- Foot protection -- plant-issue shoes, shoe covers, rubbers.
- Hand protection -- canvas, rubber, or leather gloves.
- Head protection -- cloth or rubber hats.
- Respiratory protection -- respirators, assault masks, fresh air masks, breathing air supply, or Chemox masks.

Before removal, protective clothing should always be surveyed with detection-type instruments for contamination. This is done in the S.W.P. Lobby which is the exit from all Danger Zones. Removal of foot protection is done first in a manner so that the individual steps from a potentially contaminated area into a clean area without transfer of possible contamination to the floor of the clean area. The shoe covers are discarded into a bag for contaminated laundry. The next step involves the survey of all protective clothing and exposed skin surfaces. Both the Poppy and G.M. instruments are used for a complete survey for alpha, beta, and gamma-emitting radioelements. If contamination is found, extra precaution must be taken in the removal of the clothing so that contamination is not spread. A resurvey of the individual must be done after his clothes are removed. The used clothing is placed in another hamper and, if it is contaminated, it is wrapped and labeled for guidance of the laundry.

Regardless of the estimated possibility of contamination spread, hand and shoe counts must be made on both alpha and beta-gamma-type

The Standard Parallel Plate Chamber or the Long Tom Chamber is used for counting the alpha activity which is emanated from radon, thoron, their daughters, and plutonium (or uranium). Two counts are taken, the "six-hour" count and the "twenty-four-hour" count. From these two counts the background due to radioactivities controlled by the Th B decay rate can be obtained and the activity of the plutonium (or uranium) can be calculated. If both plutonium and uranium are possibly present in the air, their concentrations can be determined either by chemical analysis of the contamination collected on the filter paper or by range determinations on the alpha particles. Respiratory protection is required if the activity determined from an air sample indicates air contamination in excess of one of the following working limits:

Fission products (mixed) --- 1×10^{-9} microcurie/cu.cm.

Plutonium ----- 3×10^{-11} microgram/cu.cm.

Uranium ----- 3×10^{-5} microgram/cu.cm.

4. Stack Gas Monitoring

The stack gas is monitored for particulate activity; at present, activity due to radioactive noble gases is not monitored. Prior to the installation of scrubbers and filters in the waste gas lines from the precipitation process plants, much difficulty was experienced⁽⁸⁾ with contamination of the areas around stacks by radioactive droplets, dust particles, and radioiodine. Both the precipitation process plants and the Redox Plant have extensive filtering and treatment facilities so that ground contamination from stack gases should be eliminated. However, monitoring of the stack gases is necessary as a check on the satisfactory operation of this equipment.

In the Redox Plant, waste gas sampling points are provided at the inlets and outlets for each of seven filters. A large sand filter is provided for filtration of outgoing ventilation air. Separate glass wool filters are provided for the following: (a) each of the three dissolvers, (b) oxidizer, (c) vessel vent header, and (d) condenser vent header. In addition, gas samplers are installed in the stack at positions ten feet above the breeching inlet to the stack line and four feet below the top of the stack. For particulate activity, samples similar to those used for ventilation monitoring are taken at these points on a routine basis and analyzed by the Health Instrument Division. No samples are taken specifically for radioiodine, krypton, and xenon, but the filter paper is known to retain about five per cent of the radioiodine activity.

5. Environs Monitoring

During 1948 to 1951, the amount of radioactive materials (i.e., particulate matter and iodine) released into the environment has been greatly reduced, particularly that from the separation process plant stack gases, however, release of radioactive noble gases (xenon, krypton, etc.) has not been reduced. It is necessary to know with accuracy that

1138

the wastes released are not adversely affecting the welfare of the region. A typical month's monitoring⁽⁷⁾ involves taking and analyzing 600 samples of river and well water; 4000 air samples; 500 samples of vegetation, soil, and mud; and making 15 surveys of special areas with portable instruments. Month-by-month distribution of radio-materials in the air, water, and earth around the reservation is mapped, and, in addition, radioactivity measurements at scores of locations outside the reservation are reported.

D. EFFECTS OF RADIATION ON THE BODY(4)

The material to be presented in the subsequent paragraphs on radiation effects and their treatment is included for general interest only. The reader should keep in mind that the previously described design and control methods employed in plant operation during the past seven years have provided an extremely safe operational environment. The material is offered to give the reader an appreciation of the need for the precautions and controls described previously so that he may conduct himself in his work with the awareness that considerable thought and effort has gone into the evolution of workable and reliable safe practices. Every effort is being made to expand and apply new knowledge on radiation hazards and treatment as it becomes available. Therefore the subject matter to be described will have to be amended and revised from time to time.

1. General Principles Governing Biological Effects

1.1 Effects on tissue

The site of action of radiation upon human and animal tissues is the individual cell. The part of the cell most sensitive to radiation is the cell nucleus; the material surrounding the nucleus is also sensitive, but to a lesser degree. Specific changes which may be detected in a cell following irradiation are as follows:

- (a) Cytolysis --- dissolution of the cell with a shrinking nucleus and clumping of the chromatin in the nucleus. A structureless mass results which may go to liquidation.
- (b) Changes in cell division --- mitosis may be stopped, or daughter cells may develop into giant cells.
- (c) Changes in function of the cell --- e.g., motility is stopped or depressed, secreting cells may stop secreting, and change in cell nutrition may occur.

It should be emphasized that any of these changes can result from other stimuli besides radiation, and that a specific irradiation effect does not exist.

1.2 Radiosensitivity and reversibility

Although all body tissues are affected by radiation, certain tissues display a higher degree of vulnerability than others when exposed to the

same source of radiation. Radiosensitivity is a term which denotes relative vulnerability of various tissues. Lymphoid tissue, bone marrow, sex organs, and the lining of the small intestine are the most radiosensitive tissues. Muscles, nerves, and fully-grown bones are the least radiosensitive; and other tissues, such as skin, liver, and lung, lie in between these extremes.

The reversibility of radiation effects is important particularly in occupational exposure. Reversibility is a term which denotes the relative ability for tissue to return to its previously normal state after it has been exposed to radiation. The degree of reversibility depends upon the intensity of the radiation received and upon the regenerative or reparative properties of the tissue. Some tissues such as skin, the blood-forming elements, membranous linings of body cavities, or glands, are endowed with a special mechanism for repair and regeneration. Other tissues, such as muscle, brain, and certain structures of the kidney or eye have no provision for regeneration, and repair is formed by a scar which does not take the place of the tissue it replaces. The latter effect is said to be irreversible. Although a tissue may be repaired a few times following exposure to radiation, it may not have sufficient recuperative capacity to regenerate itself again and again. Hence, previously sustained radiation injury should be properly appraised and repetition should be avoided.

1.3 Total exposure and time factor

In all acute radiation injuries, the total amount of radiation received and the exposure rate are the critical factors. Exposure to radiation of high intensity for a short time will cause much more damage than the same integrated exposure divided and administered at intervals. A certain degree of tissue recovery may take place in the intervals between such periodic exposures.

1.4 Biological effectiveness of various radiations

The various ionizing radiations produce qualitative effects which are indistinguishable from each other. However, the biological effects of the different radiations are not quantitatively equivalent, as indicated in Section C2 of this chapter. The biological effectiveness of a radiation depends on the specific ionization or linear ion density induced by the radiation which varies directly with the square of the particle's charge and inversely with its speed. If the radiation (such as gamma) does not consist of charged particles but indirectly ejects charged particles from the matter through which it passes, its effectiveness is considered as that of the ejected particles.

2. Effects of External Radiation

The characteristic effect on the skin of overexposure to radiation is the production of erythema or redness. This effect resembles sunburn except that the interval between a single exposure to the radiation and erythema is about 4 weeks. At Hanford Works the concern for this injury

1140

is not from a single exposure but from small daily overexposures which may lead to more serious effects.

Radiation has no appreciable effect directly on the circulating blood. The effect is primarily on the tissues which form the blood. Changes in the blood count may be observed within an hour after total body overexposure. The rapidity and magnitude of the observable effect and the recuperation time depend upon the dose and the regenerative powers of the blood-forming tissue. Blood counting is, therefore, an early and available index of overexposure to radiation. When some cells in the blood are destroyed, many functions of the blood (i.e., respiratory, nutritive, excretory, and protective) are impaired, the degree of impairment depending upon the severity of cell destruction.

The following excerpt from The Effects of Atomic Weapons⁽¹⁾ presents the most recent information relative to the effect on humans of large acute exposures to radiation:

Because large acute exposures to radiation have been accepted by human beings only as a result of accidents, it is impossible to state definitely that a particular amount of radiation will have certain consequences. Nevertheless, from experiments with animals, whose sensitivity to radiation relative to that of human beings has been studied, certain general conclusions have been drawn. These cannot be exact, in any event, since there are marked variations among individuals insofar as sensitivity to radiation is concerned. The probable early effects of acute radiation exposures to the whole body are shown below:⁽¹⁾

<u>Acute Dose</u>	<u>Probable Effect</u>
0-25 r.	No obvious injury.
25-50 r.	Possible blood changes but no serious injury.
50-100 r.	Blood-cell changes, some injury, no disability.
100-200 r.	Injury, possible disability.
200-400 r.	Injury and disability certain, death possible.
400 r.	Fatal to fifty per cent.
600 r. or more	Fatal.

With reference to any of the specific acute doses in the above table, somewhat larger exposures may be received, with an equivalent likelihood of injury, if exposure is protracted over several days or weeks, or if it is limited to a portion of the body.

3. Effects of Internal Radiation

The effects of taking radioactive materials into the body depend on the nature of the radioactive materials and, to some extent, on the path by which they enter. An important factor is the tendency for certain

DECLASSIFIED

1141

2117

elements to concentrate in specific body tissues. For example, iodine concentrates in the thyroid glands whether it is inhaled or ingested. Plutonium (which deposits in the bone marrow) is more dangerous when inhaled or introduced through a wound than when it is ingested.

Radioactive materials in the body cause injuries similar in nature to those from external radiation but more localized. Iodine has a tendency to destroy the thyroid gland cells and, therefore, indirectly cause interference with the regulation of growth and other functions of the body. Plutonium and fission products destroy the blood-forming mechanism in the bone marrow.

4. Treatment of Radiation Injuries

A great deal of experimental work has been done on treating of radiation injuries. (6) No practical method has been found for preventing the death of cells or tissues heavily injured by radiation. However, the regenerative powers of the body are great, and if the body can be helped to survive the acute stage of illness, even the most radiosensitive tissues may be able to resume their normal functions. Many treatments help the body through the acute stage of the illness. Whole blood, plasma, and plasma substitutes revive the blood supply to the body. Penicillin limits infections. Certain materials, such as toluidine blue, help to reverse the tendency to bleeding. Physicians also maintain the salt and water content in the patient's body. Adequate nutrition, especially with substances used by the body to manufacture proteins and cells, is also necessary.

DECLASSIFIED

DECLASSIFIED

REFERENCES

- (1) Los Alamos Scientific Laboratory, The Effects of Atomic Weapons, P. 342, (June, 1950).
- (2) H. M. Parker, H.I. Divisions, Hanford Works, private communication, (Feb., 1951).
- (3) Parker, Radiology 54 257 (1950).
- (4) Parker et al., Introductory Lecture Series in Health Instrumentation, Part I, Chapters III, X, and XII, Hanford Works, (1947).
- (5) Patterson et al., Manual of Standard Procedures for 100, 200 and 300 Area Survey Work, Hanford Works, (1949).
- (6) United States Atomic Energy Commission, Sixth Semiannual Report, Washington, D.C., (1949).
- (7) United States Atomic Energy Commission, Eighth Semiannual Report, Washington, D.C., (1950).
- (8) HW-9259 Review of the Stack Discharge Active Particle Contamination Problem. H. M. Parker. 3-22-48.
- (9) HW-10475 H.E.W. Technical Manual, Section C. Author not stated. Pp. 131-134, 1203-1215. 5-1-44.

DECLASSIFIED

PART V: SAFETY, continued

CHAPTER XXII. SHIELDING

<u>CONTENTS</u>	<u>Page</u>
A. ABSORPTION OF ALPHA AND BETA PARTICLES	2202
1. Alpha Radiation	2202
2. Beta Radiation	2202
B. ATTENUATION OF GAMMA RAYS	2203
1. The Gamma-Ray Attenuation Problem	2203
2. Attenuation by Distance	2204
3. Attenuation by Passage through Matter	2204
3.1 General	2204
3.2 Absorption mechanisms	2204
3.21 Photoelectric absorption	2204
3.22 Compton scattering	2205
3.23 Pair production	2205
3.24 Absorption in lead	2205
3.3 Attenuation calculations	2205
4. Attenuation by Scattering	2207
C. REDOX PLANT SHIELDING	2209
REFERENCES	2211

DECLASSIFIED

CHAPTER XXII. SHIELDING

Radioactive fission products are formed during irradiation of the uranium slugs, as described in Appendix A. The high initial beta and gamma radioactivity due to these fission products in the slugs decreases with "cooling", as discussed in Chapter II. Since this radioactivity is harmful to personnel, they must be protected from it by distance or by intervening shielding materials. As discussed below, the vessel walls absorb the beta radiation, but several feet of concrete are required to reduce the very penetrating gamma rays to a harmless level.

Irradiated uranium emits three principal types of radioactivity: alpha and beta particles, which are discussed in Section A, below, and gamma rays, or photons, which are discussed in Section B of this chapter.

A. ABSORPTION OF ALPHA AND BETA PARTICLES1. Alpha Radiation

The isotopes of uranium and some of the transuranic elements which are formed during irradiation emit alpha particles, which are helium nuclei. Due to their large mass (compared with electrons or photons) and double charge, the ion production per unit length of path (i.e., rate of energy absorption by matter through which the particle passes) is high. This means that the total energy of the particle is absorbed in passing through a relatively small amount of matter, the distance traveled being known as the range in that material. For example, the range of the 4.18 M.e.v. (Million electron volts) alpha particle from U^{238} is approximately 1 inch in air, 0.001 inch in the dead layer of skin, 0.0006 inch in aluminum, and 0.00035 inch in lead. Because of the above-mentioned short range of alpha particles, alpha radiation is an important hazard only when the alpha emitter is taken into the body. No shielding is required to protect personnel from external alpha radiation.

2. Beta Radiation

Fission products and some of the transuranic elements which are formed during irradiation, as well as some of the daughter elements of uranium, emit electrons known as beta particles, or beta rays. Beta particles do not produce as many ions per unit length of path as alpha particles and, therefore, are more penetrating. For example, the 2.3 M.e.v. beta particle from either UX_2 or Rh^{106} has a range of approximately 25 feet in air or 0.15 inch in aluminum. Beta particles do not normally penetrate container walls. They constitute a radiation hazard only when taken into the body, or when the individual is exposed directly to the source, such as the exposed surface of a solution containing beta emitters, or a bare radioactive metal.

DECLASSIFIED

1145
DECLASSIFIEDB. ATTENUATION OF GAMMA RAYS1. The Gamma-Ray Attenuation Problem

Most fission products and transuranic elements which are formed during irradiation, as well as most isotopes of uranium and its daughter elements, emit a very penetrating form of radiation known as gamma rays. Gamma rays are electromagnetic radiations, or photons, originating from a nucleus. Unlike alpha and beta particles, gamma rays have no definite range in matter, but are absorbed approximately according to an exponential law on passing through the material. The range of gamma ray energies of interest in the 200 Areas is from 0.1 to 2.3 Million electron-volts (M.e.v.).

Attenuation (i.e., intensity reduction) of gamma rays may be accomplished by distance, by passage through matter, and by scattering. The various attenuation mechanisms are considered in detail on the following pages of this section. These mechanisms are employed in the Redox Plant to reduce intensities to values consistent with personnel safety. As discussed in Chapter XXI, the tolerance level for uncontrolled zones, such as the storage and operating galleries, is 0.1 mr./hr. (milliroentgens per hour). For controlled zones, such as the sample galleries or the canyon deck, the tolerance level is 1 mr./hr.

The table below lists gamma ray intensities and required attenuation factors corresponding to typical radiation sources in the Redox Plant. The tabulated intensities are values at points which are 8 feet from the equipment piece, in the case of tanks, or 12 feet from the equipment piece, in the case of columns. Each of these dimensions approximately equals the effective distance from the particular radiating source to the outside of the shielding wall. Therefore, the attenuation factor for that source is only that required of the mass of the shield and is not a function of distance. Attenuation factors listed are those required for uncontrolled zones.

<u>Source</u>	<u>Gamma Ray Intensity</u>	
	<u>Intensity, R./Hr. (a)</u> <u>(90 Days "Cooling")</u>	<u>Attenuation Factor</u> <u>Required</u>
IAF Tank	1750	2×10^7
IAF Tank (b)	3200(b)	4×10^7
Waste Concentrate Receiver	600	6×10^6
IA Column	186	2×10^6
IB Column	0.2	2000
IBP Receiver	0.4	4000
3EU Receiver	0.0007	7

Notes: (a) One r. (roentgen) of radiation liberates 83.8 ergs in each gram of air. (See Chapter XXI).

(b) This intensity and attenuation factor result from 40-day, rather than 90-day, "cooling".

DECLASSIFIED

DECLASSIFIED

2. Attenuation by Distance

Apart from the attenuating effects of any matter through which the radiation passes, the intensity of gamma rays at any point varies with the distance from the source. It is also a function of the shape of the source.

For a mathematical point source gamma ray intensity is inversely proportional to the square of the distance from the source. For an infinite line source the intensity is inversely proportional to the first power of the distance. At points close to very large plane or bulk sources the intensity is not reduced due to distance alone, although, of course, attenuation takes place by the absorption mechanisms discussed under 3.2, below.

As an approximation usually sufficiently close for practical purposes, a real object source may be considered a point source when the distance of the receptor from it is greater than the largest dimension of the source. Thus a sample or a tank viewed from a sufficient distance may be treated as a point source.

Similarly, a long source, like a column or pipeline, may be treated as an infinite line source if it is longer than the distance to the receptor and its diameter subtends an angle smaller than 60° at the receptor.

Large bulk sources or surface sources, such as process vessels or spills viewed from above, produce an intensity which either does not vary with distance or decreases more slowly than inversely with the first power of the distance. This is true when the distance is less than the diameter of the source. The intensity varies inversely with nearly the square of the distance when the distance is larger than the diameter of the source.

3. Attenuation by Passage through Matter

3.1 General

Unlike alpha and beta particles, gamma rays are not completely stopped by passing through a certain thickness of matter, but are attenuated by a factor which is, approximately, an exponential function of the thickness of matter traversed. This attenuation is the result of partial absorption of the gamma rays by three possible mechanisms: photoelectric absorption, Compton scattering, and pair production. These absorption mechanisms are described, and their relative importance under various conditions is discussed, under 3.2, below. The calculation of attenuation factors for gamma rays of various energies passing through various shielding materials is discussed under 3.3, below.

3.2 Absorption mechanisms

3.21 Photoelectric absorption

Photoelectric absorption occurs when the entire energy of the photon is used to eject an electron from one of the inner orbits of an atom. Absorption by this mechanism predominates at low gamma energies and increases with the atomic number of the absorber. In light elements, such

DECLASSIFIED

DECLASSIFIED

as aluminum, the photoelectric effect accounts for most of the absorption up to about 0.1 M.e.v. In heavy elements, such as lead, it is effective up to about 1 M.e.v.

3.22 Compton scattering

Compton scattering is a collision of a photon and an electron in one of the outer orbits of an atom in which part of the photon's energy is used to eject the electron from an atom, while the remainder of the energy appears as a scattered photon. This process accounts for most of the absorption in the intermediate energy range (0.1 to 10 M.e.v. in aluminum; 1 to 4 M.e.v. in lead). Compton absorption varies with the number of electrons per cubic centimeter of absorber and hence is proportional to the density of the absorber. Therefore, in the energy range where this process predominates, the effectiveness of a shield is roughly proportional to its sectional density, expressed in grams per square centimeter, and is nearly independent of the composition of the shield. Compton absorption decreases with increasing gamma energy.

3.23 Pair production

Pair production occurs when a photon enters the field of a nucleus and is converted into a positive electron (positron) and a negative electron, plus a certain amount of translational energy of these particles. The electron is absorbed like a beta ray; the positron collides with another electron and the mass of the two particles is converted into two 0.5 M.e.v. photons. This phenomenon occurs to a significant extent only at very high gamma energies (above 10 M.e.v. in aluminum; above 4 M.e.v. in lead) and increases rapidly with the energy of the photons and the atomic number of the absorber. Pair production does not take place to any significant extent in Redox Plant shielding, since the highest gamma energy encountered is only approximately 2.5 M.e.v.

3.24 Absorption in lead

Figure XXII-1 shows the contribution of each of the absorption mechanisms to the total absorption of gamma radiation in lead. Individual and total absorption coefficients are plotted as functions of photon energy. Below approximately one M.e.v., photoelectric absorption is the predominating mechanism; from about one to four M.e.v., Compton scattering accounts for most of the absorption; and above this range absorption by pair production becomes particularly significant.

3.3 Attenuation calculations

3.31 The attenuation equation

The attenuation of gamma radiation upon passage through matter may be computed from the following equation, based on the combined effects of the absorption mechanisms involved:

$$I = I_0 e^{-\mu t}, \dots \dots \dots (1)$$

DECLASSIFIED

8511

where I = radiation intensity after traversing t centimeters of absorber, in roentgens/hour;

B = a correction factor for secondary photons produced by Compton scattering (see text and table below);

I_0 = initial radiation intensity in r./hr. at 1 cm. (see 3.23, below);

e = 2.718;

μ = absorption coefficient in reciprocal centimeters (see Figure XXII-2).

The absorption coefficient, μ , is equal to the reciprocal of the mean free path, in centimeters, of the radiation in the absorber. This mean free path is the thickness of absorber required to reduce gamma ray intensity by a factor of e .

The empirical correction factor B allows for the photons which are not destroyed (but merely reduced in energy and diverted) by Compton scattering. The magnitude of B varies with the absorber material, with energy level, and, probably, with shield thickness. Previously, it was believed that the value of B becomes constant after the radiation has traversed several mean free paths. Recent data⁽⁸⁾ indicate that this is not true. It is possible that B increases with the shield thickness, t , raised to some power, probably between 0.5 and 2. Several experimenters are currently working on this problem. The values of B used in designing the Redox Plant are shown below.

Magnitude of Correction Factor B (7,8)

Absorber	Correction Factor B			
	At 0.5 M.e.v.	At 1.0 M.e.v.	At 1.5 M.e.v.	At 2.0 M.e.v.
Air	---	---	6	---
Water	6	3	---	3
Concrete	---	1.5	---	---
Steel	1.2	1.2	1.2	1.2
Lead	1.0	1.0	1.0	1.0

For use in the equation above, Figure XXII-2 presents a plot of the total absorption coefficient (μ) as a function of gamma ray energy, for each of several common absorbing materials. Also included are two other ordinates, related to the absorption coefficient, which in some cases are more convenient to use: (a) the thickness in inches required to reduce the primary radiation intensity by a factor of 10 and (b) the mean free path, in centimeters. It should be emphasized, however, that the thickness to reduce the primary radiation by a factor of 10 does not allow for secondary photons produced by Compton scattering, which are taken care of in the equation above by the "B" term.

DECLASSIFIED

1149
HW-10700

3.32 Calculation of initial radiation intensity

For the practical application of Equation (1), above, the initial radiation intensity, I_0 , of the source must be known in the current units. Values of I_0 , in r./hr. at one cm., for point sources and large sources, may be calculated by means of the equations shown below.

The intensity of radiation from a point source, in r./hr. at one cm., may be computed from the curies of radioactivity, C, and the photon energy, E, in M.e.v., as follows:

$$I_0 = 5500CE \dots\dots\dots(2)$$

In a large source, such as the IAF Tank, a considerable fraction of the intensity is absorbed in the source itself and appears as heat energy. It is evident that radiation from incremental volumes near the surface is not attenuated, but radiation from incremental volumes some distance from the surface will be attenuated to an extent dependent on the distance the ray traverses in reaching the surface. Thus, the fractional contribution to the total radiation leaving the surface decreases exponentially as incremental volumes further from the surface are considered. It may be shown by integration that the total radiation from an infinitely thick source is equal to the radiation from a source one mean-free path in thickness, measured in the direction of the beam, without self-absorption. The intensity of radiation from the IAF Tank is thus computed from the curies per ml. of IAF, c, for each photon energy, E; the mean free path, $1/\mu$, in cm.; and the projected area, A, of the tank in sq. cm. as "seen" by the receptor.

$$I_0 = \frac{5500 cEA}{\mu} \dots\dots\dots(3)$$

To compute the intensity penetrating a shield the intensity arrived at by Equation (3) is divided by the square of the distance between source and receptor and by the attenuation factor of the shield. For a rigorously accurate solution, this must be done for each energy and the intensities summed to obtain the total intensity. However, a solution accurate enough for most practical purposes may be obtained by the use of conservative simplifying assumptions about the photon-energy spectrum of the source. For example, in shielding calculations for Redox process materials, the assumption that all the photons have an energy of 1.5 M.e.v. will generally yield approximately correct results.

4. Attenuation by Scattering

4.1 Scattering by solid objects

As discussed previously, when a primary gamma ray impinges on matter, such as a thick slab, the mechanism of Compton scattering produces photons of reduced energies. These photons are scattered in all directions, some of them escaping from the slab on the same side as the source. The net effect is a "reflection" of a portion of the primary ray. However, unlike the reflection of light, the fraction of the photons which rebound are scattered back away from the surface in all directions.

DECLASSIFIED

In the design of shielding, gamma ray attenuation resulting from scattering by the shield must be considered in addition to attenuation by passage through the shield. If there is any possibility for radiation to be scattered around a shield or through an opening in the shield, the design must insure adequate attenuation by scattering. In practice this is accomplished by means of labyrinths. The labyrinth provides an adequate thickness of shielding for attenuation (by absorption) of straight-line radiation and, at the same time, attenuates to a harmless intensity the radiation which is scattered through the labyrinth by successive "reflections".

Figure XXII-3 gives relationships useful for estimating energy and intensity value for photons scattered from a thick slab. The problem is illustrated by the sketch which shows a ray from a source, S, incident at a given angle θ_1 , to a massive scatterer of unit projected area as defined in Figure XXII-3, and scattered into unit solid angle at a given angle, θ_2 . The scattered angle, θ , measures the deviation of the scattered ray from the path of the primary ray. All angles are measured in a plane passing through the source, the scatterer, and the receptor.

The two plots in Figure XXII-3, for primary rays at energies of 2 and 0.5 M.e.v., respectively, show intensity functions versus angle of "reflection", θ_2 , for various values of angle of incidence, θ_1 . If the cross-sectional area of the incident gamma ray at the scatterer is less than the projected area of the scatterer, the smaller area is used in computing the scattered radiation intensity. The use of these figures to compute the radiation scattered from a thin scatterer (on the order of one mean free path) will yield intensities considerably too high. When the source and/or the scatterer may not be considered "points" they should be divided into parts; each small part is then considered a "point", and the total intensity is the sum of the intensities from all parts of the scatterer resulting from exposure of each to all parts of the source.

The energy of the major component of the scattered radiation may be computed with the equation given on Figure XXII-3. The remainder of the scattered radiation will be even less energetic since it originates from multiple scattering.

When an opening, such as a doorway, is provided in a shield, it must be in the form of a labyrinth so that direct radiation will traverse the usual shield thickness. For example, an opening in a 5-foot shield must be constructed so that any straight radiation path passes through at least 5 feet of shield calculated by adding the distance in each part of the labyrinth. In addition, the radiation which enters the opening must be subjected to a sufficient number of scatterings to reduce the intensity of radiation reflected through the labyrinth to a harmless level.

4.2 Sky shine

"Sky shine" is a special case of scattering from a massive "shield", the atmosphere, with both the source and the receiver in the shield. The radiation intensity due to sky shine is presented, in Figure XXII-4, for radiation projected vertically in a moderately narrow cone (approximately

1 steradian* or a 60° angle) with the receptor at the level of the source at a horizontal distance, d. However, for radiation projected into a cone of solid angle approaching 2π steradians (i.e., a hemisphere), this figure yields intensities several times too low. For large angles (greater than π steradians or 120°), the equation given on the figure may be used as an approximation. This equation is based on 2 M.e.v. primary radiation.

C. REDOX PLANT SHIELDING

After its discharge from the piles, irradiated uranium is transported to the 212 Building for storage. From storage, it is transported, as required, to the Redox Processing Building (202-S) for processing. During all phases of these operations, shielding adequate for personnel safety is required. Such shielding has been incorporated into the design of facilities in accordance with principles discussed above. Radiation intensities are thereby reduced to a maximum of 0.1 mrep./hr. (milliroentgen equivalent physical per hour) in uncontrolled zones or 1.0 mrep./hr. in controlled zones.

Irradiated uranium slugs are transported, by railroad, in massive casks (described in Chapter XVI) which provide 12 inches of lead for shielding. This shielding reduces gamma intensity outside the cask to the order of 1 mr./hr. Each cask houses one bucket of uranium (approximately one-half ton). Upon arrival at the 212 Building, the irradiated uranium is stored under a minimum of 16 feet of water. Since the water provides adequate shielding, the remainder of the 212 Building is of conventional construction. After the required "cooling" period, the slugs are transported to the 202-S Building.

At the 202-S Building, the bucket of slugs is removed from the cask by means of the crans. During this operation, the intensity of radiation beamed through the railroad tunnel is high; therefore, casual bystanders are excluded from entering the tunnel by a fence on the north side of the building. Also, since no special shielding is provided for railroad personnel, they must withdraw to the Gatehouse.

The principal shielding elements in the 202-S Building are concrete walls and roofs. For economy of design and construction, the thickness of any continuous wall is constant. The thickness is that required to give protection from the radiation source of maximum intensity shielded by the wall. Thus, the shielding for many parts of the building is more than adequate.

The upper walls of the canyon are 3 feet 10 inches thick and were designed to protect personnel in the operating gallery when one bucket of

*) A steradian is defined as the solid angle subtended at the center of a sphere by an area on the sphere's surface equal to the square of the radius. (Thus, the surface of the entire sphere subtends 4π steradians.)

1152 [REDACTED] **DECLASSIFIED**

2210

HW [REDACTED]

slugs is suspended near the wall. The ceiling of the cross-canyon passage is 4 feet thick and protects personnel from slugs overhead. The lower canyon wall, on the north, is 5 feet thick and protects an operator in the sample gallery (a controlled zone) from a full charge in a tank directly through the wall from him. The lower canyon wall, on the south, is 5 feet 6 inches thick and protects an operator in the storage gallery (an uncontrolled zone) from a full charge in a tank on that side of the canyon.

The roof over the dissolver cells and railroad tunnel is 9 inches thick. This protects people outside the building from sky shine. Over "colder" parts of the building, roof thickness is reduced to 6 inches. Except for the westernmost cell cover on the north side, all cell covers are 4 feet thick. This permits access to the canyon when covers are in place and no radioactive material is above deck level.

To eliminate direct radiation to the crane cab, the cabway is shielded by a concrete wall 2 feet 2 inches thick. The crane operator in the cab is protected from scattered radiation by 4-1/2 inches of steel on the top and upper sides, 3 inches on the lower sides, and 1-1/2 inches on the bottom.

The silo-wall thickness of 3 feet 6 inches was determined by the shielding requirements for the IA Column filled with IAF. Silo windows are 3 feet thick for the IA and IS Columns, and 20-inches thick for the other columns.

DECLASSIFIED

[REDACTED] [REDACTED]

DECLASSIFIED

1153
HW-18700REFERENCES

- [REDACTED]
- (1) Cork, Radioactivity and Nuclear Physics, D. Van Nostrand Co., New York (1947).
 - (2) Heitler, The Quantum Theory of Radiation, 2nd. Ed., Oxford Univ. Press, London (1944).
 - (3) Rasetti, Elements of Nuclear Physics, Prentice Hall, Inc. New York (1936).
 - (4) HW-10475 H.E.W. Technical Manual, Section C. Author not stated. 5-1-44. Pp. 131-144, 1101-1109.
 - (5) HW-17415 Activity of Fission Products. P. R. Gillette. 4-14-50.
 - (6) KAPL-317 Compton Scattering of Gamma Rays from a Thick Slab at Skew Angles. L. Tanks and L. H. Root, General Electric Co. 3-20-50.
 - (7) KLX-24 Nomograms for the Calculation of Gamma Shielding. J. L. Balderston, J. J. Taylor and G. J. Brucker, Kellogg Corp. 11-15-48.
 - (8) R-132 Scattering and Absorption of Gamma Rays and Neutrons. M. S. Flesset and S. T. Cohen, Rand Corp. 3-1-49.
 - (9) TNX-7 The Computation of Radiation Hazards, C. W. J. Wende, du Pont Co. 11-11-44.
- [REDACTED]

DECLASSIFIED

1154

HV-18700

DECLASSIFIED

[REDACTED]

THIS PAGE
INTENTIONALLY
LEFT BLANK

[REDACTED]

DECLASSIFIED

[REDACTED]

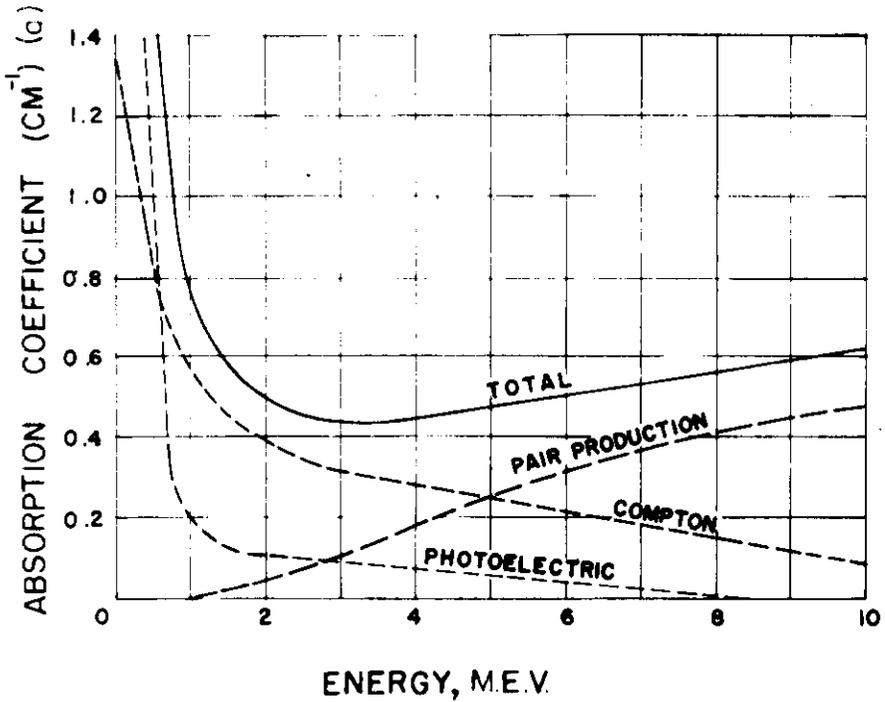
DECLASSIFIED

[REDACTED]

Figure XXII-1

THE ABSORPTION OF GAMMA RADIATION IN LEAD

Data from Cork⁽¹⁾, Figure 6.6 page 152



Note: (a) As explained in the text, the absorption coefficient is the reciprocal of the shield-thickness required to reduce the incident gamma-ray intensity by 2.718-fold. This thickness is also the mean free path of the gamma ray in the shield material.

This plot gives only approximate values of the absorption coefficient. For shielding calculations the more exact values presented in Figure XXII-2 should be used.

[REDACTED]

DECLASSIFIED

[REDACTED]

1156

HW-18700



DECLASSIFIED

**THIS PAGE
INTENTIONALLY
LEFT BLANK**



DECLASSIFIED

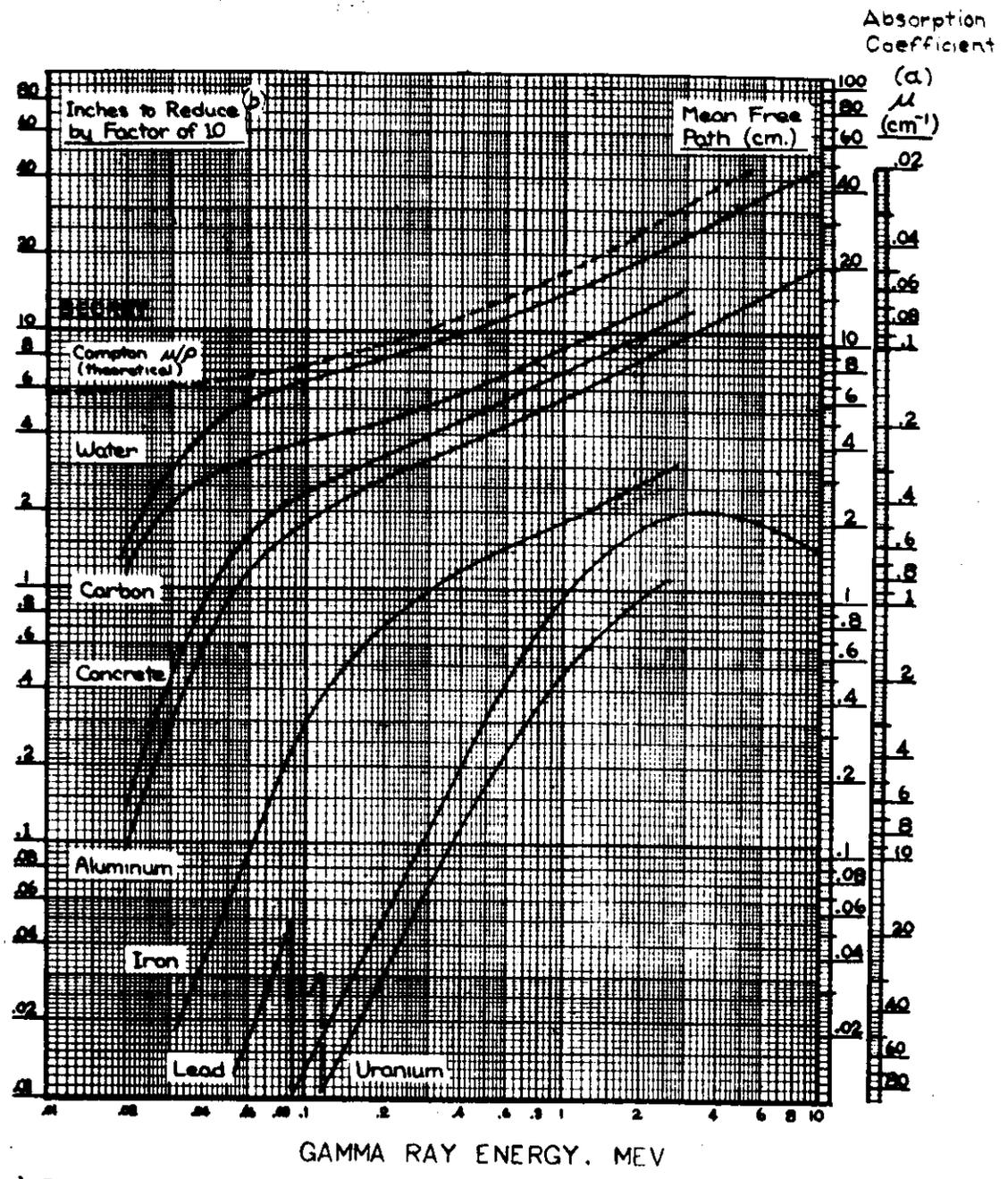


DECLASSIFIED

FIGURE XXII - 2

HW-18700

ABSORPTION OF GAMMA RADIATION



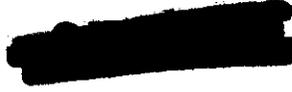
- Note:** (a) Refer to the text and Figure XXII-1 for further explanation of the absorption coefficient. The use of the absorption coefficient in calculations is explained under C 3.3 in the text.
- (b) This ignores the secondary photons produced by Compton scattering. (See C 3.3 in text).

DECLASSIFIED

1158

HW-18700

DECLASSIFIED

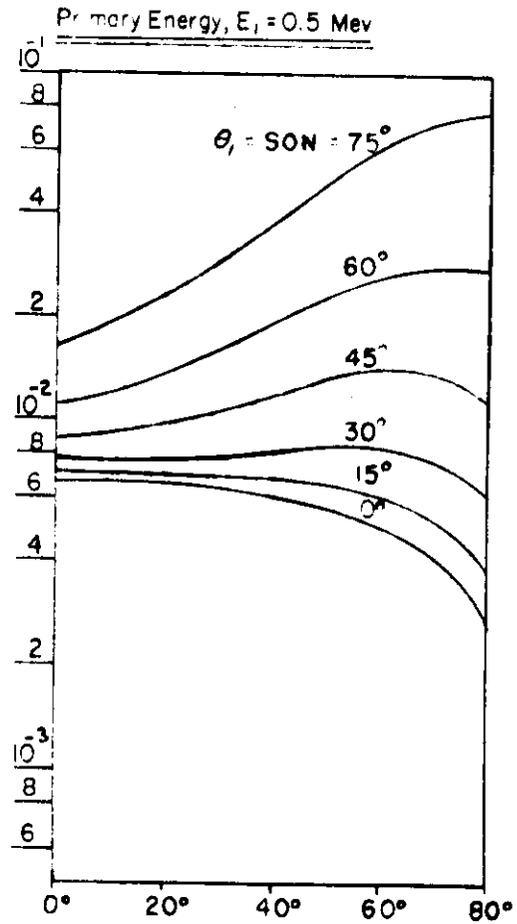
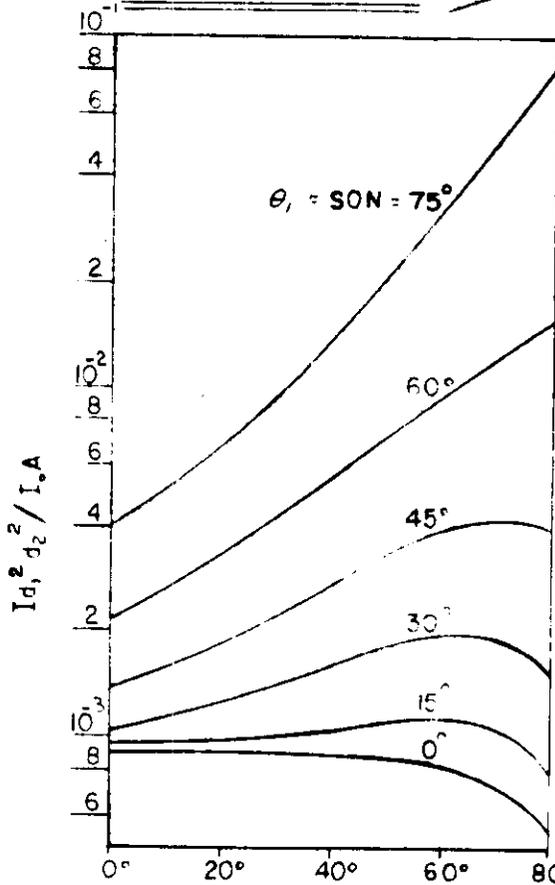
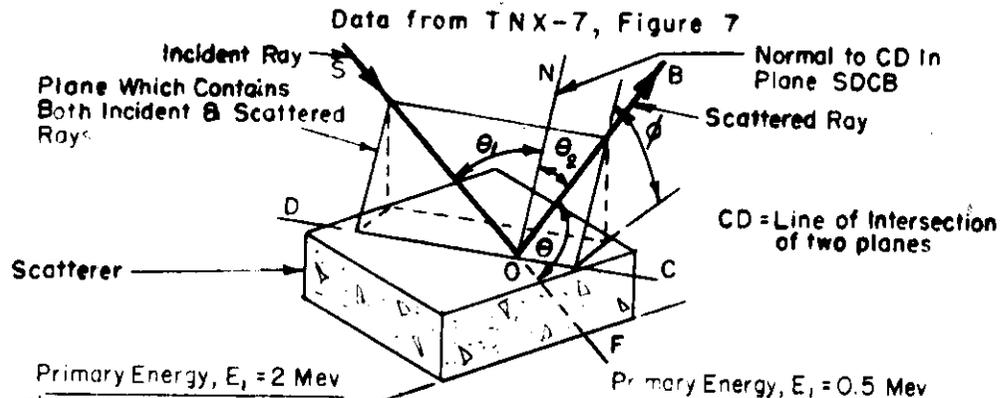


THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

REFLECTION COEFFICIENT FOR COMPTON SCATTERER IN A THICK SLAB



Nomenclature

- I = Intensity at receptor, r./hr.
- I_0 = Intensity at source, r./hr. at 1 cm
- a = Distance from source to scatterer, cm.
- d_2 = Distance from scatterer to receptor, cm.
- A = Projected area of scatterer, sq. cm.
 $= (\sin \phi \cos \theta_1) (\text{area of scatterer})$
- θ = Scattered angle (FOB)
- ϕ = Angle of inclination of plane of incident and scattered ray to scatterer

Note

The energy, E_2 in MEV. of the scattered ray may be computed from the following equation:-

$$\frac{E_2}{E_1} = 1 + 1.96 E_1 (1 - \cos \theta)$$

Equation from TNX-7, Figure 5

1160

HW-18700

DECLASSIFIED



THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

DECLASSIFIED

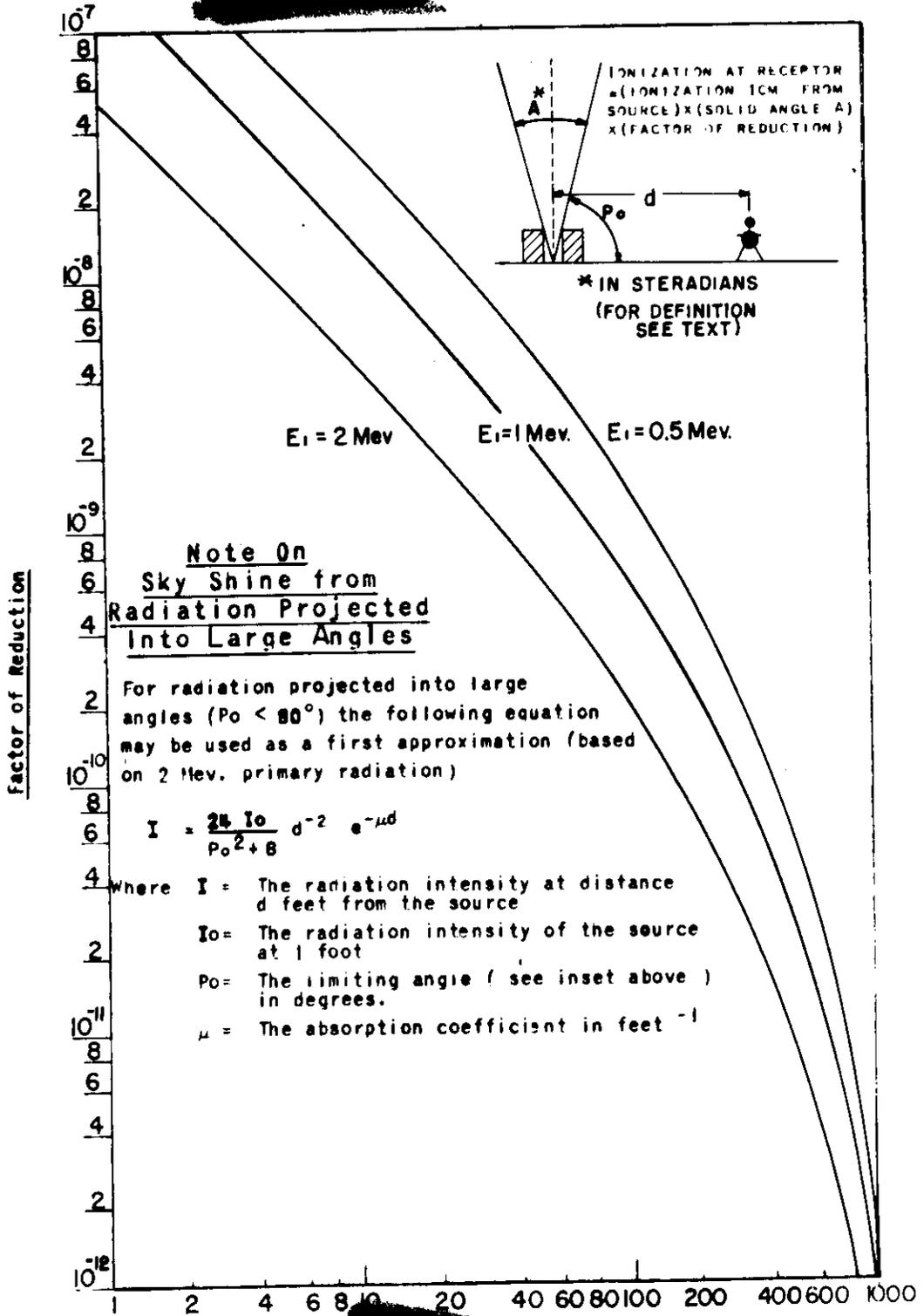
1141

HW-18700

Figure XXXI-a

SKY SHINE

from TNX-7 Figure 9



DECLASSIFIED

1162

HW-18700

DECLASSIFIED



**THIS PAGE
INTENTIONALLY
LEFT BLANK**



DECLASSIFIED

PART V: SAFETY, continued

CHAPTER XXIII. DECONTAMINATION OF SURFACES

<u>CONTENTS</u>	<u>Page</u>
A. INTRODUCTION	2302
1. General	2302
2. Terminology	2303
B. APPLICATION TO REDOX PLANT	2303
1. Factors Influencing Decontamination	2303
2. Provisions for Application of Decontamination Procedures ..	2304
C. STAINLESS STEEL.....	2305
1. Internal Alpha Contamination	2305
2. External Alpha Contamination	2305
3. Internal Beta and/or Gamma Contamination	2306
4. External Beta and/or Gamma Contamination	2307
D. OTHER MATERIALS OF CONSTRUCTION	2307
1. Iron and Carbon Steel	2307
2. Concrete	2308
3. Glass	2308
4. Lucite	2308
5. Wood	2309
E. PROTECTIVE COATINGS	2309
1. Requirements of a Protective Coating	2310
2. Components of a Protective Coating	2310
3. Decontaminants	2311
4. Redox Plant Protective Coatings	2311
5. Strippable Coatings	2312
6. Polyethylene	2312
F. SKIN	2313
G. CLOTHING	2314
REFERENCES	2315

DECLASSIFIED

HW 19

CHAPTER XXIII. DECONTAMINATION OF SURFACESA. INTRODUCTION1. General

Surface decontamination will find application in the Redox Plant for the removal of radioactivity from the various operating equipment and areas in order that personnel may approach the equipment to make necessary maintenance changes. The circumstances requiring the removal of activity from surfaces will vary widely. The intensity of radioactivity present in the various areas within the plant will cover a very wide range and the types of work which require decontamination of equipment and areas will also vary considerably. The total radioactivity entering the plant will pass successively through the dissolver cells, feed treatment, first decontamination column, and the waste handling cells; the balance of the plant will be processing material reduced in radioactivity by factors up to 10^2 compared to the original specific activity. Consequently, for most maintenance work it will be necessary to remove equipment from the areas associated with process steps preceding the IB Column because of the high degree of contamination present. Areas and equipment associated with process steps subsequent to this point, although designed for remote handling and maintenance, may possibly be reduced in radiation intensity to a point permitting personnel to work on the equipment in place under SWP (Special Work Permit) conditions. The first-noted condition requires that only the equipment necessitating maintenance attention be reduced in the degree of contamination. The second condition demands not only that the specific piece of equipment be decontaminated, but also that all other pieces and structural elements which "see" the zone where work is to be performed be reduced to a tolerable level as determined by the length of time required to perform the work.

The decontamination of process equipment resolves essentially to the problem of removal of radioactivity from stainless steel. This particular material has received considerable study, and a fair degree of success has been realized up to the present time. The structural and supporting elements of the plant are fabricated almost solely from concrete and mild steel. These materials are extremely difficult, if not impossible, to decontaminate. Within the plant, all non-stainless steel elements with a few very minor exceptions have been protected with Amercoat No. 23, a protective coating which has good resistance to process chemicals and prohibits wetting the bare material with contaminants. This permits the use of chemical reagents for decontamination purposes which might otherwise react with the unprotected surfaces.

Decontamination of the surfaces of equipment and structural elements of the Redox Plant will necessarily be performed on the basis of empirical procedures which result from knowledge obtained at Hanford Works, in plant practice and laboratory studies, and from Oak Ridge National Laboratories (ORNL) experience in semiworks and pilot plants. The usefulness and feasibility of decontamination has been demonstrated at those sites. For example, at ORNL one building has been used, successively, for pilot plant

DECLASSIFIED

operations on the BiPO_4 process and various solvent-extraction processes. During these operations, total radioactivity ranged from tracer level to full Hanford level. The principal difficulties at that site were encountered in the decontamination of concrete and mild steel surfaces. The stainless steel process equipment lent itself readily to adequate decontamination. The ability to decontaminate under these conditions has enabled the unit, which is maintained solely by contact methods, to function more or less continuously for six years. The confidence in decontamination which has been developed at ORNL is exemplified by a report⁽¹⁰⁾ describing a proposal for a separations plant employing only contact maintenance.

Previously developed decontamination techniques satisfied specific conditions but will not necessarily constitute optimum procedures for the Redox Plant. For example, nitric acid is a widely used reagent which could give unfavorable results under some circumstances because of its etching action on stainless steel. Similarly, many other reagents have been reported to be efficient in the removal of radioactivity, but the effects of their repeated use on the surface being treated have not been noted or correlated. The following sections describe the reagents and techniques which have been employed for decontamination procedures, together with any qualitative or quantitative results which have been obtained. Further study of decontamination problems is expected to lead to more rapid and less costly methods.

2. Terminology

The procedure of decontamination has given rise to the use of certain special terms and concepts.

The term decontamination is used to designate the removal of radioactive chemical elements from solid surfaces.

Contaminants are the radioactive elements present on the solid surface.

Mechanism of contamination is the means whereby the radioactive elements are transferred to and fixed to the solid surface.

Decontamination methods are the means utilized to remove the radioactive elements. They may be generally classified as (a) physical -- total or partial removal of the contaminated surface; (b) chemical -- reaction with the radioactive elements or the larger mass of the associated non-radioactive materials to convert to a soluble or extractable condition; and (c) physico-chemical -- suspension by surface-active agents.

B. APPLICATION TO REDOX PLANT

1. Factors Influencing Decontamination

Because of particular process and design characteristics, it is anticipated that decontamination of surfaces will find more application to the Redox Plant than has been the case with the BiPO_4 plants. Some of these characteristics and their effects are described below.

- 11/10/62
- (a) The inactive anions and cations in the Redox process solutions do not normally form insoluble compounds, and any deposits formed by exceeding the saturation point, such as would result from leakage and evaporation on an external surface or concentration within stagnant zones in evaporators or concentrators, should be removable with water flushes. In contrast, relatively insoluble phosphate and fluoride compounds constitute a necessary part of the Bismuth Phosphate process. Consequently, the removal, by simple water flushes, of deposits resulting from leakage or splashing onto normally dry surfaces has not been effective.
 - (b) The Redox Plant incorporates more advanced design for confining process materials within the interior of processing equipment. Most generating equipment such as agitators and centrifuges are totally sealed. All tanks are connected to a closed, venting system which will confine the particulate activity resulting from agitation and movement by pumps and jets from vessel to vessel.
 - (c) The employment of continuous flow equipment in the Redox process necessitated increased mechanical complexity with a greater possibility for equipment replacement and adjustment.
 - (d) The zones of activity level will be reduced to a low level within the first decontamination cycle. This will increase the proportion of the total processing area which can potentially be serviced by direct-contact, SWP maintenance.
 - (e) Facilities (Remote Shop, Regulated Shop, Decontamination Room), as described in Chapter XVIII, have been provided for servicing repairable contaminated equipment.

2. Provisions for Application of Decontamination Procedures

2.1 Protective coatings or sheathing

Structural elements in the plant have been either protected with a chemically resistant coating, such as Amercoat No. 23, or constructed of 18-8 Cr-Ni stainless steel. Thus, all exposed concrete within cells has been protected with Amercoat No. 23, with the exception of the areas immediately around the extraction columns which are protected with stainless steel sheathing. Structural steel elements and certain equipment fabricated from carbon steel have been protected with Amercoat No. 23. This type of construction will permit removal of the gross radioactivity by simple water flushing.

2.2 Materials of construction

Process equipment which is normally wetted by process solutions has been fabricated almost entirely from stainless steel. Some important but relatively small elements utilize Stellite, boron carbide, and Teflon. All of these materials have exceptionally good resistance to chemical attack and are expected to be readily decontaminable.

1167
DECLASSIFIED

2.3 Design features

Process equipment design utilizes drainable and flushable surfaces for all components normally in contact with process solutions. The process equipment also incorporated water-flooded seals for all pumps and agitator shafts which, in conjunction with the vent header system, effectively restrict major contamination to interior surfaces of the process system.

C. STAINLESS STEEL

The process equipment components (tanks, lines, pumps, etc.) of the Redox Plant are fabricated almost entirely from the 300 series of chrome-nickel stainless steels. The specific type employed has been chosen on the basis of corrosion resistance and the type of fabrication permissible. The decontamination of stainless steel will consequently be of prime interest. Since the problem of decontamination is solved by an empirical approach, discrimination between the types of the 300 series is not justifiable except by reason of the superiority to corrosion resistance of the 25-12 Cr-Ni type over that of the 18-8 Cr-Ni type.

The contamination of stainless steel can be placed in four categories: (a) alpha contaminants on internal surfaces, (b) alpha contaminants on external surfaces, (c) beta and/or gamma contaminants on interior surfaces, (d) beta and/or gamma contaminants on exterior surfaces. The recommended procedures are based on empirical results obtained at Oak Ridge National Laboratories and Hanford Works. In general the least corrosive decontaminant should be used so that attack upon the equipment may be maintained at a minimum. Internal surfaces should be first in the sequence of decontamination because of the greater freedom and control associated with this operation.

1. Internal Alpha Contamination

Internal alpha contamination will generally be most severe in equipment associated with steps subsequent to the IA Column and, primarily, with steps subsequent to the 2D and 2A Columns.

Nitric acid is the preferred decontamination reagent, as the chemistry of the principal alpha contaminants (Pu and U) favors solution in this medium. Sixty per cent acid is the most effective, although lesser concentrations have been used successfully. Some judgment must be exercised, as it is possible to roughen highly polished surfaces with strong (20% or greater) acid. Normally, a temperature of 25 to 30°C. is adequate. General physical and chemical principles indicate that higher temperatures would be more effective, although there is no substantial information to support this.

2. External Alpha Contamination

The most probably areas of external alpha contamination within the Redox Plant will be coincident with those for internal contamination. The

DECLASSIFIED

DECLASSIFIED

problem of decontaminating external surfaces is complicated by the possibility of extending the contamination to otherwise clean areas. Therefore, caution must be exercised, since the need for decontaminating surfaces adjacent to those originally contaminated may be increased by unrestricted and uncontrolled flushing.

The following precautions should be observed in decontaminating external surfaces:

- (a) The redistribution of existing contamination should be limited to the smallest possible area.
- (b) The surface should not be flooded with water or other decontaminating reagents.
- (c) The surrounding surfaces which might be wetted during the decontamination treatment should be protected.
- (d) Contaminated materials such as tools, rags, swabs, or gloves should not be placed in uncontaminated areas. Disposable containers such as bags or boxes should be used for storing of all cleaning supplies.

The choice of decontamination reagents will be dependent on factors such as the original surface finish, necessity for preserving the finish, and limitations of drainage facilities for solvents or highly reactive chemical agents. The materials listed below have been found to be useful for room-temperature application, but their relative effectiveness has not been established.

- (a) Nitric acid (60 per cent).
- (b) Organic solvents; e.g., Stoddard Solvent, CCl_4 .
- (c) Citric acid (20 per cent).
- (d) Permanganate-bisulfite. The sequence of operations consist of scrubbing the surface with saturated KMnO_4 solution, removing the KMnO_4 by wiping, scrubbing the surface with 10 per cent NaHSO_3 solution, and flushing the surface with water.
- (e) Chromic acid (corrosive to stainless steel).
- (f) Abrasives; e.g., Bon Ami.

3. Internal Beta and/or Gamma Contamination

Beta and gamma contamination will be the predominant contamination through the IA Column and, because of the less favorable chemistry of the fission products, may accumulate in subsequent process equipment despite the large decontamination achieved through the first decontamination cycle. Since most of the surfaces contaminated with beta and/or gamma contaminants will also be contaminated with alpha contaminants, it is general practice

DECLASSIFIED

to use nitric acid for the first flush, particularly if any significant amount of plutonium holdup is suspected. Although beta and/or gamma contaminants are not completely removed by nitric acid, it is believed that it is useful in removing the major portion of non-radioactive materials constituting the film in which the radioactivity is bound.

Oxidizing, reducing, and complexing agents have been successfully used at Oak Ridge National Laboratories. In one instance, a dissolver tank with an original activity level of 80 roentgens/hr. at 10 feet was reduced to 10 mr./hr. at a distance of 3 inches. The various decontaminating agents used and their relative effectiveness are indicated in Table XXIII-1.

In addition to these liquid decontaminants, live steam has been reported to assist materially in the decontaminating process. The optimum conditions of its use have not been established. The mechanism of decontamination with steam is not fully understood. It is conjectured that it penetrates minute recesses inaccessible to liquids. It is believed that it also acts by the exertion of some abrasive action.

4. External Beta and/or Gamma Contamination

The most probable zones of contamination will be coincident with those for internal contamination. This decontamination problem is the most difficult of the four discussed because (a) the flush solution is not confined by the equipment and (b) precautionary measures to restrict the spread of contamination by the decontaminating agents cannot be employed because the range of the gamma rays prohibits the approach of personnel to the contaminated surfaces. The decontaminating agents recommended for the preceding case (Subsection 3.) can be employed for removal of the contamination. To minimize the fraction of contamination on the surfaces contacted by the decontaminating agents in the course of their flow from the area undergoing treatment to the collection point (sump or drain), the entire wetted area should be liberally flushed with water as a concluding treatment.

D. OTHER MATERIALS OF CONSTRUCTION

1. Iron and Carbon Steel

1.1 General

Iron and carbon steel have been employed for machine and structural elements (e.g., electric motors, jumper braces) which are not normally wetted by process solutions. As installed, these elements are protected by a chemically resistant coating, Amercoat No. 23. The type of contamination expected on these surfaces follows the pattern given in Section C of this chapter. Experience with decontamination of unprotected iron or steel has been generally unfavorable. Complete removal of the contaminated piece, if possible, appears to be the most practical solution to the problem.

DECLASSIFIED

1.2 Decontaminants

Nitric acid, although effective in decontaminating chrome-nickel steels, is not effective in the decontamination of unprotected iron and steel. The degree of re-adsorption of the highly diluted, radioactive elements by the freshly formed, unoxidized metallic surface appears to create a practical obstacle which limits the decontamination. In the course of trying to decontaminate some unprotected iron and steel surfaces at Oak Ridge National Laboratories (8) water flushing reduced the measured radiation from 10 roentgens/hr. at a 3-foot distance to 10 roentgens/hr. at a distance of 1.5 feet. Subsequent treatment with solutions of HNO_3 and HCl did not significantly reduce the radiation intensity. In addition to the ineffectiveness of acidic solutions, their use increases the difficulty of successfully removing the contamination with subsequent decontaminating agents because of the surface-etching effect of the acid.

Alkaline solutions (sodium carbonate) and detergents have been reported, on a qualitative basis, to be the most effective agents.

2. Concrete

Concrete, in the absence of a protective surface coating, retains contaminants to a high degree. Chemical or physico-chemical reagents have not been effective in removing either chemically fixed or physically adsorbed radioactivity. The Redox Plant has been designed and constructed on the basis that concrete surfaces will always be protected by a chemically resistant coating (Amercoat No. 23). In the event of contamination which penetrates through to the concrete base material, only two courses appear practical: (a) physical removal of the contaminated surface, or (b) shielding of contaminated concrete surface to permit necessary maintenance work in the immediate area of contamination.

3. Glass

The use of glass in the 202-S Building is limited to the silo viewing windows. Glass finds its greatest application in the construction of laboratory equipment. As such, no general predictions can be made regarding the probable type of contamination. A five per cent solution of NH_4HF_2 has been effective in decontaminating glass at ORNL (8). Etching does not result if the time of contact is kept to a minimum.

4. Lucite

Lucite (polymerized methyl methacrylate), a transparent thermo-plastic, is a construction material of the PR Cage and also finds numerous applications as a component in laboratory equipment. The transparency of Lucite is an essential requirement in its PR Cage application; therefore, precautions must be taken to use decontaminating agents which do not cause "fogging". In laboratory applications loss of transparency is of less concern. Cleaning solution (95% sulfuric acid saturated with sodium dichromate), routinely used in laboratories as a decontaminant for Lucite, causes "fogginess", which increases with the number of applications.

DECLASSIFIED

The primary contaminant in the PR Cage is plutonium in an aqueous nitric acid system. The preferred procedure for removal of plutonium contamination is as follows:

- (a) The adjacent uncontaminated areas are protected with absorbent paper.
- (b) 5 to 10% nitric acid solution is applied by swabbing. (Nitric acid in concentrations in excess of 20% attacks Lucite). The swabbed area is permitted to remain wet for 3 to 5 minutes.
- (c) The nitric acid is removed by sponging the surface with water.
- (d) A detergent, 1% Muslor 224 or a saturated aqueous solution of Calgon, is applied by swabbing or sponging. (Muslor 224 is a product of Synthetic Chemicals, Inc.; Calgon, of Calgon, Inc.).
- (e) The detergent is removed with water.
- (f) The surface is dried with soft, clean, non-abrasive cloth or paper.

Personnel carrying out the decontamination must be adequately protected from the alpha radiation present, according to procedures described in Chapter XXI. In order to avoid recontamination of the surface separate containers must be provided for clean and used cleaning materials.

The transparency of a polished Lucite surface may be impaired and permanent fixation of plutonium may be caused if the surface is wetted by a reagent in which Lucite is soluble. Since Lucite is soluble in many common organic solvents, including hexone, no organic solvents should normally be used for cleaning or decontaminating it.

5. Wood

Wood is utilized primarily for those structural or equipment items, such as office fittings and furniture, not normally subject to contamination. Occasional temporary requirements may result in the introduction of wood into process or laboratory areas. Decontamination of wood is extremely difficult because of its porous, absorbent structure.⁽²⁾ Protection from fixation of activity is dependent upon the applied protective coating.⁽³⁾ In the event that contamination penetrates the protective coating either partial or total removal of the wood appears to be the most practical and economical procedure.

E. PROTECTIVE COATINGS

The surfaces embraced by this classification are second in importance only to the stainless steels since the other principal materials of construction for radioactive zones (concrete, iron, and mild steel) do not generally lend themselves to decontamination by treatment with chemicals. Therefore, to permit decontamination of these essential materials of construction, they must be protected with a surface film.

1172

1. Requirements of a Protective Coating

The ideal protective coating should meet the following specifications:

- (a) The coating must form a permanent and tenacious bond to the base material.
- (b) The coating must have chemical resistance to the process solutions with which it may be wetted and to the decontaminating agents with which it will be accidentally or intentionally wetted.
- (c) The coating must have flexibility compatible with the surface to which it is applied, as this surface may change dimensionally due to mechanical or thermal stresses.
- (d) The coating must have adequate abrasion resistance. Extreme brittleness or low cohesion will permit the coating to be destroyed by normally expected mechanical action.
- (e) Only materials which set with a smooth and glossy surface are satisfactory. Finishes similar to "crackle" may result in a small, but finite, retention of solutions or their residue upon evaporation.
- (f) Unsaturated linkages tend to react irreversibly with iodine to form a permanent fixation. Otherwise, the chemical composition does not appear to correlate with susceptibility to decontamination; i.e., vinyl, methyl methacrylate, furfuraldehyde, or formaldehyde resins exhibit no differences. (8)(2)
- (g) Decontamination appears to be most readily accomplished on those films which are the least wetted by water.

2. Components of a Protective Coating

In effect, a complete protective coating should be built up in three layers: the seal coat, the permanent surface coat, and the final surface coat. Three separate materials or a single material may be used. In either case, the requirements noted below must be satisfied.

2.1 Seal coat

This coat must penetrate the porous material (concrete to a depth of several millimeters) and fill all pores or small voids.

2.2 Permanent surface coat

This is preferably a homogeneous extension of the seal coat and must exhibit good chemical resistance to attack by process or decontaminating solutions as well as low adsorptivity.

1173
DECLASSIFIED

2.3 Final surface coat

This film should be smooth, chemically resistant to process and decontaminating solutions, and not readily wetted by them.

3. Decontaminants

Since the protective films are the only barrier to essentially permanent contamination of the base materials, it is important to use a decontaminant which will inflict the minimum damage to the coating. Highly reactive materials such as nitric acid, chromic acid, or caustic soda should be used only as a last resort. The following agents, listed in order of preference, are recommended.

- (a) Water.
- (b) Detergent solutions.
- (c) Complexing agents, oxalates, citrates, tartrates.
- (d) KMnO_4 -- NaHSO_3 . This requires direct manual application of a 1 to 2 per cent KMnO_4 solution for a five-minute period followed by scrubbing with a 10 per cent solution of NaHSO_3 and, finally, wiping or washing with water.

4. Redox Plant Protective Coatings

The protective coatings employed in the Redox Plant for application to steel and concrete surfaces are Amercoat No. 23 and, to a lesser extent, Amercoat No. 33. The Amercoats are manufactured by Amercoat Division of the American Pipe and Construction Company from a resin of vinyl chloride polymerized to varying degrees and dissolved or suspended in a mixed organic solvent. The organic solvents are predominantly ketones and all of the formulations contain 10 to 20 per cent methyl ethyl ketone, which has an open-cup flash point of 66°F. and lower and upper explosive limits of 1.8 to 11.5 volume per cent. After complete drying the surface finish is free of organic solvents and no fire or health hazard exists.

Amercoat No. 23 consists of two prime coats, three body coats and, lastly, three seal coats. It represents as near an approach to the desired properties of protective coatings as it was possible to procure for application by conventional brush or spray methods. Since the material is not completely resistant to the hexone solvent, care must be exercised to prevent contact in the event of hexone leakage. Water should be employed to flush the surface to prevent damage to the coating and to minimize the likelihood of fixing any contamination in the protective coating. Amercoat No. 23 exhibits a high retentive capacity for contamination when wetted by hexone.

Amercoat No. 33 is a single-component finish applied as a minimum of three coats. The base resin is polyvinyl chloride. The finish has essentially as good chemical and abrasion resistance as Amercoat No. 23 but it is not suitable for prolonged contact with aqueous solutions. It

DECLASSIFIED

is used only in those areas which are subject to wetting only by splashing or which are accessible to operating personnel for immediate flushing.

Another Amercoat, No. 55, is a three-component finish consisting of prime, body, and seal coats. The base resin is polyvinyl chloride. It is so formulated that it has better resistance to concentrated (60%) nitric acid than either No. 23 or No. 33, but it lacks the abrasion resistance of these coatings. It is not used in the Redox Plant, but it will be employed to cover the interior surface of the concrete pipe trench connecting the 200 East and 200 West Areas.

5. Strippable Coatings

Strippable coatings, unlike the permanent coatings discussed so far, function by retaining the contamination in a soft, flexible, slightly adhesive film which can be physically removed from the protected surfaces. Such coatings are usually porous or tacky and readily wetted by process solutions. Their chemical or solvent resistance must be sufficient to prevent disintegration.

Although coatings of this type are not specified in the Redox Plant, the advantages inherent in a strippable coating may render its use desirable in certain applications, particularly in the Laboratory Building (222-S).

A series of studies at ORNL⁽⁹⁾ on the retention of contaminants and the chemical resistance of various strip coats to HCl, HNO₃, H₂SO₄, and hexone indicated that D-1000, polyvinyl butyral dispersion, made by Monsanto Chemical Company, was the most effective in resisting chemical attack and fixing the contaminants in the coating. Other strip coats evaluated by ORNL, Liquid Strip Coat 533-45A, a product of American Resinous Chemical Corp., Cocoon Strip Coat, a product of Hollingshead Corp., and Spraylat, a product of Spraylat Corp., were inferior to D-1000 in terms of retention of radioactivity or chemical resistance.

6. Polyethylene

Polyethylene is a high molecular weight, ethylene polymer. When applied as a sheet or flame-sprayed coat, it is nearly totally resistant to attack by inorganic chemicals or solvents. The surface of the coating is extremely easy to decontaminate. Polyethylene was not originally specified for application to the Redox Plant, but it is available for use in special situations calling for its desirable properties.

Highly specialized techniques are required for obtaining a satisfactory polyethylene coating. The occurrence of pinholes in the surface was the principal deficiency observed during the development of methods of applying polyethylene coatings to a concrete surface. This condition did not prevail on application to a metallic surface. The problem has been reduced in magnitude through improved techniques of application and the preparation of a smooth and dense concrete surface prior to flame spraying. Pinholes now occur at a frequency of one per square foot and their total elimination is considered possible.

Only un compounded polyethylene, free of color additives such as TiO_2 , should be used for coatings since these additives have been found to act as adsorption centers for contaminants. Because of the high degree of water repellency of polyethylene, water flushes are generally adequate for decontamination, although more reactive agents, such as nitric, hydrochloric, or hydrofluoric acids, as well as suitable solvents (hexone), may be used without injury to the material. Prolonged contact of polyethylene with concentrated solutions of inorganic chemicals or nitric acid may result in embrittlement and cracking.

F. SKIN

Skin decontamination is especially important because of the danger of the entrance of contaminants into the body, either orally or through skin breaks.

The rate of skin decontamination varies considerably among individuals and is largely dependent on the original condition of the skin. In all cases where a rough outer layer of skin is present, decontamination is more difficult until this outer layer is removed and the skin surface is polished.

It has been found at Hanford that the best decontaminating agent for removal of uranium contamination is a mixture of sodium bicarbonate and a detergent (such as Duponol) combined in a one-to-one ratio and applied to the wetted, contaminated skin. The material should be worked into a lather for about one minute, then rinsed off under running water.⁽⁴⁾ A detergent and sodium bicarbonate should be used for plutonium removal and, if necessary, a permanganate-bisulfite procedure. The permanganate-bisulfite procedure consists of wetting the hands and lathering them with $KMnO_4$ crystals, rinsing and lathering with $NaHSO_3$ crystals, and then re-rinsing. The procedure should be repeated if necessary. The removal of UF_4 from the skin may be accomplished by use of the following substances, listed in the order of their effectiveness.⁽³⁾

- (a) Corn meal and sodium bicarbonate.
- (b) Boraxo and sodium bicarbonate.
- (c) Liquid soap and sodium bicarbonate.
- (d) Calgonite and Aerosol solution.
- (e) Boraxo.
- (f) Liquid soap.
- (g) Old Dutch cleanser.

Old Dutch cleanser seemed reasonably effective on the first washing, but upon further use seemed to have little effect. Apparently, material which was not removed with the first wash was worked into the skin by further use of the cleansing powder.

Fission-product contamination on the skin is removed by the following procedure:

- (a) The contaminated area is swabbed with liquid soap until a good lather is obtained. The lather is removed with water swabs. The procedure should be repeated, as necessary.
- (b) If the contaminant is still present, the area is swabbed with 4% KMnO_4 solution. Three applications, with drying between successive applications are required. The color produced by the KMnO_4 is removed with swabs wet with 4% NaHSO_3 solution. Finally, the area is swabbed with water.
- (c) If the contamination remains, TiO_2 paste is applied to the area and removed by swabbing with water.

F. CLOTHING

In those areas within the separation plant where there is a hazard of personnel contamination with radioactive materials, all persons entering are required to wear coveralls, shoe covers or overshoes, caps, and gloves as a protection against contamination of skin and street clothing. In addition to these items, towels, socks, undergarments, and shoes are furnished where required. This clothing is monitored for contamination both before and after laundering. In the laundry, Igepal CA, a liquid soap, is used as a disinfectant for washing the plant-issue items. Acetic acid is used as the decontaminating agent for beta and gamma-emitting contaminants. Rubber goods and some cloth items are cleaned with 3% nitric acid solution. Soda ash or Wyandotte OS is used with granulated soap for removal of beta, gamma, and alpha-emitting contaminants from cloth. If the contaminant is solid, Wyandotte 33, a detergent, is used.

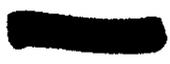
DECLASSIFIED

REFERENCES

- (1) Memorandum: Decontamination of Stainless Steel Surfaces. Haught to Weidenbaum. 12-16-50.
- (2) AD-146 (C) Survey of Decontamination X -- Decontaminability of Woods. W. W. Hawes, B. Singer, Navy Radiological Defense Laboratory. 8-11-50.
- (3) AD-202 (C) Survey of Decontamination XIV -- Behavior of Painted Wood. W. W. Hawes, B. Singer, Navy Radiological Defense Laboratory. 8-16-50.
- (4) HW-10457 H.E.W. Technical Manual, Section C. Author not stated. 1945. Pp. 1301-1311.
- (5) HW-14301 Decontamination of Personnel and Materials from Uranium. I. M. Rehn. 8-30-49.
- (6) HW-14532 Observations and Evaluations of the Decontamination Procedures Employed at ORNL -- Redox Pilot Plant Equipment. J. M. Smith, J. G. Bradley. 9-19-49.
- (7) K-459 Comparative Study of Hand Decontamination Agents for Uranium. J. C. Bailey. 7-15-49.
- (8) ORNL-381 Radioactive Decontamination Properties of Laboratory Surfaces -- Glass, Stainless Steel, and Lead. P. C. Tompkins, O. M. Bizzell, C. D. Watson. 9-26-49.
- (9) ORNL-382 Radioactive Decontamination Properties of Laboratory Surfaces -- Paints, Plastics, and Floor Materials. P. C. Tompkins, O. M. Bizzell, C. D. Watson. 9-26-49.
- (10) ORNL-466 Recommendations for Design of Radioactive Solvent Extraction Units. D. G. Reid. 9-29-49.
- (11) ORNL-732 Decontamination and Corrosion Resistance Properties of Selected Laboratory Surfaces. C. D. Watson, T. H. Handley, G. A. West. 8-29-50.



DECLASSIFIED

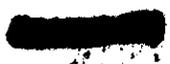


1178

HW-18700


DECLASSIFIED


**THIS PAGE
INTENTIONALLY
LEFT BLANK**


DECLASSIFIED


DECLASSIFIED

1179

HW-18700

Table XXIII-1

DECONTAMINATION EXPERIENCE AT OAK RIDGE

Data from HW-14532

Equipment Piece: 309 SCB Stainless Steel Dissolver Tank (107 Gal. Capacity)

Flush No.	Reagent Used	Treatment	Radioactivity of Effluent Flush Solution, Beta Dis./Min./ML.	Beta Curies Removed	Radiation Level Roentgens/Hr. (1)	
					Start	End
1	60% HNO ₃	24 hr. at 95 - 105°C.	1.4 x 10 ¹⁰	89	80	75
2	60% HNO ₃	Same	8.8 x 10 ⁶	0.6	75	3
3	60% HNO ₃	Same	1.9 x 10 ⁶	0.14	3	4.5
4	60% HNO ₃	24 hr. refluxing	1.4 x 10 ⁷	2	4.5	1
5	35% HNO ₃ , NH ₄ HF ₂	15 min. at 30°C. 1 hr. H ₂ O flush	--	--	--	--
6	4% Oxalic acid	4 hr. 65°C.	2.7 x 10 ⁸	20	2.5	0.7
7	0.6% NH ₄ HF ₂	4 hr. 60°C.	3.4 x 10 ⁸	53	0.7	2.0
8	2.5% NaOH	24 hr. 95 - 105°C.	1.2 x 10 ⁷	1.7	2	--
9	30% HNO ₃ + 3% Na ₂ Cr ₂ O ₇	24 hr. at 95 - 105°C. H ₂ O flush	2.0 x 10 ⁸	15	--	3.4 r/hr. at 3 in.
10	5% HNO ₃ + 4% (NH ₄) ₂ SiF ₆	4 hr. at 80 - 105°C.	8.5 x 10 ⁵	0.1	--	--
11	55% HNO ₃	Same	6.0 x 10 ⁶	0.4	--	1.2 r/hr. at 3 in.
12	43% NaOH + 13% citric acid	Same	1.8 x 10 ⁵	0.1	--	--
13	Same	Same	4.7 x 10 ⁵	0.1	--	--
14	Same	Same	--	--	--	--
15	Same	Same	5.7 x 10 ⁴	0.01	--	--
16	Same	Same	6.4 x 10 ⁴	0.01	--	--
17	1.2% (NH ₄) ₂ SiF ₆	Same	1.8 x 10 ⁴	0.01	--	--
18	1% NH ₄ HF ₂	16 hr. at 30°C.	8.7 x 10 ³	0.01	--	--
19	3.5% HNO ₃ + 1.6% NH ₄ HF ₂	16 hr. at 80 - 105°C.	2.4 x 10 ⁴	0.01	--	10 mr./hr. at 3 in.

(1) Measured at 10 ft. in flushes 1 through 8.
 Inconsistencies in the data with respect to the decrease in radiation level with the number of beta curies removed are unaccounted for.

DECLASSIFIED

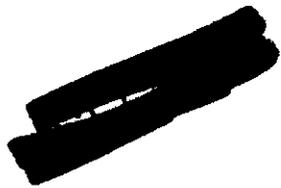
180

HW-18700



DECLASSIFIED

THIS PAGE
INTENTIONALLY
LEFT BLANK



DECLASSIFIED

PART V: SAFETY, continued

CHAPTER XXIV. HAZARDS OTHER THAN RADIATION

<u>CONTENTS</u>	<u>Page</u>
A. FLAMMABILITY AND EXPLOSIVENESS.....	2402
1. Hexone (Methyl Isobutyl Ketone).....	2403
1.1 Flammability and explosiveness of hexone.....	2403
1.2 Extent of hazard.....	2403
1.3 Plant precautions -- 276-S Building.....	2404
1.4 Plant precautions -- 202-S Building.....	2404
1.41 Detection.....	2404
1.42 Inert-gas blanketing.....	2405
1.43 Ventilation.....	2405
1.44 Electrical system.....	2406
1.45 Fire protection.....	2406
1.46 Explosion venting.....	2406
1.47 Emergency exits.....	2406
1.5 Hexone-nitric acid reactions.....	2407
2. Hydrogen.....	2407
3. Propane.....	2408
B. PHYSIOLOGICAL EFFECTS OF PROCESS CHEMICALS.....	2408
1. Hexone.....	2408
2. Nitric Acid.....	2409
3. Oxides of Nitrogen.....	2410
4. Sulfuric Acid.....	2412
5. Sodium Hydroxide.....	2413
6. Sodium Dichromate.....	2414
7. Uranium, Plutonium, and Radioactive Fission Products.....	2414
8. Other Process Chemicals.....	2415
REFERENCES.....	2416

CHAPTER XXIV. HAZARDS OTHER THAN RADIATIONA. FLAMMABILITY AND EXPLOSIVENESS

The Redox process, being a solvent-extraction process, introduces to separations technology a new material to be considered from the viewpoint of flammability and explosiveness. This material, the process solvent, is commonly known as hexone. The process and design engineering incorporated in the Redox process had as a prime consideration the elimination of a fire or explosion, and has made such an occurrence unlikely during actual plant operation. The design has also incorporated features to minimize danger and damage should such an incident occur. This section of the manual is aimed at a discussion of these hazards with particular emphasis on (a) their extent, (b) engineering features designed to eliminate or minimize them, and (c) any special operational precautions required.

The potentially hazardous materials, other than hexone, are hydrogen and propane. Both of these gases have been provided for successfully in the design of the Bismuth Phosphate Plants. A definition of special terms used in this chapter, relative to flammability and explosiveness, is presented below to provide the reader with a better basis for understanding the scope of the problems involved and the extent to which they have been eliminated or minimized.

Class I Locations (National Electrical Codes) -- Flammable gases are, or may be, present in the air in sufficient quantity to produce explosive or ignitable mixtures.

Division 1 -- Those locations in Class I where hazardous concentrations exist continuously, or intermittently, under normal operating conditions.

Division 2 -- Those Class I locations where flammable liquids are normally inside closed containers from which they can escape only in case of tank rupture or in case of an abnormal operating procedure.

Flash Point -- The temperature at which a solvent vaporizes sufficiently to produce a flammable vapor-air mixture capable of ignition by an open flame. This is not necessarily the point where combustion would be sustained. Such a point is termed the fire point and is usually somewhat higher than the flash point.

Ignition Temperature -- The temperature at which a solvent spontaneously ignites without the application of visible means of ignition.

Explosive Limits (L.E.L. and U.E.L.) -- Mixtures of the vapors of flammable solvents with air are explosive only within certain limits related to the respective percentages of flammable vapor by volume mixed with air (lower explosive limit and upper explosive limit). Flashes of flame will appear in mixtures outside these limits, but flame propagation of an explosive nature will not take place.

DECLASSIFIED

1. Hexone (Methyl Isobutyl Ketone)1.1 Flammability and explosiveness of hexone

Hexone is an organic solvent, with a characteristic sweetish odor, which offers a lesser flame and explosion hazard than gasoline. It is used in industry as a component of some lacquer thinners. Vapors of hexone are heavier than air and tend to accumulate at low points. Hexone has a boiling point slightly higher than that of water and, at room temperature, evaporates more rapidly than water. It is less volatile than all common varieties of gasoline.

Physical properties of hexone, pertinent to flammability and explosiveness, are listed below:

Flash point (Tag closed cup)	--	60°F. (10)
(Tag open cup)	--	81°F. (10)
Minimum oxygen content of gas-hexone mixtures necessary to sustain flame propagation	--	11.1% by volume (12)
Ignition temperature in air, dry	--	459°C.(858.2°F.) (12)
Lower explosive limit	--	1.34% by volume (7)
Upper explosive limit	--	8.00% by volume (7)
Temperature corresponding to explosive limits*-- Lower	--	122°F. (12)
Upper	--	212°F. (12)
Odor detection threshold	--	Less than 0.01% by volume
Boiling point (760 mm.)	--	240°F. (12)
Vapor pressure (20°C.)	--	15.2 mm. (12)

The maximum explosive pressure, 88 lb./sq.in. gage, occurs at concentrations of 3 volume per cent hexone when mixtures of dry hexone and air are ignited at atmospheric pressure (7). Normal Processing Building ambient temperatures approximate the flash point of hexone, but are much lower than the ignition temperature.

1.2 Extent of hazard

The storage of quantities of hexone, required to satisfy plant inventory requirements, has been arranged in a manner to minimize any hazard resulting from the presence of large volumes of the solvent. Of the total 67,000 gal. required inventory, 43,000 gal. are stored underground in tanks, SO-141 and SO-142, each a 21,500-gal. carbon steel tank, vented to atmosphere through individual flame arrestors. These tanks are located

*) Explosive limits correspond to vapor pressures at these temperatures.

DECLASSIFIED

DECLASSIFIED

40 ft. north of the Solvent Recovery Building, 276-S, and approximately 130 ft. north and 75 ft. west of the Processing Building, 202-S. An additional 22,000 to 24,000 gal. are normally in process in the Solvent Recovery Building 276-S, in 3 inert-gas-blanketed stainless steel tanks, Organic Treatment Tank, O-1, 13,770 gal., Organic Sampler and Treatment Tank, O-2, 13,820 gal., and Organic Header Feed Tank, O-3, 13,770 gal.

The remaining 2000 to 6000 gal. of hexone is located in the various process lines, tanks, and contactors in the 202-S Building. Of the 2000 to 6000 gal. normally in process, 400 gal. are located in the Organic Head Tank, 804, at the head-tank level of the silo; from 1000 to 5000 gal. (normally 1000), in the Organic Surge Tank, G-1, in G Cell in the canyon; and the remaining 600 gal., in process in the silo and various cells in the canyon area.

Hexone is unloaded from tank cars into the Organic Storage Tanks, SO-141 and SO-142, according to normal chemical plant practice. The tank cars are grounded and Protectoseal manhole covers are used during the unloading operation. The Organic Storage Tanks are underground to reduce the effects of atmospheric temperature variations.

1.3 Plant precautions -- 276-S Building

Besides inert-gas blanketing of the solvent tanks, this building includes such other safety features as (a) complete Class I, Division 1 explosion-proofing of electrical equipment in the process area, (b) isolation of the solvent side from the operating side by a concrete wall, (c) provision of a sump to contain all of the solvent should it spill, (d) a static grounding system, and (e) automatic decant lines to remove any excess water which might be present from operation of the water-fog system. A thermal-detector-actuated, water-fog fire system, with suitable alarms, is provided. The ventilation system provides a change of air every minute in the process side and exhausts the air from floor level to remove any (heavier-than-air) hexone vapors. The processing area is ventilated by two 4400-cu.ft./min. exhaust fans. Ventilation of the operating area is accomplished by one exhaust fan with a capacity of 1000 cu.ft./min., drawing the air from the well in which Tank O-2A is located.

1.4 Plant precautions -- 202-S Building

1.41 Detection

Hexone spills or leaks can be detected by tank liquid-level indicators, sump liquid-level indicators, sump samplers, and air samplers. Over each sump there is an air sampler line which terminates in one of the sample galleries. Three portable gas analyzers are available for checking the explosivity of the atmosphere at each of these points by connecting the analyzer to a sampling point through its gallery terminal point. Frequent checks will be necessary during operation to assure that there is no accumulation of hexone vapor at the sumps. The viewing windows in the silo permit visual inspection of the column shaft for leaks and spills.

DECLASSIFIED

1.42 Inert-gas blanketing

All hexone and hexone-saturated aqueous solutions in the 276-S Building and 202-S Building are handled in inert-gas-blanketed, static-grounded, closed systems. The inert gas is obtained by burning propane in air to give a product gas of approximately the following composition:

N ₂	87 to 88%
CO ₂	10 to 12%
CO	1% max.
H ₂ O	1% max.
O ₂	0 to 0.5%

The O₂ content of this gas is well below the 11.1 per cent by volume necessary to sustain flame propagation. This gas is supplied by two Inert Gas Generators which may be operated from either the normal electrical supply, or the emergency electrical system, in case of failure of the normal power supply. Inert gas is supplied to the vessels in these systems and to the system headers by instrument dip tubes, by sampler jets, and by two, constantly-blowing, inert-gas stations connected to the system headers.

During transfers of solution from vessels within the inert-gas-blanketed system to vessels beyond the system, additional inert gas is required to replace the liquid transferred. This is especially true during the period when the tank is empty and the jet is gassing, since the gassing of the jet results in a rapid depletion of the inert gas within the closed system. This additional gas is supplied by means of an interlock on the air control to the steam jets transferring out of the system, with valves in the inert-gas-supply headers, which results in additional inert gas blowing into the blanketed system each time a jet is operated to transfer liquid out of the system.

1.43 Ventilation

The total blower capacity for ventilation air supplied to the 202-S Building is 133,000 cu.ft./min. A major portion of this volume is in the system serving the process areas. For this system, critical supply and exhaust fans are provided with stand-by units for use in the event of mechanical failure.

The ventilation systems are designed to direct the flow of air from hexone-free areas into the hexone processing areas. The Organic Head Tank, 804, is the only vessel containing hexone located in a "cold" zone of the 202-S Building. This tank is located in a small enclosure on the Silo Feed Tank level. All of the ventilation air for this enclosure is drawn from the Feed Tank Area to give about 40 air changes per hour within the enclosure. Ventilation air is supplied to the canyon at the Crane Cab Gallery level and is exhausted through ports at the bottom of the cells.

1188

The pressure above the canyon deck is -0.2 in. water, with respect to atmosphere. The cell pressure is maintained negative with respect to the canyon. Air flow out of the cells results in 8 air changes per hour and the negative pressure is sufficient to overcome the pressure drop across the cell cover blocks. Calculations have indicated that there is sufficient dilution of hexone vapor to maintain the exhaust ventilation air stream below the lower explosive limit (1.34% hexone by volume) even though all cells which handle organic solutions were flooded with the type of solution normally present in the vessels of those cells.

1.44 Electrical system

All of the electrical equipment in those areas where hexone is processed meets the National Electrical Code Specification for Class I, Division 1 locations. It was not practical to design the electrical equipment on the cranes over the cells and silo, or the canyon and silo lighting, to be explosion proof, but this equipment is totally enclosed. The possibility of fire caused by an electrical discharge at these levels is considered negligible because of (a) remoteness from the possible organic vapor source, (b) the fact that hexone vapors are heavier than air, and (c) the downward sweep of ventilation air.

1.45 Fire protection

The Solvent Treatment Building process area, the organic feed tank enclosure, the silo column shaft, and all cells containing equipment in which hexone is present (Cells D, E, F, and G) have water-fog systems with nozzles directed to blanket the affected area. Each system is controlled from the corresponding cell control panel. Indication of fire or explosion is afforded by temperature elements in each location, which actuate visual and audible alarms at each cell control panel and in the dispatcher's office.

The fact that the individual cells are isolated one from another will tend to localize a fire in any particular cell and prevent its spread.

1.46 Explosion venting

The railroad tunnel door presents a large-area weak point in the canyon structure and pressure increases which escape the cells upward into the canyon will be expended through it. The column-carrier outlet door and the large equipment doors at the silo crane levels will serve to expend pressure increases which might occur in the silo.

In the event of an explosion, a part of the force would be directed through the ventilation system to atmosphere.

1.47 Emergency exits

Emergency exits are located in all galleries, in the canyon, and at all levels in the silo.

1.5 Hexone-nitric acid reactions

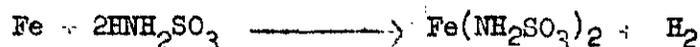
Normal static contact of up to 4M nitric acid in hexone at room temperature produces only a slow reaction. Rapid reactions approaching explosive violence are produced when concentrated nitric acid is brought into sudden contact with an equal or smaller volume of hexone. The greatest opportunity for such a condition to occur exists when nitric acid must be introduced into hexone to prepare solvent streams 0.2 to 0.5M in nitric acid. To avoid such contact, concentrated nitric acid is metered into the hexone by proportioning pumps wherein the ratio of nitric acid flow to hexone flow is automatically controlled. The hydraulics of the metering system are designed so that the two materials cannot become admixed in undesirable proportions, even under abnormal operating conditions.

Aqueous-hexone contact within the process is maintained at a minimum to avoid the production of oxidation products that affect the ability of the process to remove radioactivity from the plutonium and uranium and not because of any chance of a rapid chemical reaction. Further details of these reactions are given in Chapter IV.

2. Hydrogen

In the event that ferrous sulfamate is produced within the Redox Plant, the method of preparation constitutes the only source of evolved hydrogen. As indicated in Chapter III, the evolution of hydrogen during the coating removal step is eliminated by the addition of sodium nitrate.

Hydrogen is evolved in the preparation of ferrous sulfamate from iron powder and sulfamic acid:



In the preparation of a 3-day supply of ferrous sulfamate solution, about 1700 cu.ft. of hydrogen are produced. Since the reaction rate is quite high initially, the bulk of the hydrogen is produced during the first hour of the preparation. Ignition of hydrogen is prevented by purging the Ferrous Sulfamate Preparation Tank, 504, with inert gas during the digestion period. This gas is supplied at 30 cu. ft./min. The inert-gas purge and gaseous reaction products are removed from the Ferrous Sulfamate Preparation Tank by a blower in the vessel vent stack and discharged to atmosphere outside the building.

The physical properties of hydrogen pertinent to flammability and explosiveness are listed below:

Ignition temperature	--	1085°F. (9)
Lower explosive limit	--	4.1% by vol. in air (9)
Upper explosive limit	--	74.2% by vol. in air (9)

3. Propane

Propane is a hydrocarbon which is used industrially and domestically as a bottled fuel gas. Although it is a gas under normal conditions, it can be liquefied at ordinary temperatures at a pressure of about 120 lb./sq. in. absolute.

Propane presents about the same explosion and fire hazard as that involved in the distribution of fuel gas in a city. It is used in the Redox Area as a fuel gas for the inert-gas generators and the laboratory burners of the 222-S Laboratory Building. Two Propane Storage Tanks, SG-161 and SG-162 each with a capacity of 6500 gal., are located east of the Redox Exclusion Area. The Inert-Gas Generators are located in a small building just south of the 202-S Building. No propane is piped into the 202-S Building.

The physical properties of propane, pertinent to flammability and explosiveness, are listed below:

Flash point	--	Below-room temperature
Ignition temperature	--	817°F. (9)
Lower explosive limit	--	2.37% by vol. in air ⁽⁹⁾
Upper explosive limit	--	9.5% by vol. in air ⁽⁹⁾
Boiling point	--	-42.17°C. (-43.9°F.)

B. PHYSIOLOGICAL EFFECTS OF PROCESS CHEMICALS

This review of the physiological effects of the process chemicals is presented to assist supervision in recognizing and minimizing the health hazards involved in the operation of the Redox Plant. Maximum allowable concentrations (M.A.C.) are given for gaseous substances and those which may be present as a mist or a dust. The maximum allowable concentration is defined as the amount of a material to which the average worker may be exposed, for 8 hours daily, without significant harmful effects.

In the Redox process the chemicals which may present a health hazard are hexone, nitric acid, oxides of nitrogen, sulfuric acid, sodium hydroxide, sodium dichromate, and uranium, plutonium, and radioactive fission products.

1. Hexone (Methyl Isobutyl Ketone)

Hexone is an organic solvent, possessing a strong, sweetish odor, which is used in the paint industry as a component of solvent blends. Vapors of hexone are heavier than air and tend to accumulate at low points.

1.1 Tolerance concentrations

The maximum allowable concentration in air, for personnel, is 100 p.p.m.⁽⁴⁾ The expression of this concentration value is abbreviated "M.A.C.".

DECLASSIFIED

1189

1.2 Extent of hazard

In the Solvent Treatment Building, 276-S, 22,000 to 24,000 gal. of hexone are in process or storage. The only possibility of exposure to hexone fumes at this location or in the Processing Building, 202-S, lies in small process leaks (pump glands, valve packing glands, etc.) combined with malfunctioning of the ventilation system. Distribution of the solvent inventory is given in detail in Section A of this chapter.

1.3 Precautions

Hexone can be detected by odor in concentrations considerably less than 100 p.p.m. Since all process hexone is handled in closed systems, there is little opportunity for hexone vapor to be present in the atmosphere. Hexone spills or leaks can be detected by tank liquid-level indicators, sump liquid-level indicators, sump samples, and air samples. Three portable gas analyzers are available for checking the concentration of hexone vapor in the atmosphere over the cell sumps.

The ventilation systems of the 276-S Building and the 202-S Building are designed to direct the flow of air from areas where personnel are normally present to the process areas, thus preventing flow of hexone vapor into personnel areas. In the 202-S Building the pressures in the Operating Galleries and Pipe Galleries are + 0.2 in. and + 0.1 in. water gage, respectively, and in the canyon -0.2 in. water gage. The ventilation system is designed to give 8 air changes per hour in the Operating Galleries.

1.4 Physiological effects

Hexone has the property, common to all organic solvents, that in contact with the skin it removes the natural oils, producing dryness, irritation, and cracking of the skin.

Hexone vapor inhalation causes irritation of the mucous membrane of the eyes and nose at concentrations below 0.1 vol. per cent (1000 p.p.m.).⁽¹¹⁾ A group of workers exposed to approximately 100 p.p.m. of hexone during a normal work-week complained of headache and nausea. Ill effects noted during the week disappeared over the weekend.⁽⁴⁾ Animal experimentation indicated that higher concentrations can cause unconsciousness and that exposure to 1.0 volume per cent concentration (10,000 p.p.m.) causes death in about 4 hours.⁽⁸⁾ Complete recovery could be effected by removal of the animals at any but the terminal stages.

A worker experiencing any of the symptoms mentioned above should be removed to fresh air for recovery.

2. Nitric Acid

Nitric acid is a corrosive mineral acid which is widely used in the chemical industry. Contact with nitric acid causes severe burns. Therefore, the proper types of protective gloves, clothing, and goggles must be worn when handling the material.

DECLASSIFIED

1190

2.1 Tolerance dose and concentration

No limits are specified in the literature for external surface exposure, but about 10 ml. of concentrated nitric acid(3) taken internally is considered a fatal dose.

2.2 Extent of hazard

The daily process consumption of 60 per cent nitric acid is 21,000 lb. (1852 gal.). Approximately 90 per cent of the 60% nitric acid is used in the uranium dissolution step, and some is used in the preparation of aqueous extractant solutions with concentrations of 0.25 per cent (9500 gal.), 0.3 per cent (625 gal.), and 0.6 per cent (500 gal.). The remainder of the nitric acid is employed in acidified organic streams. Nitric acid requirements for equipment decontamination are not included in these figures. The greatest contact hazards are experienced during surface decontamination work and in sampling "cold" aqueous and organic solutions containing nitric acid.

2.3 Precautions

As indicated above, the proper types of protective gloves, clothing, and goggles must be worn when handling nitric acid. Standard chemical plant design practice has been applied to all nitric acid handling facilities. Since nitric acid solutions can be detected visually, proper precautions can be taken in handling liquid spills around process equipment which contains nitric acid. Safety showers are provided at strategic locations in operating areas to provide for rapid irrigation in cases of serious surface exposure.

2.4 Physiological effects

Indication of the magnitude of the contact hazard of nitric acid is given by tests which showed that 70% HNO₃ produces definite skin burns in 5 to 15 seconds. Burns of first, second, and third degree may result from nitric acid contact. Immediate irrigation of nitric acid splashes with water will greatly minimize its effect on the skin.

In case of ingestion, the patient should be given milk of magnesia, up to 8 fluid ounces, and quantities of water or milk, followed with egg white and milk. Emetics and carbonates should be avoided.

3. Oxides of Nitrogen

Oxides of nitrogen are formed when nitric acid is spilled on organic or reducing materials such as sawdust or iron filings. These oxides, known generally as "nitrous fumes", consist of a mixture of NO, NO₂, and N₂O₄.

3.1 Tolerance concentrations

The effects of nitrous fumes over a wide concentration range are listed below: (6) (8)

Concentration, as NO₂, in
Parts per Million

Physiological Response

200 to 700

Rapidly fatal for short exposures.
(1/2 hr. or less at 700 p.p.m.).

100 to 150

Dangerous for even a short period.
(1.2 to 1 hr.).

100

Least amount causing coughing.

60

Least amount causing immediate throat
irritation.

10

Maximum concentration (MAC) for con-
tinuous exposure according to Massachu-
setts State Law, recognized by most
authorities.

3.2 Extent of hazard

Large quantities of nitrous fumes are formed during the dissolution of uranium in nitric acid. From one cut, 2570 lb. of uranium, 1550 lb. of nitrous fumes are evolved with a volume of about 15,000 cu.ft. The uranium dissolution is accomplished in a closed vessel in the process area and the fumes are removed through the Dissolver Off-Gas System. This off-gas system terminates in the 291-S Building stack, where the off-gas is diluted by mixing with the exhaust air from the 202-S Building ventilation system. All of the Dissolver off-gas lines are located in the "hot" zones.

3.3 Precautions

It is estimated, Chapter III, F, that the peak rate of evolution of nitrous fumes from the dissolver is 20 lb.-moles/hr. or 120 cu.ft./min. Stack dilution of these fumes results in dilution to 3500 p.p.m. of nitrous fumes leaving the stack. The most unfavorable atmospheric conditions, causing the fumes to fall to the ground at the base of the stack, gives a dilution factor of 200 from the top of the stack to the ground. This would result in a nitrous fume concentration of 18 p.p.m. at ground level, a concentration considered safe for prolonged exposure of several days but not for continuous exposure. The average concentration of nitrous fumes at ground level during the entire dissolving period would be 6 p.p.m. under the most unfavorable atmospheric conditions.

The presence of oxides of nitrogen may be detected by odor and, to a certain extent, by color. (9a) A characteristic odor is distinct at concentrations of less than 5 p.p.m. in air. In well-lighted areas, 100 p.p.m. or more of nitrogen dioxide (NO₂) in air exhibits a visible, reddish-brown tint. It should be noted, however, that other oxides of nitrogen (NO and N₂O₄) are practically colorless and that the relative proportions of the different molecular forms are temperature dependent. Thus, an atmosphere colored by oxides of nitrogen is probably dangerous, but the absence of color does not necessarily indicate safety.

1192

The concentration of oxides of nitrogen in air can be determined precisely over the range of 5 to 500 p.p.m. by volume by the phenoldisulfonic acid method. (1)

3.4 Physiological effects

Inhalation of nitrous fumes in concentrations above 60 p.p.m. at first causes a painful burning and choking sensation. Exposure to concentrations greater than 120 p.p.m. may cause immediate loss of consciousness. In either case, the aftereffects of the exposure can be very serious, leading to pulmonary edema (swelling of the lung tissue due to effusion of a watery liquid into the cellular tissue), developing several hours after exposure. The greatest danger from nitrous fumes is from exposure to concentrations less than 60 p.p.m., which do not cause any immediate discomfort, but can result in a delayed serious effect.

Complete rest is very important after inhalation of nitrous fumes. The individual should be removed, or remove himself, from the nitrous fume cloud as soon as possible. It is most important that the exposed individual does not exert himself and that he rest and keep warm while waiting for transportation to first aid or the hospital.

4. Sulfuric Acid

Sulfuric acid is a corrosive mineral acid widely used in the chemical industry. In handling sulfuric acid the proper type of gloves, clothing, and goggles must be worn.

4.1 Tolerance concentration

The maximum allowable concentration (M.A.C.) as mist is stated to be 5 mg./cu.m. (2)

4.2 Extent of hazard

In the Redox Plant, 50 lb. (3.3 gal.) of 66° Baumé sulfuric acid is used daily for regeneration of the water demineralizer unit beds. The hazard is considered low degree because of the small quantities involved.

4.3 Precautions

As indicated above, the proper protective clothing must be worn by personnel handling the material. Standard chemical plant practices are employed in handling sulfuric acid. Facilities for providing water irrigation of surface exposures are provided. Being a liquid, the material can be detected visually.

4.4 Physiological effects

Sulfuric acid causes severe burns on contact with the skin. Concentrated sulfuric acid is a strong dehydrating agent, and to this property is due much of the burning and destructive action associated with it. Sulfuric acid mist or vapor effects the upper respiratory tract, but the action is not severe.

DECLASSIFIED

Sulfuric acid splashes on the skin should be rinsed immediately with copious quantities of water. In case of ingestion of sulfuric acid, the patient should be given milk of magnesia, up to 8 fluid ounces, and quantities of water or milk, followed with egg whites and milk. Emetics and carbonates should be avoided.

5. Sodium Hydroxide

Sodium hydroxide is commonly used industrially. Proper protective safety equipment, such as gloves, clothing, and goggles, should be worn when it is handled.

5.1 Tolerance dose and concentration

No limits are specified in the literature for external exposure, but about 2 grams of NaOH taken internally may be sufficient to cause death.⁽³⁾

5.2 Extent of hazard

The daily consumption of sodium hydroxide as 50 per cent solution is about 48,000 lb. (3770 gal.). A portion of this 50 per cent sodium hydroxide is used in making 9800 lb. (820 gal.) of 40 per cent solution and 3260 lb. (308 gal.) of 25 per cent solution. Surface exposure may occur as a result of accidental line leaks, tank rupture, or spills from small sample vessels.

5.3 Precautions

Equipment handling sodium hydroxide solutions was designed in accordance with normal chemical plant practice. Safety showers are provided throughout the operating areas so that serious surface exposures may be irrigated with large quantities of water. As indicated above, the proper protective clothing should be worn by operating personnel.

5.4 Physiological effects

Sodium hydroxide is a dangerous alkali to handle without proper protective clothing, as in any form it quickly attacks the flesh and eyes. There seems to be an inactive period between the time of contact of caustic with the skin and the appearance of the actual burn. No time should be lost in washing the part with water, since this period probably will not exceed a few minutes. The skin should be washed with 2% acetic acid, followed by water, to neutralize the residual caustic. If the caustic is in the eyes, they should be washed with 5% boric acid solution.

Sodium hydroxide, when dispersed as dust or mist of concentrated solutions, is intensely irritating to the upper respiratory organs. Ulceration of the nasal passages may result from long or severe exposure to such compounds.⁽⁴⁾ The swallowing of caustic solutions is considered deadly. If sodium hydroxide has been swallowed, the patient should be given up to 6 fluid ounces of 2% acetic acid, followed with egg whites and milk. The patient should be kept quiet and warm.

DECLASSIFIED

1194

6. Sodium Dichromate

Sodium dichromate is a common, industrial, heavy chemical handled both in solid form and in solution in the Redox process. The formula of the solid is $Na_2Cr_2O_7 \cdot 2H_2O$.

6.1 Tolerance dose and concentration

The maximum allowable concentration (M.A.C.) as CrO_3 mist is stated to be 0.1 mg./cu.m.⁽⁴⁾ A fatal dose varies in amount, but is usually under 8 g.⁽¹¹⁾

6.2 Extent of hazard

Daily consumption of sodium dichromate in the Redox Plant is 490 lb. The material is received as a solid, $Na_2Cr_2O_7 \cdot 2H_2O$, which is used to prepare 50 per cent solution. The greatest opportunity for exposure occurs at the solids handling stage during the preparation of the dichromate concentrate. The resulting solution is at all times within closed vessels. Exposure to solutions is not considered as hazardous as contact with chromate mist or dust.

6.3 Precautions

Conventional packaging and solids handling facilities are provided within the plant. Very adequate ventilation is also provided in the operating areas to minimize the dust and mist hazard.

6.4 Physiological effects

The chief effects of chromate dust or mist are ulceration of the nasal passages and inflammation of the skin. Serious chrome ulceration may result from inhalation of sodium dichromate dust. An abnormal incidence of lung cancer has been reported in workers exposed to chromates.⁽⁴⁾

Sodium dichromate, if taken orally, produces corrosive effects and inflammation of the kidneys in one to forty-eight hours. The effects begin with sore throat, vomiting, diarrhea, and presence of albumin and blood in the urine. Nervous symptoms develop later. The blood pressure is low and hemorrhages in the gastrointestinal tract occur. Less than 0.5 gram of sodium dichromate may cause severe poisoning.⁽¹¹⁾

In case of ingestion of sodium dichromate, the patient should be given 6 to 8 ounces of sodium bicarbonate solution or milk of magnesia.

7. Uranium, Plutonium, and Radioactive Fission Products

Uranium, plutonium, and radioactive fission products present a serious health hazard. The principal physiological effects of these substances is due to their radioactivity. The hazards involved in the handling of these substances are discussed in Chapter XXI.