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CHAPTER 10

10.0 STEAM AND POWER CONVERSION SYSTEM

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CHAPTER 10
STEAM AND POWER CONVERSION SYSTEM

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10.1 SUMMARY DESCRIPTION

The Steam and Power Conversion System consists of components of conventional design, acceptable for use in large central power stations. The equipment is arranged to provide high thermal efficiency with no sacrifice to safety. The system converts thermal energy of the steam produced in the steam generators into electrical energy by means of the turbine generator unit. Exhaust steam from the low pressure (LP) turbines is condensed, reheated in the feedwater heaters, and returned to the steam generators as feedwater. The steam and power conversion system also provides steam for driving the turbine driven auxiliary feedwater pump and for turbine gland steam, reheater steam, waste evaporator, boric acid evaporators, gas strippers, and tank and building heating.

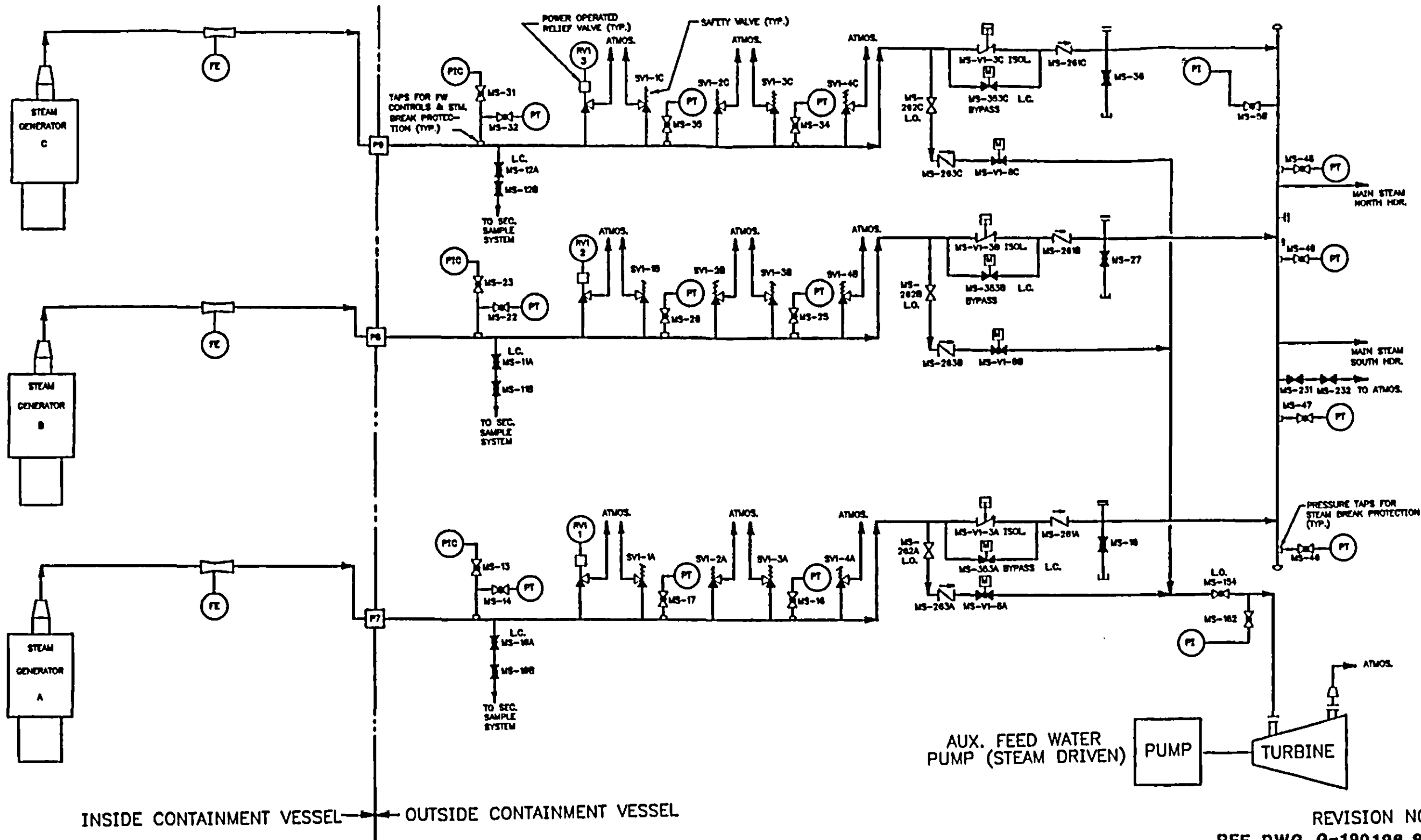
The system design incorporates backup means of heat removal under any loss of normal heat sink to accommodate at least reactor shutdown heat rejection requirements. These backup means include three independent auxiliary feedwater pumps which can be supplied from three independent water supplies.

The system design provides means to monitor and restrict radioactivity releases to the environment such that, considering all controlled plant discharges, 10CFR20 limits are not exceeded under conditions of normal operation and under anticipated system malfunctions or failures.

No radiation shielding is required for the components of the steam and power conversion system outside of the containment. Continuous access to the components of this system will be possible during normal conditions.

Trips, automatic control actions and alarms will be initiated by deviations of system variables within the steam and power conversion system. In the case of automatic corrective action in the steam and power conversion system, appropriate corrective action will be taken to protect the reactor coolant system.

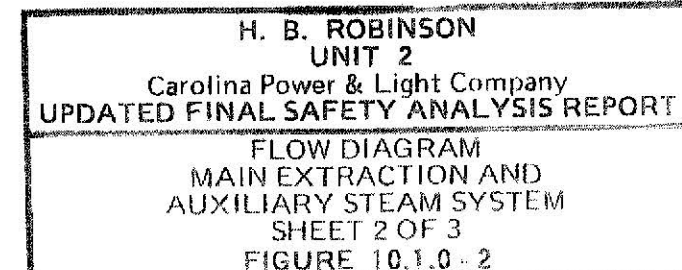
Simplified flow diagrams for the Steam and Power Conversion System are shown on Figures 10.1.0-1 through 10.1.0-8.

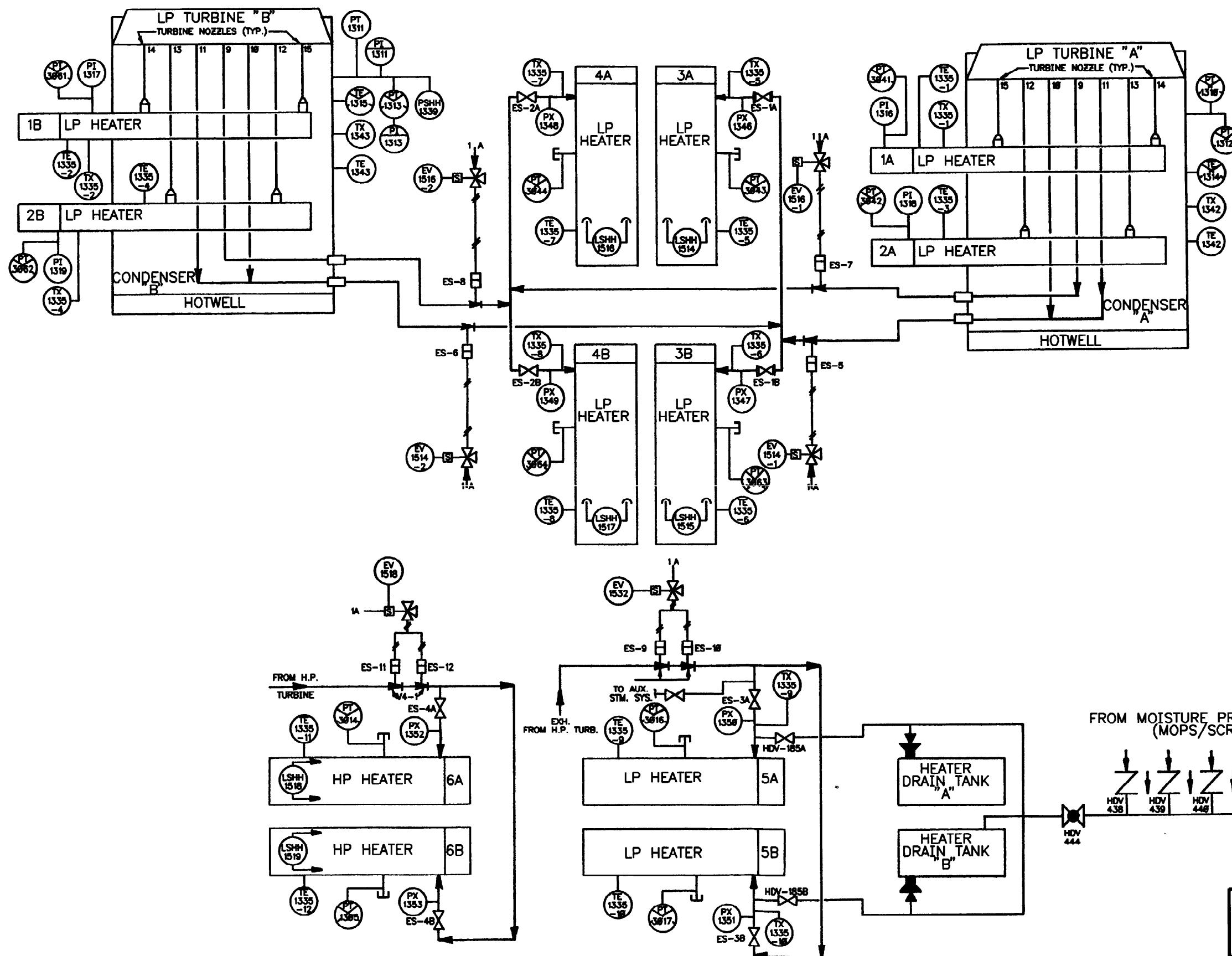


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FLOW DIAGRAM
MAIN, EXTRACTION, AND
AUXILIARY STEAM SYSTEM
SHEET 1 OF 3
FIGURE 10.1.0-1





REF. DWG. G-190196 SHEET 3

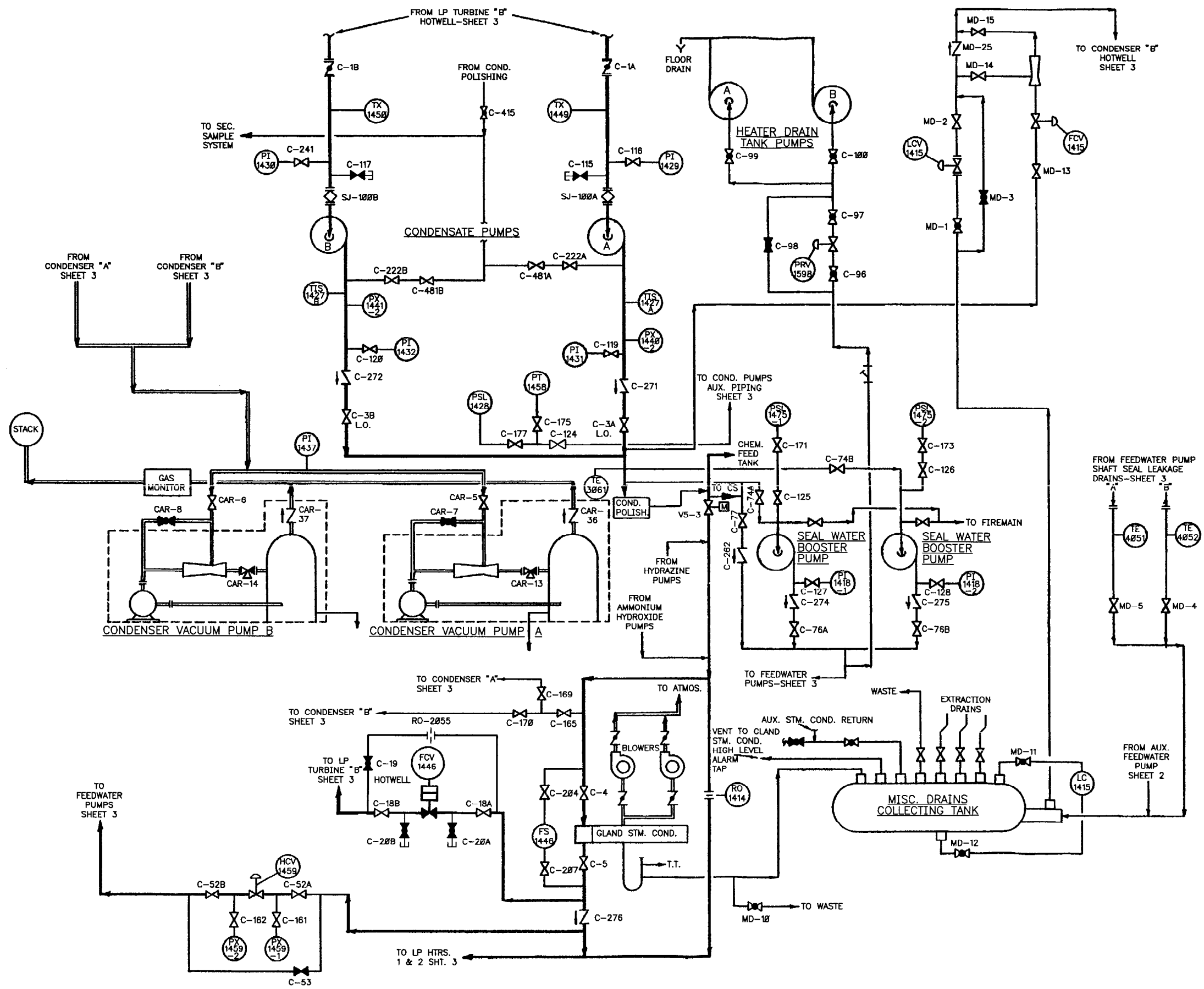
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FLOW DIAGRAM
MAIN EXTRACTION AND AUXILIARY
STEAM SYSTEM SHEET 3 OF 3

FIGURE 10.1.0-3

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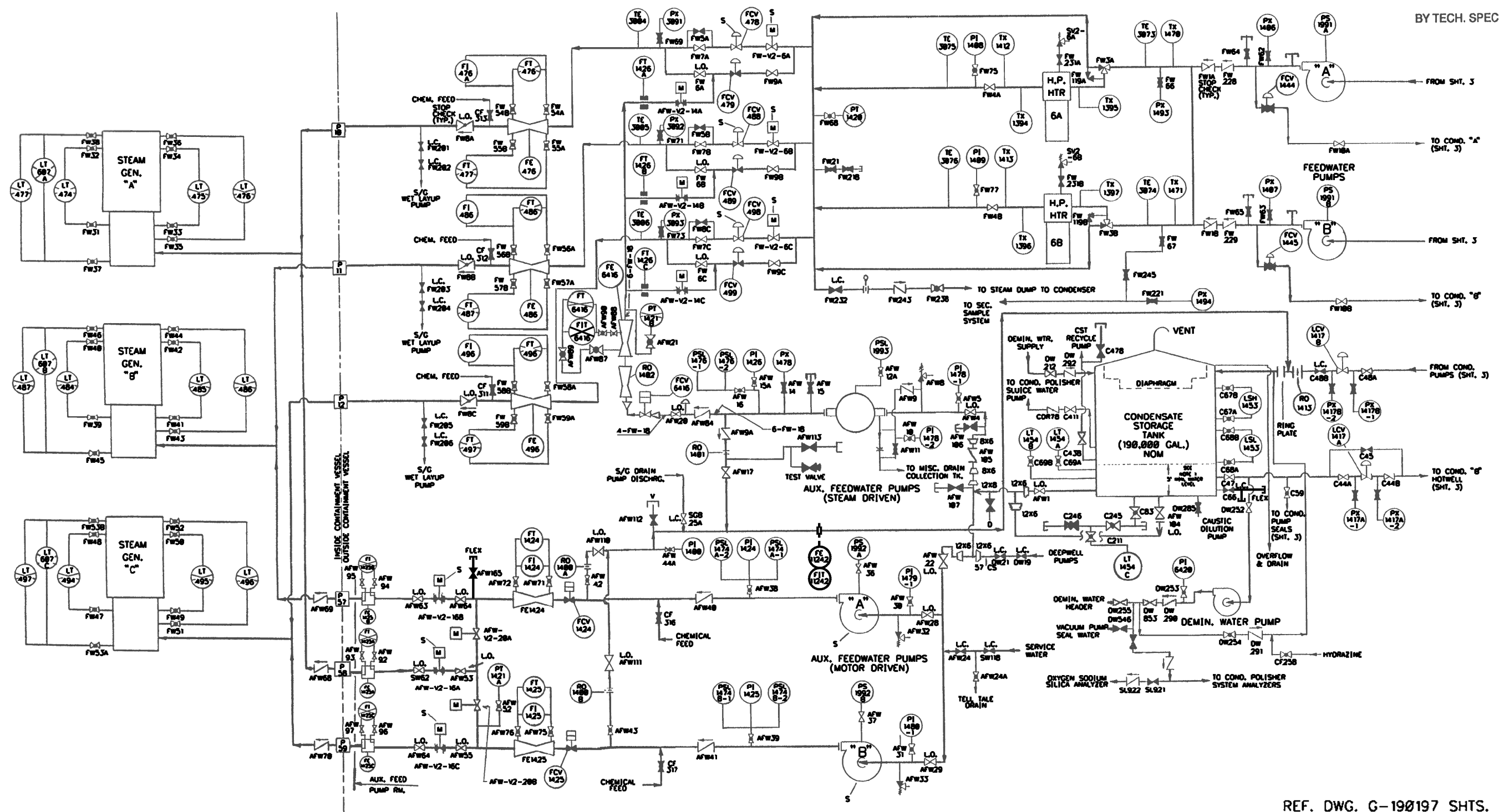
FLOW DIAGRAM
FEEDWATER, CONDENSATE, AND AIR
EVACUATION SYSTEM
SHEET 1 OF 3

FIGURE 10.1.0-4

REVISION NO. 17

NOTES:

1) MIN. WATER LEVEL AS DETERMINED
BY TECH. SPEC. SECTION 3.7.5.



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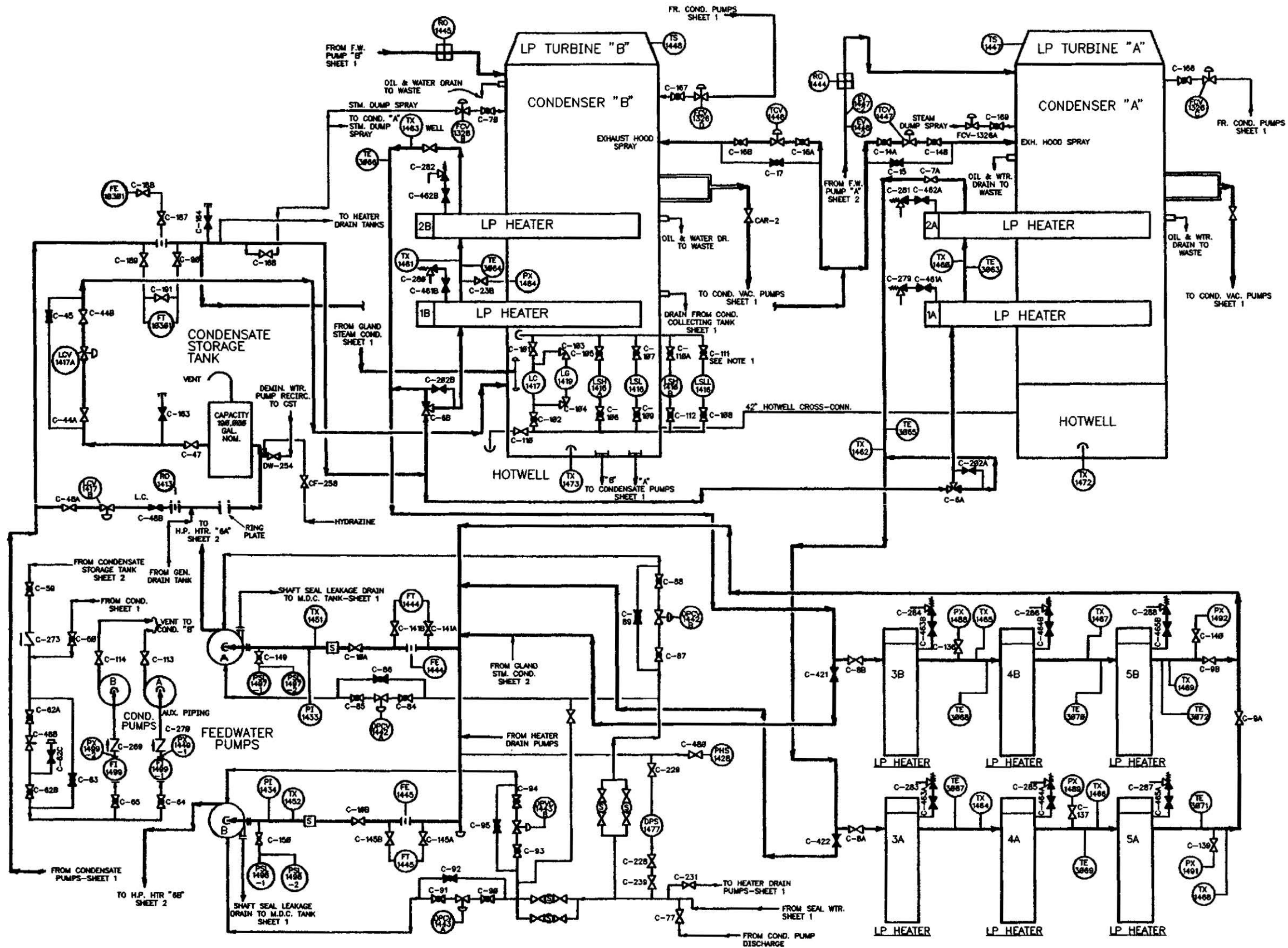
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FLOW DIAGRAM
FEEDWATER, CONDENSATE, AND AIR
EVACUATION SYSTEM
SHEET 2 OF 3

FIGURE 10.1.0-5

REVISION 26

NOTE:
1. THIS COMPONENT HAS BEEN DISABLED.

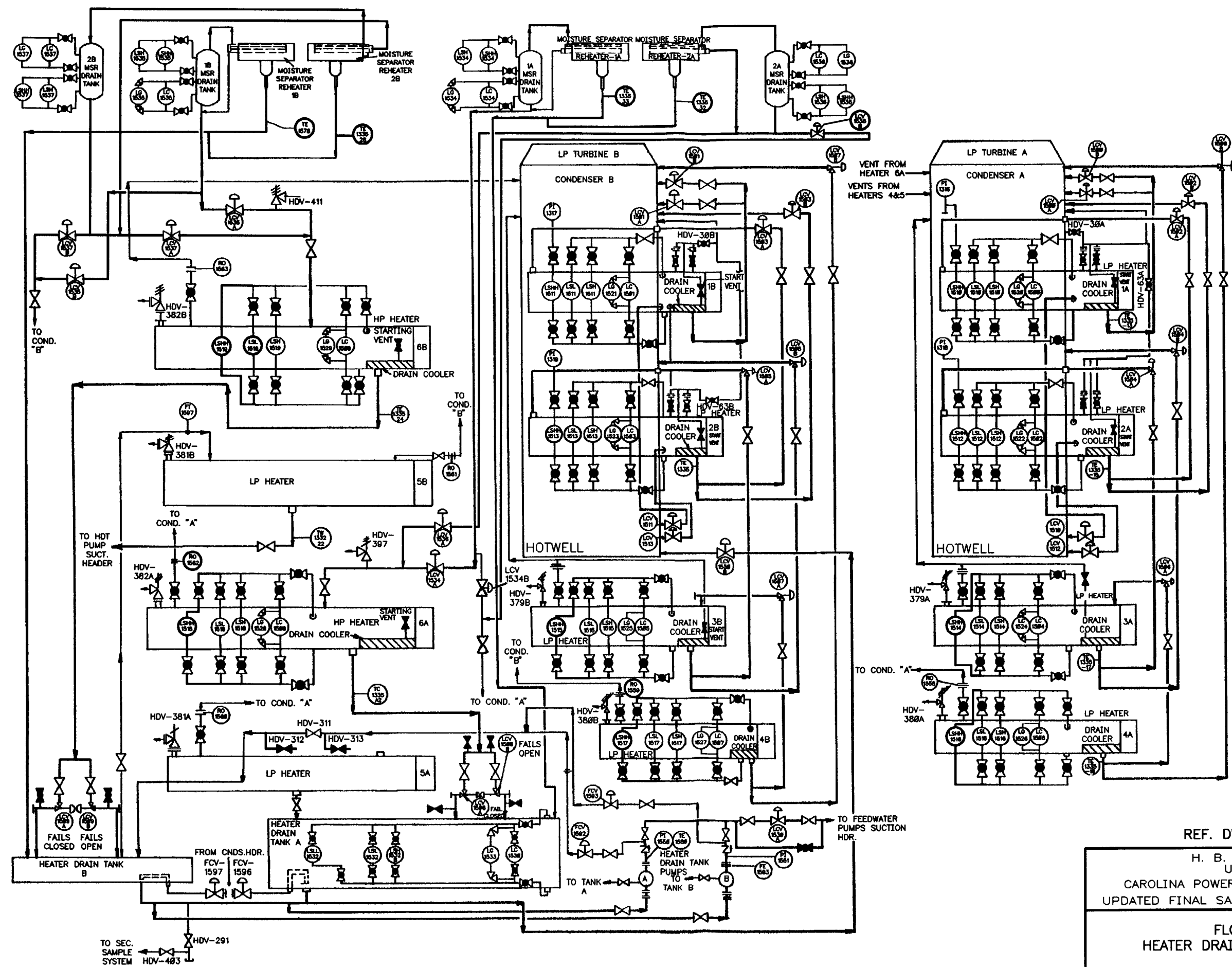


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FLOW DIAGRAM
FEEDWATER, CONDENSATE, AND AIR
EVACUATION SYSTEM
SHEET 3 OF 3

FIGURE 10.1.0-6 REVISION NO. 18



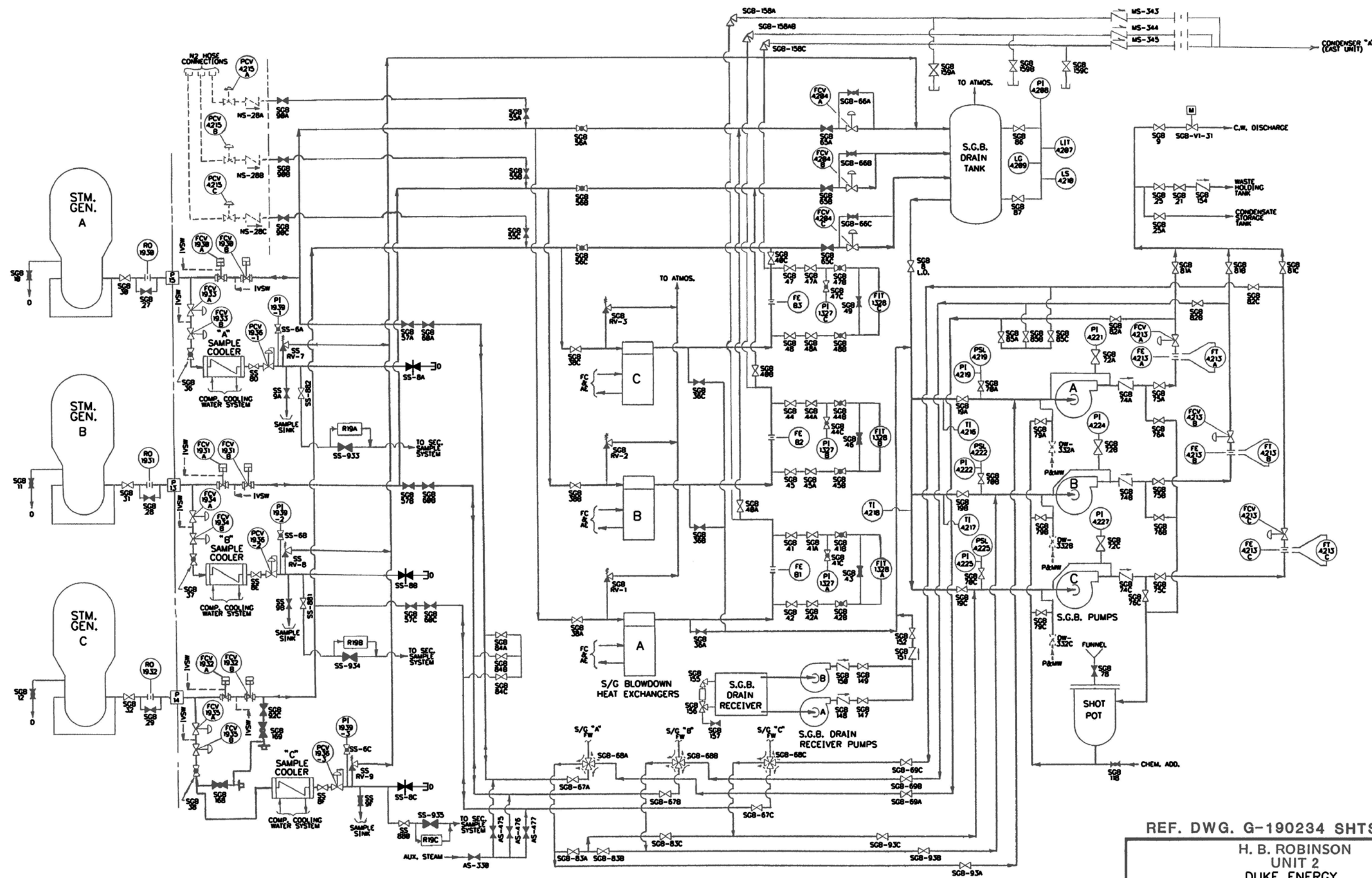
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FLOW DIAGRAM
HEATER DRAINS AND VENT SYSTEM

FIGURE 10.1.0-7

REVISION 19



REF. DWG. G-190234 SHTS. 1-2

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FLOW DIAGRAM
STEAM GENERATOR BLOW DOWN
AND WET LAYUP SYSTEM

FIGURE 10.1.0-8

REVISION NO. 27

10.2 TURBINE GENERATOR

10.2.1 DESIGN BASIS

The design parameters for the turbine generator are provided in Table 10.2.1-1 (References 10.2.3-2 and 10.2.3-3.

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TABLE 10.2.1-1

DESIGN PARAMETERS-TURBINE GENERATOR

Turbine Type	Three-element, tandem-compound four-flow exhaust
Turbine Capacity (kW)	
Nominal capacity at 2.00 in. Hg (0.982 psia)	821,537 kw
Generated Rating (kVa)	896,900
Turbine Speed (rpm)	1800

10.2.2 DESCRIPTION

The original turbine-generator unit and accessories were supplied by Westinghouse Electric Corporation (now Siemens Energy, Inc.) and are suitable for outdoor installation. The high pressure (HP) and low pressure (LP) Turbines were later upgraded by Siemens with new rotors and blade paths. The turbine is a three-element, tandem-compound, four-flow exhaust, 1800 rpm unit with 45 in. LP last row blades, and has moisture separation and live steam reheat between the HP and LP elements. The AC generator and rotating rectifier exciter are direct-connected to the turbine shaft.

The turbine consists of one double-flow, HP element in tandem with two double-flow, LP elements. Four combination moisture-separator, live-steam reheater assemblies are located alongside the LP turbine.

The turbine has a nominal gross rating of 821,537 kw with the planned LP upgrade at 2.00 in. Hg absolute, zero percent makeup, and with six stages of feedwater heating in service.

The hydrogen inner-cooled generator is rated at 896,900 kVa at 75 psig hydrogen gas pressure. The generator has sufficient capability to accept gross kW output of the steam turbine with its control valves wide open at rated steam conditions.

The turbine oil system is of a conventional design. It consists of three parts: a HP oil system, a lubrication system, and an electro-hydraulic control system. The electro-hydraulic control system is completely separate from the other two parts. Lube oil is also used to seal the generator glands to prevent hydrogen leakage from the machine. The oil used for the control system is a fire resistant synthetic.

The turbine has low speed, motor driven, spindle turning gear equipment which is side mounted on the outboard bearing of the LP turbine nearest the generator.

Turbine Controls

High Pressure steam enters the turbine through two stop valves and four governing control valves. An electro-hydraulic, servo-actuator controls each stop valve so that it is either in the wide-open or closed position. The control signal for this servo-actuator comes from the mechanical-hydraulic overspeed trip portion of the electro-hydraulic control system. The major function of these stop valves is to shut off the flow of steam to the turbine in the event the unit overspeeds beyond the setting of the overspeed trip. These valves are also tripped when the protective devices function. The control valves are positioned by a similar electro-hydraulic servo-actuator acting in response to an electrical signal from the main governor portion of the electro-hydraulic control system. Upon loss of load resulting in a high rate of acceleration, the auxiliary governor portion of the electro-hydraulic control will act to close the control valve rapidly.

As shown in Figure 10.1.0-2, the steam, after passing through the stop and control valves, passes through the HP turbine, then through the moisture separator and reheater. The reheat stop valves and reheat intercept valves are located between the reheater and the LP turbine inlet. Their purpose is to control the steam flow to the LP turbines in the event of turbine overspeed.

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The reheat stop valve is an open-closed type valve, closed upon operation of the overspeed trip in a manner similar to the operation described above for the main stop valves. The reheat intercept valve is a positioned valve controlled from the auxiliary governor portion of the electro-hydraulic control system.

The electro-hydraulic turbine control system combines a solid state electronic controller with a HP fire resistant fluid supply system which is independent of the lubricating oil.

The electro-hydraulic control system includes the following features:

- a) Governor valve controller
- b) Intercept valve controller
- c) Load limit controller
- d) Auxiliary governor
- e) Speed controller
- f) Load controller
- g) Operators panel to provide for a centralized turbine control station
- h) High pressure hydraulic fluid pumping unit
- i) Turbine protective devices

The mechanical overspeed trip mechanism consists of an eccentric weight mounted in the end of the turbine shaft, which is balanced in position by a spring until the speed reaches approximately 110 percent of rated speed. Its centrifugal force then overcomes the spring and the weight flies out striking a trigger which trips the overspeed trip valve and releases the autostop fluid to drain. The resulting decrease in autostop pressure causes the governing emergency trip valve to release the control oil pressure, closing the main stop and governing control valves and the reheat stop and intercept valves.

In the steam admission system any steam path has two valves in series which are controlled by completely independent systems. Furthermore, the high pressure oil system that actuates the steam valves is completely independent of the LP lubrication oil. The turbine control and protection system is fail-safe. The loss of oil pressure or voltage causes closure of the steam valves.

The autostop valve is also tripped when any one of the protective turbine trip devices is actuated. The protective devices are all included in a separate assembly but are connected hydraulically to the overspeed trip relay.

The following malfunctions or faults will cause an automatic turbine generator trip.

- a) Generator/electrical faults
- b) Low condenser vacuum
- c) Thrust bearing failure
- d) Low lubricating oil pressure
- e) Turbine overspeed
- f) Reactor trip
- g) Manual trip
- h) AMSAC trip

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10.2.3 TURBINE DISK INTEGRITY

The technology utilized to manufacture and inspect low pressure turbine rotor forgings, ensures turbine rotors with high structural integrity. Low pressure turbine rotor inspections are completed every 100,000 equivalent operating hours as recommended by the manufacturer (reference WCAP-11525, accepted by NRC November 2, 1989). The inspection interval is based upon the probability of generating a turbine missile as a function of actual operating time. The missile probabilities associated with the turbine rotors are discussed in Section 3.5.1.3 of this FSAR document. The Siemens Advance Disc Design shrunk-on disc eliminates the harmful stress concentration points present in earlier shrunk-on disc design rotors.

Due to the redundancy and reliability of the turbine control protection system and of the steam system, the probability occurrence of a unit overspeeding above the design value, i.e., 120 percent, is very remote.

Due to conservative design, very careful rotor forging procurement and rigid inspection, Siemens (previously Westinghouse) turbine generator units had, at the time HBR 2 was licensed, never experienced a massive failure.

A survey of the available literature on turbine generator unit failure shows that the last massive failure of a turbine generator occurred about eight years prior to the submittal of the original HBR FSAR in November, 1968. The causes of failure were identified at that time, and provisions were adopted to prevent the recurrence of massive failures. The record since that time demonstrates the soundness of these provisions and correct design.

The no-failure record of Siemens turbine generator units, plus the experience gained from the referenced incidents, together with the improvement in the design and inspection techniques in the past, indicated the likelihood of massive turbine generator failure to be extremely remote.

With regard to design and inspection techniques, it is worthwhile to mention that a technical committee of forging suppliers and equipment manufacturers was formed about ten years prior to the submittal of the original HBR FSAR under ASTM to study turbine and generator rotor failures. This group developed the high toughness NiCrMoV material, now used in all turbine rotors and disks. This Task Force was very active in making additional improvements in quality and soundness of large forgings.

The survey of the literature on massive turbine failures in the 20 years prior to the original FSAR indicates that all of them occurred between 1953 and 1958.

This survey has pointed out that the rate events of a catastrophic failure of turbines fell into one of two categories:

- a) Failure by overstressing arising from accidental and excessive overspeed
- b) Failure, due to defects in the material, occurring at about normal speed

No failure falling in the first category had occurred in the United States during this period. The only two documented examples occurred in the United Kingdom. Both accidents were caused by the main steam admission valves sticking in the open position after full load rejection, because of impurities in the turbine control and lubrication oil. The probability of this occurrence in this plant is very remote as previously pointed out.

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Besides the provisions in the design of the turbine control and protection system during plant operation, valves are exercised on a periodic basis, to further preclude the possibility of a valve stem sticking. Analysis of oil samples are performed as required.

The turbine is periodically overspeeded to check the tripping speed. The remaining tripping devices are periodically checked.

Siemens specified the quality and method of manufacturing of the purchased forgings. Written specifications covered the manufacturing process, the chemical and mechanical properties, the tests performed, etc. Specifically, the tests performed were both destructive and nondestructive in nature. The destructive tests included tension tests, impact tests, and transition temperature measurement tests. The tension specimens were taken in a radial and/or longitudinal direction. The tensile properties were determined in accordance with ASTM A-370 on a Standard Round 1/2 in. Diameter 2 in. Gage Length Test specimen. The yield strength was taken as the load per unit of original cross section at which the material exhibits an offset of 0.2 percent of the original length. The Charpy impact specimens were taken in a radial direction and the minimum impact strength at room temperature measured. The transition temperature was determined from 6 specimens tested at different temperatures in accordance with ASTM A-443. The specimens were taken in a radial direction and machined in such a manner that the V-notch was parallel to the forging axis. Two specimens were machined from each test bar. All specimens were taken following all heat treatment. Curves of impact strength and percent brittle failure versus test temperature were drawn.

| The nondestructive tests included, magnetic particle test, thermal stability test, and ultrasonic tests.

A magnetic particle test was made on each forging to demonstrate the freedom from surface discontinuities. The end faces of the main body over and beyond the fillets joining the main body to the shaft portions were magnetic particle tested. These inspections were done by Siemens inspectors prior to Siemens accepting these forgings. After final machining by Siemens, rotors were again magnetic particle inspected on the external surfaces by Siemens.

| A thermal stability test was performed on the forging at the place of manufacture after all heat treatment was completed.

The forgings were ultrasonically inspected at the place of manufacture by Siemens inspectors.

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The Low Pressure turbine rotors are periodically inspected to ensure the integrity of the blades and rotor forging. The inspection frequency is maintained consistent with current manufacturers recommendations (reference WCAP-11525 accepted by NRC November 2, 1989) (References 10.2.3-3 and 10.2.3-5.

Based on conservative design, reliable turbine control system, careful rotor forging procurement, and rigid inspection, the probability of a combination of excessive overspeed, new-born large forging defects, and operating temperature below the transition temperature is considered practically zero.

10.2.3.1 Materials Section

10.2.3.1.1 High Pressure Turbine

The high pressure turbine, shown in Figure 10.2.3-1, is a double flow element with nine stages of reaction blading in each end of the element. The steam enters the high pressure element through two stop valves and four control valves. The control valve outlets are connected to the high pressure casing through four inlet pipes, each of which connects to a nozzle chamber enclosed within the high pressure casing. Two of these inlet connections are in the base and two are in the cover. The steam flows axially in both directions from the nozzle chambers, through the reaction blading to the four exhaust openings (two at each end) in the casing base.

Steam exhausts from the HP turbine base, through cross-under piping, to the four combined moisture separator live steam reheater assemblies.

The HP rotor is made of NiCrMoV alloy steel. The specified minimum mechanical properties are given in Table 10.2.3-1.

The main body of the rotor weight is approximately 120,000 lb. The approximate values of the transverse centerline diameter, the maximum diameter, and the main body length are 36 in., 66 in., and 138 in., respectively.

The outer casing cover and base are made of carbon steel casings. The specified mechanical properties are given in Table 10.2.3-2.

The bend test specimen shall be capable of being bent cold through an angle of 90 degrees and around a pin one inch in diameter without cracking on the outside of the bent portion.

The approximate weight of the four blade rings, the casing cover, and the casing base is 80,000 lb, 140,000 lb, and 160,000 lb, respectively.

The casing cover and base are tied together by means of more than 100 studs. The stud material is an alloy steel having the mechanical properties given in Table 10.2.3-3.

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The studs have length ranging from 18 to 66 in. and diameter ranging from 3.00 in. to 4.5 in. About 90 percent of them have diameter ranging between 3 and 4 in. The total stud cross-sectional area is about 900 in.² and the total stud free-length volume is about 36,000 in.³.

10.2.3.1.2 Low Pressure Turbine

The double flow LP turbine, shown in Figures 10.2.3-3 and 10.2.3-4, incorporates high efficiency blading diffuser type exhaust and liberal exhaust hood design. The LP turbine cylinders are fabricated from steel plate to provide uniform wall thickness, thus reducing thermal distortion to a minimum. The entire outer casing is subjected to low temperature exhaust steam.

The temperature drop from the crossover steam temperature to the exhaust steam temperature is taken across two walls; an inner cylinder and a thermal shield. The thermal shield functions to reduce the temperature gradient across the single inner cylinder wall, thereby virtually eliminating thermal distortion. The fabricated inner cylinder is supported by the outer casing at the horizontal centerline and is fixed transversely at the top and bottom and axially at the centerline of the steam inlet, thus allowing freedom of expansion independent of the outer casing. The inner cylinder is surrounded by the thermal shield.

The steam leaving the last row of blades flows into the diffuser where the velocity energy is converted to pressure energy, thus improving efficiency and reducing the excitation forces on the last rotating row of blades.

The LP rotors are made of NiCrMoV alloy steel. The specified minimum mechanical properties are given in Table 10.2.3-4. The Siemens Advance Disc Design shrunk-on disc rotors consist of a forging shaft and three discs at each end (for a total of six discs per LP turbine) to each of which are attached nine rows of rotating blades. The rotating blades are machined or drop forged and the nine rows are attached to the rotor by a T-root design in the front end drum stage blades and serrated root type of fastening in the back end free-standing blades. The rotor shaft and fitted blades make up each LP turbine rotor assembly.

The outer cylinder and the two inner cylinders are mainly made of carbon steel material. The minimum specified properties are given in Table 10.2.3-6.

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TABLE 10.2.3-1

MINIMUM MECHANICAL PROPERTIES – HP ROTOR

Tensile Strength, psi, min.	105,000
Yield Strength, psi, min.	90,000
Elongation in 2 in., percent, min.	19
Reduction of Area, percent, min.	59

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TABLE 10.2.3-2

MINIMUM MECHANICAL PROPERTIES – HP CASING AND BLADE RINGS

	<u>CASING</u>	<u>BLADE RINGS</u>
Tensile Strength, psi, min.	70,000	110,000
Yield Strength, psi, min.	36,000	80,000
Elongation in 2 in., percent, min.	22	15
Reduction of Area, percent, min.	35	40

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TABLE 10.2.3-3

MINIMUM MECHANICAL PROPERTIES – HP STUD MATERIAL

Material	Size, Inches			
	Low Alloy			12 Cr Stainless
	2½ and less	Over 2½ to 4	Over 4 to 7	All Sizes
Tensile Strength, psi, min.	125,000	115,000	110,000	135,000
Yield Strength, psi, min. (0.2 percent offset)	105,000	95,000	85,000	110,000
Elongation in 2 in., percent, min.	16	16	16	14
Reduction of Area, percent, min.	50	50	50	32

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TABLE 10.2.3-4

MINIMUM MECHANICAL PROPERTIES - LOW PRESSURE ROTORS AND DISCS

	Rotor Shaft	Disc 1	Disc 2 & 3
Tensile Strength, psi, max.	149,000	146,000	154,000
Yield Strength, psi, min. (0.2 percent offset)	107,000	113,000	119,000
Elongation in 2 in., percent, min.	15	15	15
Reduction of Area, percent, min.	45	50	50
Impact Strength, Charpy V-Notch, ft-lb min. at room temperature	74	96	96
50 Percent Fracture Appearance Transition Temperature, °F, max.	-58	-112	-112

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TABLE 10.2.3-6

MINIMUM MECHANICAL PROPERTIES – LOW PRESSURE TURBINE CYLINDERS

Grade A	Outer Cylinder	Inner Cylinder
Tensile Strength, psi, min.	55,000	58,000
Yield Strength, psi, min.	30,000	29,000
Elongation in 8 in., percent, min.	24	22
Elongation in 2 in., percent, min.	28	23

Whenever plates of thicknesses > 2 in. are employed, they are made of ASTM-212

For the outer cylinder, parts are mainly made of ASTM A-285 Grade C material. Whenever plates of thickness > 2in. are employed, they are made of ASTM A-212 Grade A.

For the inner cylinder (also called the inner casing), the inner rings are made of ASTM A-516 Grade 70 and the main parts are made of Modified ASTM A-516 Grade 60 (Reference 10.2.3-6, Table 3.1-1).

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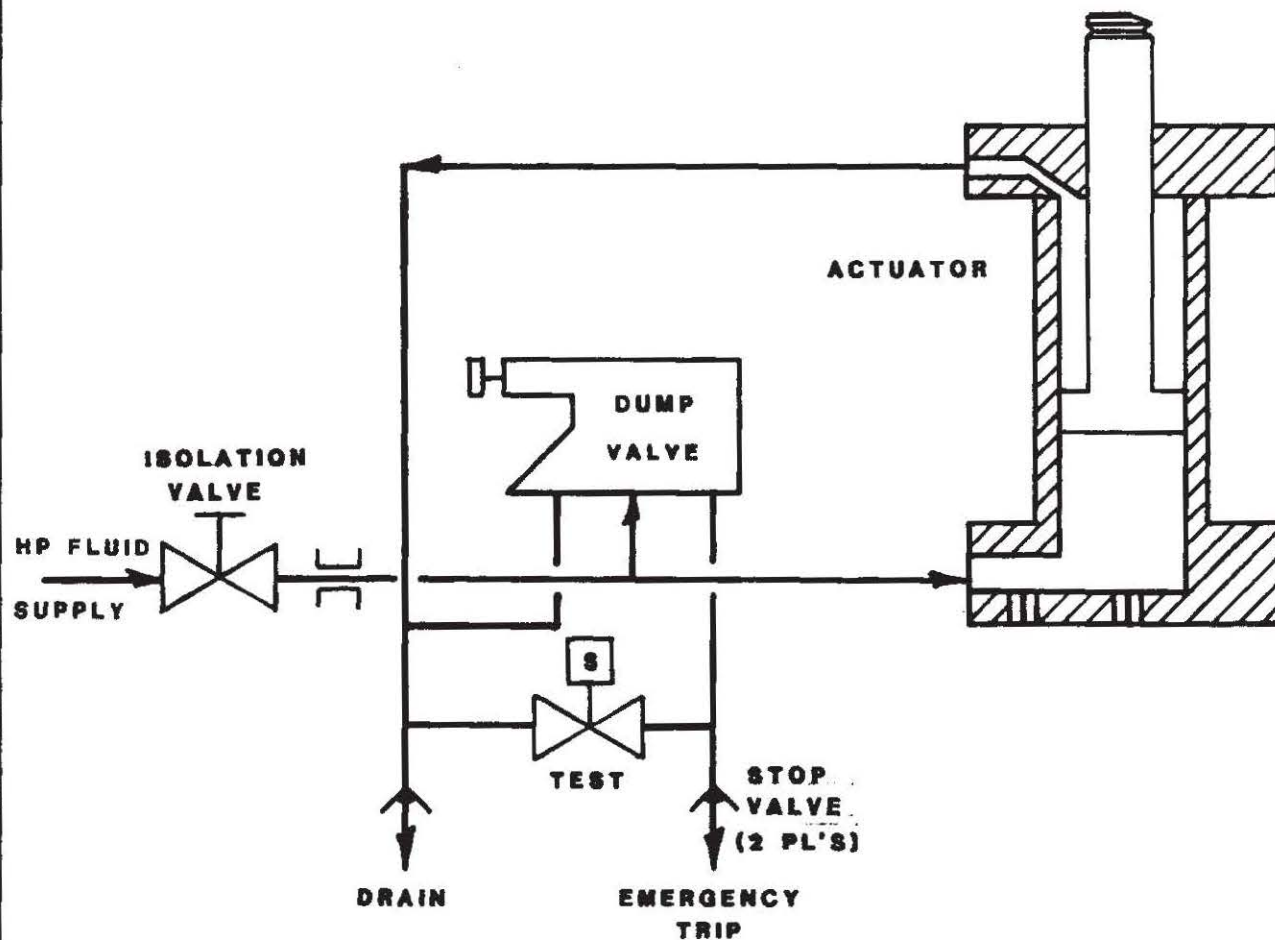
10.2.4 EVALUATION

The plant is designed to accommodate a step change in load of ± 10 percent or a ramp change of ± 5 percent per minute within the range of 15 to 100 percent power. The power conversion system, under nominal operating conditions, is capable of accepting load changes up to generation load increases of 14 percent of full load per minute and accepting step load increases or decreases of 19 percent of full load, within the load range of 15 to 95 percent load. These limits are based on full load rating of 2348 MWt per Heat Balance Diagram WB-16924.

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REFERENCES: SECTION 10.2

- | | | |
|----------|---|--|
| 10.2.3-1 | Deleted by Revision No. 15 | |
| 10.2.3-2 | EC-17027, "Duke Energy Robinson Unit 2 LP Replacement", April 13, 2017, Siemens Energy, Inc. | |
| 10.2.3-3 | EC-0702S, "Progress Energy Robinson #2, Generator Uprate Study", January 2007, Siemens Power Generation, Inc. | |
| 10.2.3-4 | WCAP-11525, "Probabilistic Evaluation of Reduction In Turbine Valve Test Frequency", June 1987, Westinghouse Electric Corporation. | |
| 10.2.3-5 | TP-04124, "Missile Probability Analysis for the Siemens 13,9m2 Retrofit Design of Low-Pressure Turbine by Siemens AG", June 7, 2004, Siemens Westinghouse Power Corporation, For Public Record with Nuclear Regulatory Commission Safety Evaluation dated March 30, 2004. | |
| 10.2.3-6 | EC-17034, "BB81R-13.9m2 Low Pressure Turbine Design Analysis Report for Robinson Unit 2", April 26, 2017, Siemens Energy, Inc. | |



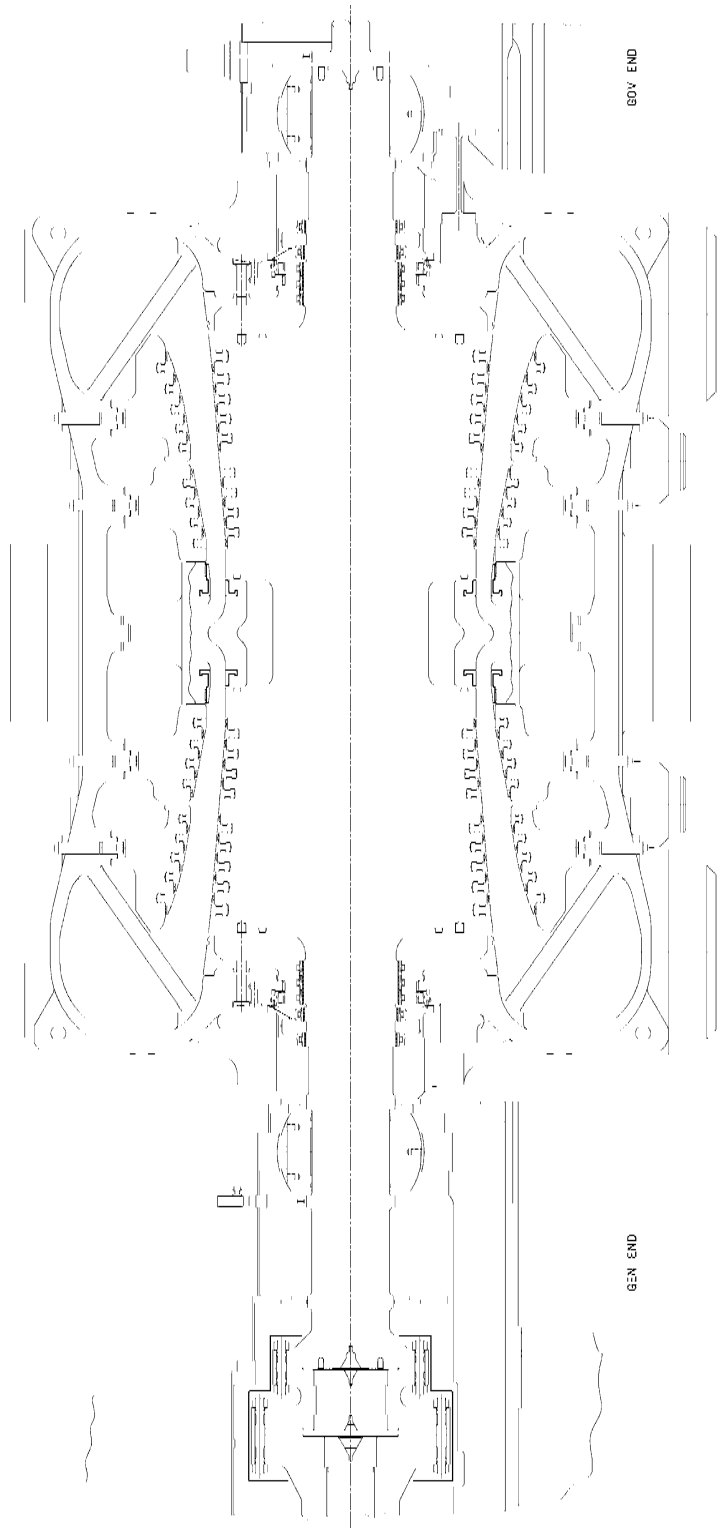
(THERE IS ONE ACTUATOR PER TURBINE VALVE)

Amendment No. 12

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VALVE ACTUATOR DUMP

FIGURE
10.2.2 - 1



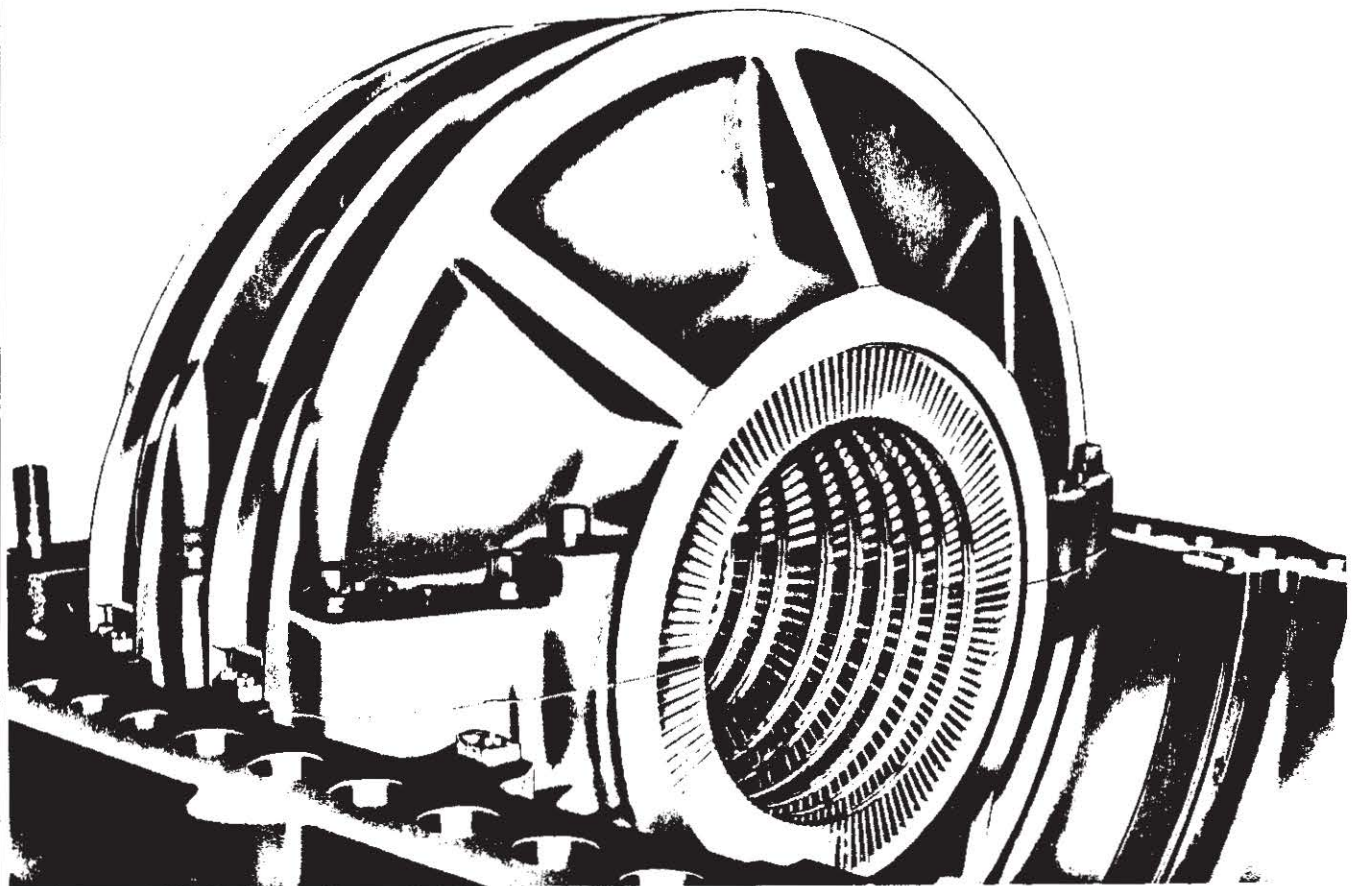
Revision No. 24

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Unit 2
Carolina Power & Light Company
UPDAED FINAL SAFETY
ANALYSIS REPORT

HIGH PRESSURE
CYLINDER – 1800 RPM
DOUBLE-FLOW DESIGN

FIGURE No. 10.2.3-1

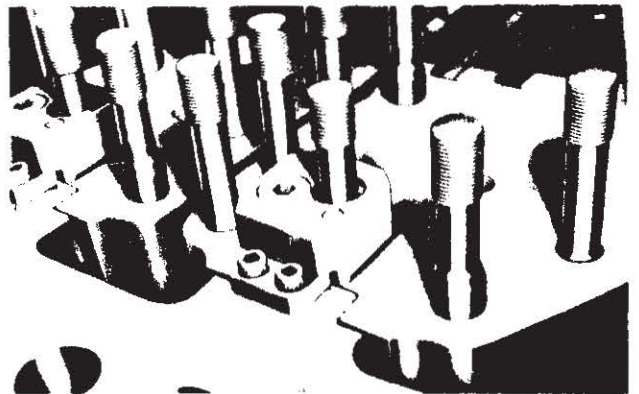
BLADE RINGS



Blade rings of large high-pressure, high temperature turbine, with stationary blades in place.

FEATURES

1. Centerline supporting block insures center alignment while allowing differential expansion between blade ring and cylinder.
2. Blades are inserted in blade ring halves.
3. Tongue and groove holds blade ring in position.
4. Metallic seals between blade rings and cylinder prevent leakage of steam in support grooves.
5. Upper plate, in cylinder cover, prevents any "riding-up" of the blade ring.

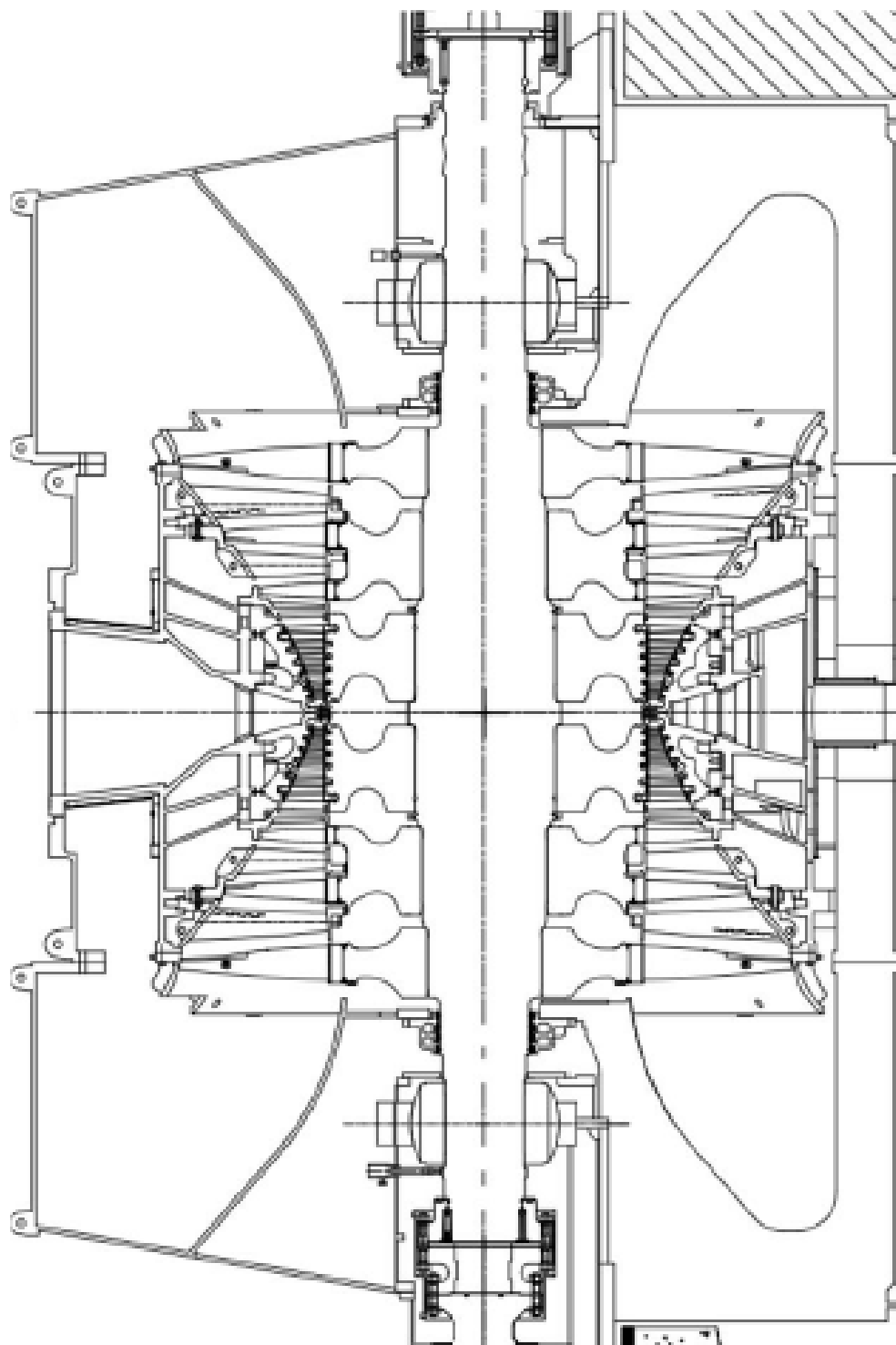


View of turbine cylinder and blade ring, showing method of supporting and locking lower blade ring in position.

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SAFETY ANALYSIS REPORT

BLADE RINGS

FIGURE
10.2.3 - 2

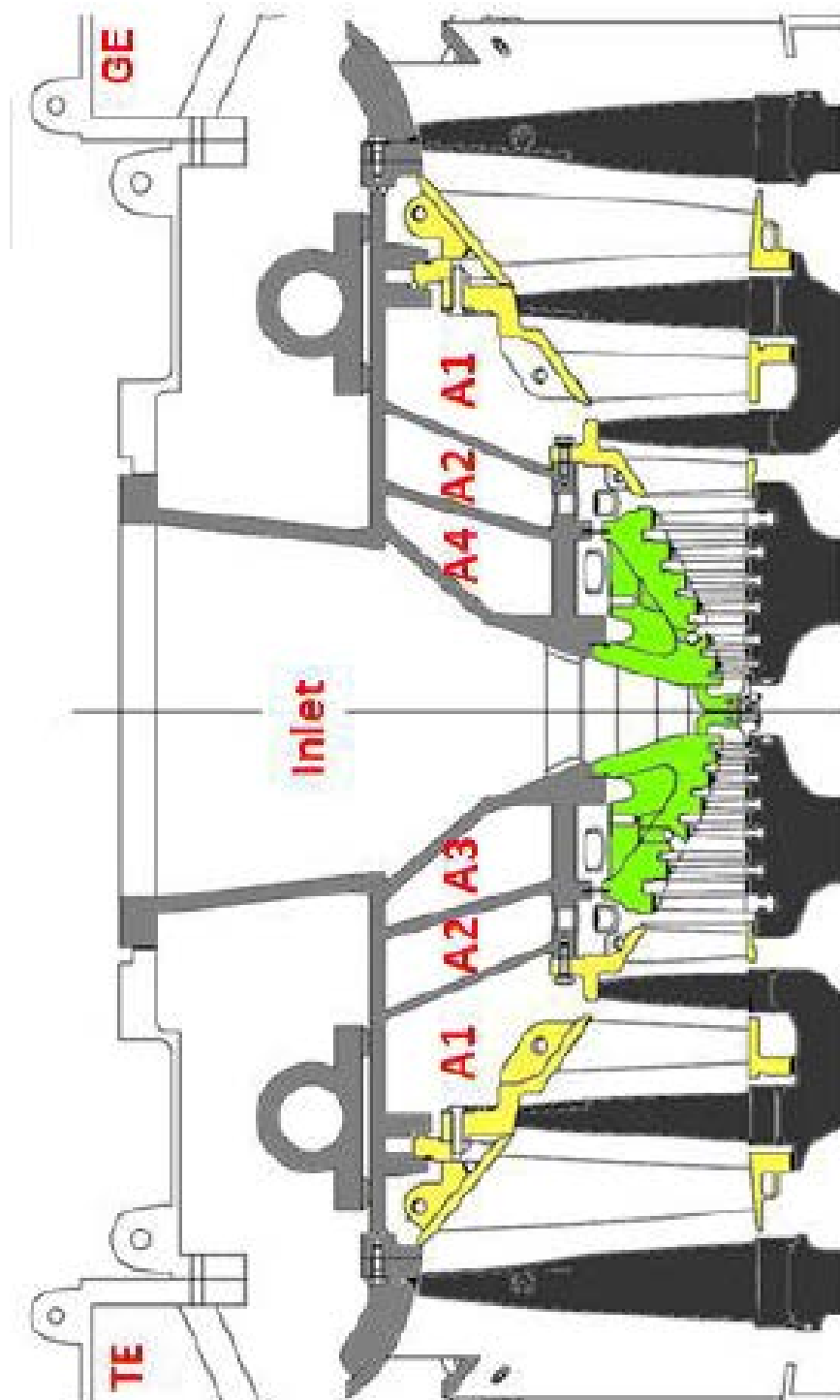


Revision No. 28

H. B. Robinson
Unit 2
Duke Energy
UPDAED FINAL SAFETY
ANALYSIS REPORT

LOW PRESSURE
ELEMENT – 1800 RPM
DOUBLE-FLOW DESIGN

FIGURE No. 10.2.3-3



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Unit 2
Duke Energy
UPDAED FINAL SAFETY
ANALYSIS REPORT

TYPICAL LP CYLINDER

FIGURE No. 10.2.3-4

10.3 MAIN STEAM SUPPLY SYSTEM

10.3.1 DESIGN BASIS

The Steam and Feedwater System is designed to remove heat from the reactor coolant in the three steam generators, producing steam for use in the turbine generator. The Steam and Feedwater System can receive and dispose of the total heat existing and produced in the reactor coolant system following an emergency shutdown of the turbine generator from a full load condition.

10.3.2 SYSTEM DESCRIPTION

The main steam supply system is shown on Figures 10.1.0-1 through 10.1.0-3. Steam from each of the three steam generators is supplied to the turbine, where the steam expands through the high pressure (HP) turbine, and then flows through a moisture preseparator system, reheaters and intercept valves to two, double-flow, low-pressure (LP) turbines, all in tandem. Six stages of extraction are provided, two from the HP turbine, one of which is the exhaust, and four stages from each of the LP turbines, plus the exhaust to the condenser. The feedwater heaters for the lowest two stages are located in the condenser neck. All feedwater heaters are horizontal, half-size units (two strings). The feedwater string is the closed type with deaeration accomplished in the condenser hotwell to less than 0.005 cc per liter of residual oxygen. The moisture preseparator system consists of four Moisture Preseparator/Special Crossunder Pipe Separator (MOPS/SCRUPS) devices. MOPS are concentric chambers in the crossunder line directly at the HP outlet. The moisture is removed from the crossunder line through a gap at the upper end of the chamber and is enhanced since the extraction steam is also removed through this same concentric gap. SCRUPS is a specially designed elbow with turning vanes that are designed to remove moisture from the steam path. An outer shell is provided as a separating chamber from which the extraction steam is vented and condensate is drained.

There are four, horizontal-axis, cylindrical-shell, combined moisture-separator, live-steam reheater assemblies. Steam from the exhaust of the HP turbine element enters each assembly at one end. Internal manifolds in the lower section distribute the wet steam. The steam then passes through a chevron moisture separator where the moisture is removed. Live steam from the steam generators enters at the other end of each assembly, passes through the tubes and leaves as condensate. The lower pressure steam leaving the chevron separator flows over the tube bundle where it is reheated. This reheated steam leaves through openings in the top of the assemblies and flows through individual stop and intercept valves to the LP turbines.

10.3.2.1 Main Steam Isolation Valves

Steam from each of the steam generators flows through a 26 in. swing disc type isolation valve and a swing disc check valve to a 72 in. common header. The main steam line isolation valve bodies are cast carbon steel with stainless steel trim. The valves each pass 3.4×10^6 lb of steam/hr at approximately 800 psig with 0.25 percent moisture. The design pressure and temperature of the valves are 1085 psig and 600°F, respectively, each isolation valve is equipped with a top mounted air operator with accumulators and will fail as-is in the event of loss of instrument air pressure. The MSIVs fail closed on loss of control or actuation power. A bypass valve is provided around each isolation valve to equalize pressure across the valve and for steamline warmup. The valve design has been analyzed in Reference 10.3.2-1 to confirm the integrity of the MSIVs under the dynamic loads associated with postulated steam line breaks.

10.3.2.2 Main Steam Safety Valves

The steam generator safety valves provide emergency pressure relief for the steam generators as a result of imbalance between steam generation and steam

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consumption. These valves have pressure settings in compliance with the applicable ASME code and have sufficient capacity to prevent the secondary system pressure from exceeding 110% of the design pressure during normal operation and Anticipated Operational Occurrences.

There are four safety valves located on each of the three 26 in. main steam lines outside the reactor containment and upstream of the nonreturn valves and the swing disc isolation valves. Discharge from each of the safety valves is carried to atmosphere. The lowest safety valve set pressure is 1085 psig.

10.3.2.3 Main Steam Power-Operated Relief Valves

Three power operated relief valves (PORV) are provided which are capable of releasing heat to the atmosphere. These valves are automatically controlled by pressure or may be manually operated from the control board. In addition, in the event of a load rejection of greater than approximately 40 percent, the steam dump controls can take over the operation of these valves.

The PORVs together have a designed capacity to release 1,740,000 pounds per hour of steam at 790 psia. One power operated relief valve, located on each main steam line upstream of the nonreturn valve and the swing disc isolation valve, is provided for each steam generator. Discharge from each of the three power operated relief valves is carried to the atmosphere.

The steam generator power operated relief valves provide the means for plant cooldown by steam discharge to the atmosphere if the condenser steam dump is not available. The relief valves are of the modulating type, remote pressure controlled with remote adjusted relief pressure setting.

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10.3.3 EVALUATION

Pressure relief is required at the system design pressure of 1085 psig, and the first safety valve is set to relieve at this pressure. Additional safety valves are set at pressures up to 1140 psig, as allowed by the ASME Code. In addition to the safety valves, one modulated pressure relief valve is installed for each steam generator which can be manually operated from the control room.

The pressure relieving capacity of the safety valves is sufficient to prevent the secondary system pressure from exceeding 110% of the design pressure during normal operation and Anticipated Operational Occurrences.

The evaluation of the capability to isolate a steam generator to limit the loss of radioactivity and the steam break accident analysis are presented in Section 15.1.5.

An evaluation of the integrity of the main steam isolation valves and main steam line check valves under the dynamic loads associated with postulated steam line break is contained in Reference 10.3.3-1.

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10.3.4 Inspection and Testing Requirements

The main steam line isolation valves are tested during plant shutdown to verify closure times. The most challenging testing condition for the main steam isolation valves is against maximum steam line pressure and with the normal non-safety related Instrument Air Supply isolated.

The main steam line isolation valves serve to limit an excessive reactor coolant system cooldown rate and resultant reactivity insertion following a main steam break accident. Their ability to close upon receipt of an isolation signal is verified at periodic intervals.

10.3.5 WATER CHEMISTRY

10.3.5.1 Chemistry Control Basis

Feedwater chemistry is maintained within limits during power operation in accordance with EPRI Secondary Water Chemistry Guidelines.

With the condensate polisher in service, these limits are maintained by the addition of ammonium hydroxide and/or an alternate amine such as ethanolamine, as pH additives. These chemicals are injected into the condensate at the discharge of the condensate polisher. In addition, hydrazine, an oxygen scavenger is injected. With the condensate polisher bypassed, these limits are maintained by the addition of hydrazine and/or an alternate amine such as ethanolamine.

The steam generators are operated with blowdown to maintain the steam generator chemistry within specification. The blowdown rate is adjusted as required to remove dissolved and suspended solids.

The condensate polisher, located downstream of the condensate pumps and upstream of the gland steam condenser, is provided to maintain steam generator chemistry within specification, during startups and periods of condenser inleakage. The polisher removes suspended solids and ionic constituents and is designed to operate in both the hydrogen and ammonia cycles without effecting effluent concentrations. Resins from the polisher vessels are regenerated with an external regeneration unit.

A review of feedwater chemistry data has shown that during power operations all feedwater chemistry is maintained within specification. Condensate oxygen levels occasionally rise above their specification due to air leakage to the condensers but are returned to normal levels by hydrazine addition and repair of leakage.

The All Volatile Treatment (AVT) chemistry specifications for the feedwater makeup, condensate storage, and steam generators during periods of operation or wet layup are in accordance with the EPRI Guidelines.

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10.3.6 STEAM AND FEEDWATER SYSTEM MATERIALS

10.3.6.1 Fracture Toughness

There were no special fracture toughness requirements for the feedwater system.

10.3.6.2 Materials Selection and Fabrication

The materials selection and fabrication for the steam and power conversion system was in accordance with the code requirements shown in Section 3.2.

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REFERENCES: SECTION 10.3

- 10.3.2-1 Letter from NRC to CP&L, "Safety Evaluation by Office of NRR, Main Steam Isolation Valve Closure, Carolina Power & Light Company, H. B. Robinson Steam Electric Plant Unit 2," March 18, 1976.
- 10.3.2-2 ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsection IWB Inservice Testing of Valves in Nuclear Power Plants, 1980 Edition Through Winter 1980 Addenda.
- 10.3.2-3 NRC IE IN 85-84, Inadequate Inservice Testing of Main Steam Isolation Valves, October 30, 1985.
- 10.3.2-4 Modification 1137, "Instrument Air Filters for MSIV's" installed and accepted by Operations, February 7, 1994.
- 10.3.3-1 Letter from CP&L to NRC, "Integrity of Swing-Check MSIV's" dated February 5, 1976.

10.4 OTHER FEATURES OF THE STEAM AND POWER CONVERSION SYSTEM

10.4.1 MAIN CONDENSER

10.4.1.1 Design Basis

The design parameters for the main condenser are shown in Table 10.4.1-1.

10.4.1.2 System Description

The condenser is the radial flow type with semicylindrical water boxes bolted at both ends. The hotwell is the deaerating type with storage sufficient for five minutes operation at maximum throttle flow with an equal free volume for surge protection. It has required manholes, a water gauge glass to indicate the condensate level, and two condensate outlets with coarse strainers. An automatic tube cleaning system is provided for the condenser. Expansion joints for all circulating water inlet and outlet connections are provided.

A condenser drain system is installed which provides a means to recirculate or empty the Unit 2 condenser hotwells. In the case of a primary to secondary steam generator leak, the contaminated condensate can be transferred to the waste condensate tanks.

Nitrogen gas can be injected in the condenser to assist in condensate dissolved oxygen control.

10.4.1.3 Instrumentation Application

The more significant malfunctions or faults in the main condenser which cause alarms are:

- a) Low vacuum in condenser
- b) Low water level in condenser hotwell, and
- c) High temperature in low pressure exhaust hood.

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TABLE 10.4.1-1

DESIGN PARAMETERS

MAIN CONDENSER

Type	Radial flow, semicylindrical water boxes, deaerating
Number	2
Condensing Capacity at maximum Calculated Turbine Capacity (lb of steam/hr)	7,237,828
Materials:	
Condenser Shell, Tube Supports, and Water Boxes	Carbon Steel ASTM-A-283, GR. C
Tube Sheets	Stainless Steel, Type 304, ASTM-A-240
Tubes	Stainless Steel, Type 439

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10.4.2 MAIN CONDENSER EVACUATION SYSTEM

10.4.2.1 Design Basis

The main condenser vacuum system is designed to establish and maintain condenser vacuum during plant startup and shutdown and to remove air and noncondensable gases during plant operations. The design parameters for the condenser evacuation system are shown on Table 10.4.2.-1.

10.4.2.2 System Description

The mechanical vacuum pumps for the turbine condenser discharge to the plant vent. The exhausted air passes by a shielded radiation monitor before going to the plant vent.

The plant vent is located in the northeast quadrant adjacent to and just outside of the reactor containment.

The flow diagram for the condenser vacuum (air evacuation) system is shown on Figures 10.1.0-4 and 10.1.0-6.

10.4.2.3 Safety Evaluation

Under normal operating conditions, there are no radioactive contaminants present in the steam and power conversion system unless steam generator tube leaks develop. In this event, monitoring the vacuum pump off-gas will detect any contamination. Refer to Section 11.5 for the radiation monitoring system description.

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TABLE 10.4.2-1

DESIGN PARAMETERS

MAIN CONDENSER VACUUM SYSTEM

Condenser Vacuum Pumps

Number Provided	2
Type	Nash, Single Jet
Model	CL-3005
Capacity	24 scfm @ 1" Hg abs
Motor HP	150 HP
Power Supply	A - 480 V Bus 1 B - 480 V Bus 3

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10.4.3 TURBINE GLAND SEALING SYSTEM

10.4.3.1 System Description

A gland steam condenser maintains a pressure slightly below atmospheric in the turbine gland leakoff system. Sealing steam and air leakage along the shaft from each turbine gland is fed to this condenser. Two motor driven exhausters, one an installed spare, are mounted on the gland condenser to remove noncondensable gases. The Turbine Gland Sealing steam supply and exhaust system is shown on Figure 10.1.0-2.

10.4.4 STEAM DUMP SYSTEM

10.4.4.1 Design Basis

The automatic steam dump system has been included to increase the transient capability of the plant to provide a means for an orderly reactor power reduction in the event the unit is suddenly disconnected from the distribution network. The time for a return to full power operation is therefore minimized.

The steam dump controls operate the five main condenser dump valves, and when required, the three atmospheric discharge power operated relief valves (PORV) located upstream of the main steam isolation valves, one on each steam generator line. Following a secondary load rejection or turbine runback, the system reduces the Reactor Coolant System (RCS) average temperature, T_{avg} , to within a preset temperature value of the programmed T_{ref} at the new load condition. After a turbine trip, the system reduces T_{avg} to a preset value. During a unit cooldown, it cools the reactor coolant system until the Residual Heat Removal System (RHRS) can take over.

10.4.4.2 System Description

Dump is initiated by coincidence of a large rapid load change together with a large error signal between T_{avg} and the desired reference T_{avg} at the new load condition. For very large reductions, e.g., loss of load to the auxiliary power level, both PORV and condenser dumps are actuated to serve as a short term artificial load. As the control group is inserted by the T_{avg} reactor control system, reactor power is reduced, thereby reducing T_{avg} . The steam dump is modulated proportional to the same T_{avg} measurement and is thus reduced as rapidly as the rods are able to reduce core power. PORV is closed first, followed by closure of the condenser dump. In this manner the minimum amount of steam is lost from the system. The transient is terminated with the plant at equilibrium conditions at auxiliary load and there is no further steam dump to the condenser.

10.4.4.3 Safety Evaluation

The steam dump to the condenser and the PORV can handle approximately a 50 percent load rejection without lifting the main safety valves.

If the condenser heat sink is not available during a turbine trip, excess steam, generated as a result of reactor coolant system sensible heat and core decay heat, is discharged to the atmosphere.

If the control valves should fail to dump steam, the result is a loss of load transient. If they operate to dump steam inadvertently, the result would be a load increase equivalent to a small steamline break. In either case, the reactor control and protection system precludes unsafe operation. These protection systems are provided to trip the reactor in the event of a sustained load mismatch between the reactor and turbine. Normal turbine overspeed protection and the steam generator safety valves provide protection for these systems completely independent of any steam dump valve operation.

10.4.5 CIRCULATING WATER SYSTEM

10.4.5.1 System Description

Condenser circulating water is conveyed to the plant from Lake Robinson through a conduit approximately 10 ft in diameter. Condenser water discharge is via a conduit and canal from the plant to the lake. The circulating rate is approximately 482,100 gpm. The intake system is designed to withstand, without loss of function, ground accelerations of 0.133g acting in the vertical and 0.2g acting in the horizontal planes simultaneously.

Redundant traveling water screens, 3/8 in. mesh, located in the screen house, remove trash from the cooling water. At conditions of full flow, the velocity at the intake screen racks is approximately 2.1 ft per second. The plant cooling water requirements during an accident would be approximately 16,000 gpm which would result in a velocity of .07 ft per second.

A sodium hypochlorite system is provided for periodic chlorination of the circulation water system to control biological fouling of the condenser tubes and system piping.

A discussion of the potential for flooding and failure of safety related equipment due to a failure in the circulating water system is contained in a letter from Mr. E. E. Utley, CP&L, to Mr. D. J. Skovholt, NRC, "Flooding of Critical Equipment," dated September 22, 1972.

The flow diagram for the circulating water system is shown on Figure 9.2.1-1.

10.4.6 Condensate and Feedwater System

10.4.6.1 Design Basis

The feedwater system is designed to supply water to the steam generators under all operating conditions. During normal power operation the main feedwater pumps are utilized to supply the needed water. During periods of shutdown or abnormal conditions, one steam driven and two motor operated auxiliary feedwater pumps may be used.

Feedwater regulator and bypass valves in the feedwater line to each steam generator maintain the proper water level in the steam generators for all load conditions. The feedwater bypass valves are used at low power levels to prevent erosion damage to the feedwater regulating valve and for finer feedwater flow control. At higher power levels, the feedwater regulating valve is in operation while the bypass valve is shut. The feedwater header block valve is normally open and is utilized to isolate feedwater pump discharge to the feedwater regulator valve.

The design parameters for the condensate and feedwater systems are shown on Table 10.4.6-1.

10.4.6.2 System Description

The feedwater train is the closed type with deaeration accomplished in the condenser. Condensate is taken from the condenser hotwell through the condensate pumps, condensate polisher (when in service), gland steam condenser, and low pressure (LP) heaters to the suction of the feedwater pumps. The feedwater pumps then send feedwater through the high pressure (HP) heaters to the steam generators. Also, feedwater can be recirculated from the condenser hotwell through the condensate polishing system, low pressure heaters 1, 2, 3, 4, and 5, high pressure heaters 6A and 6B, and returned to the Main Condenser B.

The flow diagram for the condensate and feedwater system is shown in Figures 10.1.0-4, 10.1.0-5, and 10.1.0-6. The flow diagram for the heater drain and vent system is shown on Figure 10.1.0-7.

There are two multi-stage, vertical, pit-type, centrifugal condensate pumps with vertical motor drives. Each pump delivers 35 percent of the feedwater flow that the steam system requires for normal operation. The remaining 30 percent feedwater requirement is delivered by the two heater drain pumps.

Two barrel-type, motor driven feedwater pumps are provided and each is equipped with minimum flow protective devices. The design discharge pressure is the required steam generator pressure plus feedwater system losses. There is an alarm on low pressure at the feedwater pump suction.

Drains from the reheaters and extraction steam flow to the HP heaters, 6A and 6B, drains from the HP heaters flow to the heater drain tanks. The last stage LP heaters, 5A and 5B, and the moisture separators, also drain to these tanks. The heater drain pumps take suction from the drain tanks and discharge to the feedwater pumps suction. Drains from the four lower pressure heaters, 4 through 1, cascade to the condenser.

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10.4.6.3 Safety Evaluation

A reactor trip from power requires subsequent removal of core decay heat. Immediate decay heat removal requirements are normally satisfied by the steam dump system. Therefore, core decay heat can be continuously dissipated via the steam bypass to the condenser as feedwater in the steam generator is converted to steam by heat absorption. Normally, the capability to return feedwater flow to the steam generators is provided by operation of the turbine cycle feedwater system.

As noted in paragraph 10.4.7.2, under normal operating conditions, there are no radioactive contaminants present in the steam and power conversion system unless steam generator tube leaks develop. The condensate polisher wastewater monitor will provide delayed indication of such leaks.

A high activity signal initiates closure of air piston operated valve RCV-10549, isolating the polisher waste from the storm drain system. Refer to Chapter 11 for additional information about the polisher wastewater radiation monitor.

A sampling system, consisting of a flowmeter and an automatic sampling module, is provided to allow identification of radionuclides in the polisher waste.

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TABLE 10.4.6-1

DESIGN PARAMETERS

CONDENSATE AND FEEDWATER SYSTEM

Condensate Pumps

Type	Multi-stage, vertical, pit-type, centrifugal
Number	2
Design Capacity (each-gpm)	8,000
Total Head in ft of H ₂ O	1,130
Motor Type	Vertical
Motor Rating (HP)	3,000

Feedwater Pumps

Type	High Speed, barrel-type, horizontal single stage, centrifugal
Number	2
Design Capacity (each-gpm)	12,700 @ 1670 ft developed head
Motor Type	Horizontal
Motor Rating (HP)	6,000

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TABLE 10.4.6-1 (Cont'd)

Feedwater Heaters

LP 1A and 1B		<u>Shell</u>	<u>Tube</u>
	Design Temp., °F	200	280
	Design Press., psig	50	600
	Test Press., psig	76	900
	FW Temp. Increase Through Heater, °F	-	63.1
	Number of Passes		2
	Tubes:		
	Number	1,453 U's	
	Material	SA-268 TP 439	
	Size	5/8 in. O.D. x 20 BWG	
LP 2A and 2B		<u>Shell</u>	<u>Tube</u>
	Design Temp., °F	240	290
	Design Press., psig	50	600
	Test Press., psig	76	900
	FW Temp. Increase Through Heater, °F	-	34.9
	Number of Passes		2
	Tubes:		
	Number	942 U's	
	Material	SA-268 TP 439	
	Size	5/8 in. O.D. x 20 BWG	

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TABLE 10.4.6-1 (Cont'd)

LP 3A and 3B		
	<u>Shell</u>	<u>Tube</u>
Design Temp., °F	290	290
Design Press., psig	60	600
Test Press., psig	90	900
FW Temp. Increase Through Heater, °F	-	53.4
Number of Passes		2
Tubes:		
Number	1148 U's	
Material	Stainless Steel	
Size	5/8 in. O.D.	
LP 4A and 4B	<u>Shell</u>	<u>Tube</u>
Design Temp., °F	325	330
Design Press., psig	100	600
Test Press., psig	150	900
FW Temp Increase Through Heater, °F	-	51.8
Number of Passes		2
Tubes:		
Number	746 U's	
Material	Stainless Steel	
Size	3/4 in. O.D.	

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TABLE 10.4.6-1 (Cont'd)

LP 5A and 5B		<u>Shell</u>	<u>Tube</u>
	Design Temp., °F	400	400
	Design Press., psig	225	600
	Test Press., psig	338	900
	FW Temp. Increase Through Heater, °F	-	60.2
	Number of Passes		2
	Tubes:		
	Number	709 U's	
	Material	Stainless Steel	
	Size	3/4 in. O.D.	
HP 6A and 6B		<u>Shell</u>	<u>Tube</u>
	Design Temp., °F	475	465
	Design Press., psig	460	1,525
	Test Press., psig	690	2,290
	FW Temp. Increase Through Heater, °F	-	67.1
	Number of Passes		2
	Tubes:		
	Number	1,705 U's	
	Material	Stainless Steel	
	Size	5/8 in. O.D.	

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TABLE 10.4.6-1 (Cont'd)

Condensate Polisher

Type	Six (6) deep bed regenerative vessels
Flowrate (Maximum)	15,000 gpm
Maximum Flow per Vessel	3,000 gpm
System Pressure Loss	Normal 30 psig Maximum 65 psig

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10.4.7 Steam Generator Blowdown and Wet Layup System

10.4.7.1 System Description

10.4.7.1.1 Steam generator blowdown

A blowdown line is routed from each of the three (3) steam generators and out of the containment through penetrations to the steam generator drain tank. The steam generator drain tank is located adjacent to the north side of the Turbine Building. Each blowdown line is provided with:

1. A flow restriction orifice sized for 130,000 lbs./hr. located proximate to the respective steam generator,
2. Two air operated containment isolation valves which permit stream sampling to a continuous radiation monitor and to a sample station,
3. Two air operated shutdown (containment isolation) valves which are located proximate to the respective penetration outside containment,
4. Provision for heat recovery of 20,030 lbs./hr. of blowdown through a heat exchanger to the main condenser,
5. An air operated flow control valve which is located at the inlet of the steam generator drain tank is used for controlling blowdown flows in the range of 0-140 gpm. A manual control valve for blowdown rates below 50 gpm is located near the heat exchanger,
6. Provision for pumped draindown of the steam generators while bypassing the steam generator drain tank,
7. Provisions for circulation during wet layup operation, and
8. Branch connections for future addition of more heat exchangers.

Blowdown flow is normally diverted through the blowdown heat exchangers (tube side) where heat is lost to the condensate feed to the LP heaters in lieu of flashing to steam in the drain tank or condenser. The heat exchanger shells are provided with drain connections which are routed to the drain tank to allow complete drainage of the exchangers. Regulation of condensate flow is through orifices designed for maximum heat recovery. Condensate for heat recovery is tapped from the condensate system downstream of the condensate pumps and in parallel with condensate flow to the gland steam condenser. Isolation valves are provided such that the blowdown heat exchangers may be bypassed if necessary.

The blowdown fluid accumulated in the steam generator drain tank is adjusted by using any one or a combination of three (3) steam generator drain/wet layup pumps. Level is maintained within the drain tank by a level controller which positions an air operated control valve in the discharge of the pumps. The pumps may discharge the fluid to the catch basin, the waste disposal system, or the condensate storage system.

The flow diagram for the steam generator blowdown system is shown on Figure 10.1.0-8.

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10.4.7.1.2 Steam Generator Wet Layup

Each steam generator has its own means of recirculating the internal water mass in either upward or downward flow directions utilizing the respective steam generator drain/wet layup pump for circulation through portions of the feedwater and blowdown piping. Each of the steam generator wet layup circulation loops is provided with:

- a) Bi-directional flow capability,
- b) Branch connections for addition of a filtration unit,
- c) Nitrogen sparging/purging,
- d) Provisions for addition of chemicals,
- e) Stream sampling to a continuous radiation monitor and to a sample station,
- f) An air operated flow control valve, and
- g) Provision for pumped draindown of the steam generators.

The flow diagram from the steam generator blowdown and wet layup system is shown on Figure 10.1.0-8.

10.4.7.2 Safety Evaluation

Under normal operating conditions, there are no radioactive contaminants present in the steam and power conversion system unless steam generator tube leaks develop. In this event, monitoring of the steam generator blowdown will detect any contamination.

A radioactivity monitor is provided for steam generator blowdown. Blowdown is taken from each steam generator, with each stream passing through its separate sample cooler and then into a radiation monitor which detects total activity present in the blowdown. A high activity signal initiates closure of the remote operated blowdown stop valves, the blowdown rate control valve, and blowdown sample valves of the affected steam generator. The circulating water discharge valve will shut if all three radiation monitors go into alarm.

Refer to Section 11.5 for the Radiation Monitoring System description for the steam generator.

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10.4.8 Auxiliary Feedwater System

10.4.8.1 Design Basis

The design parameters for the auxiliary feedwater system components are shown on Table 10.4.8-1. Motor driven auxiliary feedwater pumps A and B and the steam driven pump and all piping and equipment in their trains are designed and constructed in accordance with the Seismic Class I requirements presented in Section 3.2. The equipment and piping in the AFW Pump C train are non-safety related, non-seismic and are not credited in the safety analyses. AFW Pump C serves to reduce plant risk following a beyond design basis event of losing all three safety related AFW pumps.

10.4.8.2 System Description

The flow diagram for the auxiliary feedwater system is included with the condensate and feedwater flow diagram Figures 10.1.0-4, 10.1.0-5, and 10.1.0-6.

The auxiliary feedwater system can provide feedwater to the steam generators from any one or combination of three auxiliary feedwater (AFW) pumps, two are motor driven pumps and the third is steam driven.

Two motor driven auxiliary feedwater pumps are supplied power from the emergency busses E-1 and E-2. The emergency busses also supply power to the motor driven auxiliary feedwater pump's discharge isolation valves and the steam driven auxiliary feedwater pump's steam supply and feedwater discharge isolation valves. The emergency busses are supplied power either from offsite or plant diesel generators. The steam driven auxiliary feedwater pump can be operated independent of electrical power where steam produced from decay heat drives the turbine. The auxiliary feedwater pumps supply feedwater to the steam generators for decay heat removal if main feedwater is not available or steam generator level is not adequate, as described below. The auxiliary feedwater pumps can be used to fill the steam generators under any plant condition, except that the steam driven auxiliary feedwater pump requires the plant to be heated up above 350°F, and the motor driven AFW pumps require power.

Upon receipt of an auto start signal to the steam driven auxiliary feedwater pump, the steam supply valves will open supplying steam to drive the turbine-pump. At the same time, the feedwater discharge valves open to the steam generators. The turbine-pump builds up speed and supplies feedwater to the steam generators.

A cavitating venturi is located in the discharge piping of the steam driven auxiliary feedwater pump. Its function is to prevent excess flow from the pump into a low pressure steam generator in the case of a failed discharge flow control valve. This prevents excess mass/flow into containment during a main steamline break and prevents steam driven auxiliary feedwater pump runoff.

Upon receipt of an auto start signal to the motor driven auxiliary feedwater pumps, the feedwater discharge valves open while the motor is accelerating up to speed and supplies feedwater to the steam generators.

The motor driven auxiliary feedwater pumps are supplied with bearing cooling water from the service water system. The SDAFW pump is self-cooled using water from the CST.

The capacity of the steam driven auxiliary feedwater pump is based on preventing the water level in the steam generators from receding below the lowest level within the indicated level range in the event of a loss of offsite power. This will prevent the tube sheet from being uncovered. A signal indicating a low low steam generator water level in any two steam generators or a direct signal of undervoltage on 4160 buses 1 and 4 will automatically start the steam driven AFW pump by opening steam admission valves and auxiliary feedwater discharge valves to individual steam generators. The initiating signals for starting the motor driven AFW pumps

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are: both main feedwater pump breakers open, low low water level in any steam generator, initiation of a safety injection signal, or blackout (loss of offsite power) condition on the pump's respective emergency bus. In addition, both the motor driven AFW pumps and the steam driven AFW pumps are initiated automatically by AMSAC, and, if required, may be initiated manually. The AMSAC system is described in Reference 10.4.8-1 and 10.4.8-2. No operator action is required since flow control valves maintain the required flow into the steam generators under varying backpressures. At some time, it may be desirable to manually isolate the flow to the individual steam generators. Provision is made in the control room for isolation of the individual steam generator flow. The AFW Flow Indication System continuously monitors the flow to the steam generators through the AFW piping and presents this information to the operator by meters mounted on the RTGB. Similarly, control is provided to modulate the total AFW flow. Key switches are provided for the purpose of blocking selected auxiliary feedwater pump auto start signals and steam generator blowdown valve closure signals during plant outages.

The steam supply to the steam driven AFW pump is taken off upstream from the main steam isolation valves, thereby assuring a source of steam to the pump. Main steam nonreturn valves (power operated stop-checks) are provided in each steam generator steam line. In the unlikely event of a steam line break the action of the nonreturn valve on the broken line prevents steam from the other two steam generators from discharging through the break. Feedwater to the unit with the ruptured line is isolated and the unit allowed to boil dry. The auxiliary feedwater pumps operation is automatic.

Should a steam line break occur in the header between the main steam isolation valves and the turbine, all main steam isolation valves are closed automatically. With the coincident loss of auxiliary power, emergency cooldown procedures are followed. If one main steam isolation valve fails to close, the feedwater line to the affected unit is isolated and the unit allowed to boil dry. Plant cooldown is then effected using the remaining two steam generators. Alternative shutdown control capability is discussed in Section 7.4.

10.4.8.3 Safety Evaluation

In the unlikely event of complete loss of offsite electrical power to the station, decay heat removal would continue to be assured by the availability of one steam driven, and two motor driven auxiliary feedwater pumps, and steam discharge to atmosphere via the main steam safety valves and power operated relief valves. In this case, feedwater is available from the condensate storage tank by gravity feed to the auxiliary feedwater pumps. The 132,000 gallons of water normally maintained in the condensate storage tank are adequate for decay heat removal for a period of at least twelve hours. Alternate sources of water are available from the lake via either leg of the plant service water system for an indefinite time period, and from the deep wells if offsite power is available. Deep well pump water is available for 24 hours following loss of offsite power using alternate power source.

If an auxiliary feedwater pump failed to start following a loss of main feedwater, sufficient redundancy of feedwater pumps is available to provide the required feedwater. One motor driven pump has sufficient capacity to prevent relief of fluid through the primary side relief valves.

A discussion of the automatic bus transfer feature for certain auxiliary feedwater system components is contained in CP&L letter NLS-85-218, dated June 14, 1985.

The maximum starting time requirement for the motor driven auxiliary feedwater pumps is one minute. This allows sufficient time for the diesels to be started and auxiliary systems of higher priority to be loaded on the diesels. The motor driven auxiliary feedwater pumps are sized assuming the pumps are started within one minute including the allowance for starting the diesels and the loading sequence.

The maximum starting time requirement for the steam driven auxiliary feedwater pump is at most equal to that of the motor driven auxiliary feedwater pumps. This allows for starting delays and bringing the steam driven AFW pump to full load.

The adequacy of the auxiliary feedwater pump capacities is demonstrated in the Loss of Normal Feedwater Accident of Section 15.2.7.

A discussion of the considerations used in establishing auxiliary feedwater system flow requirements is contained in a letter from E. E. Utley, CP&L to D. G. Eisenhower, "Auxiliary Feedwater System," dated April 29, 1980.

The analysis of the effects of loss of full or partial load on the reactor coolant system is discussed in Section 15.2.2.

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In the event of a failure of Lake Robinson Dam, shutdown would be accomplished in an orderly manner using the condensate storage tank. When the condensate storage tank reaches a low level limit, auxiliary feedwater pump suction would be changed to the deepwell pump discharge. This source would provide the required feedwater indefinitely or until such time some other source of feedwater can be established. It is assumed that emergency power is not required for this accident.

The effects of tornado generated missiles on the auxiliary feedwater system are discussed in letter LAP-83-385, dated August 29, 1983 and NLS-84-197, dated May 29, 1984.

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After boration is complete, the plant can be slowly cooled down by allowing the decay heat to be removed through the steam generator utilizing the steam driven auxiliary feedwater pump. This pump can be operated without external seal cooling water. With the minimum volume of water available in the condensate storage tank (35,000 gallons), the plant could be maintained at hot shutdown for at least two hours before makeup from the deep well pumps would be required.

Due to the location of the auxiliary feedwater steam driven and motor driven pumps inside buildings, reasonable assurance is provided that no loss of function of the system will occur because of tornado damage. In the event the steam lines supplying steam to the turbine driven pump are damaged, the motor driven pump, powered by the emergency diesel generators located in Auxiliary Building, can be used.

10.4.8.4 Tests and Inspections

The auxiliary feedwater pumps can be periodically operated to verify their operability during plant shutdown.

Proper functioning of the steam admission valve and subsequent starting of the steam driven AFW pump demonstrate the integrity of the system. Verification of correct operation can be made both from instrumentation within the main control room and direct visual observation of the pump.

10.4.8.5 Instrumentation Requirements

The controls used to automatically start the auxiliary feedwater pumps are designed to meet the single failure criterion, with the exception of the opening of both feedwater pump circuit breakers and AMSAC. The following pump starting logic is used:

1. The two motor driven auxiliary feedwater pumps are started automatically on:
 - a. 2/3 low low level in any steam generator
 - b. Opening of both feedwater pump circuit breakers (one contact per pump breaker is used)
 - c. Any safety injection signal
 - d. Loss of offsite power (i.e., the blackout sequence)
 - e. Manually.
 - f. AMSAC trip (two of three SG below low-low setpoint at 40% power)
2. The steam driven auxiliary feedwater pump is started automatically on:
 - a. 2/3 low low level in any two steam generators

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- b. Loss of voltage on both 4.16 kV buses 1 and 4. Two sensors are provided for each bus with 2/2 logic to indicate a loss of voltage on any one bus
- c. Manually.
- d. AMSAC trip (two of three SG below low-low setpoint 40% power)

The relay logic for starting the auxiliary feedwater pumps is separated into train A and train B logic as is done for the relay logic used to actuate engineered safety features equipment. Logic train A will start one motor driven pump and logic train B will start the second motor driven pump. Either logic train will open appropriate steam system valves to start the turbine driven pump. The circuits used to start the auxiliary feedwater pumps will also open and control the appropriate valves to ensure delivery of flow to the steam generators. The failure analysis for the auxiliary feedwater system is shown in Table 10.4.8-2.

Implemented for compliance with 10CFR50.62, the ATWS Mitigation System Actuation Circuitry (AMSAC) System provides a means to automatically trip the turbine and actuate auxiliary feedwater flow in the event of a complete loss of feedwater transient. The AMSAC System is independent of and isolated from the existing Reactor Protection System (RPS) from sensor to the output actuation device. The AMSAC setpoints and time-delayed actuation will ensure that the RPS has had time to perform its function before any AMSAC-initiated trip. Therefore, the AMSAC signal will be of no consequence unless the RPS has failed.

The AMSAC System utilizes the steam generator level monitoring option as defined by Logic 1 of WCAP 10858-P-A, Revision 1. The system uses the output from existing steam generator narrow-range level sensors fed into a microprocessor-based AMSAC controller. The AMSAC controller also monitors turbine first-stage pressure to identify the 40% power level at which the AMSAC must be armed. Class 1E qualified isolators protect the safety-related circuits currently associated with both of these sets of sensors from any perturbations that could be introduced by malfunction of the nonsafety-related AMSAC circuitry. A timer associated with the AMSAC arming logic maintains the AMSAC in an armed condition after turbine pressure drops below the 40% power level. This ensures that a turbine trip will not disarm AMSAC before it has had time to initiate auxiliary feedwater flow if the steam generator level criteria are met. During operation, the controller continuously scans the sensor inputs. The AMSAC System will be armed when the turbine pressure indicates that the plant is above 40% power. If AMSAC is armed and the controller identifies a coincident low level in two out of three steam generators, the controller will actuate a turbine trip and initiate auxiliary feedwater flow after appropriate timer delay to ensure that it does not preempt the RPS trip functions. The AMSAC outputs tie in to the existing safety-related actuation circuits using isolation relays to protect the existing systems from problems induced by AMSAC malfunctions.

Condensate storage tank level is indicated in the control room. A redundant low-level alarm is actuated before the tank is completely emptied, to allow AFW pump suction to be transferred from the condensate storage tank to an alternate source.

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TABLE 10.4.8-1

DESIGN PARAMETERS
AUXILIARY FEEDWATER SYSTEM

Motor Driven Auxiliary Feedwater Pumps

Number	2
Stages	10
Type	JTCH
Capacity	300 gpm
Total Head in ft of H ₂ O	3,000
Motor HP	350

Steam Driven Auxiliary Feedwater Pump

Number	1
Type	TBA-16
Capacity	600 gpm*
Total Head in ft H ₂ O	3000
Steam Supply Pressure	Range 120 to 1005
Steam Supply Temperature	Range 350°F to 547°F
Speed (running)	9,400 RPM
Speed (trip)	10,800 RPM
Turbine HP	733

<u>Emergency Feedwater Source</u>	35,000 gallons available in the condensate storage tank. Alternate supply from the service water system and deep well pumps.
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* This was the original design flow for the Steam Driven AFW Pump. The flow from the SDAFW pump is controlled by FCV-6416 and a cavitating venturi and may be less than the pump design flow. The maximum flow to a faulted steam generator will be less than 630 gpm, limited by the cavitating venturi. The setpoint for FIC-6416, the controller for FCV-6416, is 500 gpm.

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TABLE 10.4.8-2

MALFUNCTION ANALYSIS OF AUXILIARY FEEDWATER SYSTEM

<u>Component</u>	<u>Malfunction</u>	<u>Comment</u>
Motor Driven Pump	Fail to start	Second motor driven pump or steam driven pump supplies adequate feedwater
Steam Gen. Level Switch	Fails to signal low level	Three switches per generator provided
Steam Admission Valve to Pump Turbine	Fails to open	Three valves, one from each steam generator
Discharge Valve From Motor Driven Pump Header	Fails to open	If steam driven pump has not started, one steam generator will reach low level alarm point. Operator must manually start steam driven pump.

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REFERENCES: SECTION 10.4

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|----------|--|
| 10.4.8-1 | "Plant-Specific AMSAC Submittal," CP&L to NRC, dated October 30, 1987, Serial NLS-87-219. |
| 10.4.8-2 | "Supplemental Plant-Specific AMSAC Information," CP&L to NRC, dated June 24, 1988, Serial NLS-88-058 |