ENCLOSURE 3

CONSUMERS POWER COMPANY
PALISADES PLANT
DOCKET 50-255

Palisades Plant
Steam Generator/Auxiliary
Feedwater Review

August 15, 1983
14 Pages

ENCLOSURE 3
PALISADES PLANT

STEAM GENERATOR/AUXILIARY FEEDWATER REVIEW

Three concerns exist with respect to adding Auxiliary Feedwater (AFW) to the steam generators given this proposed event (refer to Enclosure 2 for the event description). First, is the AFW system sufficiently reliable to assure water flow to the steam generators? Second, is it likely that the addition of this cold feedwater will cause failure of steam generator U-tubes due to thermal shock? Third, if the tube failures do not occur, will heat removal by AFW be significantly reduced by "steam binding" as the cold water contacts the hot steam generator? Each of these concerns is discussed in detail below.

1. The Auxiliary Feedwater System (AFWS) has undergone several modifications and will be further modified during the upcoming refueling outage scheduled for August to December 1983. Two figures are attached to illustrate these changes. Figure 1-1 shows the original system and Figure 1-2 shows the system as it will exist after the 1983 refueling outage. Changes between Figure 1-1 and Figure 1-2 are as follows:

   a) The AFWS piping no longer joins the main feedwater piping outside the containment. AFW runs through its own 4-inch piping to each steam generator. It enters the steam generator through a nozzle separated from the main feedwater nozzle by 30 inches. Inside the steam generator the AFWS has its own feed ring.

      This change allows addition of AFW to a steam generator with a faulted main feedwater pipe.

   b) A second motor-driven AFW pump (P8C) is being added. This pump will have separate discharge piping and flow control valves from the two existing pumps. This discharge piping will join that piping from the existing pumps just outside the containment penetration.

      Suction is from a common source, but separate alternate supplies of Lake Michigan water are available. The original two pumps can be supplied via the fire system; the new pump via the service water system. The fire and service water systems are normally separate, but can be cross-connected.

      The new pump, P8C, is powered by the 2.4 KV safeguards bus and diesel generator which are opposite to the bus and generator which serve the original motor-driven pump, P8A. Instrumentation power supplies for the two AFWS trains are separate DC supplies.

   c) An automatic start for the AFW pumps has been added. Low level in either steam generator will start P8A. If P8A is not running AND supplying water to at least one steam generator in 15 seconds, P8C will auto start. (Similary, if P8C also fails to operate, the turbine driven pump, P8B will receive a start signal. This particular steam generator blowdown event, however, eliminates any steam supply.)

These changes significantly reduce the probability of total failure of the Auxiliary Feedwater System.

2) The FSAR Section 4.3.4 (Attachment 1 Pages 2 and 3) states that the steam generators are designed "such that no component will fail either by rupture or by developing deformations (elastic or plastic) that impair the function, performance, or integrity of the steam generator for further operation" when subjected to, among other transients, "eight cycles during which the primary side is at 2500 psia and 600°F while the secondary side is depressurized to atmospheric pressure" and "8 cycles of adding a maximum of 300 gpm of 70°F feedwater with the steam generator dry at 600°F."

While there are no analyses available for a two steam generator blowdown, the Steam Line Rupture Incident Analysis, Section 14.14 of the FSAR, shows PCS pressure and temperature, and steam generator pressure as functions of time (refer to Attachment 1 Pages 6, 7 and 8). With two steam generators blowing down, it can be assumed that the dryout would take somewhat longer while TAVE would drop approximately twice as much.

Figure 14.14-4 (Attachment 1, Page 7) shows the failed steam generator "drying out" about 45 seconds into the accident. The first AFW pump should start five seconds after the steam generator level reaches the low level setpoint. If the first pump fails to start at that point, the second pump will start ten seconds later. Acceleration time for these pumps is less than five seconds. Assuming ten seconds for steam generator level to reach the low level alarm point, and assuming the first pump fails to start, the plant should still be adding AFW more than 20 seconds before the faulted steam generator goes dry. The other steam generator will empty more slowly due to blowing down through the entire main steam piping. It is, therefore not likely that AFW flow would be starting with a steam generator already dry.

FSAR Figures 14.14-3 and 5 (Attachment 1, Pages 6 and 8) show Tave to have cooled about 100 degrees to 475°F and PCS pressure reduced to 600 psia at the proposed time of AFW initiation. With two steam generators blowing down, the PCS would be significantly cooler and at a lower pressure. It should also be noted that AFW flow is initiated at 150 gpm; just half the design condition flow rate. Even if the operator delays the addition of AFW, due to the high initial cooldown rate, the referenced FSAR figures indicate PCS conditions stay far below the 600°F/2500 psia design condition even for a single steam generator blowdown. The thermal and hydraulic stresses on the steam generator tubes would thus be greatly reduced from the design condition of 600°F and 2500 psia.

3) The third concern, that of steam blanketing (or binding), is highly unlikely to be problem. This conclusion can be drawn when looking at a section view of a Palisades steam generator (see Figure 2).

If steam flow, caused by boiling a small portion of the AFW, is to carry the remainder of the AFW out of the break, it must take one of two paths from the tube sheet/tube bundle region to the break. The first path would be that of normal steam flow up through the tube bundle and through the steam separators, then either through the steam dryers and out a faulted main steam line or down around the outside of the separator deck and out a faulted main feedwater line. The second path would be back under the edge of the wrapper and up the outer annulus, then out through a faulted feed line or through the Chevron dryers and out a faulted main steam line.

The first flow path has separators, and possibly dryers, capable of reducing a steam flow of 5.86×10^6 lb/hr to less than 1/4% moisture. Thus, there should be little carryover (carry out) with the AFW flow of 300 gpm (0.15×10^6 lb/hr). Significant AFW moisture carryout is unlikely even in the event that the separators and dryers structurally fail due to the velocity of the steam which is developed as an immediate result of the MSLB. The velocity of the steam that is developed by boiling of the incoming AFW is considered incapable of supporting any significant AFW droplet size. Given the AFW flow rate of 0.15×10^6 lb/hr, a flow area of 288.5 ft^2 near the entrance to the separator deck, a steam generator shell pressure of 20 psia and steam at saturated conditions, the resulting steam velocity is only about 2.9 ft/sec.

The second path has a free cross-sectional area of 80 ft^2 mid-way up the conic section below the main feedwater ring. If all of the 300 gpm were to boil at a pressure as low as 20 psia, the velocity in this area would be about 10 ft/sec and would not support a very large droplet size. If the flow is out a failed steam line, the flow must still exit through the Chevron separators.

The ratio of free areas of path one to path two, at the middle elevation of the tube bundle, is greater than six to one. Most of the flow would therefore take path one where it will pass through the separators. Most of the feedwater added must then remain inside the generator where it must boil and remove heat.

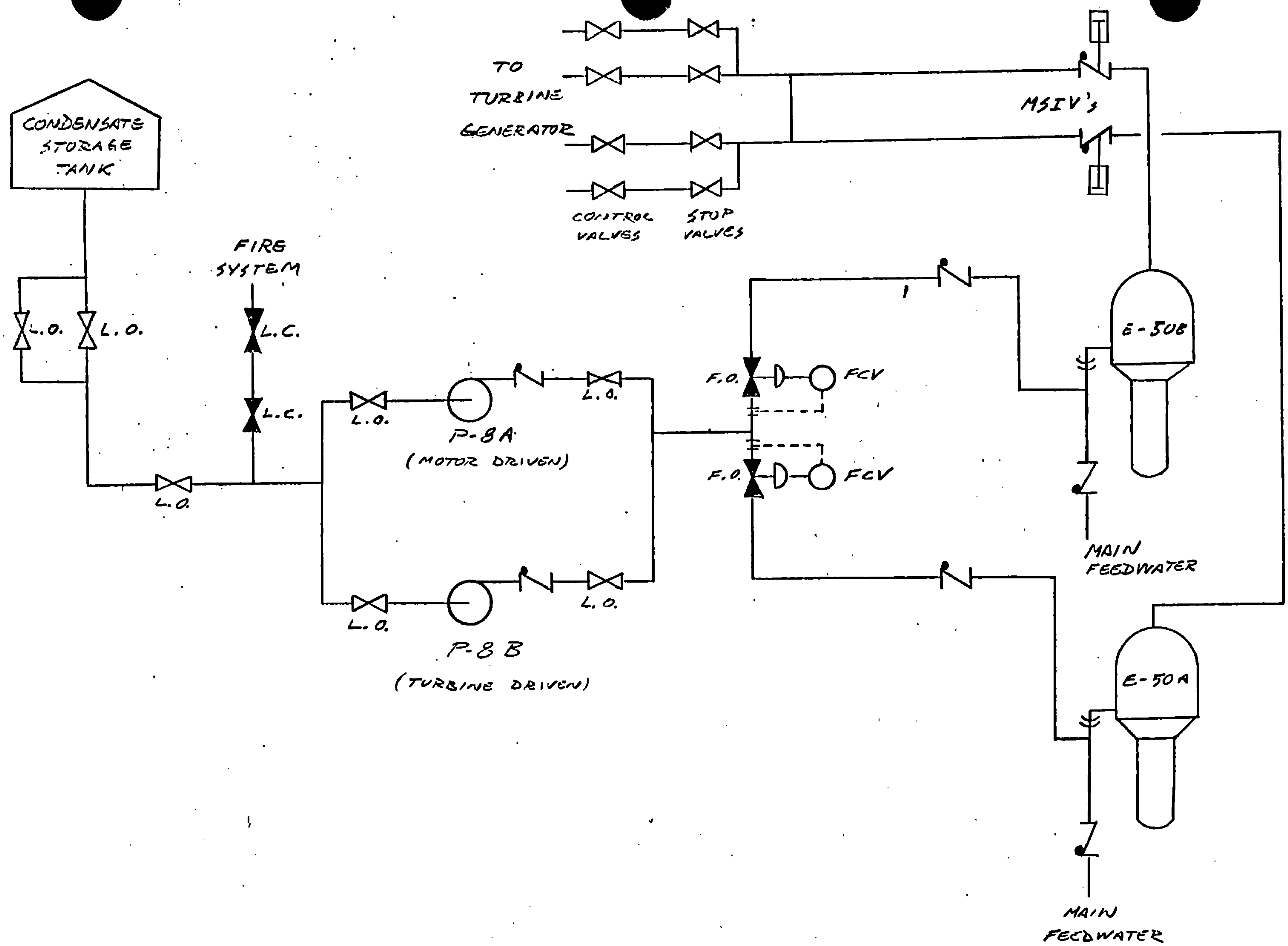

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Figure 1-1

Original Palisades Auxiliary Feedwater System

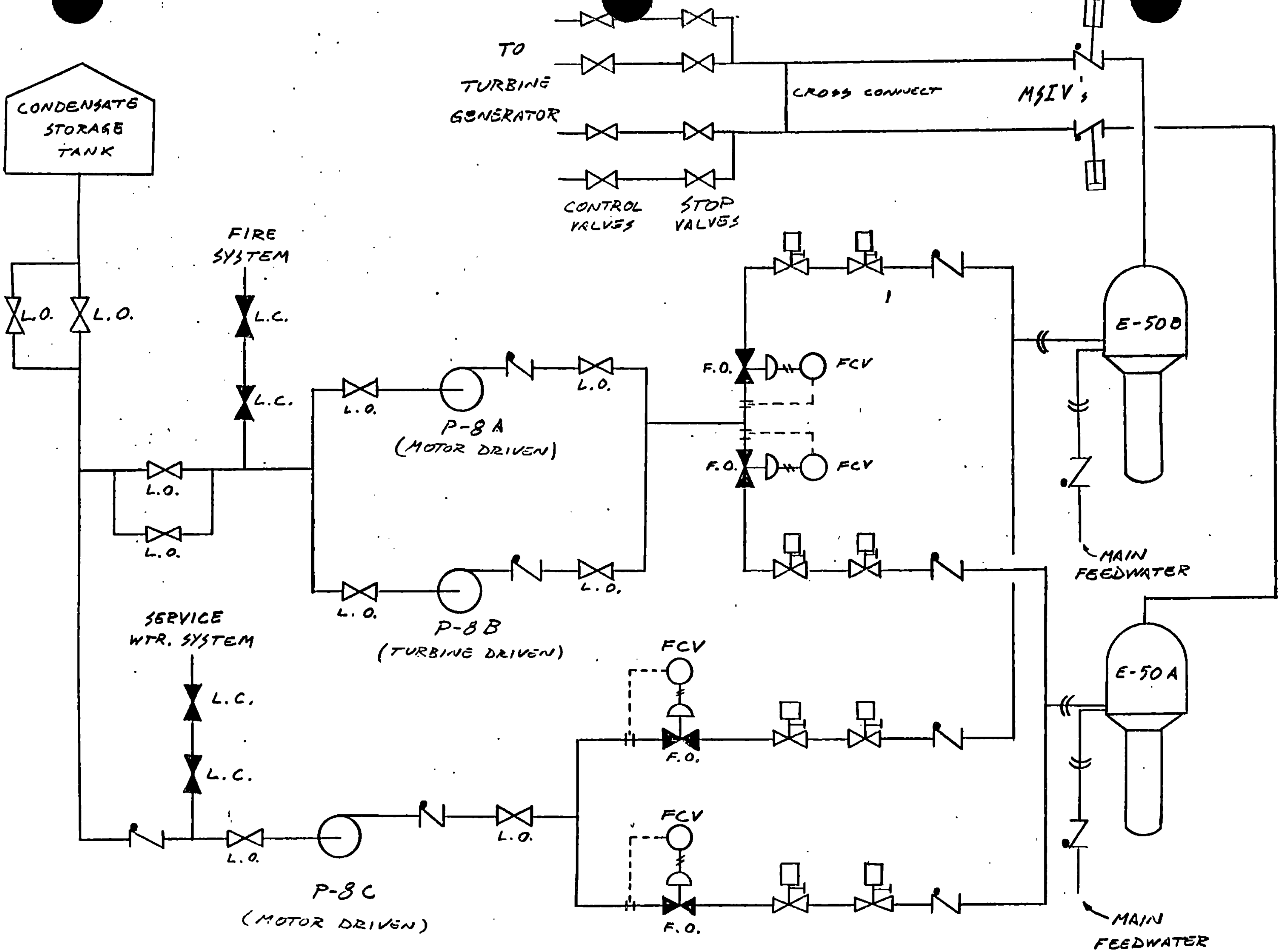

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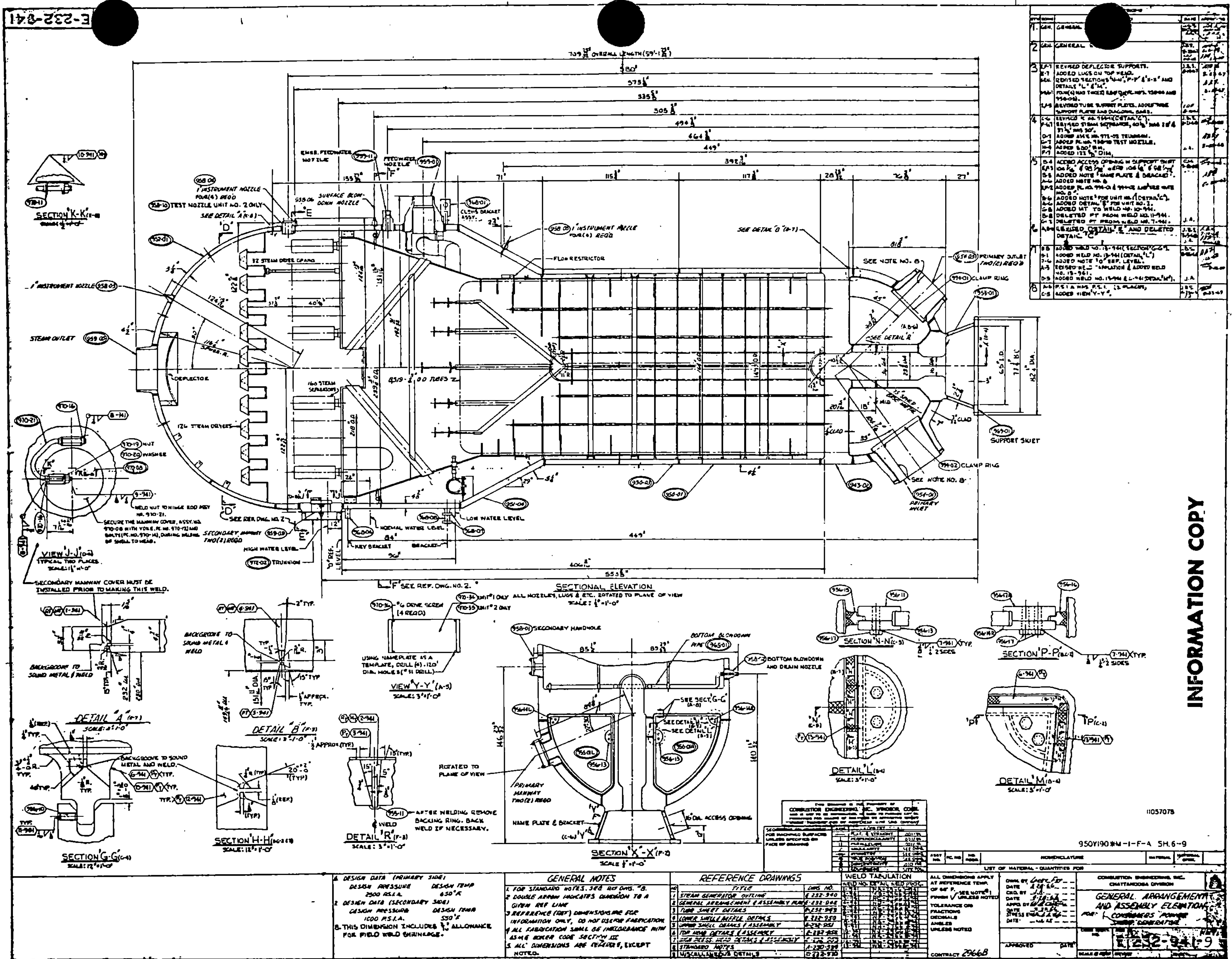
Figure 1-2

New Palisades Auxiliary Feedwater System


E-232-941
SECTIONAL ELEVATION
SECTION 'K-K'
STEAM OUTLET
DEFLECTOR
126 STEAM DRYERS
32 STEAM DRYER CANS
160 STEAM SEPARATORS
FLOW RESTRICTOR
SEE NOTE NO. 8
PRIMARY OUTLET TWO(2) REQ'D
CLAMP RING
SUPPORT SKIRT
PRIMARY INLET
LOW WATER LEVEL
NORMAL WATER LEVEL
HIGH WATER LEVEL
TRUNNION
KEY BRACKET
VIEW 'J-J'
SECONDARY MANWAY COVER MUST BE INSTALLED PRIOR TO MAKING THIS WELD.
DETAIL 'A'
DETAIL 'B'
SECTION 'G-G'
SECTION 'H-H'
DETAIL 'R'
VIEW 'Y-Y'
SECONDARY HANDHOLE
BOTTOM BLOWDOWN PIPE
BOTTOM BLOWDOWN AND DRAIN NOZZLE
PRIMARY MANWAY TWO(2) REQ'D
NAME PLATE & BRACKET
SECTION 'X-X'
SECTION 'N-N'
SECTION 'P-P'
DETAIL 'L'
DETAIL 'M'
INFORMATION COPY
11057078
950Y190#M-1-F-4 SH.6-9
GENERAL NOTES
1. FOR STANDARD NOTES, SEE REF DWG. "B.
2. DOUBLE ARROW INDICATES DIMENSION TO A GIVEN REF LINE
3. REFERENCE (REF) DIMENSIONS ARE FOR INFORMATION ONLY, DO NOT USE FOR FABRICATION
4. ALL FABRICATION SHALL BE IN ACCORDANCE WITH ASME BOILER CODE SECTION III
5. ALL DIMENSIONS ARE REFERENCE, EXCEPT NOTED.
6. DESIGN DATA (PRIMARY SIDE) DESIGN PRESSURE 2500 PSIA DESIGN TEMP 650°F
7. DESIGN DATA (SECONDARY SIDE) DESIGN PRESSURE 1000 PSIA DESIGN TEMP 550°F
8. THIS DIMENSION INCLUDES ALLOWANCE FOR FIELD WELD SHRINKAGE.
REFERENCE DRAWINGS
WELD TABULATION
COMBUSTION ENGINEERING, INC. CHATTANOOGA DIVISION
GENERAL ARRANGEMENT AND ASSEMBLY ELEVATION
CONSUMERS POWER STEAM GENERATOR
CONTRACT 2966B
E-232-941-9

Enclosure 3
Attachment 1
Palisades Plant Final Safety
Analyses Report
Extract
8 Pages

4.3.4 STEAM GENERATOR

The nuclear steam supply system utilizes two steam generators, Figure 4-3, to transfer the heat generated in the reactor coolant system to the secondary system. The design parameters for the steam generators are given in Table 4-5.

The steam generator is a vertical U-tube heat exchanger and is designed in accordance with ASME Boiler and Pressure Vessel Code, Section III, Class A. The steam generator operates with the primary coolant in the tube side and the secondary fluid in the shell side.

Primary coolant enters the steam generator through the inlet nozzle, flows through 3/4" OD U-tubes, and leaves through two outlet nozzles. Vertical partition plates in the lower head separate the inlet and outlet plenums. The plenums are stainless steel clad, while the primary side of the tube sheet is Ni-Cr-Fe clad. The vertical U-tubes are Ni-Cr-Fe alloy. The explansion process is used for expanding the steam generator tubes in the tube sheet. The tube-to-tube sheet joint is welded on the primary side.

Feedwater enters the steam generator through the feed-water nozzle where it is distributed via a feed-water distribution ring having bottom apertures which direct the flow through the downcomer. The downcomer is an annular passage formed by the inner surface of the steam generator shell and the cylindrical shell which encloses the vertical U-tubes.

Upon exit at the bottom of the downcomer, the secondary water is directed upward over the vertical U-tubes. Heat transfer from the primary side converts a portion of the secondary water into steam.

Upon exiting from the vertical U-tube heat transfer surface, the steam-water mixture enters the centrifugal type separators. These impart a centrifugal motion to the mixture and separate the water particles from the steam. The water exits from the perforated separator housing and combines with the feedwater. Final drying of the steam is accomplished by passage of the steam through the corrugated plate dryers. The moisture content of the exiting steam is limited to a maximum of 0.2% at design flow.

The power operated steam dump valves and steam bypass valve prevent opening of the safety valves following turbine and reactor trip from full power. The steam dump and bypass system is described in Section 9.

The steam generator shell is constructed of carbon steel. Manways and handholes are provided for easy access to the steam generator internals.

Overpressure protection for the shell side of the steam generators and the main steam line piping up to the inlet of the turbine stop valve is provided by twenty-four (24) safety valves. These valves are ASME Code spring loaded, open bonnet, safety valves and discharge to atmosphere. Twelve safety valves are mounted on each of the main steam lines upstream of the steam line isolation valves but outside the containment. The valves are divided into three groups of four valves, each valve within a group having the same nominal opening pressure, but with staggered group opening pressures consistent with ASME Code allowances. The valves can pass a steam flow equivalent to an NSSS power level of 2650 Mwt at the nominal 1000 psia set pressure. Parameters for the secondary safety valves are given in Table 4-4.

TABLE 4-4

SECONDARY SAFETY VALVE PARAMETERS

Design Pressure, Psia	1,000
Design Temperature, ^{o}F	550
Fluid - Saturated Steam	
Capacity, Minimum per Valve, Lb/Hr	486,600
Total Capacity, Lb/Hr	11,678,400
Set Pressure	
Eight Valves, Four per Unit, Psia	1,025
Eight Valves, Four per Unit, Psia	1,005
Eight Valves, Four per Unit, Psia	985
Body Material	ASTM 216, Gr WCB
Trim Material	Stainless Steel

The steam generators are mounted vertically on bearing plates to allow horizontal motion parallel to the hot leg due to thermal expansion of the reactor coolant piping. Stops are provided to limit this motion in case of a coolant pipe rupture. The top of the unit is restrained from sudden lateral movement by energy absorbers mounted rigidly to the concrete shield.

In addition to the transients listed in Section 4.2.2 each steam generator is also designed for the following accident conditions such that no component will fail either by rupture or by developing deformations (elastic or plastic) that will impair the function, performance, or integrity of the steam generator for further operation.

1. Eight cycles during which the primary side is at 2500 psia and 600^{o} F while the secondary side is depressurized to atmospheric pressure.

2. One cycle during which the steam on the shell side is at 900 psia and 532° F while tube (primary) side is depressurized to atmospheric pressure.

3. 2400 cycles of transient pressure differentials of 85 psi across the primary head divider plate due to starting and stopping the primary coolant pumps.

4. 10 cycles of hydrostatic testing of the secondary side at 1250 psia.

5. 320 cycles of leak testing of the secondary side at 1000 psia.

6. 5,000 cycles of adding 425 gpm of 70° F feedwater with the plant in hot standby condition.

7. 8 cycles of adding a maximum of 300 gpm of 70° F feedwater with the steam generator secondary side dry and at 600° F.

The unit is capable of withstanding these conditions for the prescribed numbers of cycles in addition to the prescribed operating conditions without exceeding the allowable cumulative usage factor as prescribed in ASME Code, Section III.

TABLE 4-5

STEAM GENERATOR PARAMETERS

Number	2
Type	Vertical U-Tube
Number of Tubes	8,519
Tube Outside Diameter	0.750 Inch

	Quantity	Size
Nozzles and Manways		
Primary Inlet Nozzle	1	42 Inch ID
Primary Outlet Nozzle	2	30 Inch ID
Steam Nozzle	1	34 Inch ID
Feedwater Nozzle	1	18 Inch Nominal
Instrument Taps	9	1 Inch Nominal
Primary Manways	2	16 Inch ID
Secondary Manways	2	16 Inch ID
Secondary Handhole	1	5-11/16 Inch ID
Secondary Drain & Blowdown	1	2 Inch Nominal
Surface Blowdown	1	1 Inch Nominal
Spare	1	4 Inch Nominal

	Initial	Stretch
Primary Side Design		
Design Pressure, Psia	2,500	2,500
Design Temperature, °F	650	650
Design Thermal Power (NSSS), Mwt	2,212	2,650
Cold Leg Temperature, °F	545	540.5
Hot Leg Temperature, °F	591	595
Coolant Flow Rate (Each), Lb/Hr	62.5×10^6	65.45×10^6
Normal Operating Pressure, Psia	2,100	2,250
Secondary Side Design		
Design Pressure, Psia	1,000	1,000
Design Temperature, °F	550	550
Normal Operating Steam Pressure, Full Load, Psia	770	764
Normal Operating Steam Temperature, Full Load, °F	514	514
Steam Moisture Content, Maximum, %	0.20	0.20
Blowdown Flow, Lb/Hr	2,000	2,000
Drying Capacity at 770 Psia, Maximum (Each), Lb/Hr	5.86×10^6	5.86×10^6
Design Thermal Power (NSSS), Mwt	2,212	2,650
Steam Flow (Each), Lb/Hr	4.701×10^6	5.81×10^6
Feed-Water Temperature, °F	418	438

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TABLE 4-5 (Contd)

Dimensions	
Overall Height, Including Support Skirt	59 Feet - 2 Inches
Upper Shell Outside Diameter	20 Feet - 10 Inches
Lower Shell Outside Diameter	13 Feet - 8 Inches
Dry Weight	924,600 Lb
Flooded Weight	1,496,000 Lb
Operating Weight	1,109,000 Lb

STEAM LINE RUPTURE INCIDENT

PRIMARY COOLANT TEMPERATURE VS TIME

FULL LOAD INITIAL CONDITION

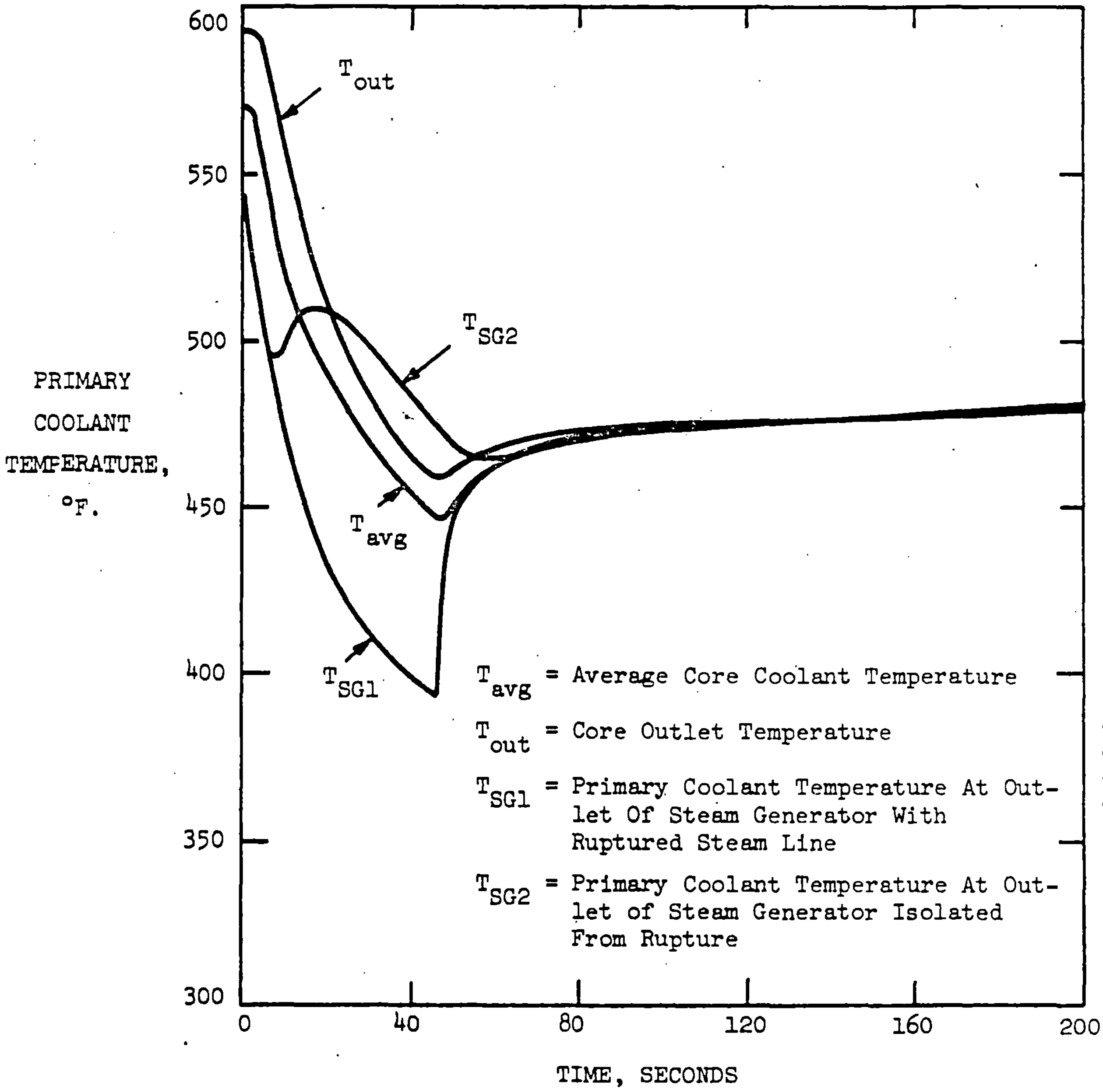

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FIG. 14.14-3

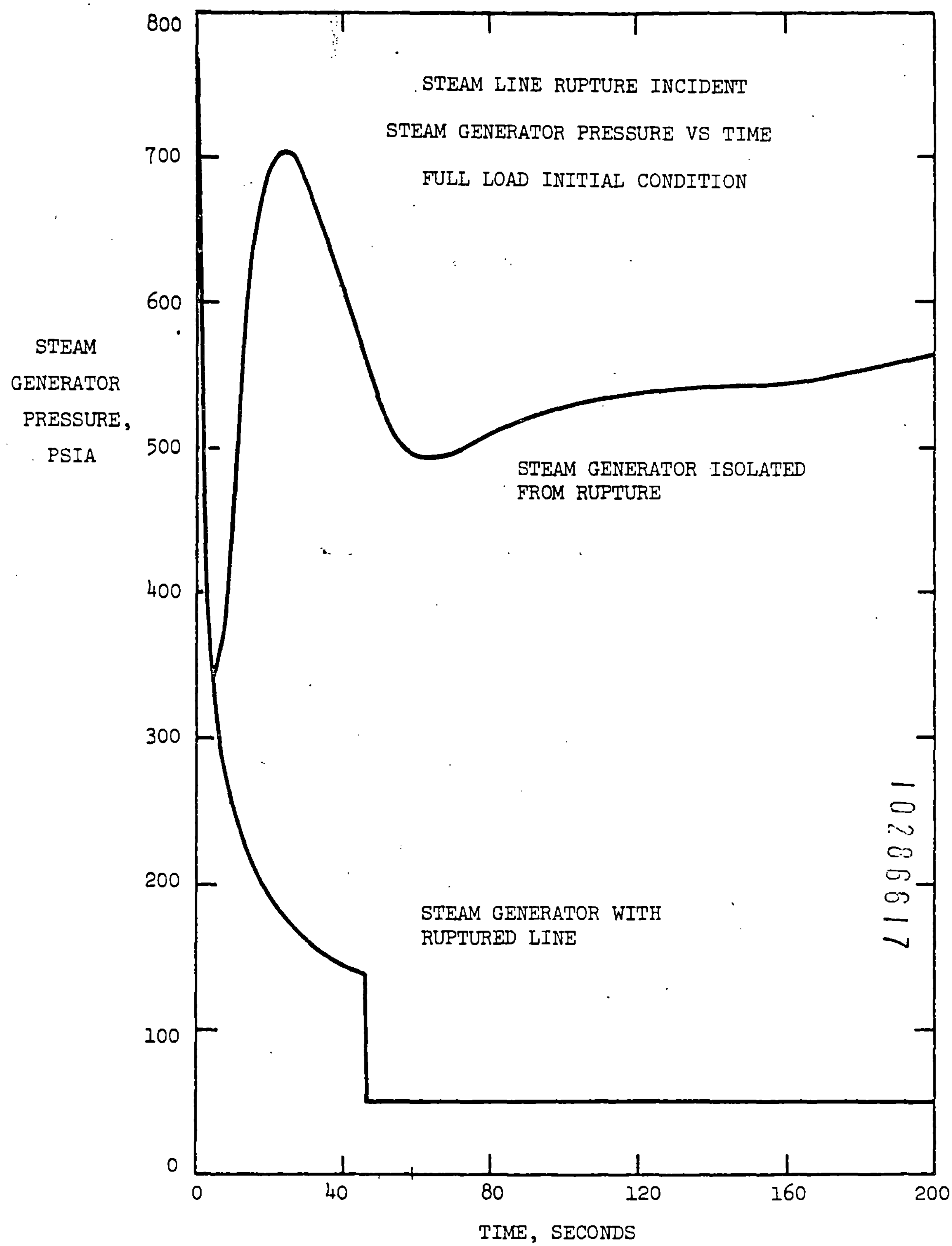

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FIG. 14.14-4

STEAM LINE RUPTURE INCIDENT

PRIMARY COOLANT SYSTEM PRESSURE VS TIME

FULL LOAD INITIAL CONDITION

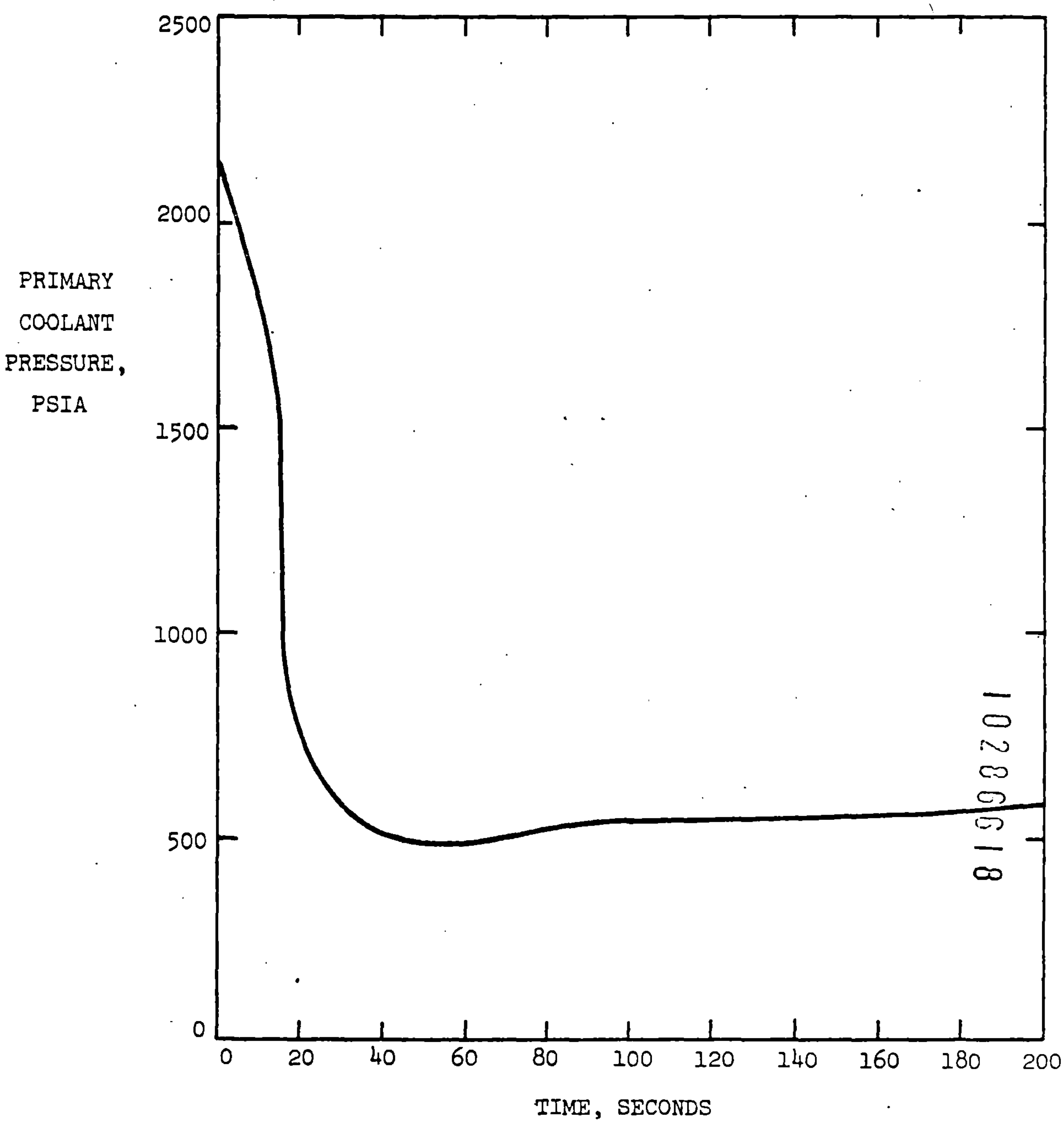

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FIG. 14.14-5