SCE Report P801-04-2

AUXILIARY FEED PUMP ROOM
ANALYSIS OF CONDITIONS RESULTING FROM A BREAK IN THE 4 INCH STEAM SUPPLY PIPE TO THE AUXILIARY FEED PUMP TURBINE
INDIAN POINT 3

NEW YORK POWER AUTHORITY

June 1984

Prepared by Kevin J. Iepson
K. Iepson, Principal Engineer

Reviewed by
J. A. Murphy, Manager,
Philadelphia Office

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Executive Summary

Executive Summary

This report contains the results of an evaluation of the effects in the Auxiliary Feed Pump Room of a break in the 4 inch steam supply pipe to the auxiliary feed pump turbine. The report was prepared in response to an NRC request to provide the analyses necessary to determine the room conditions following a break and confirm the parameters used for evaluating environmental qualification of safety-related electrical equipment located in the room.

The report addresses:

- Break locations
- Steam flow patterns from the break
- Break detection
- Break Isolation
- Temperature and Pressure in the Auxiliary Feed Pump Room resulting from the break.

The analyses to determine the Auxiliary Feed Pump Room conditions were performed using the RELAP-4 and CONTEMPT-LT computer programs. These programs were selected because of their extensive usage in analyzing the effects of High Energy Line Breaks in Nuclear Power Plants.

Conclusion

Based on the analyses performed it is concluded that a break in the 4 inch steam supply pipe to the auxiliary feed pump turbine would be isolated within four seconds and the room temperature would not exceed 115^{0}F. Due to possible delays in the isolation function, analyses were conducted for up to an 8 second isolation time which demonstrated that the room temperature would not exceed 145^{0}F.

It is considered that the room temperatures determined in the analyses are conservative because no venting of steam from the room was considered. In actuality there is approximately 3 square feet of vent area which would remove some of the steam from the room, prevent any pressure buildup and result in a lower room temperature. The equipment located in the room is

Conclusion (cont'd)

qualified for more severe environments than the environment determined by the analyses described in this report.

I. Introduction

I. Introduction

In an SER dated December 30, 1982 on Environmental Qualification of Electric Equipment Important to Safety for Indian Point 3, the NRC stated that analyses which were submitted by NYPA to NRC were not accepted by the staff for the pressure/temperature service conditions outside on containment.

One of the areas questioned by the NRC staff was the Auxiliary Feed Pump Room.

A. Description of the Auxiliary Feed Pump Room

The Auxiliary Feed Pump Room is a concrete enclosure housing the three auxiliary feed pumps with associated piping and control. Also contained in this area are the main feed flow transmitters and main steam pressure transmitters. The room is located on the West side of the Reactor Containment Building between the containment wall and a concrete shield wall which provides biological shielding for streaming paths associated with the containment penetrations for the main steam and feedwater pipes. Figures 1, 2 and 3 show the plan, sections and elevations for the Auxiliary Feed Pump Room.

B. Effects of a High Energy Line Break (HELB) in the Auxiliary Feed Pump Room

In the analysis of high energy lines for Indian Point 3 dated May 9, 1973, it was stated that no significant temperature build-up could occur because of the steam supply to the auxiliary feed pump would be isolated by redundant isolation valves actuated by temperature switches almost immediately following a break. This information was reaffirmed by NYPA in the May 1983 submittal to NRC pursuant to 10CFR50.49.

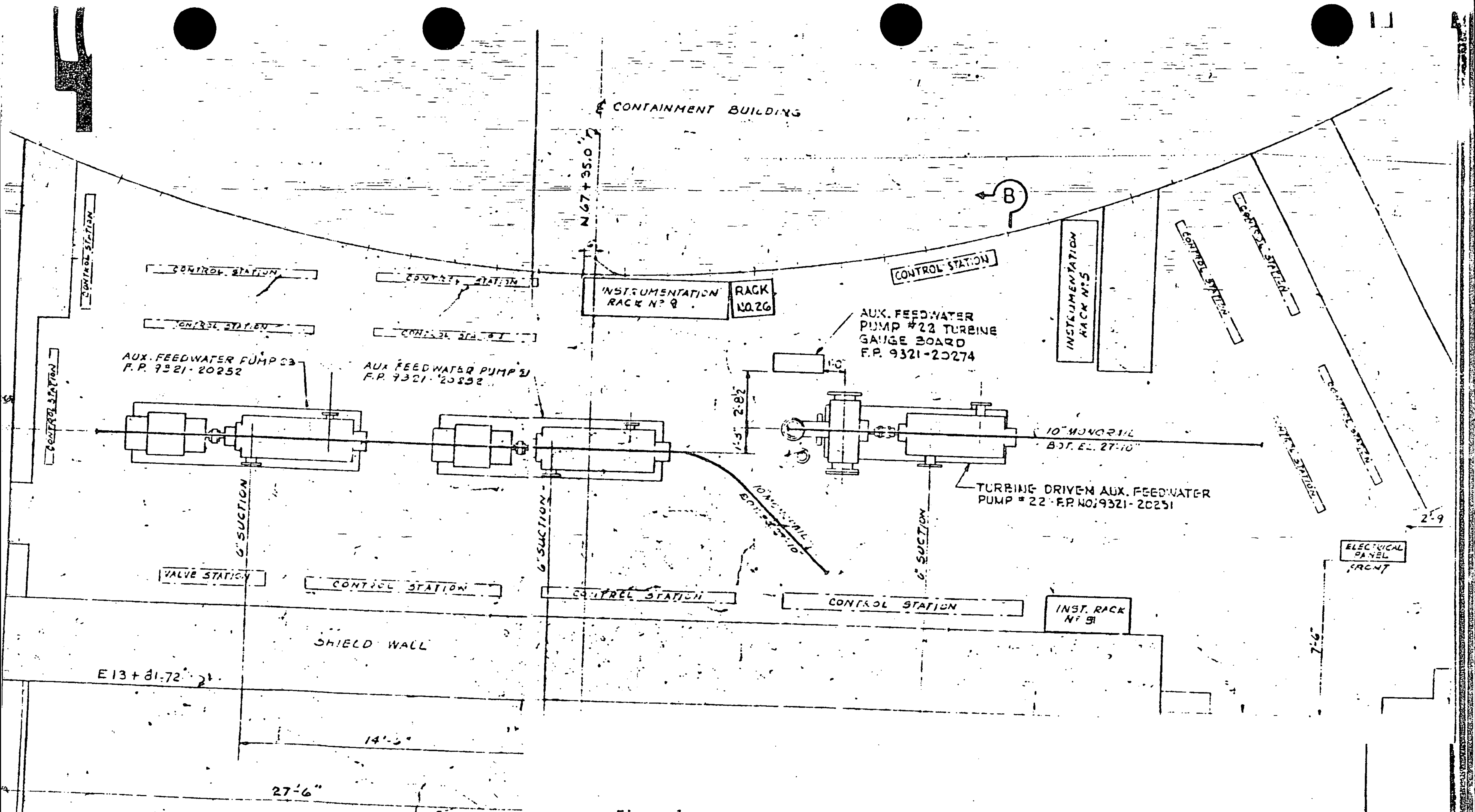
℄ CONTAINMENT BUILDING
N 67 + 35.0'
B
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
INSTRUMENTATION RACK Nº 8
RACK NO.26
CONTROL STATION
INSTRUMENTATION RACK Nº5
CONTROL STATION
CONTROL STATION
AUX. FEEDWATER PUMP 23
F.P. 9321-20252
AUX FEEDWATER PUMP 21
F.P. 9321-20852
AUX. FEEDWATER PUMP #22 TURBINE GAUGE BOARD
F.P. 9321-20274
1'-0"
2'-8½"
1'-5"
10" MONORAIL
BOT. EL. 27'-10"
10" MONORAIL
BOT. EL. 27'-10"
TURBINE DRIVEN AUX. FEEDWATER PUMP # 22 - F.P. NO. 9321-20251
CONTROL STATION
CONTROL STATION
6" SUCTION
6" SUCTION
6" SUCTION
2'-9
ELECTRICAL PANEL FRONT
VALVE STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
INST. RACK Nº 91
SHIELD WALL
7'-6"
E 13 + 81.72'
14'-3"
27'-6"

Figure 1

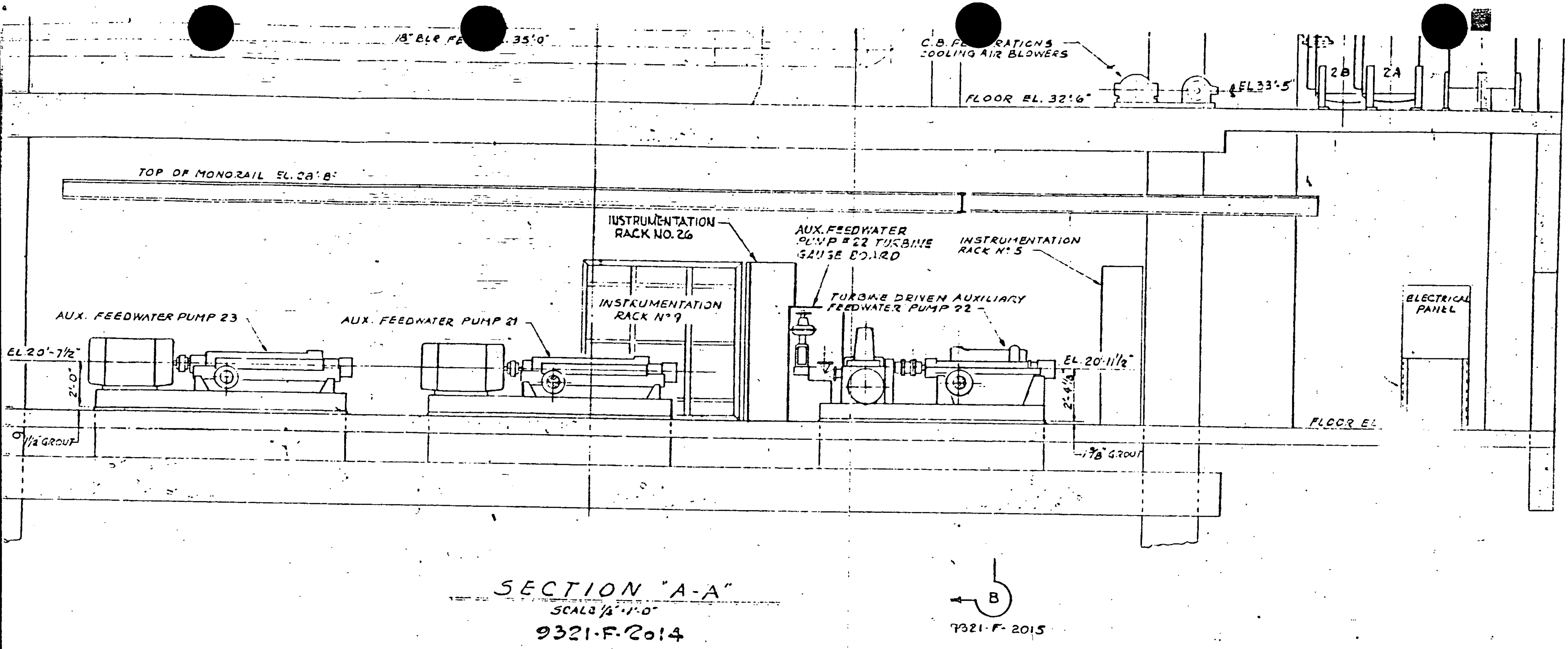
18" BLR FE 35'0"
C.B. PE RATIONS
COOLING AIR BLOWERS
FLOOR EL. 32'6"
EL 33'-5"
2B
2A
TOP OF MONORAIL EL. 28'-8"
INSTRUMENTATION RACK NO. 26
AUX. FEEDWATER PUMP #22 TURBINE GAUGE BOARD
INSTRUMENTATION RACK N° 5
INSTRUMENTATION RACK N° 9
TURBINE DRIVEN AUXILIARY FEEDWATER PUMP 22
ELECTRICAL PANEL
AUX. FEEDWATER PUMP 23
AUX. FEEDWATER PUMP 21
EL 20'-7½"
2'-0"
1½" GROUT
EL. 20'-11½"
2'-4½"
1⅞" GROUT
FLOOR EL
SECTION "A-A"
SCALE ½"=1'-0"
9321-F-2014
B
9321-F-2015

Figure 2

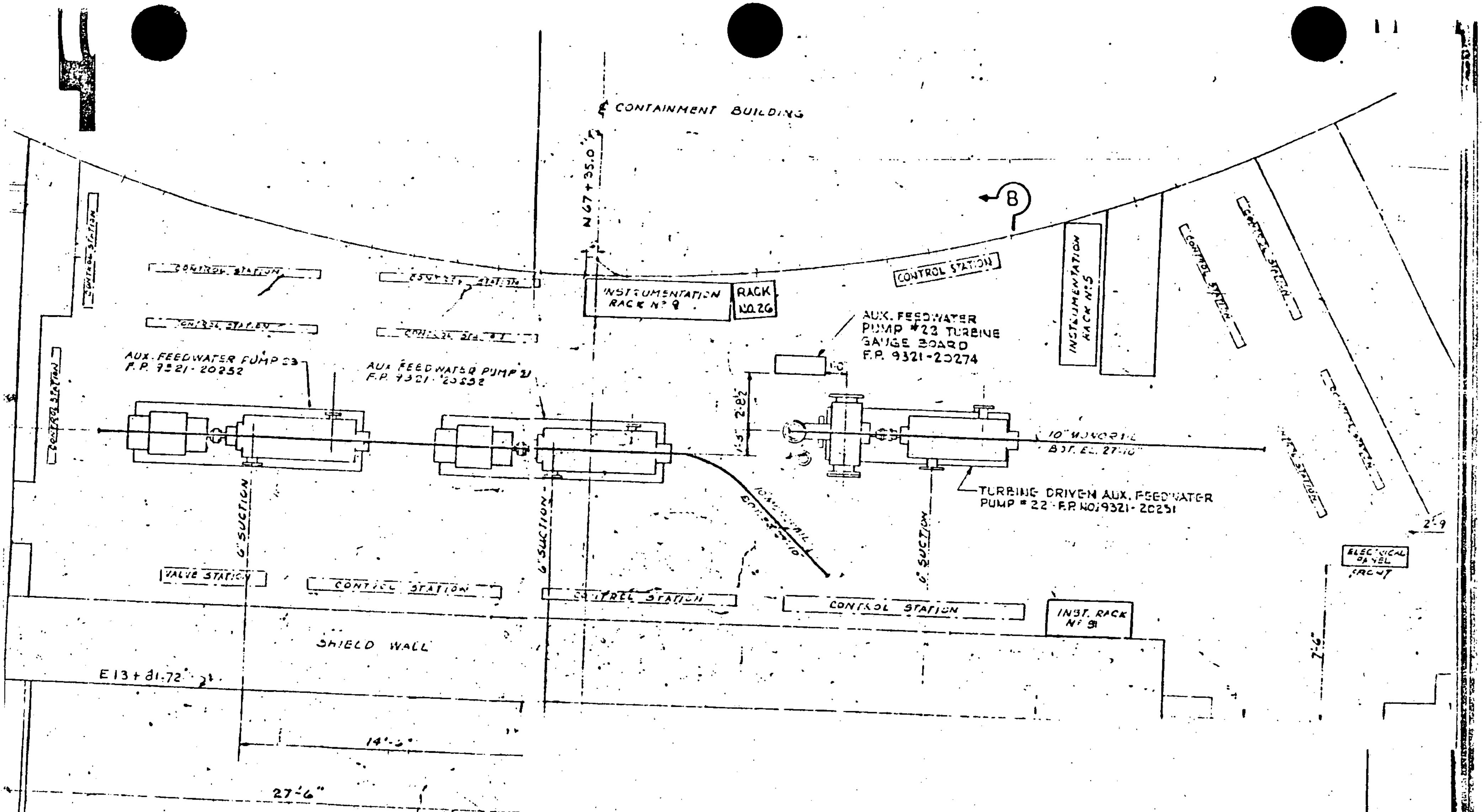
CONTAINMENT BUILDING
N 67 + 35.0
B
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
INSTRUMENTATION RACK Nº 9
RACK NO.26
INSTRUMENTATION RACK Nº 5
CONTROL STATION
CONTROL STATION
AUX. FEEDWATER PUMP 23
F.P. 9321-20252
AUX FEEDWATER PUMP 21
F.P. 9321-20252
AUX. FEEDWATER PUMP #23 TURBINE GAUGE BOARD
F.P. 9321-20274
2'-8½"
1'-5"
10" MONORAIL
BOT. EL. 27'-10"
TURBINE DRIVEN AUX. FEEDWATER PUMP # 22 F.P. NO. 9321-20251
6" SUCTION
6" SUCTION
6" SUCTION
2'-9
ELECTRICAL PANEL FRONT
VALVE STATION
CONTROL STATION
CONTROL STATION
CONTROL STATION
INST. RACK Nº 31
SHIELD WALL
E 13 + 81.72
7'-6"
14'-3"
27'-6"

Figure 1

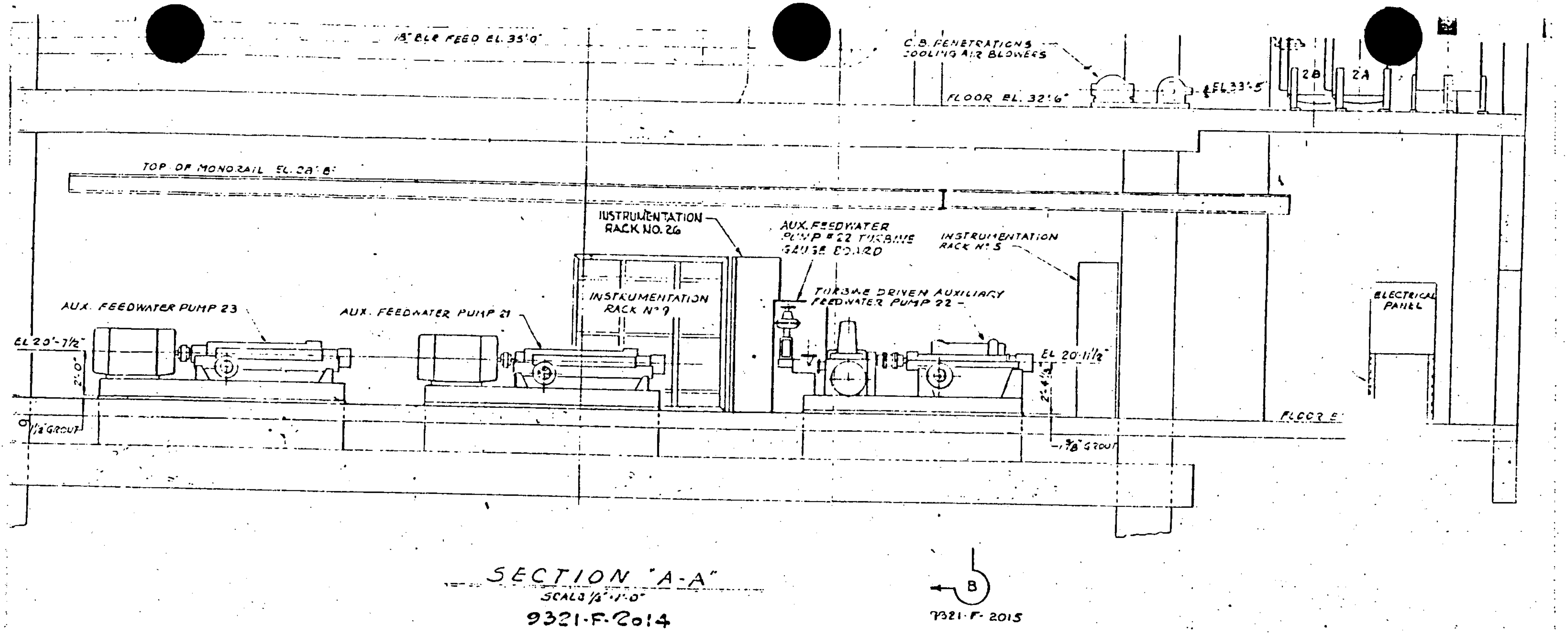
18" BLR FEED EL. 35'0"
C.B. PENETRATIONS COOLING AIR BLOWERS
FLOOR EL. 32'6"
EL 33'5"
2B
2A
TOP OF MONORAIL EL. 28' 8"
INSTRUMENTATION RACK NO. 26
AUX. FEEDWATER PUMP #22 TURBINE GAUGE BOARD
INSTRUMENTATION RACK N° 5
INSTRUMENTATION RACK N° 9
TURBINE DRIVEN AUXILIARY FEEDWATER PUMP 22
AUX. FEEDWATER PUMP 23
AUX. FEEDWATER PUMP 21
ELECTRICAL PANEL
EL 20'-7½"
2'-0"
1½" GROUT
EL 20'-1½"
2'-4½"
1⅞" GROUT
FLOOR E
SECTION "A-A"
SCALE ½"=1'-0"
9321-F-2014
B
9321-F-2015

Figure 2

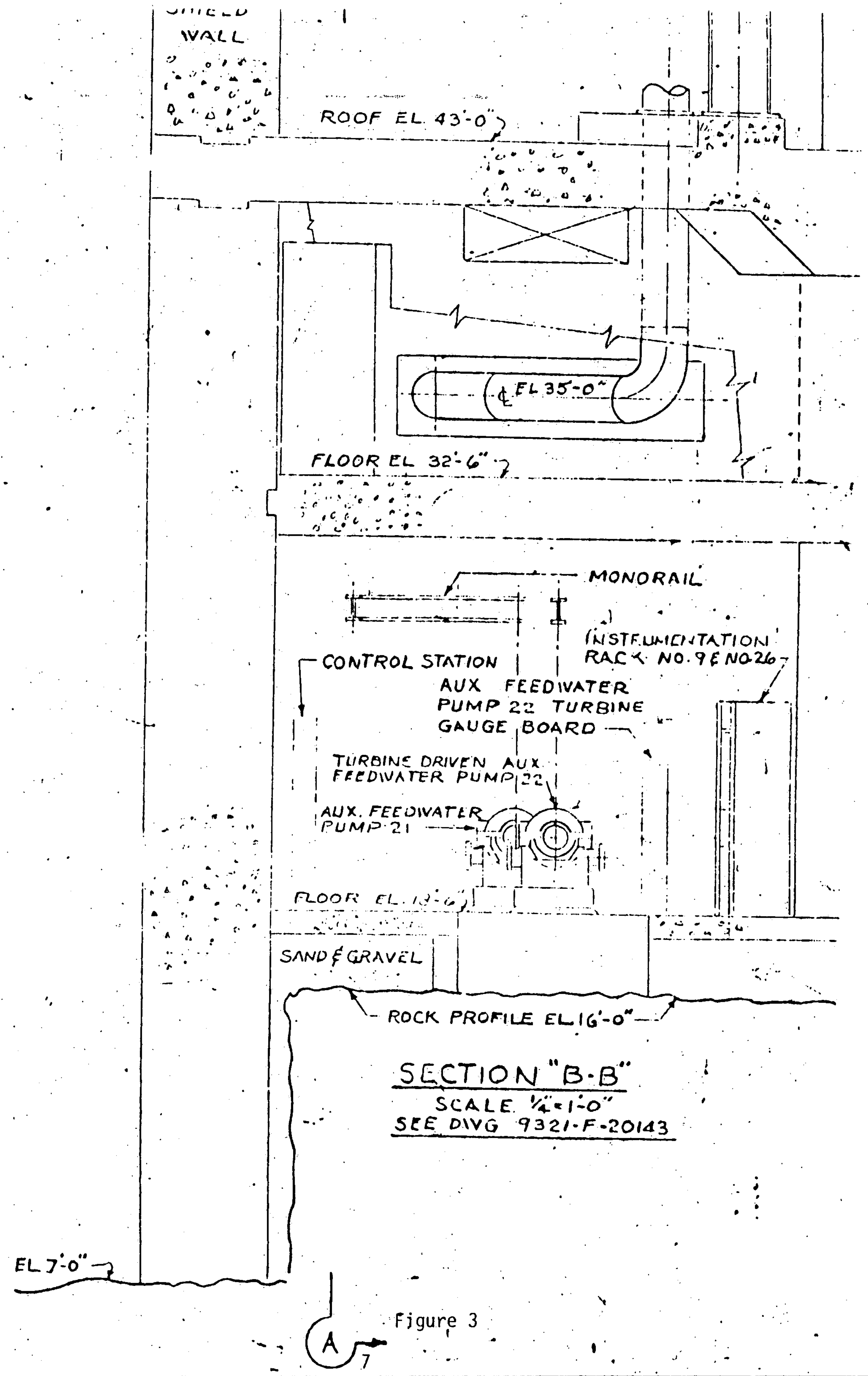
WALL
ROOF EL 43'-0"
℄ EL 35'-0"
FLOOR EL 32'-6"
MONORAIL
INSTRUMENTATION RACK NO. 9 & NO. 26
CONTROL STATION
AUX FEEDWATER PUMP 22 TURBINE GAUGE BOARD
TURBINE DRIVEN AUX FEEDWATER PUMP 22
AUX. FEEDWATER PUMP 21
FLOOR EL. 18'-6"
SAND & GRAVEL
ROCK PROFILE EL 16'-0"
SECTION "B-B"
SCALE 1/4"=1'-0"
SEE DWG 9321-F-20143
EL 7'-0"
A
7

Figure 3

During a meeting among NYPA and NRC staff representatives on April 25, 1984, it was determined that COBREE analysis performed by NRC did not consider the rapid isolation of the break due to actuation of the temperature switches. NYPA indicated that the temperature switch precludes any temperature or pressure buildup in the auxiliary feed pump room. As a result of the discussions, the staff requested NYPA to provide:

1. An analysis of the pressure and temperature conditions resulting from a break in the steam supply to the auxiliary feed pump turbine.
2. An evaluation of considerations made concerning diversity of instrumentation to detect a break in the steam supply to the auxiliary feed pump turbine.
3. Demonstration of the performance of the temperature switch and isolation function under simulated accident conditions.

C. Purpose of Report

The purpose of this report is to document the analyses requested by NRC.

II. Statement of the Problem

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The auxiliary feed pump room contains one turbine driven and two motor driven auxiliary feed water pumps, the instrumentation and control equipment for the auxiliary feedwater system and instrumentation for the main steam and feedwater system. The only high energy line of concern in the auxiliary feed pump room is the 4 inch steam supply to the auxiliary feed water pump turbine. Figure 4 shows the configuration of the steam supply pipe. The pipe designated as MS-326 enters the room through a penetration in the concrete floor at elevation 32' 6" and drops vertically to a 4 inch Tee. From the Tee there is a short horizontal 4 inch pipe run to control valve PCV-1139 which is a normally closed valve. It is this section of pipe that is normally pressurized from the main steam system during power operation of Indian Point Unit Number 3.

This line is seismic Class I and was designed for circumferential failures at points of discontinuity and longitudinal failures at any location including fittings.

Pipe whip restraints are provided to prevent whip of this line into lines of smaller diameter or wall thickness or into any safe shutdown equipment. No damage to critical equipment would result from pipe whip.

The original design basis pipe ruptures in Indian Point Unit #3 were (1) circumferential ruptures occurring at points of discontinuity, and (2) longitudinal rupture occurring anywhere in straight pipe runs or fittings. Only one break was postulated to occur at any one time. For the circumferential rupture a squarely severed pipe cross-section was considered, while for the longitudinal rupture an opening parallel to the pipe interior cross-section and length equal to twice the pipe nominal diameter. Longitudinal pipe rupture could occur anywhere around the periphery of the pipe.

Where whipping was to be prevented, the restraints are spaced so that the bending stress due to dead-weight and pipe rupture load would not exceed 1.8 x code allowable stress or Sy, which ever is greater. Where Sy is the material yield stress.

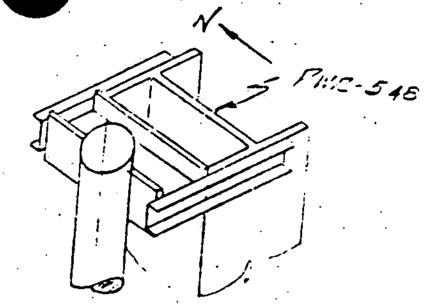
The structural members of the restraints were designed to have tensile stresses not exceeding the yield stress of the material for the maximum load. It is concluded that the restraints are adequate to withstand pipe whip loads. An evaluation was made to determine the ability of the structural steel to withstand combined whip and jet impingement loads.

To calculate the effect of simultaneous pipe break thrust and jet force loads on pipe whip restraint steel, possible pipe break locations were postulated in the following manner:

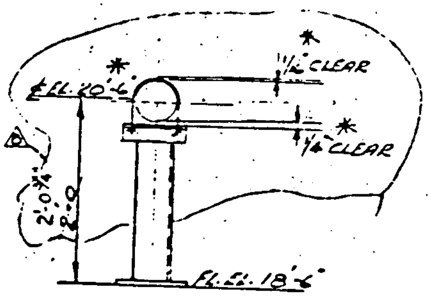
1. The piping stress analysis was reviewed for each line.
2. The terminal points were chosen as break locations.
3. Any point where primary or secondary stresses exceeded 80% of allowable was selected as a break location.
4. If there were fewer than two points which exceeded 80% of allowable stress then the highest stress locations (to a maximum of two) were chosen so that breaks were postulated at a minimum of four locations per line.
5. If the pressure stress contributes more than half of the primary stress then a slot or longitudinal type failure is postulated.
6. Primary stresses were calculated by adding pressure, dead weight and design basis seismic stresses.

The configuration of the pipe whip restraints is shown on figure 4-a.

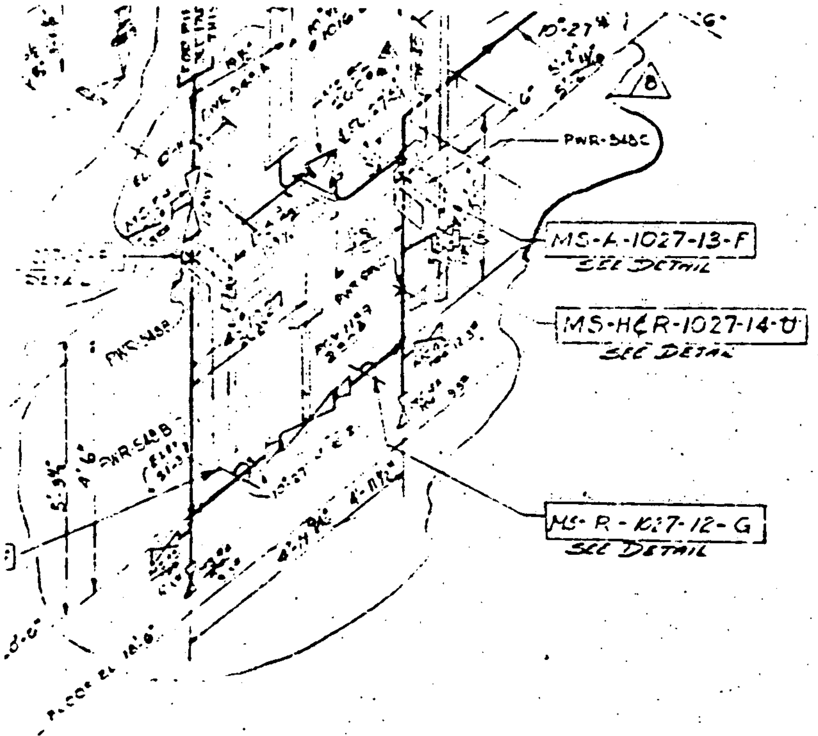
The pipe is 4 inch seamless schedule 80 carbon steel to specification 9321-05-248-1B. The line is welded to a forged steel gate valve MS-84, to a forged steel Tee and to the forged steel control valve PCV-1139. While it is theoretically possible to have a break in the pipe at any location from the penetration to the control valve, the most probable locations would be in one of the 6 weldments or the heat affected zones adjacent to the 6 weldments.

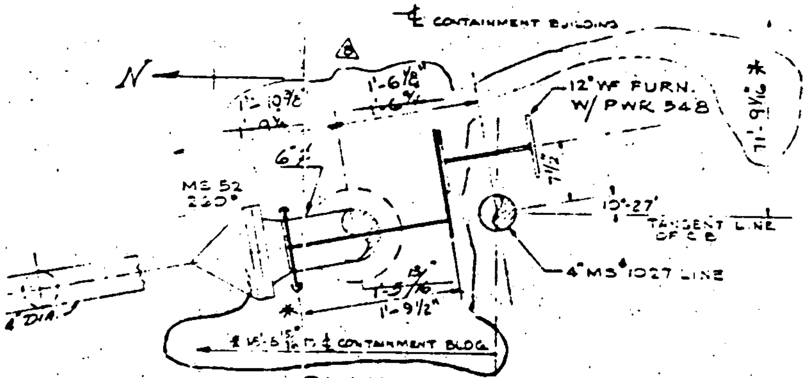


DETAIL
MS-A-1027-10-F
MS-A-1027-13-F



DETAIL - MS-R-1027-11-G
MS-R-1027-12-G





PLAN

DETAIL - MS - H¢R - 1027 - 14 - U

NOTE:- THIS ¢T TO BE MADE FINGER
TIGHT - [illegible] [illegible] NUTS

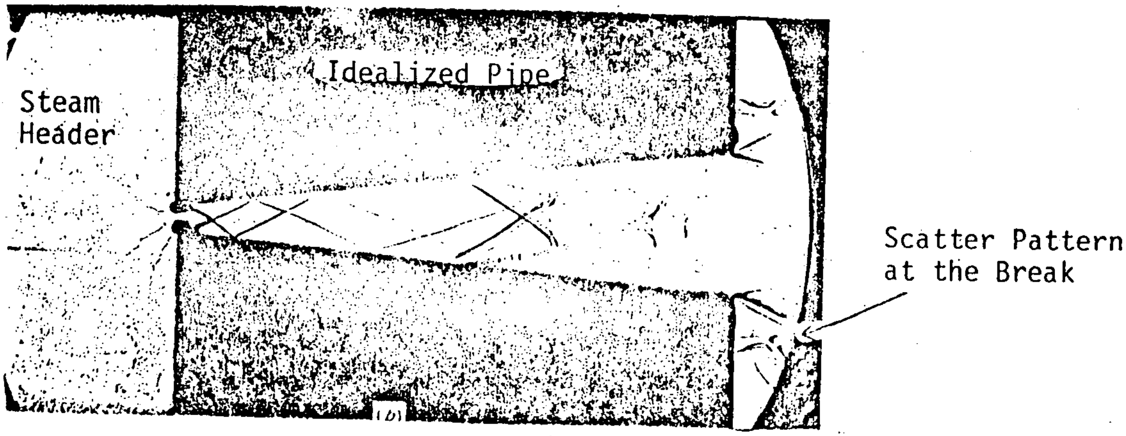
Figure 4-a

The weldments represent possible locations of discontinuities (either structural or metallurgical) and the most probable locations for failure would be at the discontinuities.

Because the steam supply to the auxiliary feed pump turbine comes only from the main steam headers located outside of the Auxiliary Feed Pump Room and combines into a single supply (4") in the Steam and Feed Line Penetration Area, a break at any of the 6 weldments in the Auxiliary Feed Pump Room would be a single ended break. The steam pattern emanating from a break at either of the weldments between the pipe and the gate valve would be directed downwards if no pipe restraints were installed. The pipe restraints, however, prevent the pipe from moving far enough (i.e. less than 4") to direct all of the flow towards the floor. Much of the flow would be scattered outward and towards the ceiling.

A break in either of the weldments in the vertical pipe run at the Tee connection would direct most of the flow towards the floor with some of the flow being scattered horizontally. Similarly, a break at either of the weldments (at the Tee connection or at the control valve PCV-1139) would direct part of the flow in a circumferential pattern normal to the break and part of the flow horizontally as shown below.

The effect of these flow patterns on performance of the temperature switches used as steam line break detectors is discussed in section III-C.



A break at any of the 6 weldments would result in choked (sonic) flow at the break. The mass flow rate, temperature, pressure, specific volume, enthalpy and entropy of the steam are limited by the friction losses in the valves, piping, fittings and 3" root connection to the main steam header.

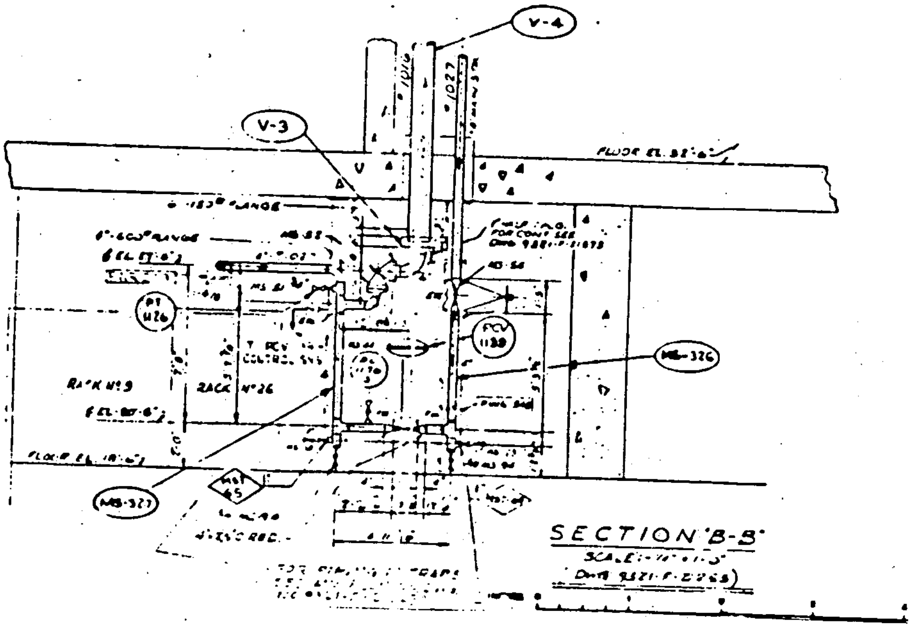

V-4
V-3
FLOOR EL.
PT
FCV
1139
MS-326
MS-327
RACK No 9
RACK No 26
FLOOR EL.
SECTION 'B-B'

Figure 4

In order to determine the steam conditions at the break, the RELAP-4 computer program was selected as the most practical method for performing this part of the analysis. In order to evaluate the temperature and pressure conditions in the auxiliary feed pump room resulting from the break, the CONTEMPT-LT computer program was selected to perform the analysis.

III. Method of Sensing and Terminating a Break in the 4" Steam Supply to the Auxiliary Feed Pump Turbine

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A. Break Detection

The turbine driven auxiliary feed pump is an accident mitigating device for various plant transient and accident conditions, however, it cannot mitigate the one accident to which it is exposed, i.e., a break in the steam supply to the turbine drive because steam would not be available to drive the turbine and pump. Therefore, in order to assure that the turbine driven pump is available for the accidents which it is intended to mitigate, any method of detecting a break in the steam supply must not cause isolation of the steam supply unless there is an actual break in the 4" line in the auxiliary feed pump room. In addition, any detection and isolation method must be rapid in order to prevent any significant pressure and temperature buildup and must be qualified for the environments to which it could be exposed.

There are two approaches to break detection which could be taken, viz: in-line fluid flow or external to the pipe itself.

1. In line flow measurement. The most logical place to locate a flow transmitter used to detect the steam line break would be outside the auxiliary feed pump room, in the steam and feed line penetration area. Because the environment in the steam and feedline penetration area could become harsh the transmitters should be qualified. (Qualification is needed to assure that the flow transmitter would not fail in such a manner as to trip the isolation valves and thereby preclude the possibility of using the turbine driven auxiliary feed pump to mitigate the line break). At present the qualified transmitters are the Barton 764, the Foxboro NE-13 and the Rosemount 1153 series trans-

mitters. Of the three qualified devices, the Rosemount 1153D series has the fastest response time as measured by test becasue the sensing element is a liquid filled capacitor and there are no moving parts. (The response time of a transmitter is defined as the time required after a step change in flow for the transmitter output to reach 63.2% of the final output). For the Rosemount 1153D this time response is 2 seconds at 100°F ambient and 4.5 seconds at 70°F ambient as reported in Rosemount Report 108026 dated February 1981. It requires an additional 3 to 5.5 seconds to reach 100% of the required output for the original step change. In order to assure a trip signal which would result in isolation of the break befoer the temperature and pressure in the auxiliary feed pump room changes significantly it would be necessary to have the flow trip set to actuate at 2 to 3 seconds after the break occurred when the instrument accuracies and response times are considered. Such a trip setting could cause an inadvertant trip when the pump is required. The flow data obtained from the RELAP-4 transient analysis indicates that the flow during the first few seconds of the transient at the only locations in which a flow meter could be installed would vary between 7 and 10 pounds per second which is in the same range as the steady state steam flow to the turbine which is 8.7 pounds per second. The flow, due to a steam line, does not reach a steady state condition at the locations where a flow meter could be installed until approximately 10 seconds after the break occurred. Such a time delay would be unacceptable. While there are faster response flow meters available commercially, none of them are environmentally qualified. It is, therefore, concluded that a flow transmitter is not suitable as a break detector because it could cause a steam flow trip under conditions which would require operation of the steam driven auxiliary feed pump.

2. Use of External Break Detector

Any instrumentation external to the pipe used for break detection must be located in the auxiliary feed pump room and qualified for the environment to which it is exposed up to the time that its trip function occurs. Use of pressure detectors would require an actual increase in pressure in the room and would therefore be of little use in preventing a pressure buildup. Humidity and moisture detectors have characteristically slow response times (in the order of minutes rather than seconds) and would be unacceptable to detect a line break and prevent a significant temperature or pressure buildup. The only other instrumentation are temperature detectors. Depending upon the materials and construction of the sensing element, temperature detectors have response times (to a step change in temperature) varying between 0.1 second and several minutes. The detectors used at Indian Point Unit No. 3 have elements which have negligible thermal inertia (oil filled stainless steel capillary) and respond in 8 seconds to a step change in temperature. By setting the temperature switches at 135°F inadvertant trips due to swings in ambient temperature (60°F to 105°F) are avoided and a response time of less than three seconds to trip can be realized with incident steam in the 212°F range.

B. Description of Temperature Switches Installed at Indian Point Unit 3

The temperature switch consists of a sealed oil filled 304 stainless steel tube, a metal bellows, two on-off snap action switches, and a terminal block in an explosion-proof housing. The units are designed for, and have extensive operating experience in ambient temperatures ranging between -40°F and 160°F, and 100% salt, dust and humidity environments.

The switch portion of the assembly consists of a heavy wall explosion proof aluminum enclosure meeting UL Class 1 Group B, C, D; Class II, Groups E, F & G; Class III and CSA Class I, Groups C & D; Class II, Groups E, F & G and Class III. Inside the enclosure are 2 on-off Single-Pole Double-Throw (SPDT) snap action switches rated at 15 amps 125/250 VAC, and a terminal block for electrical connections.

The thermal element consists of 9/64" OD bulb 42 $\frac{15''}{16}$ long made of type 304 stainless steel and filled with oil and connected to a stainless steel bellows which actuates the switch elements. The bellows and bulb are a sealed system. The bellows housing is made of nickel-plated die cast zinc. (see figures 5 and 6)

Temperature variations of the liquid filled sensing bulb are hydraulically transmitted to a bellows which in turn actuates one or two snap-acting switch(es).

Range/Model Selection

			*Thermal Assembly Std. 6 Capillary and choice of bulb S/S	
			**Bulb Data	
Catalog Model	Adjustable Range	Minor Scale Divisions†	Style	OD and Length (inches)
		REMOTE MOUNTED		
1AS 1BS 1CS	−180°F to +120°F −115°C to + 50°C	5°F 5°C	A B C	11/16 x 3-7/8 3/8 x 3-23/32 9/64 x 34-7/8
2AS 2BS 2CS	−125°F to +350°F − 85°C to +175°C	5°F 5°C	A B C	11/16 x 2-3/8 3/8 x 2-19/32 9/64 x 22-3/4
3AS 3BS 3CS	−125°F to +500°F − 85°C to +260°C	10°F 5°C	A B C	11/16 x 7-1/2 3/8 x 2-3/32 9/64 x 15-1/8
4AS 4BS 4CS	− 40°F to +120°F − 40°C to + 50°C	2°F 2°C	A B C	11/16 x 7-7/8 3/8 x 6-23/32 9/64 x 66-7/8
5AS 5BS 5CS	− 40°F to +180°F − 40°C to + 80°C	5°F 2°C	A B C	11/16 x 5-5/8 3/8 x 5 9/64 x 48-3/4
6AS ~~6BS~~ 6CS	0 to 250°F − 20°C to +120°C	5°F 2°C	A ~~B~~ C	11/16 x 4-7/8 ~~3/8 x 4-15/32~~ 9/64 x 42-15/16
7AS 7BS 7CS	0 to 400°F − 20°C to 200°C	5°F 5°C	A B C	11/16 x 2-7/8 3/8 x 2-7/8 9/64 x 27
8AS 8BS 8CS	50°F to 650°F 10°C to 340°C	10°F 5°C	A B C	11/16 x 3-1/8 3/8 x 3-7/32 9/64 x 29-5/32
M9A M9B M9C	50°F to 1000°F 10°C to 540°C	20°F 10°C	A B C	7/8 x 6 3/8 x 4-9/32 5/32 x 42-1/2
		LOCAL MOUNTED		
102	0 to 225°F 20°C to 110°C	5°F 2°C	—	1/2 NPT x 1-9/32 BT
108	200°F to 425°F 90°C to 220°C	5°F 2°C	—	

†Applies only to E110 and E110A.

*Over Temperature Protection: Thermal systems are designed to withstand up to 50° beyond range limit without damage or loss of calibration accuracy.

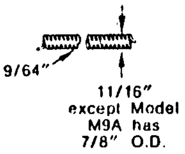
Materials: Thermal assembly Model M9C, M9B, and M9A, 347 St. St. mercury filled; all others 304 St. St., oil filled.

Bellows Housing: Die-cast zinc.

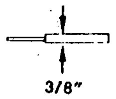
Set point typically shifts approx. 1 per cent of range for 50°F ambient temperature change.

**Bulb Data: Style "B" is small, rigid, easy to install, suitable for most uses. Style "C" may be easily shaped to fit the installation. Style "A" is a compact coiled version of style "C". Styles "C" and "A" provide fast response for applications requiring minimum lag or control differential.

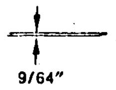
STYLE "A" BULB



STYLE "B" BULB,



STYLE "C" BULB



Performance Characteristics

Adjustable Range (set point): 0°-250°F.

Operating Ambient Temperature Range: -40 to +160°F.

Shock Resistance: 15 G's 10 millisecond duration.

Vibration Resistance: 2.5 G's 5 to 500 H_z.

Set Point Shift: 2.5°F for a 50°F ambient temperature change.

Response Time: Step change 80° to 200°F; 8 seconds (15°F/second).

Over Temperature Protection: Thermal systems are designed to withstand up to 50°F beyond range limit without damage or loss of accuracy.

Installation Requirements

Instructions state:

"1. Remote Bulb Mounting:

The control may be mounted in any position, via the (4) 1/4" screw clearance holes provided in either the enclosure or bracket, depending on model. (See mounting dimensions, page 4). Locate unit where vibration, shock and temperature fluctuations are minimal.

NOTE: It is recommended that you avoid mounting control with conduit connection on top, especially in outdoor installation. Use sealing fittings (see codes) to prevent entry of water or moisture into conduit."

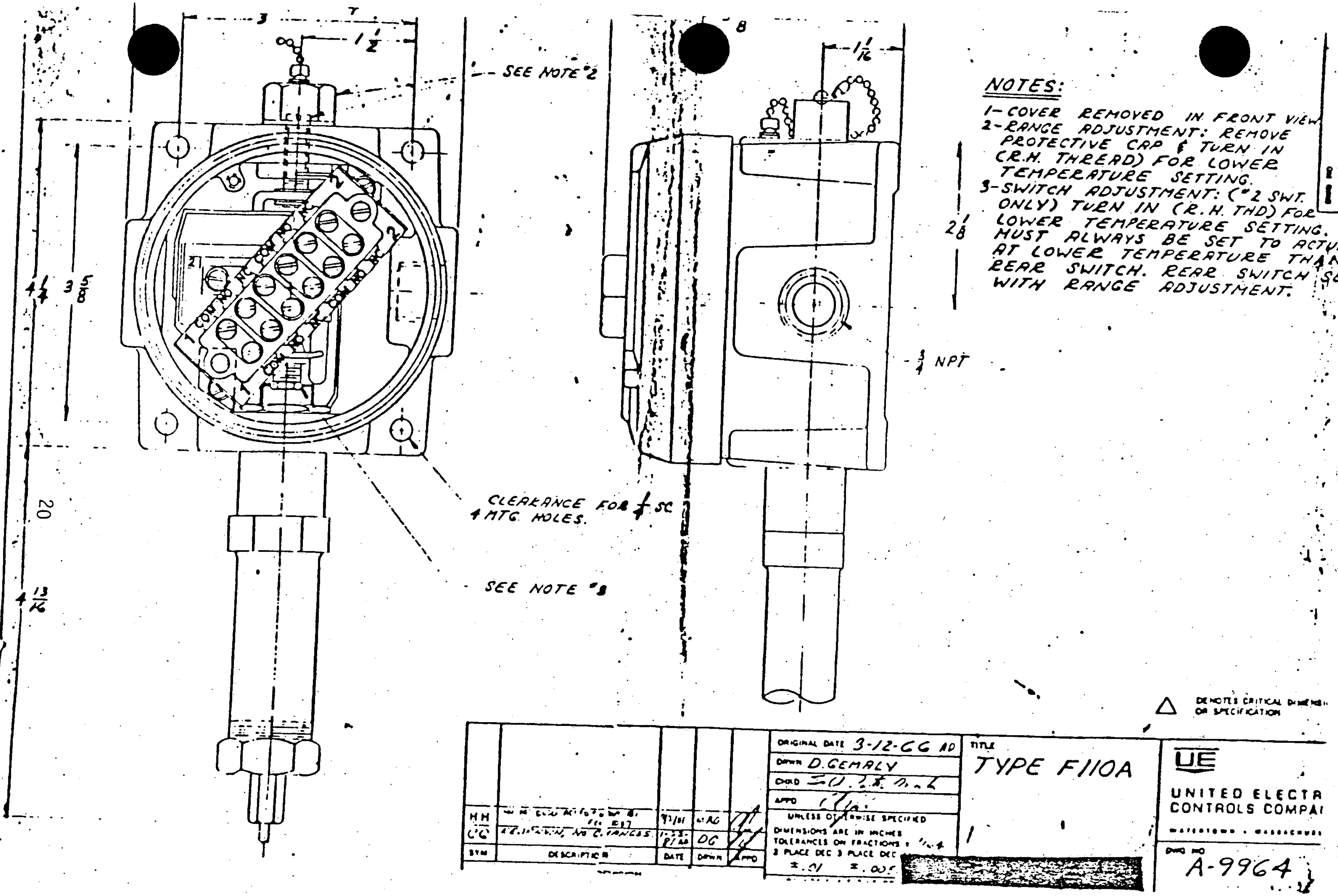
Failure Mode Analysis (see Figure 5)

The only possible mode of failure would be for steam from a break in the AFP turbine steam supply to infiltrate the housing and provide a conducting path between adjacent wires in the terminal block and cause a short circuit which could prevent valve closure. Since the conductor in the wires is not exposed, the distance between the screws is greater than 1/8 inch and steam is a poor conductor, bypassing of the switch is highly unlikely. In addition, there is negligible probability that steam could be admitted to the switch internals because threaded joints and conduit paths are highly restrictive and the switch would actuate long before any steam could enter. Furthermore, steam will not have any effect on the mechanical part of the switch assembly. The probes are supported to prevent damage due to direct steam impingement.

As noted in the manufacturers instructions it is necessary, however, to prevent entry of moisture into the conduit and thence into the switch.

The threaded connections and conduit have been sealed using RTV for the housing cover and for the conduit and cable entry areas. RTV was qualified by LOCA tests on conduit outlets sealed with RTV in Wyle test for J. A. Farley Plant (Wyle Report #44354-1, page 6, Test Item 4).

Because the switches are completely sealed from entry of steam the switch assembly will respond to the ambient change irrespective of what causes the temperature change.



NOTES:

1- COVER REMOVED IN FRONT VIEW
2- RANGE ADJUSTMENT: REMOVE PROTECTIVE CAP & TURN IN (R.H. THREAD) FOR LOWER TEMPERATURE SETTING.
3- SWITCH ADJUSTMENT: (#2 SWT. ONLY) TURN IN (R.H. THD) FOR LOWER TEMPERATURE SETTING. MUST ALWAYS BE SET TO ACTU AT LOWER TEMPERATURE THAN REAR SWITCH. REAR SWITCH SE WITH RANGE ADJUSTMENT.

△ DENOTES CRITICAL DIMENSI OR SPECIFICATION

SYM	DESCRIPTION	DATE	DRWN	APPD
HH	[illegible] FCN 837	9/3/81	[illegible]	
CG	REDRAWN, NO CHANGES	1-25-81	DG	

ORIGINAL DATE 3-12-66 AD
DRWN D. GEMALY
CHKD [illegible]
APPD [illegible]
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± 1/64
2 PLACE DEC 3 PLACE DEC
±.01 ±.005

[redacted]

TITLE TYPE F110A

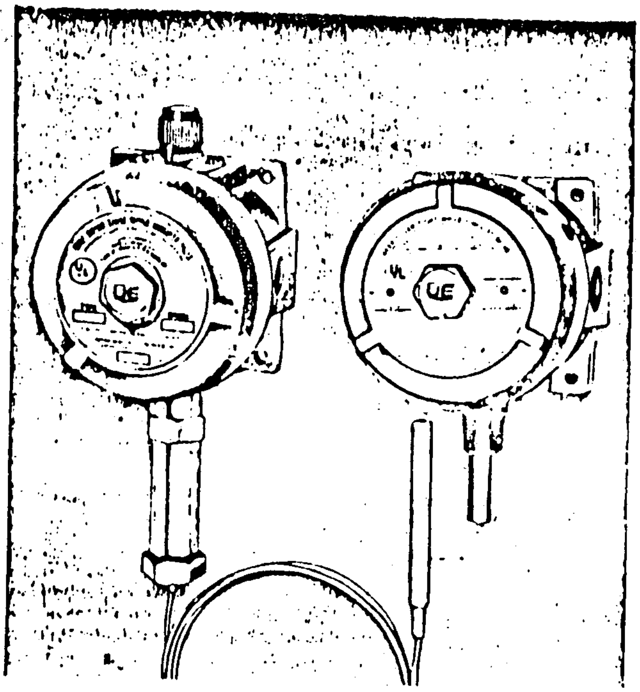
UE
UNITED ELECTR
CONTROLS COMPA
WATERTOWN · MASSACHUS

DWG NO A-9964

Figure 5

Temperature controls

Remote or local mounted



110 Series temperature controls offer a broad selection of standard temperature ranges from −180° to +1000°F. One or two 15 amp snap action switches with liquid filled thermal systems provide dependable on-off control. Remote or local mounted sensors suit a variety of installations. Adjustments are accessible by an internal tamperproof hex screw or external calibrated knob and dial. Dual switch types are factory set within 5% of range apart, but may be adjusted up to 25% of range separation. Many optional switches are available.

Choose from these Standard Types

	Remote Mounted
F110	One on-off switch, internal adjustment
E110	One on-off switch, external adjustment
F110A	Two on-off switches, internal adjustments
E110A	Two on-off switches, external adjustments
	Local Mounted
C110	One on-off switch, internal adjustment
B110	One on-off switch, external adjustment
C110A	Two on-off switches, internal adjustments
B110A	Two on-off switches, external adjustments

Stock List

Many models in stock for immediate delivery!

REMOTE MOUNTED TYPES

Type-Model	Stock No.
One Setpoint	
F110-4BS	9102
E110-4BS	9157
F110-5BS	9130
F110-6BS	9116
E110-6BS	9164
F110-7BS	9109
E110-7BS	9178
F110-8BS	9123
F110-8BS	9185

Type-Model	Stock No.
Two Setpoints	
E110A-4BS	9192
F110A-6BS	9278
E110A-6BS	9199
E110A-7BS	9206
F110A-8BS	9292

LOCAL MOUNTED TYPES

Type-Model	Stock No.
One Setpoint	
C110-102	9283
B110-102	9359
Two Setpoints	
C110A-102	9062

LOCAL MOUNTED TYPES WITH SEP. WELLS

Type/Model	Stock No.
One Setpoint	
C110-108W (½" NPT, Brass Well)	9181-97
(¾" NPT, Brass Well)	9181-98
(½" NPT, St St Well)	9181-99
(¾" NPT, St St Well)	9181-100

Type/Model	Stock No.
Two Setpoints	
C110A-102W (½" NPT, Brass Well)	9104-97
C110A-102W (¾" NPT, Brass Well)	9104-98
C110A-102W (½" NPT, St St Well)	9104-99
C110A-102W (¾" NPT, St St Well)	9104-100

Range/Model Selection

Catalog Model	Adjustable Range	Minor Scale Divisions†	*Thermal Assembly Std. 6 Capillary and choice of bulb S/8 **Bulb Data Style	 OD and Length (inches)
REMOTE MOUNTED				
1AS 1BS 1CS	−180°F to +120°F −115°C to + 50°C	5°F 6°C	A B C	11/16 x 3-7/8 3/8 x 3-23/32 9/64 x 34-7/8
2AS 2BS 2CS	−125°F to +350°F − 85°C to +175°C	5°F 5°C	A B C	11/16 x 2-3/8 3/8 x 2-19/32 9/64 x 22-3/4
3AS 3BS 3CS	−125°F to +500°F − 85°C to +260°C	10°F 6°C	A B C	11/16 x 7-1/2 3/8 x 2-3/32 9/64 x 15-1/8
4AS 4BS 4CS	− 40°F to +120°F − 40°C to + 50°C	2°F 2°C	A B C	11/16 x 7-7/8 3/8 x 8-23/32 9/64 x 66-7/8
5AS 5BS 5CS	− 40°F to +180°F − 40°C to + 80°C	5°F 2°C	A B C	11/16 x 5-5/8 3/8 x 5 9/64 x 48-3/4
6AS ~~6BS~~ ~~6CS~~	0 to 250°F − 20°C to +120°C	5°F 2°C	A ~~B~~ C	11/16 x 4-7/8 ~~3/8 x 4-15/32~~ 9/64 x [illegible]/16
7AS 7BS 7CS	0 to 400°F − 20°C to 200°C	5°F 6°C	A B C	11/16 x 2-7/8 3/8 x 2-7/8 9/64 x 27
8AS 8BS 8CS	50°F to 650°F 10°C to 340°C	10°F 5°C	A B C	11/16 x 3-1/8 3/8 x 3-7/32 9/64 x 29-9/32
M9A M9B M9C	50°F to 1000°F 10°C to 540°C	20°F 10°C	A B C	7/8 x 6 3/8 x 4-9/32 5/32 x 42-1/2
LOCAL MOUNTED				
102	0 to 225°F 20°C to 110°C	5°F 2°C	—	1/2 NPT x 1-9/32 BT
108	200°F to 425°F 90°C to 220°C	5°F 2°C	—	

†Applies only to E110 and E110A.

*Over Temperature Protection: Thermal systems are designed to wi stand up to 50° beyond range limit without damage or loss calibration accuracy.

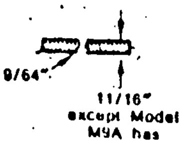
Materials: Thermal assembly Model M9C, M9B, and M9A, 347 St. mercury filled; all others 304 St. St., oil filled.

Bellows Housing: Die-cast zinc.

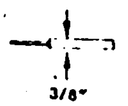
Set point typically shifts approx. 1 per cent of range for 50°F ambi temperature change.

**Bulb Data: Style "B" is small, rigid, easy to install, suitable for m uses, Style "C" may be easily shaped to fit the installation. St "A" is a compact coiled version of style "C". Styles "C" and provide fast response for applications requiring minimum lag or c trol differential.

STYLE "A" BULB



STYLE "B" BULB



STYLE "C" BI

Figure 6

C. Location of Temperature Detectors at Indian Point Unit 3

The preceeding discussions established that a fast acting temperature switch would be the most practical method of sensing a break in the 4 inch steam supply to the auxiliary feed pump turbine without the possibility of causing trips when the turbine driven pump is required for a transient or accident mitigating function.

At Indian Point Unit 3 the temperature switches are located approximately 12 ft. 3 in. above the floor. The sensing element for one switch is above the inlet piping to the turbine driven auxiliary feed pump. The sensing element of the second switch is above the Number 1 motor driven pump (see figures 7 and 8). Each temperature switch is connected to separate power supplies and actuate solenoids for separate pneumatically operated Globe valves which are located outside of the auxiliary feed pump room.

The locations of the temperature switches were selected to avoid direct steam impingement from a break and to rapidly respond to the localized temperature increase resulting from the break.

As described in Section II;

- Flow from a break in either of the welds to Valve MS-54 would be directed primarily downward to the floor. However, because of the locations of the pipe whip restraints, part of the steam flow would be directed towards the ceiling and switch Number 1 (see figures 7 and 8).

- Flow from a break at either of the weld in the vertical run of the Tee connection would be primarily directed to the floor where the steam would be scattered isotropically with some of the steam directed towards both of the temperature switches.

- Flow from a break at either of the welds in the small horizontal pipe runs would be directed towards the turbine driven pump and scattered towards the floor and ceiling. While it is obvious that switch number 1 would quickly experience the effects of most of the potential breaks, it appears that switch number 2 is too far away from the steam source to respond in a sufficiently short time to minimize temperature buildup in the Auxiliary Feed Pump Room. Accordingly, the Authority plans to relocate switch number 2 to the the structural support for Rack No. 5. The switch

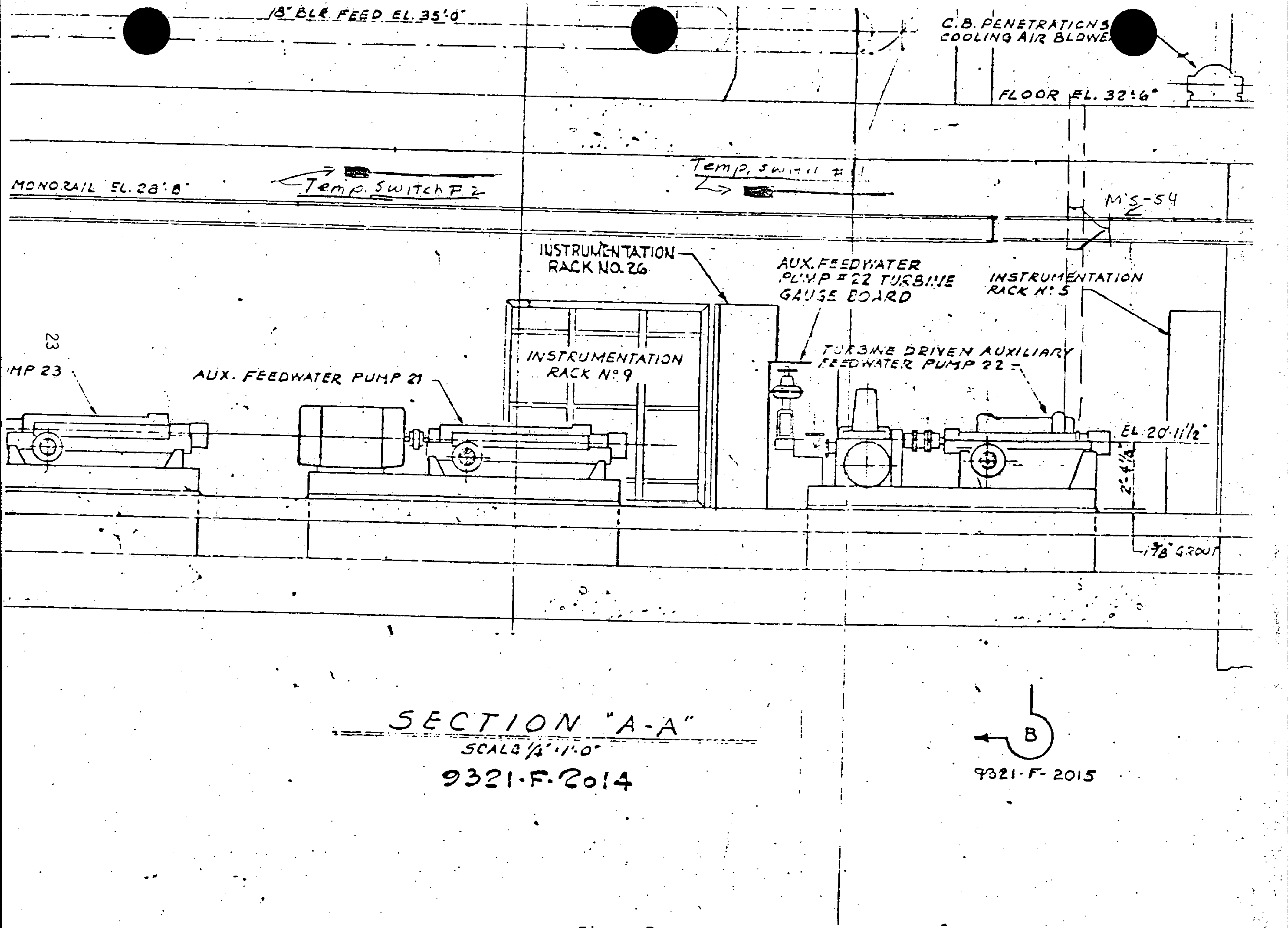

18" BLR FEED EL. 35'0"
C.B. PENETRATIONS
COOLING AIR BLOWE
FLOOR EL. 32'6"
MONORAIL EL. 28'8"
Temp. Switch #2
Temp. switch #1
M'S-54
INSTRUMENTATION RACK NO. 26
AUX. FEEDWATER PUMP #22 TURBINE GAUGE BOARD
INSTRUMENTATION RACK N° 5
23
MP 23
AUX. FEEDWATER PUMP 21
INSTRUMENTATION RACK N° 9
TURBINE DRIVEN AUXILIARY FEEDWATER PUMP 22
EL 20'11½"
2'4⅛"
1⅞" GROUT
SECTION "A-A"
SCALE ¼"=1'-0"
9321-F-2014
B
9321-F-2015

Figure 7

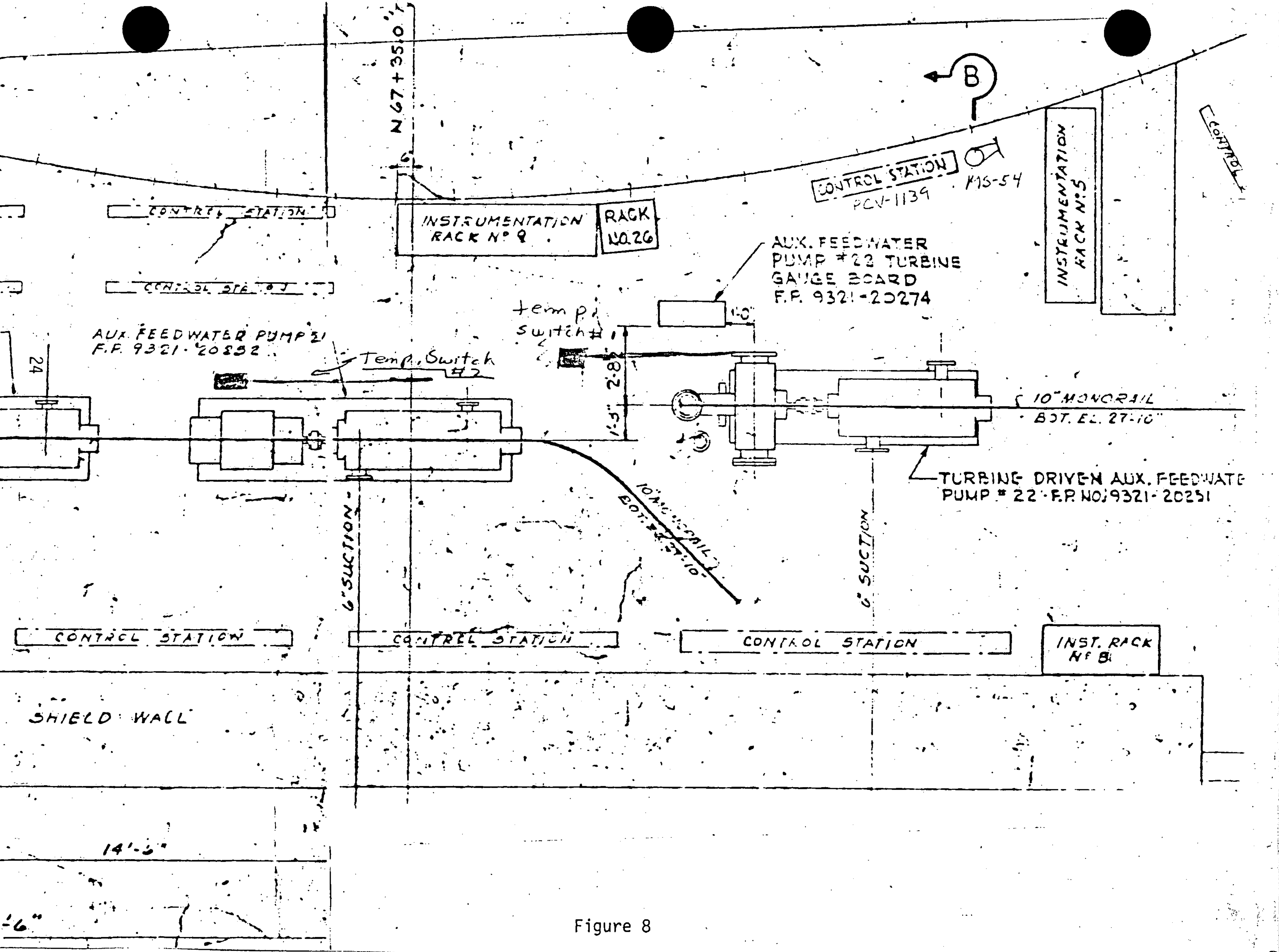

N 67 + 35.0
B
CONTROL STATION
CONTROL STATION
PCV-1139
MS-54
INSTRUMENTATION RACK Nº 5
CONTROL
CONTROL STATION
CONTROL STATION
INSTRUMENTATION RACK Nº 9
RACK NO.26
AUX. FEEDWATER PUMP #22 TURBINE GAUGE BOARD F.P. 9321-20274
1'-0"
temp. switch #1
2'-8"
1'-5"
AUX. FEEDWATER PUMP 21 F.F. 9321-20852
Temp. Switch #2
24
10" MONORAIL BOT. EL. 27-10"
10" MONORAIL BOT. EL. 27-10"
TURBINE DRIVEN AUX. FEEDWATE PUMP # 22 F.P. NO. 9321-20251
6" SUCTION
6" SUCTION
CONTROL STATION
CONTROL STATION
CONTROL STATION
INST. RACK Nº 8
SHIELD WALL
14'-6"
'-6"

Figure 8

will be mounted at the top of the rack with the long probe pointing downwards. The probe will be protected from physical damage by suitable supports. This location will permit rapid response to breaks in the lower section of pipe.

IV. Line Break Analysis

IV. Line Break Analysis

Because of the relatively short duration of the transient and the need to accuractly model the conditions of the steam flowing from the break, it was concluded that the RELAP-4 computer program should be used.

RELAP-4 is a computer program, written in FORTRAN IV, that was developed primarily to describe the thermal-hydraulic transient behavior of water-cooled nuclear reactors subjected to postulated accidents such as those resulting from loss of coolant, pump failure, or nuclear power excursions. Fundamental assumptions inherent in the thermal-hydraulic equations are that a two-phase fluid is homogeneous and that the phases are in thermal equilibrium. Models are available in the code to modify these homogeneous assumptions. The program is sufficiently general to be applied to experimental water reactor simulators and many other hydrodynamic experiments.

The program requires numerical input data that completely describe the initial conditions and geometry of the system being analyzed. The input data include physical characteristics such as fluid volume geometry, pump characteristics, power generation, heat exchanger properties, and material composition. Starting with system initial flow, pressure, temperature, and power level boundary conditions, transients can be initiated by the control action inputs to the program. These can describe breaks in fluid piping, valve actions, pump changes, and core power level variations. The program computes (for each time advancement) fluid conditions such as flow, pressure, mass inventory, and quality. Also computed are thermal conditions within the solid materials such as temperature profiles and power, and the fluid-solid interface conditions such as heat flux and surface temperature.

The degree of detail to which the system is described is specified by the program user. This includes nodalization of fluid flow paths within the piping, vessels, and reactor core as well as heat transfer modeling within solids such as the fuel rods, piping, and vessel walls. Both the reactor primary and secondary flow systems can be modeled. The permitted system detail is limited by the maximum dimensions within RELAP-4. These dimensions can be adjusted to fit a particular computer.

The definition of the thermal-hydraulic system is also completely specified by the user. A portion of a system, such as a single reactor channel, can be analyzed by supplying appropriate time-dependent boundary conditions. The boundary conditions can be defined by the user if known, or they can be obtained from a previous RELAP-4 analysis. For example, analysis of a reactor blowdown transient may be performed using a RELAP-4 integral system that describes the entire primary flow loop, the upper and lower plenums, and a simple nodalization of the total reactor core. A second RELAP-4 calculation that uses the previously computed fluid conditions in the upper and lower plenums as a boundary condition can be performed for a hot channel analysis.

RELAP-4/MOD5 was intended primarily as a blowdown code. It will calculate system phenomena from initial operating conditions at the time of pipe rupture through system decompression up to the beginning of core recovering with emergency core coolant.

The configuration of the steam driven auxiliary feedwater pump piping from the main steam header to the pump turbine is shown in Figure 9. The steam conditions at the header are 1100 psia and 556^{0}F.

Appendix A contains the results of the RELAP-4 analyses.

The analytical method used for determining the pressure and temperature in the auxiliary feed pump room was CONTEMPT-LT.

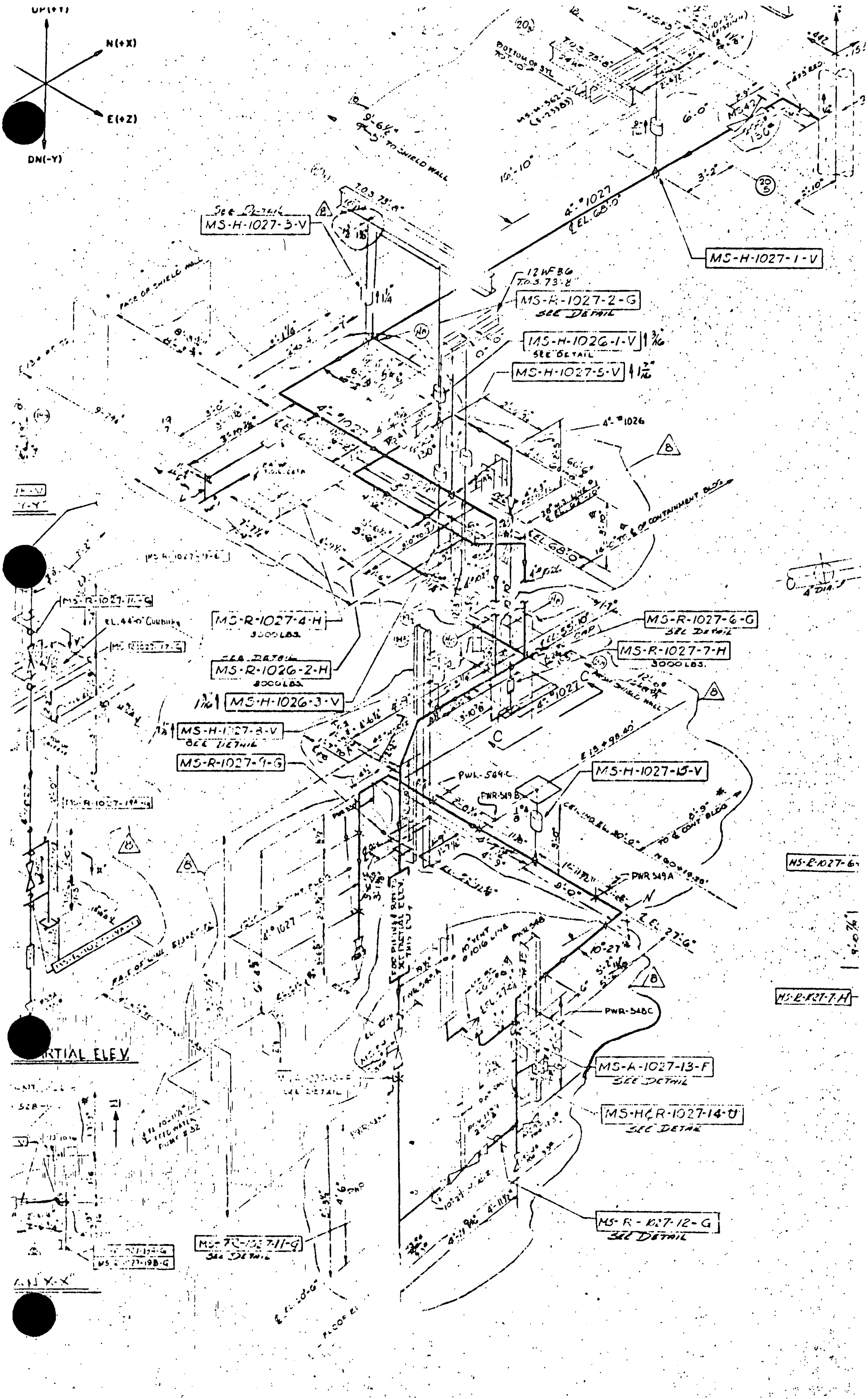

UP(+Y)
N(+X)
E(+Z)
DN(-Y)
SEE DETAIL
MS-H-1027-3-V
MS-H-1027-1-V
4" #1027
EL. 68'-0"
12 WF 36
T.O.S. 73'-8"
MS-R-1027-2-G
SEE DETAIL
1MS-H-1026-1-V
SEE DETAIL
MS-H-1027-5-V
4" #1026
FACE OF SHIELD WALL
9'-6¼" TO SHIELD WALL
16'-10"
6'-0"
3'-2"
EL. 68'-0"
MS-R-1027-4-H
3000 LBS.
SEE DETAIL
MS-R-1026-2-H
3000 LBS.
MS-H-1026-3-V
MS-H-1027-8-V
SEE DETAIL
MS-R-1027-9-G
MS-R-1027-6-G
SEE DETAIL
MS-R-1027-7-H
3000 LBS.
4" #1027
MS-H-1027-15-V
PWR-549C
PWR-549B
PWR-549A
PWR-548C
EL. 27'-6"
MS-A-1027-13-F
SEE DETAIL
MS-H&R-1027-14-U
SEE DETAIL
MS-R-1027-12-G
SEE DETAIL
MS-TC-1027-11-G
SEE DETAIL
PARTIAL ELEV.
EL. 44'-0"
MS-R-1027-6-G
MS-R-1027-7-H
4" DIA.
TO ℄ OF CONTAINMENT BLDG.
FACE OF WALL
C
N
8

Figure 9

CONTEMPT-LT is a computer program developed to describe the thermal-hydraulic behavior of reactor containment systems subjected to postulated accident conditions. CONTEMPT-LT provides a numerical method for analyzing the transient containment behavior of pressurized water reactors, boiling water reactors (Mark I, Mark II, or Mark III), and experimental water reactor simulators or related experiments. CONTEMPT-LT predicts the interrelated effects of reactor system blowdown, heat transfer, atmosphere leakage, safeguard system operation, pressure suppression system response, and miscellaneous mass and energy additions.

Compartments modeled with CONTEMPT-LT may contain two separated regions (vapor and liquid pool) at different temperatures. Models allow pool boiling or evaporation, and condensation from the vapor region is calculated. Up to four unique compartments may be modeled in the program. Various input tables control time-dependent mass and energy additions to the drywell compartment. Spray system operation, heat transfer, and leakage also modify mass and energy inventories of the various compartments.

CONTEMPT-LT/028 is the most recent code in a series of computer programs developed to describe the thermal-hydraulic conditions attendant to various postulated transients in the containments of light-water reactor systems. CONTEMPT-LT/028 incorporates the various improvements and modifications to CONTEMPT-LT since publication of the CONTEMPT-LT document (1). The major modification and improvements are:

(1) A drywell pressure flash model, added as a user option, for use in ECCS back pressure analysis.

(2) A Tagami heat transfer correlation analytical model.

(3) An annular fan analytical model to control the annular compartment pressure and to monitor the radionuclide release to the biota.

(4) Several new heat structure modifications and options.

(5) A maximum pressure stop switch to terminate the code if the pressure in any compartment (except the primary) exceeds the input switch value.

(6) An expanded spray edit output.

(7) A dial to specify the amount of the condensate formed in cooling coils and heat structures that will fall into the pool region.

(8) Corrections to the pool evaporation/condensation models and the Uchida heat transfer models.

The initial conditions in the auxilairy feed pump room were taken to be 75^{o}F at atmospheric pressure.

The volume of the auxilairy feed pump room is 15,833 cubic feet.

Equipment Volumes

Motor Driven Pumps (2) = 148.5f^3
Turbine Driven Pump (1) = 55.2f^3
Instrument Racks (5,9,8,26) = 144.7f^3
Control Stations = 147.4f^3
Valve Stations = 13.5f^3
Gage Board = 12.5f^3
Electrial Panel = 10.5f^3
Piping, Conduit, Cable Trays, = 56.5f^3
Monorail, Instrument Trays

Equipment Volume, Total = 588.8f^3

Available Volume = 15244.2f^3

The mass flow and energy entering the room were obtained from the RELAP-4 analysis (Appendix A).

The results of the CONTEMPT-LT analysis are contained in Appendix B.

V. Isolation Valve (PCV-1310A,B) Closure Time and Temperature Switch (TC-1112S, 1113S) Response Time

V. ISOLATION VALVE (PCV-1310A, B) CLOSURE TIME AND TEMPERATURE SWITCH (TC-1112S, 1113S) RESPONSE TIME

A. Isolation Valves: The isolation valves are pneumatically actuated globe valves. The valves are maintained in the open position during normal operation by air supplied to the diaphragm from normally closed/fail open, solenoid valves (ASCO 8316). The pneumatically operated globe valves are installed so that pressure is above the seat when the valves are closed. This configuration enhances the closing time in the event of a line break because the fluid flow exerts an additional force to drive the valves to their closed position. When the valves are closed, the actuator does not have sufficient force to reopen against line pressure. The plant must be shut down and the steam headers depressurized to permit reopening of the valves once they are closed.

Maunfacturer's data for the valves indicates a closure time of 2 seconds with no differential pressure across the valve. No data is available for the reduced closing time which would occur with the flow through the valve after a steam line break. Plant surveillance testing indicates a closure time of 3.3 seconds for one of the valves and 16.3 seconds for the other valve with no flow in the line. This is apparently due to excessive tightening of the packing glands on the valves. The authority plans to retest the valves and repack the valves as necessary during the 1985 outage to restore the closure time to the design value. (Present surveillance test acceptance standards for the valves is a closure time of less than 60 seconds. This value will be revised to assure that the closing time is within design values)

B. Temperature Switch Response Time: Tests were conducted by the manufacturer (United Electric Controls) to determine the respose of the F110A6CS temperature switch to a step change in temperature from 75°F to 212°F. The test was performed in an open chamber where the switch was stabilized at 75°F and steam at 212°F was introduced into the open chamber. The temperature switch reached 212°F in 8 seconds. In addition, testing was conducted on the same model switch at Indian Point Unit No. 2. The switch was stabilized at 75°F and then the bulb was immersed in water at 135°F. The switch reached 135°F in 8 seconds. In addition a calculation of the response time of the switch was performed using the methodology contained in Chapter 3 of McAdams "Heat Transmission" third edition and the Gurney-Lurie charts of Figure 3-8. Refer to Appendix C. The results indicate that for a 137° change in temperature at the switch, the center of the switch reaches the 135°F trip point in 1.7 seconds and the entire element becomes saturated at 212°F in slightly less than 8 seconds which confirms the manufacturer's test data.

It is therefore, concluded that incident steam on the switch at 212°F or higher would cause actuation at a 135° trip point setting in 2 seconds or less.

C. <u>Simulation of Steam Line Break to Confirm Performance of the Temperature Switch Trip Time</u>: It is not possible to simulate the performance of the temperature switch under accident conditions in the plant without having an actual break in the 4" steam supply pipe to the auxiliary feed pump turbine. Based on the manufacturer's test and calculations which confirm the manufacturer's data, the Authority does not consider that a specific test is required. In particular, one of the switches is presently located where it will immediately see the effects of a break in the upper portion of the pipe and the other switch will be relocated so that it will immediately see the effects of a break in the lower portions of the pipe. The Authority is, however, determining whether it would be possible to mock up the configuration and perform a simulation of a steam line break to confirm that the switch will actuate at the set point of 135°F in less than 2 seconds.

APPENDIX A

RELAP-4/MOD 5 Thermal Hydraulic Code

APPENDIX A

RELAP-4/MOD 5 THERMAL HYDRAULIC CODE

PURPOSE: TO DETERMINE THE TIME DEPENDENT MASS FLOW RATE AND CONDITIONS OF STATE AT THE BREAK POINT OF THE STEAM SUPPLY LINE TO THE AFW PUMP TURBINE.

ASSUMPTIONS: THE FOLLOWING ASSUMPTIONS WERE MADE IN THE DEVELOPMENT OF THE MODEL:

a. The AFW pump Turbine steam line break is complete and circumferential with flow from only one end.

b. The mass flow stops immediately and completely once the isolation valves reach the fully closed position.

c. There is no heat transferred through the pipe.

d. The steam line leg with the shortest equivalent length will be used to minimize the pressure drop and maximize the mass flow rate at the break.

PROCEDURE

The isometric piping drawing, Fig. 9, shows the AFW Feed pump turbine steam supply line. It was first necessary to calculate the equivalent lengths of the steam lines from each of the two main steam headers to the Tee connection, and from the Tee connection to the break. The shortest possible equivalent length of pipe would be chosen because it would represent the minimum pressure drop and therefore the maximum mass and energy flow from the broken pipe. After determining the shortest pipe run, the pipe run will be subdivided into discrete control volumes based upon information such as: diameters, elevation changes, valves, reducers, and length of pipe run.

The volume control, junction control, and results output control are input and the computer code executes the transient analysis.

RESULTS

Tables A-1, A-2, and A-3 provide the data concerning the pipe runs of interest. As can be seen from these tables, the shortest equivalent pipe run is that from Main Steam Line #3. The total equivalent pipe length in this problem is L_e = 320.29 ft. or $L_e/D \simeq 1000.00$ ft.

From this information and based on the limitations of the computer program, the control volumes to be used in the model were prepared and are presented in Table A-4. Figure A-1 is a schematic representation of the model used in this problem.

Enclosure 1 (Computer Printout for RELAP-4/MOD 5 problem) contains the detailed results of this analysis. The results show initially high mass flow rates at both the break and root connection. Shortly thereafter, however, these flows become sonic and the flow rates decrease. Subsequently a period of more uniform mass acceleration begins and the mass flow rates begin to increase. Steady state conditions are not reached during the first 10 seconds after the break. The oscillations in mass flow rates and velocities are primarily due to the fact that the pipe is acting as a very long converging/diverging nozzle with a compressible fluid. The large pressure drops across the reducer, bends, and globe valves also tend to make the initial mass acceleration erratic. For the worst case,i.e. a 10 second isolation valve closure time, approximately 200 lbm of steam discharges from the break. This mass has an average enthalpy of 915 BTU/lbm. This means that about $1.8\text{x}10^{6}$ BTU enter the AFW pump room in 10 seconds (an average rate of $6.6\text{x}10^{8}$ BTU/hr).

The results for control volume 17 (the AFW Pump Room) indicate average compartment temperatures after 10 seconds of 207°F. It should be noted, however, that the RELAP-4 model used in this analysis did not consider any heat transfer to the air or walls nor did it take into account any venting from the AFW pump room to the atmosphere. The following table provides a brief summary of the significant data from the numerical analysis:

	Conditions at the Break			Room Conditions	
TIME seconds	SPECIFIC VOLUME cu.ft./lbm	AVERAGE ENTHALPY	MASS FLOW lbm/sec	TEMPERATURE °F	PRESSURE psia
1	33.903	802.94	17.97	114.37	16.762
2	65.521	833.46	9.036	121.47	17.267
3	62.715	935.83	9.538	126.52	17.665
4	48.671	927.55	12.45	132.40	18.167
5	38.209	911.59	15.987	139.24	18.814
6	31.638	900.27	19.443	146.73	19.61
7	27.218	893.58	22.67	157.64	20.621
8	24.104	889.21	25.605	174.19	21.914
9	21.948	886.06	28.107	190.82	23.341
10	20.262	1164.69	30.422	207.16	24.886

It is emphasized that the room temperature and pressure represent the upper bound of conditions following the break because the analysis does not consider heat transfer to the air in the room or to the walls. Appendix B contains the final room conditions based on the CONTEMPT-LT computer analysis.

TABLE A-1 EQUIVALENT PIPE LENGTHS

RUN DESCRIPTION: AFW Turbine Steam Supply Line From Main Steam Line #1 to Tee Connection Elevation 62' 10" + ½(28") = 64' 0"

Item Number	Section Description	Diameter in. (ft.)	Actual Length ft.	Equivalent Length ft.	Elevation Change
1.	Weldolet	3 (0.2416)	0.5	0.5	64'0"-64'6"
2.	Reducer	4"X 3"	0.25	*	64'6"-64'9"
3.	Straight Pipe	4 (0.31883)	1.917	1.917	64'9"-66'8"
4.	90^o Elbow	4	-	10.2**	-
5.	Straight Pipe	4	2.526	2.526	-
6.	90^o Elbow	4	-	10.2**	-
7.	Straight Pipe	4	2.5417	2.5417	-
8.	Gate Valve (Open)	4	1.333	2.232	-
9.	Straight Pipe	4	7.61	7.61	-
10.	90^oElbow	4	-	10.2	-
11.	Straight Pipe	4	5.67	5.67	-
12.	45^o Elbow	4	-	4.782**	-
13.	Straight Pipe	4	1.62	1.62	-
14	90^o Elbow	4	-	10.2	-
15.	Straight Pipe	4	10.833	10.833	66'8"-55'10"
16.	90^o Elbow	4	-	10.2**	-
17.	Straight Pipe	4	1.25	1.25	-
18.	Tee Connection (Entering Run)	4	-	19.13	-

Total Equivalent Length 104.612 ft + Reducer

* Reducer Equivalent Length is Calculated in RELAP-4 Code

** Values Obtained From Reference 1 Based on Hydraulic Diameters

TABLE A-2 EQUIVALENT PIPE LENGTHS

RUN DESCRIPTION: AFW Turbine Steam Supply Line From Main Steam Line #3 to Tee Connection Elevation 68' 0"

Item Number	Section Description	Diameter in. (ft.)	Actual Length ft.	Equivalent Length ft.	Elevation Change
1.	Weldolet	3 (0.24167)	0.5	0.5	(68' 0")
2.	Reducer	3" X 4"	0.25	*	-
3.	Straight Pipe	4 (0.31883)	0.5833	0.5833	-
4.	90^{o} Elbow	4	-	10.2**	-
5.	Straight Pipe	4	$2.083\overline{3}$	$2.083\overline{3}$	-
6.	Gate Valve (Open)	4	1.333	2.232	-
7.	Straight Pipe	4	13.4167	13.4167	-
8.	90^{o} Elbow	4	-	10.2**	-
9.	Straight Pipe	4	7.625	7.625	-
10.	90^{o} Elbow	4	-	10.2**	-
11.	Straight Pipe	4	12.25	12.25	68'0"-55'10"
12	Tee Connection (Entering Run)	4	-	19.13	-

Total Equivalent Length 88.42 ft + Reducer

* Reducer Equivalent Length is Calculated in RELAP-4 Code

** Values Obtained from Reference 1 Based on Hydraulic Diameters

TABLE A-3 EQUIVALENT PIPE LENGTHS

RUN DESCRIPTION: AFW Turbine Steam Supply line From Tee Connection to Break Location (Upstream of Turbine Control Valve) Elev. 55'10" - 27'1½"

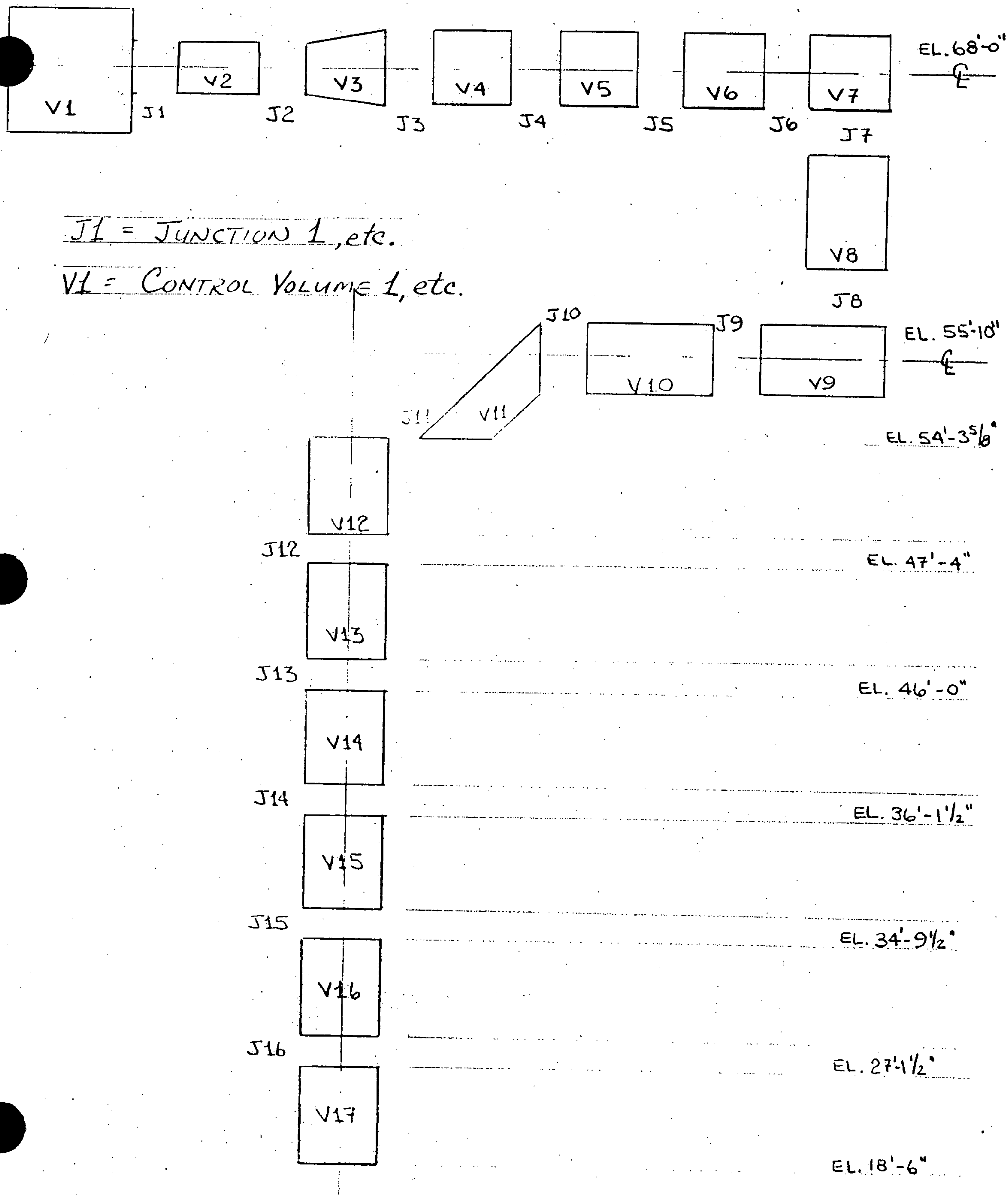
Item Number	Section Description	Diameter In. (ft)	Actual Length ft.	Equivalent Length ft.	Elevation Change
1.	Straight Pipe	4 (0.31883)	2.989	2.989	(55'10")
2.	45^{O}Elbow	4	-	4.782*	-
3.	Straight Pipe	4	2.1667	2.1667	55'10"-54'3$\frac{5''}{8}$
4.	45^{O} Elbow	4	-	4.782*	-
5.	Straight Pipe	4	6.969	6.969	54'3 $\frac{5''}{8}$-47'4"
6.	Globe Valve (Open)	4	1.333	95.65	47'4"-46'0"
7.	Straight Pipe	4	11.21	11.21	46'0"-36'1½"
8.	Globe Valve (Open)	4	1.333	95.65	36'1½"-34'9½"
9.	Straight Pipe	4	7.667	7.667	34'9½"-27'1½"

Total Equivalent Pipe Length 231.87 ft.

* Values Obtained From Reference 1 Based on Hydraulic Diameters

TABLE A-4 MODEL VOLUME DESCRIPTIONS

VOLUME NUMBER	TABLE NUMBER	ITEM NUMBERS	DESCRIPTION
1.	-	-	Main Steam Line #3
2.	1-B	1	Weldolet
3.	1-B	2	Reducer
4.	1-B	3,4,5	Pipe with 1 Bend (90^o)
5.	1-B	6	Gate Valve
6.	1-B	7	Pipe
7.	1-B	8,9,10	Double Bend (90^o + 90^o)
8.	1-B	11	Pipe
9.	1-B	12	Tee
10.	1-C	1	Pipe
11.	1-C	2,3,4	Double Bend (45^o +45^o)
12.	1-C	5	Pipe
13.	1-C	6	Globe Valve
14.	1-C	7	Pipe
15.	1-C	8	Globe Valve
16.	1-C	9	Pipe
17.	-	-	AFW Pump Room (Large Volume)



J1 = JUNCTION 1, etc.

V1 = CONTROL VOLUME 1, etc.

FIGURE A-1 RELAP4 THERMAL HYDRAULIC CODE VOLUME & JUNCTION MODEL SHOWING ELEVATIONS

APPENDIX B

CONTEMPT-LT/026
Thermal Hydraulic Code
Analysis

Appendix B

CONTEMPT-LT/026 THERMAL HYDRAULIC CODE ANALYSIS

PURPOSE

To determine the temperature and pressure response in the AFW pump room as a function of time, using the results of the RELAP-4/MOD 5 Analysis (mass flow rate and conditions of state from pipe break).

ASSUMPTIONS

The following assumptions were made in the development of the model.

a. All air/steam mixing in the AFW pump room is complete and instantaneous.

b. There is no venting of compartment atmosphere, despite the 3 ft^2 vent.

c. The steam supply is isolated completely when the valve reaches the fully closed position.

d. The AFW pump room will be modeled as a rectangular structure constructed entirely of concrete. The concrete walls, ceiling and floor will be considered to be of equal thickness.

e. The initial temperature of the heat structures is equal to the compartment atmosphere temperature.

f. Condensation occurs on walls, ceiling and floor; no evaporation occurs and no pool forms on the floor.

g. No equipment is operating at the time of the break.

h. No credit is taken for: condensation on equipment surfaces, better conduction through metal barriers (doors, vents,...), thinner heat transfer structures, or lower wall and ground temperatures.

ASSUMPTIONS (cont'd)

The initial conditions used are provided on the computerized results (Enclosure 2).

PROCEDURE

CONTEMPT-LT/026* is designed to model a nuclear reactor accident situation. It requires the user to define, at a minimum, the primary reactor system and the drywell. In our case, the AFW pump-turbine steam line is the primary reactor system and the AFW pump room is the drywell.

Figures 1 through 3 depict the plan, elevation and section views of the AFW pump room. To calculate the temperature and pressure response in the room it was first necessary to define the initial room conditions; namely, dimensions, materials and material properties, temperatures, pressures and humidity. The outside environment was also described.

The results of the RELAP-4/MOD5 analysis were used as the input to the CONTEMPT-LT/026 code to model the reactor primary system. Many of the available CONTEMPT-LT/026 options were not used due to the simplified nature of this problem.

The assumptions used in developing the model were made with two objectives in mind: maximize the conservatism of the results and simply the computational model to reduce costs.

RESULTS

The initial conditions and results of this analysis are contained in Enclosure 2 (computer printout of CONTEMPT-LT/026 code). Note: Output descriptions refer to the "primary system" (compartment 1) and "drywell" (compartment 3) for the AFW steam line and AFW pump room, respectively. Information provided by the NYPA described the AFW pump room as having a volume of 15833 cu.ft. and a free volume of 15244.2 cu.ft. Using Figures 1, 2, and 3, a rectangular room was defined which has the same volume and surface area. The steam conditions were obtained from

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*Note: The changes between CONTEMPT-LT versions 026 and 028 do not affect this analysis.

the RELAP-4/MOD 5 analysis. Due to the fact that the mass flow conditions in the AFW steam line varied radically during the first 2 seconds after the break, more values of time dependent mass and energy flow were used to describe the conditions during this period. The data density was decreased after 2 seconds due to a more uniform flow distribution in the pipe and code restraints on the number of allowable data points.

1. 4 Second Isolation Valve Closure Time

The results of this AFW pump turbine steam line break analysis (Table B-1) show that a temperature of 115.27^{O}F is obtained after 4 seconds; a pressure of 16.905 psia is obtained after 4 seconds. The temperature and pressure after 1 minute are 115.38^{O}F and 16.908 psia, respectively. This represents a change of 0.1% after the isolation valve closes. These results were predictable from the RELAP-4/MOD 5 analysis. The temperature/pressure response of Volume 17 after 4 seconds showed 132.40^{O}F and 18.167 psia. Since Volume 17 is an adiabatic compartment, these values represent the limiting case. Extrapolation of these results would provide the limiting envelope for the room conditions for this valve closure time.

2. 8 Second Isolation Valve Closure Time

The results of this AFW pump turbine steam line break analysis (Table B-2) show that a temperature of 140.47^{O}F is obtained after 8 seconds; a pressure of 19.022 psia is obtained after 8 seconds. The temperature and pressure after 1 minute are 140.8^{O}F and 19.032 psia, respectively. This represents a change of 0.23% after the isolation valve closes. These results were also predictable from the RELAP-4/MOD 5 analysis. The temperature and pressure in Volume 17 after 8 seconds were 174.19^{O}F and 21.94 psia. Since Volume 17 is an adiabatic compartment, these values represent the limiting case. Extrapolation of these results would provide the limiting envelope for the room conditions for this valve closure time.

Table B-1. AFW Pump Room Temperatures and Pressures - 4 Second Isolation Valve Closure Time.

Time, Seconds	Temperature, °F	Humidity, %	Pressure, PSIA
0.0	75.00	80.00	14.686
1.0	98.52	99.99	15.881
2.0	104.50	99.99	16.219
3.0	109.53	99.99	16.527
4.0	115.27	99.99	16.905
5.0	115.28	99.99	16.905
6.0	115.28	99.98	16.905
7.0	115.28	99.98	16.905
8.0	115.28	99.97	16.905
9.0	115.28	99.97	16.905
10.0	115.28	99.96	16.905
11.0	115.29	99.96	16.905
12.0	115.29	99.95	16.906
13.0	115.29	99.95	16.906
14.0	115.29	99.94	16.906
15.0	115.29	99.93	16.906
16.0	115.30	99.93	16.906
17.0	115.30	99.92	16.906
18.0	115.30	99.92	16.906
19.0	115.30	99.91	16.906
20.0	115.30	99.90	16.906
25.0	115.31	99.87	16.906
30.0	115.32	99.85	16.906
35.0	115.33	99.82	16.907
40.0	115.34	99.79	16.907
45.0	115.35	99.76	16.907
50.0	115.36	99.73	16.907
55.0	115.37	99.70	16.908
60.0	115.38	99.68	16.908

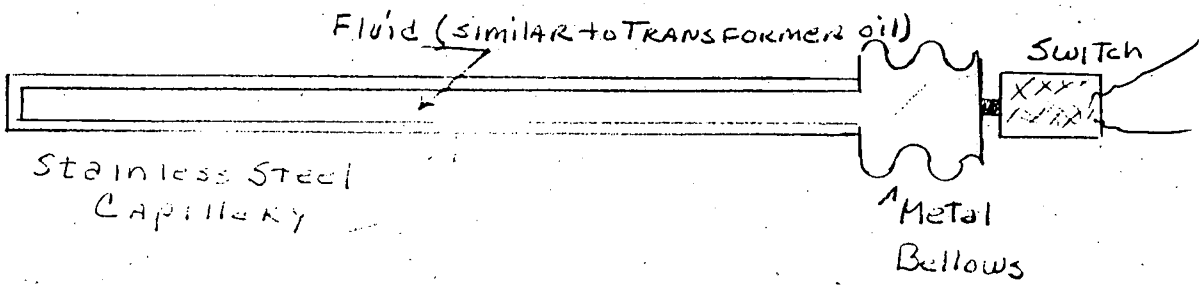
Table B-2. AFW Pump Room Temperatures and Pressures - 8 Second Isolation Valve Closure Time.

Time, Seconds	Temperature, °F	Humidity, %	Pressure, PSIA
0.0	75.00	80.00	14.686
1.0	98.52	99.99	15.881
2.0	104.50	99.99	16.219
3.0	109.53	99.99	16.527
4.0	115.27	99.99	16.905
5.0	121.10	99.99	17.324
6.0	127.42	99.99	17.823
7.0	133.95	99.99	18.392
8.0	140.47	99.99	19.022
9.0	140.47	99.98	19.023
10.0	140.48	99.96	19.023
11.0	140.49	99.95	19.023
12.0	140.49	99.93	19.023
13.0	140.50	99.91	19.023
14.0	140.51	99.89	19.023
15.0	140.51	99.88	19.024
16.0	140.52	99.86	19.024
17.0	140.52	99.84	19.024
18.0	140.53	99.82	19.024
19.0	140.54	99.81	19.024
20.0	140.54	99.79	19.024
25.0	140.58	99.71	19.025
30.0	140.61	99.63	19.026
35.0	140.64	99.54	19.027
40.0	140.67	99.46	19.028
45.0	140.71	99.37	19.029
50.0	140.74	99.29	19.030
55.0	140.77	99.20	19.031
60.0	140.80	99.12	19.032

Appendix C

Analysis of Temperature Switch Time Response

While there are several available heat transfer analysis programs which could be utilized to evaluate the transient response of the temperature switch to a change in the temperature of its surroundings, all of the programs require certain input data which the switch manufacturer considers to be proprietary. Referring to sketch (a), the switch functions as follows:



(a)

when the capillary is subjected to a change in temperature, heat is transferred to the fluid through the stainless steel sheath. The fluid expands forcing the bellows to grow and depress the switch to make or break an electrical contact.

In order to employ the analytical methods available, the following information must be known:

1. Sheath - Inside and outside diameter, length, thermal conductivity, heat capacity, density.
2. Fluid - Density, heat capacity, thermal conductivity, expansivity, volume.
3. Bellow - Volume, spring constant.

Data is available for the sheath. The fluid, fluid characteristics and bellows design details are proprietary.

Therefore, an exact analytical computation cannot be performed. There is, however, a pragmatic approach which can be utilized to perform an analysis of switch response relative to known test data. While the approach is not rigorous it is reasonable from an engineering viewpoint.

The approach is based on the following assumptions.

- The switch assembly is stabilized at a known temperature (viz 75°F).
- The capillary is subjected to a step increase in temperature (viz 75°F to 212°F) as a result of surrounding the capillary with a steam/air environment.
- The wall thickness and heat capacity of the sheath delays the transfer of heat and, therefore, temperature rise of the fluid.
- The fluid must increase in temperature as heat is transferred to the sheath.
- The fluid expands and extends the bellows as a result of the change in temperature.
- When the total expansion of fluid and bellows extension reach a predetermined point the snap action switch is opened or closed.

If the time response to the end point of a step change is known, then by conservatively calculating the rate at which heat is transferred from the surrounding medium through the wall of the capillary, the time response to reach a set point lower than the end point can be conservatively calculated. The simplest analytical method is that described in McAdams, "Heat Transmission", Third Edision, Chapter 3. (Pages 40 and 41 are reproduced in this appendix as Figure C-1).

The capillary is treated as a long cylinder. The sheath thickness is taken to be the radius of the capillary probe to provide a maximum resistance to heat transfer. Equation 3-5 (figure C-1) is used to determine the apparent heat transfer coefficient from the manufacturer's test results.

$$-\ln Y = \left(\frac{A\ rm}{V}\right)\left(\frac{1}{m}\right)\left(X\right)$$

$$-\ln\left(\frac{ta - t}{ta - tb}\right) = \left(\frac{2h\ Rm}{k}\right)\left(\frac{k\ \theta}{\rho c_p r_m^2}\right) \qquad \text{(c-a)}$$

where: t_a = the ambient surrounding the probe = 212^0F.

t_b = the temperature of the probe prior to the transient = 75^0F.

t = the temperature at time 0 = 211^0F.

k = thermal conductivity of the sheath = 9.4 BTU/hr/Ft^2/Ft/^{0}F

r_m = radius of the probe = 5/64" = 0.00586 ft.

C_p = heat capacity of the sheath = 0.12 BTU/lb^{0}F

ρ = density of the sheath = 501 lbs/ft^3

0 = time to reach 211^0F = 8 seconds.

h = heat transfer coefficient. BTU/hr Ft^2 ^{0}F

Solving the equation (c-a) for h from the manufacturers test gives a value of 389.9 BTU/hr Ft^2^{0}F. This value is in reasonable agreement with measured data for steam air mixtures. (Figure C-2).

The heat transfer coefficient for the concrete walls of the AFW pump room calculated by CONTEMPT-LT (Appendix B) was 287 BTU/hr Ft^2^{0}F.

In order to assure conservatism in calculating the time for the switch to trip at 135^0F when exposed to a steam/air environment resulting from a steam line break in the AFW pump room, it was concluded that a lower heat transfer coefficient than calculated above or by CONTEMPT should be used. Based on the location of the switches and their mounting, engineering judgement and experience indicates that a heat transfer coefficient in the range of 200 to 225 BTU/hr Ft^{20}F should be used. A value of 215 BTU/hr Ft^{20}F was selected for the calcualtion. In addition, although the RELAP-4 analysis indicates a steam temperature of $\sim 230^0$F issuing from the break, a 212^0F temperature for ambient near the switch at 0.1 seconds after the break was used to calculate the response time of the switch to perform the analysis consistent with the manufacturer's test conditions.

Solving equation C-a for the time to reach a 135^0F set point in response to a 212^0F steam/air ambient results in a response time of 1.699 seconds; rounded to 1.7 seconds.

It is therefore concluded, that switches set at 135°F will trip within 2 seconds or less in the event of a break in the 4" steam supply to the auxiliary feed pump turbine.

Spheres and Long Cylinders. Figures 3-7 and 3-8 show the values of Y for spheres and long cylinders plotted vs. X, for the various values of m and n. The curves given in Figs. 3-7 and 3-8 are based on the assumption of constancy of t_a, m, n, and $\alpha = k/\rho c_p$. Olson and Schultz[34] give interpolation tables of Y for the long cylinder, for values of X ranging from 0 to 0.4.

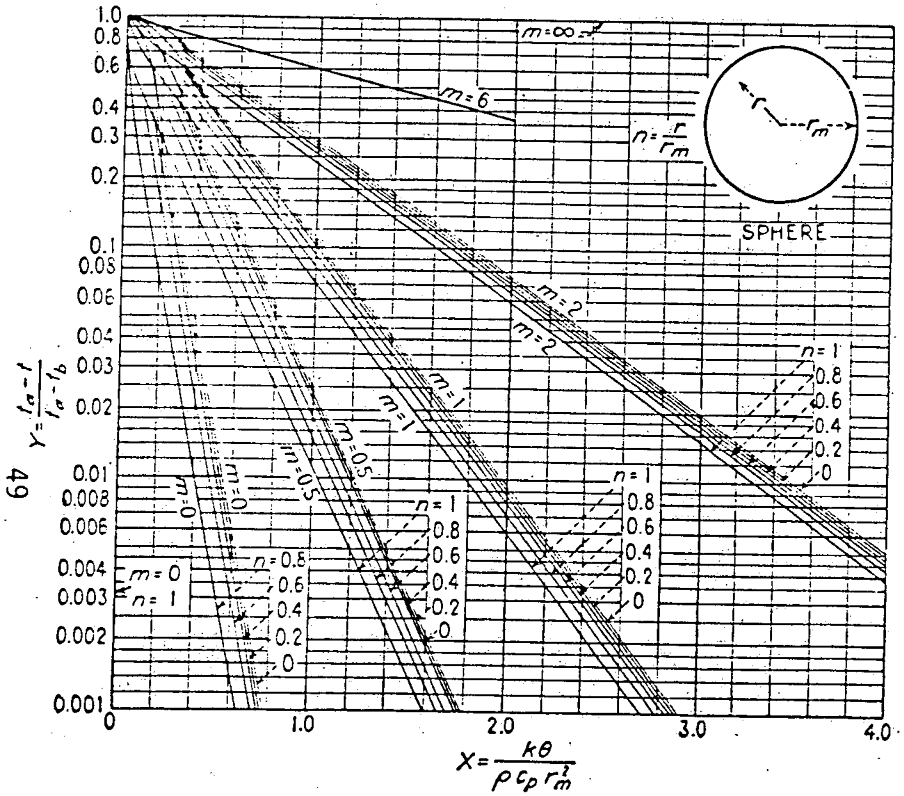


FIG. 3-7. Gurney-Lurie chart[19] for spheres.

Buried Long Cylinder. Figures 3-8*a* and *b* are Gemant[15] graphs of the dimensionless accomplished temperatures and of the dimensionless instantaneous rates of heat transfer per unit length, respectively, plotted vs. the dimensionless time X after the surface temperature has suddenly been increased from t_b to t_s. Gemant used these relations to estimate the results of submerging multiple parallel steam-heated pipes near the surface of a concrete slab at the surface of the ground.

Hooper and Chang[22] measured the thermal conductivity of a sandy soil by means of a submerged heat probe and found that the thermal conductivity increased with increase in depth and with increase in ratio of water to soil.

Surface Resistance Controlling. In Figs. 3-2, 3-7, and 3-8, in order to facilitate extrapolation to values of m above 2, the approximate positions of curves for $m = 6$ are shown. The curves for $m = 6$ were based on the approximate equation (3-1), which was obtained by ignoring the temperature gradient in the solid. Substituting Y for the dimensionless ratio of temperature differences $(t_a - t)/(t_a - t_b)$, X for the dimensionless term $k\theta/\rho c_p r_m^2$, and m for the dimensionless term k/hr_m, Eq. (3-1) becomes

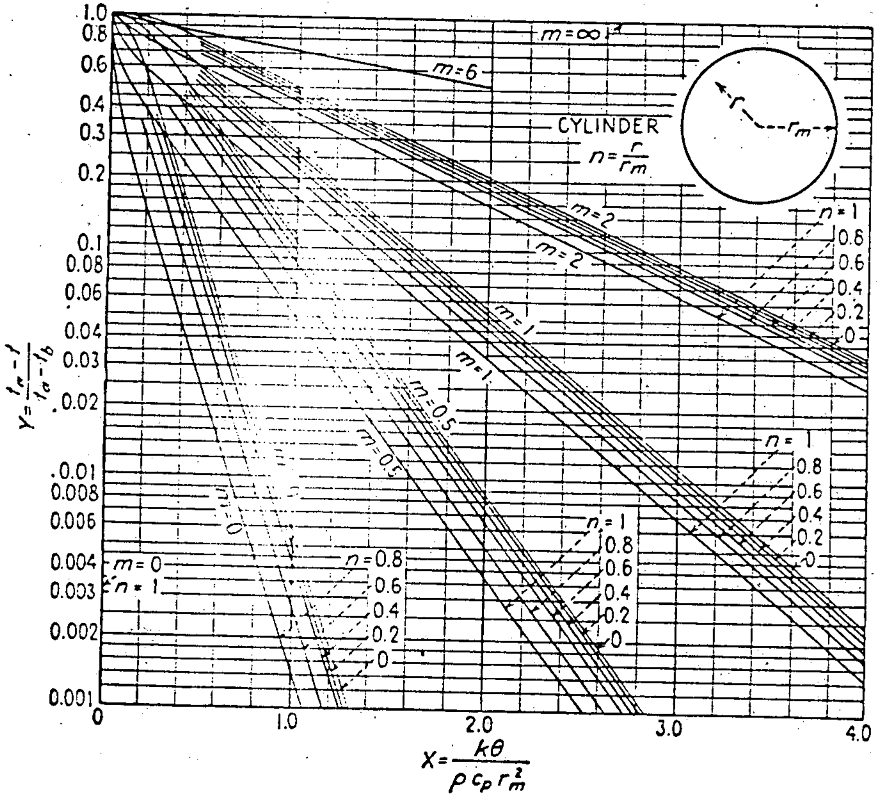
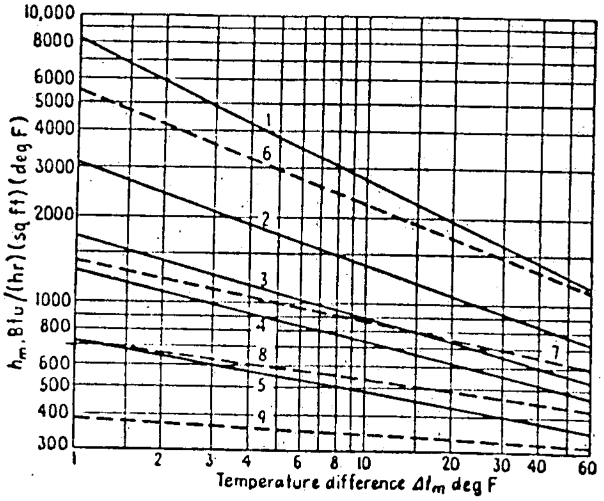


FIG. 3-8. Gurney-Lurie chart[19] for long cylinder; values of Y for short cylinder may be obtained from Figs. 3-2 and 3-8 by use of the Newman method.[33]

$$-\ln Y = \frac{Ar_m}{V}\frac{1}{m}X \qquad (3\text{-}5)\,\star$$

For various shapes the dimensionless ratio Ar_m/V has the following values:

	Ar_m/V
Slab having a large ratio A/r_m	1
Long cylinder	2
Cube or sphere	3



Side Lines (t_v = 230°F)

1 = 0 per cent air
2 = 1.07 per cent air
3 = 1.96 per cent air
4 = 2.89 per cent air
5 = 4.53 per cent air

Broken Lines (t_v = 212°F)

6 = 0 per cent air
7 = 1.42 per cent air
8 = 3.47 per cent air
9 = 6.21 per cent air

Fig. 13-9. Coefficients for steam condensing on a horizontal 3-in. tube. Per cent air by volume. (Othmer.[67]) (*Courtesy W. J. King.*)

Figure C-2

REFERENCES

1. McAdams, W. H., Heat Transmisson, Third Edition, McGraw Hill Book Co.,NY, NY, © 1954
2. Holman, J. P., Heat Transfer, Fourth Edition, McGraw Hill Book Co.,NY, NY, © 1976
3. Thompson, P.A., Compressible Fluid Dynamics, McGraw Hill Book Co.,NY, NY, © 1972