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ANALYSIS OF HIGH ENERGY LINES

Consolidated Edison Company of New York, Inc.

Indian Point Station, Unit No. 2

Docket No. 50-247

April 9, 1973

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PART 1

Analysis of a Postulated Main Steam or Feedwater Pipe Break Outside Containment

1.0 Introduction

Equipment in the vicinity of the main steam and feedwater lines outside containment which is required for safe shutdown are the auxiliary boiler feed pumps, the steam line isolation valve control panels and the relief valve control panels. This equipment is located in the shield wall area. The shield wall area is divided into four separate compartments. These compartments are: 1. Shield Wall El. 18'-6"; 2. Shield Wall El. 32'-6:; 3. Shield Wall El. 43'0", and; 4. Pipe Bridge and Steel Tower. Each of these areas was analyzed to determine the consequences of high energy line failures within the area.

2.0 Description of Piping

2.1 Routing & Seismic Classification

The main steam and feedwater lines penetrate the containment on an east-west line at El. 62'-10" and 57'-6" respectively. The center two main steam lines rise vertically to El. 75'-6" then turn in opposite directions to form large, flexible loops around the concrete shield wall before they each return to the pipe bridge and proceed to the turbine inlets.

The outer two main steam lines turn immediately in opposite directions to form large, flexible loops around the concrete shield wall also returning to the pipe bridge.

The steam supply to the turbine driven auxiliary feedwater pump is taken from two main steam lines, headered together and runs vertically downward to the turbine mounted at El. 18'-6". The turbine is protected from overpressure by a relief valve downstream of the control valve. The relief valve exhaust

line passes vertically upward through the structure to discharge to atmosphere.

The main steam stop and check valves are located approximately 30 feet from the penetration to permit the installation of the five (5) safety valves and one (1) atmospheric dump valve (in each line).

The main steam lines are Class I seismic from the penetrations to, and including, the non-return valves. The steam to the turbine driven auxiliary feedwater pump is Class I seismic.

The main feedwater lines rise from their individual feedwater regulators located in the tower north of the shield wall to El. 35'-0" at which point they run south, enter the second level of the auxiliary feed pump building and turn up to the individual penetrations at El. 57'-6".

The main feedwater lines are Class I seismic from the check valves outside containment to the penetrations.

The two motor driven and one turbine driven auxiliary feedwater pumps are located at El. 18'-6" in the auxiliary feed pump building. Each motor driven pump discharge is connected to two main feedwater lines with a control station located near the pump at El. 20'-6", the piping then running south to a common vertical pipe chase. The lines each run north between El. 49'-10" and 54'-4" until they reach the designated main feedwater line.

The auxiliary feedwater system is Class I seismic including the suction line from the condensate storage tank. That portion of the city water piping inside the auxiliary pump room is designed to Class I seismic requirements.

2.2 Quality Assurance for Piping

The 18" boiler feed piping located in the area is ASTM A-106 Gr. C seamless pipe. All circumferential welds are 100% radiographed.

The 28" main steam piping located in the area is ASTM A-155 Gr. KC-70, Class I rolled and welded pipe. The longitudinal seam and all circumferential welds are 100% radiographed.

Radiographic inspection is performed in accordance with Para. UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code. The steam supply piping to the auxiliary feed pump turbine is ASTM A-106 Gr. B seamless pipe. All circumferential welds required liquid penetrant or magnetic particle inspection of the root pass and finished weld. In addition, 20% of the finished welds, selected at random, required 100% radiographic examinations. Socket welds on 2" and smaller piping required liquid penetrant inspection of the finished weld.

The auxiliary feed pump discharge lines are ASTM A-106 Gr. B seamless pipe. Circumferential welds 2-1/2" and larger required liquid penetrant or magnetic particle inspection of the root pass and finished weld. In addition, 20% of the finished welds, selected at random, required 100% radiographic examination. Socket welds on 2" and smaller piping required liquid penetrant inspection of the finished weld.

3.0 Description of Structure

3.1 Shield Wall

The seismic Class I shield wall is a rectangular shaped reinforced concrete wall west of the containment building. It is a 62' high, cantilevered structure founded in rock and extending to El. 80'-0". It provides biological shielding from the main steam and feedwater penetrations into the containment and supports structural steel between the containment and the wall.

3.2 Shield Wall Elevations 18'-6" and 32'-6"

The seismic Class I structure is reinforced concrete enclosure that houses the auxiliary boiler feed pumps

and associated electrical equipment, instrumentation and piping. In addition, the auxiliary feedwater piping passes vertically through the structure. The east and west boundaries of the structure are the containment and the shield wall respectively. Reinforced concrete walls enclose the north and south ends of the structure. An intermediate floor slab is located at El. 32'-6" (top of concrete). The roof at El. 43'-0", (top of concrete) serves as the bottom support for columns between the containment building and the shield wall.

3.3 Shield Wall Elevation 43'-0" Structural Steel

Structural steel is provided between the shield wall and containment to provide pipe whip restraint for the seismic Class I main steam and feedwater piping. The steel forms a box around the piping and the loads are transmitted to the shield wall and to columns which extend to the roof of the auxiliary boiler feed building. All steel in this area is seismic Class I.

3.4 Structural Steel Tower

This structure, which is adjacent to the sheild wall, provides support for main steam and feedwater piping. The portion of the piping supported is downstream of the main steam isolation valve and upstream of the feedwater check valves and, therefore, is Class III. The tower is supported on 4 steel columns which are supported on a reinforced concrete footing which rests on rock. The structural steel for the tower is Class I.

3.5 Bridge between Shield Wall and Turbine Building

The structural steel in the bridge supports Class III main steam and boiler feed piping. The structure is Class III. At the shield wall, a sliding connection is provided to allow for thermal expansion of the bridge. The bridge is connected to the tower by flexible structural steel, thus no significant loads can be transmitted from the bridge to the tower. The bridge is supported on columns which are supported

on piers extending the length of the bridge and resting on rock.

3.6 Enclosure

The entire shield wall area above elevation 43'-0", structural steel tower area and pipe bridge area is provided with a weather enclosure that is a sandwich panel metal siding.

4.0 Evaluation

4.1 Shield Wall Area at Elevation 18'-6"

This 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.

High energy lines in this room are the eight auxiliary boiler feedwater lines and the main steam line to the auxiliary boiler feed pump turbine. A postulated break in any of these lines could cause a pressure, temperature and humidity build up in the room and jet impingement on equipment.

Double ended breaks were considered for both the auxiliary feedwater lines and the main steam line to the steam driven auxiliary feedwater pump. These breaks were assumed to occur at any location along a straight run of pipe in any one of these 9 lines.

Pipe whip restraints are provided for each of these lines to prevent whip into any other lines or any safe shutdown equipment. No damage to critical equipment would result from pipe whip.

The environmental conditions in this room were evaluated on the basis of a steam line failure to the auxiliary boiler feed pump turbine. Initial conditions for this pipe break were taken to be 1,100 psia saturated steam. The discharge rate, as found by Napiers formula, was 652,000 pounds per hour. The vent area assumed for the pressure/

temperature calculation was 21 square feet which includes an open door to the outside. The resultant pressure/temperature transient was calculated by using the digital computer code Contempt-M. Final conditions in the room, based on steady state calculation, were 0.9 psig and 213°F. This pressure is well within the 7.2 psig limit for the room (the north wall controlling) calculated by maintaining stresses within the requirements of ACI-318 Building Code Limits (Part IVB "Ultimate Strength Design").

For the purpose of evaluating the effects of environment on equipment in this room, the following conditions were used.

Average Temperature	= 213°F	
Maximum Temperature	= 320°F	(Due to Jets)
Humidity	= 100%	
Pressure	= 0.9 psig	

It is believed that the components in the auxiliary feed system, such as pump motors, controls and instruments within the area, could withstand these conditions for a substantial period of time. However, no specific test data are available at this time to substantiate this belief. Therefore, for this analysis it has been conservatively assumed that the auxiliary feedwater system will not perform as designed for this postulated piping failure.

Loss of all Auxiliary Boiler Feed Pump's ("ABFP") would not prevent safe shutdown as long as normal AC power is available to run the normal feedwater system. There is no reason to believe that pipe breaks in this room would cause loss of normal AC power supply. However, AEC practice is to assume that any incident which causes plant trip will cause loss of normal AC power.

A complete failure of an auxiliary feedwater line or steamline in this room would cause a plant trip. Only if it is assumed that all three ABFP's are disabled and AC power is lost would this event jeopardize safe shutdown. To preclude this unlikely occurrence, the following modifications will be made:

(a) Add check valves in the auxiliary feedwater lines outside this room to prevent backflow from the main feedwater line into this room.

(b) Add redundant valves in the main steam line to the ABFP turbine outside this room. These valves will be signaled to close on high temperature in the auxiliary feed pump room.

4.2 Shield Wall Area at El. 32'6"

This room is a concrete enclosure located above the El. 18'6" room and is used to house the main feed lines, the air blowers for the main steam and main feed penetrations, and the chemical feed system.

High energy lines in the room are the four main feed lines. The four auxiliary boiler feed lines and the steam line to the ABFP turbine pass vertically through the room. No shutdown related equipment is located in this room.

Whip restraints are provided for the auxiliary feed lines and the main steam line to the ABFP turbine. There are no whip restraints for the main feed lines since these portions of the feed lines are seismic Class III upstream of the main feed check valves. Whip restraints are not required for the main feed lines in this room since the lines cannot impact safety-related equipment. It is only necessary to show that a failure of a feed water line could not cause structural damage which might damage equipment in the El. 18'6" room below.

The worst case pipe failure assumed was an 18" boiler feed line double-ended break. The initial conditions assumed for the line were water at 427°F and 1,100 psia. The calculation was based on the total content of the main feedwater system from the main feed pumps to the first check valve outside Containment discharging into the room. The discharge rate was based on the feedwater control valve being in the full-open position. The maximum flow was found to be 17,000 gpm, or 1,982 pounds per second, of which

458 pounds per second flashed to steam in the feedwater regulating valve. The analysis of the resulting load on the floor slab showed that no elements are overstressed using Ultimate Strength design procedures of Part IVB of the ACI 318-63 Code. The allowable stresses of the code were used without capacity reduction factors. Pipe whip in this room would not affect critical equipment in the El. 18'6" room below.

All water released to the room was conservatively assumed to flash in the room. Vent area assumed was 69 square feet which includes two doors open to the outside. The final pressure/temperature conditions, based on a steady-state calculation, were 0.5 psig and 213°F. This pressure is well within the maximum pressure allowable for the room of 9.0 psig with the floor slab of El. 32'6" being the controlling structure.

The loads resulting from 0.5 psig pressure and the 213°F temperature were assumed to act simultaneously with the pipe whip loads previously described and the results showed that no overstress would occur.

Since equipment required for safe shutdown is not located in this room, effects of temperature, humidity, and jet impingement need not be considered.

4.3 Shield Wall Area at El. 43'0"

This enclosure provides weather protection for the main steam and boiler feed piping. Sheet metal paneling similar to that used in other areas of the plant is fastened to stringers which are jointed to the structural steel. Loads of 60 psf (0.42 psi) will cause the panels to fail.

High energy lines in this enclosure are the main boiler feed lines upstream and downstream of the check valves, main steam lines upstream and downstream of the main stop valves, main stream supply to the ABFP turbine and auxiliary feed lines to the main feed lines. Safe shutdown equipment in the area are the main steam isolation valve control panels and the relief valve control panels.

Pipe whip restraints are provided for the seismic Class I portion of these lines to prevent damage to adjacent Class I steam or feedwater lines.

The pipe whip structure was evaluated by statically applying pipe break and jet loads that would result from the postulated breaks as determined by AEC guidelines. Applying these combined loadings on the structure resulted in stresses less than 0.9 Sy. The analysis performed is described in Section 4.5 below.

No significant pressure buildup could occur due to the low pressure differential at which the siding panels fail. Failure of this siding prevents excessive loads on the basic structure.

Temperature buildup in the room would not be significant since siding would blow off almost immediately following a break. The main steam isolation valves would be signaled to close immediately upon steam line break (these valves are not required to operate following a feed line break). The controls would have performed this function long before any temperature effects could cause significant damage. Power operated relief valves are not required for hot shutdown. They are only required for cold shutdown if the condenser is unavailable. Should the control panels be damaged by temperature and humidity, the relief valves can be operated locally at such time as it is desired to bring the plant to cold shutdown.

Both the relief valve and main steam isolation valve control panels could be damaged by effects of a jet on the electrical controls. If the relief valve control panel is damaged, the valves can be operated locally at such time as it is desired to bring the plant to cold shutdown.

Main steam stop controls must function to isolate the affected steam line in the event of a piping failure. Therefore, shields for the control panels will be provided to prevent direct jet impingement on the control panel.

4.4 Pipe Bridge and Steel Tower Area

These structures contain only main steam and feedwater lines. They contain no safe shutdown equipment. The pipe restraints in the shield wall area above El. 43'-0" are designed such that the main steam isolation valves or feedwater check valves remain functional if a line failure in the pipe bridge and steel tower area occurs. Safe shutdown equipment in the shield wall area is protected from the bridge and tower area by concrete walls or impingement shields. Pipe failure in this area would have no effect on any safe shutdown equipment.

4.5 Analysis of the Adequacy of Pipe Whip Restraints

The original design basis pipe ruptures in Indian Point 2 were (1) circumferential rupture occurring anywhere along the straight pipe run or at the weld junction of the straight pipe and the fitting, valve or equipment; and (2) longitudinal rupture occurring anywhere along the straight pipe run. 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 axis having an area equal 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.

The pipe rupture loads were 340K for the 28" main steam, 200K for the 18" main feedwater pipes and the product of the break opening area and the system design pressure for all other pipes. These rupture loads act perpendicular to the rupture opening. All analyses considered the pipe as a beam statically loaded at the rupture opening and supported at the restraints. The loads on the restraint were based on the rupture location which would cause maximum load on the restraint. The restraint spacings were based on the rupture location which would induce maximum stress on the pipe.

Where whipping was to be prevented, the restraints were spaced so that the bending stress due to pipe rupture load would not exceed the remainder of 1.8 x code allowable stress less the pressure 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 ship 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. The two points of maximum stress in the direction of maximum stress were chosen as pipe break locations.

4. Stresses were checked to assure that they were less than .8 of allowable stress. (All stresses were less than .8 of allowable stress, therefore, no additional pipe breaks were postulated.)

5. Maximum stresses were calculated by adding the thermal, maximum dead weight and seismic stresses.

In accordance with the above procedure the following break locations were postulated:

<u>Main Steam Line 21</u>

1. Near anchor point in Turbine Building (19,567 psi)

2. North end of first elbow beyond isolation valve (16,398 psi)

Main Steam Line 22

1. Near anchor point in Turbine Building (19,154 psi)

2. North end of first elbow beyond isolation valve (17,705 psi)

Main Steam Line 23

1. South end of first elbow beyond isolation valve (16,789 psi)

2. Second elbow beyond isolation valve (16,882 psi)

Main Steam Line 24

1. Near anchor point in Turbine Building (18,918 psi)

2. East end of first elbow outside Containment Penetration (17,637 psi)

Boilder Feed Line 21

1. In tower beyond shield wall (12,306 psi)

2. Inside concrete Auxiliary Boiler Feed Building (9,333 psi)

Boilder Feed Line 22

1. East end of first elbow outside Containment Penetration (10,459 psi)

2. In tower beyond shield wall (8,097 psi)

Boiler Feed Line 23

1. In tower beyond shield wall (10,070 psi)

2. Lower end of first elbow above the roof of the Auxiliary Boiler Feed Building (8,371 psi)

Boiler Feed Line 24

1. East end of first elbow outside Containment Penetration (9,635 psi)

2. In tower beyond shield wall (7,839 psi)

All the above stresses are in the longitudinal direction, therefore, the only pipe breaks considered were circumferential breaks.

The magnitude of the jet load was assumed equivalent to the magnitude of the pipe thrust loads (340 kips for Main Steam and 200 kips for Boiler Feed). The area of pipe break from which the jet originated was equal to the cross sectional area of the pipe. The jet was assumed to act parallel to the pipe (or normal to the plane of circumferential failure) if the pipe were free to displace one pipe diameter from its original location. If the pipe were restrained from this movement, it was assumed a gap opened of dimension required to provide an area around the circumference of the pipe equal to the cross sectional area of the pipe. This created a jet 360° around the pipe circumference. Jets were assumed to expand 10° in all directions. The total jet force was assumed constant at any distance from its origin. The ratio of the area of structural steel contacted by the expanded jet to the total area of the expanded jet was multiplied by the jet force to determine the load on the structure.

The structural steel was analyzed using the pipe break locations and directions and the jet force and thrust loads discussed above. Consideration was given to the structural steel of the Class I pipe whip restraints in the area between the containment building and the shield wall up to and including the steel on the south end of the tower (Col. Line 22.1) and the steel at the main steam isolation valve south of the shield wall. Loads from pipe breaks were considered as follows.

1. The following pipe break locations were eliminated from consideration since they were not in the area of the Class I steel discussed above.

   (a) Terminal points at the Turbine end of all Main Steam and Boiler Feed lines.

(b) Main Steam Line 21 break 1

(c) Main Steam Line 22 break 1

(d) Main Steam Line 23 break 2

(e) Main Steam Line 24 break 1

(f) Boiler Feed Line 21 break 1 and 2

(g) Boiler Feed Line 22 break 2

(h) Boiler Feed Line 23 break 1

(i) Boiler Feed Line 24 break 2

2. Since the pipe is restrainted from displacement, a circumferential break at the Containment Penetration anchor point for all Main Steam and Boiler Feed lines will produce a jet east of Column Line H.8 and hence east of all Class I pipe whip restraint steel. Therefore, these terminal points are eliminated from consideration of loading on the steel.

3. Main Steam Line 21 Break 2

It is assumed that the Class III pipe downstream of this break will displace; therefore, the jet will be parallel and behind the shield wall. It will have no effect on the pipe whip restraint structural steel.

4. Main Steam Line 22 Break 2

See item 3 above.

5. Main Steam Line 23 Break 1

The Class III pipe beyond the break is assumed to displace; therefore, the jet will be expelled north and away from the Class I steel.

6. Main Steam Line 24 Break 2

The circular jet (since displacement of pipe is not possible in these restrained Class I lines) will impinge on Columns H.8 - 20.9 and H.8 - 20.7. The force on each column will be less than one half of 340^k. Since each column has been designed to resist a pipe thrust of 340^k acting in the same direction as the postulated jet no further analysis is required.

7. Boiler Feed Lines 22 and 24 Break 1

The jets will impinge on columns H.8 - 20.7; H.8 - 20.5 and H.8 - 20.3 in the same manner as discussed in item # 6 above.

8. Boiler Feed Line 23 Break 2

The circular jet will impinge on Cols. H.8 - 20.9 and H.8 - 21.2 with components in a direction not common to the direction assumed for pipe thrust loads in the original column design. Therefore, it is necessary to analyze the columns for the subject jet loads. The addition to the jet loads, the dead and live loads from the original design were added.

The columns were analyzed as beam - columns in accordance with Formula 1.6-2 of the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, 1969. The summation of the ratio of stress to allowable stress for each direction of bending and the axial load for each column was $\approx$.60 compared to a code allowable of 1.0. This is based on the allowable stresses given in the code. The allowables can be increased to .9 fy for pipe break load as discussed in Section 1 of this report; therefore, the columns are well within 50% of the maximum allowable stresses for the pipe break condition.

The concrete structures in the shield wall area were analyzed for impingement loads using the same loadings used for steel structure and were found to be well within allowable stresses.

TABLE 1

Formulas Used for Pipe Whip Analysis

1) Beam on simple support with load F kips, b inches wide and l_1 support span.

Moment, $M = \frac{F}{4}(l_1 - \frac{b}{2})$

Bending stress, $Sb = \frac{M}{Z}$

Z = Section Modulus

2) Cantilever beam loaded at free end

Moment, $M = F \times l_2$

Bending stress $= \frac{M}{Z}$

Z = Section Modulus

3) Calculations

a) Main Steam = 28" OD x .912 Wall
Design Press = 1.085 KSI
Material = ASTM A 155 KC70 Cl I
Code Stress = 17.5 KSI
Pressure Stress = 7.53 KSI
Section Modulus = 510 in.^{3}
l_1 = 172"
l_2 = 36"

b) Main Feed Water = 18" OD x Sch. 60
Design Press = 1.085 KSI
Material = ASTM A 106 Gr. C
Code Stress = 17.5 KSI
Pressure Stress = 5.71
Section Modulus = 168.3
l_1 = 105"
l_2 = 22"

c) For a cantilever one directional restraint with cantilever length to the load of 22 inches.

M = 340 X 22 = 7480 in K

$Z\ req = \frac{7480}{.9 \times 36} = 231\ in^3$

Use 33 WF 141 , Z = 446.8

FORM 5015

GENERAL COMPUTATION SHEET

LEGEND

THRUST FORCE = 340K

JET FORCE = 340K

united engineers & constructors inc.

NAME OF COMPANY

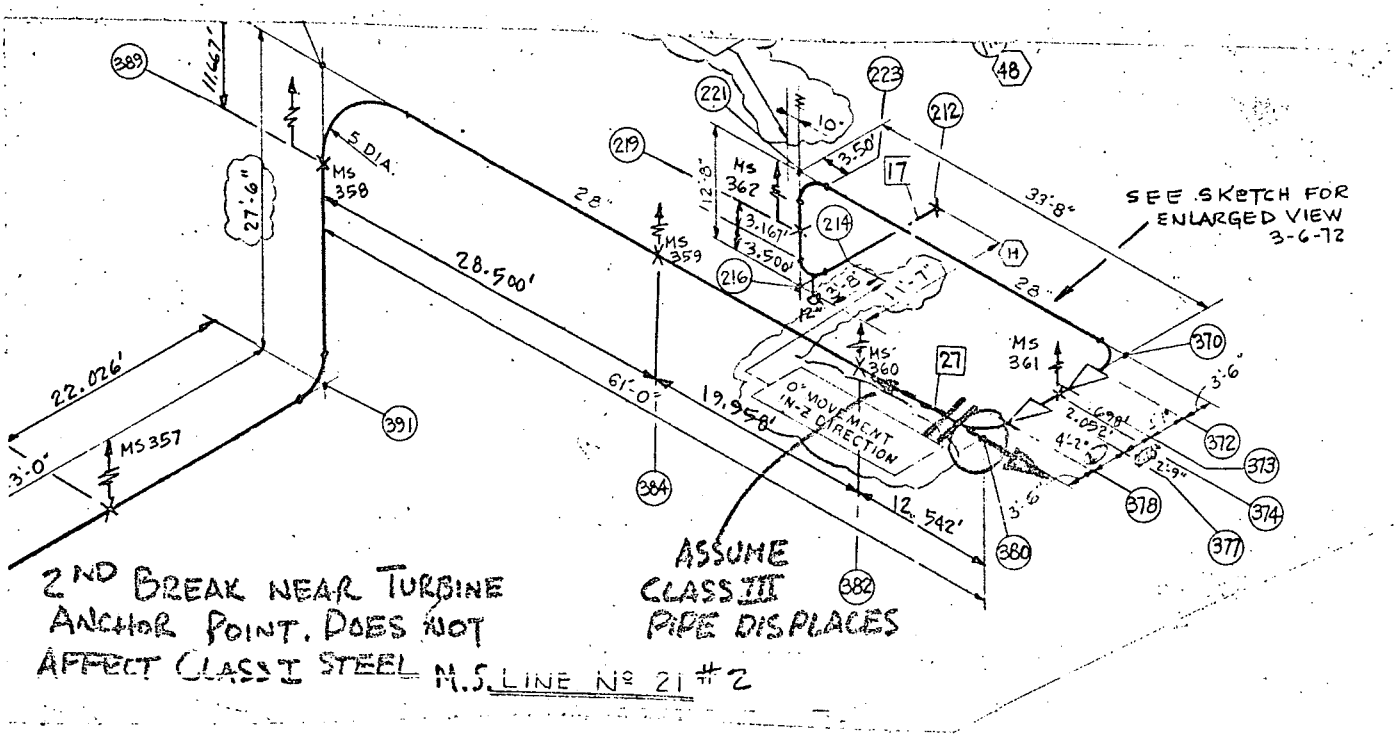
SUBJECT

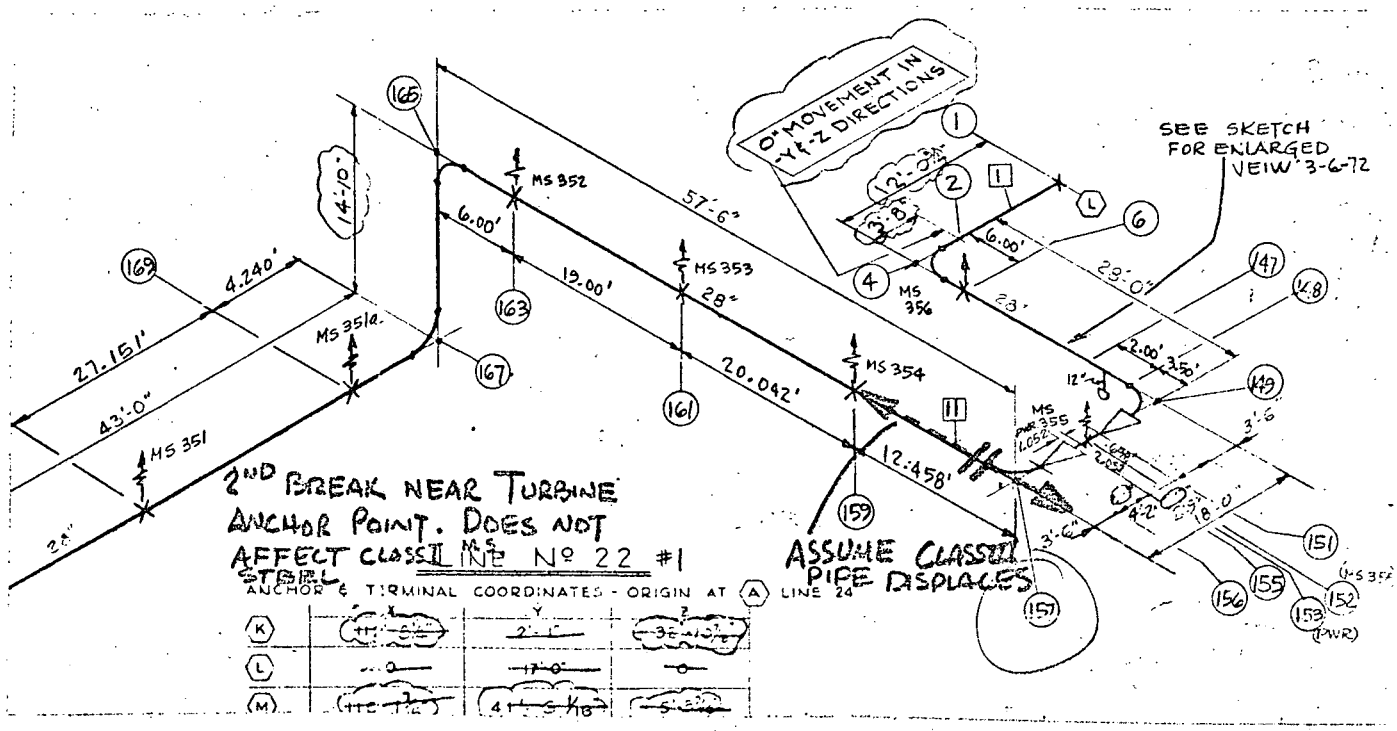
J. O. NO.

SHEET NO. 2 OF

DATE

COMP. BY C'K'D BY





FORM 5015

GENERAL COMPUTATION SHEET
UNITED ENGINEERS & CONSTRUCTORS INC.

NAME OF COMPANY

THRUST FORCE = 200K

JET FORCE = 200K

J. O. NO.

SHEET NO. 3 OF

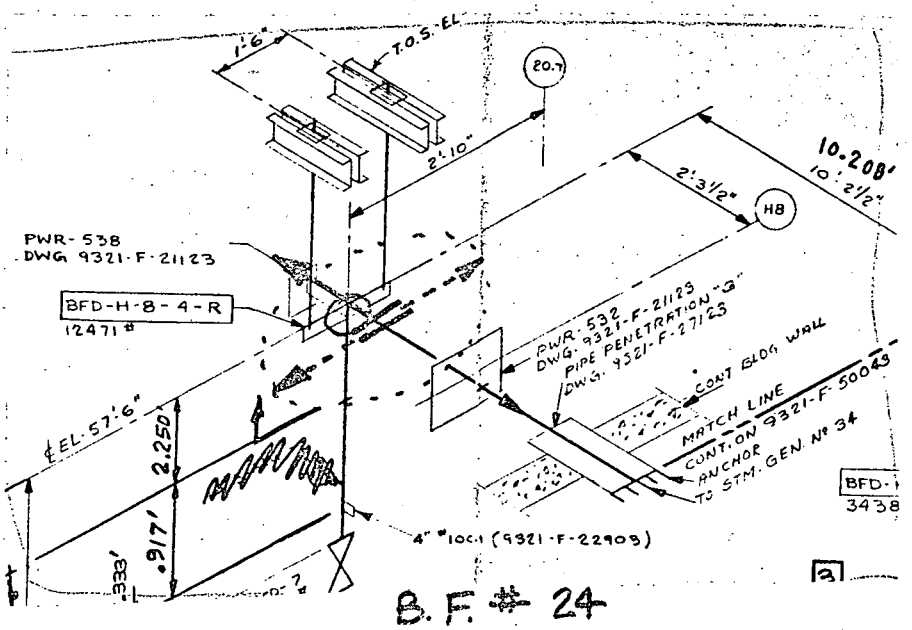
DATE

SUBJECT

COMP. BY C'K'D BY

B.F. #21 HAS ONE BREAK IN AUX. BOILER FEED BLDG AND ONE BREAK IN TOWER BEYOND THE SHIELD WALL. DOES NOT AFFECT CLASS I STEEL

B.F. # 22, #23 & #24 HAVE SECOND BREAK IN TOWER BEYOND SHIELD. DOES NOT AFFECT CLASS I STEEL



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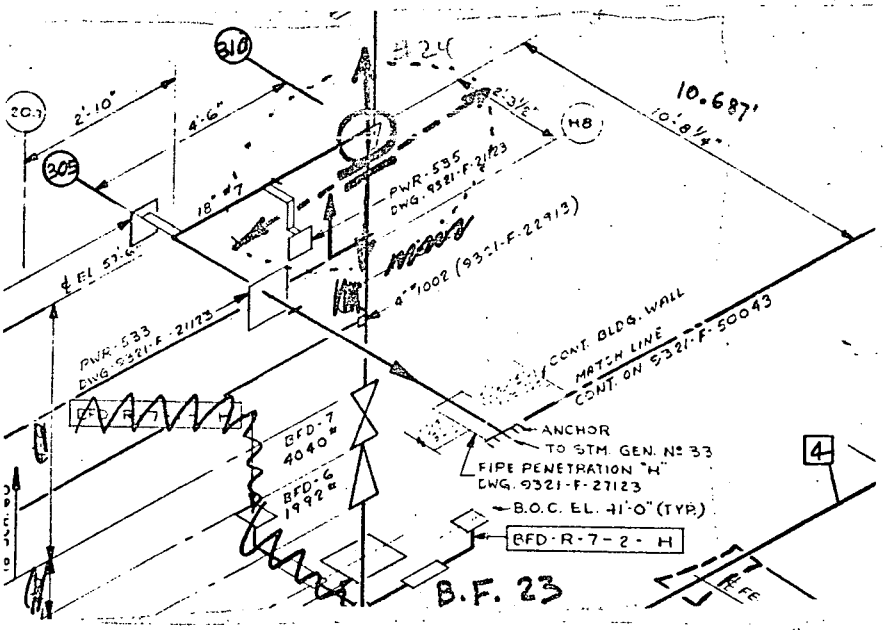
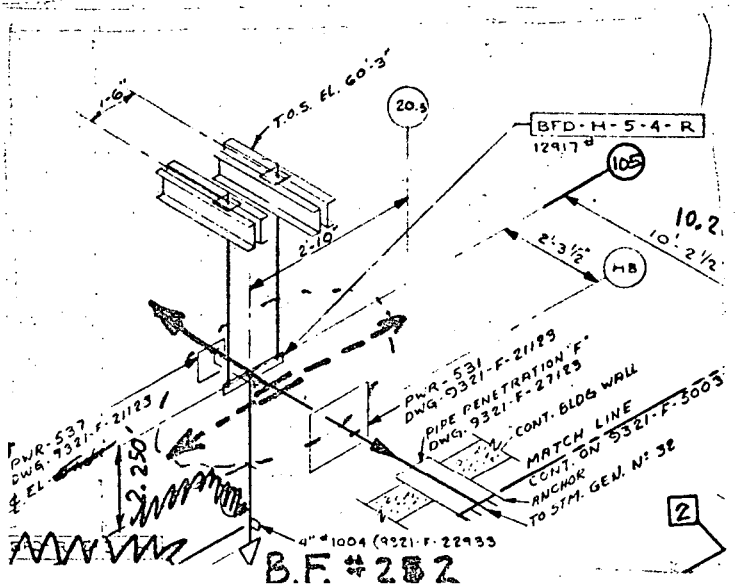
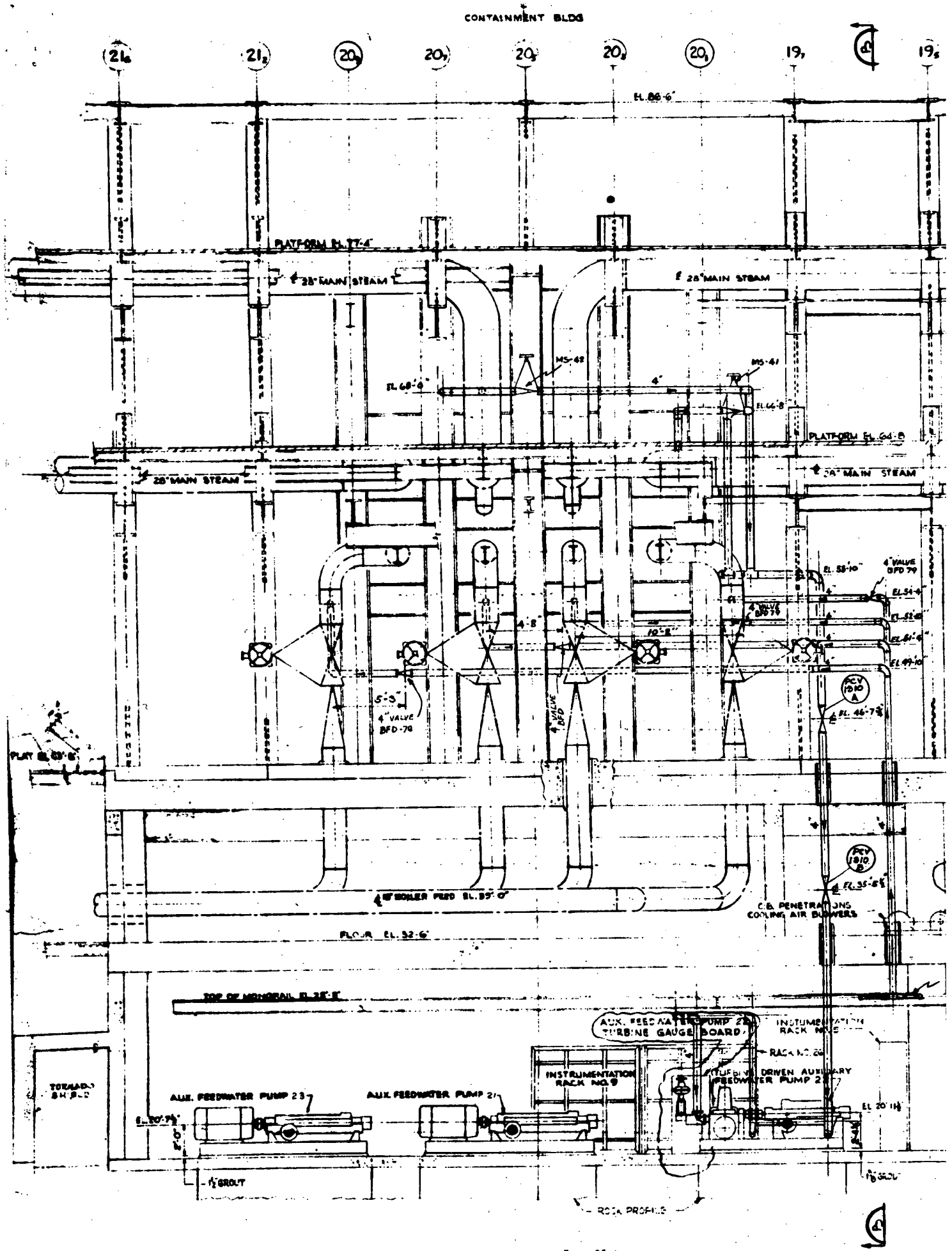


B.F. 23



B.F. # 22



SECTION "A-A"
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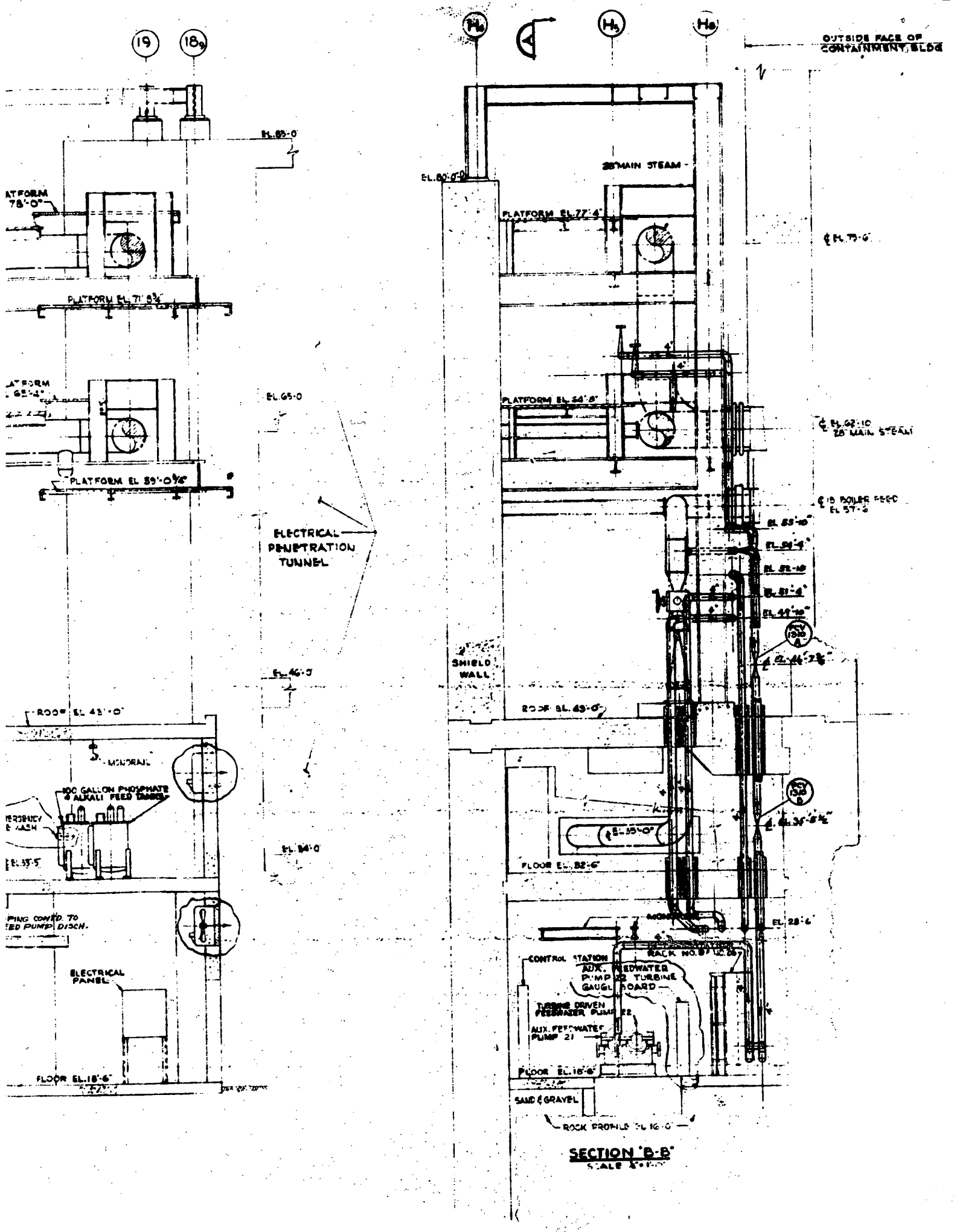
19
18
EL. 85'-0"
PLATFORM EL. 71'-8¾"
PLATFORM EL. 59'-0 3/16"
EL. 65'-0
ELECTRICAL PENETRATION TUNNEL
EL. 46'-0
ROOF EL. 43'-0"
MONORAIL
100 GALLON PHOSPHATE & ALKALI FEED TANKS
EL. 34'-0
ELECTRICAL PANEL
FLOOR EL. 18'-6"
OUTSIDE FACE OF CONTAINMENT BLDG
28" MAIN STEAM
EL. 80'-0"
PLATFORM EL. 77'-4"
PLATFORM EL. 64'-8"
℄ EL. 62'-10 28" MAIN STEAM
℄ 18" BOILER FEED EL. 57'-6
EL. 55'-10"
EL. 54'-4"
EL. 52'-10
EL. 51'-4"
EL. 49'-10"
SHIELD WALL
ROOF EL. 49'-0"
℄ EL. 35'-0"
FLOOR EL. 32'-6"
EL. 28'-6"
RACK NO. 87
CONTROL STATION
AUX. FEEDWATER PUMP 22 TURBINE GAUGE BOARD
TURBINE DRIVEN FEEDWATER PUMP 22
AUX. FEEDWATER PUMP 21
FLOOR EL. 18'-6"
SAND & GRAVEL
ROCK PROFILE EL. 16'-0"
SECTION "B-B"

PART 2

Analysis of Postulated High Energy Line Breaks In Areas Other Than the Shieldwall And Containment Area

Each area of the plant was investigated for potential whip, impingement and temperature and pressure environment resulting from a postulated failure of a high energy line. The areas investigated were: Turbine Building, Control Building, Primary Auxiliary Building, Diesel Generator Building and Fuel Storage Building.

In each area all high energy lines were located. A line was considered to be high energy if either the temperature exceeded 200° F or the pressure exceeded 275 psig more than 1% of the time during plant operation. In lieu of determining high stress locations by rigorous analysis for each line, it was conservatively assumed that a high energy line would fail at any location. The type and orientation of breaks was determined in accordance with AEC guidelines.

Restraints were evaluated based on the same criteria used for the main steam and feedwater line restraints.

Jet impingement temperatures and thrust loadings were calculated taking into account air entrainment. The method used was based on Abromovith, Theory of Turbulent Jets, MIT Press, Cambridge, Mass., 1963. Thrusts and temperatures were conservatively based on peak values.

For each high energy line a survey was made, using both drawings and field inspection, to determine if any critical equipment might be damaged by the postulated break. Evaluation was made using the following three criteria:

1. Failure of any non-Class I line must not result in damage to any Class I systems or equipment.

2. Failure of any Class I line must not result in damage which would jeopardize the ability to bring the plant safely to hot shutdown.

3. Small leaks in any line which would not result in plant trip must result in no damage to any Class I systems or equipment.

Safe Shutdown Considerations

All systems required for safe shutdown (hot or cold) are Class I. Criteria 1 and 3 guarantee that shutdown will not be jeopardized. In order to satisfy Criterion 2 it is necessary to define the minimum equipment required for hot shutdown. Requirements for hot shutdown are discussed in Appendix 14A to the Indian Point 2 FSAR. The following is a brief summary of systems required for hot shutdown:

1. Reactor protection system.

2. Emergency power system.

3. Auxiliary boiler feedwater system.

4. Reactor coolant letdown isolation. This requires isolation of the letdown and excess letdown lines. Isolation should be accomplished within 2 hours to minimize loss of reactor coolant. Both the letdown and excess letdown lines are provided with manually and remotely operated valves both inside and outside containment. Therefore, no single line break could prevent isolation of these lines.

5. Reactor coolant makeup. No makeup is required for at least 30 hours after shutdown. Makeup can be provided by either the charging pumps or the safety injection pumps. Suction to the charging pumps can be provided either from the boric acid tanks or from the refueling water storage tank. Suction to the safety injection pumps can be provided either from the boron injection tank or the refueling water storage tank. The charging pumps can provide makeup through either the charging line or the seal water injection line. The safety injection pumps can provide makeup through either of the safety injection lines.

6. Boration. Boration is not required for at least 24 hours after shutdown. Boration can be provided either from the boric acid tanks through the charging pumps or from the boron injection tank through the safety injection pumps.

7. Pump cooling. In order to operate the charging or safety injection pumps cooling water must be provided. Cooling of these pumps can be provided by either the auxiliary cooling system or by connections from the city water system.

Based on the preceding discussion the following conservative criteria were derived to insure that damage caused by a postulated break of a Class I line would not jeopardize safe, hot shutdown.

1. Ability to isolate letdown must not be jeopardized by any line failure. Since multiple isolation valves are provided both inside and outside containment this criterion is met.

2. No postulated line break which results in damage to the boric acid tanks, charging pumps or makeup or seal-water injection lines can cause any damage to the boron injection tanks, SI pumps or SI lines. Conversely, any postulated break which would result in damage to the SI system must result in no damage to the charging system. This assures that one complete system will always be available to provide makeup and boration.

3. Any postulated line break which might result in damage to the auxiliary coolant system or the service water system must result in no damage to the city water system. The converse must also be true. This assures that one complete system will always be available to cool the charging or SI pumps.

4. No postulated line break may result in damage to the reactor protection system or the emergency power system.

Turbine Building

The turbine building contains no essential equipment. Since the turbine building adjoins the control building, high energy lines in the turbine building were investigated for potential effects on the control building. High energy lines in the turbine hall which are nearest to the control building are auxiliary steam, main steam dump to condenser and piping around the moisture separator/reheaters. Except for the auxiliary steam lines, these lines are about 100 feet from the control building so there is no potential for whip near the control building. Jets from postulated breaks in these lines were

calculated and resulted in negligible loads on the control building walls. The volume of the turbine building is so great and the ventilation flow so large (approximately 1.1 million cfm) that temperature and pressure buildup in the building would be small. In any case the doors to the control building are kept closed. Should any steam leak into the control building it would be noticed by the operators who would trip the plant thereby stopping the flow of steam.

Some auxiliary steam lines in the turbine building run close by the control building. The wall between the buildings is conventional steel siding. The auxiliary steam lines are 10" and smaller in diameter and operate at 45 psig. It is unlikely that a postulated rupture of one of these lines would damage the control building. To provide assurance that no damage would be done, protection will be provided between the auxiliary steam lines and the control building.

Control Building

The control building contains no high energy lines other than a short length of instrument air line. This line is located so that it could not damage essential equipment following a postulated failure.

Primary Auxiliary Building (PAB)

The PAB contains the following high energy lines:

1. Letdown line
2. Charging line and piping around charging pumps
3. Seal water injection lines
4. Steam generator blowdown lines
5. Sample lines
6. Auxiliary steam lines
7. Nitrogen lines

Each line will be discussed separately for pipe whip and jet impingement effects. Temperature and pressure buildup in various parts of the PAB will be discussed subsequently.

1. Letdown line. The letdown line is a Class I line which passes from the containment through the penetration area into a piping tunnel to the non-regenerative heat exchanger.

Beyond the non-regenerative heat exchanger it ceases to be a high energy line. In the penetration area it passes near the charging and seal water lines and one of the SI lines. The letdown line is 2 inches in diameter and operates at 295° F and 350 psig. The SI line is 6 inches in diameter and hence could not be damaged by the letdown line. No SI equipment or electrical cables pass near the letdown line. Since the criteria required that either SI or charging system remain intact and since SI would not be damaged, the criteria are met. To provide added assurance that the plant could be safely shutdown following a postulated break in the letdown line it was decided to restrain the letdown line so it could not whip into equipment used for normal makeup. The existing supports on the line were generally adequate to achieve this. Several additional stops will be added to the line to preclude whip. Jet impingement from the letdown line might damage valves on either the charging or seal injection lines but could not damage both paths. Therefore, both charging and SI systems would be available for makeup and boration following a postulated letdown line failure.

2&3. Charging line and piping around charging pumps seal water injection lines. These are Class I lines, 4" and smaller, which operate at 2500 psig and 135° F. The only source of pressure in these lines is the charging pumps which have a maximum flow of 300 gpm. Therefore, these lines have no potential for whip. The effects of a cold water jet from a crack in one of these lines was investigated. While instrumentation associated with a particular line or pump might be damaged, the system would still remain functional. No damage to SI or electrical systems would result.

4. Four steam generator blowdown lines. These lines are Class I from the containment to a point just past the isolation valves and Class III from this point to the steam generator blowdown tank. They are 2" and 3" in diameter and operate at 1000 psig and 550° F. Class I equipment near these lines in the penetration area consists of several cable trays, the isolation valves on the lines, and several other containment isolation valves. Pipe whip restraints will be added to the Class III portions of these lines in the penetration area to prevent whipping following a postulated break. Shielding will be provided to prevent jet impingement.

The portion of the steam generator blowdown lines from containment to the isolation valves is Class I. This portion of the lines is sufficiently far from cable trays so that jet impingement would cause no damage. Since isolation valves need not be protected from a postulated Class I line failure, restraint of this portion of the lines is not required.

5. Sample lines. Several sample lines pass from the containment through the penetration area into a pipe tunnel to the sample room. These lines are less than 1" in diameter so pipe whip need not be considered. No Class I equipment which might be damaged by impingement is located near these lines except for one cable tray in the penetration area. A plate will be provided between this tray and the sample lines to protect the cables from jet impingement.

6. Auxiliary steam lines. Auxiliary steam lines in the PAB include one 1", 250 psig line, three 1", 100 psig lines and a variety of lines 8" and smaller which operate at 45 psig and 15 psig. These lines pass by various Class I mechanical and electrical equipment. None of the auxiliary steam lines contain sufficient energy to damage any nearby Class I piping. However, several areas were identified where steam lines pass near Class I electrical equipment. Since all auxiliary steam lines are relatively small and low energy it is not believed that significant damage would result from a postulated failure of one of these lines. Since no tests have been performed on the effects of pipe whip or jet impingement on the cable trays, cables, motor control centers or valve operators, it is impractical to prove that this equipment would function following a postulated incident. At locations where jet impingement or pipe whip on electrical equipment is possible, protection will be provided to prevent damage to the equipment.

Restraints and shield plates will be provided for auxiliary steam lines in the electrical tunnel and near motor control centers 26A and 26B. The 3", 45 psig auxiliary steam line which serves containment during shutdown passes near several Class I valves in the pipe trench and penetration areas. A valve will be provided in this line where it enters the area. This valve will be kept closed whenever the plant is in operation. No damage could result to Class I equipment due to a postulated break in this line.

7. Nitrogen lines. Several nitrogen lines in the vicinity of the nitrogen tanks are high energy lines. These lines are all 1" or less. The only Class I equipment in this area is the boron injection tank. A postulated line failure in this area would have no effect on the boron injection tank.

Temperature and Pressure Buildup in the PAB.

All areas of the PAB are sufficiently open and maximum flow from high energy lines sufficiently limited so that no significant pressure buildup could occur. The charging lines, seal water injection lines and nitrogen lines all operate below 135° F so no increase in ambient temperature would result from a postulated failure of one of these lines.

The letdown line, steam generator blowdown line, sample lines and auxiliary steam lines all pass through the penetration area. This area has a ventilation flow of about 4000 cfm. Temperature sensors will be located in the penetration area. These sensors will cause an alarm in the control room before the temperature in the penetration area reaches 150° F. The operators will isolate all high energy lines in the area immediately on indication of high temperature. Since isolation can be effected within minutes, no damage to any electrical equipment in the area would result from a postulated high energy line failure. None of the high energy lines in the area are required for safe shutdown of the plant.

The cable tunnel contains auxiliary steam lines. Temperature sensors will also be installed in this area with an alarm in the control room. The operators will isolate the auxiliary steam system on indication of high temperature in the cable tunnel. No damage to cables in the tunnel would result from this postulated failure.

Only the letdown line, auxiliary steam lines and sample lines pass through areas of the PAB other than the penetration and tunnel areas. Flow from a broken sample line would be limited to about 4000 lb/hr due to line size. Flow from a broken letdown line would be limited to about 80 gpm by the letdown orifice. Flow from the auxiliary steam system would be limited to about 20,000 lb/hr by a pressure control valve. Natural circulation combined with ventilation flow would disperse the

steam throughout the building. Condensation combined with the normal building ventilation flow of about 50,000 cfm would prevent significant temperature increase in the building.

Diesel Generator Building.

The only high energy lines in the diesel generator building are the starting air lines. These are 1-1/2 inch lines which operate at 300 psig. No damage to any Class I equipment would result from a postulated failure of one of these lines.

Spent Fuel Building.

The only Class I equipment in this building is the spent fuel pit. The only high energy lines are 15 psig auxiliary steam lines which could do no damage to the pit as the result of a postulated failure.