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Analysis of High Energy Lines

Consolidated Edison Company of New York, Inc.
Indian Point Station, Unit No. 3
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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 are required for safe shutdown are the auxiliary feedwater pumps and the steam line isolation and relief valve control panels. This equipment is located in the shield wall area, which 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'-9", 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. Potential flooding problems attendant with such failures have been evaluated in a previous response, submitted January 1973.

2.0 Description of Piping

2.1 Routing & Seismic Classification

The main steam lines penetrate the containment on an east-west line at El. 62'-10". 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 (El. 62'-10") turn immediately in opposite directions to form large, flexible loops around the concrete shield wall also returning the the pipe bridge.

The steam supply to the turbine driven auxiliary feedwater pump is taken from two main steam lines, headered together and routed 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 line 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 turn south to enter the elevation 32'-6" level of the auxiliary feed pump building where the main feed flow nozzles are located. Downstream of the flow nozzles the lines turn upward through the slab at elevation 43'-0" and then pass through the main feed check and main feed stop valves, respectively, before turning again to enter the individual containment penetrations at Elevation 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 runs south to a common vertical pipe chase, where it joins with the discharge of the turbine driven ABF pump. The lines pass through the slab at Elevation 32'-6" and then turn horizontal and north to enter the room above El. 32'-6" containing the main feed flow nozzles. Individual lines then turn upward penetrating the 43' slab in the vicinity of the main feed lines. A vertical check valve, installed in each auxiliary feed line just prior to where it enters the main feedwater line, serves as a pressure boundary between the auxiliary feed system and the steam generator.

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 finished weld, in addition to 100% radiographic examination. 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 finished weld, in addition to 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 a reinforced concrete enclosure that houses the auxiliary feedwater 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 shield 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 seismic 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 seismic Class I.

3.5 Bridge between Shield Wall and Turbine Building

The structural steel in the bridge supports seismic Class III main steam and boiler feed piping. The structure is seismic 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 resting on rock.

3.6 Enclosure

The entire shield wall area above elevation 43'-0", the structural steel tower area and pipe bridge area are 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, main steam pressure transmitters, and auxiliary feed pump information.

The only high energy line in this room is the main steam line to the auxiliary feedwater pump turbine. A postulated break in this line could cause a pressure, temperature and humidity buildup in the room and jet impingement on equipment.

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 environmental conditions in this room are evaluated on the basis of a steam line failure to the auxiliary feedwater pump turbine. Initial conditions for this break were taken to be 1,100 psia saturated steam. The discharge rate, as found by Napiers formula is approximately 650,000 pounds per hour. Vent area assumed for the pressure/temperature calculation was 21 square feet which includes a door hinged to open outward when under pressure. Final conditions in the room, based on steady-state calculation, were 0.9 psig and 213°F. This pressure is well within the 9.0 psig limit for the room 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 Feedwater Pumps (AFP) would not prevent safe shutdown as long as normal AC power is available to run the normal feedwater system. This is no reason to believe that pipe failure 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 the main steam line in this room could cause a plant trip. Only if it is assumed that all three AFP's are disabled and AC power is lost would this event jeopardize safe shutdown. To preclude this unlikely occurrence, the following modification will be made:

> Add two redundant valves in the main steam supply line to the AFP turbine outside this room. Each valve will be signaled to close automatically on high temperature by its own temperature sensor located in the auxiliary feed pump room. Each valve will have control room indication, control and alarm. Each system is completely independent of the other.

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. The four auxiliary boiler feed lines and the main steam supply to the auxiliary feedwater pump turbine pass through the room. There is no shutdown related equipment located in this room.

Because the auxiliary feed lines were routed through this area, the original design provided for pipe whip restraints on the main feed lines in this area. These restraints will be installed even though analysis in accordance with the AEC guidelines does not identify postulated pipe breaks within this area.

No damage to the auxiliary feed piping will occur due to critical cracks in the main feed piping.

Though none of the postulated main feed line breaks occur within this area, the room has been evaluated for such an occurrence. The analysis performed considered impact of the failed line on the slab at elevation 32'6" concurrent with the pressure and temperature buildups within the room due to steam release.

The failure assumed was a circumferential break of an upturning elbow in the 18" feed line. The calculations were based on initial conditions of 1100 psia at 427°F with the entire contents of the feed system between main feed pumps and containment isolation check valves discharging to the room. The rate of discharge was limited by the feed regulator valve being in the full open position to approximately 2000 pounds per second of which 460 pounds per second flash to steam in the valve.

Static analysis of the resulting load on the floor slab shows 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 are used without capacity reduction factors.

Environmental conditions due to the failure assumed all water released to the room flashed in the room. With the available vent area of 69 square feet, the resulting environmental conditions were less than 1 psig at 213°F; well within the allowable for the room when considered concurrently with the impact load.

For Unit No. 2 an analysis is being made to show the dynamic effects of the pipe rupture on the floor slab. The results of this analysis will also be applied to Unit No. 3.

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Since equipment required for safe shutdown is not located in this room, effects of temperature, humidity and jet impingement on equipment 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 and main stream supply to the ABFP turbine. Safe shutdown equipment in the area are the main steam isolation and relief valve control panels.

Pipe whip restraints are provided for the seismic Class I portion of these lines where necessary 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 Fy. 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 are signaled to close immediately upon steam line break (these valves are not required to operate following a feed line break). The control circuits would have performed their function long before any temperature effects could build up to impair their operation.

Power-operated relief valves are not required for hot shutdown. Should the control panels for the power-operated relief valves 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 manually at such time as it is desired to bring the plant to cold shutdown.

Main steam stop valve controls must function to isolate all main steam lines in the event of a full size rupture downstream of the stop valves. They are not required to function in the event of a critical crack. The stop valve solenoids are protected by the shield wall from postulated breaks at locations identified per the AEC guidelines. Hence, the stop valve solenoids are adequate as installed.

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 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 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 are spaced so that the bending stress due to deadweight and pipe rupture load would not exceed 1.8 x code allowable stress or Sy, whichever is greater.

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 exceed 80% of allowable was selected as a break location.

4. If there were fewer than two points which exceed 80% of allowable stress then the highest stressed 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, deadweight and design basis seismic stresses.

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

Main steam line 31

1. Penetration anchor (9877 psi - slot)

2. Inlet to elbow immediately upstream of pipe bridge (15,289 psi - guillotine)

3. Outlet of elbow immediately upstream of pipe bredge (16,793 - guillotine)

4. Inlet to turbine stop valve (11,078 psi - slot)

Main steam line 32

1. Penetration anchor (9208 psi - slot)

2. Inlet of bend immediately upstream of turbine stop valve (17,712 psi - guillotine)

3. Outlet of bend immediately upstream of turbine stop valve (17,235 psi - guillotine)

4. Inlet to turbine stop valve (11,748 psi - slot)

Main steam line 33

1. Penetration anchor (10,464 psi - slot)

2. Inlet of elbow downstream of main steam stop and check valves (17,571 psi - guillotine)

3. Outletof elbow immediately upstream of pipe bridge (14,828 psi - slot)

4. Inlet to turbine stop valve (10,544 psi - slot)

Main steam line 34

1. Penetration anchor (9855 psi - slot)

2. Inlet of second elbow downstream of main steam check valve at north west corner of pipe tower (13,735 psi - slot).

3. Outlet of bend immediately upstream of turbine stop valve (13,903 psi - slot).

4. Inlet to turbine stop valve (10,107 psi - slot)

Main feed line 31

1. Penetration anchor (10,193 psi - slot)

2. Outlet of elbow immediately upstream of penetration (13,840 psi - guillotine)

3. Inlet to elbow immediately downstream of main feed stop valve (14,777 psi - guillotine)

4. Terminal point at 30" header (8572 psi - slot)

Main feed line 32

1. Penetration anchor (8104 psi - slot)

2. Outlet of elbow immediately upstream of penetration (13,883 psi - guillotine)

3. Inlet to elbow upstream of feed regulator valve (12,005 psi - slot)

4. Terminal point at 30" header (11,281 psi - slot)

Main feed line 33

1. Penetration anchor (8789 psi - slot)

2. Inlet to elbow immediately downstream of main feed stop valve (11,839 psi - slot)

3. Outlet of elbow upstream of feed regulator valve (12,400 psi - slot)

4. Terminal point at 30" header (10,945 psi - slot)

Main feed line 34

1. Penetration anchor (8,053 psi - slot)

2. Outlet of elbow downstream of main feed stop valve (12,678 psi - slot)

3. Outlet of elbow immediately upstream of feed regulator valve (11,772 psi - slot)

4. Terminal point at 30" header (10,945 psi - slot)

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 Main Feed). The area of pipe break from which the jet originated was equal to the cross sectional area of the pipe.

For circumferential failures, 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.

For longitudinal breaks the jet acts along a radius of the pipe (or normal to a tangent plane at the failure). Length of the break is twice the pipe diameter with a width as required for a break area equal to cross sectional area of the pipe.

Jets are assumed to expand by 10 degrees in all directions with the total jet force 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. Main steam line 31, breaks 2, 3 and 4

    b. Main steam line 32, breaks 2, 3 and 4

    c. Main steam line 33, breaks 2, 3 and 4

d. Main steam line 34, breaks 2, 3 and 4

e. Main feed line 31, break 4

f. Main feed line 32, breaks 3 and 4

g. Main feed line 33, breaks 3 and 4

h. Main feed line 34, breaks 3 and 4

2. The slot failure in each line at the containment penetration will blow out the seal on the shield wall side of the penetration. The annular shaped jet parallel to the pipe axis will impinge on restraint steel designed for full pipe break load in a direction assumed in the design. The thrust loading due to the slot failure will be resisted by the containment concrete with stresses well within allowables.

3. Main feed line 31, break 2

The guillotine failure produces a circular jet which impinges on columns designed to resist the full blowdown force of 200 kips acting in the same direction as the jet. Because displacement of these Class I lines is very limited, the fraction of the jet which could act on a single column is approximately half the total jet.

4. Main feed line 31, break 3

The failure produces a circular jet which may partially impinge on columns with face in a direction not assumed in the original column design. Further analysis will be performed and the columns strengthened if required (A similar situation existed on Unit #2). The analysis performed showed the columns to be acceptable without modification.

5. Main feed line 32, break 2

Segments of the circular jet impinge on columns designed to carry the full load as discussed in item 3 above.

6. Main feed line 33, break 2

   The postulated longitudinal failure can be oriented in a direction so as to produce a bending moment about the weak axis of a column which is also resisting the pipe thrust load. Though the analysis is not complete, initial indications are that strengthening will be required.

7. Main feed line 34, break 2

   The postulated slot failure will produce an impingement load on the restraint opposite to that of the thrust load. The original design provided for this and no modifications are required.

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 less than the code allowable of 1.0. This is based on the allowable stresses given in the code which can be increased to 0.9 Fy for pipe break load; therefore, the columns are well within 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.

For Unit #2, the main steam pipe whip restraints are being dynamically evaluated for a circumferential break at the containment penetration anchor. Stress analyses indicate that the failure at this terminal point for Unit #3 will be a slot type failure and therefore the Unit #2 analysis will not be strictly applicable to Unit #3. However since the design of Units #2 and #3 is essentially identical in this area, the analysis performed for Unit #2 will show the design adequacy of Unit #3.

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 area 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 could 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 Abromovich 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 3 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 from 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 tank, 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 safety 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 main steam dump to condenser and piping aroung the moisture separator/reheaters. These lines are about 75 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.

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 a 2 inches in diameter and operates at 305° F and 300 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 on cable trays.

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 shield 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 include one 10"-50 psig line in the tunnel area, a variety of lines 8" and smaller located throughout the PAB which operate at 50 psig and 5 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, 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. The 3", 50 psig auxiliary steam line which serves containment during shutdown passes near several Class I valves in the pipe penetration area. 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. There is no Class I equipment in this area.

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.

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 1480 lb/min 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 70,000 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 50 psig auxiliary steam lines which could do no damage to the pit as the result of a postulated failure.

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 K070 Cl I
Code Stress	= 17.5 KSI
Pressure Stress	= 7.53 KSI
Section Modulus	= 510 in.^{3}
l_1 = 226"	
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 = 128"	
l_2 = 22"	

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

$M = 340 \times 22 = 7480$ in K

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

Use 33 WF 141 . Z = 446.8

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FORM 5016

GENERAL COMPUTATION SHEET

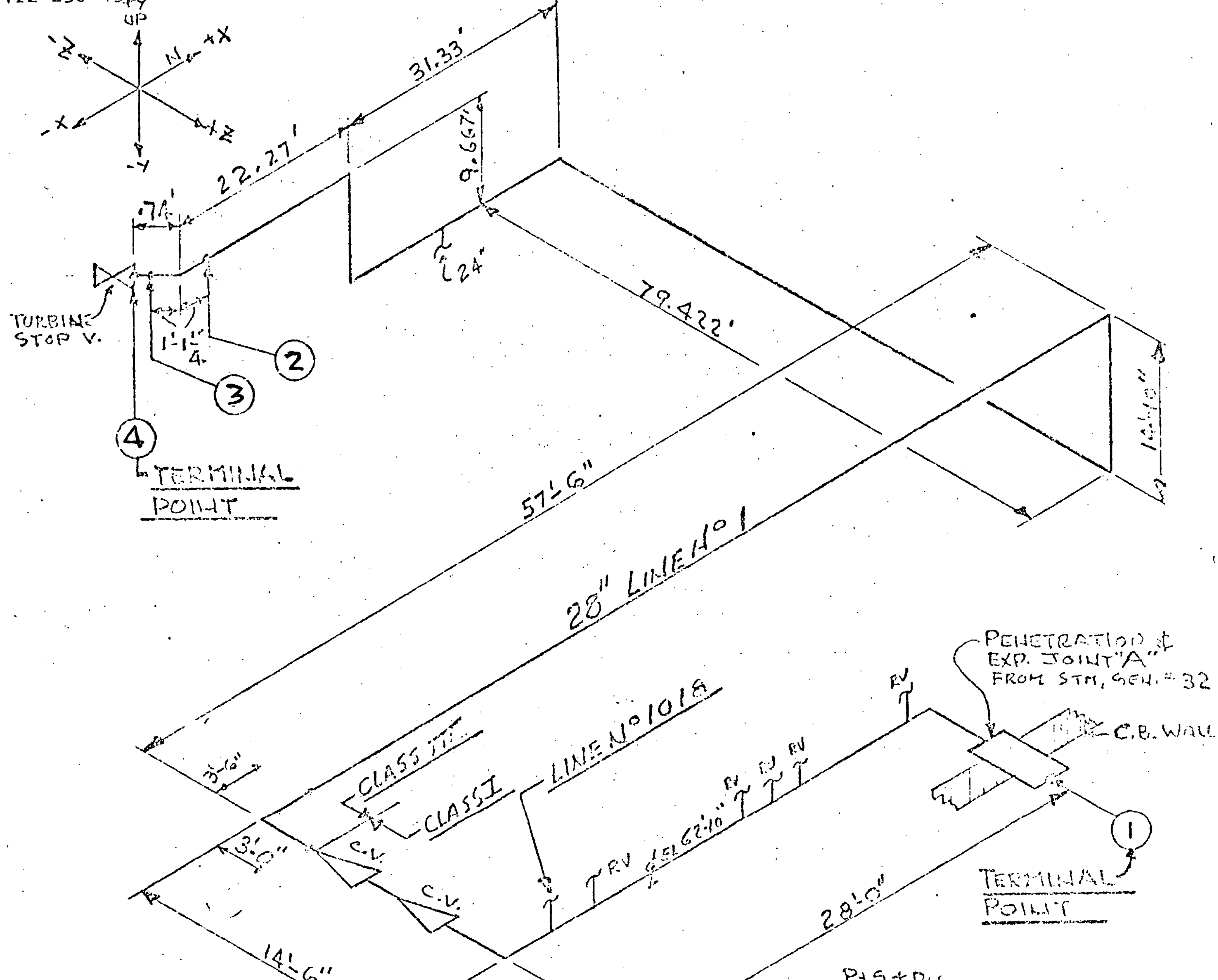
united engineers & constructors inc.

TC# 3481
May 1, 1973

J. O. NO. 9321.66
SHEET NO. 1 OF 8
DATE 5-1-73
COMP. BY [illegible] C'K'D BY WT

NAME OF COMPANY INDIAN POINT UNIT N° 3 SG #32

SUBJECT HIGH ENERGY LINE BREAKS – LINE N° 1



POINT	P+S+Du PRIMARY STRESSES PSI	THERMAL STRESSES PSI	TYPE OF BREAK
1	9208	358	SLOT
2	17,712	3085	GUIL.
3	17,235	2982	GUIL.
4	11,743	1361	SLOT

.8 (1.2 S) = 16,800

.8 (1.25 S_A COLD + .25 S_A HOT) = 21,000

W. Thayne

FORM 5016

GENERAL COMPUTATION SHEET

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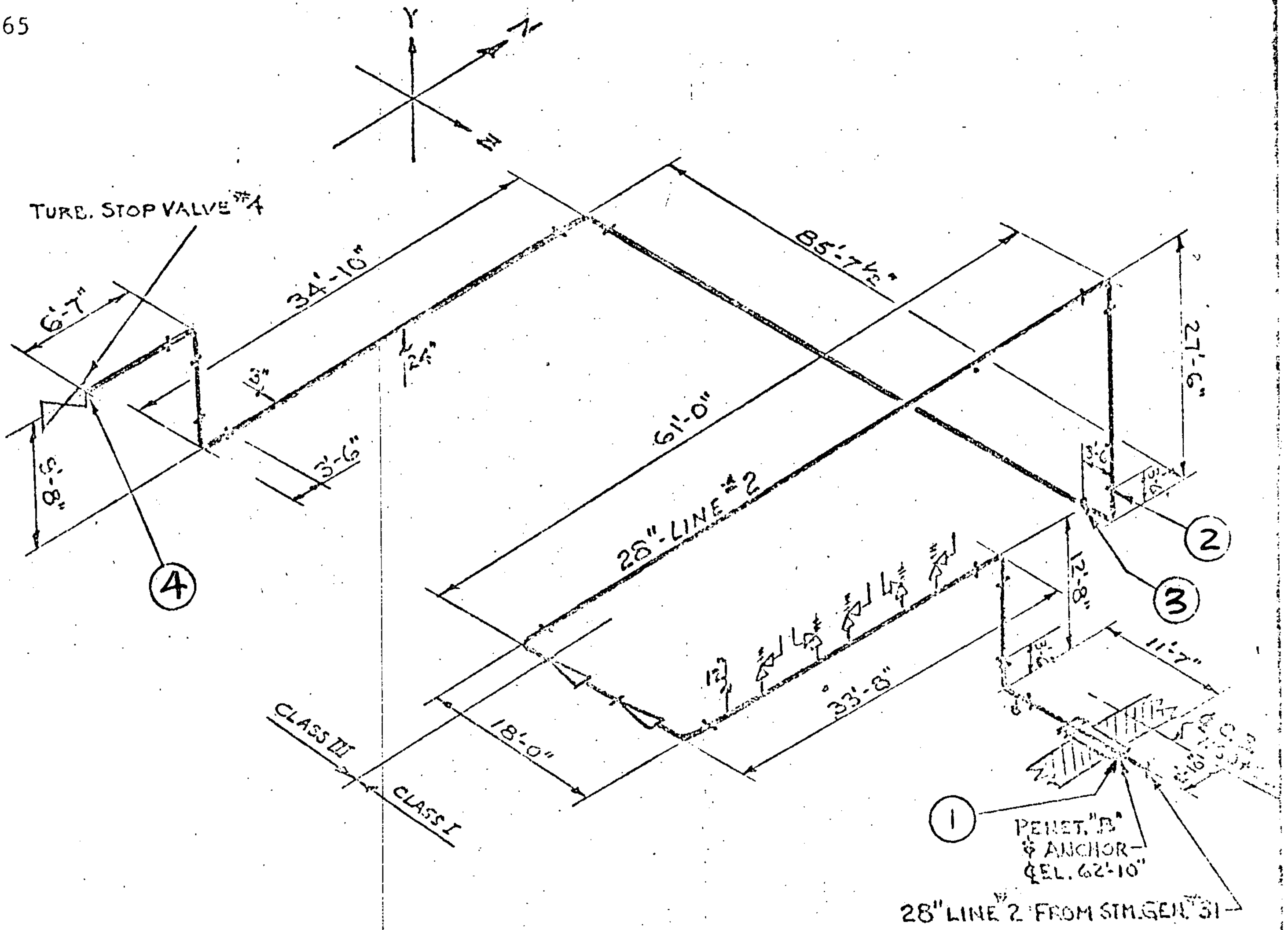
TC# 3481
May 1, 1973

J. O. NO. 9321.66
SHEET NO. 2 OF 8
DATE 5-1-73
COMP. BY JEH C'K'D BY WT

NAME OF COMPANY INDIAN POINT - UNIT #3 SG #31

SUBJECT HIGH ENERGY LINE BREAKS - LINE Nº 2



POINT	PRIMARY STRESS PSI (P+S+D)	THERMAL STRESS PSI	TYPE OF BREAK
1	9,877	632	SLOT
2	15,289	2,926	GUIL.
3	16,793	5,244	GUIL.
4	11,078	1,246	SLOT

$.8(1.2\,S_A) = 16{,}800$ PSI

$.8(1.25\,S_{A\,COLD} + .25\,S_{A\,HOT}) = 21{,}000$ PSI

W. Thayne

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FORM 5015

GENERAL COMPUTATION SHEET

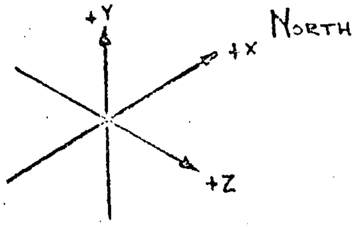
united engineers & constructors inc.

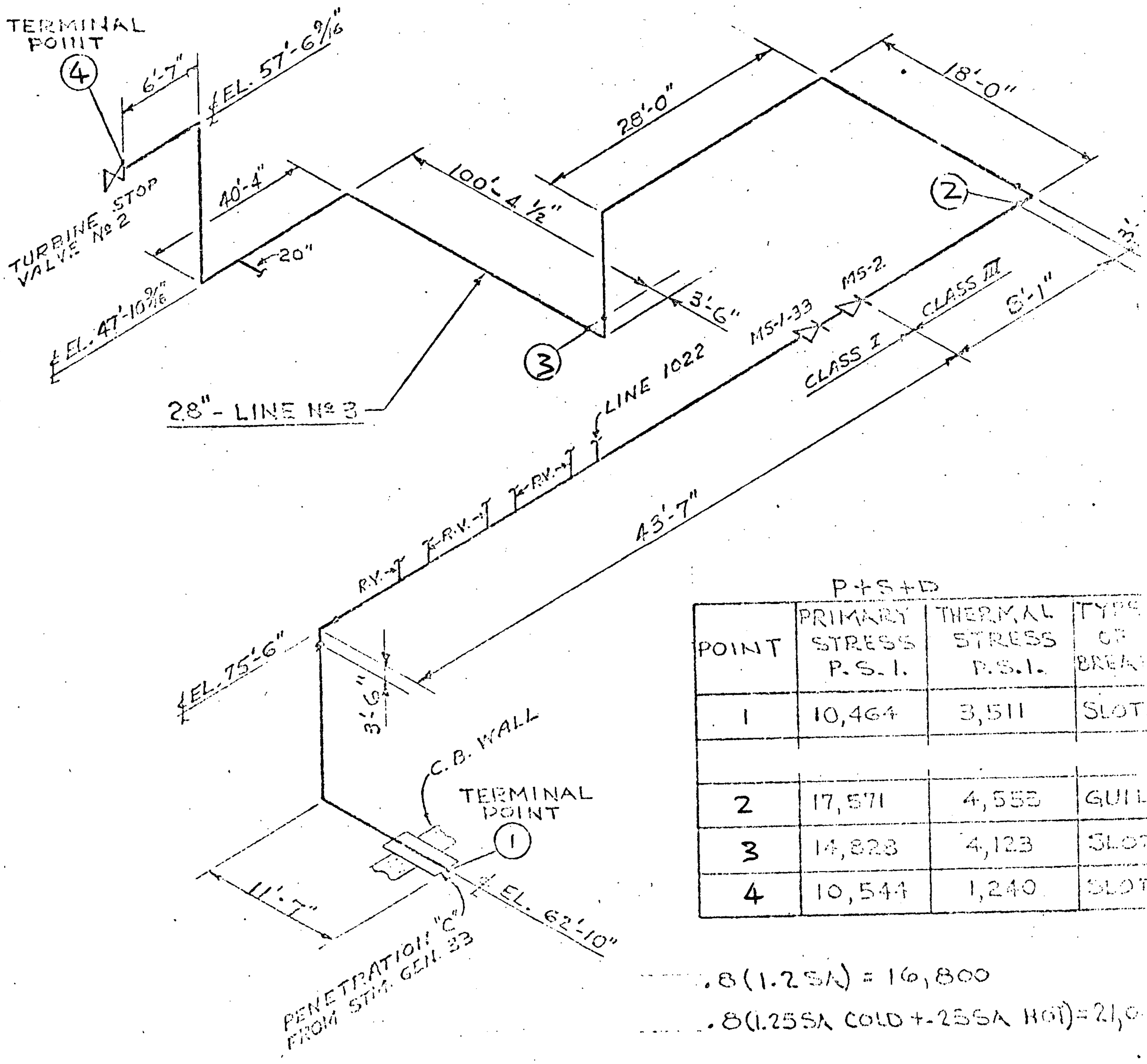
TC# 3481
May 1, 1973

J. O. NO. 9321.66
SHEET NO. 3 OF 3
DATE 5-1-73
COMP. BY [initials] C'K'D BY [initials]

NAME OF COMPANY INDIAN POINT - UNIT #3 SG #33

SUBJECT HIGH ENERGY LINE BREAKS — LINE No 3





POINT	P+S+D PRIMARY STRESS P.S.I.	THERMAL STRESS P.S.I.	TYPE OF BREA[K]
1	10,464	3,511	SLOT
2	17,571	4,555	GUIL[LOTINE]
3	14,828	4,123	SLOT
4	10,544	1,240	SLOT

$.8(1.2S_A) = 16,800$

$.8(1.25S_A\ COLD + .25S_A\ HOT) = 21,0$…

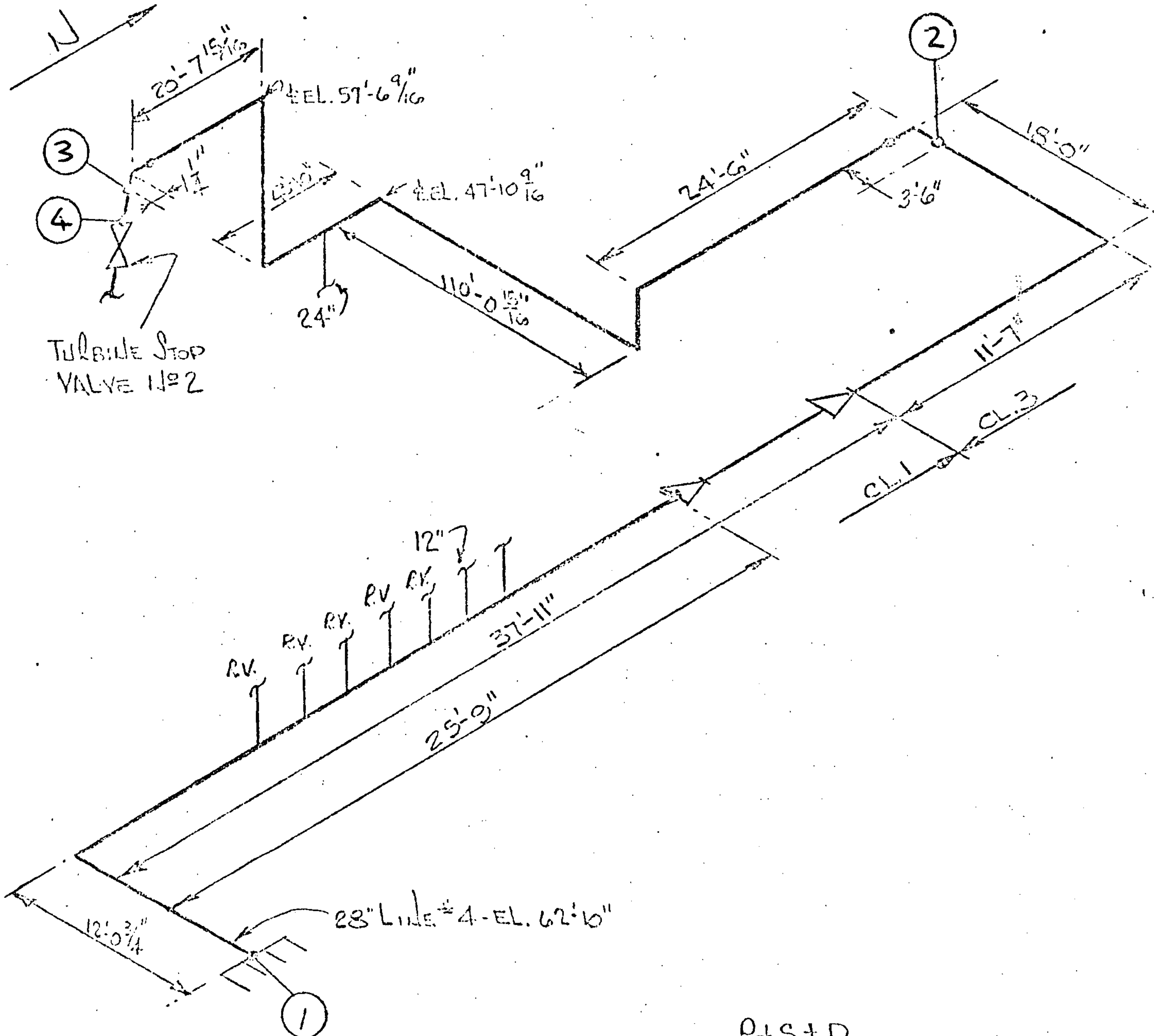
GENERAL COMPUTATION SHEET May 1, 1973

united engineers & constructors inc.

NAME OF COMPANY Indian Point Unit No 3 SG #34

J. O. NO. 9321.66
SHEET NO. 4 OF 8
DATE 5-1-73
COMP. BY HB C'K'D BY WT

SUBJECT High Energy Line Breaks - Line No 4



P+S+D

Pt.	Primary Stresses PSI	Thermal Stresses PSI	Type of Break
1	9855	4317	Slot
2	13,735	6243	Slot
3	13,903	5946	Slot
4	10,107	2329	Slot

$.8(1.25) = 16,800$ PSI
$.8(1.25 S_A \text{ Cold} + .25 S_A \text{ Hot}) = 21,000$ PSI

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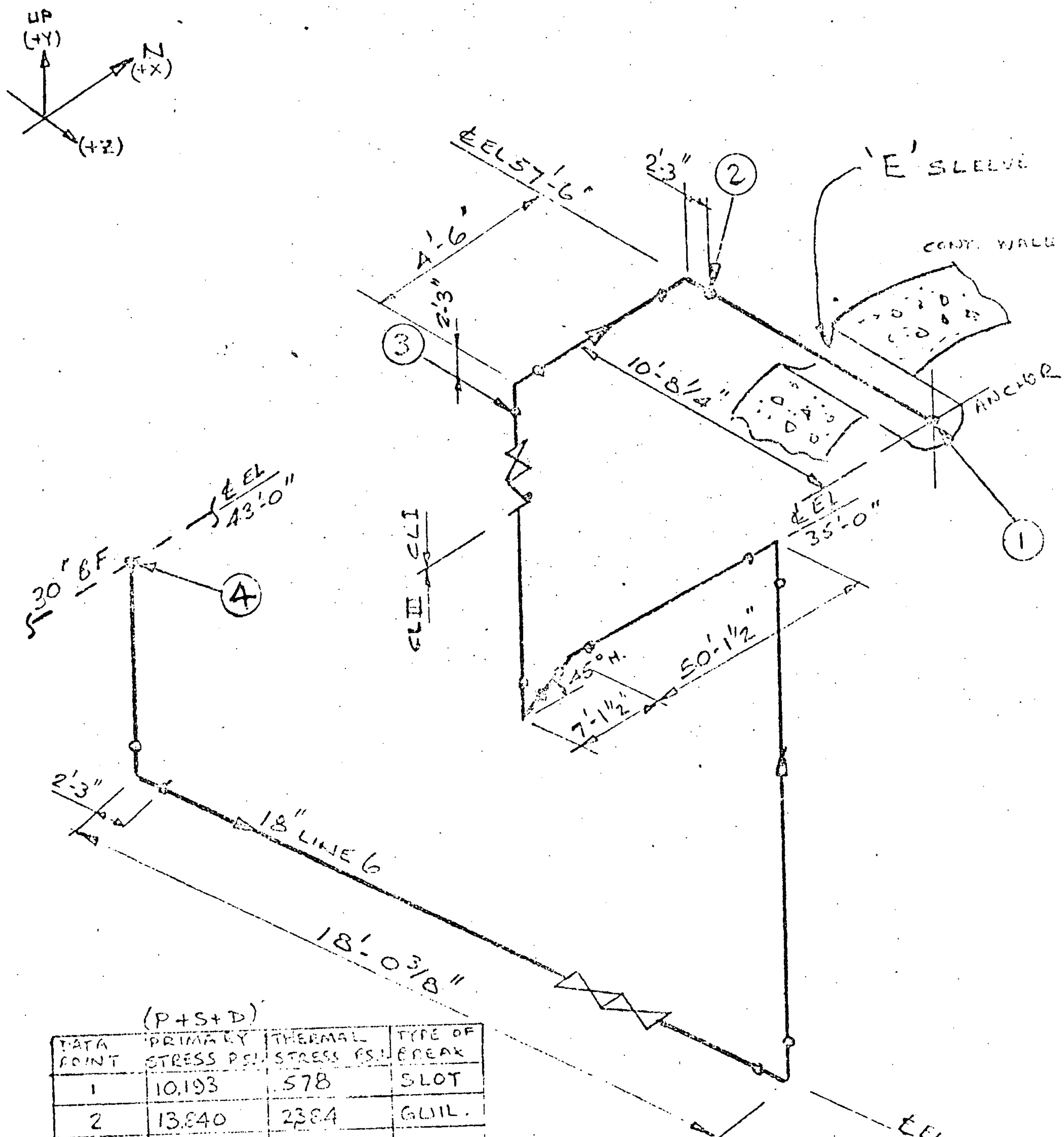
J. O. NO. 9321.66
SHEET NO. 6 OF 8
DATE 5-1-73
COMP. BY C.P. C'K'D BY WT

NAME OF COMPANY INDIAN POINT UNIT N°3 SG#31

SUBJECT LINE N° 6 ~ HIGH ENERGY LINE BREAKS



DATA POINT	(P+S+D) PRIMARY STRESS PSI	THERMAL STRESS PSI	TYPE OF BREAK
1	10,193	578	SLOT
2	13,840	2384	GUIL.
3	14,772	2263	GUIL.
5	8572	1488	SLOT

$.8(1.25S_A) = 16,800$ PSI

$.8(1.25S_{A\,COLD} + .25S_{A\,HOT}) = 21,000$ PSI

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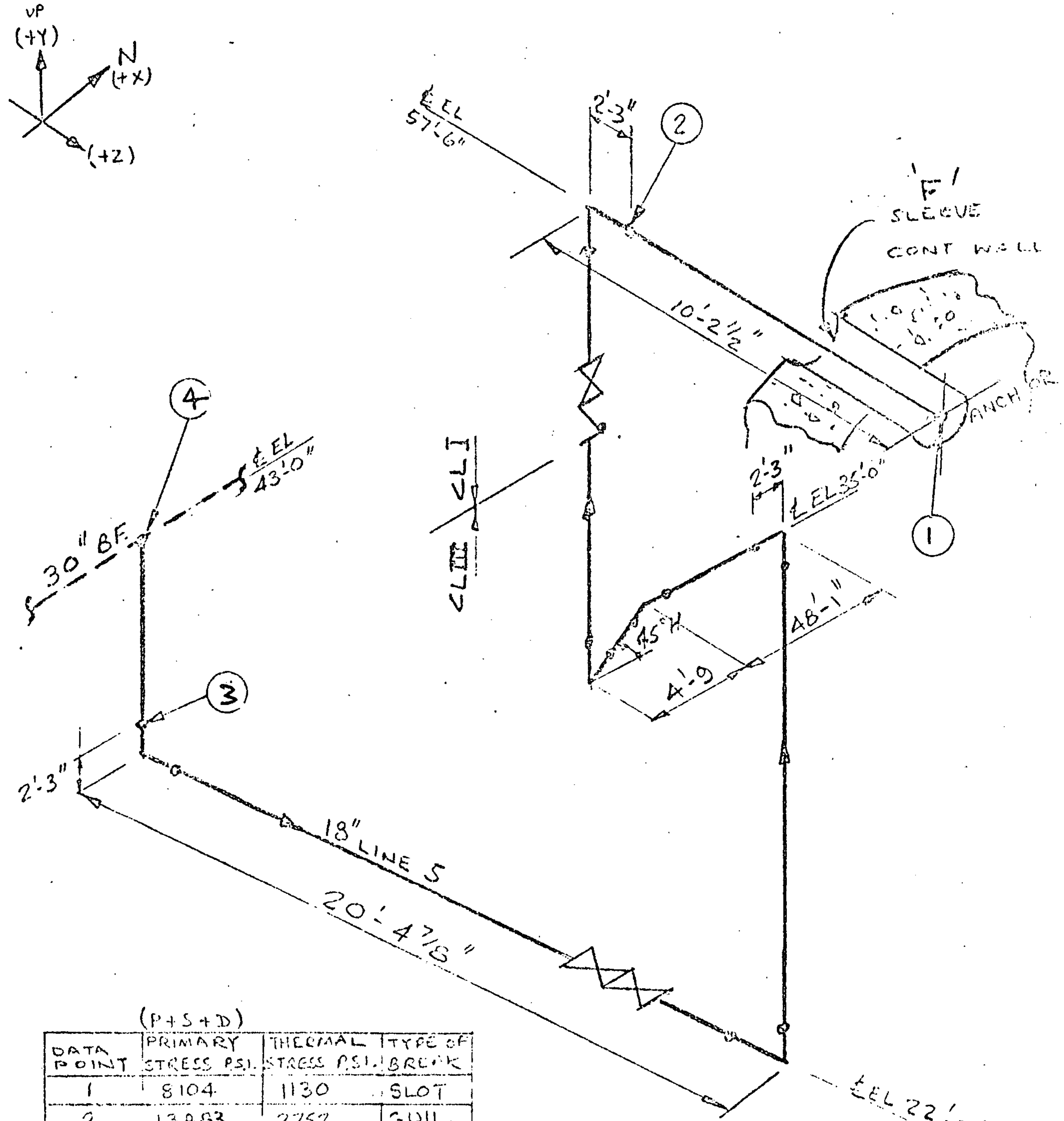
SUBJECT LINE Nº5 ~ HIGH ENERGY LINE BREAKS



DATA POINT	(P+S+D) PRIMARY STRESS PSI.	THERMAL STRESS PSI.	TYPE OF BREAK
1	8104	1130	SLOT
2	13883	2752	GUIL.
3	12005	1783	SLOT
4	11281	1436	SLOT

$\cdot 8\,(1.2\,S_A) = 16{,}800$ PSI

$\cdot 8\,(1.2\,S_{A\,COLD} + .25\,S_{A\,HOT}) = 21{,}000$ PSI