OYSTER CREEK NUCLEAR GENERATING STATION

MAIN STEAM RELIEF VALVE PIPING SYSTEM

Summary of Final Analysis

October 1973

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I. SCOPE OF WORK

This review of the design of the relief valve installations at the Oyster Creek Nuclear Generating Station emphasized treatment of transient reaction loads which were significant factors in the failures at other nuclear plants. The scope of this review was as follows:

- ° To review existing architect-engineer calculations for the design of the safety and relief valve installations.
- ° To perform any additional analyses necessary to evaluate the designs according to applicable code criteria.
- ° To determine if any system modifications were required to assure the adequacy of the system by the analyses described above.
- ° To design any needed system modifications.

This review was executed in three phases beginning in April 1972. The work done and the major results obtained are described below.

A. Review of Existing Calculations

Original analyses for the design of the relief valve installations were reviewed in detail. These analyses included determination of various loadings and calculation of resultant stresses.

Major Results

For the relief valve installation, the review of the original design analyses indicated that transient reaction loads had not been considered. For this reason, it was necessary to perform new analyses of the system.

B. Initial Analyses

The first analysis of the relief valve installation was conducted using an analytical model of the relief valve piping system as the basis for computer codes assessing the thermodynamic, fluid dynamic, and mechanical behavior of the system during transient and steady-state conditions.

Major Results

The results of the first analysis of the relief valve installation, based on ANSI B31.1.0 design criteria, indicated that portions of the system would be overstressed during simultaneous actuation of all the relief valves in either steam header. Consequently, snubber type pipe supports and a wire rope restraint were designed and added to the drywell and torus portions, respectively, of the piping system in June 1972.

The relief valve installation was reevaluated with the added supports and restraints. The results indicated that the design of the drywell piping complied with ANSI B31.1.0 and that the design of the torus piping would prevent failure of the system. These analyses and the design adequacy of the support modifications are documented in Reference 1.

C. Final Analyses

Subsequent to the analyses described above, it was concluded that the wire rope restraint was not suitable as a permanent installation, so a detailed analysis was made of the piping within the torus to determine the functional requirements for a permanent replacement for the wire rope.

Major Results

The results of the revised analysis indicated that the system design would comply with ANSI B31.1.0 design criteria if the wire rope were replaced with a rigid support, one additional rigid hanger were installed and one spring hanger modified in the drywell.

The new drywell hangers and the permanent torus supports were designed, fabricated, and installed in the system in May 1973. The final relief valve system design analysis and the designs of these final support modifications are contained in Section II of this report.

With the completion of this last phase in the review of the relief valve installations, the modified design of this system fully meets the applicable design criteria of ANSI B31.1.0.

II. RESULTS OF FINAL ANALYSES

The electromatic relief valve installation at Oyster Creek consists of five electrically actuated valves and associated inlet and discharge piping. Two of these valves are located on the north main steam header and three are located on the south header. The valves on each header discharge steam through common piping routed through the drywell to the pressure suppression chamber (torus).

As described in Section I, further analyses were begun on the design of the modified relief valve installation after the preparation of Reference 1. These analyses were designed to incorporate a refined analytical model for the piping system and to investigate the long term adequacy of the torus piping wire rope restraints.

The results of the analyses showed the design of the piping system to be acceptable except for the following areas:

- The 8" x 14" x 14" lateral "Y" connection in the south header would be slightly overstressed according to ANSI B31.1.0 design criteria under the most severe loading conditions. The situation was corrected by designing and installing a new rigid hanger and modifying an existing spring hanger in the drywell portion of the south header system. These modifications are discussed in subsection A of this section. Because the north header system has only two relief valves, there is no such lateral connection and no similar modifications were needed.

- Information was obtained that indicated the wire rope restraints located on the torus piping portions of both the north and south header piping system were unacceptable as permanent modifications. Accordingly, new supports were designed and installed on both piping systems inside the torus. These new torus supports are discussed in subsection B of this section.

A final analysis of the south header piping system was conducted using a model which reflects the effect of the above modifications. A description and summary of this final analysis is located in subsection C of this section.

A. New Drywell Hangers

1. Description

To reduce stress levels in the 8" x 14" x 14" lateral connection in the south header relief valve piping in the drywell, a new rigid hanger (S-5) was added and an existing spring hanger modified. Figure II-1 shows the location of these hangers. The new rigid hanger consists of a pipe bracket connected by a telescoping two inch schedule 80 pipe to a fabricated bracket secured to the vent jet deflector. The hanger is rigidly locked by a weld securing the two segments of the telescoping connector. The spring hanger modification involved adding a larger variable support and increasing the cold spring on the hanger from 830 to 1310 pounds.

2. Requirements

The hanger modifications meet the following requirements:

a. Functional

The hangers act to reduce the stresses in the 8" x 14" x 14" lateral connection in the south header piping system under all loading conditions defined for the piping system. (See subsection C of this section.)

b. Design

The hangers are designed in accordance with applicable ANSI B31.1.0 design criteria. Acceptability of the variable support was determined by comparing the rating of the support with the largest loading on the hanger. For both hangers, the design loads were determined by picking the peak loading from the results of the computer model studies of the system.

c. Fabrication and Installation

During fabrication of the vent jet deflector bracket for the new rigid hanger and the installation of the hanger, requirements in excess of ANSI B31.1.0 rules were invoked. Specifically, the one inch carbon steel plate used in the deflector bracket was checked for adequate impact test properties and all welds made on the bracket as well as during installation of the hanger were liquid penetrant tested.

3. Results

Highlights of the results of this analysis are shown in Table II-1. The table also shows the margin in the rating of the replacement variable spring support. This analysis indicates that the support modifications adequately meet the design requirements of ANSI B31.1.0.

B. New Torus Piping Supports

1. Description

In both the north and south relief valve piping systems, the piping discharge in the torus is a submerged elbow anchored concentrically in a short segment of 20-inch diameter pipe. The annular area around the outside of the elbow created by this arrangement is intended to facilitate mixing of exhausting steam with the torus water by an eductor effect. This 20-inch pipe, known as the canal fitting, is welded to gussets which are secured to a stiffening ring girder on the inside bottom of the torus.

The new torus supports are braces attached to the canal fittings that provide rigidity in the horizontal (along the centerline of the elbow) and vertical directions. The vertical supports (see attached JCP&L drawing 1083-14-21) are four-inch thick carbon steel cross-shaped arms that match the contour of the outside radii of the discharge elbow and the inside radius of the 20 inch pipe. The vertical support is wedged into position in the lower portion of the annular space in the canal fitting between the elbow and the 20 inch pipe. It is locked in place against any possible motion by tie rods connected from the front and rear of the vertical support to the outer edges of the 20-inch pipe. In this position, the vertical support acts as a rigid restraint transmitting the vertical discharge loads on the elbow directly to the torus stiffening ring girder.

The horizontal restraint (see attached JCP&L drawing 1083-14-11) acts as a compression member transmitting the horizontal discharge loads from the canal fitting to the base of the upstream torus stiffening ring girder. By providing this rigid support, the horizontal restraint significantly reduces the flexibility and resulting deflection of the canal fitting during flow discharge transients. The main part of the horizontal restraint is a pair of 10-inch schedule 40 carbon steel pipe sections. These sections, which are axially loaded, span the distance between the adjacent torus stiffening ring girders. A threaded five-inch diameter pipe is screwed into one end of the sections to allow adjustment of the length of the pipe for installation and pre-loading of the restraints.

To seat the compression members between the stiffening ring girders, brackets are fitted to the upstream stiffening ring and the canal fitting. These brackets have concave hemispherical sockets which mate with convex caps welded to each end of the pipe sections. The engagement of these cap-to-socket connections along with the pre-loading and locking of the five-inch threaded extension piece provide assurance against disconnection or loosening of the pipe sections.

The brackets on the upstream stiffening ring are hook-shaped assemblies made of welded one-inch carbon steel plate. The brackets rest on leveling shims laid on top of the flange of the stiffening ring girder. This prevents the bracket from touching and locally loading the torus shell. The brackets are also fitted against an existing welded anchor on the web of the stiffening ring girder to prevent any motion along the girder.

The canal fitting brackets are fabricated from two-inch and five-inch carbon steel plate machined to fit between the bottom of the 20-inch pipe and the top flange of the stiffening ring girder supporting the canal fitting. The brackets are shimmed to fit snugly and are held in place by the compression pipe sections.

2. Requirements

The horizontal and vertical supports meet the following requirements.

a. Functional

The supports act to reduce the stresses in the torus piping and canal fittings by reducing the flexibility and deflection of the discharge piping anchor.

b. Design

The supports are designed in accordance with applicable ANSI B31.1.0 design criteria. Specific additional design requirements met by the supports include the following:

- The supports are designed to be installed underwater by divers.
- The supports are permanently installed and anchored without welding or alteration of the existing torus piping installation or local torus structure.
- To provide further assurance of the suitability of the base materials to withstand low temperature operation, the stresses were held to the lower stress limit for fracture propagation (20% of yield strength).

The design loads were derived from the peak transient discharge reaction loading predicated for the torus piping discharge anchor from the results of the computer model studies of the south header relief valve piping system. The design of the supports installed in both the north and south headers is identical. Since the discharge flow and resulting reaction loads are less in the north header piping, the loads and stresses in the north header torus supports will be less. Accordingly, the accompanying analyses proving the design of the supports for operation in the south header are conservative for the north header supports.

c. Fabrication

Fabrication requirements in excess of ANSI B31.1.0 rules were invoked for the horizontal and vertical supports, including the following:

- Base materials one inch and thicker and all weld metal were checked for adequate impact test properties.
- All welds made on the supports were liquid penetrant tested after the root pass and final pass.
- All welds made on the supports were liquid penetrant tested after the root pass and final pass.

- A program of vendor quality assurance was required including the use of written procedures and the maintenance of quality records.

3. Results

Highlights of the results of these analyses are shown in Table II-1. The results of these analyses indicate that the stresses in the local torus structure are acceptable and that the horizontal and vertical supports adequately meet the design requirements of ANSI B31.1.0.

C. Final Piping System Design Analysis

1. The final analyses of the modified relief valve installation were performed using an analytical piping flexibility model which included the behavior of the modified drywell and torus piping supports described in this report as well as all previous changes to the system.

2. Description of Analyses

The method used to analyze the stresses in the relief valve system was a computerized piping flexibility code. This code modeled the thermal heatup, fluid dynamic forces, and mechanical behavior of the system under the following conditions:

- Case 1. Plant Cold

  The relief valve piping and the main steam line are cold. Loads on the relief valve piping are limited to piping weight and any pre-set hanger loads.

- Case 2. Plant Hot

  The relief valve piping is cold but the main steam line is at operating conditions. Loads on the relief valve piping include pipe weight, pre-set hanger loads, and the thermal motion of the main steam line nozzles.

- Case 3. Early Transient

  The main steam line is at operating conditions and the relief valve piping is experiencing initial discharge steam conditions after valve opening. The transient loads on the piping are those loads felt during the exit of the water slug from the discharge elbow including dynamic effects.

- Case 4. Late Transient

  The main steam line is at operating conditions and the relief valve piping is experiencing late transient discharge steam conditions after valve opening. The transient loads on the piping are those loads felt immediately after exit of the water slug from the discharge elbow including dynamic effects.

° Case 5. Steady-State

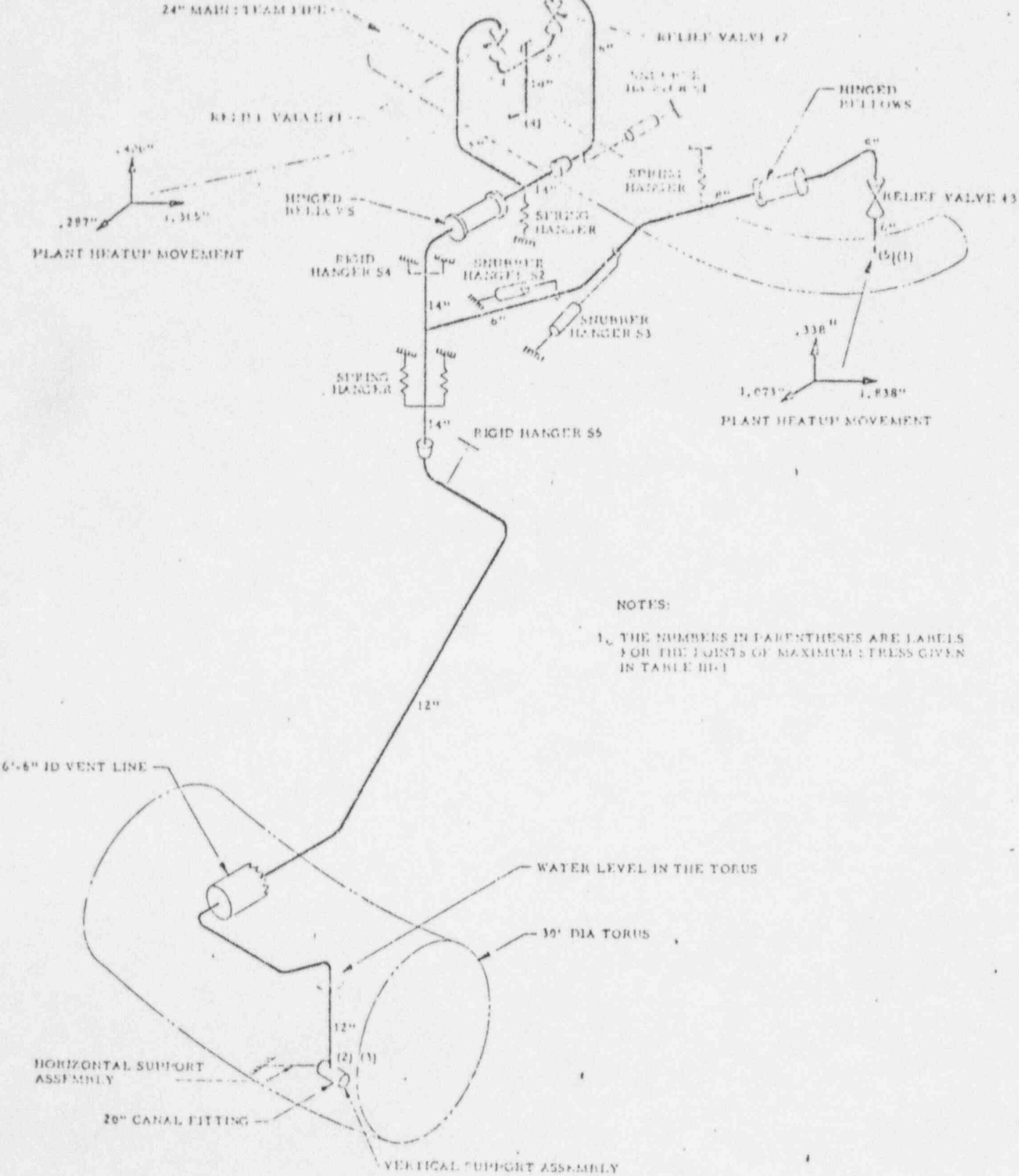
The main steam line is at operating conditions and the relief valve piping is experiencing steady state steam discharge and thermal heatup with the snubber-type hangers still locked.

° Case 6. Longitudinal Stress Case

This case included the loading effects required by ANSI B31.1.0 for evaluation of sustained longitudinal stresses without thermal heatup. The relief valve piping and the main steam line are cold. Loads on the relief valve piping are limited to steady-state steam discharge, piping weight and any pre-set hanger loads. While all these effects do not occur simultaneously in actual operation, they are combined together to conservatively estimate the worst sustained loadings as required by the Code.

3. Results

Highlights of the results of the analyses are shown in Table II-1. These results show that the relief valve piping system adequately meets the design requirements of ANSI B31.1.0.



NOTES:

1. THE NUMBERS IN PARENTHESES ARE LABELS FOR THE POINTS OF MAXIMUM STRESS GIVEN IN TABLE III-1

SOLENOID RELIEF VALVE DISCHARGE PIPING

Figure II-1

Table II-1

HIGHLIGHTS OF STRESS ANALYSES OF RELIEF VALVE PIPING SYSTEM

Location	Worst Loading Case	Location of (a) Highest Stress	Actual Value	Allowable Value	Code and Formula
Valve Inlet Piping					
Hoop Stress	Case 1	10" S 80 Pipe	.593 inch(f)	.337 inch(f)	Para. 104.1 (B31.1.0)
Expansion Stress	Case 3	Point 1	7742 psi	26,250 psi	1.5 Sm (B31.1.0)
Valve Discharge Piping					
Hoop Stress	Case 5	14" S 30 Pipe	.375 inch	.212 inch	Para. 104.1 (B31.1.0)
Sustained Longitudinal Stress (b)	Case 6	Point 2	15,980 psi	18,000 psi	1.2 Sm (B31.1.0)
Expansion Stress	Case 3	Point 3	18,731 psi	22,500 psi	1.5 Sm (B31.1.0)
Inlet Nozzle Connections to Steam Header					
-Local Membrane Stress					
Hoop Longitudinal	Case 2	10" Nozzle (Point 4)	12,780 psi 8,263 psi	21,000 psi 21,000 psi	1.2 Sm (B31.1.0)

Table II-1 (Continued)

Location	Worst Loading Case	Location of (a) Highest Stress	Actual Value	Allowable Value	Code and Formula
Inlet Nozzle Connections to Steam Header (Continued)					
-Local Membrane Stress					
Hoop Longitudinal	Case 3	6" Nozzle (Point 5)	12,287 psi 6,572 psi	21,000 psi 21,000 psi	1.2 Sm (B31.1.0)
-Local Membrane and Secondary Bending Stress					
Hoop Longitudinal	Case 2	10" Nozzle (Point 4)	21,807 psi 14,960 psi	52,500 psi 52,500 psi	3 Sm (ASME Sec III)
Hoop Longitudinal	Case 3	6" Nozzle (Point 5)	19,744 psi 14,225 psi	52,500 psi 52,500 psi	3 Sm (ASME Sec III)
New Variable Support Hanger	Case 2	Tensile Load	1,373 lbs	1,685 lbs	(c)
New Rigid Hanger S5	Case 4	Weld Shear Stress	2,025 psi	9,000 psi	.75 Sm (B31.1.0)
Canal Fitting Vertical Support Assembly					
Bending + Tensile Stress	Case 3	Radial Saddle	7,350 psi	7,500 psi	$.2\sigma_y$(d)

Table II-1 (Continued)

Location	Worst Loading Case	Location of (a) Highest Stress	Actual Value	Allowable Value	Code and Formula
Canal Fitting Horizontal Support Assembly					
Buckling Stress	Case 3	Support Column	70,100 lbs	220,000 lbs	AISC(e)
Bearing Stress		Column Threads	4,930 psi	6,000 psi	$.2\sigma_y$(d)
Bending + Tensile Stress		Canal Fitting Bracket	4,983 psi	6,000 psi	$.2\sigma_y$(d)
Bending + Tensile Stress		Support Ring Bracket	5,845 psi	6,000 psi	$.2\sigma y$(d)
Torus Stiffening Ring					
Shear Stress	Case 3	Stanchion Anchor	3,680 psi	17,500 psi	Sm
Torsional Stress	Case 3	Ring Cross Section	2,600 psi	17,500 psi	(ASME Sec VIII
Canal Fitting					
Local Membrane Stress	Case 3	12" Elbow to 20" Pipe Junction Weld	12,644 psi	18,000 psi	1.2 Sm (B31.1.0)
Local Membrane and Secondary Bending	Case 3	12" Elbow to 20" Pipe Junction Weld	31,900 psi	45,000 psi	3 Sm (ASME Sec III)

(a) Points denoting piping locations are identified on Figure II-1.
(b) This is the highest sustained longitudinal stress in either the inlet or outlet piping.
(c) This hanger is a standard Bergen-Paterson Pipe Support Corporation model designed per ANSI B31.1.0 with a load rating as shown under the "Allowable Value" column.
(d) This criteria is 20% of the minimum yield stress.
(e) "Manual of Steel Construction," American Institute of Steel Construction.
(f) These are required minimum and actual wall thicknesses corresponding to allowable/actual hoop stress.

III. REFERENCES

1. Report to the AEC, "Oyster Creek Station No. 1 Safety and Relief Valve Piping Design Report", August 1972.