CATAWBA NUCLEAR STATION

JET IMPINGEMENT STUDY

ON

3" RTD RETURN AND 10" ACCUMULATOR

DISCHARGE LINES

January 19, 1983

1.0 INTRODUCTION

This report summarizes the results of a study conducted by the Catawba Reactor Stress Analysis Group in reply to a NRC request made to the Mechanical Design Plant Environmental Group (MDPE) concerning jet loading on piping targets.

MDPE provided the following examples for the study:

- Example 1: Math Model NI-07

  Jet Load = 7815 lbs. (See Attachment 3)
  Target: 10" NI line from Accumulator Tank 1D

- Example 2: Math Model NC-07

  Jet Load = 1725 lbs. (See Attachment 3)
  Target: 3" NC crossover RTD return line, RCL 1C

The purpose of the study was to demonstrate that the above piping could sustain jet impingement loadings and maintain pressure boundary integrity.

2.0 DESIGN CRITERIA

The examples provided involve ASME Class 1 and 2 piping. Since the jet evolves following a pipe rupture, faulted condition stress allowables are appropriate for this evaluation. Accordingly, 3 S_m (ASME III, Appendix F, F-1360) and 2.4 S_h (NC-3611.2) are the applicable stress limits for Class 1 and Class 2 piping, respectively.

3.0 DESIGN METHOD

3.1 Pipe Stresses

Pressure integrity can be guaranteed by showing that the stresses in the entire piping network under faulted loading conditions are below the collapse level. To evaluate these conditions, conservative static analyses were performed utilizing the SUPERPIPE computer program. Distributed and point forces were used to simulate the jet impingement loadings on the specified target areas. The resulting stresses were then combined with other faulted load case stresses as prescribed in Tables 3.9.3-7 and 3.9.3-8 of the Catawba FSAR (Attachments 1 and 2).

3.2 Support/Restraint Loads

Jet impingement loads were generated for all support/restraints (S/R) in each math model, and added absolutely to the existing faulted design load. Whenever S/R reaction loads exceeded their design capability, the analyses were modified to exclude those S/R from the model. This iterative procedure was continued until it was shown that the additional load from jet impingement was within the limits of the remaining S/R design.

3.3 Equipment and RCL Connections

For this assessment of pressure integrity, equipment and RCL nozzle connections were evaluated to the same criteria as the connected piping. Loads and stresses at these connections due to jet impingement were not significant in Example 1 due to the presence of S/R in the target area. Example 2, however, showed an appreciable, yet acceptable, increase at the Cold Leg nozzle due to the proximity of the jet and no S/R in the target area to take the jet loading off the piping and nozzle. Further details are presented in Section 4.0 of this report.

4.0 CONCLUSIONS

The study conducted on two (2) Catawba Nuclear Station, Unit 1 piping math models has demonstrated that pressure boundary integrity is maintained under the specified jet impingement loading. The allowable stress intensity was not exceeded for any piping component in either of the example math models.

In Example 1, only 1 out of 22 S/R failed under this additional faulted loading. The iterative analysis showed the remaining S/R's to be adequately designed to withstand the increased loading even with this snubber removed.

Example 2 indicated failure of only 2 of 29 S/R under the additional jet loading, but again the remaining S/R restrained the piping effectively and stress levels remained below the 3 S_m allowable by a substantial margin. Refer to Table 1 for a summary of maximum stress intensity for faulted conditions.

The study performed on the examples provided demonstrated adequate safety margins in piping stress levels and pipe support loads.

TABLE 1

Maximum Primary Stress Intensity for Faulted Conditions

Math Model Number	Component	Joint Name	Primary Stress Intensity (psi)	Allowable Stress Intensity, 3 S_m (psi)	Ratio
NI-07	6" Sch 160 branch connection	103	36811	48300	.762
NC-07	3" Sch 160 conn. 3-11 on Cold Leg 1C	3	29720	48300	.615

Since the requirements of Equation (9) with a 3 S_m stress limit are satisfied, the primary stress intensity for faulted conditions is acceptable.

ATTACHMENT 1

TABLE 3.9.3-7

Stress Criteria and Load Combination Requirements for Duke Class A Piping

Condition	Load Combination	Applicable Stress Criteria
Design	Pressure +Weight +OBE	ASME III NB-3652
Normal, Upset	Pressure +Weight +Thermal +Thermal transients +OBE (incl. anchor motions) +Relief Valve (as applicable) +Fluid dynamic effects	ASME III NB-3653 & 3654
Faulted	Pressure +Weight +SSE +Pipe Rupture +Relief Valve (as applicable) +Fluid dynamic effects	ASME III Appendix F (F-1360)
Faulted	Pressure +Weight +Pipe Rupture +Relief Valve (as applicable) +Fluid dynamic effects	ASME III Appendix F (F-1360)

ATTACHMENT 2

TABLE 3.9.3-8

Stress Criteria and Load Combination
Requirements for Duke Class B, C, and F Piping

Condition	Load Combination	Applicable Stress Criteria
Normal	Pressure +Weight +Thermal	ASME III NC- or ND-3652
Upset	Pressure +Weight +Thermal +OBE (incl. anchor motions) +Valve thrust +Fluid dynamic effects	ASME III NC- or ND-3652
Faulted	Pressure +Weight +SSE +Valve thrust +Fluid dynamic effects +Pipe rupture	ASME Code Case 1606
Faulted	Pressure +Weight +Valve thrust +Fluid dynamic effects +Pipe rupture	ASME Code Case 1606
Faulted	Pressure +Weight +Tornado	ASME Code Case 1606

ATTACHMENT 3

The two examples provided for this study illustrate the two different cases of jet loading on a piping target. For each example, the piping target load was calculated based on source piping conditions prior to the rupture.

The first example involves a case where the target piping is of a larger nominal pipe size and wall thickness compared to the source piping. The target piping will receive a full loading from a non-expanding jet with the jet area being smaller than the impinged pipe. The jet impingement force is assumed to be invariant with time and equals to the blowdown force times a correction factor (shape factor). The force acts normal to the target pipe surface.

The second example involves a case where the target and source piping are of equal nominal pipe size and wall thickness. The target piping will receive loading from an expanding jet (having a 10^{0} angle expansion) with the jet area being greater than the impinged target area. The source piping is 10 feet away from the target and the jet impingement force is invariant with time. The jet impingement force equals to the blowdown force times a correction factor which includes the shape factor and the ratio of target area over jet area.

For each example, jet impingement force will be calculated by using the methods and procedures established in ANSI/ANS-58.2-1980.

Example 1 =

- Source = 6" NI from Residual Heat Removal Heat Exchanger 1A
- Piping Conditions: 465 psia, 120 F (Non-expanding jet)
- Blowdown Force: Using the Simplified Method for calculation of Fluid Thrust Forces illustrated in ANSI/ANS-58.2-1980, Appendix B, pages 33-48, the blowdown force can be set equal to P x A where P is the line presource and A is the total circumferential break area.

$F = P \times A$ where $A = 21.13\ in^2$ (6" NI, Sche. 160)

$F = (465)(21.13) = 9825$ lbs

- Jet Impingement Force:

$F_{imp} = K\ F_{jet}\ (A_{target}/A_{jet})$, Ref = ANSI/ANS-58.2-1980, Appendix D, p. 56.

where K is the shape factor

F_{jet} is the blowdown force

and A_{target}/A_{jet} conservatively set to be 1.0

$K = 1 - \frac{0.424D_j}{D_o}$ For a circular Jet Impingement on Pipe with Jet Diameter less than Pipe Diameter (Non-expanding jet with source being 6" NI and target being 10" NI). Ref. ANSI/ANS-58.2-1980, Appendix D, p. 58

$D_j = 5.187$ in (6" NI, Sche. 160)

$D_o = 10.75$ in. (10" NI, Sche. 140, Outside Diameter)

$K = 1 - \frac{(0.424)(5.187)}{10.75} = 0.795$

$F_{imp} = (0.795)(9825)(1.0) - 7815$ lbs

Example 2

- Source = 3" NC Crossover RTD Return line 1B
- Piping conditions = 2250 psia, 557°F (Expanding Jet)
- Blowdown Force = P x A (See Example 1 for source of reference)

  $F = P \times A$ where $A = 4.155\ in^2$ (3" NC, Sche. XXS)

  $F = 2250 \times 4.155 = 9350$ lbs

- Jet Impingement Force:

  $F_{imp} = K\ F_{jet}\ (A_{target}/A_{jet})$ (See Example 1 for reference)

Where $A_{jet} = A_e\ (1 + \frac{2L}{D_e} \tan 10°)^2$ for an expanding jet with 10° expansion. (Ref. ANSI/ANS-58.2-1980, Appendix C. p. 54)

with A_e (circumferential break area) = $4.155\ in^2$

D_e (source pipe inside diameter) = 2.3 in

L (distance from source to target) = 120 in

$A_{jet} = 4.155\ (1 + \frac{2 \times 120}{2.3} \tan 10°)^2 = 1564\ in^2$ or $D_{jet} = 44.6$ in

$A_{target} \approx 500\ in^2$ This area is obtained by taking the surface area of the target being impinged by the expanding jet of the source 10 feet away from the target.

K, shape factor, is equal to 0.576 (for a Circular Jet Impingement on pipe with Jet Diameter Greater than Pipe Diameter) Ref. ANSI/ANS-58.2-1980 Appendix D, page 58

$F_{jet} = 9350$ lbs (blowdown force)

$F_{imp} = (0.576)(9350)(500/1564) \approx 1725$ lbs