Consumers Power Company

General Offices: 212 West Michigan Avenue, Jackson, Michigan 49201 • Area Code 517 788-0550

April 4, 1975

Re: 1. Docket 50-255, License DPR-20
Palisades Plant
2. Letters to DRL From RBSewell
Dated 12-29-74, 1-27-75 and
2-24-75

Division of Reactor Licensing
USNRC
Att: Mr. R. A. Purple
Washington, DC 20555

Gentlemen:

By letter dated November 26, 1974, the Atomic Energy Commission requested that Consumers Power Company review the Palisades Plant to determine whether the failure of any non-Category I (seismic) equipment, particularly in the circulating water system and fire protection system, could result in a condition, such as flooding or the release of chemicals, that might potentially adversely affect the performance of safety-related equipment required for safe shutdown of the facility or to limit the consequences of an accident. It was noted that a previous review had been performed but in the intervening period the cooling towers had been completed and a reanalysis should be conducted.

Consumers Power Company, in its letter of October 26, 1972, conveyed its analysis and conclusion to AEC that a potential of flooding or chemical release, that would adversely affect safety-related equipment, does not exist at the Palisades Plant.

However, in light of the modifications to the circulation water system and the addition of cooling towers, an investigation of flood potential, that may have resulted from the modifications, was conducted.

1.0 <u>DESCRIPTION OF RELEVANT MODIFICATIONS</u>

Following is a brief description of the changes made in the circulating water system which have a bearing on the flooding potential:

1. Removal of circulating water pumps from the intake structure.
2. Addition of cooling towers.
3. Layout of two 90" return pipes leading water from the cooling tower basins to the condenser: This resulted in both the pipes travelling vertically downward through the intake structure.

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4. Addition of two dilution pumps and associated piping in the intake structure.

5. Addition of expansion joints and butterfly valves in the inlet piping to the condenser.

6. Addition of expansion joints in the discharge piping from the condenser water boxes.

2.0 DESCRIPTION OF ANALYSIS

According to Attachment B of AEC - Branch Technical Position - MEB #1, (Attachment 1), circulating water system is classified as a Moderate Energy Fluid System.

Paragraph C, Section II of AEC - Branch Technical Position - MEB #1, implies that no break need be postulated if the maximum stress in the nonnuclear piping is less than $0.4\ (1.25\ S_h + S_A)$.

Stress analysis of the modified circulating water piping in the intake structure was carried out for various loads. Maximum stress encountered was found out to be much less than the permissible value referred to above.

Therefore, no break in the circulating water system piping was postulated and no protective measures against flooding are required in the intake structure building (former screenhouse).

3.0 SUMMARY

Circulating water system with its modifications falls under the category of Moderate Energy Fluid Systems (Attachment 1).

The actual stresses including seismic in the modified piping of the circulating water system in the intake structure building are much less than the allowable for a nonnuclear piping. The stresses as calculated are 1.042 ksi as compared with an allowable value of 16.2 ksi. Therefore, the postulation of any break in the circulating water piping in the intake structure building is not warranted and, as such, no protective measures are needed.

The addition of expansion joints and butterfly valves in the circulating water piping near the condenser has not altered the basis under which the previous analysis was made (10-26-72 letter to AEC).

4.0 CONCLUSIONS

From the analysis above, it is concluded that modifications to the circulating water piping have not changed flooding potential in the intake structure (former screenhouse). Therefore, no additional measures are required. Note there is only about 22 feet of water static head (9.6 psi) in this part of the system.

5.0 ADDITIONAL CONSIDERATION

In view of the Commission's concern regarding the expansion joints, an analysis was made assuming the rupture of only one expansion joint at a time, and limiting the size of rupture to half the circumference of the expansion joint and a height of four inches. From this analysis, it was estimated that the minimum time taken by the leaking water to overflow onto the turbine building floor El 590'-0", after filling the condensate pump area El 571'-0" and condenser area El 580'-0" is about 2-1/2 minutes.

To relieve this extremely unlikely discharge, we have decided to install two (2) level alarms in the condensate pump area (El 571'-0") to detect rising water level. These level sensors will provide sufficient warning to permit appropriate administrative action to be taken. This action will include opening of the roll-up door at the turbine building floor area (El 590'-0") which by itself would limit the water buildup to a maximum of several inches (above the 590' floor). This water level is considerably below the 593'-6" elevation which would result in flooding of the service water pump motor. We expect to complete the installation of the level alarm by about October 1, 1975.

Yours very truly,

Ralph B. Sewell

Ralph B. Sewell
Nuclear Licensing Administrator

RBS/map

CC: JGKeppler,
USNRC

From Draft 8 of Reg. Guide 1.xx

BRANCH TECHNICAL POSITION - MEB No. 1

POSTULATED BREAK AND LEAKAGE LOCATIONS IN FLUID SYSTEM PIPING OUTSIDE CONTAINMENT

The following criteria are the review responsibility of the Mechanical Engineering Branch with the exception of I.A., II.A., and II.D. which are the responsibility of the Auxiliary Power and Conversion Systems Branch. These items are included in this Branch Technical Position to provide clarity and continuity.

I. High-Energy Fluid System Piping

A. Fluid Systems Separated from Essential Systems and Components

For the purpose of satisfying the separation provisions of plant arrangement as specified in C.1.a of the Regulatory Position,* a review of the piping layout and plant arrangement drawings should clearly show that the effects of postulated piping breaks at any location are isolated or physically remote from essential systems and components. At the designer's option, break locations as determined from I.C and I.D of this Branch Technical Position may be assumed for this purpose.

B. Fluid System Piping Between Containment Isolation Valves.

Breaks need not be postulated in those portions of piping identified in C.2.c. of the Regulatory Position* provided they meet the requirements of the ASME Code, Section III, Subarticle NE-1120 and the following additional design requirements:

1. The following design stress and fatigue limits should not be exceeded:

For ASME Code, Section III, Class 1 Piping

(a) The maximum stress range should not exceed $2.4S_m$

(b) The maximum stress range between any two load sets (including the zero load set) should be calculated by Eq. (10) in Paragraph NB-3653, ASME Code, Section III, for upset plant conditions and an operating basis earthquake (OBE) event transient.

If the calculated maximum stress range of Eq. (10) exceeds the limit of I.B.1(a) but is not greater than $3S_m$, the limit of I.B.1(c) should be met.

If the calculated maximum stress range of Eq. (10) exceeds $3S_m$, the stress ranges calculated by both Eq. (12) and Eq. (13) in Paragraph NB-3653 should meet the limit of I.B.1(a) and the limit of I.B.1(c).

(c) The cumulative usage factor should be less than 0.1 if consideration of fatigue limits is required according to I.B.1(b).

(d) The maximum stress, as calculated by Eq. (9) in Paragraph NB-3652 under the loadings resulting from a postulated piping failure beyond these portions of piping should not exceed $2.25S_m$.

<u>For ASME Code, Section III, Class 2 Piping</u>

(a) The maximum stress ranges as calculated by Eq. (9) and (10) in Paragraph NC-3652, ASME Code, Section III, considering *upset plant conditions* (i.e., sustained loads, occasional loads, and thermal expansion) and an OBE event should not exceed $0.8(1.2S_h + S_A)$.

(b) The maximum stress, as calculated by Eq. (9) in Paragraph NC-3652 under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping should not exceed $1.8S_h$.

2. Welded attachments, for pipe supports or other purposes, to these portions of piping should be avoided except where detailed stress analyses, or tests, are performed to demonstrate compliance with the limits of I.B.1.

3. The number of circumferential and longitudinal piping welds and branch connections should be minimized. Where guard pipes are used, the enclosed portion of *fluid system* piping should be seamless construction unless specific access provisions are made to permit inservice volumetric examination of the longitudinal welds.

4. The length of these portions of pipin_ should be reduced to the minimum length practical.

5. The design of pipe anchors or restraints (e.g., connections to containment penetrations and pipe whip restraints) should not require welding directly to the outer surface of the piping (e.g., flued integrally forged pipe fittings may be used) except where such welds are 100 percent volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the limits of I.B.1.

6. Guard pipes provided for those portions of piping identified in C.2.c.(2) of the Regulatory Position* should be constructed in accordance with rules of Class MC, Subsection NE of the ASME Code, Section III, where the guard pipe is part of the containment boundary. In addition, the entire guard pipe should be designed to meet the following requirements and tests:

   (a) The design pressure and temperature should not be less than the maximum operating pressure and temperature of the enclosed pipe under *normal plant conditions*.

   (b) The design stress limits of Paragraph NE-3131(c) should not be exceeded under the loading associated with design pressure and temperature in combination with the safe shutdown earthquake.

   (c) Guard pipe assemblies should be subjected to a single pressure test at a pressure not in excess of design pressure.

C. *Fluid Systems* Enclosed Within Protective Structures

1. With the exception of those portions of piping identified in I.B., breaks in Class 2 and 3 piping (ASME Code, Section III) should be postulated at the following locations in those portions of each piping and branch run within a protective structure or compartment designed to satisfy the plant arrangement provisions of C.1.b. or C.1.c. of the Regulatory Position:*

*See Attachment A

a. At *terminal ends* of the run if located within the protective structure.

b. At intermediate locations selected by one of the following criteria:

(i) At each pipe fitting (e.g., elbow, tee, cross, flange, and non-standard fitting), welded attachment, and valve. Where the piping contains no fittings, welded attachments, or valves, at one location at each extreme of the piping within the protective structure. (A terminal end, as determined by C.1.a, may be considered as one of these extremes.)

(ii) At each location where the stresses[1/] exceed $0.8(1.2S_h + S_A)$ but at not less than two separated locations chosen on the basis of highest stress.[2/] Where the piping consists of a straight run without fittings, welded attachment, and valves, and all stresses are below $0.8(1.2S_h + S_A)$, a minimum of one location chosen on the basis of highest stress.

2. Breaks in non-nuclear class piping should be postulated at the following locations in each piping or branch run:

a. At *terminal ends* of the run if located within the protective structure.

b. At each intermediate pipe fitting, welded attachment, and valve.

[1/] Stresses under *normal* and *upset plant conditions*, and an OBE event as calculated by Eq. (9) and (10), Parag. NC-3652 of the ASME Code, Section III.

[2/] Select two locations with at least 10% difference in stress, or, if stresses differ by less than 10%, two locations separated by a change of direction of the pipe run.

D. *Fluid Systems* Not Enclosed Within Protective Structures

1. With the exceptions of those portions of piping identified in I.B., breaks in Class 2 and 3 piping (ASME Code, Section III) should be postulated at the following locations in those portions of each piping and branch run routed outside of, but alongside, above, or below, a protective structure or compartment containing *essential systems and components* and designed to satisfy the plant arrangement provisions of C.1.b or C.1.c. of the Regulatory Position.*

   Such piping should be considered as located adjacent to a protective structure if the distance between the piping and structure is insufficient to preclude impairment of the integrity of the structure from the effects of a postulating piping failure assuming the piping is unrestrained.

   a. At *terminal ends* of the run if located adjacent to the protective structure.

   b. At intermediate locations selected by one of the following criteria:

      (i) At each pipe fitting (e.g., elbow, tee, cross, flange, and non-standard fitting), welded attachment, and valve. Where the piping contains no fittings, welded attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure.

      (ii) At each location where the stresses[1/] exceed $0.8(1.2S_h + S_A)$ but at not less than two separated locations chosen on the basis of highest stress.[2/] Where the piping consists of a straight run without fittings, welded attachments, or valves, and all stresses are below $0.8(1.2S_h + S_A)$, a minimum of one location chosen on the basis of highest stress.

2. Breaks in non-nuclear class piping should be postulated at the following locations in each piping or branch run:

   a. At *terminal ends* of the run if located adjacent to the protective structure.

   b. At each intermediate pipe fitting, welded attachment, and valve.

*See Attachment A

II. *Moderate-Energy Fluid System Piping*

A. *Fluid Systems* Separated from *Essential Systems and Components*

For the purpose of satisfying the separation provisions of plant arrangement as specified in C.1.a. of the Regulatory Position,* a review of the piping layout and plant arrangement drawings should clearly show that the effects of through-wall leakage cracks at any location are isolated or physically remote from *essential systems and components*.

B. *Fluid System* Piping Between Containment Isolation Valves

Leakage cracks need not be postulated in those portions of piping identified in C.2.c. of the Regulatory Position* provided they meet the requirements of ASME Code, Section III, Subarticle NE-1120, and are designed such that the maximum stress range does not exceed $0.4(1.2S_h + S_A)$ for ASME Code, Section III, Class 2 piping.

C. *Fluid Systems* Within, or Outside and Adjacent to, Protective Structure

Through-wall leakage cracks should be postulated in *fluid system* piping located within, or outside and adjacent to, protective structures designed to satisfy the plant arrangement provisions of C.1.b. or C.1.c of the Regulatory Position,* except (1) where exempted by II.B and II.D, or (2) where the maximum stress range in these portions of Class 2 or 3 piping (ASME Code, Section III), or non-nuclear piping is less than $0.4(1.2S_h + S_A)$. The cracks should be postulated to occur individually at locations that result in the maximum effects from fluid spraying and flooding, with the consequent hazards or environmental conditions developed.

D. *Moderate-Energy Fluid Systems* in Proximity to *High-Energy Fluid Systems*

Cracks need not be postulated in *moderate-energy fluid system* piping located in an area in which a break in *high-energy fluid system* piping is postulated, provided such cracks would not result in more limiting environmental conditions than the high energy piping break. Where a postulated leakage crack in the *moderate-energy fluid system* piping results in more limiting environmental conditions than the break in proximate *high-energy fluid system* piping, the provisions of II.C should be applied.

*See Attachment A

E. *Fluid Systems* Qualifying as *High-Energy* or *Moderate-Energy Systems*

Through-wall leakage cracks instead of breaks may be postulated in the piping of those *fluid systems* that qualify as *high-energy fluid systems* for only short operational periods[3] but qualify as *moderate-energy fluid systems* for the major operational period.

III. Type of Breaks and Leakage Cracks in *Fluid System* Piping

A. Circumferential Pipe Breaks
The following circumferential breaks should be postulated in *high-energy fluid system* piping at the locations specified in Section I of this Branch Technical Position.

1. Circumferential breaks should be postulated in *fluid system* piping and branch runs exceeding a nominal pipe size of 1 inch, except where the maximum stress range[1] exceeds the limits specified in I.C.1.b.(ii) and I.D.1.b.(ii) ~~but~~ the circumferential stress range is at least 1.5 times the axial stress range. Instrument lines, one inch and less nominal pipe or tubing size should meet the provisions of Regulatory Guide 1.11.

2. Where break locations are selected without the benefit of stress calculations, breaks should be postulated at each piping weld joint to fitting, valve or welded attachment. Alternatively, a single break location at the section of maximum stress range may be selected as determined by detailed stress analyses (e.g., finite element analyses) or tests on a pipe fitting.

3. Circumferential breaks should be assumed to result in pipe severance and separation amounting to at least a one-diameter lateral displacement of the ruptured piping sections unless physically limited by piping restraints, structural members, or piping stiffness as may be demonstrated by inelastic limit analysis (e.g., a plastic hinge in the piping is not developed under loading).

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[3] An operational period is considered "short" if the fraction of time that the system operates within the pressure-temperature conditions specified for *high-energy fluid systems* is less than 2 percent of the time that the system operates as a *moderate-energy fluid system* (e.g., systems such as the reactor decay heat removal systems qualify as *moderate-energy fluid systems*; however, systems such as auxiliary feedwater systems operated during PWR reactor startup, hot standby, or shutdown qualify as *high-energy fluid systems*)

4. The dynamic force of the jet discharge at the break location should be based on the effective cross-sectional flow area of the pipe and on a calculated fluid pressure as modified by an analytically or experimentally determined thrust coefficient. Limited pipe displacement at the break location, line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs may be taken into account, as applicable, in the reduction of jet discharge.

5. Pipe whipping should be assumed to occur in the plane defined by the piping geometry and configuration, and to cause pipe movement in the direction of the jet reaction.

B. Longitudinal Pipe Breaks

The following longitudinal breaks should be postulated in *high-energy fluid system* piping at the locations of each circumferential break specified in III.A:

1. Longitudinal breaks in *fluid system* piping and branch runs should be postulated in nominal pipe sizes 4-inch and larger, except where the maximum stress range[1/] exceeds the limits specified in I.C.1.b.(ii) and I.D.1.b.(ii) but the axial stress range is at least 1.5 times the circumferential stress range.

2. Longitudinal breaks need not be postulated at:

   (a) *terminal ends* provided the piping at the *terminal ends* contains no longitudinal pipe welds (if longitudinal welds are used, the requirements of III.B.1 apply).

   (b) at intermediate locations where the criterion for a minimum number of break locations must be satisfied.

3. Longitudinal breaks should be assumed to result in an axial split without pipe severance. Splits should be oriented (but not concurrently) at two diametrically-opposed points on the piping circumference such that the jet reaction causes out-of-plane bending of the piping configuration. Alternatively, a single split may be assumed at the section of highest tensile stress as determined by detailed stress analysis (e.g., finite element analysis).

4. The dynamic force of the fluid jet discharge should be based on a circular or elliptical (2D x 1/2D) break area equal to the effective cross-sectional flow area of the

pipe at the break location and on a calculated fluid pressure modified by an analytically or experimentally determined thrust coefficient as determined for a circumferential break at the same location. Line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs may be taken into account, as applicable, in the reduction of jet discharge.

5. Piping movement should be assumed to occur in the direction of the jet reaction unless limited by structural members, piping restraints, or piping stiffness as demonstrated by inelastic limit analysis.

C. Through-Wall Leakage Cracks

The following through-wall leakage cracks should be postulated in *moderate-energy fluid system* piping at the locations specified in Section II of this Branch Technical Position.

1. Cracks should be postulated in *moderate-energy fluid system* piping and branch runs exceeding a nominal pipe size of 1 inch.

2. Fluid flow from a crack should be based on a circular opening of area equal to that of a rectangle one-half pipe-diameter in length and one-half pipe wall thickness in width.

3. The flow from the crack should be assumed to result in an environment that wets all unprotected components within the compartment, with consequent flooding in the compartment and communicating compartments. Flooding effects should be determined on the basis of a conservatively estimated time period required to effect corrective actions.

ATTACHMENT A

SUMMARY OF APPLICABLE REGULATORY POSITIONS

Regulatory Position C.1.a

Plant arrangements should separate *fluid system* piping from *essential systems and components*. Separation should be achieved by plant physical layouts that provide sufficient distances between *essential systems and components* and *fluid system* piping such that the effects of any *postulated piping failure* therein (i.e., pipe whip, jet impingement, and the environmental conditions resulting from the escape of contained fluids as appropriate to *high* or *moderate-energy fluid system* piping) cannot impair the integrity or operability of *essential systems and components*.

Regulatory Position C.1.b

Fluid system piping or portions thereof not satisfying the provisions of C.1.a should be enclosed within structures or compartments designed to protect nearby *essential systems and components*. Alternatively, *essential systems and components* may be enclosed within structures or compartments designed to withstand the effects of *postulated piping failures* in nearby *fluid systems*.

Regulatory Position C.1.c

Plant arrangements or system features that do not satisfy the provisions of either C.1.a or C.1.b. should be limited to those for which the above provisions are impractical because of the stage of design or construction of the plant; because the plant design is based upon that of an earlier plant accepted by the staff as a base plant under the Commission's standardization and replication policy; or for other substantive reasons such as particular design features of the *fluid systems*. Such cases may arise for example, (1) at interconnections between *fluid systems* and *essential systems and components*, or (2) in *fluid systems* having dual functions (i.e., required to operate during *normal plant conditions* as well as to shut down the reactor). In these cases, redundant design features that are separated or otherwise protected from *postulated piping failures*, or additional protection, should be provided so that the effects of *postulated piping failures* are shown by the analyses and guidelines of C.3 to be acceptable. Additional protection may be provided by restraints and barriers or by designing or testing *essential systems and components* to withstand the effects associated with *postulated piping failures*.

Regulatory Position C.2.c

Fluid system piping between containment isolation valves should meet the following design provisions:

1. Portions of *fluid system* piping between isolation valves of single barrier containment structures (including any rigid connection to the containment penetration) that connect, on a continous or intermittent basis, to the reactor coolant pressure boundary, or the steam and feedwater systems of PWR plants, should be designed to the stress limits specified in I.B or II.B. of the Branch Technical Position.

   These portions of *high-energy fluid system* piping should be provided with pipe whip restraints that are capable of resisting bending and torsional moments produced by a postulated piping failure either upstream or downstream of the containment isolation valves. The restraints should be located reasonably close to the containment isolation valves and should be designed to withstand the loadings resulting from a *postulated piping failure* beyond these portions of piping so that neither valve operability nor the leaktight integrity of the containment will be impaired.

2. Portions of *fluid system* piping between isolation valves of dual barrier containment structures should also meet the design provisions of 1 above. In addition, those portions of piping that pass through the containment annulus, and whose postulated failure could affect the leaktight integrity of the containment structure or result in pressurization of the containment annulus beyond design limits should be provided with an enclosing protective structure.

   For the purpose of establishing the design parameters (i.e., pressure, temperature) of the enclosing protective structure, a full flow area opening should be assumed in that portion of piping within the enclosing structure taking into account vent areas, if provided, in the enclosing structure. Where guard pipes for individual process pipes are used as an enclosing protective structure, such guard pipes should be designed to meet the requirements specified in I.B.6 of the Branch Technical Position.

3. *Terminal ends* of the piping runs extending beyond these portions of *high-energy fluid system* piping should be considered to originate at a point adjacent to these required pipe whip restraints located inside and outside containment.

ATTACHMENT B

DEFINITIONS

Essential Systems and Components. Systems and components required to shut down the reactor and mitigate the consequences of a *postulated piping failure*, without off-site power.

Fluid Systems. *High and moderate energy fluid systems* that are subject to the postulation of piping failures outside containment against which protection of *essential systems and components* is needed.

High-Energy Fluid Systems. Fluid systems that, during *normal plant conditions*, are either in operation or maintained pressurized under conditions where either or both of the following are met:

a. maximum operating temperature exceeds 200°F, or

b. maximum operating pressure exceeds 275 psig.

Moderate-Energy Fluid Systems. Fluid systems that, during *normal plant conditions*, are either in operation or maintained pressurized (above atmospheric pressure) under conditions where both of the following are met:

a. maximum operating temperature is 200°F or less, and

b. maximum operating pressure is 275 psig or less

Normal Plant Conditions. Plant operating conditions during reactor startup, operation at power, hot standby, or reactor cooldown to cold shutdown condition.

Upset Plant Conditions. Plant operation conditions during system transients that may occur with moderate frequency during plant service life and are anticipated operational occurrences, but not during system testing.

Postulated Piping Failures. Longitudinal and circumferential breaks in *high-energy fluid system* piping and through-wall leakage cracks in *moderate-energy fluid system* piping postulated according to the provisions of the Branch Technical Position.

S_h and S_A. Allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III.

S_m. Design stress intensity as defined in Article NB-3600 of the ASME Code, Section III.

Single Active Component Failure. Malfunction or loss of function of a component of electrical or fluid systems. The failure of an active component of a fluid system is considered to be a loss of component function as a result of mechanical, hydraulic, pneumatic, or electrical malfunction, but not the loss of component structural integrity. The direct consequences of a *single active component failure* are considered to be part of the single failure.

Terminal Ends. Extremities of piping runs that connect to structures, components (e.g., vessels, pumps, valves), or pipe anchors that act as rigid constraints to piping thermal expansion. A branch connection to a main piping run is a *terminal end* of the branch run.

In piping runs which are maintained pressurized during *normal plant conditions* for only a portion of the run (i.e., up to the first normally closed valve) a *terminal end* of such runs is the piping connection to this closed valve.

PE WHIP ANALYSIS

Analyses are required to assure that pipe motion caused by the dynamic effects of postulated design basis breaks will not impact or overstress any st ;ctures, systems or components important to safety to the extent that their safety function is impaired or precluded. The analysis methods used should be adequate to determine the resulting loadings in terms of:

a. the kinetic energy or momentum induced by the impact of the whipping pipe, if unrestrained, on a protective barrier or a component important to safety,

b. the dynamic response of the restraints induced by the impact and rebound if any, of the ruptured pipe.

The basis used to determine the magnitude of jet thrust force as required in dynamic analysis should be provided.

The methods of dynamic analysis specified in II and III are acceptable provided the following associated criteria are met:

I. <u>Pipe Whip Dynamic Analysis Criteria</u>

a. An analysis of the pipe run or branch should be performed for each longitudinal and circumferential postulated rupture at the design basis break locations.

b. The loading condition of a pipe run or branch prior to postulated rupture in terms of internal pressure, temperature, and stress state should be those conditions associated with reactor operating condition (normal and upset).

c. For a circumferential rupture, pipe whip dynamic analysis need only be performed for that end (or ends) of the pipe or branch which is connected to a contained fluid energy reservoir having a sufficient capacity to develop a jet stream.

d. Dynamic analysis methods used for calculating the piping or piping/restraint system response to the jet thrust developed following postulated rupture should adequately account for the effects of:

(1) mass inertia and stiffness properties of the system,

(2) impact and rebound (if any effects as permitted by gaps between piping and restraint)

(3) Static Analysis Model - The jet thrust force is represented by a conservatively amplified static loading, and the ruptured system is analyzed statically. An amplification factor of 3 can be used to establish the magnitude of the forcing function if the piping and restraint system remain elastic. However, a factor based on selection of a conservative value as obtained by comparison with the factors derived from detailed dynamic analysis performed on comparable systems is also acceptable.

III. Acceptable Dynamic Analysis for Unrestrained Pipe Whip

a. Lumped-Parameter Analysis Model as stated in II.a(1) is acceptable.

b. Energy-Balance Analysis Model as stated in II.a(2) is acceptable. The energy absorbed by the pipe deformation may be deducted from the total energy imparted to the system.

c. The assumptions used to guide the mechanism of pipe movement should be justified to be conservative.

d. The results of analysis should be expressed in terms compatible with the approach used for verifying the design adequacy of the impacted structure.

IV. Flow Thrust Force

a. The time function of the thrust force induced by jet flow at the design basis pipe break location should consider: (1) the initial pulse, (2) the thrust dip, and (3) the transient function.

b. A steady state forcing function can be used when conditions as specified in e below are met. The function should have a magnitude not less than

$$T = KpA$$

where

p = system pressure prior to pipe break
A = pipe break area, and
K = thrust coefficient.

Acceptable K values should not be less than the following:

(a) 1.26 for saturated steam, water and steam/water mixture

(b) 2.00 for subcooled water-nonflashing.

c. A pulse rise [illegible] not exceeding one millisecond should be used for the initial pulse, unless longer crack propagation times or rupture opening times can be substantiated by experimental data or analytical theory.

d. The transient function should be provided and justified. The shape of the transient function, IV a.(3) above, should be related to the capacity of the upstream energy reservoir, including source pressure, fluid enthalpy, and the capability of the reservoir to supply high energy flow stream to the break area for a significant interval. The shape of the transient function may be modified by considering the break area and the system flow conditions, the piping friction losses, the flow directional changes, and the application of flow limiting devices.

e. The jet thrust force may be represented by a steady state function, b above, provided the following conditions are met:

(1) The transient function, IV a.(3) above, is monotonically diminishing.

(2) The energy balance model or the static model is used in the analysis. In the former case, a step function amplified to the magnitude as indicated in II.a(2) is acceptable.

(3) The energy approach is used for the impact effects of the unrestrained piping.

(3) elastic and inelastic deformation of piping and/or restraint and

(4) limiting boundary conditions.

e. The allowable design strain limit for the restraint should not exceed 0.5 ultimate uniform strain of the materials of the restraints. The method of dynamic analysis used should be capable of determining the inelastic behavior of piping-restraint system response within these design limits.

f. A 10% increase of minimum specified design yield strength (S_y) may be used in the analysis to account for strain rate effects.

g. Dynamic analysis methods and procedures should consist of:

(1) a representative mathematical model of the piping system or piping/restraint system,

(2) the analytical method of solution selected,

(3) solutions for the most severe response among the design basis breaks analyzed,

(4) solutions with demonstrable accuracy or justifiable conservatism.

h. The extent of mathematical modeling and analysis should be governed by the method of analysis selected among those specified by these criteria.

II. Acceptable Dynamic Analysis for Restrained Piping Systems

a. Acceptable Models for Analysis for ASME Class 1, 2 and 3 piping systems are:

(1) Lumped-Parameter Analysis Model; Lumped mass points are interconnected by springs to take into account inertia and stiffness effects of the system, and time histories of responses are computed by numerical integration to account for gaps and inelastic effects.

(2) Energy-Balance Analysis Model; Kinetic energy generated during the first quarter cycle movement of the ruptured pipe as imparted to the piping/restraint system through impact is converted into equivalent strain energy. Deformations of the pipe and the restraint are compatible with the level of absorbed energy. For applications where pipe rebound may occur upon impact on the restraint an additional amplification factor of 1.5 should be used to establish the magnitude of the forcing function in order to determine the maximum reaction force of the restraint after the first quarter cycle of response. Amplification factors other than 1.5 may be used if justified by more detailed dynamic analysis.