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APPENDIX I.A

POSTULATED PIPE FAILURE ANALYSIS OUTSIDE CONTAINMENT

In AEC-DOL's letter to NSP of February 9, 1973 (Mr. Giambusso to Mr. Dienhart) it was requested that additional information was required for the Staff to evaluate Amendment No. 28.

The information in this Appendix is in response to the above request for information.

I.A.1 PLANT MODIFICATIONS

1.A.1.1 Structural

The tentative structural modifications to Prairie Island are mainly restricted to the south corner in the vicinity of Steam Generator #11. It is planned to isolate this area from the remainder of the Auxiliary Building by a new wall. The exterior walls will be provided with blowout panels to limit the pressure rise. Another modification will be to isolate the ground floor area from the rest of the building.

New Wall

The new wall will be located as shown in Figures I.3-1, 1.4-1, and I.A-3. The penetrations required have been identified as shown in Figure I.A-4. There will be a flexible seal between the wall and the Shield Building wall to limit leakage into the Auxiliary Building from this area. This design will preclude leakage in excess of 100 lbs/sec which is equivalent to a critical crack in the main steam line within the Auxiliary Building. This wall will be built to withstand seven (7) psi, the largest anticipated pressure.

Exterior Wall Modifications

The exterior walls have been analyzed to determine the maximum areas that can be removed without adversely effecting the required strength. Tentative elevations and sections are shown in Figures I.A-5 & 6. The panels will release the pressure at 3 psid limiting the internal pressure to 6.7 psid. The blow out panels have a total area of 500 sq. ft. and start blowing out at 3 psid.

Ground Floor

The ground floor compartment (Compartment E, Figure I.A-18) will be isolated from the rest of the Auxiliary Building by enclosing the stair wells (45 sq. ft.) and about 75 sq. ft. of miscellaneous grating. The differential pressure anticipated under the worst conditions is less than 1 psi.

I.A.1.2 Mechanical

Based on the criteria as stated in Appendix I it has been concluded that no changes in pipe routing of any of the high energy lines will be required. All protective actions required can be obtained by local action (i.e. guard pipe isolation, etc.).

The remainder of the high energy lines within the criteria in addition to the Main Steam and Feedwater are shown on the Isometric Drawings as follows:

Figures I.A-1 - Steam Generator Blowdown
I.A-2 - CVCS Letdown Line
I.A-3 - Auxiliary Feedwater Steam Turbine Line.

All figures identify the locations of breaks with respect to the criteria as given in I.1.

The South compartment does not require any mechanical modifications. Isolation from the rest of the Auxiliary Building and blowout panels preclude any further fixes in this compartment. There are no other locations on the Main Steam lines in the Main Auxiliary Building where double-ended breaks can occur (see Figure I.3-1). Only brach connections remain to be protected. Typical branch line guard pipe designs that will be applied to the Main Steam are shown in Figures I.A-7 thru I.A-10.

At the Main Steam Dump valves, located near the North wall of the Auxiliary Building, a slightly different approach will be used to ensure that problems from pipe whip and jet impingement on a branch break are controlled and minimized. The proposed modification is shown in Figure I.A-11.

Another design break location is where the Main Steam line from Steam Generator #11 crosses column Row G, at the elbow, outside the Auxiliary Building. In order to assure that a minimum amount of steam will enter the Auxiliary Building, either the method in I.A-12 or I.A-13 will be used.

Besides branch breaks, it is also contemplated to use guard pipes for jet impingement protection. Examples of an elbow guard pipe are shown in Figures I.A-15 and I.A-16.

Another example of protection is a reduction in pipe at a branch as shown in Figure I.A-14.

In the design of the guard pipe used for the branch line connections, the pipe will be able to withstand the full steam pressure of the line (1075 psi for the MS). Guard pipe for jet impingement does not require this strength and will be sized accordingly.

I.A.1.3 Electrical and I&C

No instrumentation requires relocating. Those motor starters in the Motor Control Center (MCC) in Compartment B (Figure I.A-18) necessary for the equipment listed in Tables I.3-1 and I.4-1 will be moved to Compartment E, precluding any environmental effects.

I.A.1.4 Pipe Restraints

Very few new pipe restraints will be required. On Steam Generator #11 main steam line it is presently planned to locate a pipe restraint in the new compartment, one along column Row 7 and one on column Row G. On Steam Generator #12 main steam line only one at G will be required. The restraints at G will prevent any reflection of a steam line break in the Turbine Building back into the Auxiliary Building.

I.A.1.5 Seals

In order to preclude the environment at line or branch ruptures or critical cracks from affecting the Control Room, Relay Room, and any other sensitive areas, seals will be provided on doors and penetrations. There are no doors into these areas from the Auxiliary Building. The Turbine Building pressure build up after a line break is only a few inches of water because of its large volume. The MS pipe lines are far enough away from the doors of these rooms (greater than 12 feet in all cases) that the direct pressure on these doors will be less than 2 psi under all conditions (Figure I.A-20).

I.A.1.6 Ventilation

The Control Room, Control Room Ventilation Equipment Room, the Relay Room, and the Control Rod Drive Equipment Room are isolated by walls from the rest of the Auxiliary Building precluding direct steam leakage. The only openings are doors and penetrations for piping etc. Analyses show that no structural modifications are required to prevent the adverse steam environment from entering these premises. As stated in the previous section, seals on the doors will adequately control the steam input from entering from a line rupture.

Auxiliary Building ventilation duct work is presently a square configuration. If upon further pressure analyses the differential pressure should be found to exceed the structural stress of this ducting, circular piping will be substituted.

Control Room Ventilation

The Control Room has its own independent air supply. Air is supplied through the Auxiliary Building roof at columns G6 and H14 and ducted at Elevation 764'-0" and 768'-0" respectively to the Control Room Ventilation Equipment Room. There is heated, filtered, humidified, etc., and is ducted through the slab into the Control Room and ducted through the slab into the Relay and Computer Rooms. The post incident environment in the Control Room will be maintained unaffected with regard to temperature, humidity, and airborne activity. Therefore the plant operators will not experience any adverse environmental or health hazards and normal Control Room occupancy is not affected.

I.A.1.7 Shield Building Seals

The bellows similar to those used on the penetration from the Auxiliary Building to the Shield Building annulus have been tested at the Kewaunee Reactor site with up to 20 psi differential pressure. In no case was a rupture observed. Based on this test data it is concluded that at a maximum temperature of 233°F, for less than two minutes and a differential pressure of less than 7 psi no problems will be encountered.

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I.A.2 STRESS CALCULATIONS

Stress analyses were made on the high energy lines of concern. On the main steam line only one point exceeded the $0.8(S_A + S_H)$ stress level. This point is treated as a potential double ended break. In the main steam line there was only one other stress point that was within 10% of $0.8 (S_A + S_H)$ (equal to 35,000). On no other high energy lines was there any stress point found within 10% of the $0.8(S_A + S_H)$ level. To meet the pipe whip criteria, a minimum of two intermediate points between terminal points, the two highest stress points available were picked as design break locations. The results of the analysis are shown in Tables I.A-1 thru I.A-4. These points have been identified on the isometric drawings.

Design basis break locations were not choosen at the upper tee connection or at the valve to header connection for the safety valve stations and atmospheric steam dump valve stations because the normal operational stress levels are insignificant with respect to the already low stress levels at which design basis breaks have been postulated in the main run pipe.

The safety valve stations for the number 11 (south) and number 12 (north) steam generators are almost identical in design and configuration. The only difference being that the steam supply to the steam driven auxiliary feedwater pump branches off of the upper tee section of the south safety valve station while the north branch connection is off of the main run of the steam line.

The maximum stress level in either safety valve header at any point other than those already picked as design basis break locations is less than 50% of the lowest design basis break location stress level for any intermediate or terminal point on either associated run of pipe.

The atmospheric steam dump valve station are identical in design. And although their orientation with respect to the main steam line is slightly different, the resultant stress levels are of the same magnitude and less than 40% of the lowest design basis break location stress level for any intermediate or terminal point on either associated run of pipe.

Although no additional design basis break locations have been picked above those indicated, a critical crack will be postulated and protected for where required.

I.A.3 COMPARTMENT ANALYSES

I.A.3.1 DESCRIPTION OF AUXILIARY BUILDING STRUCTURES

Compartment Volumes and Openings

The part of the Auxiliary Building through which the principal high energy piping systems pass is a concrete structure designed for Class I seismic and is the boundary of the Category I Special Ventilation Zone. Tornado resistant walls and shielding walls form much of the boundary. The part of the main Aubiliary Building associated with Unit #1 is structurally partitioned into six compartments by the floors and walls required to accommodate equipment and components of various systems. These volumes are vented to each other through grating openings and stairways. Figure I.A-18 depicts an exploded view of the Unit #1 compartments and the important parameters of the subdivided volumes used in the prediction of the pressure and temperature transients.

Compartment Pressures and Temperature

A revised CONTEMPT code was used to predict the pressure-temperature response of the Category I Zone with its associated leakage paths to adjacent volumes.

The model assumes that a steam line break accident can be separated into phases, such that the results of the analysis of one phase serves as the conditions of the time-dependent input to the next phase. Thus, the model is only concerned with the pressure and temperature in the Category I Zone structure. The computer program input provides for the description of the steam line blowdown characteristics. The Category I Zone volume is separated into a liquid region and vapor region. Each region is assumed to have a uniform temperature, but the temperatures of the two regions may be different. The Category I Zone is represented as a heat-conduction structures whose behavior can be described by the one-dimensional multi-region heat-conduction equation.

The calculation proceeds as follows: The initial atmosphere conditions are determined from ambient pressure (14.7 psia), temperature ($80^{o}F$), and 30% relative humidity. All heat sinks are initially at $80^{o}F$. Time advancement is started by evaluating the steam mass and energy input rates at the mid-point of a time interval, multiplying by the time interval, and adding these increments to the current amounts in the zone vapor region. Heat losses or gains to the heat conducting sections are estimated by using the heat transfer rates from the previous time step or the steady state conditions for the initial time step. Pressure and temperatures of the liquid and vapor regions are then calculated from the mass, volume, and energy balance equations. These new temperatures are used for the boundary conditions for the transient heat-condition solution. The resulting heat transfer rates for the end of the time step are average with the heat transfer rates at the beginning of the time step to correct the previous estimate of the energy in the containment volume. Mass, volume, and energy equations are then solved for the second time for the pressure and temperatures within the zone volume.

These conditions are then used as the initial conditions for the next time step.

The code considers leakage past the Category I boundary. The pressure outside the Category I boundary is assumed to remain at 14.7 psia. Heat removal by fan-coil units in the Category I Zone is assumed to begin 60 seconds after the pipe break occurs. The pressure and temperature results from the compartments X and Y are given in Figures I.A.-19 and I.A-20. The maximum pressure for any of the other compartments is less than 1 psi under the most adverse conditions. The maximum temperature, without any fan coil cooling for any compartment is 220^{o}F. Compartment E is not affected since it is isolated from any adverse atmosphere.

I.A.3.2 STRUCTURAL CAPABILITY TO WITHSTAND PRESSURE

To determine the capability of the Auxiliary Building to withstand forces in addition to those imposed by the support of equipment, pipe, ducts, and electrical cable tray, an additional equivalent static analysis of the South compartment floor beams, floor slabs and walls was made. The analysis considered taking the members from their working condition to 0.90 f_y of the reinforcing bars and 0.85 f'_c for the concrete.

The results of the analysis showed that the reinforced concrete members in the South compartment Y have a minimum residual load capacity of 7.0 psig and the members in South compartment X have a minimum residual load capacity of 5.0 psig. Therefore, it is concluded that the potentially affected South portion of the Auxiliary Building can withstand the imposed calculated pressures without causing a structural failure.

I.A.3.3 Jet-Impingement Pressures and Temperatures

The basis for calculating the jet impingement pressures was given in I.11. A computer program to calculate the temperatures and pressures was written to give the forces and temperature with distance. The result of this analysis are given in Figures I.A-26 through I.A.-26. These include only the Main Steam and FW since the rest of the high energy lines will not create a problem.

I.A.4 ENVIRONMENT

I.A.4.1 Location of Required Equipment

All the equipment required to bring the reactor to a cold shut down after a steam line incident, and their location in the compartments (Figure I.A-18) are found in Tables I.3-1 and I.4-1.

I.A.4.2 EQUIPMENT LOCATION AND CAPABILITY

The Safety Injection Pumps 11 & 12 (21 & 22) are located in Compartment "E" which is bring isolated from the postulated accident environment as stated above. These are 4160 V. motors whose breakers are located in the Class I corridor in the Turbine Building. The motors have Type "B" insulation capable of operation at a total temperature of 130°C (266°F). The auxiliary feedwater pumps 11 & 12 are located in the Class I corridor. The diesel cooling water pumps 12 & (22) and the cooling water pump strainers 11, 12 (21 & 22) are located in the screen house. Diesel Generators 11 & 12 with their auxiliaries are located on the ground floor outside the Auxiliary Building. The Control Room Ventilation Systems 121 & 122 are located in separate rooms at the compartment "A" level but remote from the compartment area. The Reactor trip breakers and the 480 volt buses 110, 120 (210 & 220) are located on the compartment "B" level but are in separate rooms which have no access to the Auxiliary Building hence would not be subject to an adverse environment. Batteries 11, 12, (21 & 22) and the 4160 volt buses 15, 16, (25 & 26) and their respective switch gear are located in the Class I corridor in the Turbine Building. The starters for valves 32079, (32182); 32080, (32183); 32081, (32184) & 32082 (32185) are located in Compartment "E". The starters for valves 32023, (32038); & 32024 (32029) now located in Compartment "B" will be relocated to compartment "E". The starters for valves 32025, (32030); 32027, (32026) & 32264 (32265) are located in the Class I corridor in the Turbine Building.

Discussion of Equipment Capability to Continue Operate During Incident

Motors

All motors have been purchased with an insulation class of Type "B" or better. Type "B" insulation consists of Mica, Asbestos, Fiber Glass, other inorganic materials and synthetic resins capable of operation at a total temperature of 130°C (266°F)

Note: total Temperature includes expected temperature rise above ambient due to electrical current passing through the insulated wiring in question. Total temperature is important in that it is the maximum value that the insulation can be exposed to without degradation of the insulation. As a rule of thumb each 10°C of temperature rise above the specified total temperature will approximately halve the effective life of Class "B" insulation. Degradation of the overall life of the motor after the accident is not of prime concern. There is no immediate problem of the device failing to function during the accident and for a reasonable time after.

Solenoid Valves

All solenoid valves have been purchased with an insulation class of Type "H". Type "H" insulation consists basically of silicones capable of operating at a total temperature of 180°C (356°F).

Electrical Cable

All Power and Control cables used in the Auxiliary Building has been purchased from the same vendors and to the same specifications and quality control procedures as power and control cables used inside containment and have been prototype tested to the same environmental condition as predicted inside containment.

5KV Power Cable and 600 Volt Control Cable, has been supplied by the Kerite Company. This cable has been tested to total temperature of 159°C (318°F) with no adverse effect by a steam atmosphere.

480 volt power cable has been supplied by the Okonite Company. This cable has been tested to a total temperature of 142°C (287°F) with no adverse effect by a steam atmosphere.

Motor Starters

Motor Starters are drawouts mounted in centralized motor control centers which are reasonably drip-proof but not sealed from gradual penetration of temperature and humidity. Individual components of a motor starter that might be affected by adverse environmental conditions have been analyzed as follows:

(1) Motor Starter Coils and Control Transformers

All operating coils and control transformers for motor starters are encapsulated in epoxy resin and will be capable of operating at a total temperature of 65.6°C (150°F) and being encapsulated are not affected by 100% humidity.

(2) Circuit Breakers

All circuit breakers included with motor starters will experience small reduction of their trip setting with ambient temperatures above 50°C (122°F). Since these trip settings are for short circuit protection not overload protection, an ambient increase to 65.6°C (150°F) will not cause false tripping of circuit breakers due to operation of motors during accident.

(3) Thermal Overload Relays

Due to their method of operation, thermal overload relays are temperature sensitive. An investigation was determined that the effect of predicted temperature and duration during an accident on the overload relays may falsely operate them so the presently supplied relays will be bypassed during the period of high ambient temperature.

Locally mounted fuses in the area exposed to high environment temperatures will not falsely operate due to environment temperatures predicted in their respective locations.

All Electrical Equipment-Pressure Effects:

Analysis of electrical equipment in the Auxiliary Building disclosed that no electrical equipment will be damaged or impaired by the pressure effects postulated for the accident.

I.A.4.3 INSTRUMENTATION

The instruments required for the steam and feedwater break as identified in Tables 1.3-1 and 1.4-1, will be modified by Forboro Company to replace the following parts in place of the standard parts to permit the instrument to function under a pressure (90 psig) and temperature (318F) condition.

DESCRIPTION

Pressure Seal Assembly
Amplifier
Cover O'Ring
Zero O'Ring
Detector Assembly
Armature Assembly
Base Assembly
Adhesive

This modification is the same as applied to instruments inside containment. The instruments have had prototype testing to the following conditions. 318°F at 90 psig for 1 hour then 288°F at 56 psig for 12 hours during this time all units continued to function with the output errors generally 5% with a few exceptions. The complete result of this test are incorporated in Forboro Company test report Q9-6005-April, 1971.

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TABLE I.A-1

SYSTEM : MAIN STEAM

$0.8\ S_A =$ 21,000psi

$0.8(S_A + S_H) =$ 35,000psi

CALCULATED STRESSES*
(PSI)

LOCATION	TERMINALS	LOCATION	INTERMEDIATE**
		ID	25128
IF	20180	IE	26608
	8862	IB	33609
IC	22762	IA	36668***
IE	14466	IIB	22674
IIC	17525	IIA	18494

*Calculated combined stress levels at break locations

**These stress levels represent the highest stress points in the system.

***The thermal stress level at this point exceeds $0.8S_A$

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TABLE I.A-2

SYSTEM : FEEDWATER

$0.8\,S_A =$ 18,000 psi

$0.8(S_A + S_H) =$ 30,000 psi

CALCULATED STRESSES*
(PSI)

LOCATION	TERMINALS	LOCATION	INTERMEDIATE**
VII A_o	12553	VII B	19855
VII E		VII C	19934
VII A_4	13124	VII F	15264
		VII G	16794
VII A_4	15471	VII A_3	11396
VII A_1	8376	VII A_2	13217
VII J_o	10411	VII J_1	12974
VII J_5	14473	VII J_2	10461
VII H_o	8796	VII H_1	13188
VII H_3	13043	VII H_2	9394

*Calculated combined stress levels at break locations

**These stress levels represent the highest stress points in the system.

TABLE I.A-3

SYSTEM : AUXILIARY STEAM SUPPLY

$0.8\ S_A =$ 18,000 psi

$0.8(S_A + S_H) =$ 30,000 psi

CALCULATED STRESSES*
(PSI)

LOCATION	TERMINALS	LOCATION	INTERMEDIATE**
V A_1	15653	V A_2	14925
V C_1	11353	V B	14739
V E_3	26507	V E_1	12860
		V E_3	13786
V C_4	14589	V C_3	14775
V D	14941	V C_2	15380
V E_6	8047	V E_4	9843
	5343	V E_5	9249

*Calculated combined stress levels at break locations

** These stress levels represent the highest stress points in the system.

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TABLE I.A-4

SYSTEM: CVC LETDOWN

$0.8\ S_A =$ 21500psi

$0.8(S_A + S_H) =$ 32500

CALCULATED STRESSES*
(PSI)

LOCATION	TERMINALS	LOCATION	INTERMEDIATE**
VIII A_o	6107	VIII A_1	7918
VIII A_3	5639	VIII A_2	10391
VIII C_1	3747	VIII B_o	5862
		VIII C_o	5492

*Calculated combined stress levels at break locations

**These stress levels represent the highest stress points in the system.

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