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.

The new concrete block wall will be designed in accordance with the requirements for seismic Class I structures, as defined in Appendix B. The sources of load will be those combinations listed in the table of loading conditions (Table I.A-1). The allowable stresses are those permitted by the Uniform 31

31 Building Code, Chapter 24 "Masonry", with load factors permitting f_s=0.90Y.S. and $f_m = 0.85f'_m$. Seismic loads are based on the accelerations for specific mass points, as identified in the earthquake analysis by J.A. Blume and associates, engineers, report JAB-PS-04.

The flexible seal between the new wall and the shield building will be similar to Figure I.A.-4.1 "Joint Between Auxiliary Bldg. & Reactor Bldg. Wall." The sealant is a two-component polysulfide with properties comparable to that indicated on "SPEC-DATA SHEET 07900" of the THIOKOL CHEMICAL CORPORATION. From that sheet the peel adhesion strength is 10 lbs. per inch minimum. At a temperature of 212^{o}F, sustained for 1 week, the sealant shows a 15% maximum weight loss with no cracking, chalking, or bubbles. With this pressure and temperature, the sealant will be satisfactory to limit leakage.

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. The blow-out panels have a total area of 500 sq. ft.

The design of the blow-out panel bolts to fail and vent the openings, as indicated in Figures I.A-5 & 6, is based on knowledge of the fasteners failing in a predictable range of loads. The blow-out panels in the turbine building use bolts that failed in shear with strengths documented in H.M. Harper Company "Quality Control Department Technical Services"
31 - Report No. TS-7003, dated March 11, 1970.

The particular design for the present blow-out panels may use fasteners which fail in tension rather than shear. Tension fasteners by Elwin G. Smith & Co., Inc., along with those suggested by the paneling manufacturer, will be evaluated for predictability of failure before a final decision as to choice of fastener will be made.

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

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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 only double-ended break that is postulated in the Auxiliary Building occurs in compartment "Y" (Figure I.3-1 and I.A-18). The MS line and MS Relief branch line will be encapsulated to limit the steam release in this area. 31

Only branch 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 at the elbow, where the Main Steam line 31 from Steam Generator #11 crosses column Row G, 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, the use of impingement barriers for jet impingement protection is being considered. Examples of an elbow barrier are shown in Figures I.A-15 and I.A-16.

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

In the guard pipe design used for the branch line connections, the guard pipe will be able to withstand the full steam pressure of the line (1075 psi for the MS). An impingement barrier 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.

No cables or cable trays require re-routing. In compartment "X", where the cables and cable trays are in the vicinity of theMS line,
31 an impingement barrier will protect the cable from any possible jet effect. In no other compartment is jet impingement a problem.

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.

The ventilation ducts servicing compartments X and Y will be modified to include redundant dampers in each duct to preclude any interchange of adverse environment between the Auxiliary Building and these compartments.

The Class I portion of the Turbine Building, which includes the auxiliary feedwater pump rooms, battery rooms, and the 4160 v switchgear rooms, will be similarly isolated from any adverse environment resulting from postulated high-energy pipe ruptures in the Turbine Building by 31
the inclusion of redundant dampers in each ventilation duct penetrating its boundary and by the sealing of all penetrations.

Each of the aforementioned dampers is automatically closed by the signal from an RTD set-pointed at 120°F and located in the duct.

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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 where the air 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.

The main control room will be automatically isolated from the adverse environment resulting from any of the postulated high-energy pipe ruptures by the closure of redundant ventilation dampers and by the prior sealing of all penetrations into the heating and ventilating room, control room, and relay room. These compartments are provided with redundant fans and air conditioning systems to maintain the atmosphere between 70-75F, dry-bulb. Pressure and leakage data from prototype tests is available from the manufacturer.

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. These tests showed that, with differential pressures of up to 20 psi internally, no rupture occurred. Tests with external pressurization equal to 50% of the internal differential pressure loadings were also conducted without any failures. The calculated external pressure difference these bellows will see is less than 3 psi at a temperature of less than 210°F for less than 2 minutes. Since the typical tensile strength of this material is 1443 psi, temperature capability up to 325°F, and clamping capability greater than 20 lb. loading, no problems are foreseen for these bellows.

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 Figures I.A-21 through I.A-36.

Design basis break locations were not chosen 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 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 stations 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

1.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 Auxiliary 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 provided for the description of the steam line blowdown characteristics.

The blowdown rate and duration depend on the break location and size. In the case of small breaks, the steam pressure, flow, and enthalpy are assumed to be constant due to continuous heat transfer from the reactor coolant system. Exposed steel and concrete are considered as heat sinks, and individual fan-coil units and normal ventilation are used for heat removal when available.

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 structure 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°F), and 30% relative humidity. All heat sinks are initially at 80°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-conduction 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 tempperatures 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. Since pressure and temperature peaking occurs well before this time, no credit has been taken for fan-coil cooling. The pressure and temperature results from the compartments X and Y are given in Figures I.A-19 and I.A-20. The maximum pressures and temperatures from the largest break possible for the rest of the compartments is as follows:

Compartment A - .75 psig and 185°F, Compartment B - 1.1 psig and 265°F, Compartment C - less than .5 psig and 170°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 load combinations used are listed in Table I.A-1.

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 psid and the members in South compartment X have a minimum residual load capacity of 5.0 psid. 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 Section I.11. A computer program to calculate the jet forces and temperature with distance was written. The results of this analysis are given in Figures I.A-37 through I.A-99. These include only the Main Steam and Feedwater lines since the rest of the high-energy lines will not create a problem.

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Pressure:

Trays bearing cables associated with equipment (listed in Tables I.3-1 and I.4-1) required to function to bring the reactor to a cold shutdown after a steam line incident will be protected from jet impingement forces. Calculations show that the cables and trays, as now installed, will not be prevented from needed functions by jet forces of 2 psi or less. When calculated forces exceed 2 psi, the cables and trays will be protected by adequate shields.

Temperature:

Cables required to function, as noted in the previous paragraph, have been tested with no appreciable degradation when exposed to steam temperatures of 280°F for a minimum of two hours. Industry standards for such insulated cables specify it shall not lose its operability if exposed to temperatures of 260°F for a time not exceeding 100 hours per year, for 5 such periods during the life of the cable.

When the temperature of steam jets exceeds 280°F at a point of impingement on these cables, adequate shields will be used to prevent the cable from being exposed to temperatures exceeding 280°F.

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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 **its** location in the compartments (Figure I.A-18), **is listed 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 **will be** 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.

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Discussion of Equipment Capability to Continue Operating 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 **there after.**

Motors listed in Tables I.3-1 and I.4-1 are not located in compartments that will have an adverse environment and prototype testing is not required.

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).

All solenoid valves exposed to an adverse environment will be encased and tested in an environmentally- qualified chamber.

Electrical Cable

All Power and Control cables used in the Auxiliary Building **have** 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 have been supplied by the Kerite Company. This cable has been tested to total temperatures 138°C (280°F) at 50 psia in a steam evironment for two hours and 214°F at 23 psia in a steam-air environment for 436 hours with no failures. 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) at 40 psig for 480 hours with no adverse effect by a steam atmosphere.

Terminal connections for cables associated with any device listed in Tables I.3-1 and I.4-1 which are located in areas where a steam environment can exist will be sealed with General Electric 7.4010 epoxy varnish.

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. All required motor starters will be located outside the areas where a steam environment can exist.

Fuses

Locally mounted fuses in the area exposed to high environment temperatures will not falsely operate due to environment temperatures predicted in their respective locations. Where fuses for required equipment are located in an area exposed to a steam environment, the fuses will be encased and tested in an environmentally-qualified chamber.

The instruments required for all the steam and feedwater break and are in areas which will see a steam environment, as identified in Tables I.3-1 and I.4-1, are supplied by Foxboro. These instruments will be modified by Foxboro Company to replace the following parts in pace of the standard parts to permit the instrument to function under a pressure (90 psig) and temperature (318F) condition:

hours in a steam environment, 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 Foxboro Company test report Q9-6005-April, 1971.

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^{O}F at 90 psig for 1 hour then 288^{O}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.