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Memorandum

TO : S. Levine, Chief & K. Goller
Test & Power Reactor Safety Branch, DRL

DATE: November 25, 1964

FROM : A. B. Holt, Chief & R. Impara
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SUBJECT: STEAM GENERATOR: PEACH BOTTOM ATOMIC POWER STATION

This memorandum is based on information contained in "Final Hazards Summary Report, Peach Bottom Atomic Power Station, Volume V(A) Plant Description and Safeguards Analysis (Annex F)".

The steam generators are built to the following performance specifications:

Helium side:

Flowrate	234,200 lb/hr
Pressure	329 psig
Temperature in	1367°F
Temperature out	628°F

Steam side:

Flowrate	197,500 lb/hr
Pressure	1550 psig
Temperature Saturated	660°F
Temperature Superheated	1005°F

The steam generators (2) are of the shell and tube type, the shell being cylindrical in shape, vertically erected with the tube plate at its upper head. The tubes are of the hair-pin type, suspended in hanging position from the tube plate. The tube plate has one singularity which prompted this study. One part of it has been designed in the shape of a "well", 21 inches deep and 18 inches in diameter, see C. F. Braun & Company drawing number 53856-D-108 and 53856-D-110. This part of the plate is made from SA-167-type-304 while the rest of the plate is made from SA-105-11 with SS 304 overlay for the superheater inlet section.

A failure analysis of this particular structure can best be made by comparing it with a primary coolant pipe, the rupture of which is considered the maximum credible accident for a PWR. The main parameters which one has to compare are:

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A. The Design

In a PWR pipe-design one will have a stainless steel pipe welded to a ferritic nozzle on the reactor vessel. This is similar to the weld design used in the manufacturing of the "well" where a stainless steel transition piece is welded to the small tube plate of stainless steel at the bottom and to the ferritic tube plate at the top. We believe that the two designs are basically analogous.

B. The Temperatures

In a PWR pipe one will have temperatures of the order of 500°F-550°F which causes no problem. In the case of the "well" under consideration one has temperatures of the order of 850°F-950°F. This coincides with the temperature zone where sensitizing of the 304 stainless steel starts to take place. Hence, from a temperature point of view the "well" structure under consideration is at disadvantage.

C. The Stresses

In a PWR pipe the stress level is relatively modest, of the order of 20,000 psi. In the structure under consideration the stress level has been given as 45,000 psi. Hence, the "well" structure is at a disadvantage.

D. The Temperature Fluctuations

In a PWR pipe the temperature transients are of the order of 70°F/hr. with a total span of approximately 500°F from shutdown to start-up. In the structure under consideration the temperature transients will be rapid and frequent, a situation which is inherent in the operation of superheaters. Hence the "well" structure is at disadvantage.

E. Corrosion Mechanisms

Nowhere in the primary coolant piping of a PWR is there any possibility of solids accumulation while in the case of the "well" a definite mechanism for accumulation of dirt has been designed into the structure. The mechanism is as follows: at the superheated end is a channel, welded to the lower tube plate, forming an annular gap having its opening towards the saturated steam side. Inasmuch as the saturated steam contain from 0.1 - 0.5% moisture and the moisture contains 0.1% solids carry-over, a steady accumulation will take place in the gap. This solid (salt) accumulation will be in contact with stainless steel which could fail by stress corrosion cracking. This tendency is the more pronounced because the stainless steel weld may have become sensitized by the high temperature.

From the above we conclude that the probability of failure of the well structure is considerably higher than the probability of failure of a nozzle-pipe transition section in a PWR loop.

The Consequences of Failure:

The failure will give raise to an opening of area A (in^2) allowing steam to pour into the helium side. Assuming saturated steam the formula which gives its flowrate (Napiers formula) is written

$A_{max} \doteq 50\ in^2$

$$w = A \cdot \Delta P/70$$

where

$W = \frac{50 \times 1000}{70} = 720\ lb/sec$

w = flow rate in lbs/sec.
A = area
Δp = pressure = 1500 psi ~1000

The area must now be assumed. Considering that the well has a circumference of 56 inches and assuming that a crack will at least result in an opening of 1/10 inch the area becomes 5.6 in^2. The calculated flowrate is hence 120 lbs/ of steam per second. This flow can not be stopped but will continue until the steam generator has emptied itself into the steam generator shell. Steam will mix with the Helium and be circulated to the core where the following reaction will take place: X

$$C + H_2O = CO + \frac{1}{2}H_2$$

Because it will take 11 seconds before the helium loop can be valved off between the core and the steam generator, hundreds of lbs. of steam may pass through the graphite core, burning part of it away and releasing fission gasses from the matrix. These fission gasses will be circulated back into the steam generator before this can be valved off from the core. For a moderate size crack it seems feasible to have safety valves and/or other relief valves with sufficient relief areas to keep the pressure in the primary loop down, but for larger size breaks the adequacy of any relief devices seems questionable. If wanted we may provide some preliminary calculations concerning this problem.

We can not refrain from pointing to the fact that had the designer spotted the corrosion difficulties he could have reversed the "well", i.e. making it stand up from the tube sheet, hence avoiding dirt accumulating crevices.

cc: E. G. Case, Asst. Dir., DRL
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