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Memorandum

TO : The Files
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DATE: JAN 12 1966

FROM : J. Telford, Research & Power Reactor Safety Branch, DRL J J Telford

SUBJECT: INDIAN POINT II CONTAINMENT PRESSURE AS A FUNCTION OF STEP ENERGY INPUTS RESULTING FROM THE ZIRCONIUM WATER REACTION - DOCKET NO. 50-247

Introduction

The purpose of this calculation is to show the effect of the zirconium-water reaction on the pressure in the containment following the maximum credible accident. From this result we can determine the extent of reaction that can be tolerated without exceeding the design pressure of 47 psig. No engineered safeguards are assumed to be operative and no credit is given for heat transferred to the containment sinks. The results obtained are compared with the information included in the preliminary safety analysis report.

Discussion

The Indian Point II containment vessel will be a steel lined, concrete reinforced vertical cylinder with a hemispherical dome, a flat base and a total free volume of 2.61×10^6 ft^3. The applicant has indicated that the peak pressure resulting from the coolant blowdown following a 29 inch pipe severance is 40.5 psig and the pressure with no engineered safeguards operating increases to about 42 psig which is well below the design value.

The Indian Point II Safety Analysis report indicates that a total of 33% of the zirconium in the core can react without exceeding the containment design pressure. This evaluation relies upon the following conditions:

1. The hydrogen burns as it enters the containment.
2. The hydrogen is evolved according to the parabolic rate equation and burns continually for the duration of the transient (at least an hour after a 20 sec delay).
3. Ten percent of the unreacted cladding is assumed to reacted when the clad and oxide fall into the water in the bottom of the reactor vessel.
4. The heat sinks in the containment are sufficient to transfer the heat produced by hydrogen recombination after 1300 seconds and before this time only a gradual pressure rise is calculated.

We still have reservations with respect to the credibility of hydrogen accumulation or pocketing in the containment, the core temperature as a function of time following the accident, the ability of the containment sinks to transfer the heat produced by hydrogen recombination and the effect on pressure of the postulated core drop.

The calculation by the staff does not consider the rate at which the hydrogen is evolved but simply considers the recombination of hydrogen as a step input of energy. The procedure is greatly simplified by assuming that the pressure at the time of step energy input is 40.5 psig. This eliminates time dependency of our calculation and allows us to assume that the recombination energy can be added as a step any time from 20 seconds to over an hour after the accident.

Assumptions used in calculating the pressure increase in the containment were:

1. The reaction cannot start until approximately 20 seconds after the accident.
2. There is sufficient steam present to carry on the reaction.
3. The temperature of the hydrogen entering the containment is the same as the reaction temperature and is assumed to average 2500°F.
4. The heat capacities used in the calculation are the mean molal values for gases in the ideal gas state (data from D. D. Wagman, NBS). The relationship $C_v = C_p - R$ is used to determine the heat capacity at constant volume where R is the universal gas constant.
5. The heat of combustion for hydrogen producing water in the gaseous state is 1.04×10^5 Btu/lb-Mole of H_2.
6. Dalton's law of Partial Pressures is applicable and the gases are ideal when the temperature is above the saturation temperature.
7. There are 43,785 lbs. of zirconium in the core, .022 pound moles of hydrogen are produced for every pound of zirconium reacted, and there are initially 7400 lb. moles of air and 12,500 lb. moles of steam in the containment.

Using these assumptions a mathematical model was formulated and the pressure as a function of metal water reaction was calculated. The results are presented in the attached Fig. 1. The step energy input is considered for simplicity only because as long as no heat is being transferred to the sinks or out of the containment the recombination could occur over a period of time giving the same result.

Conclusion

We have shown that the energy resulting from an 8% $Zr-H_2O$ reaction introduced as a step would increase the containment pressure to the design value, and the 15% design overpressure would be reached with the step insertion of the energy from a 17.2% reaction. These limits do not consider containment cooling or containment sinks which would reduce the pressure prior to the addition of the hydrogen recombination energy and thereby increase the extent of reaction tolerable. These results are obviously too conservative since the pressure could be decreased somewhat by the above mentioned cooling before significant quantities of hydrogen could be evolved; however, the results indicated by the applicant for the no safeguards case should be carefully scrutinized to check its conservatism. A more reasonable pressure transient analysis could be performed if the following information were known:

1. The amount of hydrogen that could accumulate at various times after the accident.
2. The effect of the minimum credible degree of containment cooling due to the engineered safeguards and the containment sinks as a function of time.
3. The increase in the rate of hydrogen evolution (with no core injection) if a faster core temperature rise is possible.
4. The time and maximum extent of metal water reaction resulting from the core drop and the amount of steam produced during this process.

Attachment:
Figure 1

Distribution
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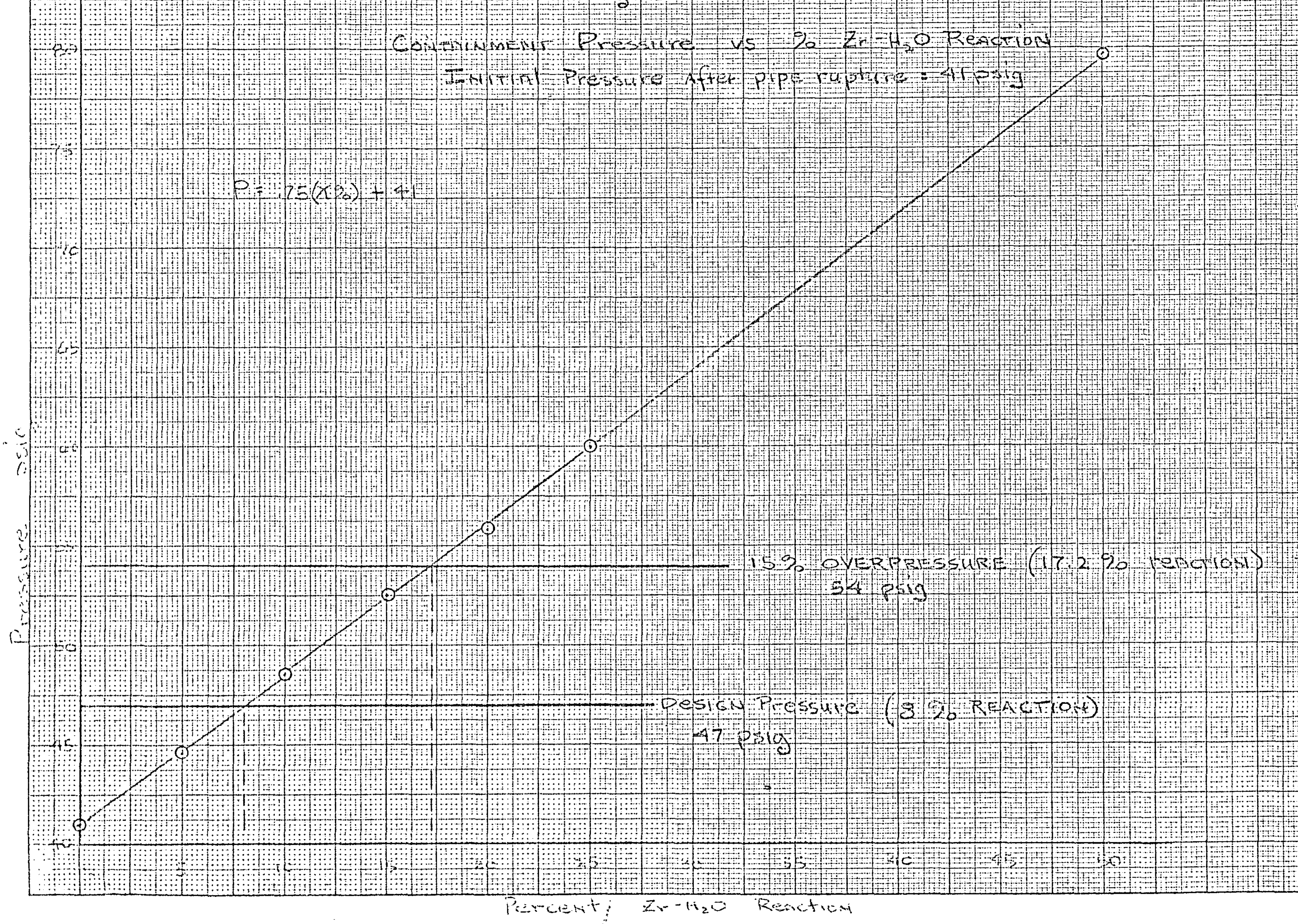
Fig 1


Containment Pressure vs % Zr-H2O Reaction
Initial Pressure after pipe rupture = 41 psig
P = .75(X%) + 41
15% OVERPRESSURE (17.2 % reaction)
54 psig
Design Pressure (8 % REACTION)
47 psig
Pressure psig
Percent Zr-H2O Reaction