REFERENCE

WANL-TMI-481

From: Engineering Mechanics

Date: February 8, 1963

Subject: A Preliminary Study
for a Destruct System

ANALYSIS REPORT

WESTINGHOUSE ASTRONUCLEAR LABORATORY

Distribution:

W. H. Esselman
W. G. Roman
M. J. Manjoine
W. H. Arnold
J. Kenney, Jr.
H. I. Kraig
C. K. Kim
F. R. Spurrier
E. I. Goodman
File (5)
Library (2) ←

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

A. P. Villasor, Jr.
A. P. Villasor, Jr.
Engineering Mechanics

fep

Approved:

M. J. Manjoine
M. J. Manjoine, Manager
Engineering Mechanics

REFERENCE

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

When the reactor is allowed to go into excursion with the cooling hydrogen shut off, the heat generated is not sufficient to raise the pressure of the gas trapped in the voids to a level comparable to the bursting pressure of the vessel, principally because of the nozzle opening. Possibilities for modifying this destruct scheme are listed for further study.

PROBLEM:

When the coolant inlet is closed and 20 megawatt is added to the core,

- (a) Will there be a pressure buildup in the vessel?
- (b) If so, will it be enough to rupture the vessel and smash the core to smithereens?

PROCESS:

1. The coolant inlet valve is shut off.
2. At the same instant, the vessel is closed momentarily at the bottom of the core.
3. Heat is added instantaneously at the core.
4. The vessel quickly reaches a common temperature.
5. Bottom closure of the vessel is suddenly removed.
6. The critical pressure at the nozzle throat is immediately attained.
7. The pressure in the vessel drops quickly to that at the nozzle throat.

ASSUMPTIONS:

1. All the voids, except those in the core, are at 1000°R and 650 psia.
2. The average conditions at the core are taken to be 3500°R @ 600 psia.
3. Gas mixing is instantaneous and there is no extraneous loss in heat.
4. There is no leakage from the inlet valve.

CONDITIONS:

a. At $t = 0^-$ sec. (Before shut-off of H_2 coolant):

Inlet H_2 : $150^\circ R$ 700 psia.

Top of Core: $1000^\circ R$ 650 psia.

Bottom of Core: $4250^\circ R$ 550 psia.

Nozzle Exit Pressure = 0

Nozzle Throat Diam. = $8\frac{1}{2}$ "

For $4250^\circ R$ @ 550 psia.: $K(H_2) = 1.2894$

$$R = 766.53 \text{ ft./}^\circ R$$

$$r_c = \left(\frac{2}{2.2894} \right)^{\left(\frac{1.2894}{.2894} \right)} = (.874)(4.45) = .55$$

$$\frac{P_e}{P_1} = 0 < .55$$

$$P_t = .55 \times 550 = 303 \text{ psia.}$$

$$w_1 = \frac{550 \times 144}{766.53 \times 4250} = .02435 \text{ lb./ft.}^3$$

$$w_2 \text{ (@ Throat)} = (.55) \left(\frac{1}{1.2894} \right) \times .02435 = .629 \times .02435 \\ = .0153 \text{ lb./ft.}^3$$

$$T_2 = \frac{303 \times 144}{766.53 \times .0153} = 3720^\circ R$$

$$V_2 = c = \sqrt{1.3027 \times 32.2 \times 766.53 \times 3720} \\ = 10^3 \sqrt{119.8} = 10,920 \text{ ft./sec.}$$

$$G = \frac{\pi}{4} \left(\frac{8.5}{12} \right)^2 \times .0153 \times 10,920 = 66.0 \text{ lb./sec.}$$

b. At $t = 1^+$ sec.:

1. Inlet $H_2 = 0$.

2. Heat Input @ Core = 20 megawatt.

COMPUTATIONS:

Core Voids = 7.14 ft.^3 (representing 24.5% of core)

All Others = 5.84 ft.^3

Density of Hydrogen in Voids:

$$(a) \text{ at Core, } w_c = \frac{600 \times 144}{766.53 \times 3500} = .0322 \text{ lb./ft}^3$$

$$\text{Wt. of } H_2 = .0322 \times 7.14 = .230 \text{ lb.}$$

$$(b) \text{ at other parts, } w_o = \frac{650 \times 144}{766.53 \times 1000} = 0.122 \text{ lb./ft}^3$$

$$\text{Wt. of } H_2 = .122 \times 5.84 = .712 \text{ lb.}$$

$$\text{Total } H_2 \text{ in voids @ } t = 0^+ \quad w_t = .942 \text{ lb.}$$

$$\text{Heat input} = 20 \text{ megawatt} = 1895.98 \text{ BTU/sec.}$$

$$(1 \text{ Kw-hr.} = 3412.76 \text{ BTU})$$

Heat Absorbed:

$$\begin{aligned} \text{By Core} &= \frac{7.14}{.245} \times (62.4 \times 2.1) \times 6(T_f - 3500) \\ &= 22,900(T_f - 3500) \end{aligned}$$

$$\begin{aligned} \text{By } H_2 \text{ (core)} &= .23 \times 3.07 (T_f - 3500) \\ &= .706 (T_f - 3500) \end{aligned}$$

$$\begin{aligned} \text{By } H_2 \text{ (others)} &= .712 \times .249 (T_f - 1000) \\ &= .177 (T_f - 1000) \end{aligned}$$

$$1895.98 = 22,900(T_f - 3500) + .706(T_f - 3500) + .177(T_f - 1000)$$

$$1896 + 80,150,000 + 2470 + 1770 = 22,900 T_f$$

$$T_f \approx 3500^\circ R \text{ (No appreciable rise in temperature)}$$

$$p = \frac{.942 \times 766.53 \times 3500}{12.98 \times 144} = 1350 \text{ psia.}$$

$$P_t(\text{Nozzle}) = .55 \times 1350 = 743 \text{ psia.}$$

@ t = 1+ sec.:

$$\text{Wt. of H}_2 \text{ in vessel} = .942 \times \frac{743}{1350} = .518 \text{ lb.}$$

@ t = 2- sec.:

$$P(\text{Vessel}) = 743 \text{ psia.}$$

@ t = 2 sec.:

$$P(\text{Nozzle}) = .55 \times 743 = 409 \text{ psia.}$$

$$T(\text{Vessel}) \cong 3500^\circ\text{R}$$

$$P(\text{Vessel}) = 409 \text{ psia.}$$

CONCLUSIONS:

On the basis of the 20 megawatt heat input at the closing of the coolant valve:

- (a) There will be no appreciable rise in temperature over the core temperature but all gas in the vessel will be brought up to the temperature of the core.
- (b) The pressure immediately rises to about twice the operating pressure but just as quickly it drops, principally because of the nozzle. Thus, no pressure buildup in the vessel is possible under these conditions. See Figure 1.

It can be shown that an increased heat input, even in the order of 1100 megawatt, cannot result in a bursting pressure for the vessel.

RECOMMENDATIONS:

In order to attain a pressure in the vessel comparable to the bursting pressure of the vessel, the following possibilities are listed for study:

1. Increased amount of hydrogen trapped in the voids.
2. Increased flow of hydrogen to create choking in the nozzle.
3. Choke nozzle by mechanical means.
4. Combinations of (1) to (3).

FIGURE 1

NRX-A REACTOR

PRESSURE OF RESIDUAL HYDROGEN

with the inlet coolant shut off

APPENDIX

Schedule of Reactor Voids

Core	= 7.14 ft. ³
Reflectors	= 2.76 ft. ³
Plenums & Shield	= 1.68 ft. ³
Support Plate	= <u>1.40 ft.³</u>
Total Voids	= 12.98 ft. ³