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TO: S. E. Beall
FROM: M. I. Lundin

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For The Atomic Energy Commission

H. R. Canale
Chief, Declassification Branch

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INTRODUCTION

The design bases proposed for the HRT pressure balancing and control systems, arrived at as a result of the meetings of the committee on pressurization control, are stated herein. Consideration is given to HRT operation at both the 5 Mw and 10 Mw levels.

The governing factor for "pressure control" can be stated as providing for the integrity of the core and pressure vessels under varying operating conditions. The inclusion of provisions to minimize the possibility of explosive mixtures in the high pressure system vapor phase is considered to be in this category.

The major components of the pressure control system were analyzed to determine their ability to provide the desired degree of protection to the core vessel.

It is recommended that provisions be incorporated in the reactor controls to provide a time delay before "normal dumps" to permit recombination of radiolytic gases. This control should be operable whenever safety considerations would permit its use, in the judgement of the operator.

The existing core vent and letdown systems are capable of limiting the overpressure to less than 200 psi at 5 Mw operation, and to somewhere between 300 - 400 psi at 10 Mw operation.

The relief system interconnecting the core and blanket is capable of passing flows that would limit core-to-blanket pressure differentials to 200 psi and blanket-to-core pressure differentials to 50 psi in case of a reactor dump. However, available rupture disc materials define the lowest attainable differential as 200 psi. Experimental work is in progress in conjunction with Black, Sivalls and Bryson to determine if titanium is a suitable substitute material.

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A "pilot-operated" type relief valve is proposed for obtaining a more positive type of core-to-blanket pressure relief.

I. Core Vessel Strength

The strength of the core vessel was reviewed on the basis of the latest information on true-stress, true-strain properties for Zr-2* and the proposed ASME Unfired Pressure Vessel Code Curves* for determining allowable external pressures. The permissible core vessel differential pressures, conservative within the limits of a code-type computation are:

Internal pressure difference = 400 psi

External pressure difference = 150 psi

Since the rate of deterioration of the core vessel from radiation and corrosion effects is not accurately known at present, it is desirable to reduce operating differentials to as low a value as practical.

II. Delay Time for Gas Destruction

An "immediate" dump or venting of system overpressure can give rise to concentrations of radiolytic gas (D_2) in the vapor phase in the order of 14% D_2 .** Although ignition may not be likely, the potential hazard (above explosive concentration of D_2) is present and both the pressurization systems and operating procedures should be designed to minimize this condition.

Recombination to safer D_2 concentrations is a function of the system copper catalyst concentration and the time delay after shutdown as illustrated in Table I.

* Personal Communication, Dr. R. G. Sturm to C. L. Segaser, March 13, 1956

** This D_2 concentration occurs at a system pressure of ~1720 psia.

It is recommended that provision be made in the reactor control systems to permit the reactor operators to set the delay time before dumping is started. The ability to set delays in the range of 1.0 to 3.0 minutes is desirable.

TABLE I
DELAY TIME VS. D_2 CONCENTRATION
(5 Mw HRT OPERATION)

Max. D_2 During Dump (%)	Recombination Before Dump (%)	at $y = 0.0019^*$ (~20% letdown) minutes	at $y = 0.0022^*$ (~10% letdown) minutes	at $y = 0.0025^*$ (~0% letdown) minutes
2	90	1.67	1.43	1.25
4	80	1.13	0.96	0.84
6	70	0.83	0.71	0.62
10	50	0.47	0.41	0.36

* Catalyst concentration y in $\frac{\text{g-mols Cu ion}^{++}}{\text{liter}}$

Note that at the 10 Mw level the required catalyst concentration for normal operation would be higher and therefore the time delays shown for recombination before dumping would be somewhat shorter.

III. Pressure Relieving Requirements

A. Core Pressure Rise After Shutdown

Conservative estimates of the core pressure rise were computed for 5 Mw HRT operation.* The values shown are based on the system liquid volume expansion as a result of the reactor "afterheat" and consider the limiting case of no heat removal.

* M. W. Rosenthal and H. C. Claiborne, "Effects of Heat Generation and Heat Removed on HRT Shutdown and Dump", ORNL-CF-56-2-128.

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The required expansion volume can be obtained by relief through either the vent or letdown systems. The required relief rates for limiting pressure rises are shown in Table II.

TABLE II
MAXIMUM PRESSURE RISE VS. RELIEF RATE
(5 Mw HRT OPERATION*)

Max. Pressure Rise (psi)	Venting Rate Required (liters/sec.)	Letdown Rate Required (gpm)
200	0.4	6.0
300	0.3	4.5
400	0.2	3.0

* At 10 Mw operation the required maximum rates of discharge would be nearly double the values shown.

IV. Relief Capabilities

A. Vent System

The core System Vent Valve (p_d cv - 250a, line 127B) has a design C_v of 0.07. Flow tests* on this valve at 2000 psi upstream pressure were extended as shown in Table III.

TABLE III
VENT VALVE CAPABILITY

Upstream Pressure (psia)	Flow Capability (liters/sec) (1)
2000	0.316
2100	0.313
2200	0.309
2300	0.305
2400	0.300

(1) Measured at upstream conditions

* Tests run by C. H. Gabbard and H. A. McLain (3/20/56 : 3/26/56).

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The data shown in Table III indicate that the vent valve alone is capable of limiting the core pressure rise to less than 300 psi at 5 Mw operation. Due to the degree of conservatism of the basic assumptions,* it appears more likely that this vent valve is capable of limiting the core pressure rise to less than 200 psi (i.e. max. pressure = 2200 psia).

B. Letdown System

The Core System Letdown Valve (LCV-145, line 144A) has a design C_v of 0.10.

When circulation stops this valve will be required to pass an overpressured, saturated liquid. A thermodynamic analysis of the flow in the letdown system would indicate that "flashing" would occur at the throat of the valve. This condition would seriously limit the flow capabilities of the system. However, the existence of the cold water section of the letdown cooler, and experience in similar systems as quoted in the literature** would indicate that the actual flow should be greater than the theoretical.

Test data under simulated reactor conditions are required to determine the system capabilities more accurately.

The theoretical flow for the two boundary conditions are shown in Table IV.

Table IV

LETDOWN VALVE CAPABILITY

Upstream Pressure psia	Flow Capability	
	Minimum ⁽²⁾	Maximum ⁽³⁾
	Liters/sec ⁽¹⁾	
2000	0.109	0.324
2100	0.114	0.332
2200	0.119	0.340
2300	0.125	0.347
2400	0.131	0.355

(1) Measured at upstream conditions
 (2) Minimum flow occurs in case of a saturated liquid flashing at throat of valve
 (3) Maximum flow occurs in case of no flashing at valve

* i.e. isentropic compression of vapor and no heat removal from system.

** Benjamin and Miller, The Flow of Saturated Water Through Throttling Orifice
 Trans. ASME Vol. 63, 1941.

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The combined capabilities of both the Vent and Letdown Systems will determine the degree of pressure buildup that occurs due to afterheat on reactor shutdown. At 5 Mw reactor operation the combined systems should be capable of limiting the pressure rise to well under 200 psi, even for operation under minimum flow conditions.

At 10 Mw reactor operation the limiting pressure would appear to be in the range of 300-400 psi, depending upon the degree of conservatism in the pressure rise calculations.

C. Interchange of Inventory During Dumping

Estimates of the maximum flows that could occur between the core and blanket system are presented below*. These rates would occur on the instantaneous opening of one dump valve while the other remains shut (or lags behind severely). The calculated maximum fluid ejection rates to the low pressure system are:

	<u>Instantaneous Dump (liters/sec)</u>	<u>Overpressure Vented (liters/sec)</u>
Core-to-blanket	60	15
Blanket-to-core	20	5

The capability of the rupture disc assembly and the line interconnecting the two pressurizers is shown in Table V.

* Letter, M. W. Rosenthal to M. I. Lundin, 2/29/56 - Max. Flow between HRT Core and Blanket.

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TABLE V
RUPTURE DISC SYSTEM CAPABILITY

P_1 psia	ΔP * (psi)	Approximate Flow Capability (liters/sec)
2000	50	23
	100	33
	200	47
	400	68

* pressurizer to pressurizer

Here again, the actually required rate of flow is less than the maximum listed due to the conservatism* of the computations, and the proposed installation is considered adequate.

The main limitation of the proposed interconnecting system lies in ability to attain the required rupture disc settings. A 1-1/2" nominal diameter, stainless steel disc, designed to rupture at a 200 psi differential is only 0.0012 inches thick. On this basis, a disc designed to rupture at 75 psi differential would be approximately 0.00045 inches thick. Due to the corrosive atmosphere present both of the above discs are considered too thin for safety. A "safer" rupture disc would involve the use of titanium as the disc material. The possibility of using titanium is now under investigation in conjunction with Black, Sivalls and Bryson, Inc.

A more positive type of core-to-blanket pressure relief control would be the use of a controlled position relief valve. This valve would be pilot operated to assume whatever percentage opening is required on the basis of the existing core-to-blanket pressure differential. Specifications are now being prepared for this type of valve. (HRT Spec. No. 306).

M. I. Lundin 385.8
M. I. Lundin

* The 60 l/s core-to-blanket flow requirement is based on the instantaneous vapor transfer rate for no pressure difference to develop if the blanket dump valve is initially wide open and the core dump valve remains closed.