MAY 6 1963

Study IV-320
EGCR
Revision 2
ACNP - 61534

OAK RIDGE OPERATIONS OFFICE

ATOMIC ENERGY COMMISSION

STUDY NO. IV - 320

INADVERTENT OPERATION
COOLANT LOOP ISOLATION VALVES
HAZARDS ANALYSIS

MASTER

EXPERIMENTAL GAS-COOLED REACTOR

Facsimile Price \$ 3.60

Microfilm Price \$ 1.37

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Prepared By
ALLIS-CHALMERS MANUFACTURING COMPANY
Atomic Energy Division
Nuclear Power Department
Washington, D. C.

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.

Study IV-320
EGCR
Revision 2

INADVERTENT OPERATION
COOLANT LOOP ISOLATION VALVES
HAZARDS ANALYSIS

Prepared By: A. DeAgazio Date: 12/7/61
A. DeAgazio
Group Leader
3/28/61

Approved By: W. F. Banks (S) Date: 3/28/61
W. F. Banks
Project Manager

Approved for Kaiser Engineers:

By: G. B. Humphreys Date: 2/1/61

Approved for Union Carbide Nuclear Company:

By: G. D. Whitman Date: 2/17/61

Approved for Atomic Energy Commission:

By: L. H. Jackson Date: 2/24/61

APPROVED

February 24, 1961

Revision 1

December 8, 1961

Revision 2

ADA
November 30, 1962

INADVERTENT OPERATION OF COOLANT LOOP
ISOLATION VALVES DURING REACTOR OPERATION
HAZARDS ANALYSIS

I. OBJECTIVE

The purpose of this study is to determine if a hazardous condition is created by accidental closing of the coolant loop isolation valves while the reactor is operating.

II. CONCLUSIONS

1. Fuel element cladding temperatures will not exceed the operational limitation of 1800 F if all fuel channels in the reactor are operating at normal power levels, corresponding to 100% operation (84.3 MWT). If a fuel channel is being refueled which will cause some fuel channels to operate above normal power levels, two fuel elements will have cladding temperatures in excess of 1800 F. 2

2. Accidental closing of one coolant loop isolation valve, with the reactor at full power, will cause the blowers in that loop to surge 50 seconds after the valve starts to close.

Inadvertent or accidental closing of both coolant loop isolation valves in a coolant loop with the reactor at full power, will cause the blower in that loop to surge 42 seconds after the valves start to close. At lower flows, surging will occur; however, the time to reach the surge limit is increased.

III. RECOMMENDATIONS

1. Consideration should be given to shortening the closing time for the coolant loop isolation valves if the results of the graphite oxidation analysis indicate that this would significantly affect the resulting hazards of graphite oxidation.

2. A complete analysis of blower stability and structural integrity during and following all accident conditions should be undertaken.

3. Pairs of valves in the same coolant loop should be interlocked to eliminate the possibility of their closure while the blower in that loop is in operation.

IV. GIVEN DATA

1) Normal operating temperatures of the fuel elements, and statistical analysis of fuel element temperatures are given in reference 1. Power distribution is as given in reference 2.

2) Coolant system fluid flow resistances (psi) are calculated from the following pressure drops at 215,000 lb/loop (reference 3).

a) Vessel outlet to and including isolation valve (when open)-----	0.48
b) Valve to bypass connection-----	0.25
c) Attemperator-----	0.25
d) Attemperator to steam generator-----	0.35
e) Steam generator to blower-----	0.56
f) Bypass to isolation valve-----	0.59
g) Isolation valve (when open) to vessel Inlet-----	0.28

3) Reactor vessel volumes (cu. ft.) are as follows (reference 4).

a) Top plenum-----	3200
b) Between temperature barrier and reflector-----	2200
c) Bottom plenum-----	2900

4) Core pressure drop at 427,000 lb/hr is 10.25 psi.

5) Total plenum pressure drop at 427,000 lb/hr is 0.45 (reference 5).

6) Gas side steam generator pressure drop at 215,000 lb/hr is 2.0 psi (reference 6).

7) Total reactor thermal power is 84.3 megawatts.

8) Temperature distribution of the fuel is based on 232 fuel channels.

9) Blower head characteristics is as given in reference 7.

V. ASSUMPTIONS

- a) The isolation valves are butterfly-type valves.
- b) The valve body inside diameter is 22 inches.
- c) Pressure drop through a partially closed butterfly valve can be expressed as pressure drop through an equivalent orifice.
- d) Initially, both blowers are assumed to be operating at 100% speed and flow.
- e) Only the blower in the loop with the partially closed isolation valves surges. The blower in the normal loop remains operating at 100% speed.
- f) Reactor scram is caused by the flux minus flow when $\phi - W = 0.10$ within 0.5 seconds after the blower surges.
- g) When the blower surges in the abnormal loop, core flow is assumed to undergo a step change to 55.2% of normal flow.
- h) Valve closing time from full open to full closed is two minutes.
- i) Valve butterfly angular position is a linear function with time.

VI. DISCUSSION

Both EGCR reactor coolant loops are equipped with isolation valves at the inlet and outlet to the reactor vessel. These valves can be used to isolate the rupture in a coolant loop from the remainder of the reactor coolant system. The operation of these valves can be remotely and manually controlled by the reactor operator. (2

There is always a possibility that flow in one loop can be reduced due to either inadvertent operation of the valves from the control room or through a valve or control system failure which would allow either one or both valves in a loop to close.

This study considered only the inadvertent operation of the isolation valves in one loop as follows: <2

- a) A mechanical or electrical failure could allow one valve to close.
- b) An electrical failure or reactor operator error could allow both valves in one loop to close.

Accidental isolation of both coolant loops is possible but is not considered here (8). <2

The results of a fluid flow analysis for the reactor system is shown on Figure 1 for both conditions, (a) and (b), above. This figure shows the fraction of normal loop flow as a function of time after the valve(s) start to close.

From the blower head curves, it can be seen that a 15% reduction of the operating flow through the blowers will cause the pressure rise across the blowers to increase to the surge line when operating at 100% speed. (This percentage increases with decreasing blower speed.) With one valve closing, the surge point is reached in 50 seconds, while with two valves closing, this time is reduced to 42 seconds. It is believed that the blower in the normal loop will operate normally, but with an increase in flow and a corresponding decrease in pressure rise as the flow through the other blower decreases. This increased flow through the normal loop will amount to approximately 5% just prior to surging of the blower in the loop with the closing valves.

Assuming that the reactor will be scrammed when flux minus flow exceeds 0.10, and that the flow and reactor power are initially 100%, a scram will not occur until after the blower in the loop with the closing valves surges since, just prior to the surge, the total flow is:

$$\frac{\frac{W_1}{W_n} + \frac{W_2}{W_n}}{2} = \frac{0.85 + 1.05}{2} = 0.95$$

Where W_1 is the flow through the loop with the closing valves,

W_2 is the flow in the remaining loop,

W_n is the normal loop flow at 100% power.

Since the flux-minus-flow comparator will provide a scram signal only when the difference equals or exceeds 0.10, a scram will occur only after the blower in the abnormal loop surges with a resultant decrease in coolant flow. When this occurs the total flow will undergo a step change to 55.2% of full flow based upon the assumption that flow through the blower, in surge, is essentially zero, as outlined in the calculations.

The transient temperature analysis assumed that the reactor was operating initially at 100% power but with 92.5% full flow. This corresponds to a condition where flow in one loop is 100% of full loop flow but the flow in the other loop is 85% of full loop flow, thus the total flow is:

$$\frac{1 + 0.85}{2} = 0.925$$

This neglects the 5% flow increase through the normal loop due to decreased total system flow and assumes that the blower in the affected loop is at the surge point. The scram was assumed to occur 0.5 second after the blower in the abnormal loop surged. The accident would actually start with both loop flows approximately equal. As the valve or valves continue to close, the total flow would decrease with a corresponding increase in temperature. The analysis, however, assumed that the reactor had been previously operating on a steady-state basis with the reduced flow (92.5% total) and consequently with higher initial temperatures than would actually exist. It is believed that this assumption results in conservative conclusions.

The transient temperature analysis was solved on the Bendix Computer G-15D digital computer, using the numerical temperature analysis program (hazards program 0002B) as described in A-C Study IV-311, and the larger reactor transient temperature program (hazards program 022C) as described in ACF Job Report 3-380-4 and A-C Study IV-312.

The results of the analyses are shown on Figure II for each of ten axial positions along the maximum power fuel channel with position 1 near the bottom of the reactor. The maximum nominal temperature occurs at position 5, which is in the third fuel assembly from the bottom of the reactor and occurs approximately one second after the accident. The maximum nominal temperature reached is 1575 F. The maximum temperature of the remaining positions is below this value.

Figure III shows the inlet and outlet temperatures of the reactor vessel. The maximum outlet temperature is 1106 F, and is reached five seconds after the accident. The reactor inlet temperature drops steadily from the beginning of the accident.

Reference 1 sets the maximum operation fuel cladding temperature at 1800 F. <2

This study assumes that the initial cladding temperature was 1518 F. The temperature change then, to cause fuel element cladding temperature to exceed 1800 F is 282 F. <2

Actually, the maximum change during the transient is 1575 - 1518 = 57 F. The maximum deviation from the nominal maximum surface temperature (reference 1) is 190 F; thus, the clad of a fuel element may actually reach a temperature of: <2

$$1518 + 57 + 190 = 1765 \text{ F}$$

If a channel is operating at 10% above normal power, as may be the case for fuel channels adjacent to a channel being refueled, the initial temperature will be greater than the 1518 F assumed, and may be as high as 1614 F. Thus, to exceed 1800 F, an element must exceed the maximum nominal operating temperature by 186 F. <2

The temperature change due to the transient is 57 F, therefore, any element initially operating with a cladding temperature above the nominal maximum by 129 F will exceed 1800 F. <2

From reference 1, it can be seen that the probability that the temperature will exceed the nominal temperature by 130 F is 0.0123 for 112 fuel elements. Thus, a maximum of 2 fuel elements may exceed the 1800 F operational limitation. <2

VII. REFERENCES:

1. Letter, Mr. Jackson to Mr. Bush, w/attachments, September 20, 1960, subject: status of EGCR fuel element design analysis, and failure criteria.
2. Letter, Mr. Jackson to Mr. Bush, w/attachments, August 15, 1960, subject: suggested operating program for EGCR control rods.
3. KE memorandum, Mr. Malm to Mr. Martin, March 11, 1960.
4. KE TWX No. 47, January 12, 1960.
5. KE letter, Mr. Bush to Mr. Banks, March 15, 1960.
6. Process calculations for EGCR steam generators, C. F. Braun Co., March 10, 1960.
7. Blower Characteristic Curves of Joy Manufacturing Co. proposal for EGCR blowers.
8. Wire, Joint to P. D. Bush and S. Matovich from L. H. Jackson, EE: CRT-68, dated July 10, 1962. <2

EFFECT OF ISOLATION VALVES UPON FLOW

STUDY N-320

FIGURE 1

FIGURE II

STUDY IV-320
2

LOWER AND UPPER PLENUM
TEMPERATURES FOLLOWING
ACCIDENT

FIGURE III

STUDY IV 320

INADVERTANT BLOCK VALVE CLOSURE

IN THE XZ PLANE

IN THE YZ PLANE

Assuming a circular disc the equation will be

$$y^2 + z^2 = R^2$$

$$z = f(\beta)$$

$$z = \frac{z'}{\sin \beta}$$

$$\therefore y^2 + \left(\frac{z'}{\sin \beta} \right)^2 = R^2$$

THE AREA OF THE DISC PROJECTED ON THE ZY PLANE IS

$$A_D = 4 \int_0^y z' dy$$

$$\text{But } z' = \sin \beta (\sqrt{R^2 - y^2})$$

$$A_D = 4 \int_0^R \sin \beta (\sqrt{R^2 - y^2}) dy$$

$$A_D = 4 \left(\frac{1}{2} \right) \sin \beta \left[y \sqrt{R^2 - y^2} + R^2 \sin^{-1} \frac{y}{R} \right]_{y=0}^{y=R}$$

SIMILAR TO

DR'N A.D.A. 11/1/60

CH'D DAL 12-8-60

APP'D

SCALE

= 12

SHEET 1 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD - W

STUDY IV - 320

$$A_D = \pi R^2 \sin \beta$$

Area Flow = Area Valve Body - Area Disc

$$A_F = \pi R^2 - \pi R^2 \sin \beta = \pi R^2 (1 - \sin \beta)$$

But $\beta = f(t)$ THE VALVE^{DISC} TURNS 90° IN 2 minutes

$$\frac{d\beta}{dt} = \frac{\frac{\pi}{2}}{120} = \frac{\pi}{240} \text{ RAD/SEC}$$

$$\beta = \frac{\pi}{240} t \quad t = \text{time in seconds}$$

$$\therefore A_F = \pi R^2 (1 - \sin \frac{\pi}{240} t)$$

(FROM CHEMICAL ENGINEER'S HANDBOOK)

PRESSURE DROP THROUGH AN ORIFICE CAN BE EXPRESSED AS FOLLOWS

$$\Delta P = \frac{W^2 N}{2g A_B^2} \left(1 - \frac{A_B}{A_F}\right)^2$$

OR

$$\Delta P = K N W^2$$

$$\text{WHERE } K = \frac{\left(1 - \frac{A_B}{A_F}\right)^2}{2g A_B^2}$$

$$K = \left[1 - \frac{\pi R^2}{\pi R^2 (1 - \sin \frac{\pi}{240} t)}\right]^2 \frac{1}{2g \pi^2 R^4}$$

$$K = \left[-\frac{\sin \frac{\pi}{240} t}{1 - \sin \frac{\pi}{240} t}\right]^2 \frac{1}{2g \pi^2 R^4}$$

SIMILAR TO

DR'N A.D.A. 11/1/60

CH'D Doc 12-1-60

APP'D

SCALE = 12

SHEET 2 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD-W

STUDY IV-320

VALVE MALFUNCTION MODES

THE BLOCK VALVES CAN MALFUNCTION IN SEVERAL WAYS

1. ONE VALVE ONLY MAY CLOSE DUE TO MECHANICAL FAILURE
2. A ~~CONTROL~~ ^{CONTROL} FAILURE COULD CAUSE ONE SET (2 VALVES) OF VALVES IN ONE LOOP TO CLOSE (THIS COULD ALSO BE CAUSED BY OPERATOR ERROR)
- 3 ALL FOUR BLOCK VALVES COULD BE CLOSED. THIS WOULD HAVE TO BE AN OPERATOR ACTION

MODE 3 FAILURE CAN BE RULED OUT SINCE IT WOULD HAVE TO BE A DELIBERATE ACTION OF THE OPERATOR. FURTHERMORE, AN INTERLOCK FAILURE MUST BE POSTULATED IN ADDITION.

MODE 1 AND 2 FAILURES WILL BE CONSIDERED IN THIS STUDY.

CONSIDER THE FOLLOWING SYSTEM

W = FLOW #/sec

R = FLOW RESISTANCE $\frac{\text{sec}^2}{\text{ft}^5}$

N = SPECIFIC VOLUME $\frac{\text{ft}^3}{\text{#}}$

P = PRESSURE PSF

Subscripts

C REACTOR CORE

B BLOCK VALVE

L, L' NORMAL, Abnormal Loop

SIMILAR TO

DR'N A.D.A 11/1/60

CH'D ~~Doc~~ 12-8-66

APP'D

SCALE = 12

SHEET 3 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD-W

STUDY IV - 320

CORE PRESSURE DROP AT 430,000 #/HR
 REACTOR VESSEL PLENUM LOSS

10.25 PSI
 .45

TOTAL

10.70 PSI

FROM ICE MEMO MALM - MARTIN, MARCH 10, 1960

TOTAL LOOP PIPING PRESSURE DROP AT 215000 #/HR 2.76 PSI
 STEAM GENERATOR PRESSURE DROP AT 215000 #/HR 2.00 PSI

TOTAL

4.76 PSI

$$k_L = \frac{\Delta P}{W^2 \sqrt{g}} = \frac{4.76 \times 144}{\left(\frac{215000}{3600}\right)^2 \frac{386.25(1503)}{303.4(144)}} = \frac{685.4}{47390} = 1.446 \times 10^{-2} \text{ sec}^2/\text{ft}^5$$

$$k_L' = 1.446 \times 10^{-2} + k_B$$

$$k_B = \left[\frac{\sin \frac{\pi}{240} t}{1 - \sin \frac{\pi}{240} t} \right]^2 \frac{1}{2g \pi^2 R^4} \quad (\text{FOR ONE VALVE - MODE 1})$$

$$k_B = \left[\frac{\sin \frac{\pi}{240} t}{1 - \sin \frac{\pi}{240} t} \right]^2 \frac{1}{g 70^2 R^4} \quad (\text{FOR TWO VALVES - MODE 2})$$

SINCE THE TOP AND BOTTOM VESSEL PLENUMS ARE COMMON TO BOTH LOOPS THE PRESSURE DROP ACROSS BOTH LOOPS MUST BE EQUAL.

THUS

$$\Delta P_L = \Delta P_L'$$

$$W_L^2 k_L N = W_L'^2 (k_L + k_B) N$$

SIMILAR TO

DR'N ADA 11/1/60

CH'D JML 1-4-61

APP'D

SCALE = 12

SHEET 4 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT. NPD-W

STUDY IV 320

$$\left(\frac{W_L'}{W_L}\right)^2 = \frac{k_L}{k_L + k_B}$$

$$\frac{W_L'}{W_L} = \sqrt{\frac{k_L}{k_L + k_B}} = \sqrt{\frac{1.446 \times 10^{-2}}{1.446 \times 10^{-2} + \left[\frac{\sin \frac{\pi}{240} \tau}{1 - \sin \frac{\pi}{240} \tau} \right]^2 \frac{1}{2gT^2 R^4}}} \quad (\text{FOR MODE 1})$$

$$\frac{W_L'}{W_L} = \sqrt{\frac{1.446 \times 10^{-2}}{1.446 \times 10^{-2} + \left[\frac{\sin \frac{\pi}{240} \tau}{1 - \sin \frac{\pi}{240} \tau} \right]^2 \frac{1}{8\pi^2 R^4}}} \quad (\text{FOR MODE 2})$$

Assuming that the VALVE DIAMETER is 22 in
and solving for $\frac{W_L'}{W_L}$ PLOT THE RESULTS

τ (sec)	$\left[\frac{W_L'}{W_L} \right]$ FOR ONE VALVE	$\left[\frac{W_L'}{W_L} \right]$ FOR TWO VALVES
0	1	1
5	1	1
10	0.996	0.9965
20	0.990	0.983
30	0.971	0.945
40	0.932	0.875
50	0.855	(0.815) $\tau = 45$ sec
60	0.726	

THE SLOPE OF THE BLOWER HEAD CURVE INCREASES AS THE SPEED OF THE ROTOR INCREASES AND THE RATIO OF $W_{\text{SURGE}}/W_{\text{NORMAL}}$ APPROACHES 1. THUS THE ALLOWABLE THROTTLING OF FLOW IS A MINIMUM AT 100% SPEED

THIS IS

$$\frac{183,000}{215,000} = 0.850$$

FOR MODE 1 THIS OCCURS AT APPROXIMATELY 50 SEC; FOR MODE 2

SIMILAR TO

DR'N ADA 11/1/60

CH'D DRL 1-4-61

APP'D

SCALE

= 12

SHEET 5 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD -W

STUDY II-320

THIS OCCURS BETWEEN 40 AND 45 SECONDS. AS THE VALVES CLOSE FURTHER THE BLOWER IN THAT LOOP WILL SURGE.

AS FLOW IS DECREASED THROUGH ONE LOOP, THE FLOW IN THE OTHER LOOP WILL INCREASE.

$$W_L + W_{L'} = W_T$$

$$\Delta P_{\text{BLOWER}} = \Delta P_C + \Delta P_L = K_C N_B W_T^2 + K_L N_T W_L^2$$

$$K_L = 1.446 \times 10^{-2} \text{ sec}^2/\text{ft}^5$$

$$K_C = \frac{10.25(144)}{(119.44)^2 \frac{386.25(970)}{313.7(144)}} = 1.247 \times 10^{-2} \text{ sec}^2/\text{ft}^5$$

$$N_B = \frac{386.25(970)}{313.7(144)} = 8.294 \text{ ft}^3/\text{ft}$$

$$N_T = \frac{386.25(1503)}{313.4(144)} = 13.287 \text{ ft}^3/\text{ft}$$

THE BLOWER SURGES AT $\frac{W_{L'}}{W_L} = 0.850$

$$\Delta P = 1.247 \times 10^{-2} (8.294) (W_L + W_{L'})^2 + 1.446 \times 10^{-2} (13.287) W_L^2$$

$$\Delta P = 0.1034 (W_L + W_{L'})^2 + 0.1921 W_L^2$$

$$\Delta P = 0.354 W_L^2 + 0.1921 W_L^2 = 0.546 W_L^2$$

Assume 62.5 ft/sec

FROM THE BLOWER CURVES $\Delta P = 2131$

$$\Delta P = 0.546 (62.5)^2 = 2132.7$$

THIS IS CLOSE AND REPRESENTS AN INCREASE OF

$$\frac{62.5}{59.7} = 1.046$$

THIS IS NOT SIGNIFICANT AND WILL BE NEGLECTED IN THIS ANALYSIS

SIMILAR TO

DR'N ADA 11/3/60 CH'D DRL-4-61 APP'D SCALE = 12 SHEET 6 OF 19 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT. NPD-10

STUDY II 320

THE CORE FLOW CAN BE DETERMINED FROM THE INFORMATION ON PAGE 5

$$\frac{W_L' + W_L}{W_{TNO}} = \frac{W_T}{W_{TNO}}$$

WHERE W_{TNO} = TOTAL FLOW FOR NORMAL OPERATION

t (Sec)	$\frac{W_T}{W_{TNO}}$ (MODE I)	$\frac{W_T}{W_{TNO}}$ (MODE II)
0	1.0	1.0
10	0.998	0.998
20	0.995	0.991
30	0.985	0.972
40	0.966	0.937
42.5	-	0.925
50	0.927	
52.5	0.925	

THE TOTAL REACTOR FLOW AT THE TIME THE BLOWER SURGES IS 92.5% OF NORMAL FULL POWER FLOW IF BOTH BLOWERS WERE INITIALLY OPERATING AT 100%

ASSUMING THAT ($\phi - W$) COMPARATOR SCRAMS WHEN THE VALUE REACHES 0.10 (OR WHEN $\frac{W_L}{W_{TNO}}$ REACHES 0.80) THEN ~~THE REACTOR IS NOT SCRAMMED BEFORE THE BLOWER SURGES. FOR THE TIME THE REACTOR IS NOT SCRAMMED~~

THE FLOW THROUGH THE NORMAL LOOP WHEN THERE IS NO FLOW THROUGH THE REMAINING LOOP CAN BE CALCULATED

$$\Delta P = 1.247 \times 10^{-2} (8.294) W_L^2 + 1.446 \times 10^{-2} (13.287) W_L^2$$

$$\Delta P = 0.29555 W_L^2$$

SIMILAR TO

DR'N A.D.A. 11/4/60

CH'D ~~DR~~ 1-4-61

APP'D

SCALE

=12

SHEET 7 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NDP -W

STUDY IV - 320

ASSUME $W_L = 66 \text{ gpm}$

FROM BLOWER CURVE $\Delta P = 1296 \text{ psf}$

$$\Delta P = 0.29555 W_L^2 = 0.29555 (66)^2 = 1287 \text{ psf WHICH IS CLOSE}$$

UNLESS THE BLOWER IN THE NORMAL LOOP SURGES, THE
~~FOR~~ REACTOR COOLANT FLOW SHOULD NOT DROP BELOW

$$\frac{66}{119.4} \times 100 = 55.2 \% \text{ OF FULL FLOW}$$

SIMILAR TO

DR'N ADA 11/4/60

CH'D DRL 1-4-61

APP'D

SCALE = 12

SHEET 8 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD-W

STUDY IV -320

A

B

TRANSIENT TEMPERATURE ANALYSIS

FROM STUDY II-312 SECTION III D CALCULATIONS
THE AVERAGE HEAT TRANSFER COEFFICIENT FOR 100%
FLOW WAS DETERMINED TO BE 359 BTU/HR-FT

THE CHANNEL OUTLET TEMPERATURE IS 1075 °F
WITH AN INLET OF 510 °F. DETERMINE CHANNEL
FLOW AT 92.5% FLOW

$$q_{max} = 1.661 \times 10^6 \text{ BTU/HR}$$

$$q = W C_p \Delta T$$

$$1.661 \times 10^6 \frac{\text{BTU}}{\text{HR}} = W (1.249 \frac{\text{BTU}}{\text{lb} \cdot \text{F}}) (1075 - 510 \text{ °F})$$

$$W_{100} = 2354 \frac{\text{#}}{\text{HR}} \quad @ \quad 100\% \text{ FLOW}$$

$$W_{92.5} = 2354 (0.925) = 2177 \frac{\text{#}}{\text{HR}}$$

THE FLOW PAST THE FUEL ELEMENTS IS APPROX 96% TOTAL FLOW
AT 100% AT 55.2%.

$$W_f = 2260 \frac{\text{#}}{\text{HR}} \quad W_f = 1247 \frac{\text{#}}{\text{HR}}$$

DETERMINE THE AVERAGE HEAT TRANSFER COEFFICIENT
AFTER ONE BLOWER SURGES

ASSUME TOTAL FLOW IS 55.2% NORMAL

$$\frac{h_{55.2\%}}{h_{100\%}} = \left(\frac{1247}{2260} \right)^{0.8} = 0.621$$

				SIMILAR TO	
DR'N A.D.A. 12/4/60	CH'D DRL 1-4-61	APP'D	SCALE = 12	SHEET 9 OF 19	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT. NPD - W				STUDY II-320	

THUS, AFTER THE ACCIDENT $h = 223 \frac{\text{BTU}}{\text{sq ft}}$

DETERMINE TEMP OF COOLANT OPPOSITE CLADDING HOT SPOT

$$\frac{\Delta T_{100\%}}{\Delta T_{85.2\%}} = \frac{1}{.582} = 1.811$$

$$\Delta T_{85.2} = (833 - 510)(1.811) + 510 = 1185 \text{ F}$$

THE NUMERICAL TEMP. ANALYSIS (002-B) WILL BE RUN USING 1000°F, 1100°F, AND 1200°F TO DETERMINE THE VALUES FOR THE TIME CONSTANT FOR HEAT DECAY FROM THE FUEL ELEMENT. ASSUME 0.5 SECOND DELAY FOR THE SCRAM.

THE VALUES FOR THE TIME CONSTANT WILL BE USED IN THE TRANSIENT TEMPERATURE PROGRAM, #022-C.

SIMILAR TO

DR'N ADA 12/4/60	CH'D DRL 1-4-61	APP'D	SCALE = 12	SHEET 18 OF 19	ISSUE
ALLIS-CHALMERS MFG. CO.			DEPT. NPD-W		STUDY IV-320

Since the accident is to assume an initial flow of 92.5% at 100% power, the clad, coolant, sleeve, and block temperatures must be readjusted from those values used in study IV 312

COOLANT TEMPERATURE ADJUSTMENT

AXIAL POSITION	T _{COOLANT} 100%	ΔT_{COOL} 100%	ΔT_{COOL} 92.5% °F	T _{COOLANT} °F (92.5%)
1	520	10	10.81	520.8
2	575	65	70.27	580.3
3	667	157	169.7	679.7
4	715	265	286.5	796.5
5	883	373	403.2	913.2
6	974	464	505.9	1015.9
7	1040	530	572.9	1082.9
8	1062	552	596.7	1106.7
9	1070	560	605.4	1115.4
10	1075	565	610.8	1120.8

SIMILAR TO

DR'N ADA 12/5/00 CH'D DAL-4-61 APP'D SCALE =12 SHEET 11 OF 19 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT. NPD-W

STUDY IV 320

CLAD TEMP ADJUSTMENT

 $\Delta T_{100\% \text{ CL}}$ TAKEN FROM STUDY IV 312

POSITION	$\Delta T_{\text{CL}(100)}$	$\left(\frac{1}{.925}\right) \Delta T_{\text{CL}(100)} = \Delta T_{\text{CL}(92.5)}$	$T_{\text{CL}} \quad 92.5$
1	178.5	189.9	710.7
2	399.7	425.3	1005.6
3	550.3	585.5	1265.2
4	611.4	650.5	1447.0
5	568.6	605.0	1518.2
6	421.2	448.2	1464.1
7	203	216.0	1298.9
8	75.7	80.5	1187.2
9	27.2	28.9	1144.3
10	9.15	9.74	1130.5

SIMILAR TO

DR'N ADA 12/6/60

CH'D

1-4-61 *DA*

APP'D

SCALE

= 12

SHEET 12 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

NPD-W

STUDY IV 320

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

SLEEVE TEMP. ADJUSTMENT

POSITION	T _{Sleeve} 100%.	ΔT 100%.	ΔT 92.5%.	T _{Sleeve} 92.5%.
1	524.8	4.8	5.08	535.9
2	585.7	10.7	11.34	695.4
3	681.8	14.8	15.68	813.8
4	791.4	16.4	17.38	935.0
5	903.6	20.6	21.83	1027.9
6	989.3	11.3	11.97	1088.7
7	1045.5	5.5	5.83	1088.7
8	1064.0	2.0	2.12	1106.8
9	1070.7	0.7	0.74	1116.1
10	1075.3	0.3	0.32	1121.1

SIMILAR TO

DR'N *ADA 12/5/00* CH'D *DALE-4-61* APP'D _____ SCALE = 12 SHEET *13* OF *19* ISSUE _____

ALLIS-CHALMERS MFG. CO. DEPT. *UPD-W*

STUDY B 320

A

B

C

BLOCK TEMPERATURE ADJUSTMENT

POSITION	ΔT 100%	T_{BL} 100%	ΔT 92.5%	T_B 92.5%
1	9.1	529.1	9.6	530.4
2	20.5	595.5	21.7	602.0
3	24.2	695.2	29.9	709.6
4	31.3	806.3	33.2	829.7
5	29.1	912.1	30.8	944.0
6	21.6	999.6	22.9	1037.8
7	10.4	1050.4	11.0	1093.9
8	3.9	1065.9	4.1	1110.8
9	1.4	1071.4	1.5	1116.9
10	0.5	1075.5	0.5	1121.3

SIMILAR TO

DR'N *ADA 12/5/80*CH'D *DR 1-4-61*

APP'D

SCALE

= 12

SHEET *14* OF *19*

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. *NPD-W**STUDY II 320*

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

THE AXIAL POWER DISTRIBUTION USED WAS FROM REF:
LTR. JACKSON - BUSH AUGUST 12 1960

POSITION	POWER ($\frac{\text{LOCAL}}{\text{MAX}}$)
1	0.292
2	0.645
3	0.900
4	1.00
5	0.930
6	0.689
7	0.332
8	0.1239
9	0.0445
10	0.1485

SIMILAR TO

DR'N ADA 12/5/60 CH'D JRL 1-4-61 APP'D SCALE = 12 SHEET 18 OF 19 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT. NPD - W

A

B

STEAM GENERATOR + MIXING DELAYS

ASSUME ONLY ONE STEAM GENERATOR IS REMOVING HEAT.

FLOW THROUGH STEAM GENERATOR AFTER ACCIDENT IS

$$215.000 \left(\frac{55.2}{30.0} \right) = 237,360 \text{ lb/hr}$$

Mass of Upper Plenum

$$M_{up} = \frac{PV}{RT} = \frac{303.4(144)(3200)}{386.25(1503)} = 240.8 \text{ lb}$$

Mass of Lower Plenum

$$M_{lp} = \frac{PV}{RT} = \frac{313.7(144)(2900)}{386.25(970)} = 349.9 \text{ lb}$$

Temp of Upper Plenum

$$T_{up} = \frac{\Delta M T_c + (M - \Delta M) T_{up}}{M_{up}} = \frac{\Delta M (T_c - T_{up}) + M T_{up}}{M_{up}}$$

$$\Delta M = W \Delta t$$

$$\therefore T_{up} = \frac{W(\Delta t)(T_c - T_{up}) + M T_{up}}{M_{up}} = \frac{W \Delta t (T_c + T_{up}) + 241 T_{up}}{241}$$

SIMILARLY

$$T_{lp} = \frac{W \Delta t (T_{sg} - T_{lp}) + 350 T_{lp}}{350}$$

SIMILAR TO

DR'N ADA 12/5/60

CH'D DRL 1-41-61

APP'D

SCALE = 12

SHEET 16 OF 19

ISSUES

ALLIS-CHALMERS MFG. CO.

DEPT.

NPD-W

STUDY R-320

$$\Delta T_{ss} = 503 - 290 = 613$$

$$\bar{T}_{ss} = \frac{(503 + 290 + (460)2)}{2} = 1055.5^\circ R$$

$$Q = UA \left(\frac{T_{sg} + T_{up}}{2} - \bar{T}_{ss} \right)$$

ALSO

$$Q = W C_p (T_{up} - T_{sg})$$

$$W C_p (T_{up} - T_{sg}) = UA \left(\frac{T_{up} + T_{sg}}{2} - 1055.5 \right)$$

$$T_{sg} = 2 \left[\frac{W C_p (T_{up} - T_{sg})}{UA} + 1055.5 \right] - T_{up}$$

ASSUMING AN OVERALL U FOR THE STEAM GENERATORS
OF $102.7 \frac{BTU}{hr ft^2}$ AT 100% FLOW (REACTOR FLOW)

THEN AT 55.2% (REACTOR FLOW)

$$U = \left(\frac{55.2}{50.0} \right)^{0.62} (102.7) = 109.4 \frac{BTU}{hr ft^2}$$

ASSIGNING A FICTICIOUS HEAT TRANSFER AREA OF 8141 WHICH
GIVES THE PROPER INITIAL CONDITIONS

$$T_{sg} = 2 \left[\frac{237,360 (1.249) (T_{up} - T_{sg})}{109.4 (8141)} + 1055.5 \right] - T_{up}$$

$$T_{sg} = 1267.3 - 0.20069 T_{up}$$

SIMILAR TO

DR'N ADO 12/5/60

CH'D DRC 1-46A

APP'D

SCALE

= 12

SHEET 17 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD-W

STUDY # 320

WHERE (FOR STEAM GENERATOR MODEL)

T = Temp $^{\circ}R$

M = MASS of GAS - lbs

W = FLOW - lb/hr

t = time - hr

LP REFERS TO LOWER PLENUM

UP " " UPPER "

SG " " STEAM GENERATOR OUTLET TEMP

C " " CORE OUTLET TEMP

SIMILAR TO

DR'N *ADA* 12/5/60

CH'D *DPL 1-4-61*

APP'D

SCALE

=12

SHEET 18 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

NPD-W

STUDY # 320

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A B C

ESTIMATE OF FUEL FAILURES

NORMAL POWER CHANNELS

TEMP RISE DUE TO TRANSIENT (AT POINT OF MAX POWER)

$$(1575 - 1518) = 57^{\circ}\text{F}$$

NOMINAL MAX TEMP = 1518°F

MAX TEMP DEVIATION FROM ~~NOMINAL~~ NOMINAL MAXIMUM
IS 190°F

MAXIMUM FUEL CLAD TEMP THAT CAN BE REACHED IS
 $1518 + 57 + 190 = 1765^{\circ}\text{F}$ WHICH IS BELOW
FAILURE CRITERIA OF 1800°F

10% ABOVE NORMAL POWER (112 ELEMENTS)

$$\bar{T} = (1518 - 1466) + 1562 = 1614^{\circ}\text{F}$$

ALLOWABLE TEMP DEVIATION (INC TRANSIENT)

$$(1800 - 1614) = 186^{\circ}\text{F}$$

ALLOWABLE DEVIATION (TRANSIENT NOT INC)

$$186 - 57 = 129^{\circ}\text{F}$$

PROBABILITY OF FUEL ELEMENTS OPERATING 130°F ABOVE
NOMINAL MAXIMUM IS 0.0123

NUMBER OF FAILURES TO BE EXPECTED

$$0.0123(112) = 1.37 \text{ OR } 2 \text{ FUEL ELEMENT FAILURES}$$

SIMILAR TO

DR'N ADA 12/5/63

CH'D DRL 1-4-61

APP'D

SCALE = 12

SHEET 19 OF 19

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT. NPD-W

STUDY TO 320

APPENDIX A

The following discussion is appended to this study report for the purpose of answering specific comments raised by the Oak Ridge National Laboratory and is added in accordance with the instructions of the attached letter. For convenience, the specific comments, which were an attachment to the letter are also included herein.

COPY

Study No. IV-320

EGCR

Revision 2

UNITED STATES
ATOMIC ENERGY COMMISSION

Oak Ridge, Tennessee
September 22, 1961

Mr. P. D. Bush
Attn: Mr. A. L. Lindsay
EGCR Project
Kaiser Engineers
Kaiser Center
Oakland 12, California

Subject: A-C STUDY IV-320 - INADVERTENT OPERATION -
COOLANT LOOP ISOLATION VALVES - HAZARDS ANALYSIS

Dear Mr. Bush:

Enclosed is one copy of ORNL "Supplemental Comments on A-C Study IV-320." These comments are forwarded for your consideration in your current work on the Hazards Summary Report, and for such revisions or extensions to Study IV-320 as are required to provide necessary information for the Hazards Summary Report.

If you believe that any of the items to which ORNL has taken exception are either not required for the HSR, or are covered elsewhere, such items should be noted in the study itself, with an explanation of the reason for not considering the item. An example might be Item 1 in the ORNL comments, since A-C apparently feels that a scram is not required if the reactor is initially operating at 50% flow or less.

Very truly yours,

LeRoy H. Jackson
Director
Engineering Division

Enclosures:
ORNL Sup. Comments

CC: W. F. Banks, A-C, w/encl.
D. F. Cope, w/encl.
C. D. Whitman, UCNS, Y-12

Supplemental Comments on A-C Study IV-320, "Inadvertent Operation Coolant Loop Isolation Valves," Approved as Noted.

- Re: 1. Memorandum attached to Approved as Noted copy of Job Study IV-320, February 16, 1961
2. Letter from Banks to Bush, Hazards Analysis Transmittal EGCR File Nos. 149 and 6-24, March 30, 1961.

Reference 1 indicated that the conclusions reached in the A-C Study are acceptable only if the following conditions are met:

1. The reactor must scram.
2. Adequate cooling must be supplied by coolant flow from the "good" loop.

Reference 1 then described how the two conditions were not adequately met in the job study. The specific answers to the questions raised by ORNL, as contained in reference 2, have not in most cases resolved any of the basic problems raised by ORNL, as indicated below.

1. With respect to a reactor scram initiated by the presently proposed safety system at power levels of 50% or less, ORNL has the following comments:
 - a. If the control rods and blowers were under manual control, the probability of a reactor scram is quite high. The closure of the valves in one loop with the reactor operating at 20% power could require that the scram originate from high reactor outlet gas temperature since the total reduction in gas flow would be only approximately 10% and the reactor flux would decrease as a result of higher internal temperatures in the fuel.
 - b. If the control rods, the blowers, and the turbine are being operated by the presently proposed control system, the probability of a reactor scram needs examination. As we interpret the control action which would follow the start of the closure of the block valves in one loop, the blower in the affected loop would speed up to attempt to maintain constant gas flow in its loop. Any increased speed in this blower would request an increased speed in the other blower, according to the proposed control system.

There would probably be relatively small changes in the temperature of the gas returning to the reactor in each of the gas loops, perhaps in opposite directions since the flow in one loop is dropping while the flow in the other is probably rising to some extent. If the total gas flow through the reactor core decreases slightly, and the reactor flux does not increase, the blower control system will attempt to increase the speed of both blowers as a result of a higher gas outlet temperature.

It is possible that a reactor scram will occur, either from flux-minus-flow or from a high reactor outlet gas temperature, but no complete analysis justifies only conclusion that this condition is not a problem. The initial power level of the reactor, the rate of operation of the block valves, the behavior of the control system, and the behavior of the safety system all form parts of this problem. In addition, the possibility of various items being under automatic control while other devices are under manual control must not be overlooked.

2. The statement made in paragraph 2 of reference 1, is still valid irregardless of which organization investigates the surging behavior of the blowers. Until the question is resolved, the conclusions reached in the job study are not valid.
3. The questions raised in paragraph 4 of reference 1 are partially answered by the information in the TWX's referred to in reference 2. This information was not available at the time the comments were made in reference 1, however, the specification for the valves of concern state that there is no action on either loss of operating fluid or electric power. Although no action is to be performed by the loss of operating fluid or electric power, ORNL is still unable to determine if there is a holding force so that at the time of a failure the valves will remain in the open or closed position. We are, therefore, concerned that the vendor could meet the specification and a failure could cause the valve to move. Specifically, the designer should show that the valves will not move upon loss of air pressure to the operating piston for any initial operation of the valve. Butterfly valves are not necessarily aerodynamically stable in all positions.
4. The question raised in paragraph 6 of reference 1 still requires further investigation. If the closure of the block valve can lead to blower damage, it is definitely a hazard and should be discussed in the hazards study. Although A-C indicated in reference 2 that they agree with the comments in the referenced paragraph the job study is not altered to reflect the comment.

One additional problem area deals with the subject of denying adequate heat removal to the core. Provision of interlocks so that it is not possible to close the block valves in each of the two main loops at the same time, will prevent denying adequate coolant to the core for but one of many credible situations. What is actually desired is that the ability to remove heat with one loop and its auxiliaries should not be denied when the other loop is not capable of removing heat. Therefore, although the most obvious protection is to prevent closure of a block valve in each loop, it is equally important that any single piece of equipment necessary for the heat removal process in a given loop is not prevented from operating if the other loop is not operating.

Until the questions discussed in reference 1 and commented on in this letter have been resolved satisfactorily, the job Study IV-320 cannot be considered as approved, nor can the conclusions in the job study be considered as valid.

The following discussions are in response to those points raised in the document reproduced on the preceding pages of this Appendix. The numbering corresponds to the numbering of the comments:

1-a. The EGCR blower control system is designed so that either a decrease in loop flow or an increase in outlet temperature (or both simultaneously) will cause blower speed, and consequently flow, to increase. Blower flow can be changed at a maximum rate of 1-1/2% per second. The maximum rate at which flow can be decreased by closing two valves simultaneously occurs between 42 and 50 seconds (Figure 1) and results in a maximum flow decrease of 0.132% per second through the reactor core (see calculation sheet A1). Based on the maximum surge line as shown on the blower head characteristics (reference 7) the rate of change of flow that can be caused by the blower control system is 1.32% per second just prior to surge in the abnormal loop. Thus, the rate of flow decrease caused by the closing block valves is well below the achievable rate of flow increase. This means that the closing block valves will not cause a real flow reduction through the reactor core. In fact a flow increase will occur since the blower speed in the abnormal loop must be increased to 30% from 25% in order to deliver 20% flow at the maximum surge point. Because of the speed synchronism between the two blowers, the blower in the normal loop will also increase in speed with a 37% increase in flow. At the time the blower in the abnormal loop surges, the core flow will be 23.7%. If the reactor control rods are on automatic control the reactor power will increase to 23.7%.

When the abnormal loop blower surges, core flow will decrease to 13.7% (assuming flow through the blower in surge is zero). The reactor may be scrambled by high flux minus flow. If the flow through the surging blower is not zero or if the control rods are not on automatic control, a reactor scram will not occur.

If the minimum surge line applies, then there is no allowable flow reduction through the blowers and the one blower will surge immediately after the valves start to close. This represents the worst possible case since the reactor may not scram since the exact value of flux minus flow is 0.10.

The EGCR analogue computer model was used to simulate this case. The results are shown on Figure A-1. The reactor was assumed to be operating normally at 20% design. The flow then underwent a step change to 10%, thus, representing surging of one blower and was followed by a flow increase at the rate of 0.75%/sec which represents the maximum achievable core flow rate of change with one blower. Reactor power reached a stable level of 40%. The maximum cladding temperature change in the average channel was less than 20 F. Although the reactor did not scram, no hazardous situation was developed.

1-b. The discussion of blower action developed in 1-a above demonstrates that the total reactor flow does not decrease based on maximum surge until surge occurs but actually increases. There is no reason to expect, then, that the reactor inlet temperature will increase, that the reactor outlet temperature will increase, or that reactor power will decrease. These may actually move in the opposite direction.

2. Allis-Chalmers agrees that surging behavior of the blowers must be investigated to validate the conclusions of this study. Every past issue of the study has recommended and this issue still recommends that the surging characteristic of the blowers be investigated. The responsibility for demonstrating the stability of the blowers during accident conditions, however does not rest with Allis-Chalmers.

3. Butterfly valves are aerodynamically stable only in the fully opened or fully closed position. However, these valves will generally open fully from a rest position of 60° or 70° (from fully closed position) if no holding force is applied and will close fully if the amount of opening is less than 60° or 70° . It is agreed, however, that the valve operator selected for operation of these valves should be such that if the operating fluid fails the valves cannot be moved by flow forces.

4. A single blower failure is a hazard and Allis-Chalmers agreed with the original comment. However, we wish to emphasize that the responsibility to demonstrate the stability and operability of the reactor coolant blowers is not the responsibility of this organization. We have, where applicable, indicated the problem of surging (which could lead to the failure suggested) should be investigated. To prevent misunderstanding of the complete intent of recommendation 2 and 4 of the approved study, we have reworded recommendation 2 which recommends a complete analysis of blower stability and structural integrity during and following all possible accident conditions in the reactor coolant system.

With regard to the necessity for the operability of at least one coolant loop we emphasize that the objective of this study is to show that block valve operation inadvertently will not present a hazard. This objective has been met. The overall problem of the operability of other components not affected by block valve closure is not a proper subject for the study; but to answer the comment specifically, we have recommended that an independent emergency cooling system be installed in the EGCR since, with the present design of the reactor, continued operability of at least one coolant loop can not be assured.

FROM THE BLOWER CHARACTERISTICS, THE MINIMUM FLOW THROUGH THE BLOWER WHEN OPERATING AT 20% LOAD SPEED IS

$$\frac{.061}{.080} \times 100 = 76.4\% \text{ OF NORMAL OPERATING FLOW (20\% FULL FLOW)}$$

FROM FIGURE 1 WE FIND THAT

$$\frac{W_L'}{W_L} = 0.85 \quad \text{AT 42 SECONDS} \quad W_L' = 17\%$$

$$\frac{W_L'}{W_L} = 0.745 \quad \text{AT 50 SECONDS} \quad W_L' = 14.9\%$$

THE TOTAL FLOW, W_T , AT 42 SECONDS IS

$$W_T = \frac{17.0 + 20.0}{2} = 18.5\%$$

AND AT 50 SECONDS IS

$$W_T = \frac{14.9 + 20.0}{2} = 17.45\%$$

THE RATE OF FLOW DECREASE IF BLOWER SPEED IS HELD CONSTANT IS

$$\frac{18.50 - 17.45}{8} = 0.1315\%/\text{sec}$$

IF THE BLOWERS CHANGE SPEED AT MAXIMUM RATE THE MINIMUM RATE OF FLOW CHANGE THROUGH THE CORE IS

$$\frac{1.5(0.764) + 1.5}{2} = 1.32\%/\text{sec}$$

INADVERTENT OPERATION OF COOLANT LOOP ISOLATION VALVES

APPENDIX A

SIMILAR TO

DR'N ADA 1/11/62 CH'D DRL 1-12-62 APP'D SCALE = 12 SHEET 11 OF 1 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT. NPD-W

STUDY B 320