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SPEED OF CONTROL FOR NO OVERBORE CASES

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EXPANSION TASK FORCE - OLD REACTORS
SPEED OF CONTROL FOR NO OVERBORE CASES

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February 22, 1960

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EXPANSION TASK FORCE - OLD REACTORS
SPEED OF CONTROL FOR NO OVERBORE CASES

SUMMARY

The Criteria for Speed of Control must be met for all cases being considered in the Expansion Studies. These Criteria are dependent upon the ratio Volume of water/Volume of uranium in the process channel, the reactor power level, and the rate at which the vertical rods are released and inserted into the reactor. For those cases wherein the graphite channel is overbored by 0.200 inch, the criteria can generally be met for the power levels under consideration since the ratio of V_w/V_u is maintained adequately small by the use of large diameter fuel elements. If the graphite is not overbored, high pressure drop across the fuel element section must be maintained in order to maintain small values of V_w/V_u , which results in a substantial increase in the front header pressure.

With the present vertical rod system, no overboring, the use of zircaloy tubes, and a 75 mil water annulus, it has been estimated that the Speed of Control Criteria can be met with reactor coolant flow rates up to approximately 107,000 gpm. This results in a front top-of-riser pressure of approximately 650-700 psig. If the rod release time is reduced from 1.4 seconds to 1 second, the Criteria are met for a flow rate of 115,000 gpm at a riser pressure of approximately 550-600 psig, and for a flow rate of 105,000 gpm at a riser pressure of approximately 450 psig. If the rod release time is reduced to 1.0 second and the rod insertion time is reduced from the present 1.6 seconds to 0.8 second, a flow rate of 115,000 gpm could be sustained at a riser pressure of approximately 500-550 psig. This latter case requires accelerated vertical safety rods.

As a base case, using Zircaloy tubes and existing seven pump operation, enlarging the rear Parker fitting to 0.61 inch, and using a 3/4 inch rear pigtail, it is estimated that a flow rate of 89,000 gpm could be achieved, which falls within the Speed of Control Criteria.

DISCUSSION

A method is developed in this document which ties together and defines the hydraulic and physics characteristics of the fuel - process channel geometry necessary to satisfy the Speed of Control Criteria over a range of feasible operating conditions. This study assumes no graphite overboring and employs throughout a smooth bore zircaloy process tube having an inside diameter of 1.650 inches. The fuel elements are self-supported, and the inner hole size was selected to provide an optimum flow split for corrosion considerations. The following hydraulic equations were utilized to obtain the flow-pressure drop relationship across the fuel elements:

$$\Delta p = K F^{1.9}$$

Fuel OD	K
1.50	0.230
1.48	0.167
1.46	0.125

The reactor is assumed to have 1800 effective central zone flow tubes. The fuel element can wall thickness is assumed to be 45 mils for both the outer and inner cans, and the fuel supports were calculated to have a total volume of 0.00016 cu. ft. for the charge of 32 fuel elements. Table I summarizes the results of the hydraulic calculations and indicates the various dimensions used. On Figure 1 is plotted pressure drop across the fuel elements vs the ratio V_w/V_u , with the total reactor flow rate as parameter. Also shown is the coolant annulus size for the range of cases studied. Details of the hydraulic calculations were prepared using data and methods supplied by P.A. Carlson.

Shown also on Figure 1 are three lines which define the boundaries of the Speed of Control Criteria. These lines are based on the following conditions relating to the release and insertion of the vertical rods after receipt of a pressure signal by a Panellit gauge:

<u>Line</u>	<u>Rod Release Time</u>	<u>Rod Insertion Time</u>
A	1.4 seconds	1.6 seconds
B	1.0 "	1.6 "
C	1.0 "	0.8 "

The rod insertion time is assumed to be the length of time required for all rods to be inserted into the reactor from the point at which the rods just become effective until the rods are 90% inserted. The rod release time is taken as that interval between the receipt of a signal by a Panellit gauge and the moment the rods just become effective. The data for these curves were prepared by Roy Nilson and Warren Nechodom.

Following is an interpretation of the use of these curves. Consider as an example the line A for the existing rod system. This speed of control line intersects the 105,000 gpm reactor coolant curve at a water-uranium ratio of 0.37. This V_w/V_u ratio describes a particular fuel element size necessary to satisfy the Speed of Control Criteria corresponding to the power level represented by the flow rate of 105,000 gpm, in this case 2300 MW. This point also describes the pressure drop across the fuel element section, 490 psi, necessary to maintain the flow of 105,000 gpm. If it is desirable to utilize a lower pressure drop, requiring a fuel element of smaller diameter and a larger V_w/V_u ratio, then the permissible power level and flow rate would decrease. Figure 2 is a cross-plot of maximum power level vs V_w/V_u .

To summarize, maximum power levels are described, as a function of fuel dimension, by the boundary line A, which must not be exceeded if the Speed of Control Criteria is to be satisfied using the existing vertical rod systems. If rod and electrical system modifications are made to decrease the rod release and insertion times, the maximum power levels are described by lines B and C. On Figure 1, these lines also describe the fuel element Δp and flow rates needed to achieve the maximum power level.

Using these same methods, but presenting the results in a different manner, an estimate has been made of the maximum capability of the existing pumps and vertical rods in satisfying the Speed of Control Criteria. The results are plotted in Figure 3, and indicate that with

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seven pump operation, 1.65 inch ID zircaloy tubes, self-supported fuel elements, and the fuel elements sized to provide a V_w/V_u ratio of 0.45, the maximum average permissible power level would be 1925 MW. This corresponds to a flow rate of 87,500 gpm. If the rear Parker fittings were enlarged to 0.61 inch, and a 3/4" rear pigtail used, a flow rate of about 89,000 gpm could be achieved, and the V_w/V_u ratio would fall within the Speed of Control Criteria. This flow rate and power level increase is a result of decreasing the pressure drop across the rear fittings, increasing the pressure drop across the fuel elements, and utilizing a larger diameter fuel element.

Figure 4 is a plot of initial conversion ratio (gr. Pu/MWD) vs the ratio V_w/V_u for the range of conditions in this study.

The data contained herein were compiled from a limited number of cases, and are subject to revision and expansion. An IBM program will be run to determine intermediate cases, including acceleration of only a fraction of the vertical rods.

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TABLE I
FLOW CHARACTERISTICS

Tube ID	Slug OD	Slug ID	Uran. OD	Uran. ID	Vol-Water cu. ft.	Vol-Uran. cu. ft.	Vw/Vu	Annulus	Active Zone ΔP	Tube Flow	React. Flow	Power Level
1.650	1.500	.363	1.410	.453	.07714	.21396	.3605	75	300	44	79	1775
1.650	1.500	.363	1.410	.453	.07714	.21396	.3605	75	400	50.5	91	2050
1.650	1.500	.363	1.410	.453	.07714	.21396	.3605	75	500	59.5	107	2400
1.650	1.500	.363	1.410	.453	.07714	.21396	.3605	75	600	70.5	127	2860
1.650	1.480	.378	1.390	.468	.08684	.2056	.422	85	300	51.5	93	2090
1.650	1.480	.378	1.390	.468	.08684	.2056	.422	85	400	60.0	108	2430
1.650	1.480	.378	1.390	.468	.08684	.2056	.422	85	500	67.5	122	2740
1.650	1.480	.378	1.390	.468	.08684	.2056	.422	85	600	74.0	133	3030
1.650	1.460	.394	1.370	.484	.09584	.1972	.486	95	300	58.2	105	2360
1.650	1.460	.394	1.370	.484	.09584	.1972	.486	95	400	67.0	121	2720
1.650	1.460	.394	1.370	.484	.09584	.1972	.486	95	500	76.0	137	3080
1.650	1.460	.394	1.370	.484	.09584	.1972	.486	95	600	83.0	149	3350

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Figure 1 - SPEED OF CONTROL - HYDRAULICS CHARACTERISTICS

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Figure 2 - RELATIONSHIP BETWEEN MAXIMUM POWER LEVEL AND V_w/V_u

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Figure 3 - SPEED OF CONTROL - HYDRAULICS CHARACTERISTICS
EXISTING PUMPS AND VERTICAL RODS

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Figure 4 - INITIAL CONVERSION RATIO v.s. V_w/V_u

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