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Page 1

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AVOIDANCE OF BULK TEMPERATURE LIMITS — 105-D AND F

By

J. P. Corley

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PLANT AND INDUSTRIAL ENGINEERING
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978

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HW-56363

Page 2

AVOIDANCE OF BULK TEMPERATURE LIMITS -- 105-D AND F

With higher power levels and probably higher river temperatures, the forthcoming warm water season is expected to impose bulk outlet temperature limits, with consequent production losses, on all Hanford reactors to an even greater extent than last year. The problem has received the attention of a number of management and engineering personnel, but the basis for this study was a letter originating in the Production Operation⁽¹⁾ suggesting two alternate schemes for increasing the flow of process water to the rear face piping, thereby reducing bulk temperatures for a given power level. The purpose of the suggestions was to provide an interim solution to the problem pending I & E loadings. Loading with I & E slugs will increase reactor flows to some degree, depending on the actual slug dimensions used, and will probably result in encountering other limits than the B.O.T. limit. The applicable period for study was therefore taken to be this summer only, since I & E loadings are expected to begin in June or July at 105-D and during the fall at 105-F. The Managers, D and F Reactor Operations, requested⁽²⁾ Plant and Industrial Engineering Operation to investigate and compare the feasibility and applicability of the suggested alternates, which is the purpose of this report.

SUMMARY

There is little doubt that avoidance of the bulk temperature limit during this warm water season will require process water flows greater than can be attained with seven pump operation without I & E loading. The required flows very probably can be attained by replacing a number of fringe tube orifices with venturis; the number and the justification, therefore, depend primarily on base river temperatures which can only be roughly predicted. On the basis of the latest temperature predictions, however, replacement of about 200 orifices at 105-D and F would be economically justified by the value of the increased production, provided that hydraulic problems do not prevent the increased flow. The extent of I & E loading during the period July 1 to October 1 will also affect the justification for D reactor.

DISCUSSION

Our analysis has been based primarily on an assumed number of 1430 effective central tubes, a tube power limit of 975 kw, and a bulk outlet temperature limit of 93° C. Foreseeable changes in any one of these will affect the justification but not the feasibility of the basic proposals. It is considered permissible to assume that additional flows of the size considered here will not significantly change the cavitation problems of the 190 pumps. Impellor replacement may, however, be hastened by a month or two. A less reliable assumption is the

(1) Letter, J. R. Young to T. Prudich, "Avoiding the Bulk Outlet Water Temperature Limit", February 24, 1958.

(2) Letter, E. J. Filip to W. W. Windsheimer, "Request for Reason Sheet", March 18, 1958.

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HW-56363

Page 3

ability of the 105-F downcomer to handle the additional flows, pending additional experience or the results of a model study just getting underway. For the extent of I & E loading, dependence was placed on information received from the Production Operation on June 6, 1958, to the effect that significant amounts of I & E slugs would not be loaded at D before September 1 or at F before October 1. No increased flow from this source has therefore been used. Additional process water of the volumes considered here is available according to the respective Power Operations, although the use of Hagan filter-aid at 183-D may be required. Using the standard power level formula:

$$\text{Power Level (MW)} = 0.2635 \times 10^{-3} \times Q \times (T_b - T_i)$$

where Q = total coolant flow in gpm

T_b = bulk outlet temperature

T_i = reactor inlet water temperature

Figure 1 has been prepared to show the required volume of flow for a given inlet temperature at B.O.T. limits of both 93 and 94° C., and 1430 and 1460 E.C.T.

Using the basic assumptions above, reactor inlet temperatures for 1957 were reviewed to determine the potential need for additional water. Results were expressed in degree-days, i.e. the sum of the number of days the 105 inlet temperature (as recorded in the daily operating reports) exceeded the permissible inlet temperature multiplied by the excess temperature in degrees C. During the warm water period, July 1 to October 15, 1957, on only one day did the 105-D inlet temperature exceed the permissible temperature for the volume of water available with seven pump operation, or a total of 0.2 degree-days. A total of about 40 degree-days were recorded based on the volume of water available from six pump operation or the equivalent of 750 MWD. At 105-F a total of 93 degree-days (or about 1740 MWD) at six pump operation, and 4 degree-days (or about 75 MWD) at seven pump operation were recorded. River water temperatures during 1957 were close to the 10-year mean; higher temperatures are expected this year due to greater upstream ponding and earlier runoff. The latest prediction by H. A. Kramer, Plant and Industrial Engineering Operation, is shown in Figure 2. Table I shows the maximum and mean inlet water temperatures, based on the predicted temperatures at 181-B and corrected for further temperature increases in the river and in the water plants.

TABLE I

	<u>PREDICTED MEAN TEMPERATURE</u>					<u>MAX. TEMPERATURE</u>
	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct. - First Half</u>	<u>Season</u>	<u>August</u>
105-D	21.3	22.7	23.0	21.5	22.2	23.0
105-F	22.3	23.3	23.5	22.0	22.9	24.0

Table II shows the variation in degree-days and MWD losses for different mean river temperatures at 181-B. It should be noted here that an increase in the bulk temperature limit of 1° C has the same effect on predicted MWD loss as a 1° C decrease in base river temperature. It is evident that for a bulk limit of 93° C, river temperatures even lower than predicted will result in significant production losses.

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HW-56363
Page 4

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Figure 2

1958 RIVER FLOW AND TEMPERATURE FORECAST

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TABLE II

	(Predicted Mean) 181-B River Temp. - 20°C		Mean 181-B River Temp. - 19°C		Mean 181-B River Temp. - 21°C	
	<u>Degree-Days</u>	<u>MWD</u>	<u>Degree-Days</u>	<u>MWD</u>	<u>Degree-Days</u>	<u>MWD</u>
105-D	120	2320	50	970	200	3860
105-F	190	3670	110	2120	270	5210

Considered first was operation of additional 190 pumps to increase front-face pressures and thus reactor coolant flow. With stable operation and approximately the same tube loadings as at present, Table III shows maximum (3) flows for 105-D (actual flows are slightly less), together with the maximum 105 inlet water temperature which would permit a B.O.T. limit of 93° C to be met with 1430 and 1460 effective central tubes. Cone valve throttling was not allowed for.

TABLE III

	<u>Maximum Normal Flow</u>	<u>ECT - 1430</u>	<u>ECT - 1460</u>
6 pumps	71,300 gpm	18.8° C	17.2
7 pumps	73,300 gpm	20.8° C	19.3
8 pumps	74,600 gpm	22.1° C	20.6

The same reference states that comparable flows at 105-F should be achieved.

The second method of avoiding bulk limits is (as proposed in reference (1)) by the increase of total reactor coolant flow through exchanging a number of fringe zone tube orifices for venturis, thereby reducing the pressure drop across the fittings and increasing the fringe zone flows. Increases of 10 - 15 gpm per tube changed are possible at seven pump operation. A decrease in the pressure at the bottom of the front face risers of less than 10 psi will be required (4) for a total flow increase of 3000 gpm. The concurrent reduction in flow through the central zone tubes should be less than 0.5 gpm. The third method for reducing bulk outlet temperatures, proposed as an alternate in reference (1), is partial quenching, i.e. the addition of cold, raw or emergency process water to the far rear riser through the recirculation system. A flow of 3000 - 4000 gpm is available by this method. By this means, an effective bulk outlet temperature of 95 - 96° C may be attained while the actual bulk water temperature entering the downcomer remains at 93° C. Details for a system of larger scope are contained in reference (5).

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- (3) HW-49651 (), "Reactor Flow Capabilities", K. W. Hess, April 17, 1957.
- (4) HW-54590 (Confidential), "Standard Laboratory Hydraulic Pressure Drop Characteristics of Various Solid and I & E Fuel Elements", E. D. Waters and G. R. Horn, January 20, 1958.
- (5) HW-54870 (Secret), "Budget Study - Reactor Effluent Quenching - 105-B, C, D, DR, F, and H", J. P. Corley, February 12, 1958.

In general, putting additional 190 pumps on the line is the cheapest way of getting greater process flows. For example, going from six to seven pump operation provides about 2000 gpm additional at an increased power demand of 2200 kw. At \$1.50 per kw-month, the present charge for interruptible power, this costs \$3300 per month, or \$1.65 per gpm per month. Adding the eighth pump provides another 1200 gpm at about the same cost per gpm. It is apparent from Table I and III and Figure 1 that even eight pump operation will not prevent significant production losses at a bulk limit of 93° C. There are other factors which must be considered before placing an eighth pump on line, of course, such as the effects on power procurement, maintenance schedules, and operation with a spare pump. For the balance of this discussion, only seven pump operation has been assumed, although the possibility of using the eighth pump for short periods is not ruled out. This pre-supposes that adequate interruptible power will be available. Present indications are that the regular B.P.A. interruptible may only be available through August 15, but that other power can be made available through the first half of October at a higher price (about \$2.00 per kw-month as compared to \$1.50 per kw-month).

Assuming seven pump operation then, with a flow of 73,100 gpm for existing tube loadings and orificing configuration, Table IV below shows the additional flows required at 105-D and F to meet a bulk limit of 93° C at the predicted mean inlet temperatures. Also shown is the approximate number of orifice replacements required for each condition to provide the additional flow and thereby avoid the production losses shown in Table II.

TABLE IV

	<u>105-D</u>			<u>105-F</u>		
	<u>Required</u> <u>Flow-gpm</u>	<u>Added Flow</u> <u>Required</u>	<u>No. Fringe</u> <u>Tubes</u>	<u>Required</u> <u>Flow-gpm</u>	<u>Added Flow</u> <u>Required</u>	<u>No. Fringe</u> <u>Tubes</u>
July	73,000	700	60	74,000	900	75
August	75,300	2200	160	76,100	3000	210
September	75,600	2500	180	76,100	3000	210
October-- first half	74,000	900	75	74,500	1400	110

The approximate cost of replacing 200 fringe tube orifices with venturis has been estimated at \$6600 (including \$530 labor cost). Approximately eight hours undisturbed front elevator time would also be required if the job were done separately; the actual additional reactor downtime would of course depend on how the work could be meshed with other outage work. Presumably, alike charge would be incurred when venturis were replaced following I & E slug loading. The total additional pumping cost for a 3000 gpm increase in flow would be about \$1700 for the season. Assessing four hours production loss, the total cost would be approximately \$15,000 for the season. Savings of 2000 MWD at D or 3300 MWD at F would result if predicted temperatures are reached, if the bulk limit stays at 93° C, and if hydraulic problems do not arise.

Partial quenching should provide the same benefits but at somewhat higher cost, primarily due to the additional instrumentation that would be needed. There

DECLASSIFIED

HW-56363

Page 8

are also unresolved questions of reactor safety and hydraulic behavior. This solution is therefore less attractive than fringe tube orifice replacement.

ACKNOWLEDGMENT

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