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FUTURE RIVER TEMPERATURES AT 181-N

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FUTURE RIVER TEMPERATURES AT 181-N

Temperatures of river water entering the N-Reactor secondary cooling system during the past winter have been significantly higher than the inlet water temperatures at K-Area, which in turn are higher than base river temperatures measured at the Priest Rapids gauge station. The obvious source is the heated upstream reactor effluents, magnified by river flow cycling resulting from fluctuations in Priest Rapids power generation. The Reactor Design Analysis Sub-Section, N-Reactor Department, General Electric Company, has requested [1] from the Radiation Protection Department answers to two questions.

1. What is the estimated maximum inlet temperature to the N-Area system that could be expected to occur?
2. What would be the temperature gradient in the river at such time?

A letter [2] giving initial estimates has been forwarded. This document provides calculations, supplementary information, and additional comments.

SUMMARY

A raw water temperature of 24-26°C at the 181-N pumphouse is possible with the existing river regime and reactor operations in August or early September. Larger temperature increases between Priest Rapids and N-Area are possible from January to April, but the base river temperature would be lower.

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- [1] Letter, H. R. Kosmata to A. R. Keene, "N-Reactor River Water Temperature", dated January 15, 1965.
- [2] Letter, J. P. Corley to H. R. Kosmata, "N-Reactor River Water Temperature", dated February 3, 1965.

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Conditions necessary to reach the maximum temperatures given are:

- a. A hot summer with a base river temperature equal to the maximum observed to date at Priest Rapids.
- b. No river cooling from manipulation of Grand Coulee releases.
- c. A minimum river flow of 36,000 cfs below Priest Rapids Dam for a period of four hours or more.
- d. B, C, and both K reactors operating on bulk outlet temperature limits, with existing outfall and trench structures.
- e. No pumps operating at the WPPSS river pumphouse.

In addition to direct discharge of upstream reactor effluents to the river, effluent system leakage and K trench discharge contribute to the over-all temperature increase between Priest Rapids and N-Area. Solar and atmospheric heating also occurs.

At a river flow of 40,000 cfs, temperature traverses of the river just above 181-N show a maximum along the plant shore, a sharp decrease between 25 and 100 yards from the plant shore, then increasing temperatures out to a maximum at about 300 yards followed by a sharp decrease to the far shore at 550 yards.

WATER TEMPERATURE COMPONENTS

The inlet water temperature at 181-N is the resultant of the following:

- a. Base river temperature.
- b. Temperature increments from solar heating.
- c. Temperature increments from upstream reactor effluents.
- d. Temperature increments from the influx of heated underground water.

Base River Temperature

Since the question has been put in the form "What maximum temperature will the river reach?", the base river temperature is the most important variable. The annual range of river temperatures at the Priest Rapids gauge is generally between 3° and 20°C. Summer temperatures have increased with the construction of upstream dams, the effect of each dam being dependent on the dimensions of the impoundment. Beginning in 1958, maximum river temperatures at Hanford have been reduced by controlled releases of sub-surface water from Grand Coulee storage. The size of the temperature reduction varies during the season and from year to year, and at any given time is dependent on the availability of excess water at Grand Coulee Dam. The program also depends at present on AEC funding, justified originally by increased production but also providing more favorable river temperatures for migrating salmon.

Maximum water temperatures will occur in a year which has unusually warm weather in late August and early September combined with unusually low river flows. Average river flows as low as 65,000 cfs could occur by the end of August, which would result in Priest Rapids flow cycling to less than 40,000 cfs at night, and no special water releases from Grand Coulee. The FPC license to Grant County P.U.D. to operate Priest Rapids specifies a minimum release of 36,000 cfs. In the maximum water temperature year of 1958, a peak temperature of 20.5°C was measured at Priest Rapids gauge, even with a Grand Coulee release effect estimated at 1°C. Neither Rocky Reach nor Wanapum Dams had been completed at that time. By assuming an increment of 1°C for these two dams, now completed, a potential maximum

temperature of 22-23°C can be foreseen. This is partially offset by normally lower temperatures during the minimum flow period of the day. An unusual sequence of upstream dam operations could cause maximum river temperature for the day to coincide with minimum flow, but the resulting temperature difference should not exceed 1°C. The effect of future impoundments on the upper Columbia system, such as the proposed Arrow Lakes outlet improvement, is not known. For example if the bottom layers of the Arrow Lakes are withdrawn, a 2-3°C reduction in maximum summer temperatures is possible [3]. Equally possible are temperature increases from other proposed dams on the Columbia and its tributaries. Until planning and extended studies are completed, it is not possible to predict the magnitude or direction of the eventual temperature increment at Hanford. No allowance has therefore been made for new impoundment effects.

Solar Heating

Water in bays and backwater areas along the river absorbs heat from the sun and warmer air. Although the net daily increase in river temperature from these effects is greatest in late spring and early summer, the greatest incremental temperature occurs in these areas in July and August. A difference of 0.5 to 1°C between the fast current temperature and adjacent slowly moving water is common. Although the peak incremental temperature will occur in the afternoon, up to half of the change may occur by the time the maximum effect of the minimum flow period is seen at 181-N.

Upstream Reactor Effluent

A major question has been the extent of upstream reactor effluent in the N-Area raw water. There are three outfall lines to be considered - B, C, and K. Since the diffusion pattern from each is different and since it was desired

[3] Davidson, F. A. "Temperature Regime of the Columbia River from Priest Rapids to the Arrow Lakes", January, 1964, Report to Grant County P.U.D. No. 2.

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to obtain dilution factors at minimum river flow, a series of dye tests were performed to measure directly the concentration of each effluent in N-Area inlet water over a range of river flows. Some data was available from other dye tests performed under a current R&D study of the effects of reactor effluent on river water quality. Data from the six runs made for this report is shown in Table I in the Appendix.

For each of the test runs, Rhodamine BX liquid (40% solution in acetic acid) was pumped continuously into either a 1904 outfall structure or 107 basin outlet. A continuous-recording automatic fluorometer (Turner Model 111) was set up at 181-N on a sample line from a backwash pump discharge line. Dye pumping was continued until an equilibrium concentration was indicated by the fluorometer, which took from 2 to 6 hours, depending on the outfall tested, the river flow, and the flow cycling. From the known weight concentration in the effluent and the indicated concentration at 181-N (based on previous calibrations with the same dye in river water), a dilution factor could be calculated:

$$DF = \frac{\text{Concentration of dye at 181-N}}{\text{Concentration of dye in the effluent}}$$

Figure 1 shows the results of these and other applicable tests, with DF plotted against river flow. From the usual diffusion equations, this relationship would be a complex power function. Where boundary effects are a factor as they are in this case, rational analysis is believed not possible. Fortunately, the short extrapolation necessary between actual tests and expected minimum river flows makes it possible to determine extreme DF's with some confidence by fitting a straight line on log-log paper to the test points.

Underground Water

Heated water from leaks in the effluent systems reaches the water table in all the old reactor areas. Studies [4] by Geochemical and Geophysical Research have shown that, in addition to visible seepage along the river bank, re-entry to the river may also occur for some distance out from the shoreline. The K-Area Liquid Waste Trench extends downstream from K-Area about 0.8 of a mile, running parallel and about 300 yards from the shoreline, and ending one mile above 181-N. Several test wells between the trench and the river routinely show underground water temperatures as high as 50-55°C [5]. The source of the heated water in the trench is leaking valves in the K effluent systems. Although the discharge rate to the trench is not known, an estimate of 5,000-10,000 gpm would correspond to the observed ground water temperature. Visual observation of seepage areas along the river indicates the seepage rate depends on whether both reactors are operating or not.

Figure 2 shows temperature profiles of the river upstream of 181-NE at several different river flows. The relatively high temperatures along the plant shore at lower river flows are obvious. Although sufficient data is not now available to distinguish between the direct contribution of upstream effluent discharges and seepage from the K Trench, in my opinion the greatest part of the inshore increment is due to trench seepage. In support of this opinion is the presence of the same temperature patterns

[4] HW-81306 (UNCL.) "Analysis of Waste Released to the River by Seepage from the 1301-N Crib", R. W. Nelson, April, 1964.

[5] Brown, D. J., Personal Communication

one mile below 1904-K (three-quarters of a mile upstream from 181-N) where dye tests from 1904-K also fail to account for the higher in-shore temperatures.

Note in Figure 2 the second traverse of 3-30-65. This data was taken while the river was rising; the main stream temperatures reflect the increased river flow, while the slower moving water along the plant shore still corresponds to the earlier low flow. The peak effluent concentration from 1904-K at 300 yards from shore is quite marked, as is the apparent boundary between the main stream and the in-shore section at about 125 yards. River velocity on this day at 100 yards from shore was 1.5 fps at low flow and 2 fps at the higher flow. With four pumps operating at 181-N and delivering 410,000 gpm, the minimum width of the river intercepted is about 100 yards at low flow and about 60 yards at the higher flow. In either flow case, then, the 181 pumps would take in the full width of the river zone apparently affected by ground water seepage. The river pumphouse now under construction for the Washington Public Power Supply System generating plant will have a greater pump capacity than 181-N. During power generation, K trench leakage should, therefore, not be a factor at 181-N.

MAXIMUM TEMPERATURE CALCULATIONS

Although the effluent temperatures at the older reactors vary somewhat over the annual cycle as different operating limits are imposed, the difference between effluent and river temperatures depends primarily on the latter. The maximum increase at 181-N over base river temperature will therefore probably occur in late winter at the time of low river temperature, while the maximum temperature at 181-N will probably occur in late summer.

The difference in total temperature increase at 181-N between the two seasons should be small, however, due to a compensating change in atmospheric heat input. The two samples below have been calculated using typical effluent temperatures for the period. It is assumed in these examples that the WPPSS pumps at 181-N are not operating, and that B and C reactors are both discharging through the C outfall lines, as has been the case in the past on occasion. It is further assumed that the rate of intake from each outfall will vary linearly with effluent flow rate.

Maximum ΔT (February)

$$Q_R = 36,000 \text{ cfs} \quad T_R = 3^\circ\text{C}$$

For each reactor, $\Delta T_i = (D.F.)(T_c - \Delta T_b - T_R)$

Where ΔT_b = temperature loss in 107 basins from previous test data

$$DF_c = 0.0067 \quad \Delta T_c = (92-3-3)(0.0067)\left(\frac{189,000}{100,000}\right) = 1.09$$

$$DF_K = 0.0165 \quad \Delta T_K = (86-3-3)(0.0165) = \underline{1.35}$$

$$\text{Total Effluent Effect} = 2.4$$

$$\text{From K Trench} \quad \Delta T = \frac{10,000 \text{ gpm}}{410,000 \text{ gpm}} (50-3) = 1.2$$

$$\text{Atmospheric Effect - may be negative, but assume} = \underline{0.0}$$

$$\text{Total } \Delta T_N = 3.6^\circ\text{C}$$

$$\text{Base Temperature} = \underline{3.0^\circ\text{C}}$$

$$181\text{-N Temperature} = 6.6^\circ\text{C}$$

Maximum Temperature (August)

$$Q_R = 36,000 \text{ cfs} \quad T_R = 22^\circ\text{C}$$

$$\text{For reactors, } \Delta T_c = (95-2-22)(0.0067)\left(\frac{189,000}{100,000}\right) = 0.90$$

$$\Delta T_K = (95-2-22)(0.0165) = 1.17$$

$$\text{Total Effluent Effect} = 2.1$$

$$\text{For K Trench, } \Delta T = \frac{10,000}{410,000} (55-22) = 0.8$$

$$\text{For atmospheric heating} = 0.5$$

$$\text{Total } \Delta T = 3.4$$

$$\text{Base River Temperature} = 22.0$$

$$\text{Maximum 181-N Temperature} = 25.4^\circ\text{C}$$

Changes in operating limits, reactor flow rates and discharge rates to the K trench could affect the calculated values slightly, but not enough to be significant in the estimate of maximum temperature. Upstream dam construction could have a greater effect. From past river records, the present probability of getting a maximum temperature of 26°C at 181-N in any given year is less than 10%. The probability of getting 24°C is considerably higher, and for a temperature of 23°C may exceed 50%. As noted above, construction of major impoundments on the upper Columbia will change these probabilities. With the WPPSS pumps operating, the temperature calculated will occur at 181-NE instead of 181-N. In this case, the total temperature increase at low river flows at 181-N should be 0.5 to 1.0°C less than calculated.

POSSIBLE IMPROVEMENTS

Three remedial actions would seem to be possible, although I cannot at present assess the feasibility or economic justification.

1. Prevention of hot water discharge to the K Trench.

Elimination of this source would lower the maximum 181-N temperature by about one degree if WPPSS were not generating at the time of occurrence. It is the author's understanding that a solution to the problem is neither simple nor inexpensive.

2. Construction of an off-shore dike.

A rock-filled dike could be constructed running parallel and 150-200 yards off the plant shore from below 1904-K to just above 181-NE. Adequate engineering design would probably require a hydraulic model study. The cost could easily exceed half a million dollars.

3. Construct intake lines from 181-N into the river.

To avoid the K effluent plume, intake lines for 181-D would have to extend at least 400 yards out from the plant shore. The cost would probably be the same order of magnitude as for a dike.

The benefit of any of these improvements would be at best about 3^o C.

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APPENDIX

Data from dye tests made specifically for this study are given in Table I.

Symbols used are:

Q_R = river flow rate

Q_e = effluent flow rate

W = rate of dye addition

C_e = concentration of dye in effluent

C_N = concentration of dye at 181-N intake

$$D.F. = \frac{C_N}{C_e}$$

θ_i = time lapse between start of pumping and initial dye pickup at
181-N

Table II is a comparison of temperature increases actually observed at 181-N versus temperature increases due to direct effluent intake only, calculated as on page 10 . The difference between the observed and calculated values should then reflect the combined effects of K Trench seepage and atmospheric heating or cooling.

TABLE I

<u>Date</u>	<u>Reactor</u>	<u>Q_R-cfs</u>	<u>Q_e-gpm</u>	<u>W-gm/sec</u>	<u>C_e</u>	<u>C_N</u>	<u>D.F.</u>	<u>θ_i-min</u>
1-22-65	B	42,000	89,000	0.57	1.0×10^{-7}	3.2×10^{-10}	0.0032	140
1-22-65	B	125,000	89,000	0.57	1.0×10^{-7}	4.8×10^{-11}	0.00048	-
1-24-65	KE	40,000	209,000	0.55	4.1×10^{-8}	3.2×10^{-10}	0.0078(1) 0.0156(2)	75
1-29-65	C	38,000	100,000	0.57	9.0×10^{-8}	5.3×10^{-10}	0.0059	150
1-30-65	B	40,000	89,000	0.57	1.0×10^{-7}	3.5×10^{-10}	0.0035	140
2-21-65	C	65,000	100,000	0.56	8.9×10^{-8}	3.0×10^{-10}	0.0034	100

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TABLE II
OBSERVED VERSUS CALCULATED TEMPERATURES

<u>Date</u>	<u>Q_R-cfs</u>	<u>T_R-°C</u>	<u>ΔT-Calculated</u>	<u>ΔT-Observed</u>	<u>(ΔT_{calc.} - ΔT_{obs.})</u>
1-22-65	42,000	4.9	1.8	2.6	-0.8
1-24-65	40,000	4.6	1.4	1.6	-0.2*
1-29-65	38,000	5.1	1.4	1.7	-0.3*
4-13-65	55,000	6.6	1.0	1.1	-0.1*
4-15-65	50,000	6.9	1.1	1.9	-0.8
4-18-65	70,000	6.8	1.0	1.7	-0.7

* Either KE or KW not operating.

Dilution Factor

FIGURE 1

Dilution Factors at 181-N from Dye Tests

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FIGURE 2

River Temperature Profiles Above 181-N