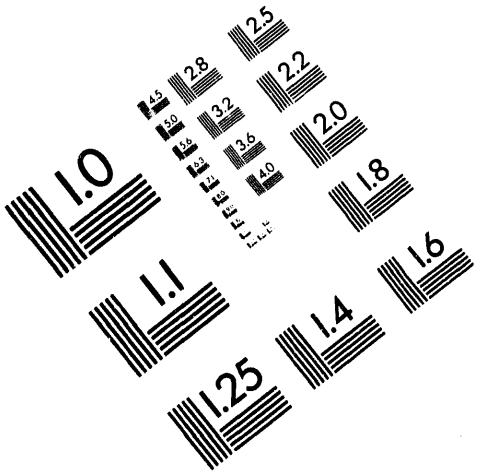
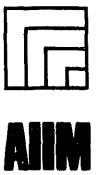
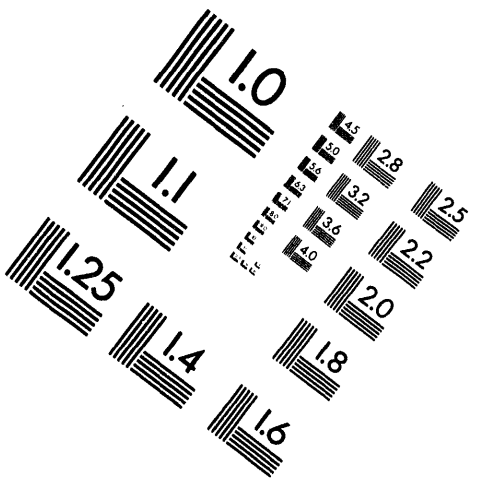
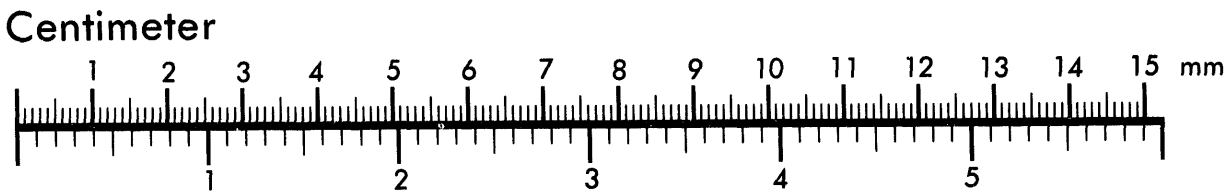
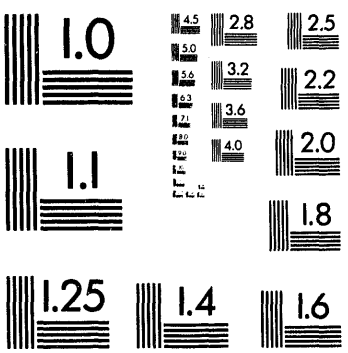


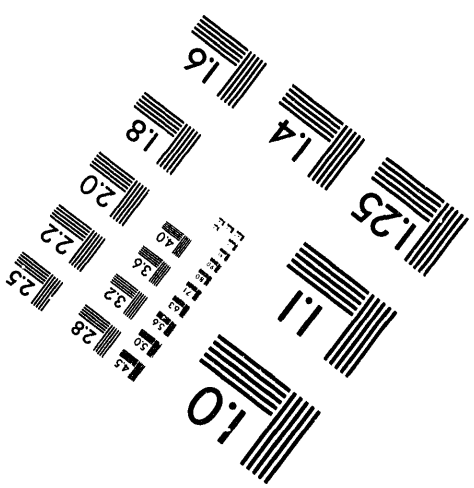


Association for Information and Image Management
1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

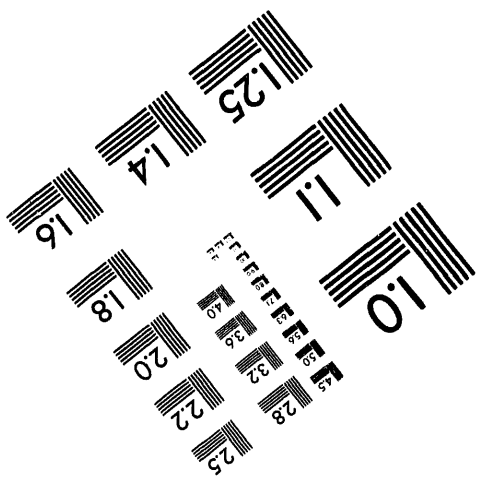








MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.



1 of 1

UNCLASSIFIED

HW-60285-PT.1

3-

ARTIFICIAL COOLING OF THE COLUMBIA RIVER BY DAM REGULATION

PART I

BATTELLE-NORTHWEST
RETURNED
OCT 1 1959
CIRCULATING COPY
TECHNICAL INFO. SECTION

H. A. KRAMER

MAY 25, 1959

IRRADIATION PROCESSING

FACILITIES ENGINEERING OPERATION

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

GENERAL ELECTRIC

MASTER

UNCLASSIFIED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

HW-60285-PT. I
~~Part I~~

ARTIFICIAL COOLING OF THE COLUMBIA RIVER BY DAM REGULATION

Part I

by

H. A. Kramer

May 25, 1959

Irradiation Processing Department
Facilities Engineering Operation
Hanford Atomic Products Operation
Richland, Washington

Operated for the Atomic Energy Commission by the
General Electric Company under Contract #W-31-109-Eng 52

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, express 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) Assume 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.

DISTRIBUTION

1. HOO-AEC
2. HOO-AEC
3. HOO-AEC
4. R. S. Bell
5. J. H. Brown
6. H. V. Clukey
7. O. H. Greager
8. A. B. Greninger
9. C. N. Gross
10. R. T. Jaske/J. P. Corley
11. R. T. Jessen/W. W. Windsheimer
12. W. E. Johnson
13. H. A. Kornberg/R. Foster
14. H. A. Kramer
15. A. R. Maguire
16. W. M. McConiga
17. J. S. McMahon
18. H. M. Parker
19. D. W. Pearce
20. C. A. Priode
21. W. D. Richmond
22. O. C. Schroeder/O. H. Pilkey
23. 300 Files
24. Record copy

25-30. Extra

TABLE OF CONTENTS

USE OF GRAND COULEE STORAGE TO COOL COLUMBIA RIVER ABOVE HAPO

I. INTRODUCTION

In early July, 1958, it appeared that Columbia River temperatures at HAPO would be near 24.5°C by the end of August. River temperatures were averaging 4° to 5°C above 1957 figures and were 3° to 4° above the ten year highs. It seemed desirable to examine the problem to determine if any corrective measure could be taken, since it was apparent that production losses were imminent. (See Plate I.)

The large storage of cold water behind Grand Coulee Dam, normally untapped, was a source of possible relief. A plan for use was proposed for the peak high temperature period and agreed to by the Bureau of Reclamation.

II. SUMMARY

It was found that part of the river temperature peak was caused by the increased spill of the hotter top water layer over the dam during low generation periods. Opening the by-pass tubes or increasing flow from the lower levels during these periods would increase the percentage of cold water and reduce the final temperature. The Bureau of Reclamation preferred to maintain high generation during normal low generation periods and to hold a higher generation level than normal. They opened by-pass tubes only if generation could not be maintained.

Temperatures at HAPO were held from 1 to 3 degrees C below the forecast highs. Careful conservation of cold water at Grand Coulee could make additional savings in 1959. It is proposed that:

1. The AEC negotiate with the Bureau of Reclamation in order to attempt the following program:
   a. Minimize the use of the lower two rows of tubes through the dam for flood control.
   b. Re-examine the possibility of the use of the lower row of tubes to gain additional cold water. Cold water should be used only as needed for holding a long-range optimum temperatures for the summer season.
2. Instrumentation to measure water temperatures at needed locations be installed by Irradiation Processing Department.
3. Daily records of temperatures and river flows at strategic points be kept by IPD as part of production continuity objectives.

III. DISCUSSION

A. Causes of Temperature Variation

Seven phenomena are responsible for varying river temperature at HAPO. These are as follows:

1. Advected Energy (Sum of Inflow and Outflow)
2. Changes in Energy Storage
3. Isolation
4. Sensible Heat Transfer from Air and Earth
5. Reflected Radiation
6. Back Radiation
7. Evaporation

1. Advected Energy (Changes Due to Variation in Inlet and Outlet Energy).

The advected energy was subject to great change due to the variation in the amount of spill. Spill water was about 10 degrees warmer than the water used by the turbines. The

resultant mixed discharge from Coulee could vary up to 6°F under normal operating conditions.

Variations in storage and water use could and did cause changes in the energy release at Chief Joseph, Rock Island, and Priest Rapids. At Chief Joseph, the pool level was dropped 10 feet one time during the month. Some re-storage occurred with minor effects on temperature. The new causeway and cribbing at Priest Rapids Dam increased the pool above the dam and improved mixing of the discharge.

Temperatures of the incoming streams increased during the month as their flows decreased. There was some evidence that probably warm underground and irrigation waste water were affecting river temperature.

2. Stored Energy

Changes in energy storage resulted from the stored heat in the river bed and the pools behind the dams.

3. Insolation

The major cause of the temperature changes of the river are due to radiation from the sun. A typical summer day with a radiation of 700 Langleys* might cause a temperature increase at HAPO of more than 6°F over the temperature at Grand Coulee. The Columbia River has large shaded areas during portions of the day, but no attempt is made to evaluate this effect. The river and its tributaries between Grand Coulee and HAPO were estimated to be over 160 square miles in area.

4. Sensible Heat Transfer

High air temperature caused minor warming of the river. Sensible

* 1 Langley = 1 gm-calorie/cm^2

heat transfer probably caused from 5 to 20 per cent of the changes due to insolation.

5. Reflected Radiation

Considerable differences of opinion exist regarding the computation of reflected radiation. We used an estimate in this study based on percentages calculated by Anderson and Pritchard in their analysis of the physical limnology of Lake Mead* in 1950. Reflected radiation is affected by shade.

6. Back Radiation

The effective back radiation is the difference between long wave radiation emitted by the river and the long wave radiation received from water vapor suspended in the air. Back radiation was estimated from the data used in the Lake Mead study by Pritchard and Anderson in 1950.

7. Evaporation

Little data exists on the cooling effects of evaporation from large bodies of water. Evaporation varies with humidity and air movement. Water temperature directly affects the amount of evaporation. Many investigators have used the unexplained losses as evaporation loss. It was found that is not practical for this study to secure a true measurement. An estimated Bowen ratio was used to figure evaporation.

B. Program of Operation

The operating plan used was as follows: Grand Coulee personnel were to maintain near a constant flow from the lower depths of

* Physical Limnology of Lake Mead, Report 258, U. S. Navy Electronics Laboratory, E. R. Anderson and D. W. Pritchard.

Coulee, either by generation or opening tubes. This plan was followed within the limits of practicability depending on the allocations to them of power load and the practical use of people to open and close tubes. (Tube operation is not simple and is done manually by a crew who must go to the top of the dam to do the work.) The program was to continue into the month of September or until no control was possible. Some control continued until September 10, 1958.

C. Test Data

The main flow into Lake Roosevelt comes from: the Arrow Lakes (unregulated); Kootenay Lake (regulated); Pend Oreille River, and the Spokane River. The main flow into the Columbia below Grand Coulee and above HAPO comes from: the Okanogan River, the Methow River, the Wenatchee River, and Lake Chelan.

The approximate conditions during August, 1958 were:

	Flow
Columbia at HAPO	92,500 cfs
Wenatchee River	800 cfs
Chelan River	900 cfs
Methow River	200 cfs
Okanogan River	700 cfs
Spokane River	1,500 cfs
Pend Oreille River	6,500 cfs
Kootenay Lake	16,400 cfs
Arrow Lakes	61,000 cfs

N.B. Reservoir storage and miscellaneous flows not shown.

Temperatures out of the Arrow Lakes on August 1, 1958 were 59° or 15° C and continued low but gradually warming during the month.

Other inflows were mostly above 70°F with high temperatures out of the Kootenay, Spokane, Pend Oreille, Okanogan, and Wenatchee Rivers. It is my opinion, confirmed by frequent checks during August, that river flow and conditions below Grand Coulee affected test results less than ±1/10 of 1°C and since adequate records of the temperature and flow on the streams below Coulee would be difficult and expensive to secure, these data were not in the study.

Grand Coulee and other associated temperatures were taken by Operating personnel and reported by phone. These thermometers were checked with a Bureau of Standards instrument and checked within ±1/2°C. Readings after Grand Coulee, a few at Coulee, and readings of the lake for the first five feet of depth were taken with a thermometer checked by a Bureau of Standards instrument. Temperatures of the turbine discharge temperature changed on the afternoon of August 29 and fluctuated thereafter. It was evident that most of the cold water above 1035 ft. m.s.l. was gone by that time and that cooling effects after that might not always be certain of attainment.

Chief Joseph Dam is different than the other dams. Reported temperature readings of the spill were at times less than the temperature of the turbine discharge. A check of the reporting thermometers at Chief Joseph indicated an accuracy of ±1/2°C. Chief Joseph Dam is built across the river, and the penstocks for the power house are off a widened place in the top part of the bank where a shelf has been cut out of the bank. Here the water is rather shallow.

River temperatures at Chief Joseph should be higher than at Grand Coulee. One third of the climatological effects between Grand Coulee and HAPO will have occurred by the time the river reaches Chief Joseph.

Another third of these effects will occur by the time Wenatchee is reached. The last third occurs between Wenatchee and HAPO.

The river temperature at Rock Island Dam, just below Wenatchee, varies little between the top and bottom. Readings show 0.1 to 0.3°C difference. Temperatures as reported were checked within ± 1/2°F.

River temperatures at Priest Rapids Dam were only a few tenths °C different from the top to bottom of the river. All along the stream, there was some evidence of hot springs at the river's edge, particularly near plant B intake.

There was about a three-hour lag between water temperatures at 105-C (shown as 100-C) and the 181-B intake. This is due to water storage in the plant.

In the starting period of the test, it was considered desirable to cool as much as possible in order to lower the stored heat content of the river. Immediate response by the river indicated further cooling was desirable. During early negotiations we were helped informally in our efforts to keep some colder water coming through Coulee Dam.

The few days check made in early August being favorable, arrangements were made and carried out for further cooling.

D. Effects of 1958 Regulation

Inlet water temperatures to the Hanford reactors were reduced 1 to 3°C below forecast levels as a result of the additional river regulation during the test period, with a reduction in the maximum temperature of 2.3°C. Economic Benefit is shown separately on Part III.

E. Future Program

It is believed that river cooling could be done almost every year, but there is no positive assurance of its success. Since there is a limited amount of cold water available, it is necessary that it be conserved and used carefully when needed.

In 1959 year it is expected that colder water may be stored at Coulee and be available for control. If sufficient water is to be had, control of tubes could be started when temperatures begin to be critical, probably in July. If tube operation is not too expensive, tubes could be operated principally to hold HAPO temperatures near an economic level.

It is estimated that it would be necessary to spend up to $100,000 to $200,000 to secure the needed data to present a complete scientific analysis of the effects of Grand Coulee Dam. As an interim measure, I believe a few recording thermometers should be enough for operational purposes, and I recommend their installation.

1. Floating bulb thermometers at surface (recorder) at Coulee reservoir.
2. Floating bulb thermometer at 5 foot depth (recorder) at Coulee reservoir.
3. One thermometer to record at Grand Coulee at 1274 foot level.
4. One at 1208 foot level at Coulee.
5. One at 1135 foot level at Coulee.
6. One at 1035 foot level at Coulee.

*7. One at point below tail race at Coulee.

*8. One at Rock Island.

*9. One at new gage to be installed at Vernita.

* These gages should be U.S.G.S. thermometers.

ACKNOWLEDGMENTS

Appreciation is given for the help of the following:

A.E.C. Engineers
Bureau of Reclamation Engineers
U.S.G.S., Tacoma and Spokane
Weather Bureau
Meteorology Tower, HLO, HAPO
Rock Island Power Engineers
Chief Joseph Engineers
Bonneville Power Administration
West Kootenay Power Engineers
Montana Power Company Engineers
Washington Water Power Company Engineers
Wenatchee Water Plant Engineers
Priest Rapids Dam Construction Engineers
Corps of Engineers personnel

TEMPERATURE CHANGES
COULEE DAM

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	Total Flow BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Total Flow Discharge °F
7-30	5 a.m.	(1)	Max.	60.9	67.6	2223	135,300	52.1	59.0	1689	87,997	223,297	113.0	1976	63.7
		(2)		86.4	67.6	2223	192,067	26.6	59.0	1689	44,927	236,994	113.0	2097	65.6
	8 a.m.	(1)	Min.	40.0	67.6	2223	88,920	73.0	59.0	1689	123,297	212,217	113.0	1878	62.0
		(2)		65.5	67.6	2223	145,606	47.5	59.0	1689	80,228	225,834	113.0	1999	64.0
		(1)	Avg.	45.5	67.6	2223	101,146	67.5	59.0	1689	114,008	215,154	113.0	1904	62.5
		(2)		65.1	67.6	2223	144,717	47.9	59.0	1689	80,903	225,620	113.0	1997	64.0
7-31	5 p.m.	(1)	Max.	45.7	67.7	2229	101,865	67.3	59.1	1695	114,074	215,939	113.0	1911	62.6
		(2)		59.8	67.7	2229	133,294	53.2	59.1	1695	90,174	223,468	113.0	1978	63.7
	6 a.m.	(1)	Min.	2.2	67.7	2229	4,904	110.8	59.1	1695	187,806	192,710	113.0	1705	59.3
		(2)		86.4	67.7	2229	192,586	26.6	59.1	1695	45,087	237,673	113.0	2103	65.6
		(1)	Avg.	32.3	67.7	2229	71,996	80.7	59.1	1695	136,786	208,783	113.0	1848	61.6
		(2)		65.1	67.7	2229	145,108	47.9	59.1	1695	81,191	226,299	113.0	2003	64.1
8-1	7 p.m.	(1)	Max.	44.3	67.8	2235	99,010	67.7	59.2	1701	115,158	214,168	112.0	1912	62.6
		(2)		58.8	67.8	2235	131,418	53.2	59.2	1701	90,493	221,911	112.0	1981	63.3
	1 a.m.	(1)	Min.	18.8	67.8	2235	42,018	93.2	59.2	1701	158,533	200,551	112.0	1791	60.7
		(2)		85.4	67.8	2235	190,869	26.6	59.2	1701	45,247	236,116	112.0	2108	65.7
		(1)	Avg.	34.7	67.8	2235	77,555	77.3	59.2	1701	131,487	209,042	112.0	1866	62.2
		(2)		64.1	67.8	2235	143,264	47.9	59.2	1701	81,478	224,742	112.0	2007	64.1
8-2	2 p.m.	(1)	Max.	51.8	67.9	2242	116,135	58.2	59.3	1708	99,405	215,540	111.0	1942	63.1
		(2)		48.3	67.9	2242	108,289	62.7	59.3	1708	107,091	215,380	111.0	1940	63.1
	2 a.m.	(1)	Min.	16.2	67.9	2242	36,320	93.8	59.3	1708	160,210	196,530	111.0	1771	60.3
		(2)		84.4	67.9	2242	189,225	26.6	59.3	1708	45,433	234,658	111.0	2114	65.8
		(1)	Avg.	40.9	67.9	2242	91,698	70.1	59.3	1708	119,731	211,429	111.0	1905	62.5
		(2)		63.1	67.9	2242	141,470	47.9	59.3	1708	81,813	223,283	111.0	2012	64.2

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	Total Flow BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-3	4 p.m.	(1)	Max.	53.5	68.0	2248	120,268	54.5	59.4	1714	93,413	213,681	108.0	1979	63.7
		(2)		54.8	68.0	2248	123,190	53.2	59.4	1714	91,185	214,375	108.0	1985	63.8
	2 a.m.	(1)	Min.	15.1	68.0	2248	33,945	92.9	59.4	1714	159,230	193,175	108.0	1789	60.6
		(2)		81.4	68.0	2248	182,987	26.6	59.4	1714	45,592	228,579	108.0	2116	65.8
		(1)	Avg.	38.2	68.0	2248	85,874	69.8	59.4	1714	119,637	205,511	108.0	1903	62.5
		(2)		60.1	68.0	2248	135,105	47.9	59.4	1714	82,101	217,206	108.0	2011	64.2
8-4	6 a.m.	(1)	Max.	56.0	68.0	2248	125,888	49.0	59.5	1720	84,280	210,168	105.0	2002	64.1
		(2)		78.4	68.0	2248	176,243	26.6	59.5	1720	45,752	221,995	105.0	2114	65.8
	10 a.m.	(1)	Min.	32.6	68.0	2248	73,285	72.4	59.5	1720	124,528	197,813	105.0	1884	62.1
		(2)		42.3	68.0	2248	95,090	62.7	59.5	1720	107,844	202,934	105.0	1933	62.9
		(1)	Avg.	44.7	68.0	2248	100,486	60.3	59.5	1720	103,716	204,202	105.0	1945	63.2
		(2)		57.1	68.0	2248	128,361	47.9	59.5	1720	82,388	210,749	105.0	2007	64.1
8-5	1 a.m.	(1)	Max.	41.1	68.1	2254	92,639	58.9	59.6	1726	101,661	194,300	100.0	1943	63.1
		(2)		73.4	68.1	2254	165,444	26.6	59.6	1726	45,912	211,356	100.0	2114	65.8
	11 a.m.	(1)	Min.	36.2	68.1	2254	81,595	63.8	59.6	1726	110,119	191,714	100.0	1917	62.7
		(2)		37.3	68.1	2254	84,074	62.7	59.6	1726	108,220	192,294	100.0	1923	62.8
		(1)	Avg.	38.9	68.1	2254	87,681	61.1	59.6	1726	105,459	193,140	100.0	1931	62.9
		(2)		52.1	68.1	2254	117,433	47.9	59.6	1726	82,675	200,108	100.0	2001	64.1
8-6	1 a.m.	(1)	Max.	29.3	68.2	2260	66,218	66.5	59.8	1738	115,577	181,795	95.8	1898	62.4
		(2)		69.2	68.2	2260	156,392	26.6	59.8	1738	46,231	202,623	95.8	2115	65.8
	12 mid.	(1)	Min.	20.6	68.2	2260	46,556	75.2	59.8	1738	130,698	177,254	95.8	1850	61.6
		(2)		46.4	68.2	2260	104,864	49.4	59.8	1738	85,857	190,721	95.8	1991	63.9
		(1)	Avg.	25.9	68.2	2260	58,534	69.9	59.8	1738	121,486	180,020	95.8	1881	62.2
		(2)		47.9	68.2	2260	108,254	47.9	59.8	1738	83,250	191,504	95.8	1999	64.0

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

				Spill Water				Thru Turbines & Tubes					Total Flow		
1958				M CFS	°F	BTU/ MCFS	Total BTU	MCFS	°F	BTU/ MCFS	Total BTU	BTU	Total CFS	BTU/ MCFS	Discharge °F
8-7	10 p.m.	(1)	Max.	22.4	68.3	2266	50,758	68.4	60.0	1751	120,469	171,227	90.8	1886	62.2
		(2)		29.8	68.3	2266	67,527	61.0	60.0	1751	106,811	174,338	90.8	1920	62.7
	1 a.m.	(1)	Min.	12.0	68.3	2266	27,192	78.8	60.0	1751	137,979	165,171	90.8	1819	61.1
		(2)		64.2	68.3	2266	145,477	26.6	60.0	1751	46,577	192,054	90.8	2115	65.8
		(1)	Avg.	16.4	68.3	2266	37,162	74.4	60.0	1751	130,274	167,436	90.8	1844	61.5
		(2)		42.9	68.3	2266	97,211	47.9	60.0	1751	83,873	181,084	90.8	1994	63.9
8-8	8 p.m.	(1)	Max.	23.0	68.5	2278	52,394	65.0	60.1	1757	114,205	166,599	88.0	1893	62.3
		(2)		34.8	68.5	2278	79,274	53.2	60.1	1757	93,472	172,746	88.0	1963	63.4
	2 a.m.	(1)	Min.	10.9	68.5	2278	24,830	77.1	60.1	1757	135,465	160,295	88.0	1822	61.2
		(2)		61.4	68.5	2278	139,869	26.6	60.1	1757	46,736	186,605	88.0	2121	65.9
		(1)	Avg.	16.1	68.5	2278	36,676	71.9	60.1	1757	126,328	163,004	88.0	1852	61.9
		(2)		40.1	68.5	2278	91,348	47.9	60.1	1757	84,160	175,508	88.0	1994	63.9
8-9	4 a.m.	(1)	Max.	23.5	68.6	2285	53,698	59.5	60.2	1763	104,898	158,596	83.0	1910	62.6
		(2)		56.4	68.6	2285	128,874	26.6	60.2	1763	46,896	175,770	83.0	2118	65.8
	9 p.m.	(1)	Min.	8.9	68.6	2285	20,336	74.1	60.2	1763	130,638	150,974	83.0	1819	61.1
		(2)		22.0	68.6	2285	50,270	61.0	60.2	1763	107,543	157,813	83.0	1901	62.4
		(1)	Avg.	15.6	68.6	2285	35,646	67.4	60.2	1763	118,826	154,472	83.0	1861	61.7
		(2)		35.1	68.6	2285	79,256	47.9	60.2	1763	84,448	163,704	83.0	1972	63.6
8-10	6 a.m.	(1)	Max.	24.4	68.8	2297	56,047	56.6	60.4	1775	100,465	156,512	81.0	1932	62.9
		(2)		54.4	68.8	2297	124,957	26.6	60.4	1775	47,215	172,172	81.0	2126	66.0
	10 p.m.	(1)	Min.	3.5	68.8	2297	8,040	77.5	60.4	1775	137,562	145,602	81.0	1798	60.8
		(2)		20.0	68.8	2297	45,940	61.0	60.4	1775	108,275	154,215	81.0	1904	62.5
		(1)	Avg.	16.8	68.8	2297	38,590	64.2	60.4	1775	113,955	152,545	81.0	1883	62.1
		(2)		33.1	68.8	2297	76,031	47.9	60.4	1775	85,022	161,053	81.0	1988	63.8

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-11	4 a.m.	(1)	Max.	25.5	68.9	2303	58,726	58.5	60.5	1782	104,247	162,973	84.0	1940	63.1
		(2)		57.4	68.9	2303	132,192	26.6	60.5	1782	47,401	179,593	84.0	2138	65.8
	11 a.m.	(1)	Min.	5.0	68.9	2303	11,515	79.0	60.5	1782	140,778	152,288	84.0	1813	61.0
		(2)		21.3	68.9	2303	49,054	62.7	60.5	1782	111,731	160,785	84.0	1914	62.6
		(1)	Avg.	15.6	68.9	2303	35,927	68.4	60.5	1782	121,889	157,816	84.0	1879	62.0
		(2)		36.1	68.9	2303	83,138	47.9	60.5	1782	85,358	168,496	84.0	2006	64.1
8-12	4 a.m.	(1)	Max.	27.3	69.1	2315	63,200	53.7	60.7	1794	96,697	159,897	81.0	1974	63.6
		(2)		54.4	69.1	2315	125,936	26.6	60.7	1794	47,720	173,656	81.0	2144	66.6
	10 a.m.	(1)	Min.	6.7	69.1	2315	15,510	74.3	60.7	1794	133,294	148,804	81.0	1837	61.4
		(2)		18.3	69.1	2315	42,365	62.7	60.7	1794	112,484	154,849	81.0	1912	62.6
		(1)	Avg.	16.4	69.1	2315	37,966	64.6	60.7	1794	115,892	153,858	81.0	1899	62.4
		(2)		33.1	69.1	2315	76,626	47.9	60.7	1794	85,933	162,558	81.0	2007	64.1
8-13	4 a.m.	(1)	Max.	27.5	69.2	2321	63,827	55.5	60.8	1801	99,956	163,783	83.0	1973	63.6
		(2)		56.4	69.2	2321	130,904	26.6	60.8	1801	47,907	178,811	83.0	2154	66.5
	2 p.m.	(1)	Min.	7.0	69.2	2321	16,247	76.0	60.8	1801	136,876	153,123	83.0	1845	61.5
		(2)		20.3	69.2	2321	47,116	62.7	60.8	1801	112,923	160,039	83.0	1928	62.9
		(1)	Avg.	17.7	69.2	2321	41,082	65.3	60.8	1801	117,605	158,687	83.0	1912	62.6
		(2)		35.1	69.2	2321	81,467	47.9	60.8	1801	86,268	167,735	83.0	2020	64.4
8-14	4 a.m.	(1)	Max.	25.0	69.3	2328	58,200	56.0	60.9	1807	101,192	159,392	81.0	1968	63.5
		(2)		54.4	69.3	2328	126,643	26.6	60.9	1807	48,066	174,709	81.0	2157	66.6
	6 p.m.	(1)	Min.	11.9	69.3	2328	27,703	68.9	60.9	1807	124,502	152,205	81.0	1879	62.0
		(2)		27.8	69.3	2328	64,718	53.2	60.9	1807	96,132	160,850	81.0	1986	63.7
		(1)	Avg.	17.2	69.3	2328	40,042	63.8	60.9	1807	115,287	155,329	81.0	1918	62.7
		(2)		33.1	69.3	2328	77,057	47.9	60.9	1807	86,555	163,612	81.0	2020	64.4

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-15	5 a.m.	(1)	Max.	27.2	69.5	2340	63,648	52.4	61.1	1819	95,316	158,764	79.6	1994	63.9
		(2)		53.0	69.5	2340	124,020	26.6	61.1	1819	48,385	172,405	79.6	2166	66.7
	11 a.m.	(1)	Min.	12.2	69.5	2340	28,548	67.4	61.1	1819	122,601	151,149	79.6	1899	62.4
		(2)		16.9	69.5	2340	39,546	62.7	61.1	1819	114,051	153,597	79.6	1930	62.9
		(1)	Avg.	19.2	69.5	2340	44,928	60.4	61.1	1819	109,868	154,793	79.6	1945	63.2
		(2)		31.7	69.5	2340	74,178	47.9	61.1	1819	87,130	161,308	79.6	2026	64.5
8-16	6 a.m.	(1)	Max.	28.2	69.6	2346	66,157	55.8	61.2	1825	101,835	167,992	84.0	2000	64.0
		(2)		57.4	69.6	2346	134,660	26.6	61.2	1825	48,545	183,205	84.0	2181	66.9
	9 a.m.	(1)	Min.	19.3	69.6	2346	45,278	64.7	61.2	1825	118,078	163,356	84.0	1945	63.1
		(2)		30.8	69.6	2346	72,257	53.2	61.2	1825	97,090	169,347	84.0	2015	64.3
		(1)	Avg.	23.8	69.6	2346	55,835	60.2	61.2	1825	109,865	165,700	84.0	1973	63.6
		(2)		36.1	69.6	2346	84,691	47.9	61.2	1825	87,418	172,109	84.0	2049	64.8
8-17	6 a.m.	(1)	Max.	26.2	69.8	2359	61,806	52.3	61.4	1837	96,075	157,881	78.5	2011	64.2
		(2)		51.9	69.8	2359	122,432	26.6	61.4	1837	48,864	171,296	78.5	2182	66.9
	8 p.m.	(1)	Min.	8.6	69.8	2359	20,287	69.9	61.4	1837	128,406	148,693	78.5	1893	62.3
		(2)		25.3	69.8	2359	59,683	53.2	61.4	1837	97,728	157,411	78.5	2005	64.1
		(1)	Avg.	18.6	69.8	2359	43,877	59.9	61.4	1837	110,036	153,913	78.5	1961	63.4
		(2)		30.6	69.8	2359	72,185	47.9	61.4	1837	87,992	160,177	78.5	2040	64.6
8-18	4 a.m.	(1)	Max.	37.4	69.9	2365	88,451	44.5	61.5	1844	82,014	170,465	81.9	2081	65.3
		(2)		55.3	69.9	2365	130,785	26.6	61.5	1844	49,050	179,835	81.9	2196	67.2
	2 p.m.	(1)	Min.	2.7	69.9	2365	6,386	79.2	61.5	1844	146,045	152,431	81.9	1861	61.8
		(2)		19.2	69.9	2365	45,408	62.7	61.5	1844	115,618	161,026	81.9	1966	63.5
		(1)	Avg.	21.4	69.9	2365	50,611	60.5	61.5	1844	111,562	162,173	81.9	1980	63.7
		(2)		34.0	69.9	2365	80,410	47.9	61.5	1844	88,328	168,738	81.9	2060	65.0

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	Total Flow BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-19	11 p.m.	(1)	Max.	31.4	70.1	2377	74,638	51.4	61.6	1850	95,090	169,728	82.8	2050	64.8
		(2)		31.4	70.1	2377	74,638	51.4	61.6	1850	95,090	169,728	82.8	2050	64.8
	9 p.m.	(1)	Min.	11.7	70.1	2377	27,811	71.1	61.6	1850	131,535	159,346	82.8	1924	62.8
		(2)		21.8	70.1	2377	51,819	61.0	61.6	1850	112,850	164,669	82.8	1989	63.9
		(1)	Avg.	21.1	70.1	2377	50,155	61.7	61.6	1850	114,145	164,300	82.8	1984	63.8
		(2)		34.9	70.1	2377	82,957	47.9	61.6	1850	88,615	171,572	82.8	2072	65.2
8-20	5 a.m.	(1)	Max.	33.8	70.3	2390	80,782	53.2	61.7	1856	98,739	179,521	87.0	2063	65.0
		(2)		60.4	70.3	2390	144,356	26.6	61.7	1856	49,370	193,726	87.0	2227	67.7
	8 p.m.	(1)	Min.	11.0	70.3	2390	26,290	76.0	61.7	1856	141,056	167,346	87.0	1924	62.8
		(2)		33.8	70.3	2390	80,782	53.2	61.7	1856	98,739	179,521	87.0	2063	65.0
		(1)	Avg.	20.5	70.3	2390	48,995	66.5	61.7	1856	123,424	172,419	87.0	1982	63.7
		(2)		39.1	70.3	2390	93,449	47.9	61.7	1856	88,902	182,351	87.0	2096	65.6
8-21	12 mid.	(1)	Max.	25.7	70.4	2396	61,577	60.5	61.8	1862	112,651	174,228	86.2	2021	64.4
		(2)		36.8	70.4	2396	88,173	49.4	61.8	1862	91,983	180,156	86.2	2090	65.4
	11 a.m.	(1)	Min.	12.1	70.4	2396	28,992	74.1	61.8	1862	137,974	166,966	86.2	1937	63.0
		(2)		23.5	70.4	2396	56,306	62.7	61.8	1862	116,747	173,053	86.2	2008	64.2
		(1)	Avg.	18.1	70.4	2396	43,368	68.1	61.8	1862	126,802	170,170	86.2	1974	63.6
		(2)		38.3	70.4	2396	91,767	47.9	61.8	1862	89,190	180,957	86.2	2099	65.6
8-22	5 p.m.	(1)	Max.	29.3	70.6	2408	70,554	51.3	61.9	1868	95,828	166,382	80.6	2064	65.0
		(2)		29.3	70.6	2408	70,554	51.3	61.9	1868	95,828	166,382	80.6	2064	65.0
	10 a.m.	(1)	Min.	8.4	70.6	2408	20,227	72.2	61.9	1868	134,870	155,097	80.6	1924	62.8
		(2)		17.9	70.6	2408	43,103	62.7	61.9	1868	117,124	160,227	80.6	1988	63.8
		(1)	Avg.	20.2	70.6	2408	48,642	60.4	61.9	1868	112,827	161,469	80.6	2003	64.1
		(2)		32.7	70.6	2408	78,742	47.9	61.9	1868	89,477	168,219	80.6	2087	65.4

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water MCFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-23	3 p.m.	(1)	Max.	26.4	70.8	2420	63,888	50.9	62.0	1876	95,488	159,376	77.3	2062	65.0
		(2)		26.4	70.8	2420	63,888	50.9	62.0	1876	95,488	159,376	77.3	2062	65.0
	8 a.m.	(1)	Min.	12.6	70.8	2420	30,492	64.7	62.0	1876	121,377	151,869	77.3	1965	63.5
		(2)		29.8	70.8	2420	72,116	47.5	62.0	1876	81,110	153,226	77.3	1982	63.8
		(1)	Avg.	19.4	70.8	2420	46,948	57.9	62.0	1876	108,620	155,568	77.3	2013	64.3
		(2)		29.4	70.8	2420	71,148	47.9	62.0	1876	89,860	161,008	77.3	2083	65.3
8-24	2 p.m.	(1)	Max.	26.6	71.0	2433	64,718	50.4	62.0	1876	94,550	159,268	77.0	2068	65.1
		(2)		26.6	71.0	2433	64,718	50.4	62.0	1876	94,550	159,268	77.0	2068	65.1
	9 p.m.	(1)	Min.	7.6	71.0	2433	18,491	69.4	62.0	1876	130,194	148,685	77.0	1931	62.9
		(2)		16.0	71.0	2433	38,928	61.0	62.0	1876	114,436	153,364	77.0	1992	63.9
		(1)	Avg.	18.7	71.0	2433	45,497	58.3	62.0	1876	109,371	154,868	77.0	2011	64.3
		(2)		29.1	71.0	2433	70,800	47.9	62.0	1876	89,860	160,660	77.0	2086	65.4
8-25	7 a.m.	(1)	Max.	40.4	71.2	2445	98,778	43.9	62.1	1882	82,620	181,398	84.3	2152	66.4
		(2)		52.0	71.2	2445	127,140	32.3	62.1	1882	60,789	187,929	84.3	2229	67.7
	11 a.m.	(1)	Min.	13.0	71.2	2445	31,785	71.3	62.1	1882	134,187	165,972	84.3	1969	63.6
		(2)		21.6	71.2	2445	52,812	62.7	62.1	1882	118,001	170,813	84.3	2026	64.4
		(1)	Avg.	22.4	71.2	2445	54,768	61.9	62.1	1882	116,496	171,264	84-3	2032	64.5
		(2)		36.4	71.2	2445	88,998	47.9	62.1	1882	90,148	179,146	84.3	2125	66.0
8-26	12 mid.	(1)	Max.	28.3	71.4	2457	69,533	53.0	62.2	1888	100,064	169,597	81.3	2086	65.4
		(2)		31.9	71.4	2457	78,378	49.4	62.2	1888	93,267	171,645	81.3	2111	65.8
	5 p.m.	(1)	Min.	12.6	71.4	2457	30,958	68.7	62.2	1888	129,706	160,664	81.3	1976	63.7
		(2)		28.1	71.4	2457	69,042	53.2	62.2	1888	100,442	169,484	81.3	2085	65.2
		(1)	Avg.	18.3	71.4	2457	44,963	63.0	62.2	1888	118,944	163,907	81.3	2016	64.4
		(2)		33.4	71.4	2457	82,064	47.9	62.2	1888	90,435	172,499	81.3	2122	66.0

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water M CFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	Total Flow BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-27	1 a.m.	(1)	Max.	30.7	71.5	2463	75,614	62.1	62.3	1894	117,617	193,231	92.8	2082	65.3
		(2)		66.2	71.5	2463	163,051	26.6	62.3	1894	50,380	213,431	92.8	2300	68.8
	12 noon	(1)	Min.	9.8	71.5	2463	24,137	83.0	62.3	1894	157,202	181,339	92.8	1954	63.3
		(2)		30.1	71.5	2463	74,136	62.7	62.3	1894	118,754	192,890	92.8	2079	65.3
		(1)	Avg.	18.8	71.5	2463	46,304	74.0	62.3	1894	140,156	186,460	92.8	2009	64.2
		(2)		44.9	71.5	2463	110,589	47.9	62.3	1894	90,723	201,312	92.8	2169	66.8
8-28	12 mid.	(1)	Max.	38.8	71.6	2469	95,797	43.9	62.4	1900	83,410	179,207	82.7	2167	66.7
		(2)		38.8	71.6	2469	95,797	43.9	62.4	1900	83,440	179,207	82.7	2169	66.7
	10 a.m.	(1)	Min.	5.3	71.6	2469	13,086	77.4	62.4	1900	147,060	160,146	82.7	1936	63.0
		(2)		20.0	71.6	2469	49,380	62.7	62.4	1900	119,130	168,510	82.7	2038	64.8
		(1)	Avg.	17.4	71.6	2469	42,961	65.3	62.4	1900	124,070	167,031	82.7	2020	64.4
		(2)		34.8	71.6	2469	85,921	47.9	62.4	1900	91,010	176,931	82.7	2139	66.2
8-29	3 a.m.	(1)	Max.	32.2	71.7	2475	79,695	44.3	62.5	1906	84,436	164,131	76.5	2146	66.4
		(2)		49.9	71.7	2475	123,502	26.6	62.5	1906	50,700	174,202	76.5	2277	67.8
	2 p.m.	(1)	Min.	0.1	71.7	2475	248	76.4	62.5	1906	145,618	145,866	76.5	1907	62.2
		(2)		13.8	71.7	2475	34,155	62.7	62.5	1906	119,506	153,661	76.5	2008	64.2
		(1)	Avg.	14.5	71.7	2475	35,888	62.0	62.5	1906	118,172	154,060	76.5	2014	64.3
		(2)		28.6	71.7	2475	70,785	47.9	62.5	1906	91,297	162,082	76.5	2119	65.9
8-30	4 p.m.	(1)	Max.	37.9	71.6	2469	93,575	45.8	62.6	1912	87,570	181,145	83.7	2164	66.7
		(2)		37.9	71.6	2469	93,575	45.8	62.6	1912	87,570	181,145	83.7	2164	66.7
	9 a.m.	(1)	Min.	8.8	71.6	2469	21,727	74.9	62.6	1912	143,209	164,936	83.7	1971	63.6
		(2)		30.5	71.6	2469	75,305	53.2	62.6	1912	101,718	177,023	83.7	2115	65.9
		(1)	Avg.	21.9	71.6	2469	54,071	61.8	62.6	1912	118,162	172,233	83.7	2058	64.9
		(2)		35.8	71.6	2469	88,390	47.9	62.6	1912	91,585	179,975	83.7	2150	66.5

TEMPERATURE CHANGES
COULEE DAM (Cont.)

(1) Actual.
(2) As it would have been at the time (1) occurred.

1958				Spill Water M CFS	Spill Water °F	Spill Water BTU/MCFS	Spill Water Total BTU	Thru Turbines & Tubes MCFS	Thru Turbines & Tubes °F	Thru Turbines & Tubes BTU/MCFS	Thru Turbines & Tubes Total BTU	BTU	Total Flow Total CFS	Total Flow BTU/MCFS	Discharge °F
8-31	12 mid.	(1)	Max.	32.4	71.5	2463	79,801	44.4	62.7	1918	85,159	164,960	76.8	2148	66.4
		(2)		32.4	71.5	2463	79,801	44.4	62.7	1918	85,159	164,960	76.8	2148	66.4
	9 a.m.	(1)	Min.	10.6	71.5	2463	26,108	66.2	62.7	1918	126,972	153,080	76.8	1993	63.9
		(2)		23.6	71.5	2463	58.127	53.2	62.7	1918	102,038	160,165	76.8	2085	65.2
		(1)	Avg.	19.0	71.5	2463	46,797	57.8	62.7	1918	110,860	157,657	76.8	2053	66.6
		(2)		28.9	71.5	2463	71,181	47.9	62.7	1918	91,872	163,053	76.8	2123	66.0
9-1	3 a.m.	(1)	Max.	49.3	71.5	2463	121,426	26.6	62.8	1924	51,178	172,604	75.9	2274	68.3
		(2)		49.3	71.5	2463	121,426	26.6	62.8	1924	51,178	172,604	75.9	2274	68.4
	8 p.m.	(1)	Min.	0.0	71.5	2463	0	79.8	62.8	1924	153,535	153,535	75.9	2023	64.4
		(2)		22.7	71.5	2463	55,910	53.2	62.8	1924	102,357	158,267	75.9	2085	65.2
		(1)	Avg.	20.6	71.5	2463	50,738	55.3	62.8	1924	106,397	157,135	75.9	2070	65.1
		(2)		28.0	71.5	2463	68,964	47.9	62.8	1924	92,160	161,124	75.9	2123	66.0
9-2	4 a.m.	(1)	Max.	39.0	71.4	2457	95,823	42.5	62.9	1930	82,025	177,848	81.5	2182	66.9
		(2)		54.9	71.4	2457	134,889	26.6	62.9	1930	51,338	186,227	81.5	2285	68.6
	7 a.m.	(1)	Min.	7.9	71.4	2457	19,410	73.6	62.9	1930	142,048	161,458	81.5	1981	63.7
		(2)		49.2	71.4	2457	120,884	32.3	62.9	1930	62,339	183,223	81.5	2248	68.0
		(1)	Avg.	20.5	71.4	2457	50,368	61.0	62.9	1930	117,730	168,098	81.5	2062	65.0
		(2)		33.6	71.4	2457	82,555	47.9	62.9	1930	92,447	175,002	81.5	2147	66.4
9-3	5 a.m.	(1)	Max.	43.4	71.4	2457	106,634	39.5	63.0	1936	76,472	183,106	82.9	2209	67.4
		(2)		56.3	71.4	2457	138,329	26.6	63.0	1936	51,498	189,827	82.9	2290	68.7
	8 a.m.	(1)	Min.	3.2	71.4	2457	7,862	79.7	63.0	1936	154,299	162,161	82.9	1956	63.3
		(2)		35.4	71.4	2457	86,978	47.5	63.0	1936	91,960	178,938	82.9	2158	66.6
		(1)	Avg.	21.8	71.4	2457	53,563	61.1	63.0	1936	118,290	171,853	82.9	2073	65.2
		(2)		35.0	71.4	2457	85,995	47.9	63.0	1936	92,734	178,729	82.9	2156	66.5

TEMPERATURE ROUTING

°F Calculated from Centigrade Readings

		Reported Temp. of Water 1035 Ft. Elevation Coulee Reservoir		Coulee Reservoir 1 Ft. Below Surface		10 a.m. 4 to 5 Ft. depth		10 p.m. Mixed Discharge at USGS Gage		Discharge Actual Readings			Actual Temp. Chief Joseph Turbo-Gen. Discharge ± 0.5°C		*Actual Temp. Rock Island 24 hrs after Coulee	Temp. 181-B 36 hrs after Coulee	
		°F	°C	°F	°C	°F	°C	°F	°C		°F	°C	°F	°C	°F	°F	°C
7-25	11a.m.	59.0	15.0					64.6	18.1				66.2	19.0	67.0	69.0	20.6
26		59.0	15.0										66.2	19.0	67.0	69.0	20.6
27		59.0	15.0										66.2	19.0	67.0	69.0	20.6
28		59.0	15.0										66.2	19.0	67.0	68.9	20.5
29		59.0	15.0	68.0	20.0	67.2	19.6	64.2	17.9				66.2	19.0	67.0	68.7	20.4
30	5a.m.	59.0	15.0										66.2	19.0	67.0	70.0	21.1
31	5p.m.	59.0	15.0										65.2	18.5	66.0	68.8	20.4
8- 1	7p.m.	59.0	15.0							USGS	63.0	17.2	65.2	18.5	66.5	68.5	20.3
2	2p.m.	59.0	15.0										64.4	18.0	66.5	67.6	19.8
3	4p.m.	59.0	15.0										64.4	18.0	66.0	67.0	19.5
4	6a.m.	59.0	15.0										64.4	18.0	67.0	69.5	20.8
5	1a.m.	59.0	15.0										64.4	18.0	67.0	70.0	21.1
6	1a.m.	59.0	15.0										59.0	15.0	66.0	70.5	20.3
7	10p.m.	59.0	15.0										62.6	17.0	65.0	68.0	20.0
8	8p.m.	59.0	15.0	69.0	20.6	68.0	20.0	62.9	17.1		63.0	17.2	64.4	18.0	65.5	68.2	20.1
		59.9	15.5														
9	4a.m.	59.9	15.5										64.4	18.0	66.0	70.0	21.1
10	6a.m.	59.9	15.5										64.4	18.0	66.0	69.6	20.9
11	4a.m.	59.9	15.5										64.4	18.0	66.0	70.0	21.1
12	4a.m.	59.9	15.5										64.4	18.0	66.0	70.0	21.1
13	4a.m.	60.0	15.6										64.4	18.0	66.5	70.0	21.1
14	4a.m.	61.0	16.1										64.4	18.0	67.0	70.9	21.6
15	5a.m.	61.0	16.1										64.4	18.0	66.5	70.0	21.1
16	6a.m.	61.0	16.1										64.4	18.0	66.5	70.0	21.1
17	6a.m.	61.0	16.1										64.4	18.0	66.5	70.3	21.3
18	4a.m.	61.0	16.1	70.4	21.9	70.0	21.1	(Noon 64.4	18.0)		63.0	17.2	65.5	18.5	67.0	70.8	21.5
		61.4	16.3	70.4	21.9	69.4	20.8	62.4	16.9								
19	11p.m.	62.0	16.7										65.5	18.5	67.0	70.5	21.4
20	5a.m.	62.0	16.7										65.5	18.5	68.0	71.5	21.9
21	Midnite	62.0	16.7										65.5	18.5	68.0	70.9	21.6
22	5p.m.	62.0	16.7										65.5	18.5	67.0	70.0	21.1
23	3p.m.	62.0	16.7										65.5	18.5	67.0	70.0	21.1
24	2p.m.	62.0	16.7										65.5	18.5	67.0	69.8	21.0

*NOTE: This not average discharge temperature.

Coulee to Chief Joseph, Approximate Change Due to Climatological Effects - Variation 0.6°C to 1.5°C, 1.1°F to 2.9°F

Chief Joseph to Rock Island, Approximate Change Due to Climatological Effects - Variation 0.6°C to 1.5°C, 1.1°F to 2.7°F

Rock Island to HAPO due to Climatological & Hot Springs - Variation 0.9°C to 2.2+°C, 1.4°F to 4.0°F

TEMPERATURE ROUTING
(Continued)

		Reported Temp. of Water 1035 Ft. Elevation Coulee Reservoir °F	°C	Coulee Reservoir 1 Ft. Below Surface °F	°C	10 a.m. 4 to 5 Ft. depth °F	°C	10 p.m. mixed Discharge at USGS Gage °F	°C	Discharge Actual Readings °F	°C
8-25	7a.m.	62.0	16.7								
26	Midnite	62.0	16.7								
27	1a.m.	62.0	16.7								
28	Midnite	62.0	16.7					(1 p.m.		63.0	17.2
								64.4	18.0)		
								61.9	16.6		
29	3a.m.	*62.5	17.2	71.6	21.9	71.0	21.7	(Noon			
				71.6	22.0	70.9	21.6	64.4	18.0)		
				71.6	21.9			62.0	16.7	63.0	17.2
30	4p.m.	*63.0						(Noon			
								64.4	18.0)		
								62.0	16.7		
31	Midnite	63.0									
9- 1	3a.m.	63.0		71.6							
2	4a.m.	63.0									
3	5a.m.	63.0									

*Actual Temp. Chief Joseph Turbo-Gen. Discharge ± 0.5°C °F	°C	Actual Temp. Rock Island 24 hrs after Coulee °F	Temp.181-B 36 hrs after Coulee °F	°C
65.5	18.5	67.5	70.0	21.1
65.5	18.5	67.0	68.8	20.5
65.5	18.5	67.0	68.8	20.5
65.5	18.5	67.5	69.0	20.6
65.5	18.5	67.5	70.0	21.1
66.2	19.0	67.5	70.0	21.1
66.2	19.0	67.0	67.0	19.5
66.2	19.0	66.5	67.0	19.5
66.2	19.0	67.0	67.0	19.5
66.2	19.0	67.0	68.7	20.4

Coulee to Chief Joseph, Approximate Change Due to Climatological Effects - Variation 0.6°C to 1.5°C, 1.1°F to 2.9°F

Chief Joseph to Rock Island, Approximate Change Due to Climatological Effects - Variation 0.6°C to 1.5°C, 1.1°F to 2.7°F

Rock Island to HAPO Due to Climatological & Hot Springs - Variation 0.9°C to 2.2°C, 1.4°F to 4.0°F

N.B. Readings at Chief Joseph checked ±0.5°C, at Rock Island ±0.5°F

*NOTE: This not average discharge temperature.

COLUMBIA RIVER TEMPERATURE PROFILES

August 26, 1958, 11:00 a.m.

Depth	181 B INTAKE		"B" Intake	"C" Intake				
	3' in from North Side	Center West Intake	3' in from South Side	3' in from North Side	Center East Intake	5' in from East Side	3' in from East Side	1 Ft. in
Air	31.8	31.8	31.8	31.8	31.8	31.8		
0'	20.5°C	20.4°C	20.2°C	20.6°C	20.7°C	----	25.0°C	23.6°C
5'	20.0°C	20.2°C	20.3°C	20.4°C	20.6°C	24.8°C	23.0°C	
Bottom	20.0°C	20.0°C	20.3°C	20.4°C	20.4°C	----	21.0°C	

August 26, 1958, Noon

Air	32.7	32.7	32.7	32.7	32.7		32.7
0'	20.4°C	20.3°C	20.2°C	20.6°C	20.7°C		23.4°C
5'	20.2°C	20.0°C	20.2°C	20.5°C	20.6°C		21.0°C
Bottom	20.0°C	20.0°C	20.2°C	20.2°C	20.5°C		21.0°C

Pump Intake - 21.1°C

Vernita Ferry, 4:00 p.m.

Depth	Shallow Water South Side	40' North from South Bank	Center of River	40' South of North Bank	Shallow Water South Side
Air	32.8	32.8	32.8	32.8	32.8
0'	21.0°C	20.6°C	20.4°C	20.4°C	20.6°C
5'		20.3°C	20.2°C	20.2°C	
Bottom			20.0°C	20.0°C	

Priest Rapids Below Dam, 5:00 p.m.

Depth	Shallow Water South Side	Center of River	Halfway between Center and North Bank	Shallow Water North Bank
Air	31.7	31.7	31.7	31.7
0'	21.0°C	20.6°C	20.4°C	20.0°C
5'		20.3°C	20.2°C	

August 27, 1958, 11:00 a.m.

Depth	181 B INTAKE		"B" Intake	"C" Intake		
	3' in from North Side	Center West Intake	3' in from South Side	3' in from North Side	Center East Intake	3' in from East Side
Air	21.8	21.8	21.8	21.8	21.8	21.8
0'	19.5°C	19.4°C	19.2°C	19.6°C	19.7°C	23.0°C
5'	19.0°C	19.2°C	19.2°C	19.4°C	19.6°C	22.6°C
Bottom	19.0°C	19.0°C	19.2°C	19.4°C	19.4°C	22.3°C

Pump Intake - 20.6°C

Vernita Ferry, 1:00 p.m.

Air Temp.	21.8°C	21.8°C	21.8°C	21.8°C	21.8°C
	Shallow Water South Side	40' from South Side	Center	40' from North Side	Shallow Water North Side
0'	20.4°C	19.4°C	19.4°C	19.4°C	19.6°C
5'		19.2°C	19.2°C	19.2°C	
		19.0°C	19.0°C	19.0°C	

Priest Rapids at Dam, 2:30 p.m.

Depth	30' from South Side	Center	20' from North Side
Air	24.4°C	24.4°C	24.4°C
0'	19.4°C	19.3°C	19.4°C
5'	19.2°C	19.1°C	19.1°C

River at Beverly Bridge, 3:50 p.m.

Depth	Shallow Water East Side	20' from East Bank
Air	25.0°C	25.0°C
0'	19.8°C	19.4°C
5'		19.2°C

Crab Creek - 4:30 p.m. 21.5°C
6:30 p.m. 24.8°C

Above Crab Creek, 5:00 p.m.

	Out 10 Ft.	Up 1/2 Mile Out 10 Ft.	Out 20 Ft.	Out 15 Ft.
0'	19.6			
5'	19.2	19.8	19.2	19.7

August 28, 1958

Priest Rapids at Dam, 9:00 a.m.

Depth	Out 20 Ft. South Side	Center	Out 20 Ft. North Side
Air	23.3°C	23.3°C	23.3°C
0'	19.4°C	19.2°C	20.0°C
10'	19.2°C	18.9°C	19.4°C

Vernita Ferry, 8:30 a.m.

	Shallow Water South Side	Out 40 Ft. South Side	Center	Shallow Water
Air	22.2°C			
0'	20.6°C		19.2°C	19.4°C
5'		19.9°C	19.0°C	
10'			18.8°C	

181 B

Depth	Center B Side	Center C Side
5'	19.5	19.5

Beverly Bridge, 10:30 a.m.

	Out 20 Ft.
10'	19.9°C

Rock Island Dam, 2:30 p.m.

Depth	Gate #1	#2	#14	#18	#36	South Fish Ladder #37	8C	2C
Air								
1'	19.4°C	19.25°C	19.3°C	19.7	19.45	19.45	19.35	19.35
10'	19.3°C	19.25°C	19.15	19.4	19.25	19.25	19.25	19.20

Wenatchee River, 6:00 p.m.

Air	North Bank	Center	South Bank
0'			
3'	19.9°C	19.9°C	19.9°C

ARTIFICIAL COOLING OF THE COLUMBIA RIVER BY DAM REGULATION

By

H. A. Kramer

ABSTRACT - Part I

It was found that the temperature of the Columbia river could be significantly reduced by increasing the amount of water flowing from the lower depths of Lake Roosevelt if the spill of the warmer top water could be stored. Increased generation and flow through by-pass tubes reduced temperatures by amounts up to 2.8°C or 5°F. Basin climatology caused temperature rises ranging upward to 8°F. The cooling effect after passing through Chief Joseph reservoirs and the river reaches was calculated to be 80 per cent of the initial cooling. A heat balance in BTU per square foot was derived from the sum of the insolation, and sensible heat transfer, less reflected heat, minus back radiation, less evaporation, all modified by heat storage. (This data to be published later.)

The report is in three parts. The first covers the changes at Grand Coulee and their effects at HAPO. The second covers climatology affecting water temperature. The third is a classified document covering economic significance.

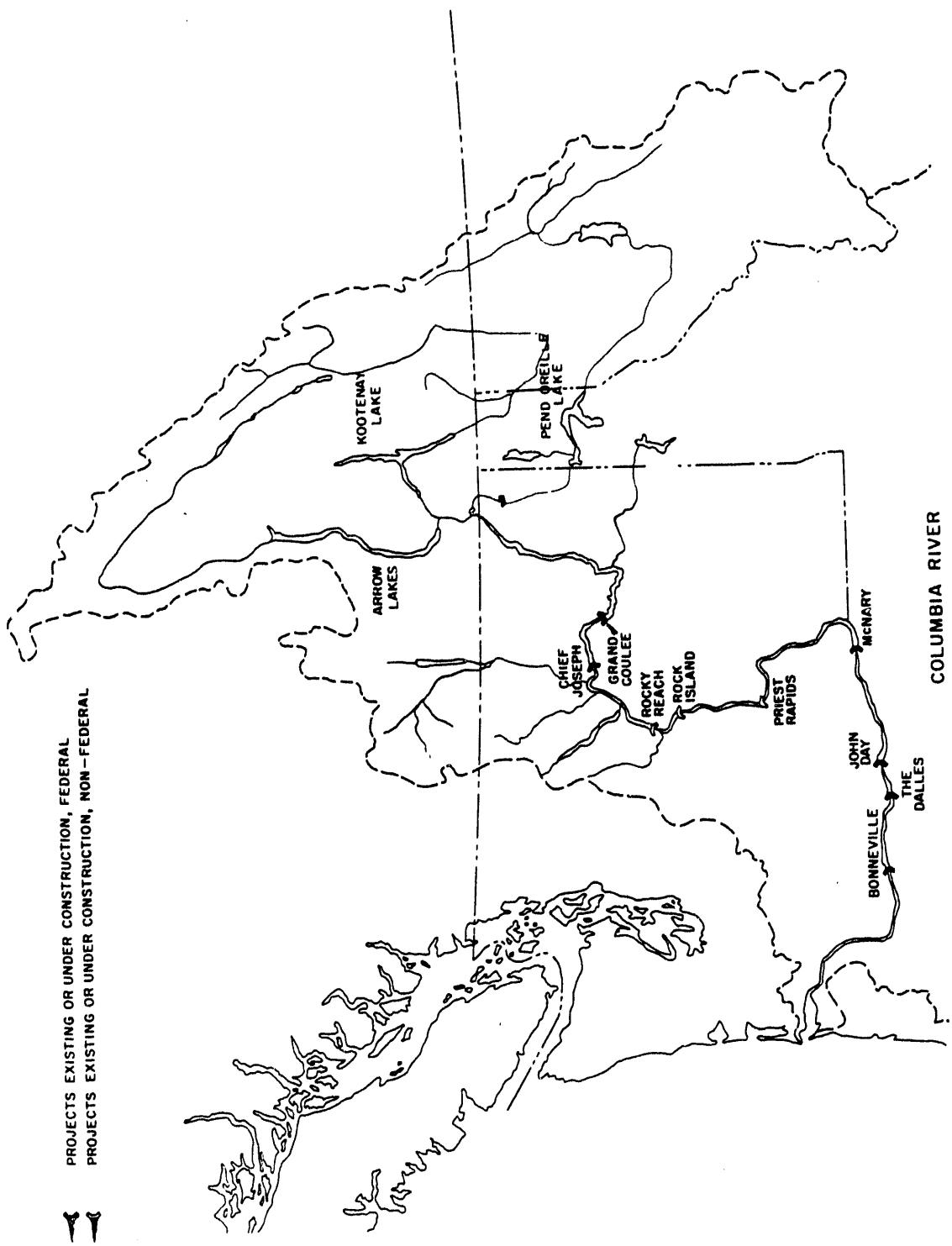
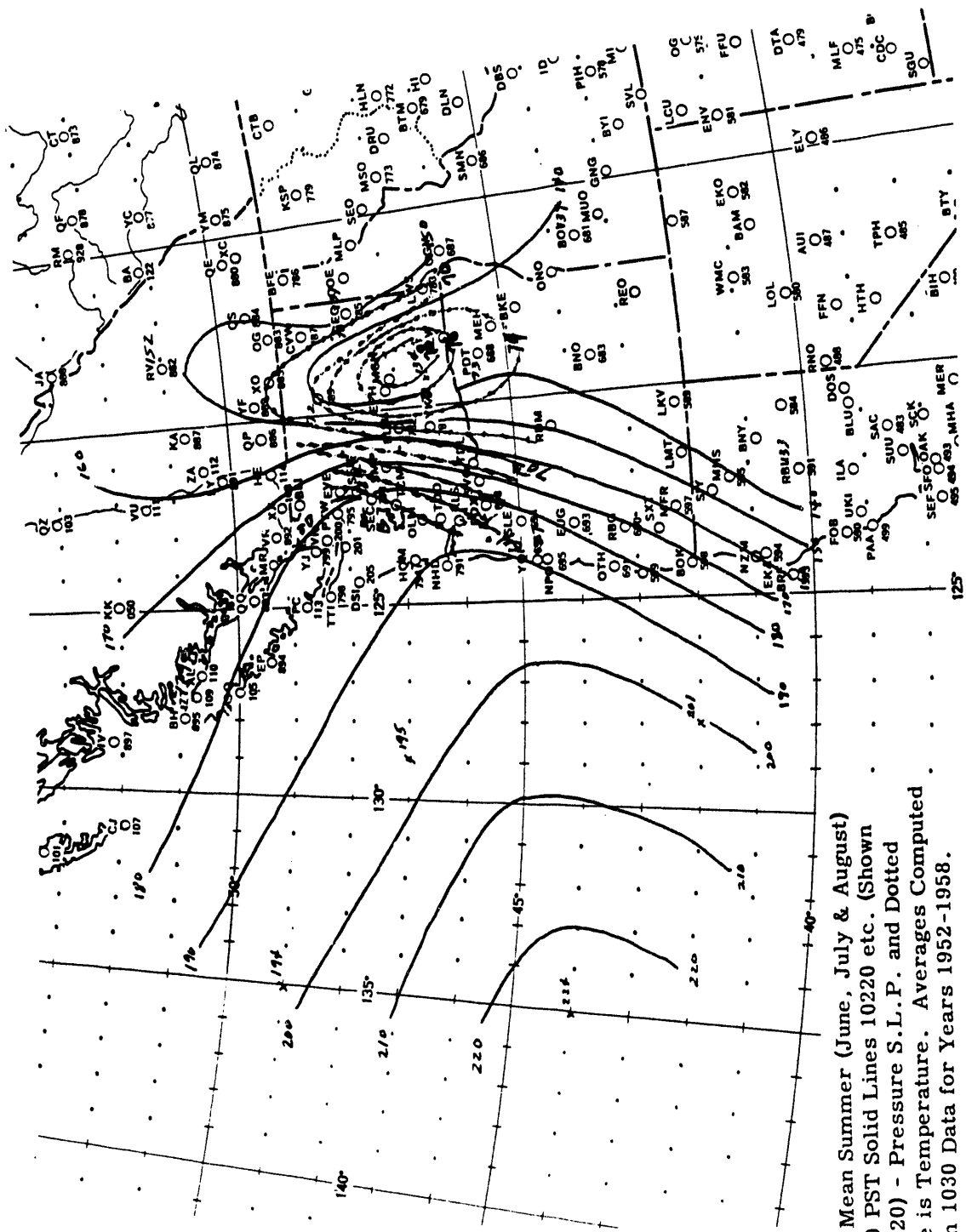


PLATE NO. 1

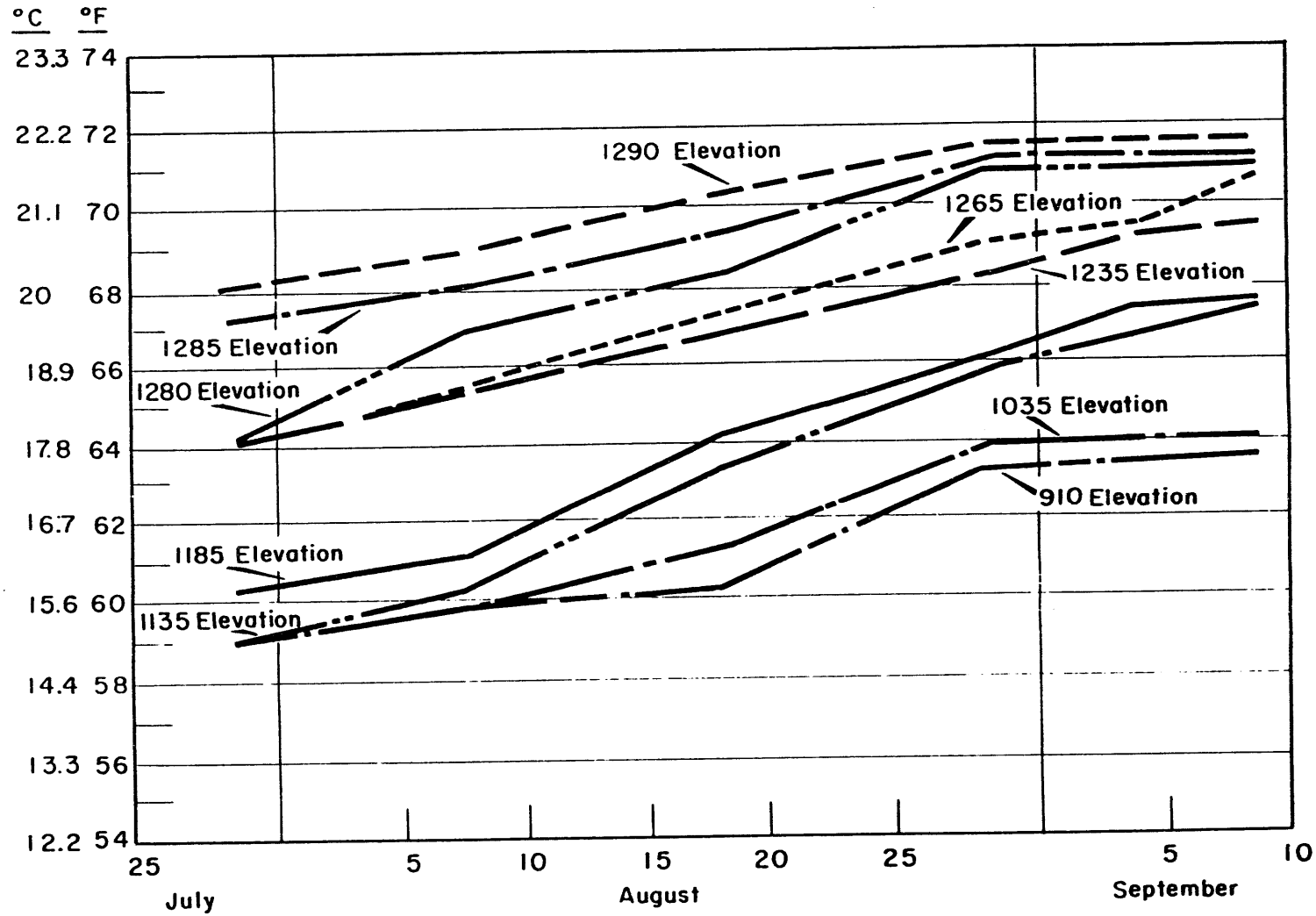
AEC-GE RICHLAND WASH



The Mean Summer (June, July & August) 1030 PST Solid Lines 10220 etc. (Shown as 220) - Pressure S.L.P. and Dotted Line is Temperature. Averages Computed from 1030 Data for Years 1952-1958.

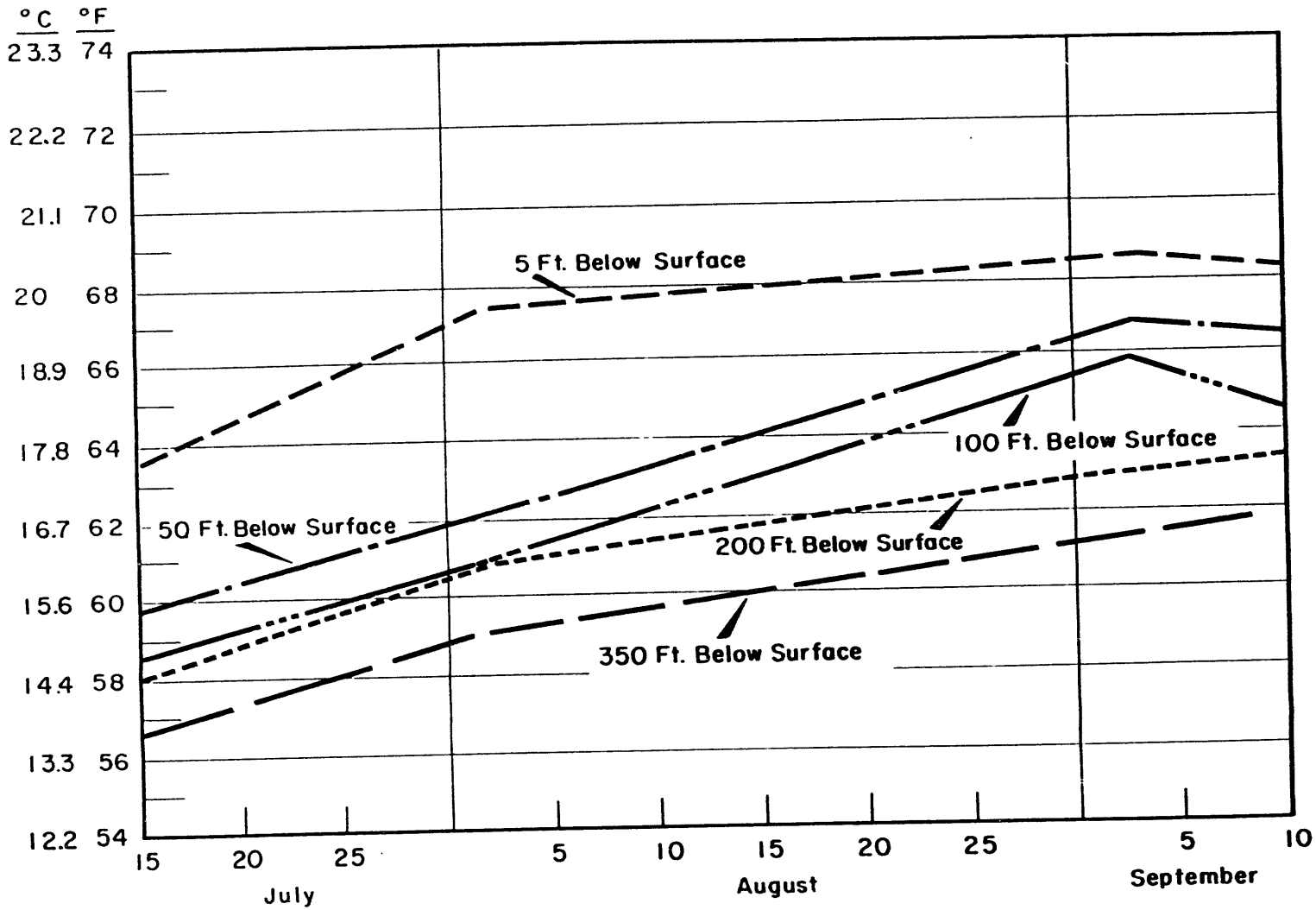
PLATE NO. 2

AEC-GE RICHLAND WASH



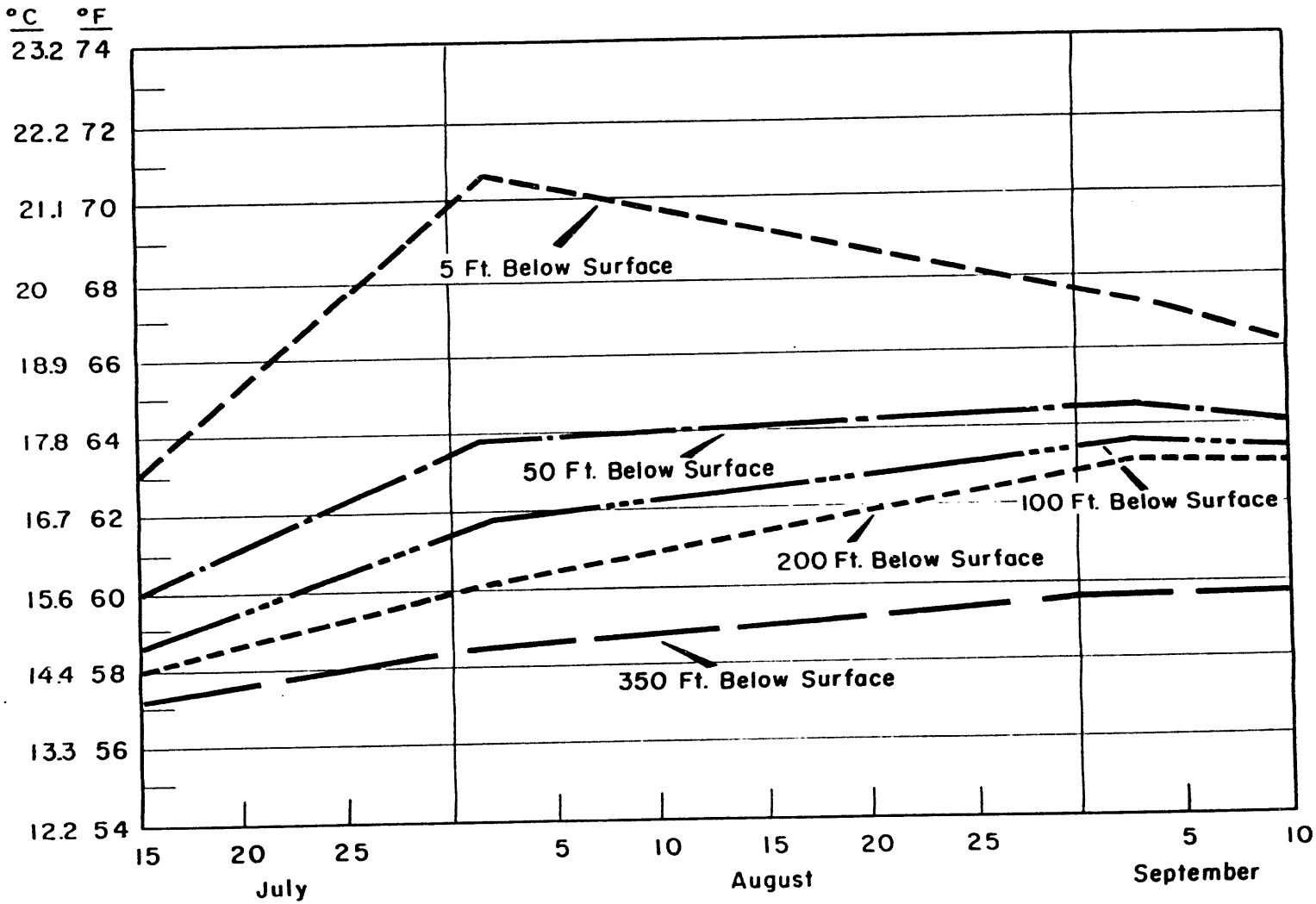
TEMPERATURE LAKE ROOSEVELT 1958

PLATE NO. 3



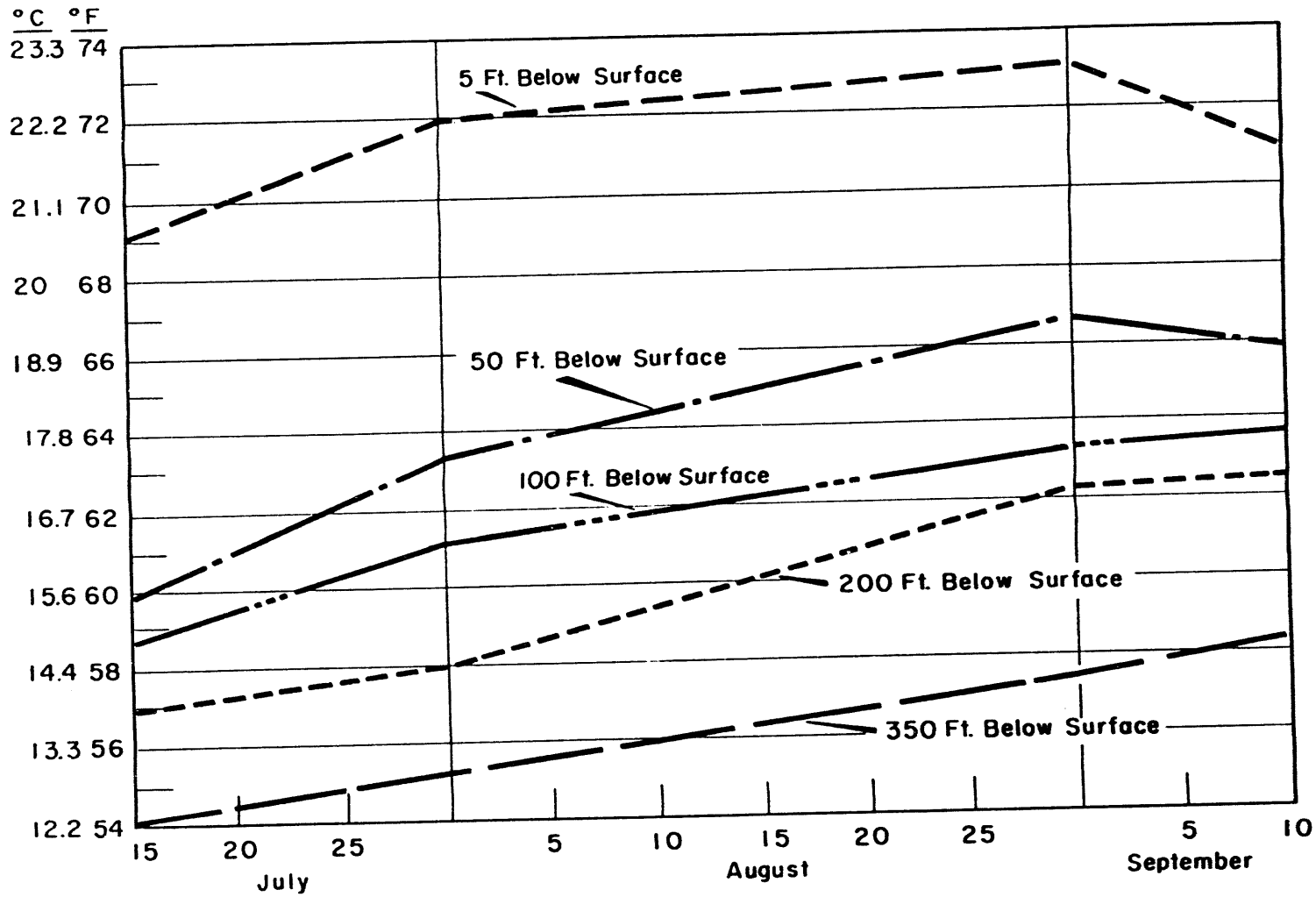
TEMPERATURE LAKE ROOSEVELT-1951

PLATE NO. 4



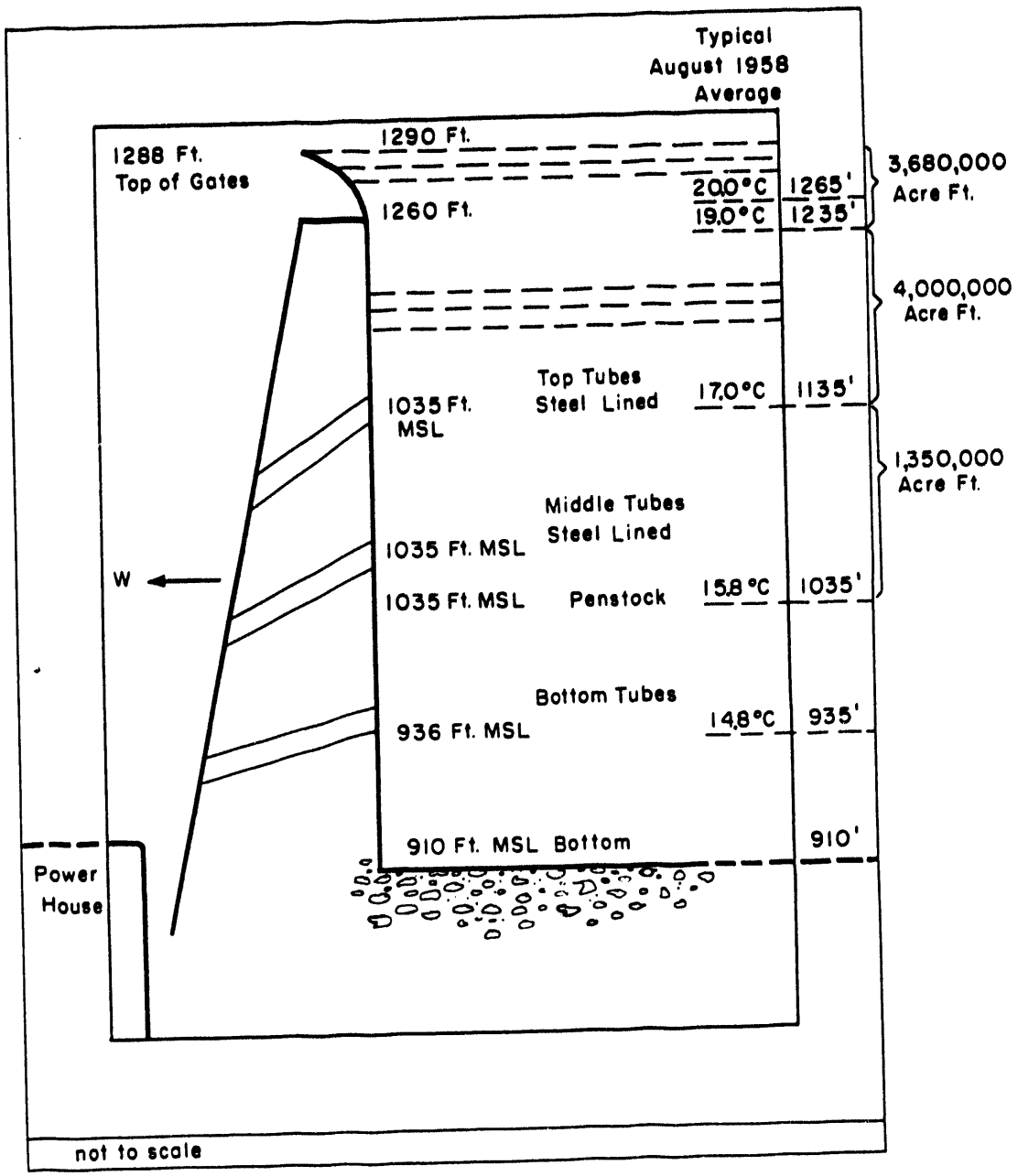
TEMPERATURE LAKE ROOSEVELT-1948

PLATE NO. 5



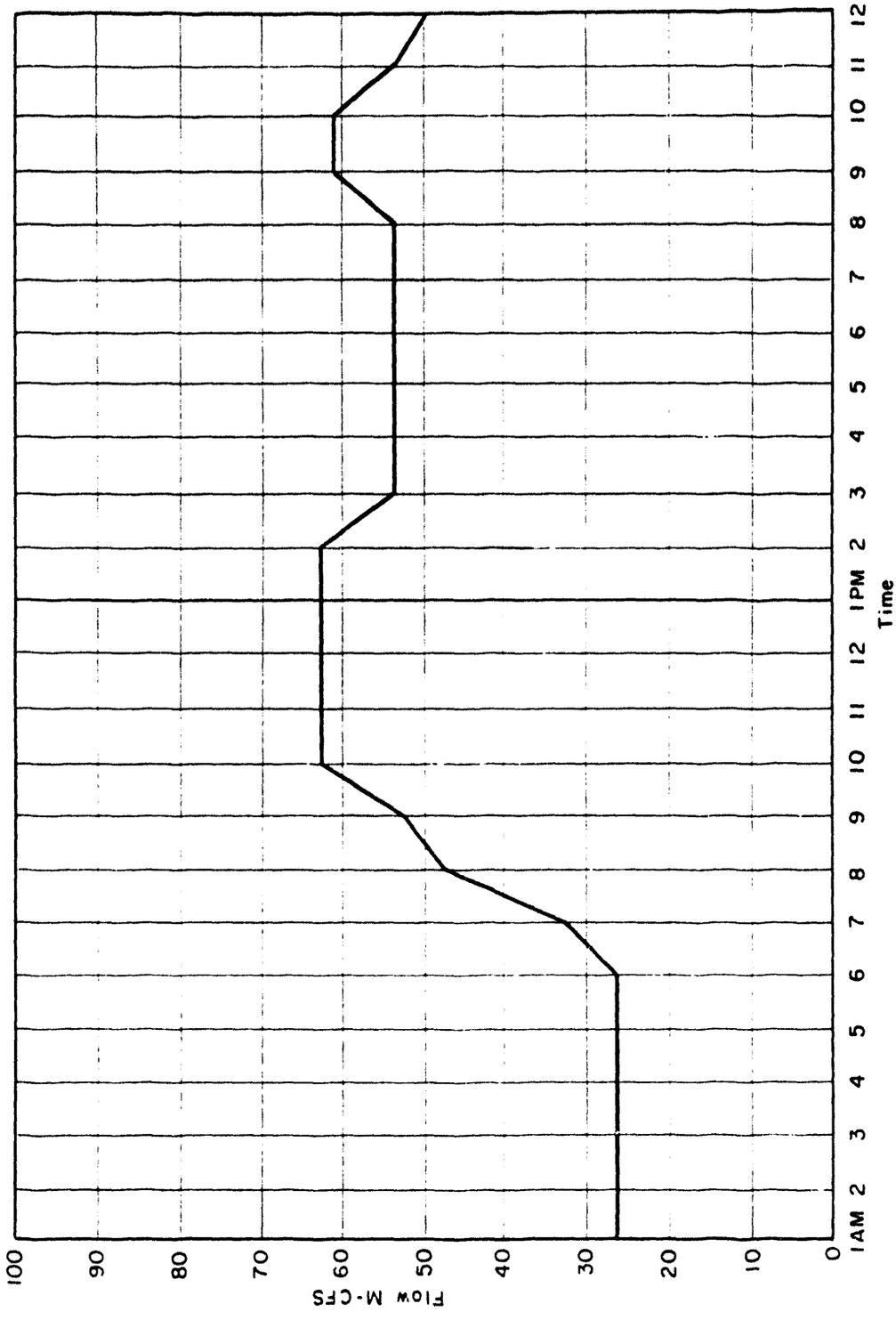
TEMPERATURE LAKE ROOSEVELT - 1949

PLATE NO. 6



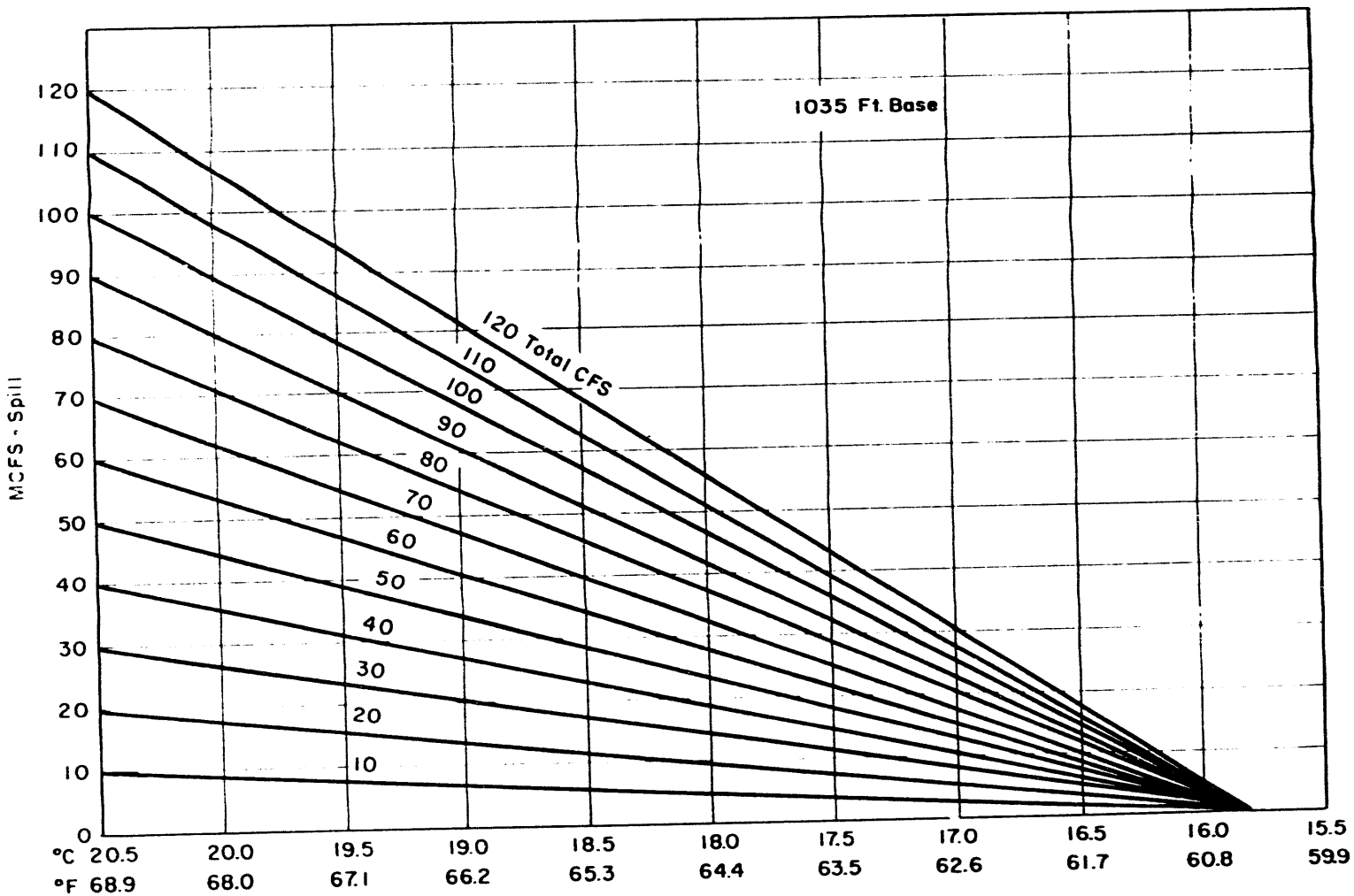
GRAND COULEE - LOOKING NORTH

PLATE NO. 7



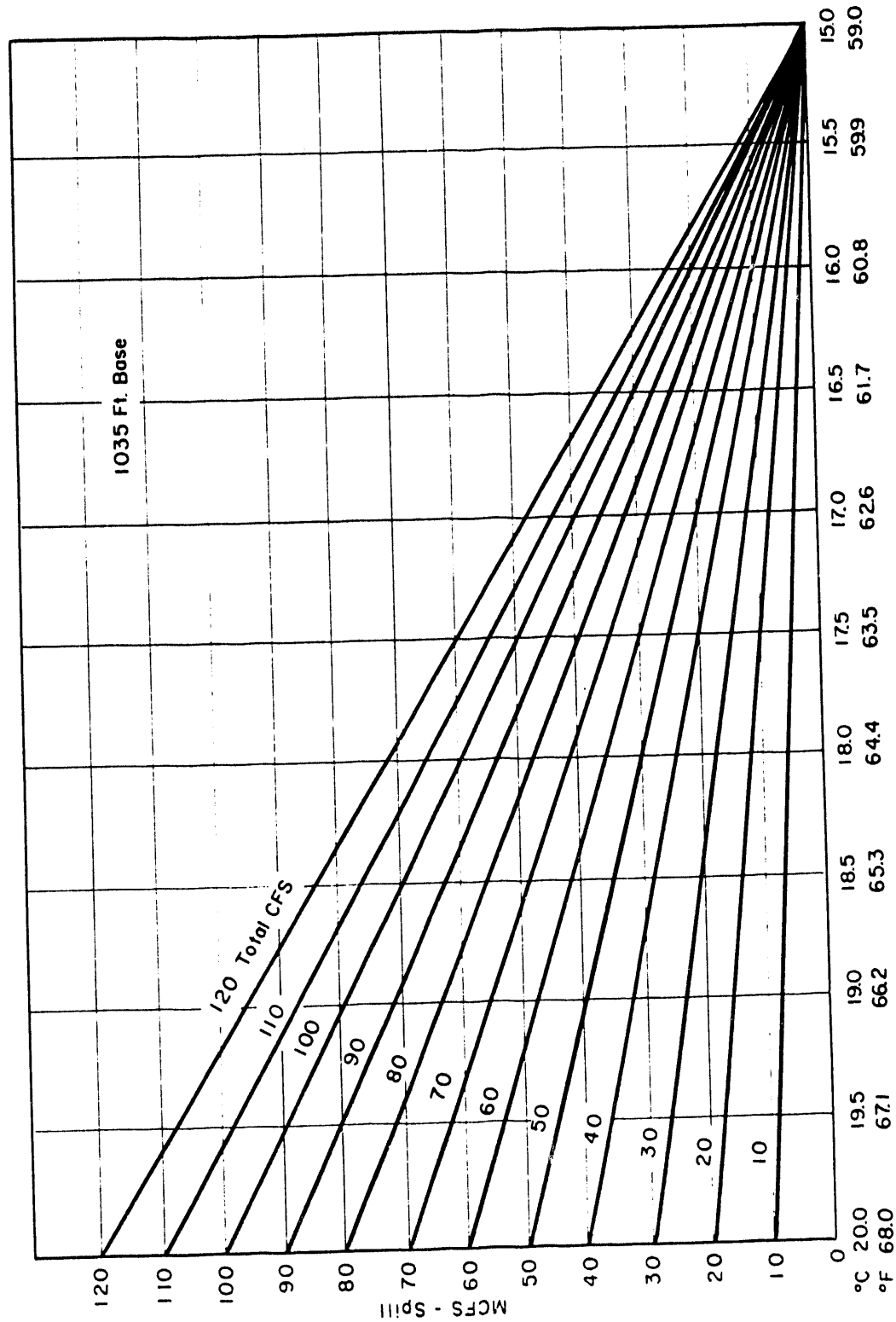
EXPECTED DAILY AVERAGE USE OF WATER-ELECTRICAL GENERATION BY COULEE GENERATORS AUGUST 1958

PLATE NO. 8



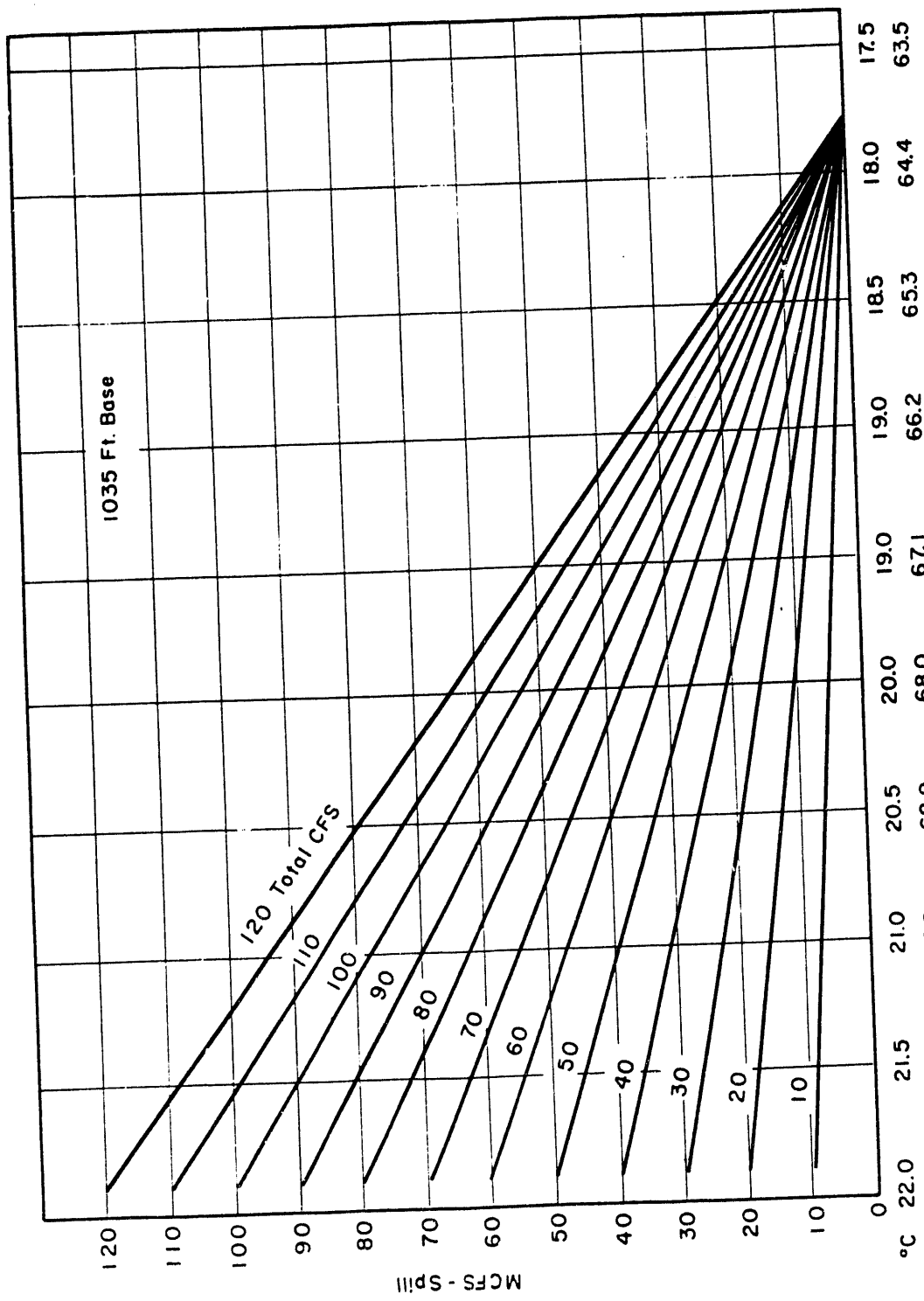
COULEE DISCHARGE TEMPERATURE (STANDARD)
Weighted August Average 1958

PLATE NO. 9



COULEE DISCHARGE TEMPERATURE - JULY 29, 1958

PLATE NO. 10

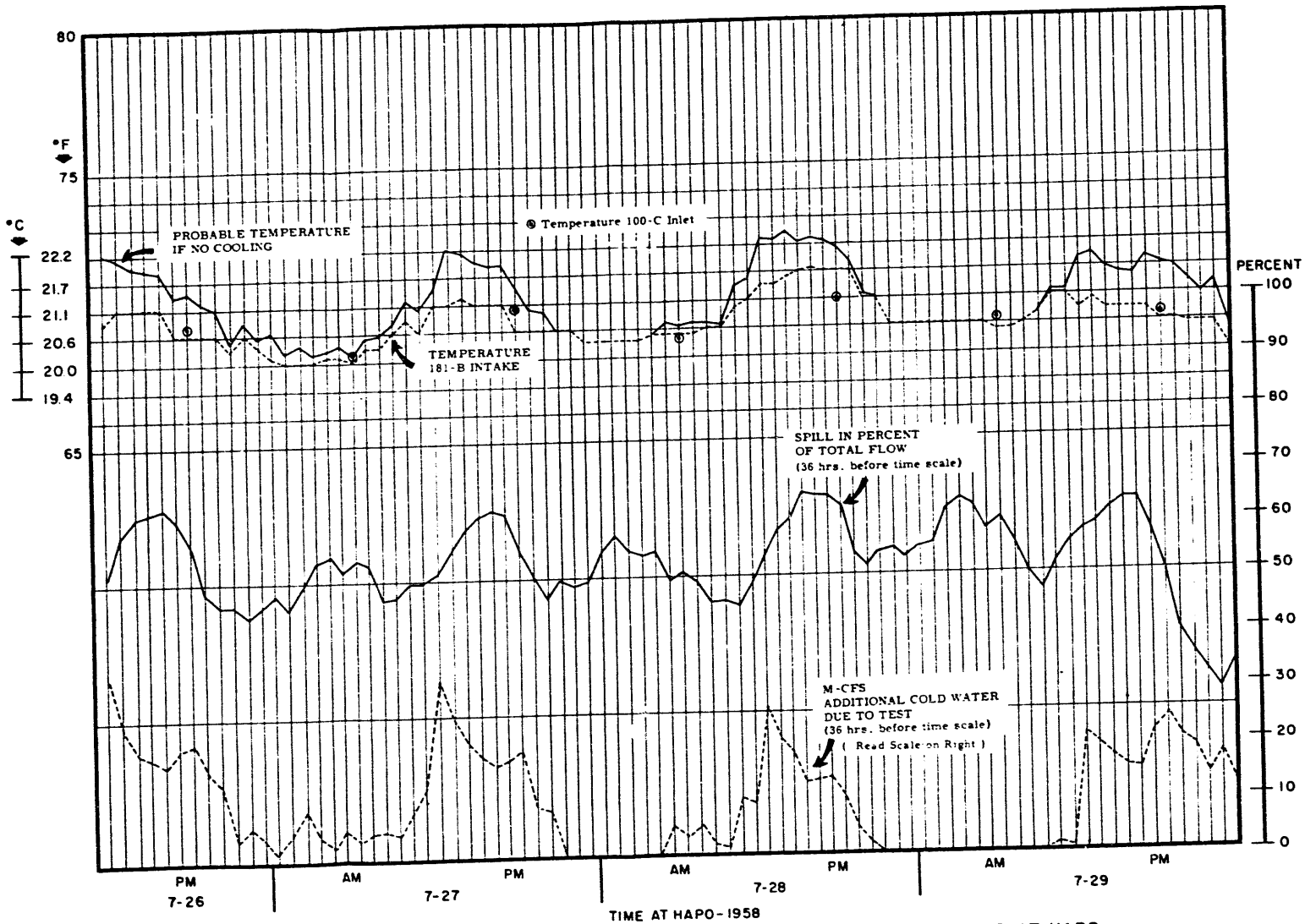


COULEE DISCHARGE TEMPERATURE SEPTEMBER 9, 1958

PLATE NO. 11

AEC-GE RICHLAND WASH

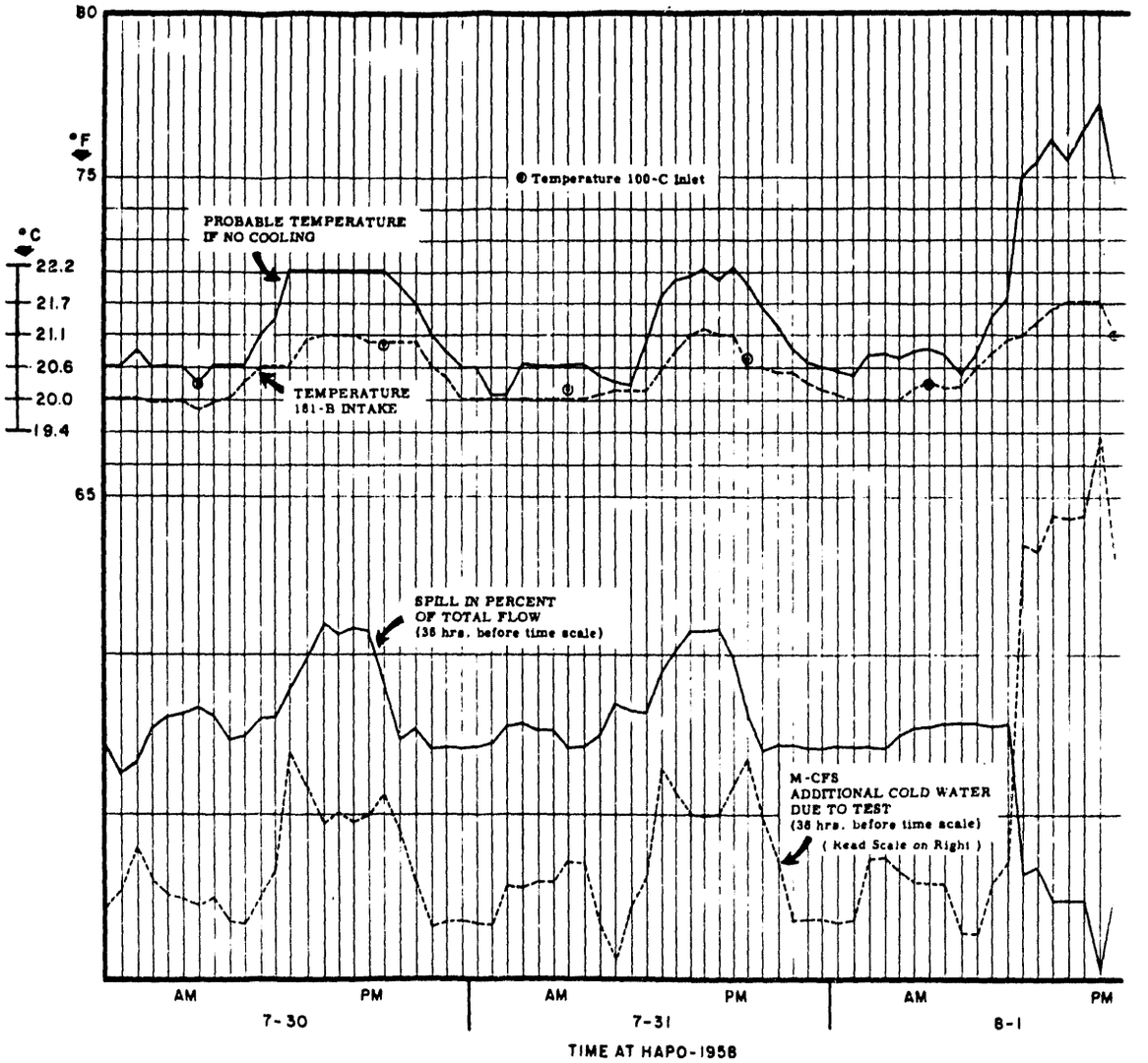
UNCLASSIFIED



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

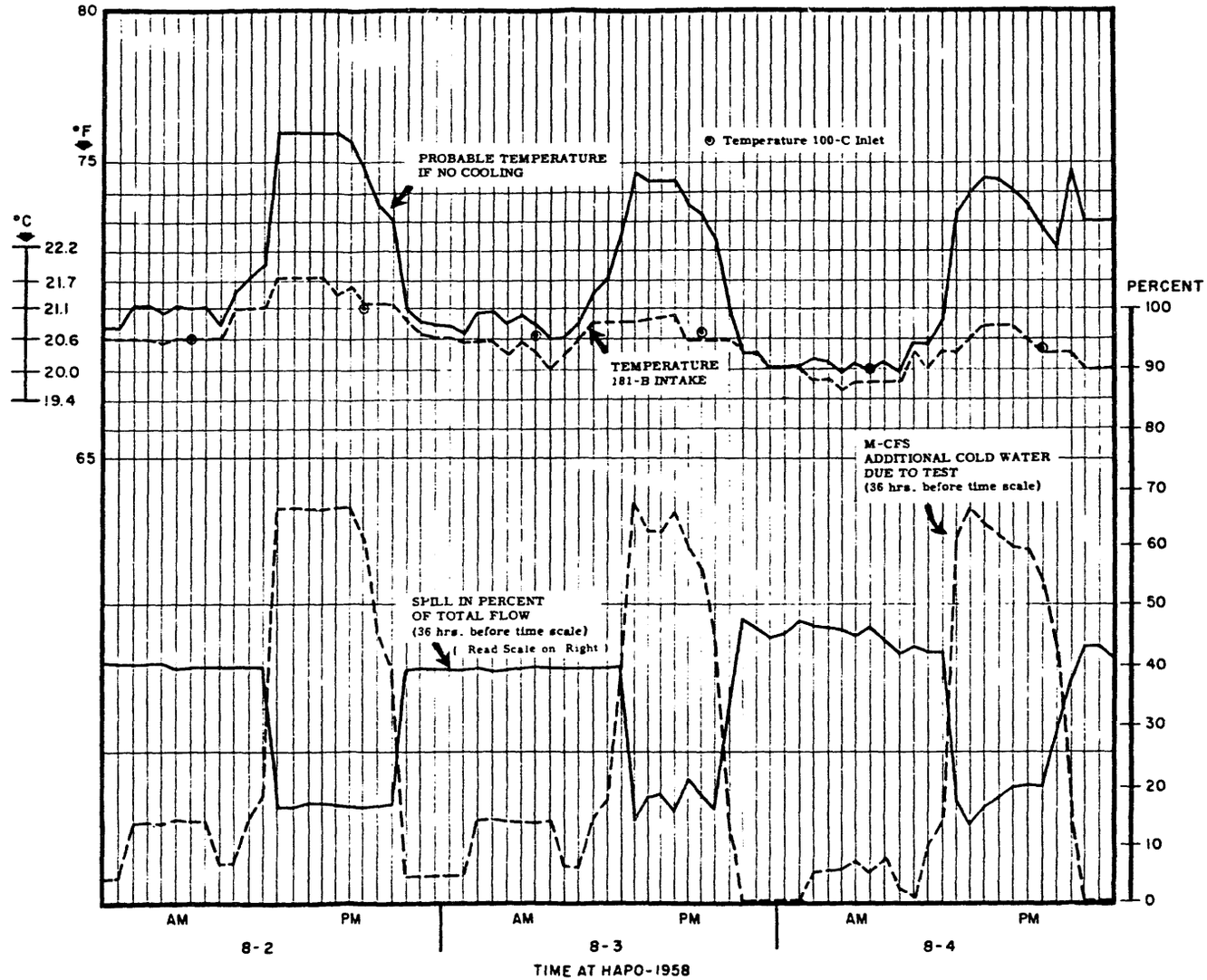
PLATE NO. 12

UNCLASSIFIED



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

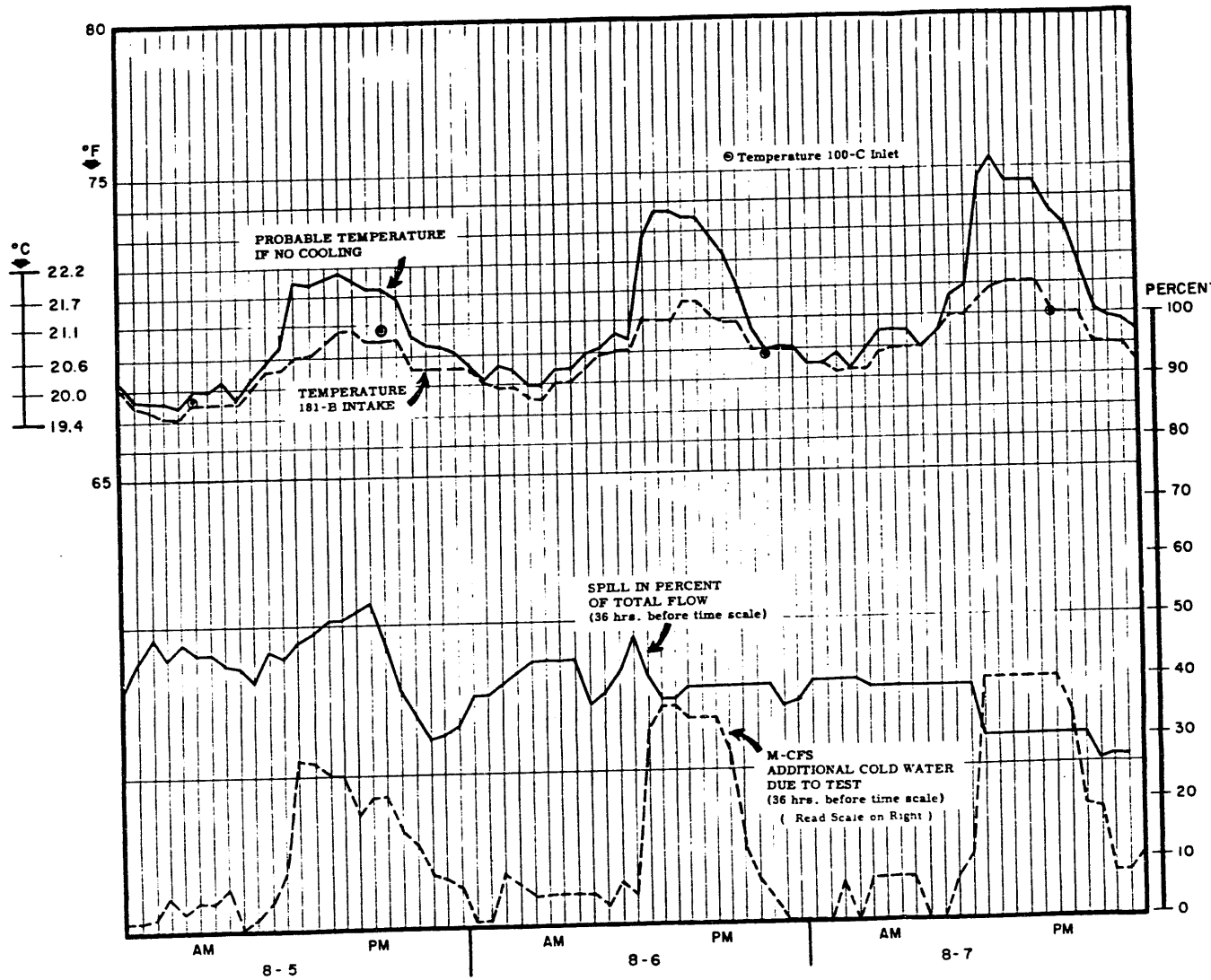
PLATE NO. 13



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 14

UNCLASSIFIED

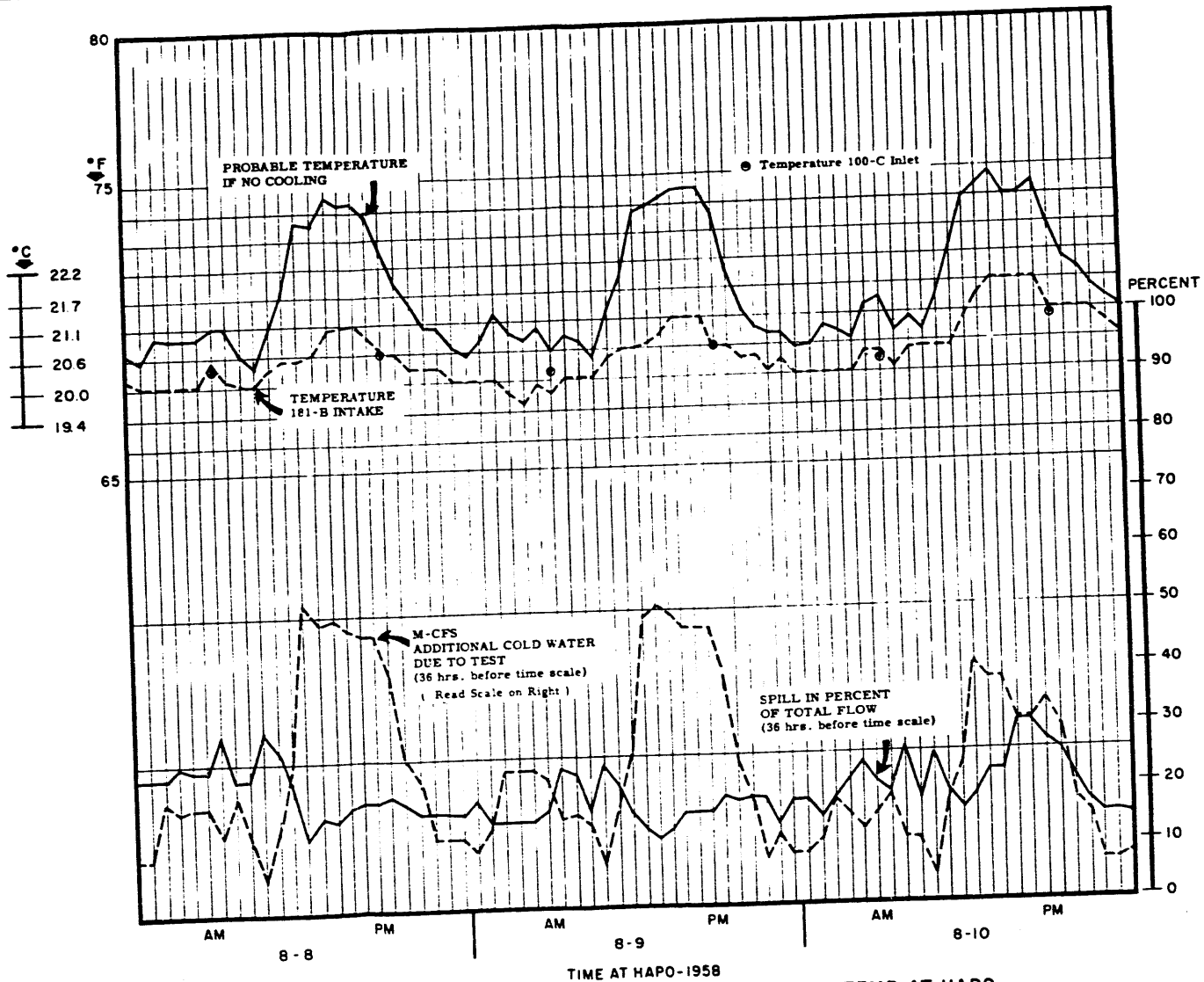


INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 15

UNCLASSIFIED

UNCLASSIFIED

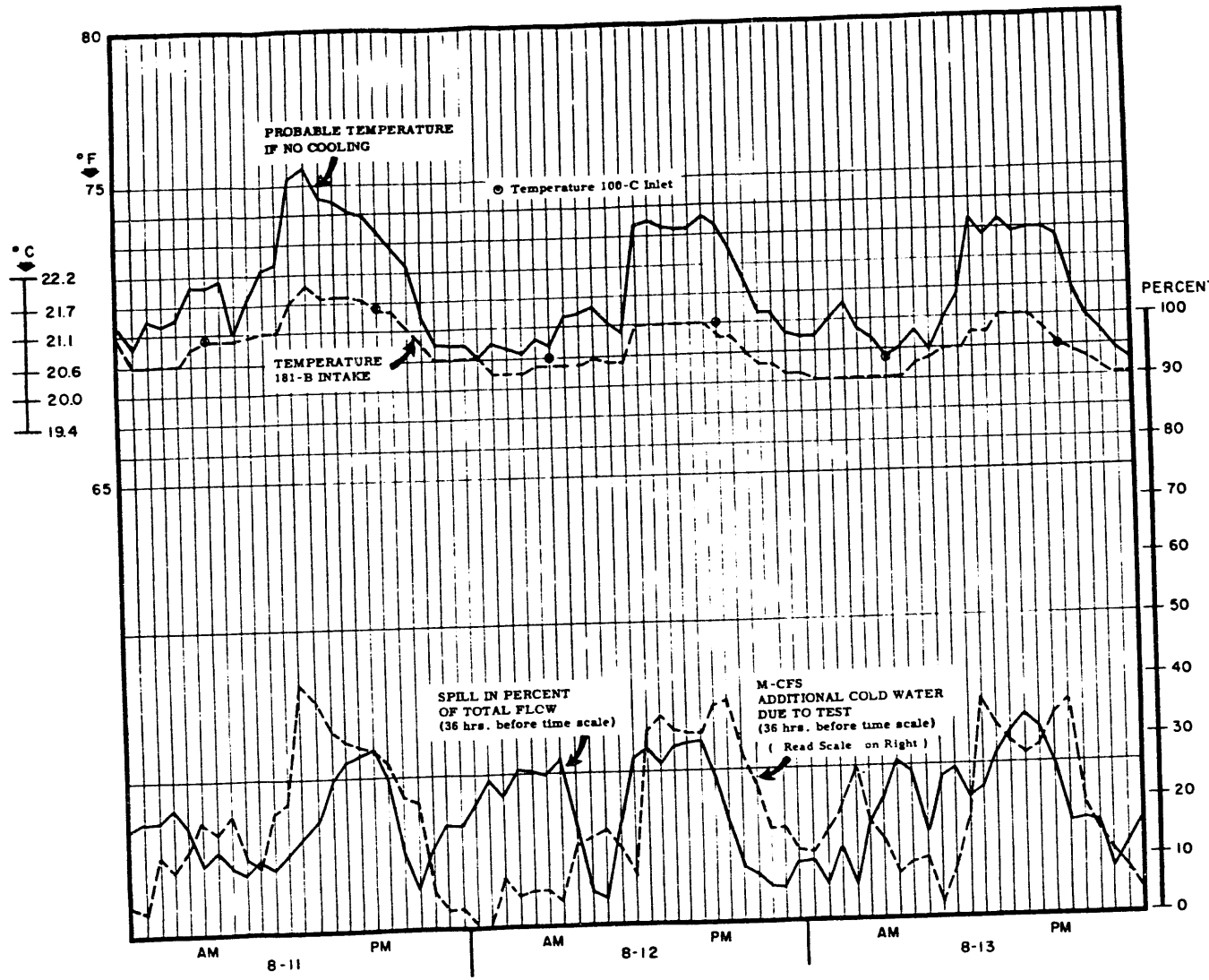


INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 16

UNCLASSIFIED

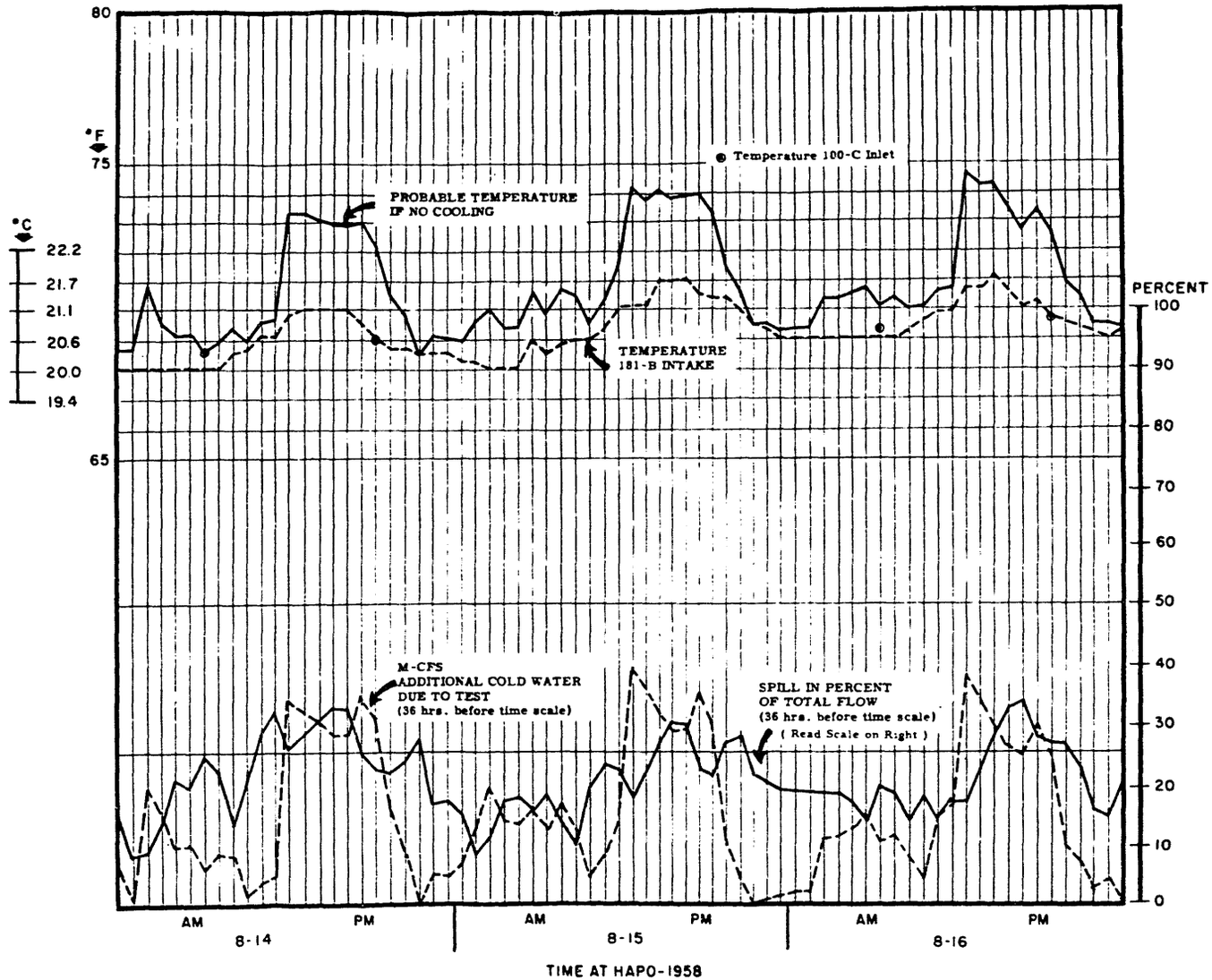
UNCLASSIFIED



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

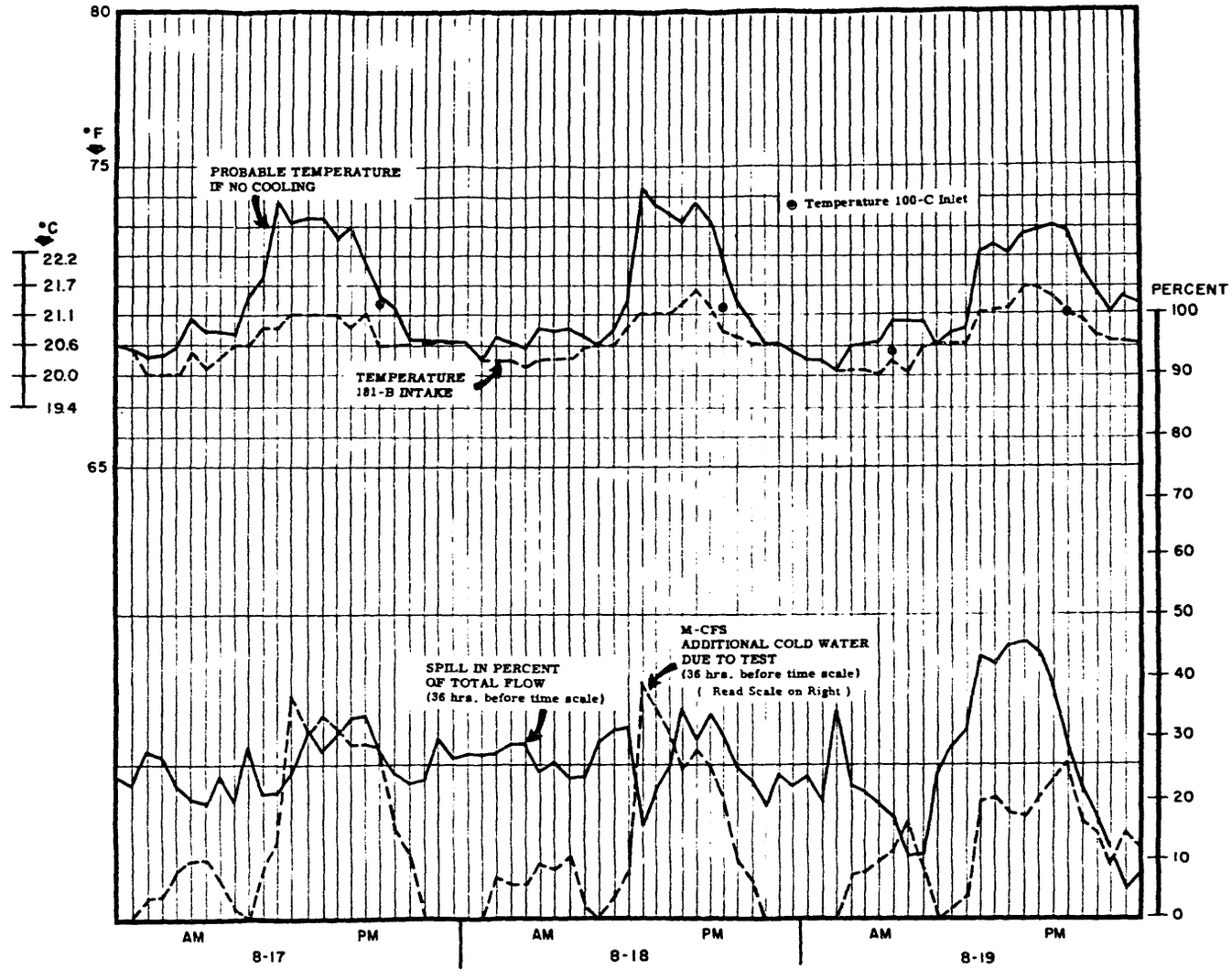
PLATE NO. 17

UNCLASSIFIED



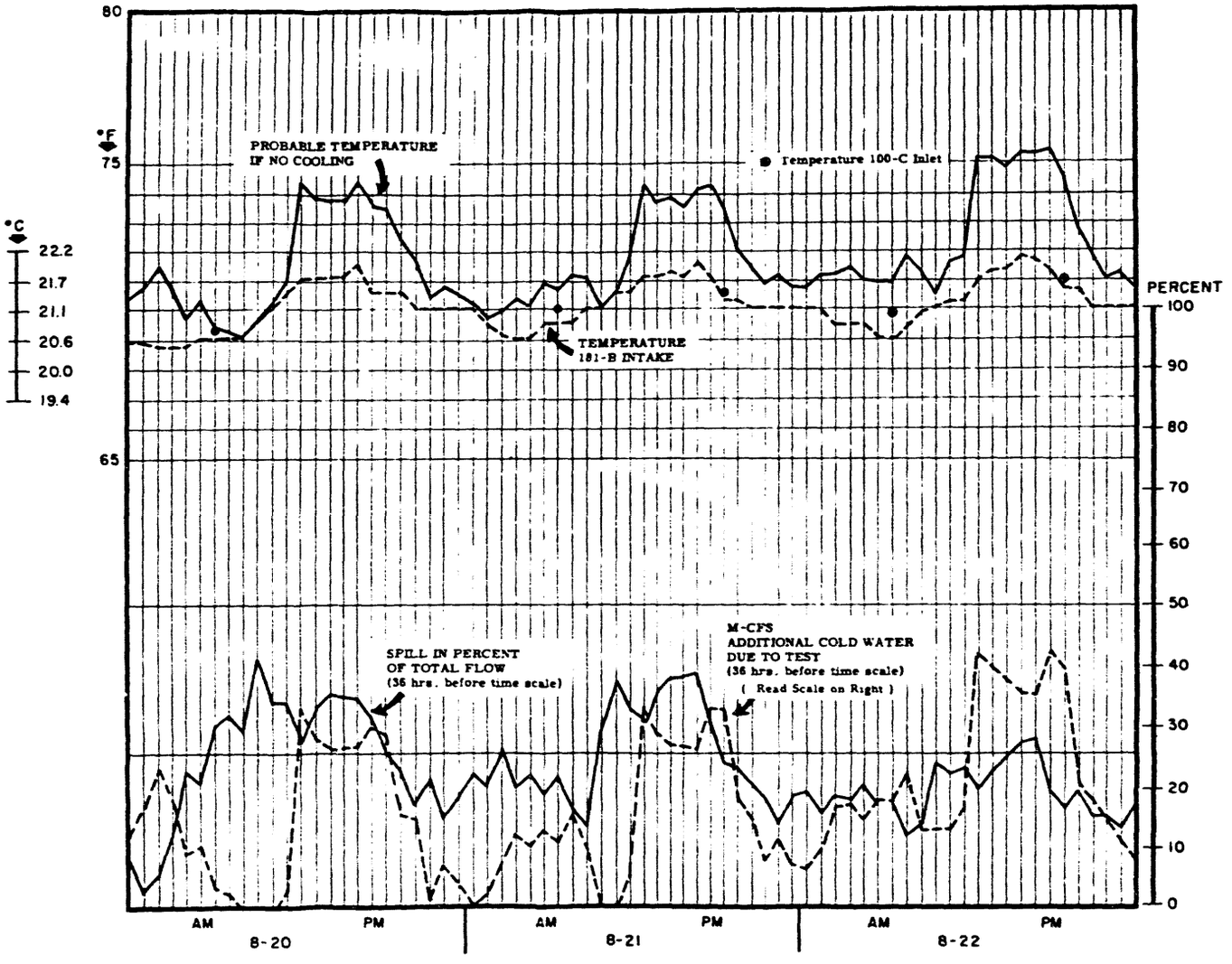
INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 18



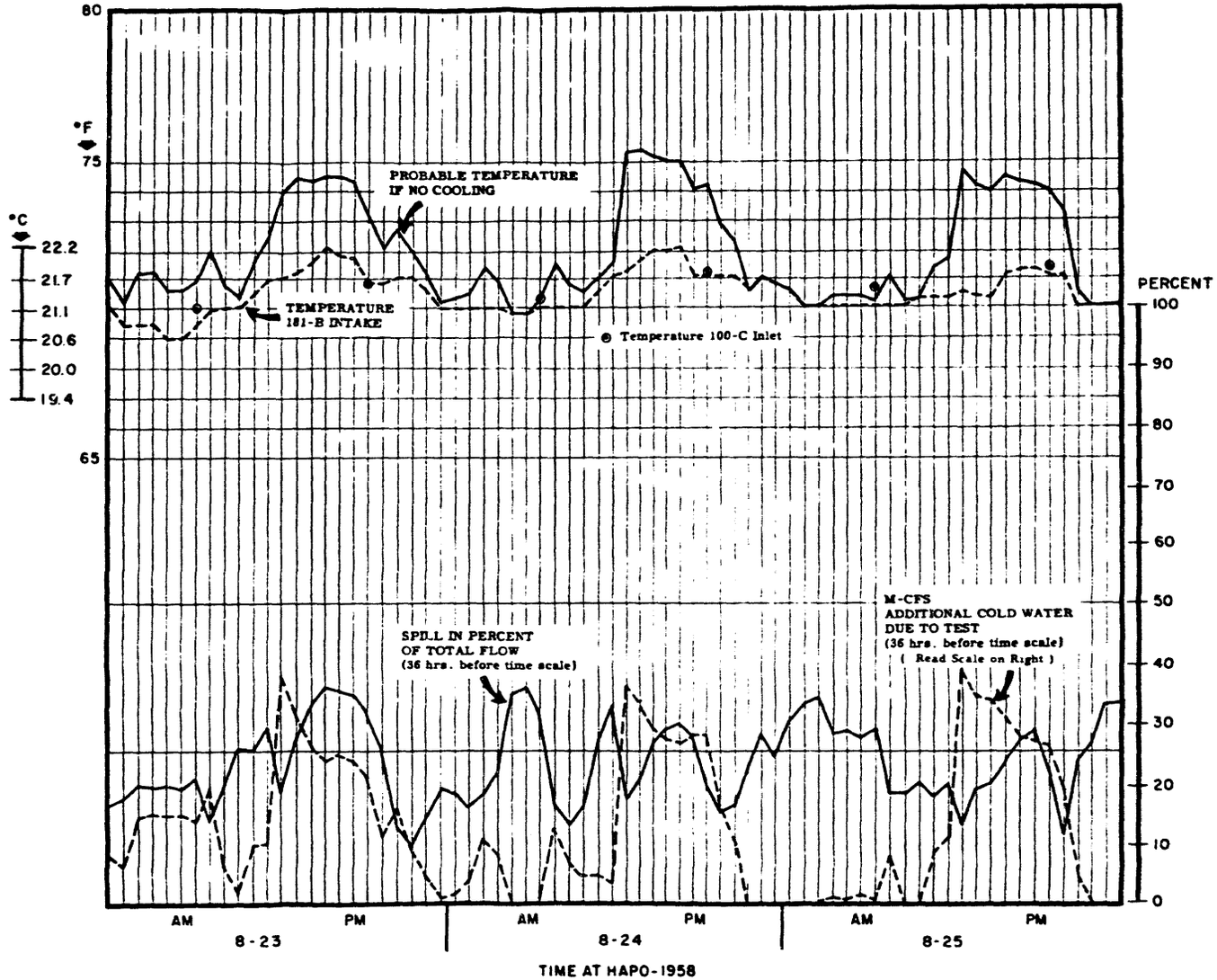
INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 19



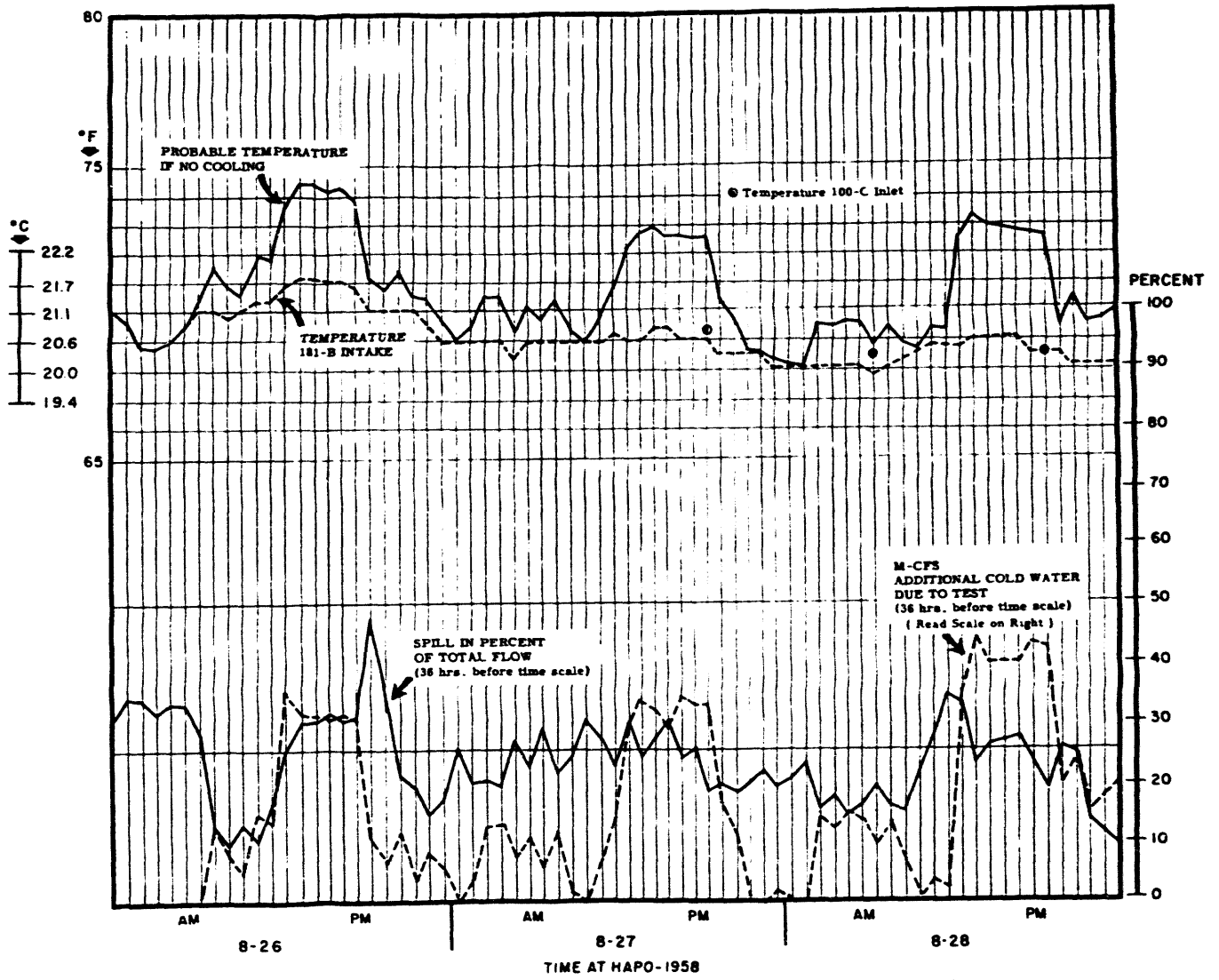
INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 20



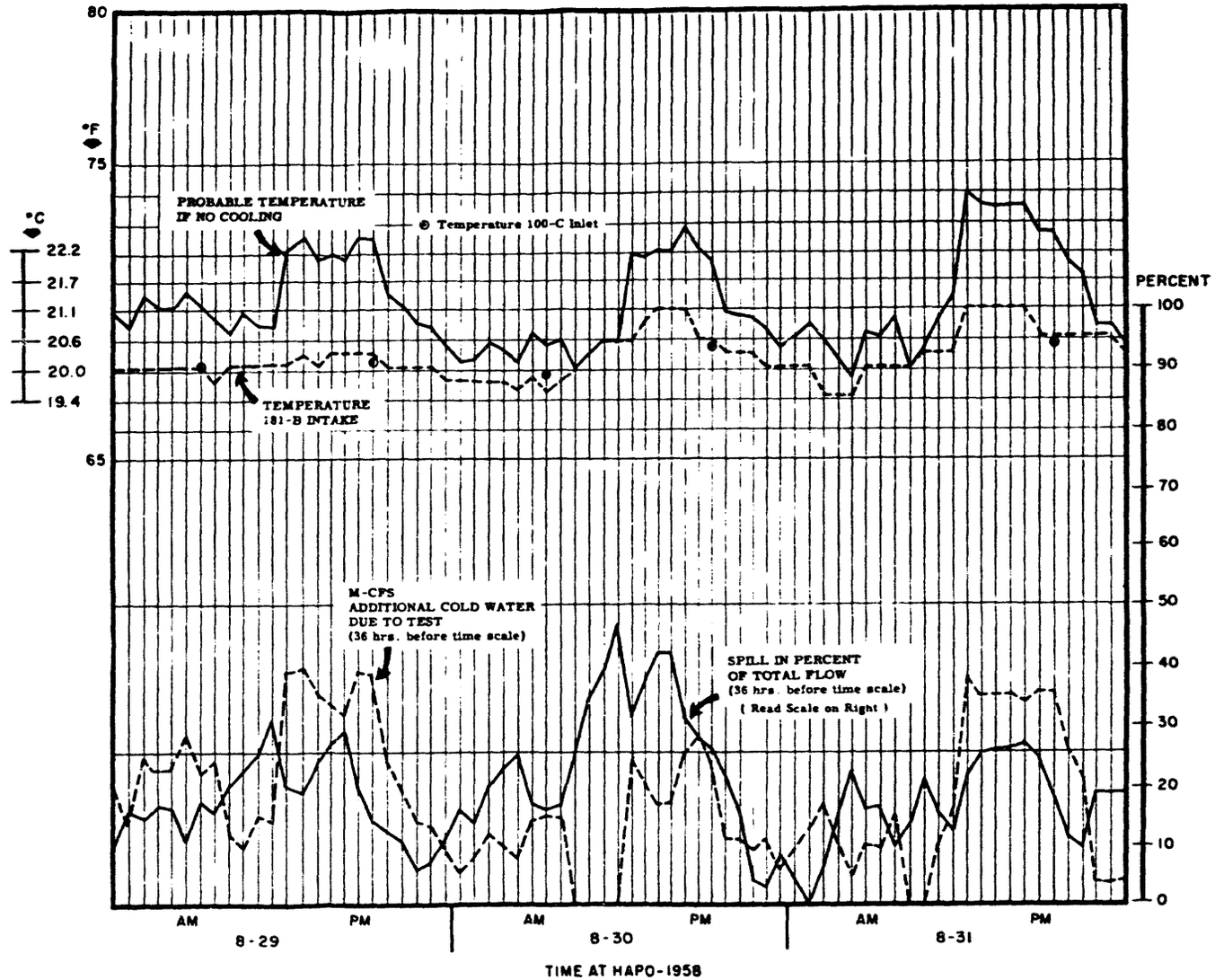
INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 21



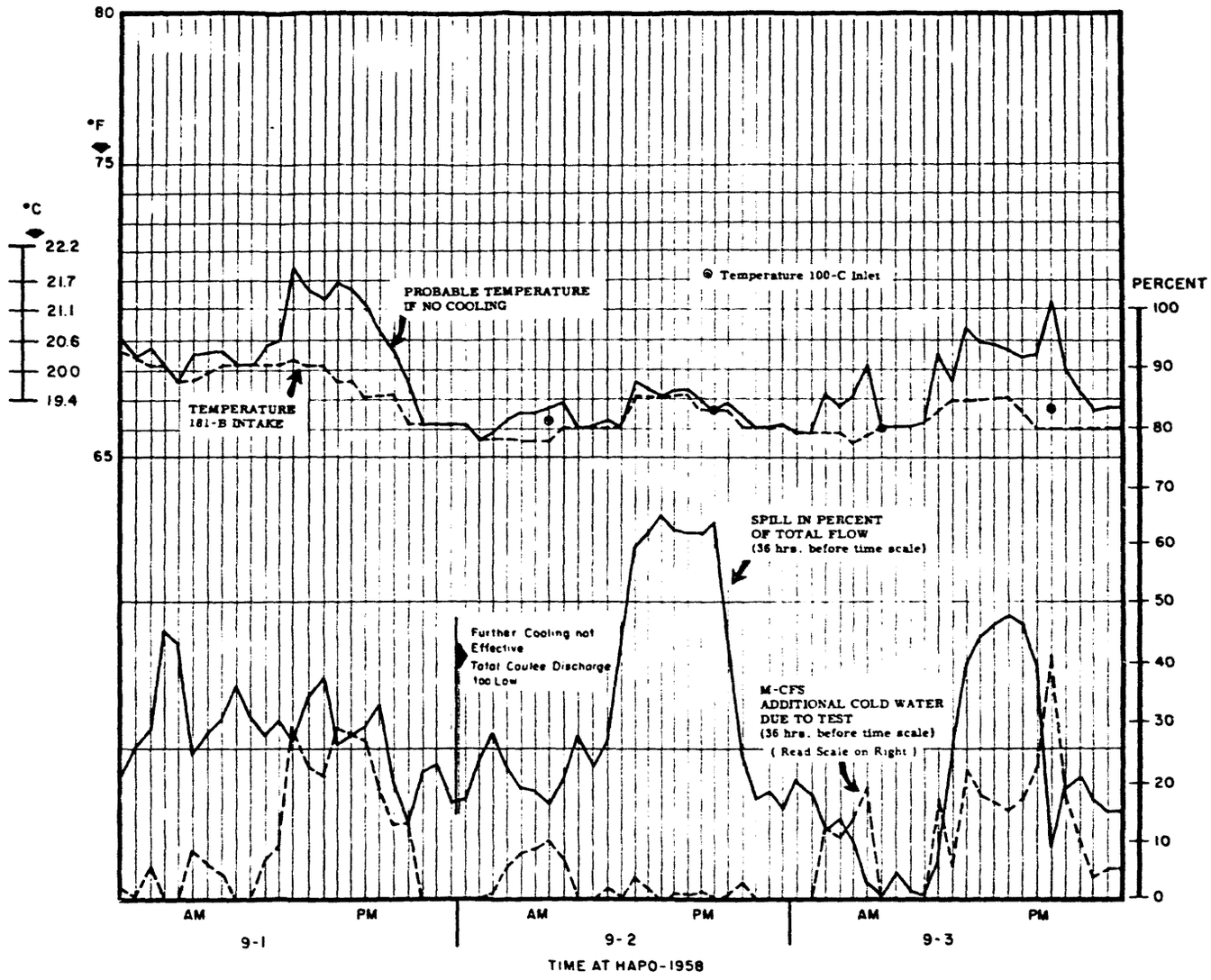
INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 22



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

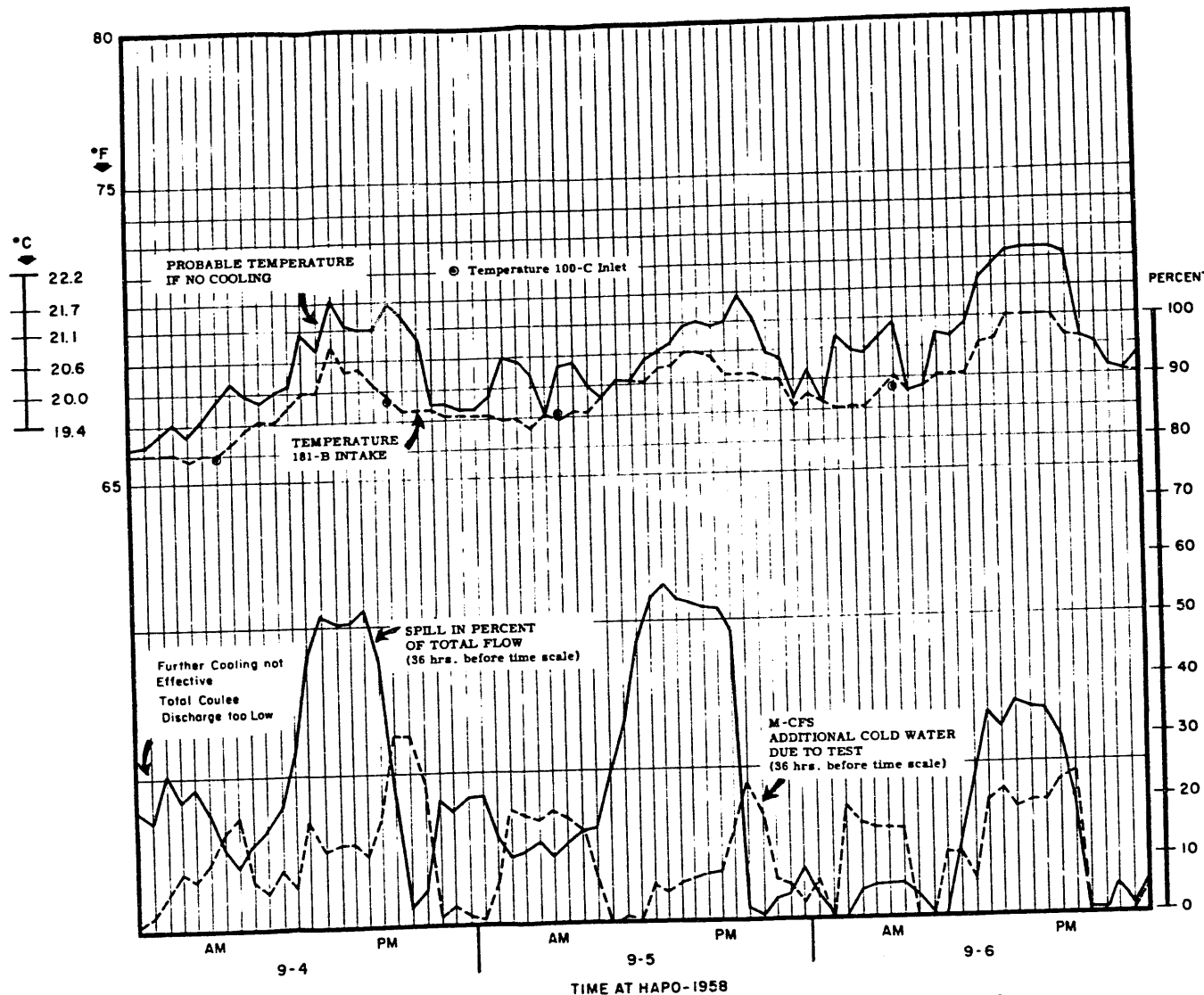
PLATE NO. 23



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 24

UNCLASSIFIED

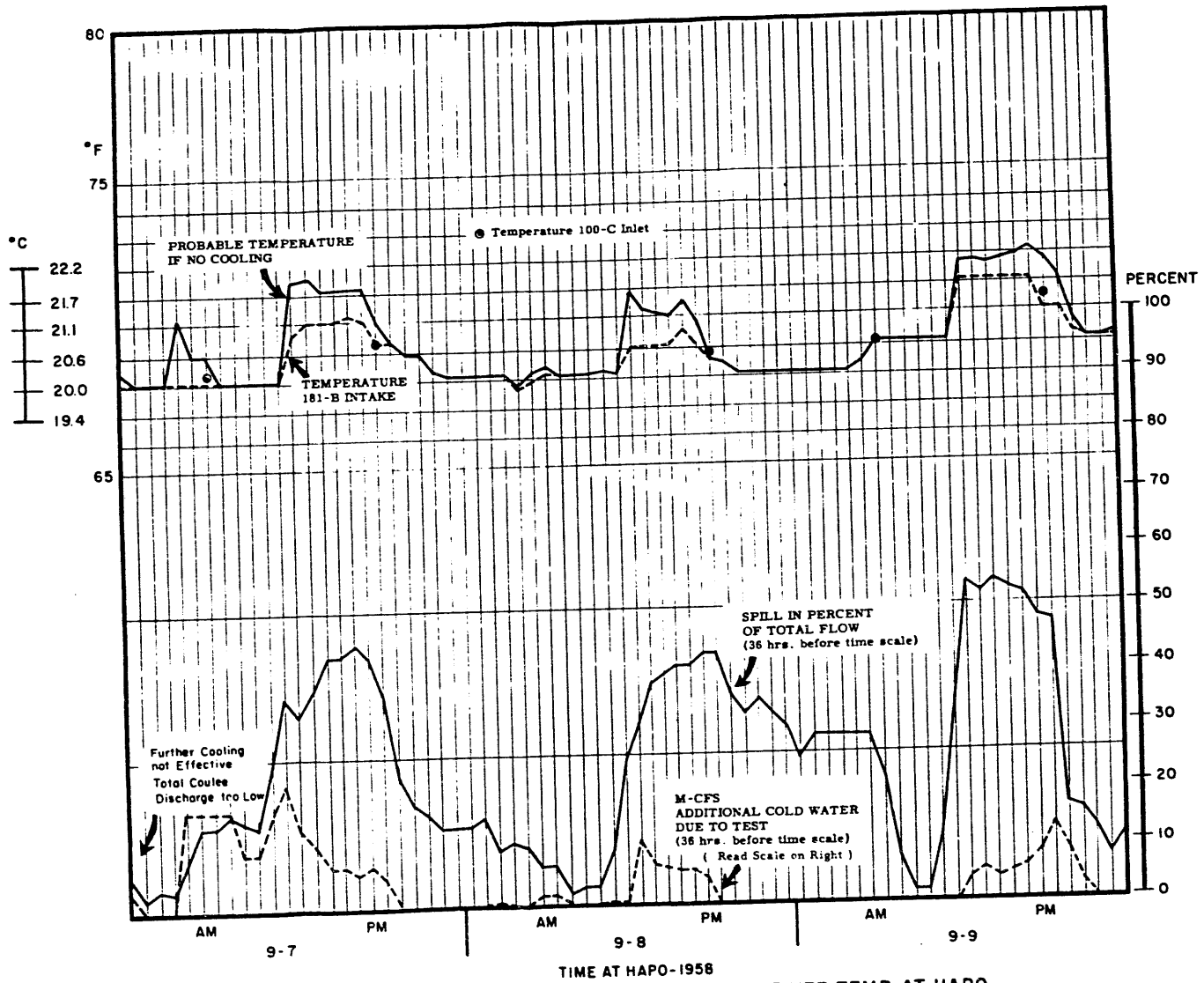


INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 25

UNCLASSIFIED

UNCLASSIFIED



INFLUENCE OF COLDER WATER FROM GRAND COULEE ON RIVER TEMP. AT HAPO

PLATE NO. 26

UNCLASSIFIED

AEC-GE RICHLAND WASH

DATE
FILMED
9/26/94

END