

PRELIMINARY ASSESSMENT OF EXTENT OF
THERMAL POLLUTION IN THE
OHIO RIVER BASIN

(measured in terms of once through
cooling water needs and cost of pro-
viding cooling towers)

UNITED STATES
DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO BASIN REGION
OHIO RIVER BASIN PROJECT
CINCINNATI

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ENVIRONMENTAL PROTECTION AGENCY

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OHIO RIVER BASIN

676019-34

INTRODUCTION

This preliminary assesement of potential thermal pollution in the Ohio River Basin was undertaken at the request of Mr. Victor F. Jelen, Deputy Project Director, Ohio River Basin Comprehensive Project. This is an attempt to measure the potential thermal pollution in terms of once through cooling water needs and in costs necessary to provide cooling towers at existing power plants.

This work document was prepared to present a set of technical knowledge expeditiously to interested parties. More work will be carried on in this area to expand this knowledge and to correlate and compare this knowledge with other information available. It is felt that while this other work is preceeding, the information gained to date should be in a form for utilization.

More detailed evaluations will be necessary to refine this study for other than preliminary planning purposes. This listing represents a compilation of known existing data. If more detailed and complete information is available, will the reader please transmit it to the Ohio River Basin Comprehensive Project Headquarters.

SUMMARY

This study is intended to point out preliminary water needs for once through cooling at thermal power plants in the Ohio River Basin. In addition, an approximate cost to install cooling towers at each plant is provided. This report only has value for broad planning purposes. More detailed evaluations would be necessary for any specific plant.

Values of flow and cooling tower costs are provided for peak and average power conditions. The peak power conditions should be used to evaluate stream flow needs at a site. All flow values in this report are based on an increase of 10° F in the effluent water from a power plant over the influent water.

In many cases the cooling tower costs for the large power plants have been calculated in Mathur's Report.^{1/} The calculated values from this current computer analysis of cost for peak power use should in all instances be greater than or equal to the values included in Mathur's Report. An explanation of the differences in these values is given in the Results section. An indication of actual cooling tower costs at plants having them are not included because this information was not available.

A listing of the results of the study is contained in the report section Results. A brief summarization of these results is given here.

No.	River Basin Name	Calculated Values for Peak Power Use		Mathur Report
		Gross Flow (cfs)	Cooling Tower Costs (\$1000)	Cooling Tower Costs (\$1000)
1	Allegheny	5,101	15,567	8,230
2	Monongahela	4,178	12,750	9,550
3	Beaver	1,891	5,773	2,840
4	Muskingham	5,227	15,953	9,030

SUMMARY (cont'd)

No.	River Basin Name	Calculated Values for Peak Power Use		Mathur Report
		Gross Flow (cfs)	Cooling Tower Costs (\$1000)	Cooling Tower Costs (\$1000)
5	Kanawha-Little Kanawha	2,986	9,113	4,250
6	Guyandot-Big & Little Sandy	480	1,465	1,340
7	Scioto	1,227	3,746	0
8	Great & Little Miami	3,127	9,543	4,150
9	Licking-Kentucky-1, Salt	498	4,573	0
10	Green	3,180	9,707	5,320
11	Wabash	7,437	22,699	9,670
12	Cumberland	2,168	6,616	2,790
13	Ohio Main Stem	33,744	102,988	56,460

RESULTS

Utilization of Results

The results do not include any of the actual dollar expenditures made in providing cooling towers in the basin. Neither do they include actual flows for once through cooling for any of these plants. They do indicate the current type of cooling practiced at each plant. 2/ This in itself gives an indication of the needs required to combat thermal loadings to the streams in the Ohio River Basin.

Two sets of thermal loading values are given. The first at 100 percent plant capacity to determine the costs required for cooling towers and/or the maximum needs for stream flow at the power plants. The second set is at average plant utilization of 65% capacity. This is provided in case flow augmentation storage at this average annual level of development is desired. However, before this 65% set of values would be used for such an analysis more detailed calculations would be necessary. Seasonal variations in water temperature and wet bulb temperature should significantly reduce total cooling flow needs in the cooler seasons except perhaps where changing maximum temperature constraints exist.

The reason a discrepancy exists for calculated once through cooling flow needs and alternatively cooling tower costs for individual power plants between Mathur's Report and this computer printout (given and calculated values respectively) is that Mathur's calculations were based on actual 1965 power generation (Kilowatt hrs of plant output) while this printout was derived from 100% and 65% utilization of the power plant capacity during the summer season.

The location of each plant in this study is provided in the map at the

end of this report from Exhibit #5, Ohio River Basin Comprehensive Survey Appendix I "Electric Power" prepared by the Federal Power Commission. 3/

Explanation of table headings in the following printout material;

(see also Definitions for more detail):

RB - river basin number (see Summary and/or Type I Ohio River Basin Comprehensive Survey Vol V Appendix D for details).

Plant name - power plant name or location.

Map - map number from Exhibit #5.

ONR - power plant owner

Capacity megawatts - power plant capacity

Given - values as per Mathur's Report

Calculated - values as per this computer analysis

Water need and flow need - synonymous terms, water requirement for once through cooling for thermal power plant.

Cost - cost required to install cooling towers.

HRF - heat rate factor for plant

Type plant - type of cooling used.

Report values - from Mathur's Report

Calculated values - from this computer analysis.

Discussion of Discrepancies in Results:

As indicated the water use values in thousands of gallons per minute for 100% utilization of the Power Plants should be greater than those reported in Mathur's Report because the plants are assumed to be operating at peak capacity rather than some lower average value, and the remainder of the analysis is the same. The major point of difference lies in the fact that the data used for 100% plant utilization was obtained in 1963 while that of

Mathur's work was 1965 data.

The three plants that follow had higher water use values than the 100% utilization values.

Plant Name	State	Location River Basin
Elmira	Pa.	Monongahela
Albright	Pa.	Monongahela
Tanners Creek	Ind.	Ohio Main Stem

It may be that the capacities of these plants has increased since 1963.

FIRST SET OF

TABLES

100% PLANT

UTILIZATION

COST AND WATER NEED THERMAL POWER PLANTS ORB - 100% PLANT ~~UTILIZATION~~ UTILIZATION

RB PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	WTR NEED THSD GPM	COST THSD DOLLARS	FLOW CFS	FLOW THSD GPM	COST THSD DOLLARS	HRF	TYPE PLANT
*****GIVEN***** *****CALCULATED*****										
1 JAYESTOWN	T0001	M	57.50	0.	0.	169.	76.	514.	12130.	OT
1 WARREN	T0002	P	73.40	80.	630.	242.	109.	739.	12130.	OT
1 OIL CITY	T0003	P	16.00	0.	0.	47.	21.	143.	12130.	OT
1 ARMSTRONG	T0004	P	326.40	290.	2170.	696.	312.	2123.	9949.	OT
1 SEWARD	T0005	P	295.30	160.	1230.	712.	320.	2173.	10714.	OT
1 JOHNSTOWN	T0006	I	74.50	0.	0.	218.	98.	666.	12130.	OT
1 TARENTUM	T0007	M	6.20	0.	0.	18.	8.	55.	12130.	NA
1 SPRINGDALE	T0008	P	416.10	280.	2090.	1220.	548.	3725.	12136.	OT
1 COLFAX	T0009	P	262.50	280.	2110.	1764.	792.	5383.	22462.	OT
1 STANWIX	T0010	P	5.00	0.	0.	15.	7.	45.	12130.	NC
REPORT VALUES				8230.					1090.	
CALCULATED VALUES				19567.		5101.			2289.	
*****GIVEN***** *****CALCULATED*****										
2 HOMESTEAD	T0011	I	67.30	0.	0.	197.	89.	602.	12130.	
2 EAST PITTSBURGH	T0012	I	43.10	0.	0.	126.	57.	386.	12130.	
2 DUQUESNE	T0013	I	15.00	0.	0.	44.	20.	134.	12130.	
2 THOMSON	T0014	I	65.00	0.	0.	190.	86.	581.	12130.	
2 CLAIRTON	T0015	I	44.00	0.	0.	129.	58.	394.	12130.	
2 ELRAVA	T0016	P	425.00	450.	3390.	994.	446.	3033.	10513.	OT
2 MITCHELL	T0017	P	448.70	350.	2610.	1016.	456.	3100.	10310.	OT
2 MONESSEN PLANT	T0018	I	6.00	0.	0.	18.	8.	54.	12130.	
2 CONNELLSVILLE	T0019	P	54.20	0.	0.	159.	71.	485.	12130.	OT
2 RIVESVILLE	T0020	P	174.80	170.	1290.	567.	255.	1731.	12985.	OT
2 CASCADE	T0021	I	8.50	0.	0.	25.	11.	76.	12130.	
2 ALBRIGHT	T0022	P	194.00	300.	2260.	511.	229.	1559.	11318.	OT
2 *****	00000	P	69.00	0.	0.	202.	91.	617.	12130.	OT
REPORT VALUES				9550.					1270.	
CALCULATED VALUES				12750.		4178.			1875.	
*****GIVEN***** *****CALCULATED*****										
3 GROVE CITY	T0023	M	7.70	0.	0.	23.	10.	69.	12130.	
3 ELLWOOD	T0024	I	6.60	0.	0.	19.	9.	59.	12130.	
3 STEEL DIV	T0025	I	7.50	0.	0.	22.	10.	67.	12130.	
3 NEW CASTLE	T0026	P	293.00	260.	1930.	699.	314.	2134.	10644.	OT
3 WARREN	T0027	I	7.40	0.	0.	22.	10.	66.	12130.	
3 MAHONINGSIDE	T0028	P	87.40	0.	0.	256.	115.	782.	12130.	OT
3 NILES	T0029	P	250.00	120.	910.	536.	240.	1634.	9979.	OT
3 YOUNGSTOWN	T0030	I	45.00	0.	0.	132.	59.	403.	12130.	
3 BRIER HILL	T0031	I	9.00	0.	0.	26.	12.	81.	12130.	
3 CAMPBELL	T0032	I	53.50	0.	0.	157.	70.	479.	12130.	
REPORT VALUES				2840.					380.	
CALCULATED VALUES				5773.		1891.			849.	
*****GIVEN***** *****CALCULATED*****										
REPORT VALUES				2840.					380.	
CALCULATED VALUES				5773.		1891.			849.	

RB PLANT NAME	WAP	ONR	CAPACITY MEGAWATT	*****GIVEN***** *****CALCULATED*****					TYPE PLANT
				WTR NEED THSD GPM	COST THSD DOLLARS	FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	
4 BARBERTON	T0060	I	87.00	0.	0.	222.	100.	678.	11100.
4 MASSILLON WORKS	T0061	I	10.00	0.	0.	26.	11.	78.	11100.
4 CANTON WORKS	T0062	I	13.50	0.	0.	34.	15.	105.	11100.
4 RITTMAN	T0063	I	14.00	0.	0.	36.	16.	109.	11100.
4 ORVILLE	T0064	M	38.50	0.	0.	98.	44.	300.	11100.
4 COVER	T0065	M	15.00	0.	0.	38.	17.	117.	11100.
4 CONESVILLE	T0066	P	433.50	310.	2270.	972.	436.	2968.	10254.
4 PHILC	T0067	P	500.00	210.	1550.	1376.	617.	4198.	11640.
4 MUSKINGUM RIVER	T0068	P	876.00	570.	4130.	1713.	769.	5229.	9471.
4 POSTON	T0069	P	232.00	150.	1080.	711.	319.	2171.	12500.
REPORT VALUES				9030.					
CALCULATED VALUES				15953.		5227.		FLOW THSD GPM	1240.
						FLOW CFS		FLOW THSD GPM	2346.
5 NITRO	T0070	I	17.50	0.	0.	40.	18.	121.	10300.
5 INSTITUTE	T0071	I	10.00	0.	0.	23.	10.	69.	10300.
5 BELLE	T0072	I	7.50	0.	0.	17.	8.	52.	10300.
5 CHARLESTON	T0073	I	40.00	0.	0.	90.	41.	276.	10300.
5 CHARLESTON	T0074	I	28.50	0.	0.	64.	29.	197.	10300.
5 CRAIN CREEK	T0075	P	273.50	60.	430.	785.	352.	2396.	11965.
5 KANAWHA RIVER	T0076	P	426.00	310.	2250.	780.	350.	2381.	9132.
5 ALCOY WORKS	T0077	I	123.00	0.	0.	278.	125.	848.	10300.
5 RAINELLE	T0078	I	6.60	0.	0.	15.	7.	46.	10300.
5 GLEN LYN	T0079	P	401.10	220.	1570.	799.	359.	2438.	9569.
5 CELCO	T0080	I	18.00	0.	0.	41.	18.	124.	10300.
5 RADFORD ARSENAL	T0081	F	24.00	0.	0.	54.	24.	166.	10300.
REPORT VALUES				4250.				FLOW THSD GPM	590.
CALCULATED VALUES				9113.		2986.		FLOW THSD GPM	1340.
6 BIG SANDY	T0082	P	265.00	200.	1340.	468.	210.	1429.	8954.
6 ASHLAND	T0083	I	5.00	0.	0.	12.	5.	36.	10600.
REPORT VALUES				1340.				FLOW THSD GPM	200.
CALCULATED VALUES				1465.		480.		FLOW THSD GPM	215.
7 SCIOTO	T0084	P	40.30	0.	0.	103.	46.	314.	11100.
7 COLUMBUS	T0085	M	45.50	0.	0.	116.	52.	355.	11100.
7 COLUMBUS	T0086	M	5.50	0.	0.	14.	6.	43.	11100.
7 WALNUT	T0087	P	75.00	0.	0.	191.	86.	584.	11100.
7 PICWAY	T0088	P	230.80	0.	0.	589.	264.	1798.	11100.
7 COLUMBUS	T0089	P	14.00	0.	0.	36.	16.	109.	11100.
7 CHILLOCOTHE	T0090	I	48.10	0.	0.	123.	55.	375.	11100.
7 PORTSMOUTH	T0091	I	21.50	0.	0.	55.	25.	168.	11100.
REPORT VALUES				0.				FLOW THSD GPM	0.
CALCULATED VALUES				3746.		1227.		FLOW THSD GPM	551.

RB PLANT NAME	VAP	CAPACITY MEGAWATT	WTR NEED THSD GPM	*****GIVEN*****				*****CALCULATED*****				HRF	TYPE PLANT
				COST THSD DOLLARS	FLOW CFS	FLOW THSD GPM	COST THSD DOLLARS	FLOW CFS	FLOW THSD GPM	COST THSD DOLLARS	FLOW THSD GPM		
8 BELLEFONTAINE	T0092 M	6.00	0.	0.	15.	7.	47.	15.	7.	11100.	5 CT		
8 PIQUA	T0093 M	53.00	0.	0.	135.	61.	413.	135.	61.	11100.	CT		
8 TROY	T0094 M	15.00	0.	0.	38.	17.	117.	38.	17.	11100.	CT		
8 ROCKAWAY	T0095 P	13.00	0.	0.	33.	15.	101.	33.	15.	11100.	CT		
8 MAD RIVER	T0096 P	75.00	30.	210.	263.	118.	803.	263.	118.	13706.	CT		
8 TAIT FM	T0097 P	44.10	300.	2240.	998.	448.	3045.	998.	448.	10263.	CT		
8 DAYTON	T0098 I	16.40	0.	0.	42.	19.	128.	42.	19.	11100.	CT		
8 DAYTON	T0099 I	9.10	0.	0.	23.	10.	71.	23.	10.	11100.	CT		
8 MIAMI	T0100 M	6.40	0.	0.	16.	7.	50.	16.	7.	11100.	CT		
8 HUTCHINGS O.H.	T0101 P	414.00	250.	1700.	955.	429.	2916.	955.	429.	10431.	CT		
8 MIDDLETOWN	T0102 I	17.50	0.	0.	45.	20.	136.	45.	20.	11100.	CT		
8 MIDDLETOWN	T0103 I	15.30	0.	0.	39.	18.	119.	39.	18.	11100.	CT		
8 LERANON	T0104 M	8.70	0.	0.	22.	10.	68.	22.	10.	11100.	CT		
8 MILLS CARTON	T0105 I	6.00	0.	0.	15.	7.	47.	15.	7.	11100.	CT		
8 HAMILTON	T0106 M	70.30	0.	0.	179.	81.	548.	179.	81.	11100.	CT		
8 HAMILTON	T0108 M	24.50	0.	0.	63.	28.	191.	63.	28.	11100.	CT		
8 READING	T0109 M	11.50	0.	0.	29.	13.	90.	29.	13.	11100.	CT		
8 LOCKLAND	T0110 I	7.50	0.	0.	19.	9.	58.	19.	9.	11100.	CT		
8 IVORYDALE	T0111 I	6.50	0.	0.	17.	7.	51.	17.	7.	11100.	CT		
8 WHITE WATER	T0112 M	30.00	0.	0.	77.	34.	234.	77.	34.	11100.	CT		
8 PICHVOND	T0113 M	40.00	0.	0.	102.	46.	312.	102.	46.	11100.	5 CT		
REPORT VALUES CALCULATED VALUES			4150. 9543.		3127.			3127.		580. 1403.			
9 PARIS	T0119 M	5.60	0.	0.	13.	6.	41.	13.	6.	10600.	CT		
9 DALE W.C.	T0120 C	196.00	0.	0.	464.	208.	1418.	464.	208.	10600.	CT		
9 BROWN F.W.	T0121 P	293.20	0.	0.	695.	312.	2121.	695.	312.	10600.	CT		
9 TYRONE	T0122 P	137.50	0.	0.	326.	146.	994.	326.	146.	10600.	CT		
REPORT VALUES CALCULATED VALUES			0. 4573.		1498.			1498.		0. 673.			
10 PARADISE	T0174 F	1408.00	700.	4510.	2487.	1116.	7592.	2487.	1116.	8955.	ST		
10 GREEN RIVER	T0175 P	263.60	120.	810.	668.	300.	2039.	668.	300.	11049.	CT		
10 HENDERSON	T0176 I	10.50	0.	0.	25.	11.	76.	25.	11.	10600.	CT		
REPORT VALUES CALCULATED VALUES			5320. 9707.		3180.			3180.		820. 1427.			

RE PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	WTR NEED THSD GPM	COST THSD DOLLARS	FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	HRF	TYPE PLANT
*****GIVEN***** *****CALCULATED*****										
11 ANDERSON	T0123	M	19.00	0.	0.	48.	21.	146.	11000.	CT
11 NORLESVILLE	T0124	P	100.00	0.	0.	252.	113.	768.	11000.	CT
11 PERRY W.	T0124	P	10.00	0.	0.	25.	11.	77.	11000.	CT
11 PERRY K.	T0126	P	47.50	0.	0.	120.	54.	365.	11000.	S
11 STOUT FLMER	T0127	P	381.10	180.	1250.	847.	380.	2585.	10198.	CT
11 ALLISON	T0128	I	6.80	0.	0.	17.	8.	52.	11000.	CT
11 PRITCHARD H.T.	T0129	P	393.60	200.	1350.	946.	425.	2889.	10695.	CT
11 EDWARDSPT	T0130	P	159.00	100.	670.	525.	236.	1604.	13149.	CT
11 WASHINGTON	T0131	M	18.00	0.	0.	45.	20.	138.	11000.	CT
11 JASPER	T0132	M	9.50	0.	0.	24.	11.	73.	11000.	S
11 RUSHVILLE	T0133	M	8.30	0.	0.	21.	9.	64.	11000.	CT
11 ST. MARYS	T0134	M	12.00	0.	0.	30.	14.	92.	11000.	CT
11 CELINA	T0135	M	12.50	0.	0.	31.	14.	96.	11000.	CT
11 PORTLAND	T0136	P	10.00	0.	0.	25.	11.	77.	11000.	NA
11 ALUFFTON	T0137	M	7.00	0.	0.	18.	8.	54.	11000.	CT
11 PERU	T0138	M	40.00	0.	0.	101.	45.	307.	11000.	CT
11 LOGANSPT	T0139	M	30.00	0.	0.	75.	34.	230.	11000.	CT
11 FRANKFRT	T0140	M	36.00	0.	0.	91.	41.	276.	11000.	CT
11 CRAWFORDSVILLE	T0141	M	27.50	0.	0.	69.	31.	211.	11000.	CT
11 RANOCUL	T0142	M	8.00	0.	0.	20.	9.	61.	11000.	CT
11 VERMILION	T0143	P	182.30	120.	820.	425.	191.	1297.	10495.	CT
11 DANVILLE	T0144	P	7.50	0.	0.	19.	8.	58.	11000.	CT
11 DRESSER	T0145	P	210.00	70.	520.	811.	364.	2474.	14666.	CT
11 WABASH RIVER	T0146	P	575.00	340.	2330.	1295.	581.	3951.	10277.	CT
11 TERRE HAUTE	T0147	I	6.00	0.	0.	15.	7.	46.	11000.	CT
11 MARSHALL	T0148	M	5.60	0.	0.	14.	6.	43.	11000.	CT
11 HUTSONVILLE	T0149	P	212.50	130.	840.	491.	221.	1500.	10444.	CT
11 BREED	T0150	P	450.00	280.	1890.	791.	355.	2415.	8932.	CT
11 ROTHISON	T0151	I	12.00	0.	0.	30.	14.	92.	11000.	CT
11 UNIVERSITY OF ILL.	T0152	S	30.00	0.	0.	75.	34.	230.	11000.	CT
11 TUSCOLA	T0153	I	12.50	0.	0.	31.	14.	96.	11000.	CT
11 MTCARMEL	T0154	P	20.50	0.	0.	52.	23.	157.	11000.	CT
11 FAIRFIELD	T0155	M	12.50	0.	0.	31.	14.	96.	11000.	CT
11 CARVI	T0156	M	10.20	0.	0.	26.	12.	78.	11000.	CT
REPORT VALUES										
CALCULATED VALUES										
						7437.	FLOW THSD GPM	1420.		
							FLOW THSD GPM	3318.		
12 PINEVILLE	T0177	P	67.50	0.	0.	145.	65.	443.	10000.	CT
12 GALLATIN	T0178	F	1050.00	440.	2790.	1959.	879.	5980.	9226.	CT
12 OLD WICKORY	T0179	I	29.50	0.	0.	63.	28.	194.	10000.	CT
REPORT VALUES										
CALCULATED VALUES										
							FLOW THSD GPM	440.		
							FLOW THSD GPM	973.		

RB PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	WTR NEED THSD GPM	*****GIVEN*****				*****CALCULATED*****				TYPE PLANT
					COST THSD DOLLARS	FLOW CFS	THSD GPM	COST THSD DOLLARS	HRF	COST THSD DOLLARS	THSD GPM	THSD GPM	
13 PITTSBURGH	T0033	I	70.00	0.	0.	189.	85.	577.	11500.				
13 PITTSBURGH	T0034	I	6.00	0.	0.	16.	7.	49.	11500.				
13 NEVILLE	T0035	I	10.00	0.	0.	27.	12.	82.	11500.				
13 REFO	T0036	P	180.00	160.	1170.	849.	381.	2590.	16997.	CT			
13 ALICUIPPA WORKS	T0037	I	57.00	0.	0.	154.	69.	470.	11500.				
13 JOSEPH TOWN	T0038	I	100.00	0.	0.	270.	121.	824.	11500.				
13 PHILLIPS	T0039	P	315.00	380.	2850.	879.	395.	2684.	11751.	CT			
13 SHIPPINGPORT	T0040	P	100.00	0.	0.	270.	121.	824.	11500.	CT			
13 MIDLAND WORKS	T0041	I	24.00	0.	0.	65.	29.	198.	11500.				
13 FAST PALISTINE	T0042	M	9.00	0.	0.	24.	11.	74.	11500.	S			
13 SAMMIS	T0043	P	740.00	550.	4070.	1405.	630.	4287.	9314.	CT			
13 TORONTO	T0044	P	315.80	100.	780.	1073.	482.	3274.	13402.	CT			
13 WEIRTON	T0045	I	108.30	0.	0.	292.	131.	892.	11500.				
13 SOUTH WORKS	T0046	I	11.00	0.	0.	30.	13.	91.	11500.				
13 TIDD	T0047	P	222.20	170.	1290.	602.	270.	1839.	11532.	CT			
13 WINDSOR	T0048	P	300.00	170.	1290.	1046.	469.	3192.	13645.	CT			
13 MARTINS FERRY	T0049	M	6.50	0.	0.	18.	8.	54.	11500.	NA			
13 RUGER	T0050	P	544.00	300.	2240.	1179.	529.	3599.	10049.	CT			
13 KAMMER	T0051	I	540.00	180.	1330.	1058.	475.	3229.	9480.	CT			
13 MARTINSVILLE	T0052	I	54.00	0.	0.	146.	65.	445.	11500.				
13 WILLOW ISLAND	T0053	P	215.00	190.	1870.	499.	224.	1522.	10461.	CT			
13 MARIETTA	T0054	I	160.00	0.	0.	432.	194.	1318.	11500.				
13 PARKERSBURG	T0055	I	30.80	0.	0.	83.	37.	254.	11500.				
13 PARKERSBURG	T0056	P	10.00	0.	0.	27.	12.	82.	11500.	CT			
13 KYGER CREEK	T0057	P	1086.30	690.	4850.	2119.	951.	6469.	9458.	CT			
13 SPORN	T0058	P	1060.00	0.	0.	2862.	1284.	8734.	11500.	CT			
13 RECKFORD POINT	T0059	I	15.00	0.	0.	40.	18.	124.	11500.				
13 RECKFORD W.C.	T0114	P	760.50	460.	3160.	1511.	678.	4613.	9557.	CT			
13 WEST END	T0115	P	224.50	110.	760.	845.	379.	2578.	14408.	CT			
13 MIAMI FORT	T0116	P	539.20	220.	1510.	1298.	582.	3960.	10700.	CT			
13 TANNERS CREEK	T0117	P	518.00	590.	3930.	914.	410.	2791.	8951.	CT			
13 CLIFTY CREEK	T0118	P	1304.00	960.	6360.	2448.	1099.	7472.	9257.				
13 CHARLESTOWN	T0157	I	55.00	0.	0.	138.	62.	422.	11000.				
13 SPEED	T0158	I	6.50	0.	0.	16.	7.	50.	11000.				
13 GALLAGHER	T0159	P	660.00	430.	2940.	1427.	641.	4356.	10035.	CT			
13 WATERIDE	T0160	P	45.00	0.	0.	113.	51.	346.	11000.	CT			
13 CANAL	T0161	P	50.00	0.	0.	126.	56.	384.	11000.	CT			
13 PADDY S RUN	T0162	P	337.50	100.	650.	1091.	490.	3329.	12951.	CT			
13 CANE RUN	T0163	P	535.30	350.	2320.	1151.	517.	3514.	10003.	CT			
13 KOSMOSDALE	T0164	I	9.50	0.	0.	24.	11.	73.	11000.				
13 ONE'SBRC	T0165	M	52.50	0.	0.	132.	59.	403.	11000.	CT			
13 HUNTINGBURG	T0166	M	6.80	0.	0.	17.	8.	52.	11000.	CT			
13 CULLEY	T0167	P	50.00	30.	220.	125.	56.	383.	10977.	CT			
13 WARRICK	T0168	I	125.00	0.	0.	315.	141.	960.	11000.				
13 NORTHEAST G.T.	T0169	P	10.70	0.	0.	27.	12.	82.	11000.				
13 OHIO RIVER	T0170	P	121.50	70.	440.	439.	197.	1339.	13986.	CT			
13 HENDERSON	T0171	M	21.50	0.	0.	54.	24.	165.	11000.	CT			
13 JORPPA	T0172	P	1100.30	860.	5530.	2244.	1007.	6849.	9699.	CT			
13 SHAWNEE	T0173	F	1500.00	1080.	6900.	3026.	1358.	9236.	9639.	CT			
13 *****	00000	P	225.00	0.	0.	607.	273.	1854.	11500.				
REPORT VALUES					54460.		33744.		8150.		FLOW THSD GPM		
CALCULATED VALUES					102988.				15145.		FLOW THSD GPM		

SECOND SET OF

TABLES

65% PLANT

UTILIZATION

COST AND WATER NEED THERMAL POWER PLANTS ORB - 65% PLANT ~~UTILIZATION~~ UTILIZATION

RB PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	*****GIVEN***** WTR NEED THSD GPM	COST THSD DOLLARS	*****CALCULATED***** FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	HRF	PLANT TYPE
1 JAMESTOWN	T0001	M	57.50	0.	0.	110.	49.	334.	12130.	OT
1 WARREN	T0002	P	73.40	80.	630.	157.	71.	480.	13131.	OT
1 OIL CITY	T0003	P	16.00	0.	0.	30.	14.	93.	12130.	OT
1 ARMSTRONG	T0004	P	326.40	290.	2170.	452.	203.	1380.	9949.	OT
1 SEWARD	T0005	P	295.30	160.	1230.	463.	208.	1413.	10714.	OT
1 JOHNSTOWN	T0006	I	74.50	0.	0.	142.	64.	433.	12130.	OT
1 TARENTUM	T0007	M	6.20	0.	0.	12.	5.	36.	12130.	NA
1 SPRINGDALE	T0008	P	416.10	280.	2090.	793.	356.	2421.	12136.	OT
1 COLFAX	T0009	P	262.50	280.	2110.	1146.	515.	3499.	22462.	OT
1 STANWIX	T0010	P	5.00	0.	0.	10.	4.	29.	12130.	NC
REPORT VALUES				8230.						
CALCULATED VALUES				10119.		3315.		FLOW THSD GPM	1090.	
								FLOW THSD GPM	1488.	
2 HOMESTEAD	T0011	I	67.30	0.	0.	128.	58.	391.	12130.	
2 EAST PITTSBURGH	T0012	I	43.10	0.	0.	82.	37.	251.	12130.	
2 DUQUESNE	T0013	I	15.00	0.	0.	29.	13.	87.	12130.	
2 THOMSON	T0014	I	65.00	0.	0.	124.	56.	378.	12130.	
2 CLAIRTON	T0015	I	44.00	0.	0.	84.	38.	256.	12130.	
2 ELRAMA	T0016	P	425.00	450.	3390.	646.	290.	1971.	10513.	OT
2 MITCHELL	T0017	P	448.70	350.	2610.	660.	296.	2015.	10310.	OT
2 MONESSAN PLANT	T0018	I	6.00	0.	0.	11.	5.	35.	12130.	
2 CONNELLSVILLE	T0019	P	54.20	0.	0.	103.	46.	315.	12130.	OT
2 RIVESVILLE	T0020	P	174.80	170.	1290.	369.	165.	1125.	12985.	OT
2 CASCADE	T0021	I	8.50	0.	0.	16.	7.	49.	12130.	
2 ALBRIGHT	T0022	P	194.00	300.	2260.	332.	149.	1013.	11318.	OT
2 *****	00000	P	69.00	0.	0.	131.	59.	401.	12130.	OT
REPORT VALUES				9550.						
CALCULATED VALUES				8288.		2715.		FLOW THSD GPM	1270.	
								FLOW THSD GPM	1219.	
3 GROVE CITY	T0023	M	7.70	0.	0.	15.	7.	45.	12130.	
3 ELLWOOD	T0024	I	6.60	0.	0.	13.	6.	38.	12130.	
3 STEEL DIV	T0025	I	7.50	0.	0.	14.	6.	44.	12130.	
3 NEW CASTLE	T0026	P	293.00	260.	1930.	454.	204.	1387.	10644.	OT
3 WARREN	T0027	I	7.40	0.	0.	14.	6.	43.	12130.	
3 MAHONINGSIDE	T0028	P	87.40	0.	0.	166.	75.	508.	12130.	OT
3 NILES	T0029	P	250.00	120.	910.	348.	156.	1062.	9979.	OT
3 YOUNGSTOWN	T0030	I	45.00	0.	0.	86.	38.	262.	12130.	
3 BRIER HILL	T0031	I	9.00	0.	0.	17.	8.	52.	12130.	
3 CAMPBELL	T0032	I	53.50	0.	0.	102.	46.	311.	12130.	
REPORT VALUES				2840.				FLOW THSD GPM	380.	
CALCULATED VALUES				3752.		1229.		FLOW THSD GPM	552.	

RB PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	*****GIVEN***** CALCULATED*****					TYPE PLANT
				WTR NEED THSD GPM	COST THSD DOLLARS	FLOW NEED CFS	COST THSD DOLLARS	HRF	
4 RARBERTON	T0060	I	87.00	0.	0.	144.	65.	441.	11100.
4 MASSILLON WORKS	T0061	I	10.00	0.	0.	17.	7.	51.	11100.
4 CANTON WORKS	T0062	I	13.50	0.	0.	22.	10.	68.	11100.
4 RITTMAN	T0063	I	14.00	0.	0.	23.	10.	71.	11100.
4 CRRVILLE	T0064	M	38.50	0.	0.	64.	29.	195.	11100. S
4 DOVER	T0065	M	15.00	0.	0.	25.	11.	76.	11100. OT
4 CONESVILLE	T0066	P	433.50	310.	2270.	632.	284.	1929.	10254. OT
4 PHILC	T0067	P	500.00	210.	1550.	894.	401.	2729.	11640. OT
4 MUSKINGUM RIVER	T0068	P	876.00	570.	4130.	1114.	500.	3399.	9471. OT
4 POSTON	T0069	P	232.00	150.	1080.	462.	208.	1411.	12500. CT
REPORT VALUES				9030.					
CALCULATED VALUES				10370.		3398.		FLOW THSD GPM FLOW THSD GPM	1240. 1525.
5 NITRO	T0070	I	17.50	0.	0.	26.	12.	78.	10300.
5 INSTITUTE	T0071	I	10.00	0.	0.	15.	7.	45.	10300.
5 BELLE	T0072	I	7.50	0.	0.	11.	5.	34.	10300.
5 CHARLESTON	T0073	I	40.00	0.	0.	59.	26.	179.	10300.
5 CABIN CREEK	T0074	I	28.50	0.	0.	42.	19.	128.	10300.
5 KANAWHA RIVER	T0075	P	273.50	60.	430.	510.	229.	1557.	11965. OT
5 ALLOY WORKS	T0076	P	426.00	310.	2250.	507.	228.	1548.	9132. OT
5 RAINELLE	T0077	I	123.00	0.	0.	181.	81.	551.	10300. OT
5 GLEN LYN	T0078	I	6.60	0.	0.	10.	4.	30.	10300.
5 CELCO	T0079	P	401.10	220.	1570.	519.	233.	1585.	9569. OT
5 RADFORD ARSENAL	T0080	I	18.00	0.	0.	26.	12.	81.	10300.
REPORT VALUES				4250.					
CALCULATED VALUES				5923.		1941.		FLOW THSD GPM FLOW THSD GPM	590. 871.
6 BIG SANDY	T0082	P	265.00	200.	1340.	304.	137.	929.	8954. CT
6 ASHLAND	T0083	I	5.00	0.	0.	8.	3.	24.	10600.
REPORT VALUES				1340.					
CALCULATED VALUES				952.		312.		FLOW THSD GPM FLOW THSD GPM	200. 140.
7 SCIOTO	T0084	P	40.30	0.	0.	67.	30.	204.	11100. OT
7 COLUMBUS	T0085	M	45.50	0.	0.	76.	34.	230.	11100. OT
7 COLUMBUS	T0086	M	5.50	0.	0.	9.	4.	28.	11100.
7 WALNUT	T0087	P	75.00	0.	0.	124.	56.	380.	11100. CT
7 PICKWAY	T0088	P	230.80	0.	0.	383.	172.	1169.	11100. OT
7 COLUMBUS	T0089	P	14.00	0.	0.	23.	10.	71.	11100. OT
7 CHILLOCOTHE	T0090	I	48.10	0.	0.	80.	36.	244.	11100.
7 PORTSMOUTH	T0091	I	21.50	0.	0.	36.	16.	109.	11100.
REPORT VALUES				0.				FLOW THSD GPM	0.
CALCULATED VALUES				2435.		798.		FLOW THSD GPM	358.

RB PLANT NAME	WAP	ONR	CAPACITY MEGAWATT	*****GIVEN*****				*****CALCULATED*****				TYPE PLANT
				WTR NEED THSD GPM	COST THSD DOLLARS	FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	HRF			
8 BELLEFONTAINE	T0092	M	6.00	0.	0.	10.	4.	30.	11100.	5 CT		
8 PIQUA	T0093	M	53.00	0.	0.	88.	39.	268.	11100.	OT		
8 TROY	T0094	M	15.00	0.	0.	25.	11.	76.	11100.	OT		
8 ROCKAWAY	T0095	P	13.00	0.	0.	22.	10.	66.	11100.	OT		
8 MAD RIVER	T0096	P	75.00	30.	210.	171.	77.	522.	13706.	OT		
8 TAIT FM	T0097	P	444.10	300.	2240.	648.	291.	1979.	10263.	OT		
8 DAYTON	T0098	I	16.40	0.	0.	27.	12.	83.	11100.	OT		
8 OXFORD MIAMI	T0099	I	9.10	0.	0.	15.	7.	46.	11100.	OT		
8 MIAMISBURG	T0100	M	6.40	0.	0.	11.	5.	32.	11100.	OT		
8 HUTCHINGS O.H.	T0101	P	414.00	250.	1700.	621.	279.	1895.	10431.	OT		
8 MIDDLETOWN	T0102	I	17.50	0.	0.	29.	13.	89.	11100.	OT		
8 MIDDLETOWN	T0103	I	15.30	0.	0.	25.	11.	77.	11100.	OT		
8 LEBANON	T0104	M	8.70	0.	0.	14.	6.	44.	11100.	OT		
8 MILLS CARTON	T0105	I	6.00	0.	0.	10.	4.	30.	11100.	CT		
8 HAMILTON	T0106	M	70.30	0.	0.	117.	52.	356.	11100.	CT		
8 HAMILTON	T0108	M	24.50	0.	0.	41.	18.	124.	11100.	CT		
8 READING	T0109	M	11.50	0.	0.	19.	9.	58.	11100.	CT		
8 LOCKLAND	T0110	I	7.50	0.	0.	12.	6.	38.	11100.	CT		
8 IVORYDALE	T0111	I	6.50	0.	0.	11.	5.	33.	11100.	CT		
8 WHITE WATER	T0112	M	30.00	0.	0.	50.	22.	152.	11100.	CT		
8 RICHMOND	T0113	M	40.00	0.	0.	66.	30.	203.	11100.	5 CT		
REPORT VALUES CALCULATED VALUES				4150. 6203.		2032.		FLOW THSD GPM FLOW THSD GPM	580. 912.			
9 PARIS	T0119	M	5.60	0.	0.	9.	4.	26.	10600.	CT		
9 DALE W.C.	T0120	C	196.00	0.	0.	302.	136.	921.	10600.	CT		
9 BROWN E.W.	T0121	P	293.20	0.	0.	452.	203.	1378.	10600.	CT		
9 TYRONE	T0122	P	137.50	0.	0.	212.	95.	646.	10600.	OT		
REPORT VALUES CALCULATED VALUES				0. 2973.		974.		FLOW THSD GPM FLOW THSD GPM	0. 437.			
10 PARADISE	T0174	F	1408.00	700.	4510.	1617.	726.	4935.	8955.	ST		
10 GREEN RIVER	T0175	P	263.60	120.	810.	434.	195.	1325.	11049.	OT		
10 HENDERSON	T0176	I	10.50	0.	0.	16.	7.	49.	10600.	OT		
REPORT VALUES CALCULATED VALUES				5320. 6309.		2067.		FLOW THSD GPM FLOW THSD GPM	820. 928.			

RB PLANT NAME	WAP	ONR	CAPACITY MEGAWATT	*****GIVEN*****				*****CALCULATED*****				HRF	TYPE PLANT
				WTR NEED THSD GPM	COST THSD DOLLARS	FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	FLOW THSD GPM	THSD GPM	COST THSD DOLLARS		
11 ANDERSON	T0123	M	19.00	0.	0.	31.	14.	95.			11000.	OT	OT
11 NORLESVILLE	T0124	P	100.00	0.	0.	164.	73.	499.			11000.	CT	OT
11 PERRY W.	T0124	P	10.00	0.	0.	16.	7.	50.			11000.	CT	OT
11 PERRY K.	T0126	P	47.50	0.	0.	78.	35.	237.			11000.	S	OT
11 STOUT ELMER	T0127	P	381.10	180.	1250.	551.	247.	1680.			10198.	CT	OT
11 ALLISON	T0128	I	6.80	0.	0.	11.	5.	34.			11000.	CT	OT
11 PRITCHARD H.T.	T0129	P	393.60	200.	1350.	615.	276.	1878.			10695.	CT	OT
11 EDWARDSPORT	T0130	P	159.00	100.	670.	342.	153.	1042.			13149.	OT	OT
11 WASHINGTON	T0131	M	18.00	0.	0.	29.	13.	90.			11000.	CT	CT
11 JASPER	T0132	M	9.50	0.	0.	16.	7.	47.			11000.	S	CT
11 RUSHVILLE	T0133	M	8.30	0.	0.	14.	6.	41.			11000.	CT	CT
11 ST. MARYS	T0134	M	12.00	0.	0.	20.	9.	60.			11000.	OT	OT
11 CELINA	T0135	M	12.50	0.	0.	20.	9.	62.			11000.	OT	OT
11 PORTLAND	T0136	P	10.00	0.	0.	16.	7.	50.			11000.	NA	NA
11 BLUFFTON	T0137	M	7.00	0.	0.	11.	5.	35.			11000.	OT	OT
11 PERU	T0138	M	40.00	0.	0.	65.	29.	200.			11000.	OT	OT
11 LOGANSPOET	T0139	M	30.00	0.	0.	49.	22.	150.			11000.	OT	OT
11 FRANKFORT	T0140	M	36.00	0.	0.	59.	26.	180.			11000.	OT	OT
11 CRAWFORDSVILLE	T0141	M	27.50	0.	0.	45.	20.	137.			11000.	CT	OT
11 RANROUL	T0142	M	8.00	0.	0.	13.	6.	40.			11000.	CT	CT
11 VERMILION	T0143	P	182.30	120.	820.	276.	124.	843.			10495.	CT	CT
11 DANVILLE	T0144	P	7.50	0.	0.	12.	6.	37.			11000.	OT	OT
11 PRESSER	T0145	P	210.00	70.	520.	527.	237.	1608.			14666.	OT	OT
11 WABASH RIVER	T0146	P	575.00	340.	2330.	841.	378.	2568.			10277.	OT	OT
11 TERRE HAUTE	T0147	I	6.00	0.	0.	10.	4.	30.			11000.	CT	CT
11 MARSHALL	T0148	M	5.60	0.	0.	9.	4.	28.			11000.	OT	OT
11 HUTSONVILLE	T0149	P	212.50	130.	840.	319.	143.	975.			10444.	OT	OT
11 BREED	T0150	P	450.00	280.	1890.	514.	231.	1570.			8932.	OT	OT
11 ROBINSON	T0151	I	12.00	0.	0.	20.	9.	60.			11000.	CT	CT
11 UNIVERSITY OF ILL.	T0152	S	30.00	0.	0.	49.	22.	150.			11000.	CT	CT
11 TUSCOLA	T0153	I	12.50	0.	0.	20.	9.	62.			11000.	OT	OT
11 MTCARMEL	T0154	P	20.50	0.	0.	34.	15.	102.			11000.	OT	OT
11 FAIRFIELD	T0155	M	12.50	0.	0.	20.	9.	62.			11000.	CT	CT
11 CARM	T0156	M	10.20	0.	0.	17.	7.	51.			11000.	CT	CT
REPORT VALUES CALCULATED VALUES				9670. 14755.		FLOW CFS	4834.	FLOW THSD GPM	1420. 2170.				
12 PINEVILLE	T0177	P	67.50	0.	0.	94.	42.	288.			10000.	CT	CT
12 GALLATIN	T0178	F	1050.00	440.	2790.	1274.	572.	3887.			9226.	OT	OT
12 OLD HICKORY	T0179	I	29.50	0.	0.	41.	19.	126.			10000.	CT	CT
REPORT VALUES CALCULATED VALUES				2790. 4301.		FLOW CFS	1409.	FLOW THSD GPM	440. 632.				

RB PLANT NAME	MAP	ONR	CAPACITY MEGAWATT	WTR NEED THSD GPM	*****GIVEN*****		*****CALCULATED*****		COST THSD DOLLARS	FLOW NEED CFS	THSD GPM	COST THSD DOLLARS	HRF	TYPE PLANT
13 PITTSBURGH	T0033	I	70.00	0.	0.	123.	55.	375.	11500.					
13 PITTSBURGH	T0034	I	6.00	0.	0.	11.	5.	32.	11500.					
13 NEVILLE	T0035	I	10.00	0.	0.	18.	8.	54.	11500.					
13 REED	T0036	P	180.00	160.	1170.	552.	248.	1684.	16997.					OT
13 ALIGUIPPA WORKS	T0037	I	57.00	0.	0.	100.	45.	305.	11500.					
13 JOSEPH TOWN	T0038	I	100.00	0.	0.	175.	79.	536.	11500.					
13 PHILLIPS	T0039	P	315.00	380.	2850.	572.	257.	1745.	11751.					OT
13 SHIPPINGPORT	T0040	P	100.00	0.	0.	175.	79.	536.	11500.					OT
13 MIDLAND WORKS	T0041	I	24.00	0.	0.	42.	19.	129.	11500.					
13 EAST PALISTINE	T0042	M	9.00	0.	0.	16.	7.	48.	11500.					S
13 SAMV15	T0043	P	740.00	550.	4070.	913.	410.	2787.	9314.					OT
13 TORONTO	T0044	P	315.80	100.	780.	697.	313.	2128.	13402.					OT
13 WEIRTON	T0045	I	108.30	0.	0.	190.	85.	580.	11500.					
13 SOUTH WORKS	T0046	I	11.00	0.	0.	19.	9.	59.	11500.					
13 TIDD	T0047	P	222.20	170.	1290.	392.	176.	1195.	11532.					OT
13 WINDSOR	T0048	P	300.00	170.	1290.	680.	305.	2075.	13642.					OT
13 MARTINS FERRY	T0049	M	6.50	0.	0.	11.	5.	35.	11500.					NA
13 BURGER	T0050	P	544.00	300.	2240.	767.	344.	2339.	10049.					OT
13 KAMMER	T0051	I	540.00	180.	1330.	688.	309.	2099.	9480.					OT
13 MARTINSVILLE	T0052	I	54.00	0.	0.	95.	43.	289.	11500.					
13 WILLOW ISLAND	T0053	P	215.00	190.	1870.	324.	145.	989.	10461.					OT
13 MAR1ETTA	T0054	I	160.00	0.	0.	281.	126.	857.	11500.					
13 PARKERSBURG	T0055	I	30.80	0.	0.	54.	24.	165.	11500.					
13 PARKERSBURG	T0056	P	10.00	0.	0.	18.	8.	54.	11500.					OT
13 KYGER CREEK	T0057	P	1086.30	690.	4850.	1378.	618.	4205.	9458.					OT
13 SPORN	T0058	P	1060.00	0.	0.	1860.	835.	5677.	11500.					OT
13 SOUTH POINT	T0059	I	15.00	0.	0.	26.	12.	80.	11500.					
13 BECKFORD W.C.	T0114	P	760.50	460.	3160.	982.	441.	2998.	9557.					OT
13 WEST END	T0115	P	224.30	110.	760.	549.	246.	1676.	14408.					OT
13 MIAMI FORT	T0116	P	539.20	220.	1510.	843.	379.	2574.	10700.					OT
13 TANNERS CREEK	T0117	P	518.00	590.	3930.	594.	267.	1814.	8951.					OT
13 CLIFTY CREEK	T0118	P	1304.00	960.	6360.	1591.	714.	4857.	9257.					
13 CHARLESTOWN	T0157	I	55.00	0.	0.	90.	40.	275.	11000.					
13 SPEED	T0158	I	6.50	0.	0.	11.	5.	32.	11000.					
13 GALLAGHER	T0159	P	660.00	430.	2940.	928.	416.	2832.	10035.					OT
13 WATERSTE	T0160	P	45.00	0.	0.	74.	33.	225.	11000.					OT
13 CANAL	T0161	P	50.00	0.	0.	82.	37.	250.	11000.					OT
13 PADDY S RUN	T0162	P	337.50	100.	650.	709.	318.	2164.	12951.					OT
13 CANE RUN	T0163	P	535.30	350.	2320.	748.	336.	2284.	10003.					OT
13 KOSVOSDALE	T0164	I	9.50	0.	0.	16.	7.	47.	11000.					
13 OWENSBORO	T0165	M	52.50	0.	0.	86.	39.	262.	11000.					OT
13 HUNTINGBURG	T0166	M	6.80	0.	0.	11.	5.	34.	11000.					OT
13 CULLEY	T0167	P	50.00	30.	220.	82.	37.	249.	10977.					OT
13 WARRICK	T0168	I	125.00	0.	0.	204.	92.	624.	11000.					
13 NORTHEAST G.T.	T0169	P	10.70	0.	0.	18.	8.	53.	11000.					
13 OHIO RIVER	T0170	P	121.50	70.	440.	285.	128.	870.	13986.					OT
13 HENDERSON	T0171	M	21.50	0.	0.	35.	16.	107.	11000.					OT
13 JOPPA	T0173	P	1100.30	860.	5530.	1459.	655.	4452.	9699.					OT
13 SHAWNEE	T0172	F	1500.00	1080.	6900.	1967.	883.	6003.	9639.					OT
13 *****	00000	P	225.00	0.	0.	395.	177.	1205.	11500.					
REPORT VALUES	COST THSD DOLLARS		56460.		FLOW CFS		21933.		FLOW THSD GPM		8150.			
CALCULATED VALUES	COST THSD DOLLARS		66942.								9844.			

METHODOLOGY

This study was conducted using information contained in a report by S. P. Mathur of the Pollution Evaluation Section, Technical Advisory and Investigations entitled "Thermal Pollution from Steam-Electric Generating Plants"; information provided by the Federal Power Commission in their Type 1 Ohio River Basin Comprehensive Survey, Appendix I, "Electric Power"; and a 4 part table prepared by the Federal Power Commission dated March 10, 1967, titled "Cooling Methods and Source of Cooling Water Supply at Principal Utility Power Stations in the Ohio River Basin, 1963".

Where basic data for individual plant heat rate factors was not available, the average value for the subbasin was used.

Definition

1 Kilowatt Hour = 3415 British Thermal Units

1 BTU = Heat necessary to raise 1 pound of water 1° F

Water Weighs 62.43 pounds/cubic foot

Therefore: It takes 62.43 BTU's to raise the temperature of
1 cubic foot of water 1°F.

Background

In computing cooling water requirements Mathur made the following assumptions:

1. Heat loss from the boiler to the furnace and from the electric generators etc. was 0.175 of the total heat rate, heat utilization of the plant in BTU/KWHR.

From this a heat balance can be made in BTU's/KWHR.

Total Heat to Plant = Heat Loss + Heat to Cooling Water + Heat to
Convert to Electricity.

Heat to Cooling Water = Total Heat to Plant

- Heat Loss

- Heat to Convert to Electricity

Heat to Cooling Water = Total Heat to Plant

- 0.175 (Total Heat to Plant)

- 3415

In the computer program used to make this assessment,
A = Heat to Cooling Water in BTU's/KWHR.

To calculate water need for cooling from the heat transmitted to the cooling water the following factor must be used, calculated as follows:

$$\frac{1 \text{ BTU/KWHR}}{3600 \text{ Sec/hr. } 62.43 \text{ BTU/cu.ft. of H}_2\text{O. } ^\circ\text{F}} = \frac{1}{225,000} \frac{\text{cu.ft. } ^\circ\text{F}}{\text{sec. KW}}$$

So that the requirement for cooling water in

$$\frac{\text{cfs. } ^\circ\text{F}}{\text{KW}}$$

is $(A \cdot \frac{1}{225,000})$.

This is written in the program as

$$B = A/225,000.$$

Plant Capacity CAP* is measured in megawatts a unit of Power (work/unit time).

Average Power Plant utilization is assumed to be 65%. This value was obtained from the following two references:

1. Senate Select Committee - 86th Congress

Print No. 10, Page 10. 4

2. National Power Survey - Federal Power Commission,

Washington, D. C., October 1964, Table 14, Page 39. 5

Peak Power Plant utilization is assumed to be 100%.

Power Plant Water Use

Average Water Use

Power Plant Water Use in thousands of gallons/minute, (CH2O),
is computed as follows:

$$\text{CH2O} = \frac{B \times \text{CAP} \times 448.831 \times 0.65}{\text{TEMP}}$$

$$\text{CAP* in megawatts} = 10^3 \text{KW}$$

$$\text{TEMP* in } ^\circ\text{F}$$

$$B \text{ in } \frac{\text{cfs} \cdot ^\circ\text{F}}{\text{KW}}$$

448.831 is conversion factor in $\frac{\text{gpm}}{\text{cfs}}$

0.65 is plant utilization

To convert Power Plant water use from thousands of gallons/minute
to cubic feet per second multiply by 2.228.

Peak Water Use:

Replace 0.65 in the preceeding discussion by 1.00.

This set of Water use values for once through cooling should be
used in determining if the natural streamflow is sufficient to handle the
water demands of a power plant without exceeding water quality criteria
for temperature. These values assume a 10°F temperature rise of the water
passing through the power plant.

Cooling Tower Cost Computation

Quoting from Mathur's Report (pages 32 and 33)

"An estimate of the cost of Mechanical Draft Cooling Towers
for the power plants.....consists of the cost of the cooling
tower and appurtenances such as water basin, wiring, piping and

* See Definition of Factors used in the computer program

circulating lines. Operation and maintenance costs are not included.

The assumptions used in cost estimation are as follows:

- a. Approach temperature ^{a/} of 10°F. is used.
- b. Costs are based on water temperature ranges of 10°F.,
- c. A rough average of \$8.00 per gallon per minute of cooling tower capacity is used.
- d. The temperature considered is for summer months only.

The formula used in the computation is -

$$\text{Cost of Tower} = \$8.00 \times \text{Relative Rating Factor} \times \text{GPM} \\ \text{of water used.}$$

Relative Rating Factor was obtained from the graphs^{b/} of Relative Rating Factor versus Wet Bulb Temperature, plotted for various Approach temperatures^{a/}.

The costs calculated by this Program are based on the above discussion. The temperature rise allowed is 10°F., the associated Relative Rating Factor 0.85. Costs obtained are in thousands of dollars, calculated from the following formula.

$$\text{TOWER*} = 8. \times \text{CH20} \times 0.85.$$

^{a/} Approach temperature = Temperature of water leaving the cooling tower minus the wet bulb temperature

^{b/} Not included in Mathur's report.

* See Definition of Factors used in the computer program

Summing Individual Plant Data by Subbasin

The remainder of the Program sums the flow needs and costs; first for the values found in Mathur's Report (reported values), and second for the calculated values from this computer program. The 'reported values' do not include all of the power plants in the basin, only those on which complete data were available for Mathur's Report.

DEFINITION OF FACTORS USED
IN THE COMPUTER PROGRAM

NRB = River Basin Number (Same as Type 1 Numbering System)

PLNT 1

PLNT 2 = Plant Name

PLNT 3

SYMBL = Type of Plant and Map Location Number from Federal
Power Commission Map.

H = Hydroelectric Power

T = Thermal Power

N Type = Number Designator of Type of Plant

H = 1

T = 2

Owner = Type Ownership

P = Private utility

M = Municipal

C = Cooperative

S = State

F = Federal

I = Industrial

NOWNR = Number Designator of Ownership

P = 1

M = 2

C = 3

S = 4

F = 5

I = 6

CAP = Installed Plant Capacity (Megawatts)

Water = Actual Cooling Water Required (Million Gallons/Minute)

Cost = Actual Cost of Cooling Towers (Millions of Dollars)

Heat = Heat Rate Factors by Plant and Where no Better Information Exists
by Subbasin (BTU/KWHR).

Cool = Present Type of Cooling

OT = Once through cooling

CT = Cooling tower

S = Spray pond

NC = Non-condensing

NA = Information not available

TEMP = Temperature Rise of Water Allowed in °F.

TOWR = Calculated Cost of Cooling Towers in Thousands of Dollars.

CH20 = Calculated Cooling Water Required on a once through basis in
Thousands of Gallons Per Minute.

FLOW = Calculated Cooling Water Required on a once through basis in cfs.

STOWR = Sum of Cost of Cooling Towers in Thousands of Dollars for each subbasin.

SFLOW = Sum of once through Cooling Water needs in cfs for each subbasin.

SCH20 = Sum of once through Cooling Water needs in Thousands of Gallons
per minute for each subbasin.

PROGRAM LISTINGS FOR 100% AND 65%

POWER PLANT UTILIZATION

This program was written for the Honeywell 400 System

Note: Program statement #31 has the only change for
100% and 65% power plant utilization

TITLEA TW24

1005 FORMAT(F2.0,3X,F5.0)	1
1006 FORMAT(I2,ZA8,A4,A5,I1,A1,I1,2X,F7.0,F4.0,F6.0,20X,F5.0,A5)	2
1030 FORMAT(1X,//)	3
1031 FORMAT(1X,1H)	4
1040 FORMAT(1X,17HCALCULATED VALUES,5X,18HCOST THSD DOLLARS ,F12.0,5X,9 1HFLOW CFS ,F10.0,5X,14HFLOW THSD GPM ,F10.0)	5
1045 FORMAT(1X,13HREPORT VALUES,9X,18HCOST THSD DOLLARS ,F12.0,29X,14HF 1LOW THSD GPM ,F10.0)	6
1060 FORMAT(1X,12HOUT OF ORDER)	7
2000 FORMAT(1X,I2,1X,ZA8,A4,1X,A5,2X,A1,3X,F8.2,2X,F6.0,5X,F8.0,2X,F6.0 1,2X,F6.0,3X,F10.0,3X,F7.0,2X,A5)	8
CALL HEAD	9
SWTR=0.	10
SCOST=0.	11
STOWR=0.	12
SFLOW=0.	13
SCH20=0.	14
READ 1005,TEMP,RRF	15
M=1	16
10 CONTINUE	17
READ 1006,NRB,PLNT1,PLNT2,PLNT3,SYMRL,NTYPE,OWNER,NOWNR,CAP,WATER, 1COST,HEAT,COOL	18
IF END OF FILE 21,20	19
20 CONTINUE	20

K=0	21
IF (NRB=M) 28,25,30	22
28 CONTINUE	23
PRINT 1060	24
GO TO 25	25
25 CONTINUE	26
COST=COST*1000.	27
WATER=WATER*1000.	28
A=HEAT-0.175*HEAT-3413.	29
B=A/225000.	30
C 100 PERCENT EFFICIENCY USED FOR PEAK POWER ANALYSIS	
CH2O=(B*CAP*448.831*1.00)/TEMP	31
FLOW=CH2O*2.228	32
TOWR=8.*CH2O*0.85	33
STOWR=STOWR+TOWR	34
SFLOW=SFLOW+FLOW	35
SCH2O=SCH2O+CH2O	36
SWTR=SWTR+WATER	37
SCOST=SCOST+COST	38
PRINT 2000, NRB,PLNT1,PLNT2,PLNT3,SYMBL,OWNER,CAP,WATER,COST,FLOW, 1CH2O,TCWR,HEAT,COOL	39
GO TO 10	40
21 K=10	41
30 CONTINUE	42
PRINT 1031	43
PRINT 1045, SCOST,SWTR	44
PRINT 1040, STOWR,SFLOW,SCH2O	45
PRINT 1030	46
IF (K=10) 40,100,100	47

40 CONTINUE	48
M=M+1	49
SWTR=0.	50
SCOST=0.	51
STCWR=0.	52
SFLOW=0.	53
SCH2C=0.	54
GO TO 25	55
100 STOP	56
END	57

TITLEAWTW24

1005	FORMAT(F2.0,3X,F5.0)	1
1006	FORMAT(I2,2A8,A4,A5,I1,A1,I1,2X,F7.0,F4.0,F6.0,20X,F5.0,A5)	2
1030	FORMAT(1X,//)	3
1031	FORMAT(1X,1H)	4
1040	FORMAT(1X,17HCALCULATED VALUES,5X,18HCOST THSD DOLLARS ,F12.0,5X,9 1HFLOW CFS ,F10.0,5X,14HFLOW THSD GPM ,F10.0)	5
1045	FORMAT(1X,13HREPORT VALUES,9X,18HCOST THSD DOLLARS ,F12.0,29X,14HF 1LOW THSD GPM ,F10.0)	6
1060	FORMAT(1X,12HOUT OF ORDER)	7
2000	FORMAT(1X,I2,1X,2A8,A4,1X,A5,2X,A1,3X,F8.2,2X,F6.0,5X,F8.0,2X,F6.0 1,2X,F6.0,3X,F10.0,3X,F7.0,2X,A5)	8
	CALL HEAD	9
	SWTR=0.	10
	SCOST=0.	11
	STOWR=0.	12
	SFLOW=0.	13
	SCH2C=0.	14
	READ 1005,TEMP,RRF	15
	M=1	16
10	CONTINUE	17
	READ 1006,NRB,PLNT1,PLNT2,PLNT3,SYMBL,NTYPE,OWNER,NOWNR,CAP,WATER, 1COST,HEAT,COOL	18
	IF END OF FILE 21,20	19
20	CONTINUE	20
	K=0	21

IF (NRB=M) 28,25,30	22
28 CONTINUE	23
PRINT 1060	24
GO TO 25	25
25 CONTINUE	26
COST=COST*1000.	27
WATER=WATER*1000.	28
A=HEAT-0.175*HEAT-3413.	29
B=A/225000.	30
C 0.65 EFFICIENCY ASSUMMED THROUGHOUT AS PER SENATE SELECT COMM. PRINT NO. 10	
C AND NATIONAL POWER SURVEY FPC 10/64 WASHINGTON D.C. TABLE 14 PAGE 39	
CH20=(B*CAP*448.831*0.65)/TEMP	31
FLOW=CH20*2.228	32
TOWR=8.*CH20*0.85	33
STOWR=STOWR+TOWR	34
SFLOW=SFLOW+FLOW	35
SCH20=SCH20+CH20	36
SWTR=SWTR+WATER	37
SCOST=SCOST+COST	38
PRINT 2000, NRB,PLNT1,PLNT2,PLNT3,SYMBL,OWNER,CAP,WATER,COST,FLOW, 1CH20,TOWR,HEAT,COOL	39
GO TO 10	40
21 K=10	41
30 CONTINUE	42
PRINT 1031	43
PRINT 1045, SCOST,SWTR	44
PRINT 1040, STOWR,SFLOW,SCH20	45
PRINT 1030	46
IF (K=10) 40,100,100	47

40 CONTINUE	48
M=M+1	49
SWTR=0.	50
SCOST=0.	51
STOWR=0.	52
SFLOW=0.	53
SCH20=0.	54
GO TO 25	55
100 STOP	56
END	57

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