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THE OPTIMUM USE OF WATER FOR POWER CALCULATED BY DATATRON ELECTRONIC COMPUTER

By

J. D. Ellis[1/]

Pacific Power & Light Company completed installation of a Datatron Electronic Computer System at its Portland office in the Public Service Building in June, 1957. The arrangement of computer, computer console, input and output control units and paper tape, magnetic tape and punched card units in the computer room, is shown in chart 1. These principal components of the computer cost about $300,000 and do not include the auxiliary IBM equipment that we lease. The cost of the computer is justified by savings in billing and other accounting work. In addition, it makes feasible the solving of many engineering problems and the processing of much engineering and operating data otherwise not possible.

When Swift No. 1 (440,000 acre-feet of storage) and Swift No. 2 are completed in December, 1958, with existing Yale and Merwin plants there will be approximately 900,000 acre-feet of storage on the Lewis River. This will substantially control the natural flow and whenever Muddy Project (277,000 acre-feet of storage) is built twelve miles up river from Swift No. 1, the five hydro plants and four storage reservoirs with approximately 1,170,000 acre-feet of usable storage will bring the Lewis River completely under control except under extreme conditions. (See chart 2)

The calculation and summation of power generation at all five of these plants, involving drafting and refilling of four reservoirs, is a long and tedious job for an engineer using tables, curves, and a hand calculator and would take him approximately two days to figure energy output and peaking capacity for one year by months.

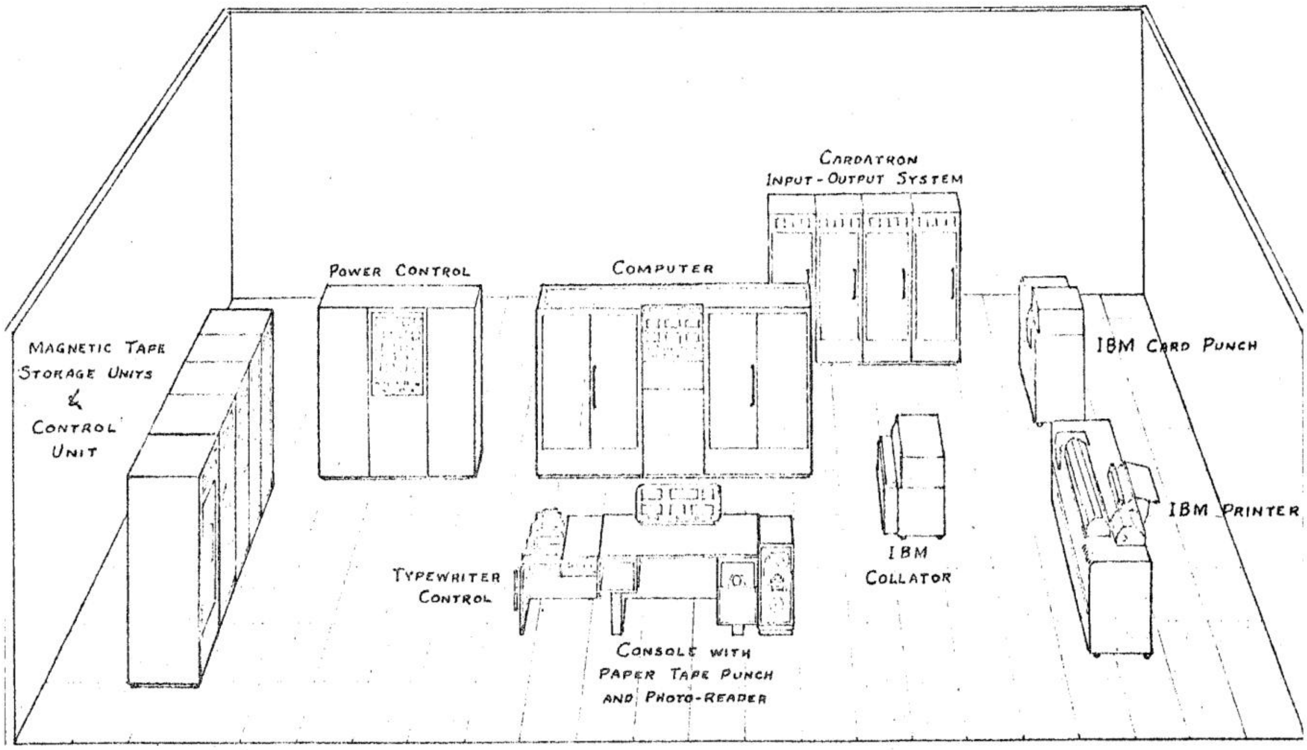
Recorded natural flows in the Lewis River at Merwin Dam vary considerably (minimum day 700 Cfs and maximum day 129,000 Cfs). This necessitates careful planning of reservoir operation.

Storage is used to augment low natural flow in the fall and winter months in adverse years and to catch excessive high flow in winter and spring months, regulating flow to within capacity of turbines and providing seasonal storage for winter heavy load periods.

1/ J. D. Ellis, Pacific Power & Light Company.

PACIFIC POWER & LIGHT COMPANY - EDP

DATATRON ELECTRONIC COMPUTER SYSTEM



INFORMATION IS INTRODUCED TO THE COMPUTER SYSTEM BY IBM CARDS THROUGH THE IBM COLLATOR, WHICH READS THE PUNCHED HOLES IN THE CARDS AT THE RATE OF 240 CARDS PER MINUTE. THE DATA IS THEN TRANSFERRED TO THE CARDATRON INPUT UNIT WHICH TRANSLATES THE IBM LANGUAGE INTO COMPUTER LANGUAGE, AND TEMPORARILY STORES THIS INFORMATION UNTIL THE COMPUTER IS READY FOR IT. THE EQUIVALENT OF THE DATA ON ONE IBM CARD IS TRANSFERRED FROM THE CARDATRON INPUT UNIT TO THE COMPUTER AT THE RATE OF 0.030 SECONDS. THE MANIPULATION OF DATA BY THE COMPUTER, SUCH AS BILLING CALCULATIONS, IS ACCOMPLISHED AT HIGH SPEEDS: 500 10-DIGIT NUMBERS CAN BE ADDED IN ONE SECOND, 120 10-DIGIT NUMBERS CAN BE MULTIPLIED CONSECUTIVELY IN ONE SECOND, AND 85 10-DIGIT NUMBERS CAN BE DIVIDED CONSECUTIVELY IN ONE SECOND.

THE INSTRUCTIONS FOR THE COMPUTER TO FOLLOW AND ADDITIONAL DATA NECESSARY FOR VARIOUS COMPUTATIONS ARE STORED IN THE MAGNETIC DRUM HOUSED IN THE COMPUTER AND ON MAGNETIC TAPE REELS IN THE MAGNETIC TAPE STORAGE UNITS. AFTER PROBLEMS HAVE BEEN SOLVED, THE COMPUTER TRANSFERS THE SOLUTIONS TO THE CARDATRON OUTPUT UNITS WHERE THEY ARE TRANSLATED INTO IBM LANGUAGE AND EITHER PRINTED OUT ON THE IBM PRINTER AT THE RATE OF 150 LINES PER MINUTE, OR PUNCHED INTO IBM CARDS ON THE IBM CARD PUNCH AT THE RATE OF 100 CARDS PER MINUTE.

DATA CAN ALSO BE FED INTO THE COMPUTER USING THE PAPER TAPE SYSTEM ATTACHED TO THE CONSOLE AND PRINTED OUT ON THE TYPEWRITER CONTROL UNIT OR PUNCHED OUT ON THE PAPER TAPE PUNCH.

THE POWER CONTROL UNIT TRANSFORMS 208 VOLT ALTERNATING CURRENT INTO 14 DIFFERENT VOLTAGES FOR VARIOUS COMPUTER SYSTEM CIRCUITS, REGULATING THESE VOLTAGES WITHIN 1% TOLERANCES.

PACIFIC POWER & LIGHT COMPANY'S DEVELOPMENT PLAN FOR LEWIS RIVER

		Max. Capability
Existing:	Merwin	100,000 KW
	Yale	133,000 KW
Under Construction:	Merwin	50,000 KW
	Swift #1	250,000 KW
	Swift #2	70,000 KW
License Pending:	Muddy	110,000 KW
Under Investigation:	Meadows	100,000 KW
Total		813,000 KW

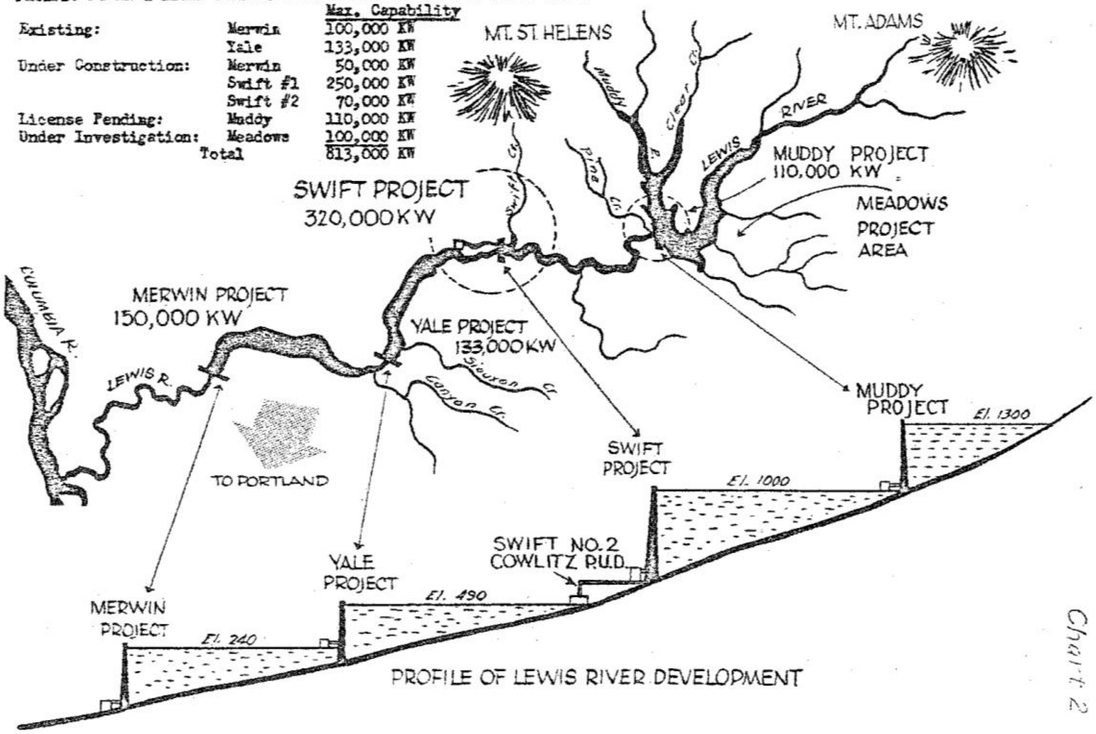


Chart 2

March 11, 1958

Median Year

PACIFIC POWER & LIGHT COMPANY
LEWIS RIVER CAPABILITY

MONTH	PLANT	ELEV FT	FLOW CFS	MOD CFS	SPILL CFS	FACTOR KW/CFS	PEAK MW	AVG MW	ENERGY MWH	MONTH TOTALS FACTOR KW/CFS	PEAK MW	AVG MW	ENERGY MWH
JUL	MUDDY	1299.0	1065	1002		22.52	111.2	22.57	16,792				
JUL	SWIFT	999.0	1459	1324		38.24	303.8	50.63	37,669				
JUL	YALE	489.0	1674	1480		18.15	132.7	26.86	19,984				
JUL	MERWIN	239.0	1790	1532		12.79	148.9	19.60	14,582	91.70	696.6	119.66	89,027
AUG	MUDDY	1300.0	680	617		22.52	111.2	13.89	10,334				
AUG	SWIFT	1000.0	949	814		38.23	303.8	31.12	23,153				
AUG	YALE	490.0	1078	884		18.15	132.8	16.04	11,934				
AUG	MERWIN	239.5	1177	951		10.95	149.8	10.42	7,752	89.85	697.6	71.47	53,173
SEP	MUDDY	1298.0	585	717		22.66	113.2	16.25	11,700				
SEP	SWIFT	994.0	826	1405		38.50	308.9	54.09	38,945				
SEP	YALE	477.0	930	2289		17.98	128.4	41.16	29,635				
SEP	MERWIN	232.0	1040	2892		13.65	141.7	39.41	28,375	92.77	692.2	150.91	108,655
OCT	MUDDY	1296.0	830	957		23.09	117.2	22.10	16,442				
OCT	SWIFT	984.0	1140	1969		38.65	304.6	76.10	56,618				
OCT	YALE	470.0	1370	2585		17.49	123.2	45.21	33,636				
OCT	MERWIN	232.0	1898	3113		13.34	141.7	41.52	30,891	92.57	686.7	184.93	137,587
NOV	MUDDY	1293.0	2300	2498		23.59	120.2	58.93	42,430				
NOV	SWIFT	975.0	2940	3770		37.68	296.1	142.05	102,276				
NOV	YALE	470.0	4374	5204		16.60	123.2	86.39	62,201				
NOV	MERWIN	232.0	5390	6220		13.20	141.7	82.10	59,112	91.07	681.2	369.47	266,019
DEC	MUDDY	1287.0	2700	3083		23.77	119.2	73.28	54,520				
DEC	SWIFT	970.0	3427	4141		37.16	291.4	153.88	114,487				
DEC	YALE	470.0	4659	5373		16.57	122.6	89.03	66,238				
DEC	MERWIN	233.0	6606	7257		13.20	142.8	95.79	71,268	90.70	676.0	411.98	306,513
JAN	MUDDY	1250.0	2550	4304		20.31	110.0	87.41	65,033				
JAN	SWIFT	970.0	3270	5024		36.97	291.4	185.73	138,183				
JAN	YALE	470.0	4789	6543		15.86	122.6	103.77	77,205				
JAN	MERWIN	233.0	6490	8244		12.61	142.8	103.95	77,339	85.75	666.8	480.86	357,760
FEB	MUDDY	1210.0	2300	3703		17.46	100.8	64.65	43,445				
FEB	SWIFT	970.0	2940	4343		36.98	291.4	160.60	107,923				
FEB	YALE	470.0	4497	5900		15.86	122.6	93.57	62,879				
FEB	MERWIN	233.0	6043	7446		13.23	142.8	98.51	66,199	83.53	657.6	417.33	280,446
MAR	MUDDY	1200.0	2390	2607		17.88	80.9	46.61	34,678				
MAR	SWIFT	968.0	3007	3355		36.91	291.4	123.83	92,130				
MAR	YALE	470.0	4276	4623		16.54	122.6	76.46	56,886				
MAR	MERWIN	233.0	5452	5800		13.29	142.8	77.08	57,348	84.62	637.7	323.98	241,042
APR	MUDDY	1240.0	3000	1868		18.85	76.1	35.21	25,351				
APR	SWIFT	975.0	3789	2179		37.61	289.5	81.95	59,004				
APR	YALE	470.0	4779	3169		17.18	122.6	54.44	39,197				
APR	MERWIN	233.0	5986	4376		13.35	142.8	58.41	42,055	86.99	631.0	230.01	165,607
MAY	MUDDY	1280.0	3960	2197		21.27	102.5	46.73	34,767				
MAY	SWIFT	980.0	4934	2834		37.00	292.8	104.85	78,008				
MAY	YALE	485.0	5689	2744		17.60	127.0	48.29	35,928				
MAY	MERWIN	237.0	6372	3173		13.56	145.0	43.02	32,007	89.43	667.3	242.89	180,710
JUN	MUDDY	1298.0	2700	1581		22.52	111.2	35.60	25,632				
JUN	SWIFT	998.0	3420	995		37.69	296.3	37.49	26,993				
JUN	YALE	488.0	3910	1303		18.09	131.9	23.57	16,970				
JUN	MERWIN	238.0	4290	1617		12.96	147.8	20.96	15,091	91.26	687.2	117.62	84,686

	SEPT THRU MARCH TOTALS PEAK MW MO	AVG MW-MO	ENERGY MWH	YEAR TOTALS PEAK MW-MO	AVG MW-MO	ENERGY MWH
MUDDY	761.5	0369.23	268,248	1273.7	523.23	381,124
SWIFT	2075.2	0896.28	650,562	3561.4	1202.32	875,389
YALE	865.2	0535.59	388,680	1512.2	704.79	512,693
MERWIN	996.3	0538.36	390,532	1730.6	690.77	502,019
TOTALS	4698.2	2339.46	1,698,022	8077.[illegible]	3121.11	2,271,225

Chart 3

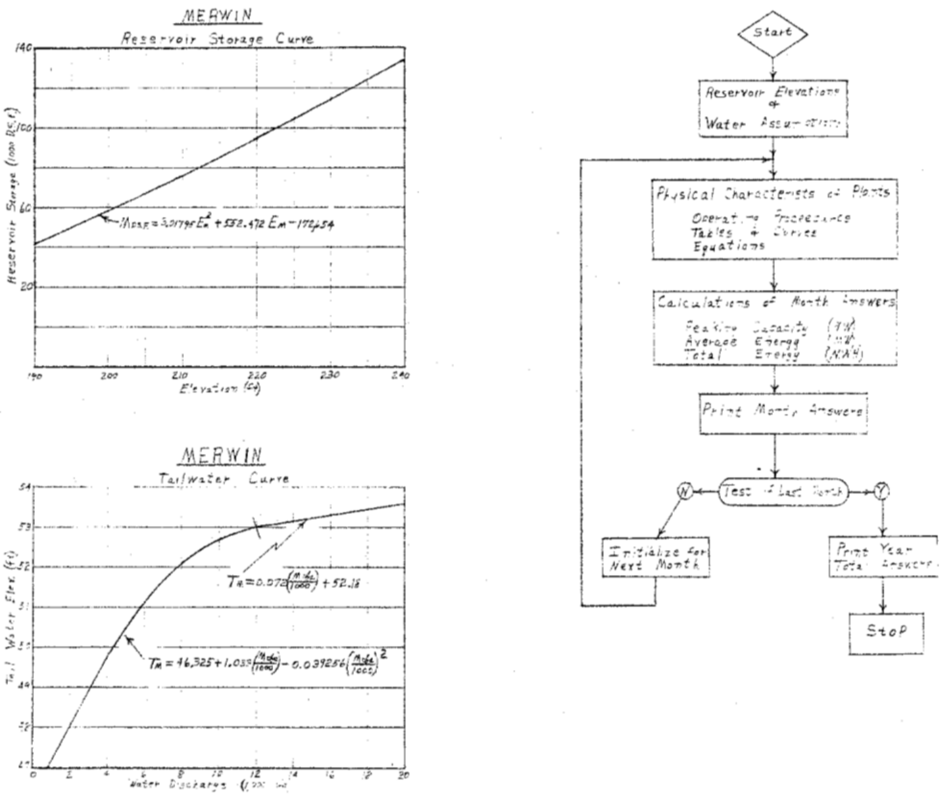
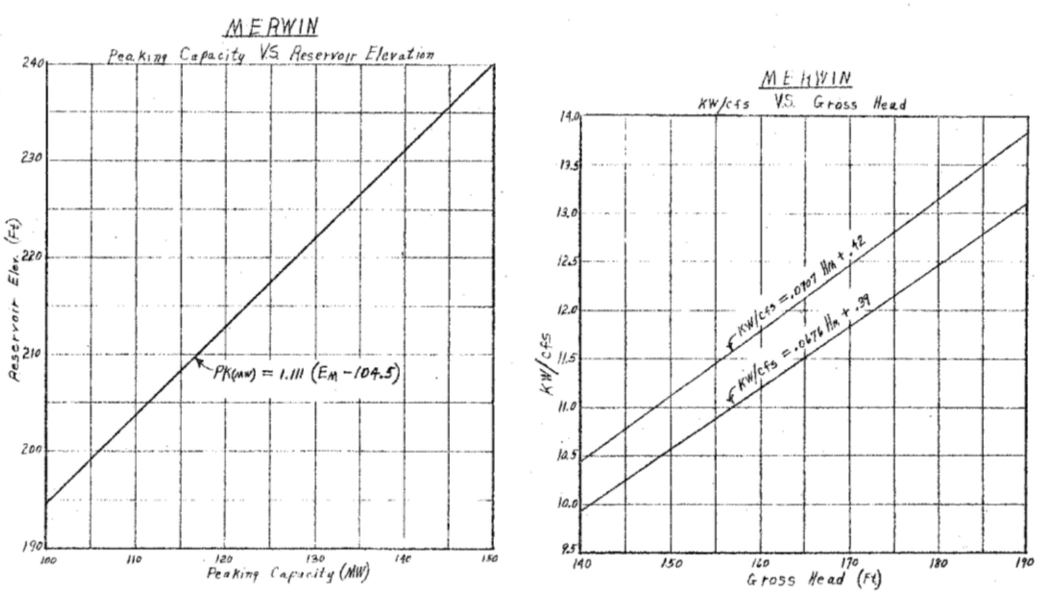


Chart 4

Chart 5



With the relatively large amount of storage that will be available with the addition of Swift Project, it will be necessary to operate on a runoff forecast basis from the 1st of January until reservoirs are filled in early summer to assure refilling of all reservoirs. Each revision of runoff estimate will require recalculation of power output from all plants for remainder of season. Long calculations like this that are repeated many times year after year are particularly suited to digital computers which save many man-days of an engineer's time.

When making studies of power resources on evaluating a proposed hydro plant, it is customary to compute monthly plant output through twenty to thirty years of historical water record. To make this calculation with desk calculator for five plants on the Lewis River covering thirty years of water record would take an engineer 60 working days. We can now, with the Datatron, make this computation in two to four hours, depending on the type of program we use.

We have just recently been making an extensive study of future power resources and firm capabilities under a number of assumptions. After studying and testing all the low water years for firm capability and establishing reservoir rule curves for each assumed condition of loads and resources, a total of eight sets of historical water years were computed. Altogether about 300 years of power generation were calculated in about 40 hours on the computer. Due to recent changes and improvements in our computer program, we could now do the same amount of work in half of the time. By the old hand method of calculation this work would have taken an engineer two years working 48 hours per week.

It is now possible with the use of the electronic computer to make many more studies, realizing greater accuracy of storage regulation and power generation under all water conditions, than were ever possible before. The calculations are uniform and consistent for comparison, thus eliminating human variations and errors. A sample page of one year's computer calculations for Merwin, Yale, Swift and Muddy hydro plants, as printed by line printer of computer system, is attached as chart 3.

The bulk of the time devoted to calculating problems on an electronic computer is tied into the preparation of the computer program; therefore, the computer's great advantage is in solving long and repetitious problems. Our first program for Yale and Merwin plants, which had about 800 steps, took an engineer six weeks to prepare, including tabulating stream flow records.

I will briefly outline the pattern in setting up a computer program. First, a block flow diagram is drawn to provide a sequential framework of related steps, including logical decisions at certain critical points, which the computer must follow for each monthly calculation. A very simplified form of such a diagram is shown on chart 4. Our complete flow chart also has all the formulas to be used in calculations, including formulas for reservoir storage, kilowatts per cfs factor, plant peak capacity and tail-water curves. All the limitations involved in the logic of a program such as generator maximum and minimum output, and upper and lower limits of storage reservoirs are also included. One set of these curves with formulas for Merwin Plant are shown on charts 4 and 5. Our present program for the five-plant computation has 2160 steps for each month, (five pages of diagrams); however, the estimated average steps the computer takes per month is 1600, or 19,200 steps for a year. Preparation of a flow diagram with formulas represents about 60% of the time in programming. The next step is to convert the flow diagram to computer language by writing, in proper sequence, tables of addresses for stored data together with computer commands for arithmetic, storing data, and for printing format. Then the program is punched on either IBM cards or punched paper tape, which we used to put our program into the electronic computer. All stream flow records for each plant are punched on IBM cards or paper tape to store in computer memory. We now have 30 years of actual water record, the pool critical water year, median year, and average water year all recorded on magnetic tape for rapid storing in computer before starting our program operation.

The last step in putting our power program into operation is the input to computer memory of the reservoir rule curves we wish to use which have been punched on paper tape. A so-called rule curve includes each month-end elevation of any desired reservoir for the full year.

At present we have several different programs for determining power output from present and future hydro plants on the Lewis River. Our basic program that works with reservoir rule curves can be modified to include Muddy Project in addition to Merwin, Yale and Swift. We have a program for figuring daily generation for the existing Yale and Merwin plants which serves as a guide in controlling the peak flows that go beyond machine capacity. Just recently a program revision was made that enabled the computer to assimilate 12 months of power requirements and calculate the corresponding reservoir rule curve. This program is valuable in figuring firm power capability and setting rule curves for calculating power through historical water years.

Mean monthly stream flows for thirty years of record have been broken down to inflow for each plant by the computer. Storage tables in steps of one-tenth foot have been figured and tabulated with line printer for four plants. Computer time per plant storage table was about two minutes.

As need requires and time permits, I expect we will continue to refine, improve and add new programs for computer use. When we have accumulated enough snow course and precipitation data, I hope to have prepared a Lewis River runoff forecast procedure for use on the computer that would facilitate power operation for the current year.

We have been one of the first to use an electronic computer to compute power output from hydro storage plants in series on a river system and it has been a great time saver and improvement over the old hand method.

I wish to acknowledge and thank Mr. Wallace Forsman for his preparation of charts and assistance on this paper.

DISCUSSION OF

"The Use of Water for Power Calculated by Datatron Electronic Computer."

By

David M. Rockwood

Many engineers are now in a position to make use of electronic computers (both digital and analog) for application to their routine engineering problems. When electronic computers were first developed, engineers usually held the general impression that such computers were designed for highly scientific application, usually involving complex mathematical relationships. Considerable such use of computers has been made, and their capacity for automatic high speed computation has opened many new horizons in mathematical techniques. Computers are, however, able to solve equally well, those routine engineering problems which involve the drudgery of large masses of arithmetic computations. Included in this type of engineering problems are earthwork quantities, structural design analysis, hydraulic backwater studies, streamflow synthesis, regression analysis, survey traverse networks, as well as many other types of engineering computations. The paper which I am discussing describes a procedure which falls within this general classification.

Experience in the use of electronic computers has led me to several general observations. The first is that there is nothing particularly mysterious in their operation and use. They simply are able to perform large amounts of arithmetic computation in phenomenally short time, and are able to do so in a completely automatic manner. A person may well visualize the use and operation of electronic computers by analogy to a room full of perhaps 1000 trained and highly efficient arithmetic machine operators. Each would have a highly efficient desk calculator, whereby each computation can be handled sequentially through a series of pre-determined instructions to each operator. Although each of the 1000 operators is completely accurate, and can add two 10-digit figures in one millesecond, they are also complete morons except for their ability to answer yes or no to a given arithmetic condition. As you can well visualize, it would require a very complete and perfect set of instructions to this group of ambitious but dim-witted arithmetic wizards to handle a highly complex and intricate problem. One more limitation of this mythical group of 1000 arithmeticians is that during the course of an operation all may be working prodigiously to provide you with an answer, but one of the operators may find a single error in one digit. In this case, the entire operation ceases, and all of remaining 999 operators will take a prolonged coffee break until that one error is corrected.

As you can see, then, the use of such a machine requires a considerable amount of experience and judgment, in order to apply it intelligently and efficiently to a given problem. Even the determination of whether a given problem should be set up for machine operation is something