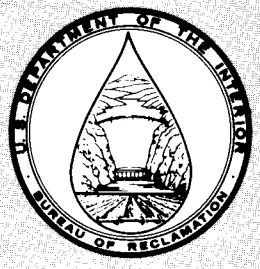

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LINEAR PROGRAMMING CONCEPTS FOR UNIT COMMITMENT

January 1992

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Denver Office
Research and Laboratory Services Division
Electric Power Branch

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16. ABSTRACT

The optimization of the Lower Colorado Powerplants, Hoover, Davis, and Parker, was studied using a linear programming model. The goal of the optimization was to minimize the flow required to produce a given amount of power, thereby increasing the average efficiency of the Lower Colorado Basin. The optimization produces an hourly generation schedule termed unit commitment.

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LINEAR PROGRAMMING CONCEPTS FOR UNIT COMMITMENT

by

Nancy C. Farabee
and
Steve C. Stitt

Electric Power Branch
Research and Laboratory Services Division
Denver Office
Denver, Colorado

January 1992

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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INTRODUCTION

The Bureau of Reclamation is committed to maximizing power production through increasing the efficiency of generator operations on the Colorado River. This effort started with the consolidation of generator operations at Hoover Dam and Powerplant in 1987, resulting in powerplant efficiency increases up to 5 percent. In continuing this effort, a proposal was made to study the benefits of consolidating all generator resources on the Colorado River.1 Consolidating generator resources means that the generators are pooled and that any generator in the pool can be used to provide the Basin (Colorado River Basin) generation and capacity requirement. Capacity is defined as the available megawatt output of a generator.

This study consisted of a linear programming optimization of the consolidated Basin which included Hoover, Davis, and Parker Dams. Glen Canyon Dam will be added to the study at a later date. The goal of optimization was to increase efficiency by increasing power production with the available water. The optimization produces an hourly generation schedule that is termed unit commitment. The study involved optimizing the above powerplants actual operations from April 17, 1988. The daily water releases from Davis and Parker powerplants were restricted to be identical to the historical water releases; Hoover powerplant's daily water release was not restricted.

CONCLUSIONS

The results of the study indicated that the Basin average efficiency can be increased by 3 percent using the unit commitment schedule from the linear programming optimization. A 3-percent increase in Basin average efficiency will result in an estimated increase in energy of 176 000 kilowatt hours per year. The efficiency increase was achieved simply by generating with the most efficient generators at their maximum efficiency levels and by motoring the less efficient generators to provide capacity as spinning reserve. Daily water releases from Davis and Parker powerplants can be shaped as desired without affecting this increase in efficiency. The shape can vary from a flat water release to a water release having multiple peaks.

The Electric Power Branch is designing the generation control function for the proposed Lower Colorado SCADA (Supervisory Control and Data Acquisition) system. One element of the control function will be to produce an optimized unit commitment schedule. In this paper, linear programming was evaluated as an optimization method for the unit commitment schedule. The advantages of linear programming are: (1) ease of modeling, and (2) calculating solution in reasonable time. In addition, linear programming consistently produced the optimal solution. The main drawback of linear programming was that it required linearization of the nonlinear turbine flow curves. The turbine flow curves used in this study were not complete from 0 megawatts to capacity. A portion of the curve near 0 megawatts had to be extrapolated as a linear segment. Linearization of the turbine flow curves introduces error. The error generated from linearizing the extrapolated turbine flow curves is unknown. The Hydraulic Machinery Section of the Electrical and Mechanical Engineering Division is developing complete flow curves for the Basin turbines. If linearizing the new turbine flow curves does not

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1 S. C. Stitt, *Colorado River Systems Operations Consolidation Proposed Concepts and Benefits*, USBR Project Notes 90–24, September 1990.

introduce significant error, then implementing the optimization with linear programming will proceed.

LINEAR PROGRAMMING DEFINITION

Linear programming is a mathematical procedure for optimizing resources. It can be used only for problems that are linear. The restrictions for variables in linear programming problems are that they be proportional, additive and continuous. The solution of the linear programming model is based on the Simplex method which proceeds from an initial feasible solution, through better solutions, until the optimal solution is obtained. The linear programming software packages (commercially available) used in this study were Lindo and What's Best.

MODEL FORMAT

The Linear Programming Model is optimized by minimizing a quantity called water energy in megawatts.

$$\text{Water energy} = 8.46 \times 10^{-5} \sum_{i=1}^{n} H_i \times Q_i \qquad (1)$$

where:

H_i = constant head of the ith turbine in feet
Q_i = flow through the ith turbine in cubic feet per second

Each generator is modeled by a turbine flow curve. The turbine flow curve is produced from the turbine flow equation which contains head and megawatts as variables. Flow, Q_i , used in equation 1 is calculated with the ith turbine flow equation using the head of the ith turbine and the megawatts of the ith generator.

The historical data for all models consists of a 24-hour generation and capacity schedule and total 24-hour water releases for Davis and Parker powerplants from April 17, 1988. The basis of all models is a 1-hour linear programming model whose function is to produce the hourly generation and capacity schedule and release a portion of the total Davis and Parker water releases. In order to generate the complete 24-hour schedule, the 1-hour model must be run 24 times.

MODEL TYPES

Lindo Single Cycle Model

The Lindo Single Cycle Model is the basis for all model development in this study; all other models are variations of this model. It runs a single-hour generation and capacity schedule and constrains Davis and Parker Dam water releases.

The Lindo Single Cycle Model was used both with integer and noninteger variables. Integer variables can only assume a value of 0 or 1, while noninteger variables in our model were continuous from 0 to 1. The model contains variables for each generator which indicate generator functions, i.e., on, off, motoring, or not motoring. In real operations, these functions always would be represented by integer variables. Initially, noninteger variables were used to decrease the problem's solution time. Later, it was discovered that using the IPTOL command—with integer variable problems—would decrease the solution time without sacrificing optimality in the solution.

The IPTOL command establishes a tolerance of a fractional number between 0 and 1. Once a feasible integer solution is determined, other solutions will only be considered if they can improve on the current best solution by the tolerance. For example, if the IPTOL is 0.02 and the first feasible solution is 100, then the program will only search for solutions better than 102. All subsequent models presented here use integer variables.

Lindo 24-Hour Single Cycle Model

The Lindo 24-Hour Single Cycle Model uses the Lindo Single Cycle Model to run the 24-hour schedule by running the model 24 times.

Lindo 24-Hour Multiple Cycle Model

The Lindo 24-Hour Multiple Cycle Model uses a multiple hour version of the Lindo Single Cycle Model to run the 24-hour schedule. Because of limitations in the number of variables, the largest multiple-hour model we could produce was 3 consecutive hours. The 3-hour model had the same hourly generation and capacity schedule as the single cycle model. The water releases for the 3-hour model were 3 times the 1-hour model water releases and were allowed to be released in any hour during the 3-hour period.

Lindo Historical Model

The Lindo Historical Model was formulated to force the Lindo 24-Hour Single Cycle Model to run the generators exactly as they ran on April 17, 1988.

What's Best 24-Hour Single Cycle Model

The What's Best 24-Hour Single Cycle Model formulated the model in What's Best. What's Best runs Lindo in a Lotus 1-2-3 environment.

Lindo 24-Hour Multisegment Flow Curve Model

The Lindo 24-Hour Multisegment Flow Curve Model was a variation on the Lindo Single Cycle Model that accounted for the nonlinear turbine flow curves of the Grand Coulee generators. Unlike the Basin turbine flow curves, the Grand Coulee turbine flow curves could not be fit

with a single linear curve. To fit the curves, multiple linear segments were used. In the model, each linear segment was treated as if it were a separate generator.

CURVE FITTING

General

In using linear programming to model generators, linear approximations for the nonlinear turbine flow curves must be made. The PC-Matlab software program was used to fit linear curves to the nonlinear turbine flow curves. The Lotus 1-2-3 software program was used with the turbine flow curve formulas to calculate the flows at various megawatt and head values.

Error Calculations

The error between the fitted curves and the turbine flow curves was calculated by subtracting the fitted curve from the turbine flow curve and dividing by the full-scale turbine flow. The maximum acceptable error between the two curves was 2 percent.

Algorithm

An algorithm was developed to linearize the turbine flow curves that consists of the following steps:

1. Select a head value of interest for each powerplant.

2. Use the turbine flow curve equations to find the following data for each turbine at its head value.
   a. Flow at speed-no-load
   b. Maximum efficiency load
   c. Flow at maximum efficiency load
   *d. 130 percent maximum efficiency load
   *e. Flow at 130 percent maximum efficiency load
   *f. 160 percent maximum efficiency load
   *g. Flow at 160 percent maximum efficiency load
   h. Flow at capacity

   * May not exist at higher values of head.

3. The linear segments are located between the following points:
   a. Speed-no-load and maximum efficiency load
   b. Maximum efficiency load and 130 percent maximum efficiency load
   *c. 130 percent maximum efficiency load and 160 percent maximum efficiency load
   *d. 160 percent maximum efficiency load and capacity

   * May not be required at higher values of head.

4. The equations for the linear segments between the upper and lower points given above are in the form $y = mx + b$.

$$m = \frac{\text{flow at upper point} - \text{flow at lower point}}{\text{MW at upper point} - \text{MW at lower point}} \quad (2)$$

$$b = \text{flow at lower point} \quad (3)$$

The Lower Colorado Basin and Grand Coulee Dam turbine flow curves were fit with the algorithm given above. The single segment linearized turbine flow curves developed for the Lower Colorado Basin Powerplants are a good approximation for all generators except those at Davis Dam. The linearized turbine flow curves for Grand Coulee Dam must be multisegmented. The difference is that the Grand Coulee turbines are smaller relative to the size of their generators than the turbines and generators of the Basin.

MODEL COMPARISONS

The data for all Basin models used in comparisons was from April 17, 1988. The generation and capacity schedule came directly from the operation of the generators on that day. The water releases for Davis and Parker powerplants used in model comparisons were releases calculated in the Lindo Historical Model. All models were required to produce:

- the exact generation schedule,
- capacity at or above the capacity schedule, and
- water releases approximately equal to the required releases.

A comparison was done between the Lindo Historical Model and the Pascal Model to compare the accuracy of the results generated from the two different types of models. The Pascal Model is a nonlinear simulation while the Lindo Historical Model is a linear simulation. Figure 1 shows comparison of the average efficiency from the two models. The Pascal Model results are consistently 2 to 2-1/2 percent below the Lindo Historical Model for all comparisons. The Pascal Model releases slightly more water at each powerplant which is reflected in the decrease in average efficiency noted on figure 1.

The What's Best 24-Hour Single Cycle Model and the Lindo 24-Hour Single Cycle Model were compared to verify that both these linear programming models were formulated in the same way. What's Best runs Lindo in a Lotus 1-2-3 environment. With What's Best, the parameters of the model are entered into a Lotus 1-2-3 spreadsheet and What's Best converts the parameters into Lindo program code. The code generated by What's Best is not exactly the same as the code we generated for the Lindo Model. This can be seen on figure 2 which shows that while both models have the same Basin average efficiency, the efficiencies of the individual plants differ. Therefore, the models are not formulated in exactly the same way. The macro capabilities of What's Best offer distinct advantages for performing calculations and altering the problem between optimizations. A macro is a program that executes commands in What's Best.

CONCEPT TESTS

Manually Controlled Release Methods

To compare the Lindo 24-Hour Single Cycle or Multiple Cycle Models with the Lindo Historical Model, the Davis Dam and Parker Dam powerplant releases must be the same in all models. With the cyclic models, this was done by choosing the upper and lower limits for Davis and Parker and running the models until the limits that produced the correct releases were found.

The models used in the comparison were a Lindo 24-Hour Single Cycle Model with an unrestricted flow and with the flow at Parker restricted to release between 9,000 to 9,270 cubic feet per second per hour. The Lindo 24-Hour Multiple Cycle Model was a 3-consecutive hour model having an unrestricted flow.

Figure 3 shows the comparison of the average efficiencies of the Cyclic Models and the Historical Model. The Cyclic Models differ in the way they run the individual powerplants, but all show the same increase in Basin average efficiency of 3 percent over the Historical Model. An interesting aspect in this comparison can be seen on figures 4, 5, and 6 is that the hourly flows for Davis and Parker powerplants can be extremely different without effecting the Basin average efficiency. Figure 7 shows the Lindo Historical Model hourly flows. There appears to be no advantage in Basin average efficiency in using a multihour model versus the single-hour model, and the multihour model tends to produce unit commitment schedules that are not practical.

Automatically Controlled Release Methods

The What's Best 24-Hour Single Cycle Model includes a macro that controls Davis Dam and Parker Dam releases by adjusting the high and low limits of the water releases before each optimization. The limits were calculated using plus and minus percentages of the average remaining flow. The average remaining flow is the total flow required minus the total flow accumulated divided by the remaining hours and is recalculated after each optimization. The limits are calculated either with a fixed or variable percentage. A *fixed percentage* uses the same percentage for every hour and produces a flat shaped limit around the average remaining flow. A *variable percentage* is a percentage that decreases by the same amount each hour and produces a funnel shaped limit around the average remaining flow.

The limits used in the average efficiency comparisons on figure 8 were fixed percentages of ±10 percent, ±20 percent, ±30 percent and a variable percentage in which the percentage at Davis Dam decreased by 0.5 percent per hour from 15 to 3 percent and the percentage at Parker Dam decreased by 1.5 percent per hour from 50 to 24 percent. Figures 9 through 12 show the hourly flows of each run for the 24-hour schedule.

Several runs using variable percentages flow limits were made and it was found that the usable percentage range at Parker Dam could be quite large, while the range at Davis had to be relatively small. If the initial percentage at Davis was large (>20%), the model solution did not release enough water in the beginning and a feasible solution could not be reached.

Although figure 8 indicates that the Basin average efficiency, with the ±30 percent limit run is increased, this is not the case. The increase in efficiency is due to the model solution not releasing as much water through Davis Dam. Also, it should be noted on figure 11 that the hourly flows for Davis Dam double at the end of the 24-hour schedule. While the ±30 percent limit run produces the same Basin average efficiency as the other runs, it's water release pattern is the least desirable.

SHAPING UNIT COMMITMENT

An attempt was made at shaping unit commitment according to the hourly generation and capacity schedules. A Lindo 24-Hour Multiple Cycle Model was used to deliver the exact water releases at Davis and Parker Dams. Shaping unit commitment was attempted by:

- Forcing at least 1 unit to remain on at all times
- Varying the number of units running depending upon the generation required
- Restricting the powerplants to provide the same percentage of generation they did in the historical data.

In the first run, Davis was allowed to run 1 to 5 units and Parker 1 to 4 units. Each 3-hour water release was equal to an eighth of the total water release. In the second run, the unit commitment was scheduled to correspond to the generation required per hour. If the required generation was 500 MW, then Davis could run 1 to 2 units and Parker could run 1 to 2 units. If the required generation was 1,000 MW, then Davis could run 3 to 5 units and Parker could run 2 to 4 units. The water releases of the second run were a percentage that varied according to the generation schedule. In the third run, the unit commitment is shaped so that Davis provided 10 to 20 percent and Parker provided 4 to 7 percent of the generation required each hour. These numbers came from the average operation of Davis Dam and Parker Dam in the historical data. The water releases were proportional to the generation that each plant was providing during the 3-hour period.

A comparison of the average efficiencies for the above three runs and the Historical Model is shown on figure 13. Again, it is seen that the Lindo 24-Hour Multiple Cycle Models provide an increase in Lower Colorado Basin average efficiency of approximately 3 percent over the Lindo Historical Model. As observed in the hourly flows for each run, on figures 14, 15, and 16, shaping the unit commitment according to the megawatts required for that hour produces the best efficiency and hourly flow results.

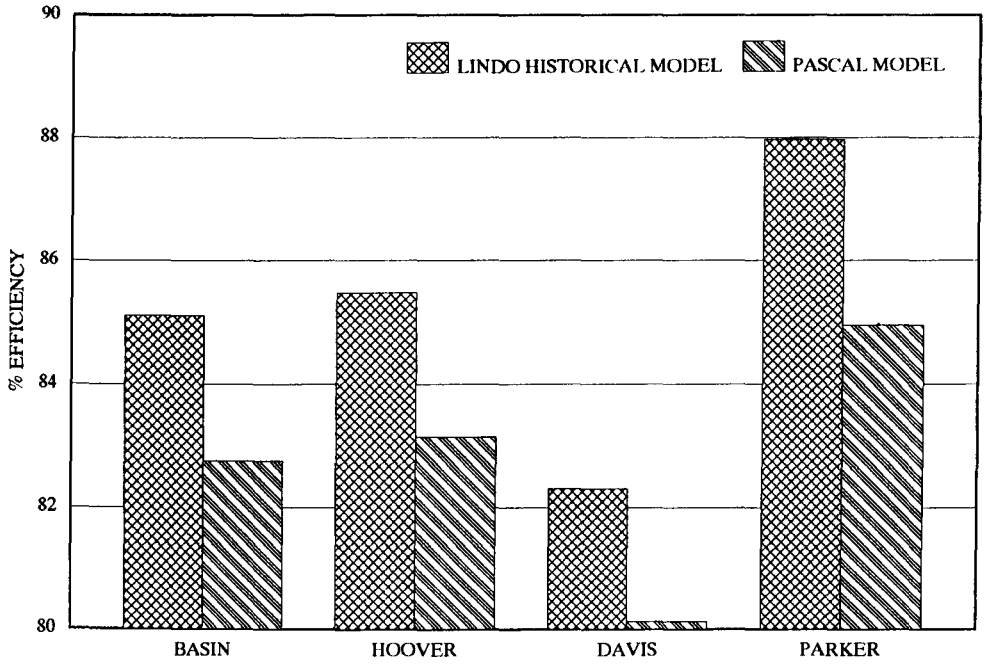

Figure 1. — Lindo Historical Model and Pascal Model. Comparison of average efficiencies. (4/17/88)

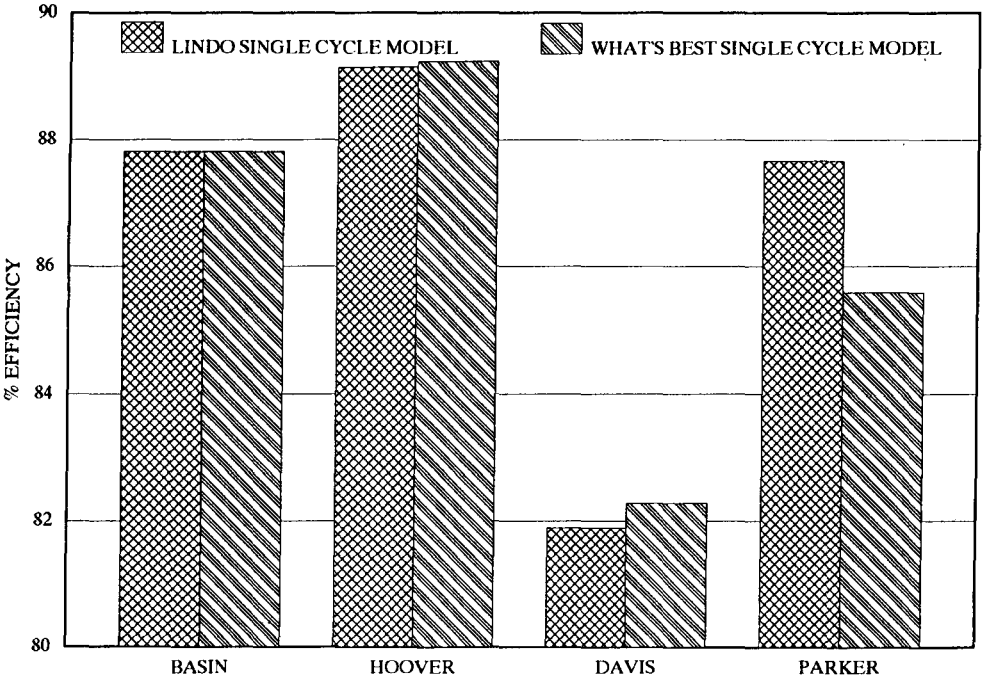

Figure 2. — Lindo Single Cycle and What's Best Single Cycle Models. Comparison of average efficiencies. (4/17/88)

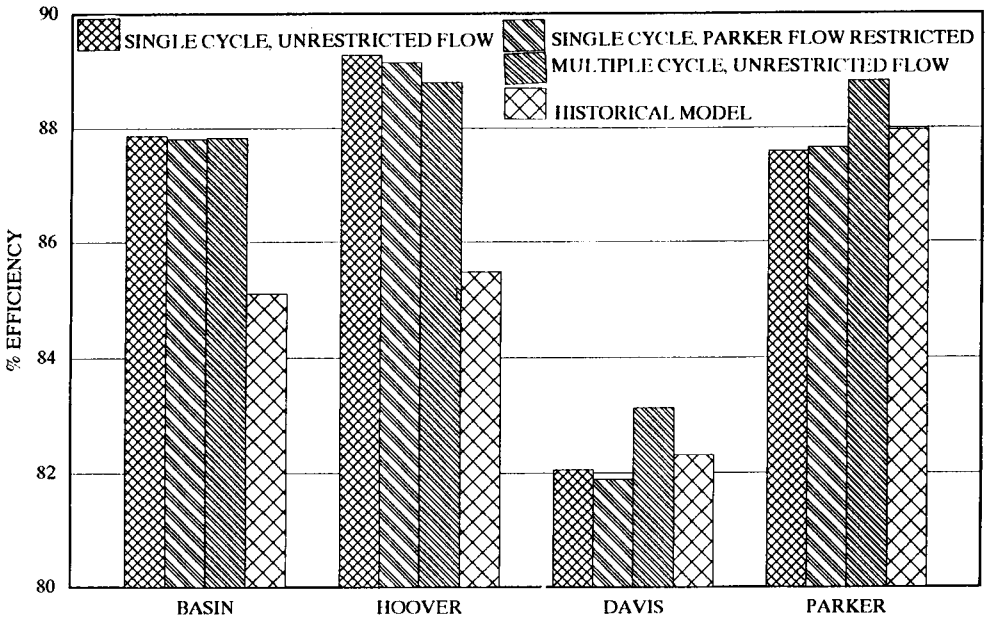

Figure 3. — Lindo Cyclic Models. Comparison of average efficiencies. (4/17/88)

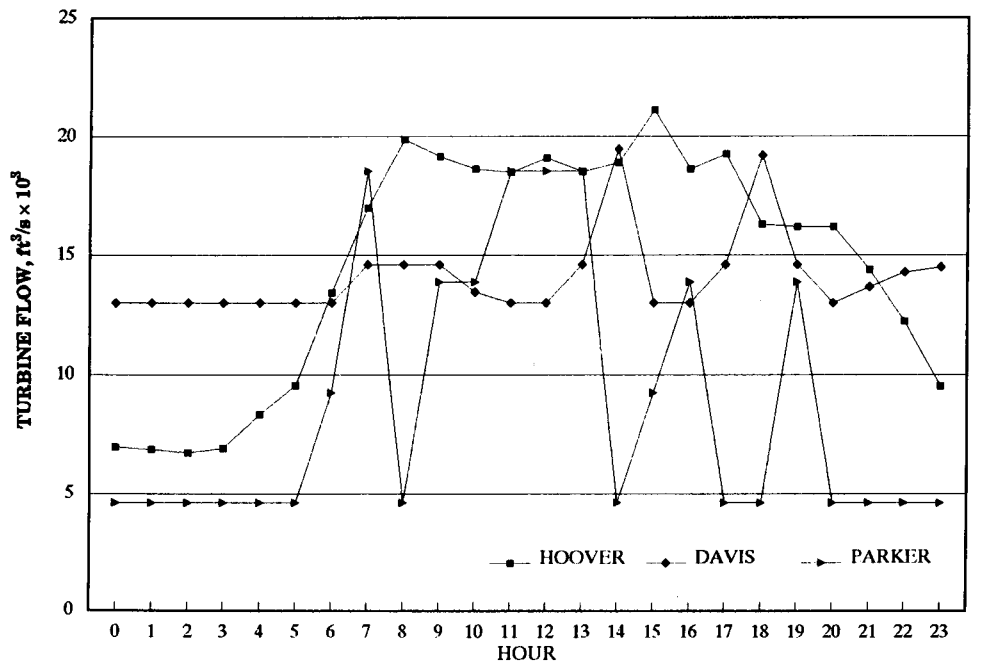

Figure 4. — Lindo Single Cycle Model, unrestricted flows. (4/17/88)

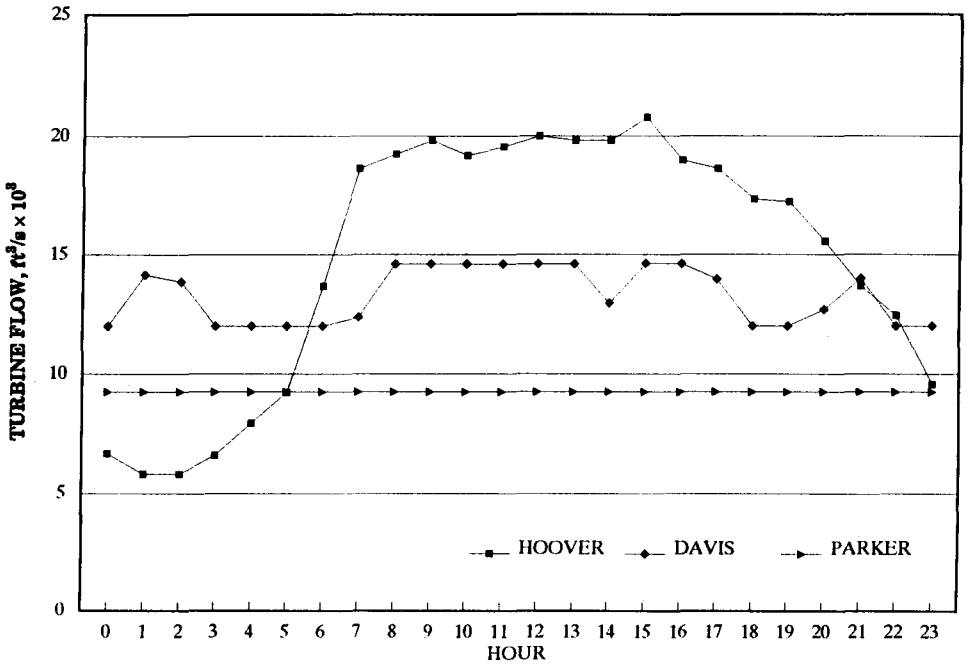

Figure 5. — Lindo Single Cycle Model—Parker Dam, flow restricted. (4/17/88)

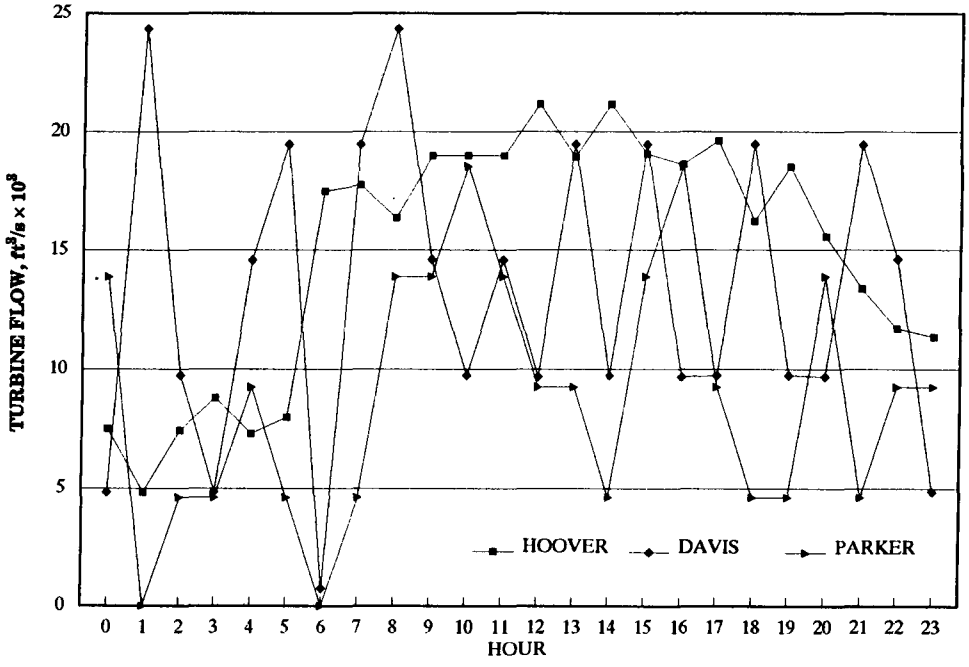

Figure 6. — Lindo Multiple Cycle Model, unrestricted flow. (4/17/88)

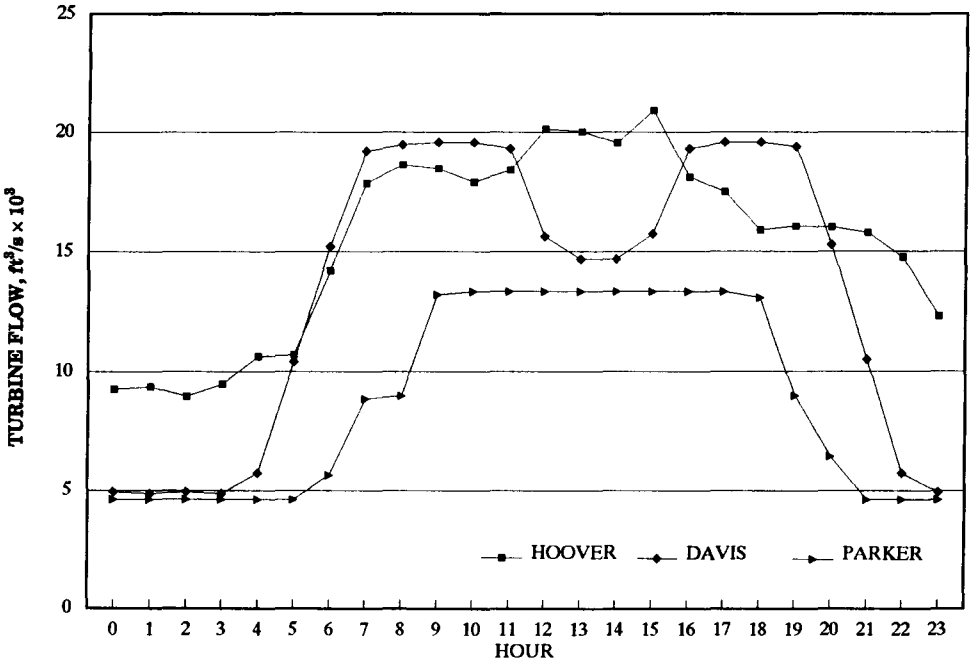

Figure 7. — Lindo Historical Model. (4/17/88)

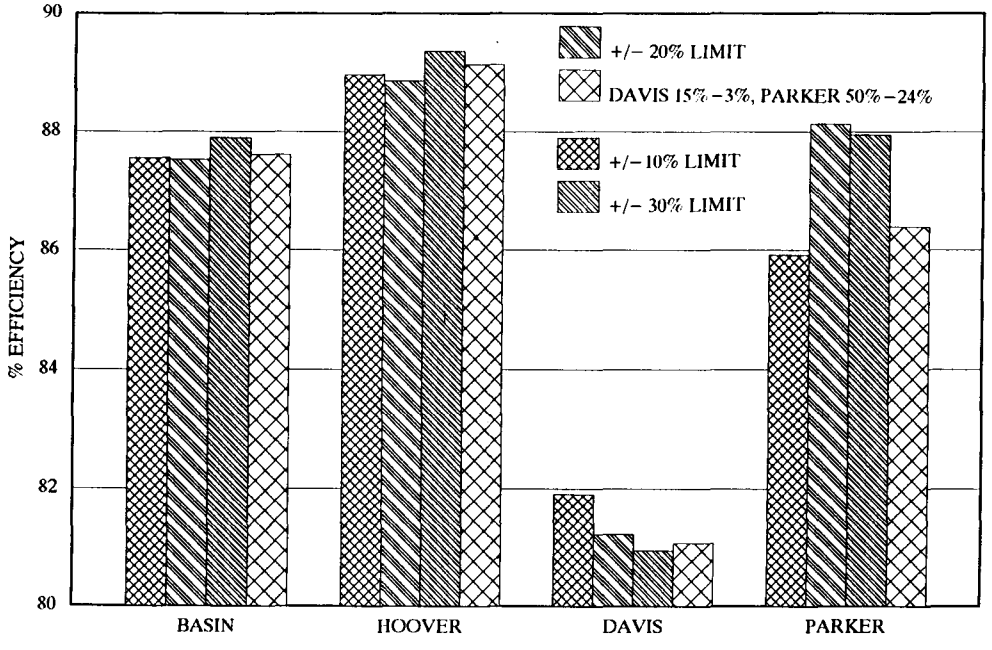

Figure 8. — What's Best Single Cycle Models, Davis and Parker Dams, flows limited—comparison of average efficiencies. (4/17/88)

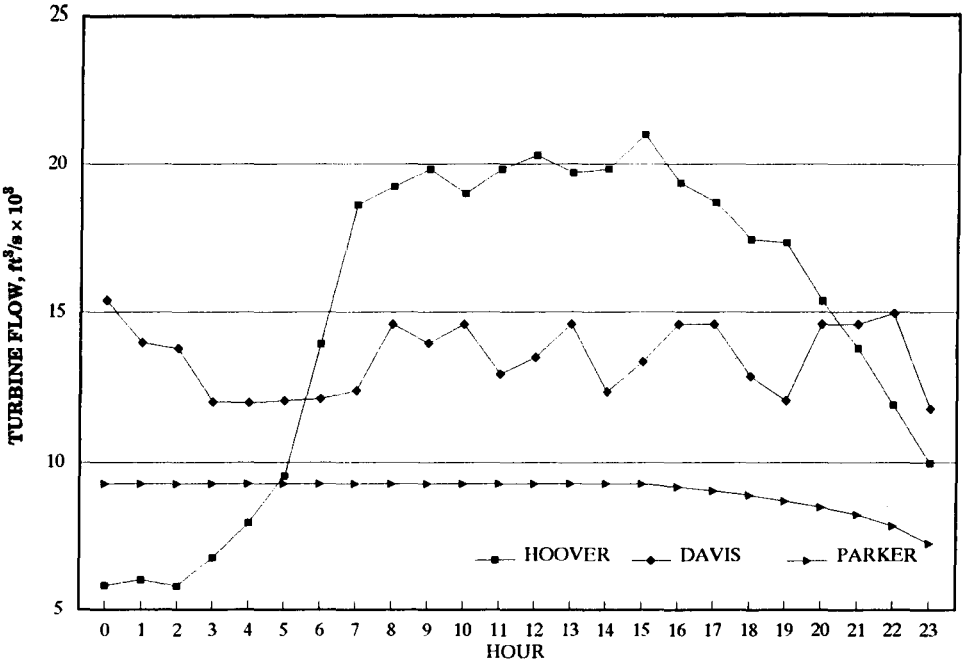

Figure 9. — What's Best Single Cycle Model—flows at Davis and Parker Dams are limited to ±10 percent of the average remaining flow. (4/17/88)

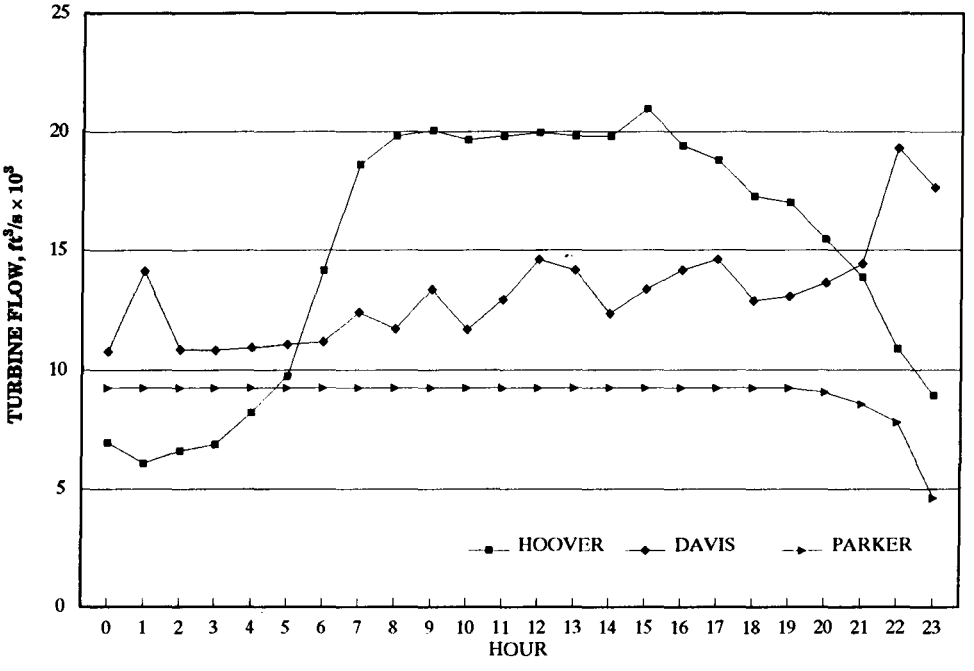

Figure 10. — What's Best Single Cycle Model—flows at Davis and Parker Dams are limited to ±20 percent of the average remaining flow. (4/17/88)

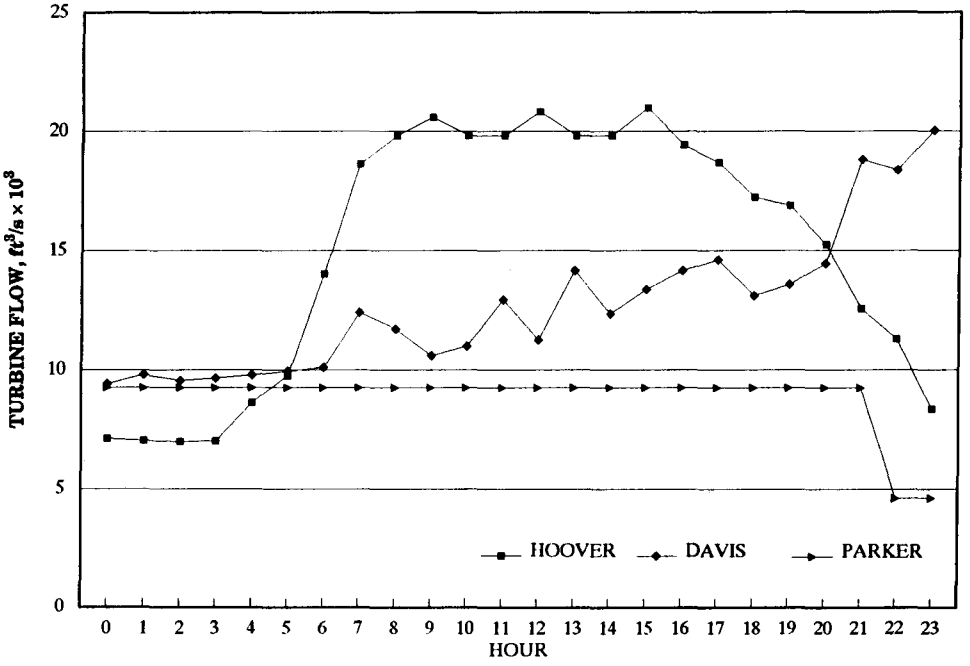

Figure 11. — What's Best Single Cycle Model—Flows at Davis and Parker Dams are limited to ±30 percent of the average remaining flow. (4/17/88)

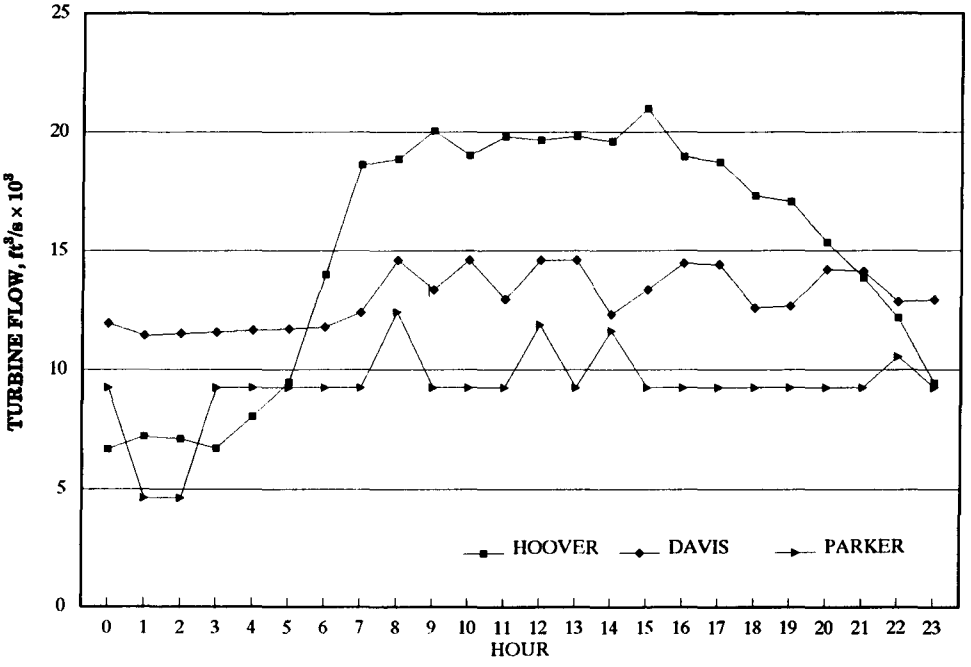

Figure 12. — What's Best Single Cycle Model—Flows at Davis Dam limited to a variable percentage from 15 to 3 percent and flows at Parker Dam limited to a variable percentage from 50 to 24 percent. (4/17/88)

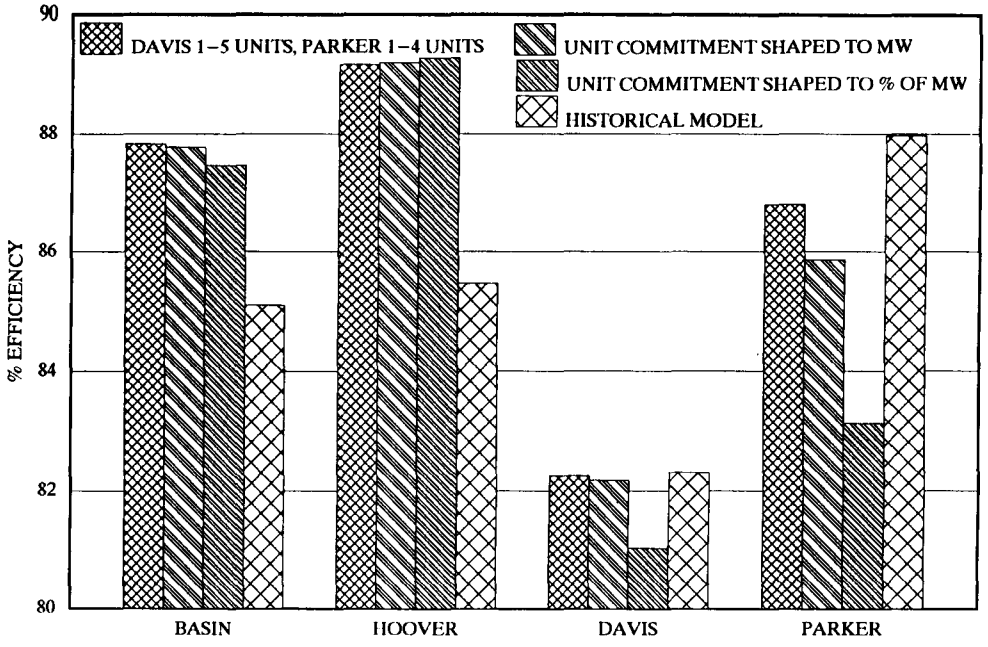

Figure 13. — Lindo Multiple Cycle Model, shaping unit commitment—comparison of average efficiencies. (4/17/88)

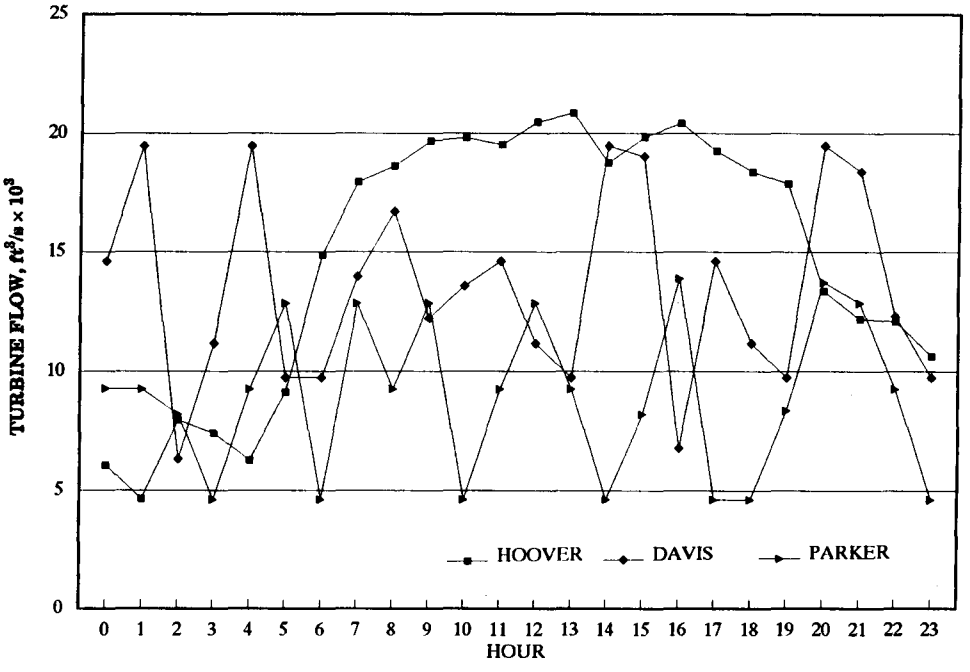

Figure 14. — Lindo Multiple-Hour Model—Davis Dam restricted to 1 to 5 units, Parker Dam restricted to 1 to 4 units. (4/17/88)

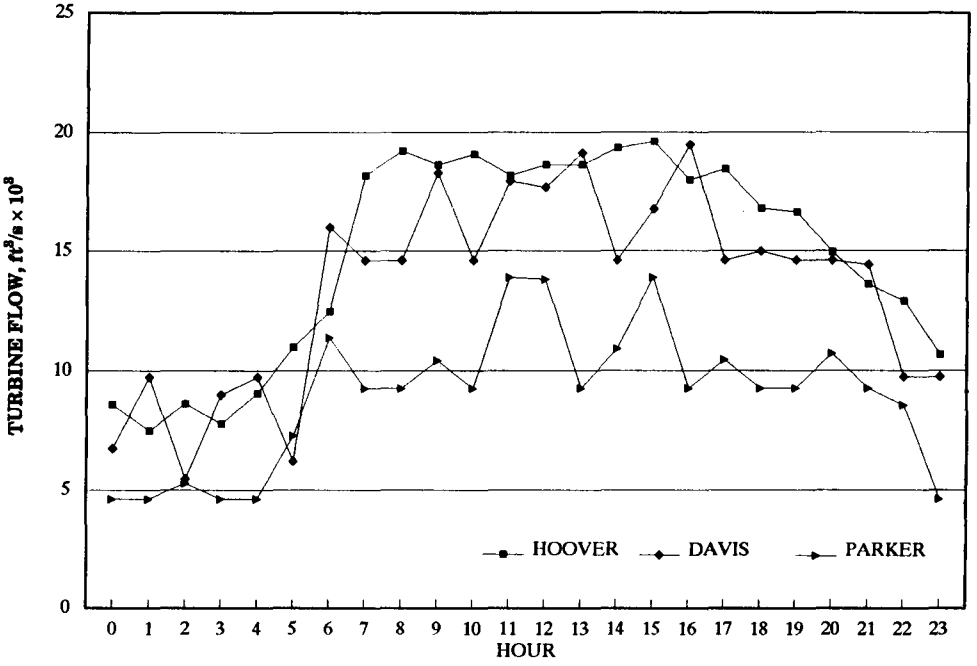

Figure 15. — Lindo Multiple-Hour Model—The number of Davis and Parker Dam units that can operate are restricted according to the generation required. (4/17/88)

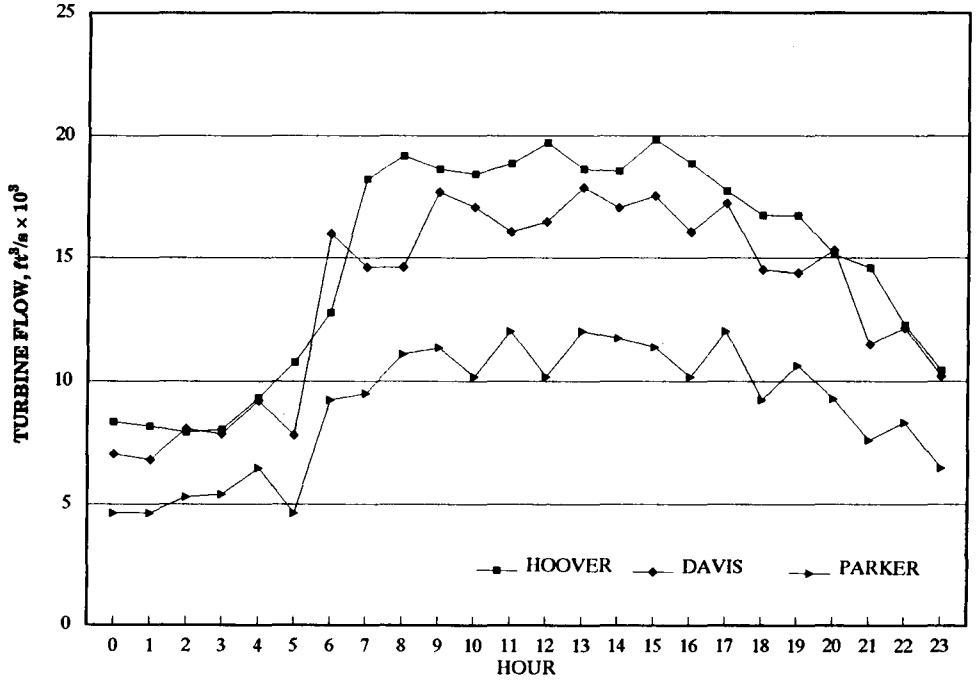

Figure 16. — Lindo Multiple-Hour Model—Davis Dam provided 10 to 20 percent of the generation required and Parker Dam provided 4 to 7 percent of the generation required. (4/17/88)

APPENDIX A

DEVELOPMENT OF GRAND COULEE LINEARIZED FLOW CURVES— Units G1 through G6

Appendix A contains the Matlab plot program generated during the development of the linear curve fitting algorithm.

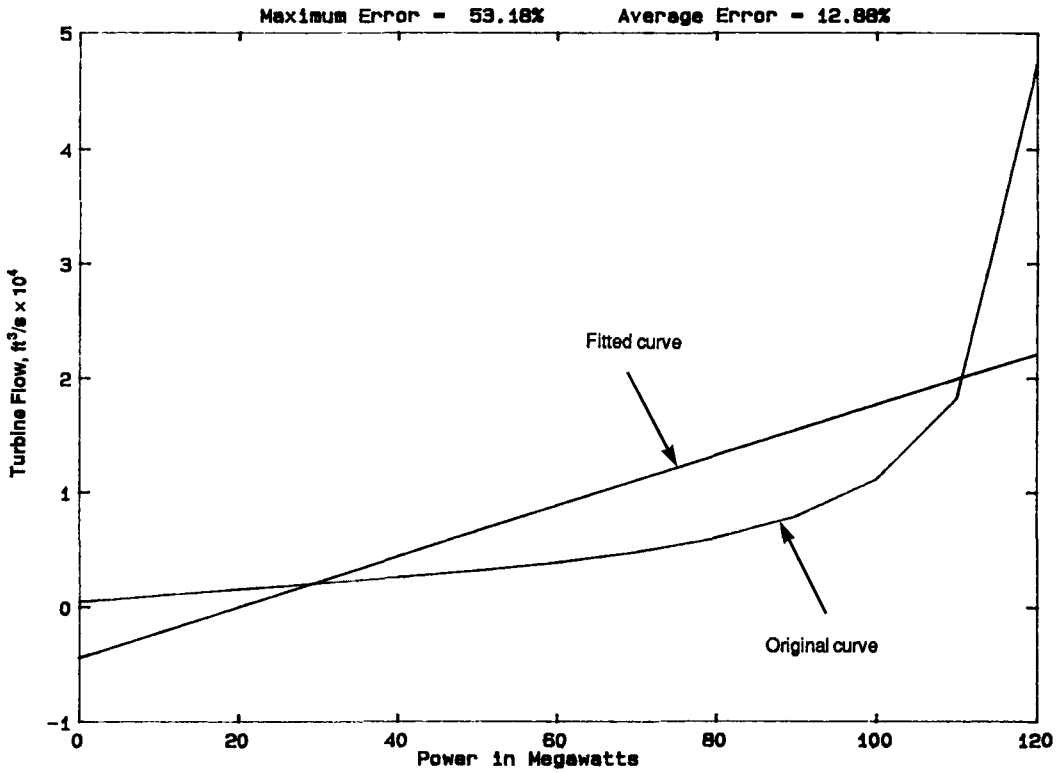

Figure 1A. — Using the first degree polynomial function of Matlab to fit a single linear curve to (units G1 through G6) turbine flow curves for a head of 220 feet (sheet 1 of 3).

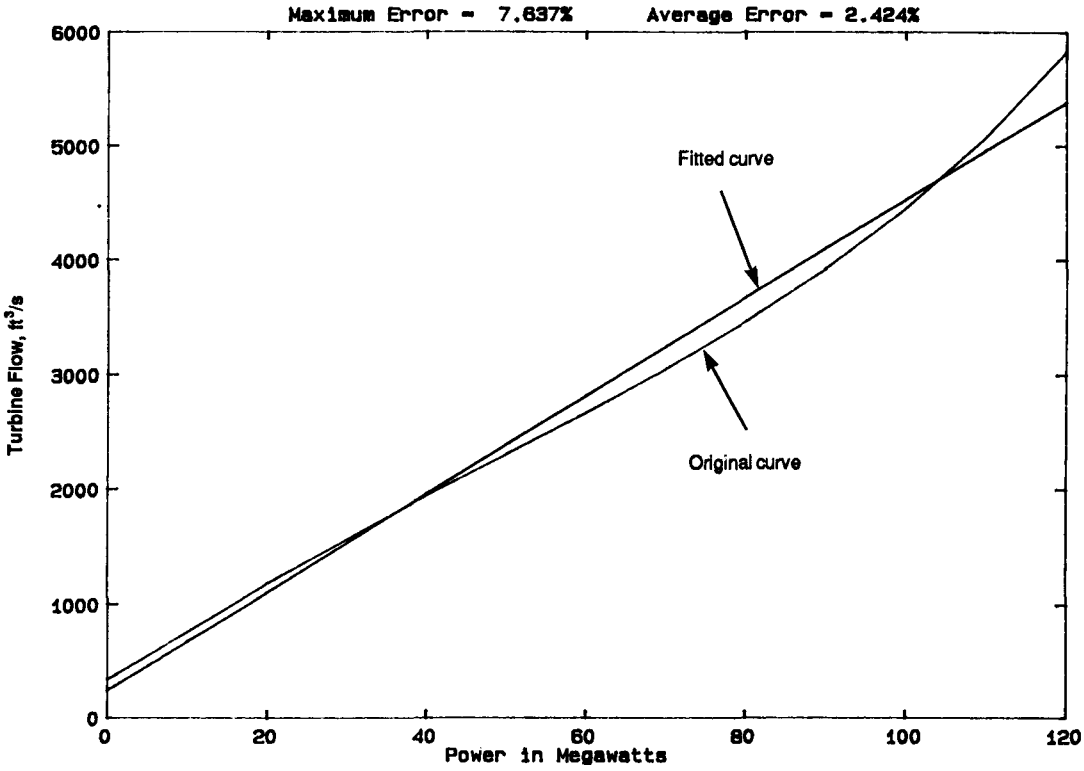

Figure 1A. — Using the first degree polynomial function of Matlab to fit a single linear curve to (units G1 through G6) turbine flow curves for a head of 300 feet (sheet 2 of 3).

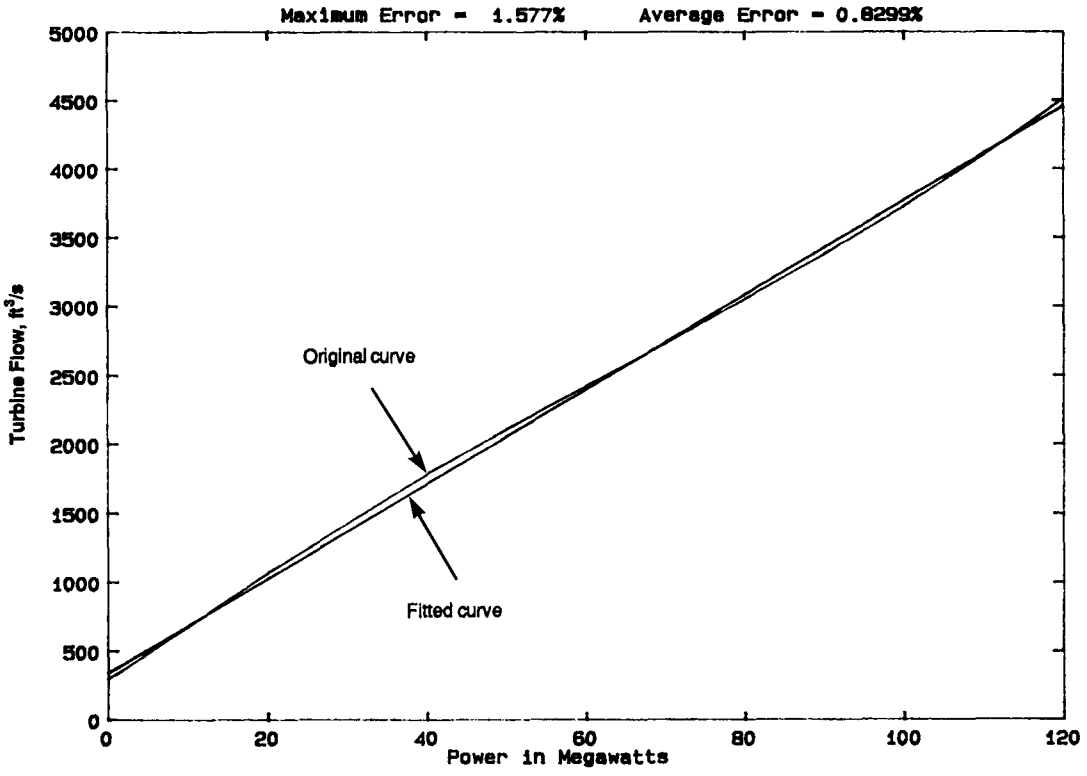

Figure 1A. — Using the first degree polynomial function of Matlab to fit a single linear curve to (units G1 through G6) turbine flow curves for a head of 360 feet (sheet 3 of 3).

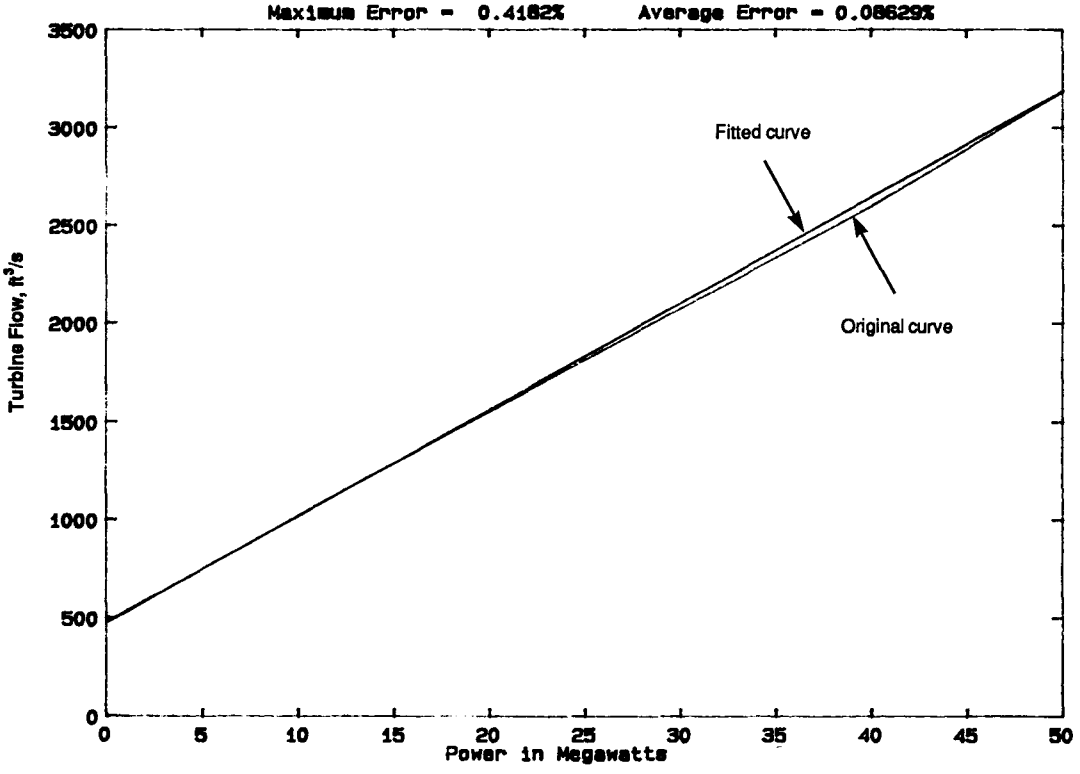

Figure 2A. — Fitting turbine flow curves (units G1 through G6) from speed-no-load to maximum efficiency load for a head of 220 feet (sheet 1 of 5).

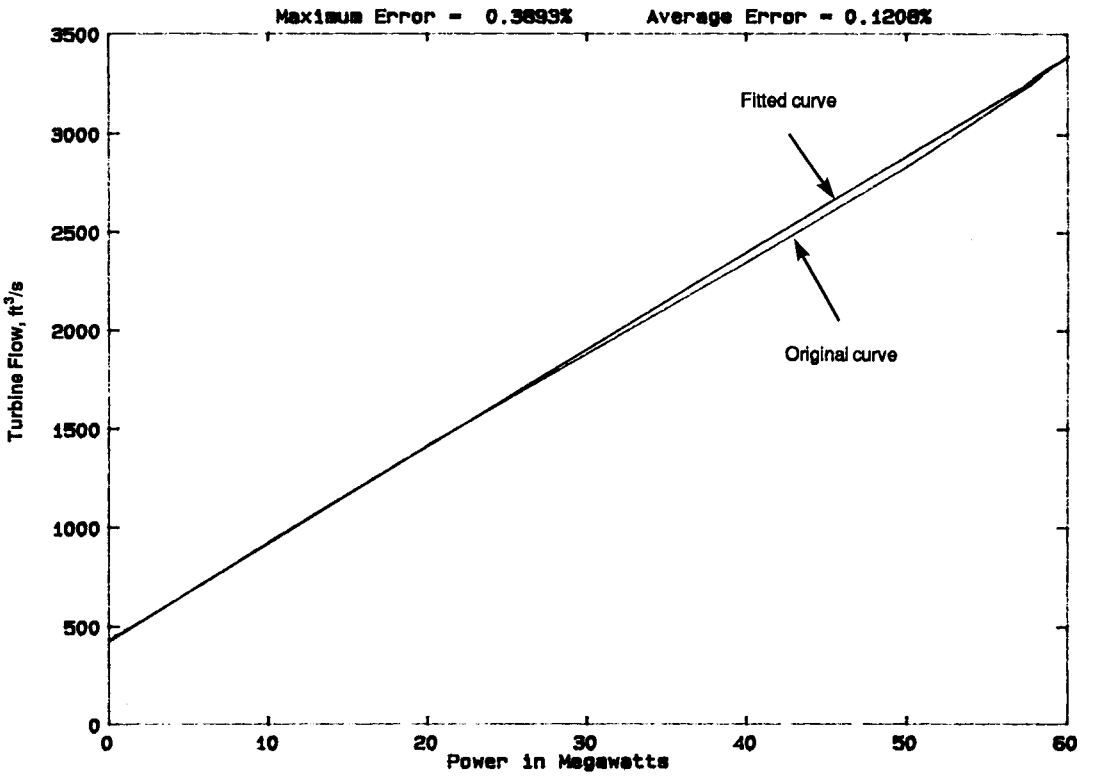

Figure 2A. — Fitting turbine flow curves (units G1 through G6) from speed-no-load to maximum efficiency load for a head of 240 feet (sheet 2 of 5).

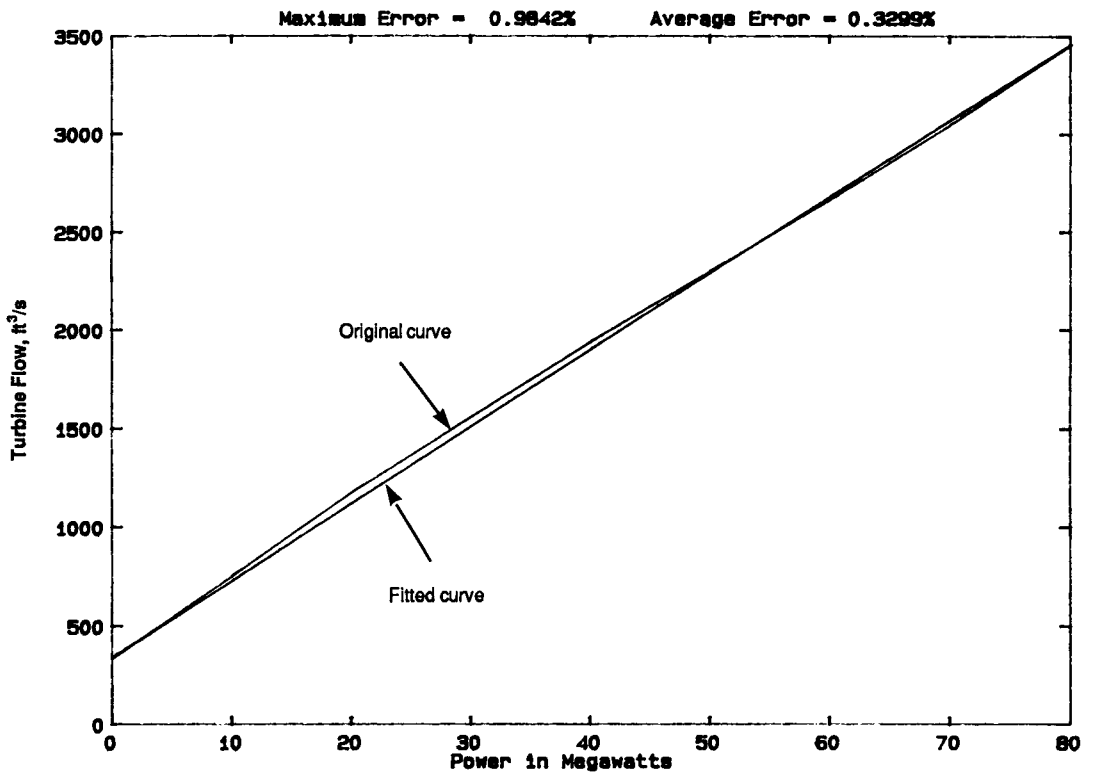

Figure 2A. — Fitting turbine flow curves (units G1 through G6) from speed-no-load to maximum efficiency load for a head of 300 feet (sheet 3 of 5).

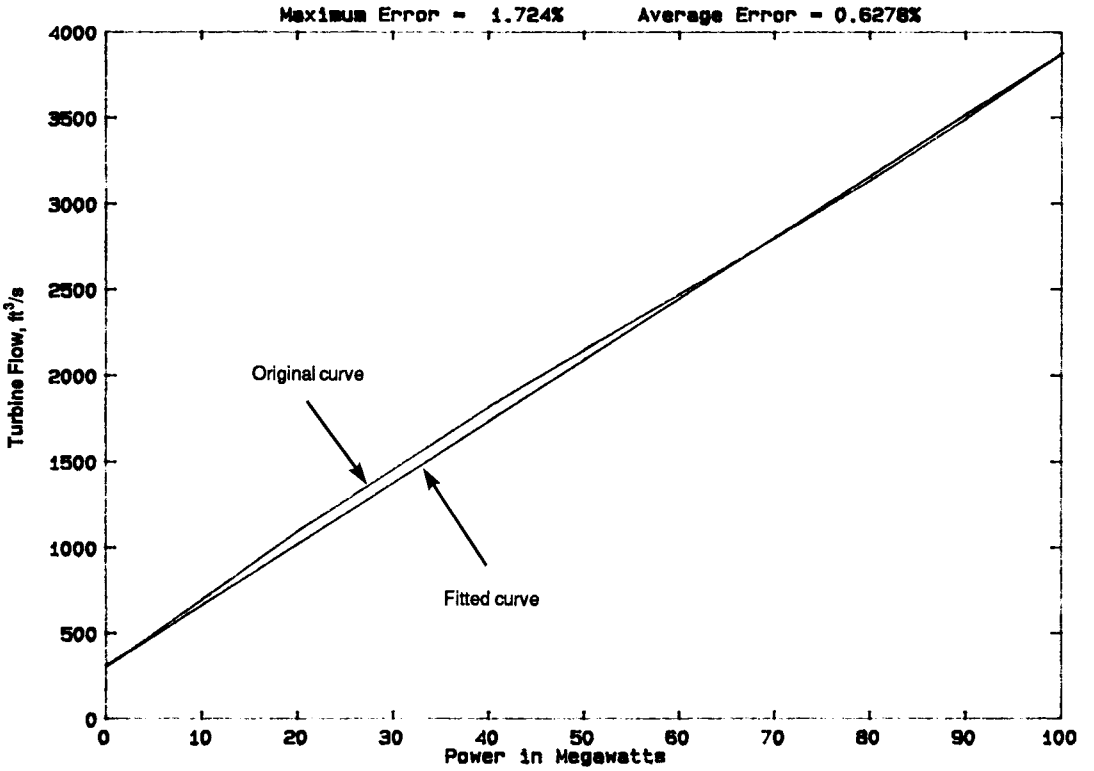

Figure 2A. — Fitting turbine flow curves (units G1 through G6) from speed-no-load to maximum efficiency load for a head of 240 feet (sheet 2 of 5).

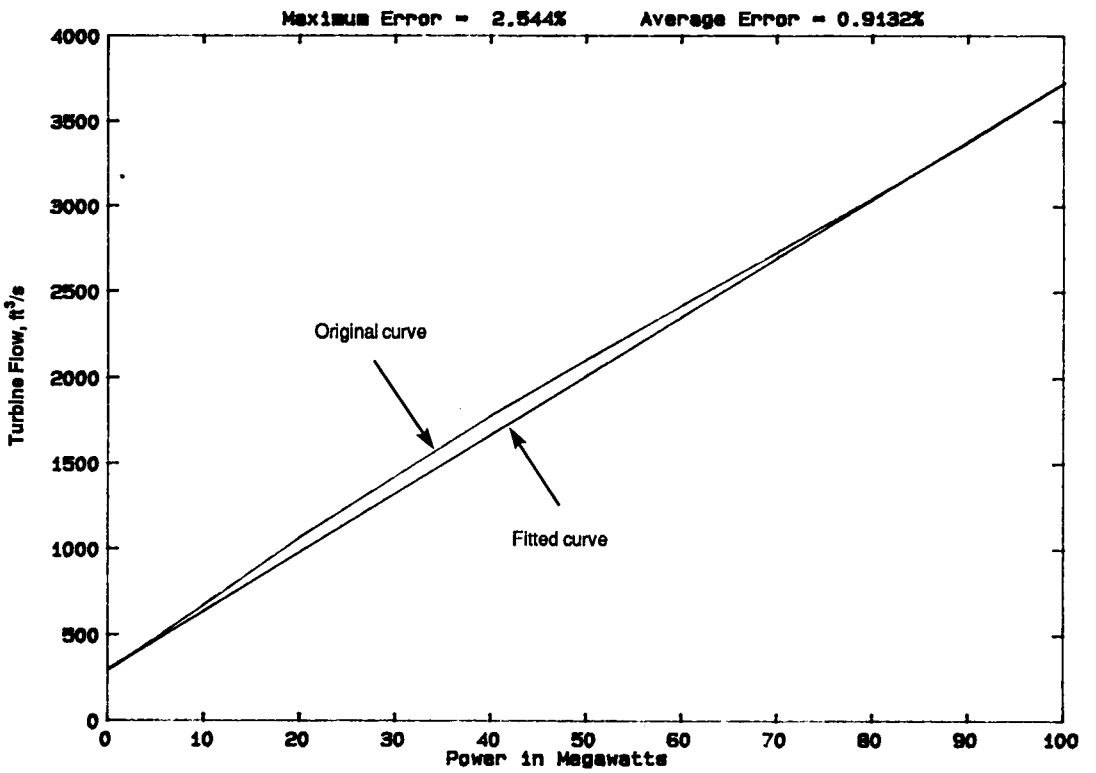

Figure 2A. — Fitting turbine flow curves (units G1 through G6) from speed-no-load to maximum efficiency load for a head of 360 feet (sheet 5 of 5).

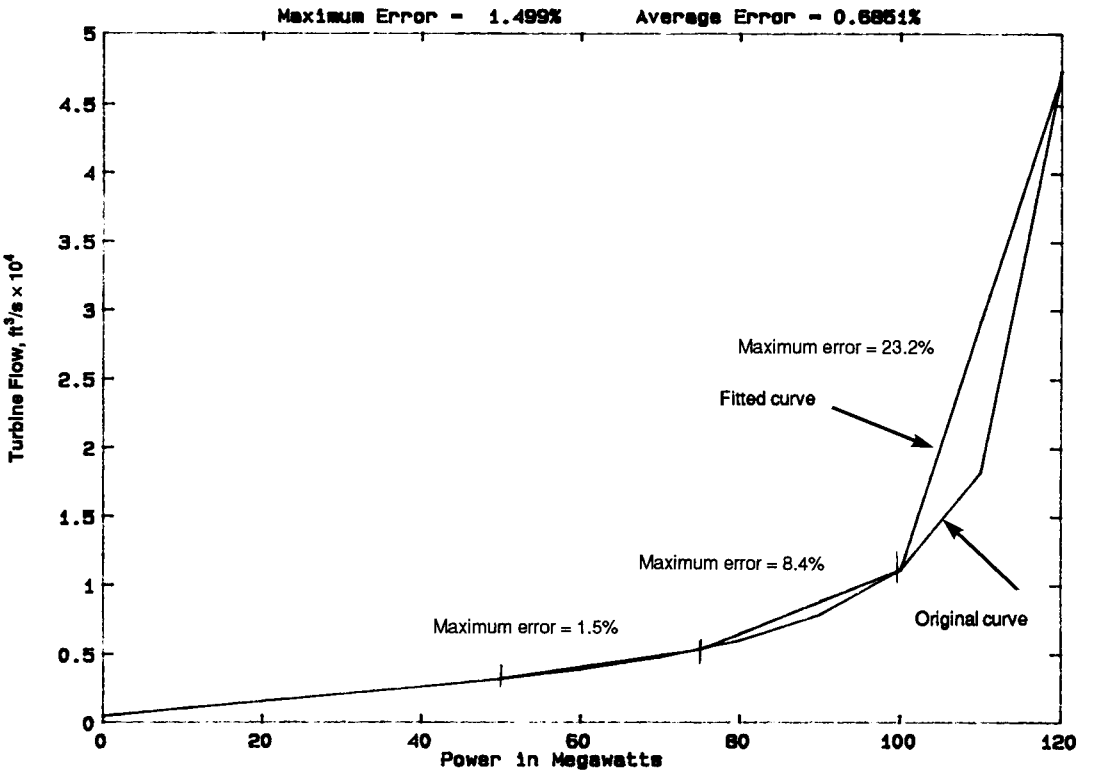

Figure 3A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 50 percent of maximum efficiency load for a head of 220 feet (sheet 1 of 3).

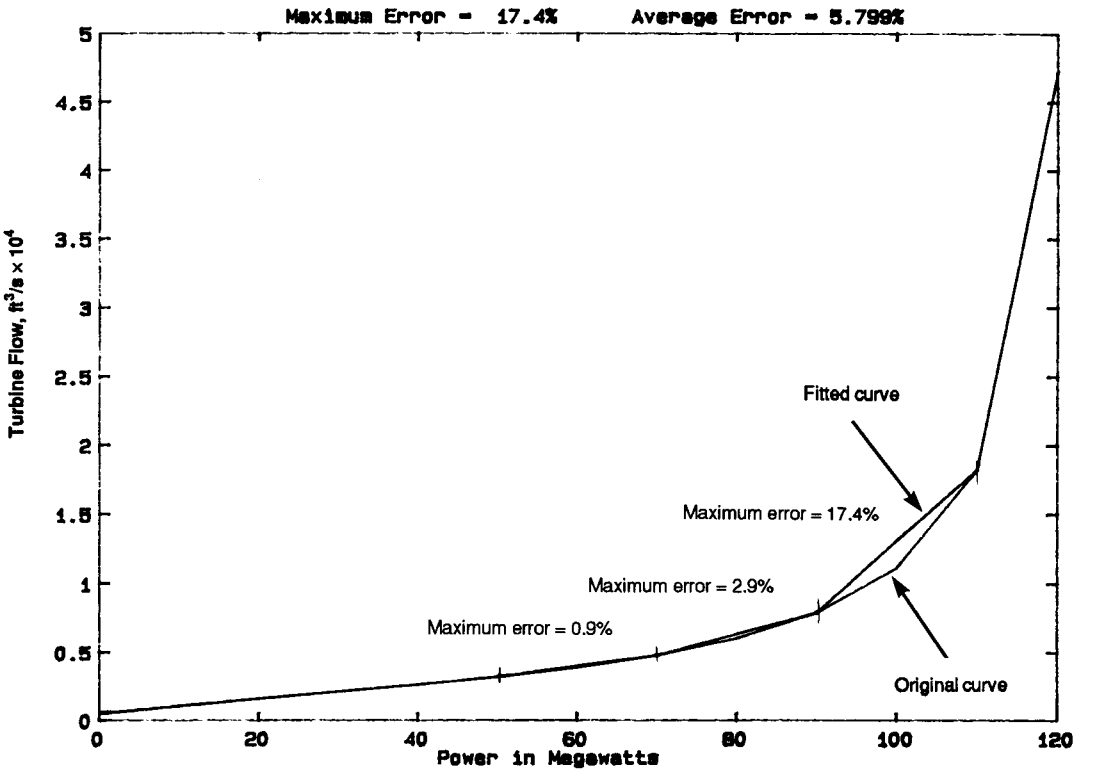

Figure 4A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 40 percent of maximum efficiency load for a head of 220 feet (sheet 1 of 3).

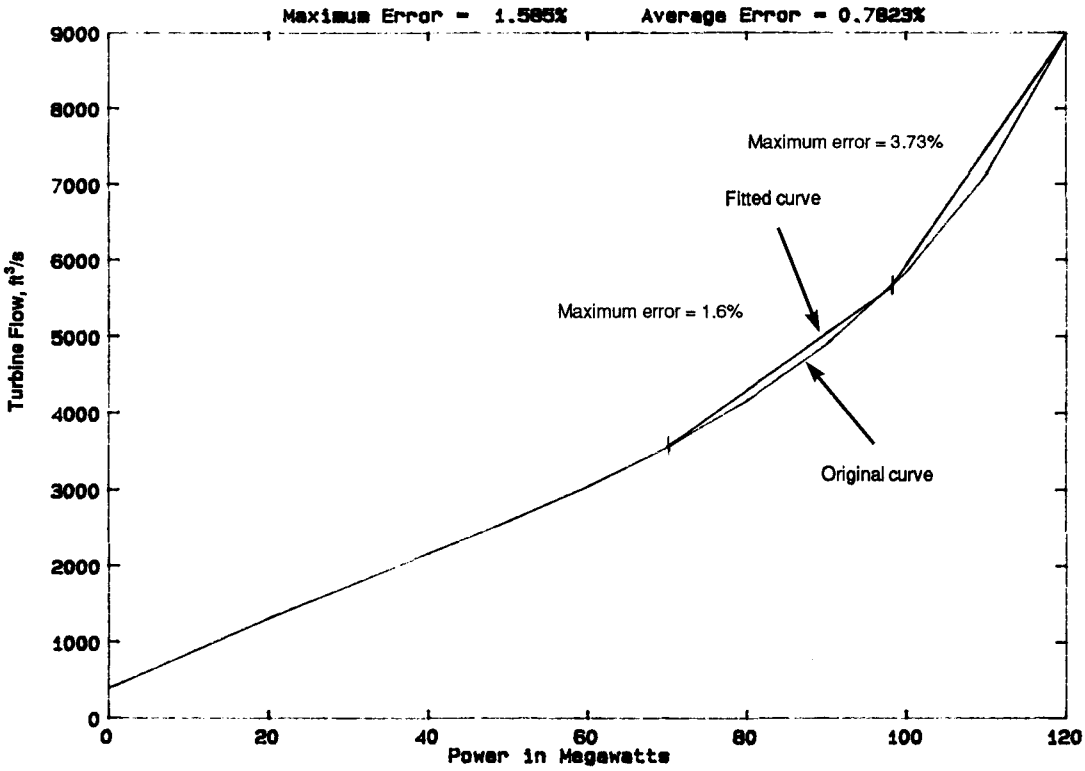

Figure 4A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 40 percent of maximum efficiency load for a head of 260 feet (sheet 2 of 3).

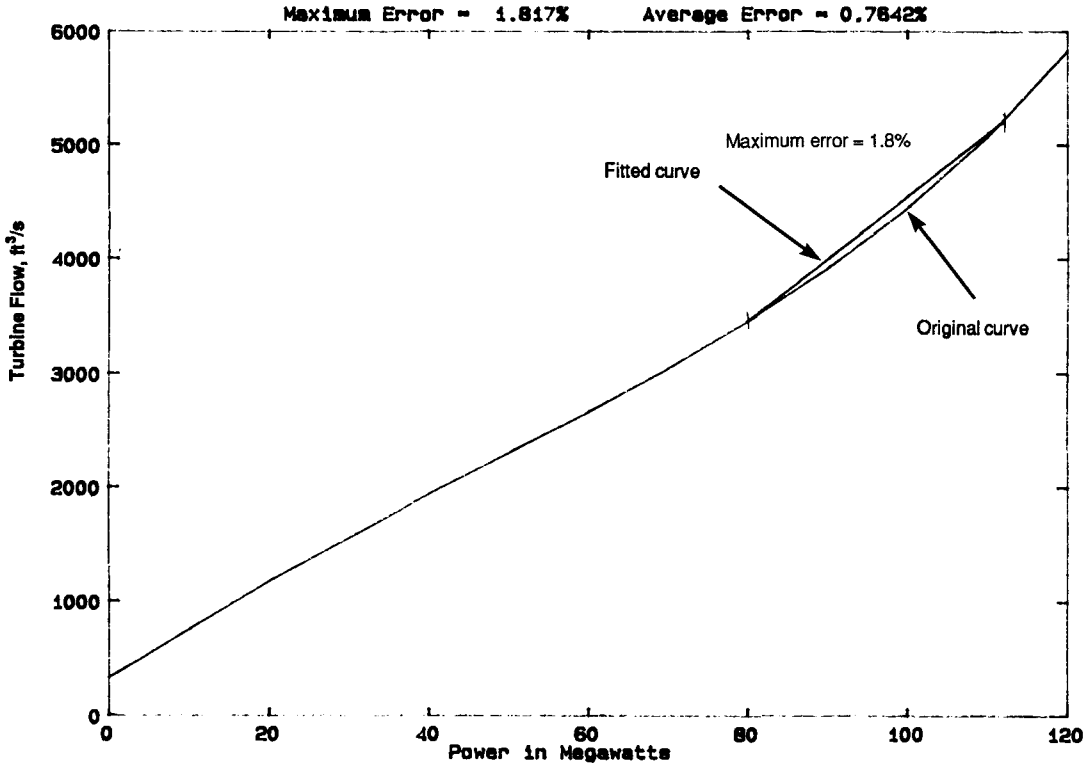

Figure 4A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 40 percent of maximum efficiency load for a head of 300 feet (sheet 3 of 3).

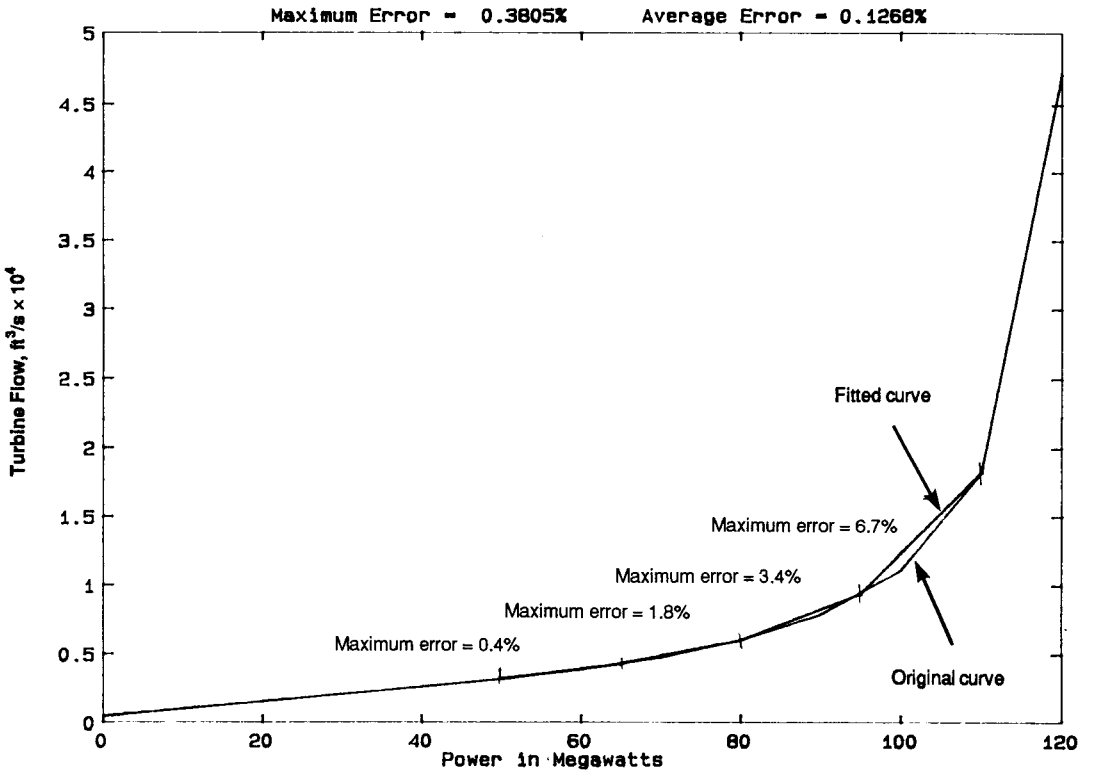

Figure 5A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 30 percent of maximum efficiency load for a head of 220 feet (sheet 1 of 3).

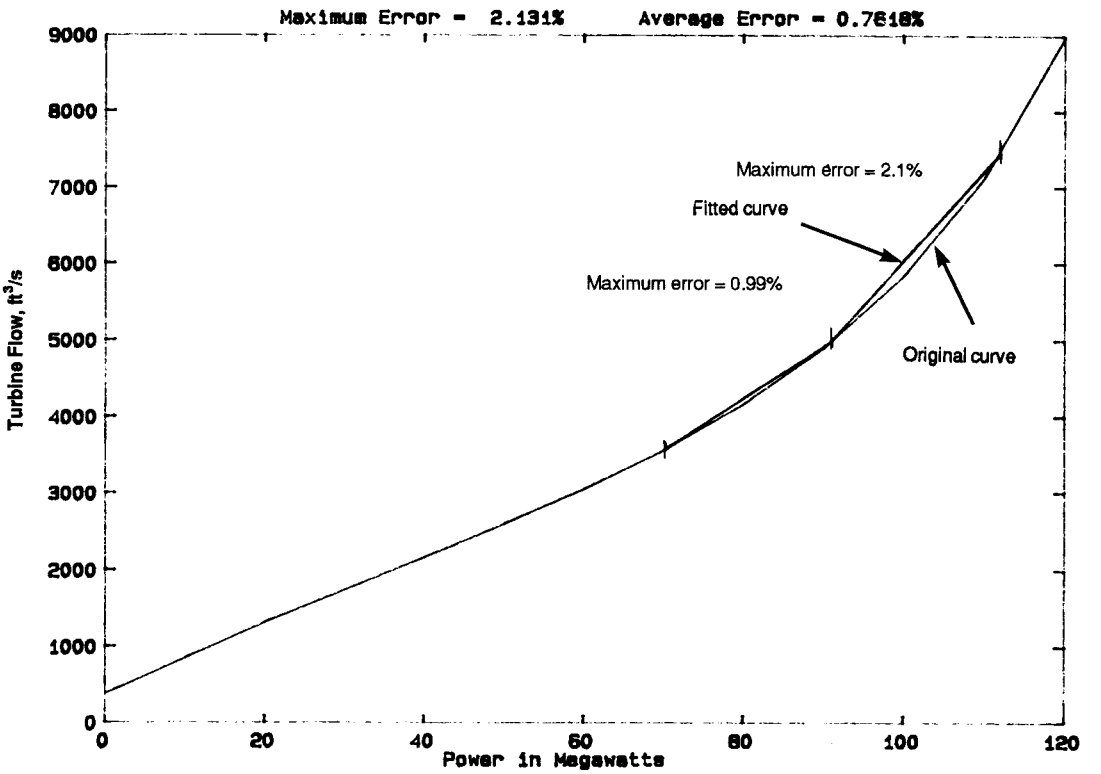

Figure 5A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 30 percent of maximum efficiency load for a head of 260 feet (sheet 2 of 3).

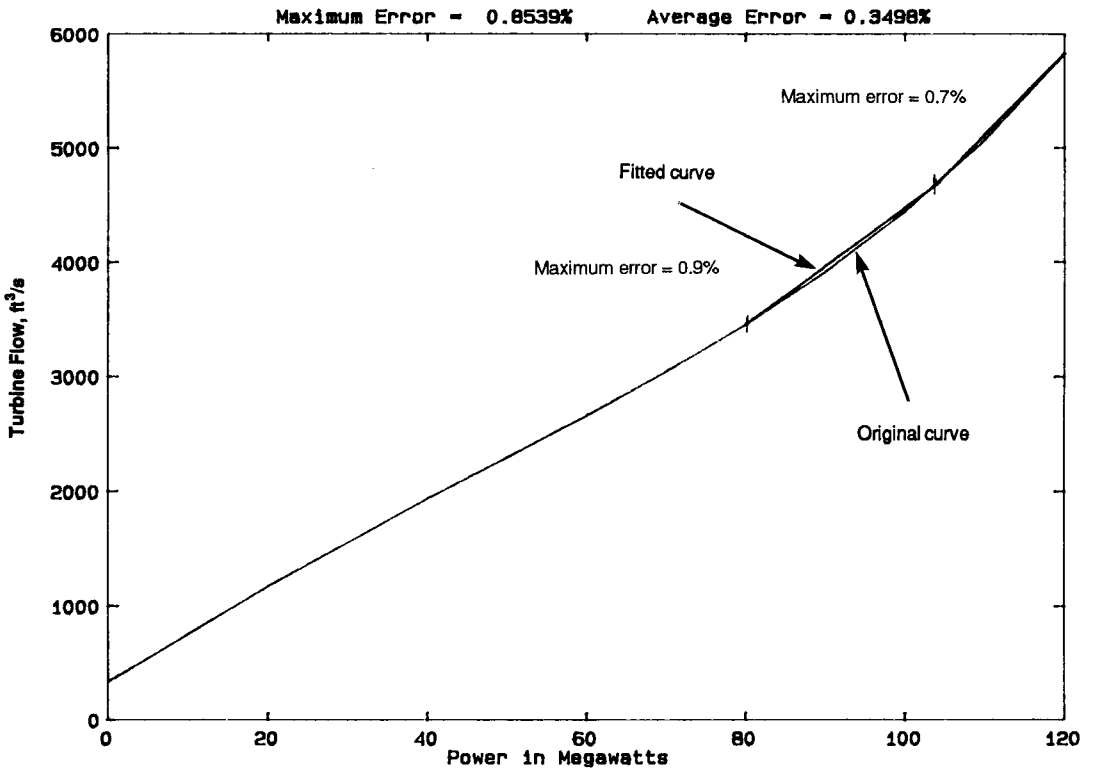

Figure 5A. — Fitting turbine flow curves (units G1 through G6) past maximum efficiency load for 30 percent of maximum efficiency load for a head of 300 feet (sheet 3 of 3).

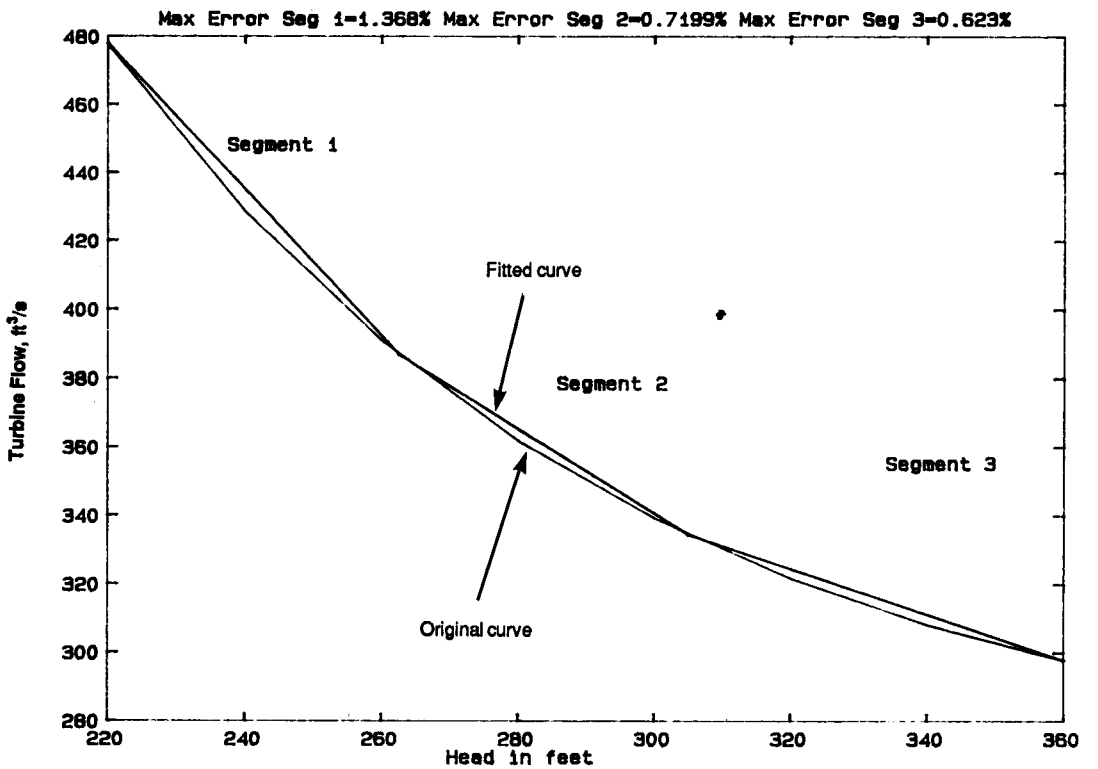

Figure 6A. — Fitting head versus turbine flow curves (units G1 through G6) in three linear segments for 0 MW (sheet 1 of 2).

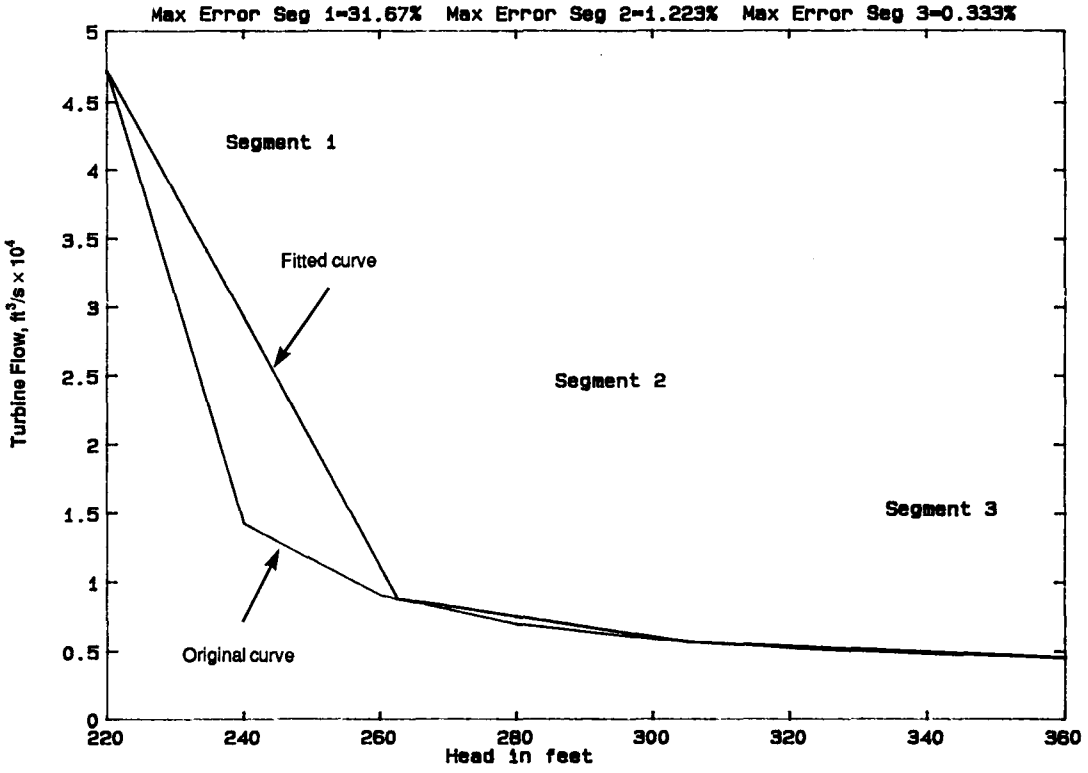

Figure 6A. — Fitting head versus turbine flow curves (units G1 through G6) in three linear segments for 120 MW (sheet 2 of 2).

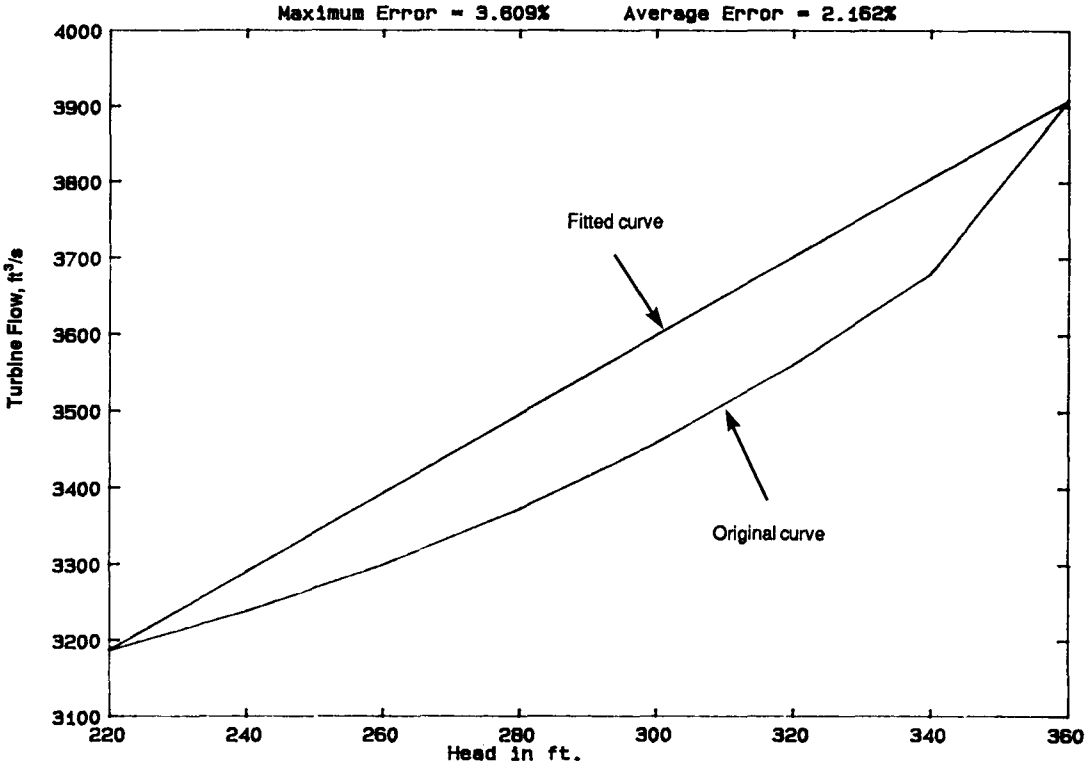

Figure 7A. — The curve is head versus flow (units G1 through G6) at maximum efficiency load for that value of head. The curves are fit in one or two segments (sheet 1 of 2).

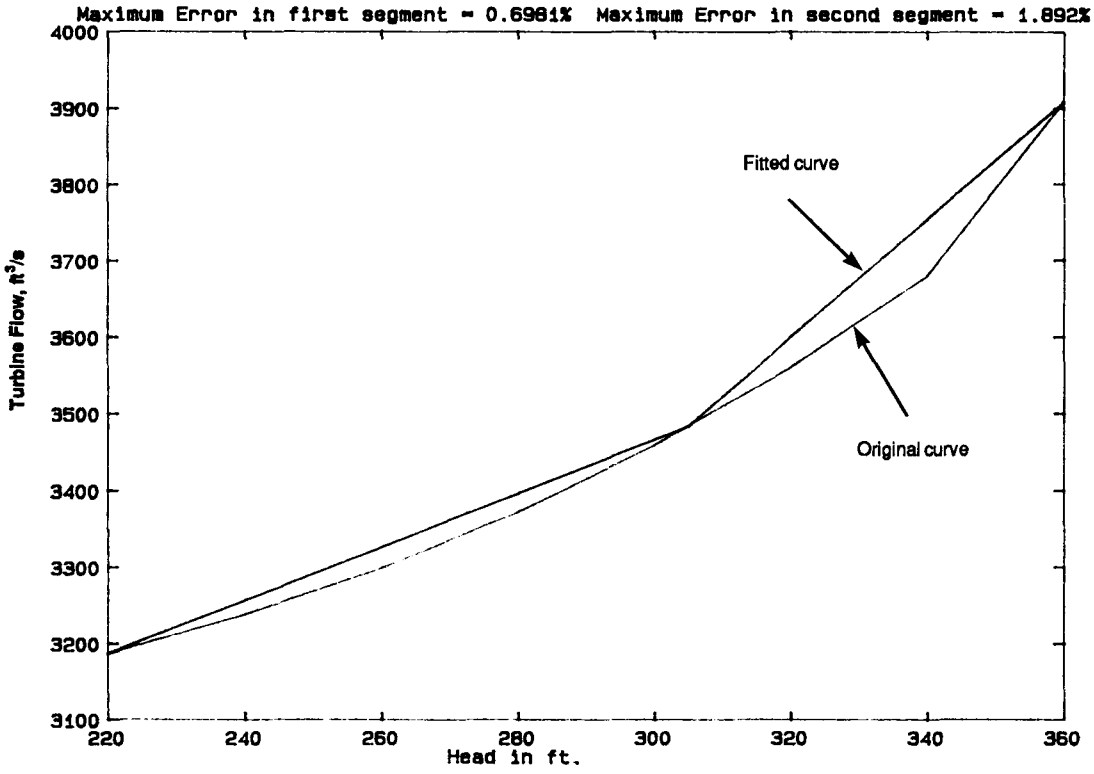

Figure 7A. — The curve is head versus flow (units G1 through G6) at maximum efficiency load for that value of head. The curves are fit in one or two segments (sheet 2 of 2).

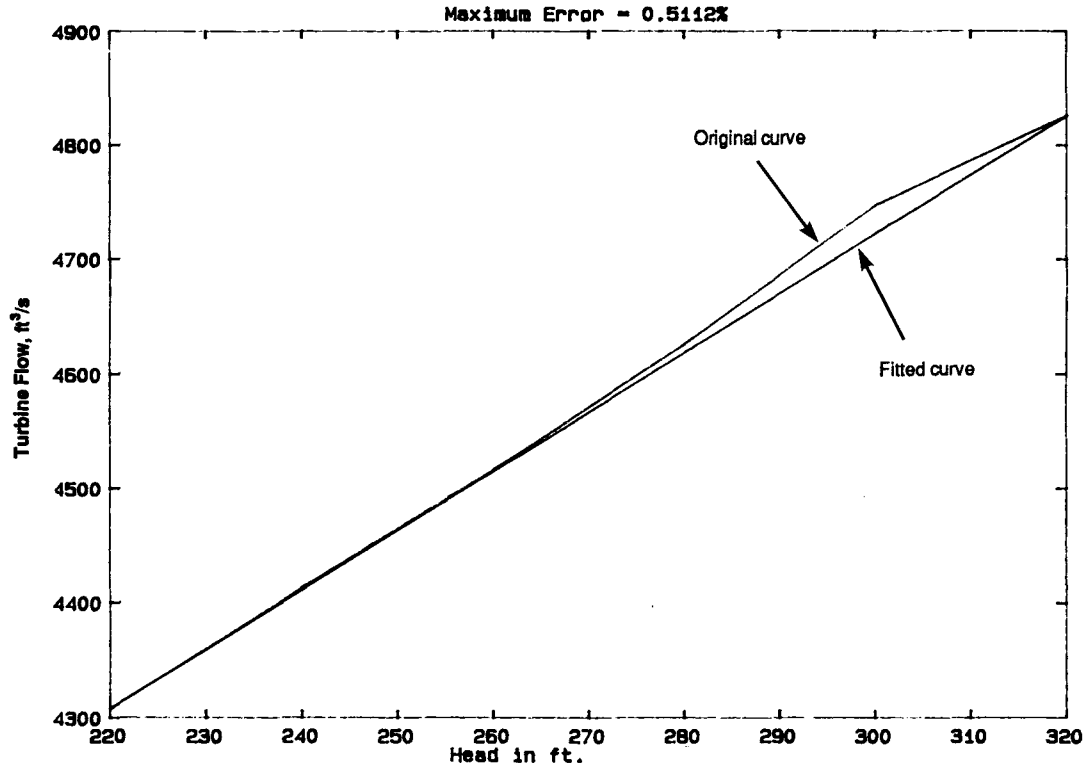

Figure 8A. — The curve is head versus the flow (units G1 through G6) at 130 percent maximum efficiency load for that value of head. The curve is fit in one linear segment.

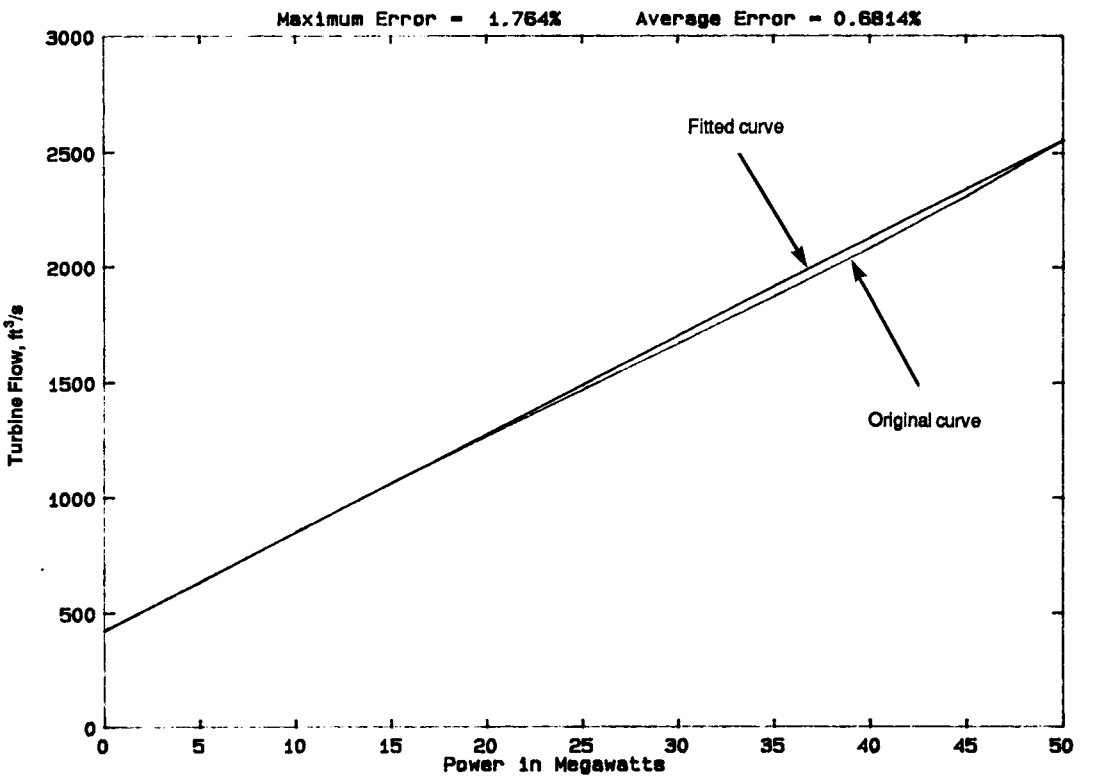

Figure 9A. — Fitting turbine flow curves (pump-generator units P/G 7 and 8) to maximum efficiency load for a head of 260 feet (sheet 1 of 3).

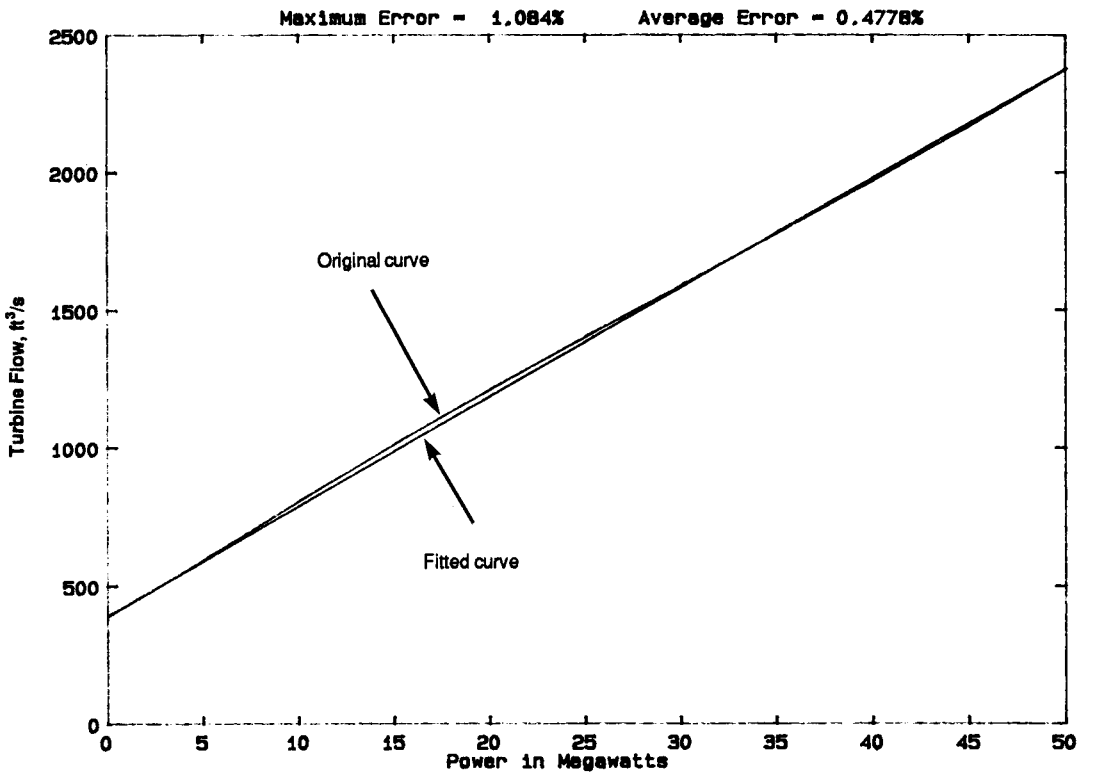

Figure 9A. — Fitting turbine flow curves (pump-generator units P/G 7 and 8) to maximum efficiency load for a head of 280 feet (sheet 2 of 3).

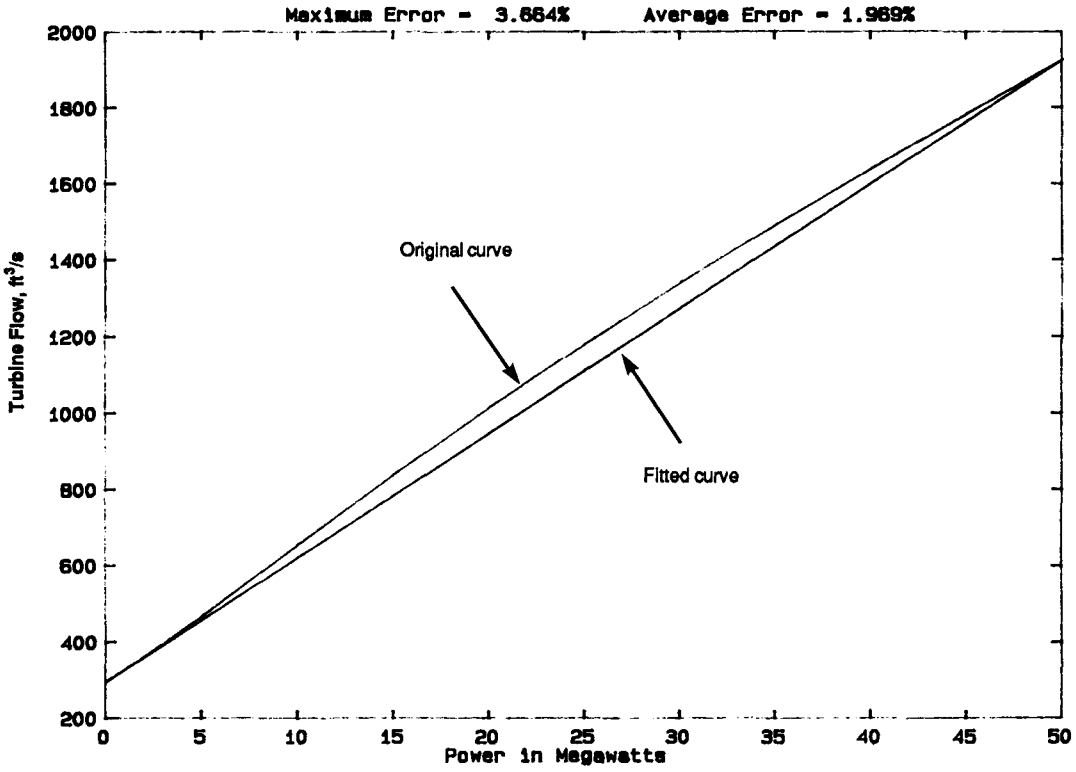

Figure 9A. — Fitting turbine flow curves (pump-generator units P/G 7 and 8) to maximum efficiency load for a head of 370 feet (sheet 3 of 3).

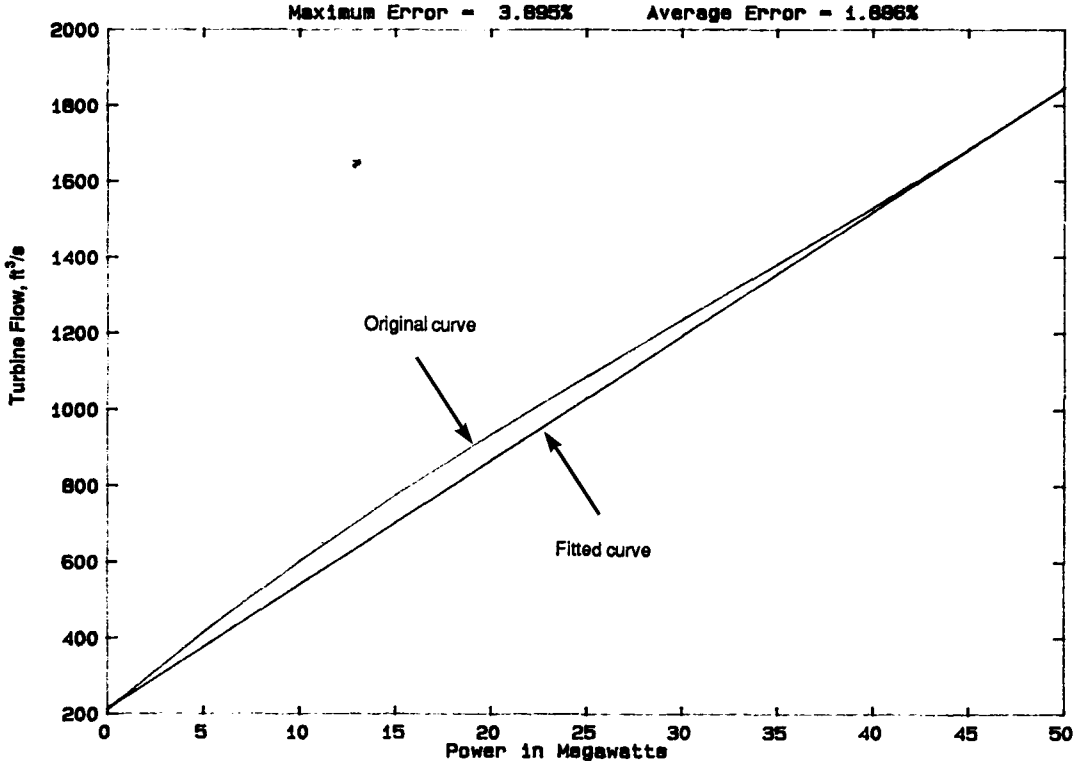

Figure 10A. — Fitting turbine flow curves (pump-generator units P/G 9-12) to maximum efficiency load for a head of 370 feet.

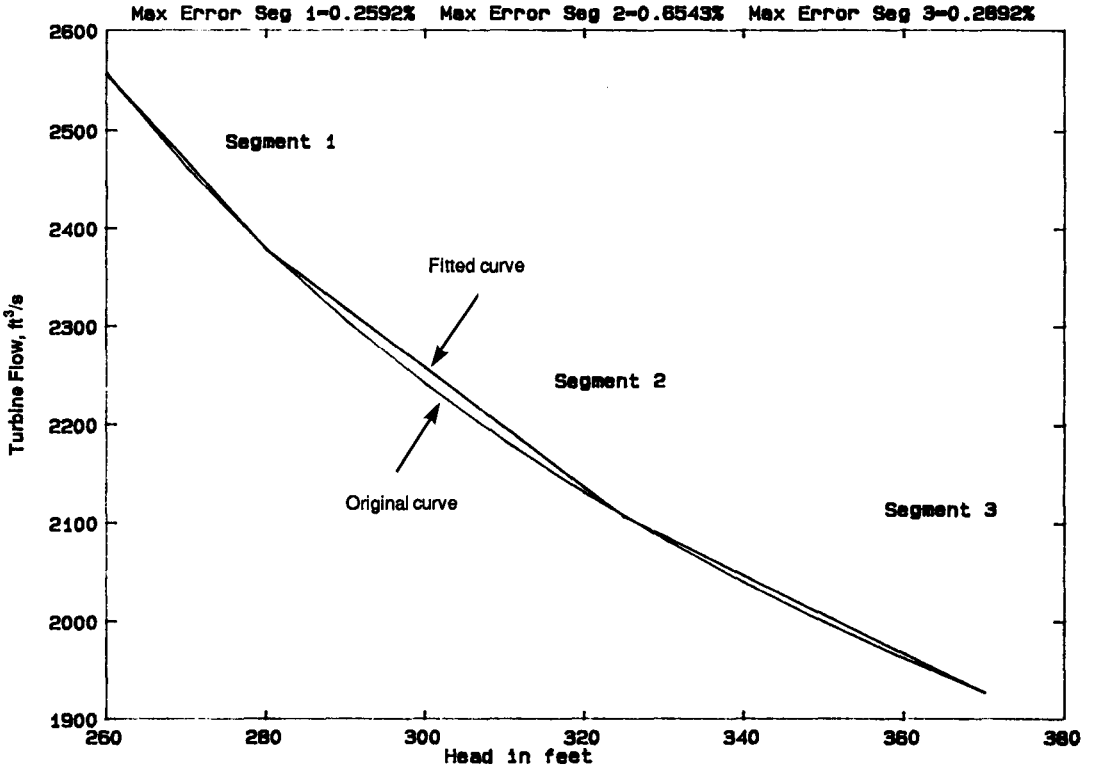

Figure 11A. — Fitting head versus turbine flow curves (pump-generator units P/G 7 and 8) in three linear segments at 50 MW.

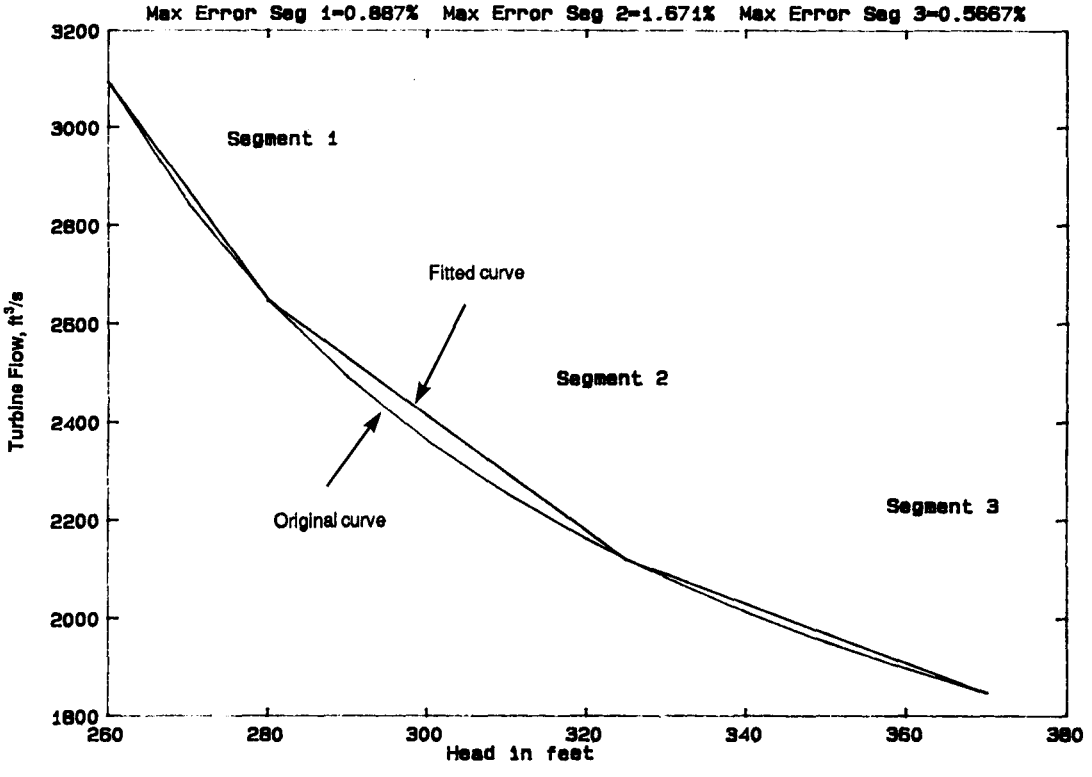

Figure 12A. — Fitting head versus turbine flow curves (pump-generator units P/G 9-12) in three linear segments at 50 MW.

APPENDIX B

LOWER COLORADO RIVER BASIN LINEAR TURBINE FLOW CURVES

Appendix B contains the linearized Lower Colorado Basin turbine flow curves that produced errors of greater than 2 percent using the curve fitting algorithm.

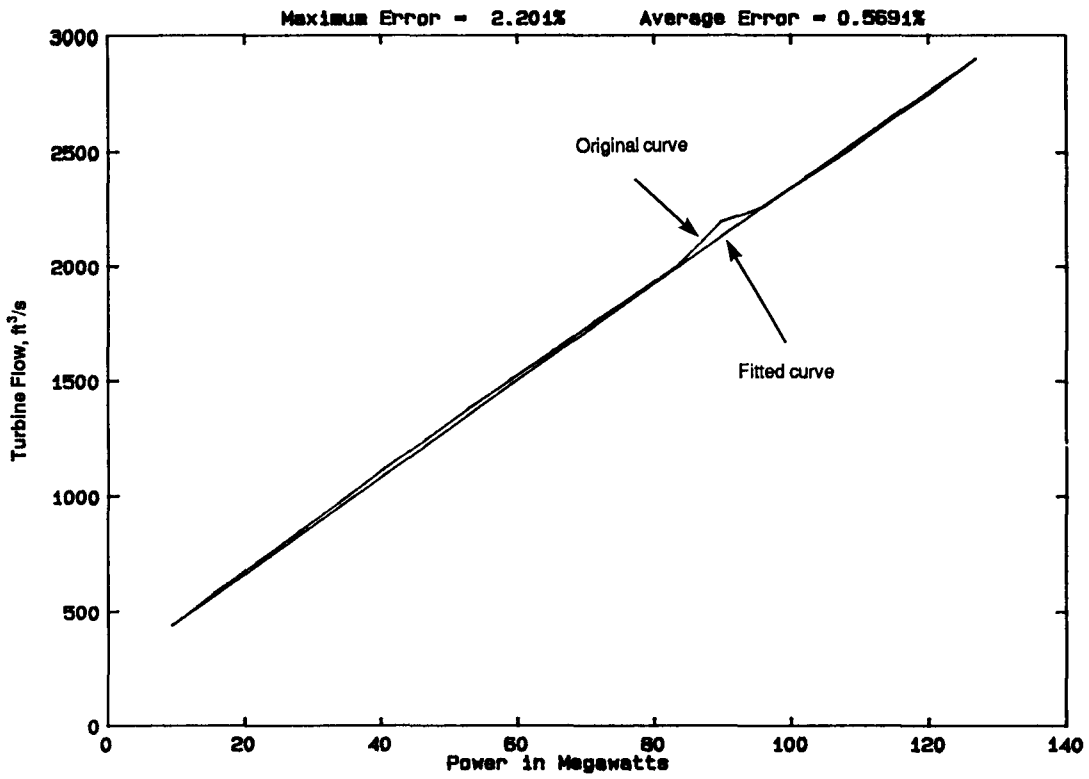

Figure 1B. — Fitting turbine flow curve (unit A5) in a single segment at a head of 552.47 feet.

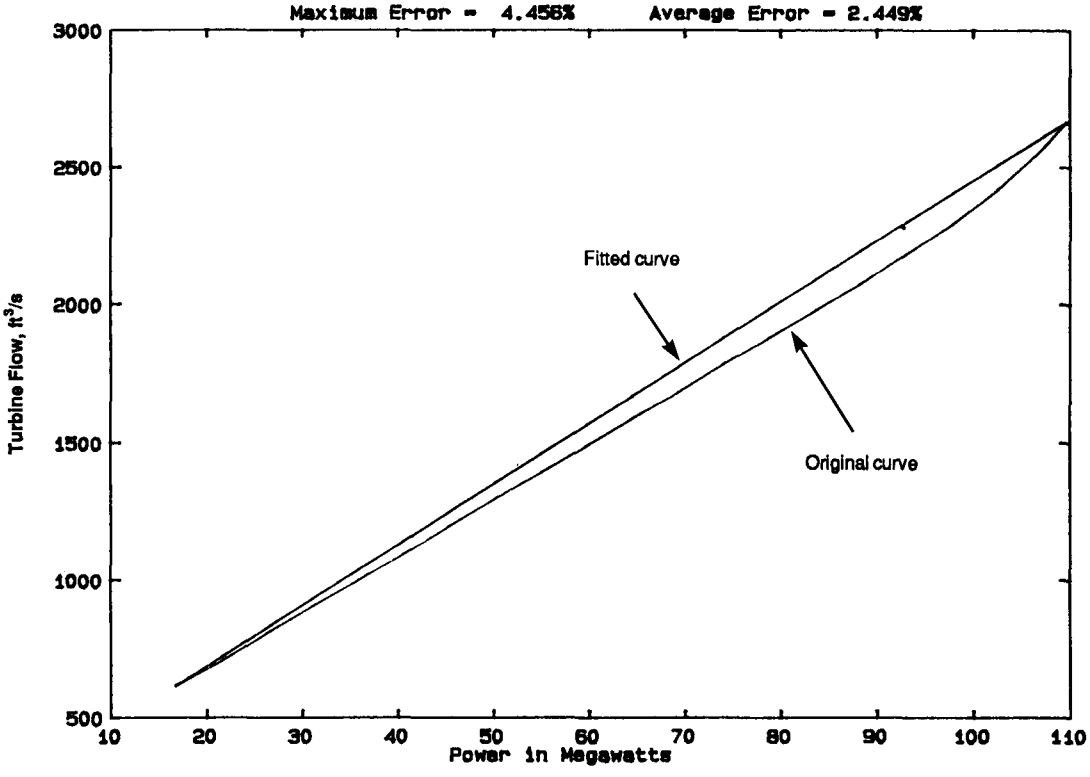

Figure 2B. — Fitting turbine flow curve (unit N8) to maximum efficiency load at a head of 552.47 feet (sheet 1 of 2).

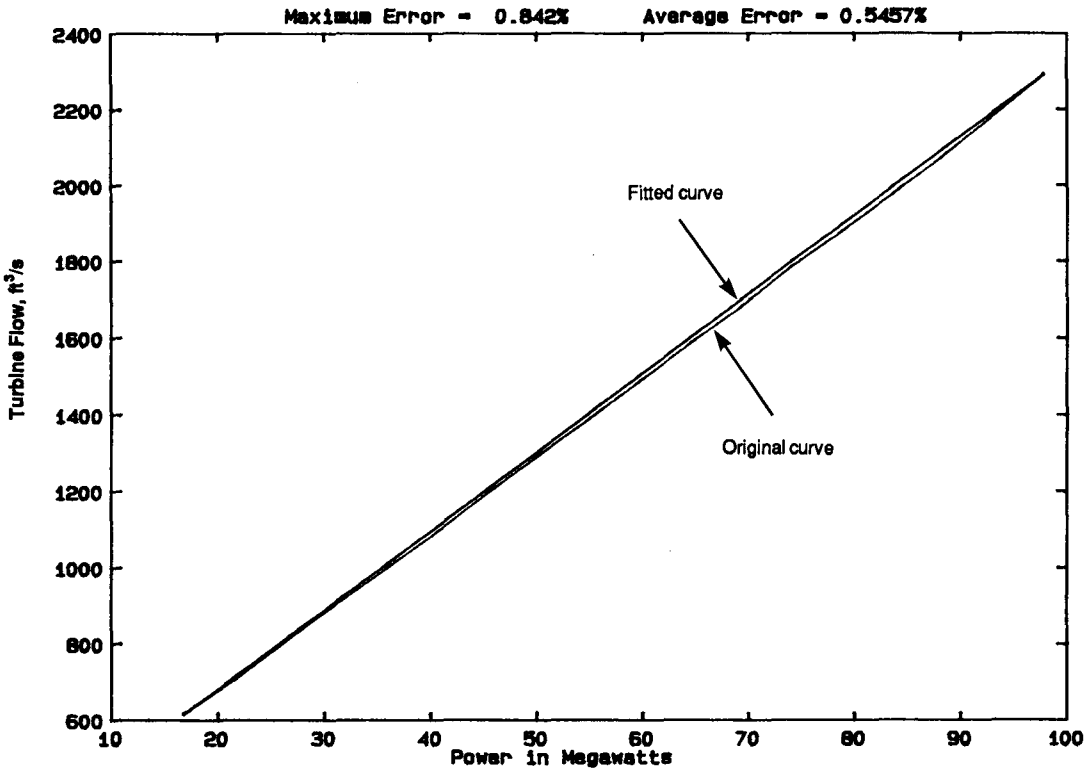

Figure 2B. — Fitting turbine flow curve (unit N8) to maximum efficiency load at a head of 552.47 feet (sheet 2 of 2).

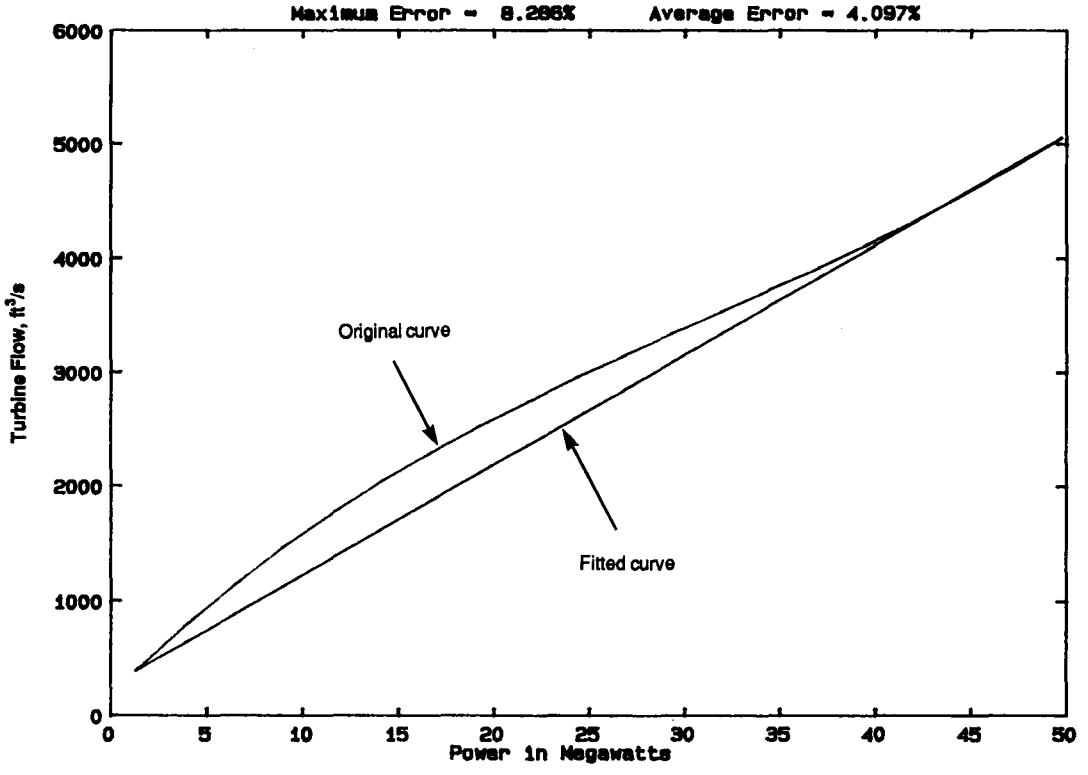

Figure 3B. — Fitting turbine flow curves (units D1 through D5) in a single segment at a head of 139.57 feet.

APPENDIX C

RUNNER REPLACEMENT TEST AT DAVIS DAM

A test using the What's Best 24-Hour Single Cycle Model was done to show the increase in efficiency that could be achieved by replacing the turbine runners at Davis Dam. The slope of Davis turbine flow curves was changed to represent this improvement. Figure 1C shows a comparison of the average efficiency between the original runners and the upgraded runners. This test shows that the Basin average efficiency can be increased by 1 percent if the suggested upgrading the Davis Dam turbine runners occurs.

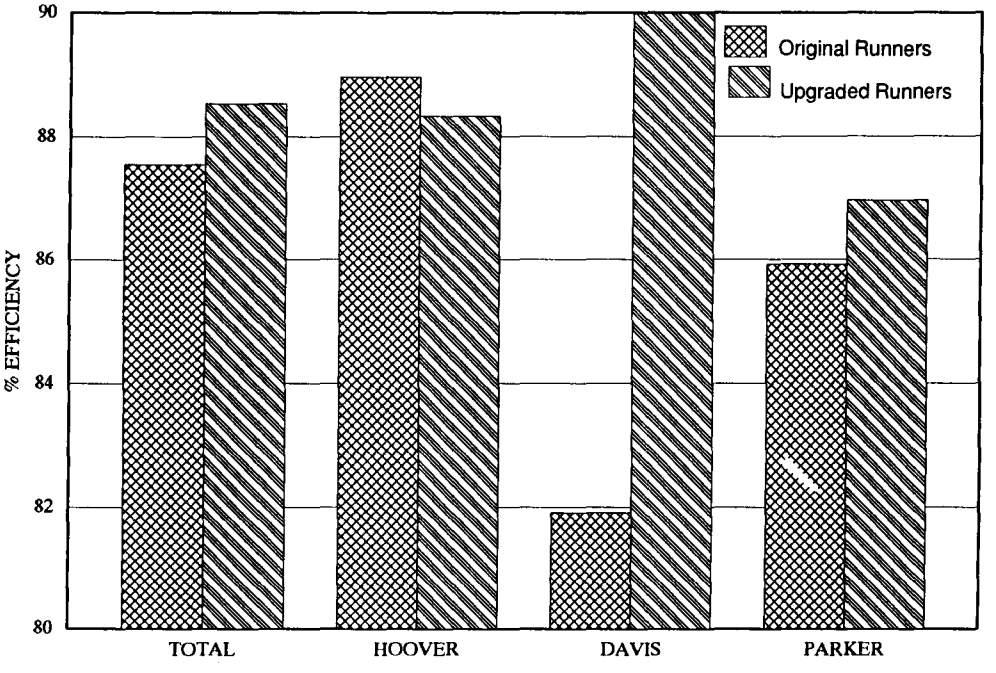

Figure 1C. — Comparison of average efficiencies between original and replacement turbine runners (4/17/88).

APPENDIX D

COMPUTER FILENAMES AND CONTENTS

There are five directories on the three Linear Programming Concepts for Unit Commitment Disks. The directories are related to the types of files they contain.

Disk No. 1 of 3

\WP51

LPUC.DOC – this is a Word Perfect 5.1 file that contains the report.

\123R31

1HLP_RES.WK3 – A worksheet that contains the result summary of the Lindo 24-Hour Single Cycle Model with Parker flow restricted.

1HLP_UN.WK3 – A worksheet that contains the result summary of the Lindo 24-Hour Single Cycle Model with no flow restrictions.

3HLP_UN.WK3 – A worksheet that contains the result summary of the Lindo 24-Hour Multiple Cycle Model for a three consecutive-hour model with no flow restrictions.

AVE_EFF.WK3 – A worksheet that contains the results of the 1-Hour Model, restricted and unrestricted flows, the 3-Hour Model, and the Historical Model.

GC.WK3 – A worksheet that contains Grand Coulee turbine flow curves.

GCLIN.WK3 – A worksheet that contains a summary of the points used to generate the multi-segment linear curves for all Grand Coulee generators.

GCOLD.WK3 – A worksheet that contains Grand Coulee turbine flow curves for the old units.

H3ATEST.WK3 – A worksheet with the result summary from the first run of the 3-hour LP model from the unit commitment shaping test.

H3CTEST.WK3 – A worksheet with the result summary from the second run of the 3-hour LP model from the unit commitment shaping test.

H3DTEST.WK3 – A worksheet with the result summary from the third run of the 3-hour LP model from the unit commitment shaping test.

HIST.WK3 – A worksheet the contains the result summary from the Lindo Historical Model.

HISTDAY1.WK3 – A worksheet that calculates the releases from Parker and Davis from the operation of the generator in the historical data of the day.

Disk No. 2 of 3

\LINDO

1HRLP.DAT – the Lindo 24-Hour Single Cycle Model.

3HLP.DAT – The Lindo 24-Hour Multiple Cycle Model for 3 hours.

GCMODEL.DAT – The Grand Coulee 1-hour Multisegment curve Model.

HIST.DAT – The Lindo Historical Model.

\MATLAB

GCFIT1.M and GCFIT2.M – Are M-files that can produce multisegment linear curves from the nonlinear flow curves.

Disk No. 3 of 3

/WB

EFFCOMP.WK3 – A worksheet that contains a result summary of the flow limiting runs in What's Best.

LCDATA.WK3 – A worksheet where data for the 24-hour generation and capacity schedule and water releases are entered and from which a 24-hour What's Best Model is run with a macro.

LCOPT.WK3 – A worksheet that contains the What's Best Model for the Lower Colorado Unit Commitment optimization problem.

LCOPT1.WK3 – A worksheet that contains the What's Best Model with a macro that controls the releases at Davis and Parker with a funnel shaped limit.

LCOPT2.WK3 – A worksheet that contains the What's Best model with manual control of the releases at Davis and Parker.

LCOPT3.WK3 – A worksheet that contains the What's Best model with a macro that controls the water releases at Davis and Parker with a fixed percentage.

RESULT1.WK3 – A worksheet that contains the result summary of the ±20 percent run.

RESULT2.WK3 – A worksheet that contains the result summary of the ±30 percent run

RESULT3.WK3 – A worksheet that contains the result summary of the What's Best 24-Hour Model with Parker restricted.

RESULT4.WK3 – RESULT9.WK3 – Worksheets that contain the result summaries from the Davis runner replacement tests.

*U.S. GOVERNMENT PRINTING OFFICE 1992-0-673-185/40013

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

A free pamphlet is available from the Bureau entitled, "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-7921, PO Box 25007, Denver Federal Center, Denver CO 80225-0007.