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A PRELIMINARY EVALUATION OF THE THERMAL EFFECTS OF THE BEN FRANKLIN DAM PROJECT ON COLUMBIA RIVER TEMPERATURES BELOW THE HANFORD PLANT

R. T. Jaske

April 1968

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By

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April 1968

PACIFIC NORTHWEST LABORATORY
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A PRELIMINARY EVALUATION OF THE THERMAL EFFECTS OF THE BEN FRANKLIN DAM PROJECT ON COLUMBIA RIVER TEMPERATURES BELOW THE HANFORD PLANT

R. T. Jaske

ABSTRACT

The planned construction of the Ben Franklin project below the Hanford production reactors poses the question of determining to what extent this project will affect the Columbia River temperatures. Using the plant operations record for the year 1966, and the weather record for the same period, a series of simulation runs was made to determine the effects of the dam on the temperature regime, and the extent to which density currents could be expected to develop. This information is to be used as background for the later evaluation of the modification of the existing radionuclide discharge. The digital simulation model, COL HEAT, was used. This model has been previously developed under Atomic Energy Commission sponsorship for use in the regional evaluation of the effects of the Hanford plant. Operations with the model, using the data period indicated, showed that:

The existence of the proposed project would have nominal effect, tending towards a slight increase in downstream temperature for both the 385 and 400-ft pool elevations. Under some conditions, in critical temperature seasons (April and September), plant operations cause amplification of the temperature transients associated with stream regulations and plant load factor.

The 385-ft pool can be considered a channel flow case for estimating travel time. However, density currents could be expected in the 400-ft pool for most of the summer months, thus causing decreased travel time and relatively adiabatic thermal conditions for the main flow system at the lower end of the reservoir.

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INTRODUCTION

As a consequence of renewed attention on the part of regulatory and conservation agencies towards stream temperature standards for the portion of the Columbia River affected by the Hanford plant, the Richland Operations Office directed the Pacific Northwest Laboratory to conduct a preliminary study to determine the effects of the Ben Franklin Dam on Columbia River temperatures. This report summarizes the computation operations performed in response to the directive, and establishes the framework for the planned radionuclide study to follow.

Conclusions of this study are based upon information developed within a single year (1966). However, the groundwork thus provided in this preliminary examination is sufficiently detailed and comprehensive to permit the handling of additional cases with relative ease and with minimum preliminary effort.

SUMMARY AND CONCLUSIONS

Based on assumptions detailed in the following discussion, and on the effects of weather and operations as determined at the Hanford plant for the year 1966, the following conclusions are appropriate:

- The construction of the Ben Franklin project could be expected to affect slightly but measurably the overall temperature regime of the Columbia River below the plant. The 385-ft reservoir could be expected to

increase the annual average temperature by 0.2 to 0.4 °C and decrease the expected maximum departure from the mean only slightly, resulting in the probability of a downstream regime similar to the present. The 400-ft reservoir could be expected to increase the annual average temperature by 0.4 to 0.6 °C and to slightly decrease the expected maximum departure from the mean, resulting in the probability of a downstream regime basically the same as present, but tending toward slightly higher maximum temperatures.

- The river temperature effects from Priest Rapids Dam load factoring and from plant operating transients would tend to be amplified by both the proposed reservoir levels. While the specific effect for each level is dynamically related to actual conditions, the relative effect is one of seasonal dependence. In general, during periods of highest heat stress such as September and April, water flow regulation and reduced surface cooling area would cause amplifications of about 1 °C in maximum daily averages as the result of construction of either reservoir.
- Temperature spikes from variable dilution accompanying transient operations at both the Priest Rapids project and Hanford plant could, as determined from previous AEC-sponsored river temperature environmental research at Hanford, be expected for distances conceivably as far downstream as the Bonneville project outlet. However, the expected filling of the John Day reservoir in the spring of 1968 is expected to minimize the effects of severe transients emanating from Hanford operations or from the Priest Rapids load regulation below that project. Noticeable effects in the McNary reservoir could be expected during the critical temperature period of September.

- No measurable effects from density current activity could be expected for the 385-ft pool. However, the 400-ft pool could be expected to develop annually (from April to November) density currents at the lower end below Mile 360 during periods of rising air temperatures, clear skies, and high solar radiation input. Under these conditions, the submerged and relatively adiabatic flow through most of the reservoir would produce little or no temperature differential through the lower project reach above the dam. This condition would be expected to slightly decrease the theoretical transit time of water through the reservoir and create a condition where the extent of stratification would relate to the dilution of conservative and nonconservative contaminants in the plant effluent. Such conditions could potentially favor recreational use aspects of the reservoir by increasing surface temperatures desirable to bathers, and creating a surface layer with a relatively lower concentration of plant effluent. A detailed examination of data compiled over several years would be required to draw any meaningful conclusions.
- The mean annual transport time of water through the reservoirs would be increased measurably over the natural conditions. Based on statistical analysis of the 1966 history and the computed daily average temperatures below the reservoirs, the mean travel time of water through the 385-ft project would be increased approximately 4 days. For the 400-ft reservoir, an increase of about 9 days could be expected.

DISCUSSION

BACKGROUND

The proposed construction of a dam at Columbia River Mile 348 has been extensively investigated in respect to effects of water levels on structural integrity, production capability and ground water contamination.[1-4]* None of these studies included an investigation of the reservoir itself below the Hanford operating areas, or an estimate of the thermal modification anticipated below the project as a result of the combined operations of the Hanford plant and the regulation of water flow imposed by the Priest Rapids project. Since long range planning for the release of project lands and for public access to the resulting reservoir are both closely related to expected joint operations upstream, the Richland Operations office authorized a preliminary investigation to determine a basis for this planning.

Prior to 1965, a basis for the prediction of the expected thermal hydrodynamic behavior of a river and reservoir system was not generally available. The digital simulation system, COL HEAT, developed under Atomic Energy Commission sponsorship for the purpose of evaluating results of the annual Columbia River Cooling program, has been fully described[6] and expanded in both scope and detail to permit temperature condition predictions for both natural and advected heat supplied from industrial activities, as well as the estimation of concentration for both conservative and nonconservative contaminants.[7] This model has provided an excellent basis for the examination of the proposed project at relatively little additional cost.

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* *These documents also contain subject matter references.*

ASSUMPTIONS

In order to avoid classification of this report and to base the study on a record of observations available to the regulatory agencies and to the public, the year 1966 was selected for this study. While the actual classified record of plant production for the year 1966 was used in the computer simulation runs, no classified output was generated by the program. The use of the public record eliminates the necessity of predicting future operations, or of requiring release of pre-1966 river temperature records, still considered sensitive to national defense by the Atomic Energy Commission.

An additional advantage of the period selected was the extended plant shutdown in 1966 during which excellent records of the extent of diurnality and the natural temperature rise through the plant reach could be obtained. In effect, this study permits examination of the effects of the impoundment somewhat independently of the AEC operations, although this is in some degree an academic consideration.

The COL HEAT simulation system (Figure 1) requires the geometrical definition of the river dimensions into a series of sections nominally called reservoirs (see Appendix A for an outline of data submission requirements). The actual computations are outlined in the flow sequence diagram accompanying the Appendix (Figure A-10). The existing limitation of the program is such that a maximum of 50 reservoir sections and 186 consecutive time periods can be handled within the core limits available in the Univac 1108 system. In addition, significant increases in processing time result from the density current check routine, somewhat in proportion to the number of reservoirs and the number of heat admission points to the system. It was thought desirable to retain as much fine structure of the diurnal character of

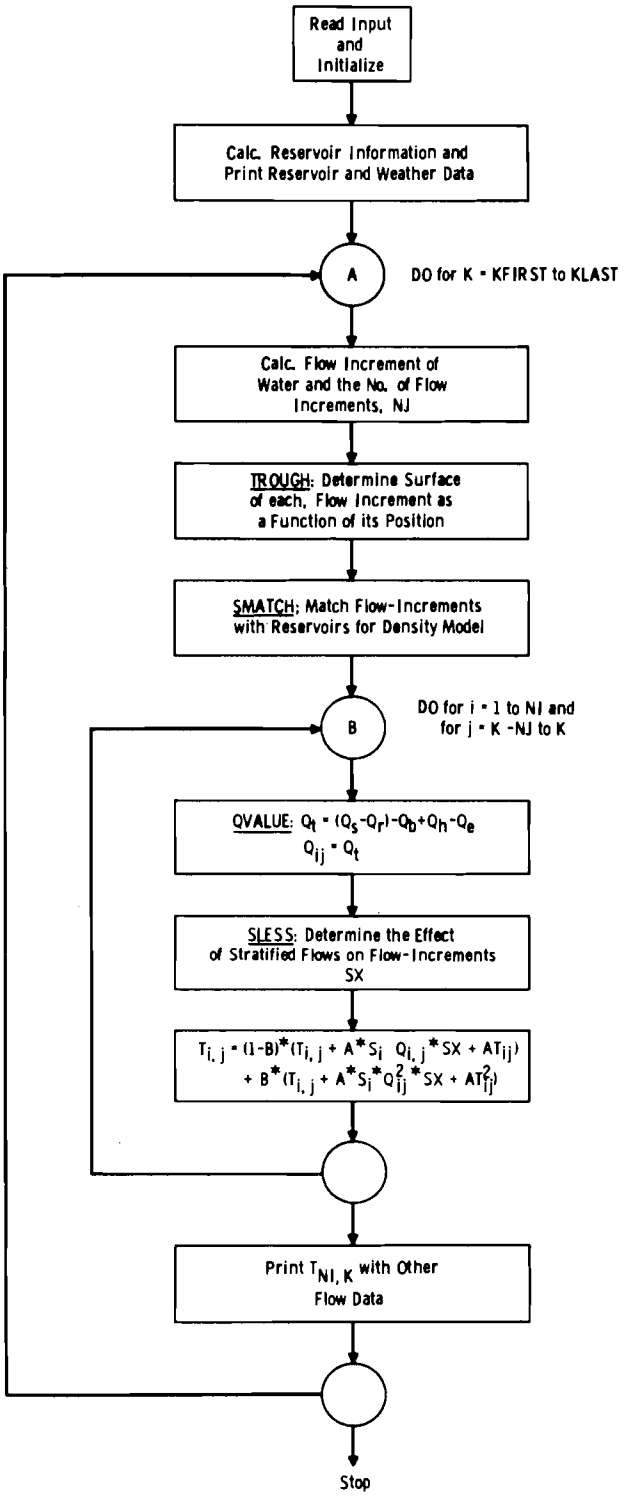

FIGURE 1. Flow Diagram, Water Quality Simulation

the transients as possible without the expense of going to hourly data. Therefore, a time period of 6 hr was used as the basic incrementation time.

All input weather cards were prepared from daily average weather and river data using a statistical expansion process for those variables related to periodicity. Fo those random variables such as cloud cover, wind speed, etc., the average for the 24-hr period was used as the average for the individual 6-hr period. This procedure leads to the masking out of a portion of the diurnal effect. However, absolute simulation of diurnality was beyond the scope of the study and, therefore, significant savings in clerical and computer time were possible. The diurnality of the input and output water temperature record was also statistically expanded in order to preserve this minor, but interesting effect. Since the conclusions of the study are based on a statistical treatment of the entire 365-day record, the individual variations introduced by this procedure were thought to be minor.

In addition, as previously indicated, the plant record of heat additions to the river was introduced entirely at the location of the 100 K area outfall to minimize operating time. While this procedure can be rigorously defended in a classified discussion only, it is mentioned for the purpose of clearly indicating any computational assumptions which reflect on the end result. Figure 2[6] shows that introducing a temperature change in the river yields a relatively long lasting result from a spacial consideration. Therefore, the extent of distortion involved in concentrating the heat additions to a single point is considered minor, or beyond the accuracy of the basic computation. A short section of the test computations simulating the natural river for the period before and after the start-up of plant operations in August 1966, is shown in Figure 3. The deviations from ideal modeling are

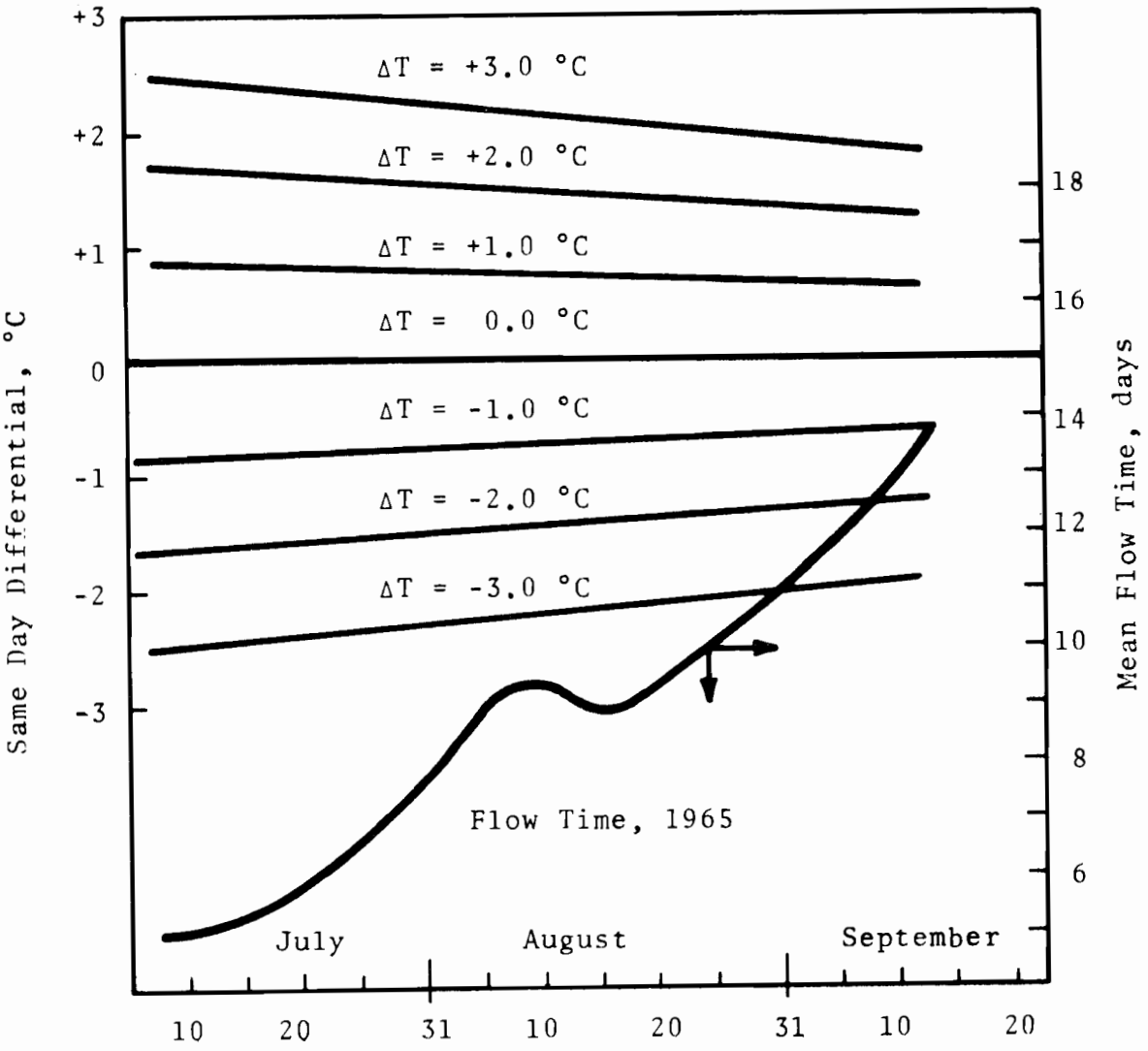

FIGURE 2. Loss or Gain of Imposed Artificial Temperature Differential--Real Time Basis--Grand Coulee to Mile 385

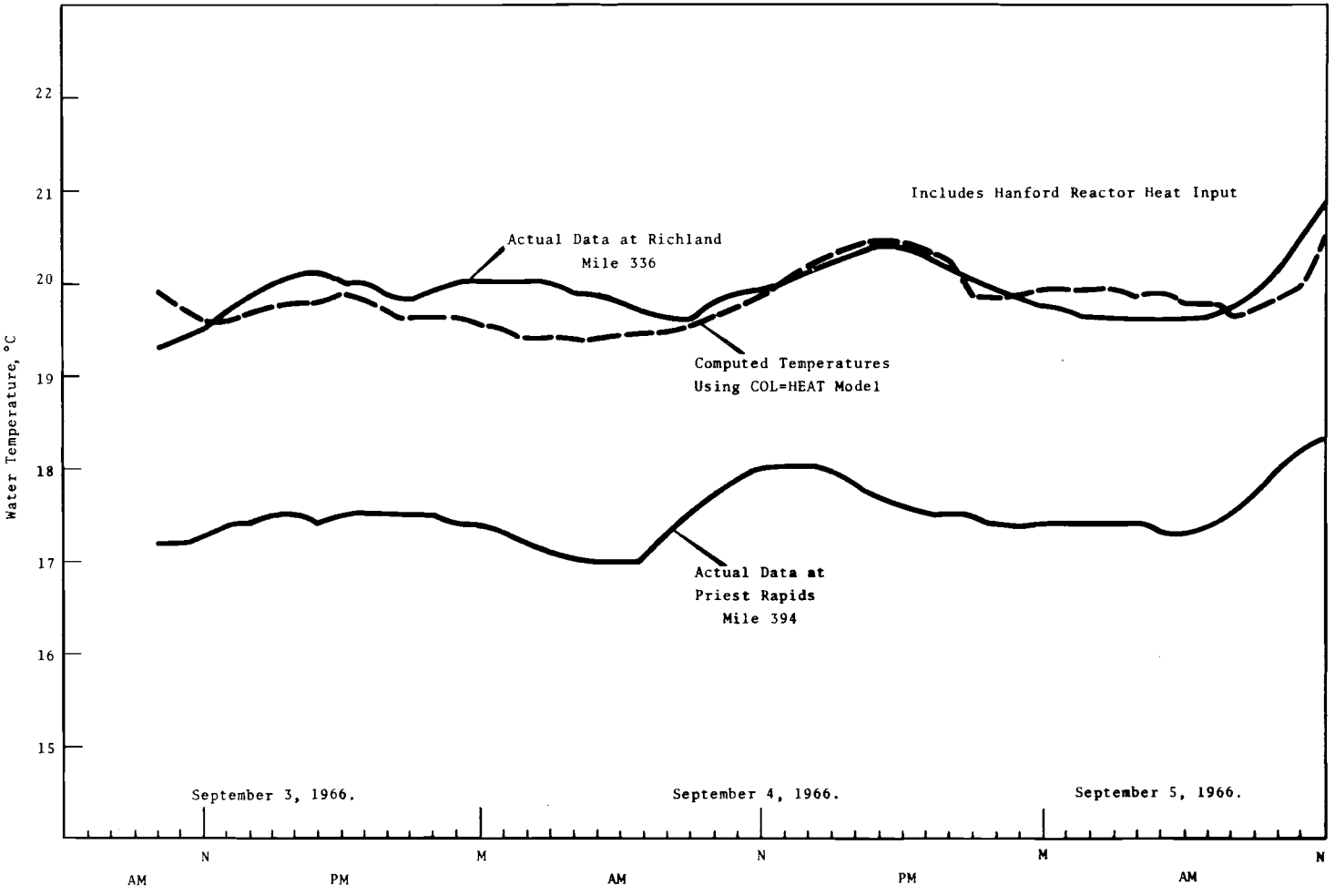

FIGURE 3. Natural River Test; Digital Simulation Model; Columbia River Mile 394 to 336.

somewhat greater than for impounded sections of the river because of the conduction coefficient sensitivity to current and wind speed. However, for the reconnaissance purposes intended, the overall result appears acceptable.

River profiles used in the development of cross sections for the computations were derived from data[5] supplied by the U.S. Corps of Engineers, Seattle District Office, and were identical to those used by other investigators.[4] On the basis of these profiles, the following reservoir and river volumes were used for the cases detailed:

TABLE I. Reservoir Volumes for Various Flows

Flow Source	75,000 ft^3/sec	150,000 ft^3/sec
Normal River	135,000 AF	178,000 AF
385-ft Dam	379,000 AF	428,000 AF
400-ft Dam	596,000 AF	672,000 AF

Contours were derived from U.S. Geological Survey maps of the Hanford plant area. The details of these reservoir sections remain in useful punch card form for future cases or other detailed examination.

COMPUTATIONS

The program for the actual computer runs included a series of stepwise sub-cases in which the reservoir volumes were adjusted for the river flow volumes under consideration as the seasons progressed. Figures 4, 5, 6, 7 and 8 summarize the results of the generated output. The diurnal effects have been eliminated in the computations in order to simplify the presentation. The results, while self explanatory, can be summarized to the extent that the following observations are pertinent.

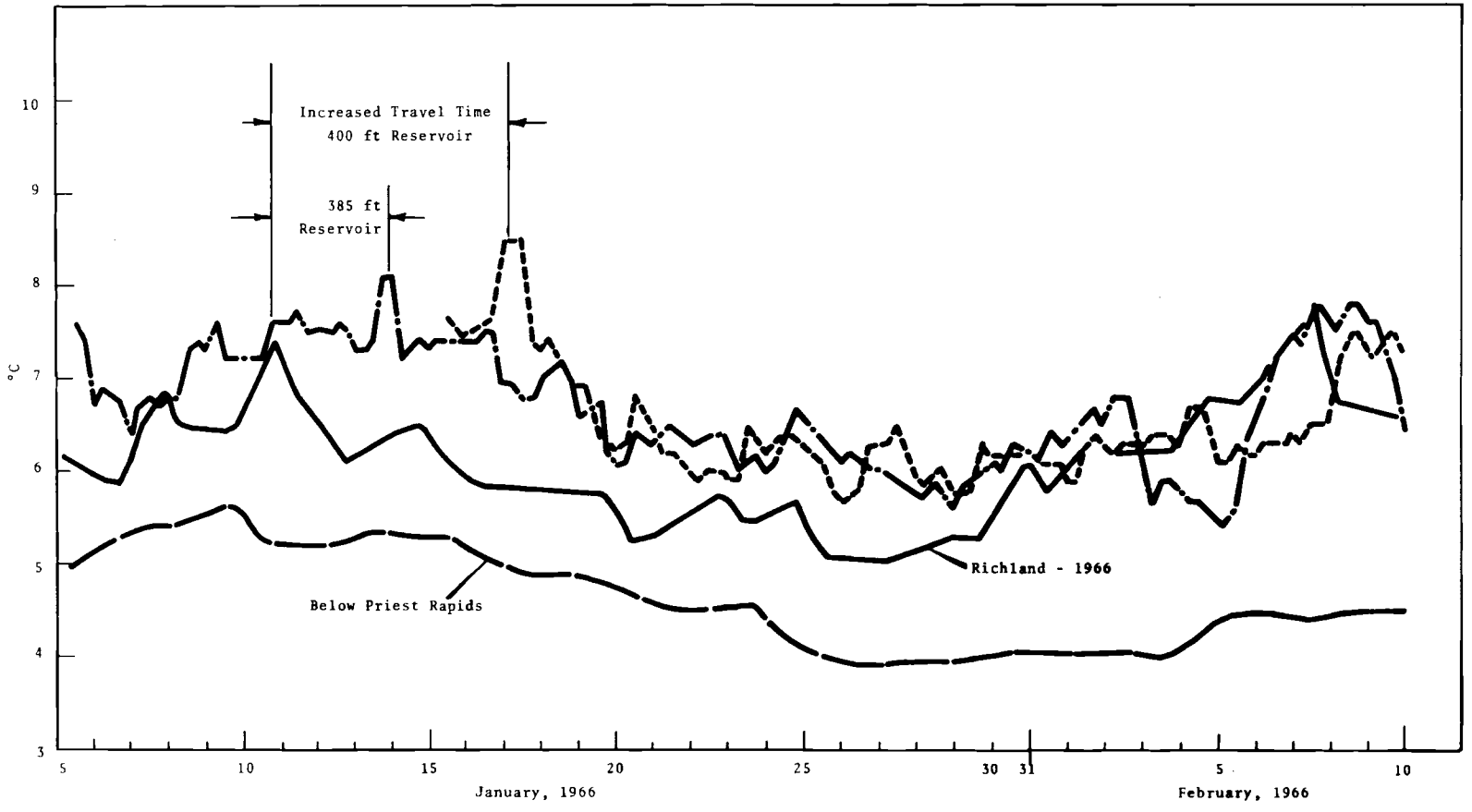

FIGURE 4. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; January 5, to February 10, 1966.

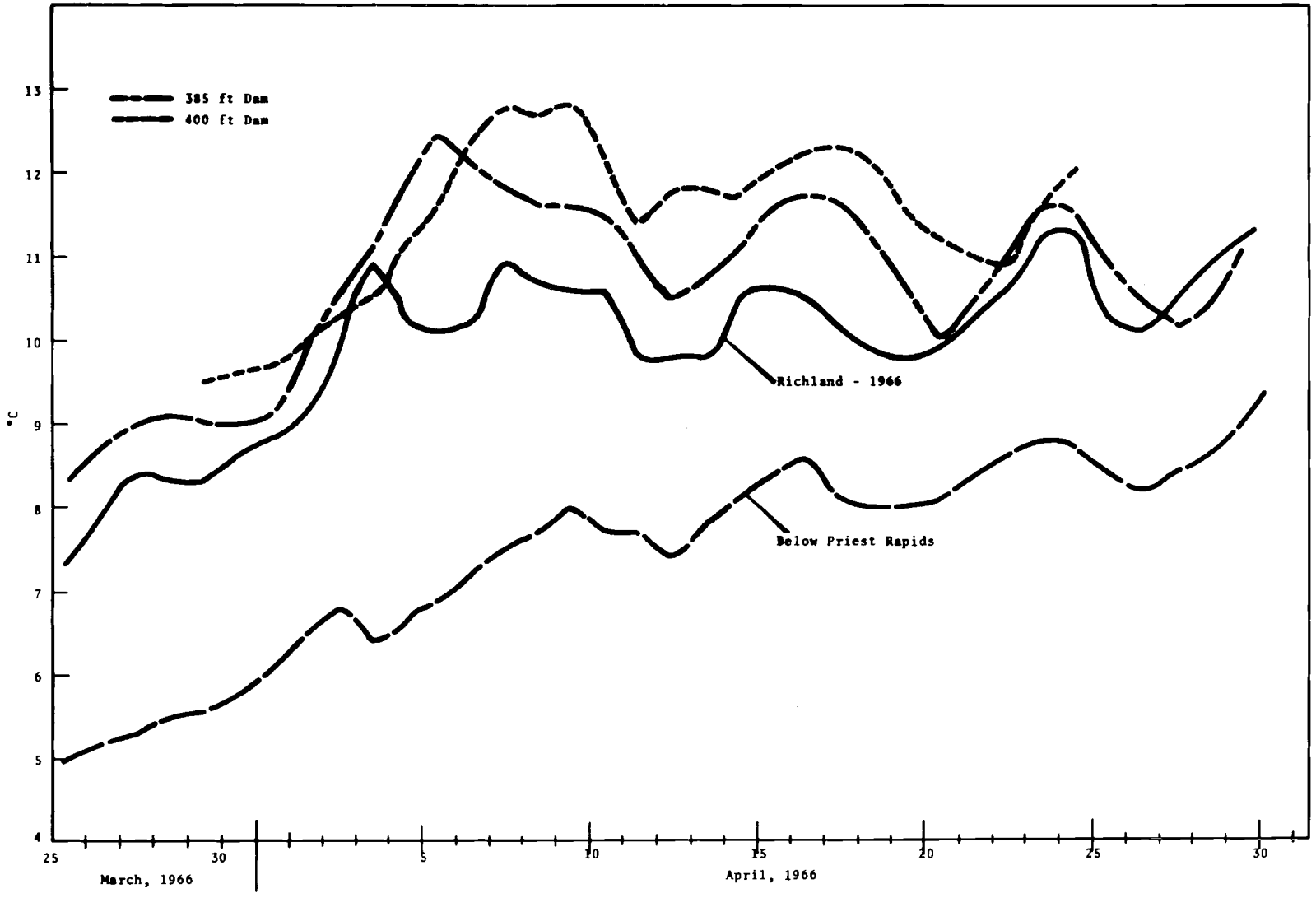

FIGURE 5. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; March 26, to April 30, 1966.

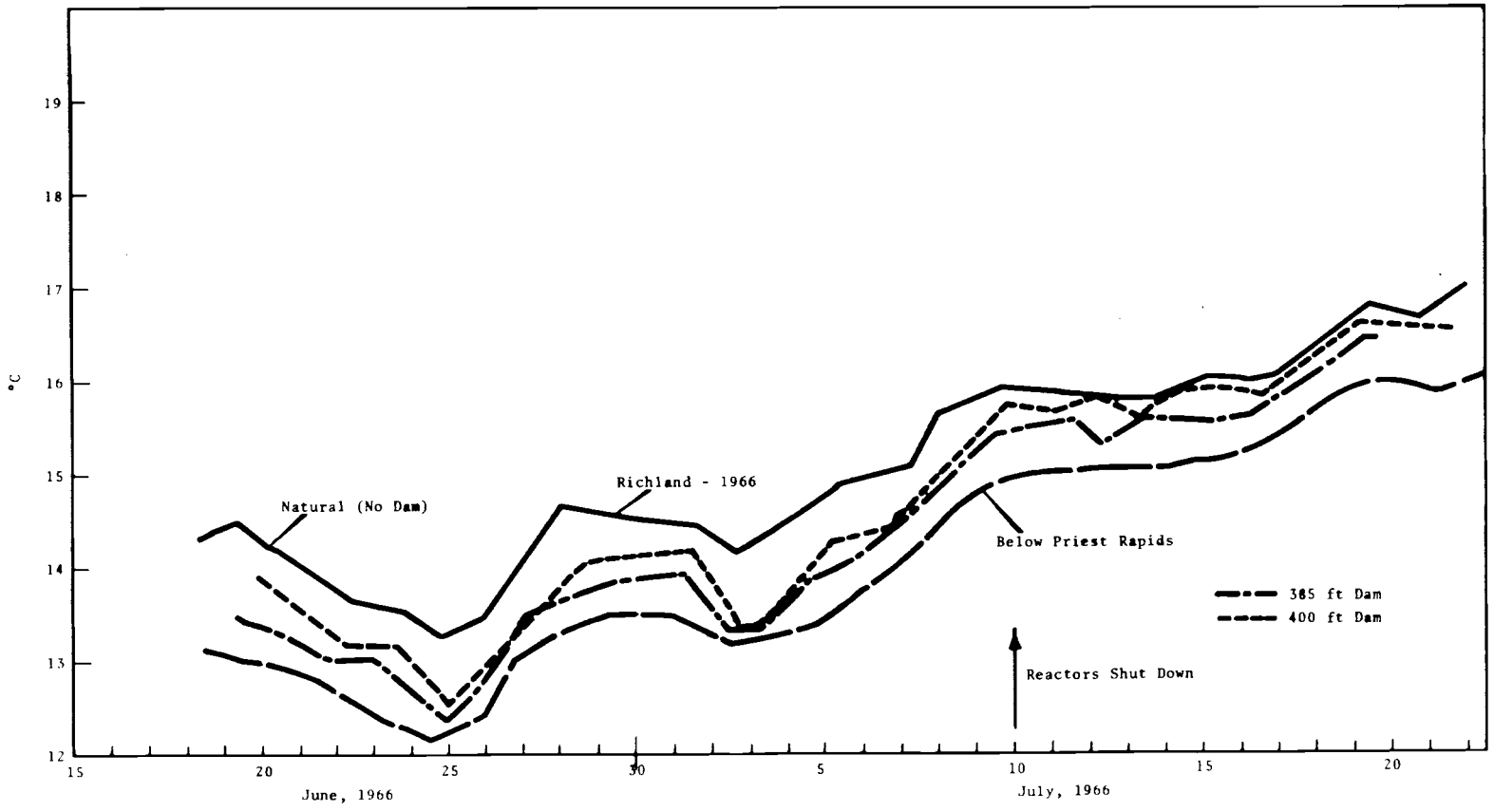

FIGURE 6. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; June 16, to July 22, 1966.

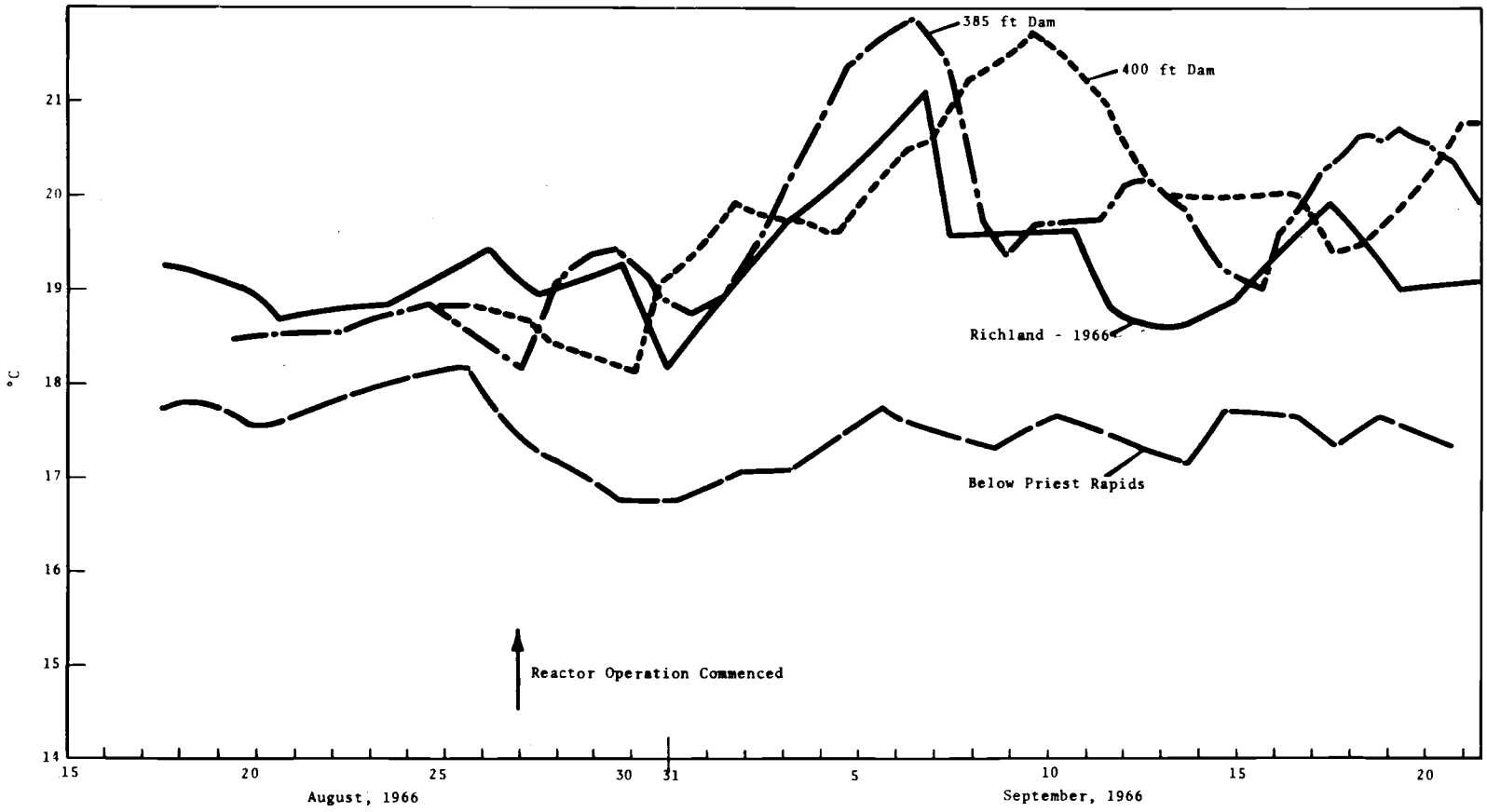

FIGURE 7. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; August 17, to September 20, 1966.

FIGURE 8. Thermal Effect of Ben Franklin Dam Superimposed on 1966 Plant Operations Record; September 20, to October 21, 1966.

- Temperatures measured at the Richland Ferry site (below the dam) are expected to be slightly higher for all but the highest flow conditions during which lower temperatures could be expected to prevail.
- Temperature transients introduced by the combination of flow regulation and Hanford plant load factor are somewhat amplified by the presence of the reservoirs, especially during April through October when density currents could be expected on the 400-ft reservoir. Figures 5 and 7 show periods of time when transients are especially noted. The Labor Day weekend, combined with low river flow from Priest Rapids regulation, could be expected to produce a relatively large effect, even more pronounced than that currently experienced without the dam. These spike transients could be expected to be measurable for considerable distances downstream and to assume special significance if downstream water temperature standards were used as a basis for regulation of integrated heat input to the Columbia River.
- Temperature peaks in excess of those measured in the natural river have been checked against the quantitative heat input and found to be justified. The explanation lies in the fact that the natural river is relatively less conservative of heat than the impounded reach, a finding verified during the reactor shutdown period of July through August 1966 when surface heat transfer for the swift, natural stream was determined to be a factor of three higher than the impounded reaches. The Bowen ratio for swift rivers thus must be corrected in order to achieve proper simulation. All simulation runs made in this series of computations reflect this correction in the Bowen ratio to the extent justified.
- The basic computations of the COL HEAT model are carried out to an accuracy of plus or minus 0.25 °C.

Within the stated accuracy of the model computations, the bulking effect of flow transients in passing through the reservoir appears to be a real one.

- Each Figure (4 through 8) indicates the extent of increased travel time through the impounded areas. Since the flows change considerably during a transit through the reservoir, travel time is difficult to illustrate except on an average basis over an extended time period.

In summarizing the results of the computation and converting them to readily usable form, all output temperature computations for the entire year were key punched and analyzed on the same least squares fitted functional model employing the LEARN routine developed at Battelle-Northwest.[8] Illustrations of the direct output from the plotting routine of this program are shown in Figures 9, 10 and 11. These figures show the computed output for the two different reservoir elevations and the actual record of 1966 measurements at the Richland Ferry site.

TABLE II. Comparative Results of Predictive Calculations

Functions fitted to the general model

$$T = A + B \sin(Cd + D),$$

where T = Computed Temperature for Day, (d), °C
A = Annual Average of Model, °C
B = Computed Extremes, °C
C = Daily Functional Movement, RAD/DA
d = Number of days under Consideration
D = Displacement of T_{max} from Arbitrary Zero
(D = 0.0173 x Days Displaced)

Richland Actual, 1966	$T = 12.04 + 6.24 \sin(0.0163d + 4.04)$
385-ft Dam	$T = 12.34 + 5.95 \sin(0.0163d + 3.97)$
400-ft Dam	$T = 12.57 + 5.86 \sin(0.0163d + 3.91)$

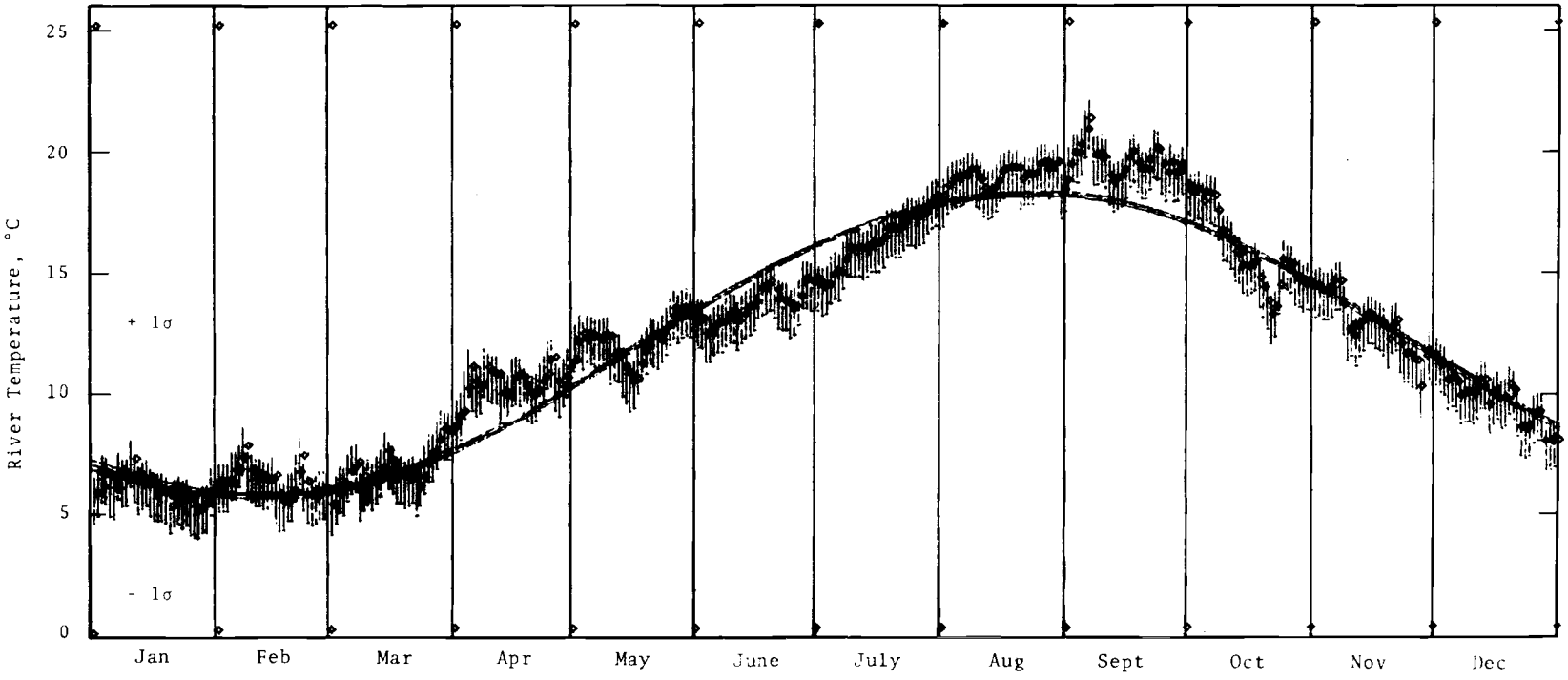

FIGURE 9. Least Squares Model Fit; T = 12.03 + 6.24 Sin(0.0163d + 4.04); Richland (CY 1966 Data)

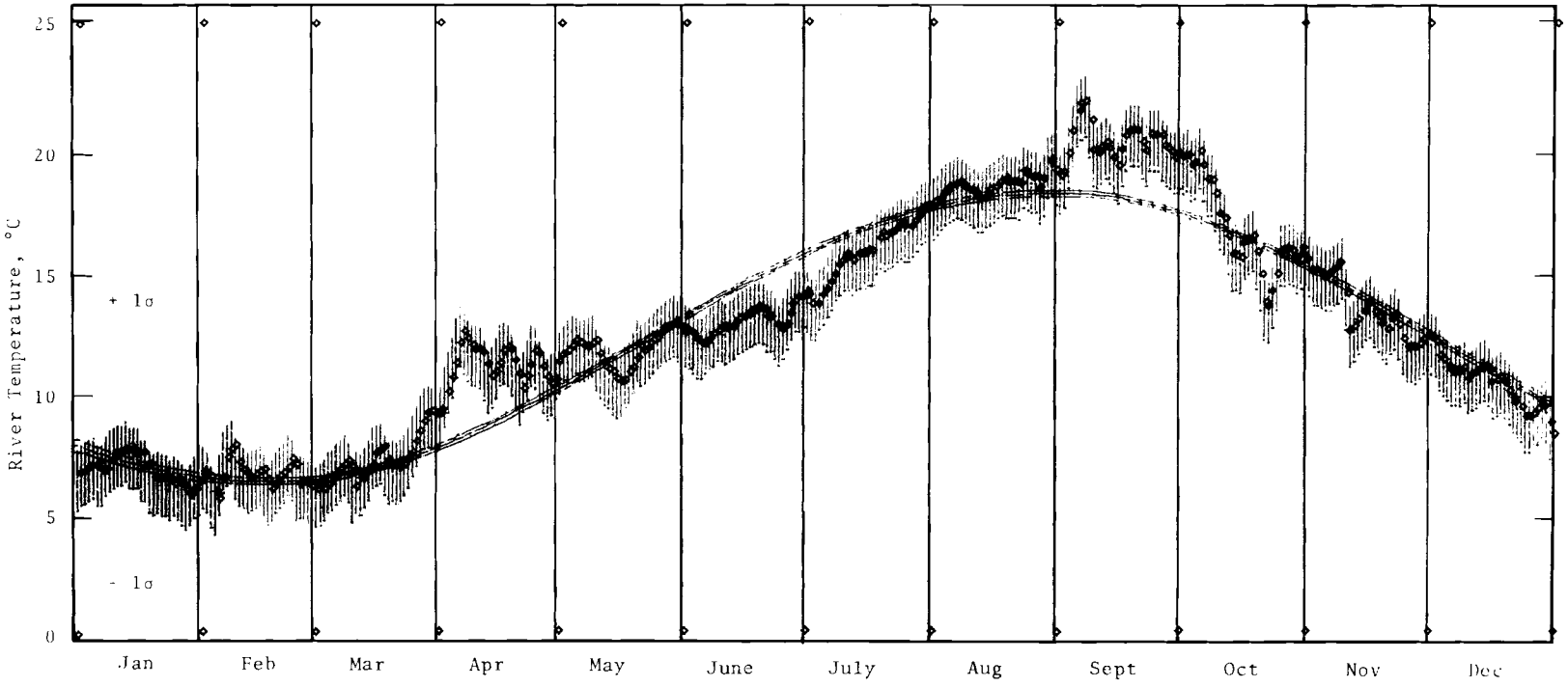

FIGURE 10. Least Squares Model Fit; T = 12.34 + 5.95 Sin(0.0163d + 3.97); Ben Franklin (CY 1966 Data) 385-ft Elevation

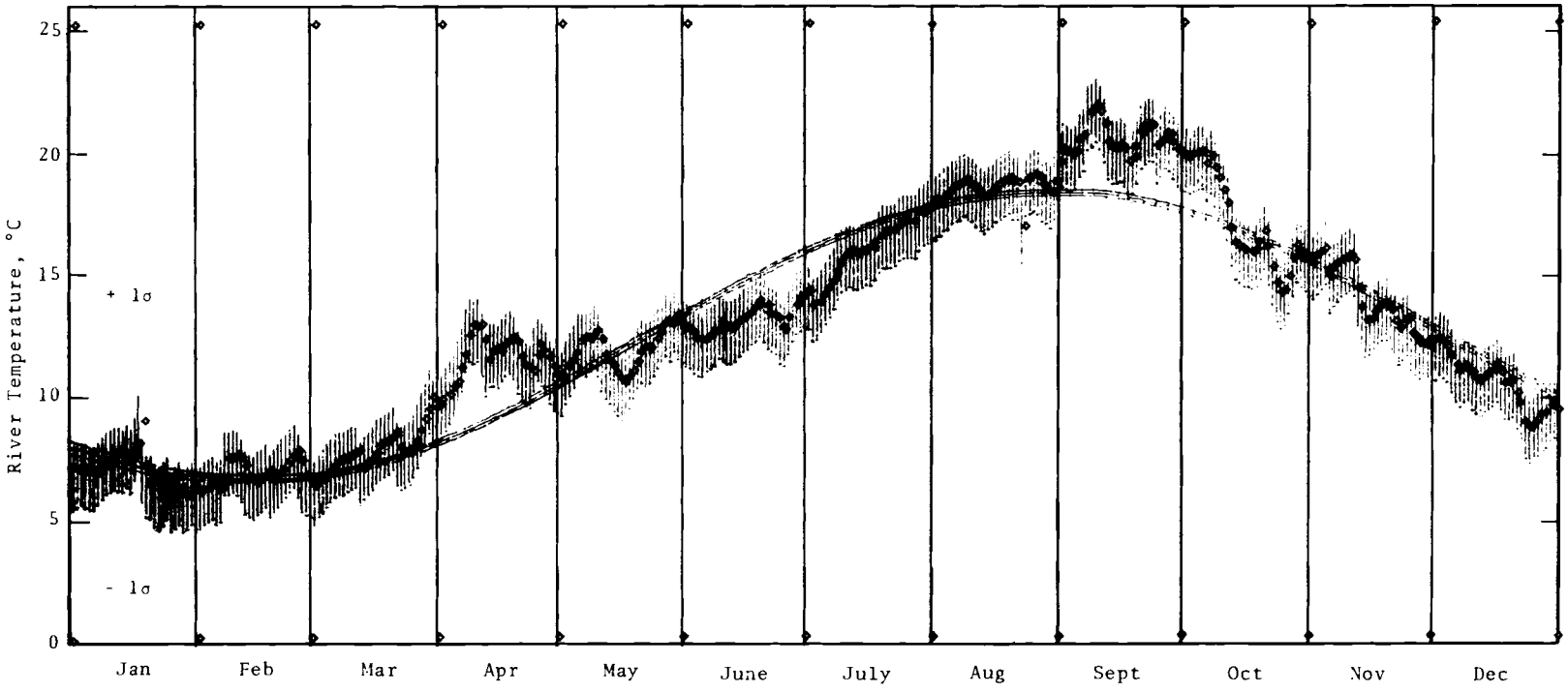

FIGURE 11. Least Squares Model Fit; T = 12.57 + 5.86 Sin(0.0163d + 3.91); Ben Franklin (CY 1966 Data) 400-ft Elevation

The values for the individual terms thus described summarize the trends expected from the construction of the reservoirs and, except for a slight net cooling trend covering an extended time period,[9,10] are quite typical of other upstream project results. The heating trend for the Ben Franklin project is related to the combination of flow regulation and reactor plant load factoring. Table III presents values for other Columbia River projects subjected to the same analysis procedure for the calendar year 1966.

TABLE III. Actual Results for Selected Points for CY 1966

Richland	$T = 12.04 + 6.24 \sin(0.0163d + 4.04)$
Priest Rapids	$T = 10.65 + 6.63 \sin(0.0166d + 3.95)$
Rocky Reach	$T = 10.44 + 6.53 \sin(0.0163d + 3.80)$
Grand Coulee	$T = 10.40 + 6.49 \sin(0.0165d + 3.67)$
International Border*	$T = 9.29 + 6.26 \sin(0.0165d + 4.16)$
Bonneville Dam	$T = 11.93 + 7.20 \sin(0.0164d + 4.17)$
McNary Dam	$T = 12.21 + 7.16 \sin(0.0165d + 4.09)$

* *The anomalous value for the International Border for CY 1966 needs further investigation and explanation. Part of the data used are of doubtful accuracy.*

A complete report of the analysis of the temperature trends for all available Columbia River dam projects temperature data is being prepared. The values in Table III show the tendency of large impoundments to delay the timing of the natural temperature peak. Temperature peaks of the lower, less significant reservoirs, on the other hand, tend to coincide more closely to the normal time periods characteristic of natural rivers. The arrival of peak temperature at Bonneville for 1966 coincides with the timing for the International Border for the 1966 season. The departures from the mean also show the tendency to return to the larger values associated with natural streams.

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APPENDIX A

DIGITAL SIMULATION SYSTEM LOGIC DIAGRAMS

(Figure A-1 Through A-9)

AND

WEATHER CONDITIONS

FOR CRITICAL TEMPERATURE MONTHS, 1966

(Figure A-10)

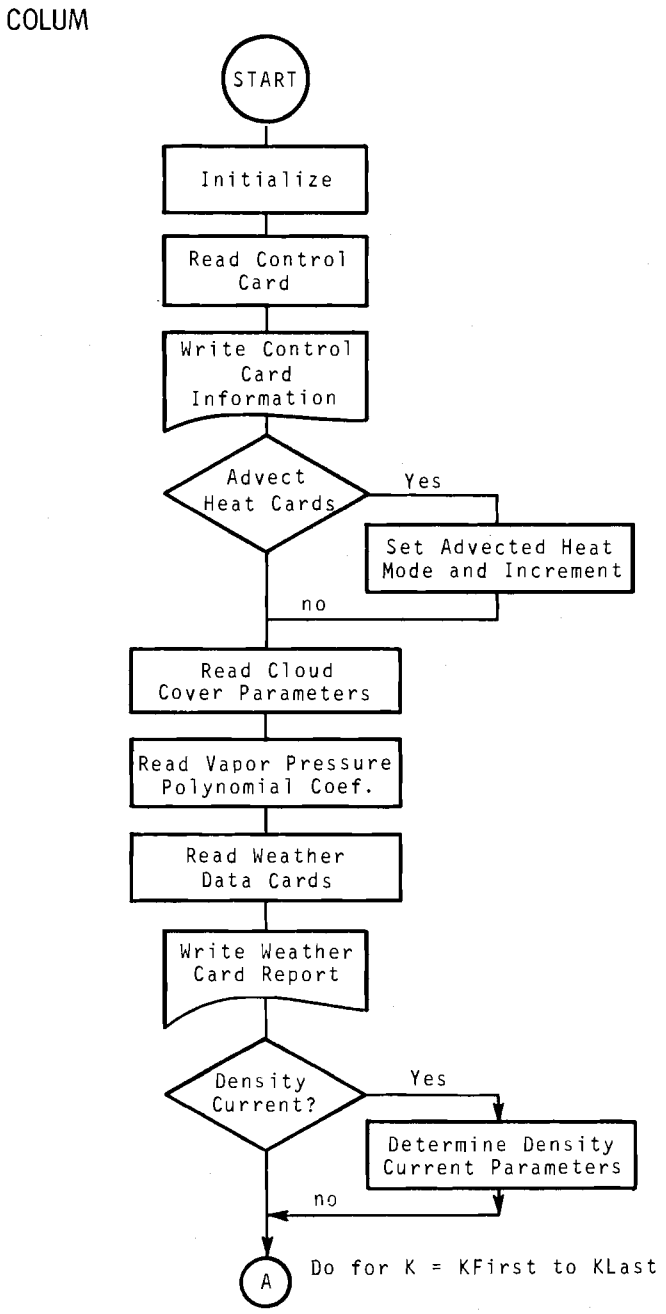

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FIGURE A-1. Digital Simulation System Logic Diagram

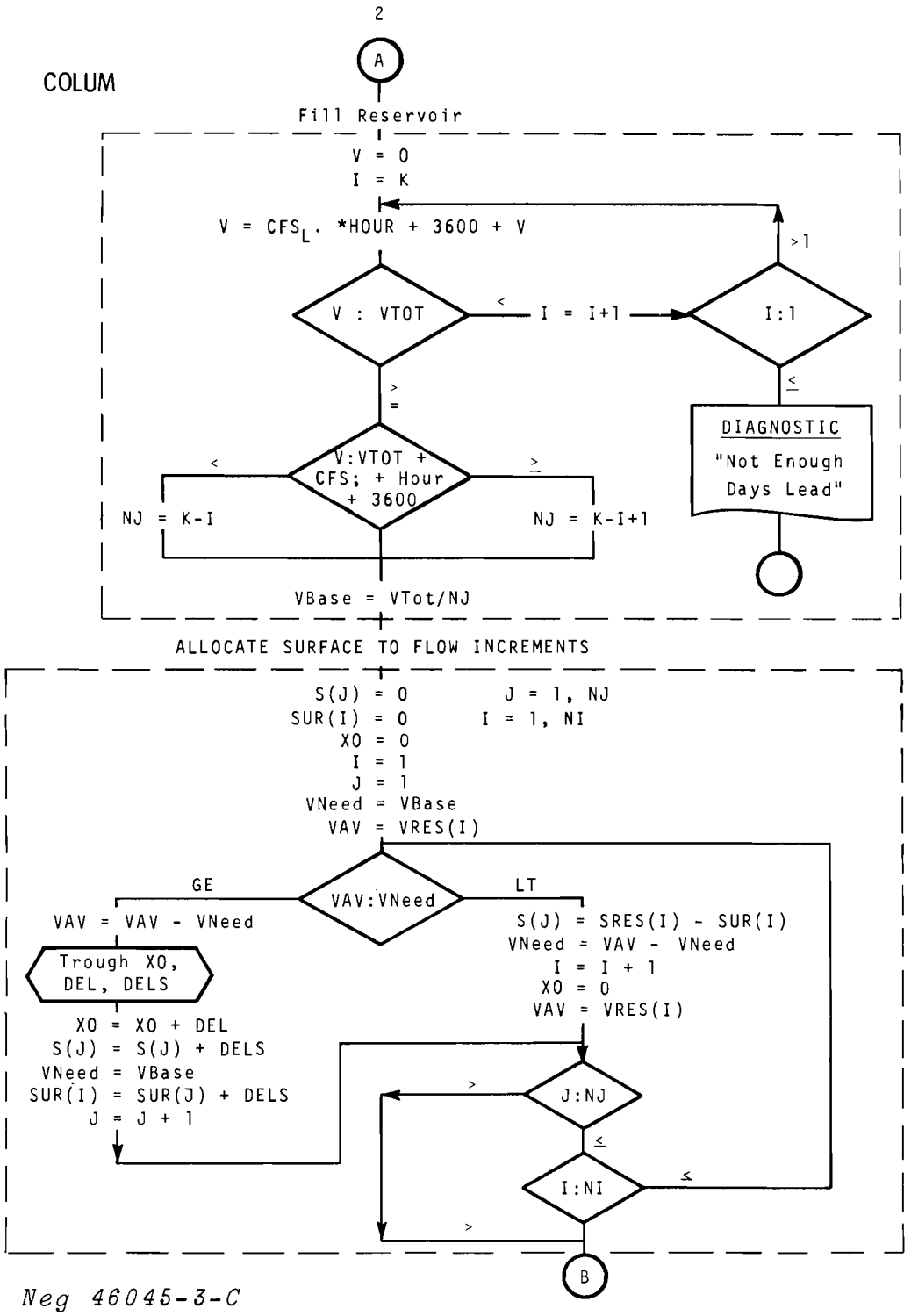

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FIGURE A-2. Digital Simulation System Logic Diagram

3

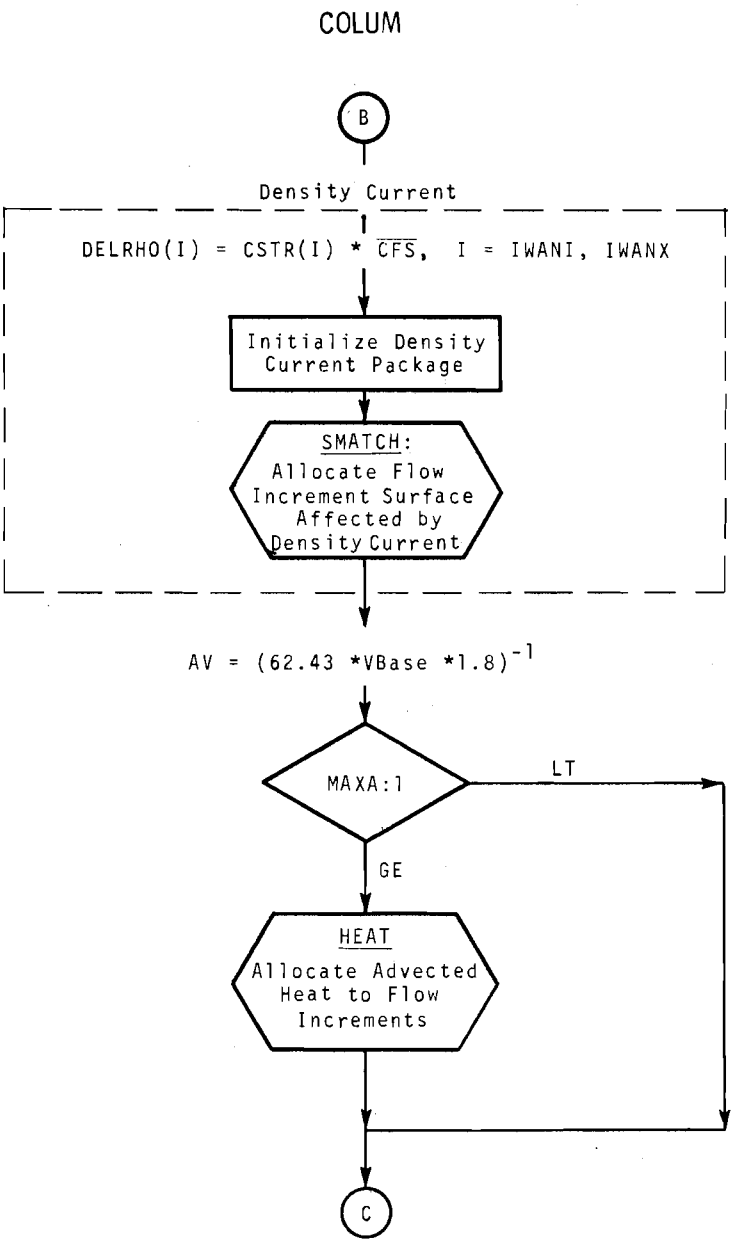

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FIGURE A-3. Digital Simulation System Logic Diagram

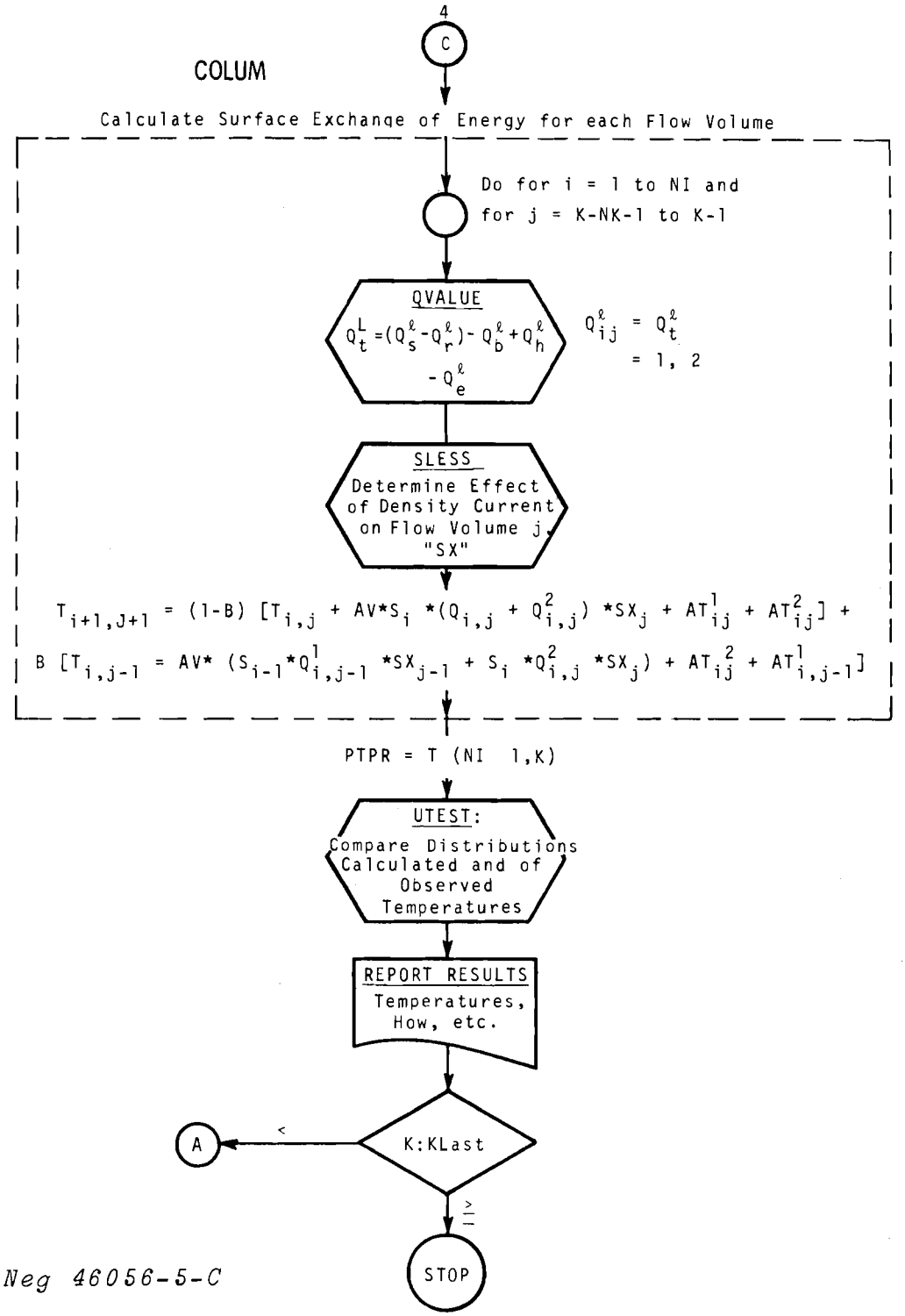

FIGURE A-4. Digital Simulation System Logic Diagram

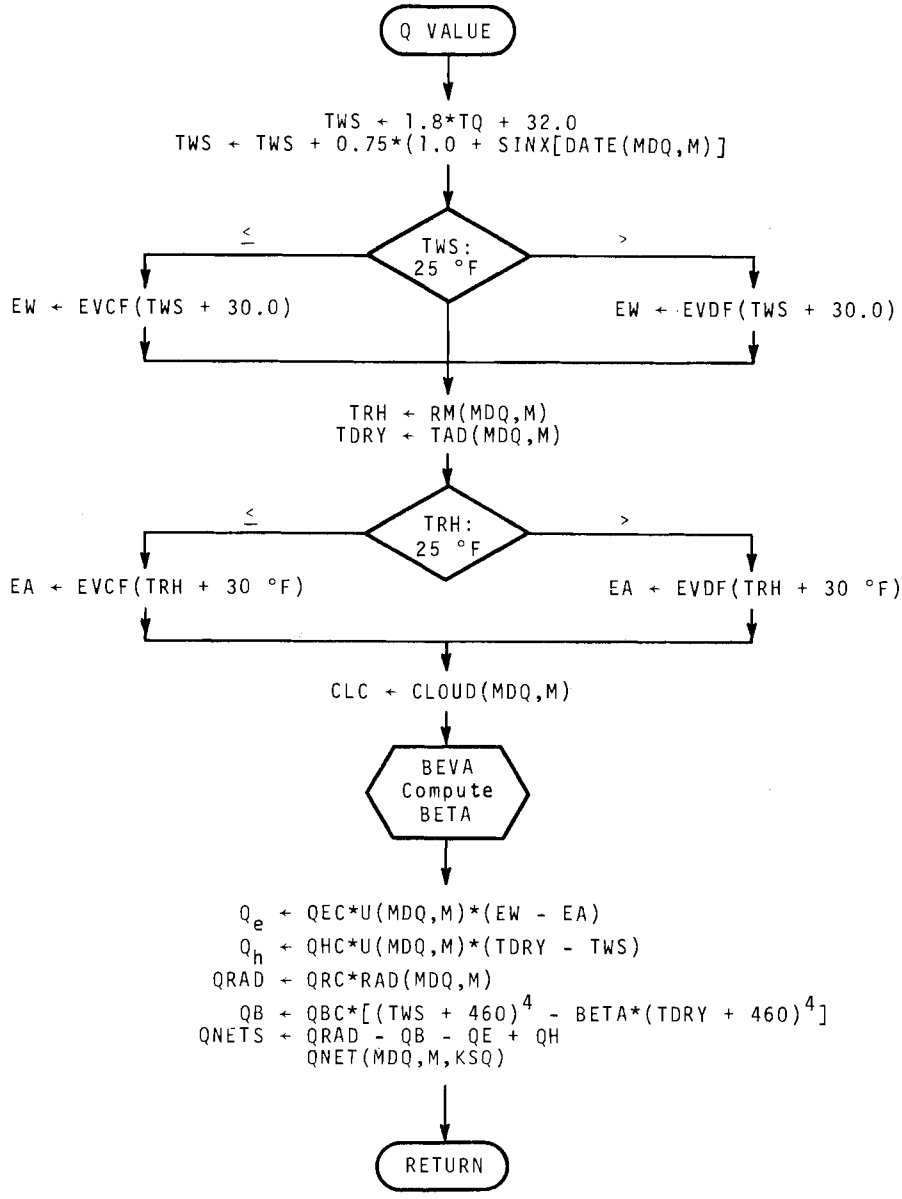

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FIGURE A-5. Digital Simulation System Logic Diagram

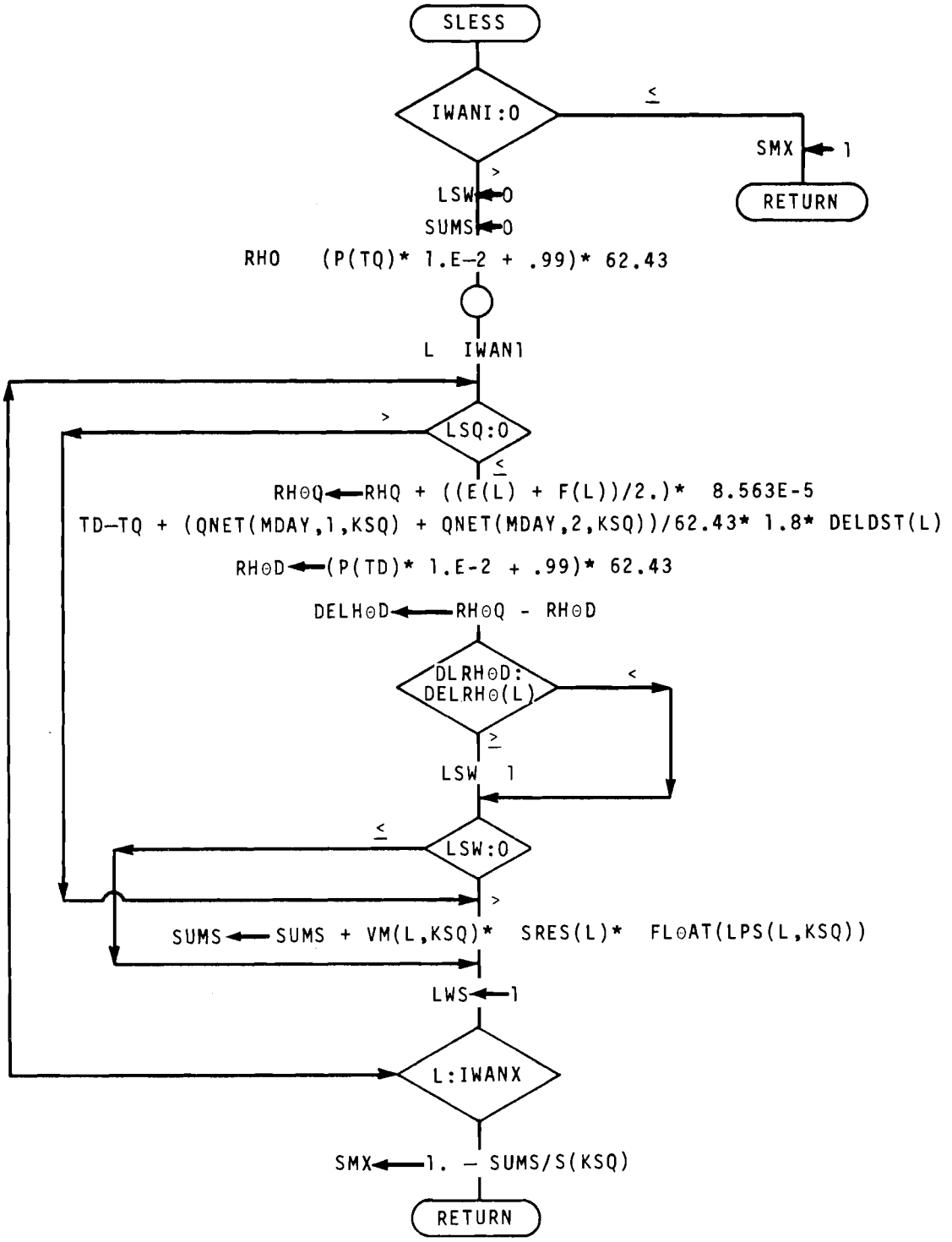

FIGURE A-6. Digital Simulation System Logic Diagram

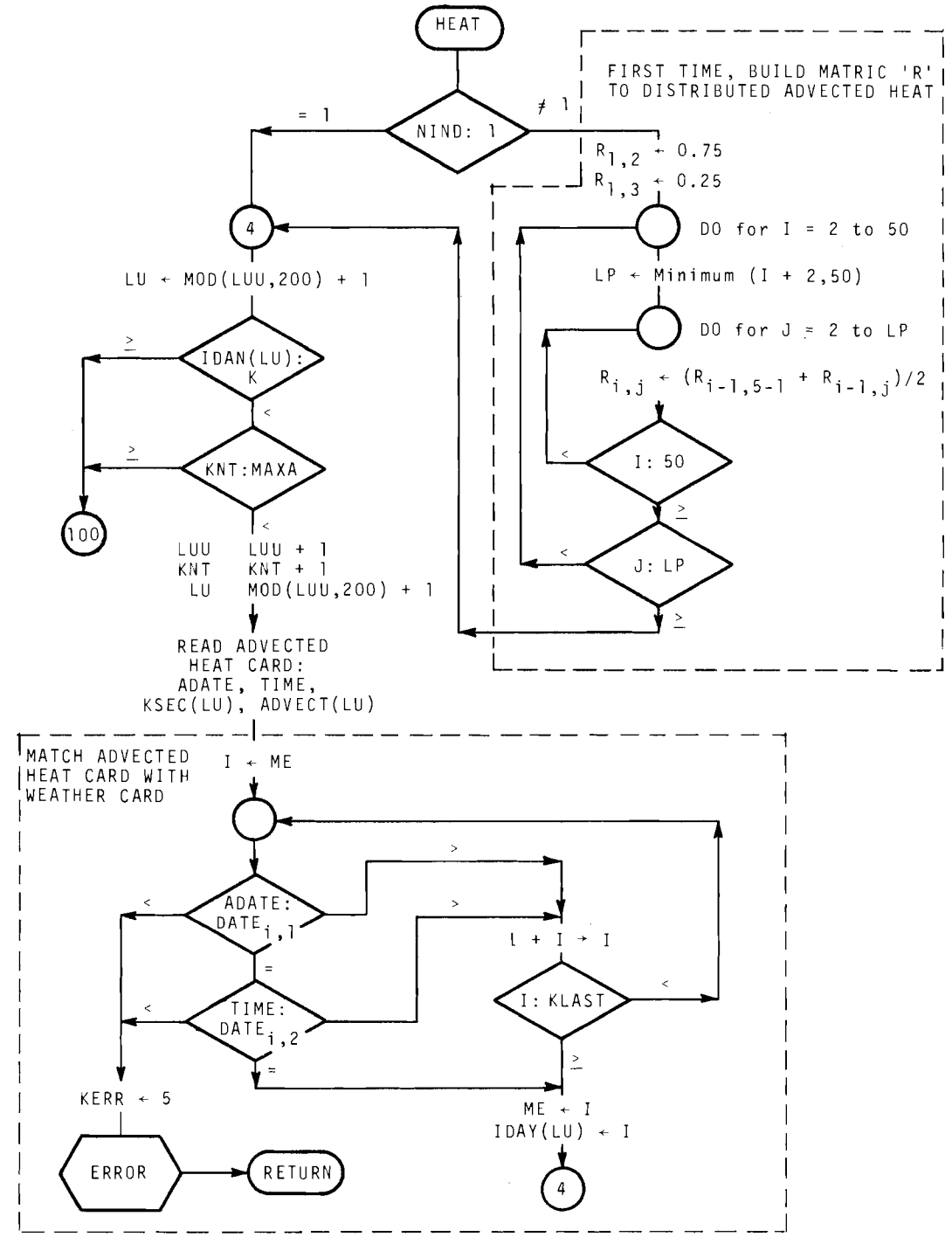

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FIGURE A-7. Digital Simulation System Logic Diagram

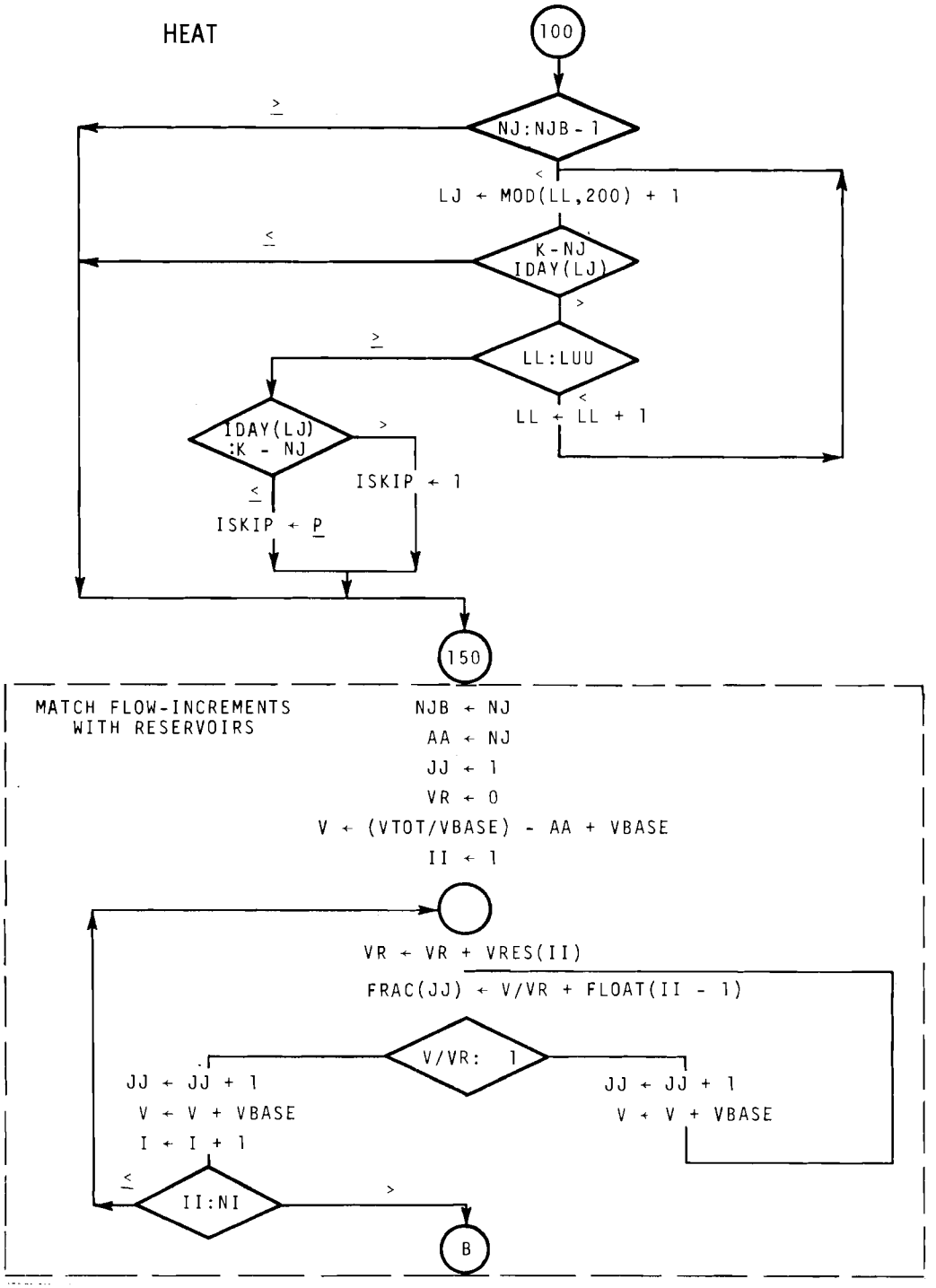

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FIGURE A-8. Digital Simulation System Logic Diagram

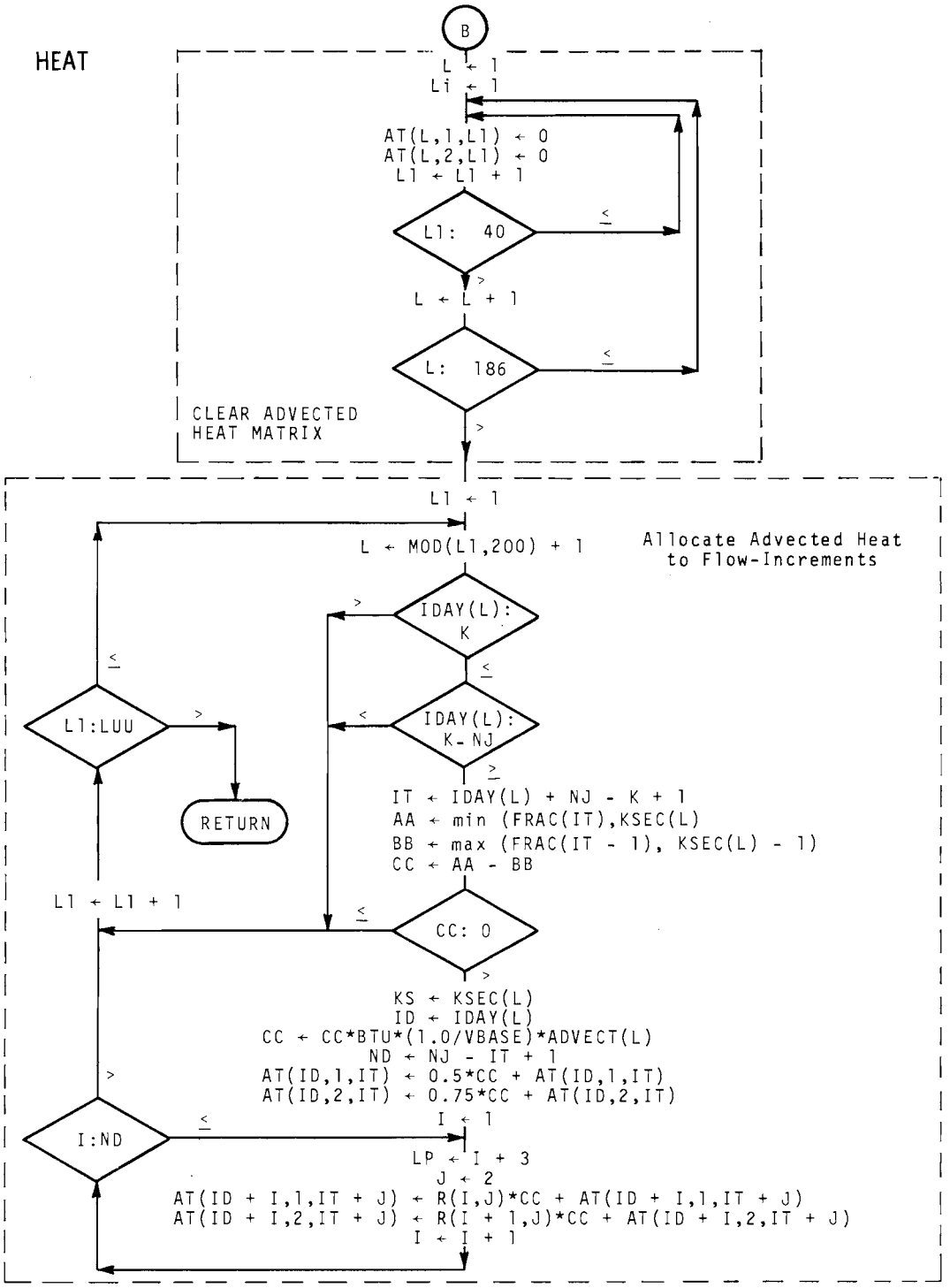

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FIGURE A-9. Digital Simulation System Logic Diagram

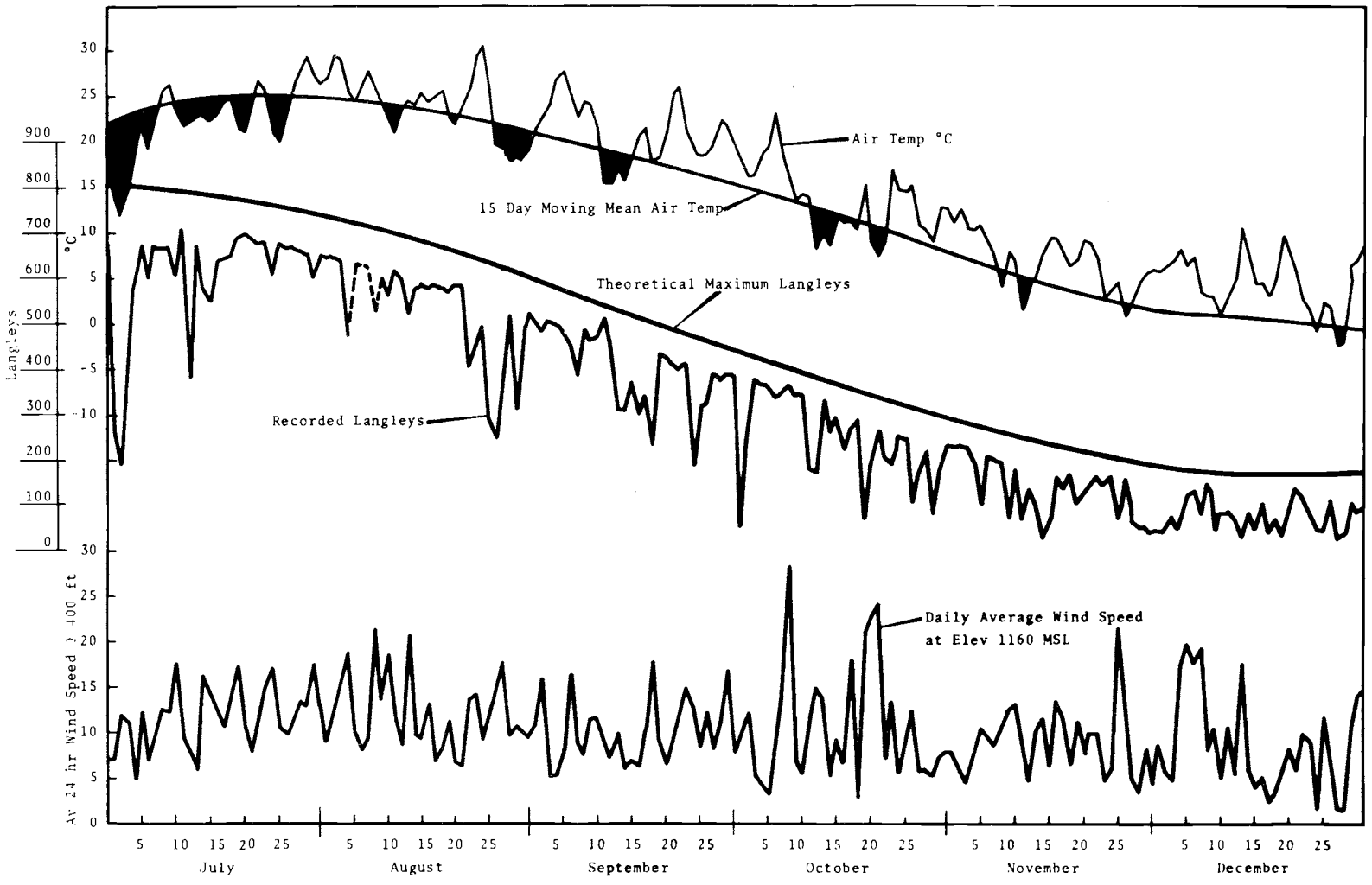

FIGURE A-10. Weather Conditions for Critical Temperature Months--1966

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