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IRON-MASONITE SHIELD STATUS
INTERIM REPORT NO. 6

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IRON-MASONITE SHIELD STATUS

INTERIM REPORT NO. 6

D. E. Clark

June 30, 1967

DOUGLAS UNITED NUCLEAR, INC.
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I. INTRODUCTION

This is number six in a planned series of reports intended to show the status and rates of deterioration of the iron-masonite biological shields of B, D, DR, F, and H reactors.[1,2,3,4,5] Since DR, F, and H reactors are in the deactivated state this is the final such report for them. Following the deactivation of D Reactor at the end of June, 1967, B Reactor will be the only one (out of the five with which the shield deterioration study began) to continue operating.

Data for this report pertain to the top and left (far) side of the reactors and covers the period from January, 1963, through December, 1966. The data collection and analysis methods plus format used in this report are essentially the same as those used in previous reports. It is assumed that the reader has access to past reports for purposes of reference.

It was concluded in the latest previous report[5] that there would be no significant problems from radiation leakage through the bulk shields provided that reactor power levels did not increase by more than five percent and that average maximum masonite temperatures were maintained at less than 90 C. However, if the biological shield temperatures were allowed to reach and sustain 160 C, radiation leakage rates of 1.0r or more could be observed within a five year period. Since that report, a one lattice unit blanket of thoria was charged around the fringes of B and D reactors, in the sides and bottom of C Reactor, and in the top and bottom of the K reactors to control shield temperatures while producing a useful product. At B and K reactors the suppression of shield temperature by the thoria blanket was significant.

II. CONCLUSIONS

Based on extrapolations from January, 1966, and assuming: (1) power levels not increased more than five percent from current levels, and (2) helium concentrations combined with proper shield poison configurations to maintain average maximum shield temperatures of 90 C or less, radiation leakage rates through the imperforate top and side shields of B and D reactors are not expected to exceed the current maximum rates of 30 mr in the next five years. Shield temperatures of 160 C would be expected to produce the undesirable result of radiation leakage through the perforate shields of about 1 r at B and D reactors. This shows no change since the last report in regard to radiation leakage rates.

The extrapolated leakage rates for F and H reactors (there was insufficient data from DR) show that more satisfactory use of fringe poisons would be necessary in order to bring these reactors into alignment with B and D reactor leakage rates. (See Figures 3-6)

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C and K reactors have cooling tubes through their shields which, combined with the fringe thoria at these three reactors, significantly reduce shield temperatures.

III. DISCUSSION

A. Background

High temperatures (and to a minor extent radiation) cause deterioration of the masonite in those reactors with iron-masonite biological shields, and as a result the radiation leakage rates through the imperforate shields have been increasing in excess of what should be expected with increases in power levels.[6] During the water plant modification project of 1956-57 (CG-558), shield temperature monitoring equipment and a facility for activating foils were installed in the B, D, DR, F, and H reactor shields in order to determine the deterioration rates of the masonite in the top and far side shields (see Figures 1 and 2).

Neutron leakage data were obtained by activating gold foils in the neutron detection facility (Figure 2) and then normalizing the data to both counter efficiency and power level. The following equation was developed to correlate normalized neutron leakage data with shield temperature data and power days: (One power day is defined as a day during which the production for a given reactor equals or exceeds 1000 MWD).

$$L = L_o e^{bt}$$

where L_o = original normalized leakage rate

L = final normalized leakage rate

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$$b = \frac{\mu b \ Xb}{m} A \sum_{i=1}^{m} e^{-B/T_i}$$

and μb = attenuation coefficient of masonite

Xb = total thickness of masonite in the shield

A, B = constants

T_i = operating temperature of the i^{th} masonite layer (°K)

m = total number of masonite layers in the shield.

The equation above considers only temperature as the source of deterioration because the effects of irradiation are relatively insignificant. A modified form of the above equation was used with the computer program ICARUS to evaluate the constant, A and find the leakage, L as follows:

$$L = L_o \; e^{\frac{\mu b \; Xb}{m}} \; A \sum_{i=1}^{n} ti \sum_{j=1}^{m} e^{-B/(T_{i,j}+273)}$$

where $\frac{\mu b \; Xb}{m}$ = 1.15 for the Hanford reactor shields

$\sum_{i=1}^{n} ti$ = time between L and L_o in power days

$T_{i,j}$ = masonite temperature (°K) during time i for masonite layer, j.

n = total number of sets of temperature data between L_o and L.

B is defined as the ratio of molar energy of activation of masonite to the molar gas constant, and is, therefore, a constant. The value of B reported by L. A. Wilson,[6] 5870, is still in current use. The constant, A, on the other hand, varies with the environment and property of masonite under study and is, therefore, determined from operating data. Values of A reported by P. D. Gross[5] were as follows:

Reactor	A	Approximate Power Days
B	3555.7	460
D	901.8	650
F	1211.4	720
H	2335.5	675
Avg.	2001.1	625

Current values of A as calculated by the ICARUS computer program on the UNIVAC 1107 digital computer are:

Reactor	A	Approximate Power Days
B	2215.4	1046
D	845.8	1082
F	2442.9	711
H	3632.4	652
Avg.	2284.1	873

(Note: Foil data collection at DR Reactor was not sufficient to determine a reliable value of A.)

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The changes in the constant A for B and D reactors reflect a decreased neutron leakage rate following the charging of thoria in the fringe lattice of these two reactors rather than an improvement in the neutron attenuation capacity of the shields. Increased values of A at F and H reactors show that radiation leakage rates would have become significant if they had continued operating without taking corrective measures to reduce the trend.

B. Obtaining Data

Leakage rate data were obtained by activating gold foils in the neutron detector facility at each of the five given reactors. (Because of the physical placement of the gas loop in DR Reactor, it was not possible to obtain neutron data until the first part of 1964. The quantity of data collected, however, was not sufficient for statistical reliability and are, therefore, not presented in this report.) Shield temperature data were obtained from thermocouples placed in the steel layers of the laminated iron-masonite shields. Masonite temperatures were taken as the average of the two adjacent iron layers. The base date on which power day counting began and shield temperature and neutron leakage data collection began was August 1, 1957.

C. General Observations

Extrapolated leakage rates, calculated by the ICARUS computer code on the UNIVAC 1107 computer are shown plotted in Figures 3-6. The graphs show that B and D leakage rates have improved whereas the leakage rates for F and H reactors have increased in magnitude since the most recent previous report. The corresponding calculated values of A show a similar trend; i.e., the magnitude of the constant A decreased for B and D reactors while increasing for F and H reactors. This is believed to be the result of having charged thoria in the fringe at B and D reactors which reduced the shield temperatures and so decreased the leakage rates, while at F Reactor the shields were allowed to operate at slightly higher temperatures in order to obtain experimental data before the reactor was shut down for deactivation. At H Reactor, both leakage rates and the constant A have been relatively high compared to the other reactors so the results given in this report were to be expected.

Figures 7-10 show the normalized neutron count data versus power days. A linear least squares fit was performed on the data and the results are drawn in a solid line on each plot. The slope of the fitted line for H Reactor is the steepest, followed by B and F reactors with D Reactor having the least slope. This shows that the rate of increase in neutron leakage through the shields was greatest at H Reactor and least at D Reactor with B and F reactors just slightly more than D, which is in agreement with data given in Figures 3-6.

Relative reactor power levels, percent helium in the reactor atmosphere, and maximum temperature for the top biological shield are presented in

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Figures 11-15. These figures show how the shield temperatures vary inversely with the helium content in the reactor atmosphere.

Dates on which fringe poison for shield protection was initially charged are given in Figures 16-20. It should be noted that lithium-aluminum charges in the far side fringe at B Reactor were replaced with thoria on November 15, 1964, and that lithium-aluminum charges in the top row of B Reactor were also replaced with thoria on January 8, 1965. The lithium-aluminum charges in the far side and top lattice units of D Reactor were also replaced with thoria on October 20, 1964.

Finally, profiles of the average temperatures of the masonite in the far side and top shields are presented in Figures 21-25. All of these are higher than they were in the most recent previous report[5] with the exception of the side shield at B Reactor which was slightly lower.

D. E. Clark
Process Physics Unit
Research and Engineering Section

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REFERENCES

1. HW-54358, "Interim Report Number I, Development Test IP-102-C, Biological Shield Data - Use of Neutron Detector Facility," W. L. Bunch, January 3, 1958. (Secret)

2. HW-57373, "Interim Report Number II, Development Test IP-102-C, Biological Shield Data - Use of Neutron Detector Facility," W. L. Bunch, August 29, 1958. (Secret)

3. HW-64951, "Attenuation Effectiveness of the Hanford Reactor Iron-Masonite Shields," W. L. Smalley, April 27, 1960. (Secret)

4. HW-69640, "Status Report - Iron-Masonite Shields," W. L. Smalley, May 26, 1961. (Secret)

5. RL-REA-1031, "Status Report - Iron-Masonite Shield Attenuation Effectiveness," P. D. Gross, April 15, 1965. (Secret)

6. HW-35202, "Hanford Shield Masonited Deterioration Studies," L. A. Wilson, August 8, 1955. (Secret)

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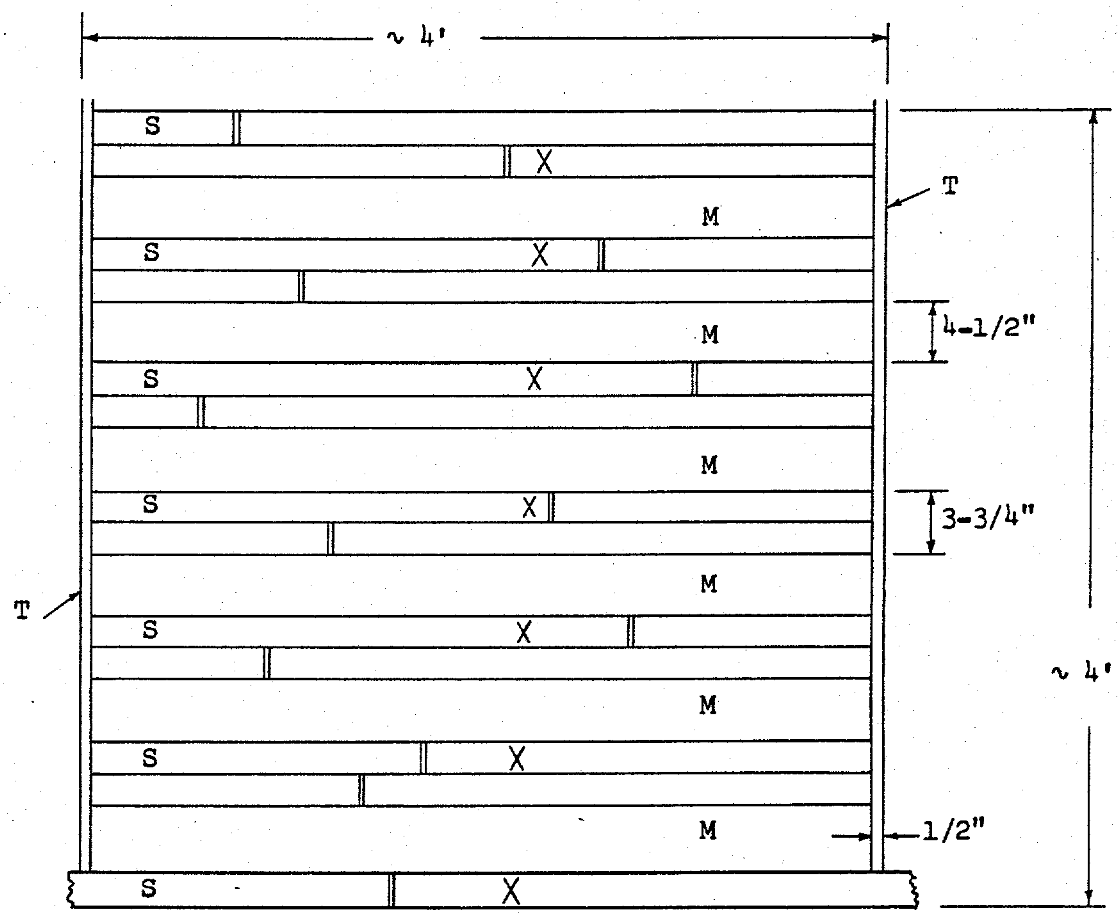
Figure 1 - Thermocouple Locations in the Biological Shields*



M = Masonite S = Steel

T = T-seam X = Thermocouple Location

Note: One group of seven thermocouples as shown here is located at the approximate geometrical center of each of the top and far side shields of B, D, DR, F, and H reactors. (These were installed as part of the CG-558 Project.)

* Taken from Reference 5.

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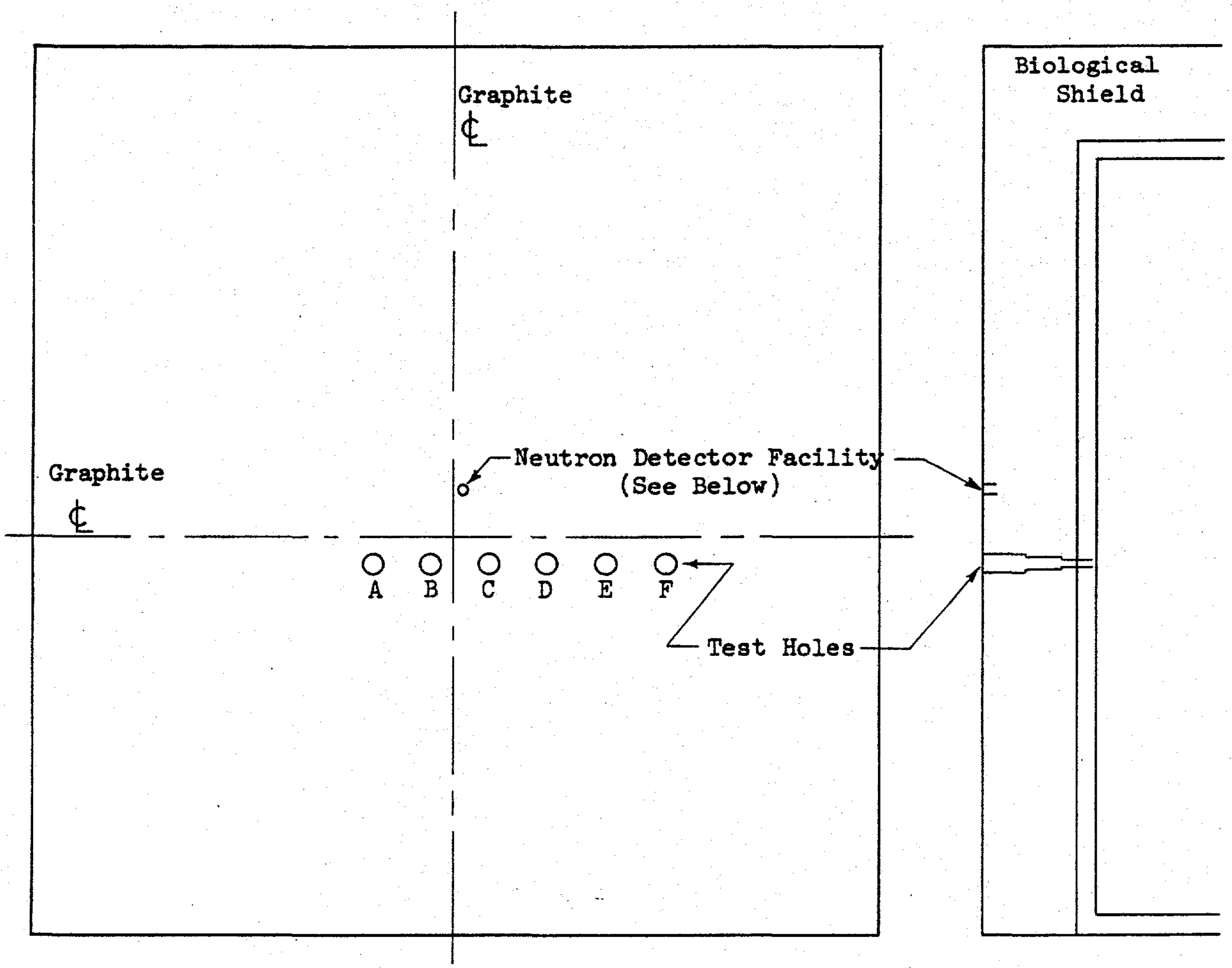
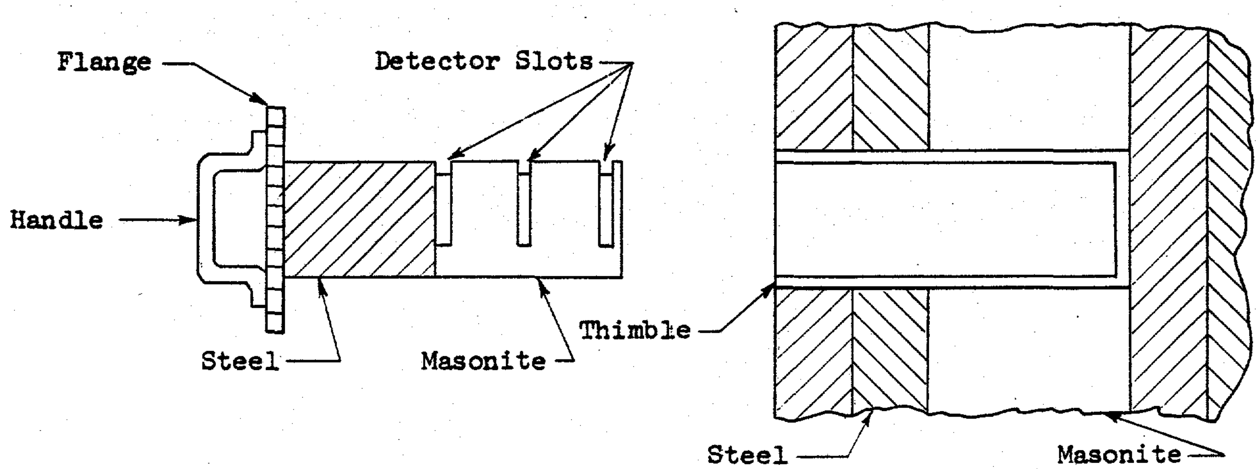
Figure 2 - Neutron Detector Facility* - Location and Details



Far Side View of Reactor Showing Approximate Location of Neutron Detector Facility



* Taken from Reference 5.

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Figure 3 - Extrapolated Leakage Rate as a Function of Time and Maximum Masonite Temperature

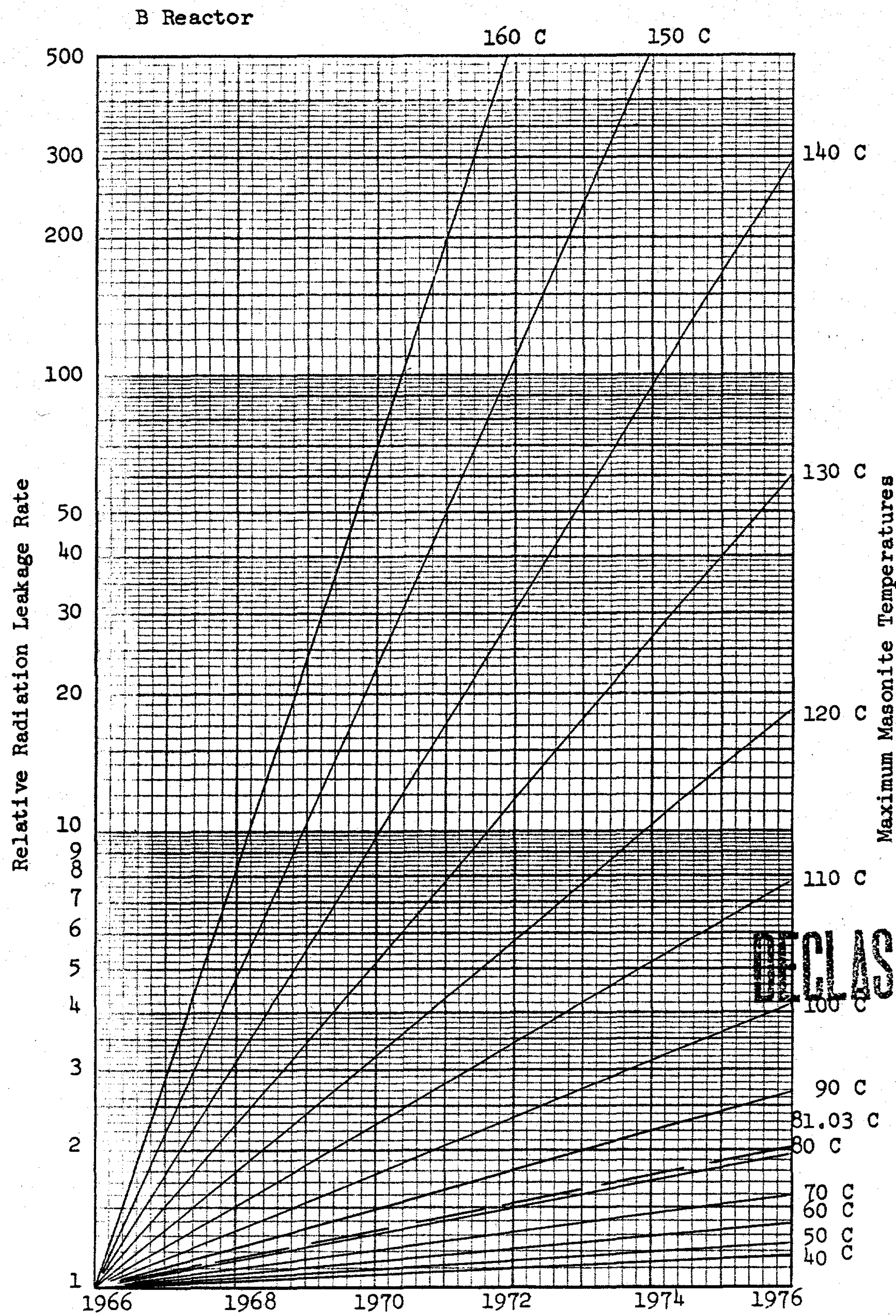

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Figure 4 - Extrapolated Leakage Rate as a Function of Time and Maximum Masonite Temperature

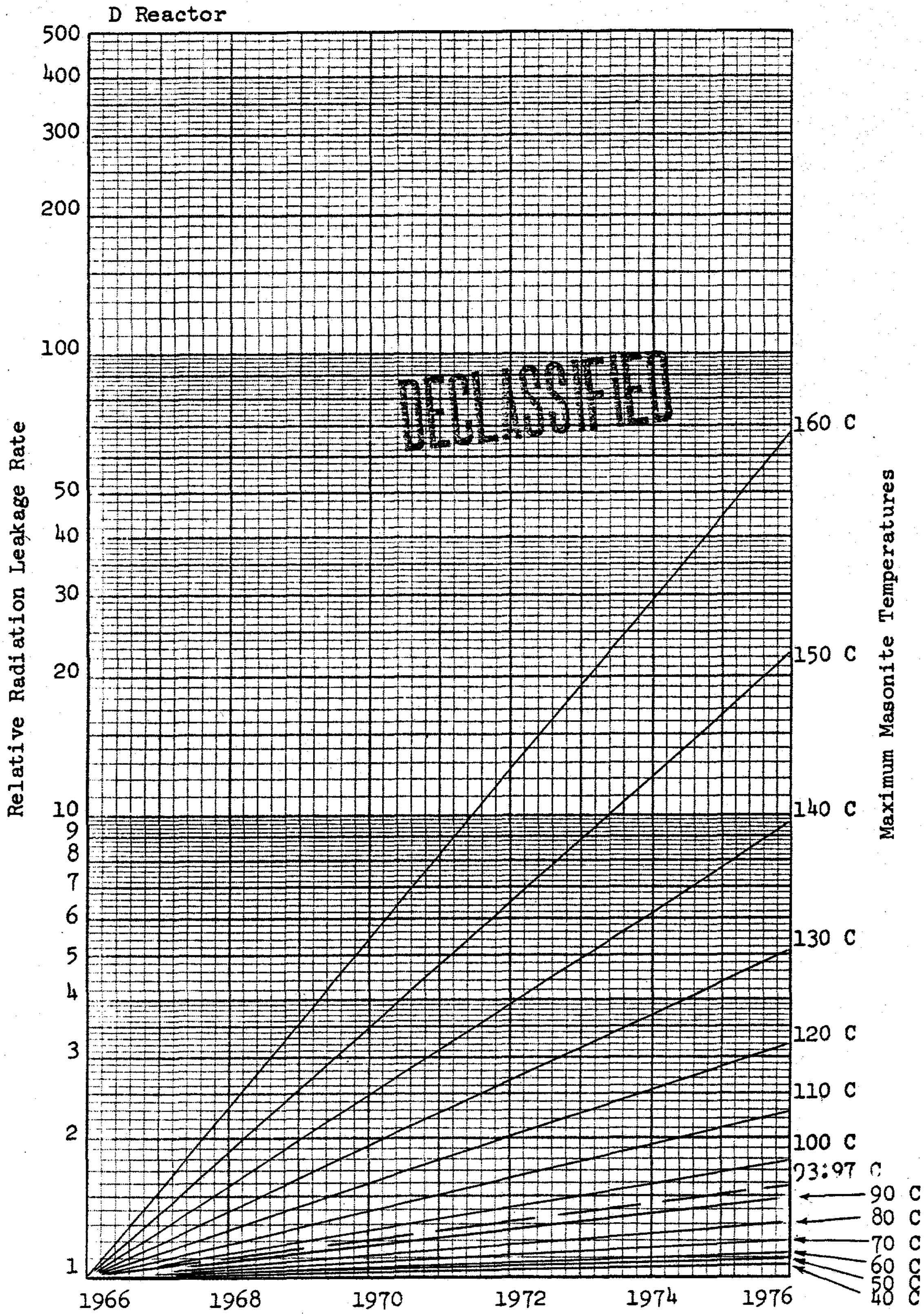

Figure 5 - Extrapolated Leakage Rate as a Function of Time and Maximum Masonite Temperature

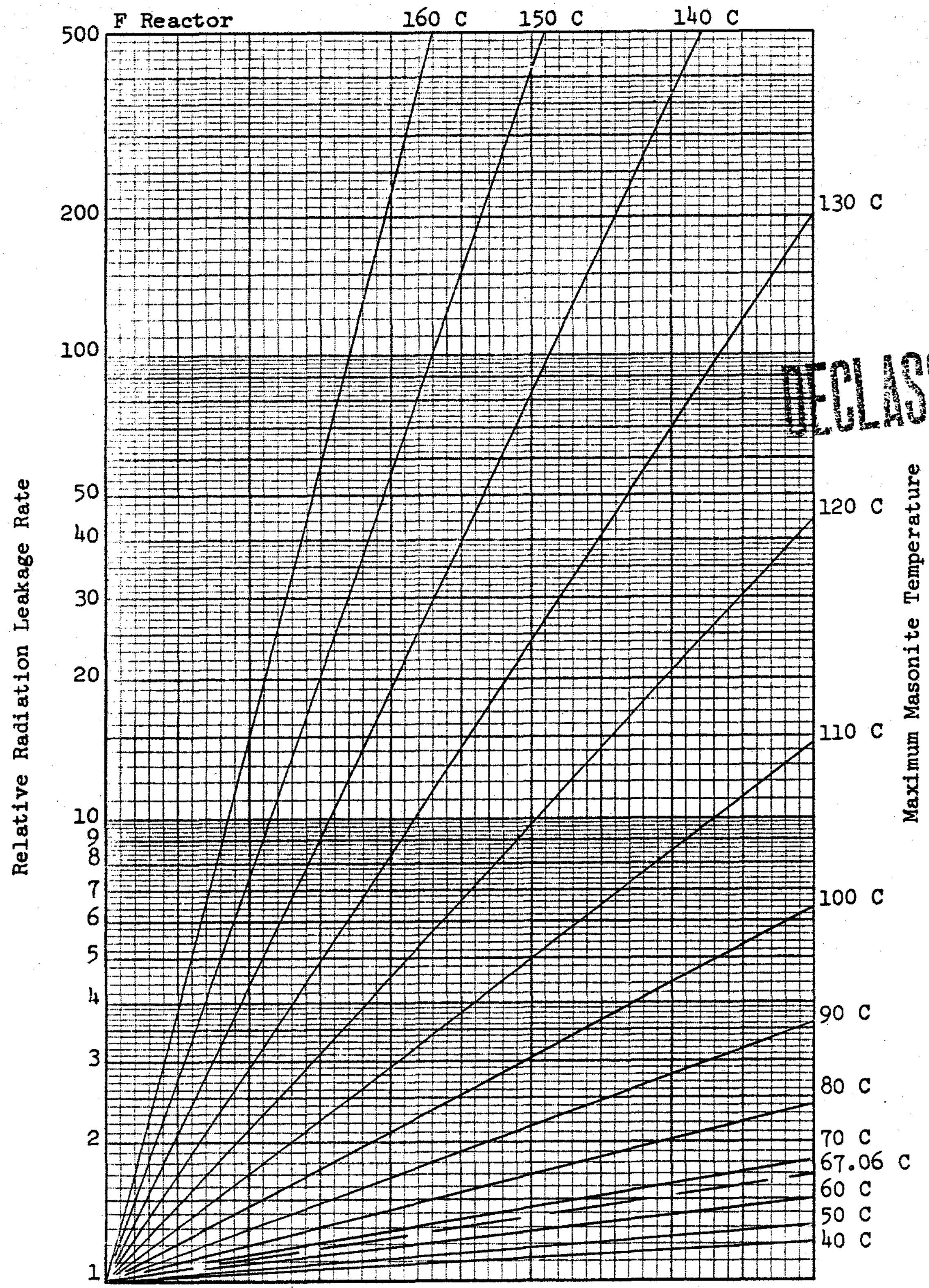

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Figure 6 - Extrapolated Leakage Rate as a Function of Time and Maximum Masonite Temperature

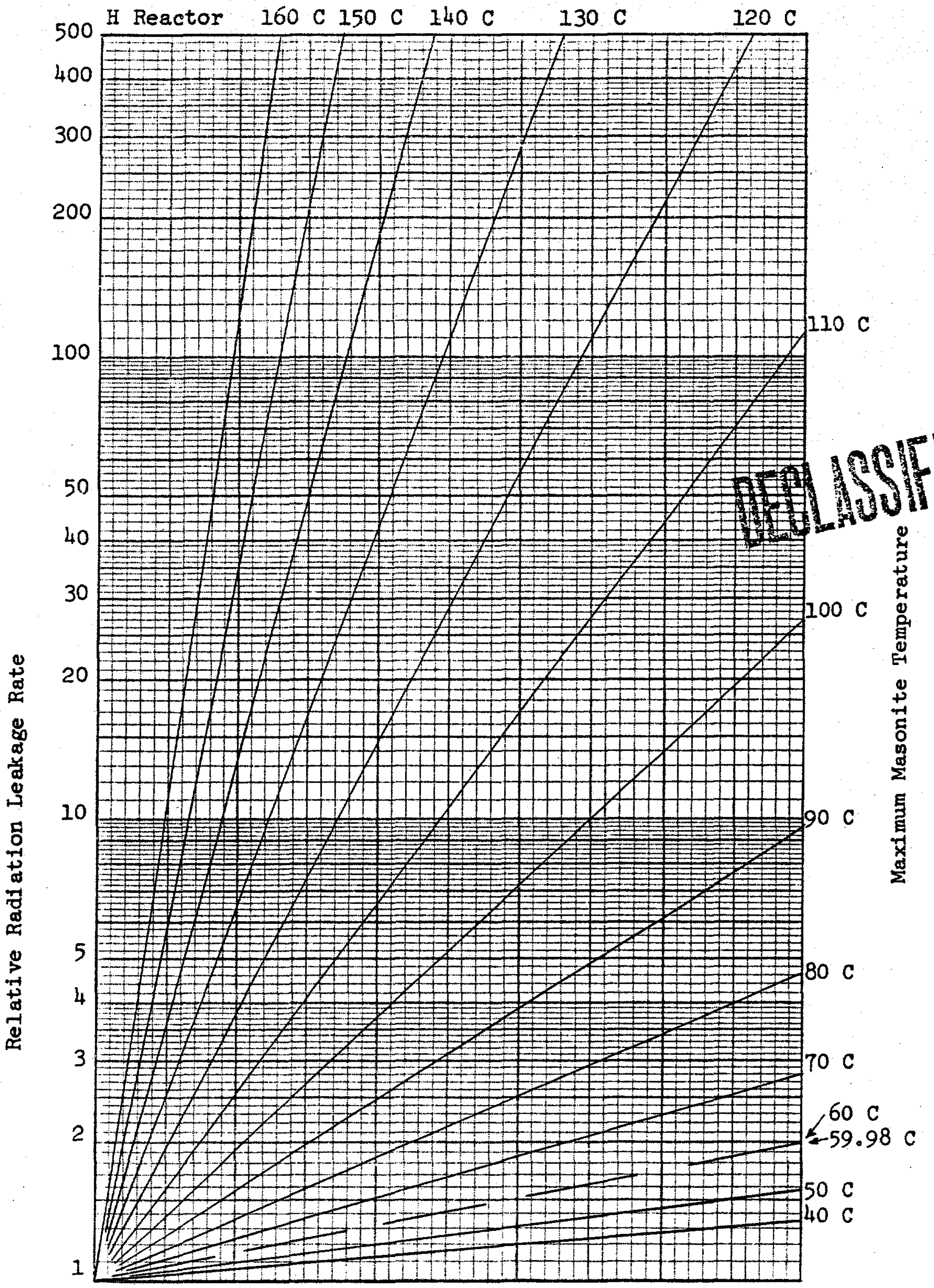

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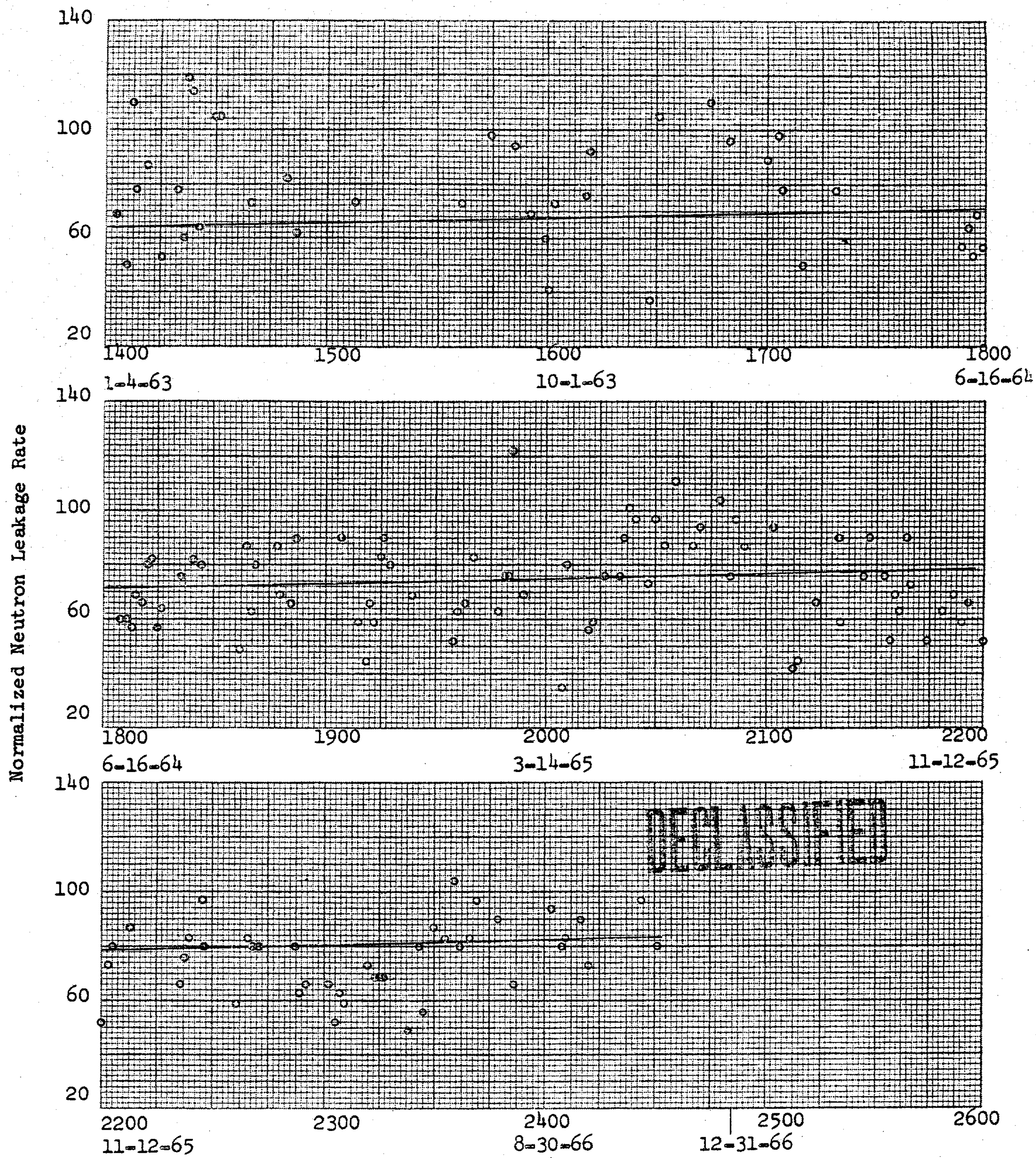
Figure 7 - Normalized Neutron Leakage Trend Through Far Side Shield - B Reactor



Power Days Since Beginning of Data Collecting

Figure 8 - Normalized Neutron Leakage Trend Through Far Side Shield - D Reactor

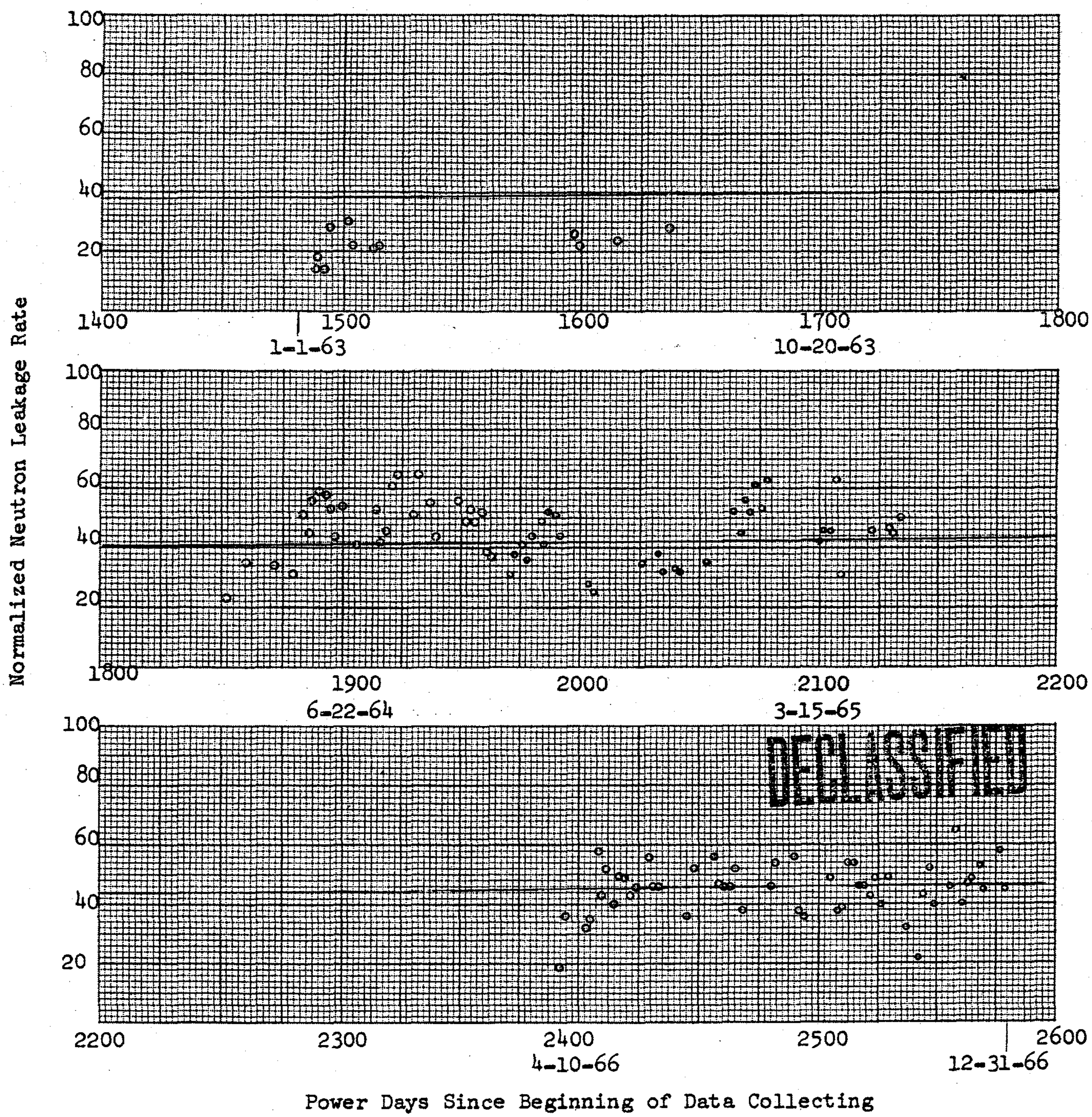


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Figure 9 - Normalized Neutron Leakage Trend Through Far Side Shield - F Reactor

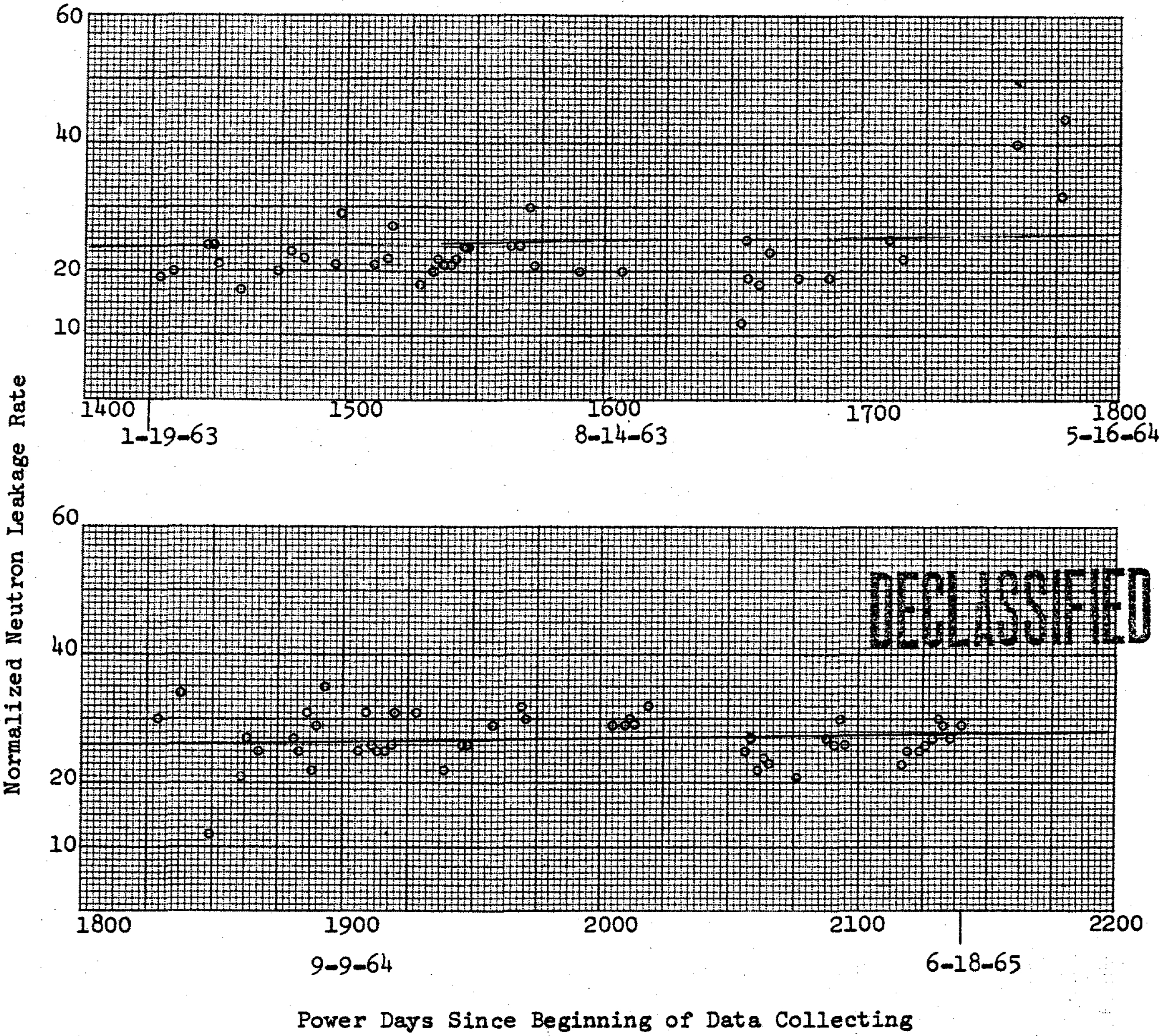

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Figure 10 - Normalized Neutron Leakage Trend Through Far Side Shield - H Reactor

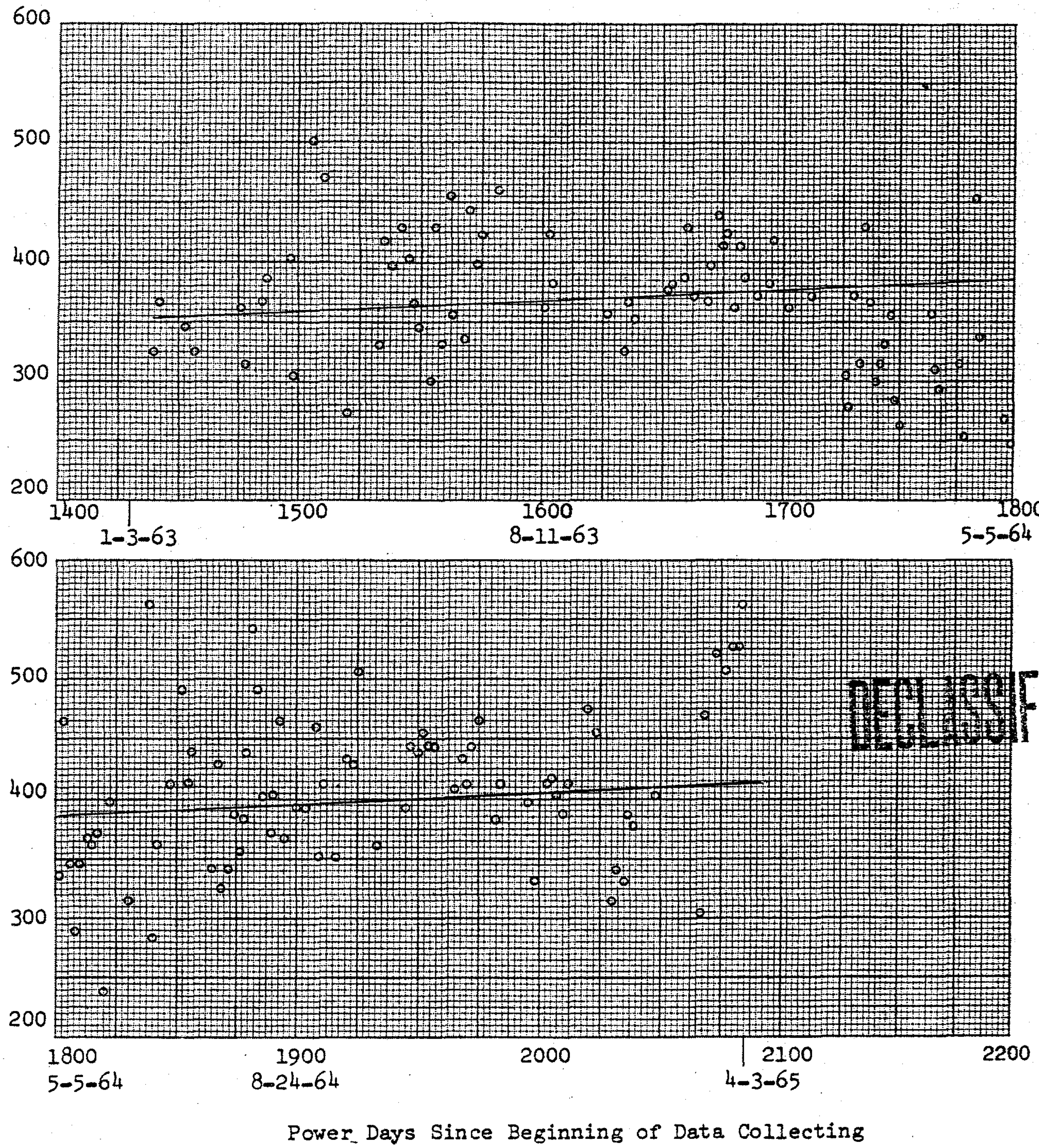

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Figure 11 - Relative Power Level, Helium Concentration
and Maximum Top Biological Shield Temperatures

B Reactor

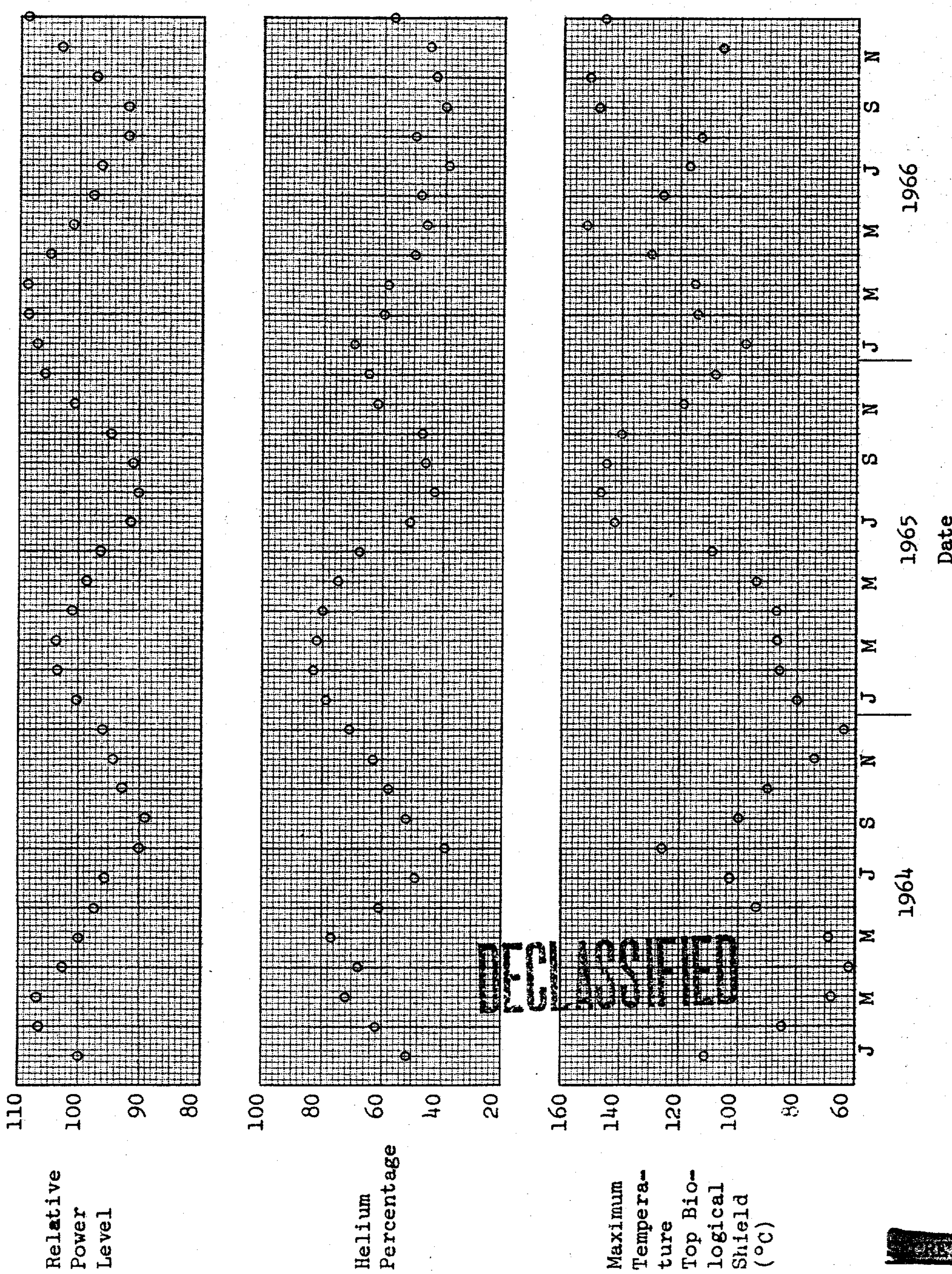

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Figure 12 - Relative Power Level, Helium Concentration and Maximum Top Biological Shield Temperatures

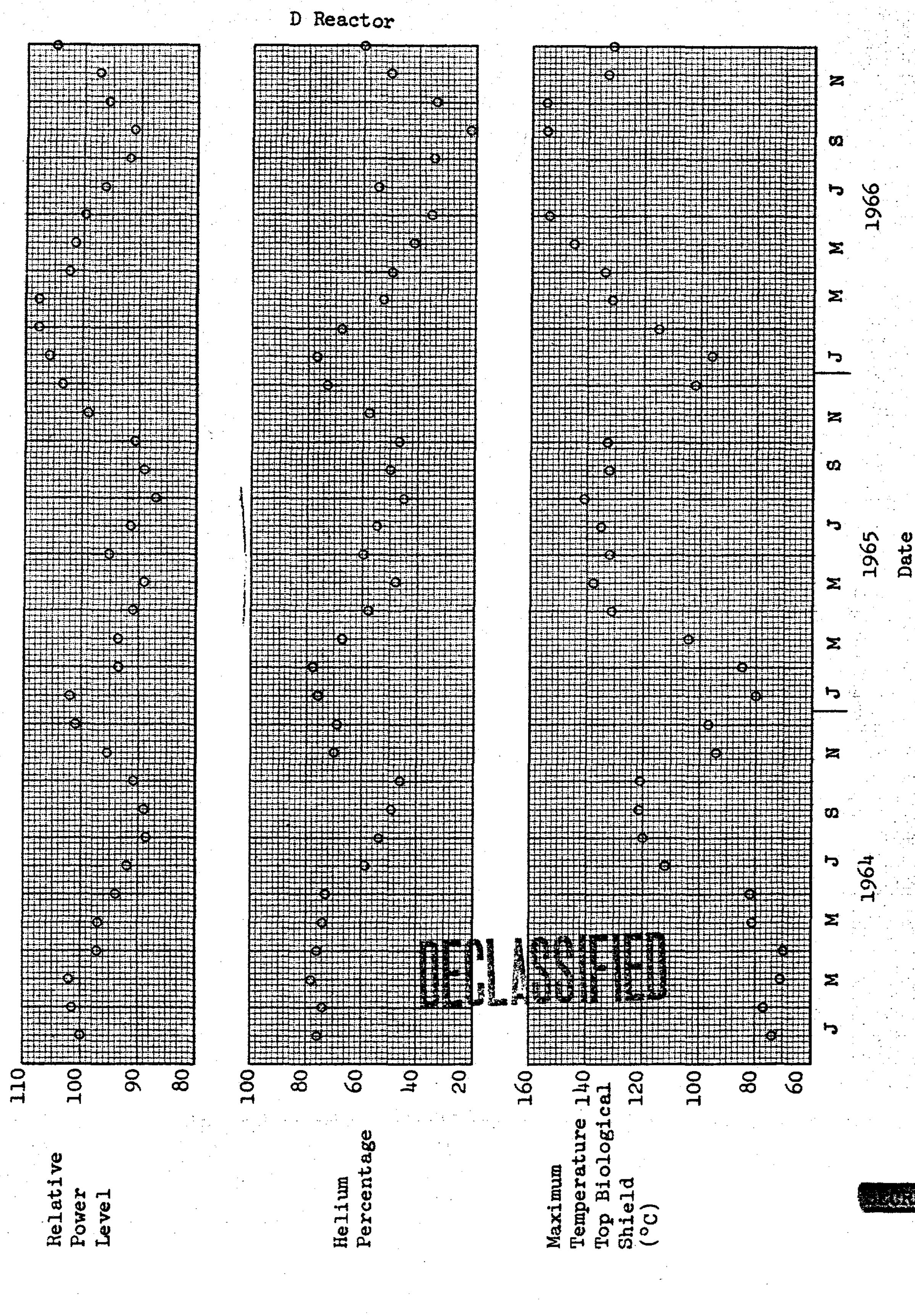

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Figure 13 - Relative Power Level, Helium Concentration and Maximum Top Biological Shield Temperatures

DR Reactor

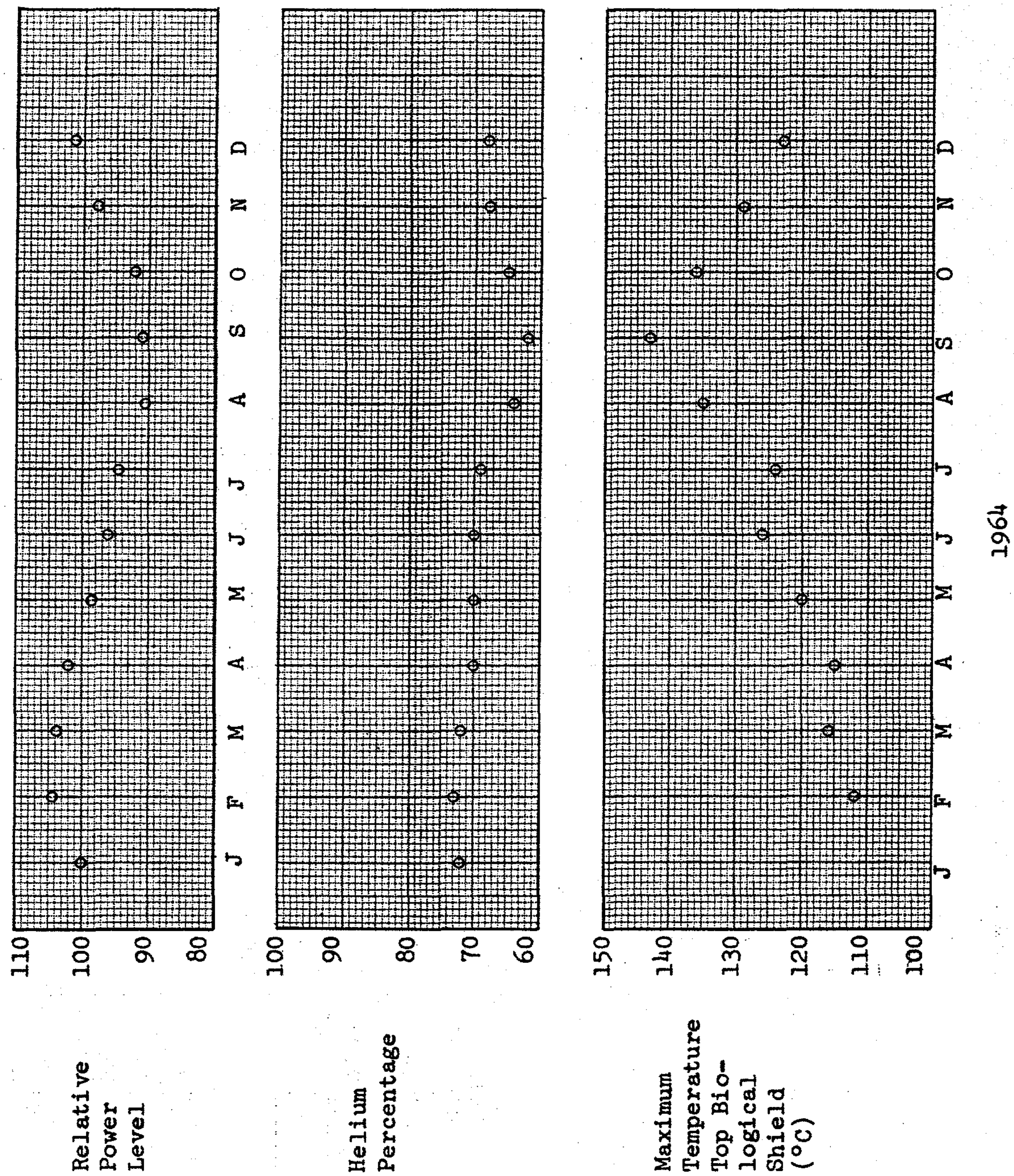

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Figure 14 - Relative Power Level, Helium Concentration and Maximum Top Biological Shield Temperatures

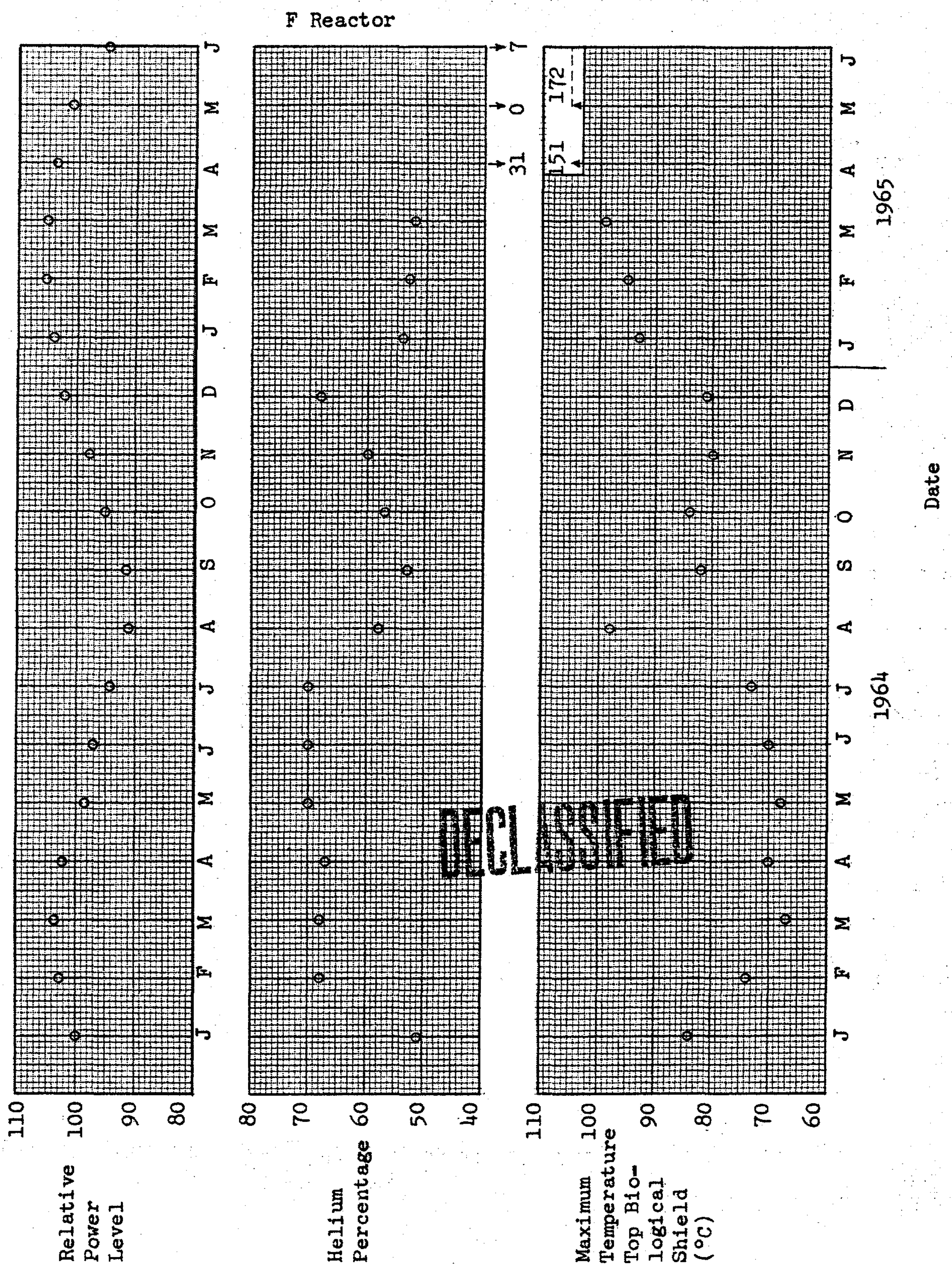

Figure 15 - Relative Power Level, Helium Concentration and Maximum Top Biological Shield Temperatures

H Reactor

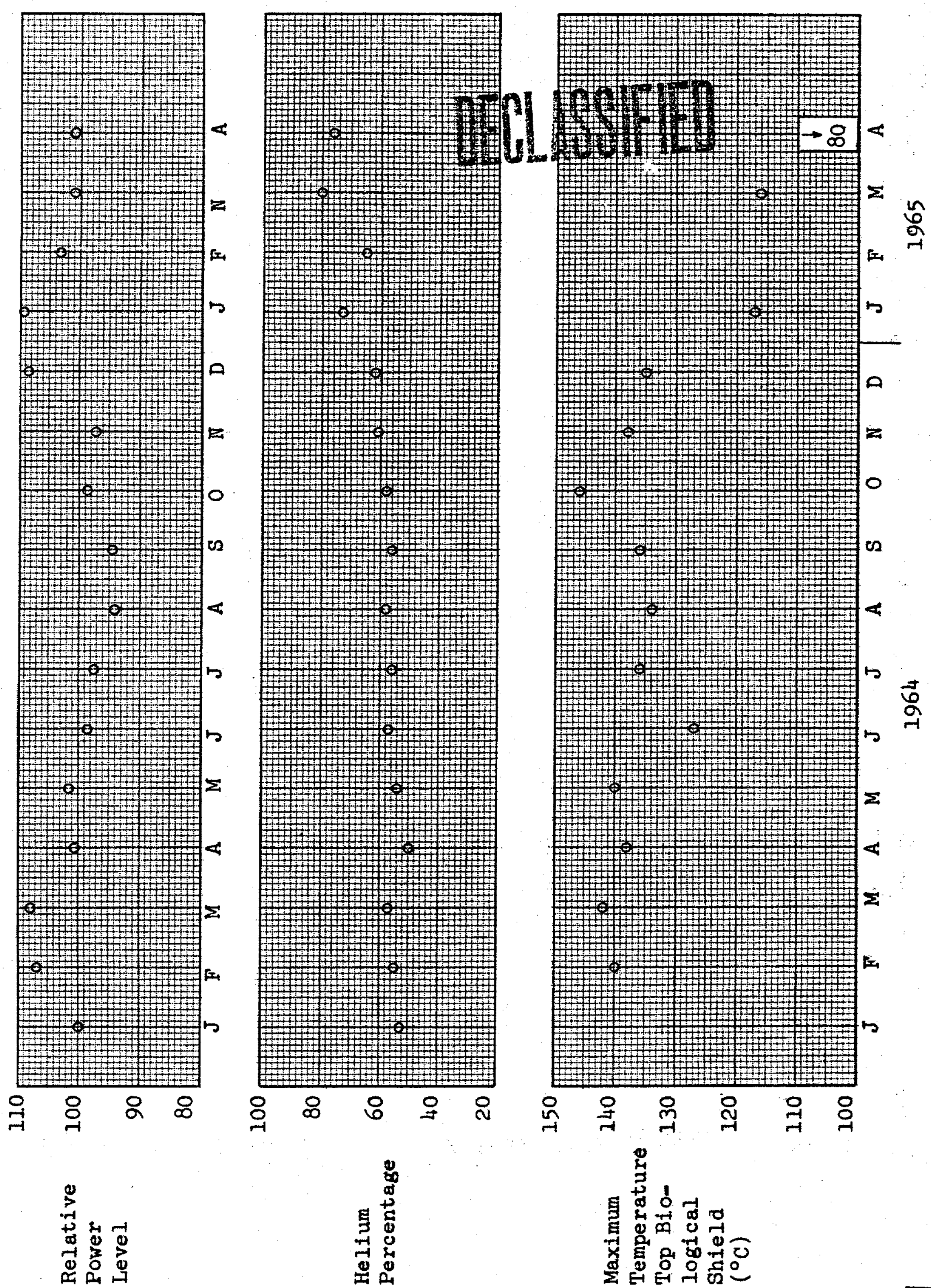

Figure 16* - Dates for Initial Charging of Fringe Poison

B Reactor

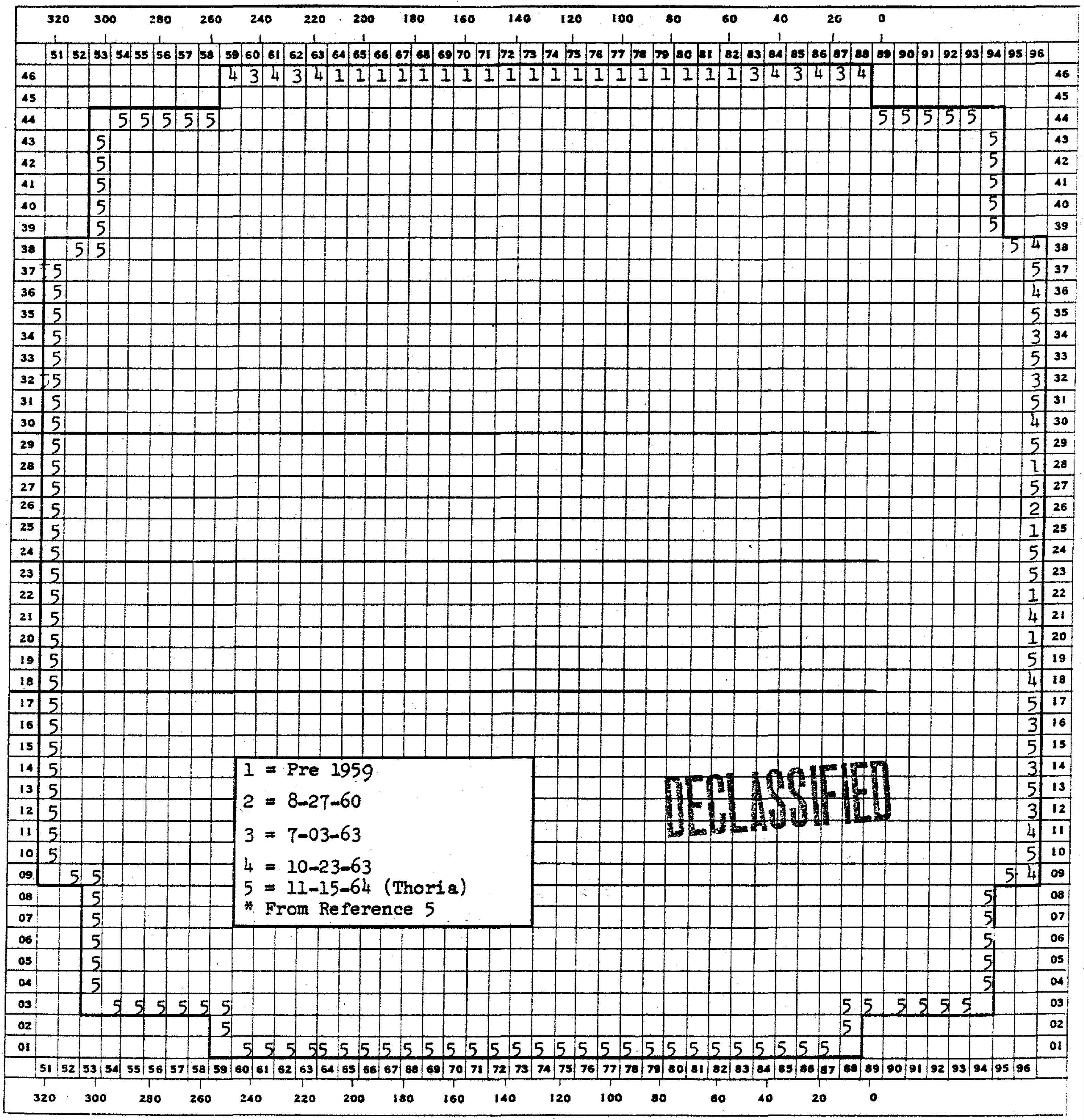

Figure 17* - Dates for Initial Charging of Fringe Poison

D Reactor

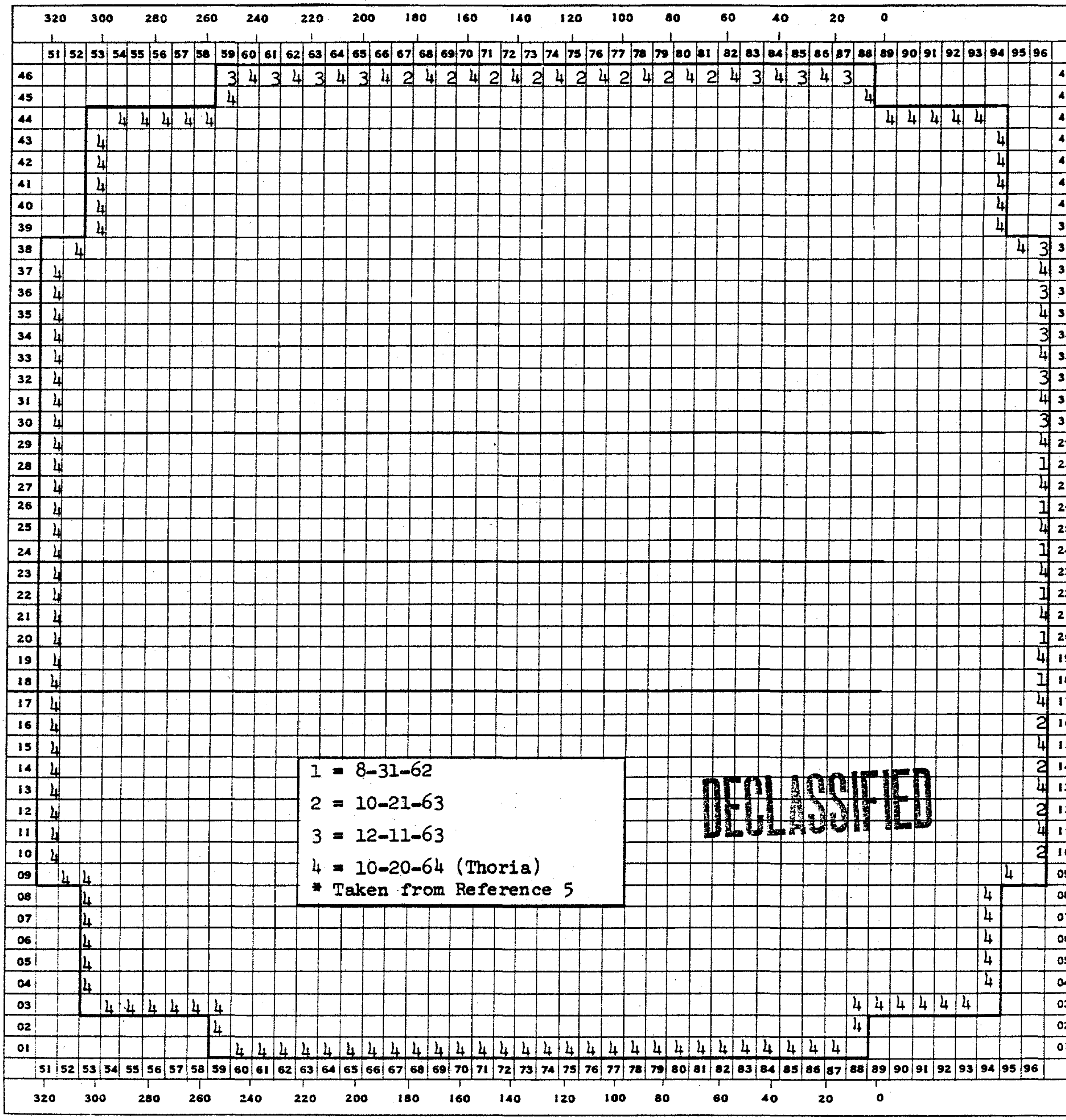

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Figure 18* - Dates for Initial Charging of Fringe Poison

DR Reactor

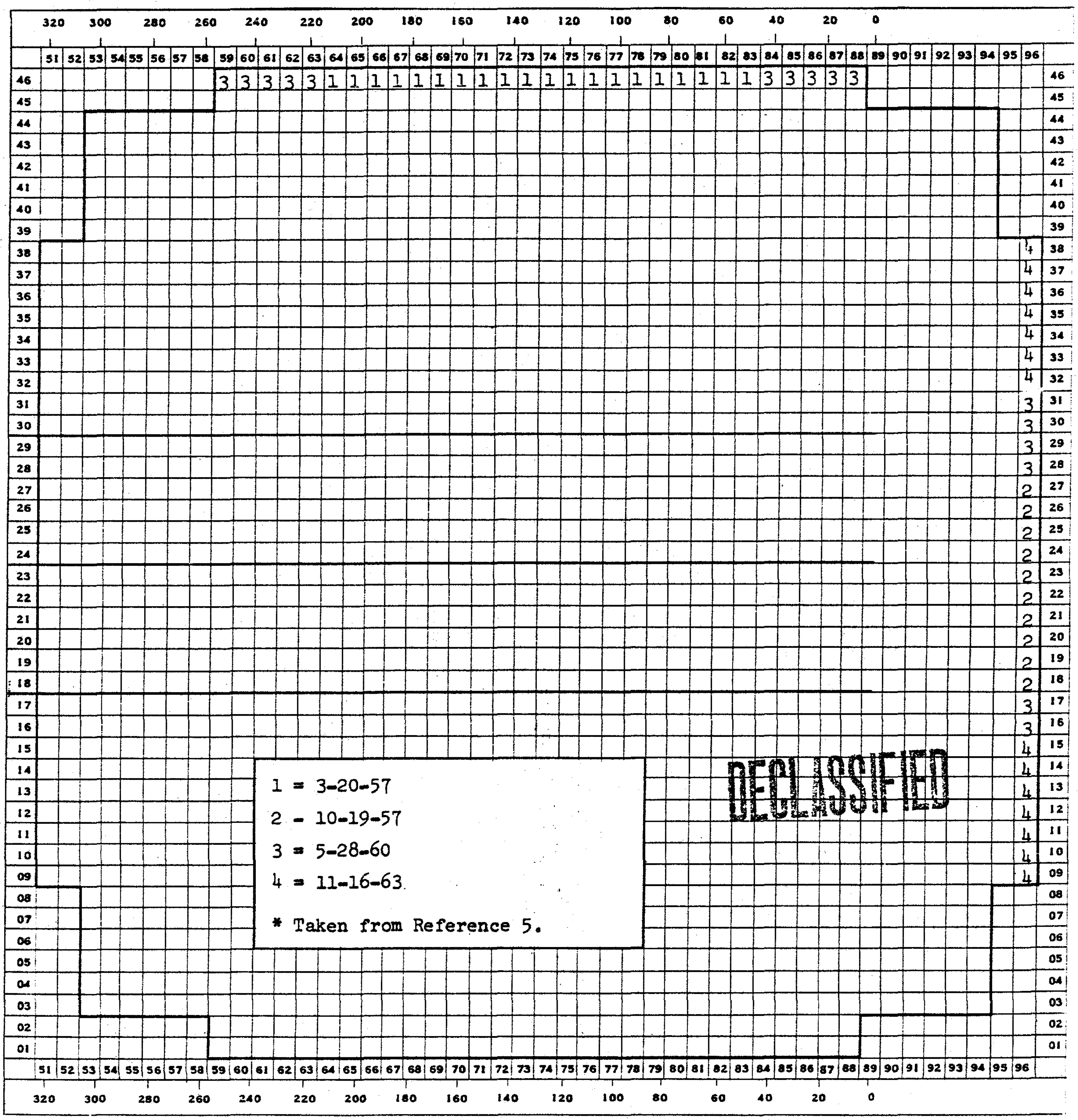

Figure 19* - Dates for Initial Charging of Fringe Poison

F Reactor

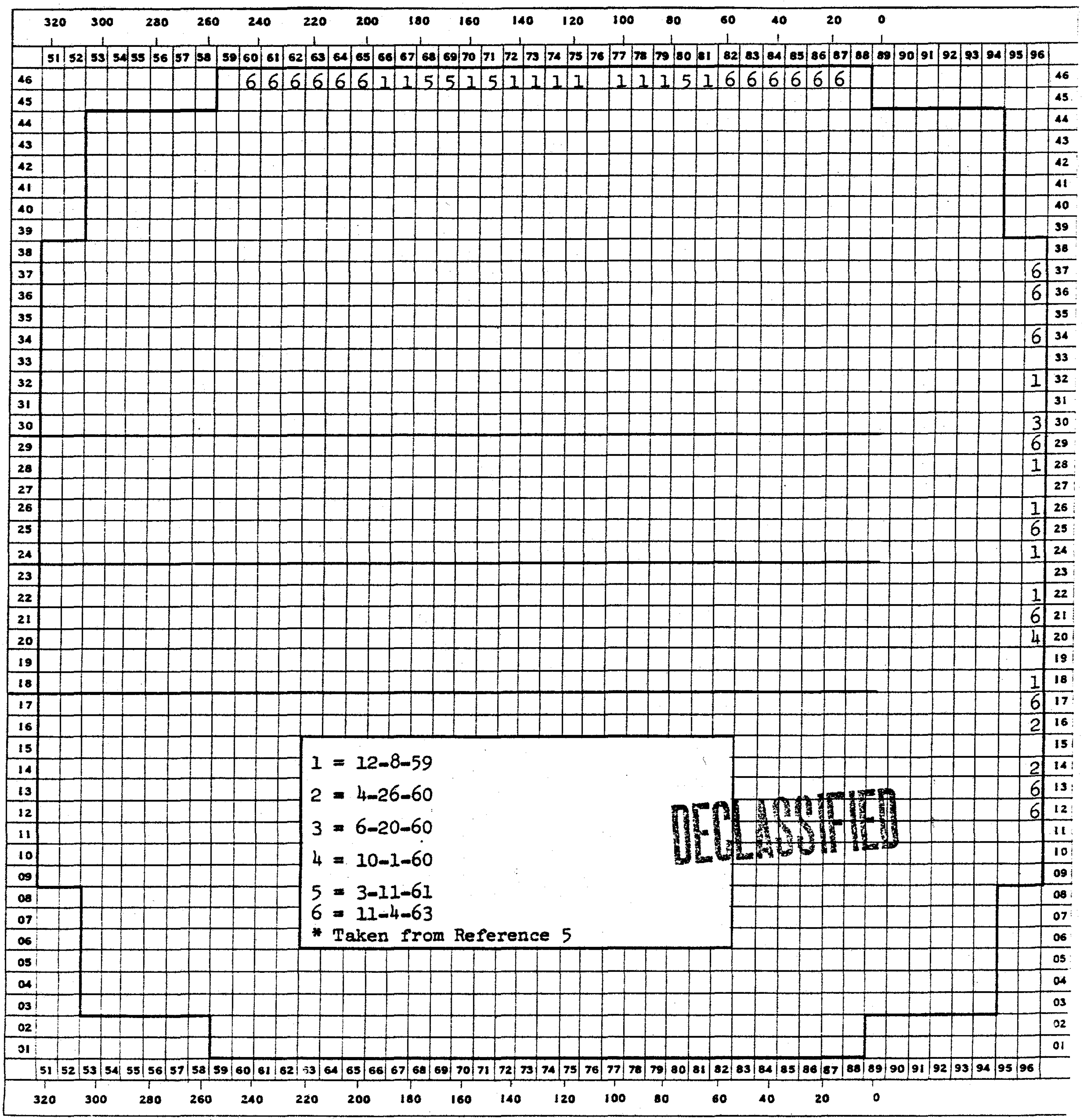

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Figure 20* - Dates for Initial Loading of Fringe Poison

H Reactor

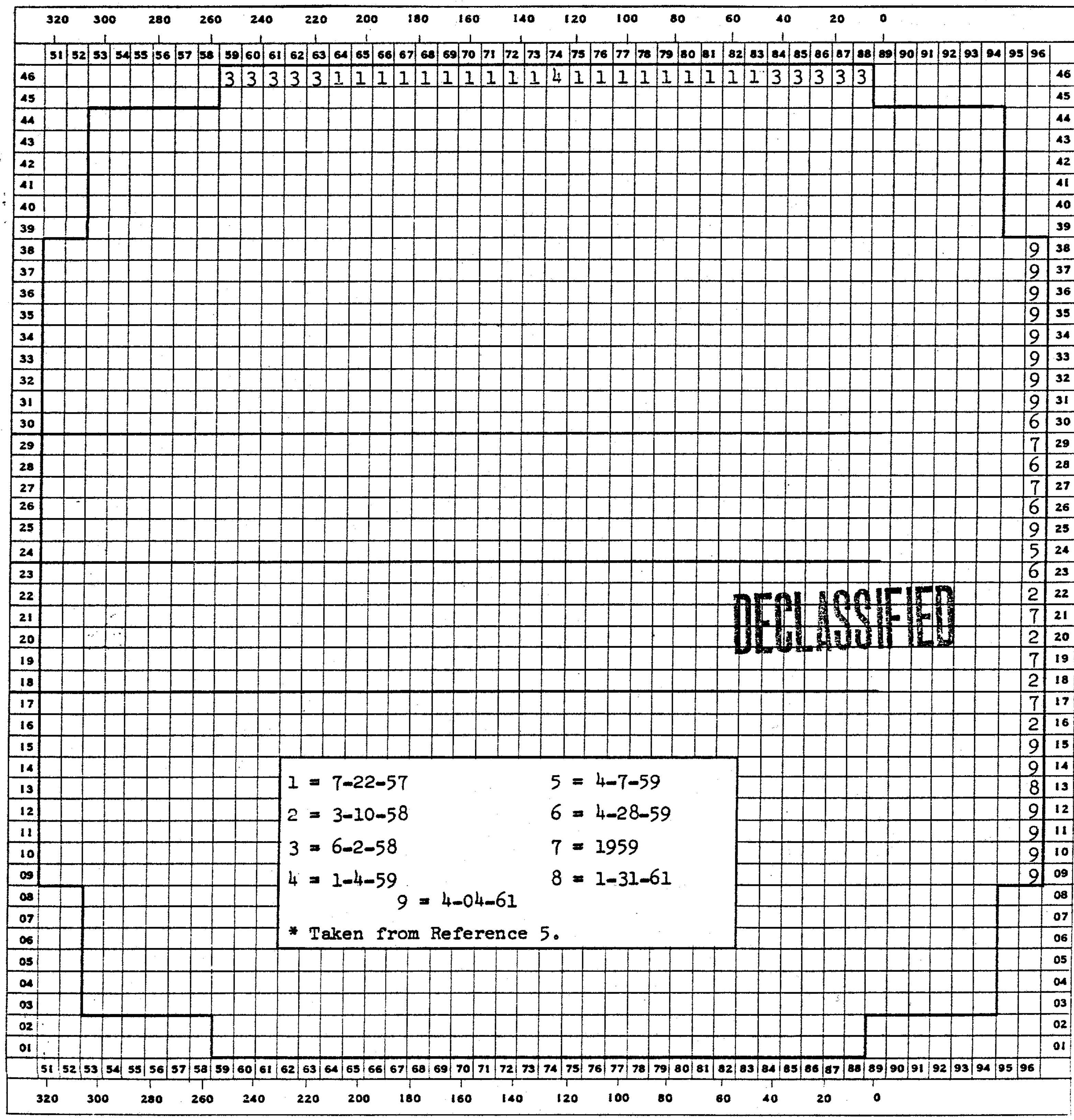

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Figure 21 - Profile of Average Biological Shield Temperatures - B Reactor

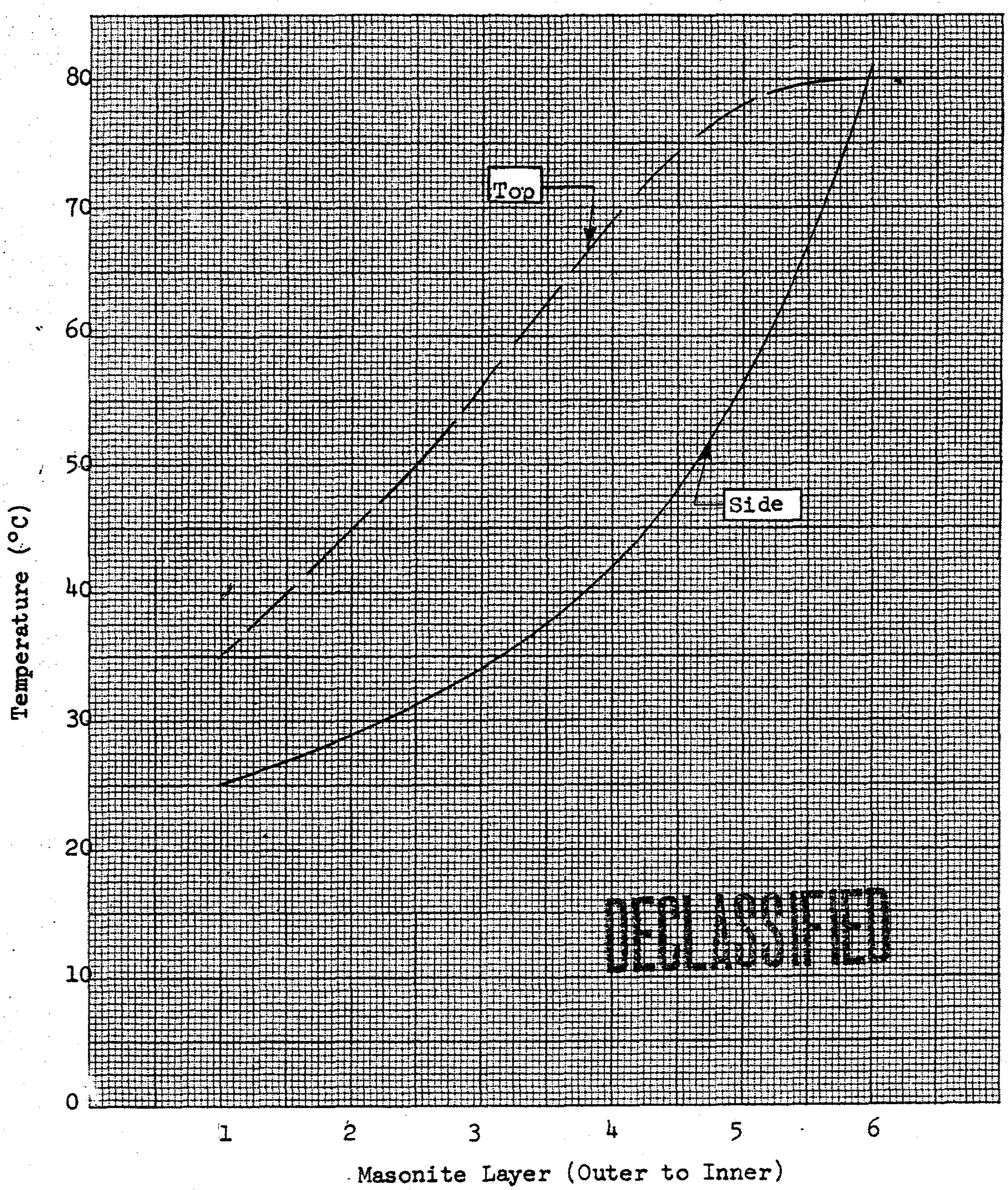

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Figure 22 - Profile of Average Biological Shield Temperatures - D Reactor

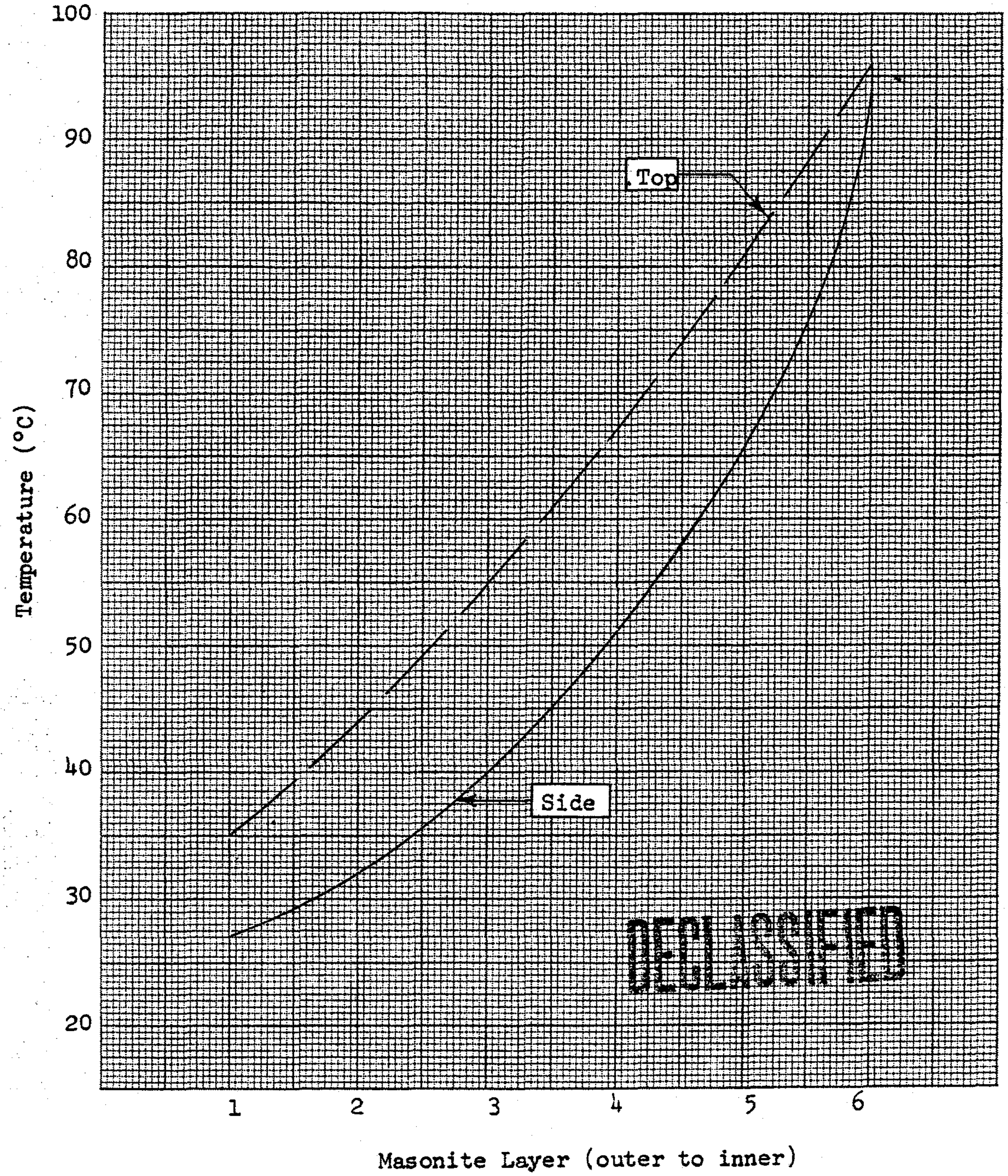


Figure 23 - Profile of Average Biological Shield Temperatures - DR Reactor

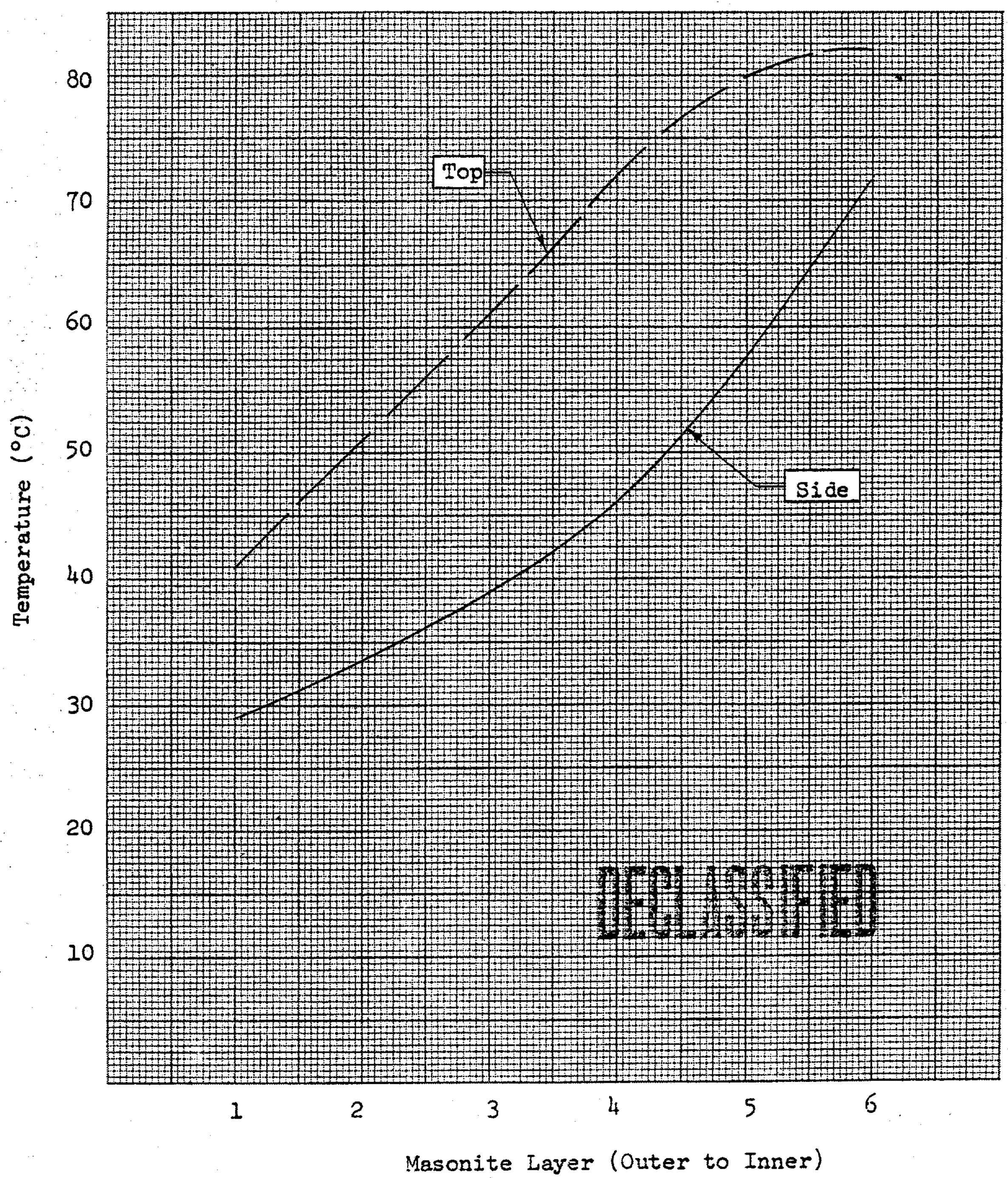


Figure 24 - Profile of Average Biological Shield Temperatures - F Reactor

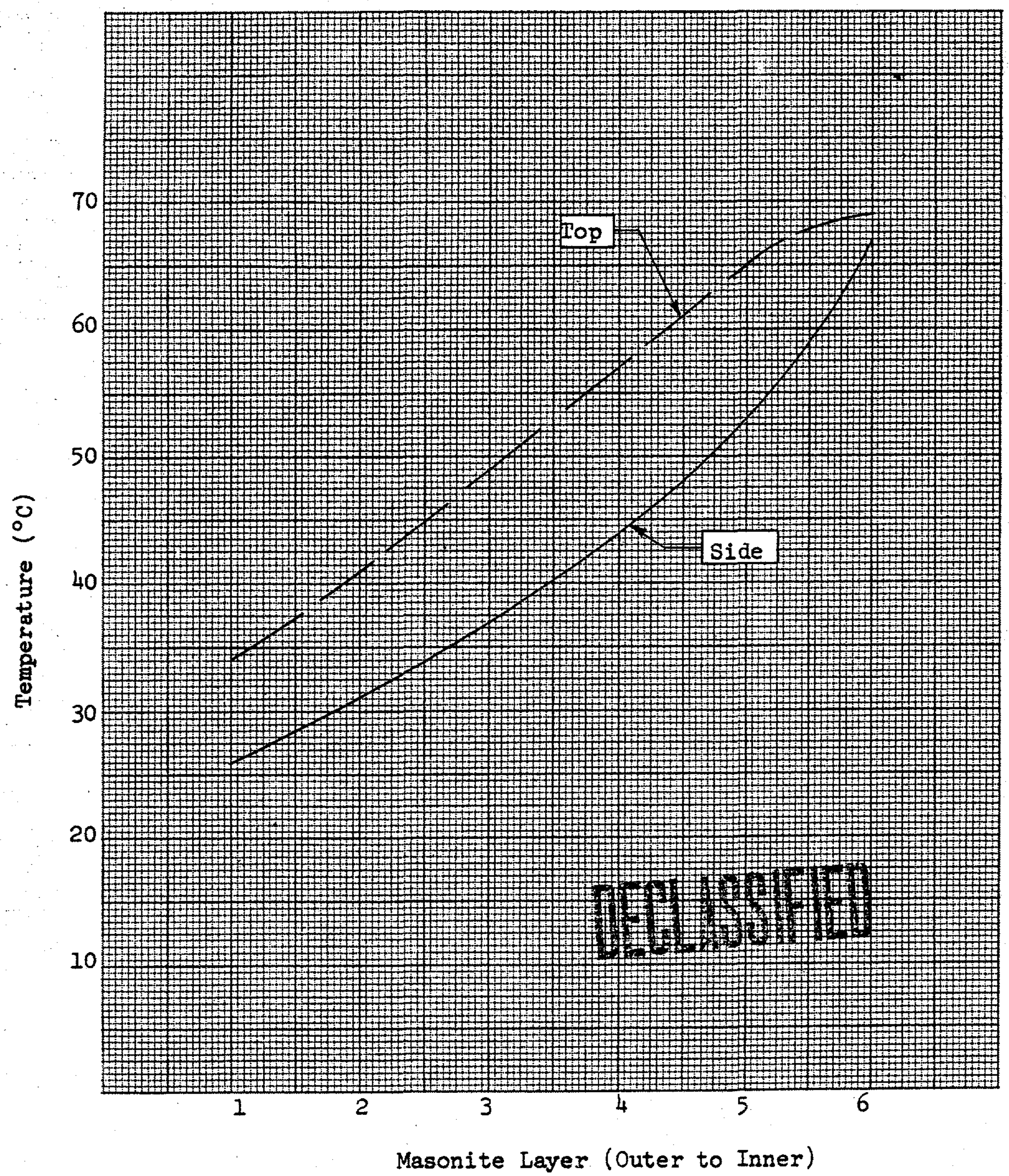
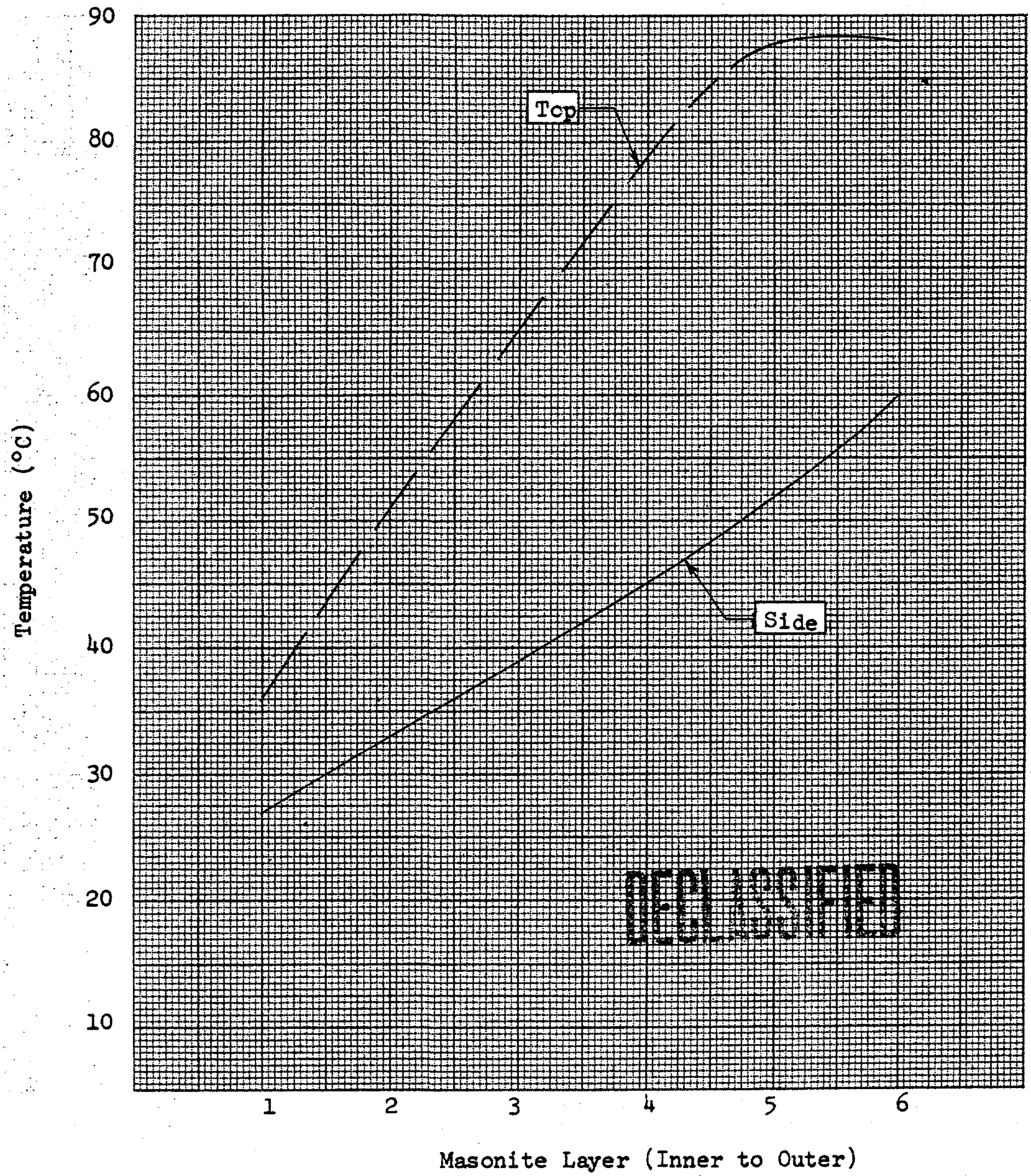


Figure 25 - Profile of Average Biological Shield

Temperatures - H Reactor



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