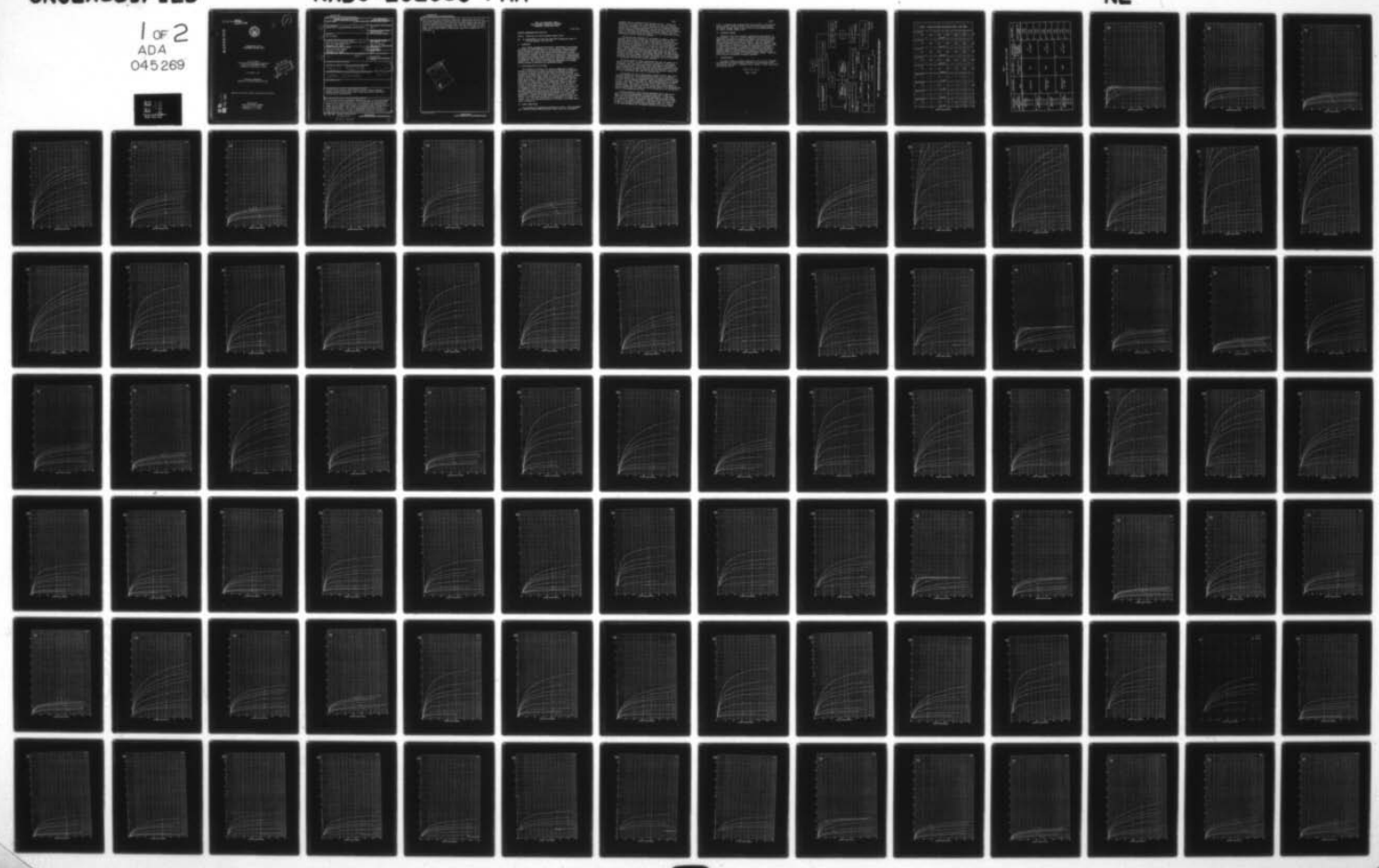
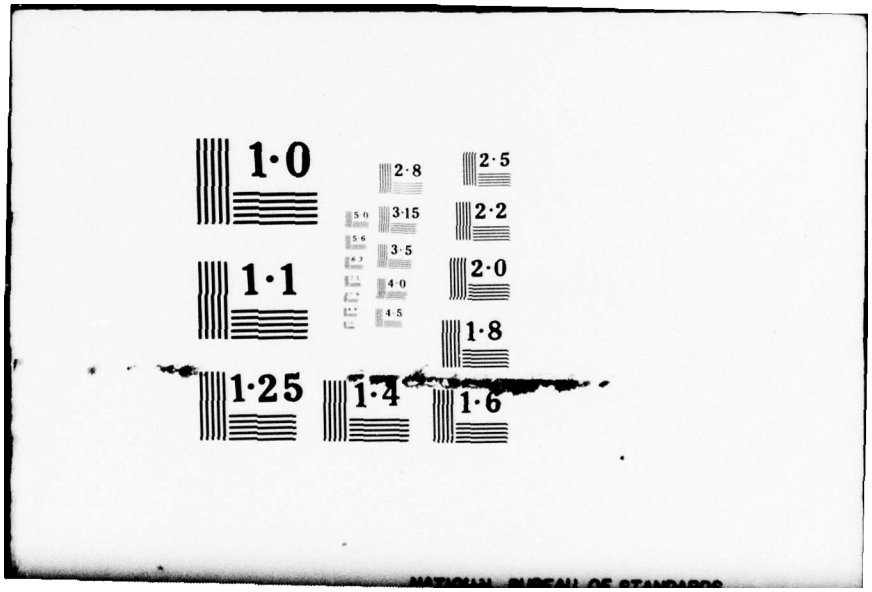
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PREDICTIONS OF FLIR PERFORMANCE AGAINST SHIPS.(U)
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PREDICTIONS OF FLIR PERFORMANCE AGAINST SHIPS

Paul M. Moser
Aero Electronic Technology Department
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

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12 December 1972

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Department of the Navy
Washington, D. C. 20360

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In a previous technical memorandum "Mathematical Model of FLIR Performance" of 19 Oct 1972 by the same author, a set of equations was developed which permits one to calculate acquisition, classification and identification ranges for ship targets when viewed by an airborne forward looking infrared (FLIR) imaging device. This technical memorandum provides results of exercising the model in the form of approximately 850 plotted curves of range versus the ratio of target-to-background temperature difference to

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AB

FLIR noise equivalent temperature difference. Range curves are given for three tasks (acquisition, classification and identification) for two classes of ships (destroyer and patrol boat) from two aspect angles (beam and bow/stern) for three aircraft altitudes (300, 4,000 and 12,000 feet) for three values of sea level absolute humidity (5.4, 14.0 and 29.7 grams per cubic meter) and for eight values of FLIR nominal resolution (ranging from 1.0 to 0.07 mrad).



NAVAL AIR DEVELOPMENT CENTER
AERO ELECTRONIC TECHNOLOGY DEPARTMENT
WARMINSTER, PENNSYLVANIA 18974

12 Dec 1972

TECHNICAL MEMORANDUM NADC-20203:PMM

Subject: Predictions of FLIR Performance Against Ships

Ref: (a) NAVAIRDEVCEN Tech Memo NADC-20203:PMM "Mathematical Model of FLIR Performance" of 19 Oct 1972

I. BACKGROUND

Under AIRTASK A360360C/001B/3F32343604, NAVAIRDEVCEN is performing operational and system analyses and state-of-the-art technology surveys and projections as a first effort in the development of FLIR (forward looking infrared) imaging devices which would be affordable in large quantities and optimized for the missions of single-place attack aircraft. To establish a framework through which target acquisition, classification and identification ranges could be related to FLIR design characteristics, a mathematical model of FLIR performance was constructed as described in reference (a). The purpose of this technical memorandum is to present results obtained by exercising the mathematical model.

II. BRIEF DESCRIPTION OF THE MODEL

The formalism of reference (a), which is summarized in figure 1, permits the calculation of target-to-background temperature differences ΔT required for FLIRs of nominal resolution α and noise equivalent temperature difference NET to acquire, classify and identify ships from the beam and bow/stern aspect angles as a function of the target's average length ℓ, width w, and height h from a sensor altitude p and sensor-to-target slant range r. Calculated values of ΔT are dependent upon the total amount of water vapor W in the viewing path which, in turn, is a function of the average water vapor concentration (absolute humidity) H along the slant path and the range r. The value of H, in turn, is related to the absolute humidity at sea level H_o and the altitude p. H_o is expressed in terms of the relative humidity at sea level H_r and the air temperature at sea level T_A. In this exercise of the model, the numbers of resolvable picture elements falling on the target n required for classification and identification were assumed to be 66 and 400, respectively. Because the average dimensions of a ship depend upon whether it is viewed from the beam aspect or the bow/stern aspect, subscripts 1 and 2 are used respectively to distinguish the two sets of values. For a more complete description of the model, the reader should peruse reference (a).

III. RANGE COMPUTATIONS

The equations and inequalities summarized in figure 1 were programmed into a Hewlett-Packard 9100A Calculator, whose output was expressed in

graphical form by a companion 9125A Calculator Plotter. Because the equations do not permit one to solve directly for range as a function of the other parameters, the range r was taken as the running independent variable and the equations were solved for the ratio $\Delta T/NET$ for various selected values of target dimensions, aircraft altitude, absolute humidity, task to be performed, and FLIR nominal resolution. However, when the graphs of the resulting data were plotted, the $\Delta T/NET$ values were plotted as abscissae and the r values as ordinates.

Calculations were performed for two classes of vessels, a 400-foot destroyer and an 80-foot patrol boat, viewed from both the beam and bow/stern aspect angles for the tasks of acquisition, classification and identification from sensor altitudes of 300, 4000 and 12,000 feet with sea level absolute humidities of 1.0, 2.6 and 5.5 cm of precipitable water vapor per nautical mile (5.4, 14.0 and 29.7 gm/m^3) for eight values of FLIR nominal resolution (1/14, 1/10, 1/8, 3/20, 1/4, 1/2, 3/4 and 1 mrad). The foregoing represents 864 combinations which were plotted on 108 sheets of graph paper with (generally) eight graphs per page corresponding to the eight values of FLIR nominal resolution. The actual number of curves plotted is somewhat less than 864 because in the cases of poorer resolution, the maximum range at which a particular task can be performed is occasionally less than the aircraft altitude.

The various cases for which computations were made are summarized in matrix form in table I in which each item is defined by a code letter. Accordingly, each combination of parameters exercised can be identified by a five-letter code. For example, code symbol CFILR corresponds to the task of classifying an 80-foot boat from the beam aspect with a 0.25-mrad FLIR at an altitude of 4000 feet when the sea level absolute humidity is 2.6 cm of precipitable water vapor for nautical mile.

To illustrate the use of these graphs to obtain specific range data, one might consider the above mentioned case (CFILR) by first locating curve R on graph CFIL. If the particular FLIR in question exhibits an NET of 0.20C° and the target-to-background temperature difference ΔT is assumed to be 4C°, the ratio $\Delta T/NET$ equals 20. The corresponding value of sensor-to-target slant range r, read from curve CFILR is then found to be 3.3 nautical miles. The reader is cautioned to note that on these graphs the vertical (range) scale runs from 0 to 20 nautical miles for the classification (F) and identification (G) tasks but that it extends from 0 to 100 nautical miles for the acquisition (E) task.

The data presented in this technical memorandum may be used in two ways: to predict the performance of existing FLIRs, and to serve as a design tool in establishing FLIR performance parameters. In the former case, the curves may be used to deduce how FLIR range performance varies as a function of target-to-background temperature difference ΔT for FLIRs of given NET and nominal resolution; in the latter case, the curves can be used to investigate how FLIR range performance varies as a function of the design parameters NET and nominal resolution at constant values

of ΔT. To simplify such interpretations of the graphs, a collection of abscissa scales is given in figure 2 for NET as the running variable for various constant values of ΔT, and for ΔT as the running variable for various constant values of NET.

IV. CONCLUDING REMARKS

Reference (a) and this technical memorandum are deterministic in their approach. That is, if specific values of variables such as ship dimensions, temperature difference and humidity, are entered into the model, specific values of range are computed. This is a temporarily satisfying situation until one asks, "How do I know what values of such variables should be inserted into the model and what criteria do I apply to judge whether the resulting ranges are operationally acceptable?" To answer these questions, a probabilistic approach is being taken to determine cumulative frequencies of occurrence of various values of absolute humidity, target-to-background temperature difference, ship dimensions, and slant ranges for successful weapons release. These will be the subjects of subsequent technical memoranda.

V. ACKNOWLEDGEMENT

The author wishes to express appreciation to Mr. Alvin M. Valentine who programmed the Hewlett-Packard calculator and plotted many of the curves and to Miss Nancy E. MacMeekin and Mr. Joseph J. Pello, who plotted the remaining curves.

Paul M. Moser

PAUL M. MOSER

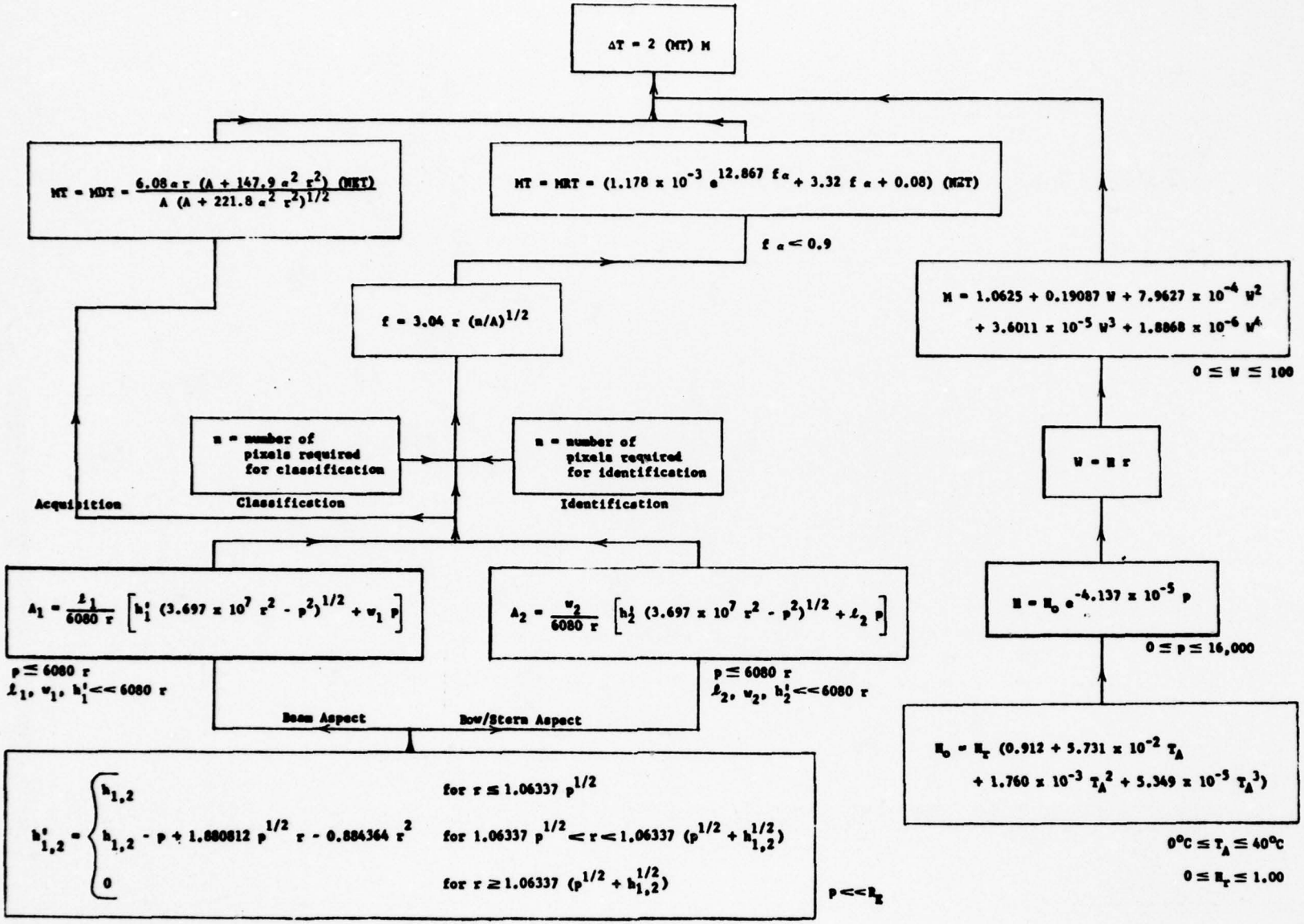


FIGURE 1. TARGET-TO-BACKGROUND TEMPERATURE DIFFERENCES REQUIRED TO PERMIT ACQUISITION, CLASSIFICATION AND IDENTIFICATION OF SHIPS BY AIRBORNE PASSIVE FLIR (FORWARD LOOKING INFRARED) IMAGING DEVICES

FIGURE 2. ABSCISSA SCALES FOR USE WITH RANGE VERSUS ΔT/NET GRAPHS

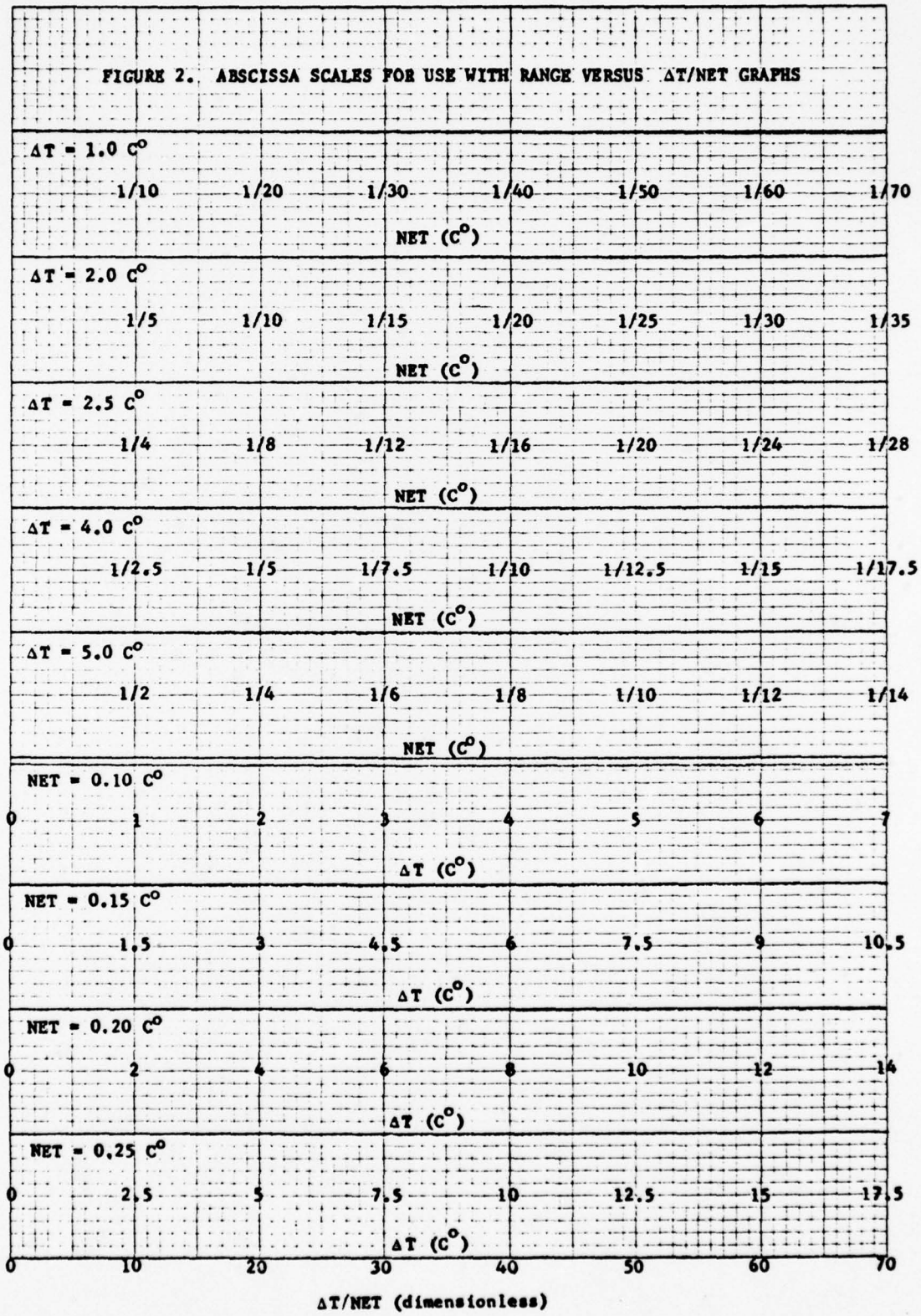
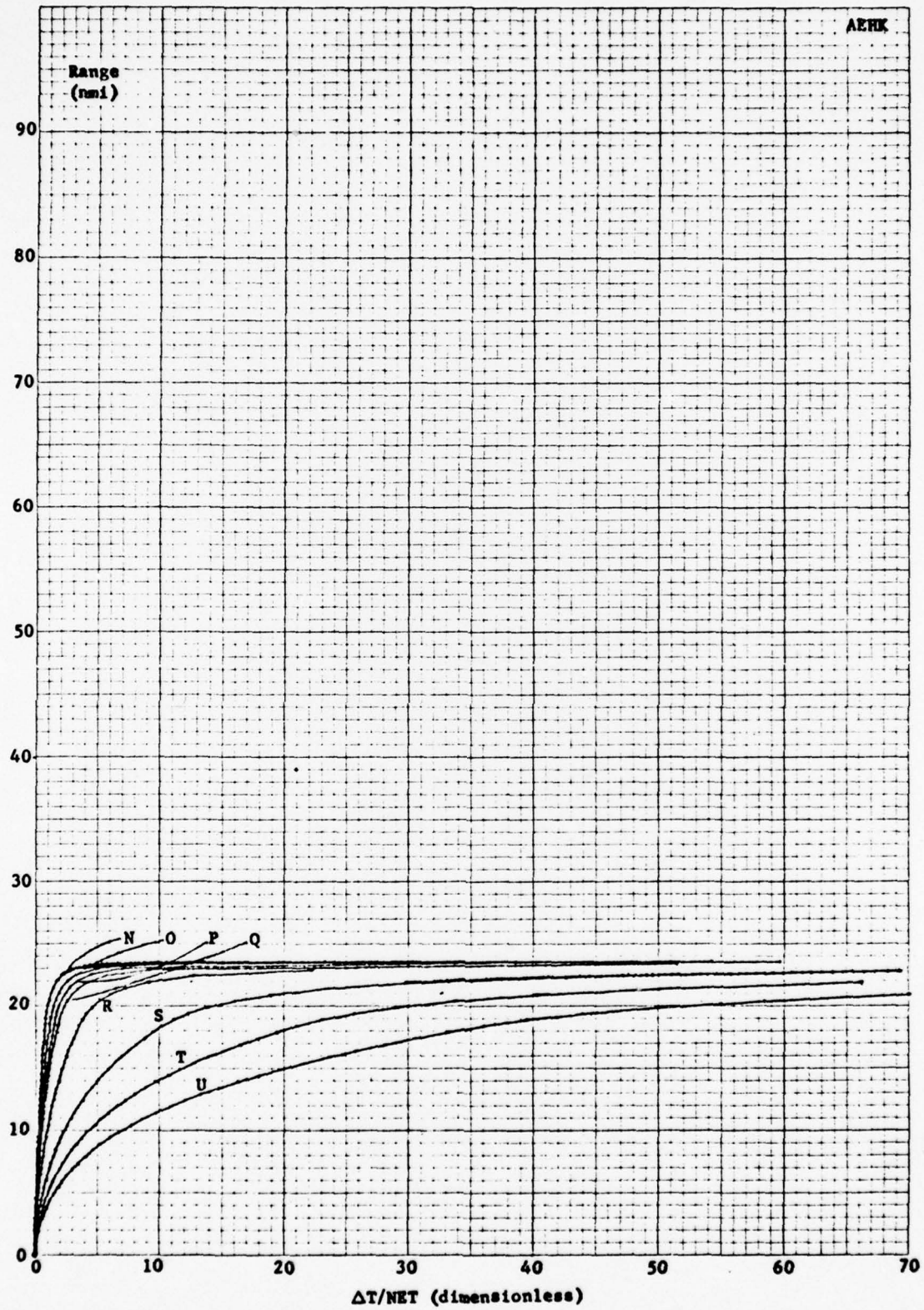
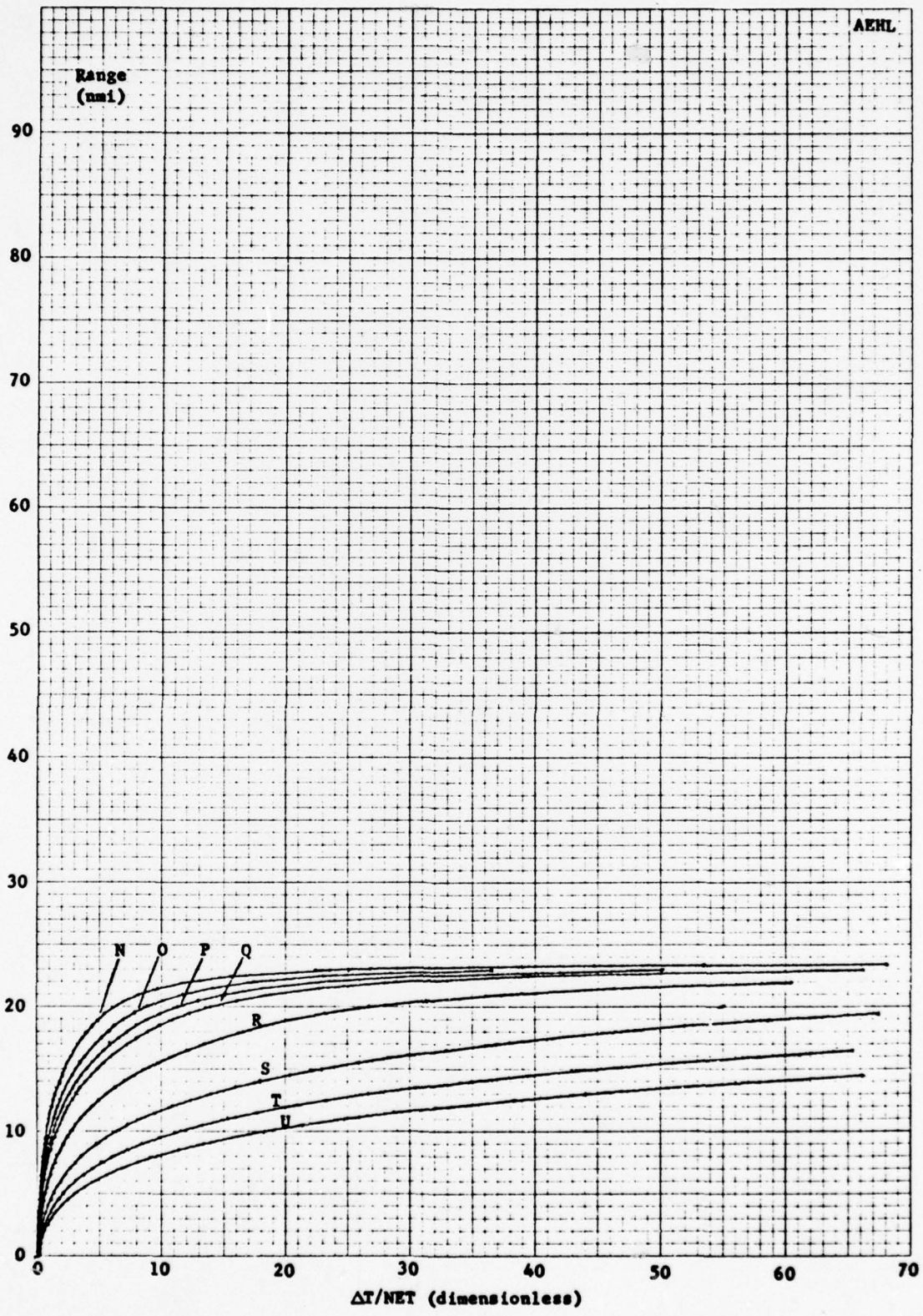


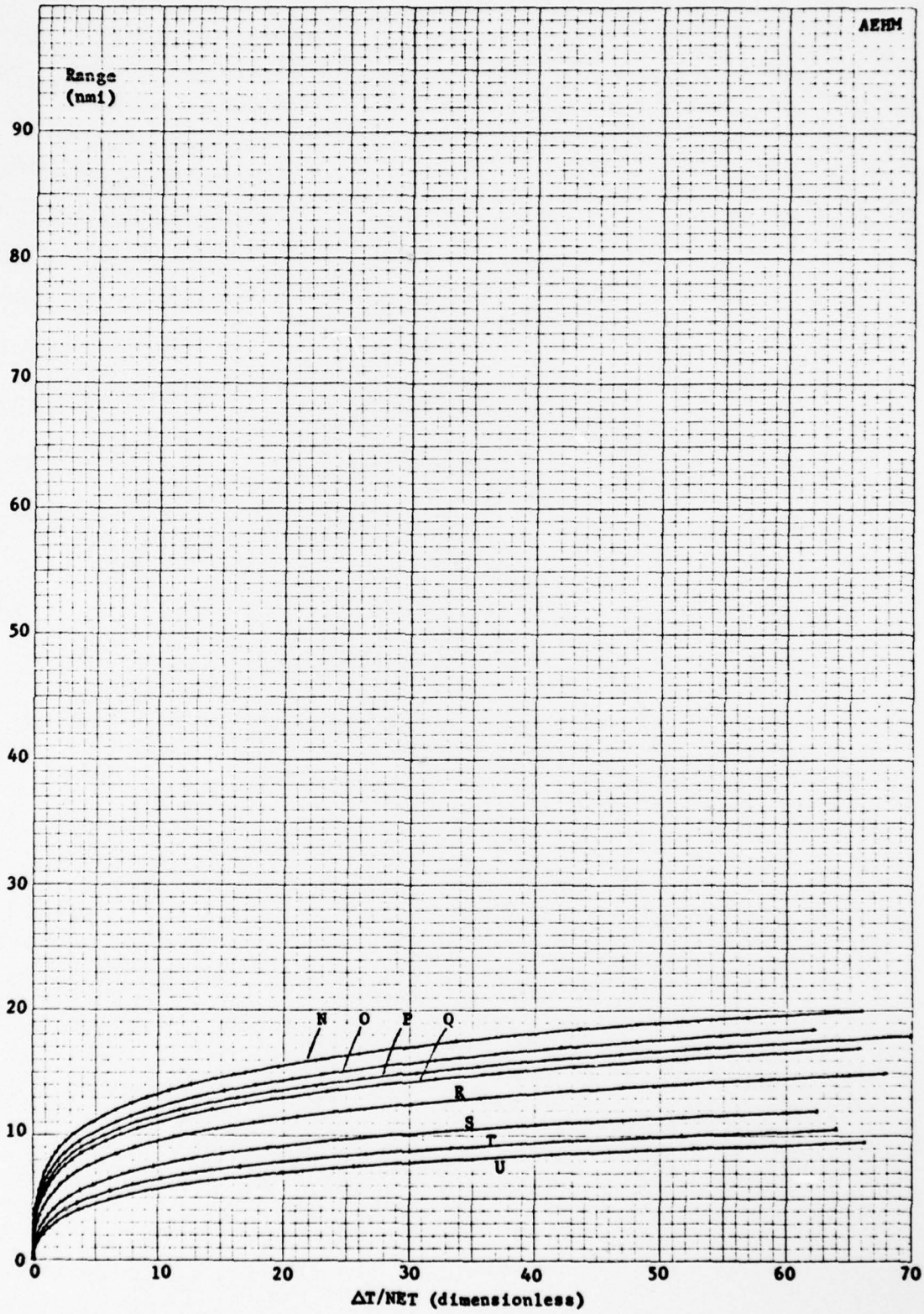
TABLE I

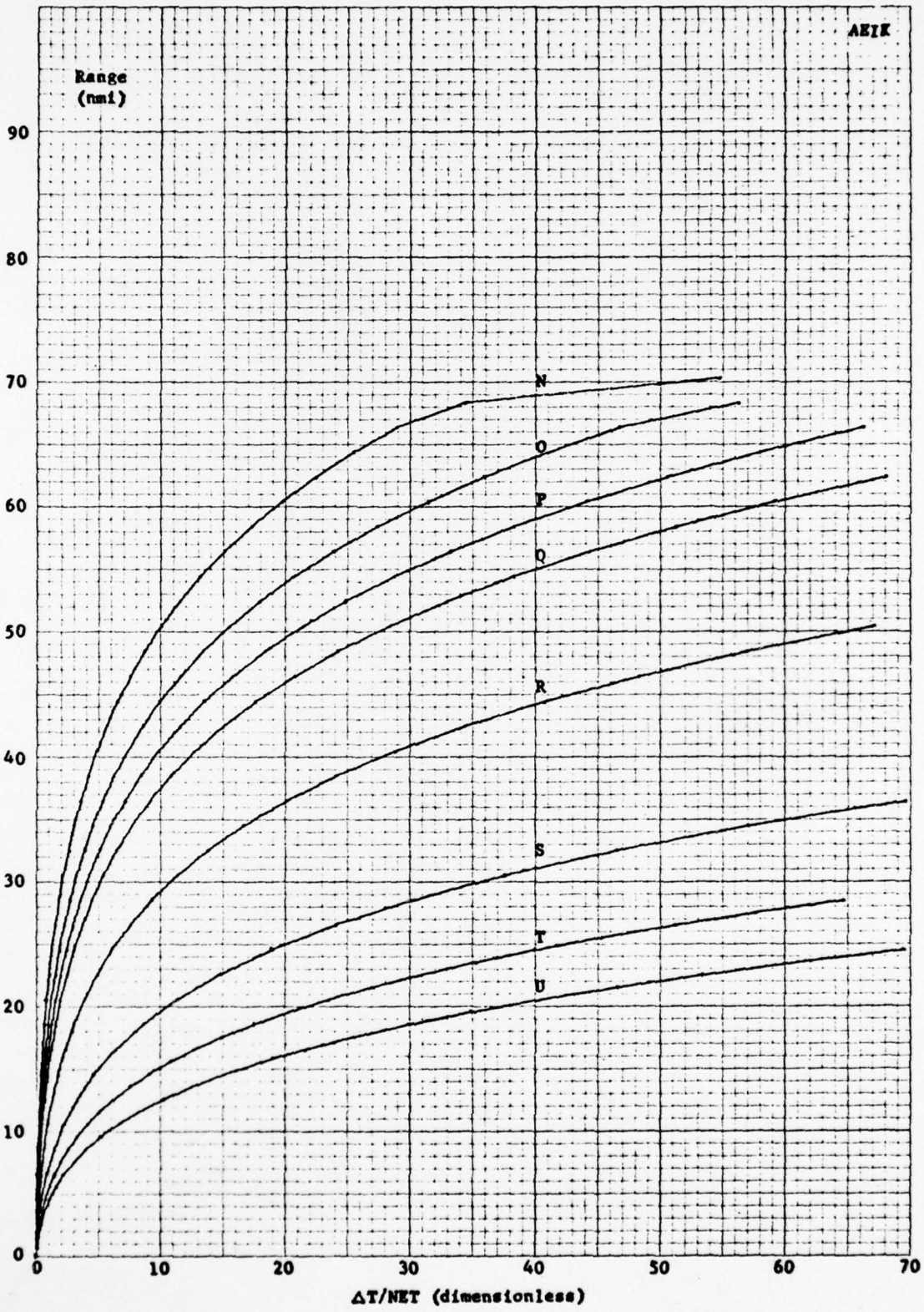
IDENTIFICATION OF CODE SYMBOLS USED ON GRAPHS

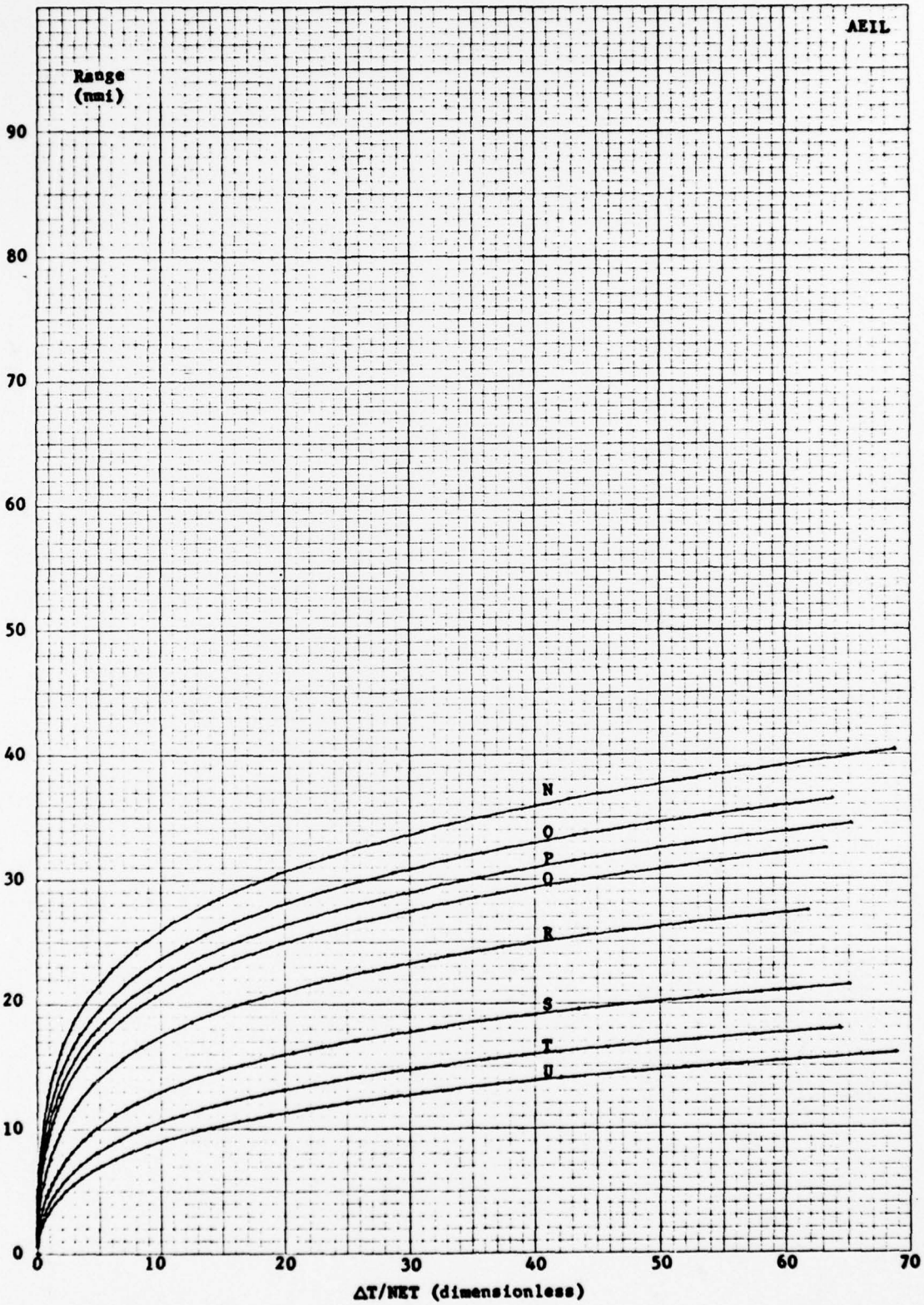
First Symbol	Second Symbol	Third Symbol	Fourth Symbol	Fifth Symbol
Target Aspect Angle Average Dimensions (ft)	Task	Aircraft Altitude p (ft)	Absolute Humidity at Sea Level H_o (cm precip water/nmi)	Nominal Resolution α (mrad)
A Destroyer Beam Aspect $\ell_1 = 400$ $w_1 = 42$ $h_1 = 24$	E Acquisition	H 300	K 1.0 (5.4 gm/m^3)	N 0.0714 (1/14)
				O 0.10 (1/10)
B Destroyer Bow/Stern Aspect $\ell_2 = 400$ $w_2 = 42$ $h_2 = 44$				P 0.125 (1/8)
	F Classification (n = 66)	I 4000	L 2.6 (14.0 gm/m^3)	Q 0.15 (3/20)
C Patrol Boat Beam Aspect $\ell_1 = 80$ $w_1 = 20$ $h_1 = 12$				R 0.25 (1/4)
	G Identification (n = 400)	J 12,000	M 5.5 (29.7 gm/m^3)	S 0.50 (1/2)
D Patrol Boat Bow/Stern Aspect $\ell_2 = 80$ $w_2 = 22$ $h_2 = 16$				T 0.75 (3/4)
				U 1.00 (1)

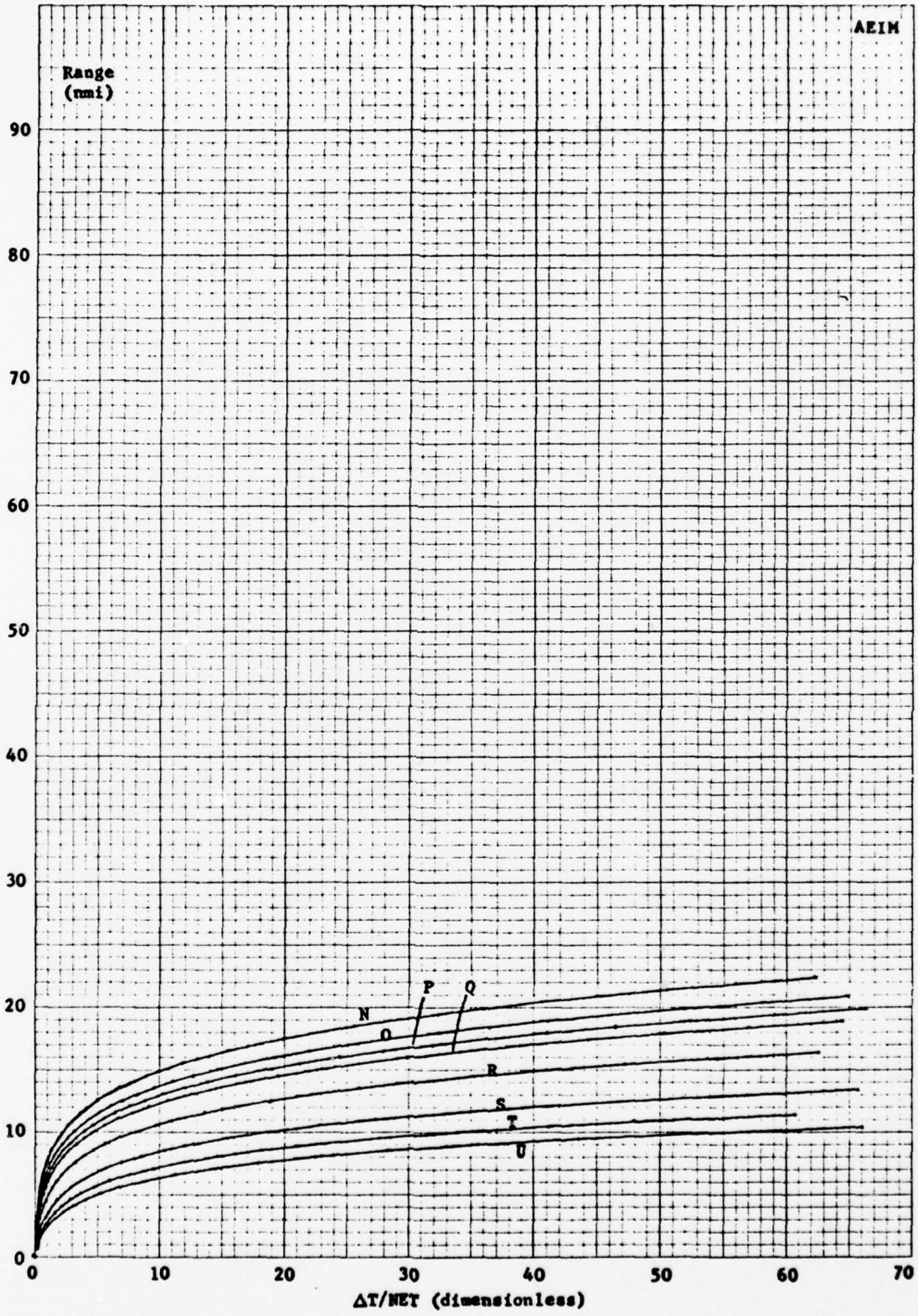

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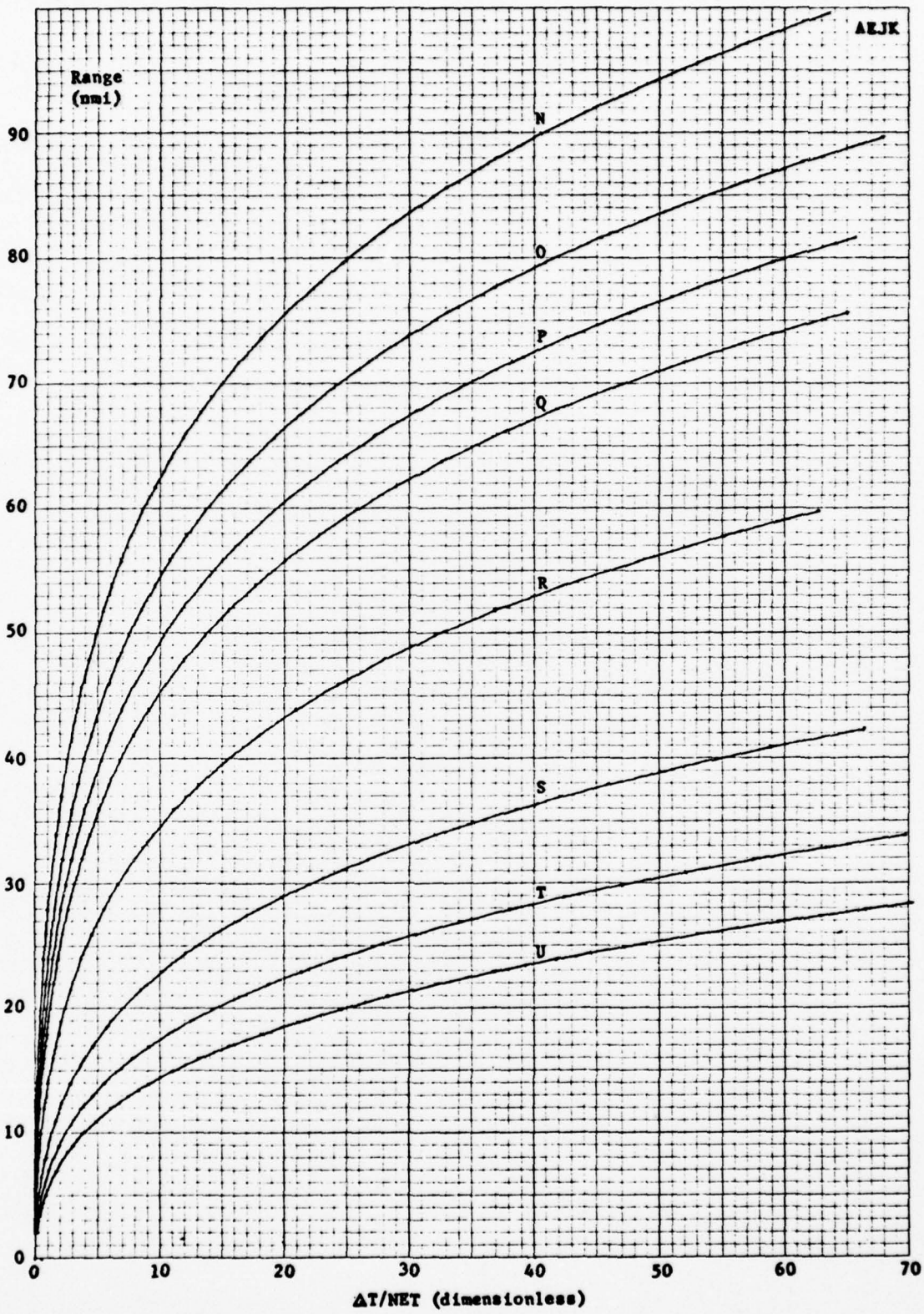

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ΔT/NET (dimensionless)

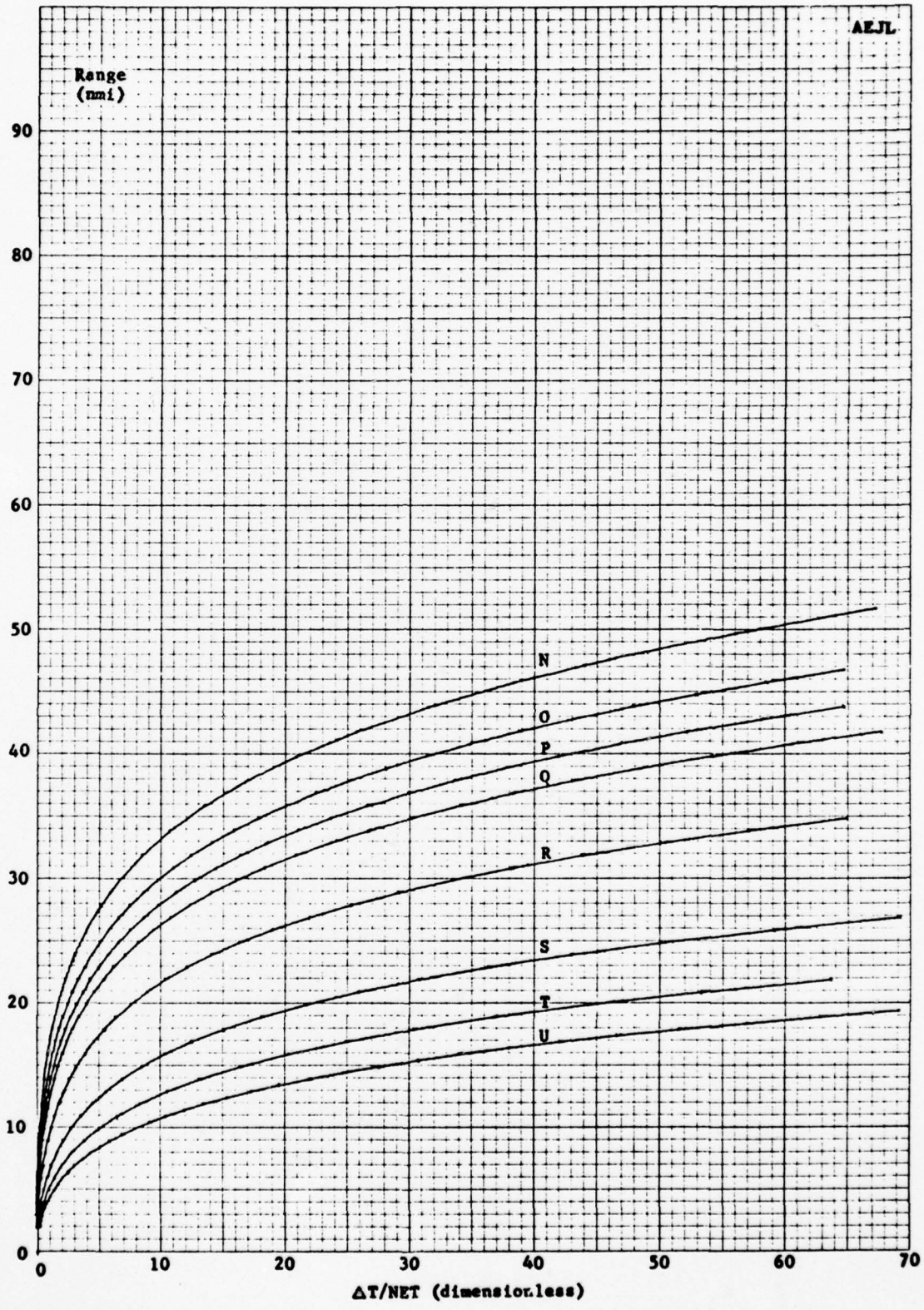

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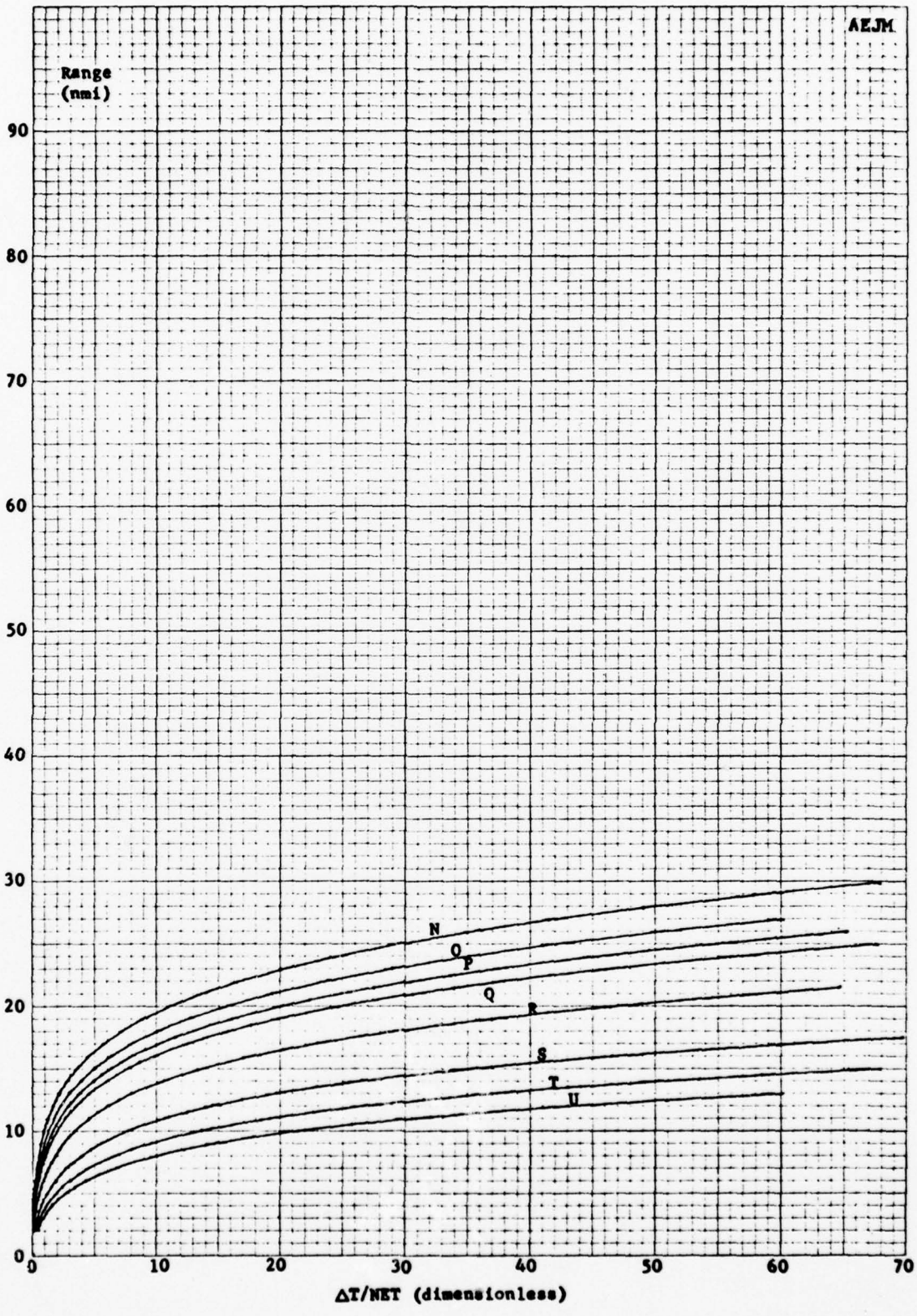

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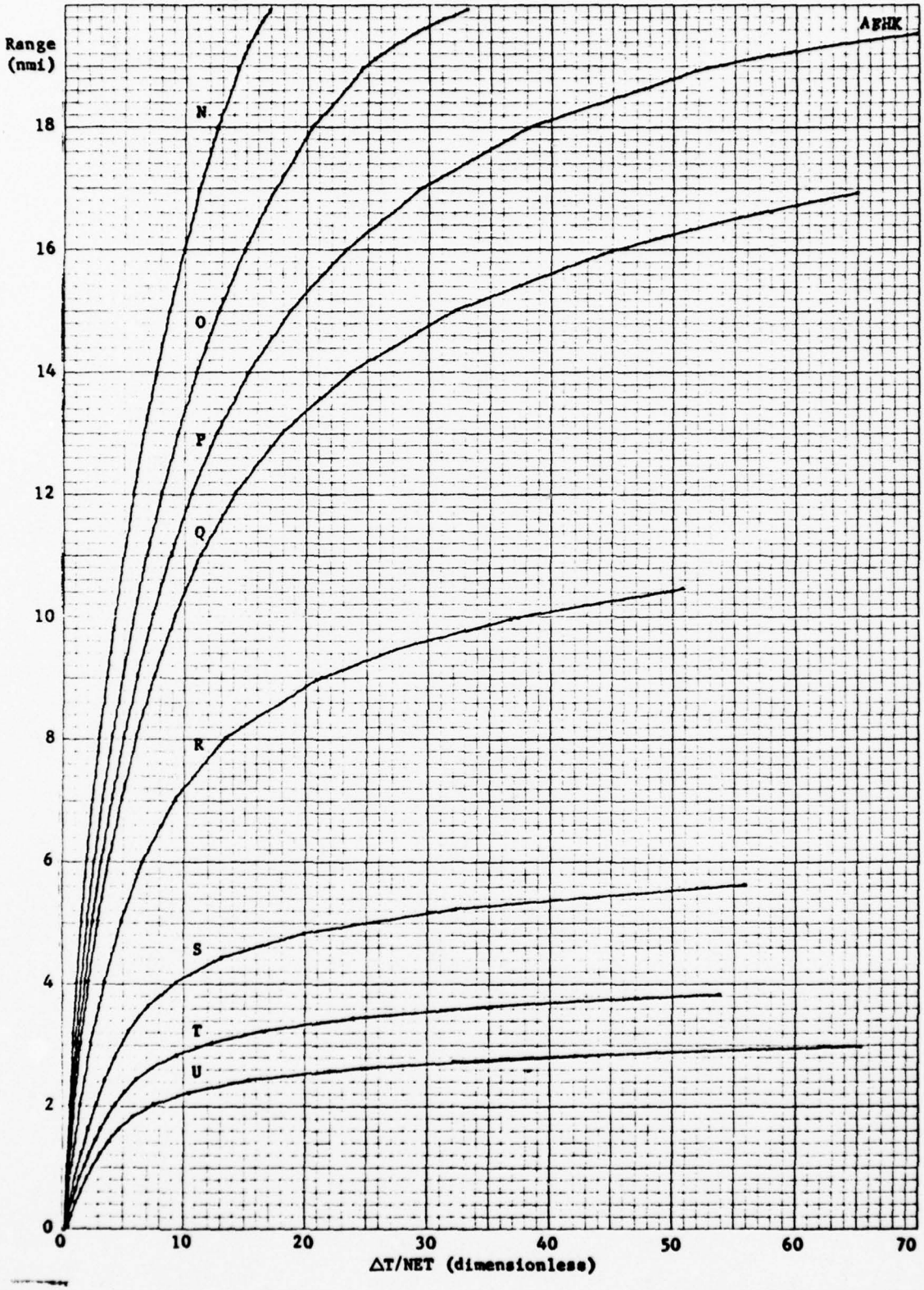

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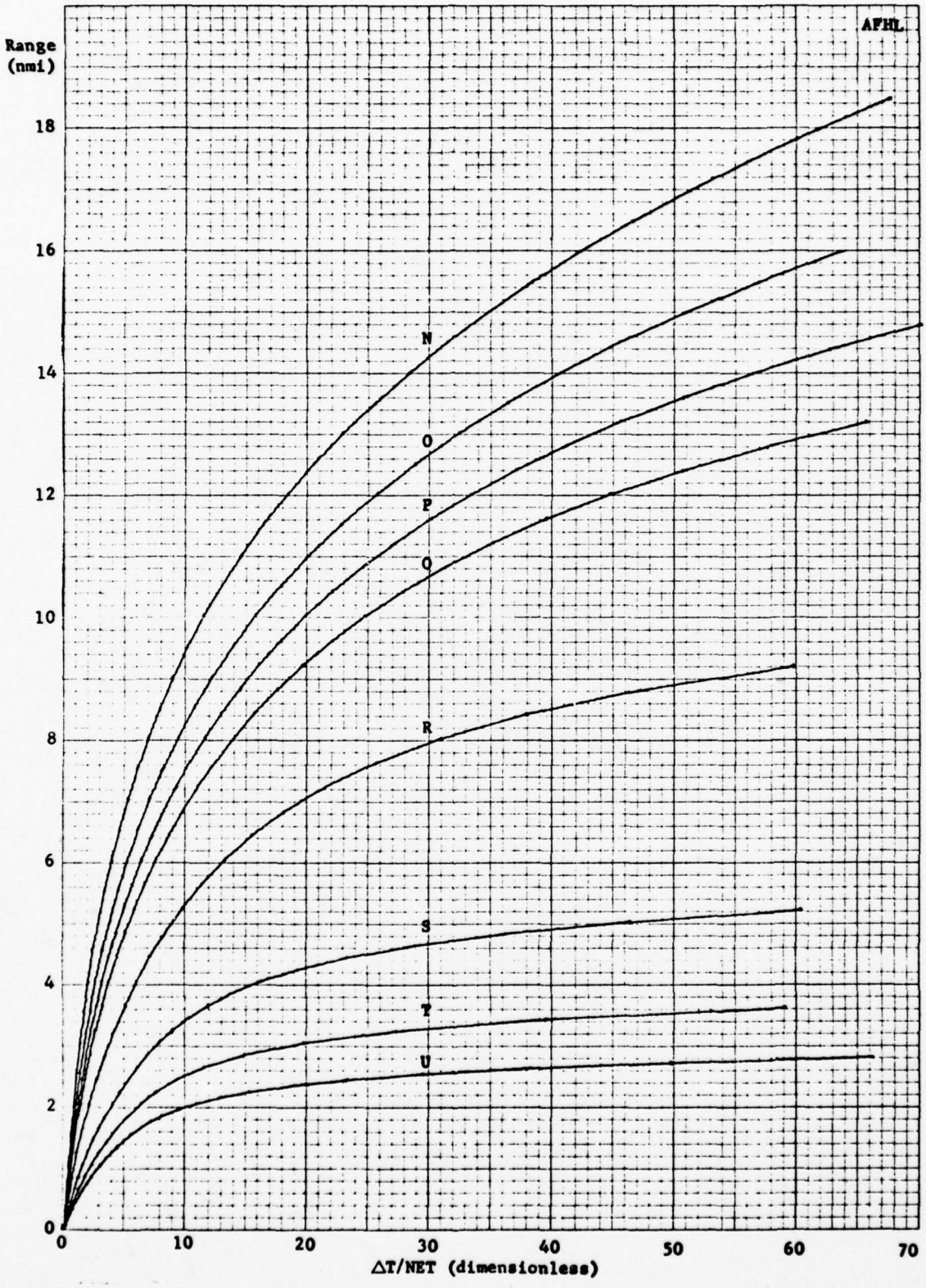

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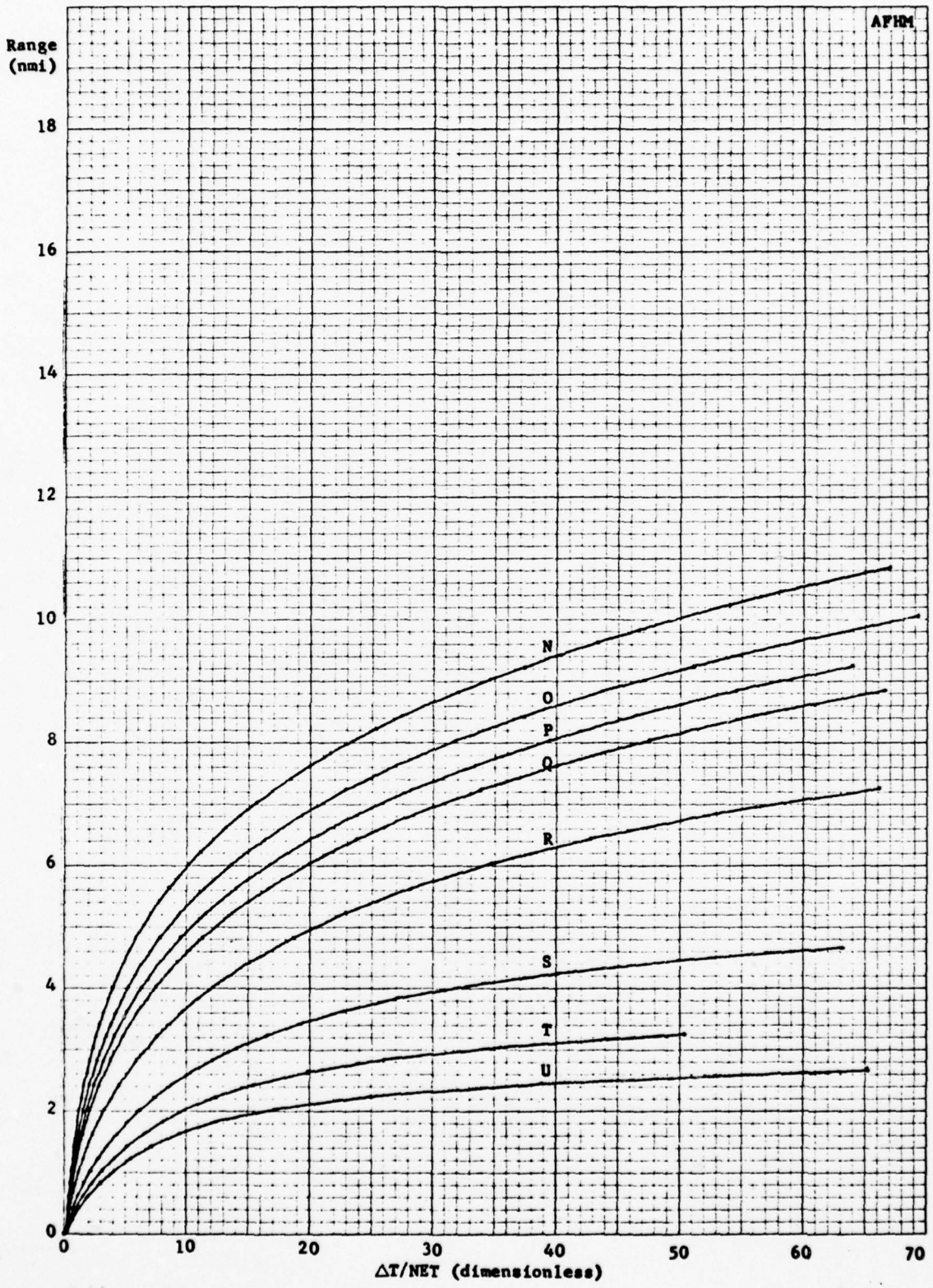

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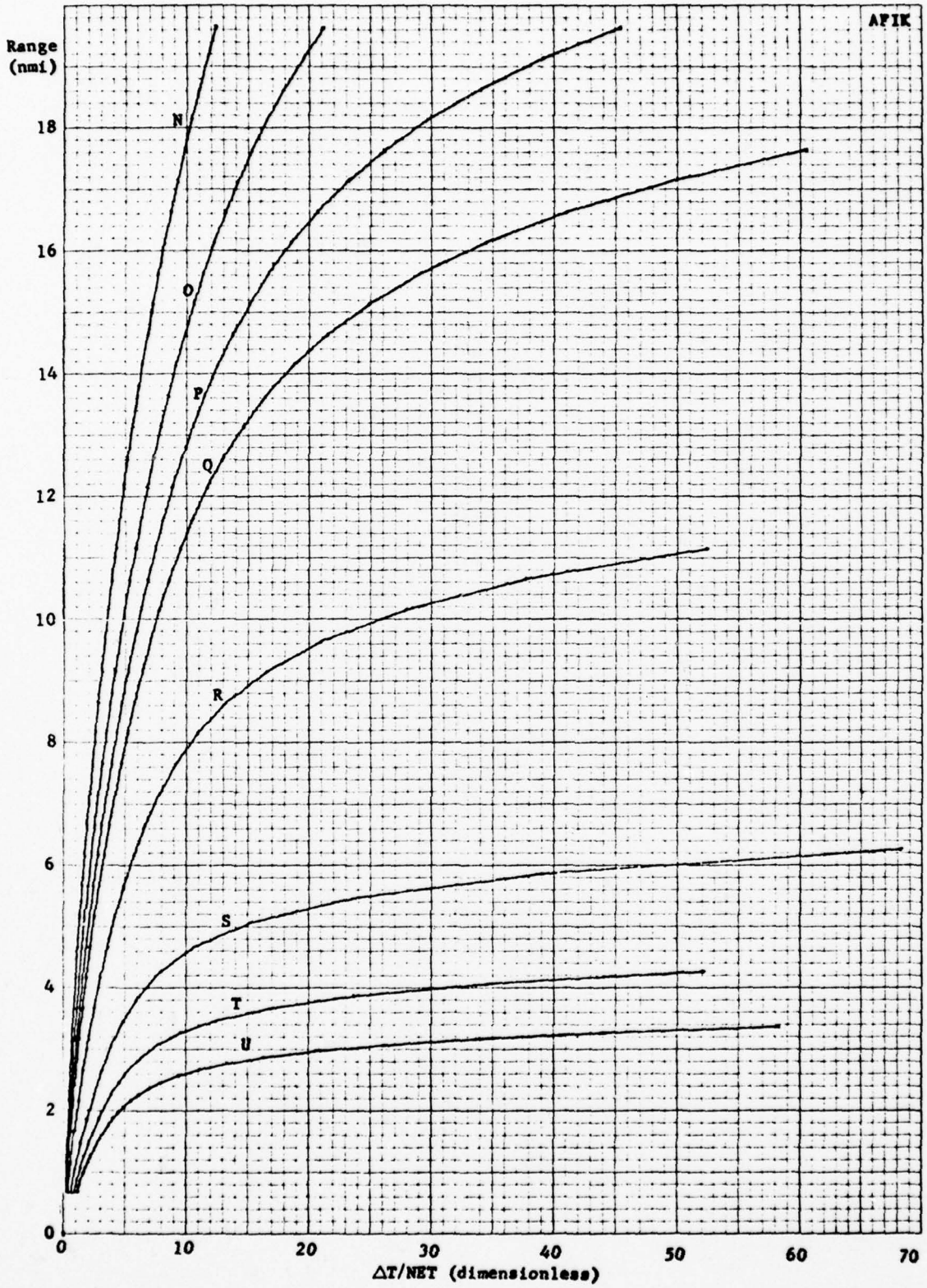

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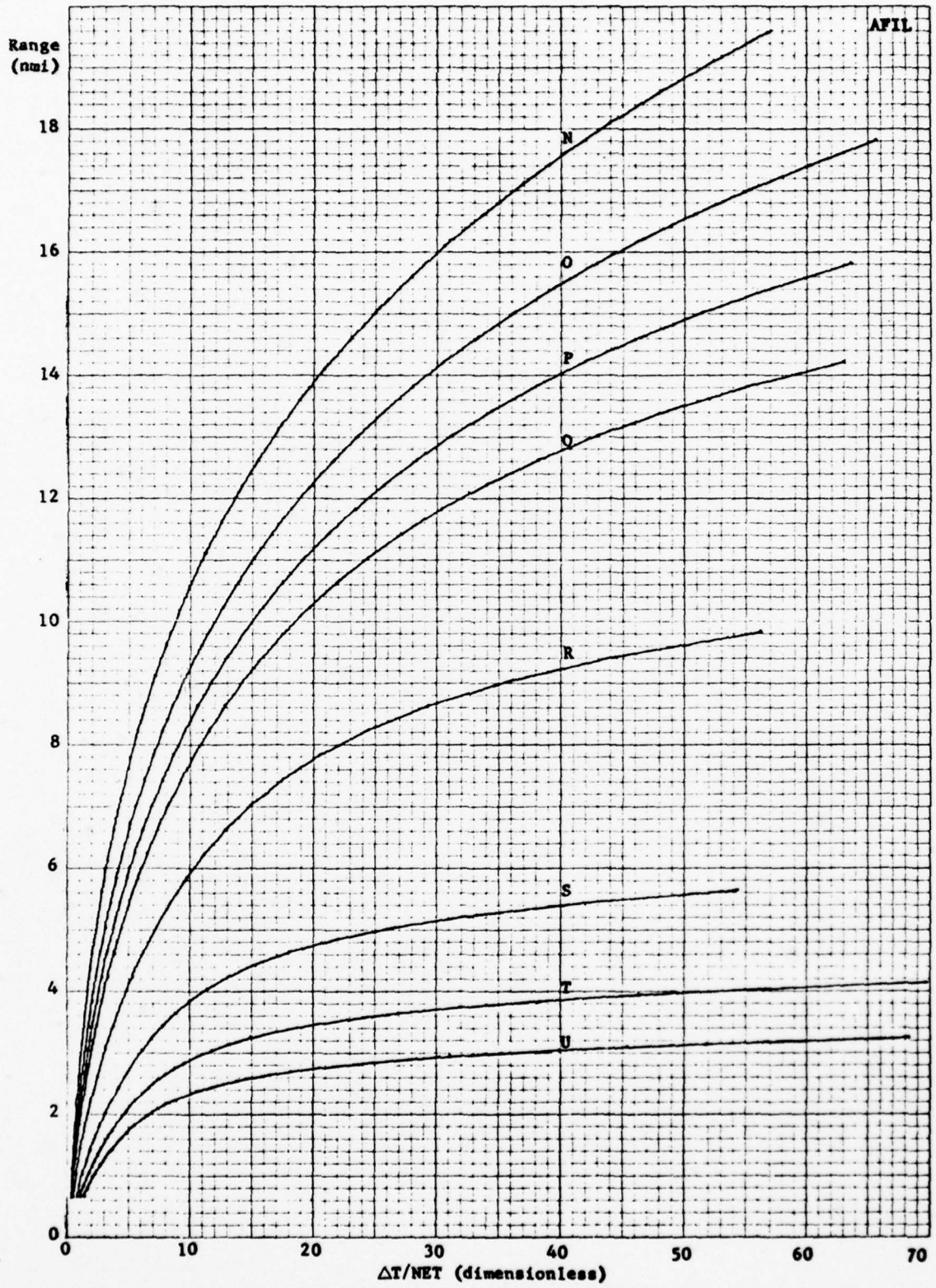

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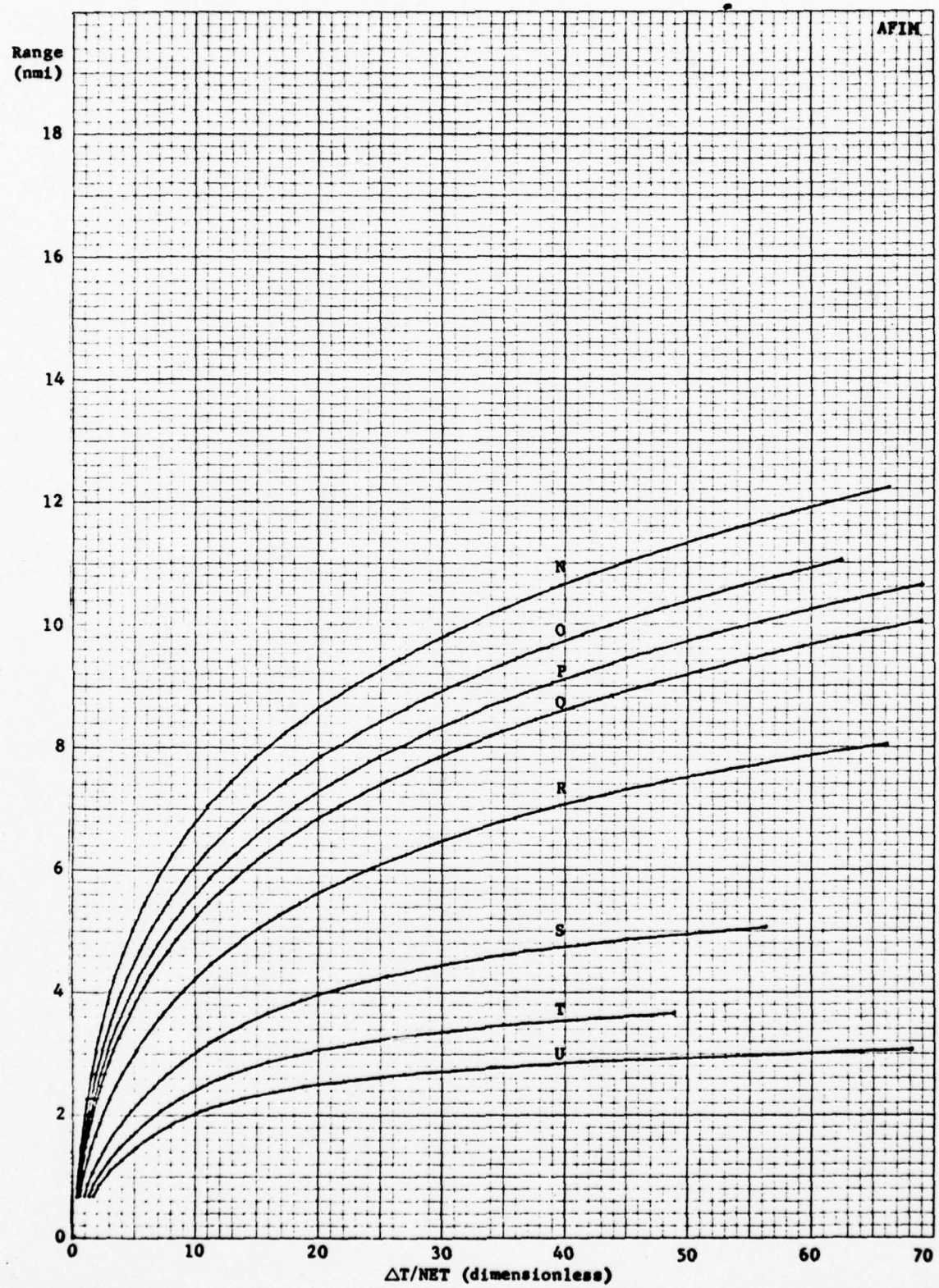

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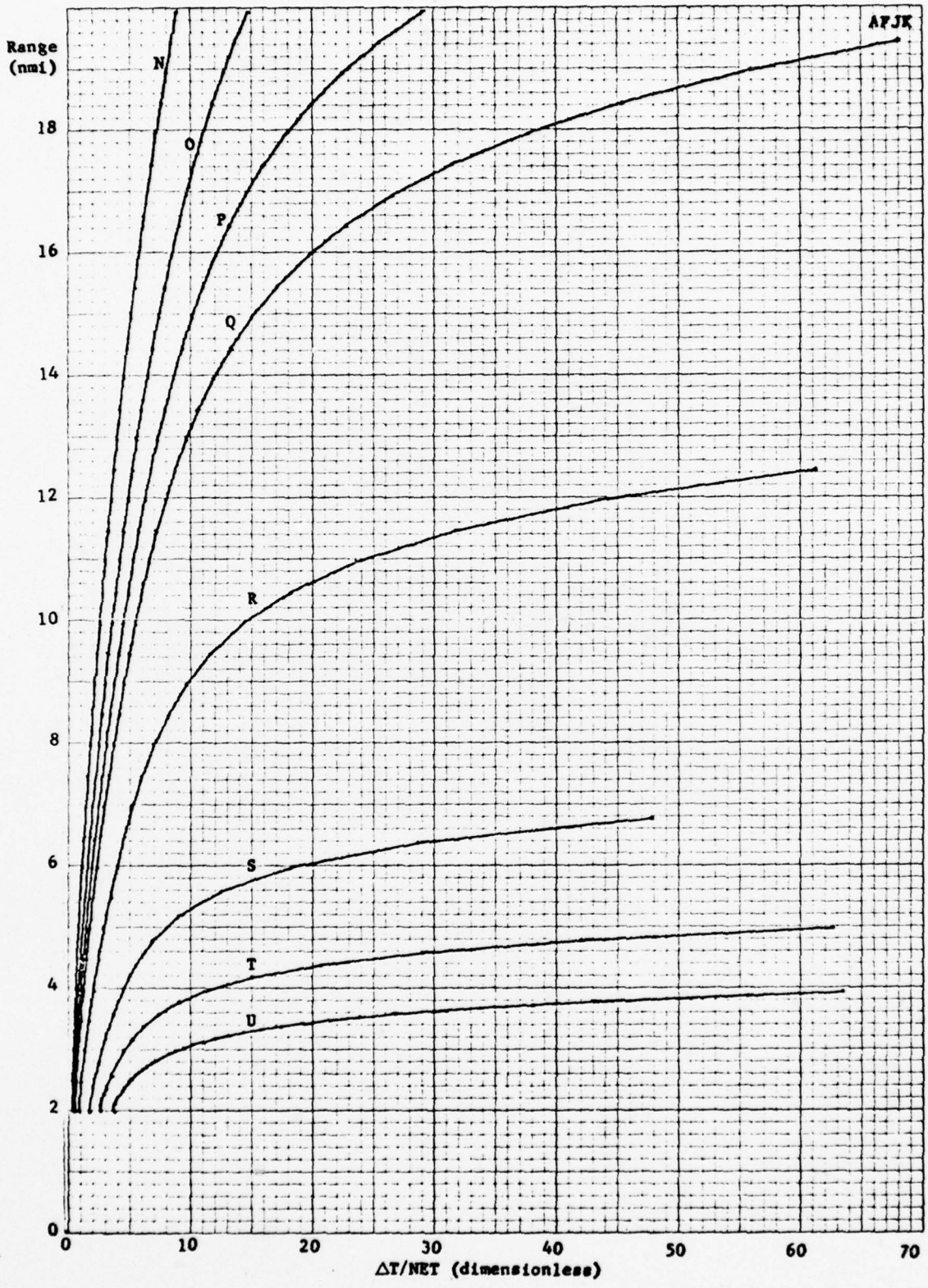

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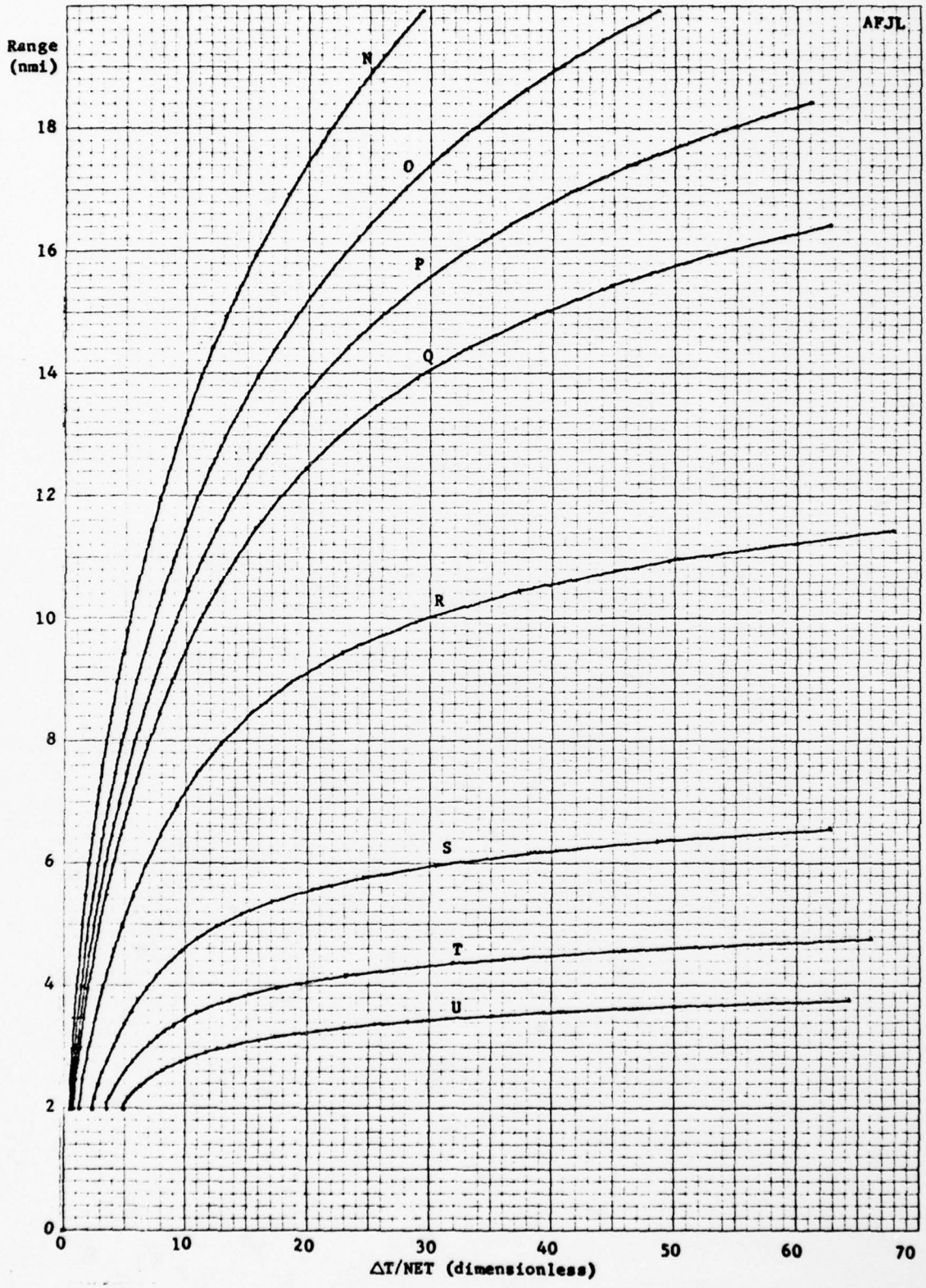

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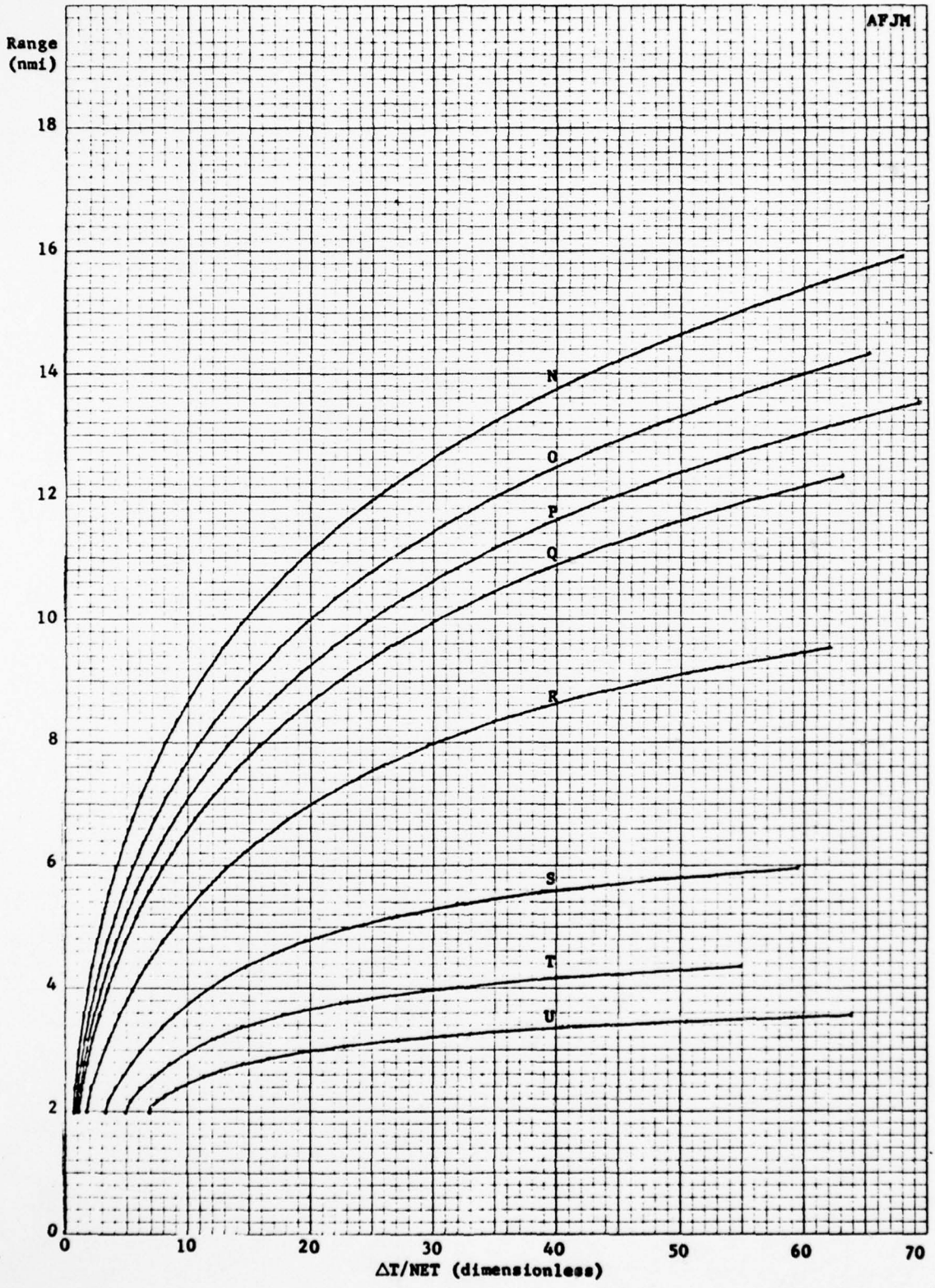

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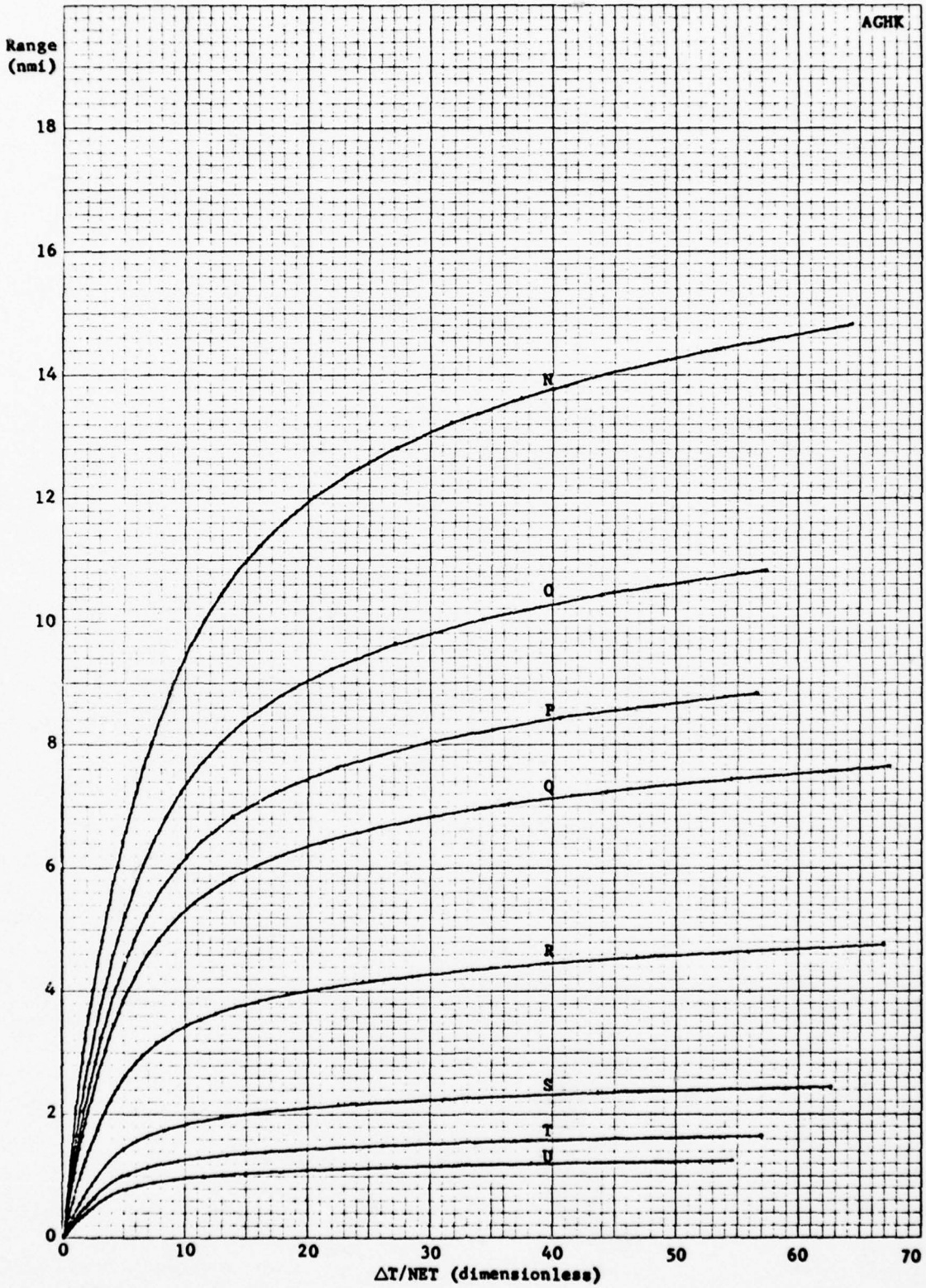

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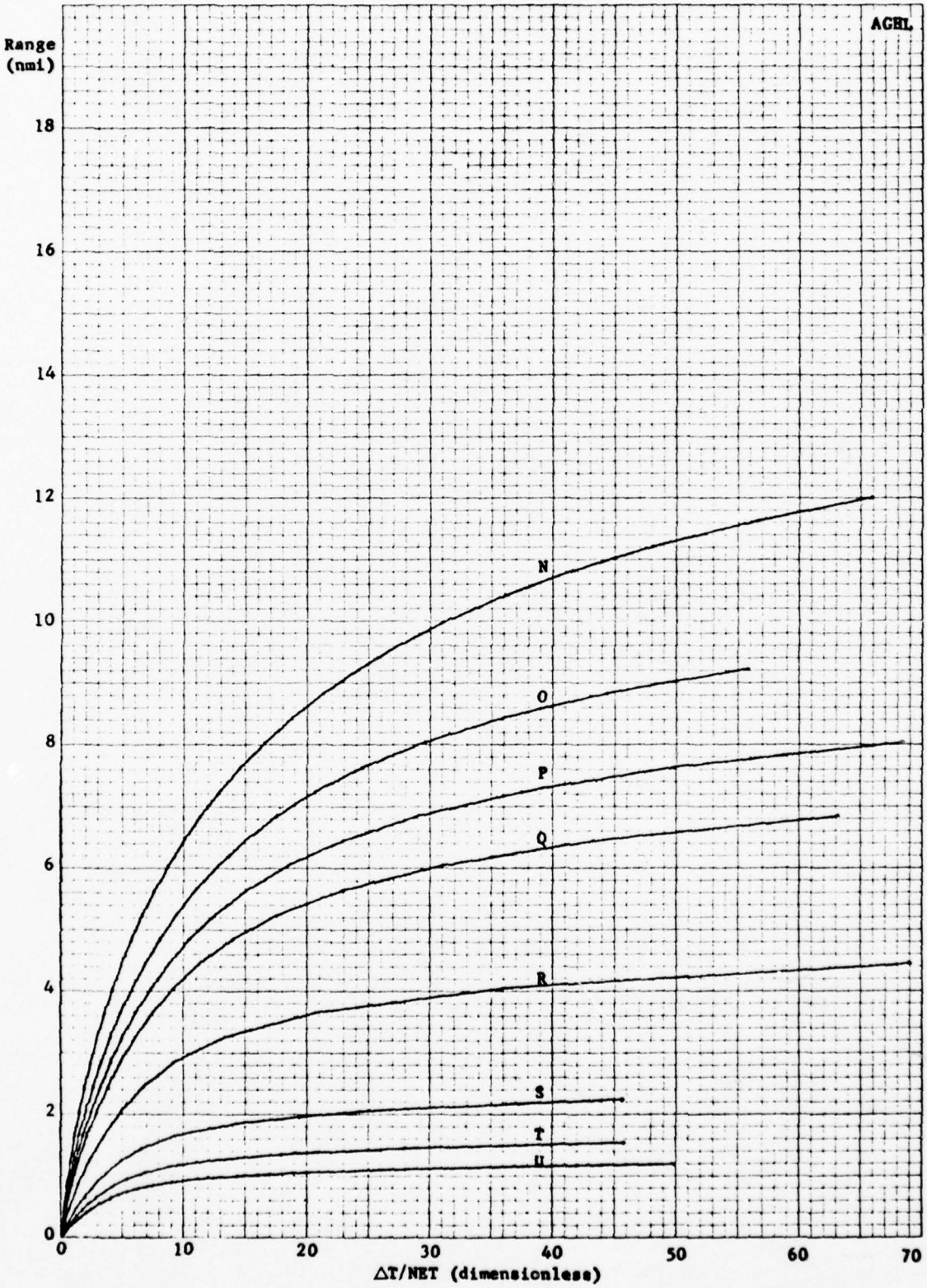

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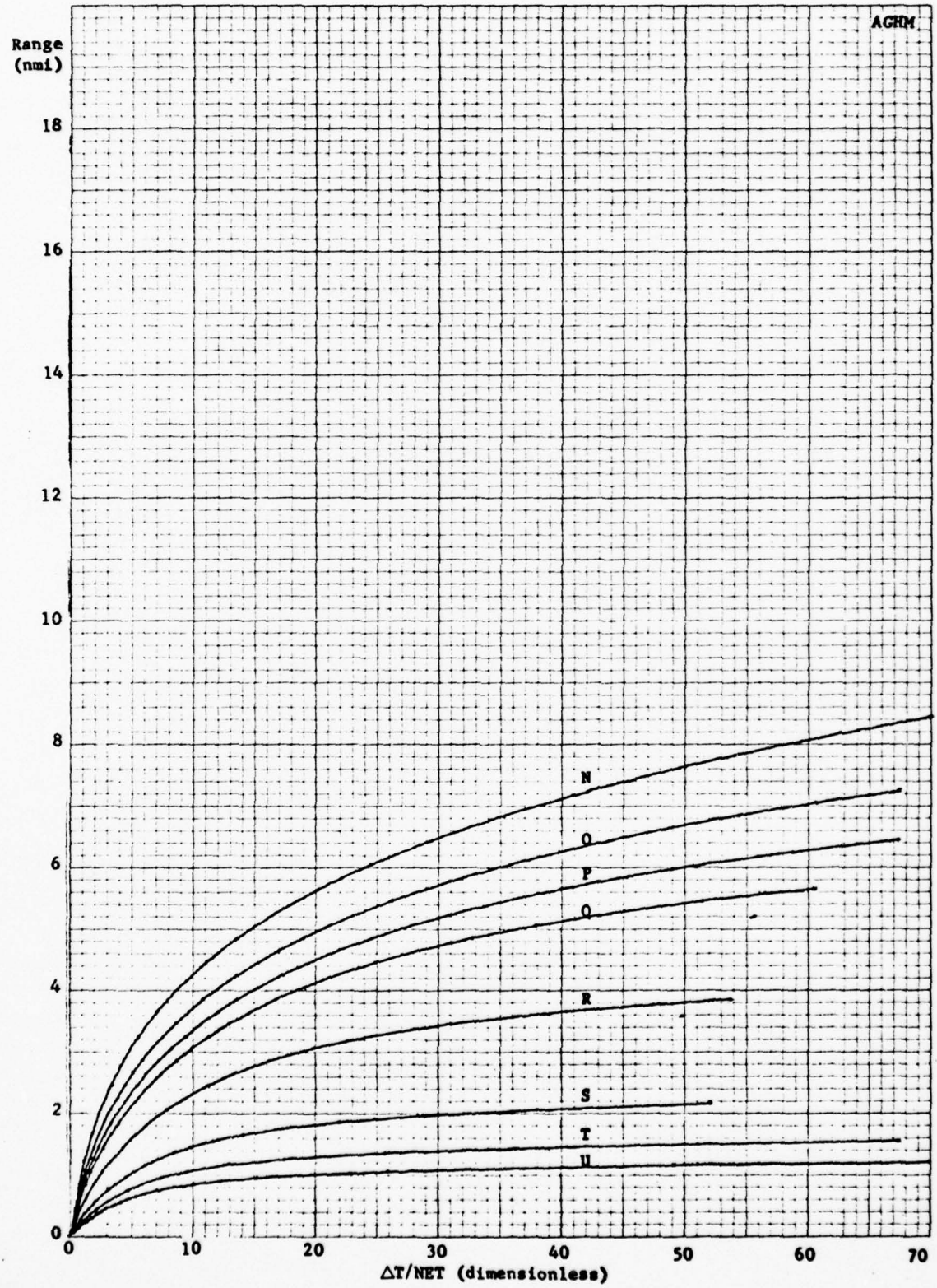

Range
(nmi)
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ΔT/NET (dimensionless)
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AFJK

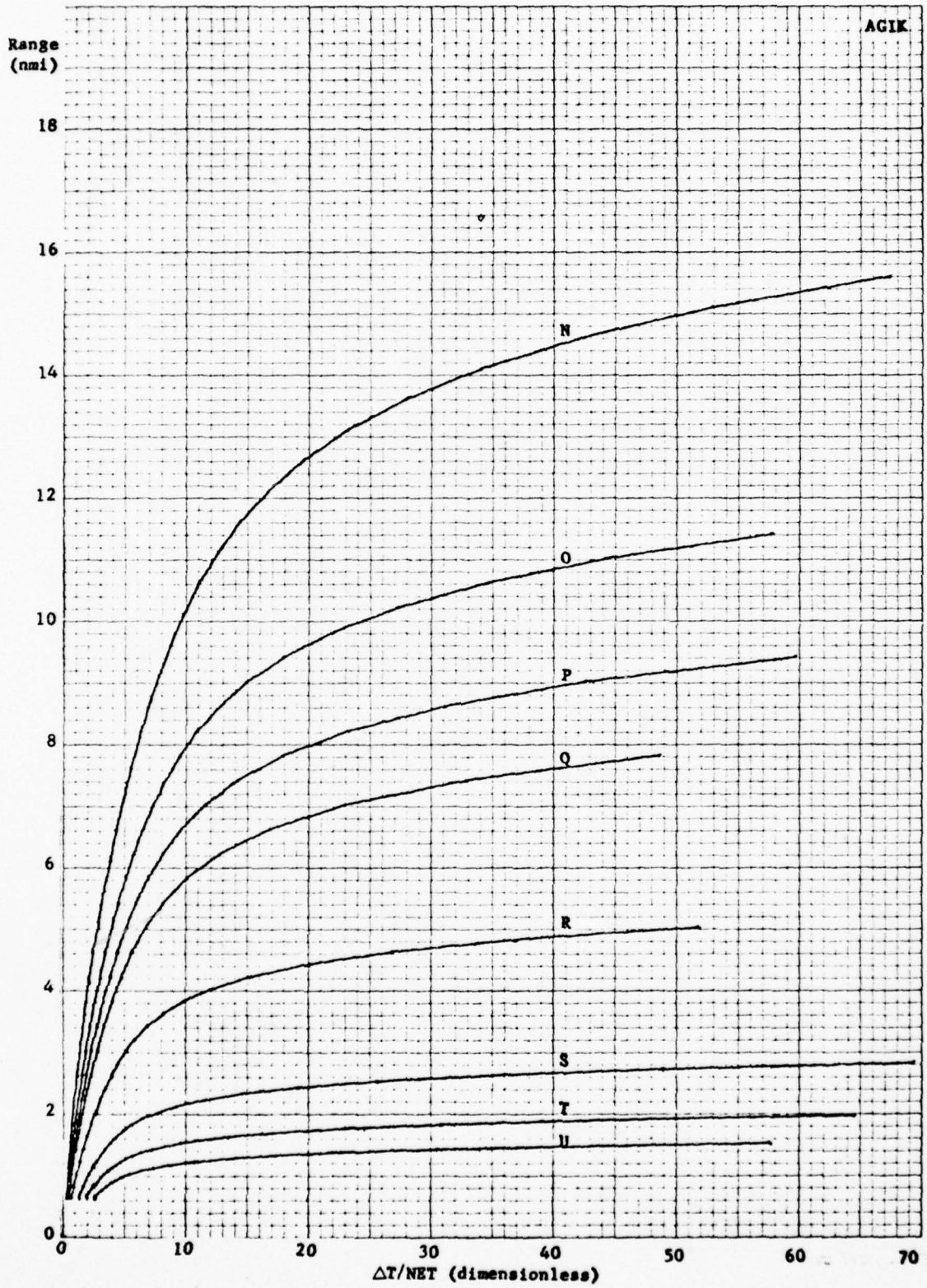

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Range
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ΔT/NET (dimensionless)

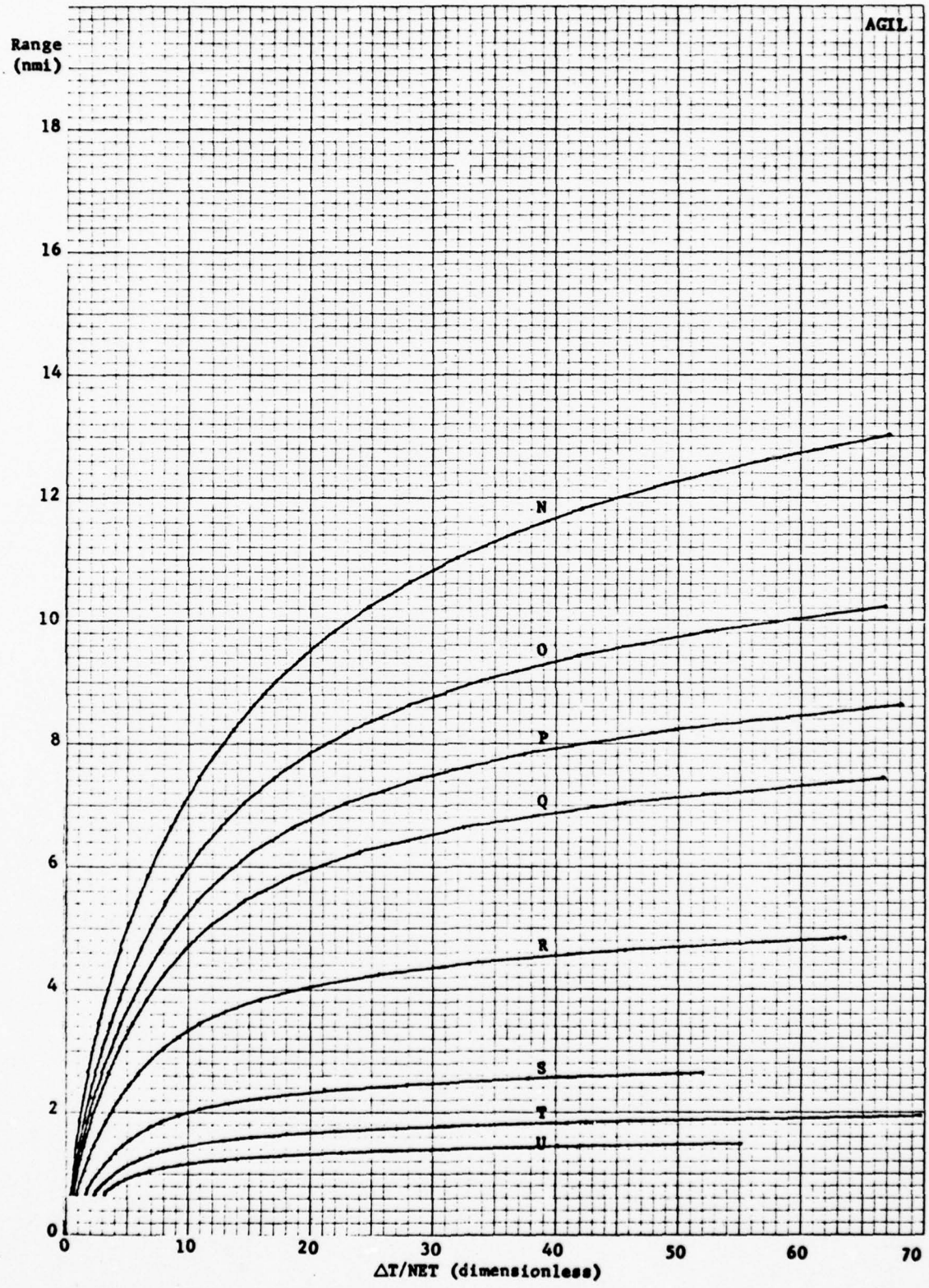

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Range
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ΔT/NET (dimensionless)
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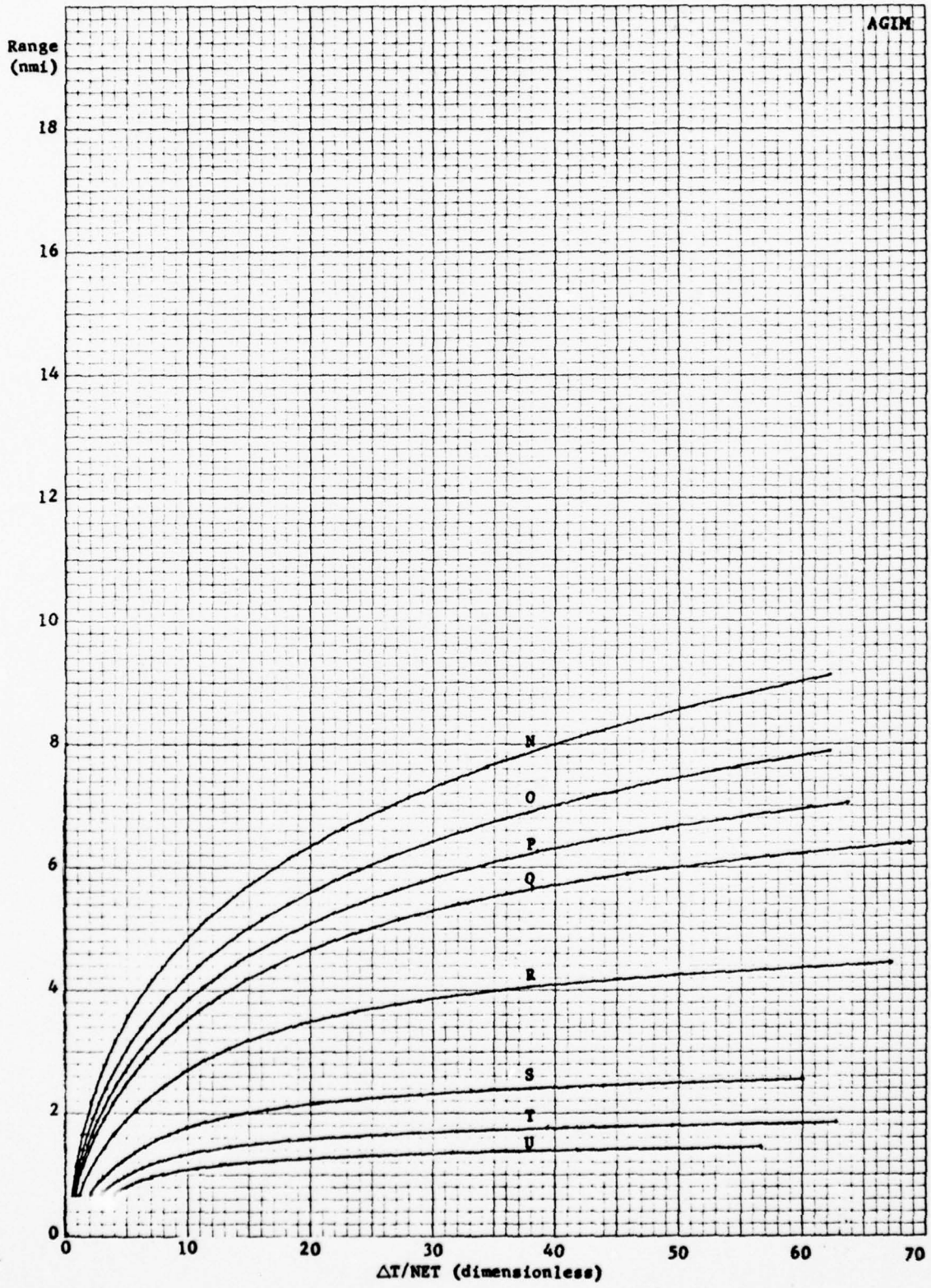

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Range
(nmi)
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ΔT/NET (dimensionless)

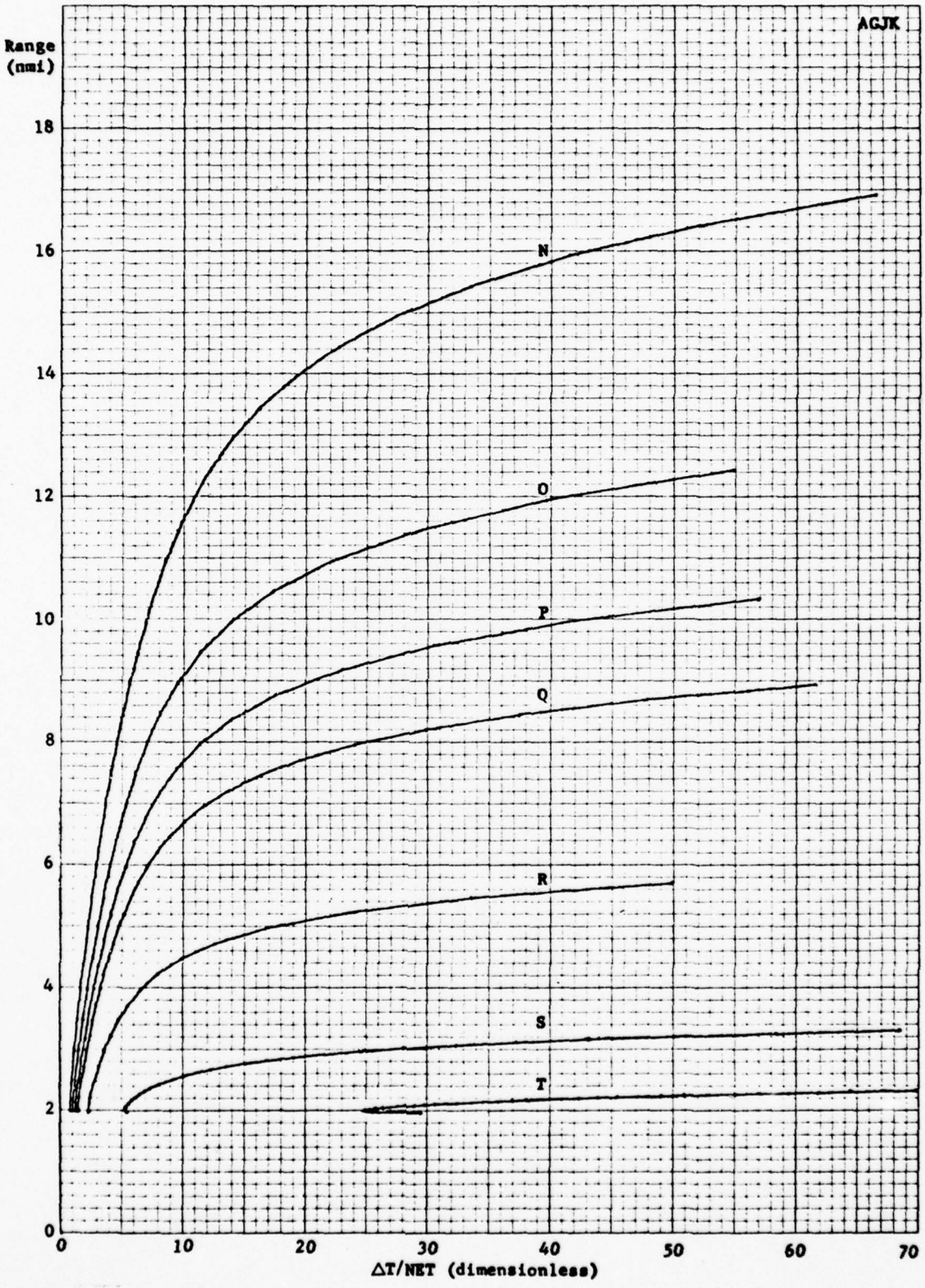

ACHL
Range
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ΔT/NET (dimensionless)

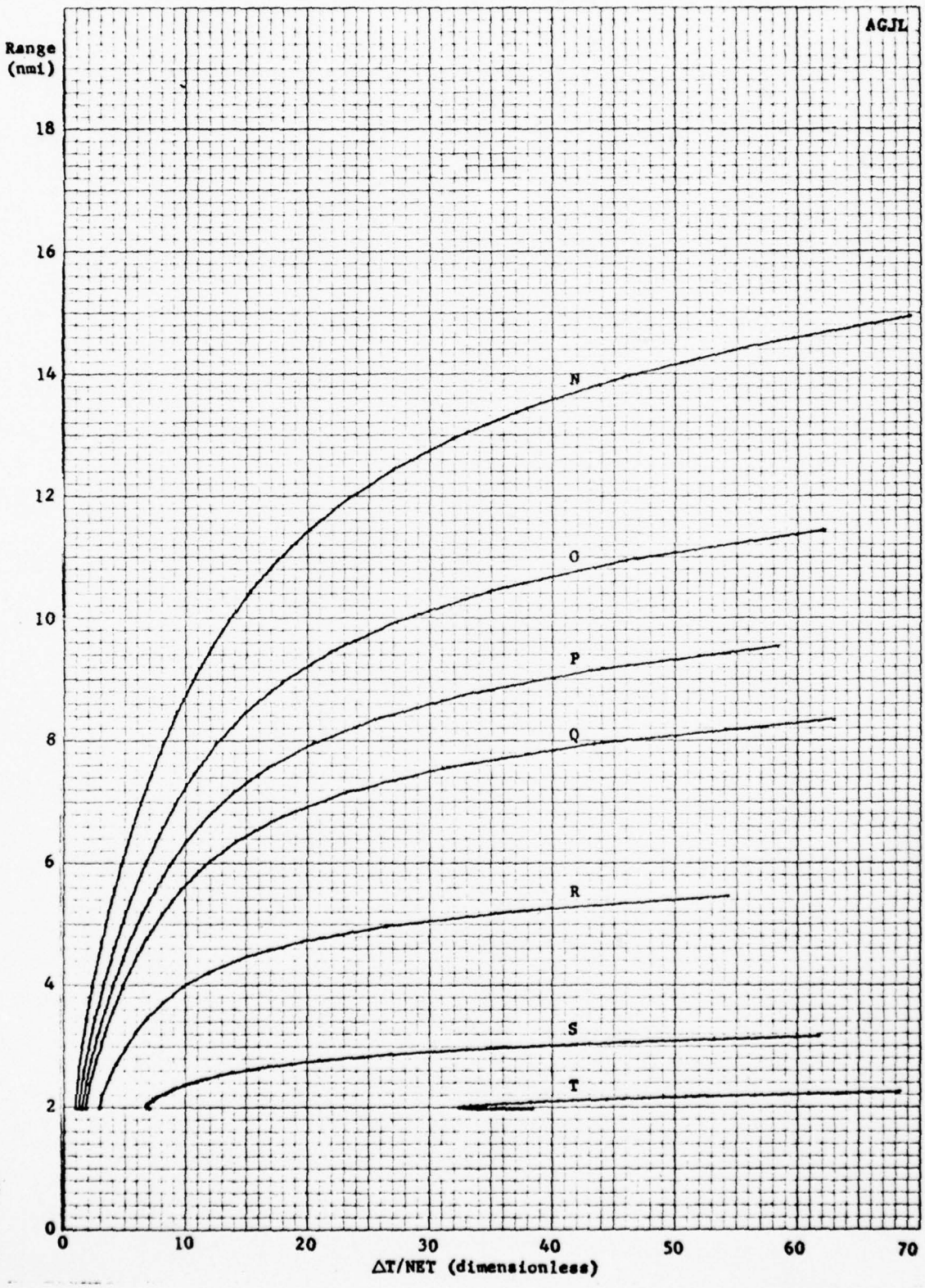

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Range (nmi)
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ΔT/NET (dimensionless)
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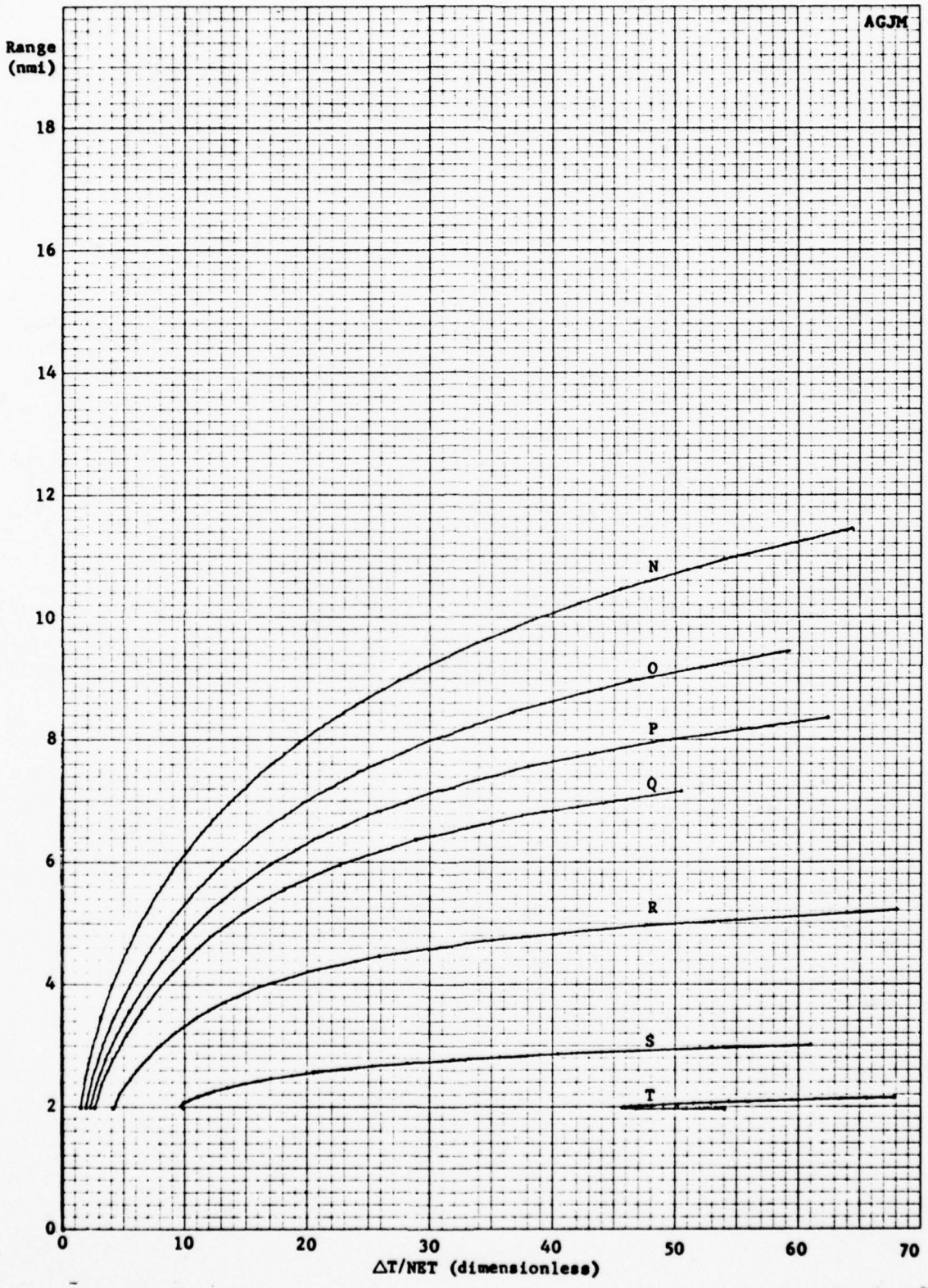

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Range (nmi)
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ΔT/NET (dimensionless)

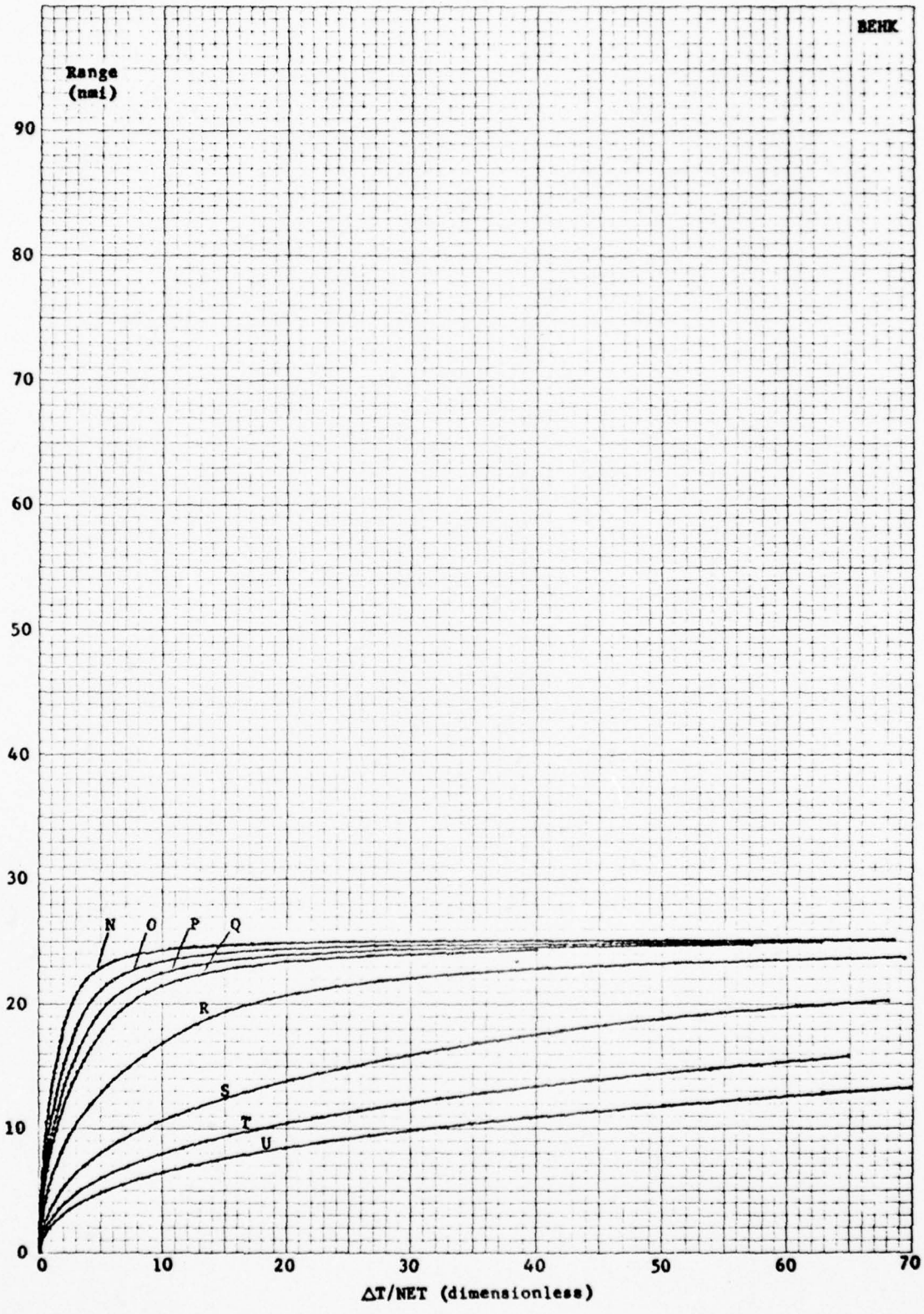

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ΔT/NET (dimensionless)

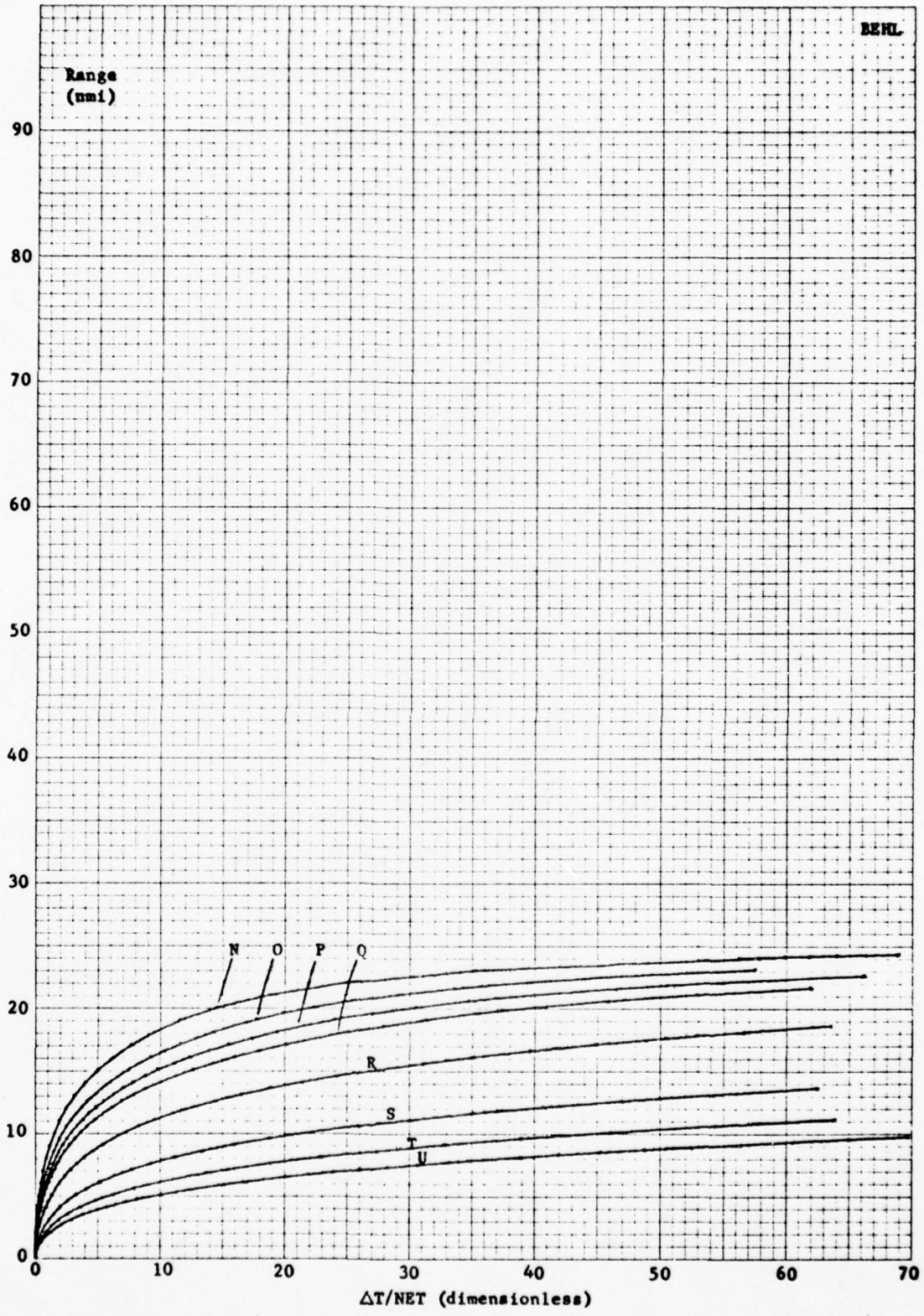

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ΔT/NET (dimensionless)

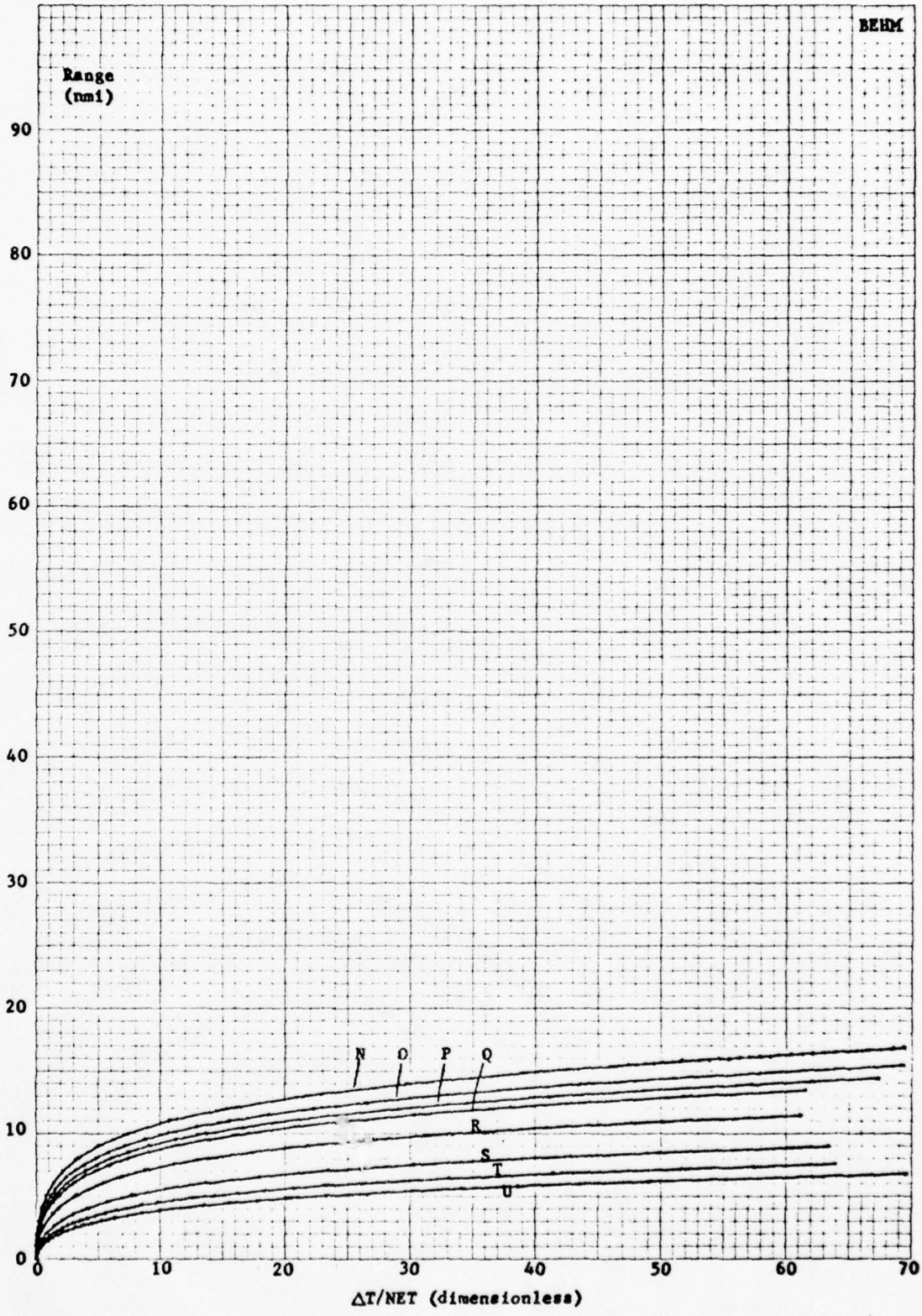

AGJK
Range (nmi)
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ΔT/NET (dimensionless)

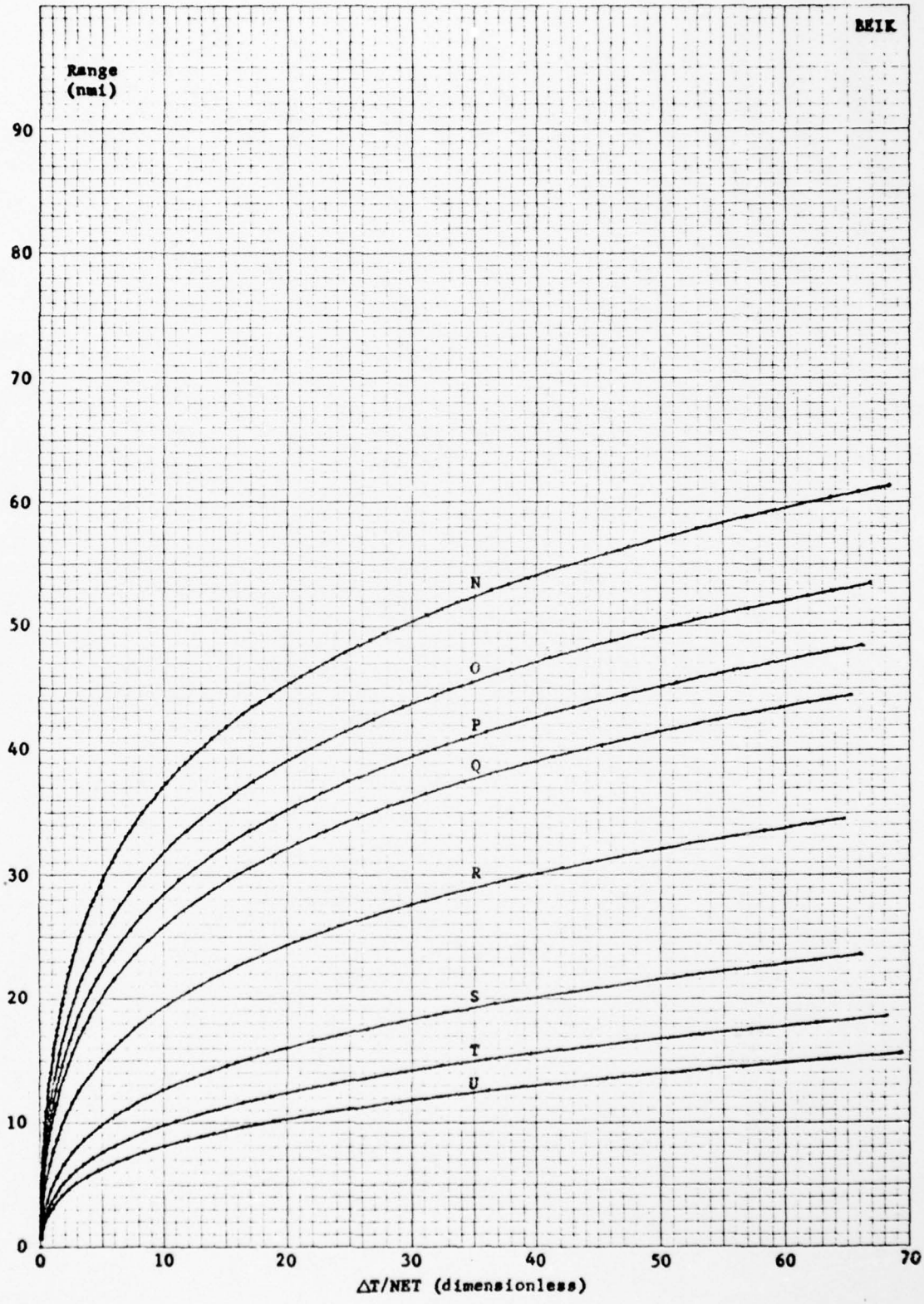

AGJL
Range (nmi)
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ΔT/NET (dimensionless)

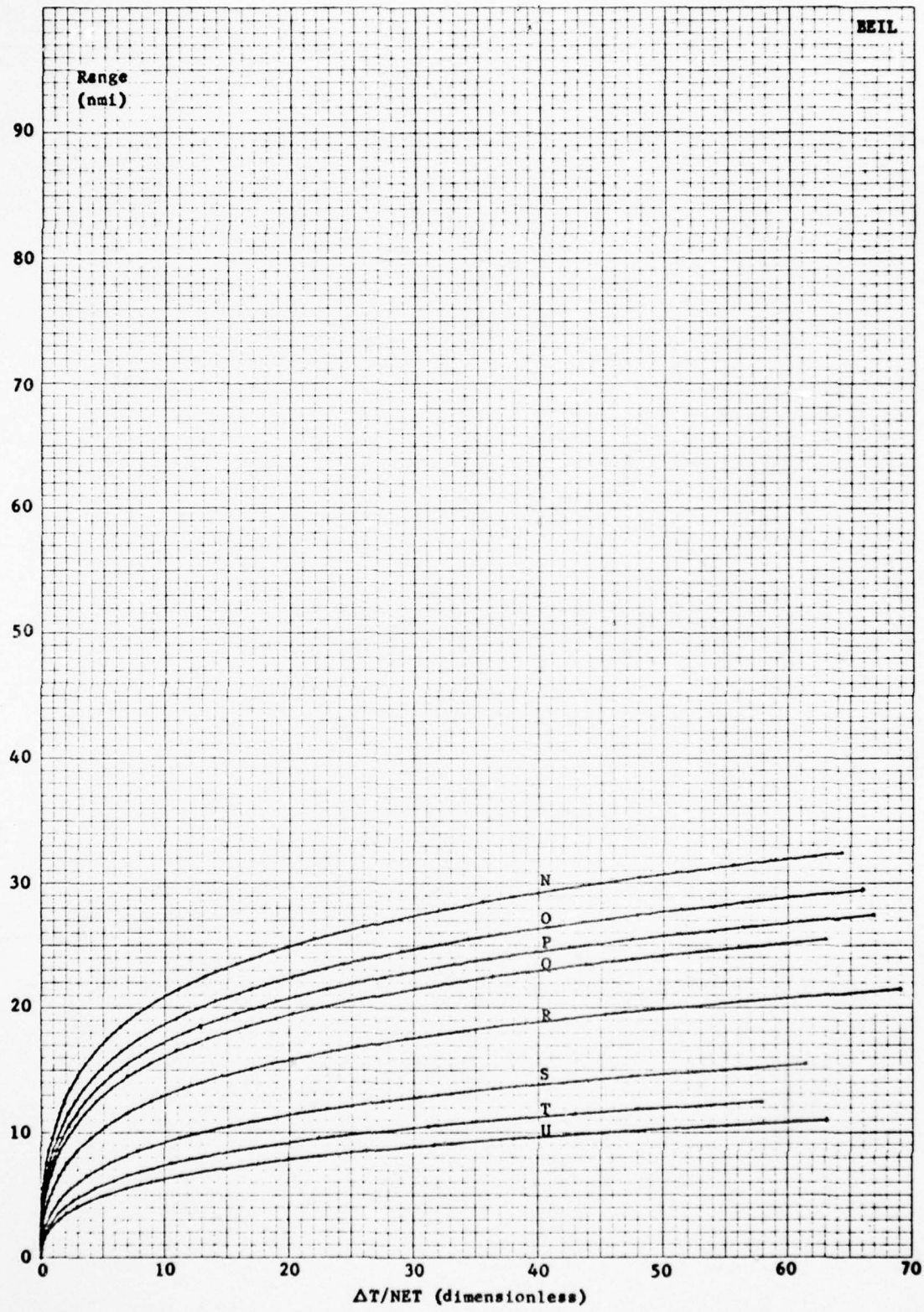

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Range
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ΔT/NET (dimensionless)
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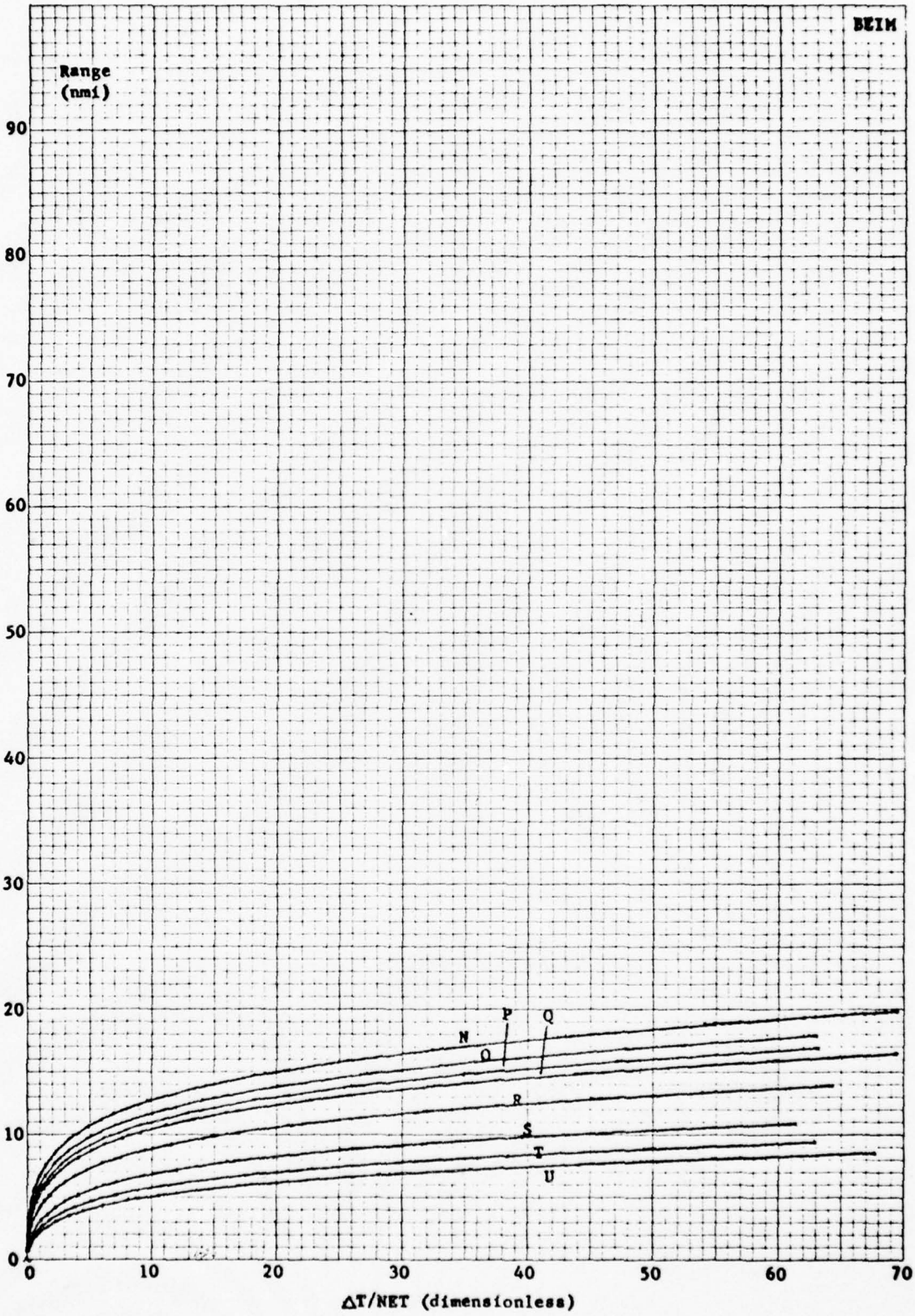

BEHK
Range
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ΔT/NET (dimensionless)

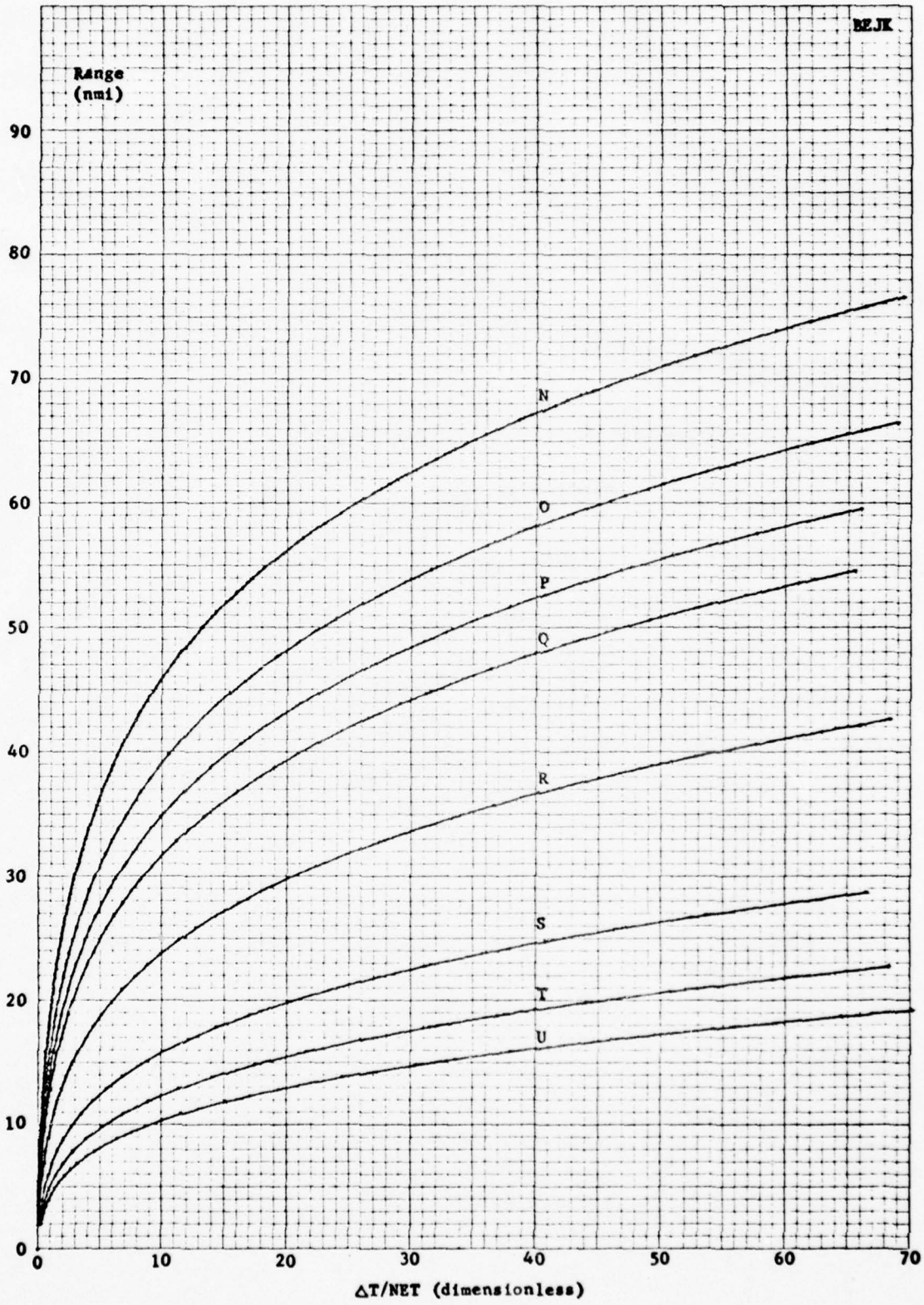

BEHL
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ΔT/NET (dimensionless)

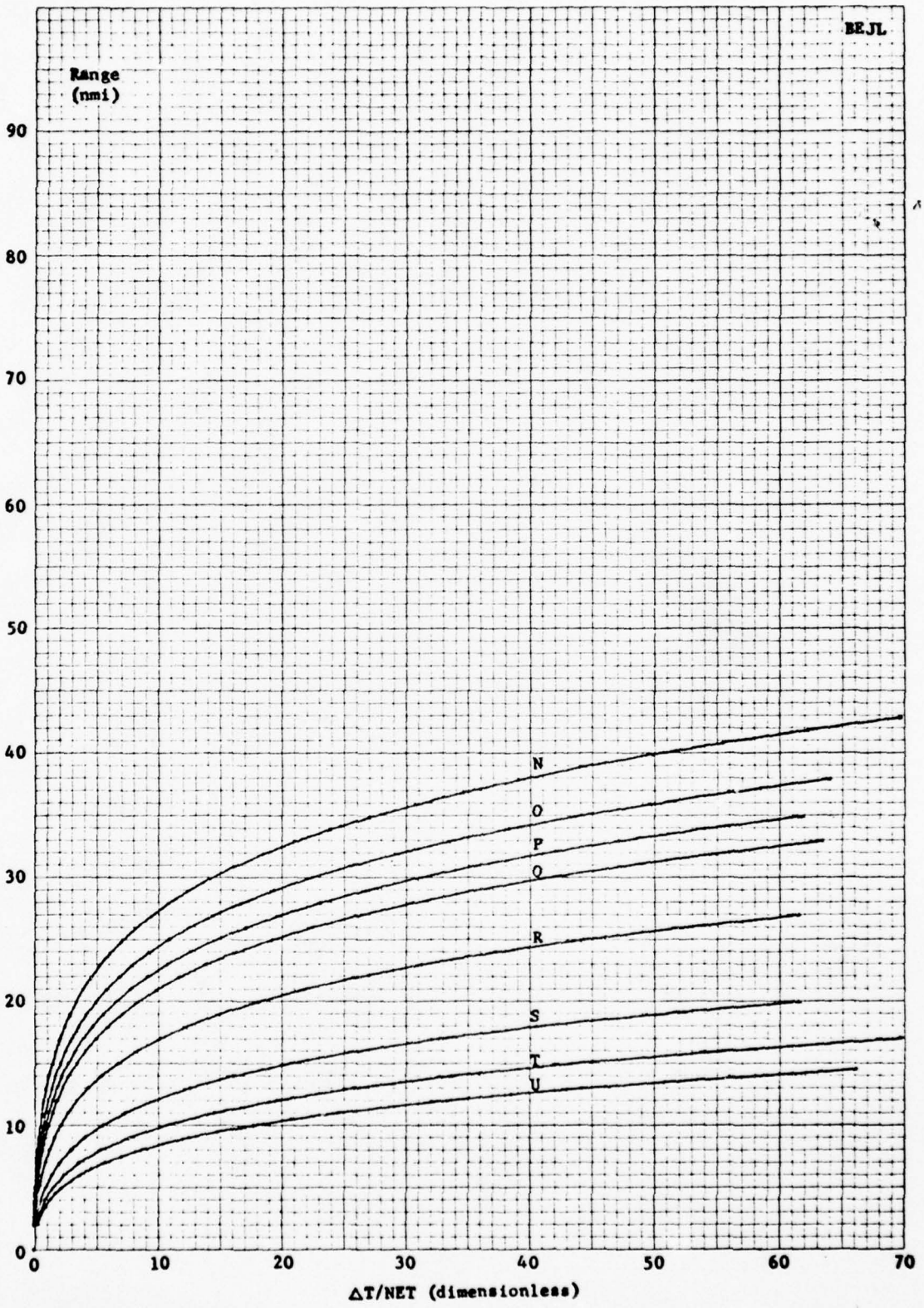

BEHM
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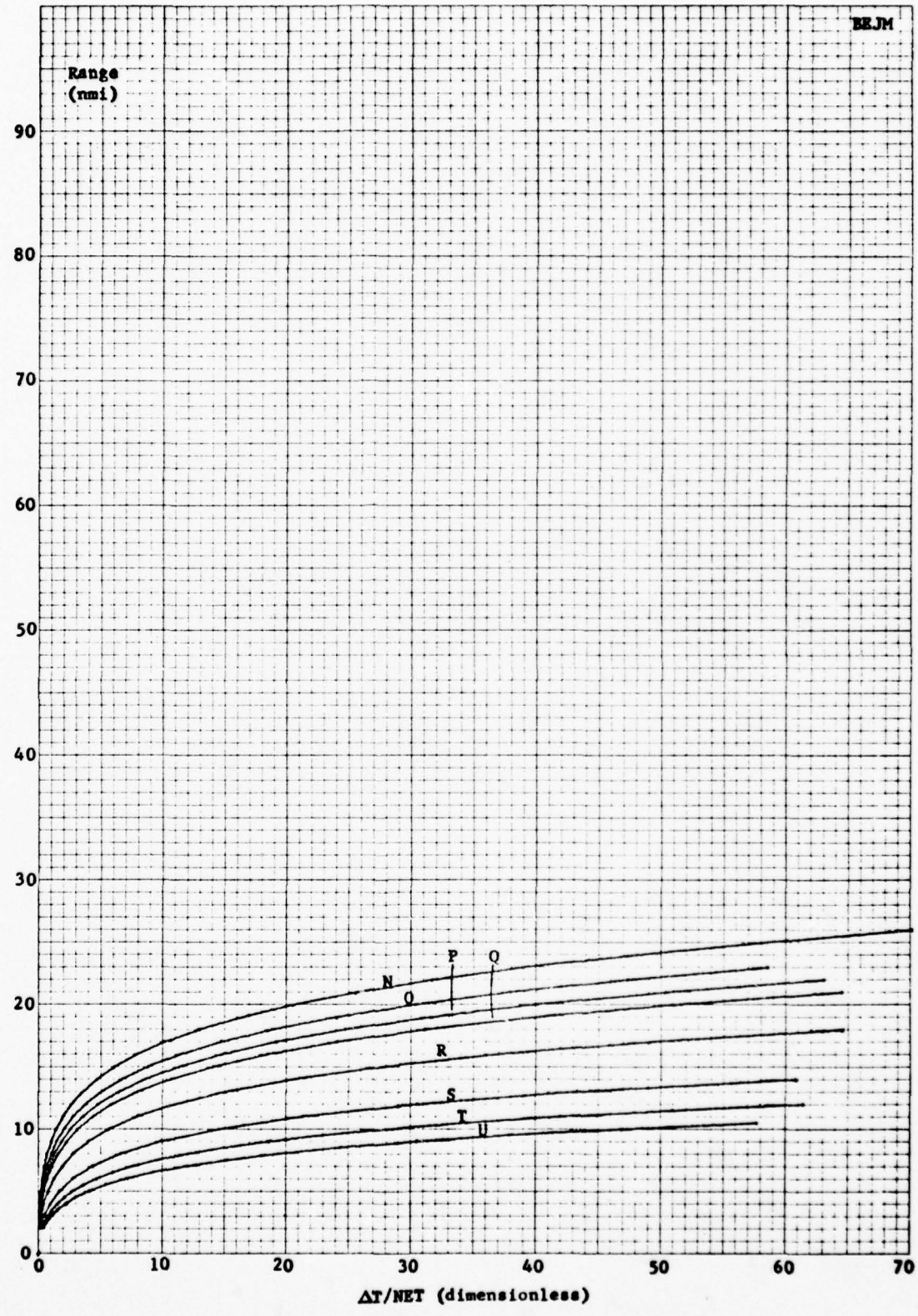

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ΔT/NET (dimensionless)
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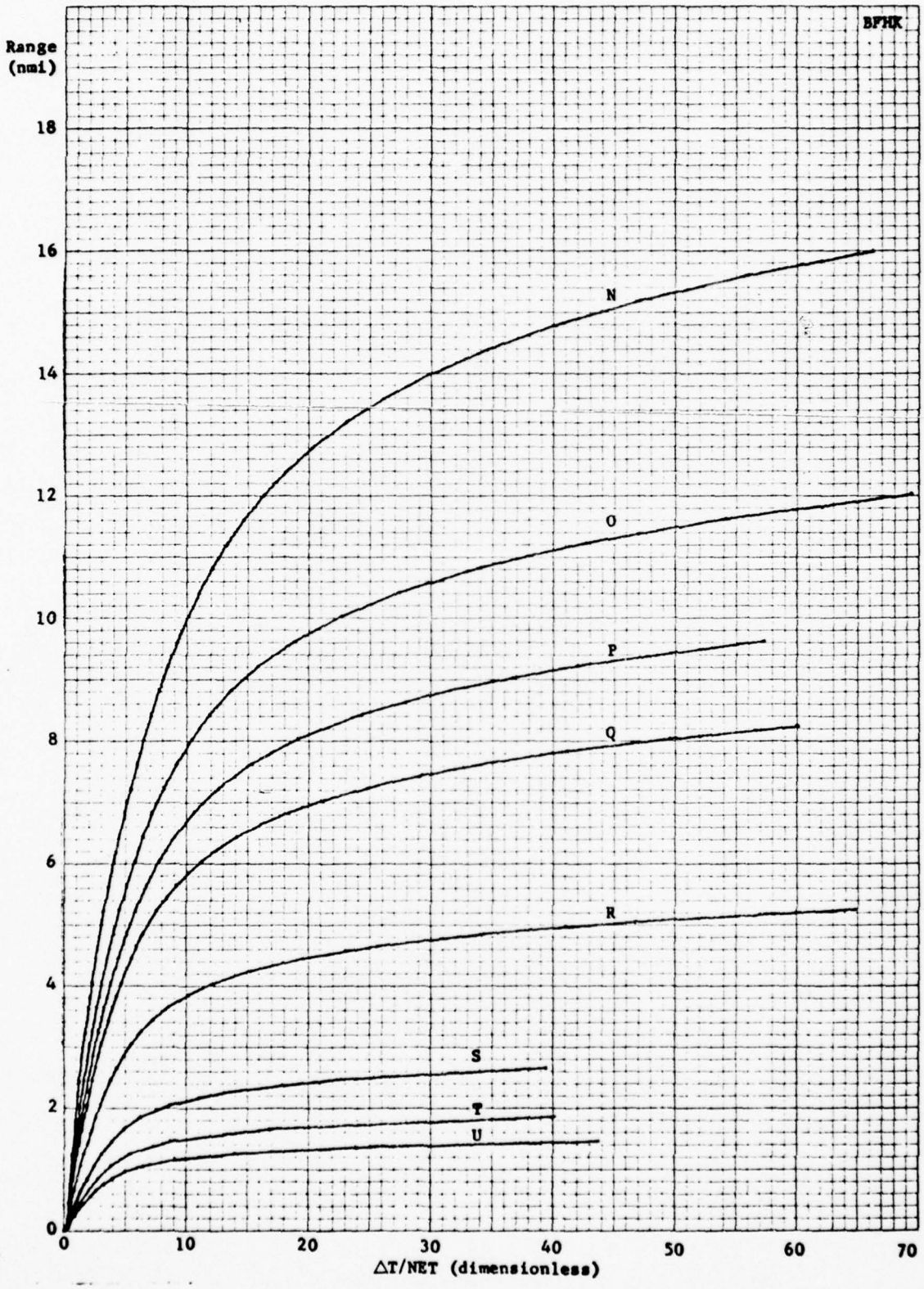

BEIL
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ΔT/NET (dimensionless)
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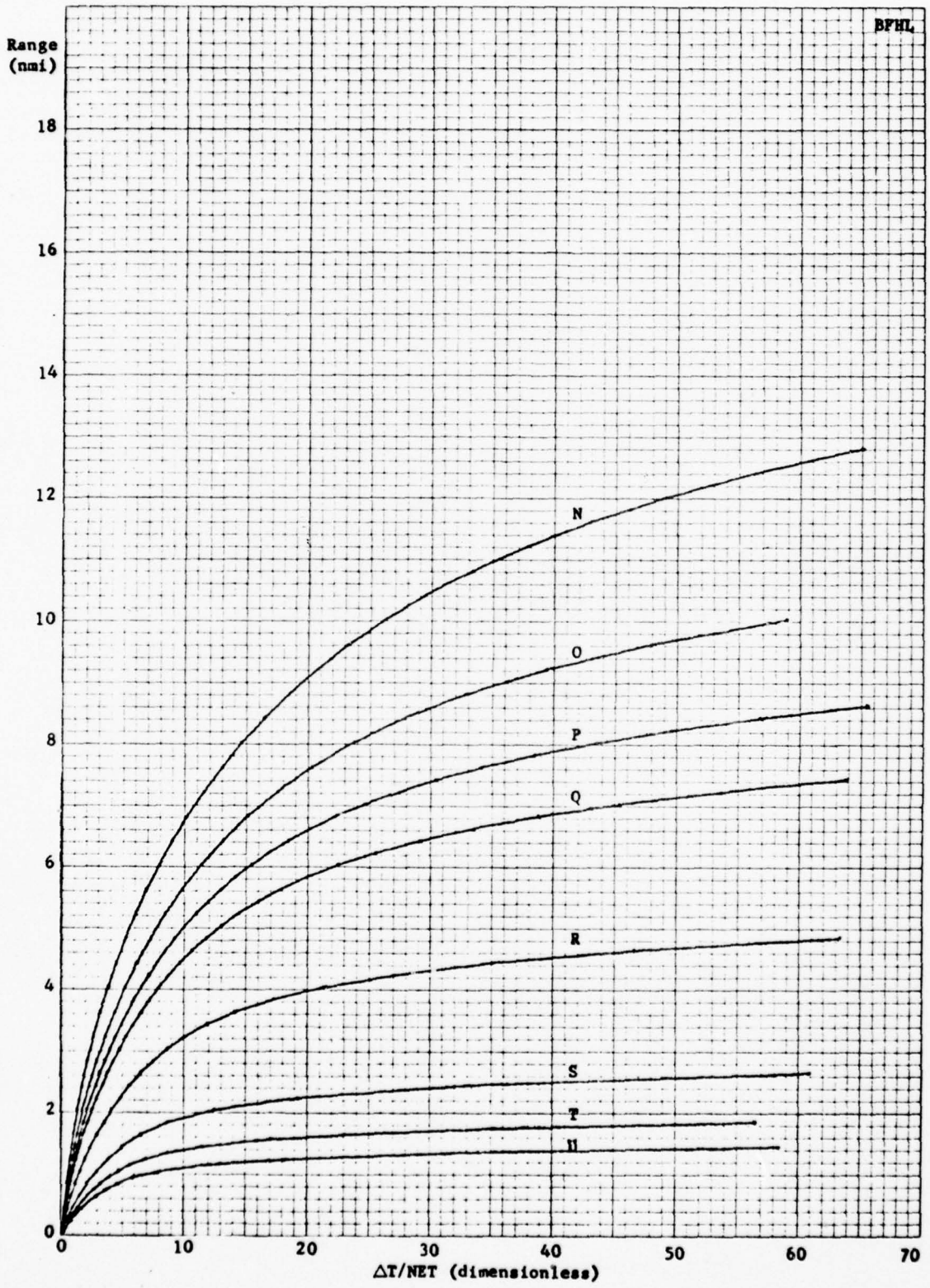

BEIM
Range
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ΔT/NET (dimensionless)
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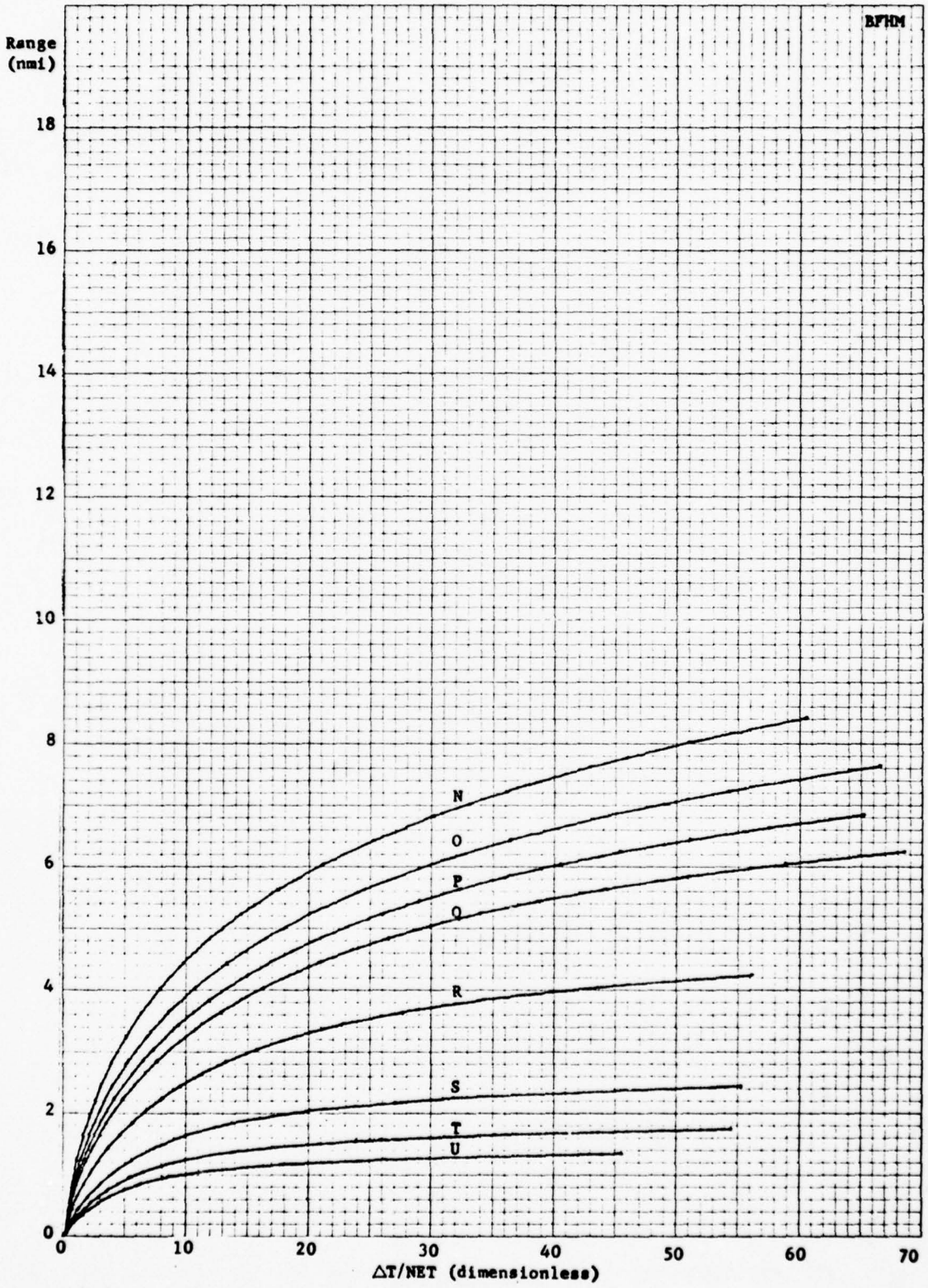

BEJK
Range
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ΔT/NET (dimensionless)

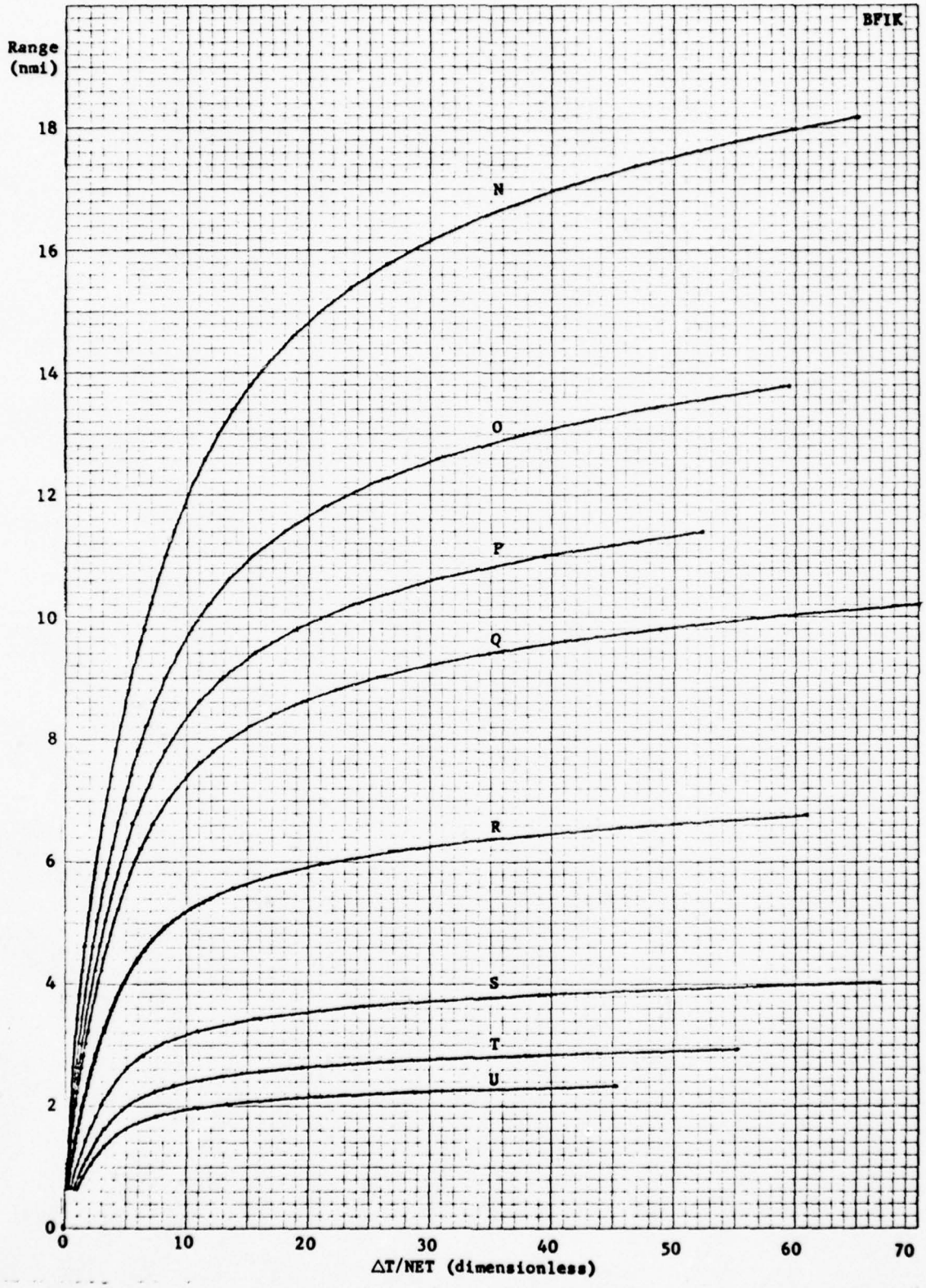

BEJL
Range
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ΔT/NET (dimensionless)
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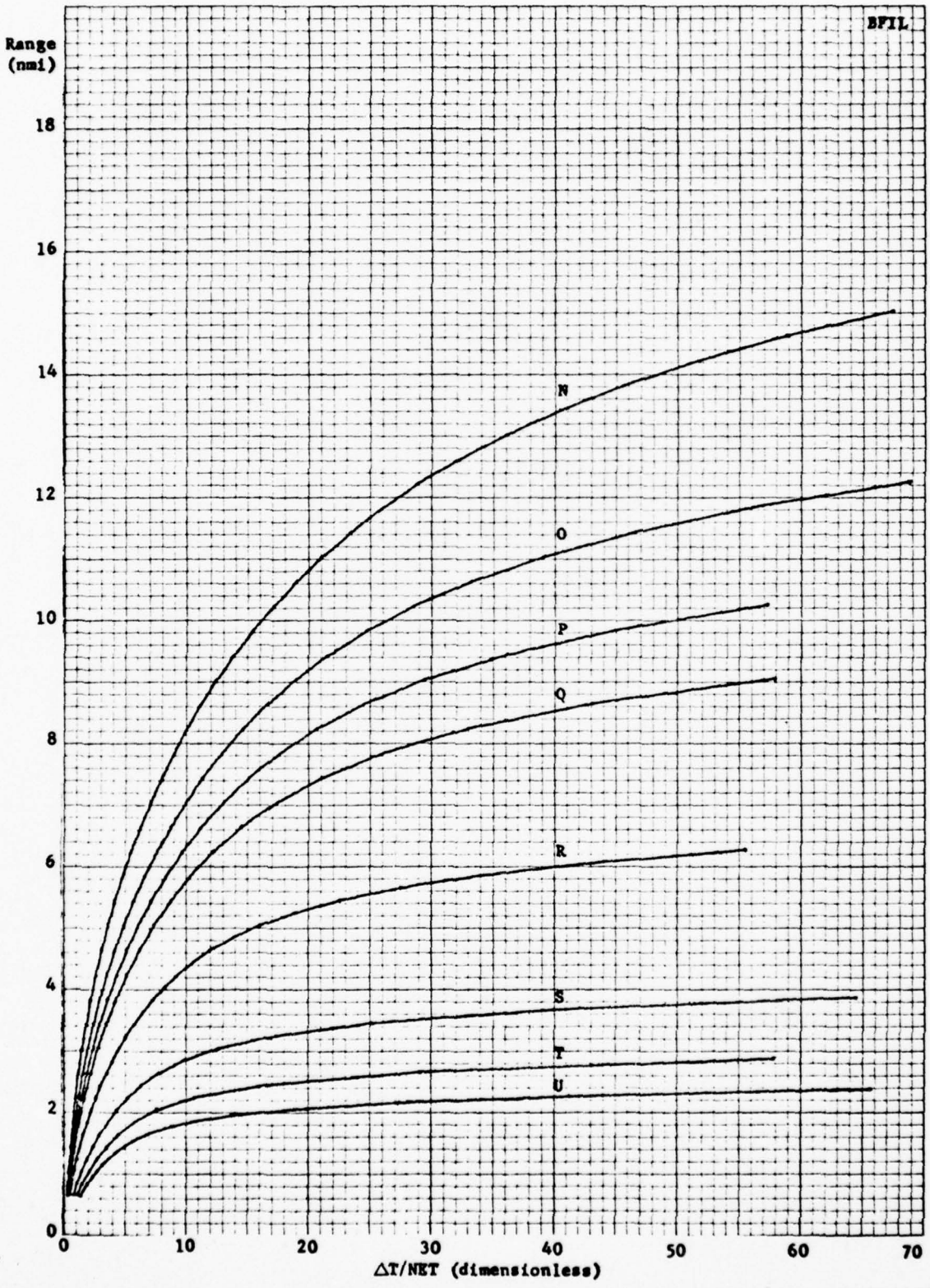

BEJM
Range
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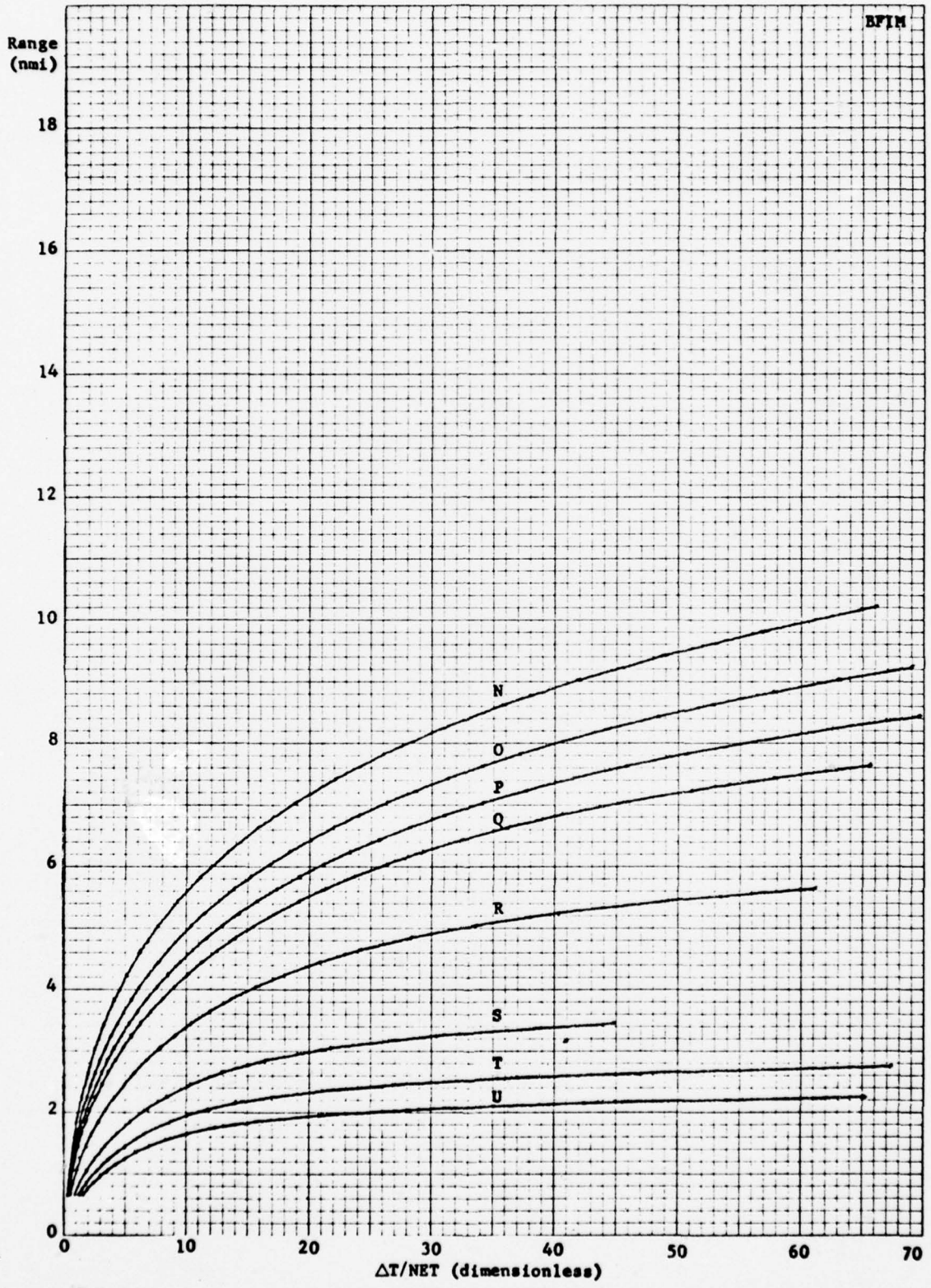

BFHK
Range
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ΔT/NET (dimensionless)

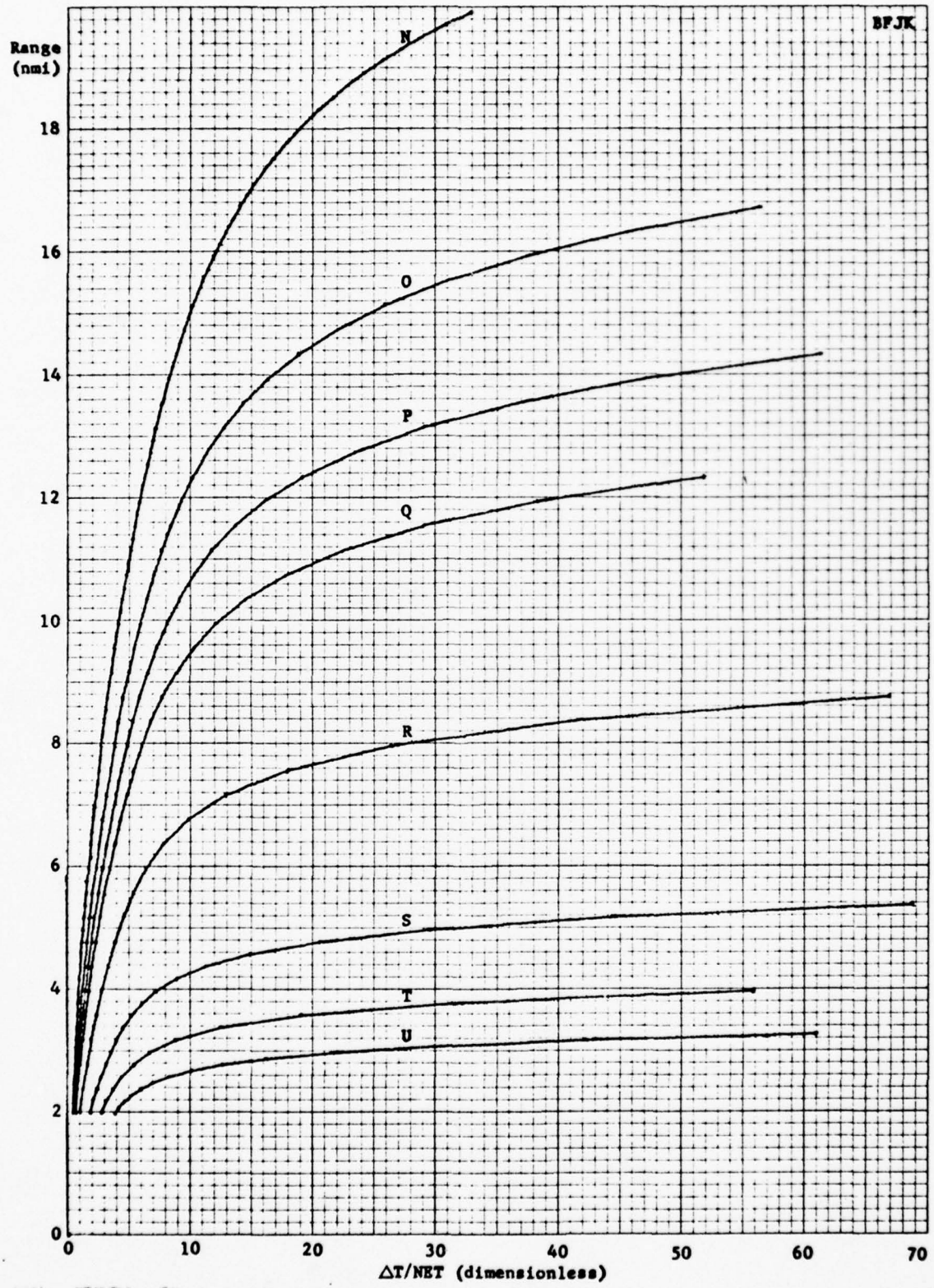

BFHL
Range
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ΔT/NET (dimensionless)

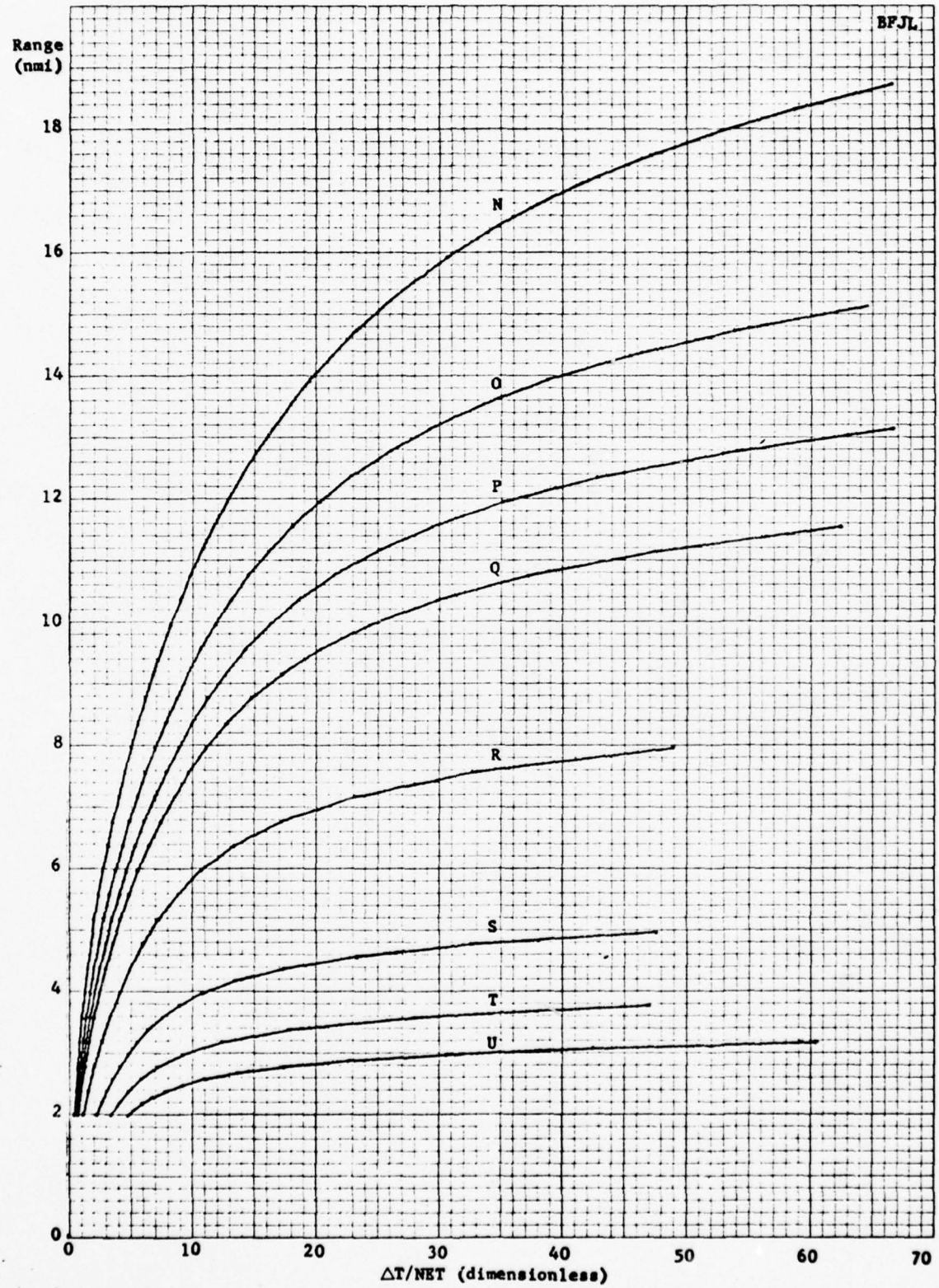

BFHM
Range (nmi)
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ΔT/NET (dimensionless)
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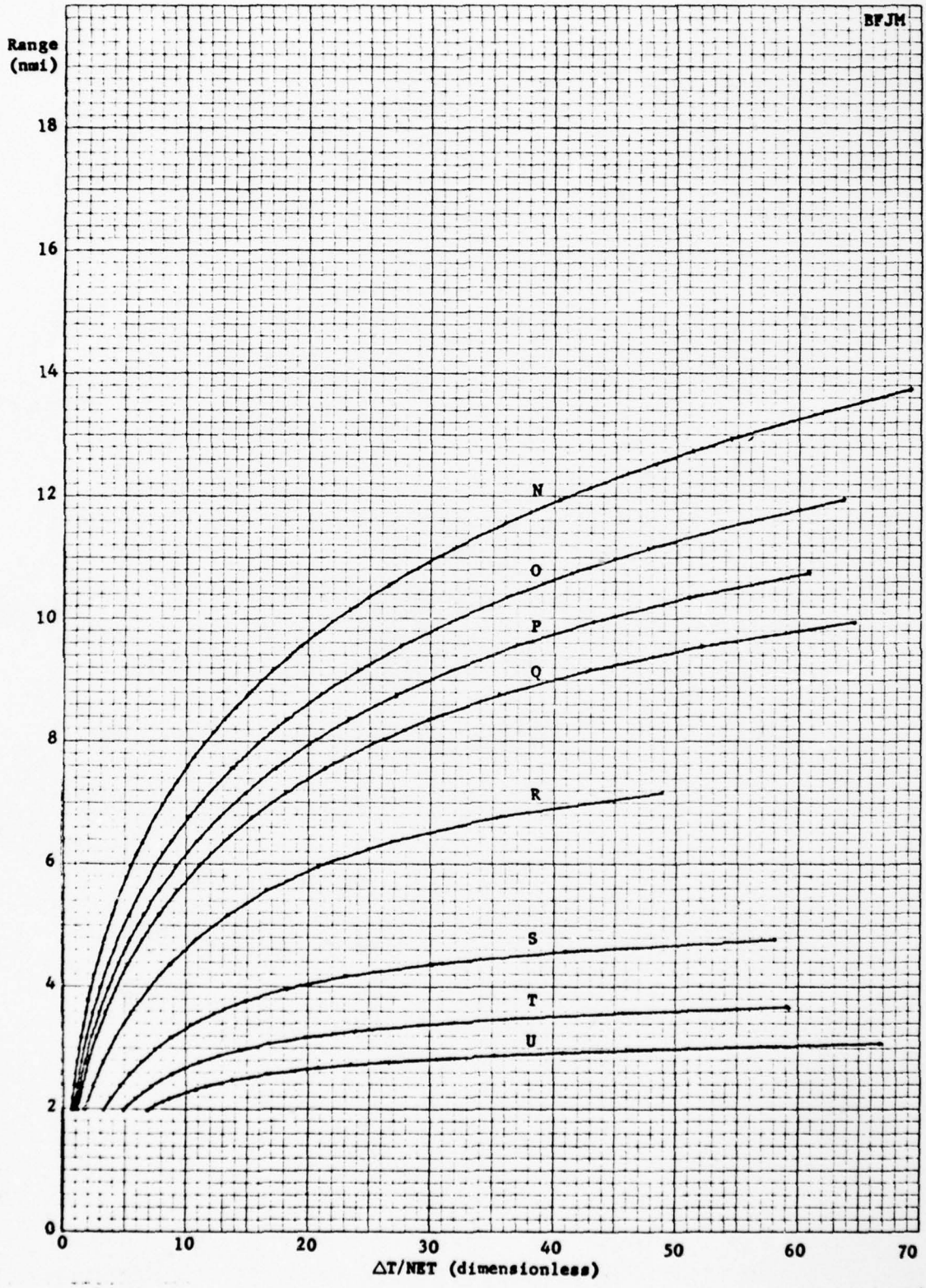

BFIK
Range (nmi)
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ΔT/NET (dimensionless)

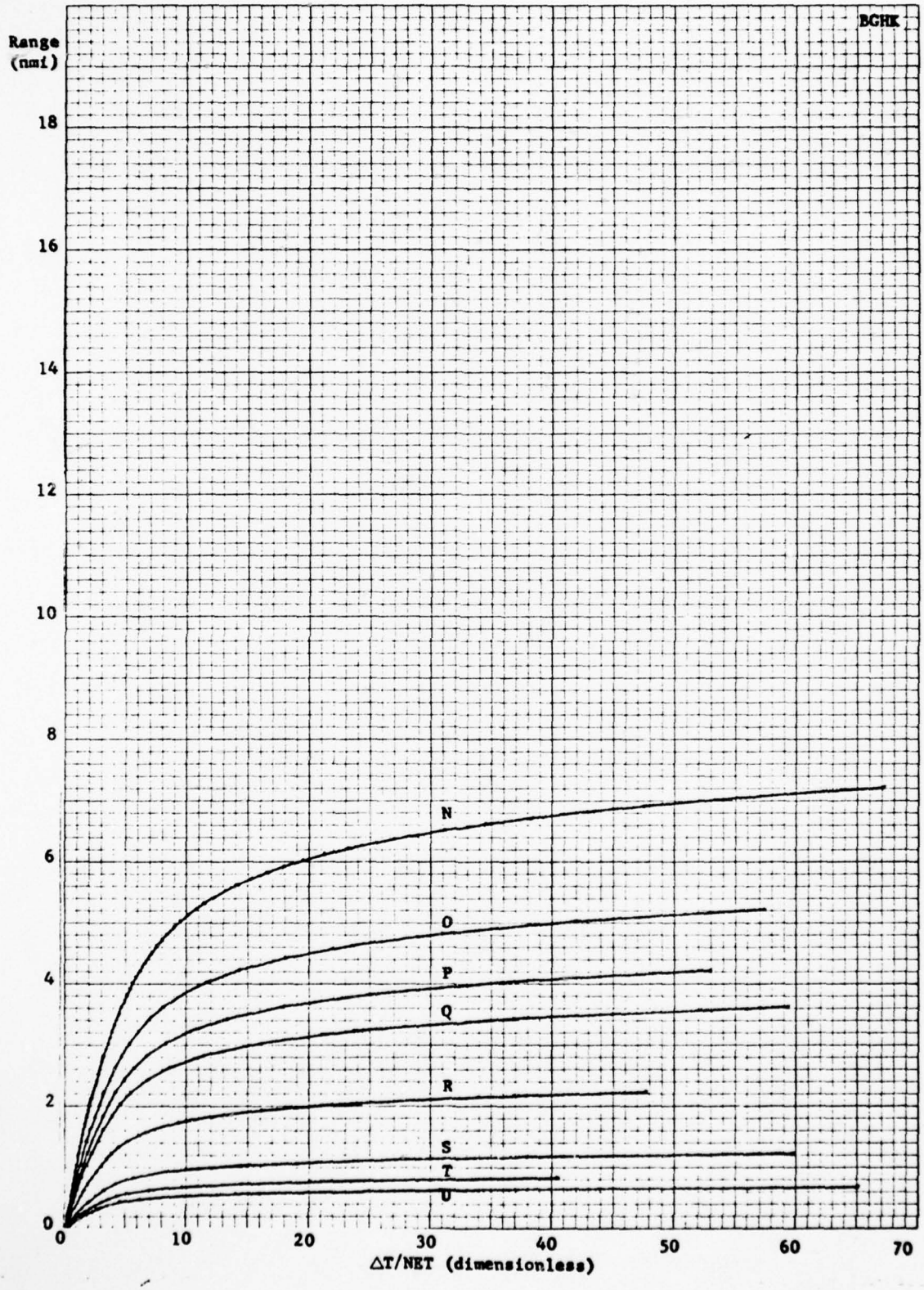

BFIL
Range
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ΔT/NET (dimensionless)
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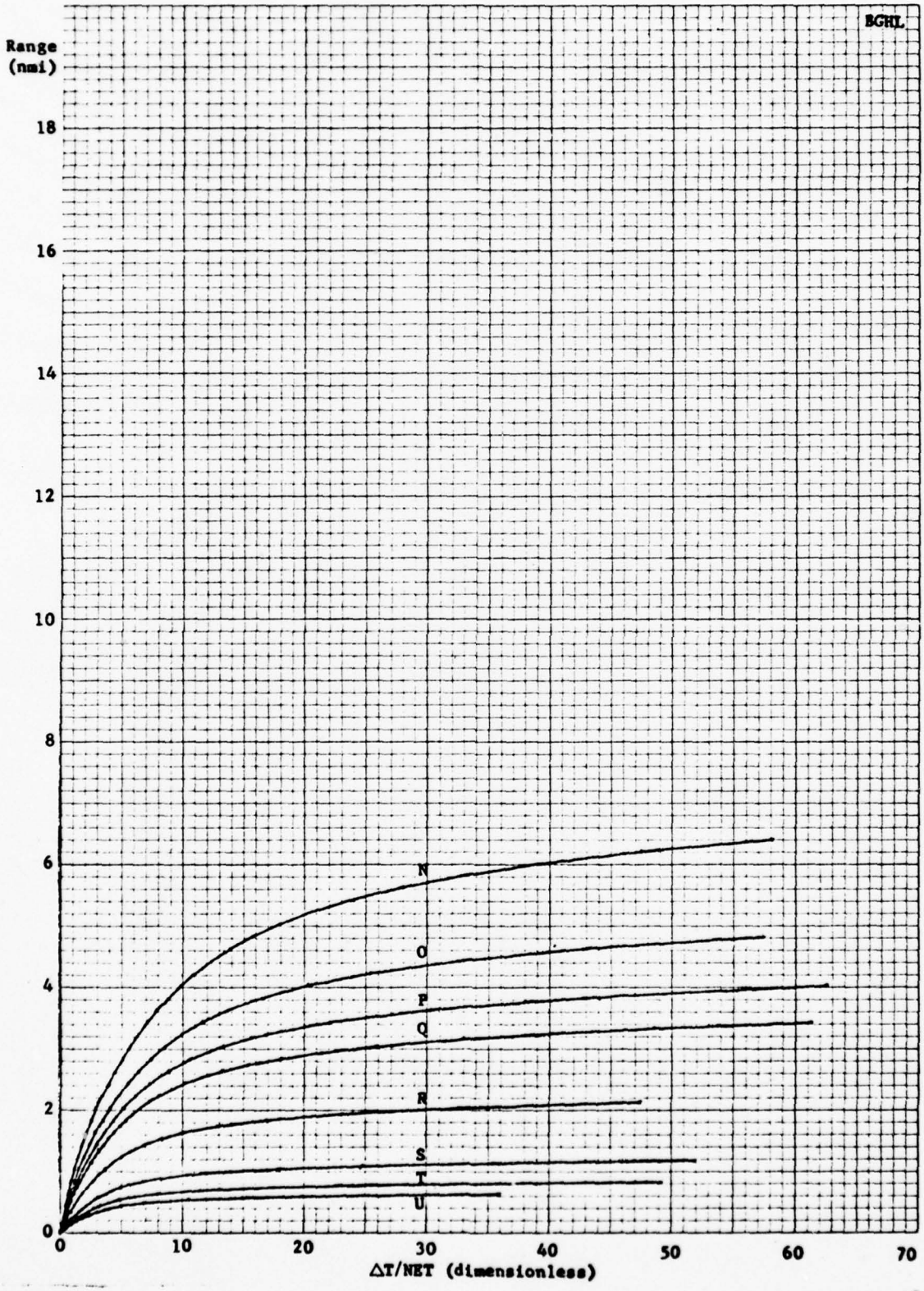

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ΔT/NET (dimensionless)

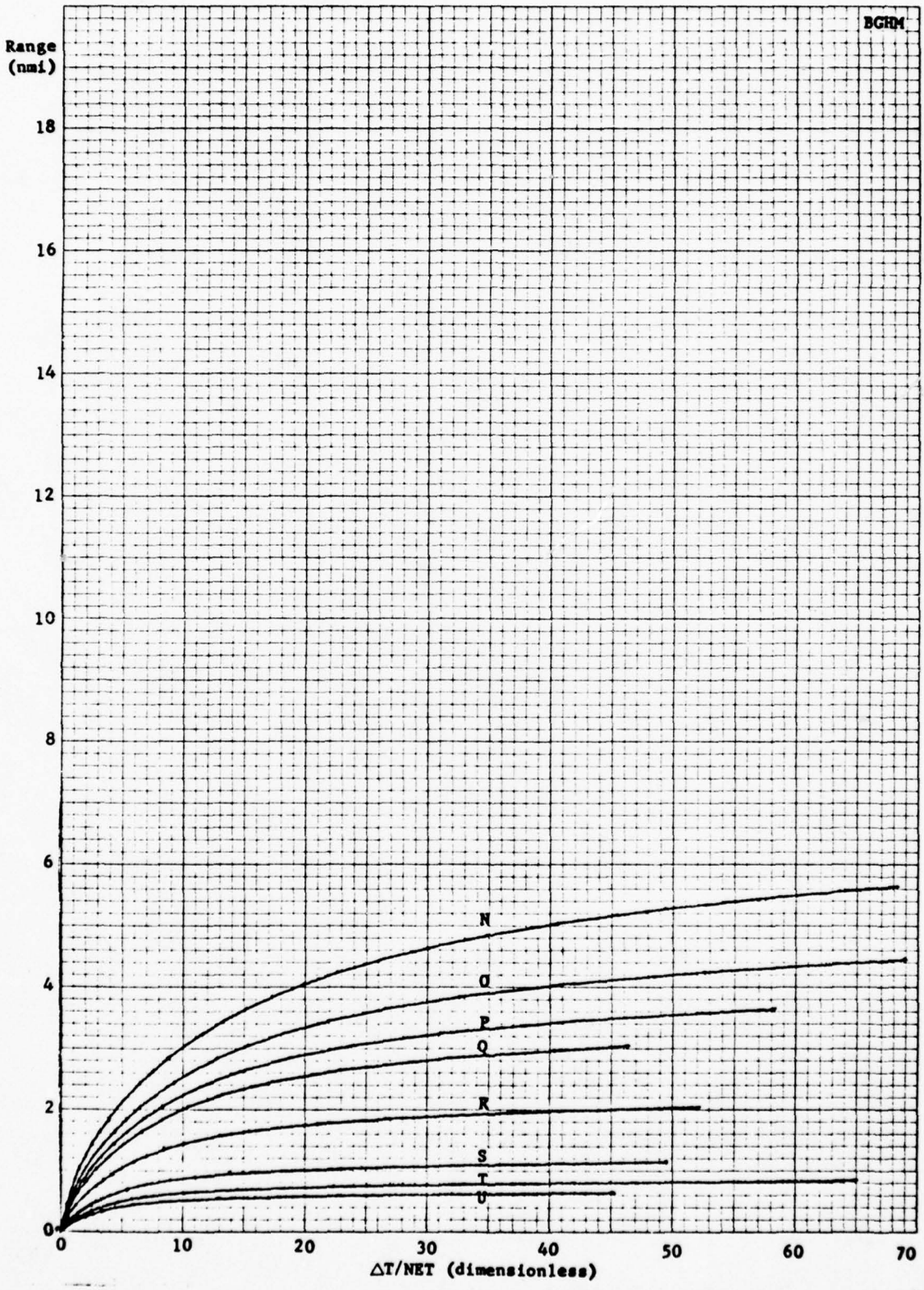

BFJK
Range (nmi)
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ΔT/NET (dimensionless)

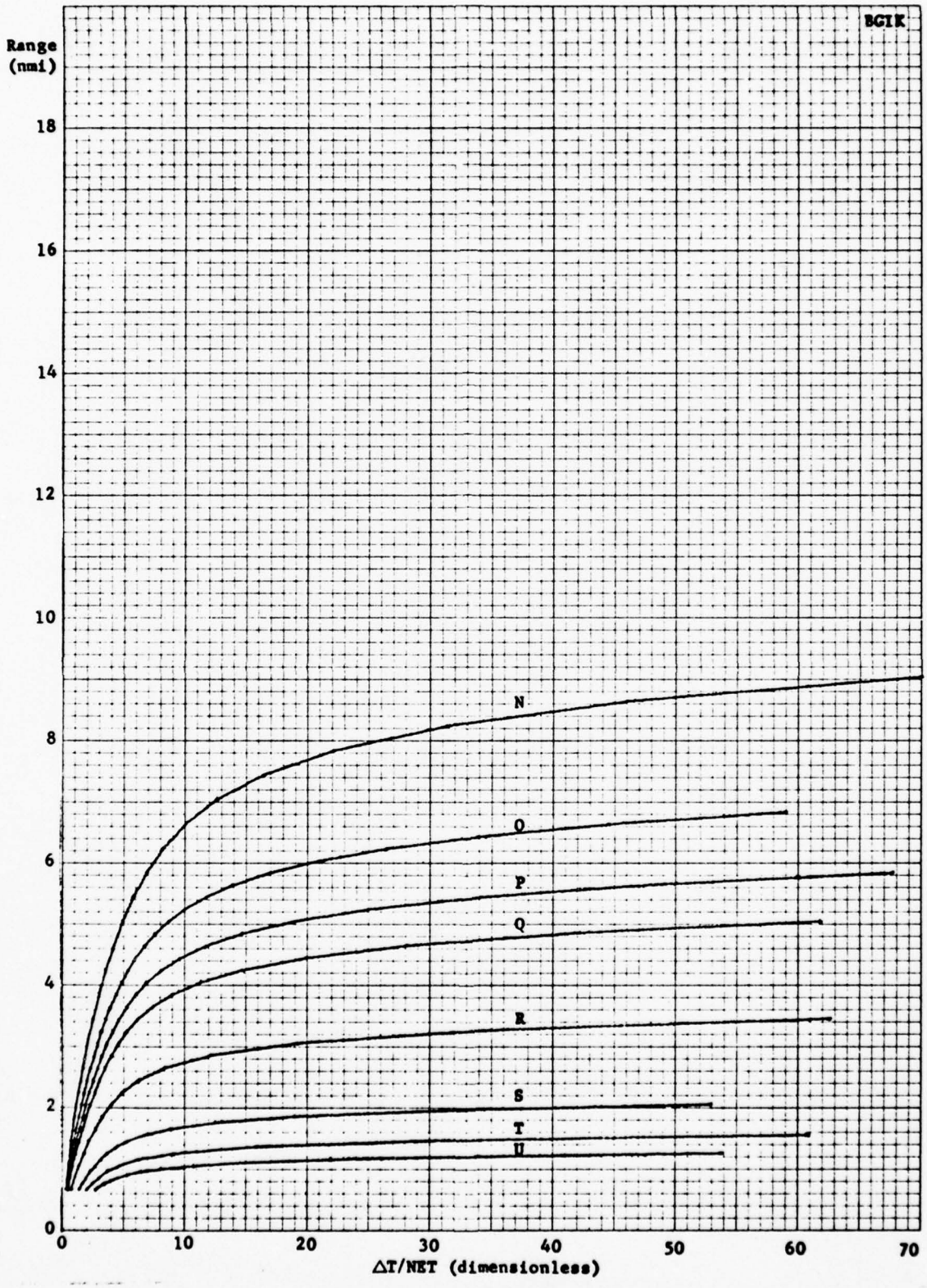

BFJL
Range (nmi)
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ΔT/NET (dimensionless)

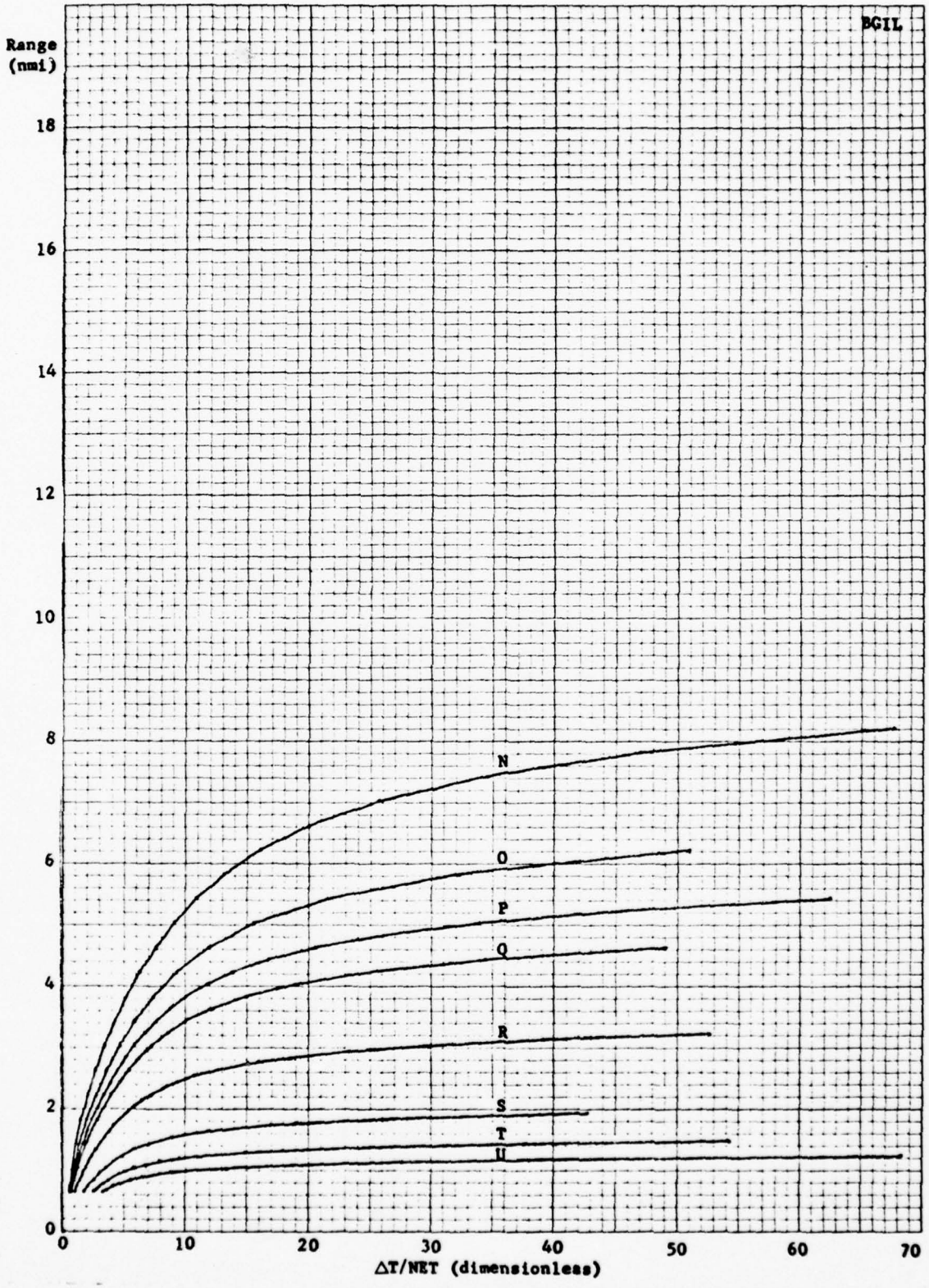

BFJM
Range
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ΔT/NET (dimensionless)

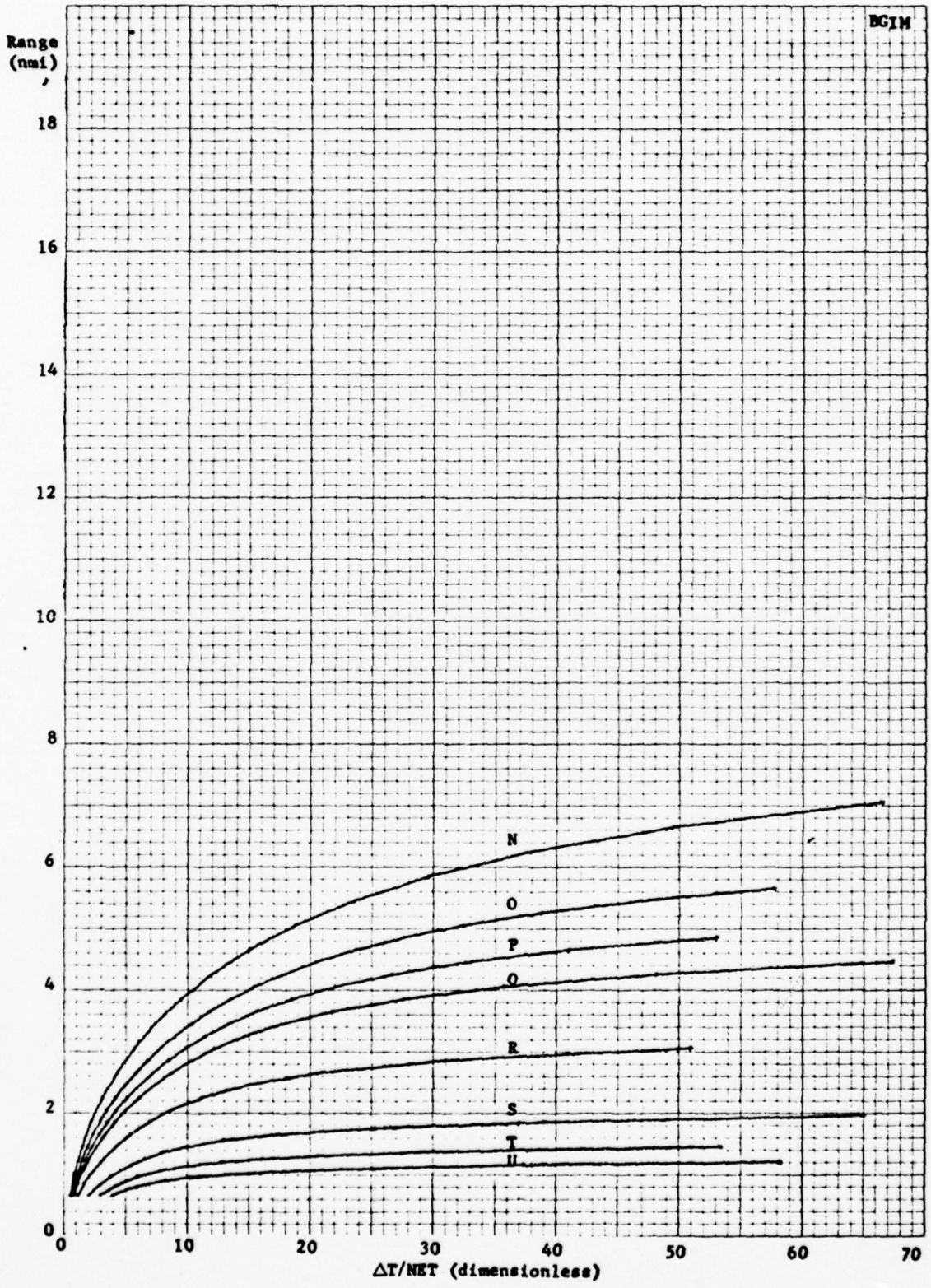

BGHK
Range
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ΔT/NET (dimensionless)
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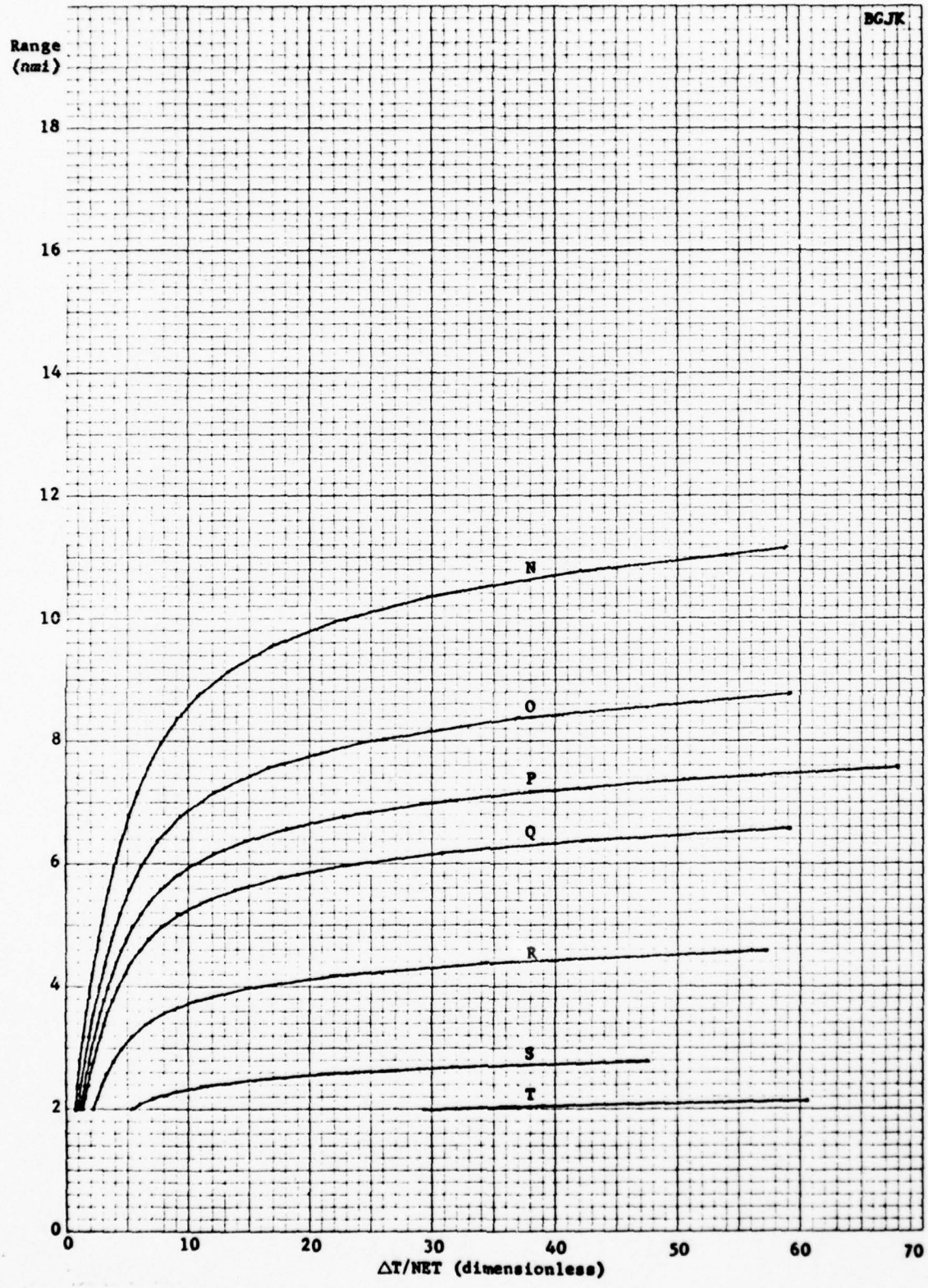

BGHL
Range
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ΔT/NET (dimensionless)
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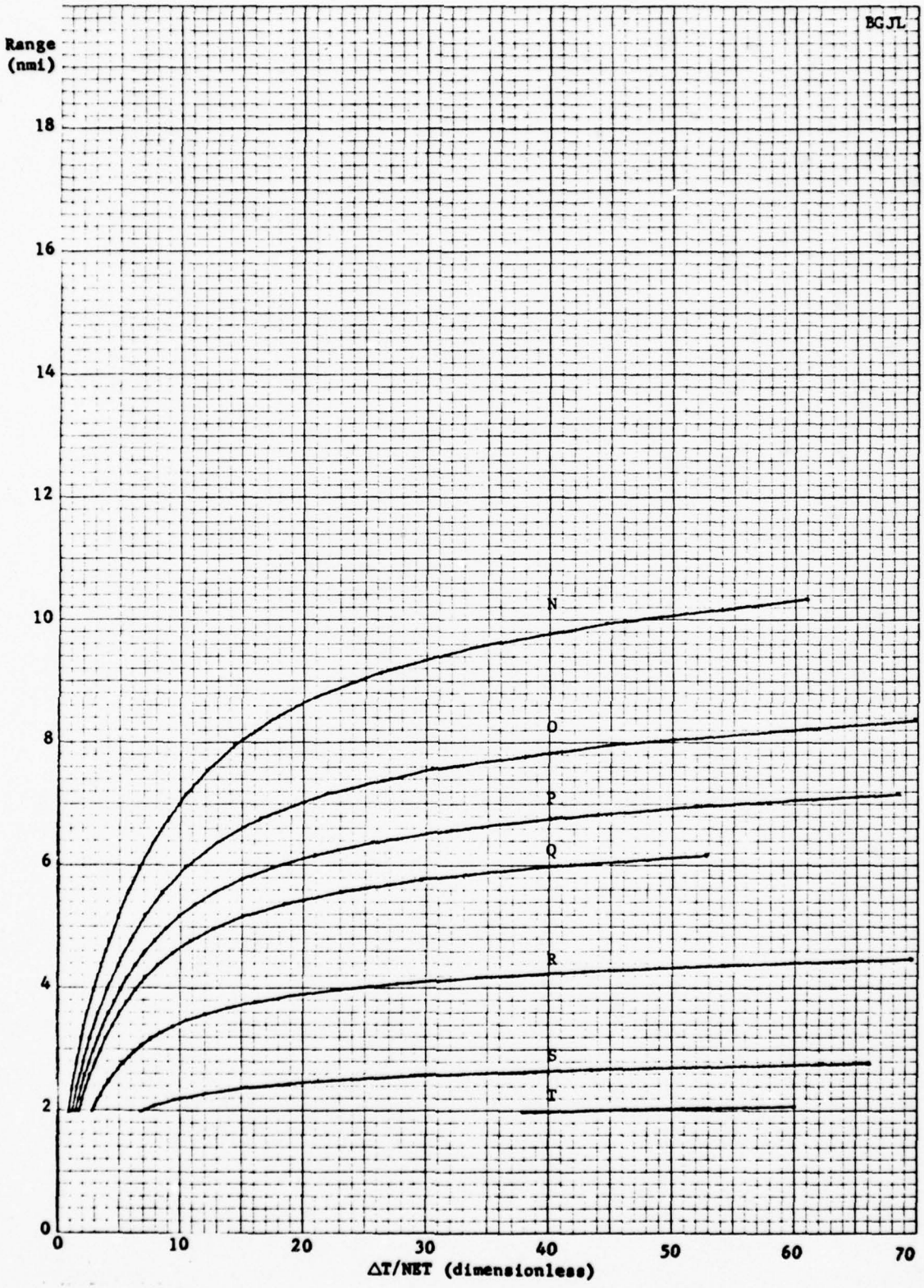

BGHM
Range (nmi)
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ΔT/NET (dimensionless)
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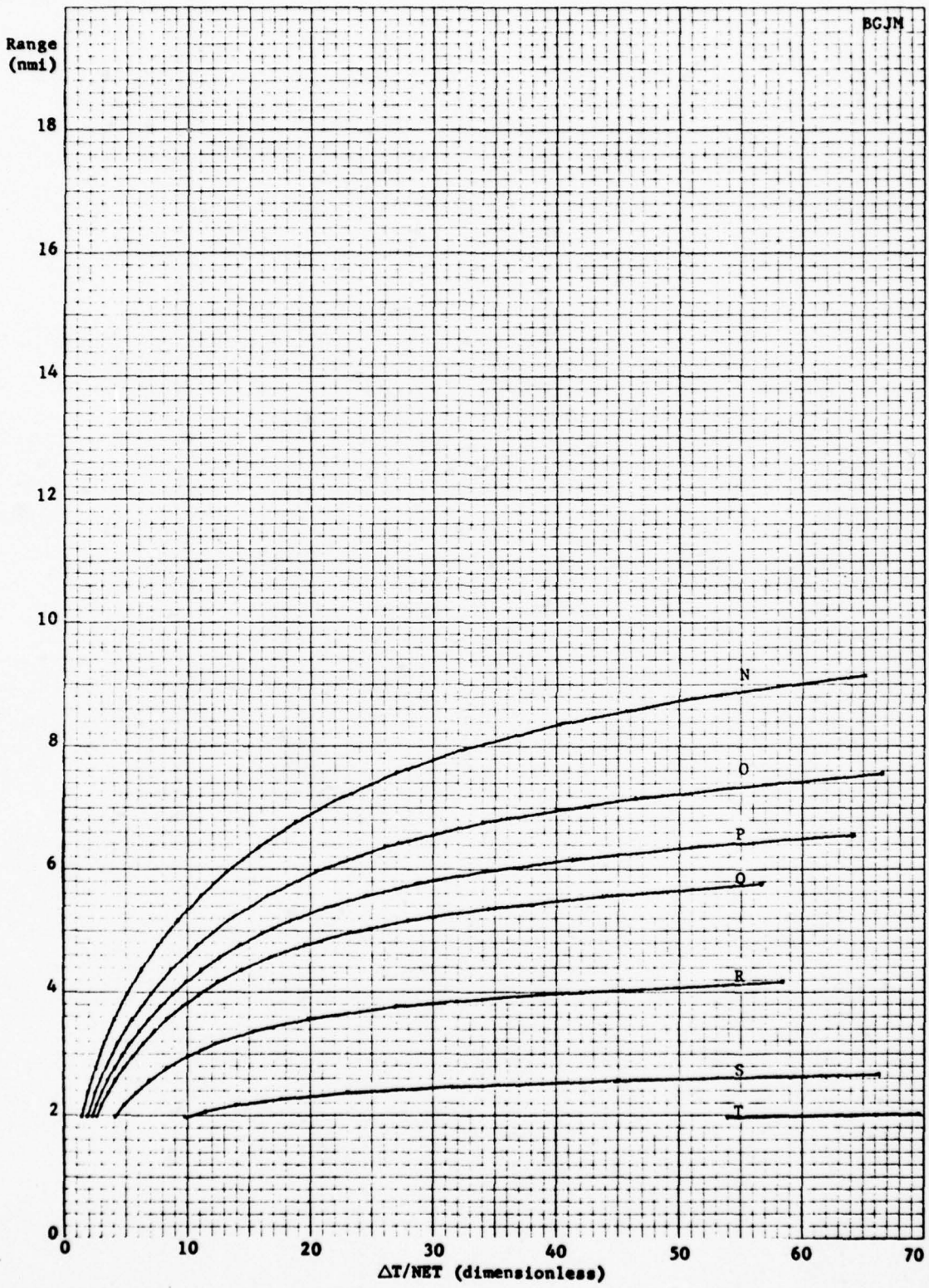

BGIK
Range (nmi)
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ΔT/NET (dimensionless)

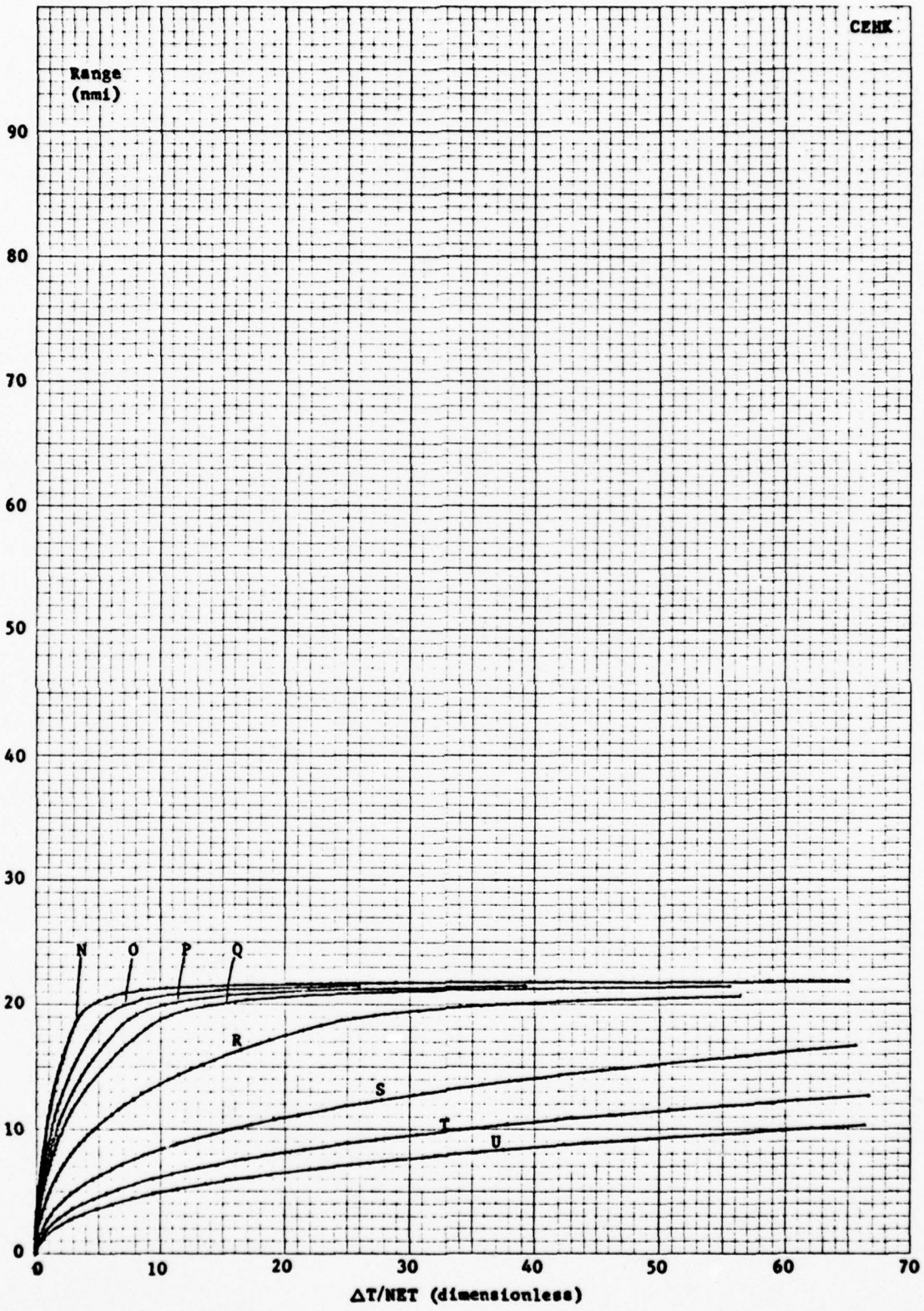

BGIL
Range (nmi)
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8
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4
2
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ΔT/NET (dimensionless)
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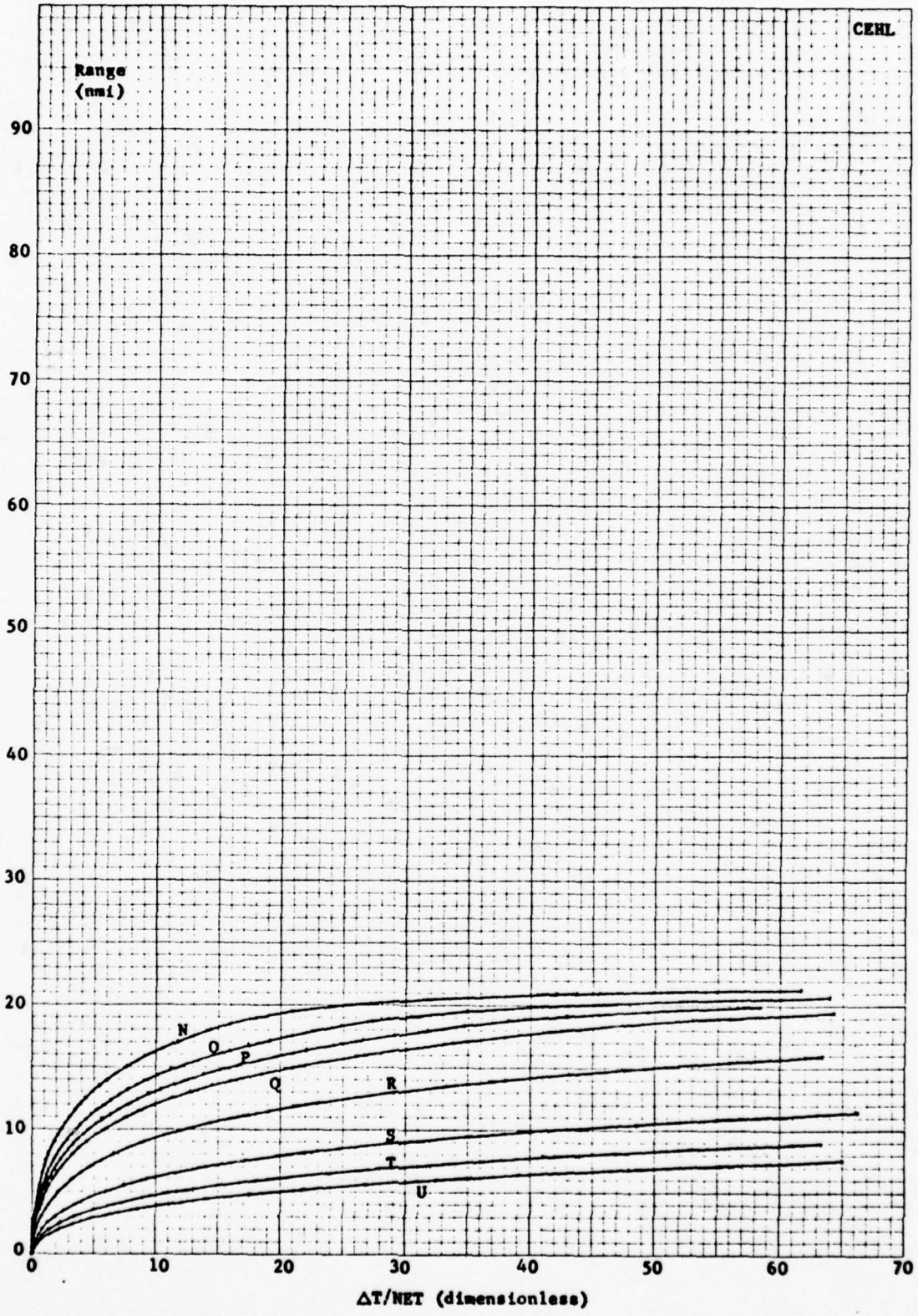

BGIM
Range (nmi)
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ΔT/NET (dimensionless)
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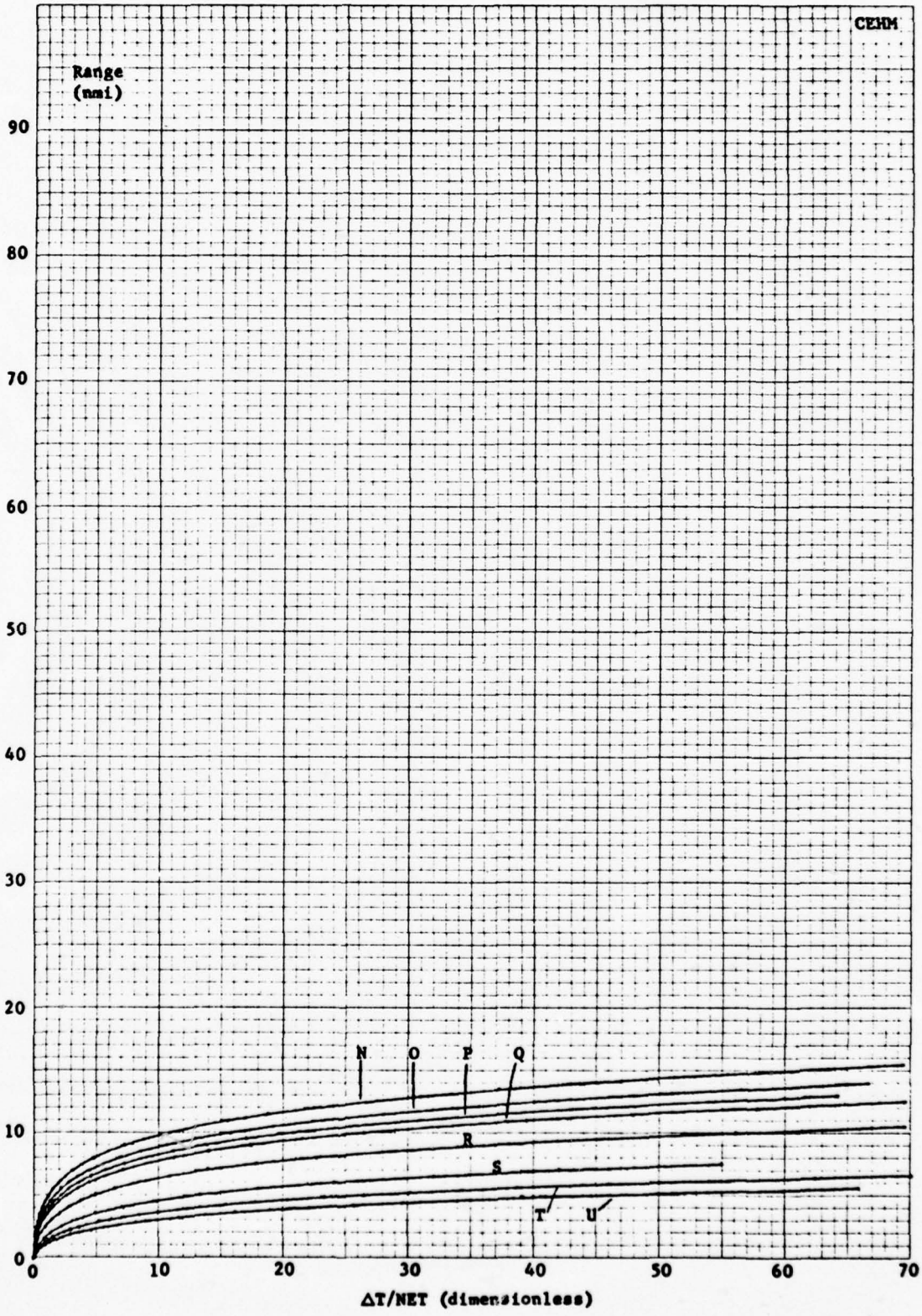

BGJK
Range
(nmi)
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ΔT/NET (dimensionless)
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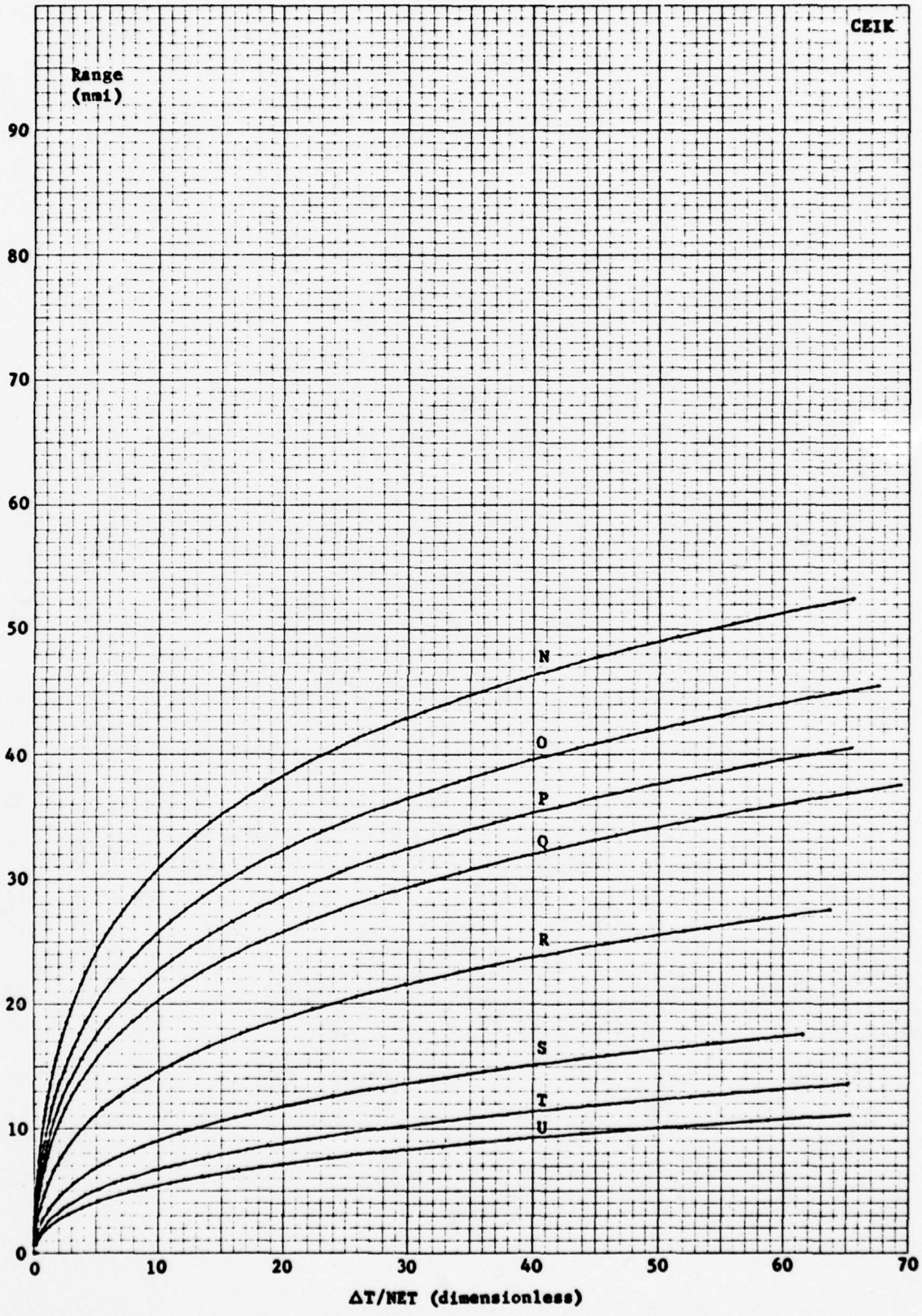

BGJL
Range
(nmi)
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ΔT/NET (dimensionless)
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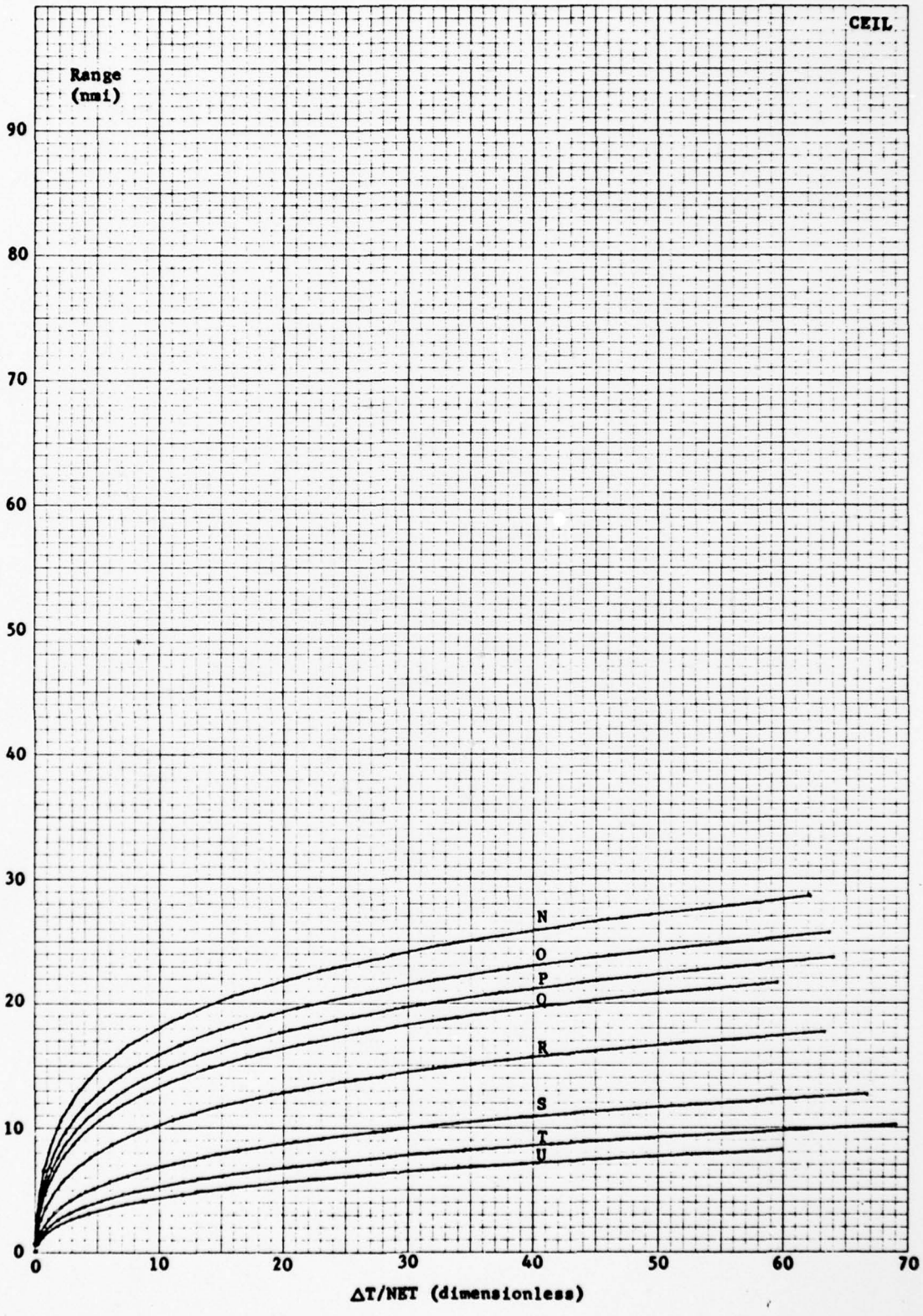

BGJM
Range (nmi)
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ΔT/NET (dimensionless)
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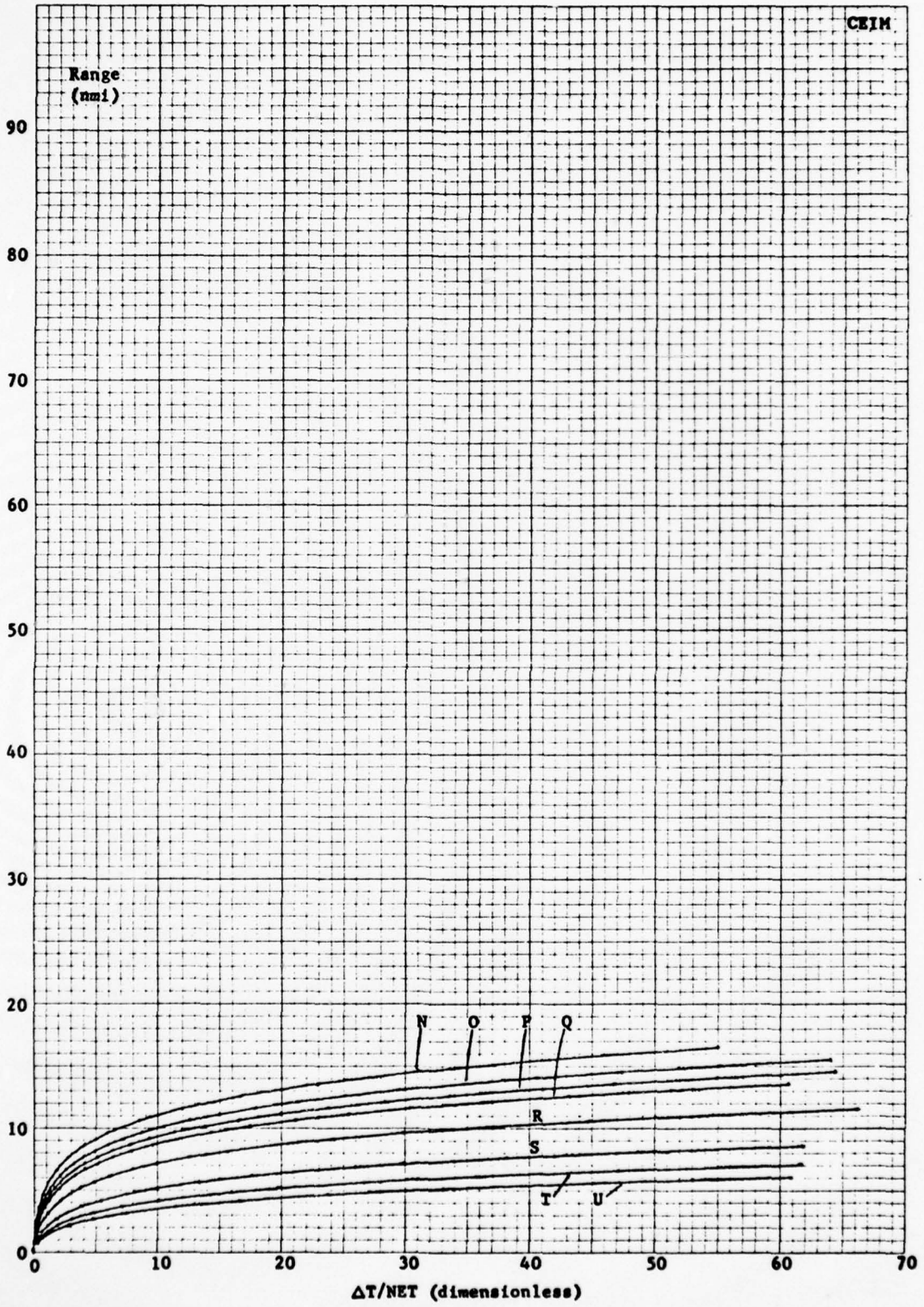

CEMK
Range
(nmi)
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ΔT/NET (dimensionless)

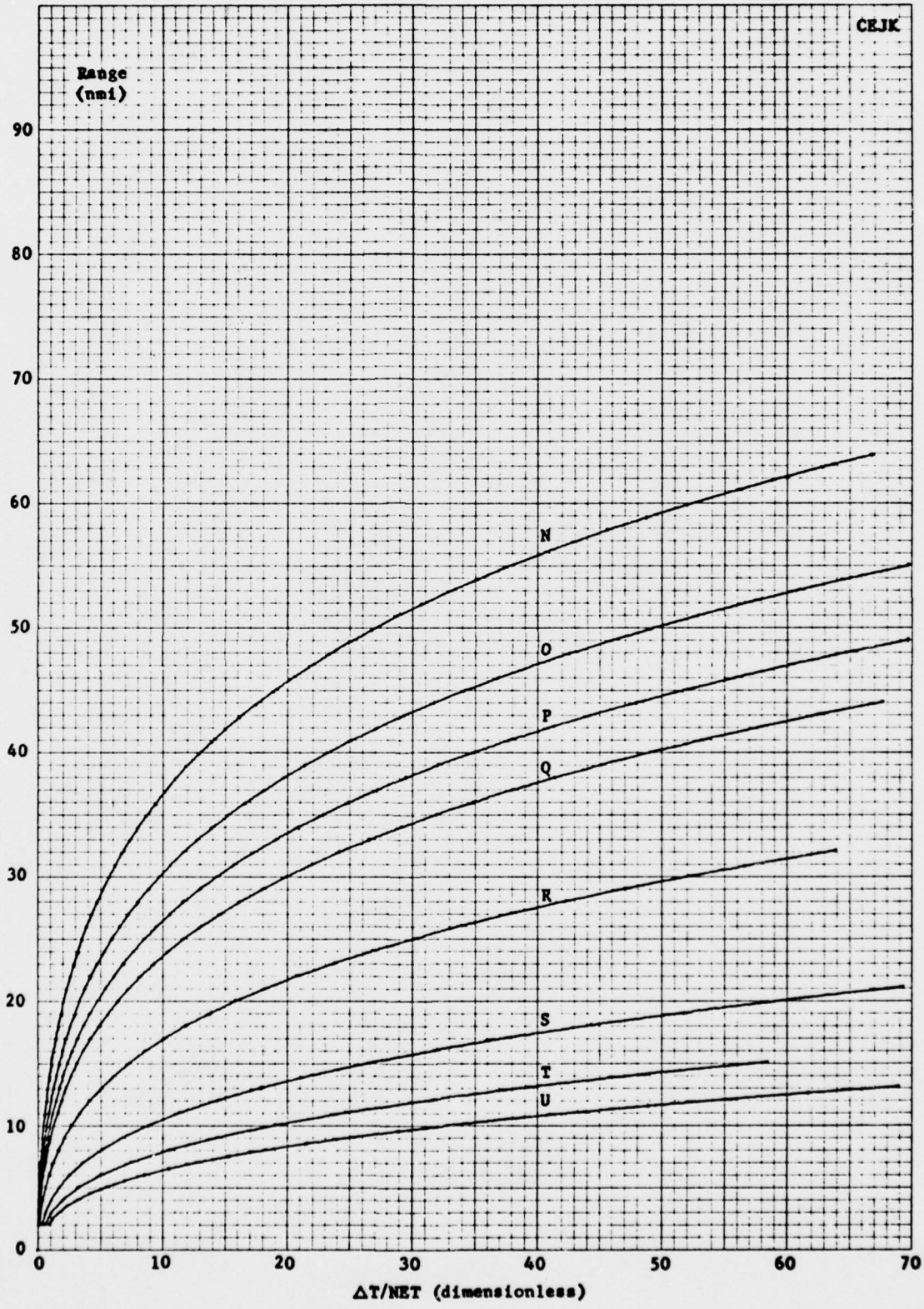

CEHL
Range
(nmi)
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ΔT/NET (dimensionless)

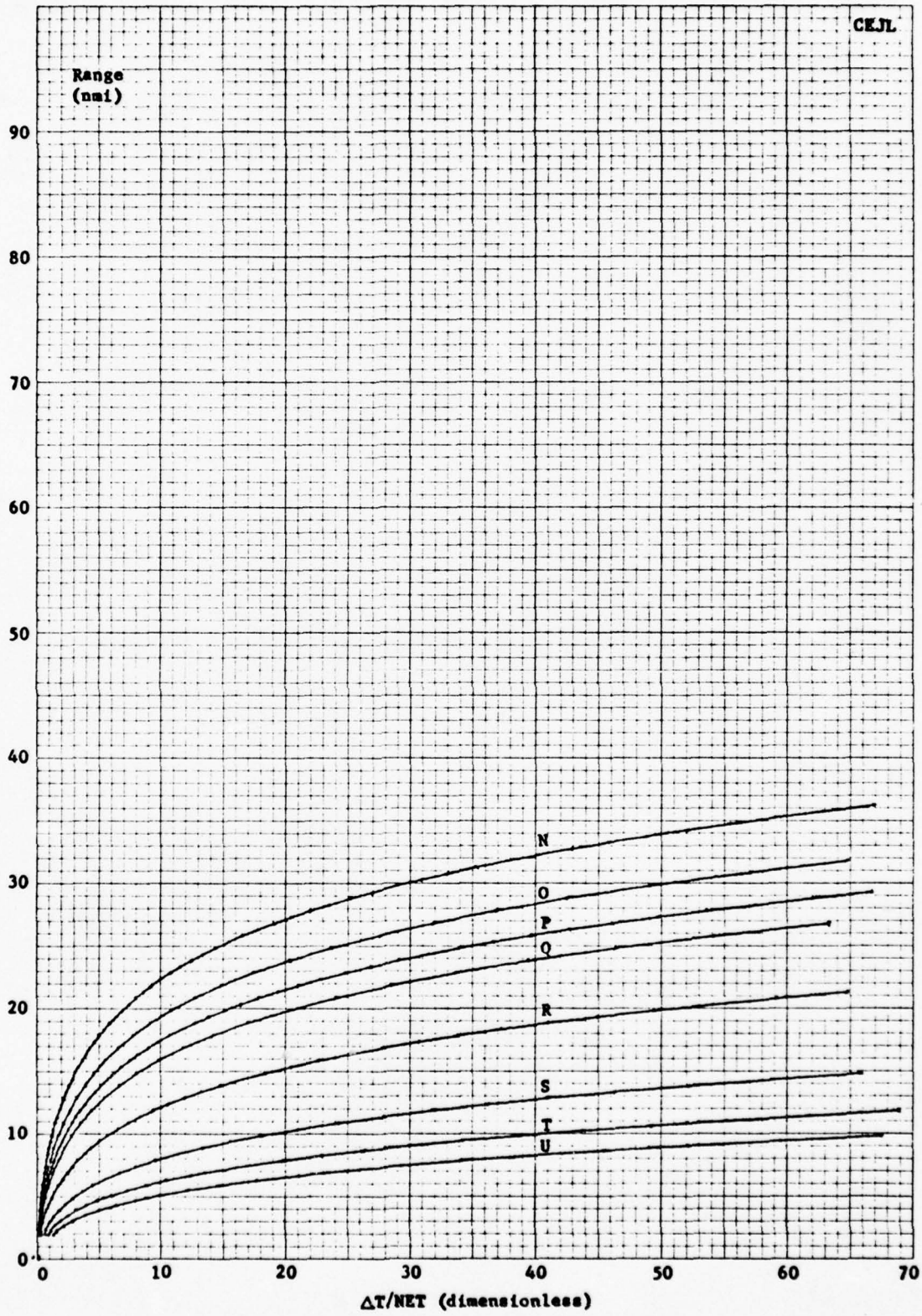

CEHM
Range
(nmi)
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ΔT/NET (dimensionless)

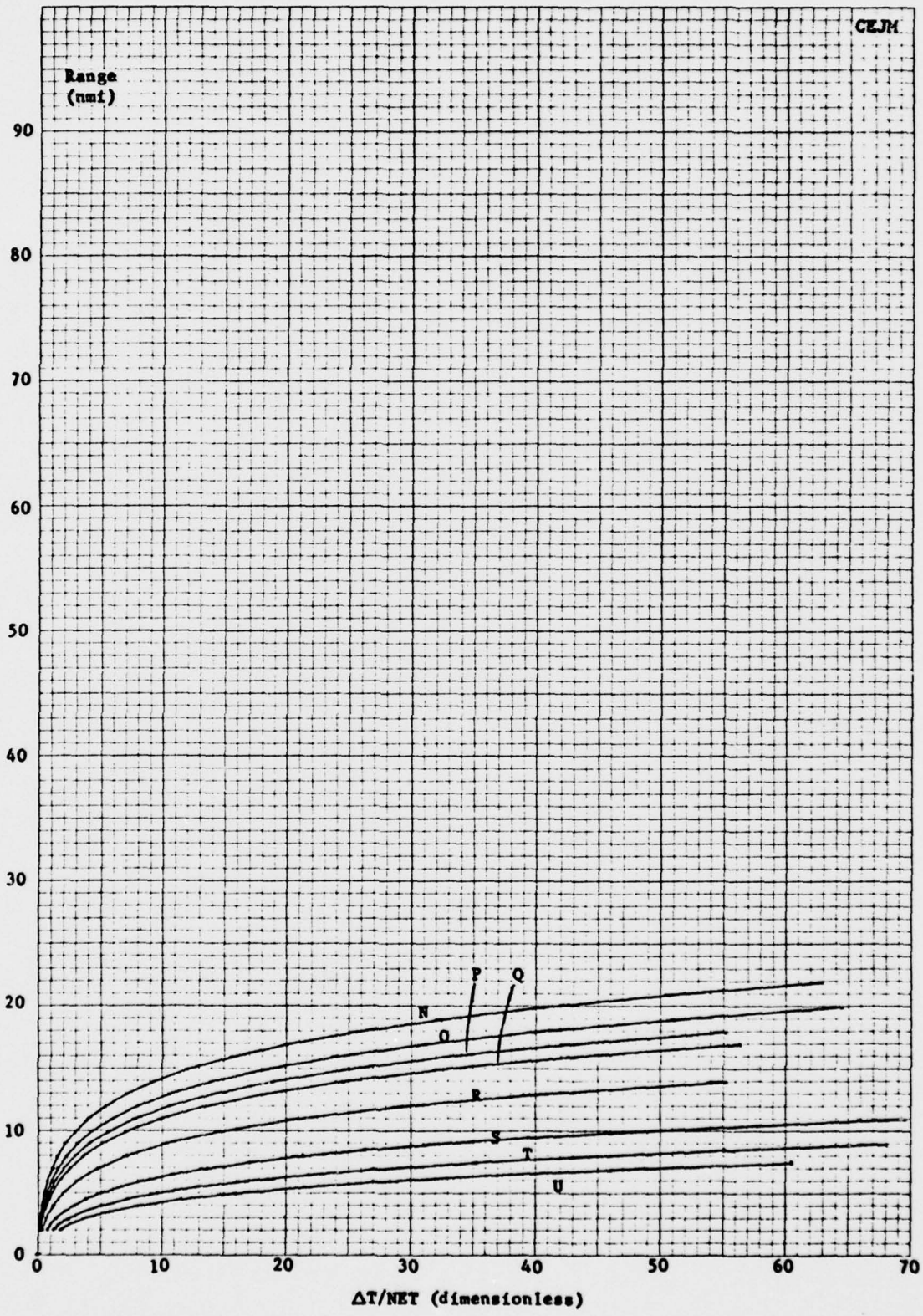

CEIK
Range
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ΔT/NET (dimensionless)

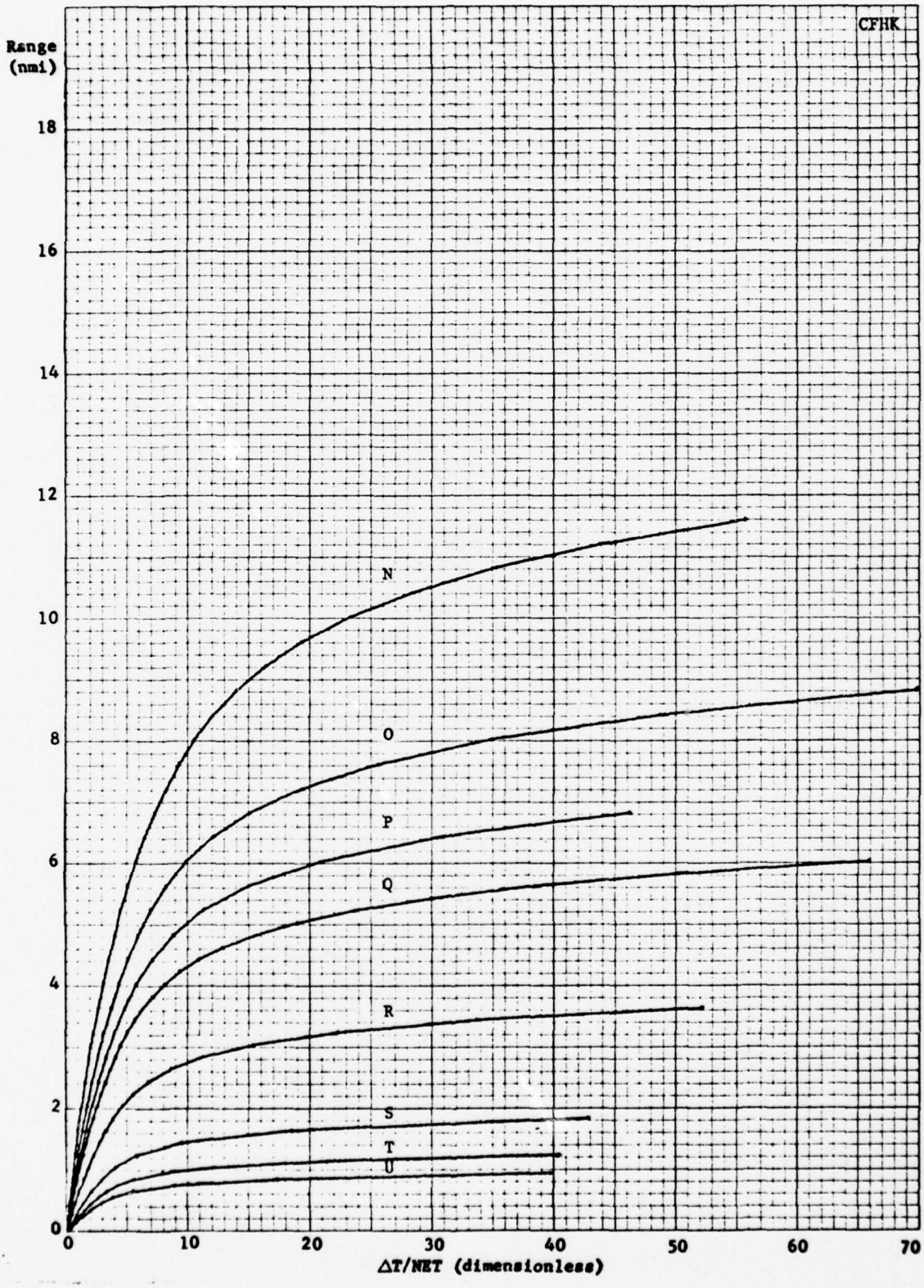

CEIL
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ΔT/NET (dimensionless)
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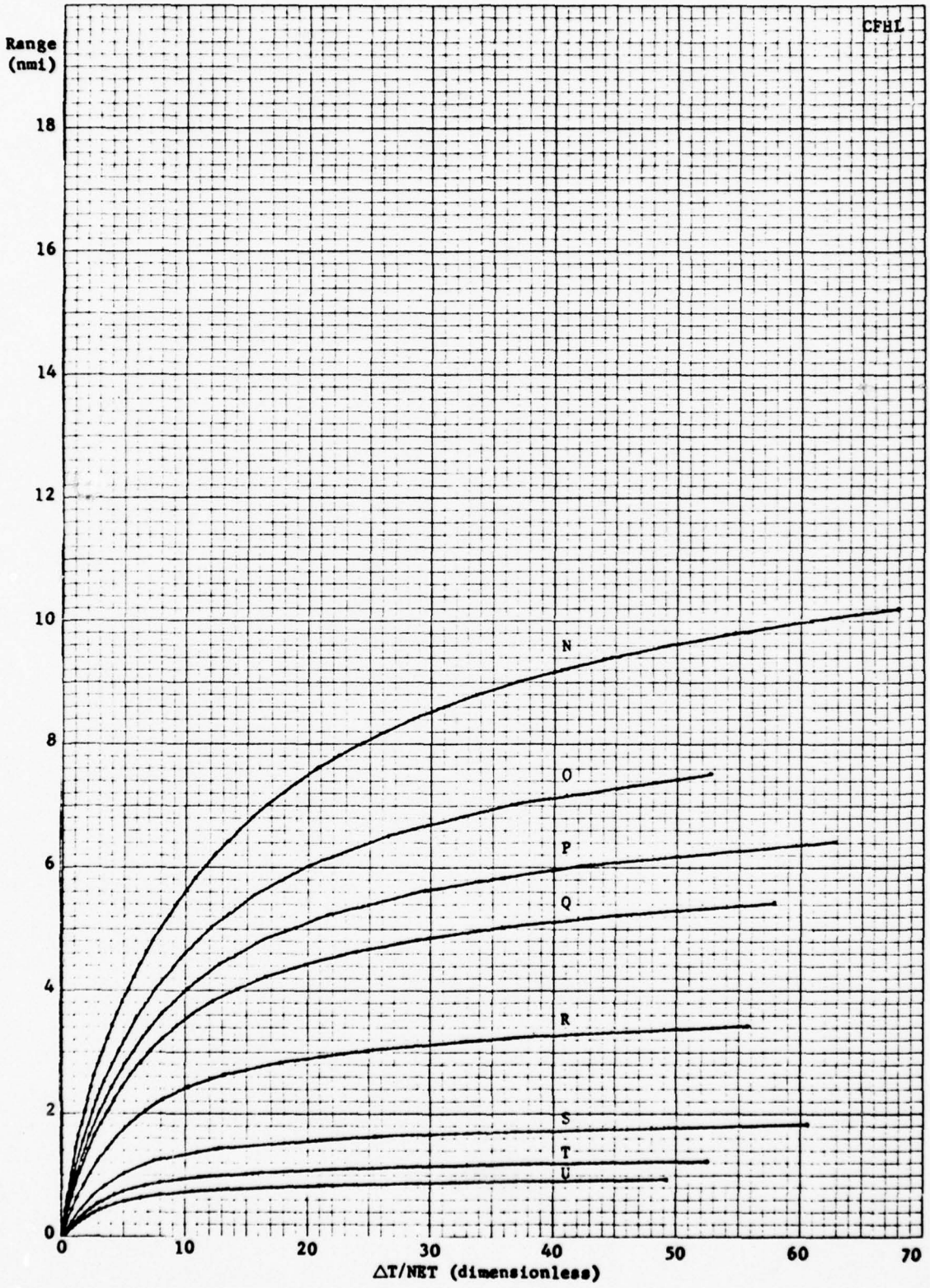

CEIM
Range
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ΔT/NET (dimensionless)
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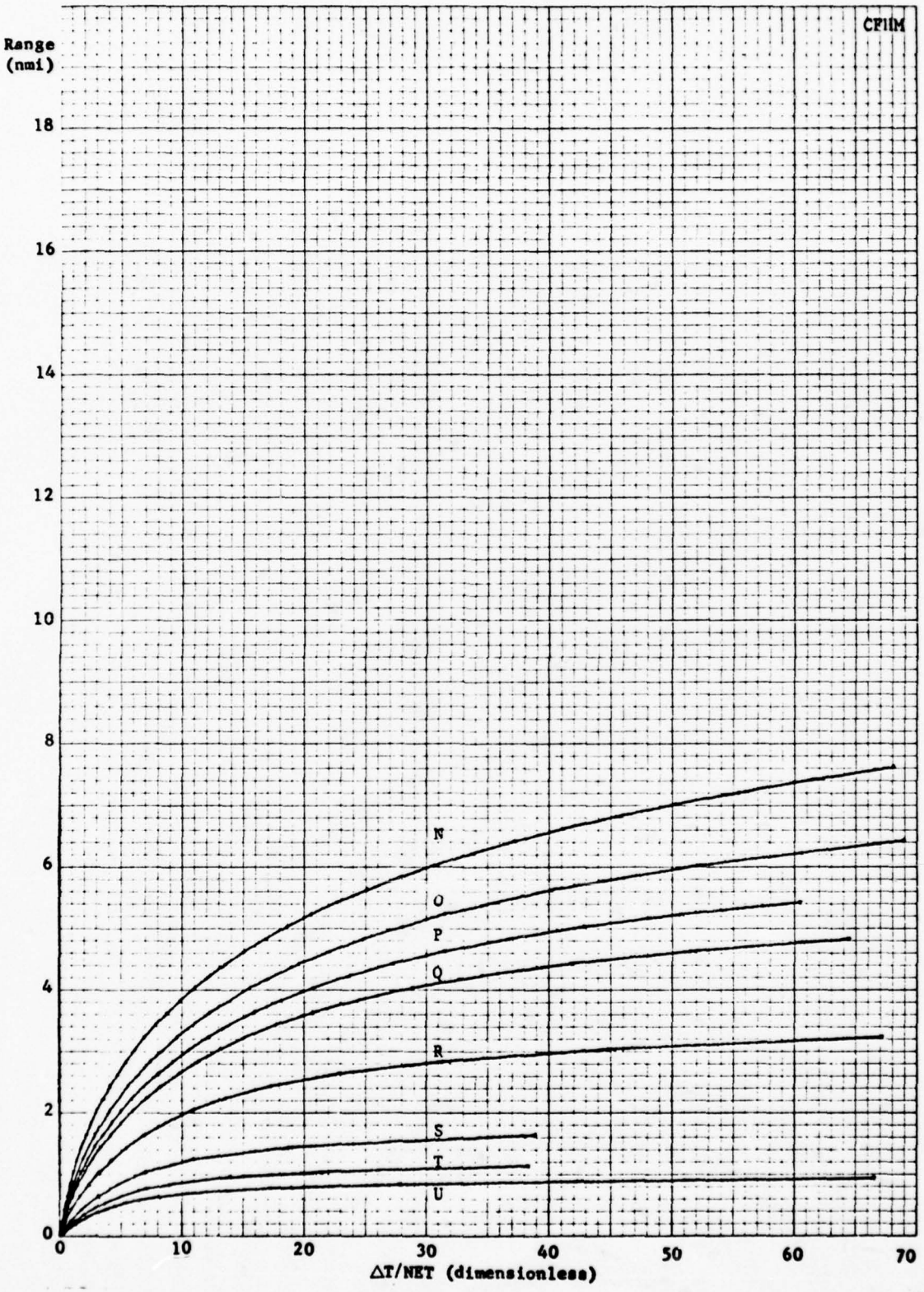

CEJK
Range
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ΔT/NET (dimensionless)

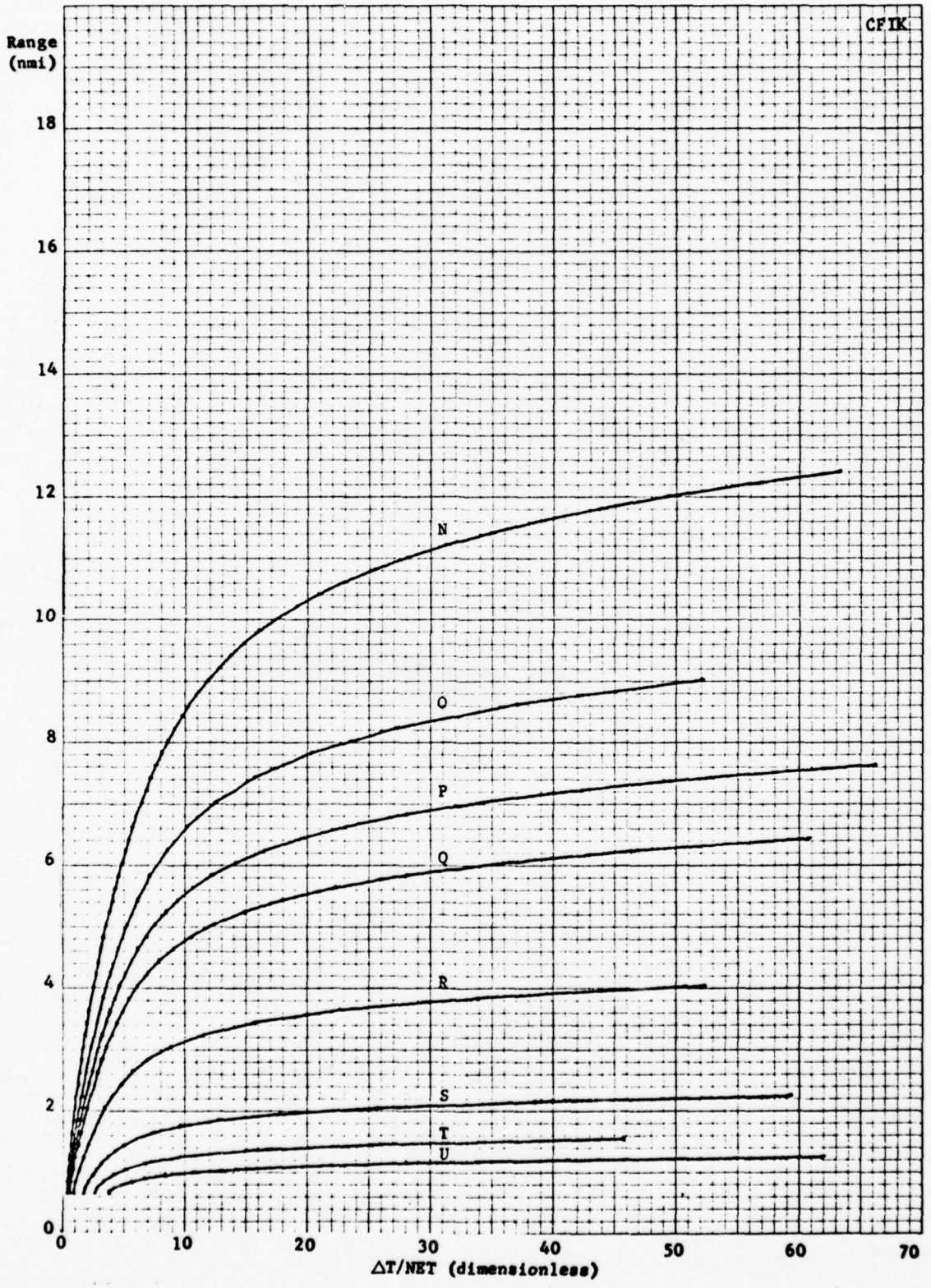

CEJL
Range
(nmi)
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ΔT/NET (dimensionless)
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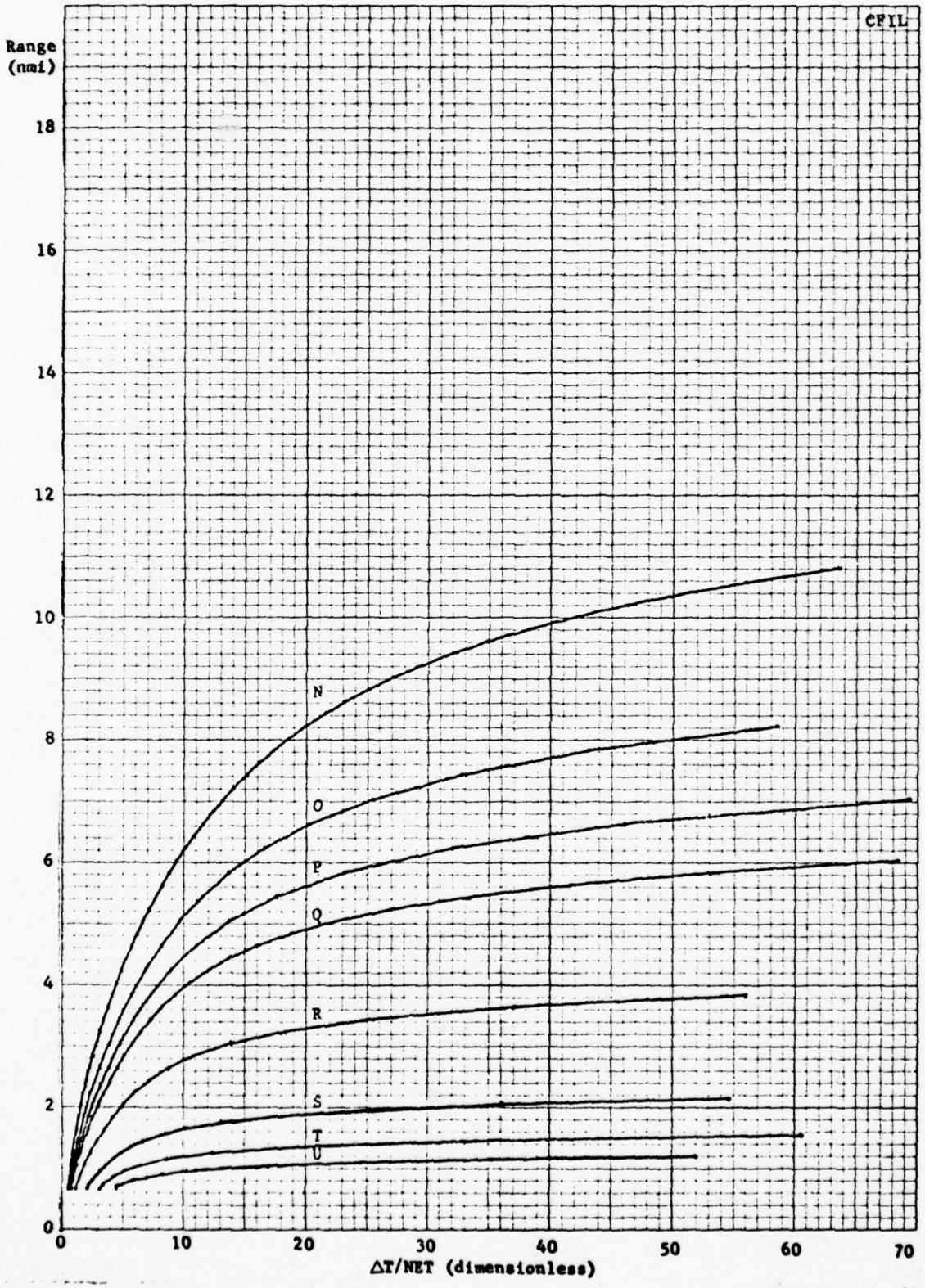

CEJM
Range
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ΔT/NET (dimensionless)
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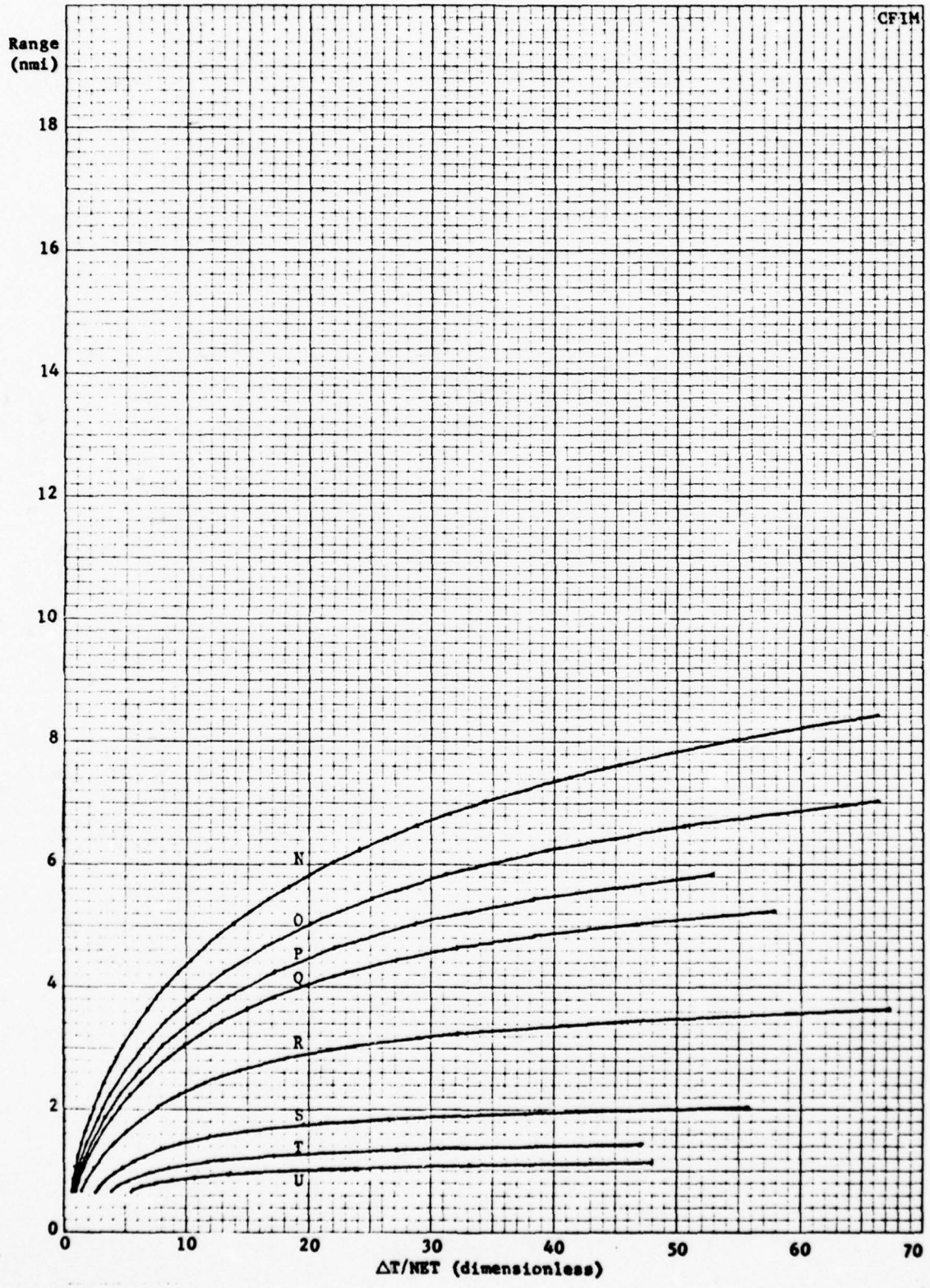

CFHK
Range (nmi)
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ΔT/NET (dimensionless)

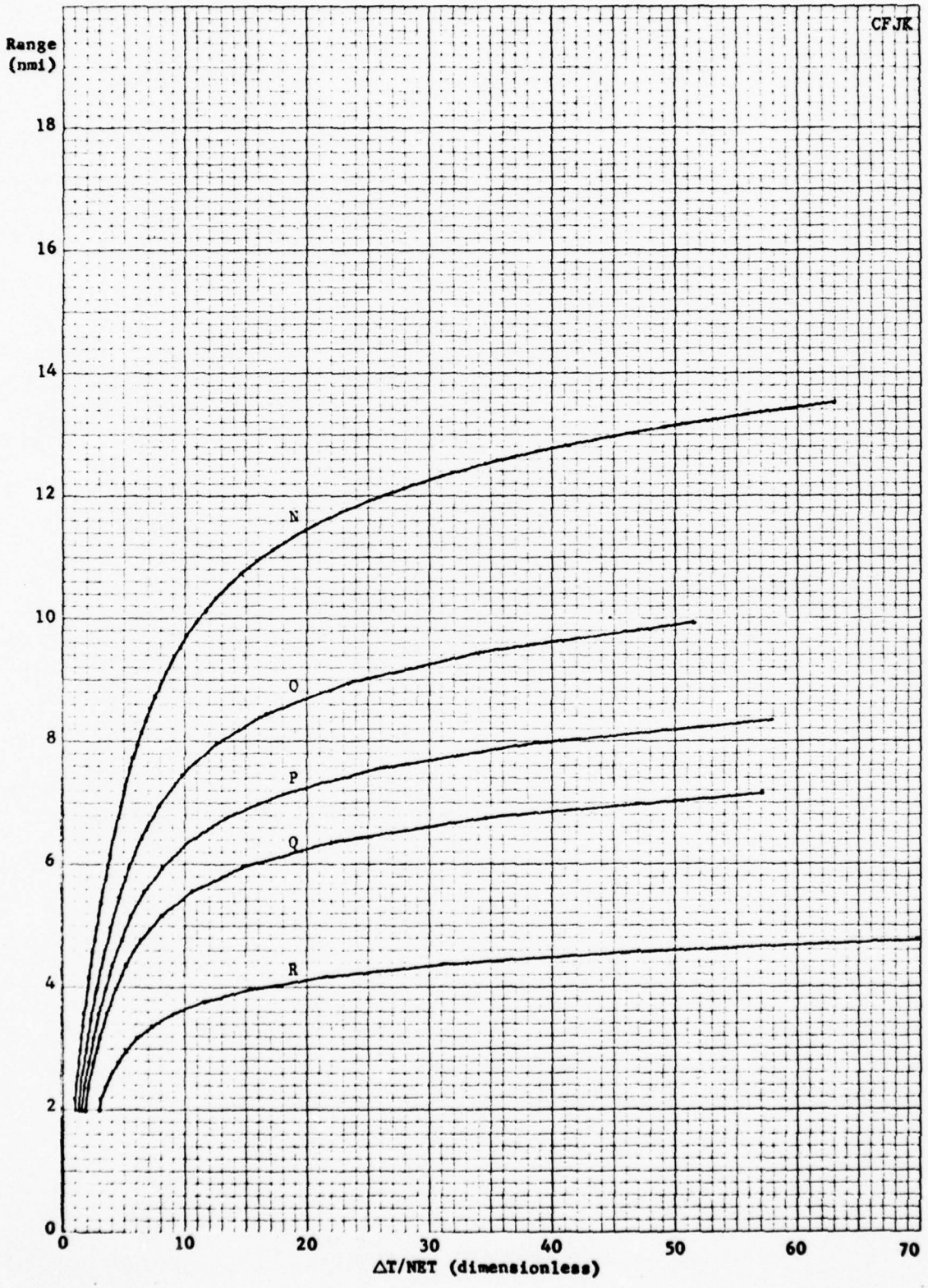

CFHL
Range (nmi)
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ΔT/NET (dimensionless)
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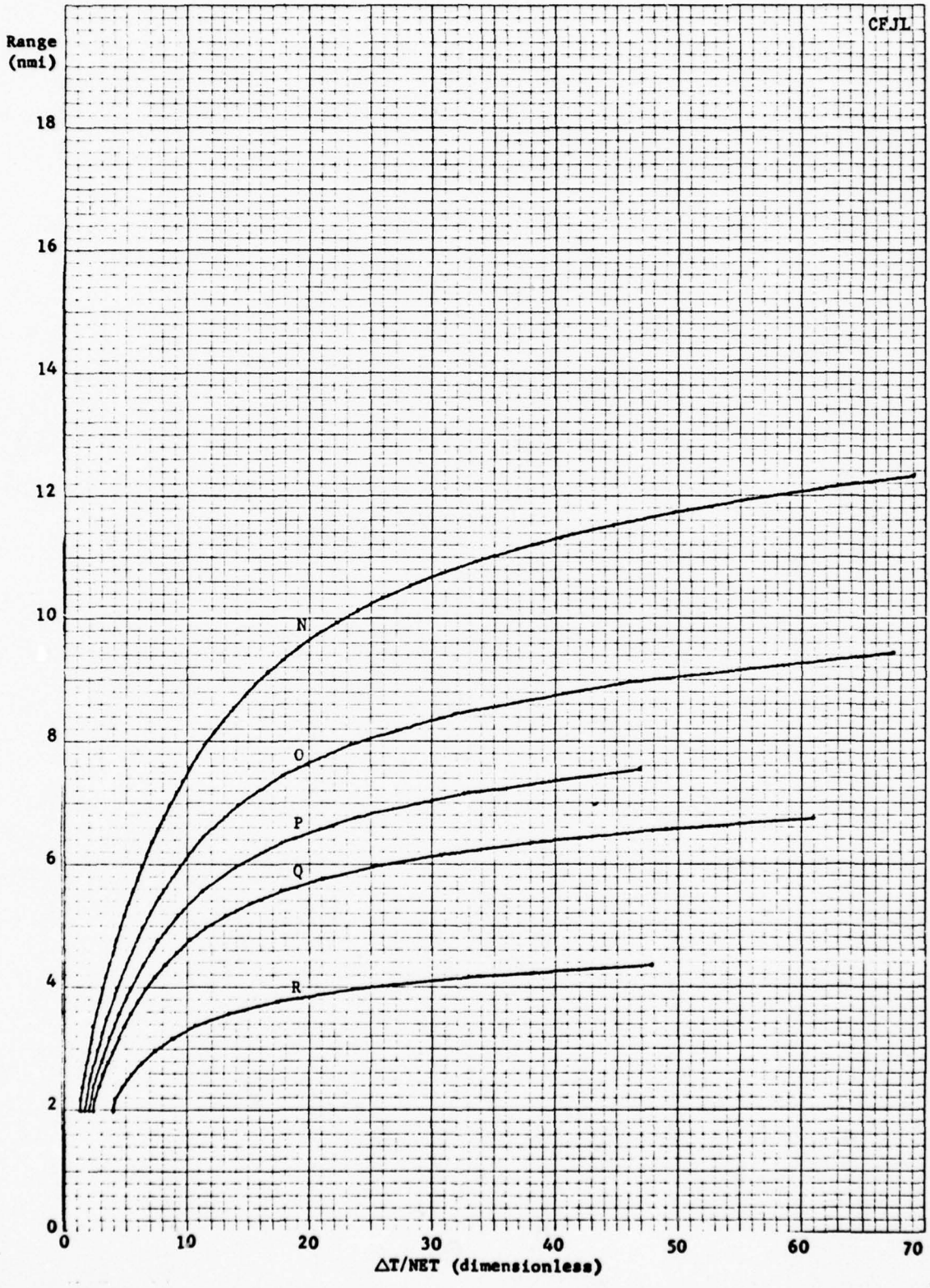

CF1IM
Range
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ΔT/NET (dimensionless)
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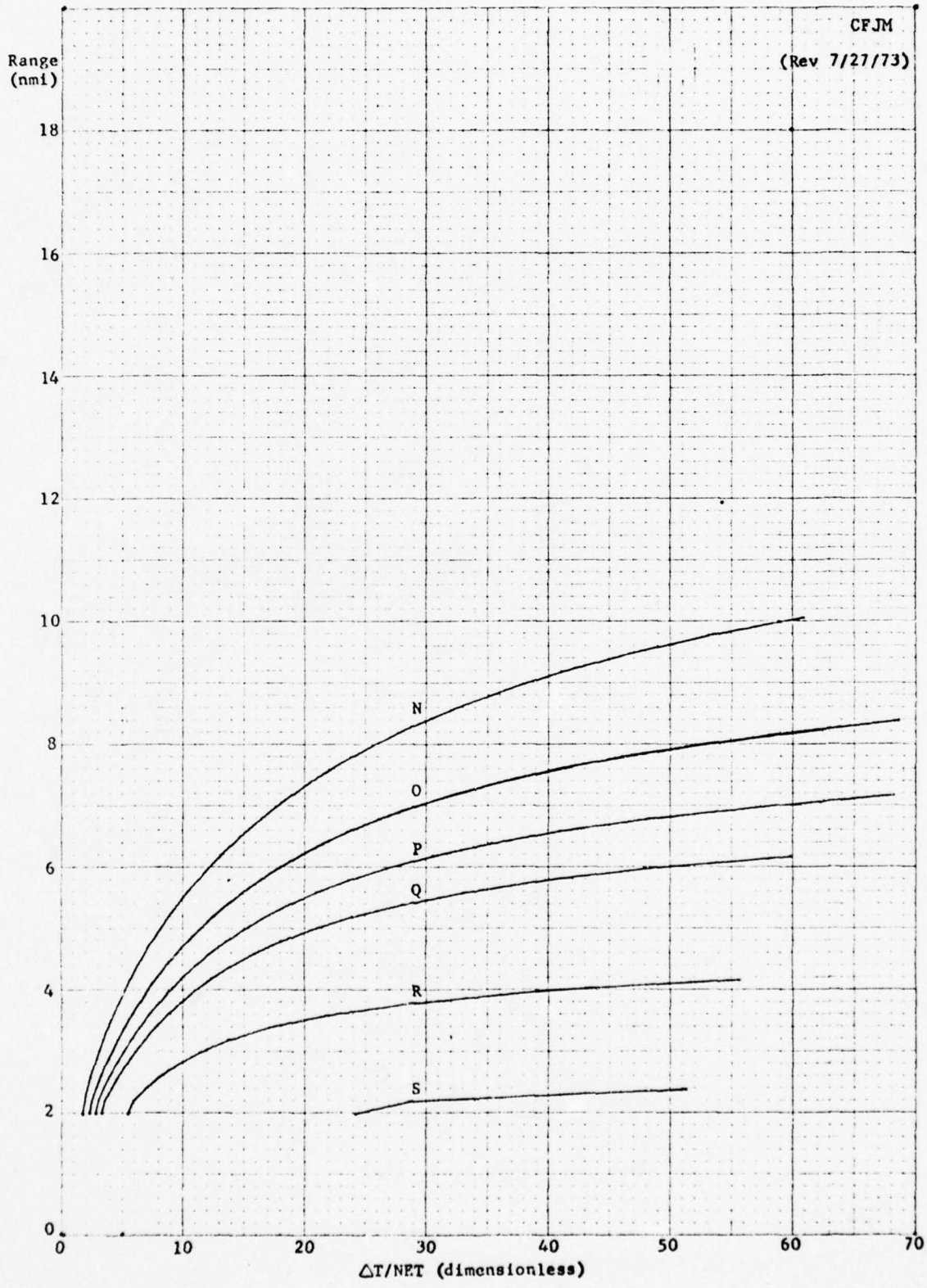

CFIK
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ΔT/NET (dimensionless)

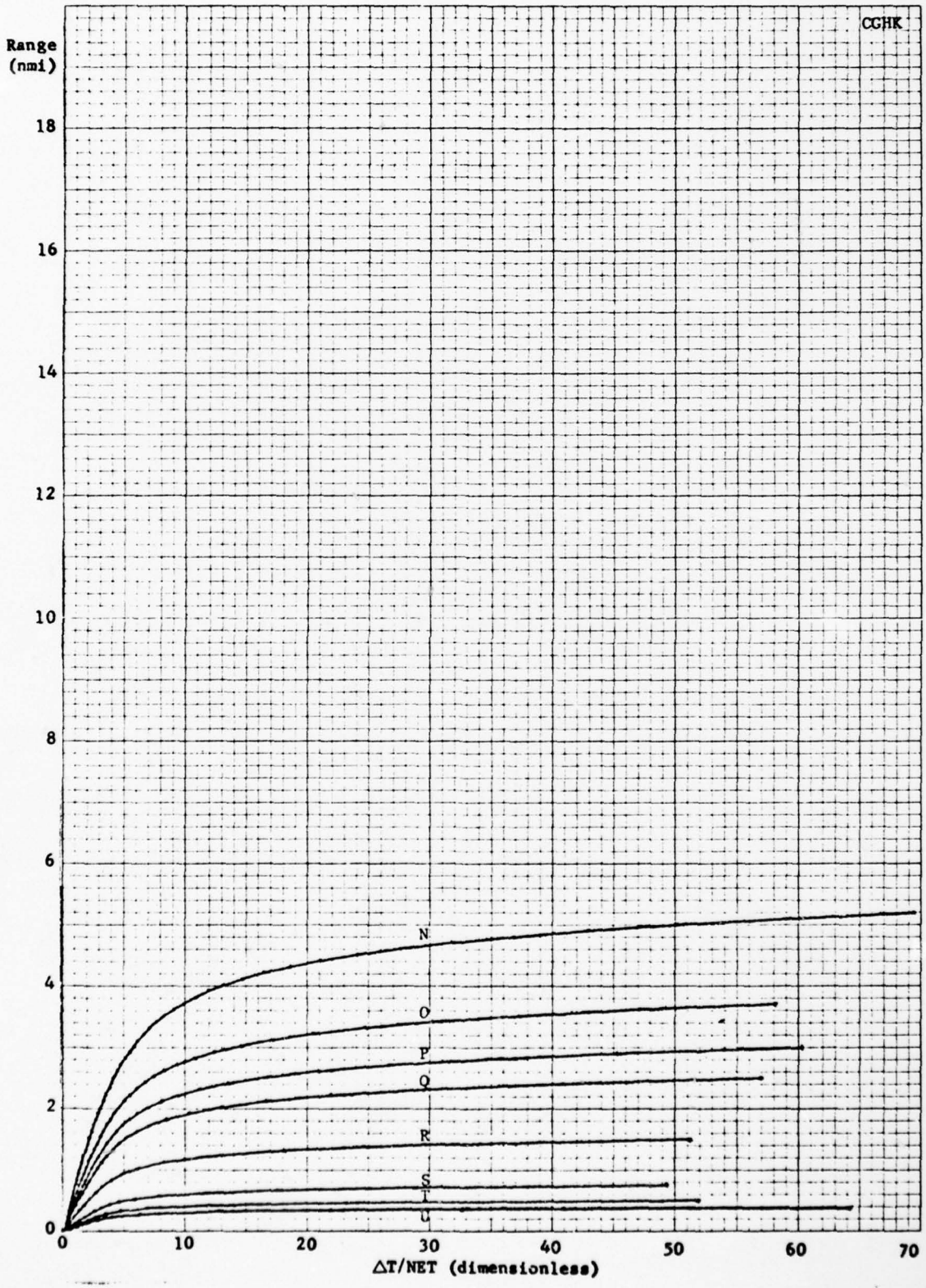

CFIL
Range (nmi)
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ΔT/NET (dimensionless)

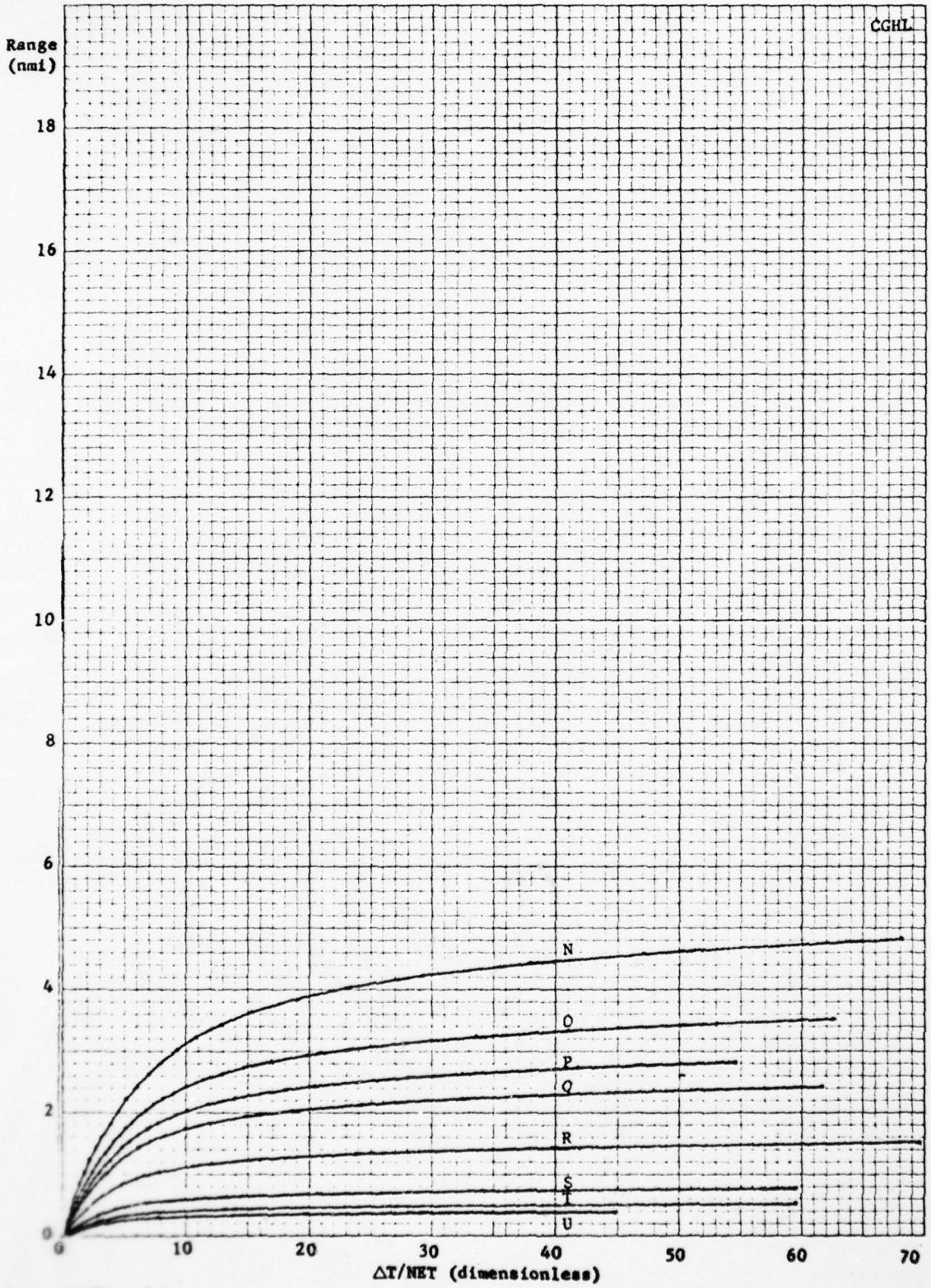

CFIM
Range
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ΔT/NET (dimensionless)

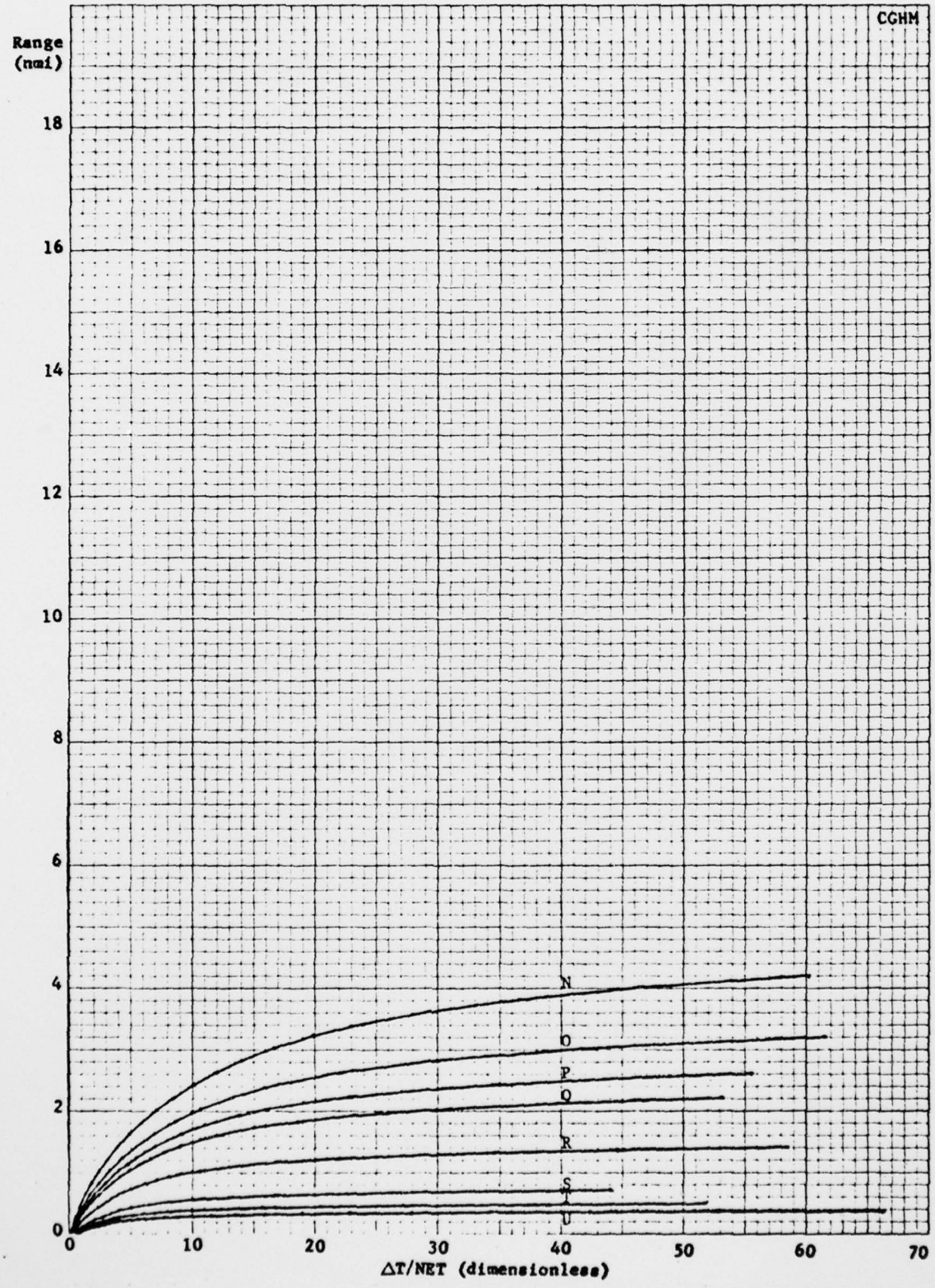

CFJK
Range
(nmi)
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ΔT/NET (dimensionless)

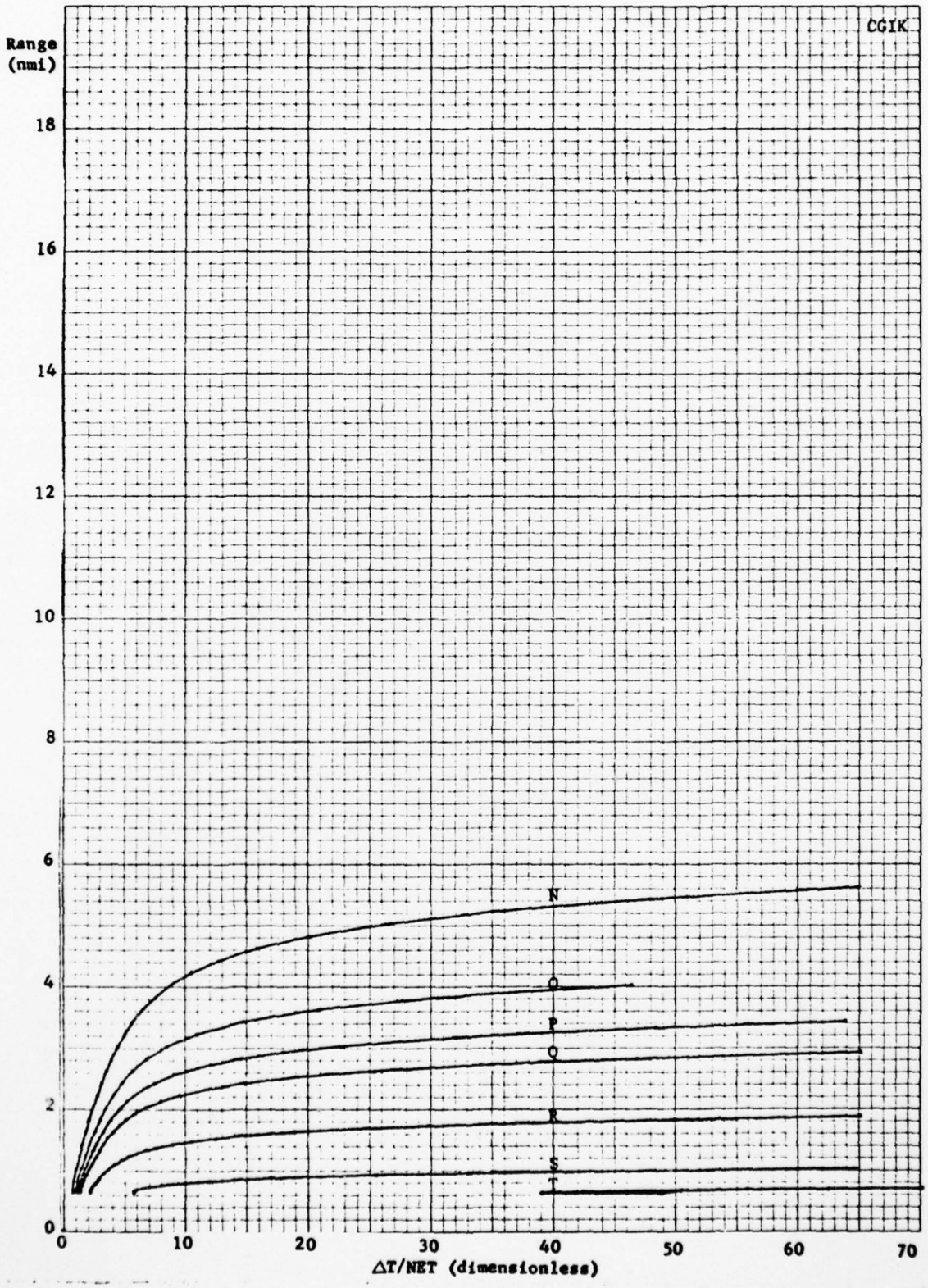

CFJL
Range (nmi)
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ΔT/NET (dimensionless)
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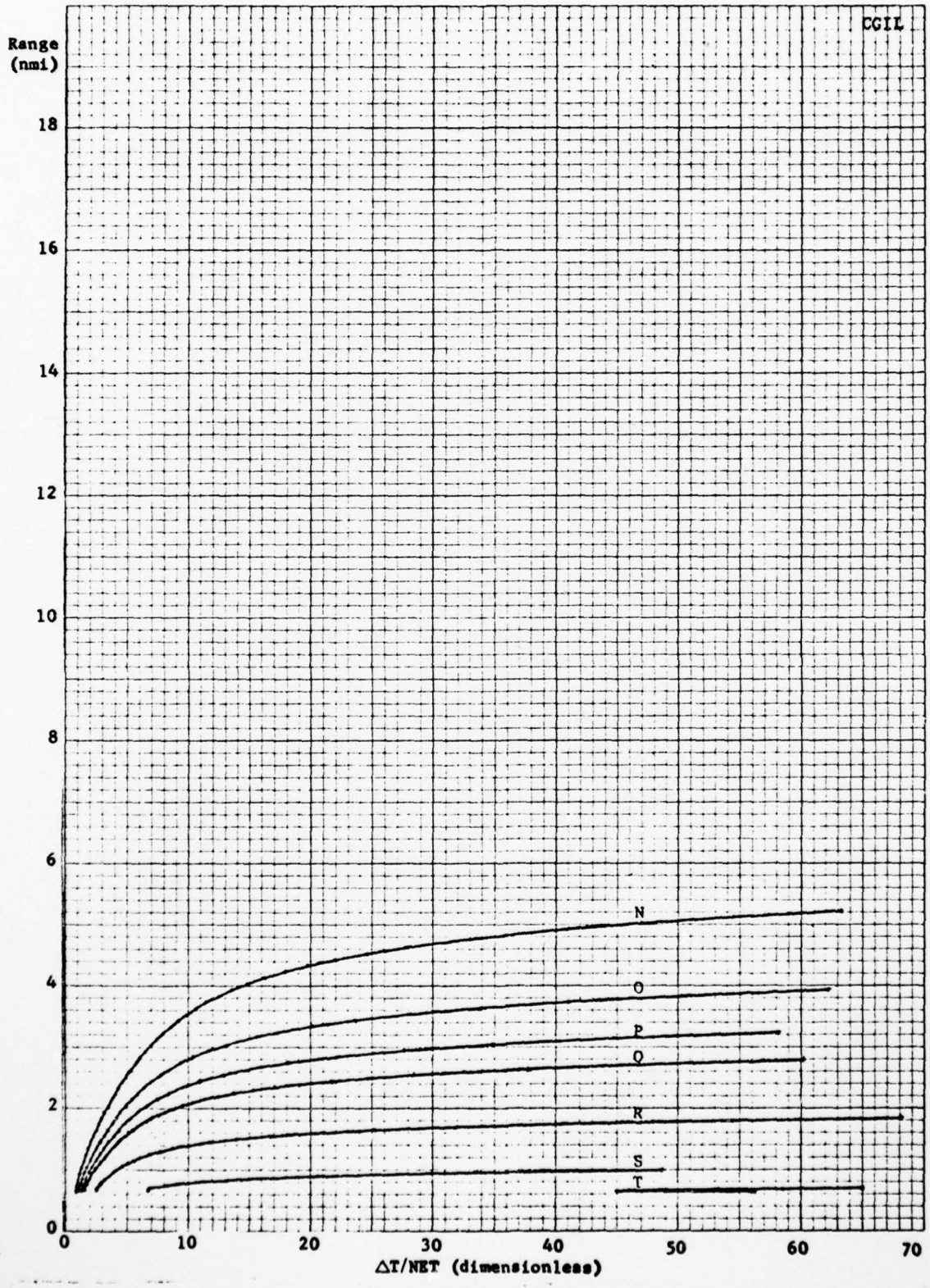

CFJM
(Rev 7/27/73)
Range
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ΔT/NET (dimensionless)
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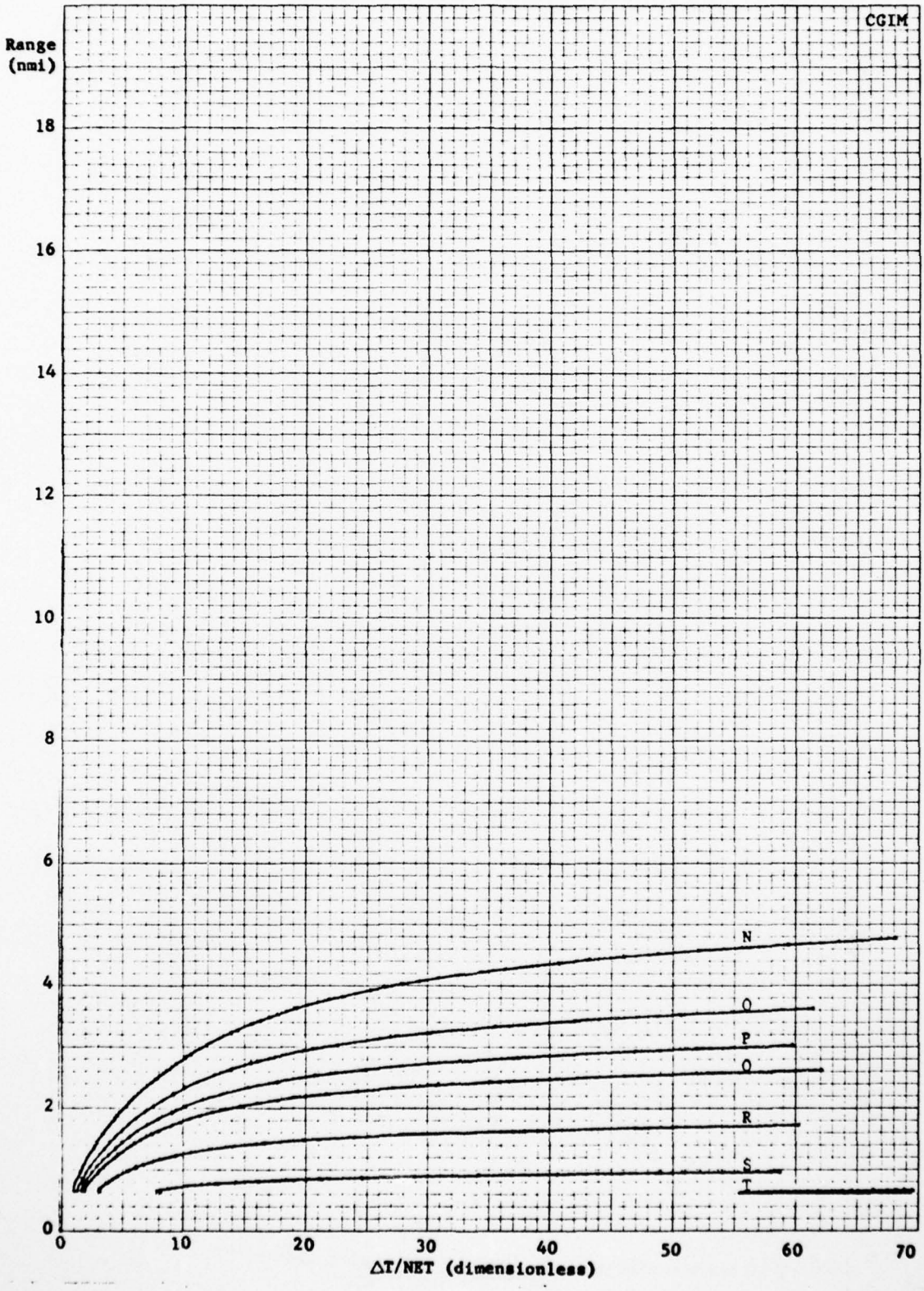

CGHK
Range (nmi)
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ΔT/NET (dimensionless)
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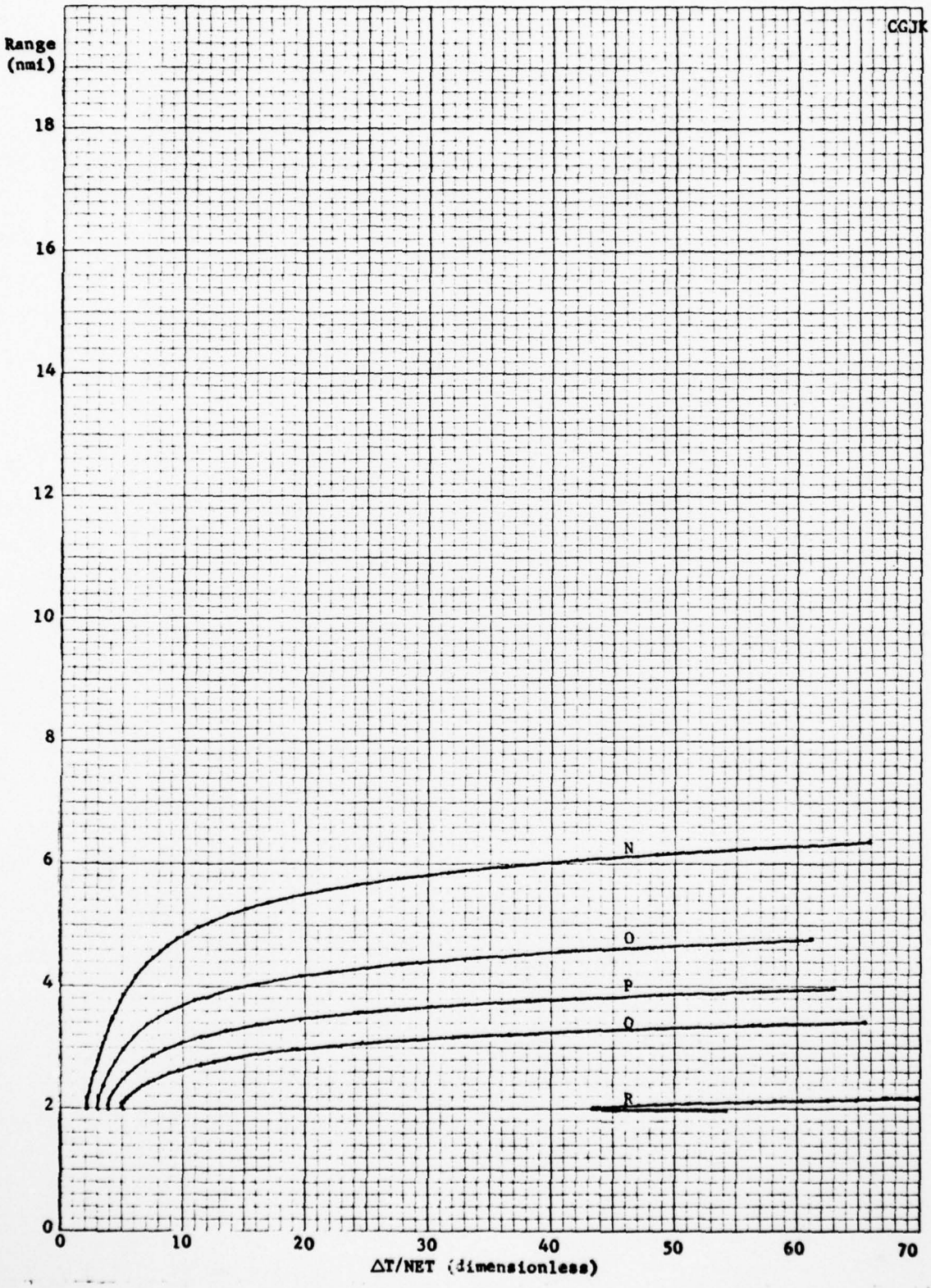

CGHL
Range
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ΔT/NET (dimensionless)
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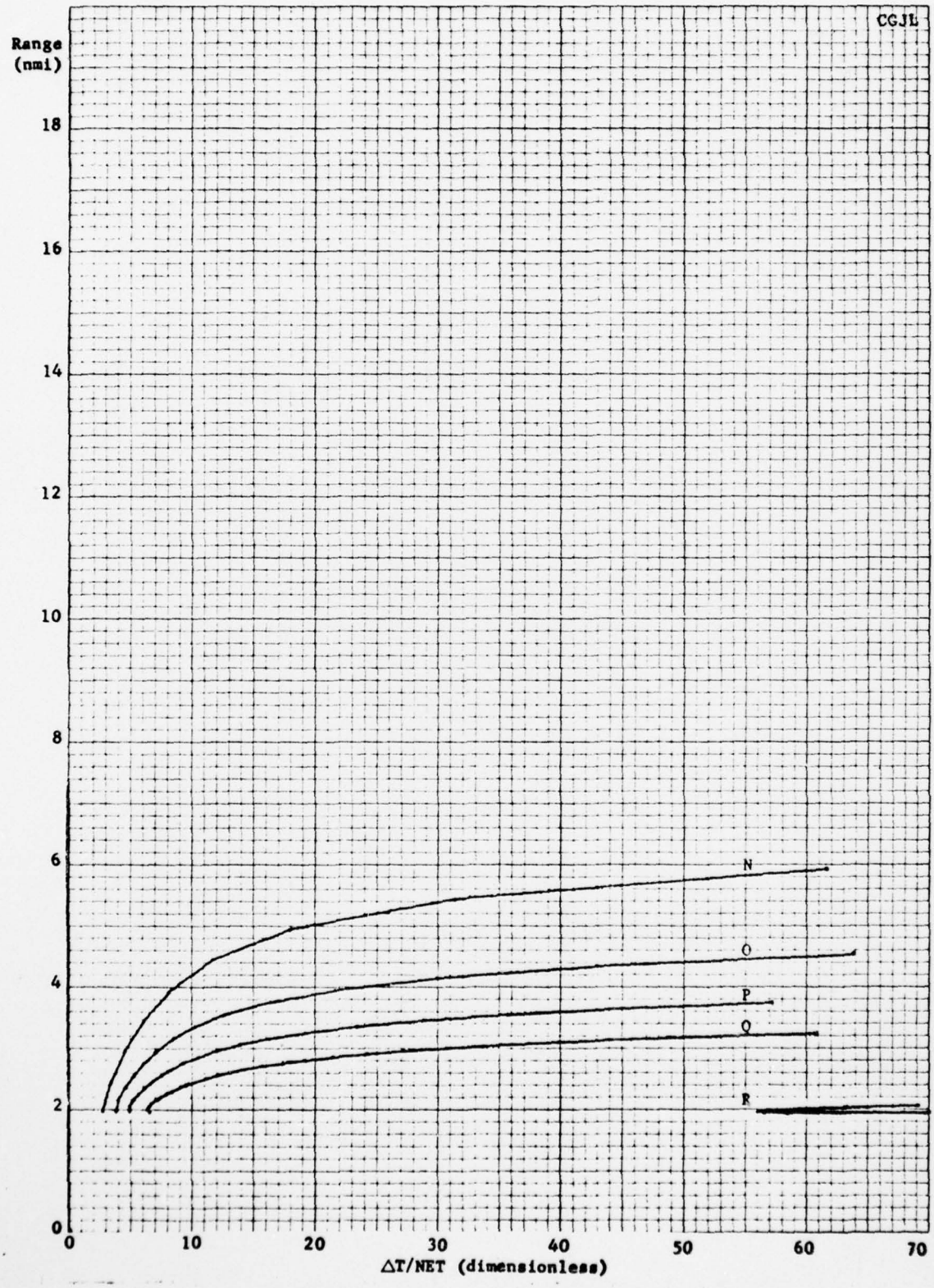

CGHM
Range (nmi)
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ΔT/NET (dimensionless)
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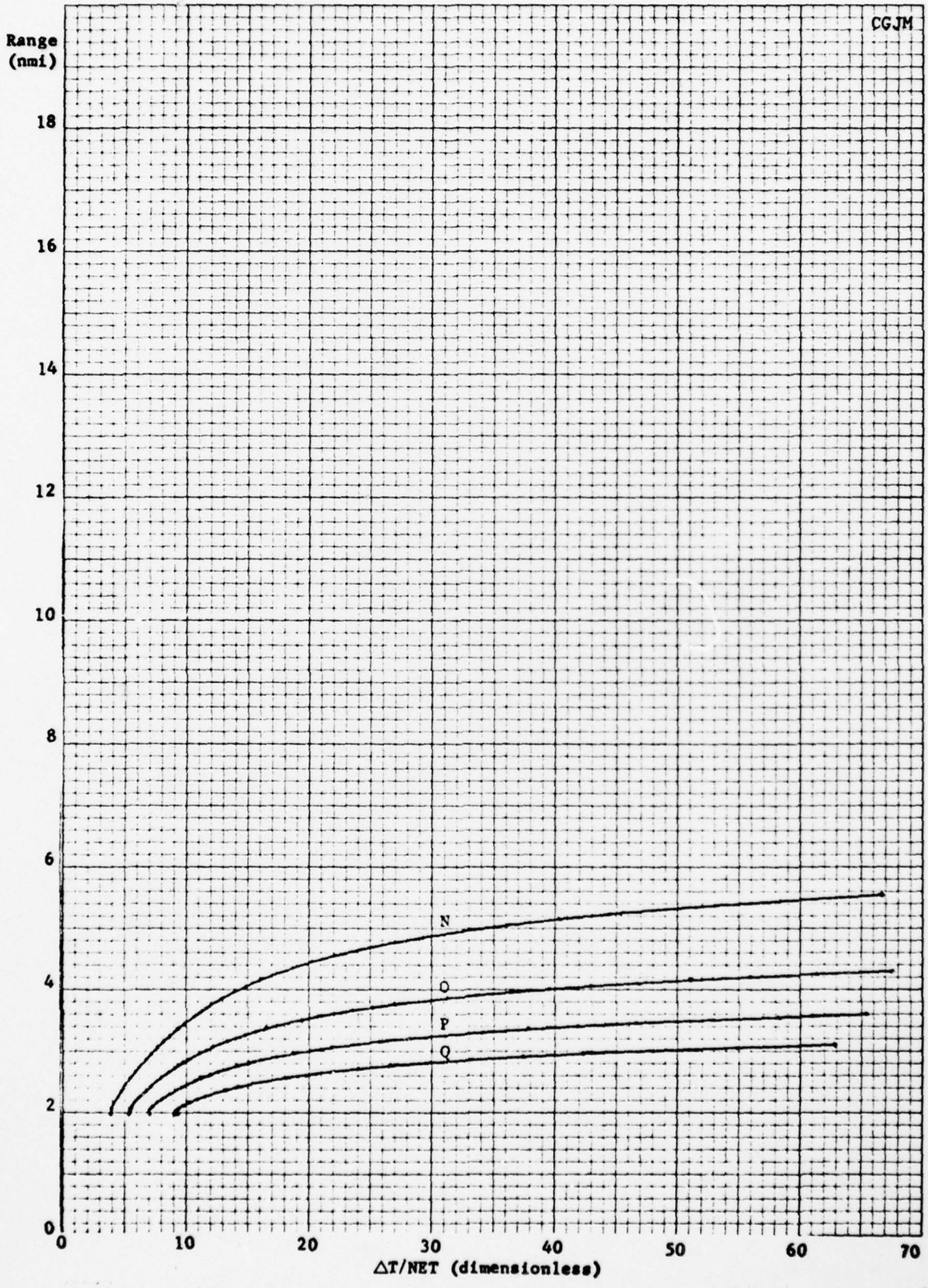

CGIK
Range (nmi)
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ΔT/NET (dimensionless)
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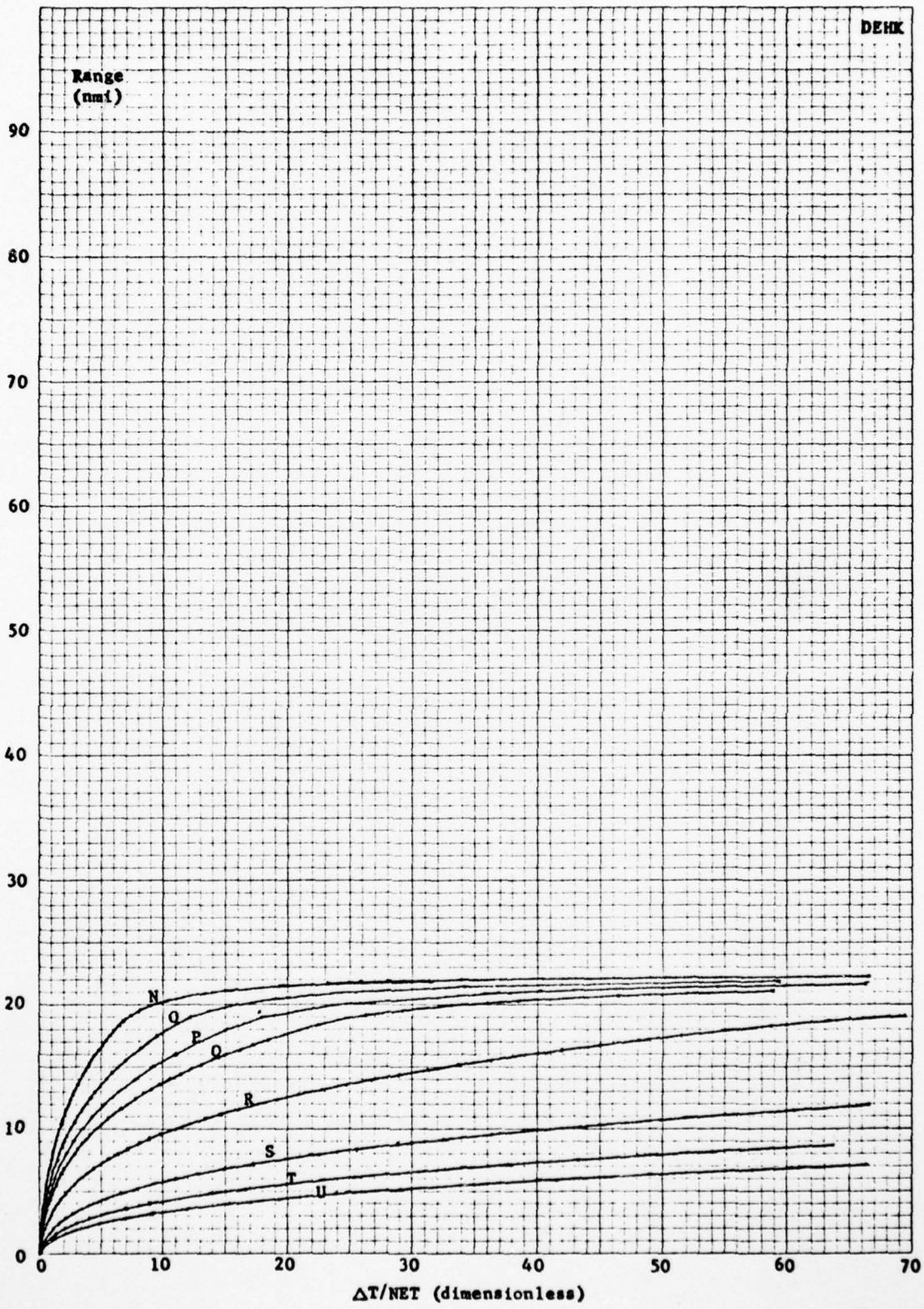

CGIL
Range (nmi)
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ΔT/NET (dimensionless)
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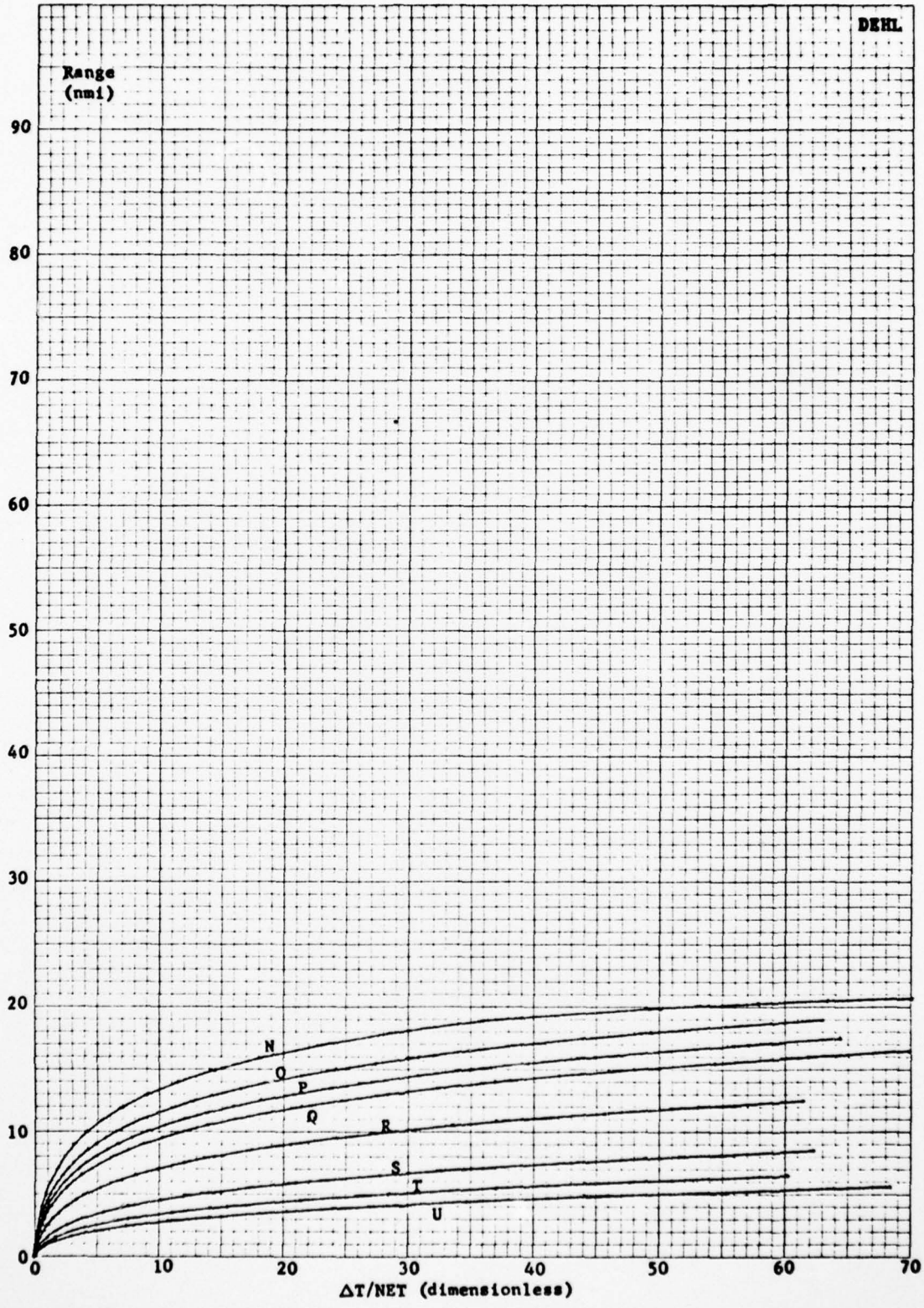

CGIM
Range (nmi)
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ΔT/NET (dimensionless)
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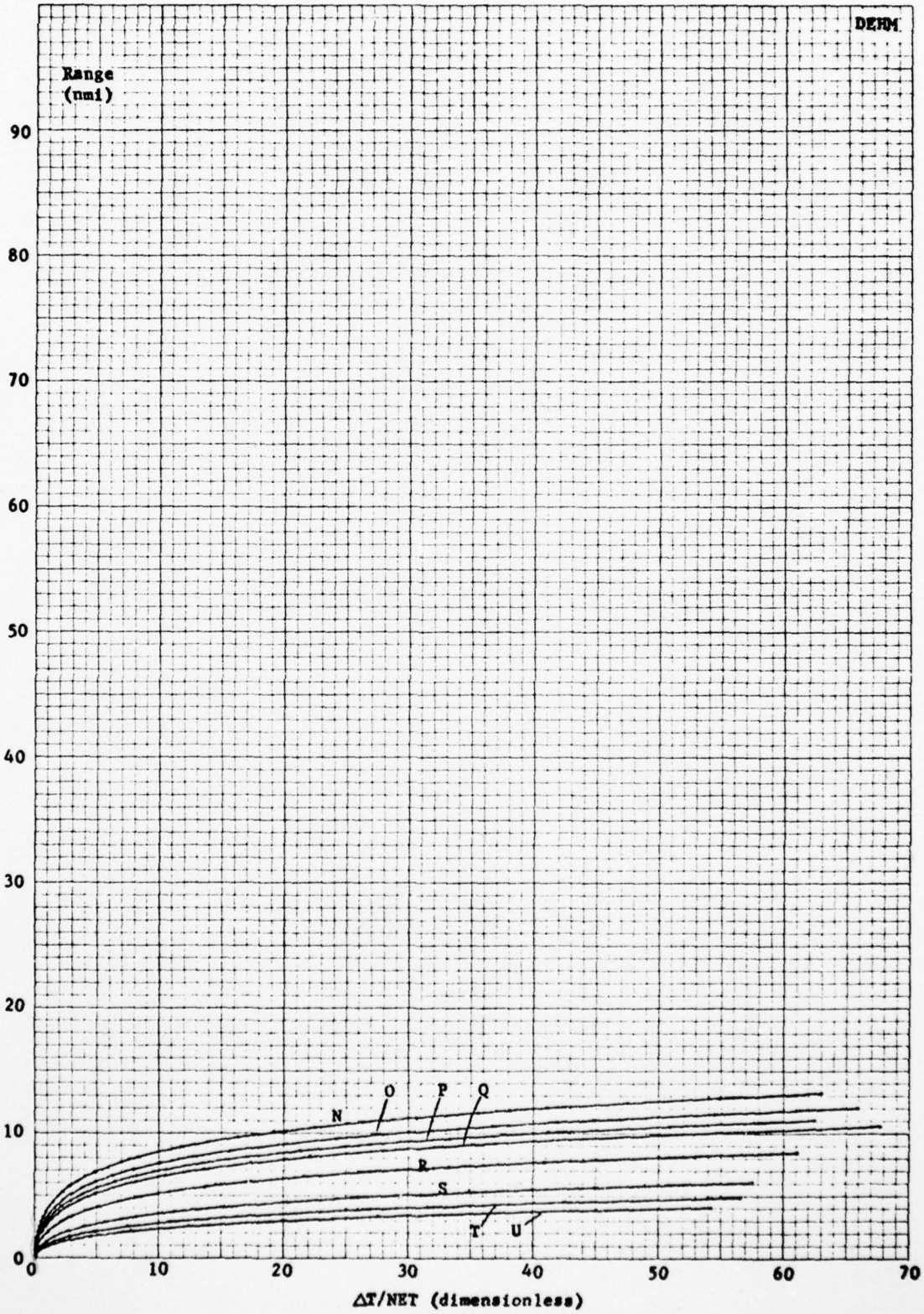

CGJK
Range (nmi)
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ΔT/NET (dimensionless)
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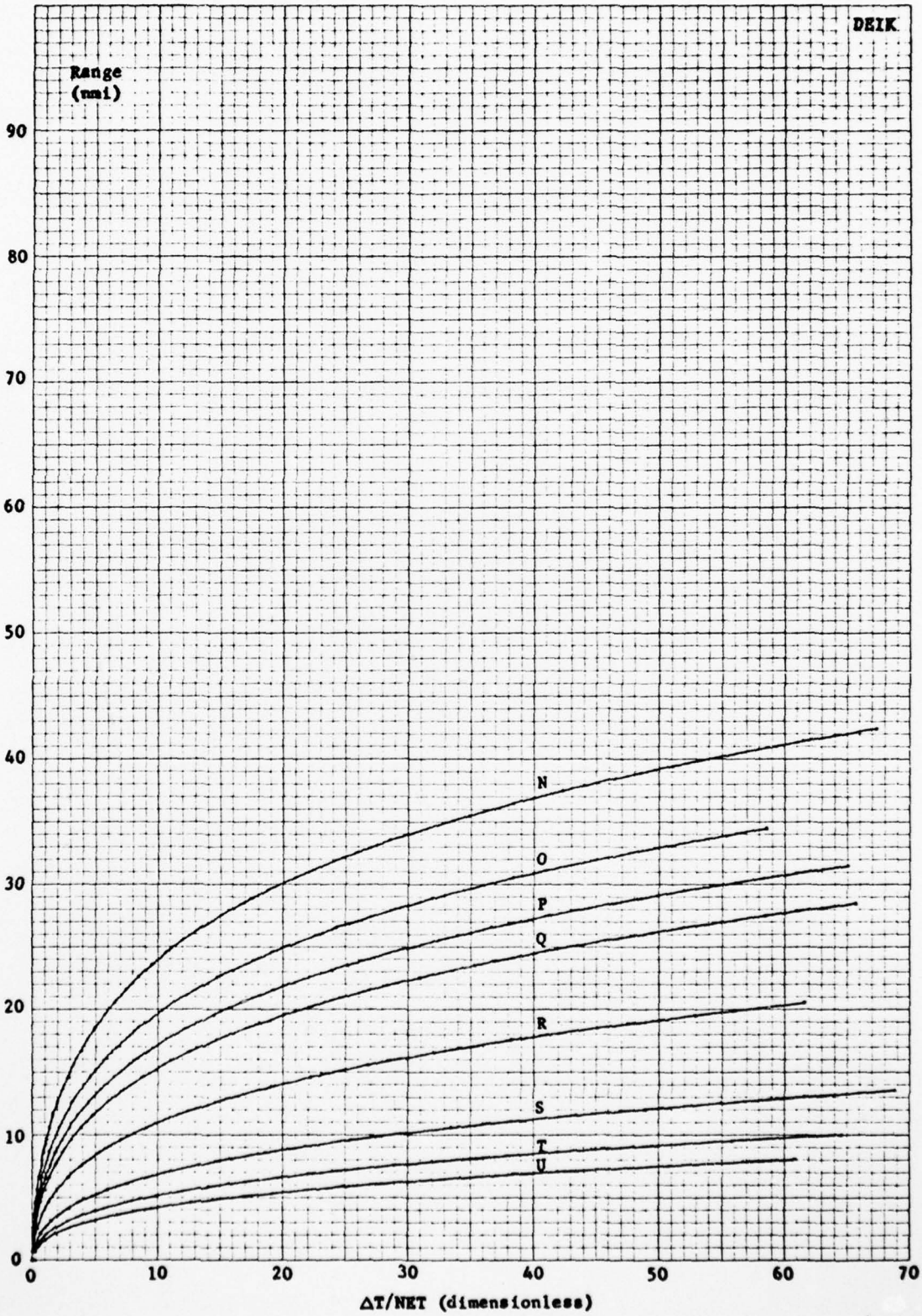

CGJL
Range (nmi)
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ΔT/NET (dimensionless)
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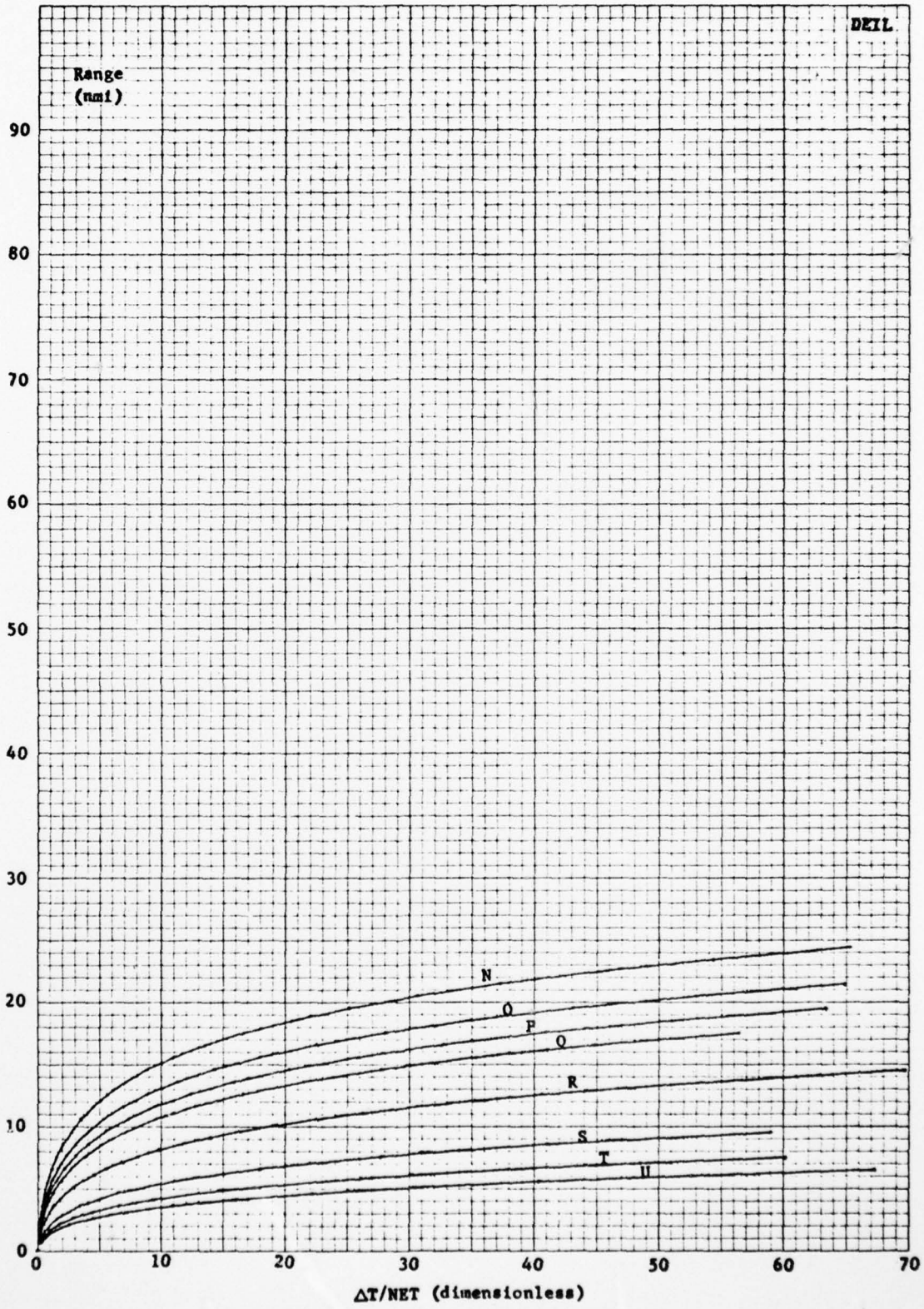

CGJM
Range (nmi)
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ΔT/NET (dimensionless)
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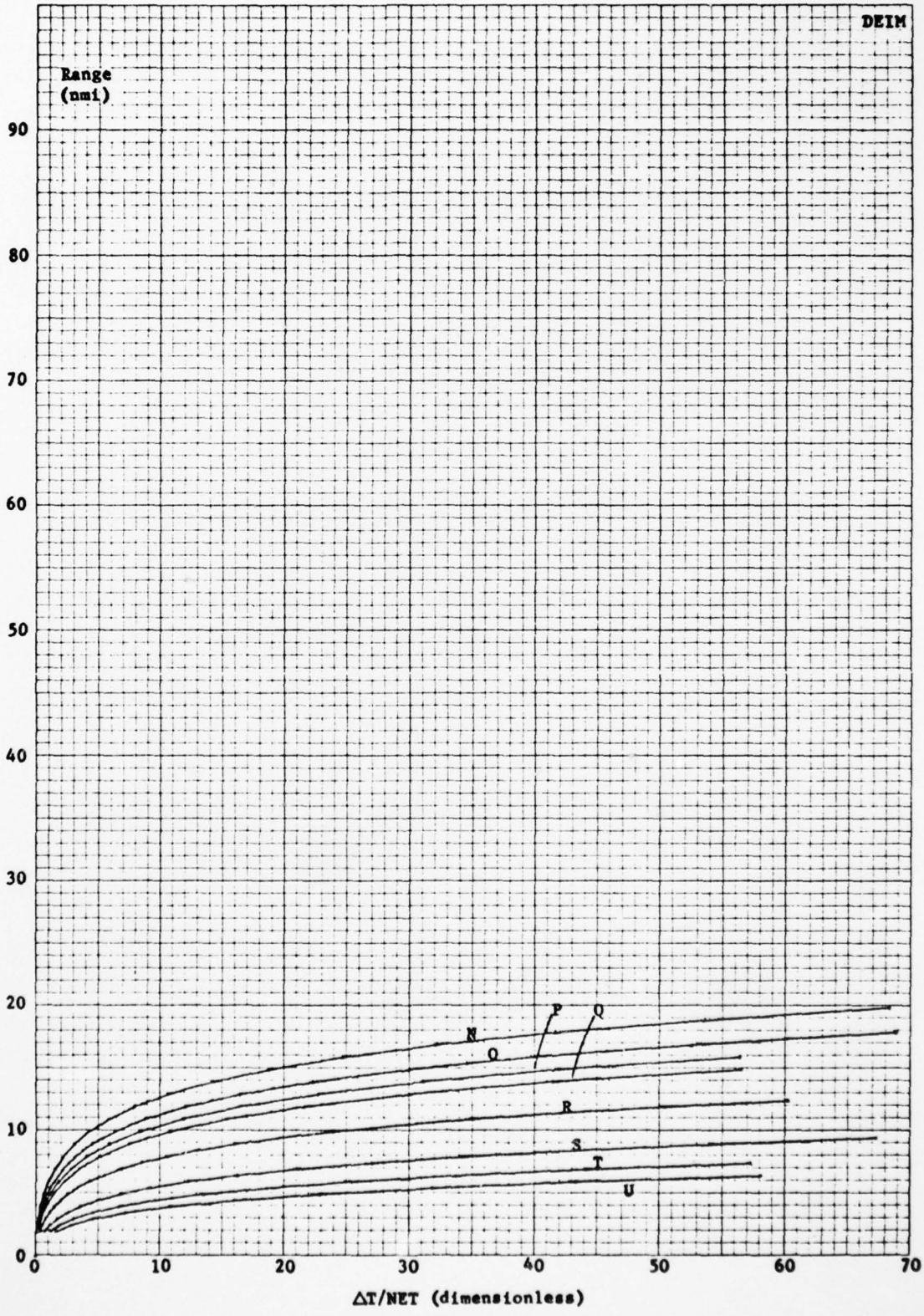

DEHK
Range
(nmi)
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ΔT/NET (dimensionless)


DEHL
Range
(nmi)
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ΔT/NET (dimensionless)
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DEHM
Range
(nmi)
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ΔT/NET (dimensionless)
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DEIK
Range
(nmi)
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ΔT/NET (dimensionless)
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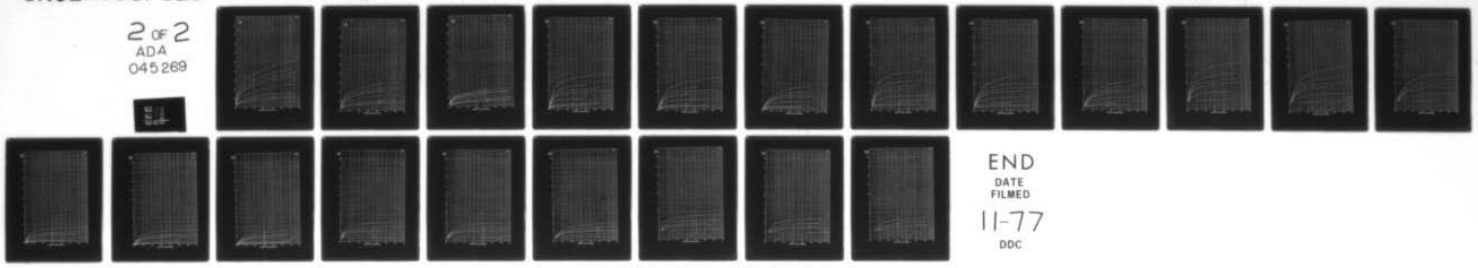

DEIL
Range
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60
70
ΔT/NET (dimensionless)
N
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DEIM
Range
(nmi)
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ΔT/NET (dimensionless)
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AD-A045 269 NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA AERO-ELECT--ETC F/G 17/5
PREDICTIONS OF FLIR PERFORMANCE AGAINST SHIPS.(U)
DEC 72 P M MOSER

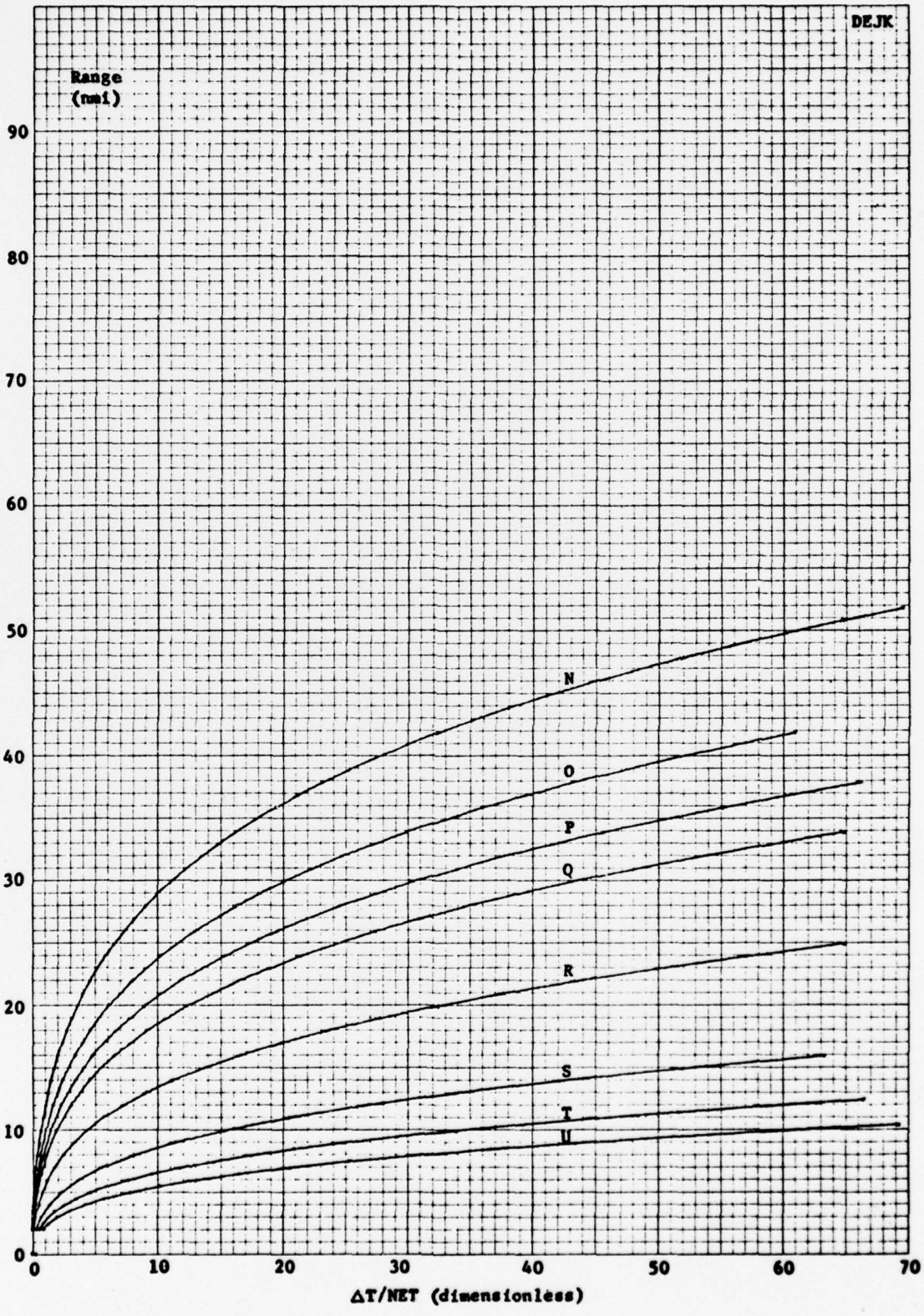
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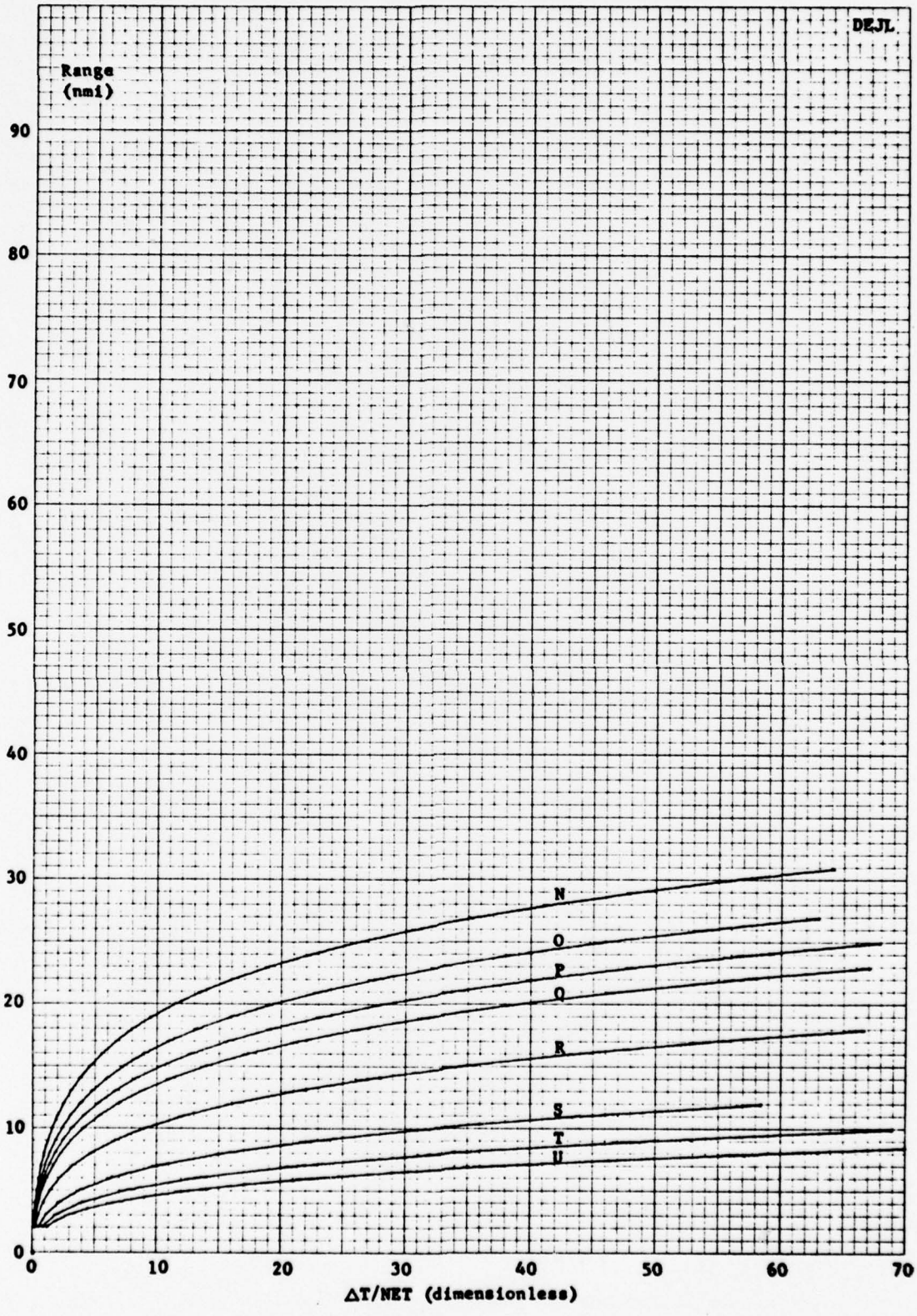
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ADA
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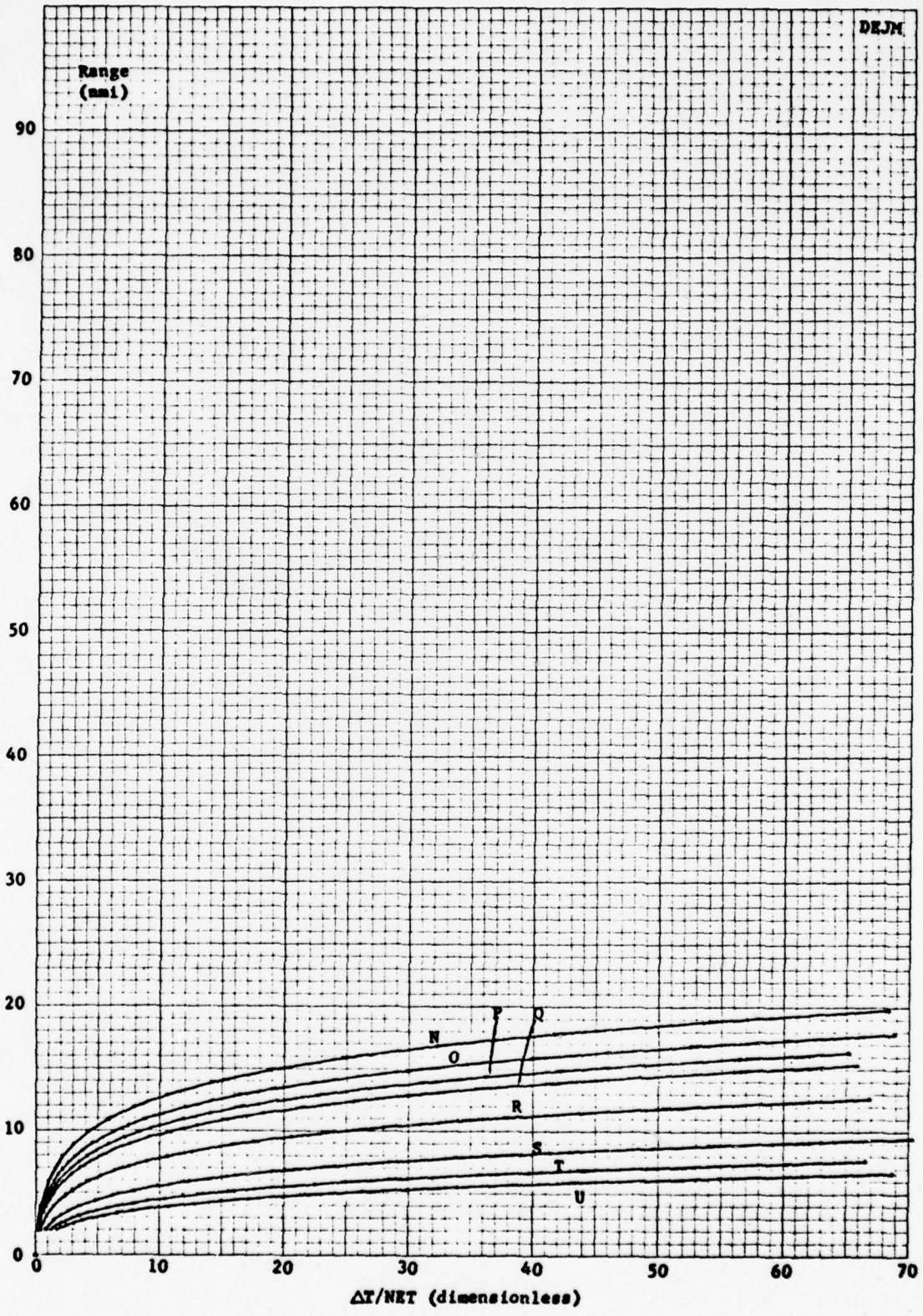


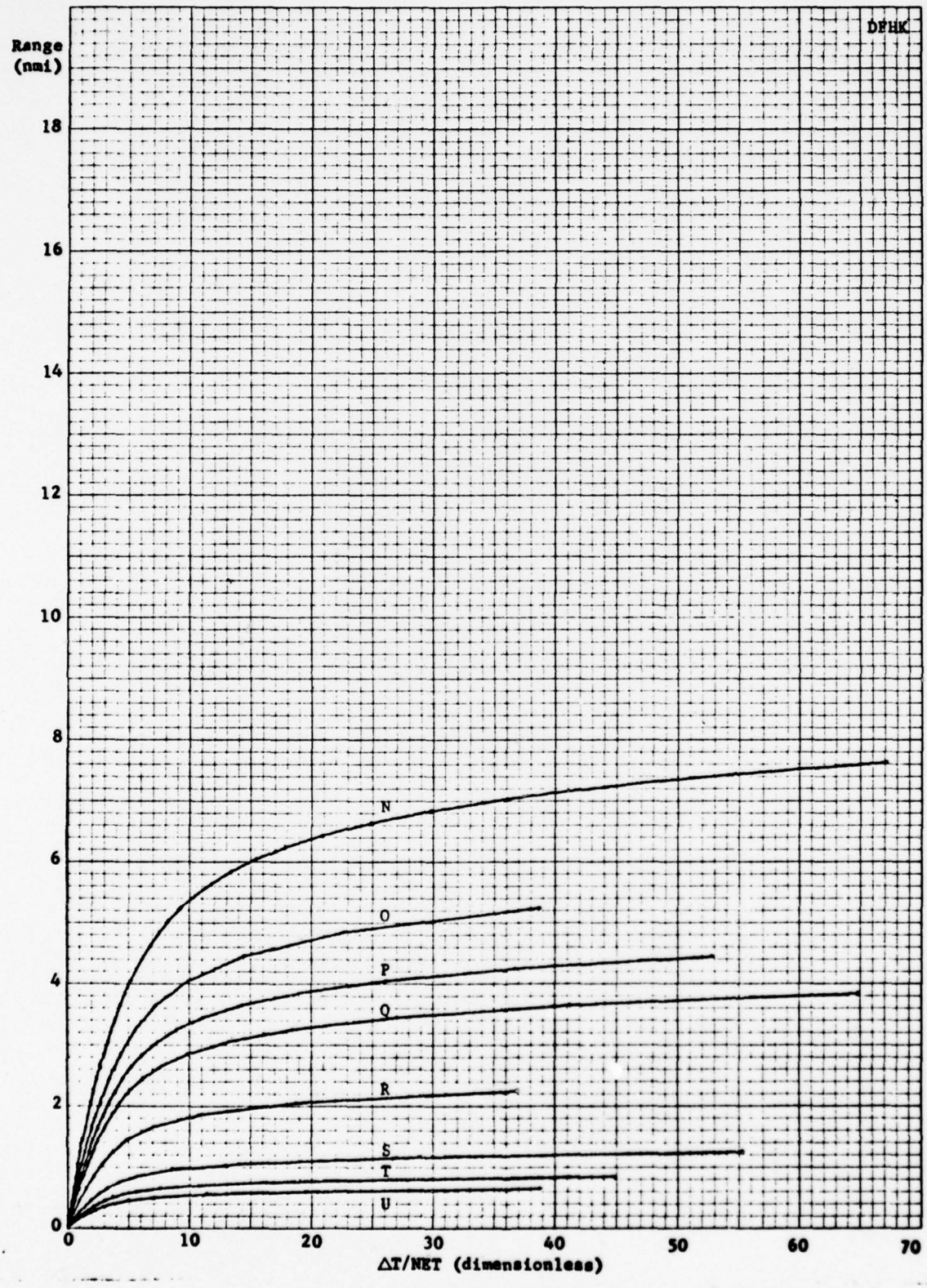
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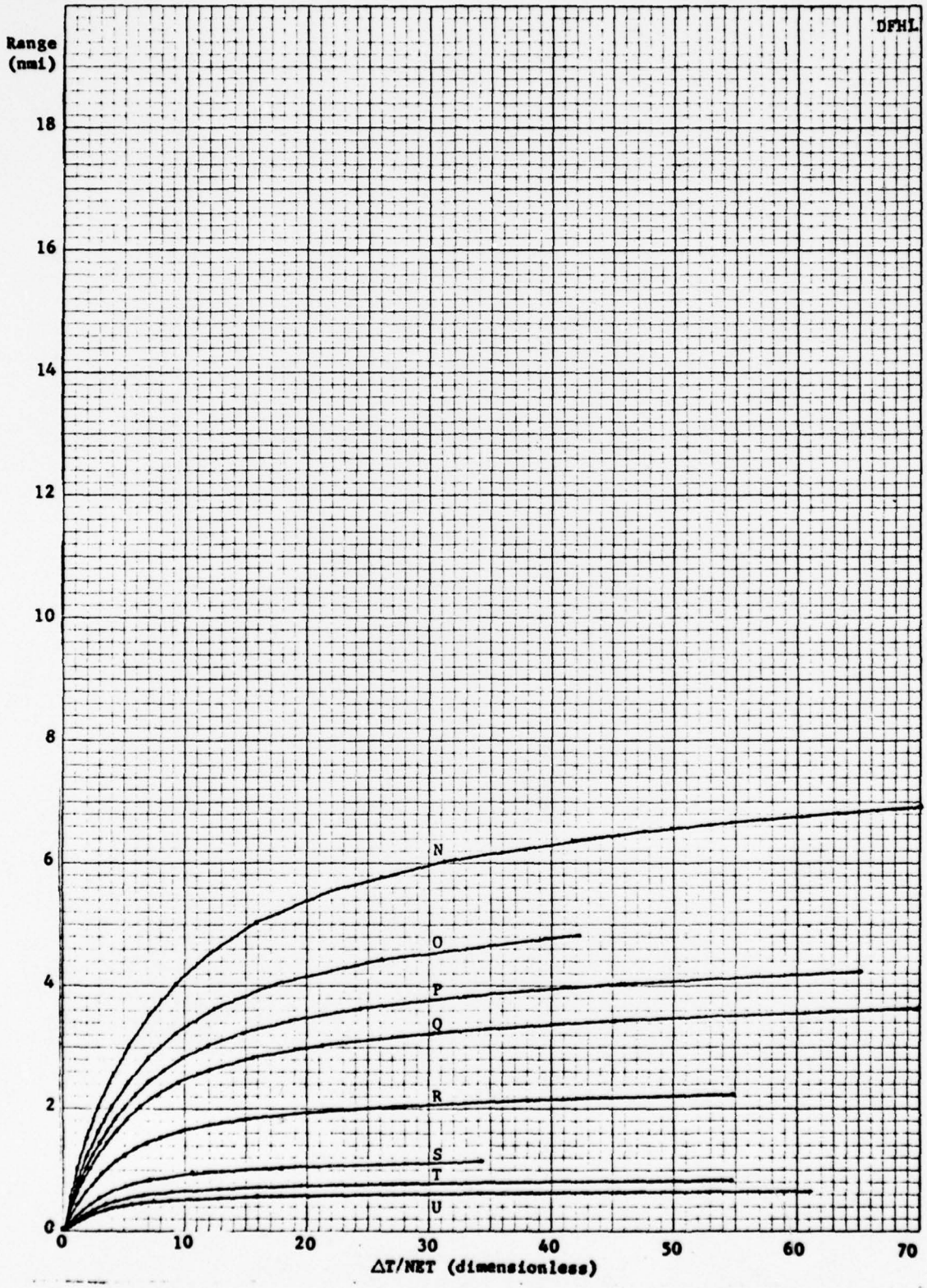

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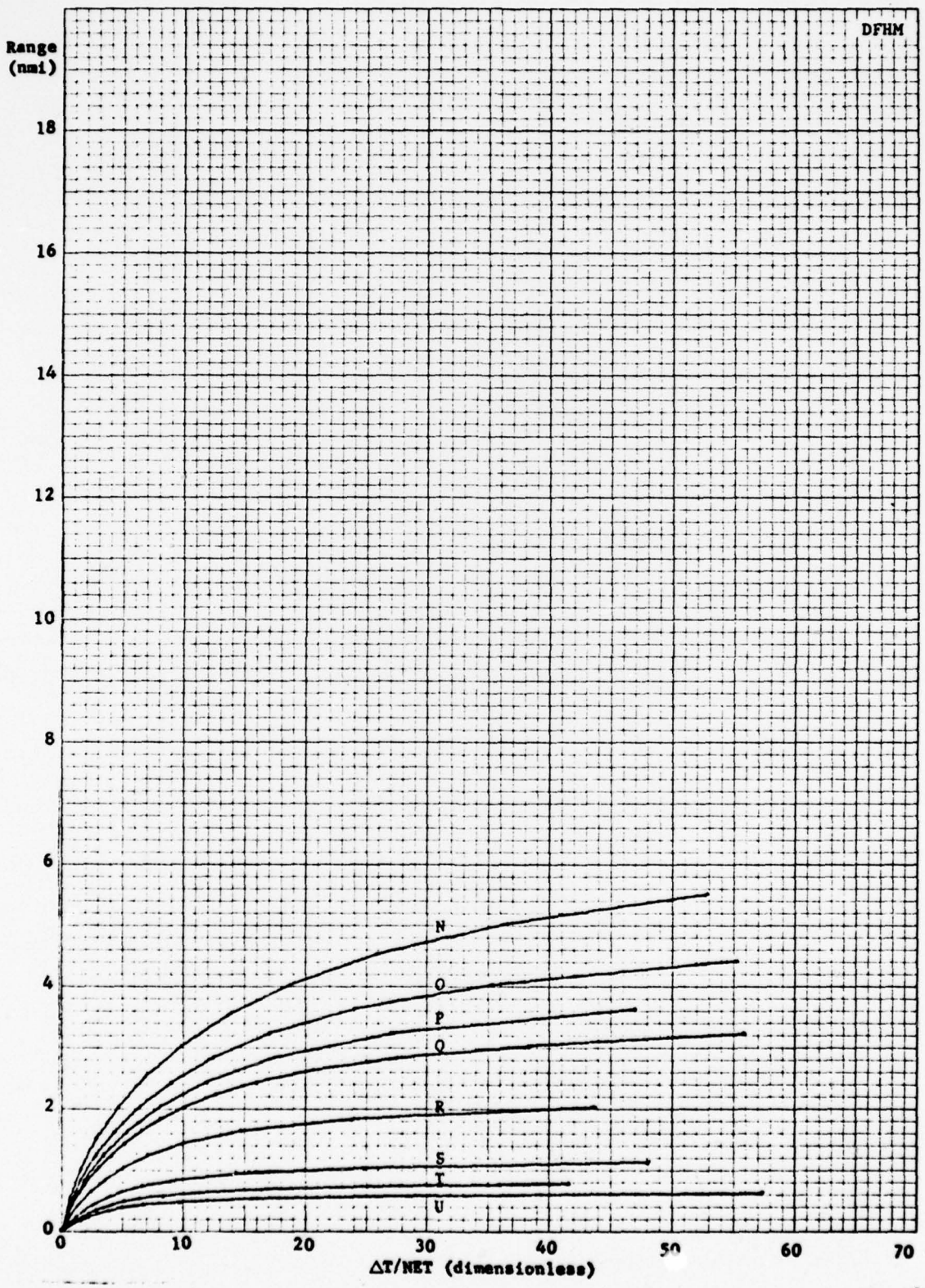

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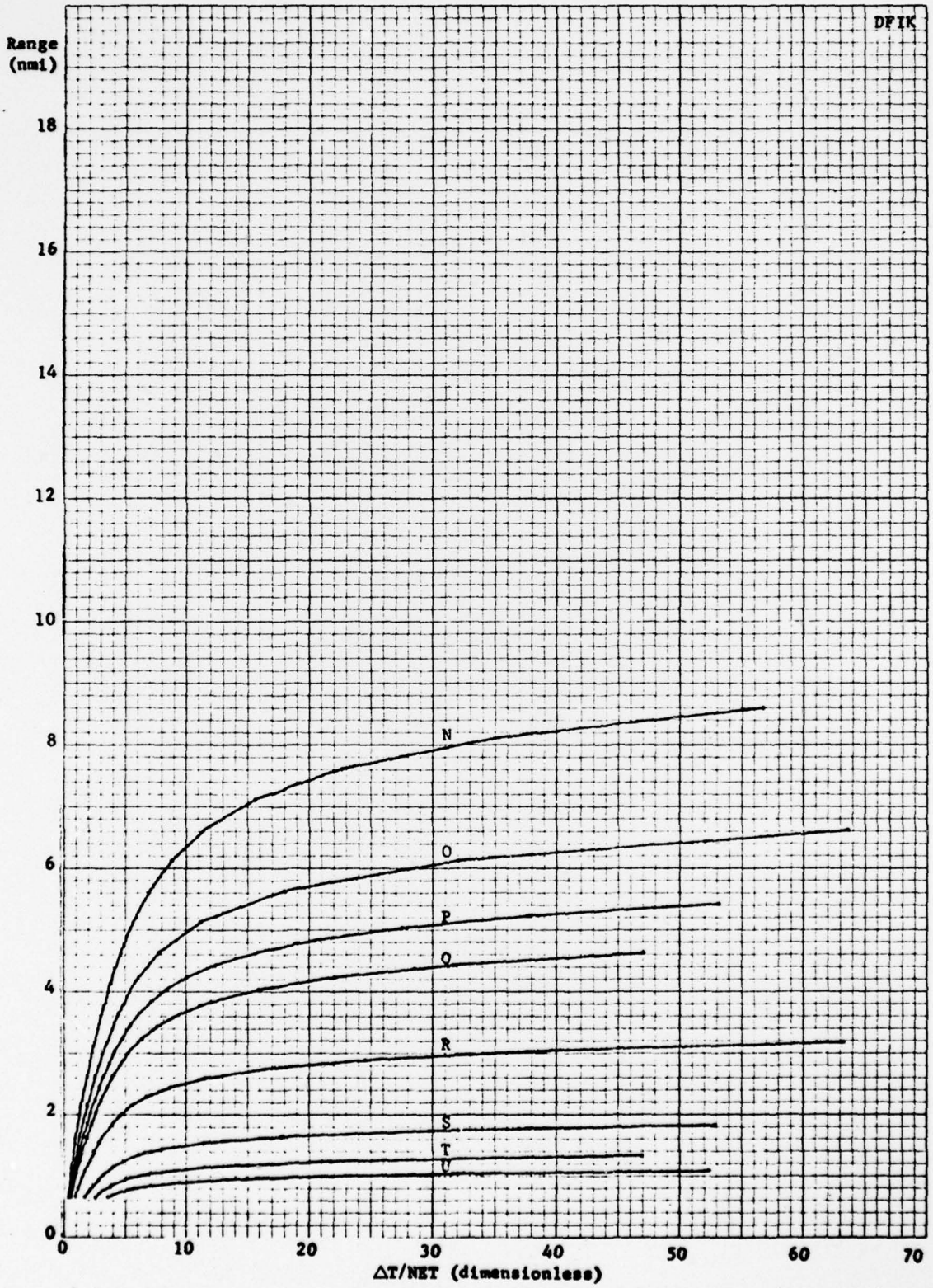

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ΔT/NET (dimensionless)
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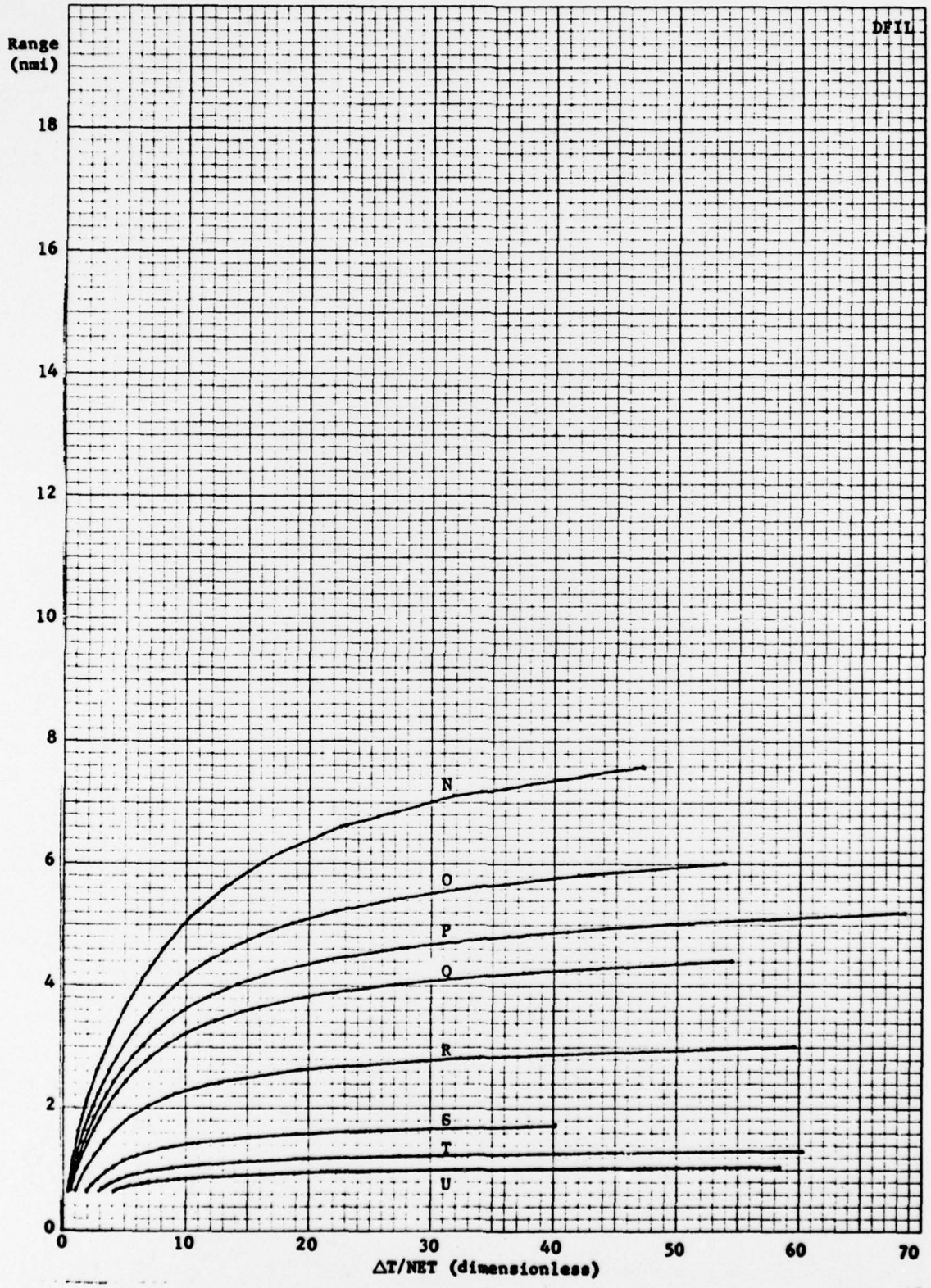

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Range
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ΔT/NET (dimensionless)
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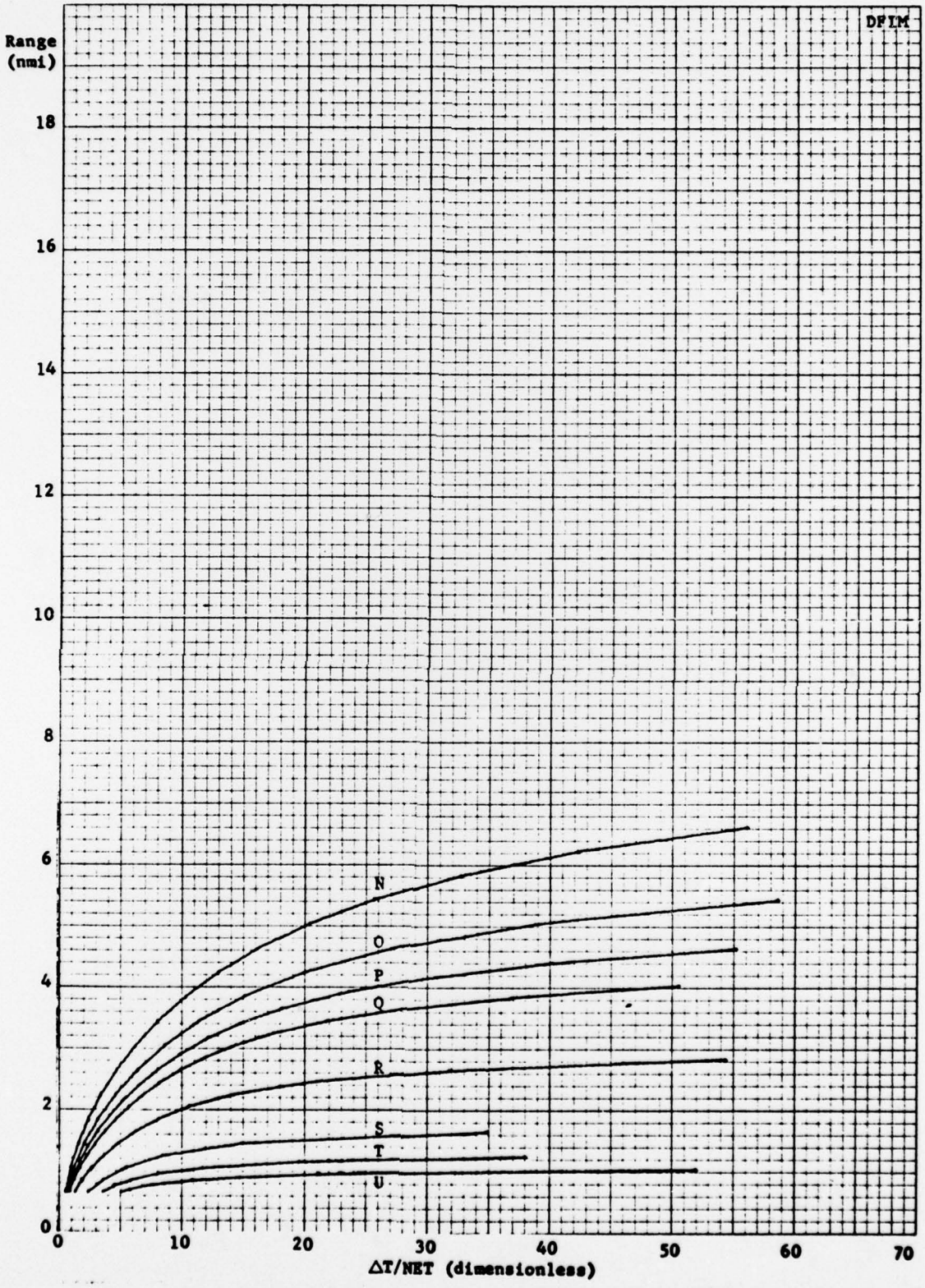

DFHK
Range (nmi)
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ΔT/NET (dimensionless)

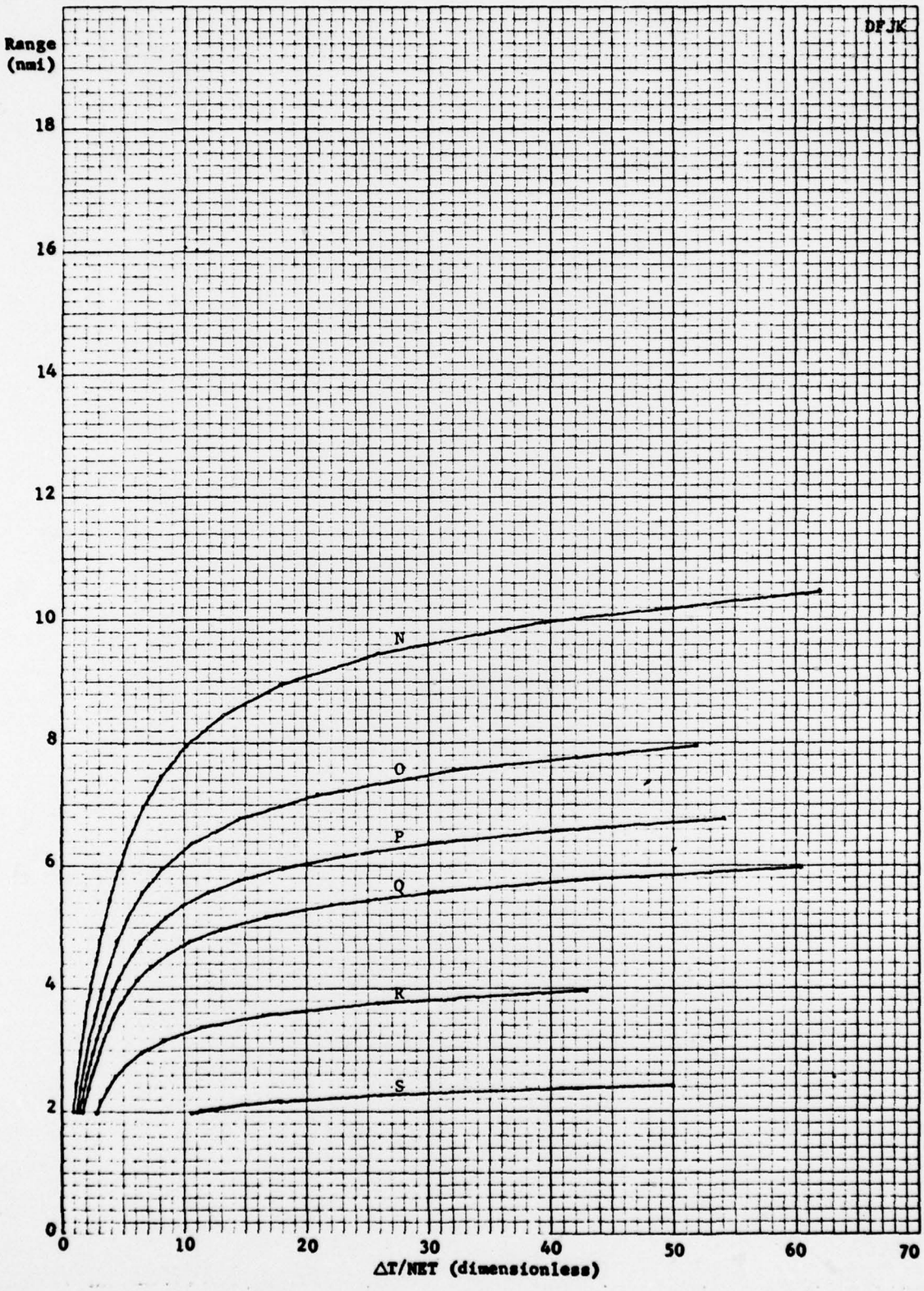

DFHL
Range (nmi)
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ΔT/NET (dimensionless)

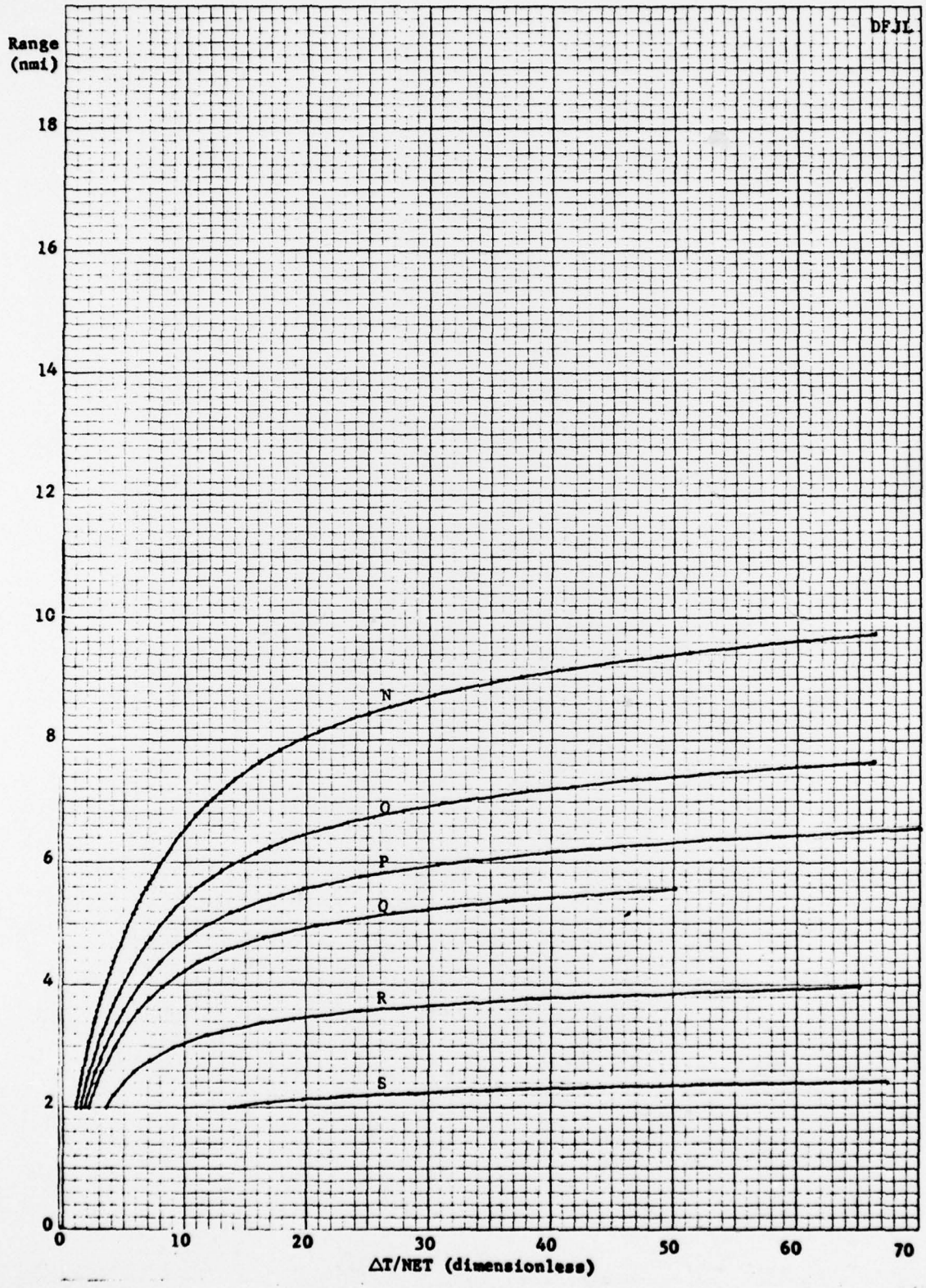

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Range (nmi)
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ΔT/NET (dimensionless)

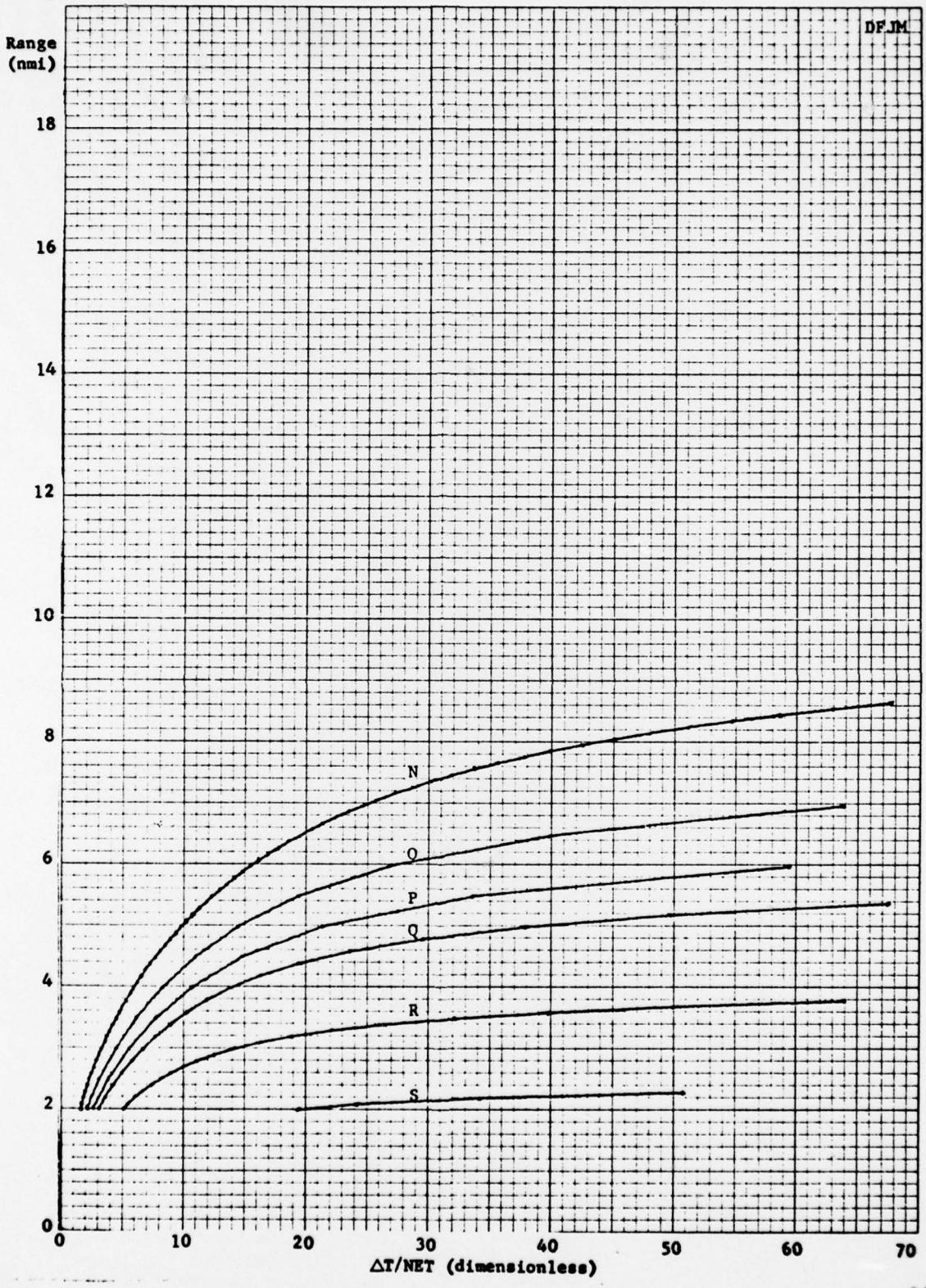

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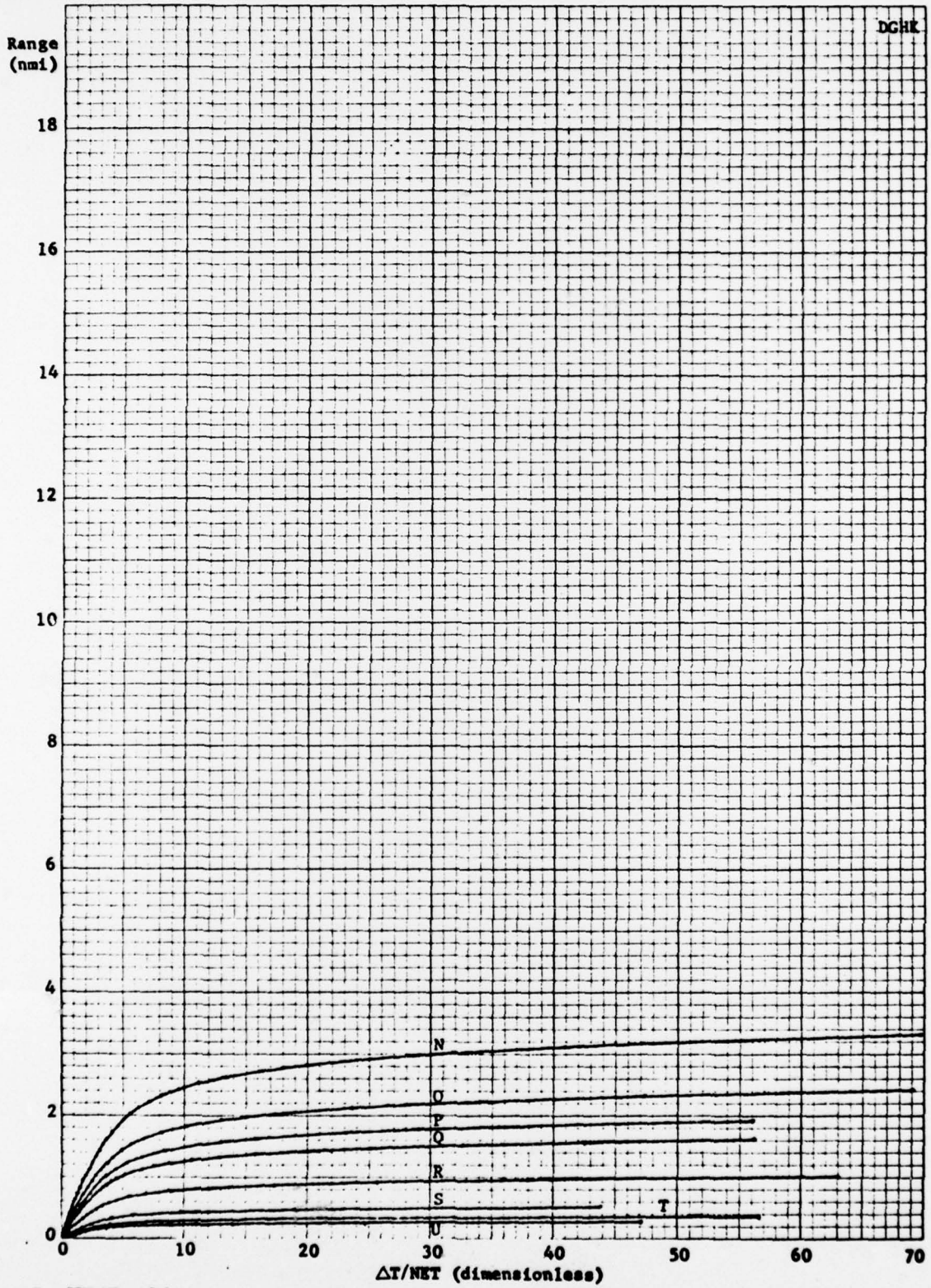

DFIL
Range (nmi)
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ΔT/NET (dimensionless)
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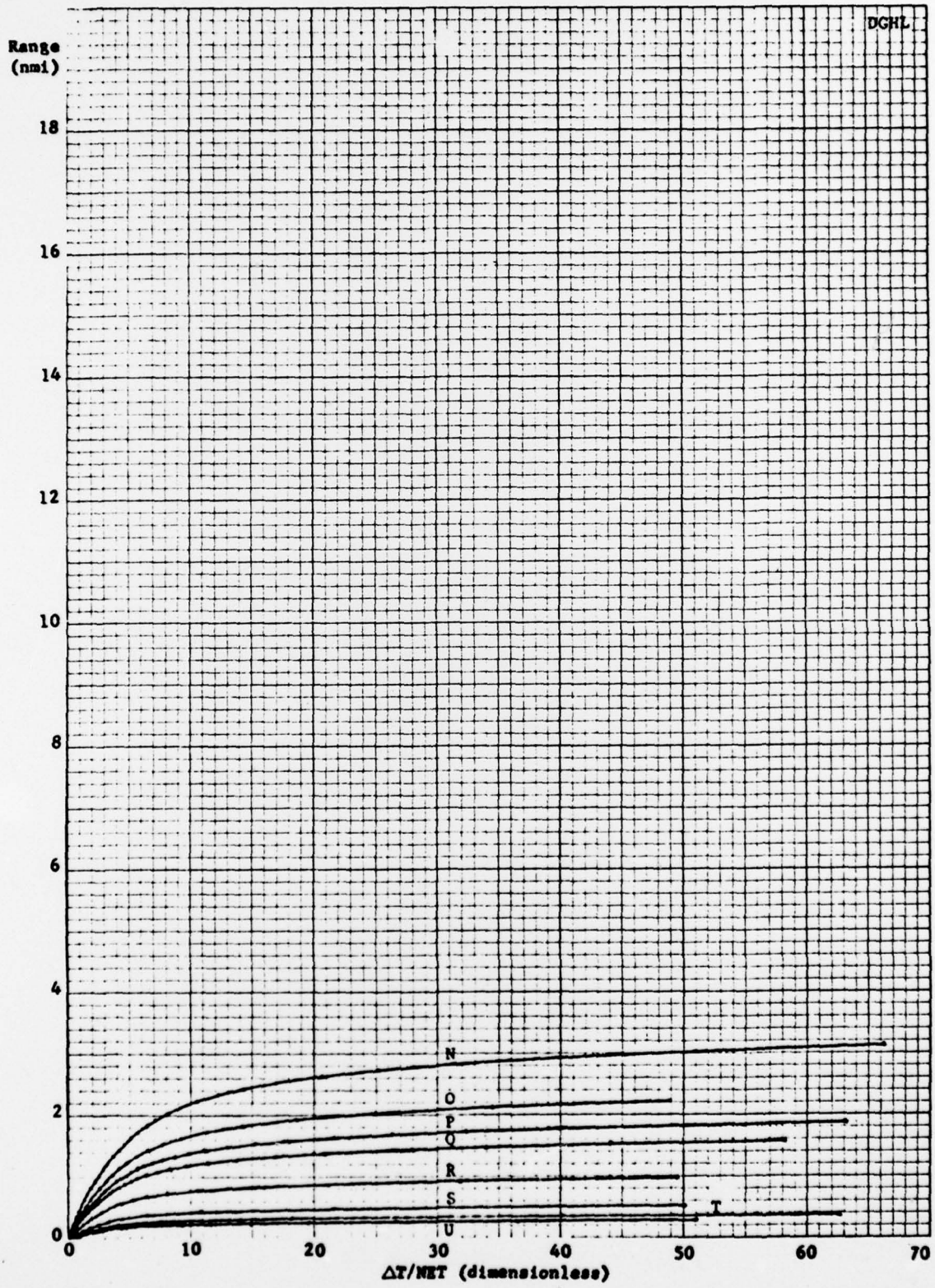

DFTM
Range (nmi)
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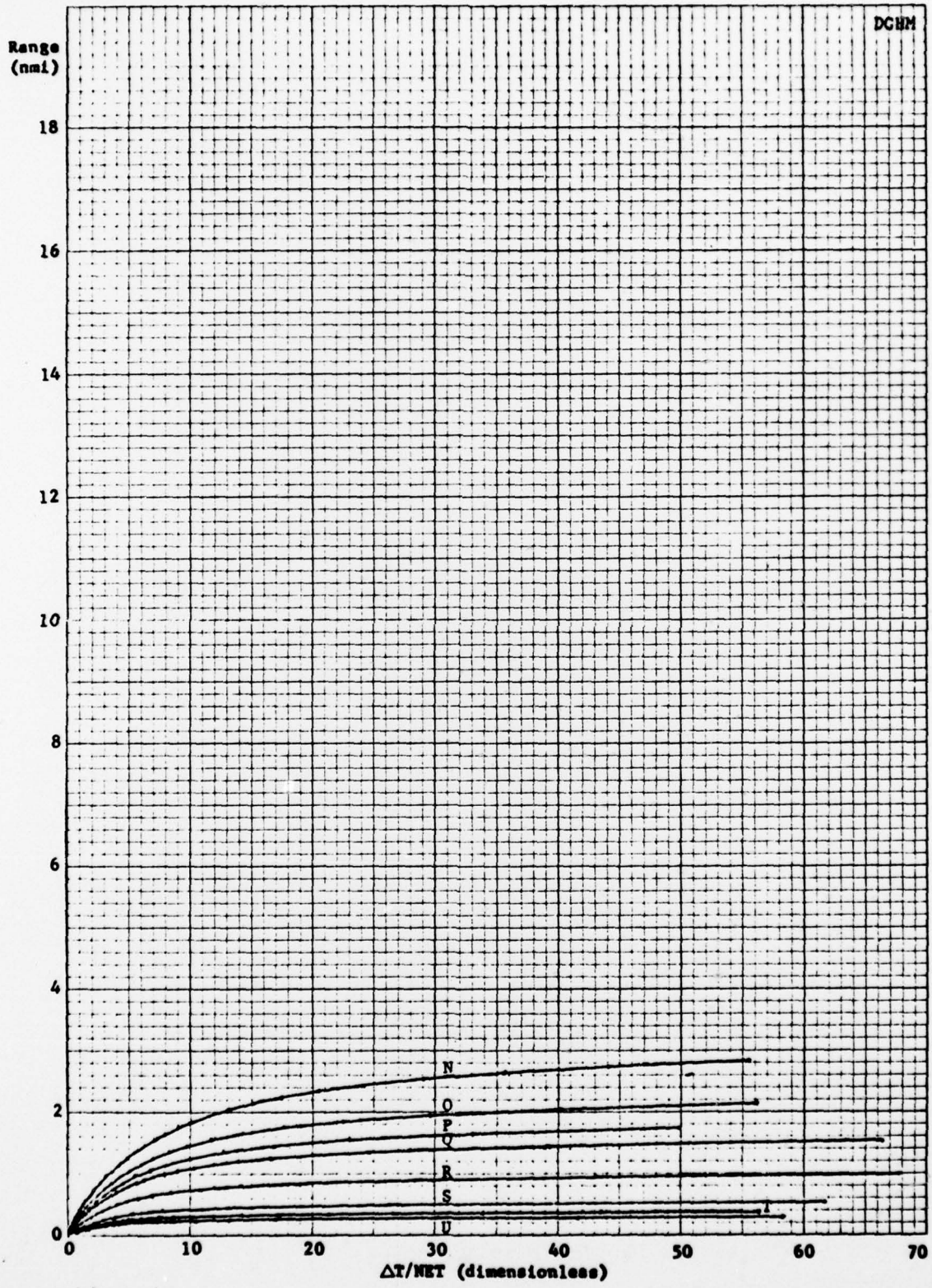

DFJK
Range
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ΔT/NET (dimensionless)

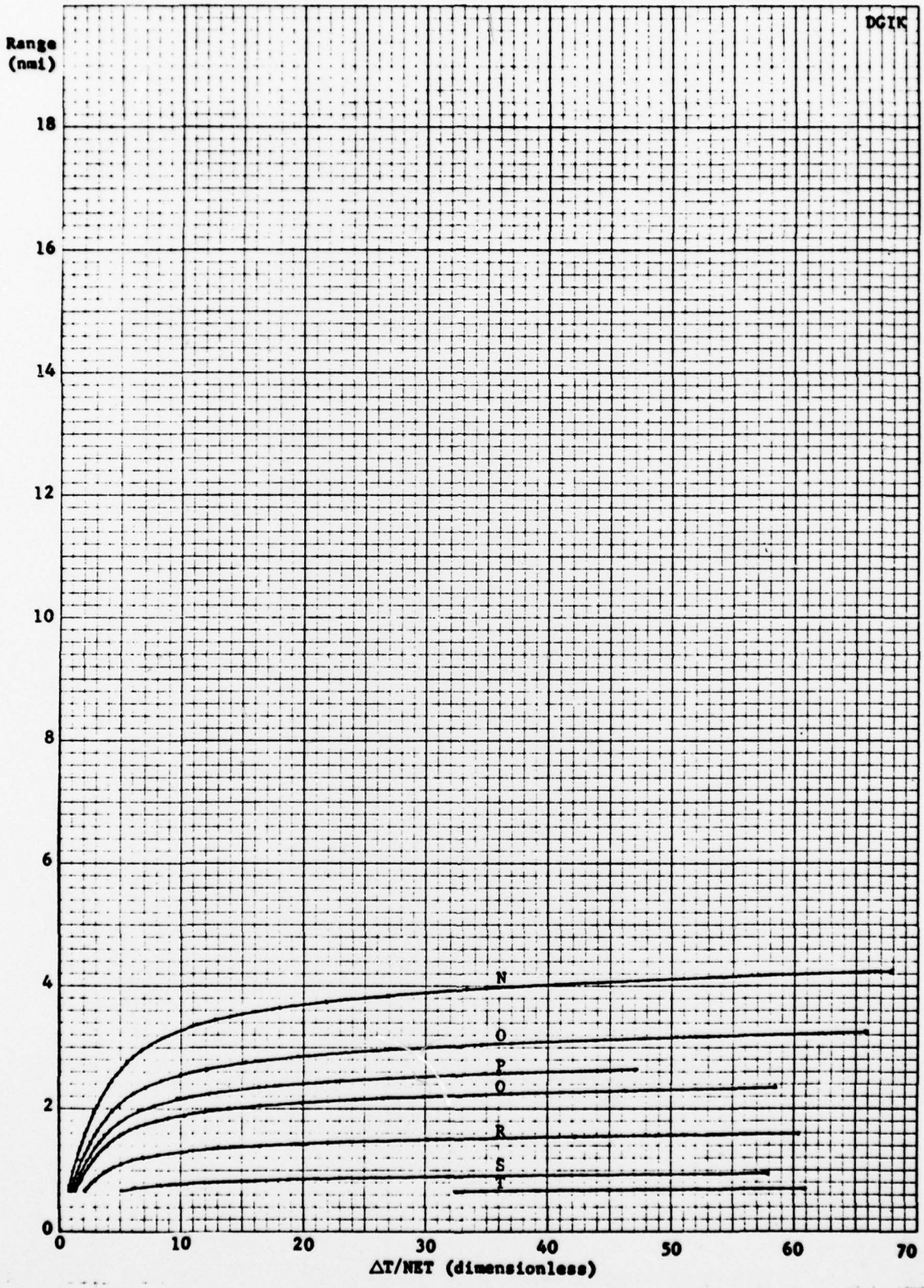

DFJL
Range (nmi)
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ΔT/NET (dimensionless)

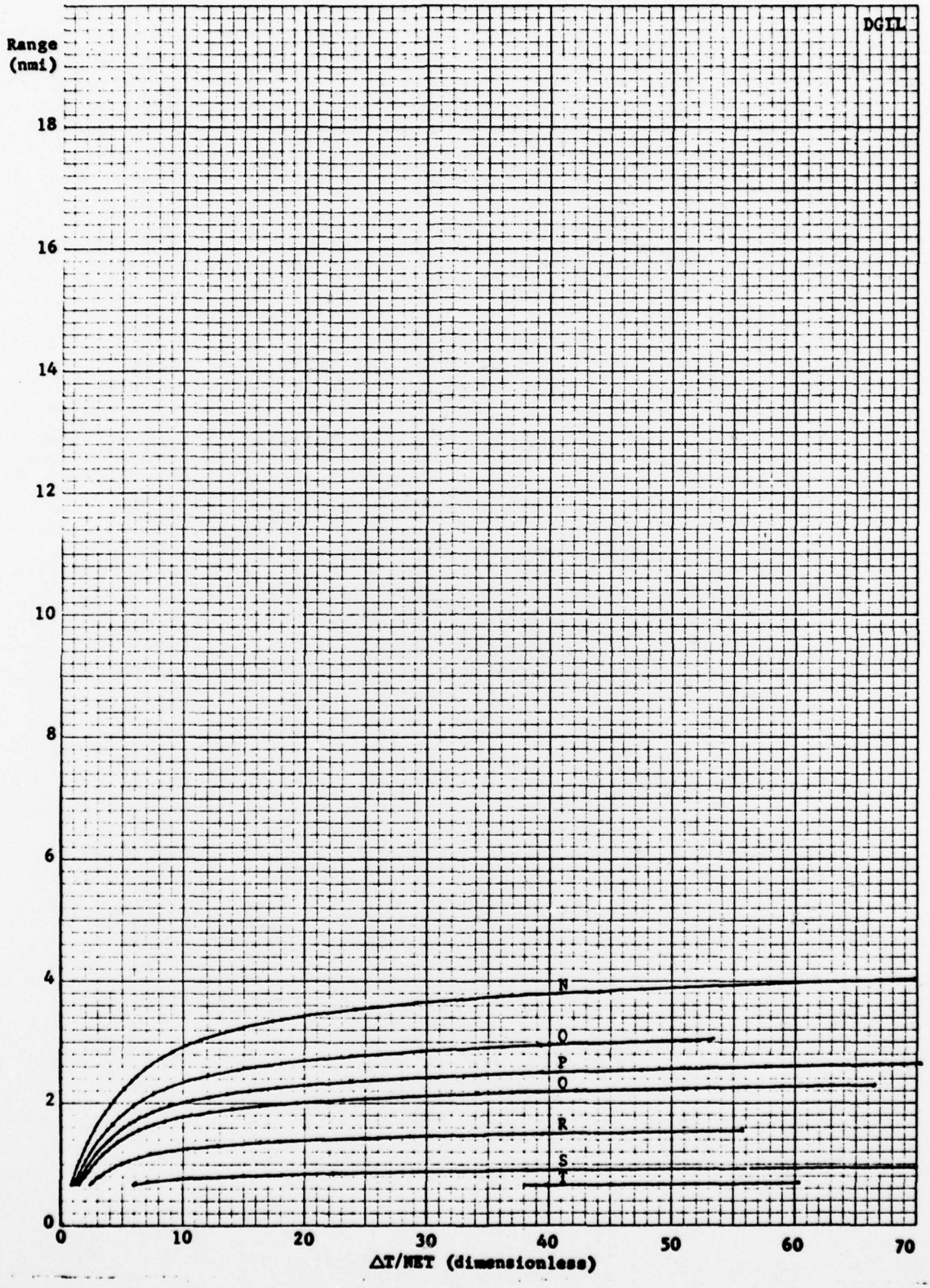

DF.JM
Range
(nmi)
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ΔT/NET (dimensionless)

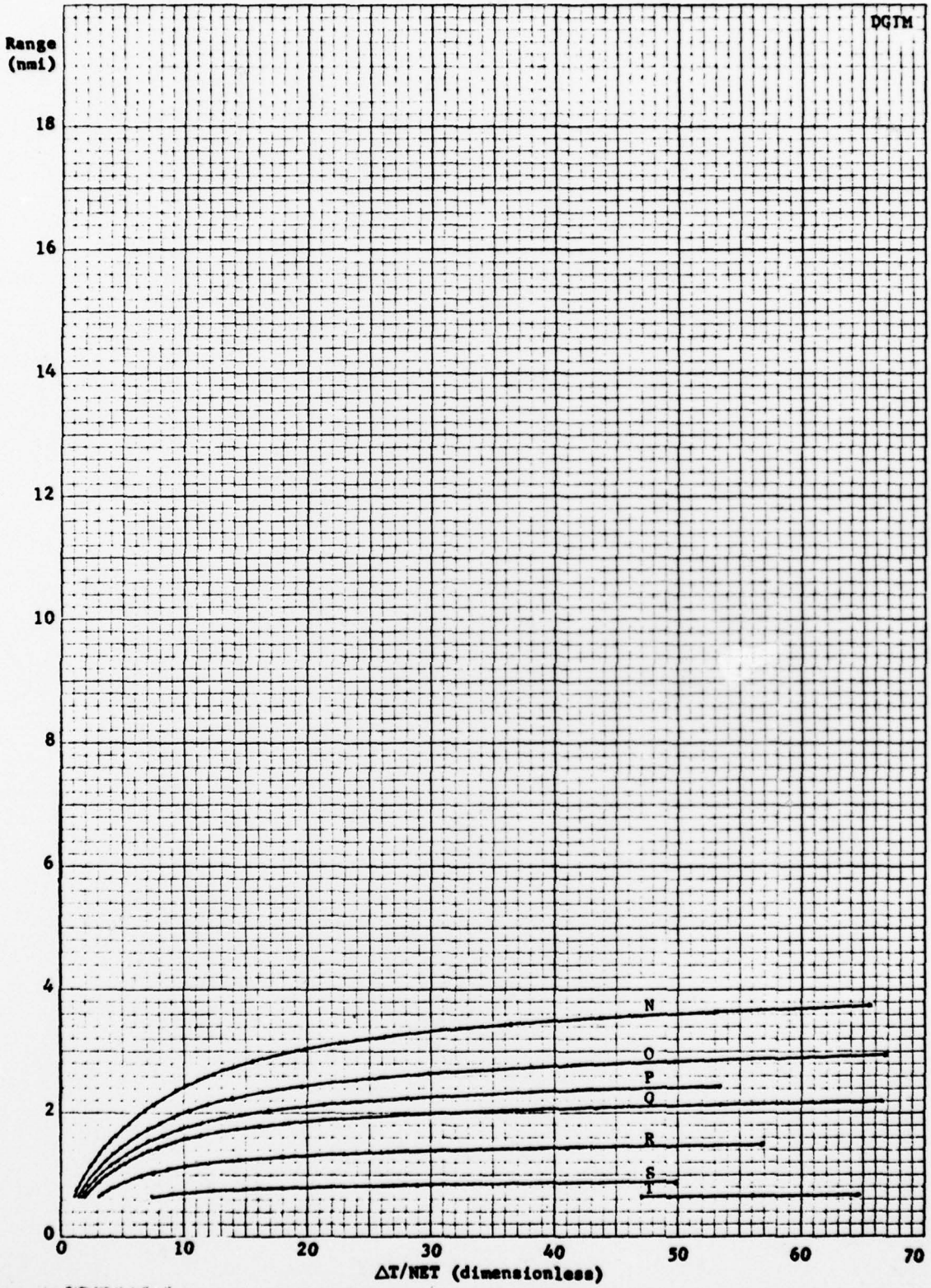

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Range (nmi)
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ΔT/NET (dimensionless)

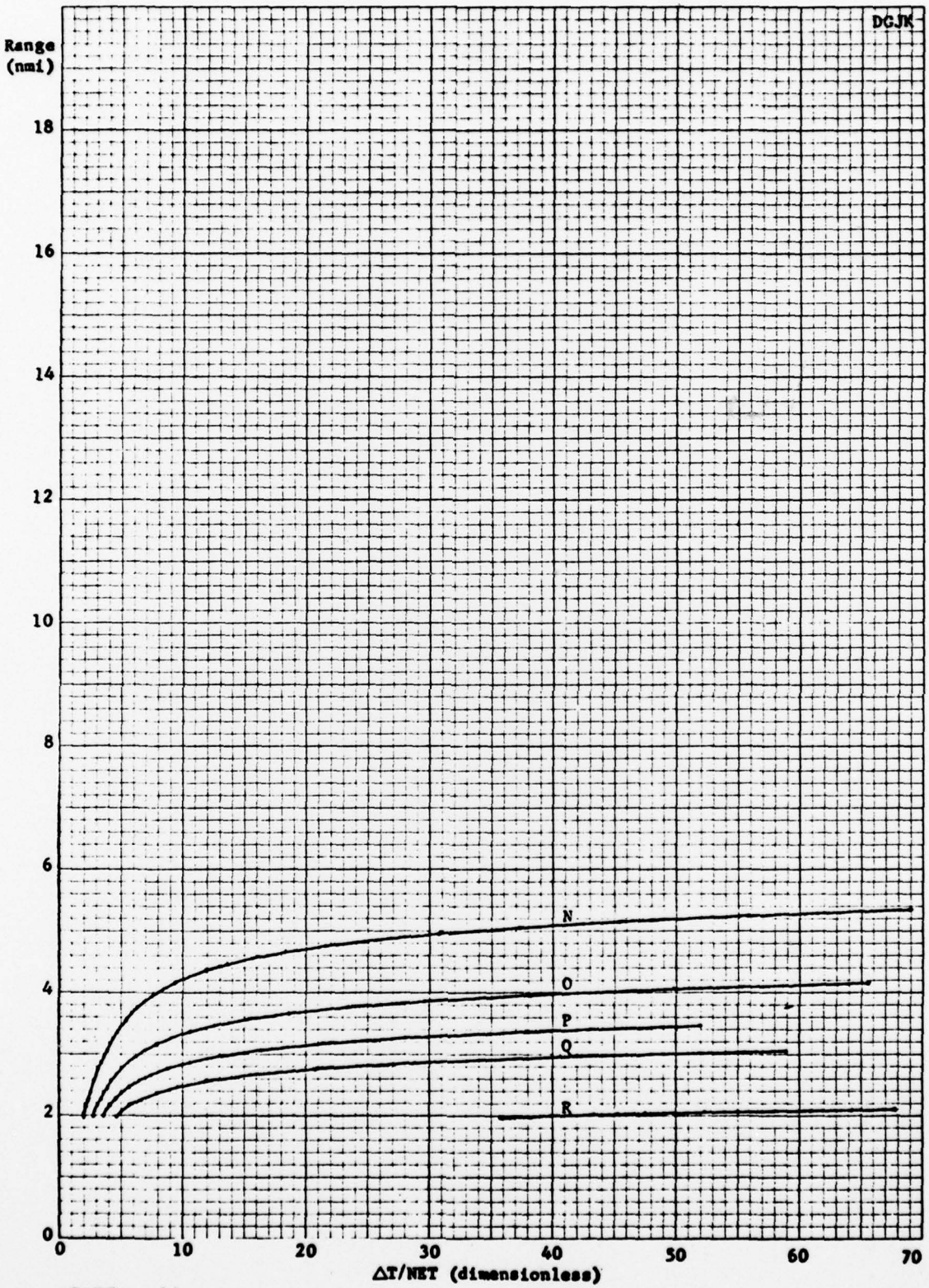

DGHL
Range (nmi)
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ΔT/NET (dimensionless)
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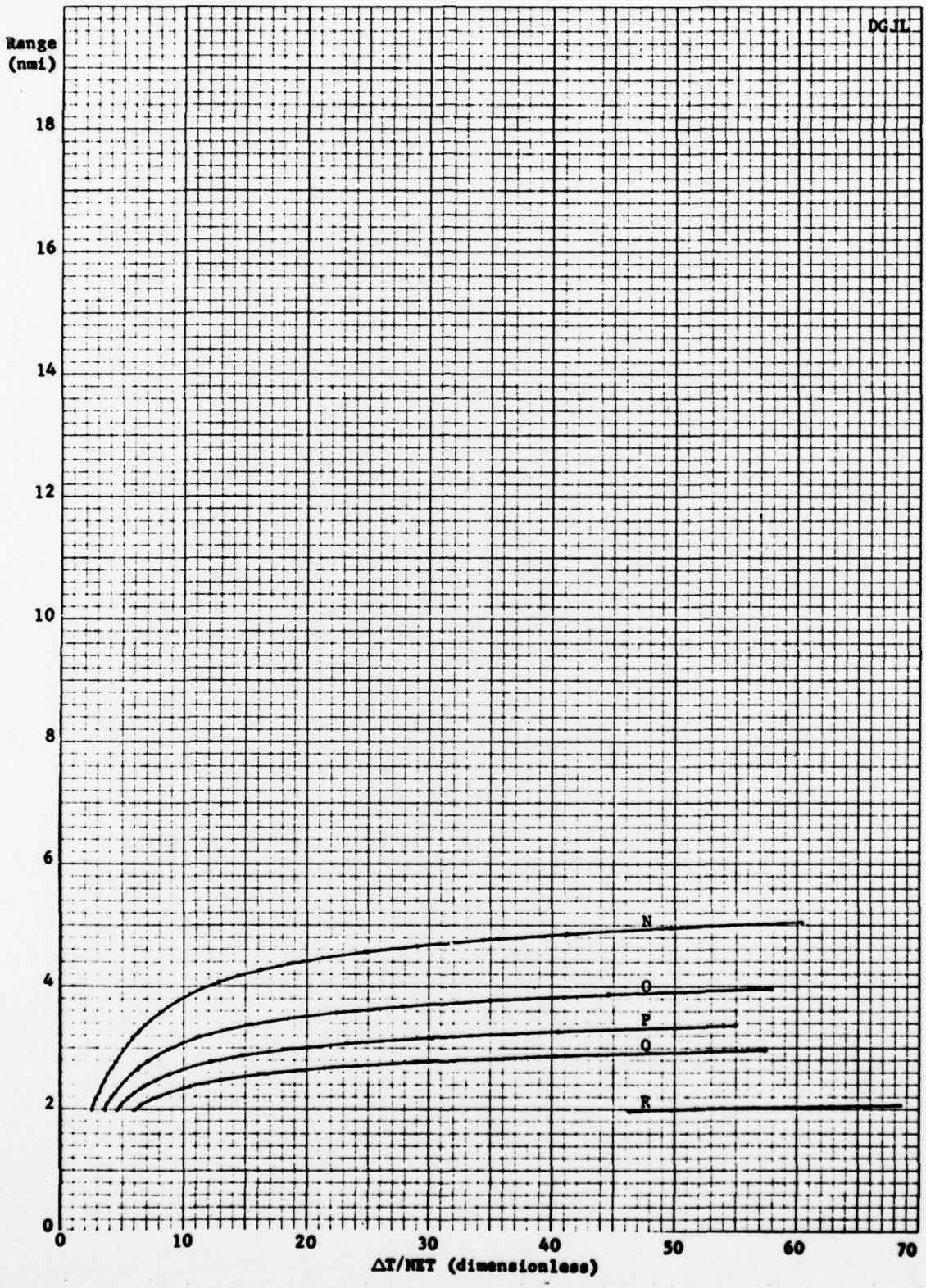

DCHM
Range (nmi)
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ΔT/NET (dimensionless)
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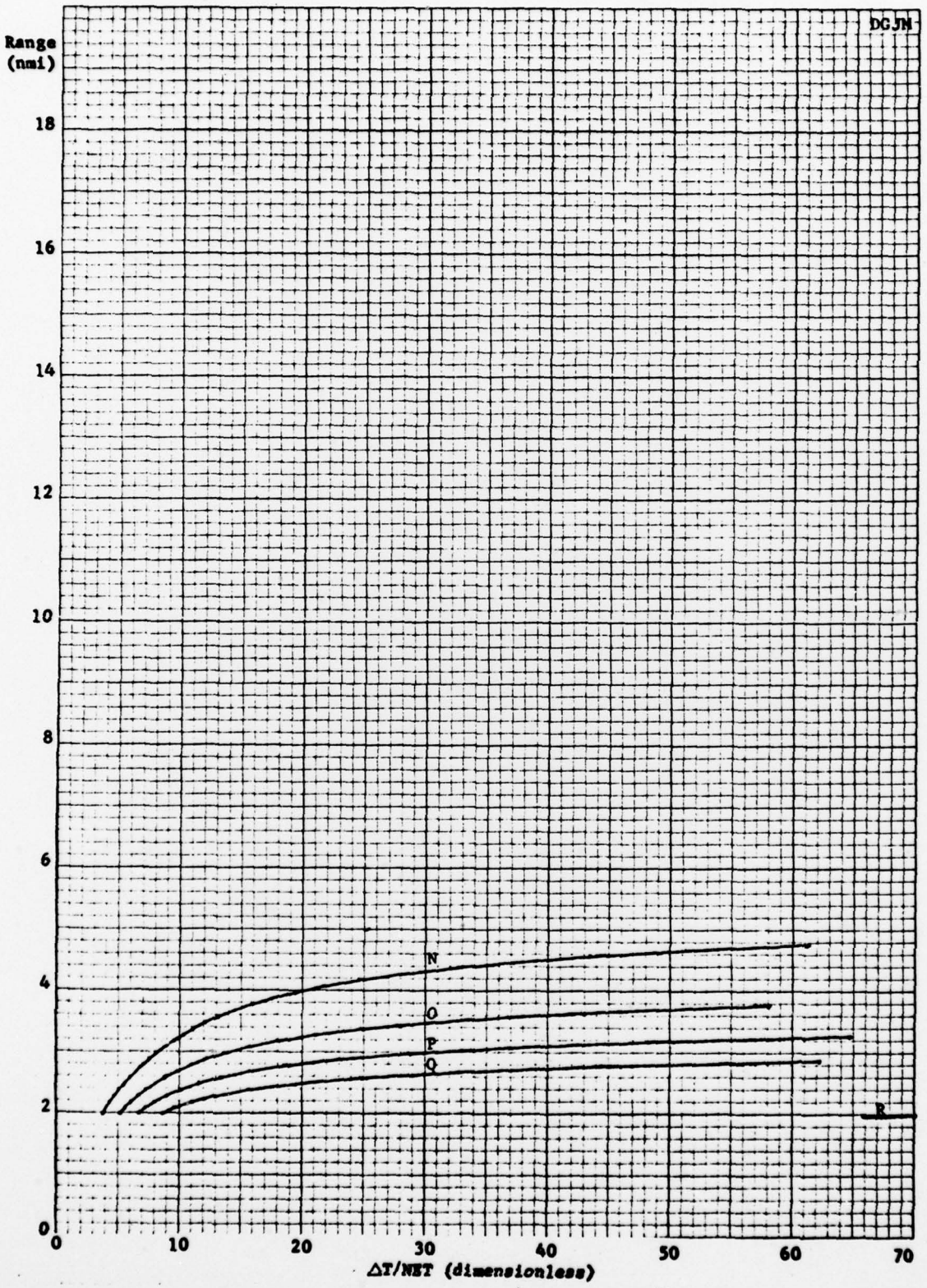

DGIK
Range (nmi)
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ΔT/NET (dimensionless)


DGIL
Range (nmi)
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ΔT/NET (dimensionless)
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DGTM
Range (nmi)
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ΔT/NET (dimensionless)
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DGJK
Range (nmi)
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ΔT/NET (dimensionless)
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DG.IL
Range
(nmi)
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ΔT/NET (dimensionless)
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DGJN
Range (nmi)
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ΔT/NET (dimensionless)
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