ENGINEERING RESEARCH INSTITUTE
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ϵ-T-E SURFACES OF FERROELECTRIC CERAMICS

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Electronic Defense Group
Department of Electrical Engineering

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ABSTRACT

The available data on ferroelectric ceramics regarding tunability and temperature are presented in chart form (ϵ-T-E Surfaces). The 21 charts are by no means a comprehensive survey of available materials because of the rapidly expanding development in this field. They represent the data currently available in a continuing materials study.

ϵ-T-E SURFACES OF FERROELECTRIC CERAMICS

1. Purpose

This report presents a series of charts which display for a number of available materials the variation in relative dielectric constant, ϵ, as both temperature and electric field are varied.

The charts are in two sections. Section 1 (Figures 1-12) deals with materials in standard production where fairly consistant results have been obtained from batch to batch. Section 2 (Figures 13-21) deals with experimental samples of new materials furnished by various laboratories. Since these materials are not in standard production, the data in each case were usually obtained from one sample, and thus no information on reproducibility is available.

2. ϵ-T-E Surfaces

Surfaces are represented in isometric projection, with ϵ plotted vertically. The electric field axis is inclined downward to the right with the electric field increasing to the right. The temperature axis is inclined downward to the left. In most cases temperature is increasing from right to left, but this was reversed where necessary to make a clearer presentation of the surface. Tunability of the material at any temperature is obtained by inspecting the variation of ϵ along the appropriate constant temperature line. The value of ϵ at any point may be scaled vertically from the appropriate datum line using the ϵ scale given on each chart.

TABLE OF CHARTS

Section 1 Standard Materials

Section 2 Experimental Materials

3. Data

In all cases the data were taken on the BLARE[1] automatic recording equipment. The small signal value of ϵ was measured at 1000 cycles, and the electric field was varied cyclically between zero and (in most cases) 40 KV/cm at a slow rate (40 to 80 seconds per cycle). The temperature was held constant during cycling by immersing the specimen in a stirred oil bath. Where hysteresis effects were observed, the data were presented only for the part of the cycle when the electric field was increasing from zero to a maximum.

4. Applications

The ϵ-T-E surfaces were primarily drawn up for design work in dielectric tuning applications. However, the surfaces may be used for a wide variety of applications, ranging from variable filter design to the design of dielectric amplifiers. Above a few megacycles, the dielectric loss increases with frequency. Thus, in design problems where the loss must be considered, the ϵ-T-E surface must be supplemented by additional data.

The technique of constructing the capacitor generally has a major effect on the high frequency loss characteristics. Greatly improved results in the 20-400 mc region are possible when special construction techniques[2] are used.

1. "Wide-Range Tuning Methods and Techniques Applicable to Search Receivers", Quarterly Progress Report No. 13 Task Order EDG-4, University of Michigan, Engineering Research Institute, Ann Arbor, Michigan, October 1954.

2. See for example, "Miniature Non-Linear Capacitors, " University of Michigan, Electronic Defense Group Technical Report No. 54, by H. Diamond, to be published.

5. General Remarks

The zero field value of ϵ is quite temperature sensitive,having a maximum value at the so-called Curie temperature of the material. The Curie temperature and maximum value of ϵ are given in Table 1. Materials with low temperature sensitivity generally have a low dielectric constant and exhibit little variation in ϵ with applied field.

The Curie temperature generally increases as the electric field is applied Thus, if the ceramic is operated at the zero field Curie temperature, it will have a positive temperature coefficient of dielectric constant when an electric field is applied.

For applications where close tolerances on the capacitance are required, it is usually necessary to apply temperature control devices to satisfy these requirements.

6. Conclusions

Although only a limited and not necessarily representative amount of data are available, it is felt that publication at this time will assist the increasing number of workers now employed in applications of these materials.

2262 C-64-106 BM 10-27-55

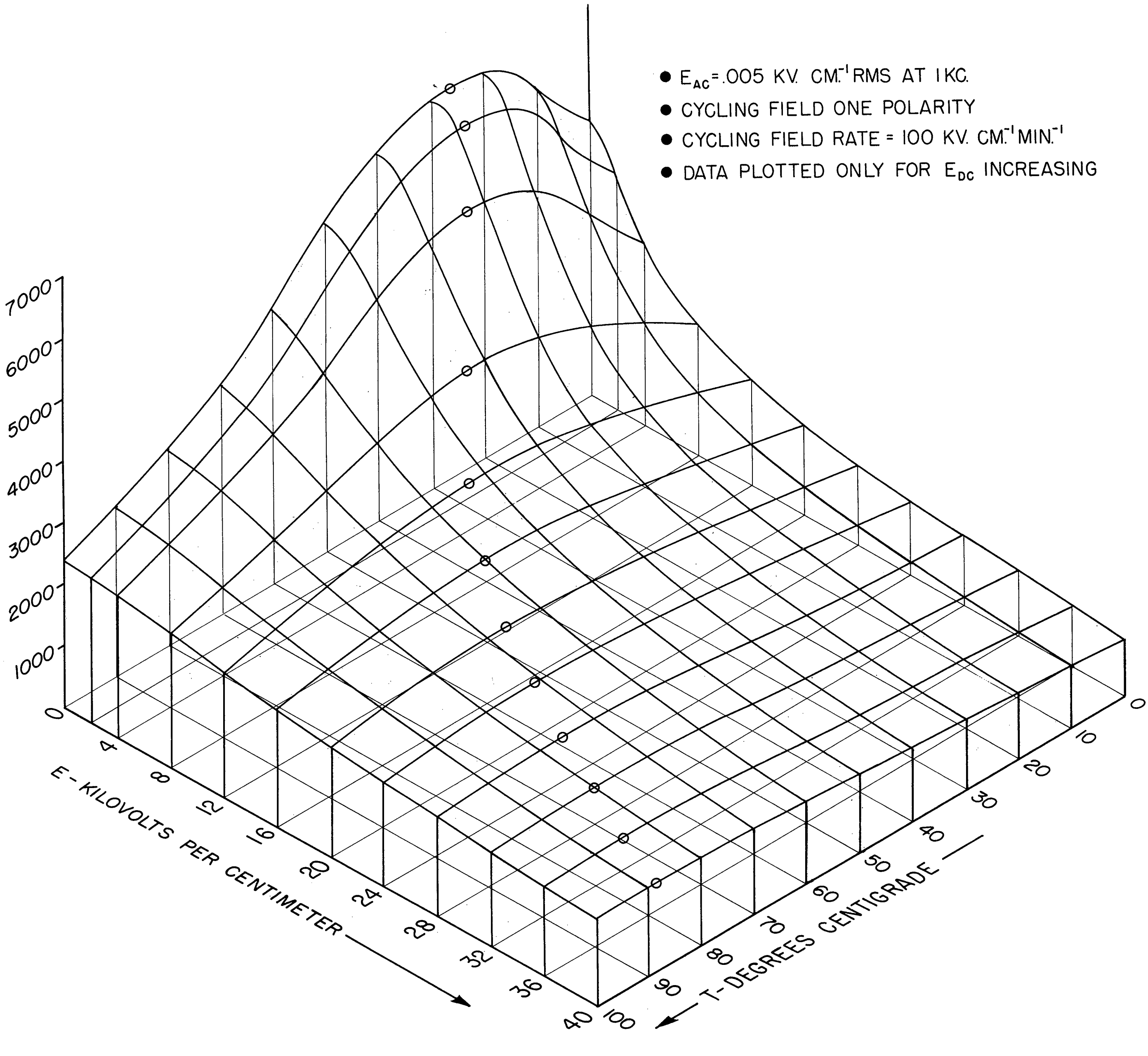
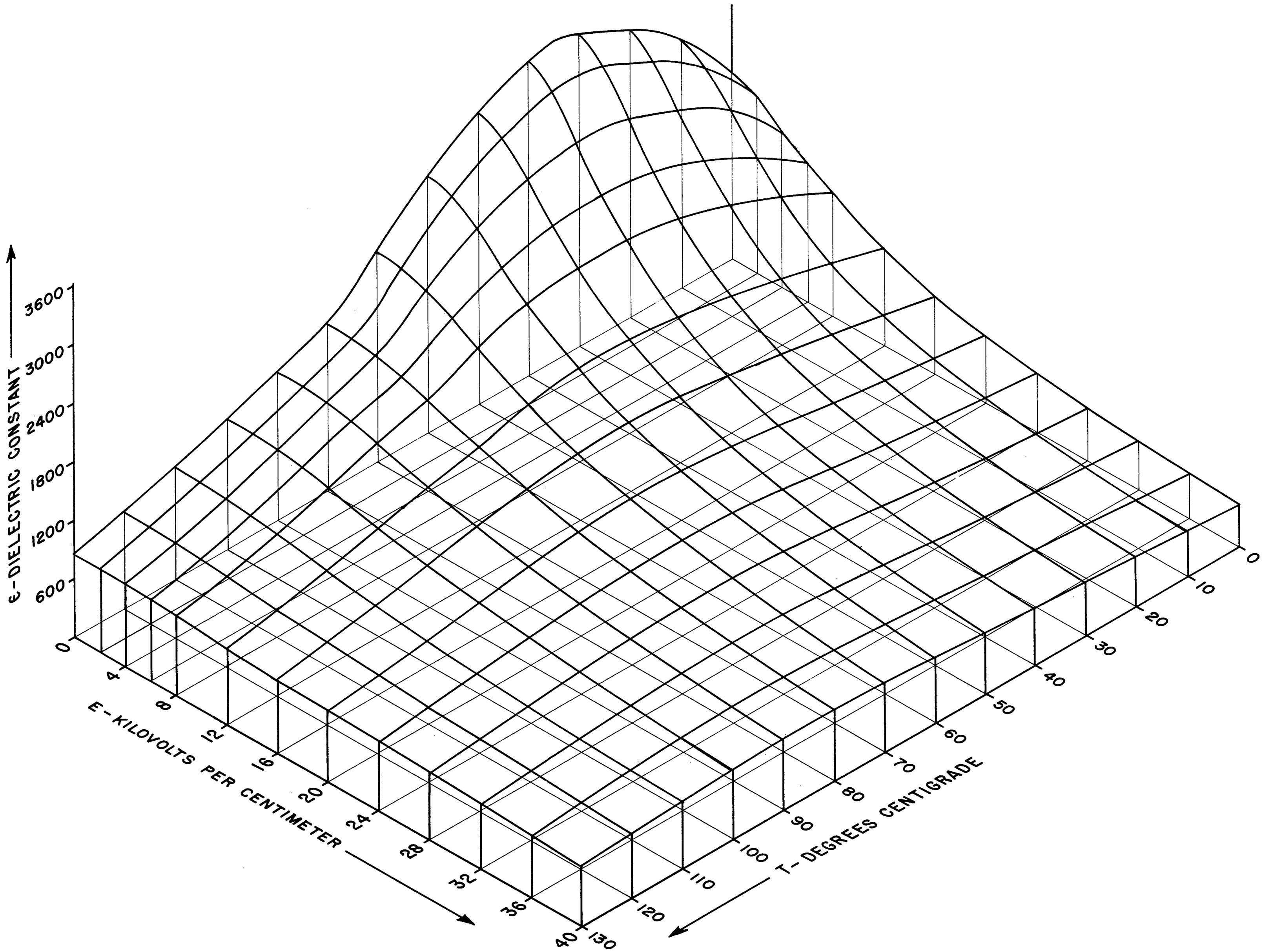


FIG. 1

ε-T-E SURFACE
FOR AEROVOX "HI-Q" 40



2262 C-64-104 AEM 8-12-55

FIG. 2

ε-T-E SURFACE

FOR AEROVOX "HI-Q"41

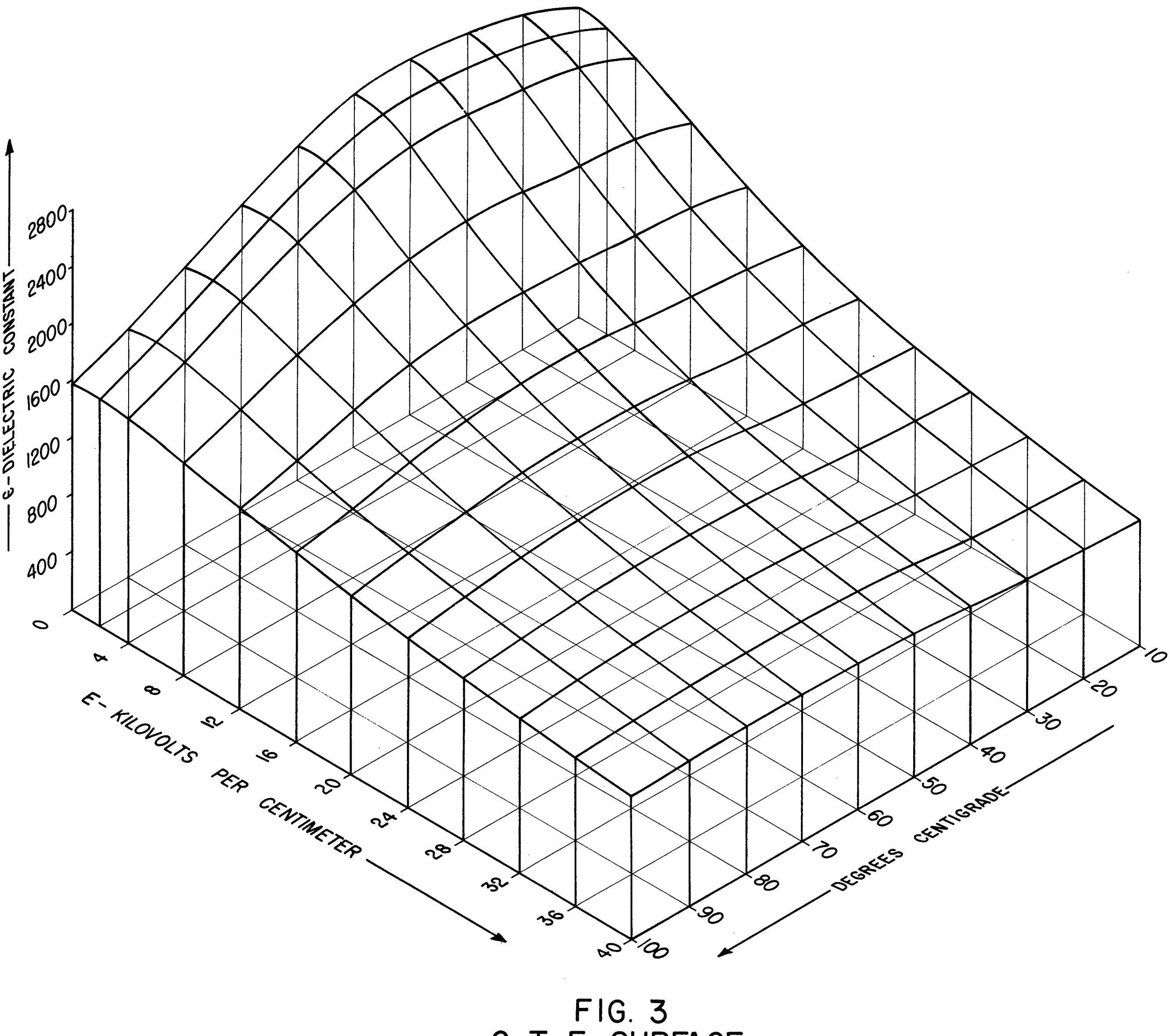


FIG. 3
ϵ-T-E SURFACE
AEROVOX HI-Q 20

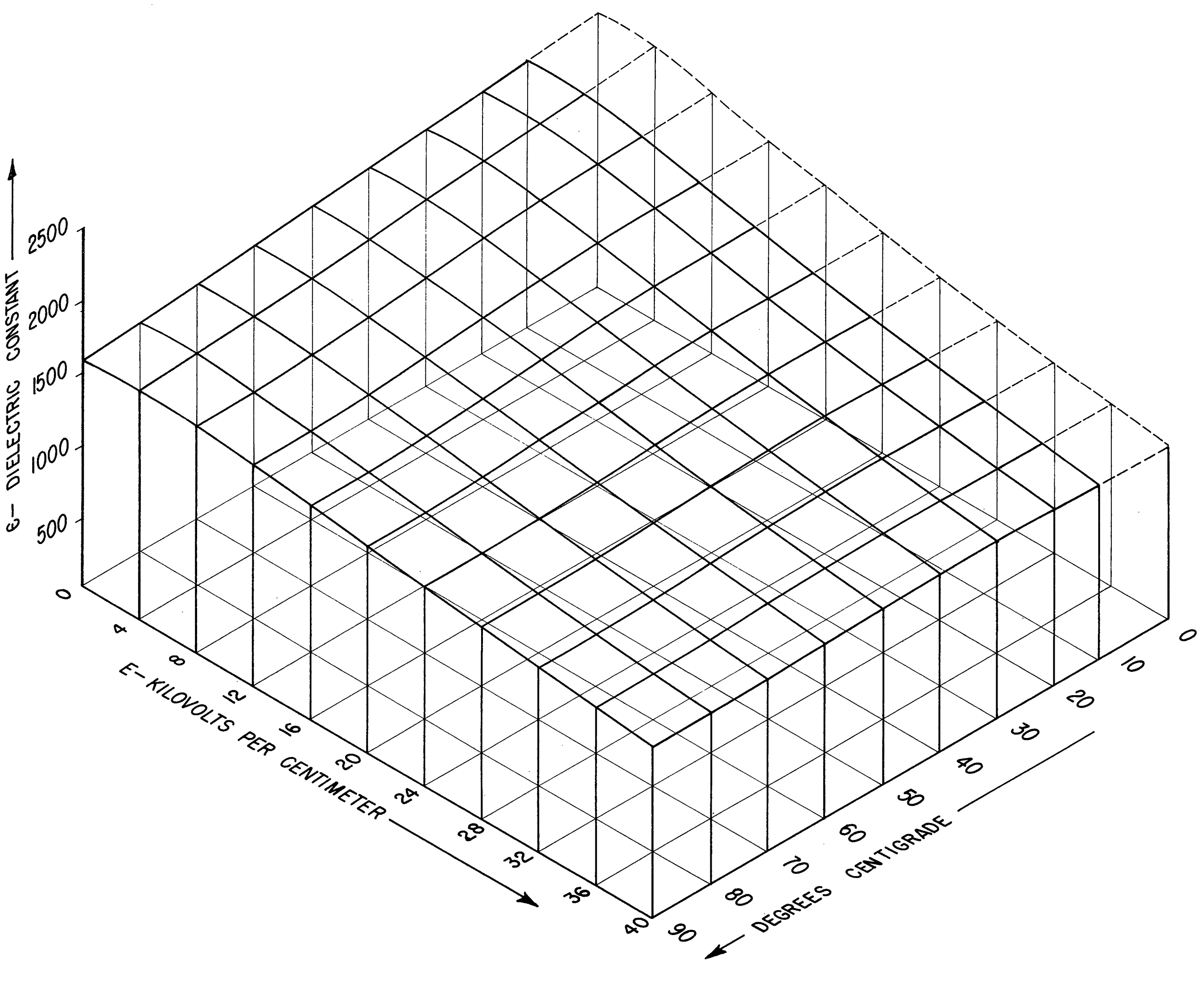


FIG. 4
ε-T-E SURFACE
AEROVOX HI-Q 80

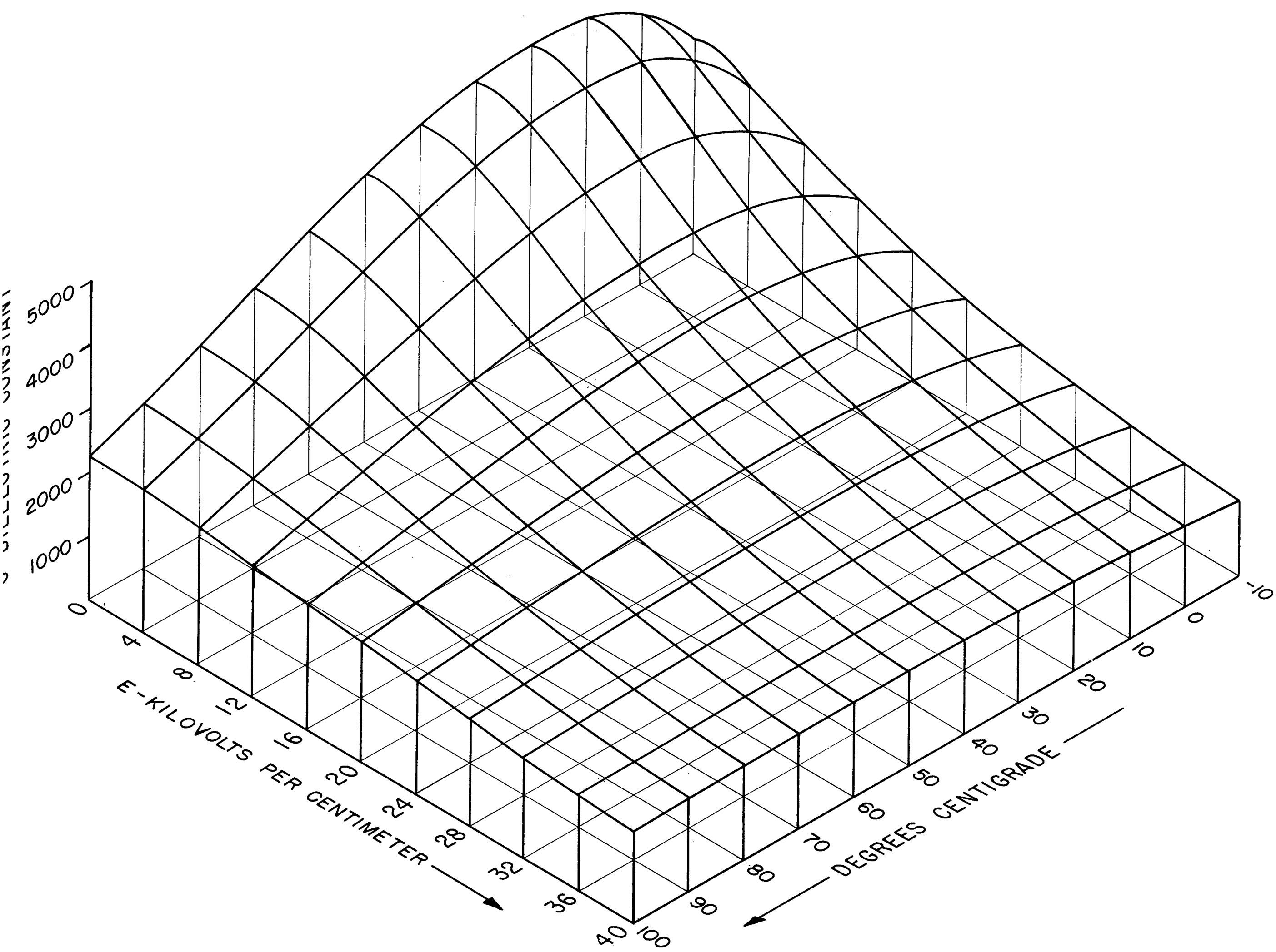


FIG. 5
ϵ-T-E SURFACE
CENTRALAB D-31

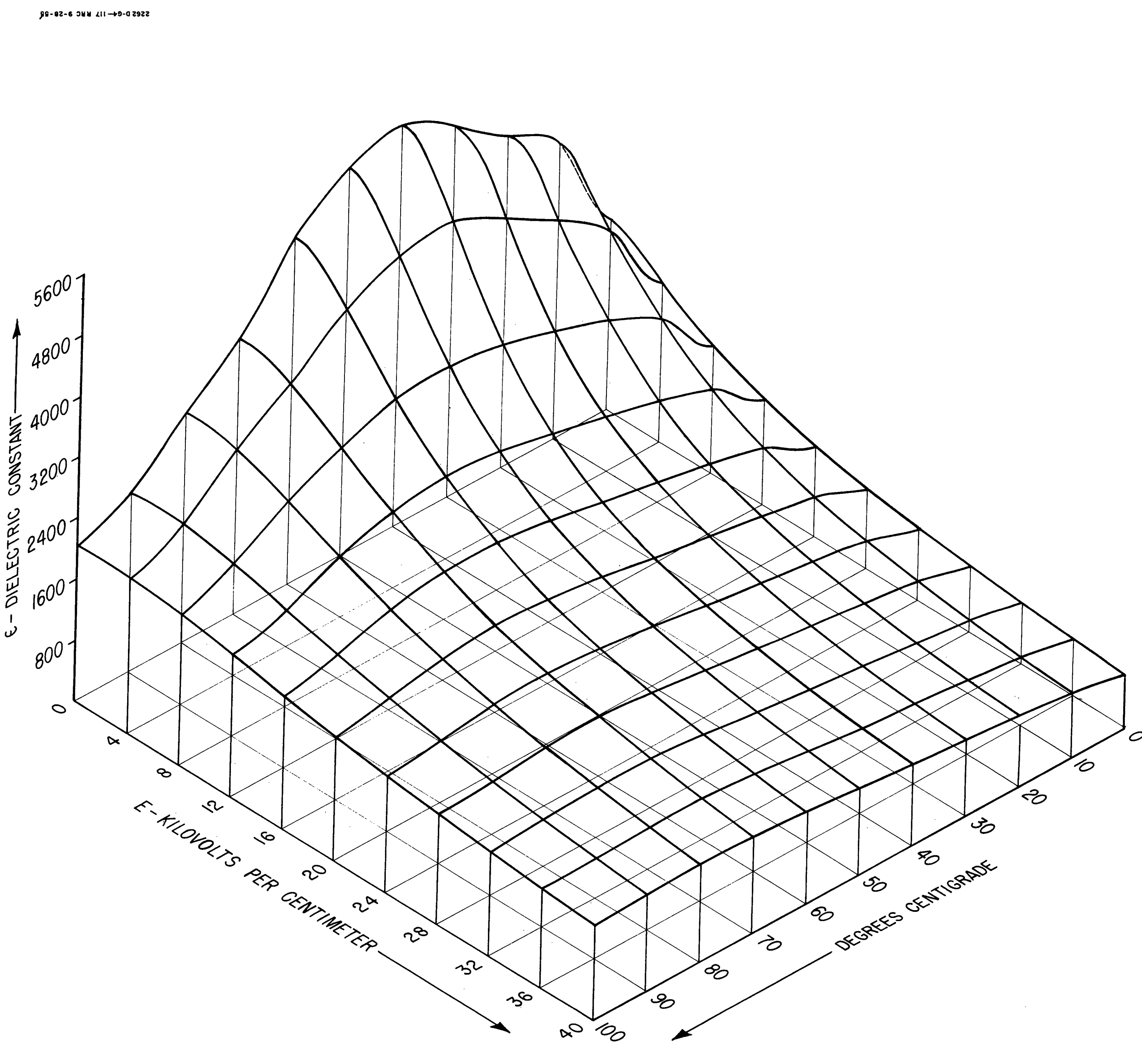


FIG. 6
ϵ-T-E SURFACE
CENTRALAB D-51

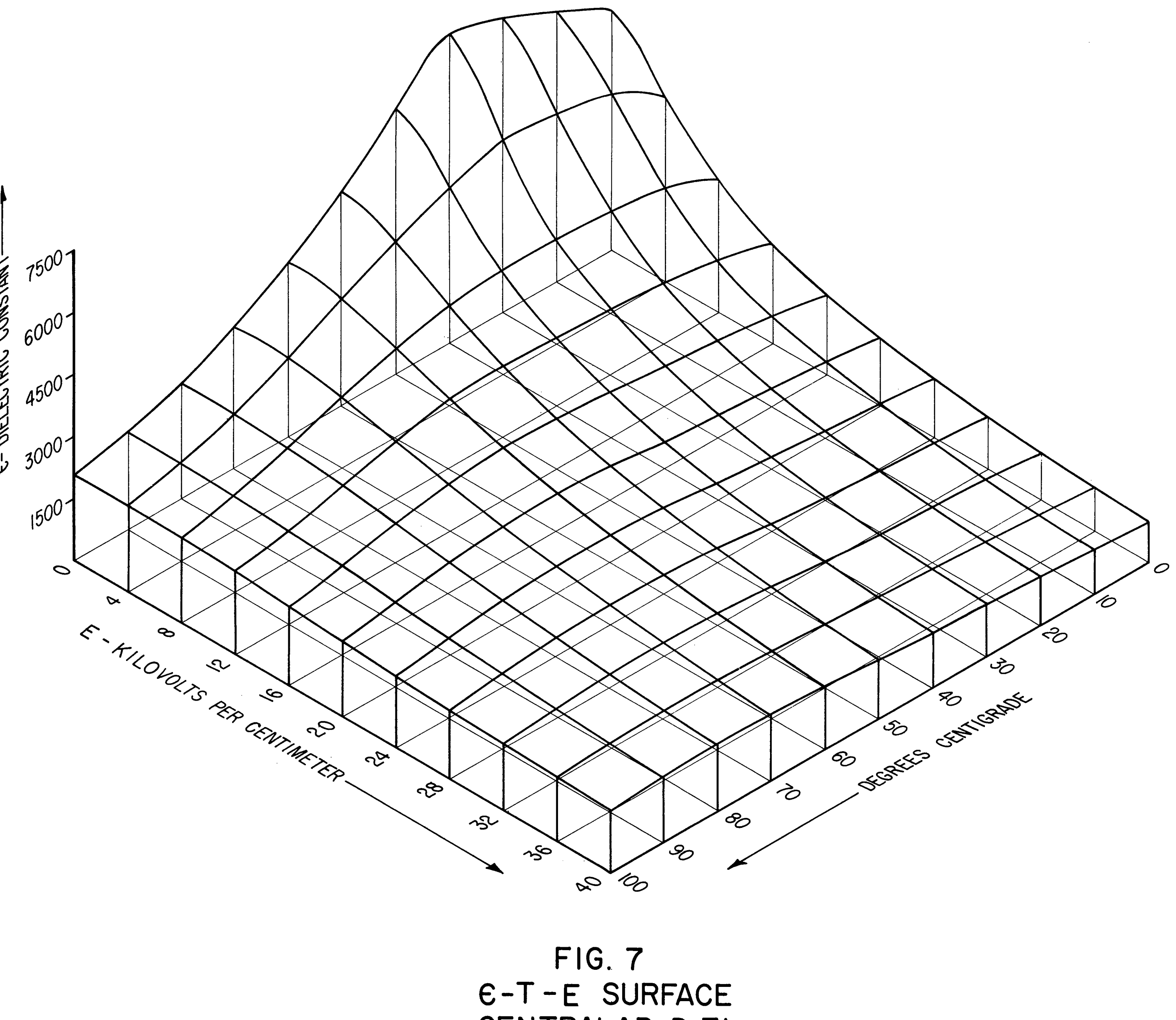


FIG. 7
Є-T-E SURFACE
CENTRALAB D-71

2262 A-64-89 DOB 12-3-54

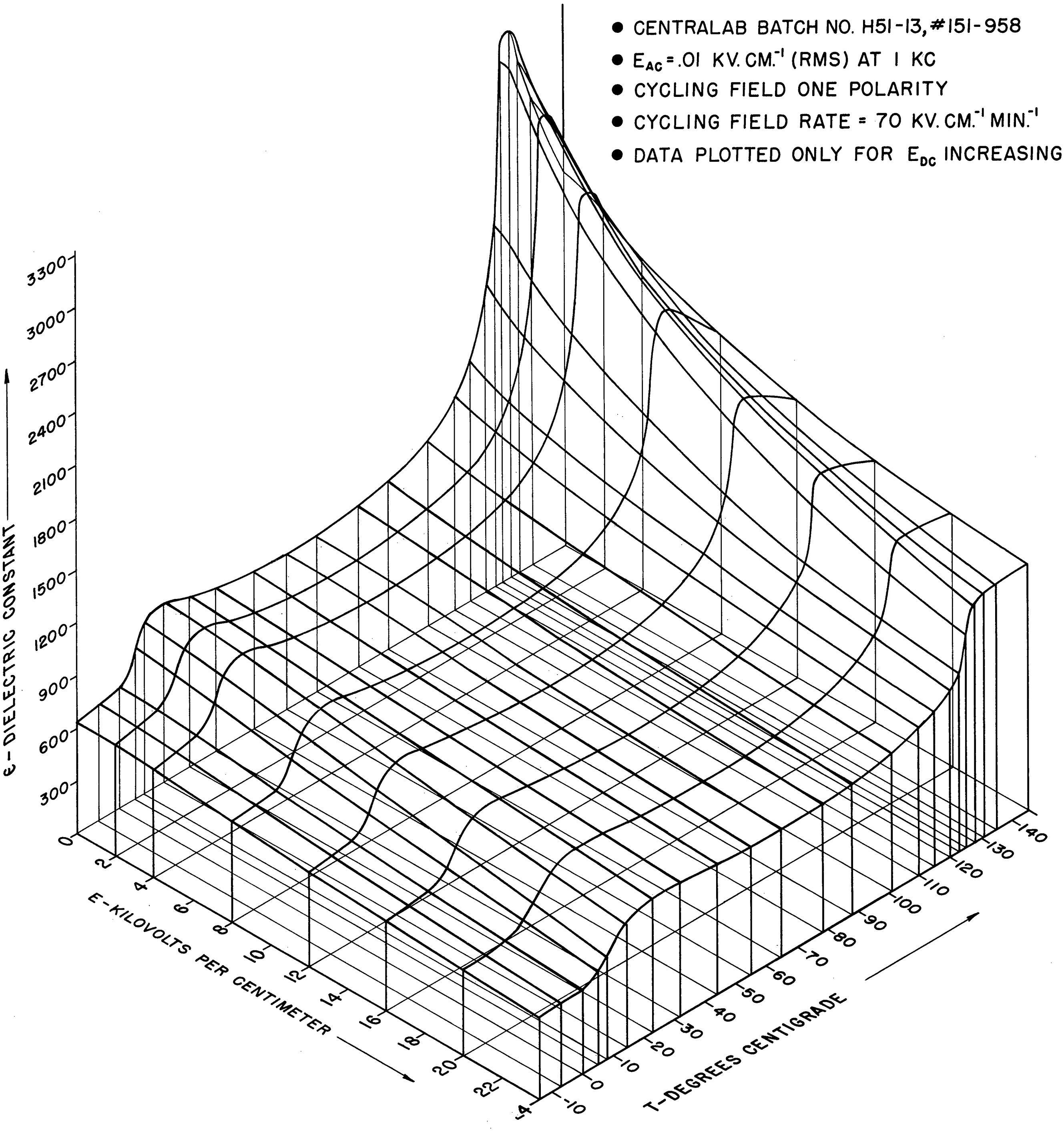


FIG. 8

ϵ-T-E SURFACE

FOR CENTRALAB D-13

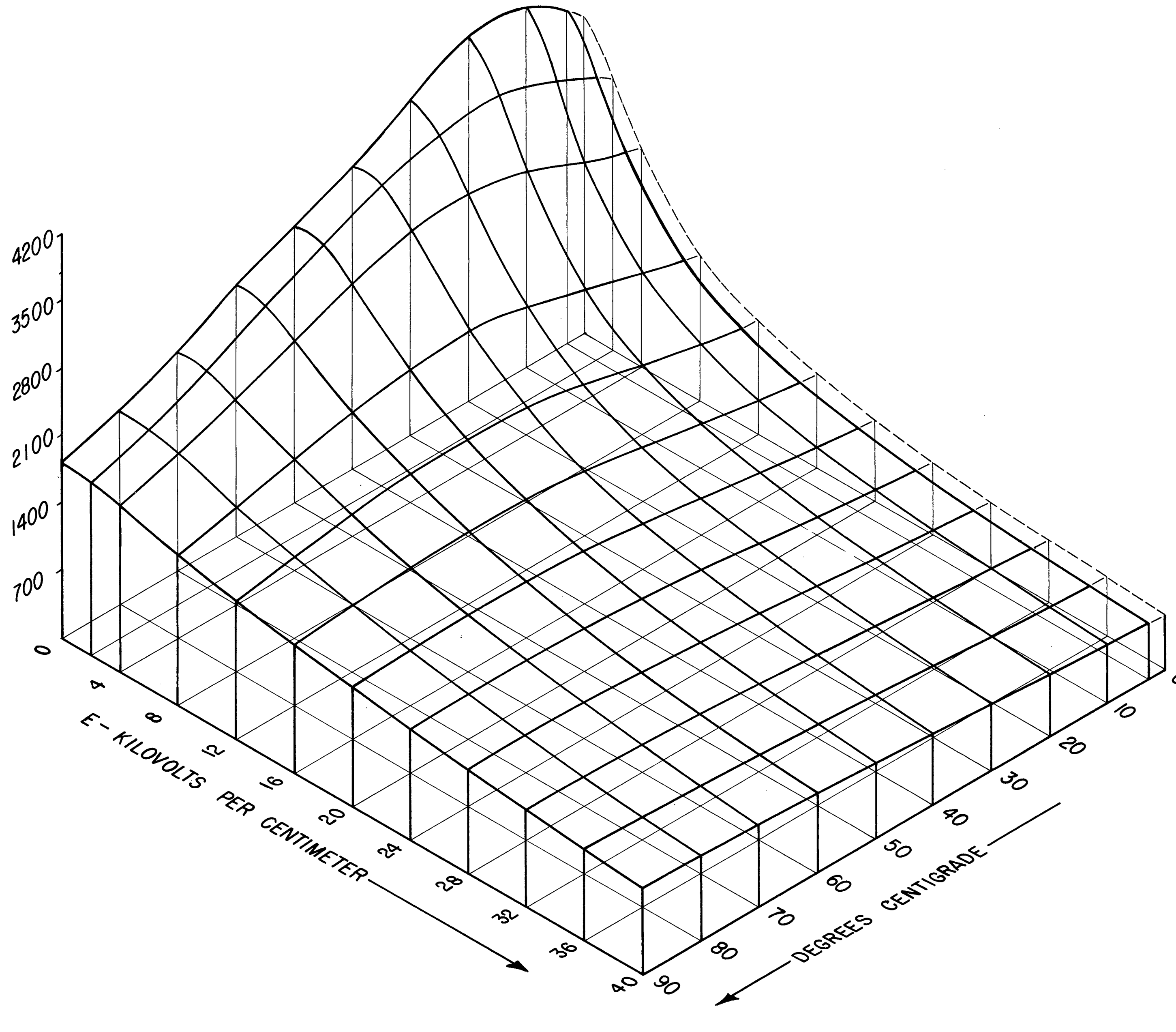


FIG. 9
ϵ-T-E SURFACE
GLENCO 3300 (1953)

2262 D-64-113 RRC 9-28-55

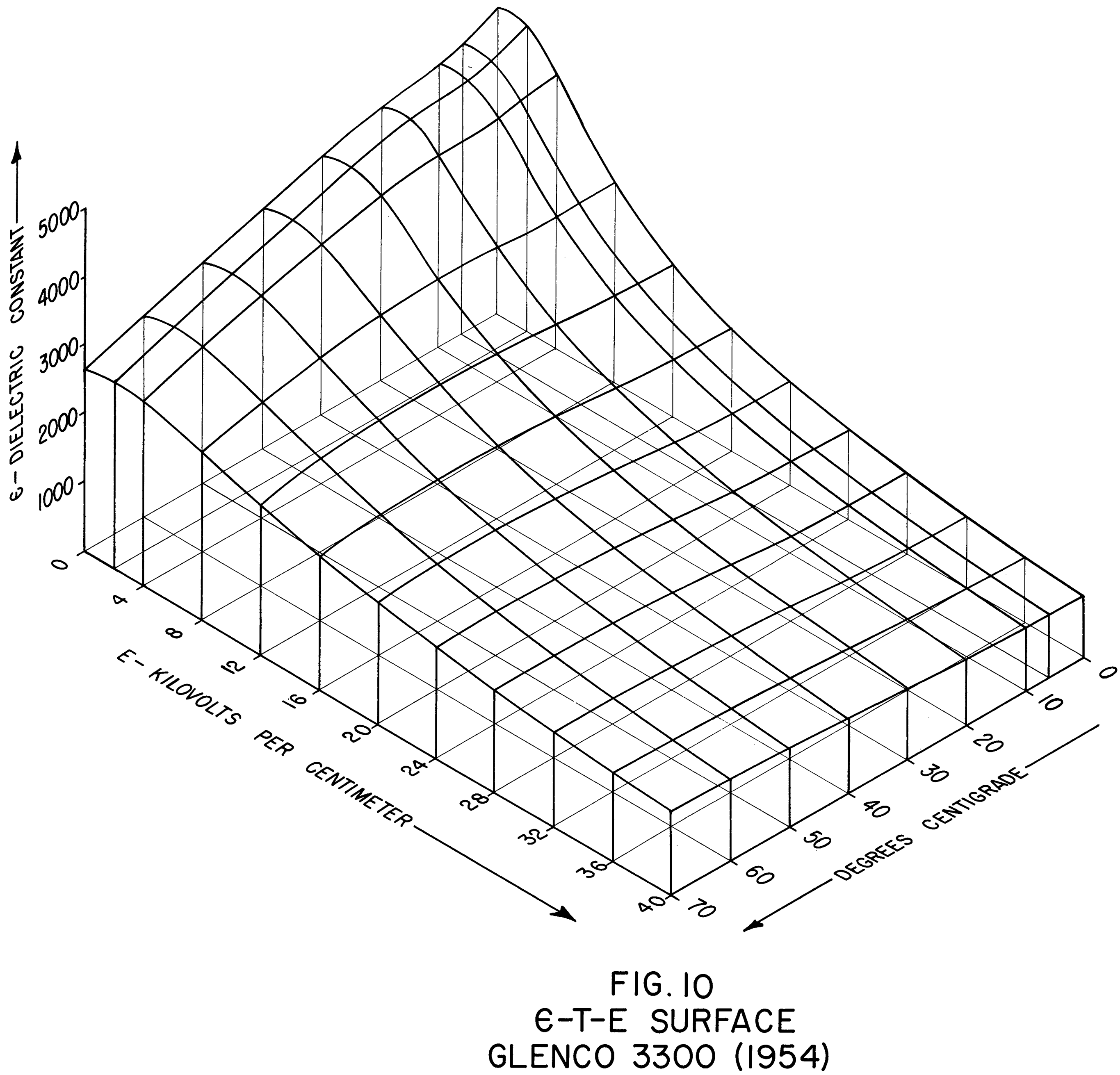


FIG. 10
ε-T-E SURFACE
GLENCO 3300 (1954)

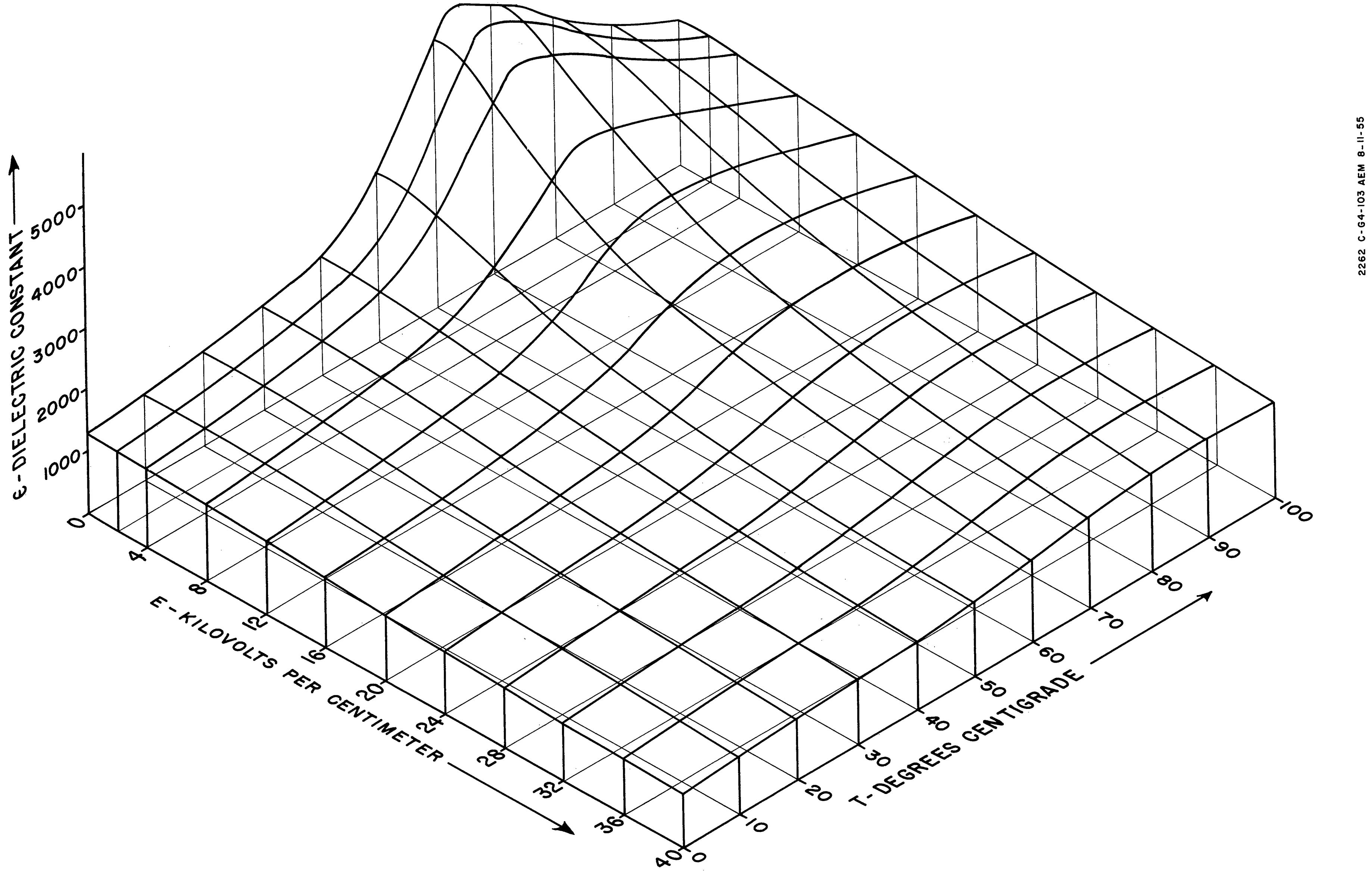


FIG. 11

ϵ-T-E SURFACE
FOR MUCON VSE

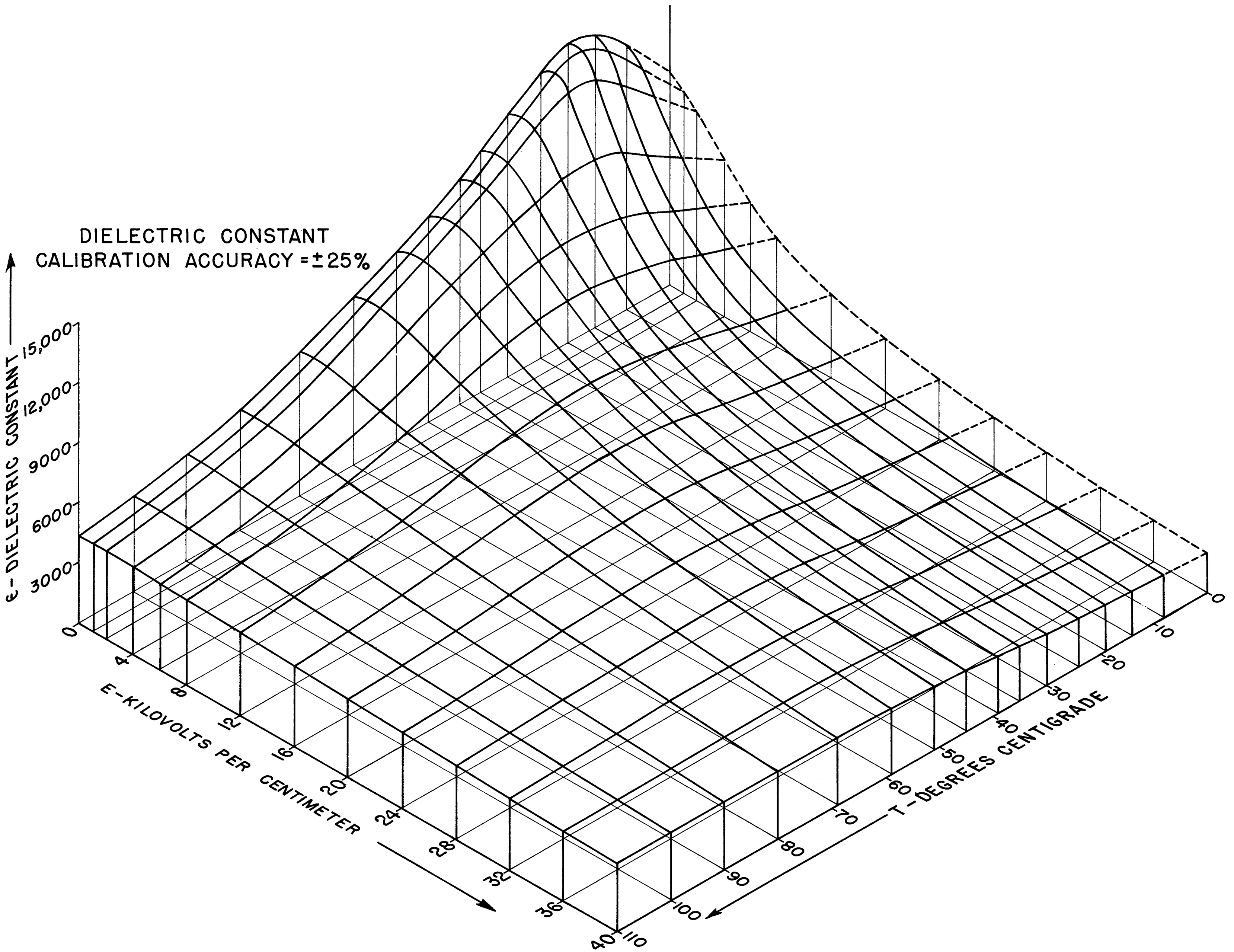


FIG. 12

ϵ-T-E SURFACE

FOR MUCON VSP

2262 D-64-112 RRC 9-28-65

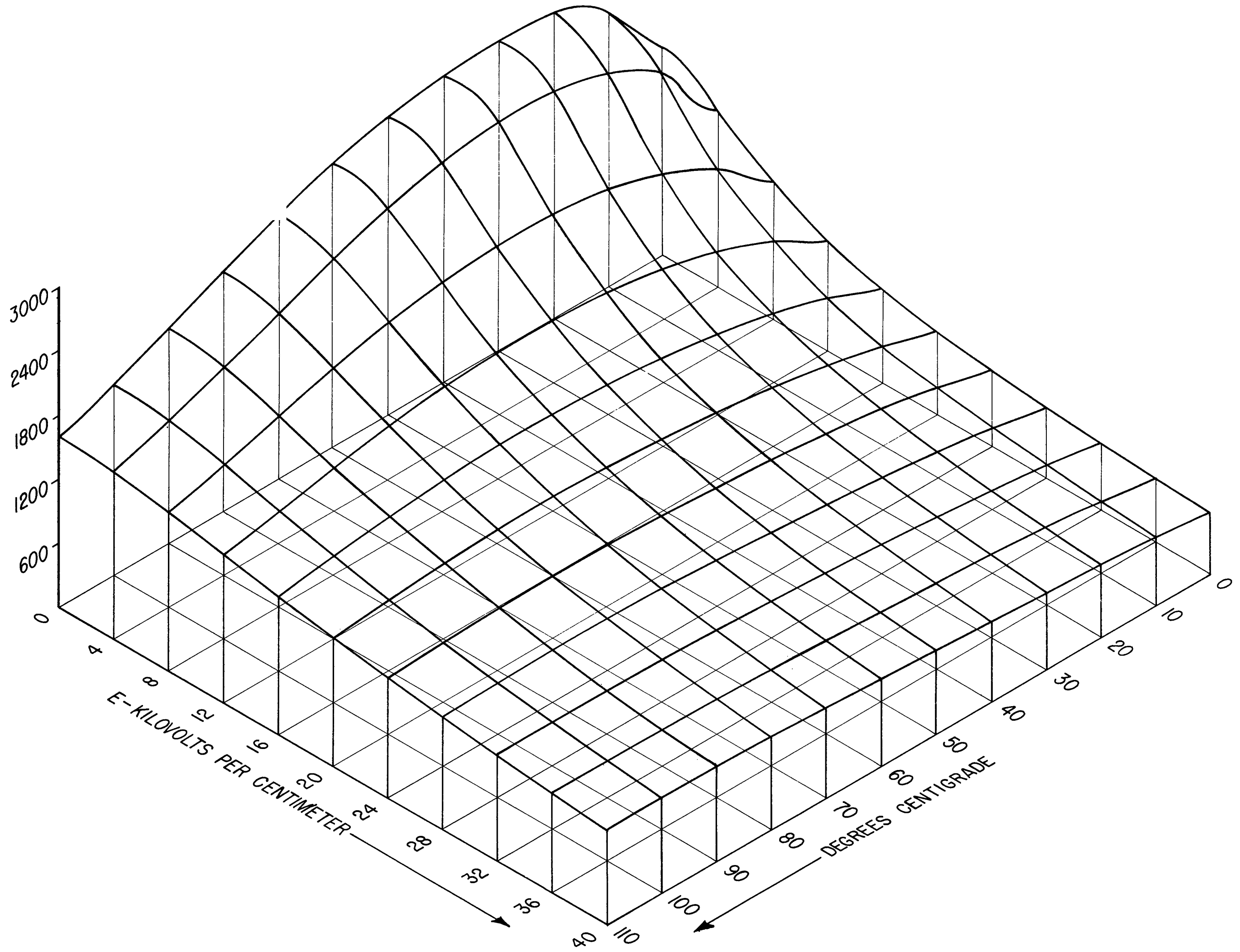


FIG. 13
ϵ-T-E SURFACE
AEROVOX BKC-1

2262 D-G4-125 BM 9-28-55

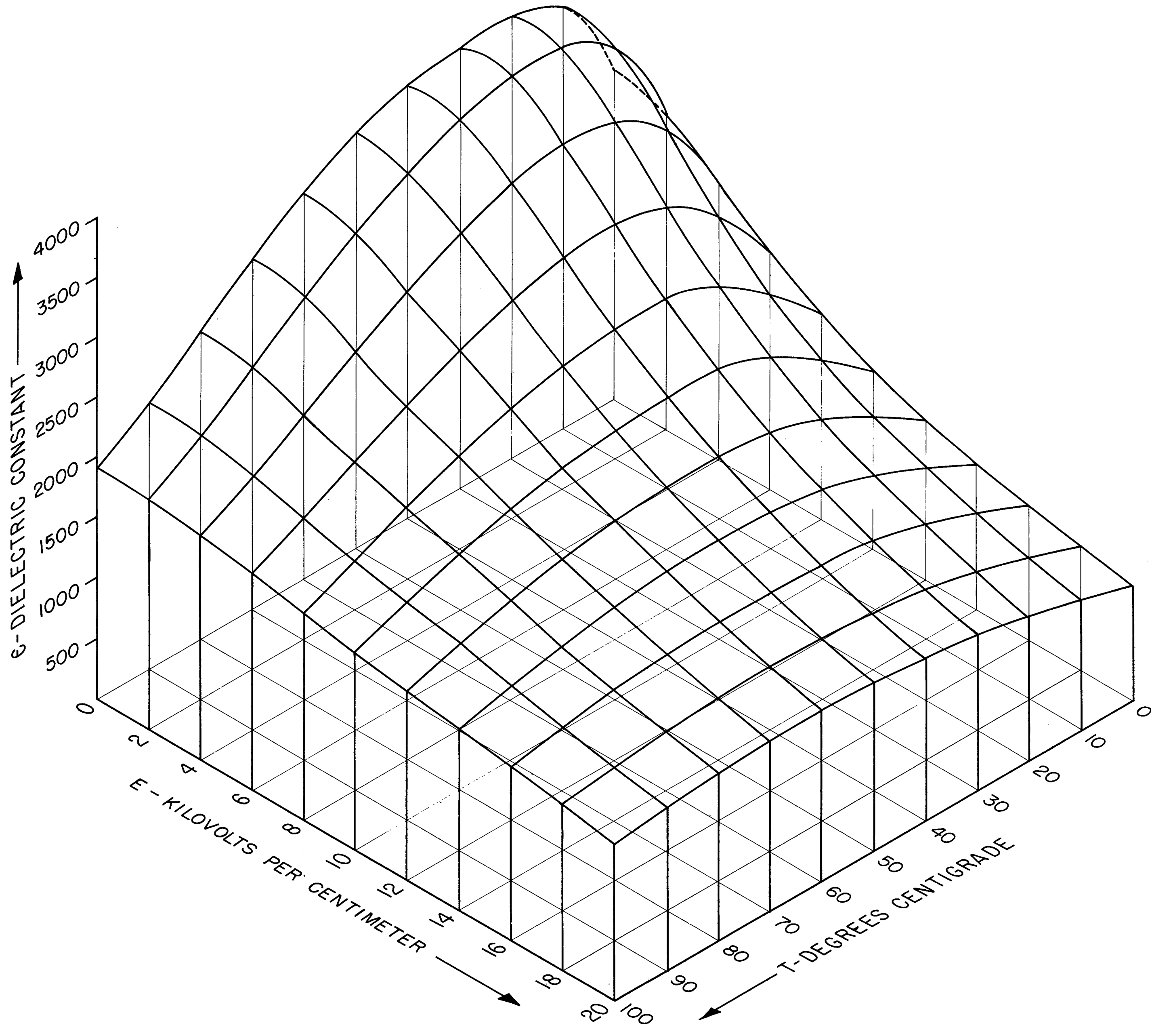


FIG. 14
є-T-E SURFACE
AEROVOX BK-PC

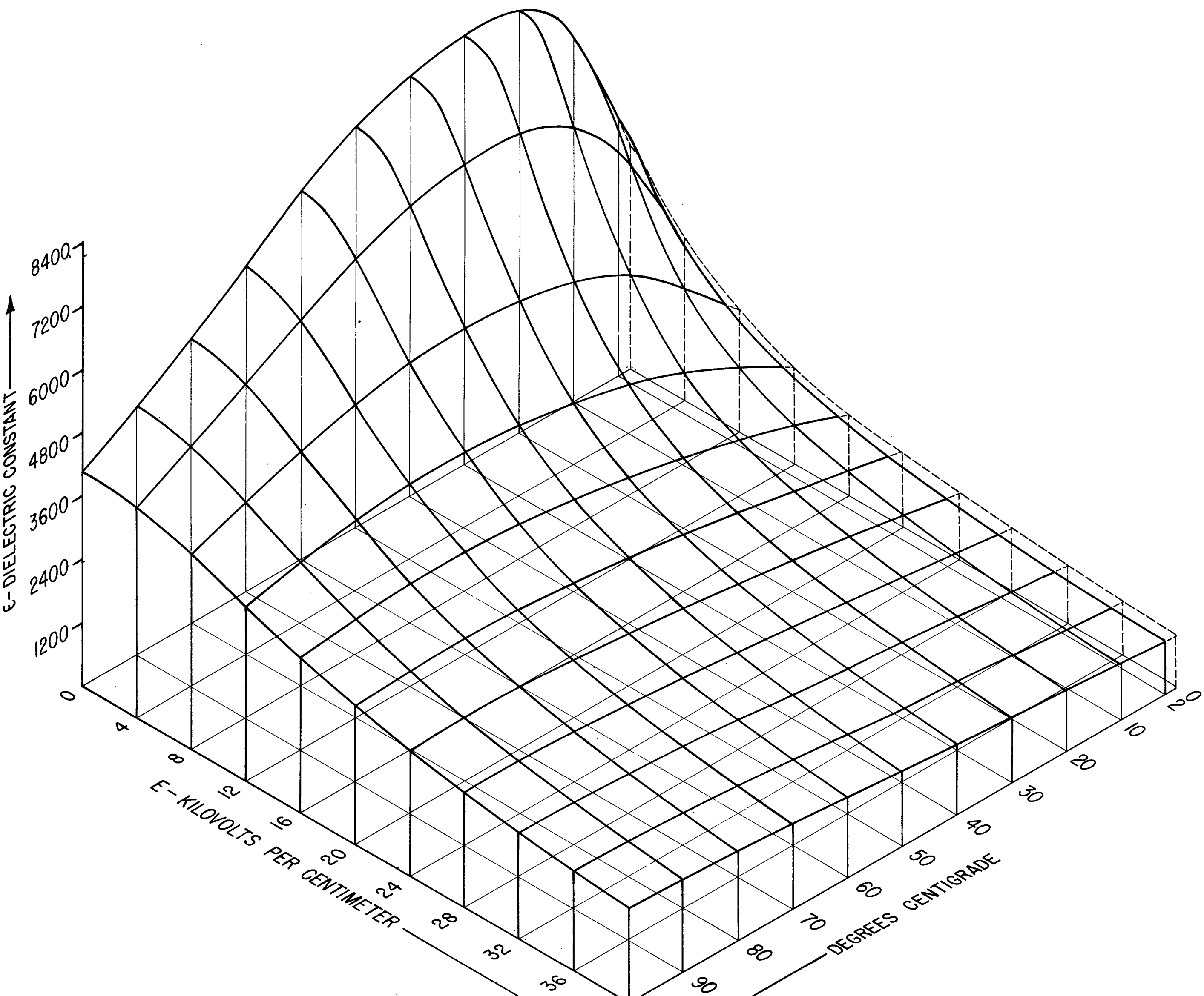


FIG. 15
ϵ-T-E SURFACE
AEROVOX BKP 1A

2262D-64-116 RRC 9-28-58

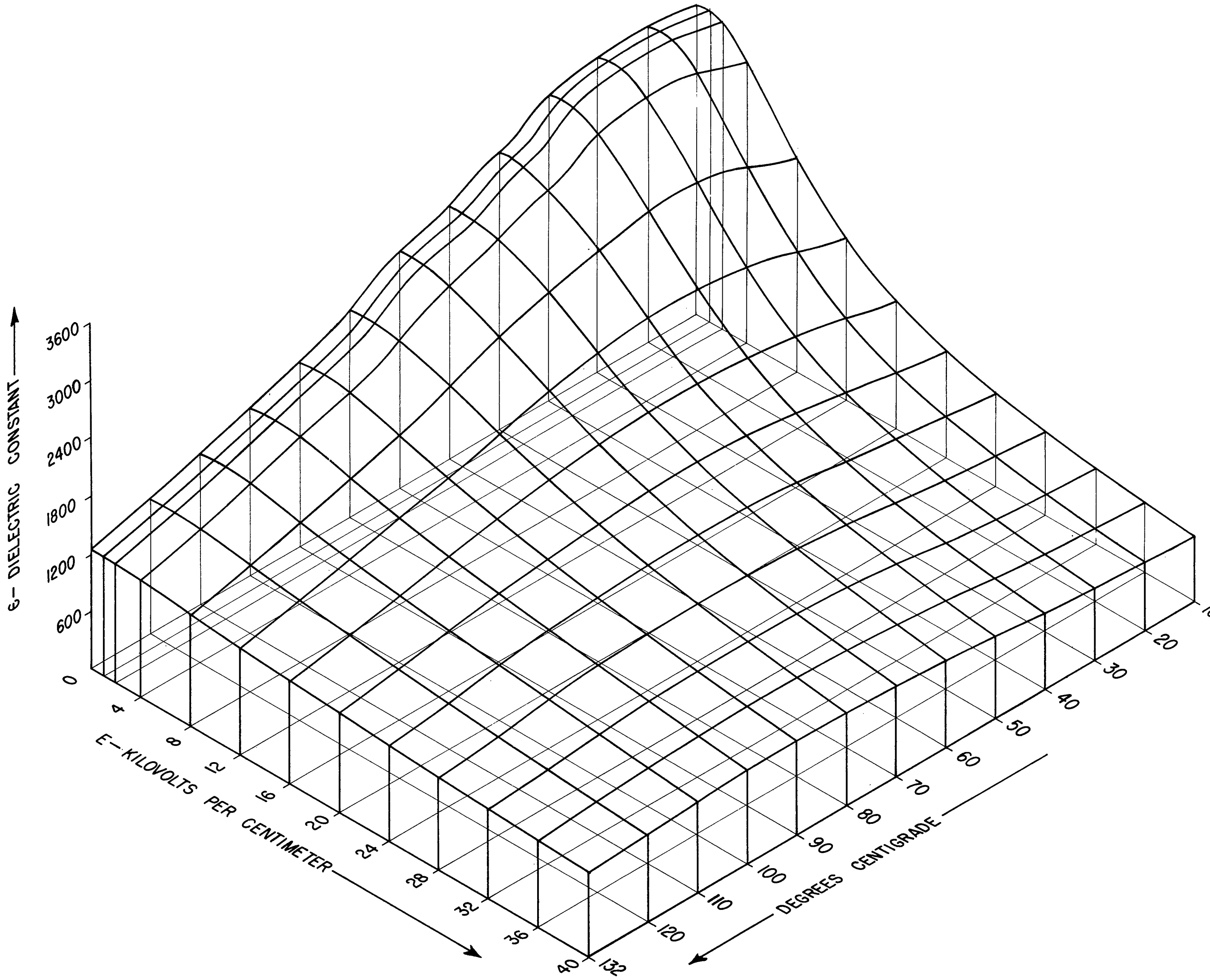


FIG. 16
ε-T-E SURFACE
AEROVOX B1K-50

2262 D-64-102 AEM 8-10-55

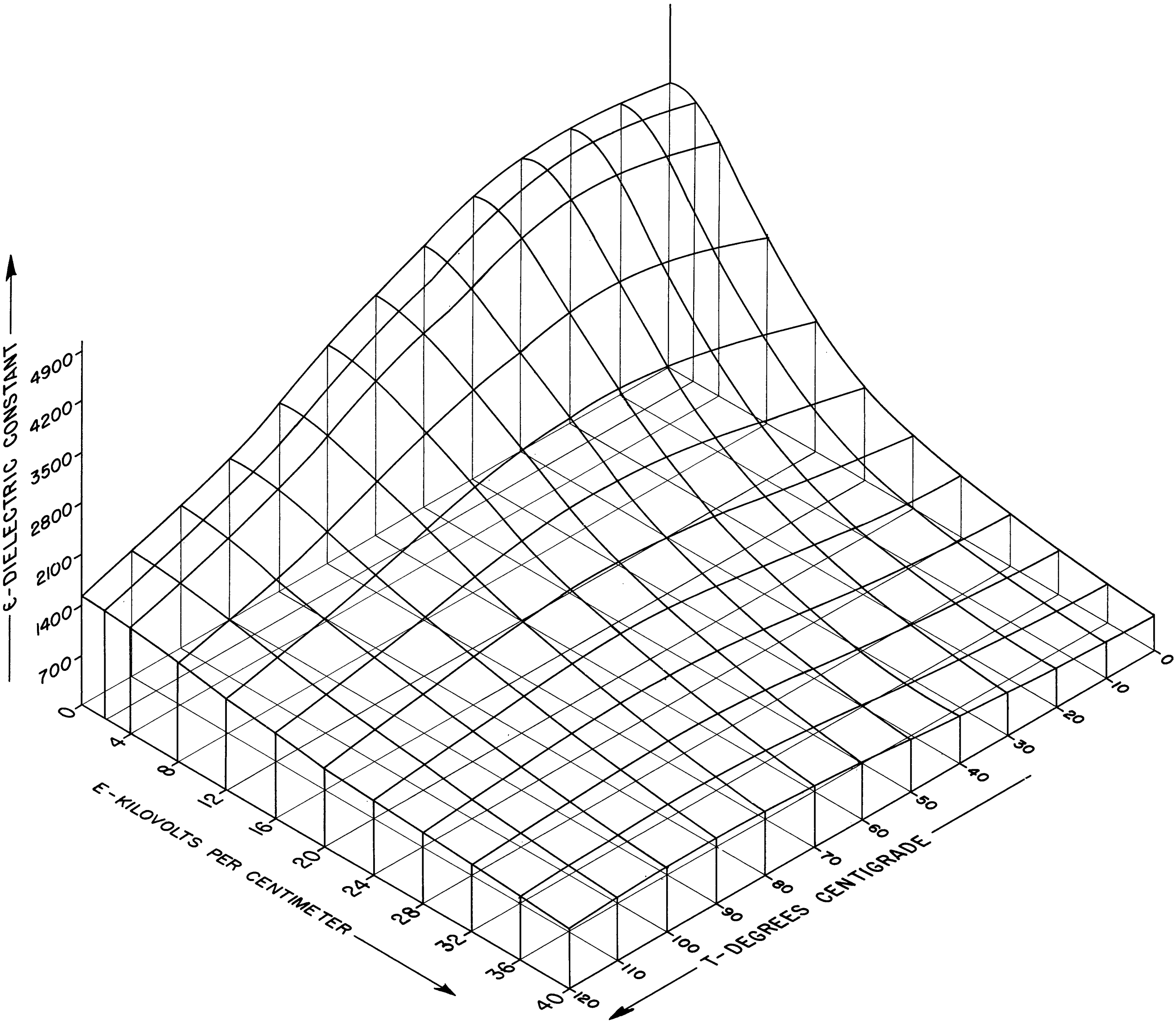


FIG. 17
ϵ-T-E SURFACE
FOR AEROVOX B_2 K45

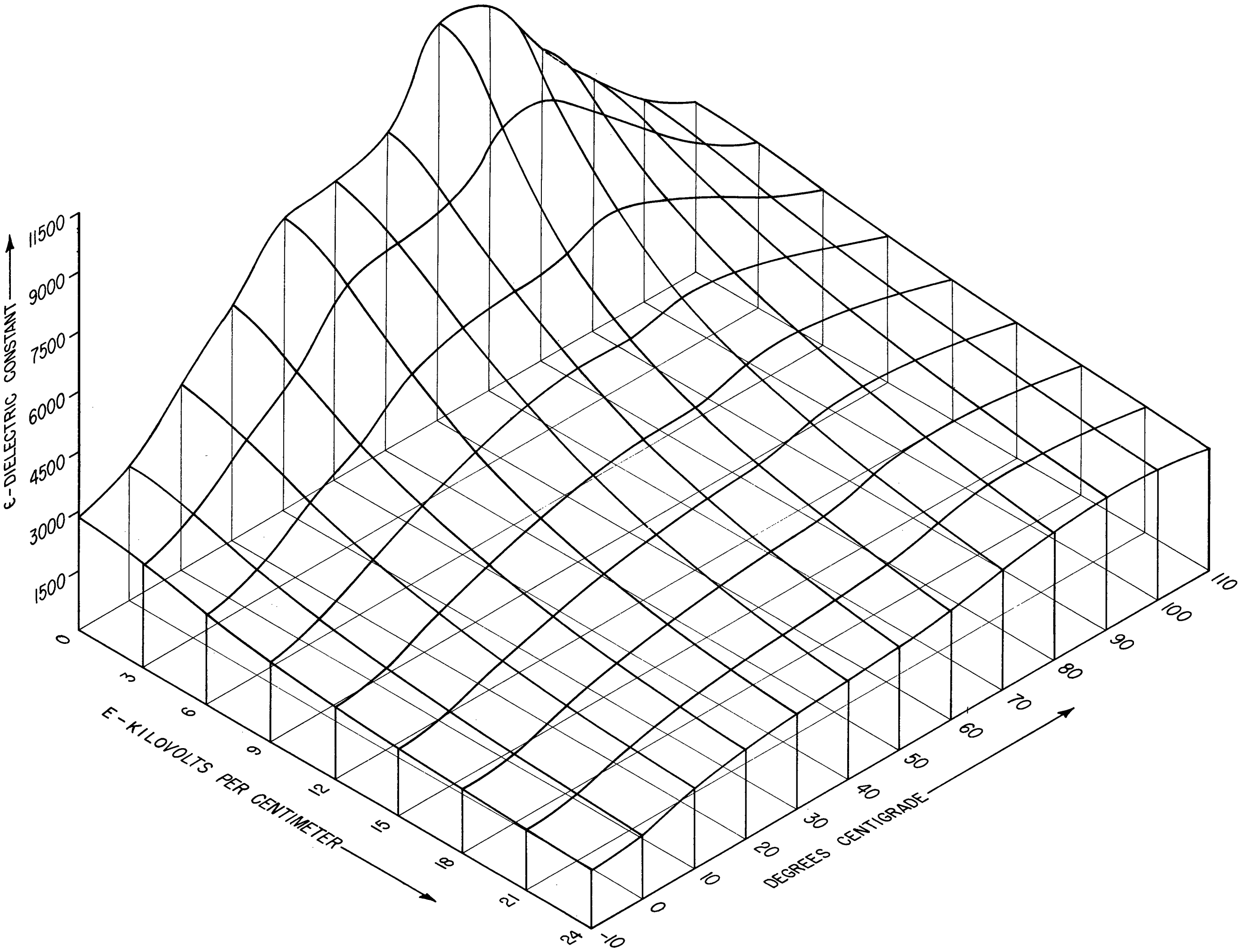


FIG. 18
ϵ-T-E SURFACE
GENERAL ELECTRIC 69ER

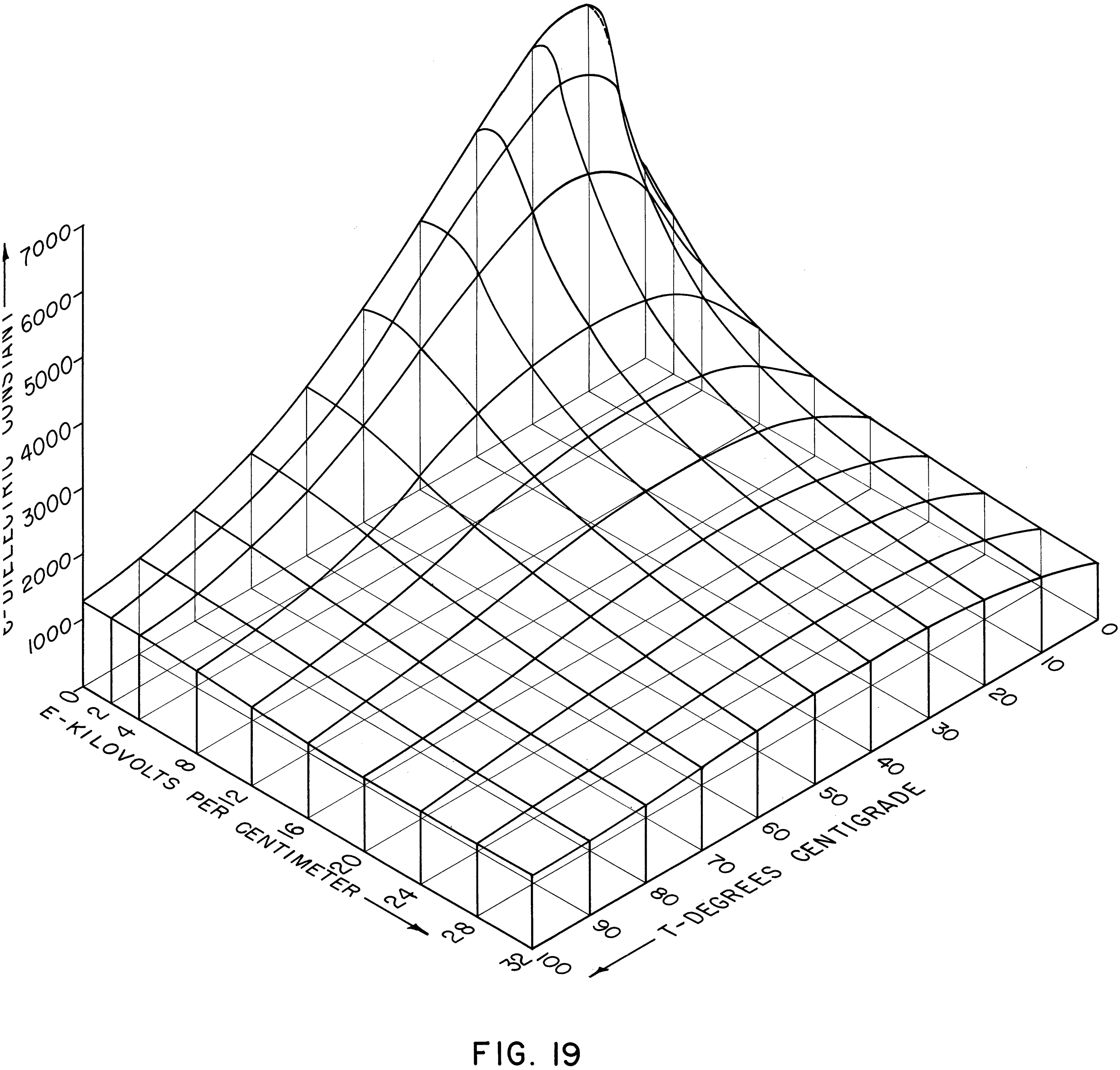


FIG. 19
ε-T-E SURFACE
GENERAL ELECTRIC 71-ER

2262 D-64-126 RRC 9 19 55

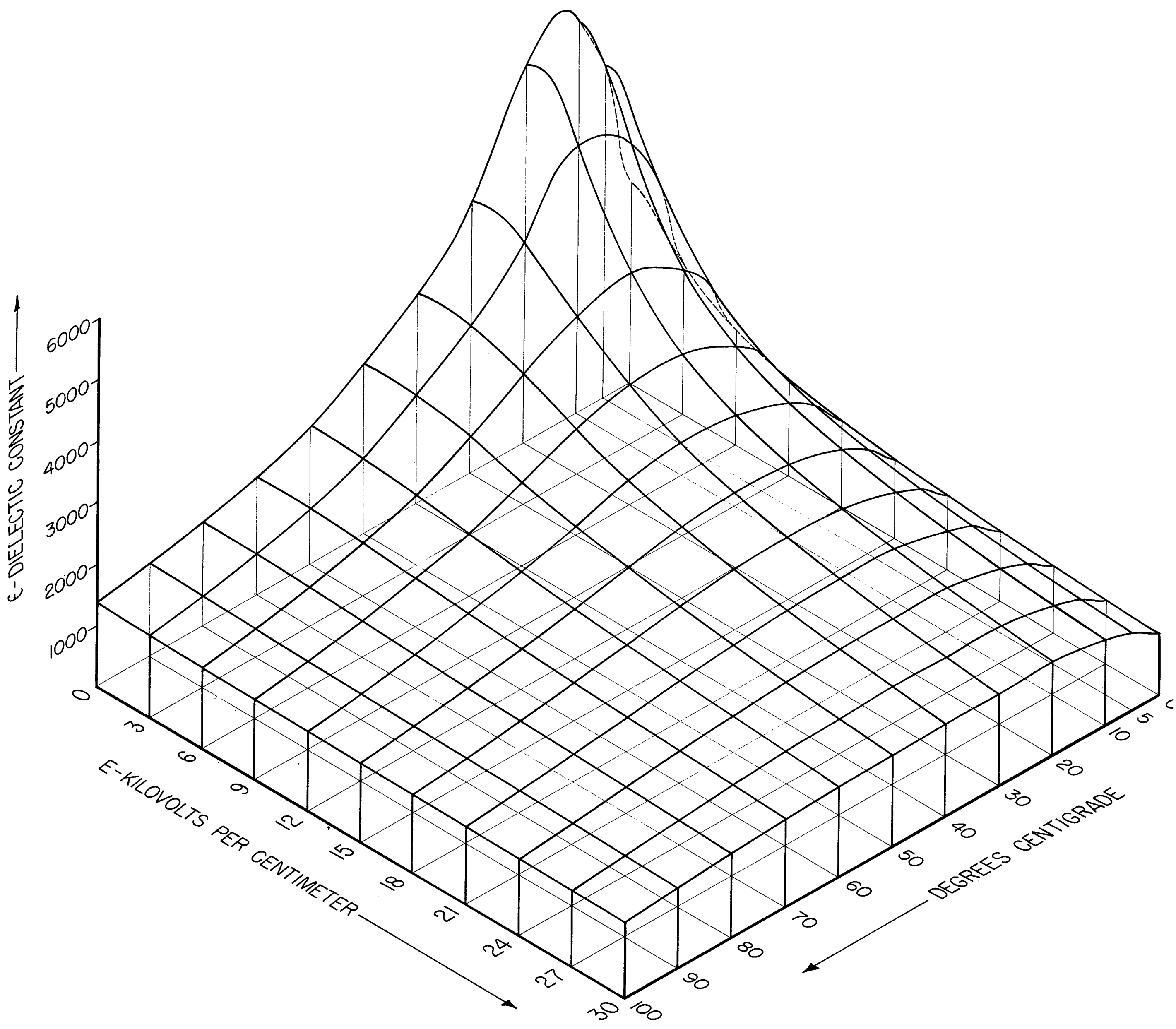


FIG. 20

Є-T-E SURFACE
GENERAL ELECTRIC 213ER

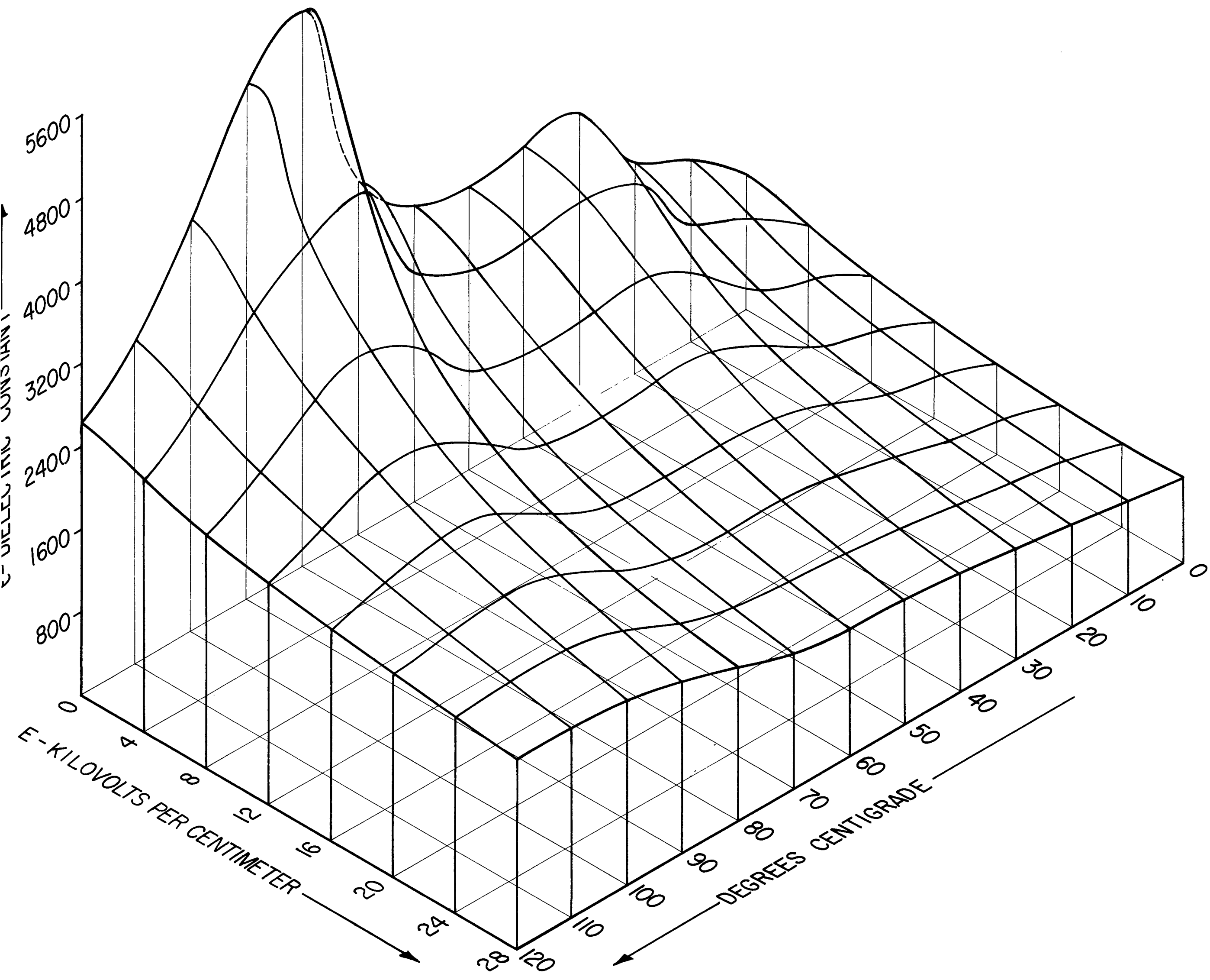


FIG. 21
ϵ-T-E SURFACE
FOR GENERAL ELECTRIC 214ER

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