MOTOROLA · Government Electronics Division

NASA CR 92424

REPORT

25 November 1966

CONTRACT NAS9-4468

FINAL REPORT FOR

MICROMINIATURE HIGH LEVEL MULTICODER

PROJECT 3114

MOTOROLA INC.

Government Electronics Division · Aerospace Center

8201 E. McDOWELL ROAD, SCOTTSDALE, ARIZONA 85252

I. SCOPE

This final report for the Microminiature High Level Multicoder contains a reliability analysis, summary of results, and conclusions and recommendations.

II. RELIABILITY ANALYSIS

A reliability analysis for the Microminiature High Level Multicoder follows. The analysis is based upon

a) The failure rates established by Motorola's Reliability and Components Group apply, and their analysis methods are used. These rates and methods are listed and described in Special Memorandum No. 188, dated September 1, 1965 (a copy is included with this report).

b) All parts have some degree of screening.

Failure rates are computed for both 80°F and +160°F, the maximum operating temperature of the equipment, and are in percent per 1000 hours.

The Multicoder consists of the following electronic parts and subassemblies.

5	Differential Amplifier	(Multichip)
5	Diff. Ampl. Output Buffer	"
2	PDM and DPDM Driver	"
1	3.6 kc Oscillator	"
1	Sequencer Bias	"
1	Encoding Control Switch	"
10	Sequencer	"
20	Multiplexer Switches	"
5	Multiplexer Sub switches	"
6	Flip-flop, Series 51	Monolithic
23	Gate, Series 51	"
20	Diode	Silicon
2	Diode	Zener
1	Diode	Germanium

3 Transistor	Silicon
62 Resistor	Carbon Composition
7 Resistor	Precision Wire Wound
32 Capacitor	Ceramic
4 Capacitor	Mica
13 Capacitor	Solid Tantalum
5 Inductor	R.F.
1 Transformer	Pulse
163 Pins & Sockets	Internal
1 Connector	100 Pins

For each part, or subassembly type, a total failure rate is computed in percent per thousand hours, based on its basic individual rate, (including complexity considerations) as modified by screening information, and finally multiplied by the appropriate quantity.

The total sum of those elements is then taken as the Multicoder failure rate, and a mean time between failures is computed from that rate.

Part or Subassembly	Failure Rates, %/1000 hrs +80°F	+160°F	Quantity	Comments
Diff. Amp.	0.007	0.07	5	Basic rate, 2-2stage ampl. complexity
	0.035	0.35		X5 for multichip
	0.0035	0.035		X0.1 for screening
Net	0.0175	0.175		X5 for quantity

Part or Subassembly	Failure Rates, %/1000 hrs +80°F	+160°F	Quantity	Comments
D.A.O.B.	0.0035	0.035	5	Basic rate, 1-2 stage amp. complexity
	0.0175	0.175		X5 for multichip
	0.00175	0.0175		X0.1 for screening
Net	0.00875	0.0875		X5 for quantity
PDM & DPDM	0.005	0.05	2	Basic rate, 1-1/2-2 stage amp. complexity
	0.025	0.25		X5 for multichip
	0.0025	0.025		X0.1 for screening
Net	0.005	0.05		X2 for quantity
3.6kc Osc.	0.0035	0.035	1	Basic rate, 1-2 stage amp. complexity
	0.0175	0.175		X5 for multichip
	0.00175	0.0175		X0.1 for screening
Net	0.00175	0.0175		X1 for quantity
Seq. Bias	0.002	0.02	1	Basic rate, 1/2-2 stage amp. complexity
	0.01	0.1		X5 for multichip
	0.001	0.01		X0.1 for screening
Net	0.001	0.01		X1 for quantity
Enc. Control Switch	0.007	0.070	1	Basic rate, 2-2 stage amp. complexity
	0.035	0.35		X5 for multichip
	0.0035	0.035		X0.1 for screening
Net	0.0035	0.035		X1 for quantity

Part or Subassembly	Failure Rates, %/1000 hrs +80°F	+160°F	Quantity	Comments
Sequencer	0.0035	0.035	10	Basic rate, 1-2 stage amp. complexity
	0.0175	0.175		X5 for multichip
	0.00175	0.0175		X0.1 for screening
Net	0.0175	0.175		X10 for quantity
Multiplexer Switch	0.007	0.07	20	Basic rate, 2-2 stage amp. complexity
	0.035	0.35		X5 for multichip
	0.0035	0.035		X0.1 for screening
Net	0.07	0.7		X20 for quantity
Multiplexer Sub switches	0.007	0.07	5	Basic rate, 2-2 stage amp. complexity
	0.035	0.35		X5 for multichip
	0.0035	0.035		X0.1 for screening
Net	0.0175	0.175		X5 for quantity
Flip-flop	0.0035	0.035	6	Basic rate, 1-2 stage amp. complexity
	0.00035	0.0035		X0.1 for screening
	0.00018	0.0018		X0.5 for digital
Net	0.00108	0.0108		X6 for quantity
Gate	0.002	0.02	23	Basic rate, 1/2-2 stage amp. complexity
	0.0002	0.002		X0.1 for screening
	0.0001	0.001		X0.5 for digital
Net	0.0023	0.023		X23 for quantity

Part or Subassembly	Failure Rates, %/1000 hrs +80°F	+160°F	Quantity	Comments
Diode	0.0001	0.001	20	Basic rate, silicon
	0.0002	0.002		X2 for voltage factor
	0.00002	0.0002		X0.1 for screening
Net	0.002	0.004		X20 for quantity, and minimum rate of 0.0001
Diode	0.001	0.001	2	Basic Rate, silicon
	0.01	0.01		X10 for zeners
	0.001	0.001		X0.1 for screening
Net	0.002	0.002		X2 for quantity
Diode	0.0001	0.005	1	Basic rate, germanium
	0.0002	0.01		X2 for voltage factor
	0.00002	0.001		X0.1 for screening
Net	0.0001	0.001		X1 for quantity, and minimum rate of 0.0001
Transistor	0.0002	0.002	3	Basic rate, silicon
	0.001	0.01		X5 for voltage factor
	0.0001	0.001		X0.1 for screening
Net	0.0003	0.003		X3 for quantity
Resistor	0.00001	0.00001	62	Basic rate, carbon composition
Net	0.00062	0.00062		X62 for quantity
Resistor	0.1	0.1	7	Basic rate, wire wound
	0.004	0.004		X0.04 for screening (approximate)
Net	0.03	0.03		X7 for quantity

Part or Subassembly	Failure Rates, %/1000 hrs +80°F	+160°F	Quantity	Comments
Capacitor	0.01	0.02	32	Basic rate, ceramic, 30% rated voltage
	0.005	0.01		X0.5 for screening
Net	0.16	0.32		X32 for quantity
Capacitor	0.00008	0.00008	4	Basic rate, Mica
Net	0.00032	0.00032		X4 for quantity
Capacitor	0.0025	0.005	13	Basic rate, solid tantalum, 30% rated voltage
	0.0005	0.001		X0.2 for screening
Net	0.013	0.013		X13 for quantity and minimum rate of 0.001
Inductor	0.005	0.005	5	Basic rate, R.F.
	0.0025	0.0025		X0.5 for screening
Net	0.0125	0.0125		X5 for quantity
Transformer	0.1	0.1	1	Basic rate, pulse
	0.05	0.05		X0.5 for screening
Net	0.05	0.05		X1 for quantity
Pins and Socket	0.0015	0.0015	163	Basic rate, internal, estimated
Net	0.2445	0.2445		X163 for quantity
Connector	0.1	0.1	1	100 pins, basic rate per contact of 0.001 estimated.
Net	0.1	0.1		X1 for quantity

Summing all these failure rates gives

0.76122 %/1000 hours at +80°F, and

2.23974 %/1000 hours at +160°F.

Applying the proper use envirnoment K-factor does not change these numbers, as only a very small part of the equipment's lifetime is spent in anything but an ideal environment. Thus, the mean time between failures (M.T.B.F.) for these failure rates is:

130,000 hours for the +80°F case, and

45,000 hours for the +160°F case.

It is interesting to note that at +80°F, discounting the reliability contribution of the connector and internal sockets raises the M.T.B.F. to 240,000 hours.

MOTOROLA INC.
Military Electronics Division
Western Center
Scottsdale, Arizona
RELIABILITY AND COMPONENTS GROUP

September 1, 1965

SPECIAL MEMORANDUM NO. 188
(Revised: Previous Issue Dated 7-1-64)

TO: 687 File

COPIES: Section Heads
R. Samuelson/R. Elsner
A. Hume/R. Yost
C. Estes/K. Porter
Reliability Coordinators

FROM: Reliability Analysis Section

SUBJECT: Part Failure Rates

This memorandum modifies MIL-HDBK-217 component part failure rates for use in estimating mean time between failures (MTBF) of Motorola Western Center equipment. The listed failure rates have been established by analysis of the results of large scale parts tests, by study of Motorola equipment failures in the field and in the plant, and by careful consideration of part application limitations. Where applicable, MIL-HDBK-217 failure rates have been adopted. However, as would be expected, some of the failure rates herein vary widely from those reported in the Handbook, and, in fact, from those used by other companies. This is due to variables such as choice of part suppliers and procurement specifications, screening tests, the manner in which the part is applied, the environment, the equipment design techniques used, and delays, on the part of the MIL-Handbook, in absorbing new inputs such as the data from the Minuteman test program. Special Memorandum No. 188 (SM-188) coverage includes integrated circuits and other new developments not presently in the MIL-Handbook. A memo comparing SM-188 failure rates with those of MIL-HDBK-217 is available from the R&C Group on request.

Motorola's failure rates generally apply for parts procured to MIL-specifications from selected suppliers with only normal incoming inspection procedures employed. There are numerous exceptions where the part is identified as "debugged" or "screened", procured to a hi-rel MIL-specification, or subjected to screening as part of the incoming inspection procedure. Normal circuit design and packaging techniques are assumed.

Motorola's failure rates include out-of-tolerance or degradation failures as well as catastrophic or "random" failures for which no cause can be established. The failure rate of the soldered or welded connections is also included in the part failure rate. When thorough stress analysis and statistical circuit tolerance analysis have been performed, the failure rates can be estimated with greater confidence and will usually be lower than if assumed conditions of 65°C and 50% rating are used. In such cases, it is particularly important to contact the Reliability Analysis Section of the R&C Group for assistance in estimating failure rates because this memo is not a complete "cookbook" on accurate reliability estimating; there is no such book.

Table 1 lists failure rates for low population parts and parts for which the failure rates are not particularly dependent upon ambient temperature. Where applicable, improved failure rates obtained by screening are shown. Failure rate curves are attached for common part types.

Tables 2 and 3 describe two procedures for using these failure rates in making MTBF estimates.

As an example of the results which have been obtained using these rates, an MTBF estimate was made for the Mariner Flight Command System, using the procedure of Table 3, and compared with the MTBF determined in actual operation. This comparison is given below.

Measured vs. Estimated MTBF for
Mariner Flight Command System

Measured MTBF: Over 50,000 hours

Estimated MTBF: 61,340 hours (45°C)

The measured data was accumulated on twelve (12) systems. The data consisted of over 50,000 hours of operation with one failure. One of the equipments had over 11,000 hours of operation. Each equipment had some exposure to vacuum, temperature extremes of +75°C to -10°C, and vibration, but with the bulk of the operation occurring in a 45°C ambient. In addition, systems successfully flew past Venus (~ 120 days) and Mars (~ 242 days), activated experiments in the vicinity of the planets, and also participated in complex midcourse maneuvers. All functions were performed with flawless accuracy in both missions, even though unexpected excessive temperatures occurred on the Venus mission. The complexity of the Mariner Flight Command System is approximately 226 transistors, 525 diodes, and 1650 other electrical component parts.

As additional test and field data accumulate, they will be analyzed to obtain additional or supplementary failure rate information. Persons with new data on equipment failure rates are urged to forward this information to the Reliability and Components Group for use in updating these failure rates.

R. F. Martin

R. F. Martin

Cliff Petersen

C. C. Peterson

F. E. Droste

F. E. Droste

RFM/mla

Table 1

MOTOROLA INC., WESTERN CENTER

PART FAILURE RATES

These basic failure rates are for parts used in fixed ground equipment with non-digital circuitry at an ambient temperature of +65°C and applied at 50% nominal electrical rating, unless otherwise specified. See Tables 2 and 3 for procedures to include the effect of digital circuitry, other application factors, and other environments.

	Component Part	Description	Failure Rate, %/1000 Hours Standard	Failure Rate, %/1000 Hours Screened
1.	Capacitors	Air, Variable (Tubular)	0.15	---
		Ceramic, Feed-thru and Stand-off	0.10	0.02
		Glass, Variable (Piston)	0.15	---
		Glass, Variable (Piston, JFD Hi-Rel Type RVC)	0.02	---
	For common capacitor types, see attached curves.			
2.	Choppers	Electromechanical (100% rating)	0.5	---
		Solid State	See Note 1	See Note 1
3.	Clutches	Electromechanical	See MIL-HBK-217, Page 143.	
4.	Coils	See Attached Curves		
5.	Component Ovens	Sealed	0.10	---
		Unsealed	0.50	---
6.	Connectors	(Size 20 contacts or larger; use multiplying factor of 1.2 for smaller size contacts.)		
	*mated, active pair of pins	Military Standard:		
		MIL-C-26482	0.0010/contact*	---
		MIL-C-26500	0.0008/contact	---
		MIL-C-5015	0.0015/contact	---
		Rack and Panel	0.0012/contact	---

Component Part	Description	Failure Rate, %/1000 Hours Standard	Screened
6. Connectors (continued)	Printed Wiring		
	Plug-in Module (Nugent)	0.0005/contact	---
	Pin and Socket	0.0015/contact	---
	Edge-on	0.0015/contact	---
	Varicon	0.0012/contact	---
	RF		
	UG Series	0.005	---
	Other Types	Consult R&C Group	
	Flat Cable	0.01/contact	---
	All other types	Consult R&C Group	
7. Crystals, Quartz	Oscillator Applications	0.10	0.003
	Crystal Filter Applications		
	Linear Phase Req'd	0.05	---
	Non-linear Phase Req'd	0.005	---
8. Crystal Ovens	Sealed (100% rating)	0.10	---
	Unsealed (100% rating)	0.50	---
9. Delay Lines	Distributed Constant	0.05	---
	Lumped Constant	See Note 1	See Note 1
	Magnetostrictive	0.10	---
	Quartz	0.20	---
10. Diodes	See Attached Curves		
11. Ferrite Devices	Circulators		
	5 Watts Maximum	0.1	0.05
	Over 5 Watts	2.00	---
	Isolators		
	5 Watts Maximum	0.05	0.025
	Over 5 Watts	2.00	---

	Component Part	Description	Failure Rate, %/1000 Hours Standard	Failure Rate, %/1000 Hours Screened
12.	Filters	Audio	See Note 1	See Note 1
		Crystal	See Note 1	See Note 1
		Microwave	0.02	0.004
		RF	0.02	0.004
		RFI	0.10	0.02
13.	Integrated Circuits	See Attached Curves		
14.	Lamps	All Types	0.10	---
15.	Magnetic Amplifiers	See Attached Transformer Curves		
16.	Motors	All Types	See MIL-HBK-217, Page 143	
17.	Meters	AC, DC, RF	0.50	---
		Time Totalizing	0.50	---
18.	Relay	Coaxial	0.60	---
	Basic rates are for 0-100 actuations/hr. Multiply basic rates by 1.5 for 101-200 and by 2 for 201-300. Consult R&C for other usage rates.	Dry Reed	0.20	---
		General Purpose	0.60	---
		Hi-Rel (Vendor Certified Data)	N/A	0.15
		Hi-Rel (Motorola Screened)	N/A	0.10
		Latching, General Purpose	0.60	---
		Latching, Magnetic, MIL Grade	0.25	---
		Mercury	0.25	---
		Military Grade, QPL-5757	0.35	N/A
		Military Grade, QPL-6106	0.30	N/A
		Military Grade, Non-std, MIL-R-5757 Type, Low-level Selected	N/A	0.25
		Military Grade, Non-std, MIL-R-5757 Type, Sensitive	0.35	---
		Power	0.30	---

	Component Part	Description	Failure Rate, %/1000 Hours Standard	Screened
18.	Relay (continued)	Solenoid Type	0.60	---
		Sensitive	0.60	---
		Stepping	0.50	---
		Telephone	0.25	---
		Time Delay, Electronic	See Note 1	---
		Time Delay, Motor Driven	1.50	---
		Time Delay, Thermal	0.60	---
19.	Resistors	Fixed and Variable - See Attached Curves		
20.	Sensistors		0.15	---
21.	Solenoids	All Types	0.50	---
22.	Switches	Coaxial, Manual	0.40	---
	Basic rates are for 0-10 actuations/hr. Multiply basic rates by 2 for 11-20 and by 3 for 21-30 actuations/hr. Consult R&C for other usage rates.	Explosive (when subjected to very tight AQL)	---	0.10
		Pushbutton	0.60	---
		Rotary (MIL-S-3786)	0.0025/contact	---
		Sensitive (Microswitch)	0.25	---
		Thermostatic	0.70	----
		Toggle and Toggle Actuated	0.30	---
23.	Synchros	All types	See MIL-HBK-217, Page 143	
24.	Thermistors	Other Than Glass Bead Types	0.01	---
		Glass Bead Type	0.001	---
25.	Thermostats	All Types	0.50	---
26.	Transformers	See Attached Curves		
27.	Transistors	See Attached Curves		
28.	Tubes, Electron	Miniature and Sub-miniature		
		Single Section Tube (also, 1/2 double section tube)	1.5	0.75

	Component Part	Description	Failure Rate, %/1000 Hours Standard	Screened
28.	Tubes, Electron (continued)	Klystron	5.0 (See Note 3)	---
		Magnetron	10.0 to 40.0 (See Notes 2 and 3)	---
		Nuvistor	0.25	---
		Power Amplifier	5.0 (See Note 3)	---
		Rectifier	2.5	1.25
		Regulator	1.5	0.75
		Thyratron	20.0	---
		TR Tube	10.0 (See Note 3)	---
		Traveling Wave Tube	10.0 (See Note 3)	---
29.	Waveguide	Fixed, per mated pair of flanges	0.001	---
		Flexible, per mated pair of flanges	0.01	---
		Shutter	1.0	---
30.	Microwave Cavities	Fixed	0.01	---
		Variable	0.10	---

Note 1. For this device, determine the failure rate by summing the failure rate of the constituent parts.

Note 2. Typical failure rate range is shown. However, for this device, the failure rate may vary widely with the individual application. Therefore, the failure rate must be determined by considering the merits of each application. Contact the R&C Group for assistance.

Note 3. Based on periodic maintenance (replacement) as follows:

Magnetrons, Klystrons, and TR tubes - 500 hours

Power amplifiers and traveling wave tubes - 1000 hours

Other tube types - 2000 hours or more, depending upon application.

Table 2

Rapid MTBF Estimates

During the proposal phase and early design stage of new electronic equipment, little specific part information is known except the types and quantities of parts proposed and whether screening is planned. Use this method for a rapid and very approximate method of estimating the equipment failure rate and MTBF.

Step 1

Assume that all parts are used at 65°C and 50% of nominal rating, except for germanium semiconductors, which are used at 30% of nominal rating. Make the estimate for each part type from the curves and from Table 1, as applicable.

Step 2

Multiply the failure rates of all parts of digital circuits by 0.25. The failure rate of digital circuits is lowered considerably by the ability of such circuits to accept large variations and drifts in part value and by the opportunity for improved design made possible by repetitive use of a few basic circuits. In addition, the parts will generally be derated to a much greater degree than that assumed in Step 1 above.

Step 3

Multiply the sum of failure rates for the part complement of the equipment, obtained in Steps 1 and 2 above, by the most appropriate K-factor listed below. This K-factor is an approximate adjustment for the effects of ambient temperature, humidity, vibration, and shock typical of various usages.

Use Environment	K-Factor
Ground Equipment, Fixed	1
Satellite (in orbit)	1
Ground Equipment, Mobile	1.5
Airborne Equipment, Standby	1.5
Airborne Equipment, Flight	2.5
Shipboard Equipment	2.5
Missile Equipment, Non-operating, Silo Storage	0.1
Missile Equipment, Standby	3.0
Missile Equipment, Flight	10.0

Table 2 (continued)

Rapid MTBF Estimates

Step 4

If all parts are assumed to be in series for reliability purposes (that is, failure of any part results in equipment failure), calculate MTBF as follows:

$$\text{MTBF (Hours)} = \frac{10^5}{\text{Total Equipment Failure Rate (\%/1000 Hours)}}$$

CAUTION: If redundant parts or circuits are used in the equipment, the MTBF figure above is not valid. In such cases, consult the R&C Reliability Analysis Section for assistance in calculating reliability for a given mission time.

Table 3

Refined MTBF Estimates

A more refined but admittedly still approximate method of preparing an estimate of equipment failure rate and MTBF is to account for the effect of anticipated ambient temperatures and derating for as many parts as possible, individually. (If the expected ambient temperature and derating are in good agreement with the assumption of Table 2, Step 1, the rapid procedure of Table 2 is preferred to this Table 3 method.)

Step 1

Using the curves and Table 1, as applicable, make a failure rate estimate for each part and temperature. The failure rates given in Table 1 for low-population (special) parts are necessarily approximate. To more accurately estimate their failure rates, each such part should be carefully analyzed to take into account its design, quality control, and specific application.

Step 2

Multiply the failure rates of all parts of digital circuits by 0.5. Since the curves have been used to account for derating, this multiplier is an adjustment only for the ability of digital circuits to accept large variations and drifts in part value, and for the opportunity for improved design made possible by repetitive use of a few basic circuits.

Step 3

Multiply the sum of the failure rates for the part complement of the equipment, obtained in Steps 1 and 2 above, by the most appropriate K-factor listed below. Since the curves have corrected for ambient temperature, this K-factor is an approximate adjustment for the effect of vibration, shock, and humidity.

Use Environment	K-Factor
Ground Equipment, Fixed	1
Satellite (in orbit)	1
Ground Equipment, Mobile	1.3
Airborne Equipment, Standby	1.2
Airborne Equipment, Flight	2.0
Shipboard	2.0
Missile Equipment, Non-operating, Silo Storage	0.1
Missile Equipment, Standby	2.3
Missile Equipment, Flight	8.0

Table 3 (continued)

Refined MTBF Estimates

Step 4

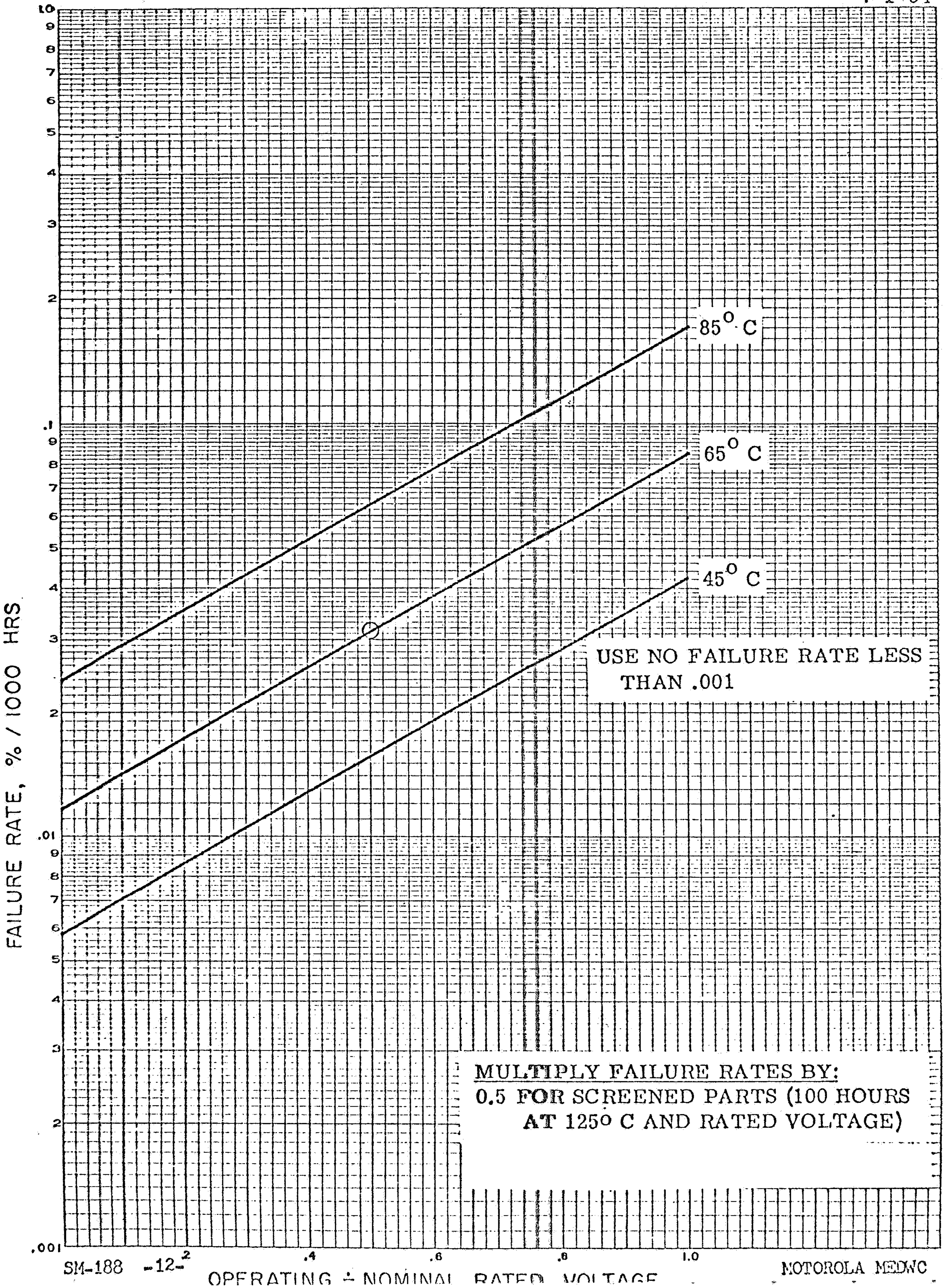
If all parts are assumed to be in series for reliability purposes (that is, failure of any part results in equipment failure), calculate MTBF as follows:

$$\text{MTBF (Hours)} = \frac{10^5}{\text{Total Equipment Failure Rate (\%/1000 Hours)}}$$

CAUTION: If redundant parts or circuits are used in the equipment, the MTBF figure above is not valid. In such cases, consult the R&C Reliability Analysis Section for assistance in calculating reliability for a given mission time.

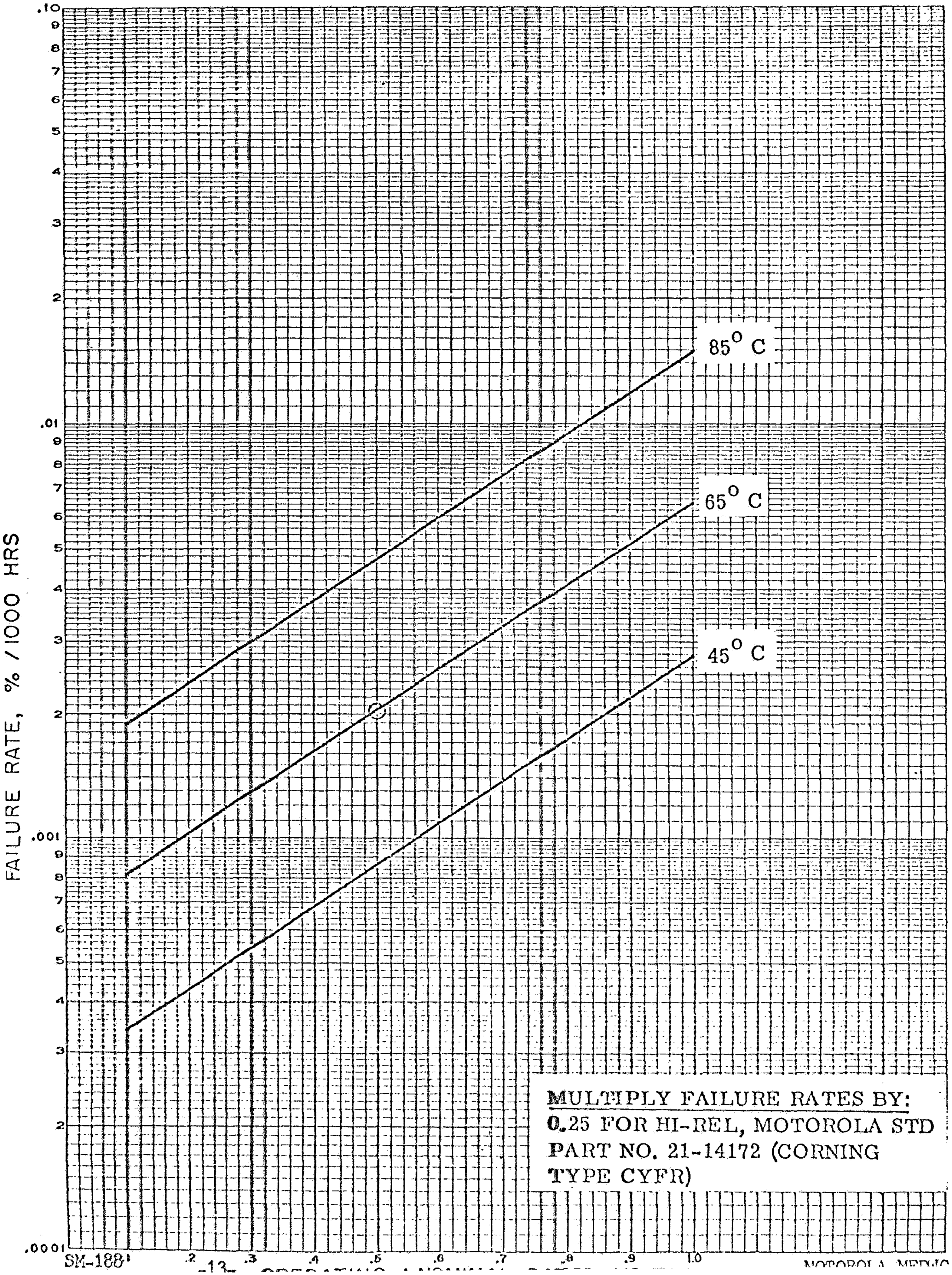
CAPACITORS, CERAMIC MIL-C-11015 & MIL-C-20

7-1-64

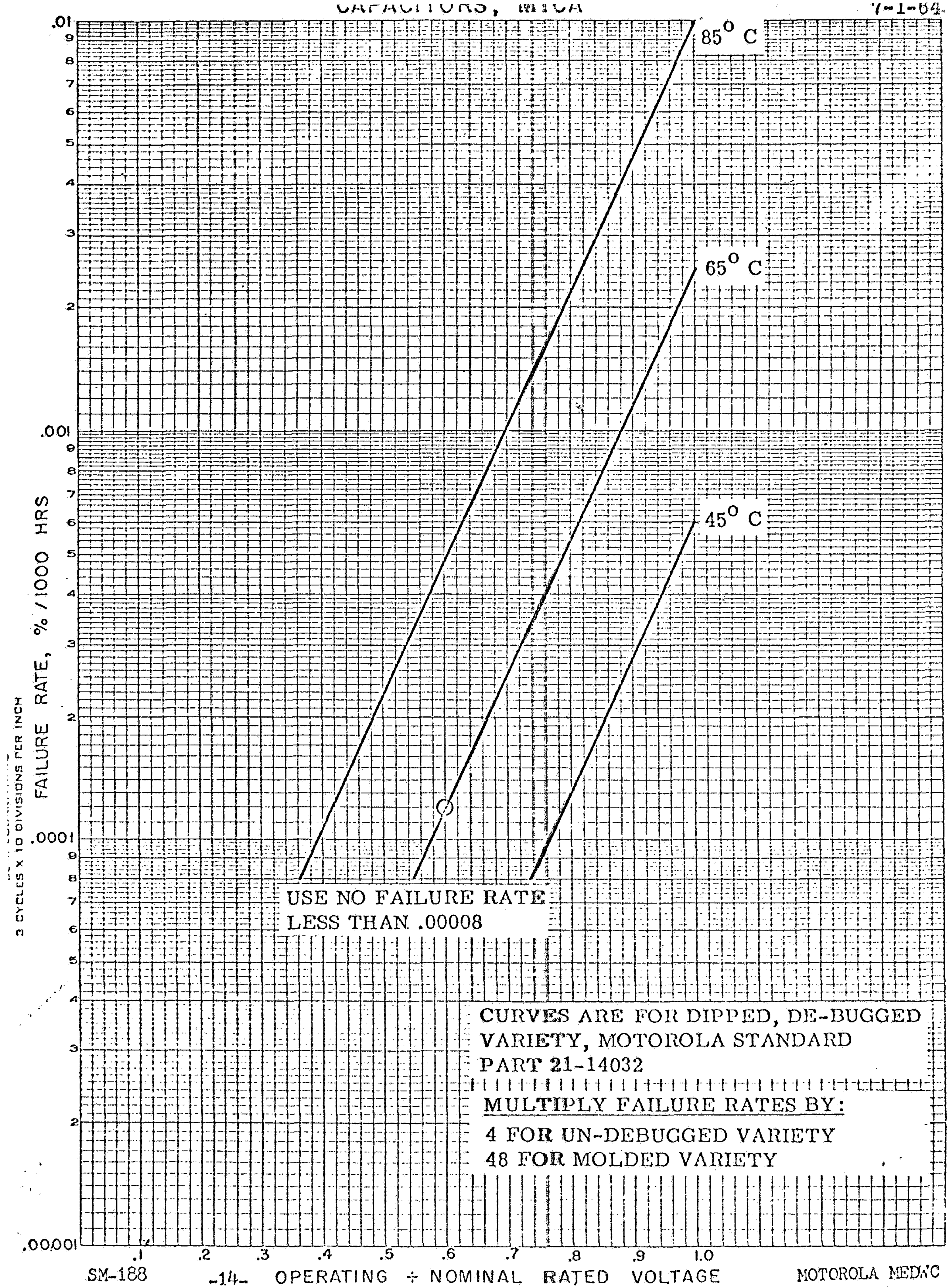


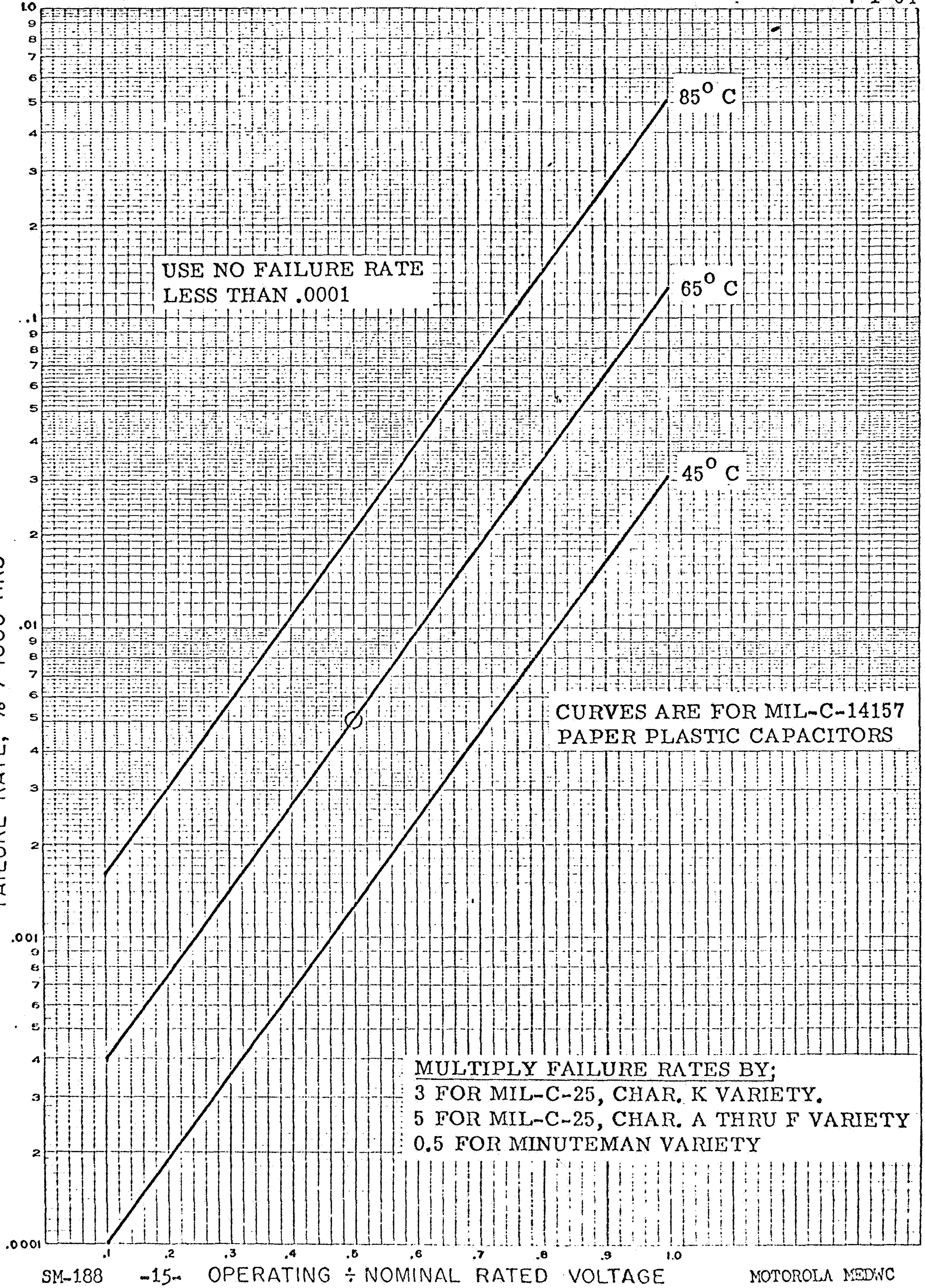
CAPACITORS, GLASS, MIL-C-11272 (CORNING CYFM)

7-1-64

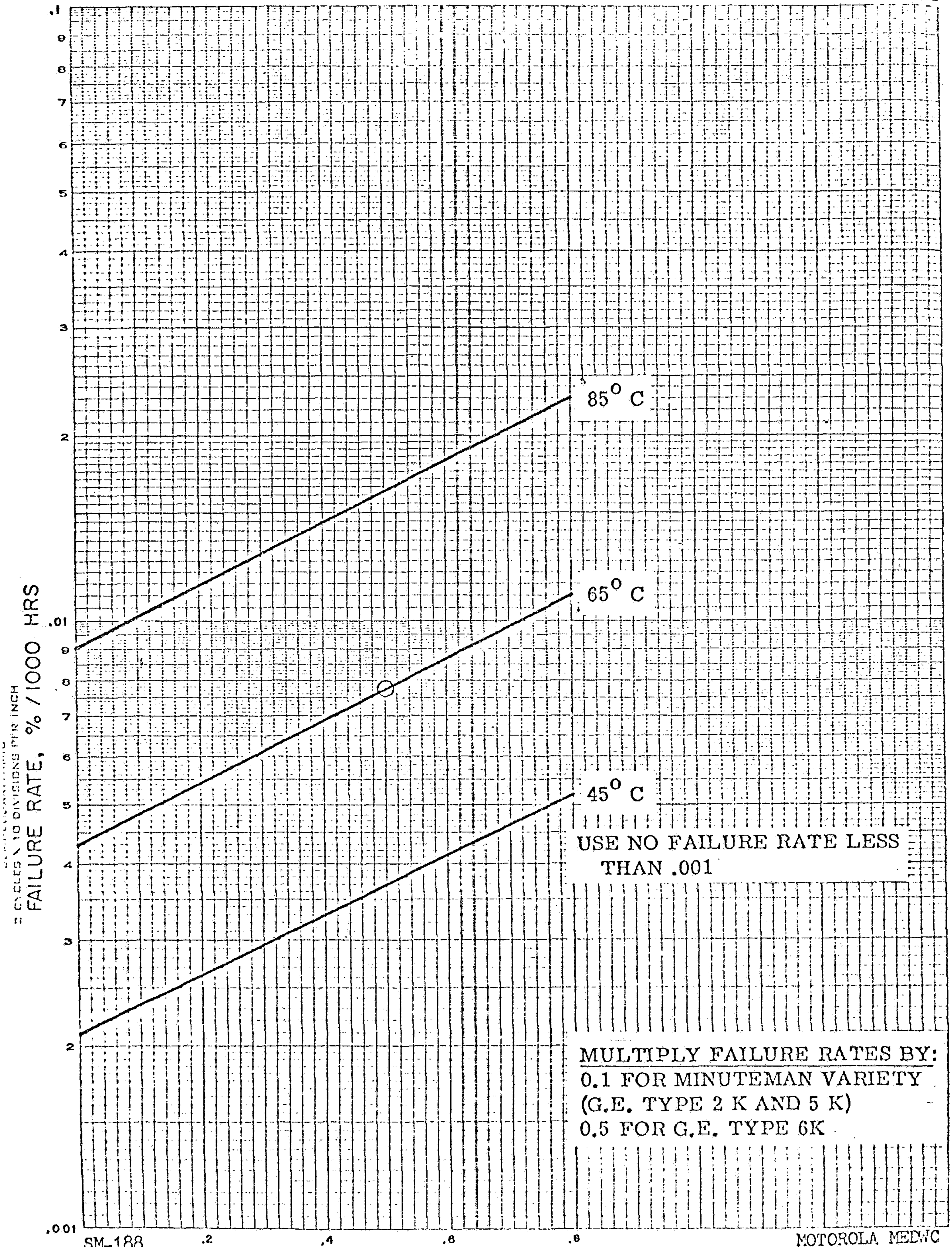


MOTOROLA MEDIC

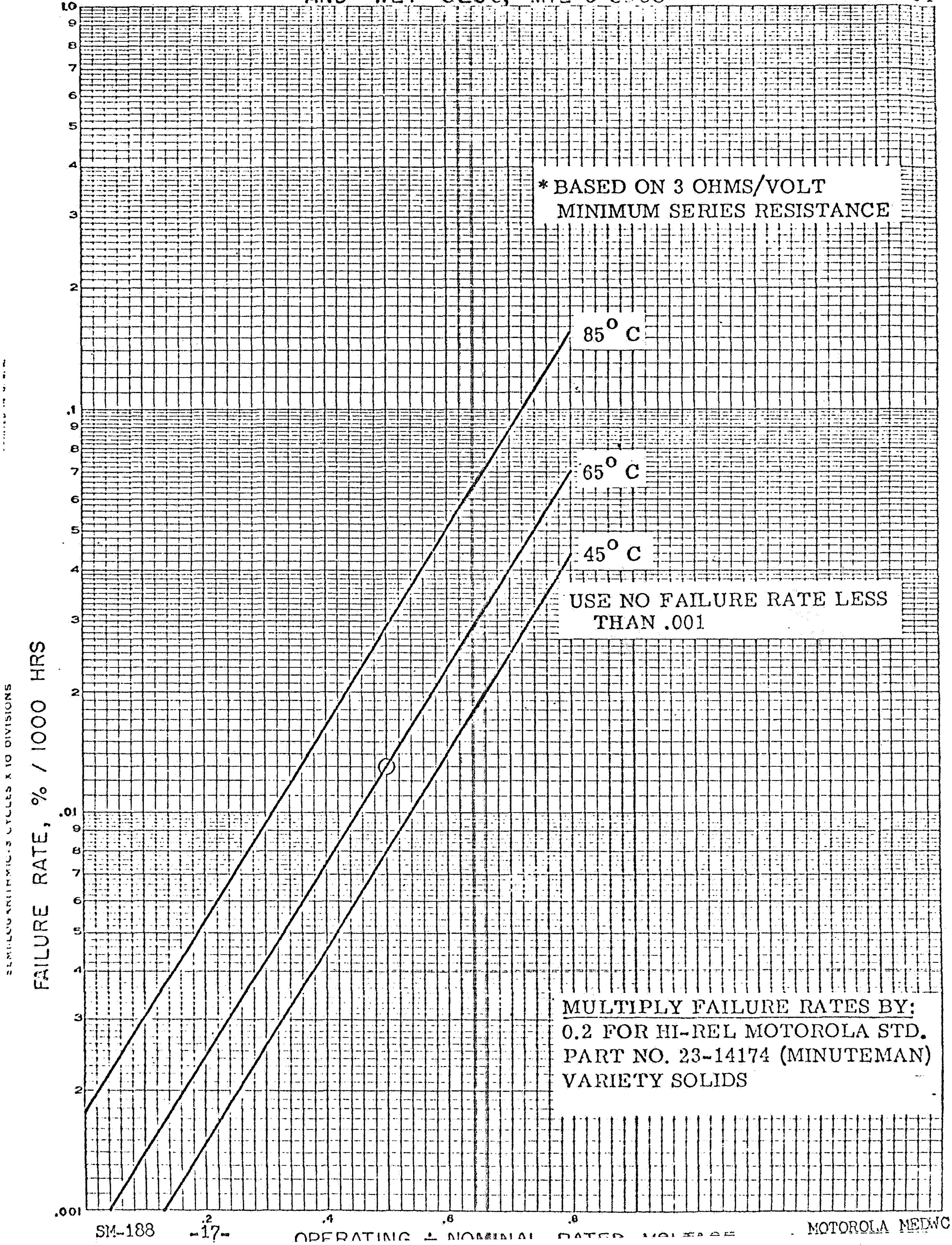

85° C
65° C
45° C
USE NO FAILURE RATE
LESS THAN .00008
CURVES ARE FOR DIPPED, DE-BUGGED
VARIETY, MOTOROLA STANDARD
PART 21-14032
MULTIPLY FAILURE RATES BY:
4 FOR UN-DEBUGGED VARIETY
48 FOR MOLDED VARIETY
FAILURE RATE, % / 1000 HRS
3 CYCLES X 10 DIVISIONS PER INCH
.01
.001
.0001
.00001
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
OPERATING ÷ NOMINAL RATED VOLTAGE

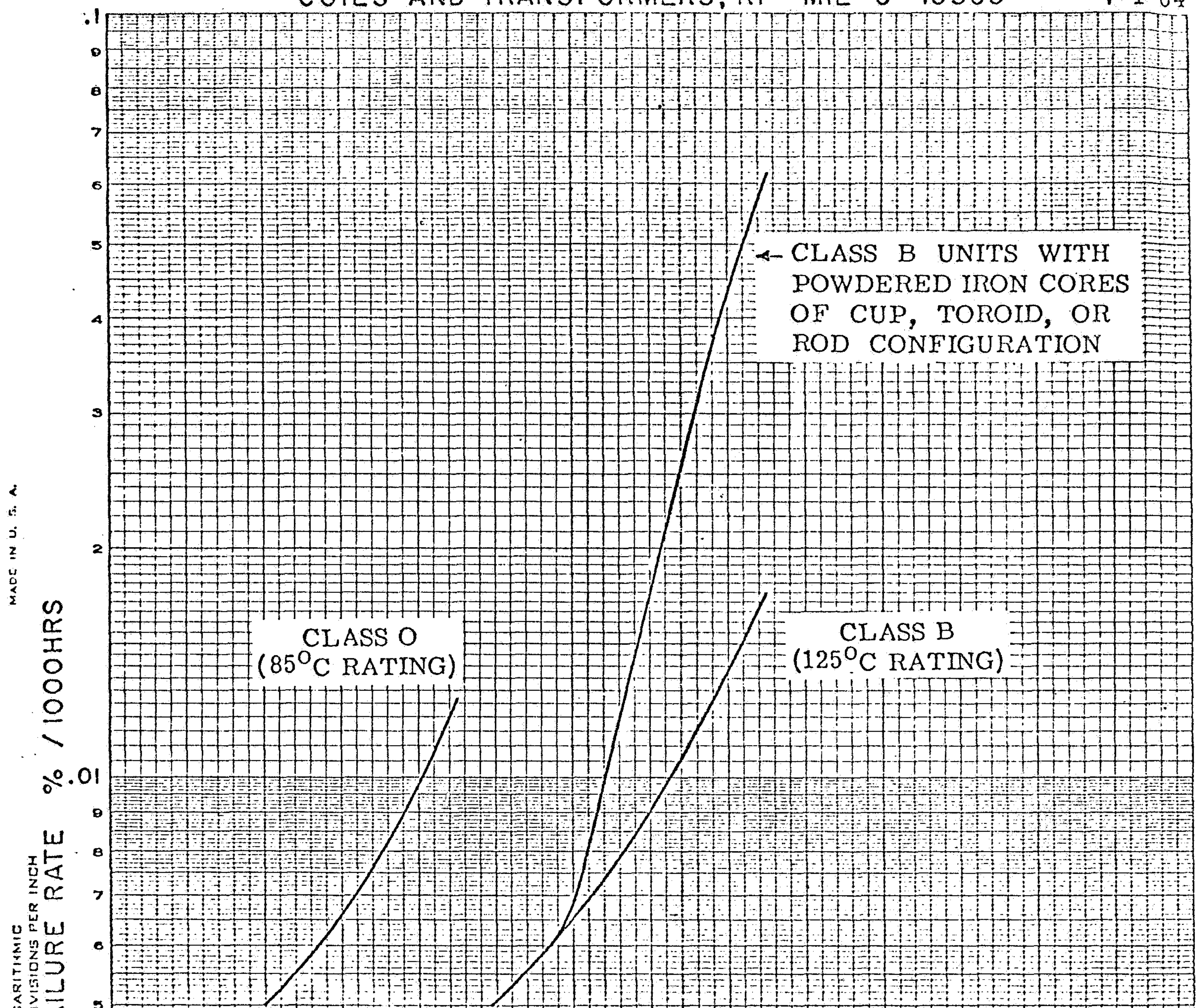

85° C
65° C
45° C
USE NO FAILURE RATE
LESS THAN .0001
CURVES ARE FOR MIL-C-14157
PAPER PLASTIC CAPACITORS
MULTIPLY FAILURE RATES BY;
3 FOR MIL-C-25, CHAR. K VARIETY.
5 FOR MIL-C-25, CHAR. A THRU F VARIETY
0.5 FOR MINUTEMAN VARIETY
FAILURE RATE, % / 1000 HRS
1.0
.1
.01
.001
.0001
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
OPERATING ÷ NOMINAL RATED VOLTAGE

CAPACITORS, TANTALUM FOIL, MIL-C-3965 7-1-64



CAPACITORS, SOLID TANTALUM *MIL-C-26655 AND WET SLUG, MIL-C-3965





USE NO FAILURE RATE LOWER THAN .0025

THESE FAILURE RATE CURVES ARE FOR FIXED RF COILS WITH WIRE SIZE #20 to #38 AWG.

MULTIPLY THESE FAILURE RATES BY:

- 2.0 FOR TRANSFORMERS
- 4.0 FOR VARIABLE UNITS
- 2.0 FOR WIRE SIZE #40 AWG OR SMALLER DIAMETER
- 0.5 FOR DRIFT SCREENING CONSISTING OF, AS A MINIMUM, INSPECTION AT 10X MAGNIFICATION, LOW-TEMPERATURE STORAGE, AND 3 TEMPERATURE CYCLES.

EXAMPLE: CLASS B VARIABLE TRANSFORMER WITH #40 WIRE, DRIFT-SCREENED, USED AT 100°C (INCLUDING TEMPERATURE RISE)
THE BASIC COIL FAILURE RATE IS .0065 AT 100°C
THE FINAL FAILURE RATE IS (.0065) (4) (2) (2) (.5) = .052 %/1000 HOURS

(INCLUDING GALLIUM ARSENIDE AND OTHER COMPOUNDS)

DETERMINE BASIC FAILURE RATE FROM CURVES AND MULTIPLY BY REVERSE VOLTAGE FACTOR. MULTIPLY BY ADDITIONAL FACTORS BELOW IF APPLICABLE.

ADDITIONAL MULTIPLYING FACTORS FOR SPECIAL TYPES AND SCREENING:

POINT CONTACT AND MICROWAVE DIODES.......................... 5.0
BONDED POINT CONTACT DIODES.................................. 2.0
SINGLE MEASUREMENT SCREENING: 1. 85°C STORAGE (1 week).......... 0.2
2. 25°C POWER LIFE (1 week)...... 0.1

DRIFT SCREENING*:
1. SINGLE DRIFT SCREEN (250 hrs) 0.05
2. DOUBLE DRIFT SCREEN (Measure after 250 and 500 hours)..... 0.03

*Temp cycling, centrifuge, shock, vibration, and power life at 25°C.

REVERSE VOLTAGE (V_R) FACTOR

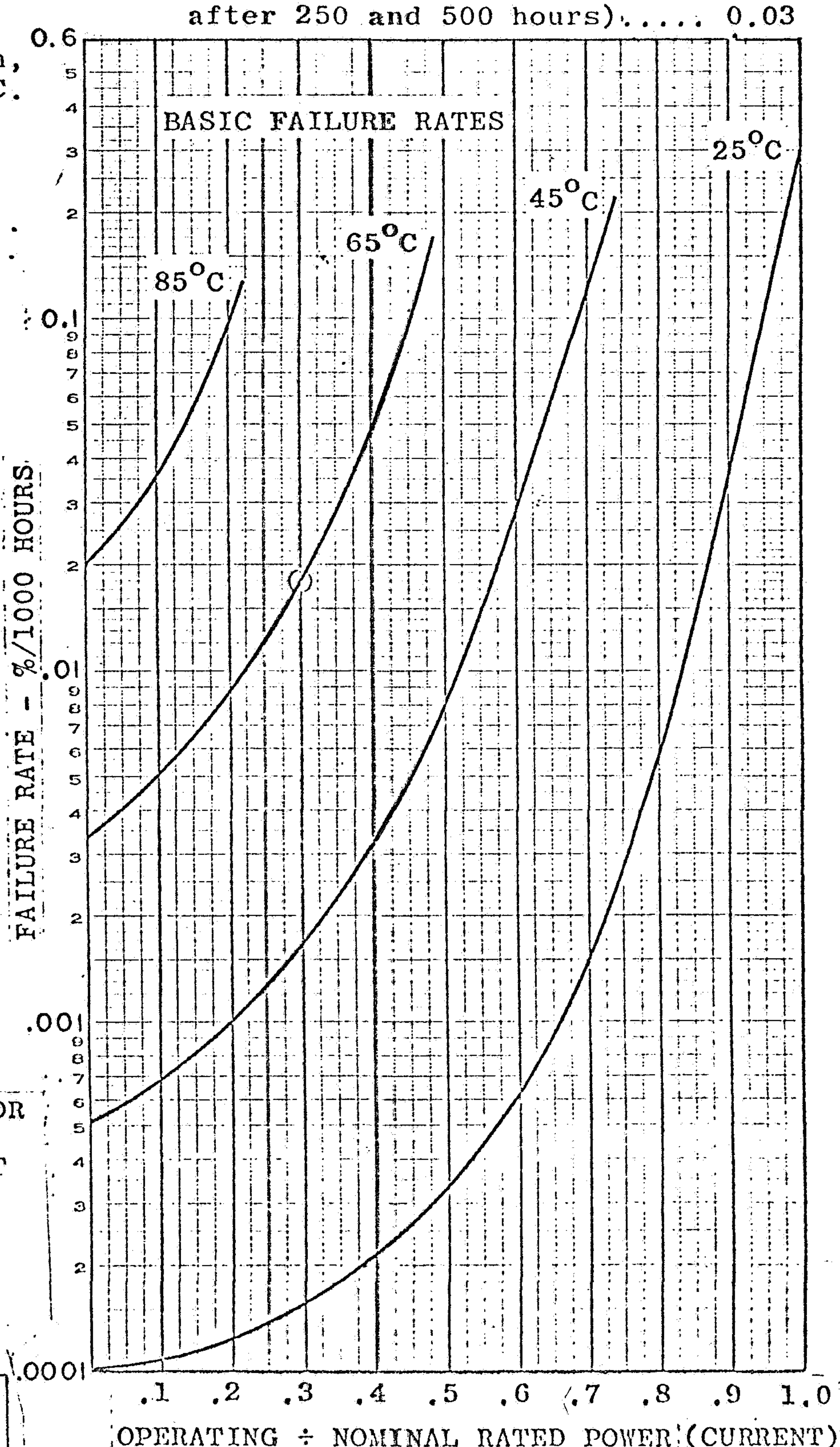
V_R RATIO**	MULT. FACTOR
0.00	2.0
0.10	2.0
0.20	2.1
0.30	2.2
0.40	2.5
0.50	2.9
0.55	3.3
0.60	$\boxed{3.7}$
0.65	4.1
0.70	4.7
0.75	5.3
0.80	6.0
0.85	6.9
0.90	7.8
0.95	8.9
1.00	10.00

IF RATIO IS UNKNOWN, USE FACTOR OF 10.0.

**RATIO OF ACTUAL V_R TO NOMINAL RATED V_R

EXAMPLE: FAILURE RATE FOR A GENERAL PURPOSE DIODE USED AT 0.3 RATED CURRENT (I_O), 0.6 RATED V_R, AND 65°C, WITH SINGLE DRIFT SCREEN IS:
.018 x 3.7 x .05
= .0033%/1000 HOURS

USE NO FAILURE RATE LOWER THAN .0001 %/1000 HOURS.



DETERMINE BASIC FAILURE RATE FROM CURVES AND MULTIPLY BY REVERSE VOLTAGE FACTOR. MULTIPLY BY ALL APPLICABLE FACTORS BELOW.

NOTE: USE NO FINAL FAILURE RATE BELOW 0.0001 %/1000 Hrs.

POINT CONTACT MIXER DIODES (RADAR) . . . 50.0 MIXER DIODES (RADAR) . . .	10.0
POINT CONTACT, MICROWAVE, PIN, AND HOT CARRIER DIODES	5.0
TUNNEL DIODES (below 250 mc) . . . . 1.0 (250 mc and over)	5.0
4 LAYER DEVICES, POWER DIODES (1 amp + over), VARACTORS	4.0
SINGLE MEASUREMENT SCREENING: 150°C STORAGE (1 week)	0.2
SINGLE MEASUREMENT SCREENING: 25°C POWER LIFE (1 week)	0.1
SINGLE DRIFT SCREENING* (250 hrs)	0.05
DOUBLE DRIFT SCREENING* (Measure after 250 and 500 hrs)	0.03

*Temp cycling, centrifuge, shock, vibration, and power life at 25°C.

**VOLTAGE VARIABLE CAPS. ARE VARACTORS OPERATING AT ZERO POWER.

REVERSE VOLTAGE (V_R) FACTOR

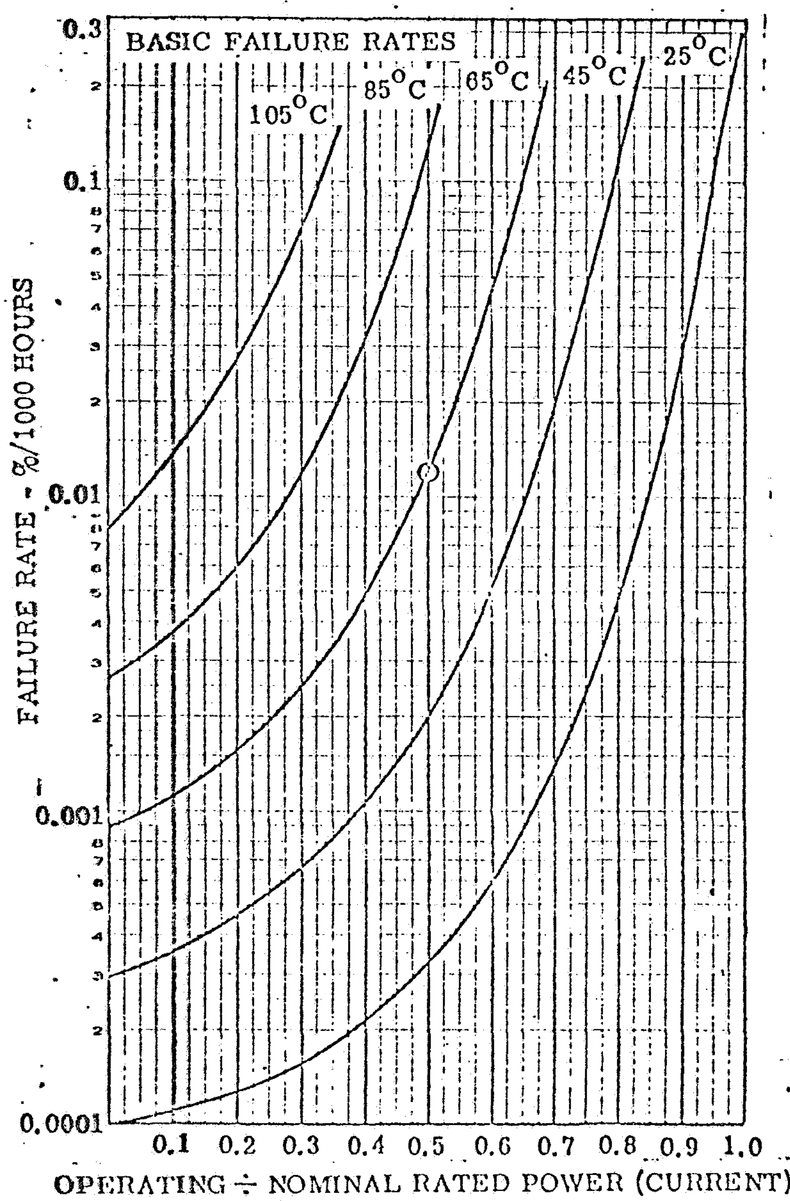
ACT. V_R / RATED V_R	MULT. FACTOR
0.00	2.0
0.10	2.0
0.20	2.1
0.30	2.2
0.40	2.5
0.50	2.9
0.55	3.3
0.60	3.7
0.65	4.1
0.70	4.7
0.75	5.3
0.80	6.0
0.85	6.9
0.90	7.8
0.95	8.9
1.00	10.00

FOR ZENERS, VARACTORS OR IF RATIO IS UNKNOWN USE FACTOR OF 10.0

EXAMPLE: FAILURE RATE FOR A GENERAL PURPOSE DIODE USED AT 0.5 RATED CURRENT (I_O), 0.6 RATED V_R, AND 65°C, WITH SINGLE DRIFT SCREEN IS:

.012 x 3.7 x .05

= .0022%/1000 HOURS



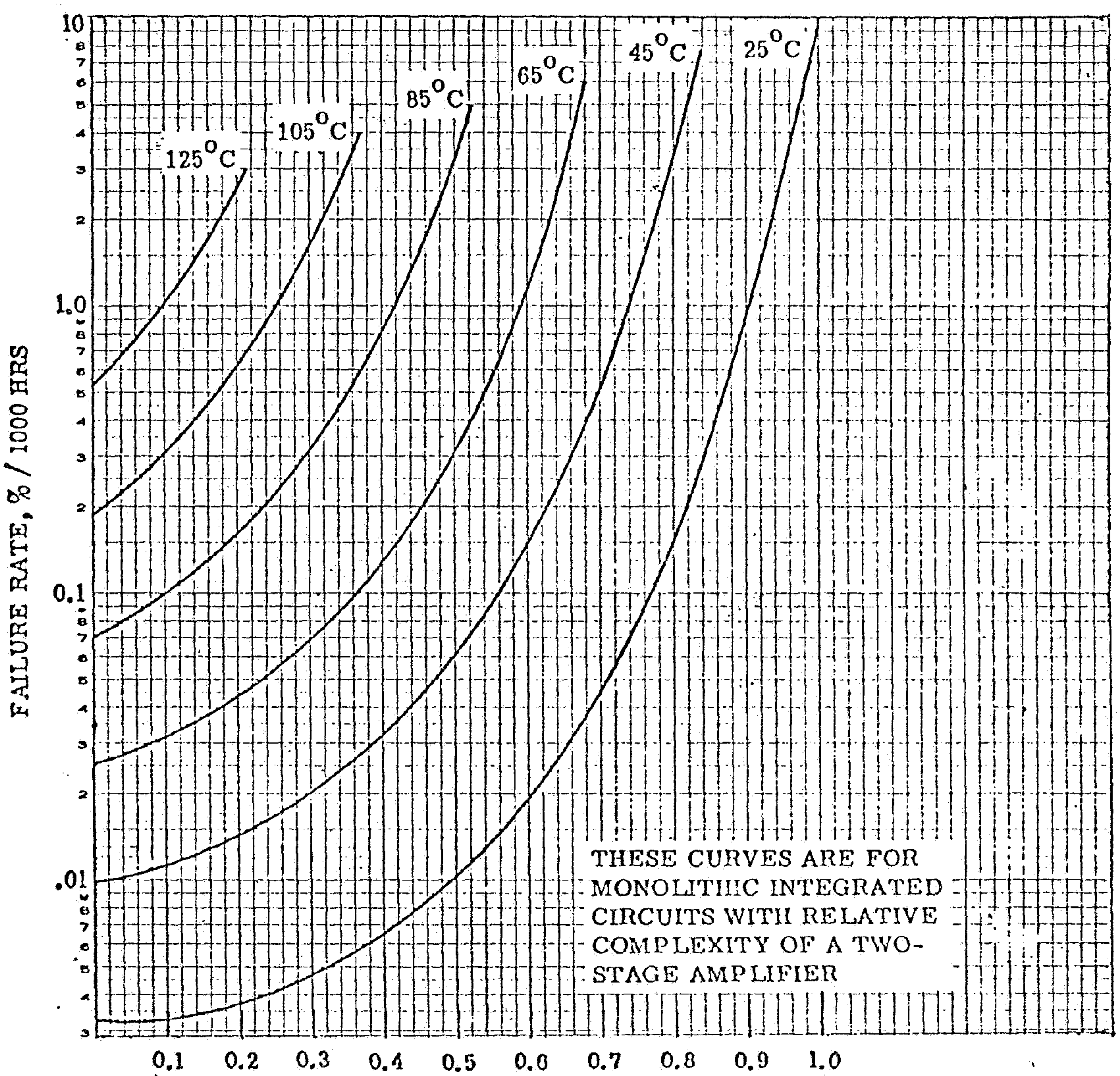
MULTIPLY FAILURE RATE BY ALL APPLICABLE FACTORS BELOW:

MULTIPLE-CHIP INTEGRATED CIRCUITS 5.0

SINGLE MEASUREMENT SCREENING (TEMP. CYCLING, CENTRIFUGE AND STEADY-STATE OPER. LIFE). 0.1

SINGLE MEASUREMENT SCREENING (TEMP. CYCLING, CENTRIFUGE AND HI-TEMP LIFE (NON-OPER.)). 0.2

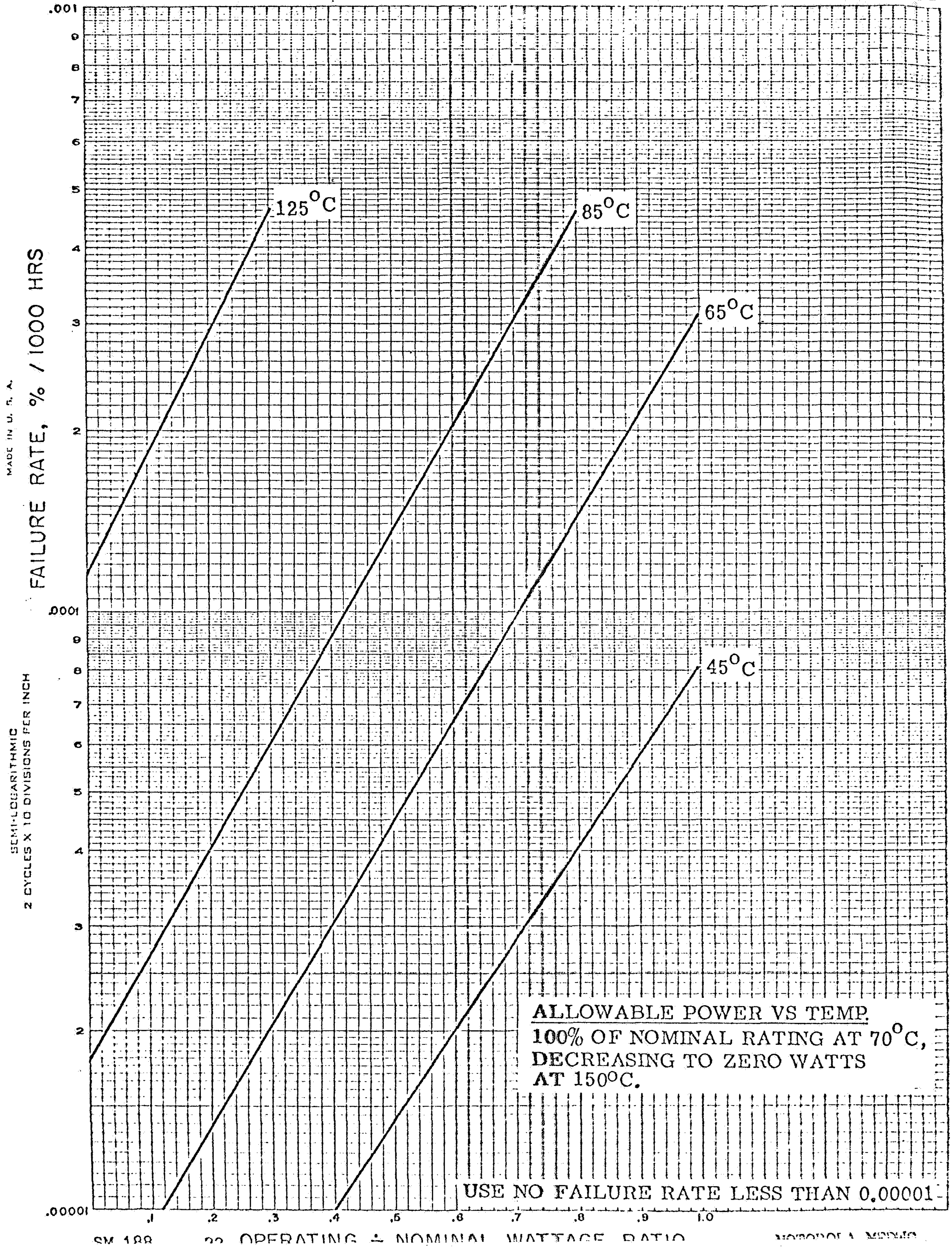
NOTE: USE NO FINAL FAILURE RATE BELOW 0.001 %/1000 HRS.

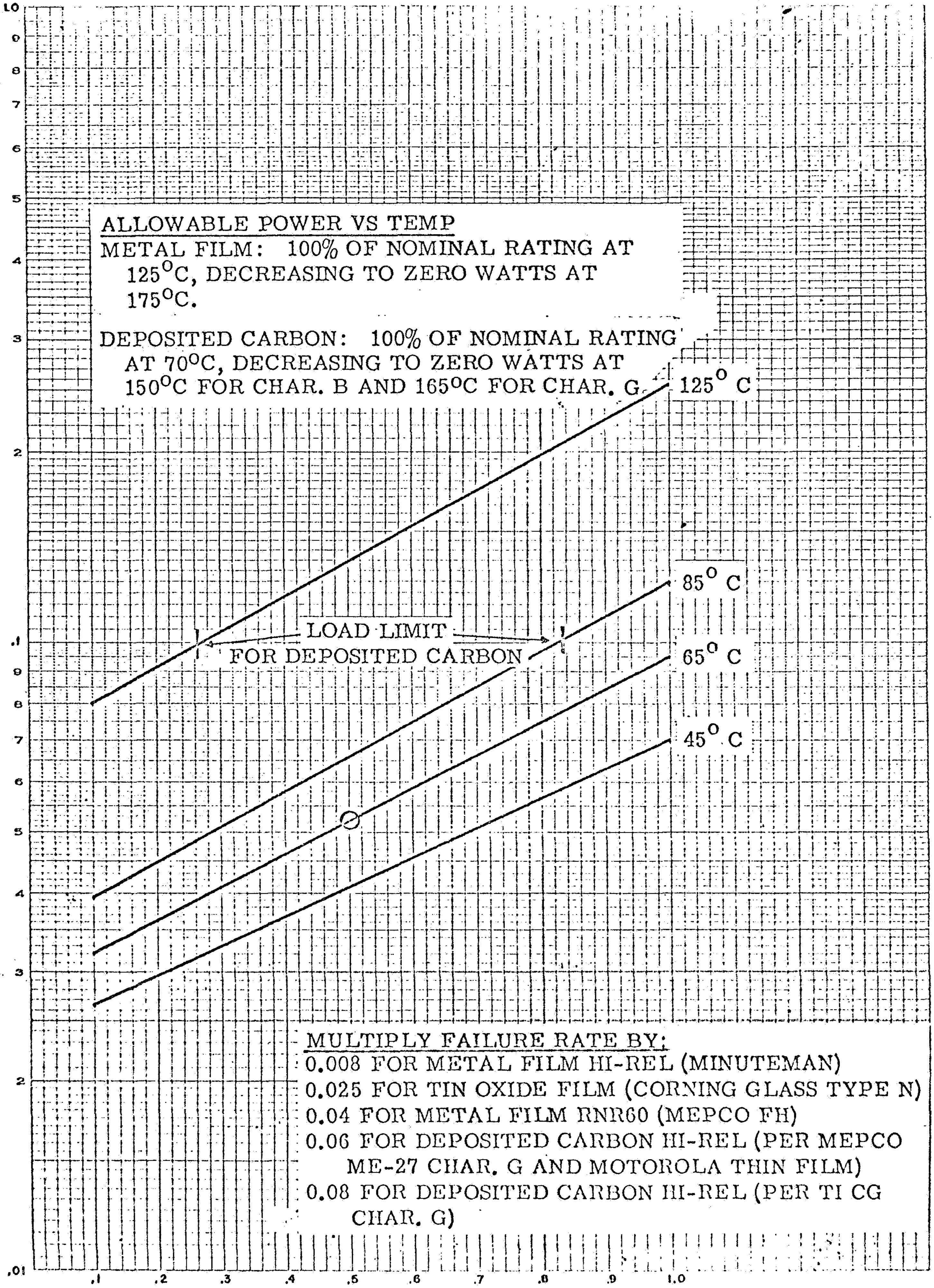


OPERATING ÷ NOMINAL RATED POWER OUTPUT*

* DEFINED AS THE RATIO OF DISSIPATED POWER TO NOMINAL RATED POWER FOR THE ENTIRE INTEGRATED CIRCUIT PACKAGE OR THE RATIO OF DISSIPATED POWER TO NOMINAL RATED POWER FOR ANY SINGLE TRANSISTOR IN THE CIRCUIT, WHICHEVER IS GREATER. FOR A SINGLE TRANSISTOR, USE NOMINAL POWER RATING WHICH THE EQUIVALENT SINGLE TRANSISTOR TYPE WOULD HAVE IF PACKAGED AND MOUNTED IN THE SAME MANNER AS THE INTEGRATED CIRCUIT.

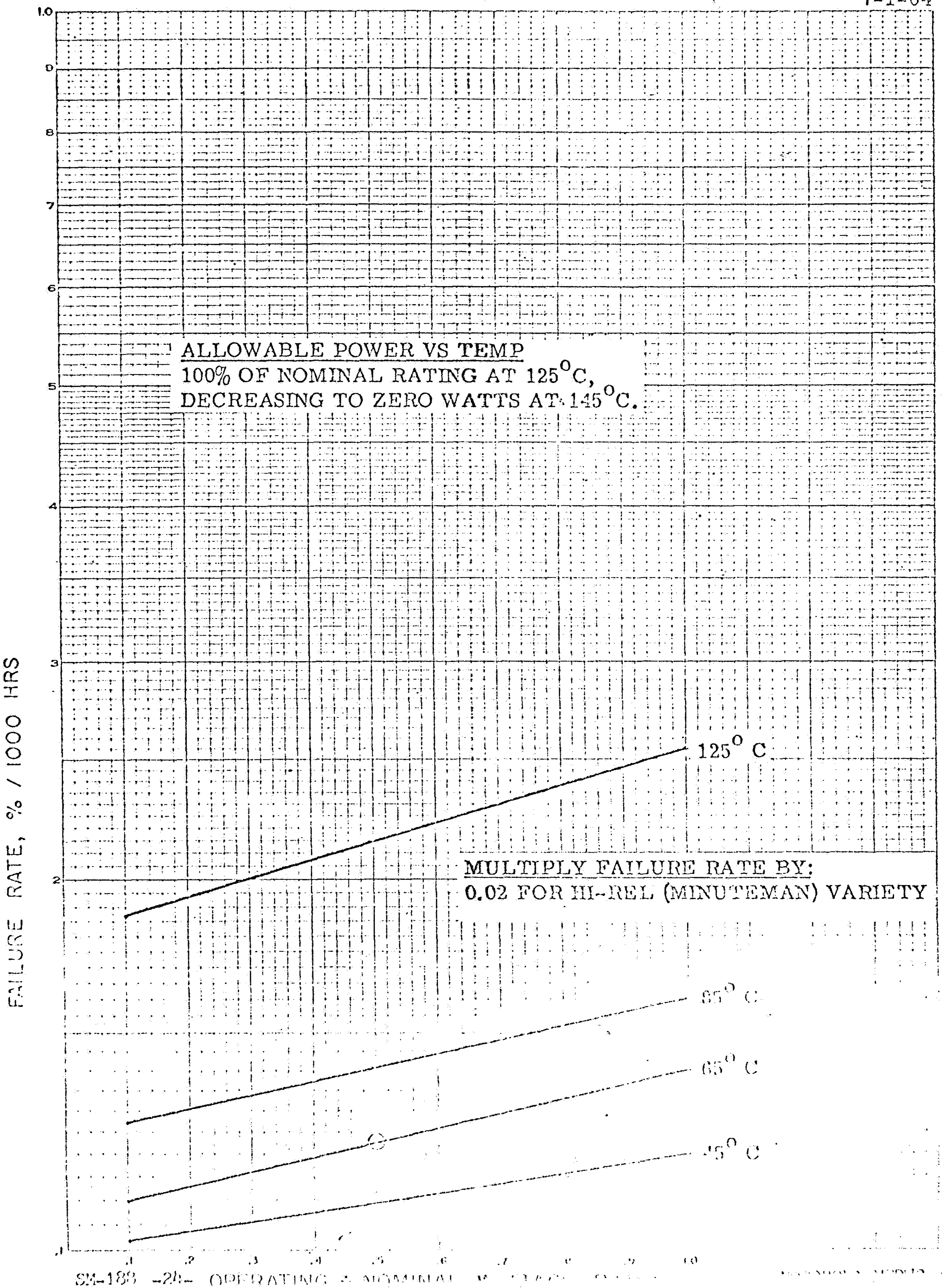
RESISTORS, COMPOSITION, MIL-R-11, Allen Bradley 7-1-64



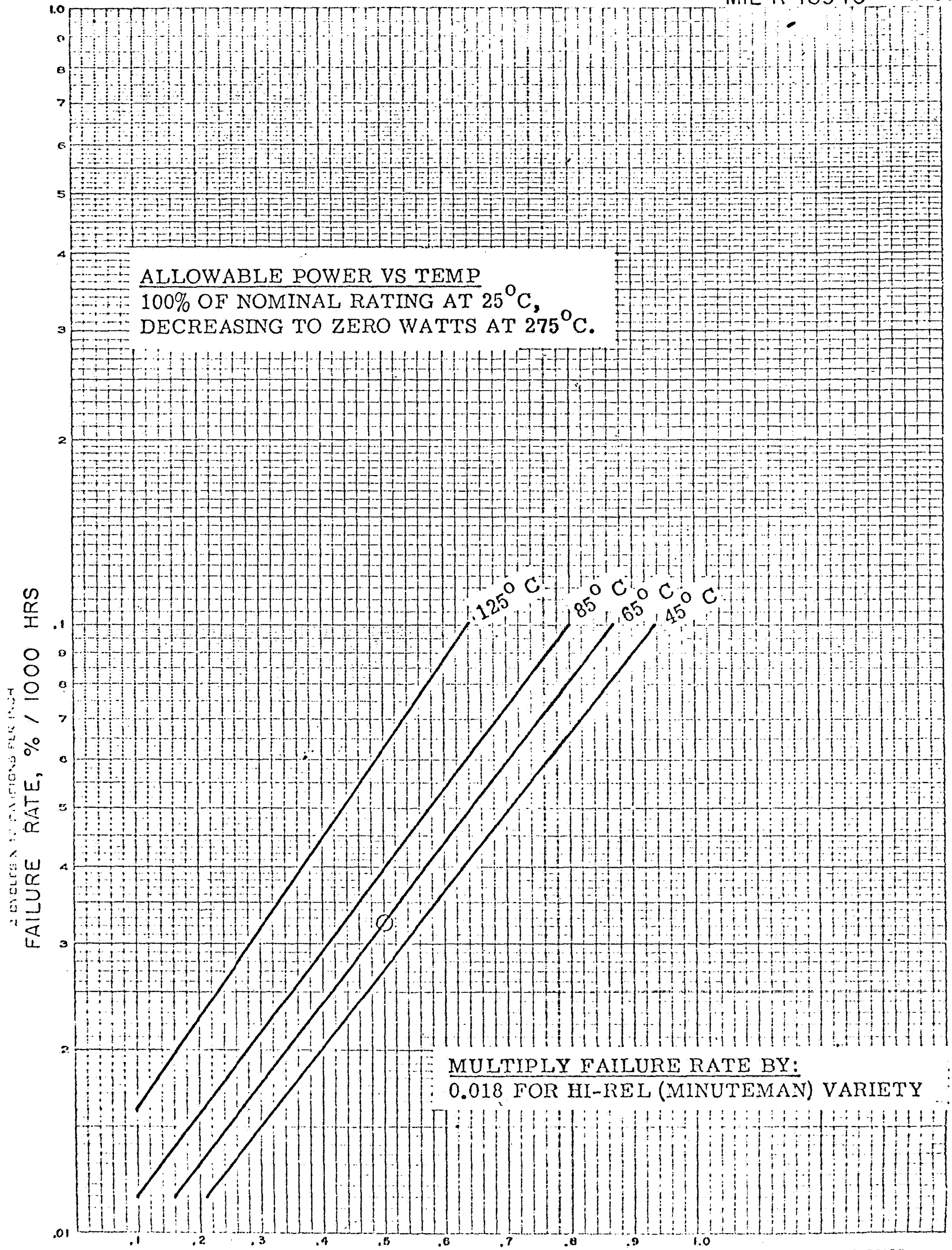

ALLOWABLE POWER VS TEMP
METAL FILM: 100% OF NOMINAL RATING AT 125°C, DECREASING TO ZERO WATTS AT 175°C.
DEPOSITED CARBON: 100% OF NOMINAL RATING AT 70°C, DECREASING TO ZERO WATTS AT 150°C FOR CHAR. B AND 165°C FOR CHAR. G
125° C
85° C
65° C
45° C
LOAD LIMIT FOR DEPOSITED CARBON
MULTIPLY FAILURE RATE BY:
0.008 FOR METAL FILM HI-REL (MINUTEMAN)
0.025 FOR TIN OXIDE FILM (CORNING GLASS TYPE N)
0.04 FOR METAL FILM RNR60 (MEPCO FH)
0.06 FOR DEPOSITED CARBON HI-REL (PER MEPCO ME-27 CHAR. G AND MOTOROLA THIN FILM)
0.08 FOR DEPOSITED CARBON HI-REL (PER TI CG CHAR. G)
1.0
9
8
7
6
5
4
3
2
.1
9
8
7
6
5
4
3
2
.01
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

RESISTORS, FIXED, WIREWOUND, ACCURATE, MIL-R-93 Char. C

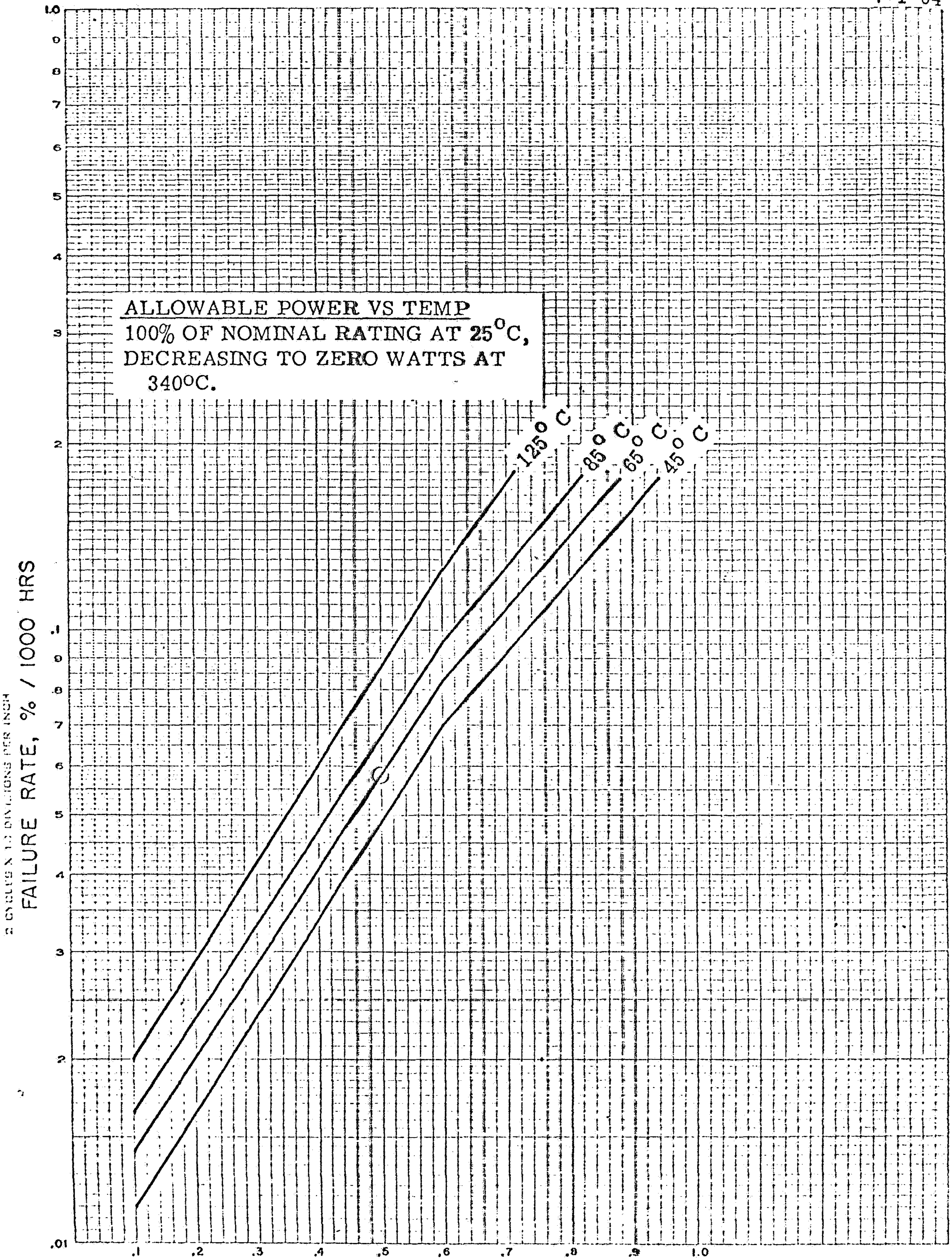
7-1-64

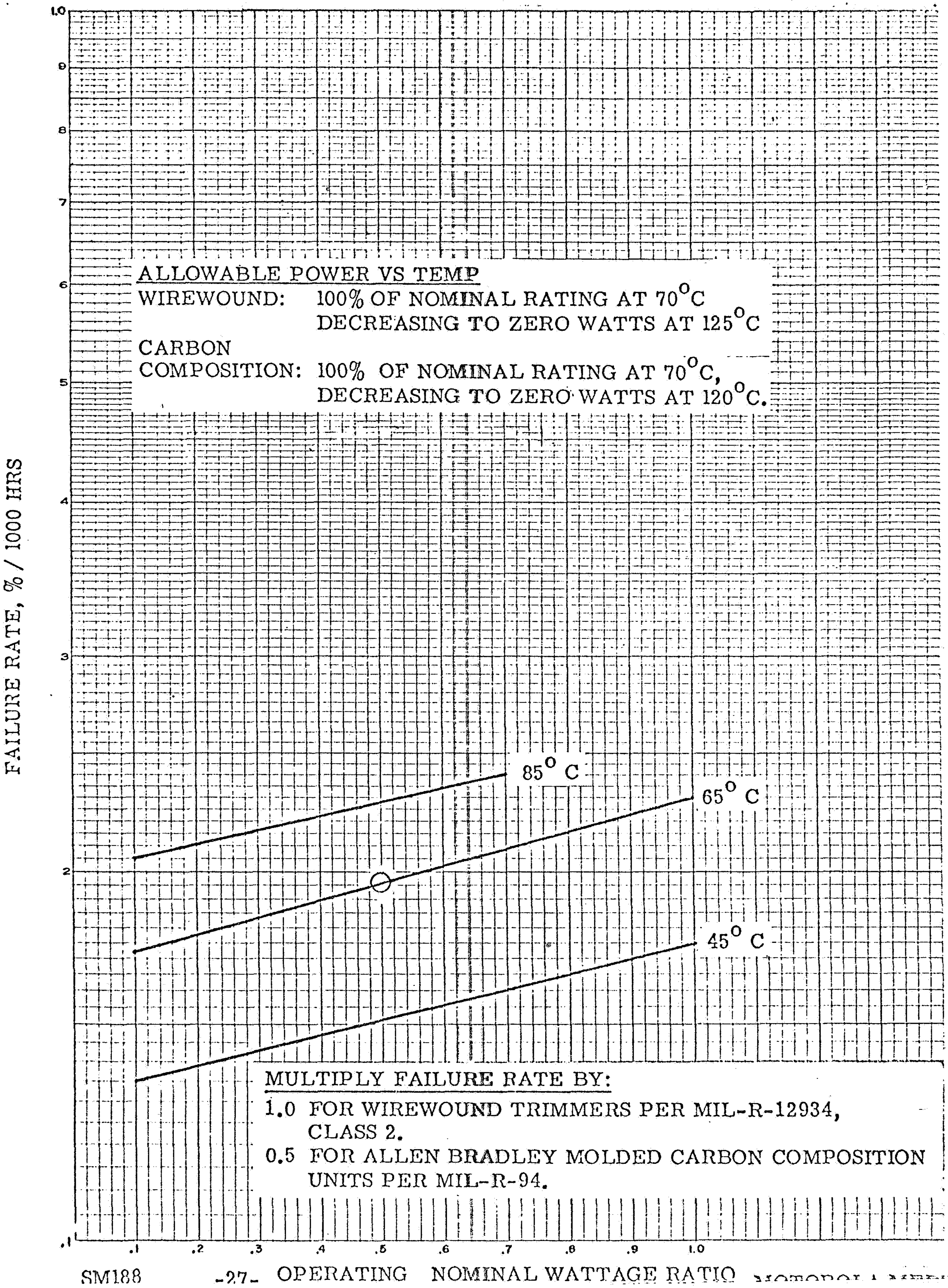


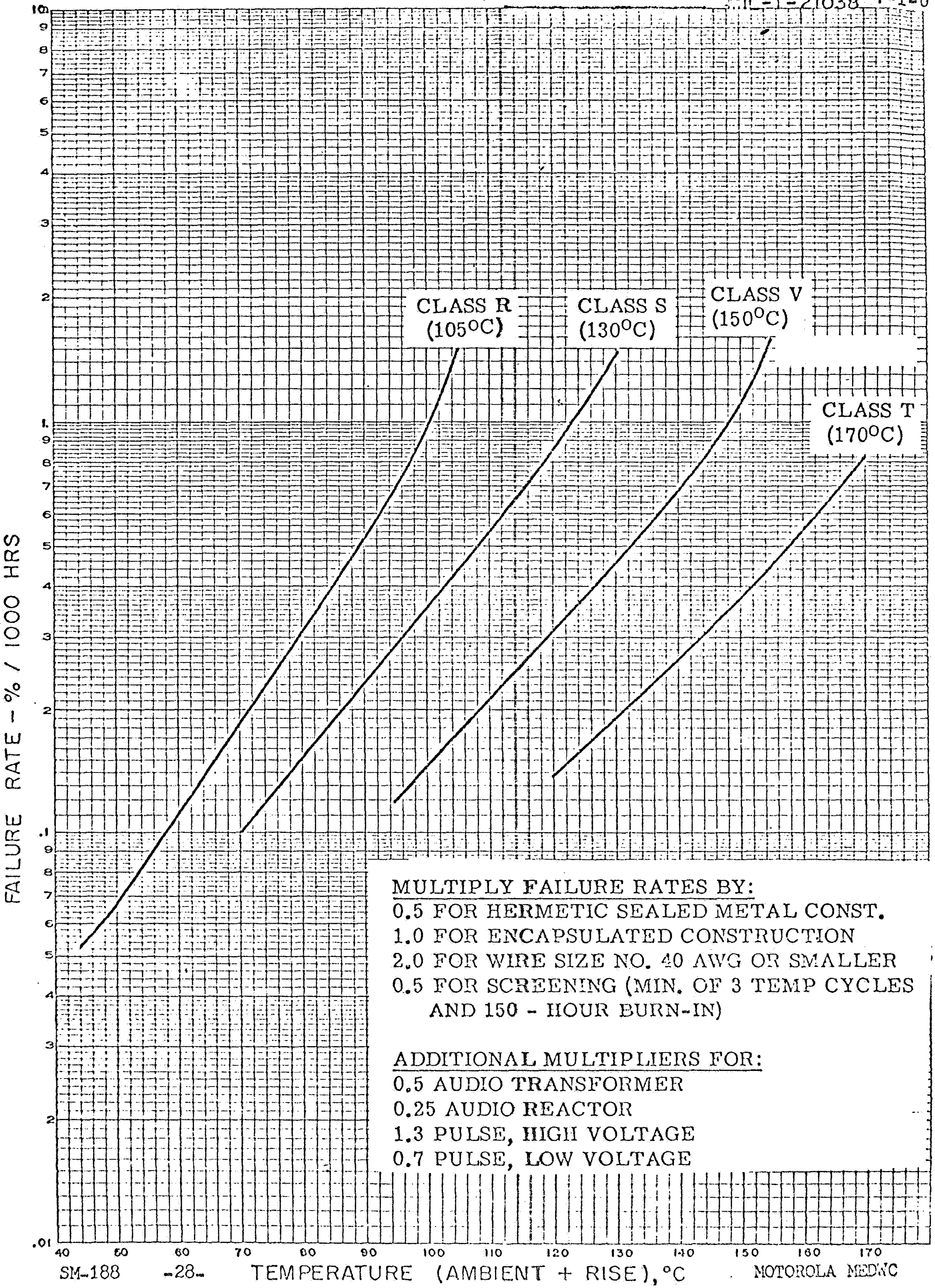
 OPERATING

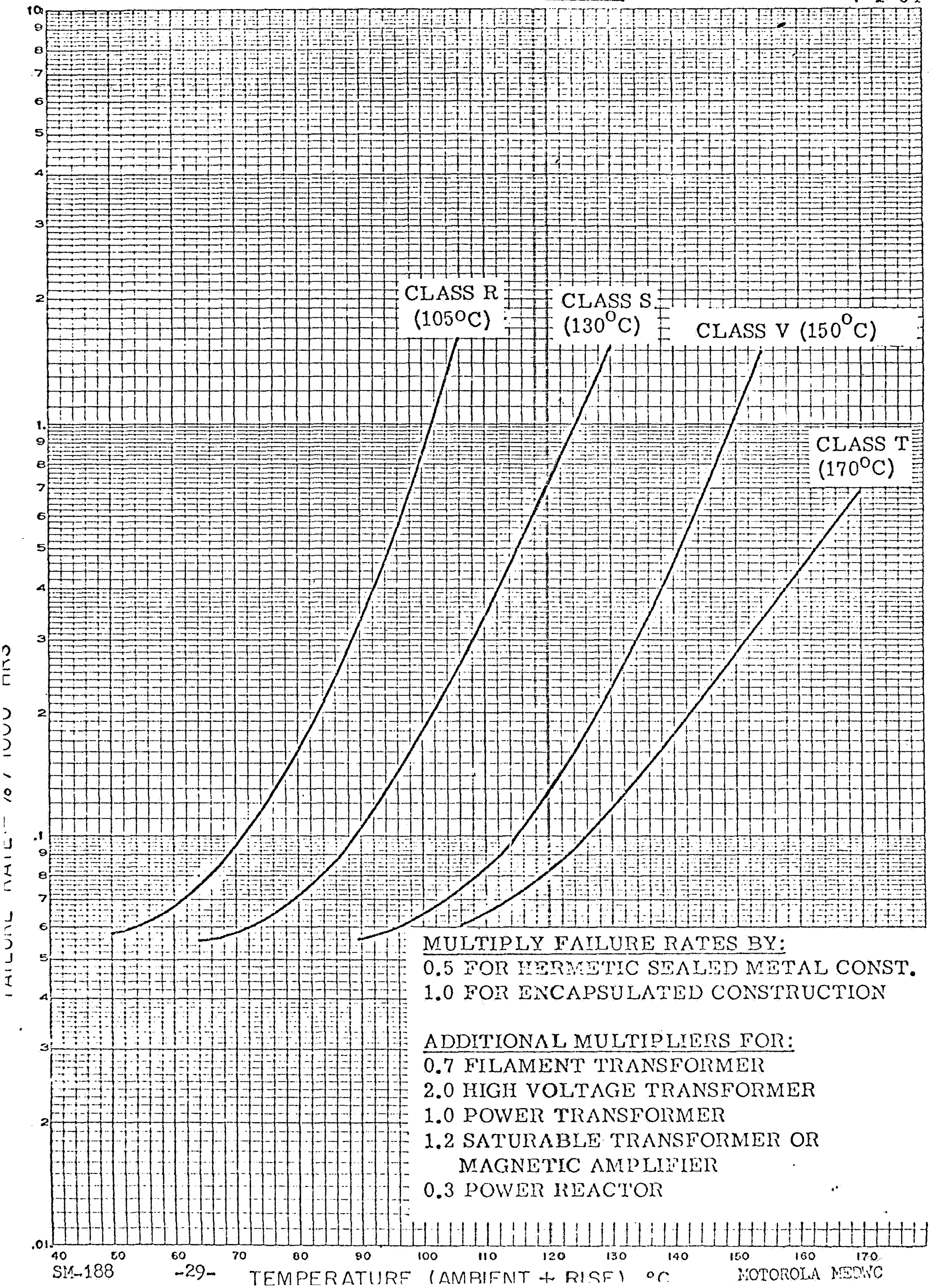


 OPERATING ÷ NOMINAL WATTAGE RATING


ALLOWABLE POWER VS TEMP
100% OF NOMINAL RATING AT 25^{o}C, DECREASING TO ZERO WATTS AT 340^{o}C.
125^{o} C
85^{o} C
65^{o} C
45^{o} C
FAILURE RATE, % / 1000 HRS
1.0
.1
.01
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
OPERATING ÷ NOMINAL WATTAGE RATIO


ALLOWABLE POWER VS TEMP
WIREWOUND: 100% OF NOMINAL RATING AT 70°C DECREASING TO ZERO WATTS AT 125°C
CARBON COMPOSITION: 100% OF NOMINAL RATING AT 70°C, DECREASING TO ZERO WATTS AT 120°C.
85° C
65° C
45° C
MULTIPLY FAILURE RATE BY:
1.0 FOR WIREWOUND TRIMMERS PER MIL-R-12934, CLASS 2.
0.5 FOR ALLEN BRADLEY MOLDED CARBON COMPOSITION UNITS PER MIL-R-94.
FAILURE RATE, % / 1000 HRS
1.0
9
8
7
6
5
4
3
2
.1
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
OPERATING NOMINAL WATTAGE RATIO


CLASS R (105°C)
CLASS S (130°C)
CLASS V (150°C)
CLASS T (170°C)
FAILURE RATE – % / 1000 HRS
10 9 8 7 6 5 4 3 2 1. 9 8 7 6 5 4 3 2 .1 9 8 7 6 5 4 3 2 .01
40 50 60 70 80 90 100 110 120 130 140 150 160 170
MULTIPLY FAILURE RATES BY:
0.5 FOR HERMETIC SEALED METAL CONST.
1.0 FOR ENCAPSULATED CONSTRUCTION
2.0 FOR WIRE SIZE NO. 40 AWG OR SMALLER
0.5 FOR SCREENING (MIN. OF 3 TEMP CYCLES AND 150 - HOUR BURN-IN)
ADDITIONAL MULTIPLIERS FOR:
0.5 AUDIO TRANSFORMER
0.25 AUDIO REACTOR
1.3 PULSE, HIGH VOLTAGE
0.7 PULSE, LOW VOLTAGE
TEMPERATURE (AMBIENT + RISE), °C


CLASS R (105°C)
CLASS S (130°C)
CLASS V (150°C)
CLASS T (170°C)
MULTIPLY FAILURE RATES BY:
0.5 FOR HERMETIC SEALED METAL CONST.
1.0 FOR ENCAPSULATED CONSTRUCTION
ADDITIONAL MULTIPLIERS FOR:
0.7 FILAMENT TRANSFORMER
2.0 HIGH VOLTAGE TRANSFORMER
1.0 POWER TRANSFORMER
1.2 SATURABLE TRANSFORMER OR MAGNETIC AMPLIFIER
0.3 POWER REACTOR
10
1.
.1
.01
40 50 60 70 80 90 100 110 120 130 140 150 160 170
TEMPERATURE (AMBIENT + RISE) °C

DETERMINE BASIC FAILURE RATE FROM CURVES AND MULTIPLY BY RELATIVE VOLTAGE FACTOR. MULTIPLY BY ADDITIONAL FACTORS BELOW IF APPLICABLE.

ADDITIONAL MULTIPLYING FACTORS FOR SCREENING:

SINGLE MEASUREMENT SCREENING: 1. 85°C STORAGE (1 week)........ 0.2
2. 25°C POWER LIFE (1 week)..... 0.1

DRIFT SCREENING*: 1. SINGLE DRIFT SCREEN (250 hrs) 0.05
2. DOUBLE DRIFT SCREEN (Measure after 250 and 500 hours)..... 0.03

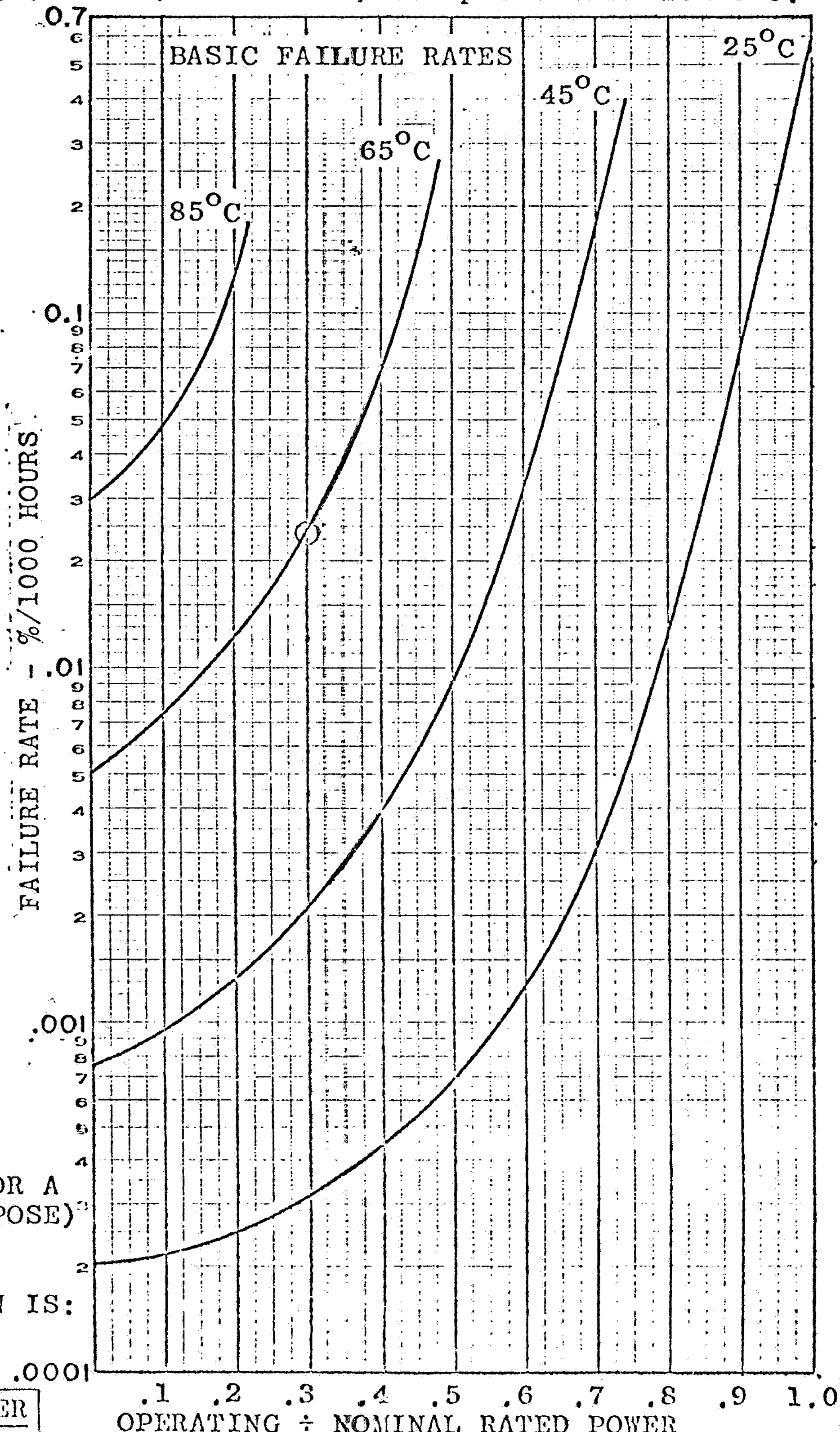
*Temp cycling, centrifuge, shock, vibration, and power life at 25°C.

RELATIVE VOLTAGE FACTOR

V_{CE} RATIO**	MULT. FACTOR
0.00	3.80
0.05	3.30
0.10	2.90
0.15	2.55
0.20	2.30
0.25	2.10
0.30	2.05
0.33	2.00
0.35	2.01
0.40	2.05
0.45	2.10
0.50	2.20
0.55	2.35
0.60	$\boxed{2.60}$
0.65	2.90
0.70	3.30
0.75	3.80
0.80	4.50
0.85	5.40
0.90	6.40
0.95	7.90
1.00	10.00

IF RATIO IS UNKNOWN, USE FACTOR OF 10.0.

**RATIO OF ACTUAL V_{CE} TO NOMINAL RATED V_{CE}



EXAMPLE: FAILURE RATE FOR A TRANSISTOR (GENERAL PURPOSE) USED AT 0.3 RATED POWER, 0.6 RATED V_{CE}, AND 65°C, WITH SINGLE DRIFT SCREEN IS:
.024 x 2.6 x .05
= .0031%/1000 HOURS

USE NO FAILURE RATE LOWER THAN .0001 %/1000 HOURS.

DETERMINE BASIC FAILURE RATE FROM CURVES AND MULTIPLY BY RELATIVE VOLTAGE FACTOR. MULTIPLY BY ALL APPLICABLE FACTORS BELOW.

NOTE: USE NO FINAL FAILURE RATE BELOW 0.0001 %/1000 Hrs.

POWER TRANSISTORS (1 watt and over), SCR's	4.0
FIELD EFFECT TRANSISTORS, DIFFUSED	5.0
FIELD EFFECT TRANSISTORS, MOST or IGFET	10.0
SINGLE MEASUREMENT SCREENING: 150°C STORAGE (1 week)	0.2
SINGLE MEASUREMENT SCREENING: 25°C POWER LIFE (1 week)	0.1
SINGLE DRIFT SCREENING* (250 hrs)	0.05
DOUBLE DRIFT SCREENING* (Measure after 250 and 500 hrs)	0.03

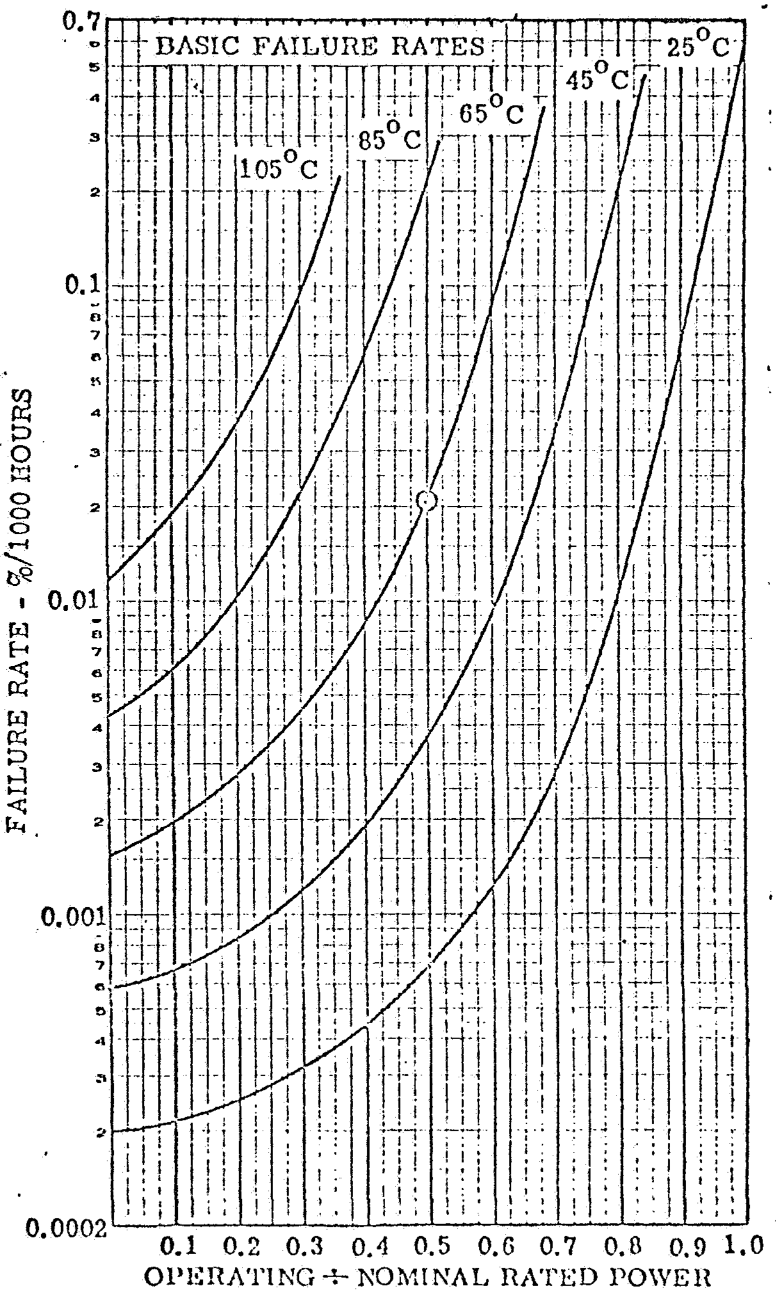
*Temp cycling, centrifuge, shock, vibration, and power life at 25°C.

RELATIVE VOLTAGE FACTOR

V_{CE} RATIO**	MULT. FACTOR
0.00	3.80
0.05	3.30
0.10	2.90
0.15	2.55
0.20	2.30
0.25	2.10
0.30	2.05
0.33	2.00
0.35	2.01
0.40	2.05
0.45	2.10
0.50	2.20
0.55	2.35
0.60	2.60
0.65	2.90
0.70	3.30
0.75	3.80
0.80	4.50
0.85	5.40
0.90	6.40
0.95	7.90
1.00	10.00

IF RATIO IS UNKNOWN, USE FACTOR OF 10.0.

**RATIO OF ACTUAL V_{CE} TO NOMINAL RATED V_{CE}



EXAMPLE: FAILURE RATE FOR A TRANSISTOR (GEN. PURPOSE) USED AT 0.5 RATED POWER, 0.6 RATED V_{CE}, AND 65°C, WITH SINGLE DRIFT SCREEN IS:
.021 x 2.6 x .05
= .0027%/1000 HOURS

III. SUMMARY OF RESULTS

A summary of the electrical performance of S/N1 and S/N2 multicoders is given below. This summary includes specification levels, worst performance at any temperature, and typical performance at room temperature, (80°F).

Indicated is total electrical compliance at all temperatures, with most parameters exhibiting large margins.

The multicoders meet both size and weight requirements and also performed satisfactorily during the following qualification tests:

a. Electromagnetic interference and susceptibility

b. Temperature

c. Altitude

d. Shock

e. Vibration

f. Acceleration

Because of a sealing problem, compliance during humidity and salt fog could not be demonstrated.

ELECTRICAL TEST SUMMARY

MICROMINIATURE HIGH LEVEL MULTICODER

ARAMETER	SPEC ALLOWANCE	WORST AT ANY TEMP. S/N1 PERF	S/N2 PERF	TYPICAL @+80°F
upply Current	<40 ma	19.8 ma	20.0 ma	19.0 ma
ack Current (Sample)	<1 ua	0.41 ua	0.27 ua	0.22 ua
ack Current Non Sample)	<100 na	60 na	70 na	1 na
nput Impedance Sample)	> 1.5 megohm	43 megohm	37 megohm	40 megohm
nput Impedance Non Sample)	>50 megohm	150 megohm	100 megohm	>300 megohm
'AM Linearity	<0.25%	0.08%	0.08%	0.08%
'DM Linearity	<0.25%	0.045%	0.03%	0.03%
rosstalk (PAM)	<0.1 %	0.02 %	0.04%	0.04%
rosstalk (PDM)	<0.1%	0.06 %	0.09%	0.04%
rame Rate	±3%	0.08 %	0.5%	0.2 %
laster Pulse Amp.	±2%	1%	1%	1%
'edestal Amp. (PAM)	±0.1V	0.003V	0.015V	0.010V
Full Scale Amp. (PAM)	±0.1V	0.030V	0.047V	0.04V
PAM Stability	±1%	±0.02%	±0.02%	±0.02%
PAM Scatter	±5 mv	± 1 mv	± 1 mv	± 1 mv
PAM Off Time Voltage	±50 mv	7 mv	7 mv	4 mv
Zero Data PDM Width	±10 usec	1.4 usec	3.0 usec	0.3 usec
Full Scale PDM Width	±10 usec	2.2 usec	3.3 usec	1.0 usec
Pulse Width Scatter	±0.7 usec	± 0.1 usec	± 0.1 usec	± 0.1 usec
Pulse Width Sitter	±0.7 usec	± 0.1 usec	± 0.1 usec	± 0.1 usec
DPDM Amplitude	±4 ma	3 ma	2.7 ma	2 ma
DPDM Width	±5 usec	2 usec	3.5 usec	1 usec
DPDM Rise Time	<8 usec	3.5 usec	3.4 usec	3.5 usec

IV. CONCLUSIONS AND RECOMMENDATIONS

Several conclusions, both positive and negative, can be drawn from this program.

a. The electrical design is more than adequate and good margins exist.

b. The MOS transistor switch is suitable for this application, and reliable unlimited life multiplexers can be assembled with this device.

c. The inter-mixture of flat-pack, TO-5 cans, and discrete components is effectively handled by the basic packaging approach.

d. The Deutsch 100 pin series HR connector is a reliable high density component. However, a back shell for moisture and EMI sealing must be fabricated.

e. The miniature ceramic capacitors used are not suitable because of their hygroscopy, which causes electrical failure by capacitor leakage in the presence of only small amounts of moisture.

f. The methods of sealing the case with epoxy and/or rubber are inadequate, as true moisture barriers seem impossible to achieve.

g. The rubber (RTV) potting within the unit is an unhappy application of a good material.

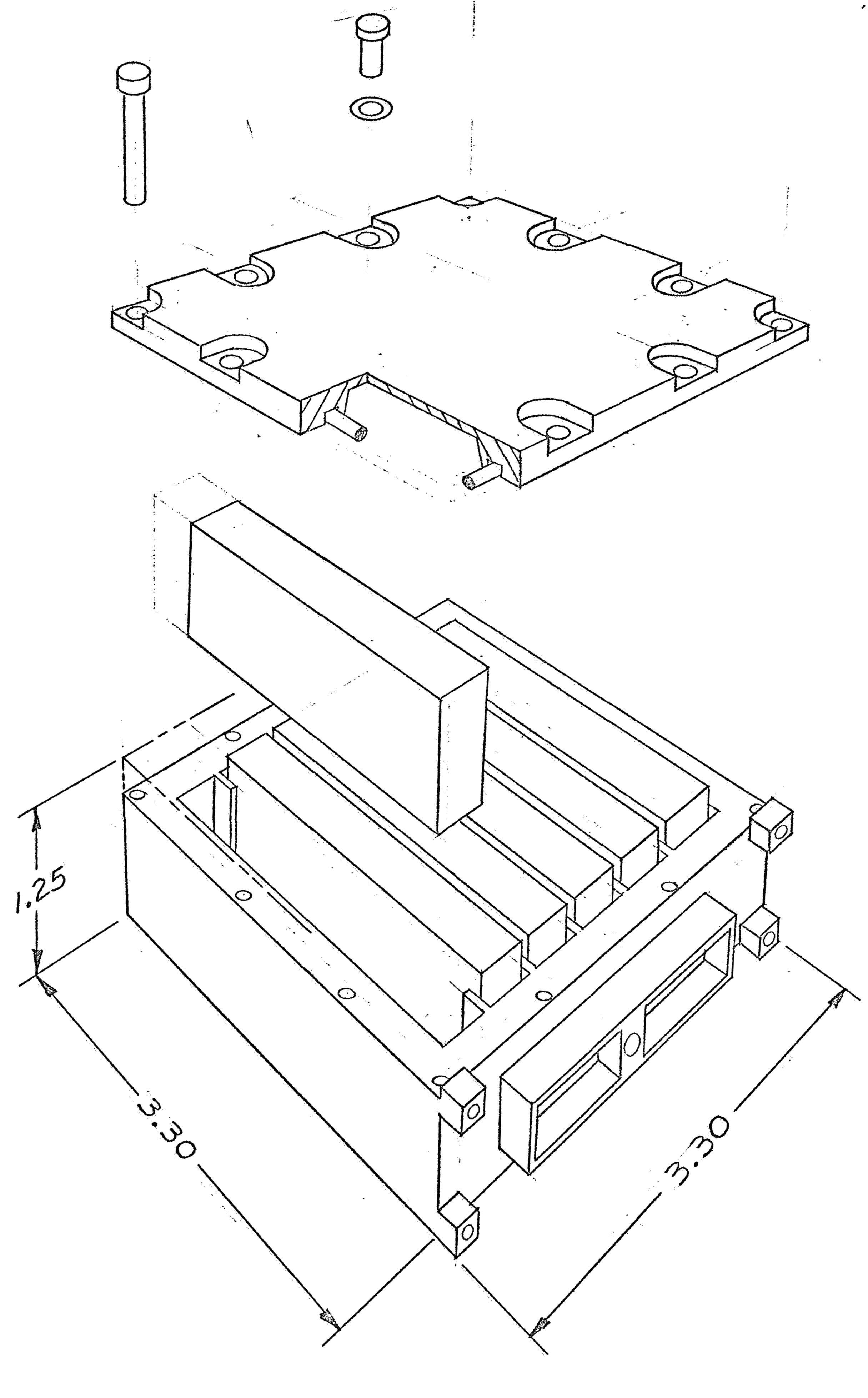
The recommendations regarding future efforts are:

a. Retain the electrical design, as is, but use hermetic capacitors rather than coated ceramics.

b. Retain the basic packaging approach, but open up the volume by about 50% (about 15% for each dimension) to 14 cubic inches, to allow incorporating the solidifying features described below.

1. Eliminate all internal potting except near the connector, and conformal coat for mechanical integrity.
2. Slot the case to accept circuit boards for added rigidity.
3. Design the case with only a single cover.
4. Seal the cover with an "O" ring and cover groove, and hold the cover in place with screws.
5. Hold the circuit boards in the vertical dimension by a rubber sheet forming a form of compressive package.

A sketch of the package is shown below.


1.25
3.30
3.30