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RELIABILITY PARTS DERATING GUIDELINES

Boeing Aerospace Company

S. L. Brummett, D. A. Cross, R. L. Davis and D. C. Towns

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, NY 13441

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APPROVED:

KEVIN R. MOORE
Project Engineer

APPROVED:

DAVID C. LUKE, Colonel, USAF
Chief, Reliability & Compatibility Division

FOR THE COMMANDER:

JOHN P. HUSS
Acting Chief, Plans Office

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Air Force, on the other hand, has no established guide or base line for evaluating the validity of the numerous deratings proposed by industry. Therefore, the objective of this effort was to develop and publish guidelines for part derating to be used as standards for evaluating contractor's design and to establish values to be implemented in system and equipment specifications. This document has established part derating levels based on mission criticality for the majority of devices included in MIL-HDBK-217. Part design application guidelines were also developed. This study indicated that some advanced technology devices (VLSI, bubble memory, microwave semiconductors, etc.) has little or no available derating data and will require a more in-depth follow on report.

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Derating can be defined as the practice of limiting electrical, thermal and mechanical stresses on devices to levels below their specified or proven capabilities in order to enhance reliability. If a system is expected to be reliable, one of the major contributing factors must be a conservative design approach incorporating part derating. Realizing a need for derating of electronic and electromechanical parts, many manufacturers have established internal guidelines for derating practices. The

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Air Force, on the other hand, has no established guide or base line for evaluating the validity of the numerous deratings proposed by industry. Therefore, the objective of this effort was to develop and publish guidelines for part derating to be used as standards for evaluating contractor's design and to establish values to be implemented in system and equipment specifications. This document has established part derating levels based on mission criticality for the majority of devices included in MIL-HDBK-217. Part design application guidelines were also developed. This study indicated that some advanced technology devices (VLSI, bubble memory, microwave semiconductors, etc.) has little or no available derating data and will require a more in-depth follow on report.

PREFACE

This final report was prepared by Parts Engineering Technology Organization of The Boeing Aerospace Company, Seattle, Washington for the Rome Air Development Center, Griffiss AFB, New York, under Contract F30602-81-C-0073. The RADC technical monitor for this program was Mr. Kevin Moore. This report covers the work performed from February 1981 to April 1982.

The Program Manager on this contract for The Boeing Aerospace Company was Mr. R. W. Brown. The principal investigators for this project were Mr. S. L. Brummett, Mr. D. A. Cross, Mr. R. L. Davis, Mr. R. A. Dinzl, Mr. W. H. Estes, Ms. P. A. Heeg, Mr. R. S. Josepher, Mr. O. A. Mulkey, Mr. W. A. Murray, Mr. D. A. Swift, Mr. D. C. Towns, Mr. R. P. Vick and Mr. G. H. Williams. Valuable assistance was provided by Ms. D. K. McGrath, Mr. D. P. Bjelke, and Mrs. F. A. Myers.

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SECTION 1

INTRODUCTION

Derating for electrical, mechanical or electromechanical parts is defined as the practice of reducing the electrical, mechanical or environmental operating stresses below the maximum levels that the part is capable of sustaining in order to increase application reliability.

1.1 Objective

The objective of this contract was to develop and document guidelines for electrical, electronic and electromechanical part derating. These guidelines could be used as standards for evaluating designs or as specifications to establish maximum allowable part operating levels for various environmental conditions.

1.2 Scope

The defined list of 74 part types in 12 categories for which derating guidelines were to be developed is shown in Table 1-1. A literature search was performed to establish existing derating methods and derating levels for the defined parts list. These data sources were analyzed and tabulated to determine which part parameters should be derated and the optimum derated stress levels for each of the required environmental conditions. There were 9 unique environments for which optimum derating was to be established:

1. Ground Benign
2. Ground Fixed
3. Ground Mobile
4. Airborne Transport Inhabited
5. Airborne Transport Uninhabited
6. Airborne Fighter Inhabited
7. Airborne Fighter Uninhabited
8. Space Flight
9. Missile Launch

In addition to establishment of derating guidelines for all of the defined part categories, critical application guidelines were to be included. An application guideline is defined as a design rule that states the limitation of the part in relation to electrical, mechanical or environmental parameters or packaging and installation procedures. Critical application guidelines for this report are those design guidelines recognized as critical for reliable designs and therefore merit inclusion with derating guidelines.

TABLE 1-1: LIST OF PARTS TO BE DERATED

PART CATEGORY	PART TYPE
MICROCIRCUITS	DIGITAL (SSI/MSI)
	LINEAR
	LSI/MICROPROCESSOR
	MEMORIES
	HYBRIDS
SEMICONDUCTORS	TRANSISTORS SILICON (NPN/PNP)
	TRANSISTORS GERMANIUM (NPN/PNP)
	TRANSISTORS FET
	TRANSISTORS UNIJUNCTION
	DIODES SILICON GENERAL PURPOSE
	DIODES GERMANIUM GENERAL PURPOSE
	DIODES ZENER/AVALANCHE
	THYRISTORS
	MICROWAVE DETECTORS
	MICROWAVE SCHOTTKY DETECTORS
	MICROWAVE MIXERS
	MICROWAVE IMPATT
	MICROWAVE GUNN
	MICROWAVE VARACTOR
	MICROWAVE PIN
	MICROWAVE STEP RECOVERY
	MICROWAVE TUNNEL
	MICROWAVE TRANSISTORS
	OPTO LEDS
	OPTO ISOLATORS
TUBES	CRT
	TWT
	MAGNETRON
	KLYSTRON
LASERS	
RESISTORS	COMPOSITION (FIXED)
	FILM (FIXED)
	NETWORK FILM (FIXED)
	WIREWOUND (FIXED)
	THERMISTOR
	NON-WIREWOUND (VARIABLE)
	WIREWOUND (VARIABLE)

PART CATEGORY	PART TYPE
CAPACITORS	PAPER/PLASTIC FILM
	MICA
	GLASS
	CERAMIC
	ELECTROLYTIC
	VARIABLE
ROTATING DEVICES	MOTORS
	SYNCHROS/RESOLVERS
	ELASPED TIME METERS
INDUCTORS	TRANSFORMERS LOW POWER PULSE
	TRANSFORMERS AUDIO
	TRANSFORMERS HIGH POWER PULSE
	TRANSFORMERS POWER
	TRANSFORMERS RF
	COILS RF CABLE
	COILS FIXED
	COILS VARIABLE
RELAYS	GENERAL PURPOSE
	CONTACTOR, HIGH CURRENT
	LATCHING
	REED
	THERMAL BIMETAL
	METER MOVEMENT
SWITCHES	TOGGLE
	PUSH BUTTON
	SENSITIVE
	ROTARY
CONNECTORS	CIRCULAR (RACK AND PANEL)
	PRINTED WIRING BOARD
	COAXIAL
MISCELLANEOUS	LAMPS (NEON/INCANDESCENT)
	QUARTZ CRYSTALS
	FUSES
	VIBRATORS
	CIRCUIT BREAKERS
	SAW DEVICES
	FIBER OPTIC DEVICES

1.3 Background

All electrical/electronic systems have minimum acceptable reliability requirements, even if not formally specified. The parts used in a system are the most critical items for achieving the required reliability. Experience has shown that most field equipment failures are due to failed parts. Prior to about 1960 control of parts reliability was accomplished by use of part specifications and testing for both the parts and the produced equipment. Part application and derating was usually left to the discretion of the designer. Reliability was usually controlled by levying specific Mean Time To Failure (MTBF) requirements on the equipment. Designers achieve this MTBF by allocating to a maximum allowable failure rate for the individual parts.

This method results in two major deficiencies in achieving the maximum cost effective reliability. First, testing does not duplicate all operating conditions and therefore does not disclose all possible field failure modes. Second, since MTBF is a function of individual part failure rates, it is often possible to compute an acceptable MTBF even if one or more parts are operating at full rated stress levels. A part operating at the full maximum rating is inherently more unreliable and is depending upon an unknown safety margin, if any, built into the device by the manufacturer. Even if a failure due to overstress does not occur in such a part, the time induced degradation rate is increased. This may account in part for the common occurrence of equipment calculated and tested to a specific MTBF which fails to achieve projected reliability in field usage.

Recognition of these factors has led to the formalization of derating, for many programs by levying derating requirements on all designs within the program. These derating requirements are in addition to those requiring part specifications to control part quality and part receiving inspection.

At the present time, there is no recognized Air Force standard devoted exclusively to part derating for all environments. In part, the reason is due to the relative newness of using derating requirements as a reliability tool. Another reason is that the establishment of derating levels is somewhat subjective and derating does not lend itself to supporting a large body of mathematical analysis as does other areas of reliability analysis. Most information relating to specific derating requirements is contained in internal contractor or program documentation and is not released for general publication. This contract attempts to summarize and develop into general guidelines that which is known and established.

SECTION 2

DATA DEVELOPMENT

2.1 Introduction

The primary tasks required by this contract were to select those part stresses (parameters) most appropriate for derating and those critical device characteristics requiring application consideration and to establish recommended stress levels for the selected parameters for the operating environments specified. There were three major data sources used:

1. A literature survey of present derating policies and practices.

2. An analysis of the part failure rate models as defined in MIL-HDBK-217C Notice 1, "Reliability Prediction of Electronic Equipment".

3. Personal experience and technical data of device technology, operating characteristics, failure history and device physics of failure.

2.2 Literature Survey

2.2.1 Boeing Technical Library Survey

The literature survey was conducted by the Boeing Company Technical Library individually for all 74 part types listed in the contract (See Table 1-1). The following key words were used in addition to the names and abbreviations of each of the part types:

A. Derating, Derating Parameters, Derating Stress, Derating Stress Levels.

B. Failure Rate, Failure History, Failure Modes, Failure Effects.

The search concentrated on literature published in the period from 1970 through 1981. Because of advancements in part technology over the past decade, data older than ten years was de-emphasized.

The primary data bases searched were:

COMPENDEX, January 1970 - present, 817,000 records, monthly updates (Engineering Index, Inc., New York, NY)

This data base provides abstracted information from the world's significant engineering and technological literature. The data base included worldwide coverage of approximately 3,500 journals, publications of engineering societies and organizations, papers from the proceedings of conferences and selected government reports and books.

INSPEC, 1969 - present, 1,404,000 citations, monthly updates (The Institution of Electrical Engineers, Savoy Place, London WS2R OBL, England)

The Science Abstracts family of abstract journals, indices, and title bulletins forms the largest English language data base in the fields of physics, electrotechnology, computers and control. The total number of journals scanned were approximately 2,000.

NTIS, 1964 - present, 765,000 citations, biweekly updates (National Technical Information Service, NTIS, U.S. Department of Commerce, Springfield, VA)

The NTIS data base consisted of government-sponsored research, development and engineering plus analyses prepared by federal agencies, their contractors or grantees. It is the means through which unclassified, publicly available, unlimited distribution reports are made available from such agencies as NASA, DDC, DOE, HEW, HUD, DOT, Department of Commerce, and some 240 other units.

Source Data for Discrete Semiconductors (Table 2-3). These sources were used to compare past derating values for discrete semiconductors.

Bibliography (Section 2.5): These sources were used for all part types.

List of MIL-STDs and MIL-HDBKs (Section 3.2): These sources were used for all part types.

2.2.2 Boeing Experience Analysis Center Survey

The Boeing Experience Analysis Center (EAC) survey consisted of a review of the following data bases of "lesson learned" experience on aircraft, missiles and space vehicles:

A. Raw field experience on over 13,000 current military, missile and avionics carriers representing over 22 million flight hours.

B. Helicopter experience data on 16 helicopter models with a total of nearly 4 million flying hours.

C. Commercial aircraft field experience data on five models representing over 3000 aircraft and 72 million flight hours.

D. Missile data such as Minuteman (LGM-30), Saturn, AGM-28, AGM-69, AGM-45, AGM-65, AIM-7, AIM-9, ADM-20, Roland, GSRS, and ALCM.

E. Space data on Apollo, Burner II, Lunar Rover, Lunar Orbiter, MVM '73, Mariner, and IUS.

F. Over 250,000 reports from GIDEP covering environmental test reports, manufacturing methods and processes, hi-rel specifications, scientific technical information, test equipment calibration procedures and ALERTS.

G. Miscellaneous ground and sea systems data on communication systems, power plants, surface transport, electrical distribution systems, ships and hydrofoil systems.

2.2.3 Military Documents

The literature survey included a review of all military specifications, handbooks and standards with information relating to applications, usage and derating for all the part types covered by the contract. Those with significant applicability to this contract are listed in Section 3, Paragraph 3.2 of this document.

2.2.4 Supplemental Information

For each of the part types of the contract, the responsible part specialist reviewed their personal data files for material applicable to derating and critical application factors. This information included books, reports, manufacturer's application notes, part evaluations, part problem analyses, technical papers and technical articles.

2.2.5 Results Of The Literature Survey

The data search showed that there is not a large body of published information defining current derating policies and practices. The primary reason for this is partly due to the lack of a mathematical or statistical data base for derating such as exists for the reliability field. Good design practice dictates operating parts below their maximum ratings and designing for "worst case" conditions results in automatic derating. This lack of an analytical base has resulted in the development of "rules for thumb" for derating which frequently result from subjective judgment of intuition. Such derivations do not usually result in published papers or documents.

The primary published sources used in developing the derating guidelines of this report are listed in the Bibliography of Paragraph 2.5 of this section. The military specifications, standards and handbooks applicable to the recommended derating guidelines are listed in Paragraph 3.2 of Section 3.

2.3.1 General Methodology Of Data Analysis

Each data source disclosed by the literature survey was analyzed to determine the following :

A. Did the source contain derating information?

B. What part types were included?

C. For each part type covered, what parameters were derated?

D. For each derated parameter, what was the derating level?

E. To what operating environments were the recommended deratings applied?

F. What special application considerations,if any, were described by the source?

These data were then tabulated by parameter, derating level and operating environment. For many of the part types there was either no data or such minimal data that tabulation was unnecessary.

Transistors and diodes were two part types with a relatively large amount of established derating data. These data will be used to demonstrate the general methodology of deriving derating level based on present derating practice.

2.3.2 Transistor and Diode Data Tabulation

Tables 2-1 and 2-2 are a tabulation of the major published derating data for transistors and diodes respectively. Table 2-3 identifies the source documents for this data. The tables indicate the parameters derated and the reported maximum allowable values for those parameters. All listed values are in percent of the maximum rating for the parameter. For example, ".8" in the I (current) column indicates the maximum current allowed by that source is 80% of the maximum rated value.

For tabulation purposes, the table defines the environment for the source. Almost universally, the present practice is to not distinguish between operating conditions within a program. Therefore, a space derating document usually levies the same derating requirement for all components in the program whether used in the space vehicle or in the ground support equipment. Exceptions for less critical applications within a program are usually not defined.

TABLE 2-1: TRANSISTOR DERATING DATA

SOURCE	ENVIRONMENT	TYPE	TJ	PWR	I	IS	VOLT	SURGE VOLT	TRANS VOLT	NOTES
	NAVAL	BIPOL		.4	.5	.6	.75			
A	SHELTERED	PWR		.4	.5	.6	.75			
	UNSHELTERED	FET		.4	.5	.6	.75			
	NAVAL	ALL			.9	.75	.75	.75		
B	SHELTERED									
	UNSHELTERED									
		GP	.6		.8		.8			
		PWR	.6		.8		.8			
		DUAL	.6		.8		.8			
C	SPACE	COMPLI	.6		.8		.8			
		CHOP	.6		.8		.8			
		UJT	.6		.8		.8			
		FET	.6		.8		.8			
D	FIGHTER-ALL	ALL	.6							
E	SPACE	ALL		.6	.75		.75			
F	SPACE	GP	.5	.5			.8			
	MISSILE LAUNCH	POWER	.5	.5			.7			
G	SPACE	ALL		.5	.75		.75			
	MISSILE LAUNCH									
	FLIGHT	ALL	.5	.5			.8			
H	INHAB-TRANSPORT									
	UNINHAB-TRANSPORT									
	MISSILE LAUNCH									
	GROUND	ALL			.75		.7		.8	
I	BENIGN	EXCEPT					.8			
	FIXED	RF PWR								
	MOBILE									
J	SPACE	ALL			.75		.7		.8	EXCEPT RF
							.8			POWER
	FLIGHT	ALL	.4		.75		.75	.9		
K	INHAB-TRANSPORT		.6							
	UNINHAB-TRANSPORT		.75							
		NPN		.83			.7			
		NPN		.93			.8			
	GROUND	PNP		.8			.7			
L	BENIGN	PNP		.92			.8			
	FIXED	FET		.83			.7			
	MOBILE	FET		.94			.8			
		UJT		.79			.7			
		UJT		.89			.8			

TABLE 2-1: TRANSISTOR DERATING DATA (CONTINUED)

SOURCE	ENVIRONMENT	TYPE	TJ	PWR	I	IS	VOLT	SURGE VOLT	TRANS VOLT	NOTES
M	FLIGHT UNINHAB-TRANS	ALL		.6			.8			
		NPN	.53				.6			
		NPN	.83				.7			
		NPN	.95				.8			
		PNP	.53				.6			
		PNP	.8				.7			
		PNP	.92				.8			
	FLIGHT	FET	.53				.6			
N	INHAB-TRANS	FET	.83				.7			
	UNINHAB-TRANS	FET	.94				.8			
		UJT	.53				.6			
		UJT	.79				.7			
		UJT	.89				.8			
		NPN/PNP PWR			.6		.7			
		NPN/PNP PWR			.7		.8			
		NPN/PNP PWR			.8		.9			
		NPN/PNP	.5	.5	.75		.75			LOW POWER
		NPN/PNP	.6	.5	.8		.75			HIGH POWER
O	MISSILE LAUNCH	NPN/PNP	.6	.5			.75			HIGH PW/FREQ
		UJT	.6	.5			.75			
		FET					.75			
P	GROUND BENIGN	ALL	.5		.75					
	FIXED	ALL	.5							
	GROUND ALL	ALL		.6	.75		.8			
Q	FLIGHT ALL	ALL		.6	.75		.8			
	SPACE	ALL		.6	.75		.8			
		NPN/PNP	.55	.2			.75			LOW POWER
		NPN	.55	.15			.75			HIGH POWER
R	SPACE	UJT	.55	.2			.75			
		FET	.55	.4			.75			SP/SW
		FET	.55	.3			.75			POWER
S	SPACE	ALL	.55	.5	.5		.75			SIL ONLY
T	GROUND-ALL MISSILE LAUNCH	ALL	.6	.3			.7			

TABLE 2-1: TRANSISTOR DERATING DATA (CONTINUED)

SOURCE	ENVIRONMENT	TYPE	TJ	PWR	I	IS	VOLT	SURGE VOLT	TRANS VOLT	NOTES
		NPN/PNP	.53				.6			
		NPN/PNP	.8				.7			
		NPN/PNP	.92				.8			
	NAVAL	FET	.53				.6			
U	SHELTERED	FET	.83				.7			
	UNSHELTERED	FET	.94				.8			
		UJT	.53				.6			
		UJT	.79				.7			
		UJT	.89				.8			
V	FLIGHT INHAB-TRANSPORT UNINHAB-TRANSPORT	ALL	.6		.75	.9	.6	.9	.75	
		NPN/PNP		.5						
W	GROUND BENIGN	FET	.6							HERMETIC
	FIXED	FET	.5							PLASTIC
		MOSFET	.6	.3			.5			
X	SPACE	ALL	.55	.5	.75	.75	.75	.75		
		MICROWAVE					.75			
Y	GROUND BENIGN FIXED	ALL		.75						

NOTE: JUNCTION TEMPERATURE DERATINGS ARE BASED ON DEGREES CENTIGRADE

TABLE 2-2: DIODE DERATING DATA

SOURCE	ENVIRONMENT	TYPE	TJ	IF	IS	POWER	PIV	SLK V	NOTES
A	NAVAL SHELTERED UNSHELTERED	RECT		0.60	0.70	0.50	0.65		
		SW		0.60	0.70	0.50	0.65		
		REF		0.60	0.70	0.50	0.70		
		REG		0.60	0.70	0.50	0.70		
		THY	0.55	0.60	0.70		0.65		
B	NAVAL SHELTERED UNSHELTERED	RECT		0.50	0.70	0.75	0.65		
		SW		0.50	0.70		0.65		
		REF		0.50	0.70		0.65		
		REG		0.50	0.70		0.65		
		THY		0.50	0.70		0.65		
C	SPACE	RECT	0.60		0.80		0.80		
		SW	0.60				0.80		
		REF	0.60				0.80		
		REG	0.60				0.80		
		CAP	0.60				0.80		
D	FIGHTER-ALL	ALL	0.60	0.75			0.75		
E	SPACE	RECT	0.66	0.60	0.75	0.60	0.75		115 FOR 175 RATING
		SW	0.67	0.50	0.50	0.60	0.70		100 FOR 150 RATING
		REF	0.65	0.50		0.60			130 FOR 200 RATING
		REG		0.50		0.60			
		MICRON				0.60			
F	SPACE MISSILE LAUNCH	RECT		0.50		0.50	0.80		
		SW		0.50		0.50	0.80		
		REF		0.50		0.50			
		REG		0.50		0.50	0.80		
		THY				0.50		0.80	
		VARACT		0.50			0.80		
G	SPACE	RECT	0.67	0.75	0.75	0.65	0.75		
		SW	0.67	0.50	0.50	0.50	0.75		
		REF	0.67			0.85			
		REG	0.67			0.50			
		PHOTO	0.67	0.50					
		VARACT	0.67	0.75		0.50	0.75		
		SCHTKY	0.67			0.75			
H	FLIGHT INHAB-TRANS UNINHAB-TRANS MISSILE LAUNCH	RECT	0.89			0.50	0.80		
		SW	0.89			0.50	0.80		
		REF	0.89			0.50			
		REG	0.89			0.50			
		THY	0.89			0.50		0.80	

TABLE 2-2: DIODE DERATING DATA (CONTINUED)

SOURCE	ENVIRONMENT	TYPE	TJ	IF	IS	POWER	PIV	BLK V	NOTES
I	GROUND BENIGN FIXED MOBILE	RECT<5W				0.50	0.70		TRANS VOLT .8 MAX
		RECT>5W		0.50	0.75		0.70		I PEAK .8 MAX
		REF				0.50			TRR 20% (RECT/SW)
		REG		0.70					
		THY	0.75	0.50				0.75	
J	SPACE	RECT<5W				0.50	0.70		TRANS VOLT .8 MAX
		RECT>5W		0.50	0.75		0.70		I PEAK .8 MAX
		REF				0.50			TRR 20% (RECT/SW)
		REG		0.70					
		THY	0.75	0.50				0.75	
K	FLIGHT INHAB-TRANS UNINHAB-TRANS	JANTX+	0.40	0.75			0.75	0.50	
		JANTX	0.60	0.75			0.75		
		JAN	0.75	0.75			0.75		
		COMM	0.75	0.75			0.75		
L	GROUND BENIGN FIXED MOBILE	RECT	0.87				0.87		
		RECT	0.77				0.77		
		SW	0.87						
		SW	0.77						
		REF/RE	0.87	0.90					
		REF/RE	0.77	0.85					
M	FLIGHT UNINHAB-TRANS	ALL				0.60			
N	FLIGHT INHAB-TRANS UNINHAB-TRANS	RECT/SW		0.87	0.87		0.50		CRIT I
		RECT/SW		0.77	0.77		0.85		CRIT II
		RECT/SW		0.53	0.53		0.60		CRIT III
		REG		0.90					CRIT I
		REG		0.85					CRIT II
		REG		0.53					CRIT III
		THY		0.80				0.83	CRIT I
		THY		0.76				0.70	CRIT II
		THY		0.54				0.54	CRIT III
O	MISSILE LAUNCH	RECT/SW	0.67	0.80		0.50	0.80		
		REF	0.67			0.50			
		REG	0.67			0.50			
P	GROUND BENIGN	ALL		0.75			0.60		
	FIXED	ALL		0.50			0.50		

TABLE 2-2: DIODE DERATING DATA (CONTINUED)

SOURCE	ENVIRONMENT	TYPE	TJ	IF	IS	POWER	PIV BLK V	NOTES
	GROUND ALL	ALL	0.65	0.75			0.80	RATED TJ=100
	FLIGHT ALL	ALL	0.65	0.75			0.80	RATED TJ=100
	SPACE	ALL	0.65	0.75			0.80	RATED TJ=100
	GROUND ALL	ALL	0.60	0.75			0.80	RATED TJ=125
	FLIGHT ALL	ALL	0.60	0.75			0.80	RATED TJ=125
	SPACE	ALL	0.60	0.75			0.80	RATED TJ=125
	GROUND ALL	ALL	0.60	0.75			0.80	RATED TJ=150
Q	FLIGHT ALL	ALL	0.60	0.75			0.80	RATED TJ=150
	SPACE	ALL	0.60	0.75			0.80	RATED TJ=150
	GROUND ALL	ALL	0.60	0.75			0.80	RATED TJ=175
	FLIGHT ALL	ALL	0.60	0.75			[illegible]	RATED TJ=175
	SPACE	ALL	0.60	0.75			0.80	RATED TJ=175
	GROUND ALL	ALL	0.60	0.75			0.80	RATED TJ=200
	FLIGHT ALL	ALL	0.60	0.75			0.80	RATED TJ=200
	SPACE	ALL	0.60	0.75			0.80	RATED TJ=200
		RECT	0.60			0.50	0.80	
		SW	0.60			0.20		
R	SPACE	RECT	0.60	0.50		0.20	[illegible]	
		REF	0.60			0.20		
		REG	0.60			0.50		
		THY	0.60	0.50		0.20		
		RECT(10		0.85			0.80	
S	SPACE	RECT)10		0.75			0.75	
		SW		0.60			0.75	
		REG				0.80		
	GROUND-ALL	GP		0.20			0.70	
T	MISSILE LAUNCH	POWER		0.50			0.60	
		REF/REG				0.40		
		GP-CL A		0.55	0.55		0.60	TD=.55(TJ+TS)
	NAVAL	GP-CL B		0.80	0.80		0.70	TD=.80(TJ+TS)
U	SHELTERED	GP-CL C		0.90	0.90		0.80	TD=.90(TJ+TS)
	UNSHELTERED	R/R CL A		0.50				TD=.50(TJ+TS)
		R/R CL B		0.80				TD=.80(TJ+TS)
		R/R CL C		0.90				TD=.90(TJ+TS)

TABLE 2-2: DIODE DERATING DATA (CONTINUED)

SOURCE	ENVIRONMENT	TYPE	TJ	IF	IS POWER	PIV BLK V	NOTES
V	FLIGHT INHAB-TRANS UNINHAB-TRANS	ALL	0.60	0.75		0.75	
W	GROUND BENIGN FIXED	RECT	0.60	0.50	0.50	0.50	
		REG/REF	0.60	0.50	0.30		
		VARACT	0.60	0.75	0.50	0.75	
X	SPACE	ALL	0.55	0.75	0.50	0.75	
		MICROWAVE			0.50	0.75	
Y	GROUND BENIGN FIXED	ALL				0.50	

NOTE: JUNCTION TEMPERATURE DERATINGS ARE BASED ON DEGREES CENTRIGRADE

TABLE 2-3: Derating Data Sources for Discrete Semiconductors

Each data source is followed by a brief description of the equipment type covered, the MIL-HDBK-217C environment designation, and program type, military, NASA or commercial.

SOURCE LETTER	SOURCE
A	NAVSEA 0967-LP-597-1010: Parts Application and Reliability Information Manual for Navy Electronic Equipment (Naval Sea Systems Command, November 1975) Naval electronic equipment: Naval, Sheltered; Naval, Unsheltered; Military
B	NAVSEA 0967-LP-597-1011: Parts Application and Reliability Manual for Navy Electronic Equipment (Naval Sea Systems Command, October 1980) Naval electronic equipment: Naval, Sheltered; Naval, Unsheltered; Military
C	PPL-14: GSFC Preferred Parts List (Goddard Space Flight Center, June 1978) Space electronic equipment: Space, Flight; Military
D	53-15-2A: F-16 Parts Derating Policy (USAF, November 1975) Fighter aircraft electronic equipment: Airborne, Inhabited, Fighter; Airborne, Uninhabited, Fighter; Military
E	RAC No. 0-06-01-1: Electronic Part Recommended Design Criteria for Comsec Equipment (October 1980) Space electronic equipment: Space, Flight; Government
F	SAMSO-STD-77-7: Standardization and Control of Parts, Materials and Processes for Missiles and Support Equipment (Space and Missile Systems Organization, Air Force System Command, August 1977) Space and missile electronic equipment: Space, Flight; Missile, Launch; Military

G MIL-STD-1547: Parts, Materials and Processes for Space and Launch Vehicles, Technical Requirements (October 1978)

Spcae electronic equipment: Spcae, Flight; Military

H D232-10327-1: Air Launched Cruise Missile (ALCM) Parts Selection List and Stress Derating Requirements (Boeing Aerospace Company, June, 1980)

Flight and missile electronic equipment: Airborne, Inhabited, transport; Airborne, Uninhabited, transport; Missile, Launch; Military

I D328-10023-1: General Support Rocket System (GSRS) Electrical/Electronic Parts Derating Criteria (Boeing Aerospace Company, December 1977)

Mobile rocket launcher system: Ground, Benign, Ground, Fixed, Ground, Mobile; Military

J D290-10020-7: Inertial Upper Stage (IUS) Electrical/ Electronic Parts Derating Criteria (Boeing Aerospace Company, March 1977)

Space electronic system: Space, Flight; Air Force

K D204-10548-1: Airborne Warning and Control System (AWACS) Derating and Application Stress Analysis Procedure-Electrical and Electronic Parts (Boeing Aerospace Company, September 1972)

Flight communications system: Airborne, Inhabited, transport; Airborne, Uninhabited, Transport; Military

L MorganTown Phase II: Electrical/Electronic Parts Derating Criteria (Boeing Aerospace Company, June 1978)

Rapid transsist vehicle system: Ground, Benign; Ground, Fixed; Ground, Mobile; Commercial

M D225-12000-2: Compass Cope Electrical/Electronic Equipment Design Equipment Design Criteria (Boeing Aerospace Company, June 1975)

Unmanned aircraft electron systems: Airborne, Uninhabited, transport: Military

N D5000 (72A1, 72A2, 72B1, 72B2): Boeing Design Manual for Electrical/Electronic Design (Boeing Commercial Airplane Company, Updated annually)

Aircraft electronic systems: Airborne, Inhabited, Transport; Airborne, Uninhabited, Transport; Commercial

O D232-10024-1: SCAD Electrical/Electronic Parts Application and Derating Guide for CAE and AVE Equipment (Boeing Aerospace Company, March 1973)

Missile electronic systems: Missile, Launch; Military

P Article: "The Reliability of Failure Rates", Microelectronics and Reliability, Vol. 12, 1973

Telephone systems: Ground, Benign; Ground, Fixed; Commercial

Q RDH-376: Reliability Design Handbook (RADC, March 1976)

RADC reliability design manual: All ground, flight, and space systems; Military

R PPL-12: GSFC Preferred Parts List (Goddard Space Flight Center, July 1972)

Space electronic systems: Space, Flight; NASA

S SPACE ZPP-2061-PPL: Electrical/Electronic Part Derating Factors (Jet Propulsion Laboratory, November 1974)

Space electronic systems: Space, Flight; NASA

T RIM H-1224: Component Derating Policy for US Roland Redesigned Equipments (Hughes Aircraft Company, September 1977)

Mobile rocket electronic systems: Ground, Benign; Ground, Fixed; Ground, Mobile; Missile, Launch; Military

U AS-4613: Application and Derating Requirement for Electronic Components, General Specification for (Naval Air Systems Command, July 1976)

Naval electronic systems: Naval, sheltered; Naval, Unsheltered; Military

V AWACS Reliability Engineering Procedure No. RE-3: Parts Derating and Application Stress Analysis Procedure (February 1973)

Flight communications systems: Airborne, Inhabited, Transport; Airborne, Uninhabited, Transport; Military

W Universal Division and Control Systems. UDACS (Boeing Aerospace Company, July 1981)

Electrical power systems: Ground, Benign; Ground Fixed; Commercial

X GT 750543: Final Report of Research into Derating and Reliability Models and Applications of Electrical and Electronic Components for ESA Spacecraft (General Technology Systems Limited, December 1976)

Spacecraft electronic systems: Space, Flight; NASA

Y "For The Real Cost Of A Design, Factor In Reliability", E. Deger and T. C. Jobe (RCA Corp.), Electronics, August 30, 1973, pp 83-88.

Consumer electronic equipment: Ground, Benign; Ground, Fixed; Commercial

2.3.3 Environmental Evaluation

The derating levels for transistors and diodes were retabulated by source and environment for each major parameter. The purpose of the retabulation was to determine if present derating practices relate the derating stress level to the nine defined operating environments (Paragraph.1.2)

The tabulation of the transistor and diode part types were divided into groups as defined by the failure rate models of MIL-HDBK-217C. A list of the groups is shown in Table 2-4. The operating environments are abbreviated per MIL-HDBK-217C and are listed in Table 2-5. The Naval Sheltered and Unsheltered environments are shown for comparison. Tables 2-6 through 2-38 shows the retabulation. The numerical values shown for the environmental factors at the bottom of the tables are the MIL-HDBK-217C multipliers to the generic failure for the listed operating environments.

TABLE 2-4: DISCRETE SEMICONDUCTOR PART GROUPS PER MIL-HDBK-217

GROUP	PART TYPE
I	TRANSISTORS, NPN/PNP, SILICON, GERMANIUM
II	TRANSISTORS, FET
III	TRANSISTORS, UNIJUCTION
IV	DIODES, GENERAL PURPOSE, SILICON, GERMANIUM
V	DIODES, VOLTAGE REGULATOR (ZENER, AVALANCHE)
V	DIODES, VOLTAGE REFERENCE (TEMP. COMP. AVALANCHE)
VI	THYRISTORS
VII	MICROWAVE, DETECTORS, MIXERS
VIII	MICROWAVE, VARACTORS, STEP RECOVERY, TUNNEL
IX	MICROWAVE TRANSISTORS
X	OPTO-ELECTRONIC DEVICES

TABLE 2-5: OPERATING ENVIRONMENTS PER MIL-HDBK-217

SYMBOL	ENVIRONMENT
GB	GROUND, BENIGN
GF	GROUND, FIXED
GM	GROUND, MOBILE
AIT	AIRBORNE, TRANSPORT, INHABITED
AUT	AIRBORNE, TRANSPORT, UNINHABITED
AIF	AIRBORNE, FIGHTER, INHABITED
AUF	AIRBORNE, FIGHTER, UNINHABITED
SF	SPACE FLIGHT
ML	MISSILE LAUNCH
NS	NAVAL, SHELTERED
NU	NAVAL, UNSHELTERED

TABLE 2-6: DERATING LEVELS FOR BIPOLAR TRANSISTORS JUNCTION TEMPERATURE (MIL-HDBK-217 GROUP I)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
C								.6			
E						.6	.6				
F								.5	.5		
H				.5	.5				.5		
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
N1				.53	.53						
N2				.82	.82						
N3				.94	.94						
O									.6		
P	.5	.5									
R								.55			
S								.55			
T	.6	.6	.6						.6		
U1										.53	.53
U2										.8	.8
U3										.92	.92
V				.6	.6						
X								.55			
AVE	0.55	0.55	0.60	0.64	0.64	0.60	0.60	0.55	0.55	0.75	0.75
MAX	.6	.6	.6	.94	.94	.6	.6	.6	.6	.92	.92
MIN	.6	.6	.6	.5	.5	.6	.6	.5	.5	.53	.53
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-7: DERATING LEVELS FOR BIPOLAR TRANSISTORS POWER (MIL-HDBK-217 GROUP I)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.4	.4
E								.6			
F								.5	.5		
G								.5	.5		
H				.5	.5				.5		
L1	.82	.82	.82								
L2	.93	.93	.93								
M					.6						
O									.5		
Q	.6	.6	.6	.6	.6	.6	.6	.6			
R1								.15			
R2								.2			
S								.5			
T	.3	.3	.3						.3		
W	.3	.5									
X								.5			
Y	.75	.75									
AVE	0.65	0.65	0.66	0.55	0.57	0.63	0.60	0.44	0.45	0.40	0.40
MAX	.93	.93	.93	.6	.6	.6	.6	.6	.5	.4	.4
MIN	.3	.3	.3	.5	.5	.6	.6	.15	.3	.4	.4
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-8: DERATING LEVELS FOR BIPOLAR TRANSISTORS CURRENT (MIL-HDBK-217 GROUP I)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONEMENT						
A										.5	.5
B										.9	.9
C								.8			
E								.75			
G								.75			
I	.75	.75	.75								
J								.75			
K				.75	.75						
N1				.6	.6						
N2				.7	.7						
N3				.8	.8						
O1									.75		
O2									.8		
P	.75	.75									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
S								.5			
V				.75	.75						
X								.75			
AVE	0.75	0.75	0.75	0.73	0.73	0.75	0.75	0.72	0.78	0.70	0.70
MAX	.75	.75	.75	.8	.8	.75	.75	.8	.8	.9	.9
MIN	.75	.75	.75	.6	.6	.75	.75	.5	.75	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-9: DERATING LEVELS FOR BIPOLAR TRANSISTORS VOLTAGE (MIL-HDBK-217 GROUP I)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.75	.75
B										.75	.75
C								.8			
E								.75			
F1								.8	.8		
F2								.7	.7		
G								.75	.75		
H				.8	.8				.8		
I1	.8	.8	.8								
I2	.7	.7	.7								
J1								.8			
J2								.7			
K				.75	.75						
L1	.7	.7	.7								
L2	.8	.8	.8								
M					.8						
N1				.6	.6						
N2				.7	.7						
N3				.8	.8						
O									.75		
Q	.8	.8	.8	.8	.8	.8	.8	.8			
R								.75			
S								.75			
T	.7	.7	.7						.7		
U1										.6	.6
U2										.7	.7
U3										.8	.8
V				.6	.6						
X								.75	.75		
AVE	0.75	0.75	0.75	0.72	0.73	0.80	0.80	0.76	0.75	0.72	0.72
MAX	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8
MIN	.7	.7	.7	.6	.6	.8	.8	.7	.7	.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-10: DERATING LEVELS FOR BIPOLAR TRANSISTORS SURGE CURRENT
(MIL-HDBK-217 GROUP I)

SOURCE	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.6	.6
B										.75	.75
V				.9	.9						
X								.75			
AVE				0.90	0.90			0.75		0.68	0.68
MAX				.9	.9			.75		.75	.75
MIN				.9	.9			.75		.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-11: DERATING LEVELS FOR FET TRANSISTORS JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUP II)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
C								.6			
D						.6	.6				
H				.5	.5				.5		
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
N1				.53	.53						
N2				.83	.83						
N3				.94	.94						
P	.5	.5									
R								.55			
S								.58			
T	.5	.6	.6						.6		
U1										.53	.53
U2										.83	.83
U3										.94	.94
V				.5	.6						
W1	.6	.6	.6								
W2	.5	.5	.5								
X								.55			
AVE	0.55	0.55	0.57	0.64	0.64	0.60	0.60	0.56	0.55	0.77	0.77
MAX	.6	.6	.6	.94	.94	.6	.6	.6	.6	.94	.94
MIN	.5	.5	.5	.4	.4	.6	.6	.55	.5	.53	.53
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-12: DERATING LEVELS FOR FET TRANSISTORS POWER
(MIL-HDBK-217 GROUP II)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.4	.4
E								.6			
G								.3	.5		
H				.5	.5				.5		
L1	.83	.83	.83	.83							
L2	.94	.94	.94	.94							
M					.6						
P	.6	.6	.6	.6	.6	.6	.6	.6			
R1								.3			
R2								.4			
S								.5			
T	.3	.3	.3						.3		
W	.3	.3									
X								.5			
Y	.75	.75									
AVE	0.62	0.62	0.67	0.72	0.57	0.60	0.60	0.49	0.43	0.40	0.40
MAX	.94	.94	.94	.94	.6	.6	.6	.6	.5	.4	.4
MIN	.3	.3	.3	.5	.5	.6	.6	.3	.3	.4	.4
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-13: DERATING LEVELS FOR FET TRANSISTORS CURRENT
(MIL-HDBK-217 GROUP II)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.5	.5
B										.9	.9
C								.8			
E								.75			
G								.75	.75		
I	.75	.75	.75								
J								.75			
K				.75	.75						
P	.75	.75									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
R								.5			
S											
U											
V				.75	.75						
X								.75			
AVE	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.72	0.75	0.70	0.70
MAX	.75	.75	.75	.75	.75	.75	.75	.8	.75	.9	.9
MIN	.75	.75	.75	.75	.75	.75	.75	.5	.75	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-14: DERATING LEVELS FOR FET TRANSISTORS VOLTAGE
(MIL-HDBK-217 GROUP II)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.75	.75
B										.75	.75
C								.8			
E								.75			
G								.75	.75		
H				.8	.8				.8		
I1	.7	.7	.7								
I2	.8	.8	.8								
J1								.7			
J2								.8			
K				.75	.75						
L1	.7	.7	.7								
L2	.8	.8	.8								
M								.8			
N1				.6	.6						
N2				.7	.7						
N3				.8	.8						
O									.75		
Q	.8	.8	.8	.8	.8	.8	.8	.8			
R								.75			
S								.75			
T	.7	.7	.7						.7		
U1										.6	.6
U2										.7	.7
U3										.8	.8
V				.6	.6						
W	.5	.5									
X								.75			
AVE	0.71	0.71	0.75	0.72	0.72	0.80	0.80	0.77	0.75	0.72	0.72
MAX	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8
MIN	.5	.5	.7	.6	.6	.8	.8	.7	.7	.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-15: DERATING LEVELS FOR FET TRANSISTORS SURGE CURRENT
(MIL-HDBK-217 GROUP II)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.6	.6
B										.75	.75
V				.9	.9						
X								.75			
AVE				0.90	0.90			0.75		0.68	0.68
MAX				.9	.9			.75		.75	.75
MIN				.9	.9			.75		.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-16: DERATING LEVELS FOR UJT TRANSISTORS JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUP III)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
C								.6			
D						.6	.6				
H				.5	.5				.5		
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
N1				.53	.53						
N2				.79	.79						
N3				.89	.89						
O									.6		
P	.5	.5									
R								.55			
S								.53			
T	.6	.6	.6						.6		
U1										.53	.53
U2										.79	.79
U3										.89	.89
V				.6	.6						
X								.55			
AVE	0.55	0.55	0.60	0.63	0.63	0.60	0.60	0.56	0.57	0.74	0.74
MAX	.6	.6	.6	.89	.89	.6	.6	.6	.6	.89	.89
MIN	.5	.5	.6	.4	.4	.6	.6	.55	.5	.53	.53
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-17: DERATING LEVELS FOR UJT TRANSISTORS POWER
(MIL-HDBK-217 GROUP III)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
E								.6			
G								.5	.5		
H				.5	.5				.5		
L1	.79	.79	.79								
L2	.89	.89	.89								
M					.6						
O									.5		
Q	.6	.6	.6	.6	.6	.6	.6	.6			
R								.2			
S								.5			
T	.3	.3	.3						.3		
X								.5			
Y	.75	.75									
AVE	0.67	0.67	0.65	0.55	0.57	0.60	0.60	0.48	0.45		
MAX	.89	.89	.89	.6	.6	.6	.6	.6	.5		
MIN	.3	.3	.3	.5	.5	.6	.6	.2	.3		
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-18: DERATING LEVELS FOR UJT TRANSISTORS CURRENT
(MIL-HDBK-217 GROUP III)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
B										.9	.9
C								.8			
E								.75			
G								.75	.75		
I	.75	.75	.75								
J								.75			
K				.75	.75						
P	.75	.75									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
S								.5			
V				.75	.75				.75		
X								.75	.75		
AVE	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.72	0.75	0.90	0.90
MAX	.75	.75	.75	.75	.75	.75	.75	.8	.75	.9	.9
MIN	.75	.75	.75	.75	.75	.75	.75	.5	.75	.9	.9
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-19: DERATING LEVELS FOR UJT TRANSISTORS VOLTAGE
(MIL-HDBK-217 GROUP III)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
B										.75	.75
C								.8			
E								.75			
G								.75	.75		
H				.8	.8				.8		
I1	.7	.7	.7								
I2	.8	.8	.8								
J1								.7			
J2								.8			
K				.75	.75						
L1	.7	.7	.7								
L2	.8	.8	.8								
M					.8						
M1				.6	.6						
M2				.7	.7						
M3				.8	.8						
O									.75		
Q	.8	.8	.8	.8	.8	.8	.8	.8			
R								.75			
S								.75			
T	.7	.7	.7						.7		
U1								.8		.6	.6
U2										.7	.7
U3										.8	.8
V				.6	.6						
X								.75	.75		
AVE	0.75	0.75	0.75	0.72	0.73	0.80	0.80	0.77	0.75	0.71	0.71
MAX	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8
MIN	.7	7	.7	.6	.6	.8	.8	.7	.7	.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-20: DERATING LEVELS FOR UJT TRANSISTORS SURGE CURRENT
(MIL-HDBK-217 GROUP I(I))

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
D										.75	.75
V				.9	.9						
X								.75	.75		
AVE				0.90	0.90			0.75	0.75	0.75	0.75
MAX				.9	.9			.75	.75	.75	.75
MIN				.9	.9			.75	.75	.75	.75
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-21: DERATING LEVELS FOR GEN PURPOSE DIODES JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUP IV)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
C								.6			
J						.6	.6				
E1								.65			
E2								.67			
G								.67			
H				.89	.89				.89		
K1				.75	.75						
K2				.6	.6						
K3				.4	.4						
L1	.87	.87	.87								
L2	.77	.77	.77								
O									.67		
Q1	.6	.6	.6	.6	.6	.6	.6	.6			
Q2	.65	.65	.65	.65	.65	.65	.65	.65			
R								.6			
V				.6	.6						
W	.6	.6									
X								.55			
AVE	0.70	0.70	0.72	0.64	0.64	0.62	0.62	0.63	0.78		
MAX	.87	.87	.87	.89	.89	.65	.65	.67	.89		
MIN	.6	.6	.6	.4	.4	.6	.6	.55	.67		
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-22: DERATING LEVELS FOR GEN PURPOSE DIODES POWER
(MIL-HDBK-217 GROUP IV)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.5	.5
B										.75	.75
E								.6			
F								.5	.5		
G1								.5			
G2								.65			
H				.5	.5				.5		
I	.5	.5	.5								
J								.5			
K					.6						
O									.5		
R1								.2			
R2								.5			
W	.5	.5	.5								
X								.5			
AVE	0.50	0.50	0.50	0.50	0.55			0.49	0.50	0.63	0.63
MAX	.5	.5	.5	.5	.6			.65	.5	.75	.75
MIN	.5	.5	.5	.5	.5			.2	.5	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-23: DERATING LEVELS FOR GEN PURPOSE DIODES CURRENT
(MIL-HDBK-217 GROUP IV)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.6	.6
B										.5	.5
D						.75	.75				
E								.6			
F								.5	.5		
G1								.75			
G2								.5			
I	.5	.5	.5								
J								.5			
K				.75	.75						
N1				.87	.87						
N2				.77	.77						
N3				.53	.53						
O									.8		
P	.75	.5									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
R								.5			
S1								.6			
S2								.75			
S3								.85			
T1	.2	.2	.2						.2		
T2	.5	.5	.5						.5		
U1										.55	.55
U2										.8	.8
U3										.9	.9
V				.75	.75						
W	.5	.5									
X								.75			
AVE	0.53	0.49	0.49	0.74	0.74	0.75	0.75	0.64	0.50	0.67	0.67
MAX	.75	.75	.75	.87	.87	.75	.75	.85	.8	.9	.9
MIN	.2	.2	.2	.53	.53	.75	.75	.5	.2	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-24: DERATING LEVELS FOR GEN PURPOSE DIODES REVERSE VOLTAGE
(MIL-HDBK-217 GROUP IV)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.65	.65
B										.65	.65
C								.8			
D						.75	.75				
E1								.7			
E2								.75			
F								.8	.8		
G								.75			
H				.8	.8				.8		
I	.7	.7	.7	.7							
J								.7			
K				.75	.75						
L1	.77	.77	.77								
L2	.87	.87	.87								
N1				.6	.6						
N2				.85	.85						
N3				.9	.9						
O									.8		
P	.6	.5									
Q	.8	.8	.8	.8	.8	.8	.8	.8			
R1								.5			
R2								.8			
S1								.75			
S2								.75			
S3								.8			
T1	.6	.6	.6						.6		
T2	.7	.7	.7						.7		
U1										.6	.6
U2										.7	.7
U3										.8	.8
V				.75	.75						
W	.5	.5									
X								.75			
Y	.5	.5									
AVE	0.67	0.66	0.74	0.77	0.78	0.78	0.78	0.74	0.74	0.68	0.68
MAX	.87	.87	.87	.9	.9	.8	.8	.8	.8	.8	.8
MIN	.5	.5	.6	.6	.6	.75	.75	.7	.6	.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-25: DERATING LEVELS FOR GEN PURPOSE DIODES SURGE CURRENT
(MIL-HDBK-217 GROUP IV)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.7	.7
B										.7	.7
C								.8			
E1								.6			
E2								.75			
G1								.5			
G2								.75			
I	.75	.75	.75								
J								.75			
N1				.87	.87						
N2				.77	.77						
N3				.53	.53						
U1										.9	.9
U2										.8	.8
U3										.55	.55
AVE	0.75	0.75	0.75	0.72	0.72			0.69		0.73	0.73
MAX	.75	.75	.75	.87	.87			.8		.9	.9
MIN	.75	.75	.75	.53	.53			.5		.55	.55
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-26: DERATING LEVELS FOR REG/REF DIODES JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUP V)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
C								.6			
D						.6	.6				
E								.65			
G								.67			
H				.89	.89				.89		
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
L1	.77	.77	.77								
L2	.87	.87	.87								
O									.67		
Q1	.6	.6	.6	.6	.6	.6	.6	.6			
Q2	.65	.65	.65	.65	.65	.65	.65	.65			
R								.6			
V				.6	.6						
W	.5	.5									
X								.55			
AVE	0.68	0.68	0.72	0.64	0.64	0.62	0.62	0.62	0.78		
MAX	.87	.87	.87	.89	.89	.65	.65	.67	.89		
MIN	.5	.5	.6	.4	.4	.6	.6	.55	.67		
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-27: DERATING LEVELS FOR REG/REF DIODES POWER
(MIL-HDBK-217 GROUP V)

SOURCE	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	MU	NS
A										.5	.5
E								.6			
F								.5	.5		
B1								.85			
B2								.5			
H				.5	.5				.5		
I	.5	.5	.5								
J								.5			
M								.6			
O									.5		
R1								.2			
R2								.5			
T	.4	.4	.4						.4		
W	.3	.3									
AVE	0.40	0.40	0.45	0.50	0.50			0.53	0.48	0.50	0.50
MAX	.5	.5	.5	.5	.5			.85	.5	.5	.5
MIN	.3	.3	.4	.5	.5			.2	.4	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-28: DERATING LEVELS FOR REG/REF DIODES CURRENT
(MIL-HDBK-217 GROUP V)

SOURCE	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	MU	NS
A										.6	.6
B										.5	.5
D						.75	.75				
E								.5			
F								.5	.5		
I	.7	.7	.7								
J								.7			
K				.75	.75						
L1	.85	.85	.85								
L2	.9	.9	.9								
N1				.53	.53						
N2				.85	.85						
N3				.9	.9						
P	.75	.5									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
U1										.55	.55
U2										.8	.8
U3										.9	.9
V				.75	.75						
W	.5	.5									
X								.75			
AVE	0.74	0.70	0.80	0.76	0.76	0.75	0.75	0.64	0.50	0.67	0.67
MAX	.9	.9	.9	.9	.9	.75	.75	.75	.5	.9	.9
MIN	.5	.5	.7	.53	.53	.75	.75	.5	.5	.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-29: DERATING LEVELS FOR REG/REF DIODES SURGE CURRENT
(MIL-HDBK-217 GROUP V)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.7	.7
B										.7	.7
U1										.55	.55
U2										.8	.8
U3										.9	.9
AVE										0.73	0.73
MAX										.9	.9
MIN										.55	.55
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-30: DERATING LEVELS FOR THYRISTOR JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUP VI)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
					ENVIRONMENT						
A										.55	.55
B						.6	.6				
H				.89	.89				.89		
I	.75	.75	.75								
J								.75			
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
Q1	.6	.6	.6	.6	.6	.6	.6	.6			
Q2	.65	.65	.65	.65	.65	.65	.65	.65			
R								.6			
V				.6	.6						
X								.55			
AVE	0.67	0.67	0.67	0.64	0.64	0.62	0.62	0.63	0.89	0.55	0.55
MAX	.75	.75	.75	.89	.89	.65	.65	.75	.89	.55	.55
MIN	.6	.6	.6	.4	.4	.6	.6	.55	.89	.55	.55
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-31: DERATING LEVELS FOR THYRISTOR POWER
(MIL-HDBK-217 GROUP VI)

SOURCE	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
F								.5	.5		
H				.5	.5				.5		
M					.6						
R								.2			
X								.5			
AVE				0.50	0.55			0.40	0.50		
MAX				.5	.6			.5	.5		
MIN				.5	.5			.2	.5		
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-32: DERATING LEVELS FOR THYRISTOR CURRENT
(MIL-HDBK-217 GROUP VI)

SOURCE	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.6	.6
B										.5	.5
D						.75	.75				
I	.5	.5	.5								
J								.5			
K				.75	.75						
N1				.54	.54						
N2				.76	.76						
N3				.8	.8						
P	.75	.5									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
R								.5			
U1										.55	.55
U2										.8	.8
U3										.9	.9
V				.75	.75						
X								.75			
AVE	0.67	0.58	0.63	0.73	0.73	0.75	0.75	0.63		0.67	0.67
MAX	.75	.75	.75	.8	.8	.75	.73	.75		.9	.9
MIN	.5	.5	.5	.54	.54	.75	.75	.5		.5	.5
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-33: DERATING LEVELS FOR THYRISTOR VOLTAGE
(MIL-HDBK-217 GROUP VI)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.65	.65
B										.65	.65
D						.75	.75				
F								.8	.8		
H				.8	.8				.8		
I	.75	.75	.75								
J								.75			
K1				.75	.75						
K2				.9	.9						
L1	.77	.77	.77								
L2	.87	.87	.87								
N1				.54	.54						
N2				.7	.7						
N3				.8	.8						
P	.6	.5									
Q	.8	.8	.8	.8	.8	.8	.8	.8			
U1										.6	.6
U2										.7	.7
U3										.6	.8
V				.75	.75						
X								.75			
Y	.5	.5									
AVE	0.72	0.70	0.80	0.76	0.76	0.78	0.78	0.78	0.80	0.68	0.68
MAX	.87	.87	.87	.9	.9	.8	.8	.8	.8	.8	.8
MIN	.5	.5	.75	.54	.54	.75	.75	.75	.75	.6	.6
ENVIRO FACTOR	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-34: DERATING LEVELS FOR THYRISTOR SURGE CURRENT
(MIL-HDBK-217 GROUP VI)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
A										.7	.7
B										.7	.7
U1										.55	.55
U2										.8	.8
U3										.9	.9
AVE										0.73	0.73
MAX										.9	.9
MIN										.55	.55
ENVIRO FACTOR	1	3	25	12	20	25	40	1	40	25	10

TABLE 2-35: DERATING LEVELS FOR MICROWAVE DIODES JUNCTION TEMPERATURE
(MIL-HDBK-217 GROUPS VII-IX)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
D						.6	.6				
G								.67			
K1				.4	.4						
K2				.6	.6						
K3				.75	.75						
Q1	.65	.65	.65	.65	.65	.65	.65	.65			
Q2	.6	.6	.6	.6	.6	.6	.6	.6			
V				.6	.6						
W	.6	.6									
X								.55			
AVE	0.62	0.62	0.63	0.60	0.60	0.62	0.62	0.62			
MAX	.65	.65	.65	.75	.75	.65	.65	.67			
MIN	.6	.6	.6	.4	.4	.6	.6	.55			
ENVIRO FACTOR											
GR VII	1	10	50	25	40	50	80	1	200	50	15
GR VIII	1	5	25	12	20	25	40	1	40	25	10

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-36: DERATING LEVELS FOR MICROWAVE DIODES POWER
(MIL-HDBK-217 GROUPS VII-IX)

	ENVIRONMENT										
SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
E								.6			
Q1								.5			
Q2								.75			
N					.6						
W	.5	.5									
X								.5			
AVE	0.50	0.50	0.50		0.60			0.59			
MAX	.5	.5	.5		.6			.75			
MIN	.5	.5	.5		.6			.5			
ENVIRO FACTOR											
GR VII	1	10	50	25	40	50	80	1	200	50	15
GR VIII	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-37: DERATING LEVELS FOR MICROWAVE DIODES CURRENT (MIL-HDBK-217 GROUPS VII-IX)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
D						.75	.75				
F								.5	.5		
G								.75			
K				.75	.75						
P	.75	.5									
Q	.75	.75	.75	.75	.75	.75	.75	.75			
V				.75	.75						
W	.75	.75									
AVE	0.75	0.67	0.75	0.75	0.75	0.75	0.75	0.67	0.50		
MAX	.75	.75	.75	.75	.75	.75	.75	.75	.5		
MIN	.75	.5	.75	.75	.75	.75	.75	.5	.5		
ENVIRO FACTOR GR VII	1	10	50	25	40	50	80	1	200	50	15
GR VIII	1	5	25	12	20	25	40	1	40	25	10

TABLE 2-38: DERATING LEVELS FOR MICROWAVE DIODES VOLTAGE (MIL-HDBK-217 GROUP VII-IX)

SOURCE	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS
D						.75	.75				
F								.8	.8		
G								.75			
K				.75	[illegible]						
P	.6	.5									
Q	.8	.8	.8	.8	.8	.8	.8	.8			
V				.75	.75						
W	.75	.75									
X								.75			
Y	.5	.5									
AVE	0.66	0.64	0.80	0.77	0.77	0.78	0.78	0.78	0.80		
MAX	.8	.8	.8	.8	.8	.8	.8	.8	.8		
MIN	.5	.5	.8	.75	.75	.75	.75	.75	.8		
ENVIRO FACTOR GR VII	1	10	50	25	40	50	80	1	200	50	15
GR VIII	1	5	25	12	20	25	40	1	40	25	10

2.3.4 Results of Data Tabulation

These retabulations are summarized in Tables 2-39 through 2-43 by group and environment for each parameter. A detailed examination of these summaries clearly shows that present practice does not define the recommended derated stress level for a parameter on the basis of the operating environment. While there is considerable consistency in the level of derating for a specific parameter, a comparison of the derated stress level to the environment indicates that environment is not a definitive variable in establishing the recommended stress level. Present derating practice essentially recommends the following derating for any environment:

PARAMETER	DERATED STRESS LEVEL FROM MAX RATING
Junction Temperature (deg C)	.64
Power	.53
Current	.71
Voltage	.75
Surge Current	.76

The lack of environmental variation can be partially explained by the fact that almost all the derating data sources were derating for a single specific environment. An additional factor is the prevalence of intuitive analysis in the selection of derating levels and consequent differing interpretations of how much derating is really necessary for a given operating condition.

This does not mean that operating environment should be ignored in developing derating requirements. Since the failure rate increases with the extremity of the operating environment, derating can compensate for environmental effects by operating the parts under stress conditions which will result in a lower failure. This can be shown by examining the effect of stress on the predicted failure rate. However, protection of the parts from the operating environments is a design problem and does not dictate the necessary derating from the device absolute maximum rating.

TABLE 2-39: DERATING LEVEL SUMMARY FOR JUNCTION TEMPERATURE

	ENVIRONMENT											
GROUP	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS	AVE
I	0.55	0.55	0.60	0.64	0.64	0.60	0.60	0.55	0.55	0.75	0.75	0.62
II	0.55	0.55	0.57	0.64	0.64	0.60	0.60	0.56	0.55	0.77	0.77	0.62
III	0.55	0.55	0.59	0.63	0.63	0.60	0.60	0.56	0.57	0.74	0.74	0.62
IV	0.70	0.70	0.72	0.64	0.64	0.62	0.62	0.63	0.78			0.67
V	0.68	0.68	0.72	0.64	0.64	0.62	0.62	0.62	0.78			0.67
VI	0.67	0.67	0.67	0.64	0.64	0.62	0.62	0.63	0.89	0.55	0.55	0.65
VII-IX	0.62	0.62	0.63	0.60	0.60	0.62	0.62	0.62				0.62
AVE	0.62	0.62	0.64	0.63	0.63	0.61	0.61	0.60	0.69	0.70	0.70	0.64
MAX	0.70	0.70	0.72	0.64	0.64	0.62	0.62	0.63	0.89	0.77	0.77	0.67
MIN	0.55	0.55	0.57	0.60	0.60	0.60	0.60	0.55	0.55	0.55	0.55	0.62

NOTE: THE TABLE IS BASED ON JUNCTION TEMPERATURE IN DEGREES CENTIGRADE

TABLE 2-40: DERATING LEVEL SUMMARY FOR POWER

	ENVIRONMENT											
GROUP	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS	AVE
I	0.65	0.65	0.66	0.55	0.57	0.59	0.60	0.44	0.46	0.40	0.40	0.54
II	0.62	0.62	0.67	0.72	0.57	0.60	0.60	0.49	0.43	0.40	0.40	0.56
III	0.67	0.67	0.65	0.55	0.57	0.60	0.60	0.48	0.45			0.58
IV	0.50	0.50	0.50	0.50	0.55			0.49	0.50	0.63	0.63	0.53
V	0.40	0.40	0.45	0.50	0.50			0.53	0.48	0.50	0.50	0.47
VI				0.50	0.55			0.40	0.50			0.49
VII-IX	0.50	0.50	0.50		0.60			0.59				0.54
AVE	0.56	0.56	0.57	0.55	0.56	0.60	0.60	0.49	0.47	0.48	0.48	0.53
MAX	0.67	0.67	0.67	0.72	0.60	0.60	0.60	0.59	0.50	0.63	0.63	0.58
MIN	0.40	0.40	0.45	0.50	0.50	0.60	0.60	0.40	0.43	0.40	0.40	0.47

TABLE 2-41: DERATING LEVEL SUMMARY FOR CURRENT

	ENVIRONMENT											
GROUP	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS	AVE
I	0.75	0.75	0.75	0.73	0.73	0.75	0.75	0.72	0.78	0.70	0.70	0.74
II	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.72	0.75	0.70	0.70	0.74
III	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.72	0.75	0.90	0.90	0.77
IV	0.53	0.49	0.49	0.74	0.74	0.75	0.75	0.64	0.50	0.67	0.68	0.63
V	0.74	0.70	0.80	0.76	0.76	0.75	0.78	0.64	0.50	0.67	0.67	0.71
VI	0.67	0.58	0.63	0.73	0.73	0.75	0.75	0.63		0.67	0.67	0.68
VII-IX	0.75	0.67	0.75	0.75	0.75	0.75	0.75	0.67	0.50			0.70
AVE	0.71	0.67	0.70	0.74	0.74	0.75	0.75	0.68	0.63	0.72	0.72	0.71
MAX	0.75	0.75	0.80	0.76	0.76	0.75	0.78	0.72	0.78	0.90	0.90	0.77
MIN	0.53	0.49	0.49	0.73	0.73	0.75	0.73	0.63	0.50	0.67	0.67	0.63

TABLE 2-42: DERATING LEVEL SUMMARY FOR VOLTAGE

	ENVIRONMENT											
GROUP	GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS	AVE
I	0.75	0.75	0.75	0.72	0.73	0.80	0.80	0.76	0.75	0.72	0.72	0.75
II	0.71	0.71	0.75	0.72	0.72	0.80	0.80	0.77	0.75	0.72	0.72	0.74
III	0.75	0.75	0.75	0.72	0.73	0.80	0.80	0.77	0.75	0.71	0.71	0.75
IV	0.67	0.66	0.74	0.77	0.78	0.78	0.78	0.74	0.74	0.68	0.68	0.73
V												
VI	0.72	0.70	0.80	0.76	0.76	0.78	0.78	0.78	0.80	0.68	0.68	0.75
VII-IX	0.66	0.64	0.80	0.77	0.77	0.78	0.78	0.78	0.80			0.75
AVE	0.71	0.70	0.77	0.74	0.75	0.79	0.79	0.77	0.77	0.70	0.70	0.75
MAX	0.75	0.75	0.80	0.77	0.78	0.80	0.80	0.78	0.80	0.72	0.72	0.75
MIN	0.66	0.64	0.74	0.72	0.72	0.78	0.78	0.74	0.74	0.68	0.68	0.73

NOTE: NO VOLTAGE DFRATING FOR GROUP V REGULATOR/REFERENCE DIODES

TABLE 2-43: DERATING LEVEL SUMMARY FOR SURGE CURRENT

GROUP	ENVIRONMENT GB	GF	GM	AIT	AUT	AIF	AUF	SF	ML	NU	NS	AVE
I				0.90	0.90			0.75		0.68	0.68	0.78
II				0.90	0.90			0.75		0.68	0.68	0.78
III				0.90	0.90			0.75	0.73	0.75	0.75	0.80
IV	0.75	0.75	0.75	0.72	0.72			0.69		0.73	0.73	0.73
V										0.73	0.73	0.73
VI										0.73	0.73	0.73
VII-IX												
AVE	0.75	0.75	0.75	0.86	0.86			0.74	0.75	0.72	0.72	0.76
MAX	0.75	0.75	0.75	0.90	0.90			0.75	0.75	0.75	0.75	0.80
MIN	0.75	0.75	0.75	0.72	0.72			0.69	0.75	0.68	0.68	0.73

2.4 Failure Rate Model Analysis

2.4.1 Failure Rate Prediction for Discrete Semiconductors

To determine if derating can be developed from an analysis of the failure rate model of a device, the failure rate prediction method for general purpose silicon transistors will be examined (reference MIL-HDBK-217C). The general failure rate model for transistors and diodes is:

$$\lambda_p = \lambda_b(\pi_E x \pi_A x \pi_Q x \pi_R x \pi_C) \qquad \text{Failures}/10^6 \text{ hours}$$

The failure rate model consists of a base failure rate, λ_b, which is multiplied by various π constants which depend on type, usage and environment. For NPN/PNP bipolar silicon or germanium transistors the multiplication factors are defined as:

π_E	Environment
π_A	Application
π_Q	Quality
π_R	Power Rating
π_{S2}	Voltage Stress
π_C	Complexity

The equation for the base failure rate, λ_b, is:

$$\lambda_b = A\, e^{\left(\frac{N_T}{273 + T(\Delta T)S}\right)}\; e^{\left(\frac{273 + T + (\Delta T)S}{T_M}\right)^P}$$

where

- $\underline{A}$ is a failure rate scaling factor
- $\underline{e}$ is the natural logarithm base, 2.718
- $\underline{N_T}$, $\underline{T_M}$ and $\underline{P}$ are shaping parameters

- $\underline{T}$ is the operating temperature in degrees C, ambient or case as applicable

ΔT is the difference between the typical maximum allowable temperature with no junction current or power and the typical maximum allowable temperature with full rated junction current and power.

S is the stress ratio of operating electrical stress to rated electrical stress.

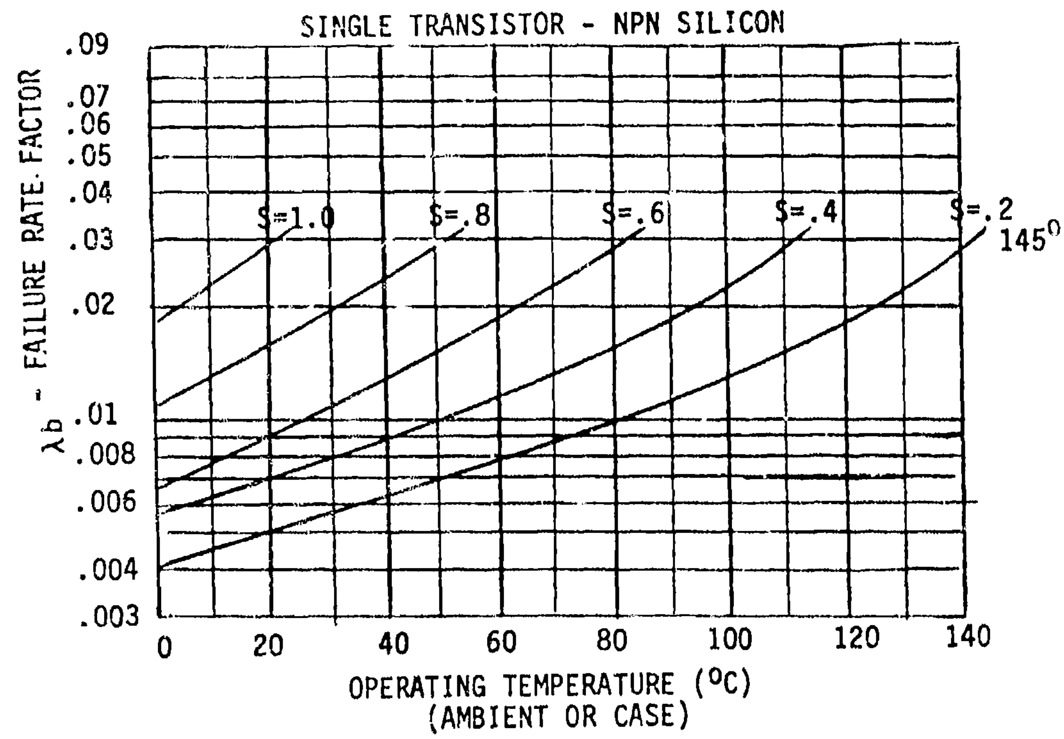
The values of the constants depend on the transistor/diode type and group. The resulting base failure rates are functions of temperature and electrical stress. The equation is based on typical maximum junction temperatures of 100 degrees C for germanium (70 degrees C for microwave types), 175 degrees C for silicon (150 degrees C for microwave types) and 125 degrees C for opto-electronic devices as well as a value of 25 degrees C for the maximum temperature at which full rated operation is permitted. If device temperature ratings are different from these values, the values of S and T for entering the equation are adjusted by procedures defined in MIL-HDBK-217C.

Calculated curves for NPN transistors are shown in Figure 2-1. The curves cover failure rates up to the full rated conditions. If a particular operating condition of S and T results in a failure rate higher than the maximums shown by the curves, the device is over-stressed and should not be operated under those conditions. A similar set of curves may be plotted for each discrete transistor and diode type including thyristors and opto-electronic devices.

2.4.2 Variation of Failure Rate with Stress Ratio

If the temperature is held constant and the change in failure rate with changes in stress is plotted, a curve such as is shown in Figure 2-2 results. This curve is typical of this type of computation for discrete semiconductors. The abscissa represents Stress Ratio which for NPN transistors is operatin[illegible]er divided by the maximum rated power. The ordinate represents the [illegible]nt change in failure rate compared to operation at a stress ratio of 1. For example, operation at 90% of rated power results in a failure rate that is 32% less than the failure rate for operation at full rated power.

The curve shows that there is a continual reduction in the predicted failure rate with stress reduction to the 10% stress level. However, experience has shown that derating should be limited to 50% because the gain in failure rate reduction is not significant, in most cases, for the design penalities incurred when derating greater than 50% is imposed.



$S = \frac{P_{OP}}{P_{MAX}}$ (SINGLE TRANSISTOR)

P_{OP} = Actual Power Dissipated

P_{MAX} = Max. rated power at temp derating point

P_1 = Power dissipated in side being evaluated

$S = \left[\frac{P_1}{P_2} + P_2\left(\frac{\frac{1}{2}P_s - P_T}{P_s P_T}\right)\right]$ (DUAL TRANSISTORS) SINGLE CASE

P_2 = Power dissipated in other side

P_s = Max. power rating at temperature derating point - other side not operating

P_T = Max. power rating at temperature derating point with both sides operating

Figure 2-1: Base Failure Rate Versus Operating Temperature and Stress Ratio For NPN Bipolar Transistors

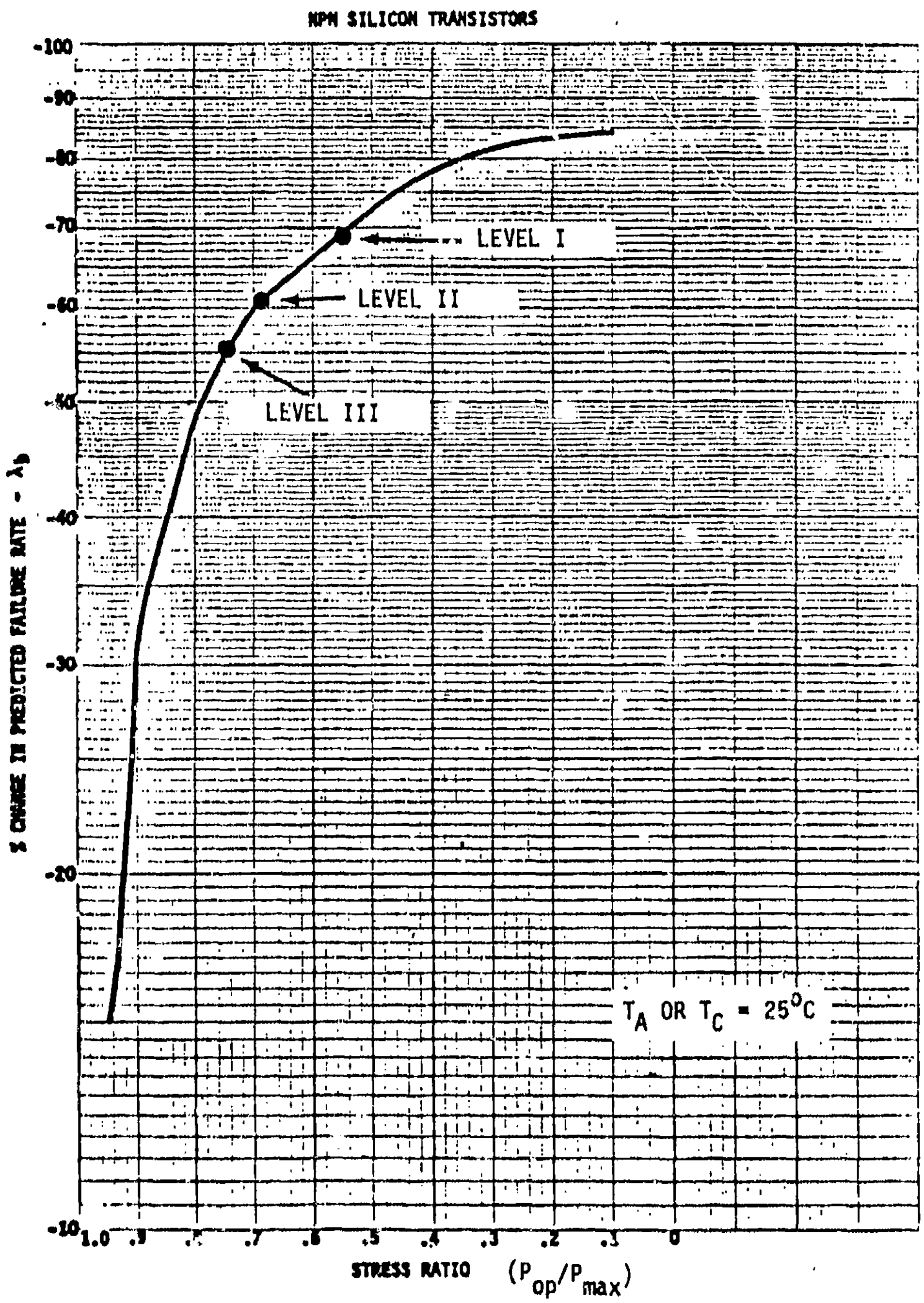


Figure 2-2: Change In Failure Rate Versus Change In Stress Ratio For Bipolar NPN Transistor

2.4.3 Selection of Derating Levels

As previously described, extreme derating to the 50% point can result in difficult and costly designs. For highly critical applications this may be necessary, however for many non critical applications it would not be justified. An obvious example would be ground support test equipment. Since the curves show considerable failure rate improvement with miniminal derating it would appear to be completely viable to establish multiple derating levels based on the criticality of the application.

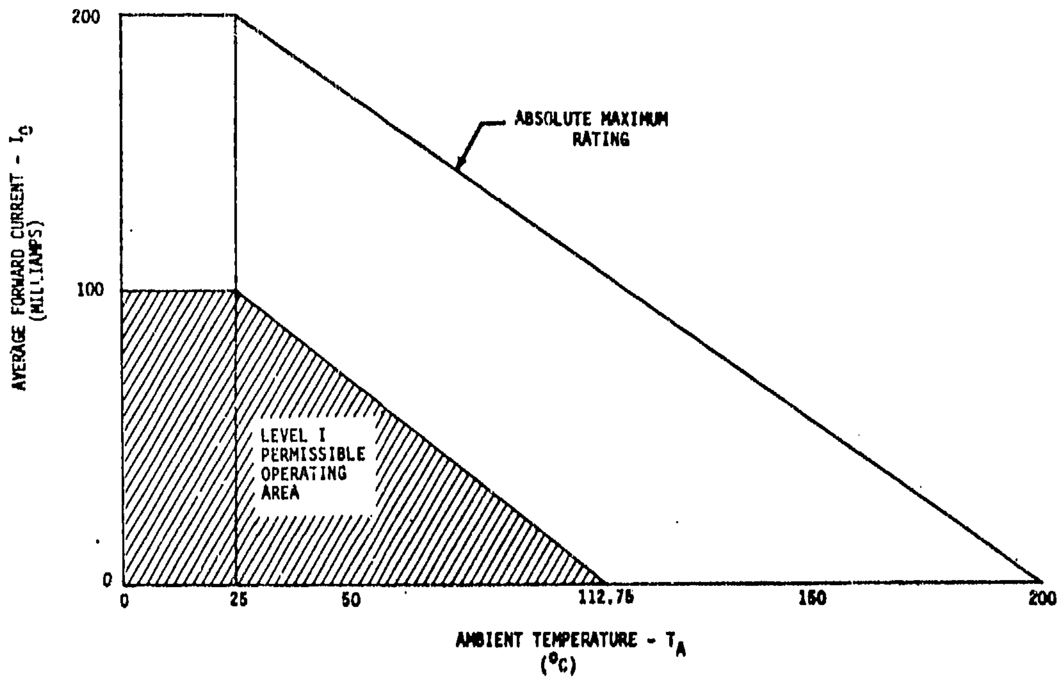
As previously described for semiconductors the maximum derating point should be 50%. For the minimum derating point extensive design history indicates that 75% derating presents almost no design penalities while offering considerable improvement in the predicted failure rate. In addition, it is obvious that allowing a 90% operating stress level would not normally be considered good design practice because of the proximity to the absolute maximum rating.

The selection of the maximum and minimum derating points and the approximate midpoint of 65% results in an acceptable selection of derating levels for differing requirements and is consistent with the literature survey of present derating practices.

2.4.4 Conversion of Derating Levels

The primary failure forcing function for semiconductors is junction temperature. Since the dominant failure mechanisms are associated with the device junction temperature, it is advisable to express the derating levels in terms of junction temperature. The method for translating the selected derated stress levels of 75%, 65%, and 50% into junction temperature was as follows.

Figure 2-3 shows the specification absolute maximum derating curve for the military preferred rectifier type 1N4148. The stress ratio for general purpose diodes is operating forward current divided by the maximum rated forward current. The maximum rating for this part is 1.0 amperes forward current up to an ambient temperature of 25 deg C. Above 25 deg C the current is derated linearly to zero at 175 deg C. The slope of this curve depends on the physical constants of the device and is approximately equal to the reciprocal of the thermal resistance. In practical terms, it is assumed that the junction temperature at every point on the curve is equal to the maximum rating of 175 deg C.



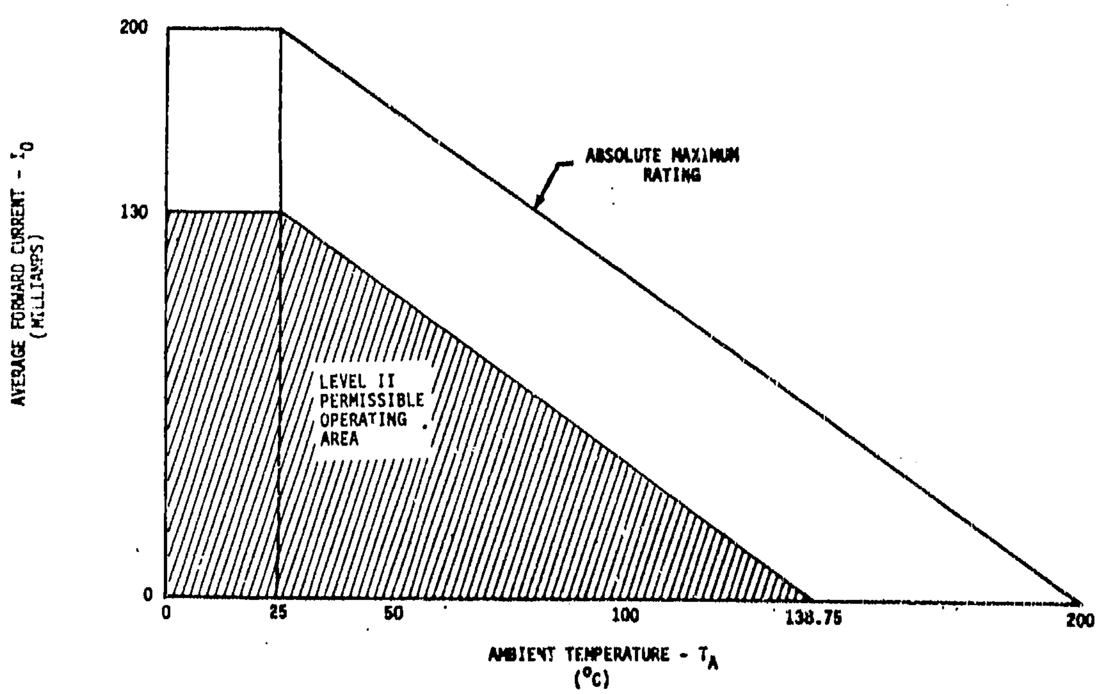


Figure 2-3: Current Level to Junction Temperature for Diode Type 1N4148/1N4148-1

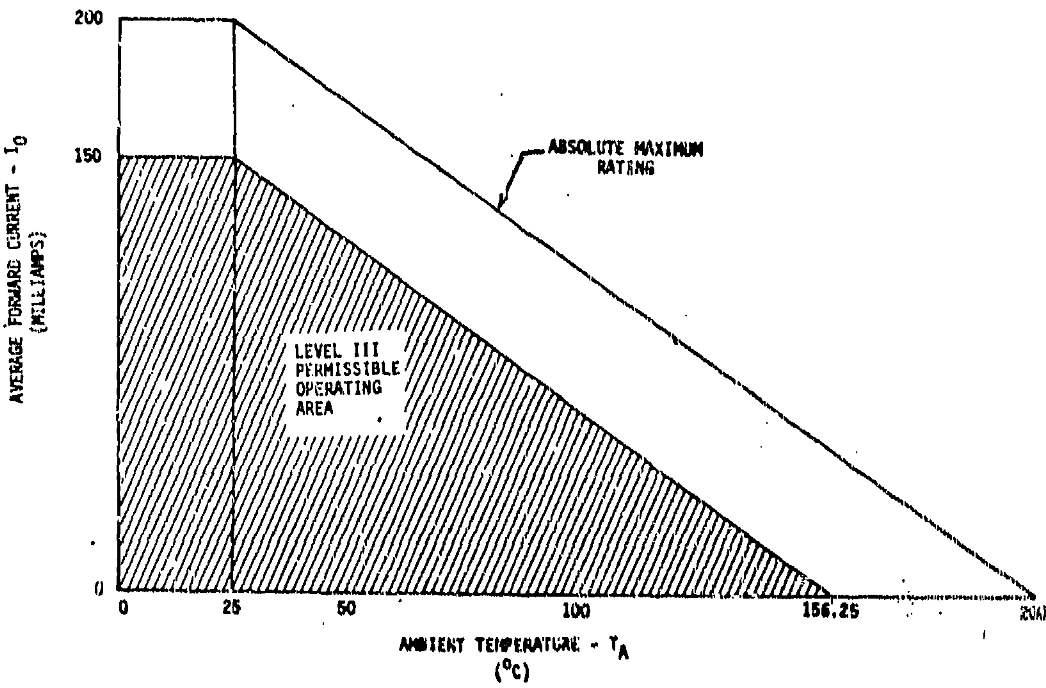


Figure 2-3: Current Level to Junction Temperature for Diode Type 1N4148/1N4148-1 (Continued)

Note that in general, low power parts have their maximum temperature ratings specified in terms of ambient temperature (TA) and high power parts are specified in terms of case temperature (TC). In some cases, maximum ratings are given for both TA and TC. The division point between low power and high power is arbitrary and not exactly defined. MIL-STD-701, which lists military preferred semiconductors, defines low power as 5 watts or less and high power as greater than 5 watts.

The derating stress ratios of 75%, 65%, and 50% are drawn on the graphs of Figure 2-3, maintaining identical slopes to the maximum rating curves. Since at zero forward current, the ambient and junction temperatures are equal, this results in maximum allowable junction temperatures of 112.75 deg C for Level I, 138.75 deg C for Level II, and 156.25 deg C for Level III stress ratios. This process was repeated for the maximum rating curves of the other highest usage military preferred transistors, Table 2-44 and diodes, Table 2-45. Table 2-46 shows the recommended maximum allowable junction temperatures for discete semiconductors. These selected temperatures are somewhat lower than that indicated by the above described analysis technique. This is due to the exceptionally high temperatures indicated and that in most cases the selected temperatures do not represent a difficult design constraint.

2.4.5 Analysis of Selected Junction Temperature Limits

An analysis of the selected derating levels (including temperatrre) was conducted by analysis of resulting failure rate as calculated per MIL-HDBK- 217C. A table of the calculated values is shown in Table 2-47. For purposes of this analysis, the failure rates were calculated beyond the limits allowed by MIL-HDBK-217C. On the table are marked the selected derated stresses, the resulting failure rate (circled) and a line the stress ratio/temperature trade off needed to maintain that failure ratio (a line). This data is then plotted in Figure 2-4. This curve is not a rigorous analysis. Its purpose is to illustrate the relative derating effect on failure rate. Note the following:

1. Large reliability gain with little derating (Level III which are not difficult to achieve in design).

2. Reliability gain rate decreases below Level I derating. Further derating would be unrealistic and difficult to achieve.

3. The selected intermediate derating Level (Level II) is still in the region of sharp gains in reliability. Achievement of the derating will require significant design effort but still would not be a overwhelming burder (i.e. + 125 deg C and 0.65 stress ratio).

4. Note the plotted temperature bar at each derating level; This shows that large temperature changes are required to trade off against the stress ratio.

TABLE 2-4A: ALLOWABLE MAXIMUM JUNCTION TEMPERATURES FOR TRANSISTOR DERATINGS OF 75%, 65% AND 50% OF THE MAXIMUM RATINGS

GENERIC PART NO	TRANS TYPE	TEMP TYPE	DERAT TEMP	MAX TEMP	MAXIMUM RATING (WATTS)	DERATED MAXIMUM TEMP LEVEL I	LEVEL II	LEVEL III
2N491A	UJT	TA	25	175	0.6	100.00	122.50	137.50
2N869A	PNP	TA	25	200	0.36	112.50	138.75	156.25
2N918	NPN	TC	25	200	0.3	112.50	138.75	156.25
2N2060	NPN/DUAL	TC	25	200	2.12	112.50	138.75	156.25
2N2219A	NPN	TA	25	200	3.0	112.50	138.75	156.25
2N2222A	NPN	TC	25	200	1.8	112.50	138.75	156.25
2N2369A	NPN	TC	25	200	1.2	112.50	138.75	156.25
2N2432A	NPN/CHOP	TC	25	200	0.6	112.50	138.75	156.25
2N2484	NPN	TC	25	200	1.2	112.50	138.75	156.25
2N2605	PNP	TA	25	200	0.4	112.50	138.75	156.25
2N2857	NPN	TC	25	200	0.3	112.50	138.75	156.25
2N2905A	PNP	TC	25	200	3.0	112.50	138.75	156.25
2N2907A	PNP	TC	25	200	1.8	112.50	138.75	156.25
2N2920	NPN/DUAL	TC	25	200	1.25	112.50	138.75	156.25
2N3019	NPN	TC	25	200	5.0	112.50	138.75	156.25
2N3251A	PNP	TC	25	200	1.2	112.50	138.75	156.25
2N3500	NPN	TC	25	200	5.0	112.50	138.75	156.25
2N3584	NPN	TC	25	200	35.0	112.50	138.75	156.25
2N3637	PNP	TC	25	200	5.0	112.50	138.75	156.25
2N3735	NPN	TA	25	200	1.0	112.50	138.75	156.25
2N3765	PNP	TA	25	200	0.5	112.50	138.75	156.25
2N3821	FET	TA	25	200	0.3	112.50	138.75	156.25
2N3868	PNP	TC	25	200	10.0	112.50	138.75	156.25
2N4856	FET	TA	25	200	0.36	112.50	138.75	156.25
AVERAGE						111.98	138.07	155.47
2N3716	NPN	TA	25	200	5.0	112.50	138.75	156.25
2N3716	NPN	TC	100	200	85.7	150.00	165.00	175.00
2N3792	PNP	TA	25	200	5.0	112.50	138.75	156.25
2N3792	PNP	TC	100	200	85.7	150.00	165.00	175.00
2N3997	NPN	TA	25	200	2.0	112.50	138.75	156.25
2N3997	NPN	TC	100	200	30.0	150.00	165.00	175.00
2N5302	NPN	TA	25	200	5.0	112.50	138.75	156.25
2N5302	NPN	TC	100	200	115.0	150.00	165.00	175.00
2N5686	NPN	TC	25	200	300.0	112.50	138.78	156.25
2N5686	NPN	TC	100	200	171.0	150.00	165.00	175.00

NOTE: TA IS AMBIENT TEMPERATURE

TC IS CASE TEMPERATURE

TABLE 2-45: ALLOWABLE MAXIMUM JUNCTION TEMPERATURES FOR DIODE DERATING LEVELS OF 75%, 65% AND 50% OF THE MAXIMUM RATINGS

GENERIC PART NO	DIODE TYPE	TEMP TYPE	DERAT TEMP	MAX TEMP	MAX RATING	DERATED MAXIMUM TEMP LEVEL I	LEVEL II	LEVEL III
1N821	REF	TA	25	175	250 MW	100.00	122.50	137.50
1N935B	REF	TA	25	175	500 MW	100.00	122.50	137.50
1N943B	REF	TA	25	175	500 MW	100.00	122.50	137.50
1N2970B	REG	TC	55	175	10 W	115.00	133.00	145.00
1N3826A	REG	TA	25	175	1 W	100.00	122.50	137.50
1N3891	RECT	TC	100	150	12 A	125.00	132.50	137.50
1N4099	REG	TA	25	175	400 MW	100.00	122.50	137.50
1N4148-1	SW	TA	25	175	200 MA	100.00	122.50	137.50
1N4150-1	SW	TA	25	175	200 MA	100.00	122.50	137.50
1N4153-1	SW	TA	25	200	150 MA	112.50	138.75	156.25
1N4565A	REF	TA	50	175	400 MW	112.50	131.50	143.75
1N4619	REG	TA	25	175	400 MW	100.00	122.50	137.50
1N4954	REG	TA	25	175	2.25 W	100.00	122.50	137.50
1N5417	RECT,FR	TA	55	175	3 A	119.00	135.80	146.80
1N5551	RECT	TA	55	175	2 A	115.00	133.00	145.00
1N5811	RECT,FR	TA	55	175	3 A	115.00	133.00	145.00
1N5614	RECT	TA	100	175	.75 A	137.50	148.75	156.25
SUB AVE						108.91	128.75	141.95
1N1190	RECT	TC	150	175	35 A	162.50	166.25	168.75
1N1202A	RECT	TC	150	200	12 A	125.00	132.50	187.50
1N5555	SUPP	TA	150	175	3 A (PK)	162.50	166.25	168.75
1N3289	RECT	TC	134	175	100 A	167.00	175.90	183.50
OVERALL AVERAGE						117.18	134.91	148.65

NOTE: TA IS AMBIENT TEMPERATURE

TC IS CASE TEMPERATURE

TABLE 2-46: DERATED MAXIMUM JUNCTION TEMPERATURE

MAXIMUM RATED Tj (deg C)	MAXIMUM ALLOWABLE Tj (deg C)		
	LEVEL I	LEVEL II	LEVEL III
200	115	140	160
175	100	125	145
150 or LOWER	MAXIMUM RATED MINUS 65	MAXIMUM RATED MINUS 40	MAXIMUM RATED MINUS 20

TABLE 2-47: GENERIC FAILURE RATE FOR SILICON NPN TRANSISTORS

	TEMP	.1	.2	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
		STRESS RATIO																
	0	.002	.004	.004	.004	.005	.005	.006	.006	.008	.008	.009	.009	.012	.013	.014	.016	.019
	5	.004	.004	.004	.005	.005	.006	.006	.008	.008	.008	.009	.011	.012	.014	.016	.018	.021
	10	.004	.004	.004	.005	.005	.006	.008	.008	.008	.009	.011	.012	.013	.015	.017	.020	.023
	15	.004	.004	.005	.005	.006	.006	.008	.008	.009	.009	.012	.013	.014	.016	.019	.022	.026
	20	.004	.004	.005	.006	.006	.008	.008	.008	.009	.011	.012	.014	.016	.018	.021	.024	.029
	25	.004	.004	.005	.006	.008	.008	.008	.009	.011	.012	.013	.015	.017	.020	.023	.028	.034
	30	.004	.005	.006	.006	.008	.008	.009	.009	.012	.013	.014	.016	.019	.022	.026	.031	.039
	35	.004	.005	.006	.008	.008	.008	.009	.011	.012	.014	.016	.018	.021	.024	.029	.036	.046
	40	.004	.005	.008	.008	.008	.009	.011	.012	.013	.015	.017	.020	.023	.028	.034	.042	.055
	45	.005	.006	.008	.008	.009	.009	.012	.013	.014	.016	.019	.022	.026	.031	.039	.050	.067
	50	.005	.006	.008	.008	.009	.011	.012	.014	.016	.018	.021	.024	.029	.036	.046	.061	.082
	55	.005	.008	.008	.009	.011	.012	.013	.015	.017	.020	.023	.028	.034	.042	.055	.074	.104
	60	.006	.008	.009	.009	.012	.013	.014	.016	.019	.022	.026	.031	.039	.050	.067	.092	.133
	65	.006	.008	.009	.011	.012	.014	.016	.018	.021	.024	.029	.036	.046	.061	.082	.117	.175
	70	.008	.008	.011	.012	.013	.015	.017	.020	.023	.028	.034	.042	.055	.074	.104	.152	.236
	75	.008	.009	.012	.013	.014	.016	.019	.022	.025	.031	.039	.050	.067	.092	.133	.203	.328
	80	.008	.009	.012	.014	.016	.018	.021	.024	.029	.036	.046	.061	.082	.117	.175	.277	.468
	85	.008	.011	.013	.015	.017	.020	.023	.028	.034	.042	.055	.074	.104	.152	.236	.390	.692
	90	.009	.012	.014	.016	.019	.022	.026	.031	.039	.050	.067	.092	.133	.203	.328	.567	1.058
	95	.009	.012	.016	.018	.021	.024	.029	.036	.046	.051	.082	.117	.175	.277	.468	.852	1.684
LEVEL I	100	.011	.013	.017	.020	.023	.028	.034	.042	.055	.074	.104	.152	.236	.390	.692	1.328	2.796
	105	.012	.014	.019	.022	.026	.031	.039	.050	.067	.092	.133	.203	.328	.567	1.058	2.158	4.859
	110	.012	.016	.021	.024	.029	.036	.046	.061	.082	.117	.175	.277	.468	.852	1.684	3.664	8.878
	115	.013	.017	.023	.028	.034	.042	.055	.074	.104	.152	.236	.390	.692	1.328	2.796	6.526	17.120
	120	.014	.019	.026	.031	.039	.050	.067	.092	.133	.203	.328	.567	1.058	2.158	4.859	12.242	35.008
LEVEL II	125	.016	.021	.029	.036	.046	.061	.082	.117	.175	.277	.468	.852	1.684	3.664	8.878	24.296	76.273
	130	.017	.023	.034	.042	.055	.074	.104	.152	.236	.390	.692	1.328	2.796	6.526	17.120	51.250	
	135	.019	.026	.039	.050	.067	.092	.133	.203	.328	.567	1.058	2.158	4.859	12.242	35.008		
	140	.021	.029	.046	.061	.082	.117	.175	.277	.468	.852	1.684	3.664	8.878	24.296	76.273		
LEVEL III	145	.023	.034	.055	.074	.104	.152	.236	.390	.692	1.328	2.796	6.526	17.120	51.250			
	150	.026	.039	.067	.092	.133	.203	.328	.567	1.058	2.158	4.859	12.242	35.008				
	155	.029	.046	.082	.117	.175	.277	.468	.852	1.684	3.664	8.878	24.296	76.273				
	160	.034	.055	.104	.152	.236	.390	.692	1.328	2.796	6.526	17.120	51.250					
MAX	165	.039	.067	.133	.203	.328	.567	1.058	2.158	4.659	12.242	35.008						
	170	.046	.082	.175	.277	.468	.852	1.684	3.664	8.078	24.296	76.273						
RATED →	180	.067	.133	.328	.567	1.058	2.158	4.859	12.242	35.008								
TEMP	185	.082	.175	.468	.852	1.684	3.664	8.878	24.296	76.273								
	190	.104	.236	.692	1.328	2.796	6.526	17.120	51.250									
	195	.133	.328	1.058	2.158	4.859	12.242	35.008										
	200	.175	.468	1.684	3.664	8.878	24.296	76.273										

NOTES: 1. ALL FAILURE RATES ARE FAILURES PER MILLION HOURS.

2. FAILURE RATES NOT SHOWN ARE GREATER THAN 99.

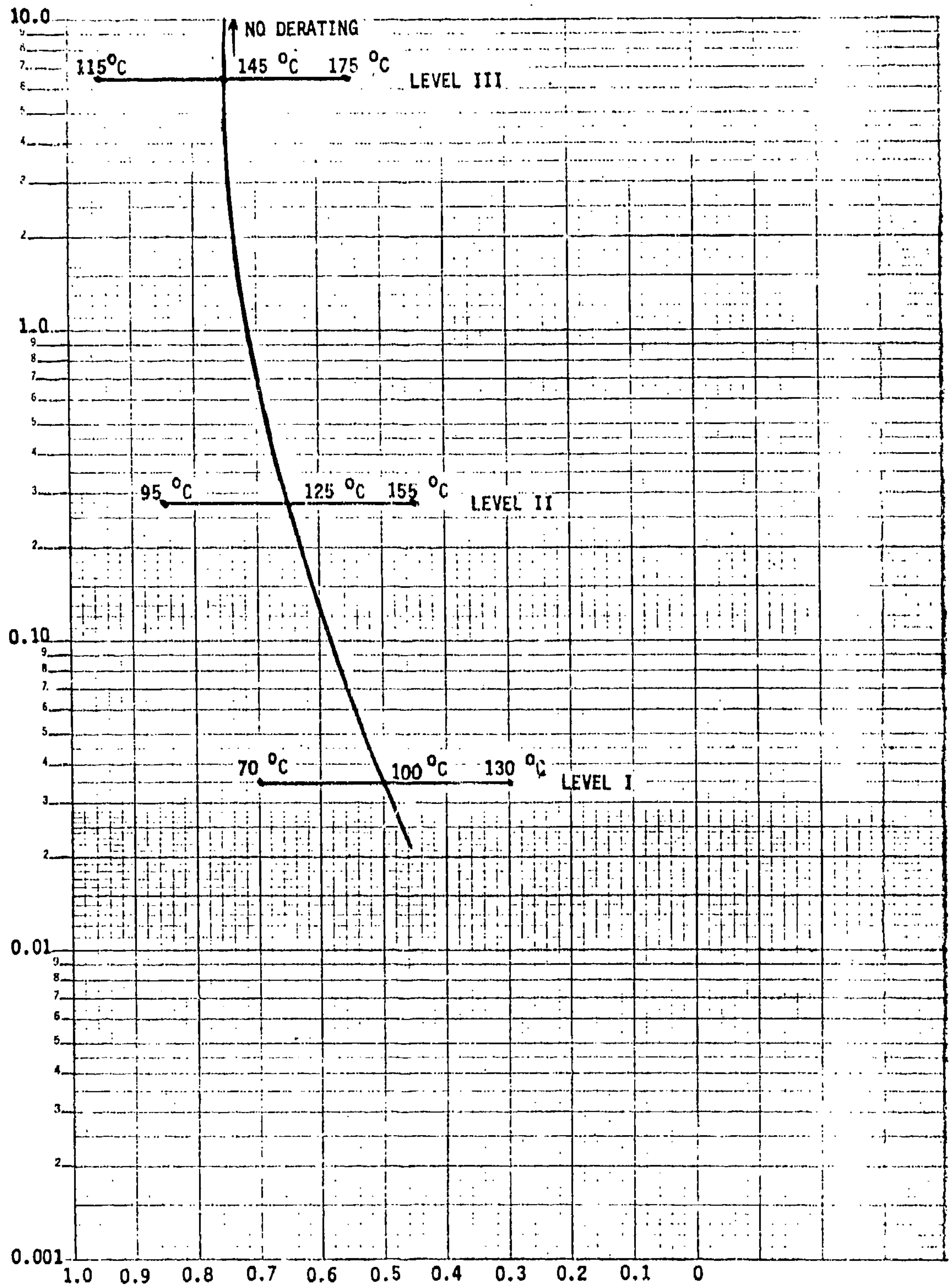


Figure 2-4: NPN Transistor Generic Failure Versus Stress Ratio by Derating Level and Derated Temperature

2.5 Bibliography

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2.6 Recommendations

The following recommendations concern further work considered desirable for the subject of derating.

2.6.1 Expansion of Literature Survey

As described in Section 2.2, a great deal of present derating practice is contained in internal user documentation and not released for general publication. Acquistion of this type of data requires more time and on-site personal coordination than was allowable by the initial effort this contract representated. An update to the material in this document could include such an effort.

For many of the part types specified to be derated by this contract, there was little or no derating data disclosed by the literature search. There were two main reasons for this lack of data. First some of the part types are very seldom used in design and therefore have never merited the effort of formalized derating requirements. Secondly, other part types are extremely sophiscated and specialized in their usage. Usually such part types have highly interdependent parameters which do not permit the independent derating of individual parameters.

Expansion of the literature survey would explore in detail the following areas: tubes, lasers, rotating devices, connectors (coaxial), quartz crystals, vibrators, SAW devices, fiber optic devices, microwave transistors and diodes, hybrids, microprocessors, memories and custom LSI devices.

2.6.2 Semiconductor Derating Curves

The derating curve from MIL-S-19500 for absolute maximum rating was used to relate the selected end points over the total application range (see Figure 2-3). Here parallel curves have been drawn connecting the selected end points. A brief review of these combined deratings suggest an over derating when conditions prevail between the end points. A study is needed to generate the proper shape of these curves which gives sufficient derating with consideration to design difficulities.

SECTION 3

GENERAL DERATING REQUIREMENTS

3.1 Scope

3.1.1 General

This section and the following sections present reliability derating guidelines for electrical, electronic and electromechanical parts. These requirements are intended for use by all organizations involved in the design, use or evaluation of electrical, electronic or electromechanical equipment and systems. The guidelines are intended for citation in whole or in part in contracts, task statements, specifications or statements of work for such equipment.

3.1.2 Necessity for Derating

It has been proven by experience and part failure rate models that derating (operating parts at less than their maximum ratings) is necessary for reliable operation. It can be shown that there is an improvement in the predicted failure rate for a part as the operating stresses are decreased. This failure rate reduction continues to a point where further stress reduction results in insufficent further reliability gains.

3.1.3 Limitations of Derating

The derating levels recommended in the following sections are guidelines only and should not be considered as absolute values. Derating always represents a compromise between size, weight, cost and failure rate. Generally, size, weight, and cost increase with increases in derating. Excessive derating can result in no part existing to perform the function. Also, the excessive derating can result in unnecessary increases in parts count and consequently of the overall circuit predicted failure rate.

For most applications, the recommended guidelines will not result in significant size, weight or cost penalities. A careful analysis of the design to establish all the trade offs should be performed for those cases where it may be advicable to exceed the recommended guidelines. Minor deviations from the guidelines usually have small effect on the predicted failure rate.

3.2 Referenced Documents

The following documents applicable to the material herein and should be consulted for supplemental information pertaining to the application and usage of electrical, electronic and electromechanical parts.

SPECIFICATIONS

MILITARY

MIL-C-20	- Capacitors, Fixed, Ceramic Dielectric (Temperature Compensating), General Specification for
MIL-T-27	- Transformers and Inductors (Audio, Power, and High Power Pulse), General Specification for
MIL-C-3098	- Crystal Units, Quartz, General Specification for
MIL-S-4040	- Solenoids, Electrical, General Specification for
MIL-E-5400	- Electronic Equipment, Airborne, General Specification for
MIL-S-8834	- Switches, Toggle, Positive Break, General Specification for
MIL-E-8189	- Electronic Equipment, Missiles, Booster and Allied Vehicles, General Specification for
MIL-C-15305	- Coils, Fixed and Variable, Radiofrequency, General Specification for
MIL-S-19500	- Semiconductor Devices, General Specification for
MIL-C-19978	- Capacitors, Fixed, Plastic Dielectric (Hermetically Sealed) General Specification for
MIL-T-21038	- Transformers, Pulse, Low Power, General Specification for
MIL-C-23269	- Capacitors, Fixed, Glass Dielectric, Established Reliability, General Specification for
MIL-M-38510	- Microcircuits, General Specification for
MIL-C-39001	- Capacitors, Fixed Mica Dielectric, Established Reliability, General Specification for
MIL-C-39003	- Capacitors, Fixed, Electrolytic, Tantalum, Solid-Electrolyte, Established Reliability, General Specification for
MIL-R-39005	- Resistors, Fixed, Wire-Wound (Accurate), Established Reliability, General Specification for
MIL-C-39006	- Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-R-39007	- Resistors, Fixed, Wirewound (Power Type), Established Reliability, General Specification for
MIL-R-39008	- Resistors, Fixed, Composition (Insulated), Established Reliability, General Specification for
MIL-R-39009	- Resistors, Fixed, Wirewound, Chassis Mount, Established Reliability, General Specification for

MIL-C-39010	- Coils, Fixed, Radiofrequency, Molded, Established Reliability, General Specification for
MIL-C-39014	- Capacitors, Fixed, Ceramic Dielectric, Established Reliability, General Specifications for
MIL-R-39015	- Resistors, Variable, Wirewound, Established Reliability, General Specification for
MIL-R-39016	- Relays, Electromagnetic, Established Reliability, General Specification for
MIL-R-39017	- Resistors, Fixed Film (Insulated), Established Reliability, General Specification for
MIL-C-39022	- Capacitors, Fixed, Metallized Plastic, Established Reliability, General Specification for
MIL-R-39035	- Resistors, Variable, Non-wirewound, Established Reliability, General Specification for
MIL-R-55182	- Resistors, Fixed Film, Established Reliability, General Specification for

STANDARDS

MILITARY

DOD-STD-1686	- Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-STD-198	- Capacitors, Selection and Use of
MIL-STD-199	- Resistors, Selection and Use of
MIL-STD-202	- Test Methods for Electronic and Electrical Component Parts
MIL-STD-454	- Standard General Requirements of Electronic Equipment
MIL-STD-701	- Lists of Standard Semiconductor Devices
MIL-STD-721	- Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety
MIL-STD-749	- Preparation and Submission of Data for Approval of Nonstandard Parts
MIL-STD-785	- Reliability Program for Systems and Equipment, Development and Production
MIL-STD-1131	- Storage Shelf Life and Reforming Procedures for Aluminum Electrolytic Fixed Capacitors
MIL-STD-1132	- Switches and Associated Hardware, Selection and Use of
MIL-STD-1346	- Relays, Selection and Use of
MIL-STD-1498	- Circuit Breakers, Selection and Use of
MIL-STD-1562	- Lists of Standard Microcircuits

HANDBOOKS

MILITARY

DOD-HDBK-2630 - Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-HDBK-175 - Microelectronic Device Data Handbook
MIL-HDBK-217 - Reliability Stress and Failure Rate Data for Electronic Equipment

3.3 Definitions

The terms and definitions used herein shall be interpreted in accordance with the definitions of MIL-STD-721 except as otherwise noted.

3.3.1 Derating

The use of parts in such a manner that the applied stresses are less than the maximum ratings.

3.3.2 Rating

For a specific parameter, the rating is the maximum value (stress) the part is designed to withstand. Rating is normally used for describing a stress such as temperature, power, and voltage or current which increases failure rate as the stress is increased.

3.3.3 Stress

Electrical, mechanical or environmental forces applied to a part which can affect failure rate.

3.3.4 Stress Ratio

The operating stress divided by the maximum rated stress.

3.3.5 Application

The method in which a part is used. This usually directly affects the predicted failure rate. Application factors include all the electrical, mechanical, and environmental characteristics of the parts operating environment. A critical application factor is a particular operating characteristic of the part which critically affects the failure rate and therefore is valid for inclusion with derating guidelines. For example, MIL-HDBK-217C lists three major application factors for bipolar transistors; linear amplification, switching, and low noise or RF usage. The generic failure rate multipliers for these three applications are 0.7, 1.5, and 15.

3.4 General Requirements

3.4.1 Equipment Derating Levels

For many part types there is a range of acceptable derating levels between the minimum derating point and the point of over derating. The optimum derating is normally considered to occur at or below the point of stress where a rapid increase in failure rate occurs for a small increase in stress. Three recommended derating levels are selected on the basis of the criticality of the application.

3.4.1.1 Derating Level I (Maximum Derating)

Equipment whose failure would substantially jeopardize the life of personnel, or seriously jeopardize the operational mission or for which repairs are unfeasible or economically unjustified.

Level I derating is judged to be those stress levels below which further reliability gain is negligible or where further derating will create unacceptably difficult design problems. This is intended for the most critical applications where the associated design difficulity can be justified by the reliability requirement.

3.4.1.2 Derating Level II

Equipment whose failure would degrade the operational mission or would result in unjustifiable repair costs.

Level II derating is considered to be still in the range where reliability gains are rapid as stress is decreased. However, achieving designs with these reductions in allowed stress, is significantly more difficult than at Level III.

3.4.1.3 Derating Level III

Equipment of lesser criticality than Levels I or II. Equipment whose failure does not jeopardize the operational mission or which can be quickly and economically repaired.

Level III derating is that stress level reduction which creates minor design difficulties and yet generates the largest incremental reliability gain. The large reliability gain is realized because the effects of stress increase dramatically as the absolute maximum rating is approached.

3.4.2 Equipment Environments

Generally, the following criticality levels apply, as minimum, for the listed operational environments:

ENVIRONMENT	LEVEL
Ground	III
Flight	II
Space	I
Missile Launch	I

3.4.3 Part Quality Levels

Derating cannot be used to compensate for using parts of a lower quality than necessary to meet usage reliability requirements. The quality level of a part has a direct effect on the predicted failure rate. Electrical testing of all parts in a lot is not guaranteed for commercial or JAN level military parts. For high reliability applications only fully tested and screened parts (including burn-in) should be used, in addition to application of the appropiate derating levels.

3.4.4 Specific Derating Guidelines

Derating guidelines for specific part types are detailed in the following sections. The order of listing is in approximate order by popularity or criticality.

SECTION NO.	PART TYPE
4	Microcircuits
5	Transistors
6	Diodes
7	Thyristors
8	Optical Semiconductors
9	Resistors
10	Capacitors
11	Inductors
12	Relays
13	Switches
14	Connectors
15	Rotating Devices
16	Lamps
17	Circuit Breakers
18	Fuses
19	Quartz Crystals
20	Tubes
21	Lasers
22	Vibrators
23	Surface Wave Acoustical Devices
24	Fiber Optic Components

SECTION 4

MICROCIRCUIT DERATING GUIDELINES

4.1 General

For purposes of derating, microcircuits may be classified as digital and linear since the stress factors of voltage and current are distinctive. Another useful subdivision is bipolar and MOS. Further subdivision of functional types and construction types can be made but their distinctiveness in derating is not significant.

Microcircuits can be generally characterized as a group of transistors, diodes, resistors, and capacitors (circuit elements), formed through diffusion processes in the surface of a silicon chip. The surface dimensions of elements are in the range of millimeters or less while the vertical dimensions are in submicron. This structure geometry leads to power dissipations in extremely small volumes in the chip surface with the heat spreading downward to the package bottom and then to the external environment. This near point source of heat and one direction of heat flow can create very high temperatures at the active junctions and high thermal gradients in the region of the junction. The junction thermal time constant can be in the low microseconds and the junction temperature can track pulsed power down to that rate. The effective junction width is quite narrow and leads to high electric field intensity within the silicon. However, the applied junction voltage is not generally under the control of the user and thus is not considered in derating. An exception is linear devices (input and output circuitry), when derated voltage can substantially aid device life time. This susceptibility is due to the generally sensitive input circuitry and the high power output sections. Note that power deratings are directed toward reducing temperatures at those high power elements where concentrated high temperatures exist.

The circuit elements are interconnected by surface metallizations, possibly multilayer with crossovers, where conductor widths are generally submillimeter with similar separations between conductors. The separations between cross overs are closer and are insulated by solid diffused materials. Current densities often will be in the range of 10E5 amps per cmE2 cross section of conductor. While the applied electric field strength and the current density are designed to be within the capability of these interconnect materials, the existence of manufacturing defects of electro-chemical reactions, and metal migration over long periods of time can lead to failure in the interconnect system.

In general, a perfect semiconductor device is considered to have virtually unlimited life under normal operating conditions. However, chemical reactions of contaminating materials, solid state reactions to extraordinary voltage and current stress will, over time, cause changes which may cause the circuit to malfunction. These reactions are most strongly accelerated by increased temperature. A brief list of typical defects leading to device failure is given:

- o Microcracks in silicon chips
- o Undesired chemicals in the enclosed atmosphere (i.e. water, sulfur, chlorine, etc.)
- o Incomplete metallization (over oxide steps and on conductor surface)
- o Solid state defects in junction regions
- o Thin insulation (or holes) between conductors (cross overs or capacitors)
- o Poor wire bonds subject to metallurgical changes.

This brief list is hardly exhaustive but merely illustrates the need to derate those stresses which when coupled with defects can cause device failure.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

4.2 Application Guidelines

1. All possible considerations should be given toward maintenance of minimum junction temperatures. Note that all heat travels to the bottom of the package and heat removal is most effective in this area. The minimum power practical should be applied to the part and consideration to external capacitance will reduce the associated current transients. Power dissipation can rise rapidly as the operating frequency approaches the maximum rated frequency. The device specification usually will characterize this parameter. The specified DC power for these device types has little meaning for high frequency operation.

Most microcircuits utilize a gold-silicon eutectic die mount method which results in low thermal resistance to the package substrate. To be avoided, where possible, are parts using high thermal resistance methods of die mount (i.e. glass, epoxy or intermediate insulating substrates).

2. Most modern microcircuits are subject to electrostatic discharge damage (there is a wide variation of sensitivity). Requiring special precautions are MOS devices and other high input impedance types which are especially susceptible to electro static discharge (ESD). Since this damage may be latent, leading to failures after application, reasonable precautions should be taken to avoid exposure to this hazard.

3. Careful precaution in circuit design is required to avoid application of reverse voltages on device leads. A common source is transient overshoots from fast, high current switching. Occurrence of such overshoots will lead to extremely high current flow with its attendent internal damage. The design should not switch faster than the function requires since this high speed increases device susceptibility to failure. Also, use of faster devices than the circuit requires introduces all those attendant weaknesses and generally increases power dissipation.

4. On bipolar digital devices, supply voltage deviation from the specified nominal will reduce noise margin as seen externally and will shift internal bias points which when coupled with thermal effects can cause erratic performance. This supply voltage stability is especially difficult during transient excursions when very high currents will flow from the supply. The supply voltage transients will be both positive and negative. This effect is also present in linear devices but is normally expected and design precautions are an obvious requirement.

5. A certain amount of parameter shift can be anticipated over the life of a microcircuit. While this will not produce a catastropic failure, it may cause the associated circuit to malfunction . Design margins should be used to assure proper circuit function with the indicated change:

Bipolar Digital

Input leakage current;	+100 %
Fan-out;	-20 %
Frequency;	-10 %

Linear

Gain;	-20 %
Offset voltages(1);	+50 %
Offset currents;	+50 % or +5 nA (whichever is greater)

(1) Low offset devices may have changes in the order of as much as 300%.

4.3 Derating Guidelines

4.3.1 Linear Microcircuit Derating Guidelines (See Table 4-1)
(Derated from procurement specification maximum values)

A. Supply Voltage: Derate from the absolute maximum.

B. Input Voltage: Derate from the absolute maximum.

C. Output Current: Derate from maximum performance value.

D. Junction Temperature: Derate per Table 4-1.

TABLE 4-1: LINEAR DERATING

PARAMETER	LEVEL		
	I	II	III
SUPPLY VOLTAGE	0.70 (1)	0.80	0.80
INPUT VOLTAGE	0.60	0.70	0.70
OUTPUT CURRENT	0.70	0.80	0.80
MAX JUNCT. TEMP (DEG C)	80	95	105

(1) Designing below 70% of the supply voltage may operate the device below the recommended operating voltage.

4.3.2 Voltage Regulator Derating Guidelines (See Table 4-2) (Derated form procurement specification maximum values)

A. Supply Voltage: Derate from the absolute maximum.

B. Input Voltage: Derate from the absolute maximum.

C. Differential Voltage Access Regulator: Derate from the absolute maximum (Note: The differential voltage should always be 110% of the specified minimum required for proper regulation).

D. Output Current: Derate from the absolute maximum.

E. Junction Temperature: Derate per Table 4-2.

TABLE 4-2: VOLTAGE REGULATOR DERATING

PARAMETER	LEVEL		
	I	II	III
SUPPLY VOLTAGE/INPUT VOLTAGE/DIFFERENTIAL VOLTAGE ACROSS THE REGULATOR	0.70	0.80	0.80
OUTPUT CURRENT	0.70	0.75	0.80
MAX JUNCT. TEMP (deg C)	80	95	105

4.3.3 Bipolar Digital Derating Guidelines (See Table 4-3)
(Derated from procurement specification maximum values)

A. Supply Voltage: Tighten tolerance from nominal value

B. Frequency: Derate from absolute maximum

C. Output Current (source and sink): Derate from absolute maximum

D. Junction Temperature: Derate from Table 4-3

TABLE 4-3: BIPOLAR DIGITAL DERATING

PARAMETER	LEVEL I	LEVEL II	LEVEL III
SUPPLY VOLTAGE TOLERANCE	+/-3%	+/-5%	PER SPECIFICATION
FREQUENCY	0.80	0.90	0.95
OUTPUT CURRENT (1)	0.80	0.90	0.90
MAX JUNCT. TEMP (DEG C)	85	100	115

(1) Reducing fan-out may increase part count, which in turn increases equipment failure rate. Where obvious, adjustment should be allowed to prevent this occurrence.

4.3.4 MOS and CMOS Derating Guidelines (See Table 4-4)
(Derated from procurement specification maximum values)

A. Supply Voltage: Derate from maximum

B. Output Current: Derate from maximum

C. Frequency: Derate from maximum specified for the applied supply voltage

D. Junction Temperature: Derate from Table 4-4

TABLE 4-4: MOS AND CMOS DERATING

PARAMETER	LEVEL		
	I	II	III
SUPPLY VOLTAGE (from absolute maximum)	0.7 (1)	0.8	0.8
OUTPUT CURRENT (Buffer & Flip-Flop only) (% of max, IOL only)	0.8	0.9	0.9
FREQUENCY (% of max at supply voltage)	0.8	0.8	0.9
MAXIMUM JUNCTION TEMPERATURE (deg C)	85	100	110

(1) Derating to 70% for supply voltage may cause operation of the device below the recommended operating voltage.

4.3.5 Complex Microcircuits

Note that no division has been made along the lines of circuit complexity (i.e. Small Scale Integration, SSI versus Large Scale Integration, LSI) or along the lines of circuit function (i.e. Microprocessor, memory or hybrid subsystems). The recommended decrease in stress level (derating) is related to the technology used to construct the active circuitry on the chip (i.e. bipolar versus MOS). Thus the appropriate derating tables of Section 4 should be used. Complex devices may represent a high failure risk on a per package basis and may merit more derating for that reason. However, other than temperature, it is difficult to derate the voltage or current or frequency of complex devices since they are truly a subsystem and generally have a narrow parameter range over which they will properly operate.

Review of published past practice shows these complex device types to be derated exactly the same as simple microcircuits of like technology. However, due to the large portion of circuitry within a single package it is recommended that special effort be made to reduce the temperature below that recommended for that technology. The required packaging and heat sink effort will be less relative to that associated with a like amount of circuitry scattered through more devices (less complex). Thus the relative reliability gain is greater for the required design constraints. Note that temperature is the strongest single degrading stress and this effort can also compensate for the general inability to derate the other stress factors.

SECTION 5

TRANSISTOR DERATING GUIDELINES

5.1 General

Transistors can be divided into four major categories:

A. Bipolar (NPN/PNP, Silicon or Germanium)

B. Field Effect (N-Channel, P-Channel, MOS, GaS)

C. Unijunction

D. Microwave

Phototransistors and other radiation sensitive types are covered in Section 8 Optical Semiconductors. Transistor chips should be derated the same as for hybrid microcircuits, Section 4.

Like all semiconductors, high temperature operation is the most destructive stress for transistors. The maximum junction temperature is always controlled for a specific device. Control is usually accomplished by specifying the maximum ambient or case temperature at which full rated power or current can be carried. From this power/temperature point, the reduction in power with increasing temperature is defined by supplying the thermal resistance or a power curve. The end point of this maximum rating is zero power at full rated junction temperature.

Voltage breakdown is the other major failure forcing function which is to be derated for transistors. Also, power transistors are subject to failure by the second breakdown phenomena even when operated within the voltage/current ratings, therefore, the defined Safe Operating Area is also derated.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

5.2 Application Guidelines

A. Allow as a minimum for the following degradation in the listed parameters over the service life of the design:

1. Gain (screened devices) +/- 10%
2. Gain (unscreened devices) +/- 20%
3. Leakage Current + 100%
4. Switching Times + 20%
5. Saturation Voltage +/- 15%

Note: Unscreened devices may be in the infant mortality region and exhibit greater gain variations than shown in "typical" ratings.

B. Power transistors are subject to failure by thermal fatigue when exposed to many temperature cycles. Thermal cycling is a normal result of on-off operation. For maximum reliability, observe the case temperature change limits shown in Figure 5-1. For example, a device which is being operated at 50% of rated power dissapation and is expected to have 50,000 on-off cycles during its useful life should not exceed a 50 deg C case temperature change from minimum to maximum.

C. The sum of the anticipated transient voltage peaks and the operating voltage peaks should not exceed the recommended derated voltage limits.

D. Avoid use of faster devices than the design requires since faster devices compromise other parameters and are more susceptible to secondary breakdown.

E. Do not use germanium devices for new designs.

5.3 Transistor Derating Guidelines

A. Derate power as shown in Table 5-1. Application of the power derating to the maximum ratings is described in paragraph 5.3.1.

B. Derate junction temperature as shown in Table 5-2.

C. Derate voltage as shown in Table 5-3.

D. For devices with defined Safe Operating Area (SOA) curves, derate as shown in Table 5-4 and described in Paragraph 5.3.2.

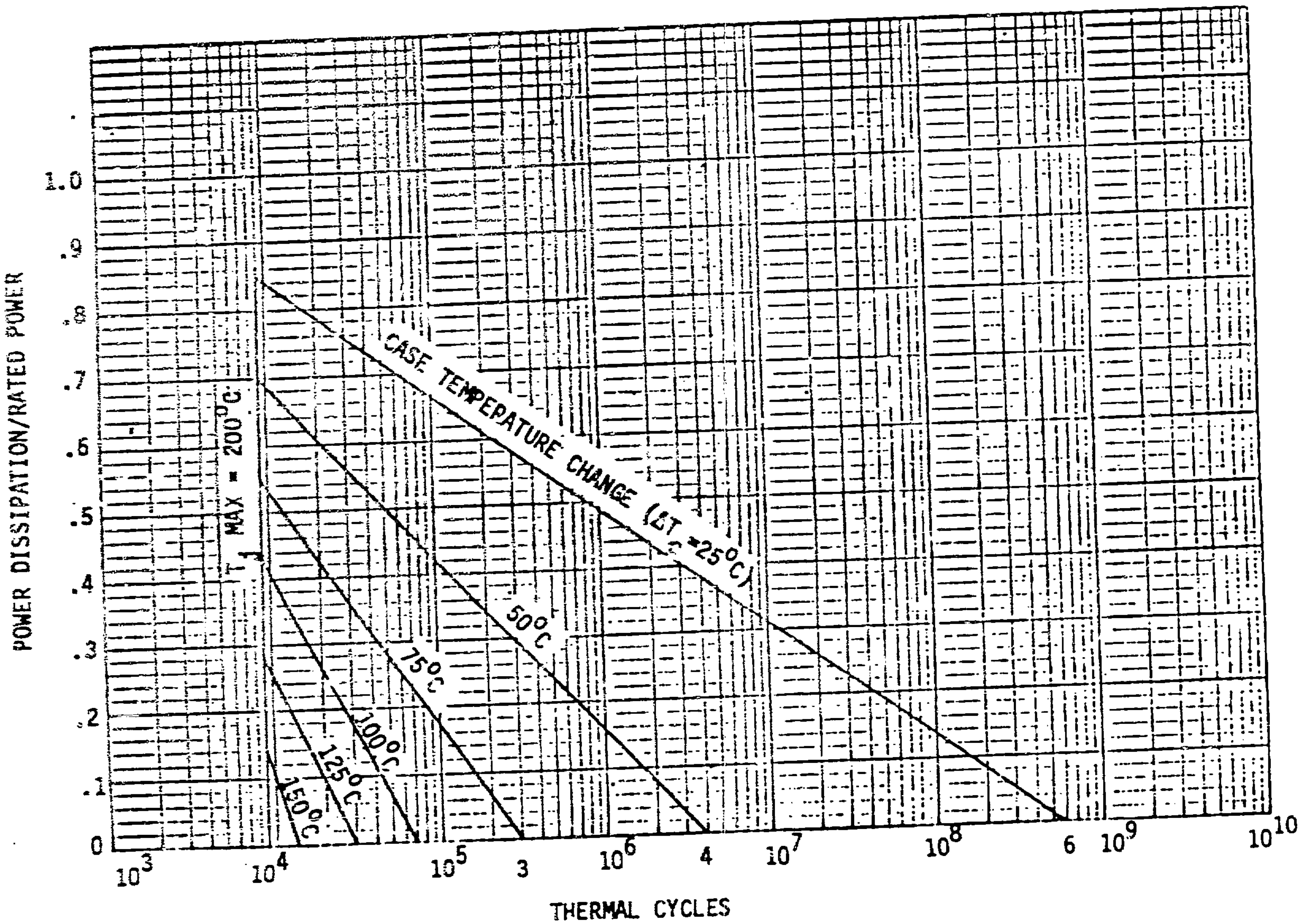


Figure 5-1: Thermal-Cycling Ratings For Power (20-150W) Transistors

TABLE 5-1: POWER DERATING

MAXIMUM ALLOWABLE TOTAL POWER DISSIPATION (PT)		
LEVEL I	LEVEL II	LEVEL III
0.50 MAXIMUM RATED	0.65 MAXIMUM RATED	0.80 MAXIMUM RATED

TABLE 5-2: JUNCTION TEMPERATURE DERATING

MAXIMUM RATED TJ (DEG C)	MAXIMUM ALLOWABLE TJ (DEG C)		
	LEVEL I	LEVEL II	LEVEL III
200	115	140	160
175	100	125	145
150 OR LOWER	MAXIMUM RATED MINUS 65	MAXIMUM RATED MINUS 40	MAXIMUM RATED MINUS 20

TABLE 5-3: VOLTAGE DERATING

MAXIMUM ALLOWABLE VOLTAGE		
LEVEL I	LEVEL II	LEVEL III
0.6 MAXIMUM RATED	0.7 MAXIMUM RATED	0.8 MAXIMUM RATED

TABLE 5-4: SAFE OPERATING AREA DERATING

DERATING PARAMETER	RECOMMENDED MAXIMUMS		
	LEVEL I	LEVEL II	LEVEL III
COLLECTOR - EMITTER VOLTAGE	0.7 VCE	0.8 VCE	0.9 VCE
COLLECTOR	0.6 IC MAX	0.7 IC MAX	0.8 IC MAX

5.3.1 Application of Power Derating Guidelines

The power ratings for transistors are expressed by specifying the total power dissipation and the temperature range over which this amount of power can be dissipated. For low power transistors, the maximum power range is normally between the temperature range of -55 deg C to 25 deg C. For power devices, this temperature range (for full rated power) usually is extended on the high temperature side. Some power devices have an upper limit for full rated power as high as 150 deg C. For all transistor types, the power rating is reduced as the temperature is increased above the upper temperature limit (defined as the temperature derating point) until zero power rating is reached at maximum rated junction temperature. Typical examples of these maximum rated power curves are shown in Figures 5-2 through 5-6 and are labeled "Absolute Maximum Rating". The junction temperature at every point is considered equal to the maximum rated junction temperature which is equal to the temperature at the zero power point.The slope of the maximum rating curves above the maximum temperature where full rated power may be dissipated is approximately equal to the reciprocal of the thermal resistance and is dependent on the physical constants of the device.

Figures 5-2 and 5-3 show the derating recommendations applied to military preferred low power, switching, NPN transistor type 2N2222A.

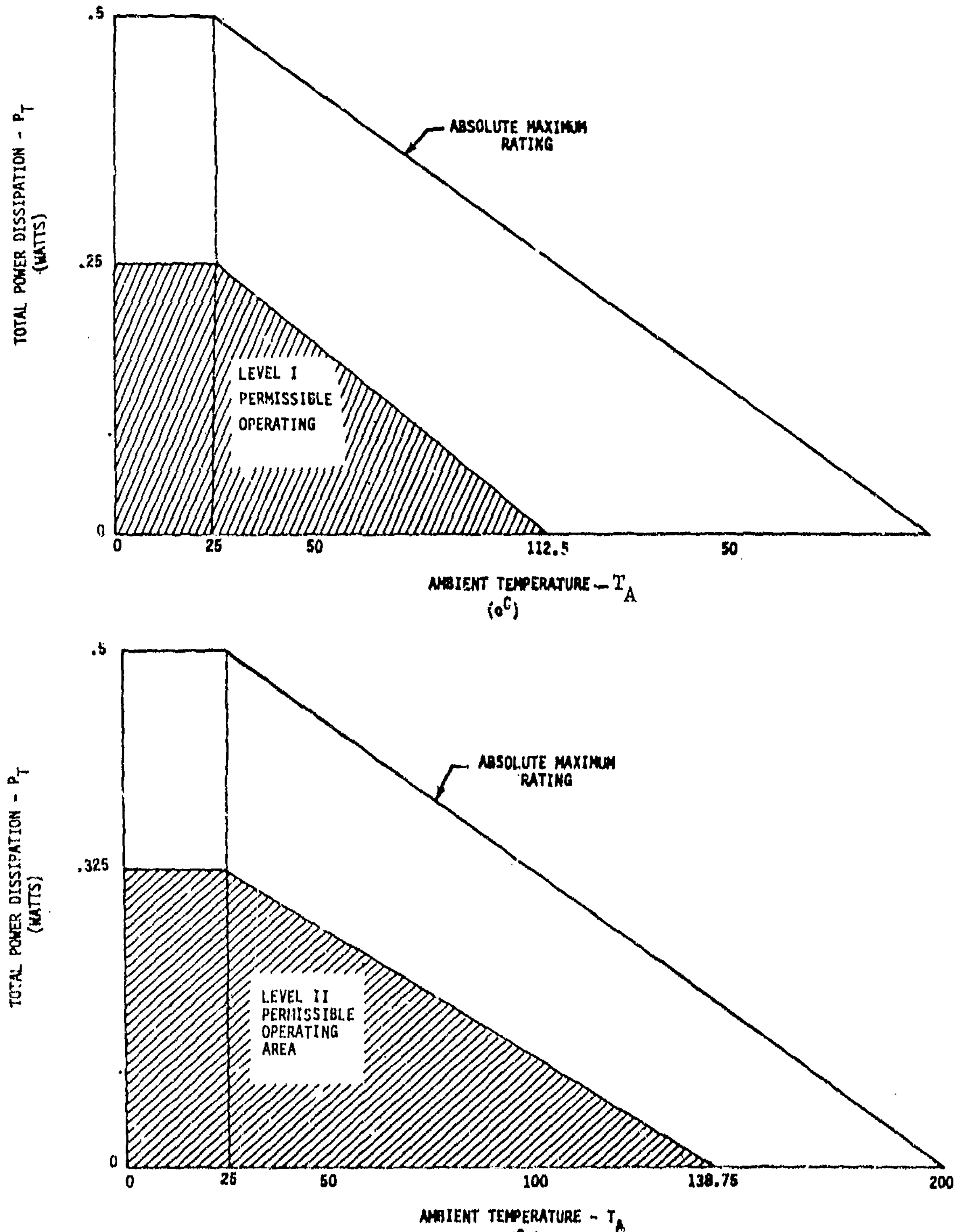


Figure 5-2: Ambient Temperature Derating for Transistor Type 2N2222A

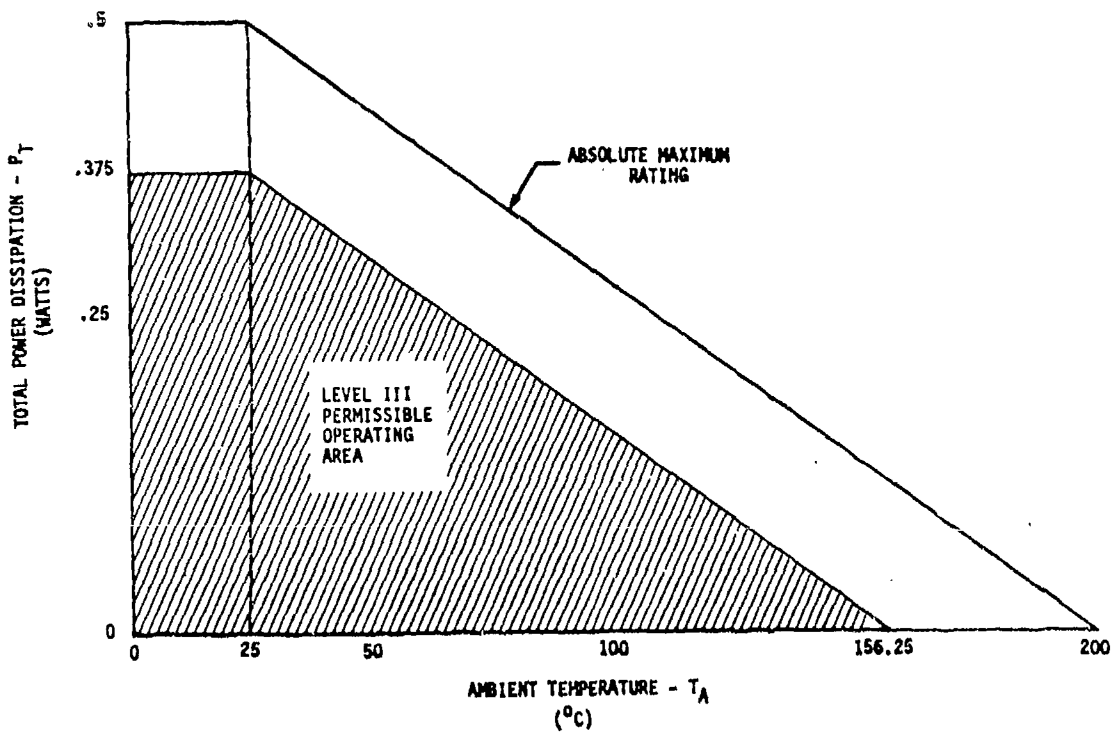


Figure 5-2: Ambient Temperature Derating for Transistor Type 2N2222A (Continued)

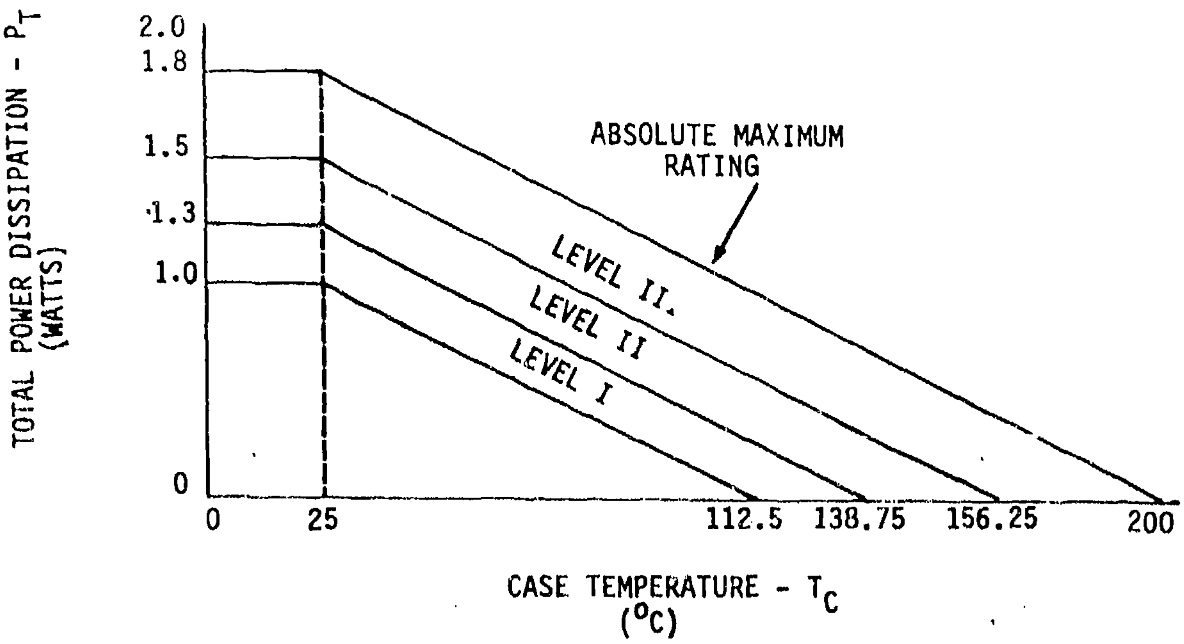


Figure 5-3: Case Temperature Derating For NPN Transistor Type 2N2222A

Figures 5-4 through 5-6 show the recommended derating levels applied to military preferred power, NPN transistor type 2N3997. These derating curves illustrate a conflict that can occur between the power and junction temperature derating for a part with a very high temperature derating point. Figure 5-4, derates type 2N3997 using the specification ambient temperature rating. Since the temperature derating point of 25 deg C is the same as for the 2N2222A, the curves are identical except for the difference in power level. Figures 5-5 and 5-6 derate the same transistor by using the specified case temperature derating which has a very high temperature derating point of 100 deg C. Figure 5-5 derates the part by using the power derating recommendations of 75%, 65%, and 50% and plotting to determine the resultant junction temperatures. It is apparent that the recommended junction temperatures are exceeded. Figure 5-6 derates the part by using the recommended maximum junction temperatures and plotting to determine the allowable power dissipation. It is apparent that this results in an overderating of the part, with the allowable power excessively restricted.

When such a conflict exists for a specific candidate part, the designer must compromise between junction temperature and power dissipation to derive the most reliable achievable design. Junction temperature is the failure forcing stress function and therefore uncertainties should be resolved in favor of the lower junction temperature.

5.3.2 Safe Operating Area Derating

The specifications for high power transistors usually include a defined safe operating area (SOA) graph to insure operation without second breakdown effects and failures. Figure 5-7 shows a typical SOA curve for DC operating and Figure 5-8 shows a typical SOA curve for pulsed operation. Safe Operating Area derating is performed by determining the maximum rated current and voltage for a specified operating condition and applying the derating criteria of Table 5-4. Figure 5-9 shows the application of derating to a typical SOA curve.

5.3.3 Microwave Transistor Derating Limitations

In general, low frequency transistors offer almost the same electrical characteristics at various power levels which allows considerable design latitude for derating. Usually this is not true for microwave types. Microwave design involves distributed constants and therefore the transistor, package, parasitics, interconnections, and other components must be considered as a single unit. This prevents consideration of derating as a separate variable.

With microwave transistors, the design may require exceeding the voltage and power derating limits recommended for low frequency designs; however the junction temperature derating limits defined in Table 5-1 should be observed.

Use the failure rate model and prediction methods for microwave transistors defined in MIL-HDBK-217C to evaluate candidate designs for maximum reliability.

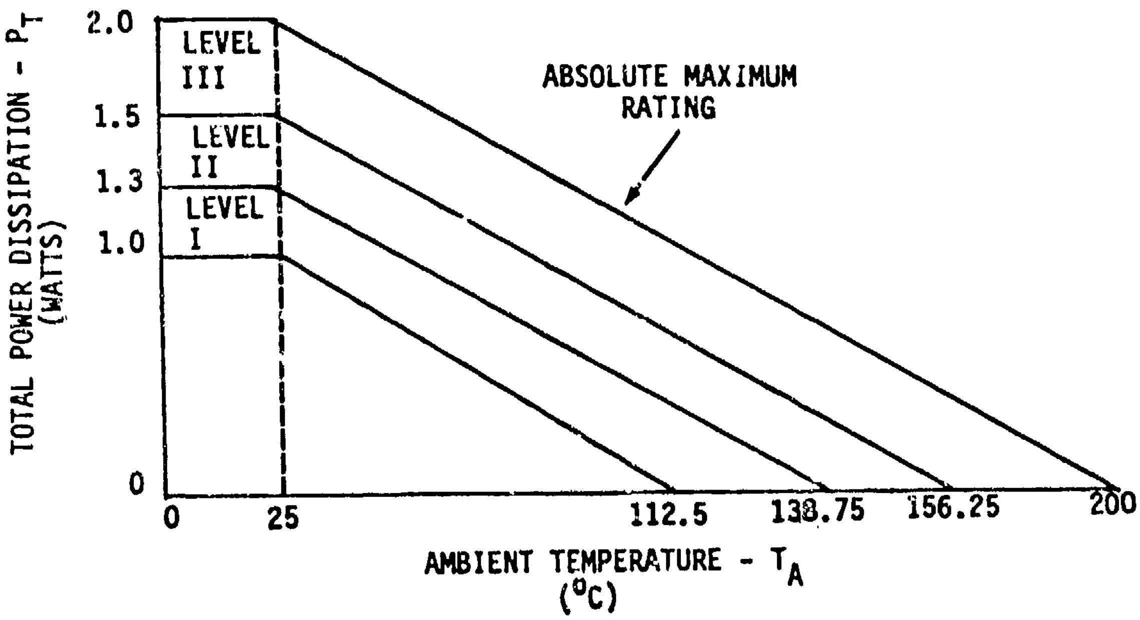


Figure 5-4: Ambient Temperature Derating For NPN Transistor Type 2N3997

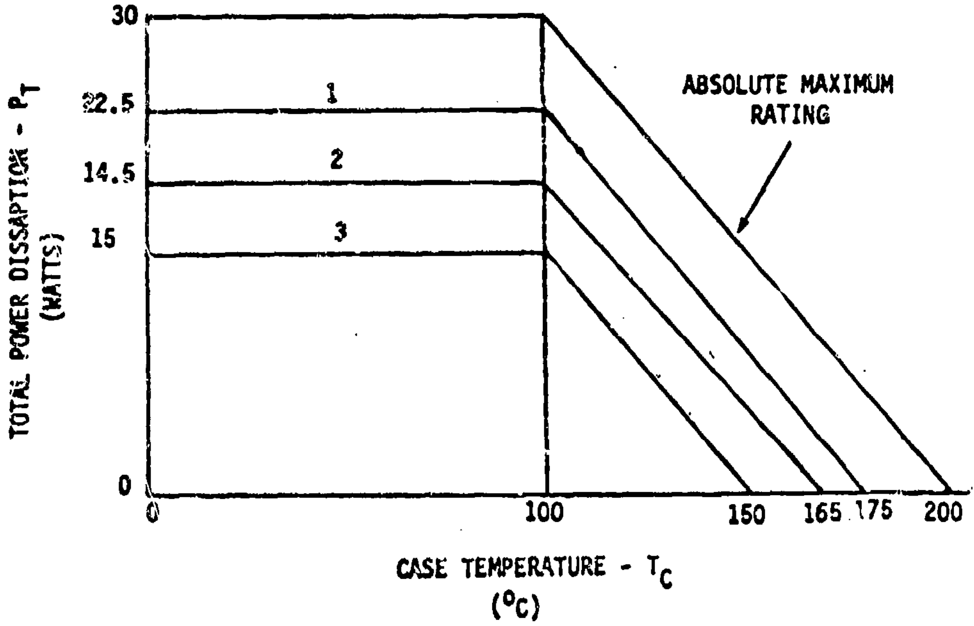


Figure 5-5: Derating of NPN Transistor Type 2N3997 By Power Only

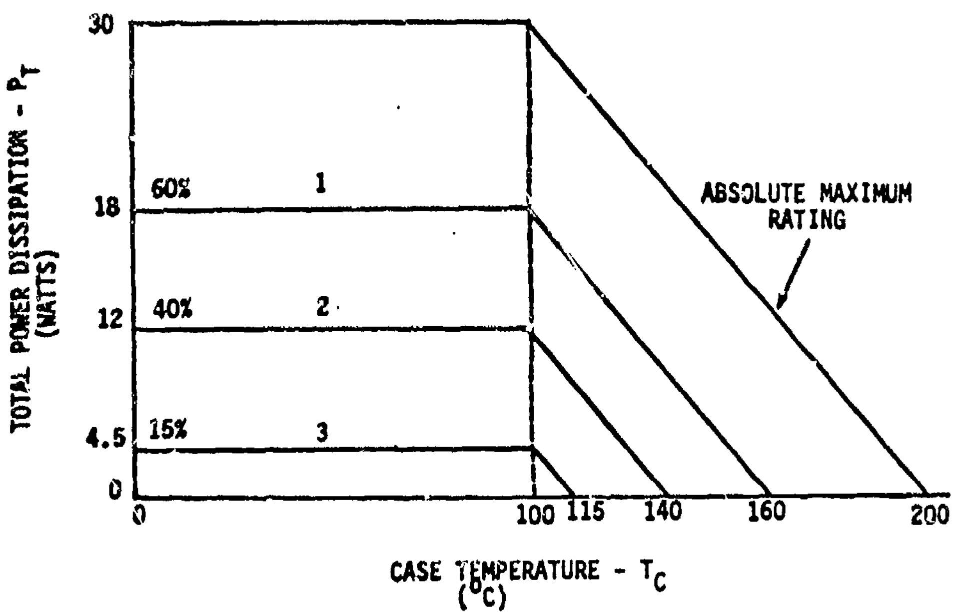


Figure 5-6: Derating for NPN Transistor Type 2N3997 By Junction Temperature Only

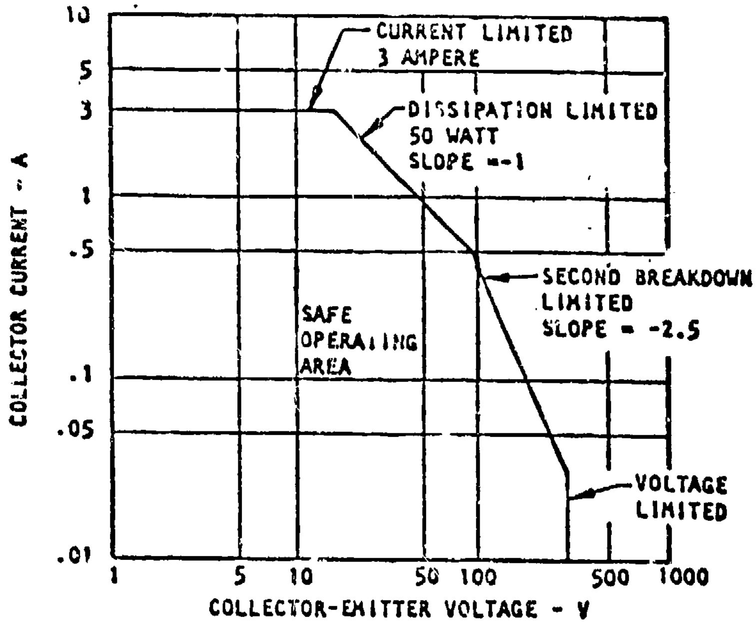


Figure 5-7: Typical Forward Bias Operating Area Graph For DC Operation

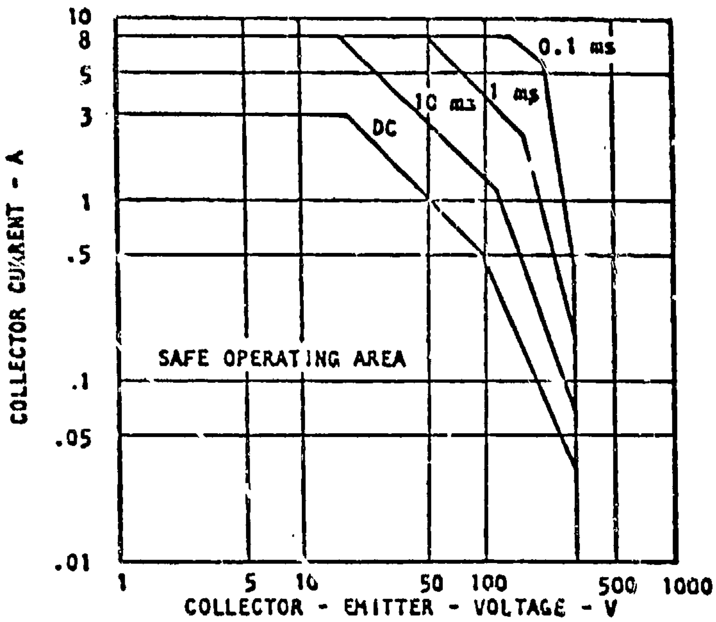


Figure 5-8: Typical Forward Bias Safe Operating Area Graph For Pulsed Conditions

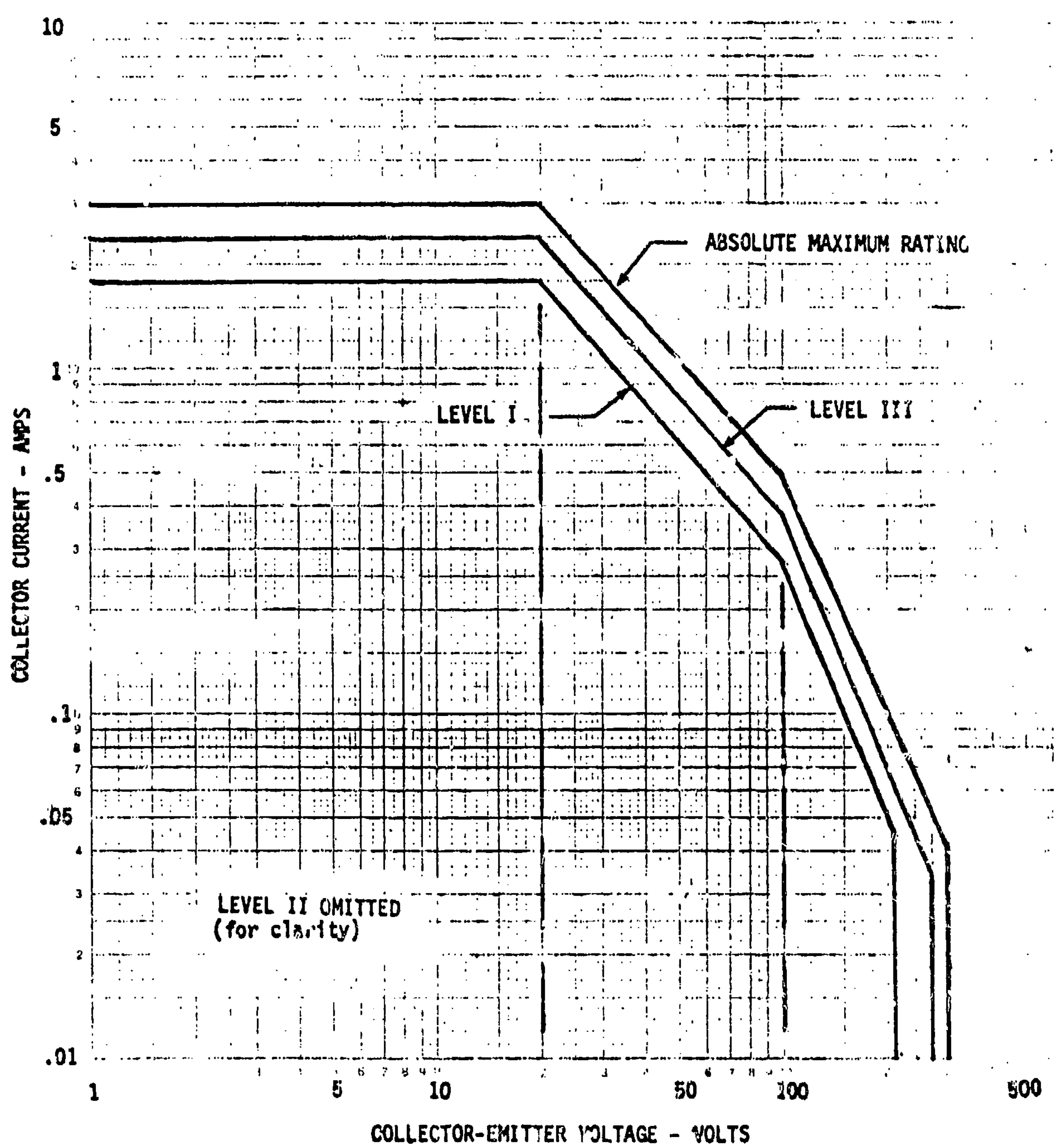


Figure 5-9: Typical Derated SOA

SECTION 6

DIODE DERATING GUIDELINES

6.1 General Derating

As for all other semiconductors, high temperature operation is the most destructive stress for diodes. Temperature accelerates the reaction rates of those phenomena which degrade semiconductors and renders the device more susceptible to damage from other stresses (i.e. voltage and current flow). Reducing junction temperature and junction voltage stress is the purpose of diode derating. In addition to temperature the primary failure forcing functions for derating (as defined by the failure rate model of MIL-HDBK-217C) is average forward current for rectifiers and switching diodes and power for most microwave and special types. Other important selection parameters for popular types are surge current ratings for rectifiers and reverse recovery times for fast recovery rectifiers and switching diodes. There are many types of specialized diodes with unique parameters for special applications such as current regulators and most microwave types.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

6.2 Application Guidelines

A. Allow for the following parameter degradation from the initial limits over the life of the design.

1.	Forward Voltage Drop	+/- 10%
2.	Reverse Leakage	+ 100%
3.	Regulator Diode Voltage	+/- 2%
4.	Recovery and Switching Times	+ 20%

B. Germanium diodes are not recommended for use for new designs.

C. Use only metallurgically bonded diodes except for microwave types where this type of bonding may not be available.

D. Use only hermetically sealed types.

E. Do not overspecify speed and forward voltage as other characteristics may suffer, affecting reliability.

6.3 Diode Derating Guidelines

A. For all diodes derate junction temperature to the limits shown in Table 6-1.

B. For all diodes except for regulator and reference types derate reverse voltage to the limits shown in Table 6-2.

C. For all diodes derate forward current per Table 6-3 or power per Table 6-4 as applicable. The parameter to be derated will be the maximum current or power stress as listed by the device specification. For example, the derating parameters for rectifiers is average forward current, and for regulator and reference diodes and most microwave types, the derating parameter is power.

D. Derate only ambient temperature for reference diodes.

E. For special types which do not fall in one of the previous categories, derate junction temperature to the limits of Table 6-1 and the maximum voltage stress to the limits of Table 6-2.

F. Derate peak surge and transient currents and peak transient voltages to the specified current and voltage limits of Tables 6-2 and 6-3.

TABLE 6-1: JUNCTION TEMPERATURE DERATING (ALL DIODES)

MAXIMUM RATED TJ (DEG C)	MAXIMUM ALLOWABLE JUNCTION TEMPERATURE (DEG C)		
	LEVEL I	LEVEL II	LEVEL III
200	115	140	160
175	100	125	145
150 OR LOWER	MAXIMUM RATED MINUS 65	MAXIMUM RATED MINUS 40	MAXIMUM RATED MINUS 20

TABLE 6-2: VOLTAGE DERATING (ALL DIODES EXCEPT REGULATORS AND REFERENCE TYPE)

MAXIMUM ALLOWABLE OPERATING VOLTAGE (VOLTS)		
LEVEL I	LEVEL II	LEVEL III
0.6 OF RATED REVERSE VOLTAGE	0.7 OF RATED REVERSE VOLTAGE	0.8 OF RATED REVERSE VOLTAGE

TABLE 6-3: CURRENT DERATING (ALL DIODES AS APPLICABLE)

MAXIMUM AVERAGE FORWARD CURRENT		
LEVEL I	LEVEL II	LEVEL III
0.50 MAXIMUM RATED	0.65 MAXIMUM RATED	0.80 MAXIMUM RATED

TABLE 6-4: POWER DERATING (ALL DIODES AS APPLICABLE)

MAXIMUM ALLOWABLE TOTAL POWER DISSIPATION (PT)		
LEVEL I	LEVEL II	LEVEL III
0.50 MAXIMUM RATED	0.65 MAXIMUM RATED	0.80 MAXIMUM RATED

6.3.1 Application of Derating Guidelines

The maximum ratings for diodes are usually specified in current or power. For example: rectifiers are rated by maximum allowable average forward current and regulators/reference diodes by maximum allowable total power dissipation. The temperature range over which the maximum current or power rating is applicable is also specified. For all devices, the low temperature limit is usually -65 or -55 degrees C. The high temperature limit for low power or current devices is normally 25 deg C while for high power or current diodes it varies and can be as high as 150 deg C. For all devices, the maximum rating is reduced for temperatures above the full rating/high temperature limit until zero current or power is reached at the point of the maximum rated junction temperature for the device. Examples of the maximum ratings curves are shown in Figure 6-1 through 6-5 inclusive and are labeled, "Absolute Maximum Rating". Note that the junction temperature at every point on the maximum rating curve is considered equal to the maximum rated junction temperature for the device.

The slope of the maximum ratings curve above the maximum temperature where full rated current or power may be dissipated is approximately equal to the reciprocal of the thermal resistance and is dependent on the physical constants of the device. Therefore, the slopes of the recommended derating curves will be identical. The method for establishing the derating for a specific diode consists of beginning at the ordinate of the maximum rating plot and the recommended derated current or power level and plotting a curve to the zero power point on the abcissa while maintaining the same slopes as the maximum rating curve.

Figures 6-1, 6-2, and 6-3 show the derating recommendations applied to military preferred switching diodes, rectifier diodes and voltage regulator diodes. Note that the curve reaches the zero current or power point below the maximum allowable junction temperature recommendations.

Figures 6-4 and 6-5 shows the recommended derating levels applied to military preferred rectifier diode types 1N1202A through 1N1206A. These derating curves illustrate a conflict that can occur between the current or power and junction temperature derating for a part with a very high temperature derating point. Figure 6-4, derates the diodes by using the current derating recommendations. Using these criteria the junction temperature derating limits are exceeded. Figure 6-5 shows a plot where the same diodes are derated by applying the junction temperature limits and plotting back to the ordinate to determine the allowable average forward current. Note that only the Level III limit of 160 deg C can be plotted and that for all three Levels the devices are overderated with excessive limits applied to the allowable derated forward current. For these cases, the designer must compromise between junction temperature and current or power dissipation to derive the most reliable design.

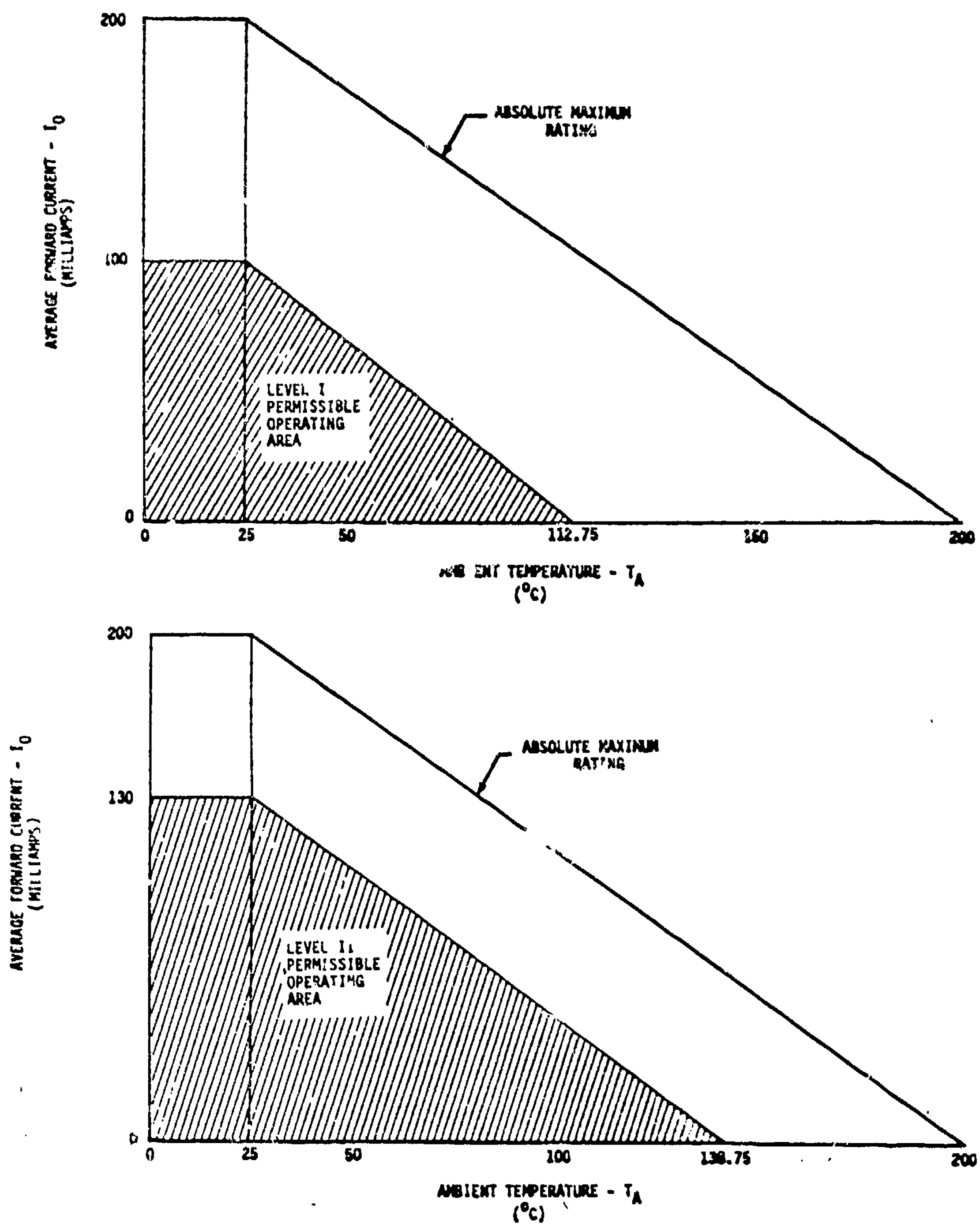


Figure 6-1: Ambient Temperature Derating for Switching Diode Type 1N4148/1N4148-1

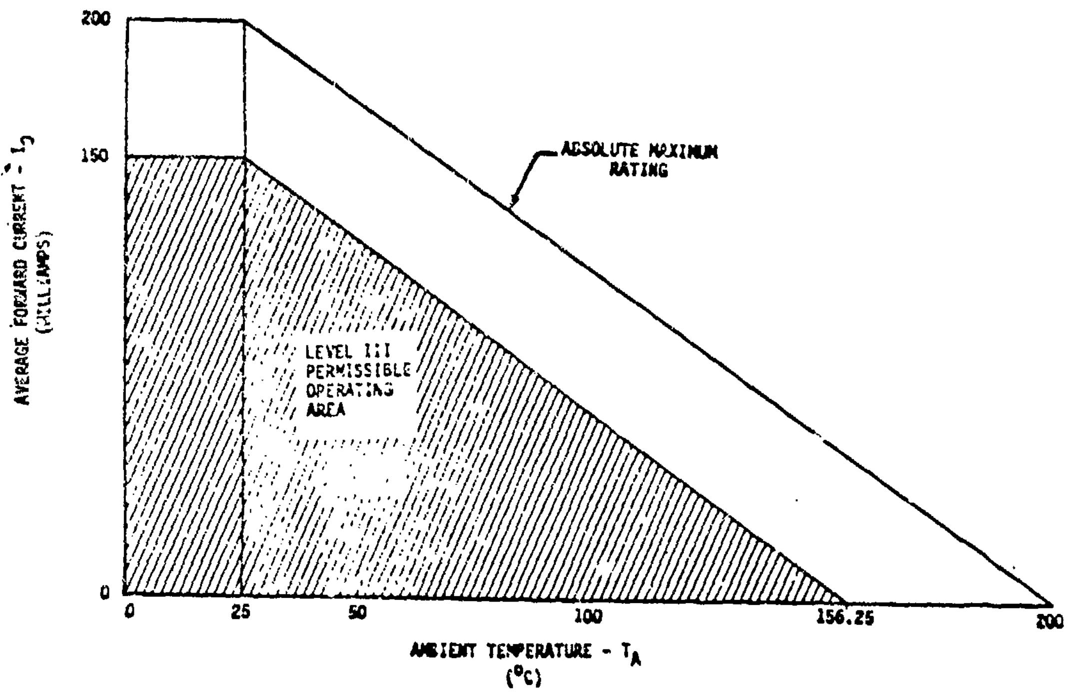


Figure 6-1: Ambient Temperature Derating for Switching Diode Type 1N4148/1N4148-1 (Continued)

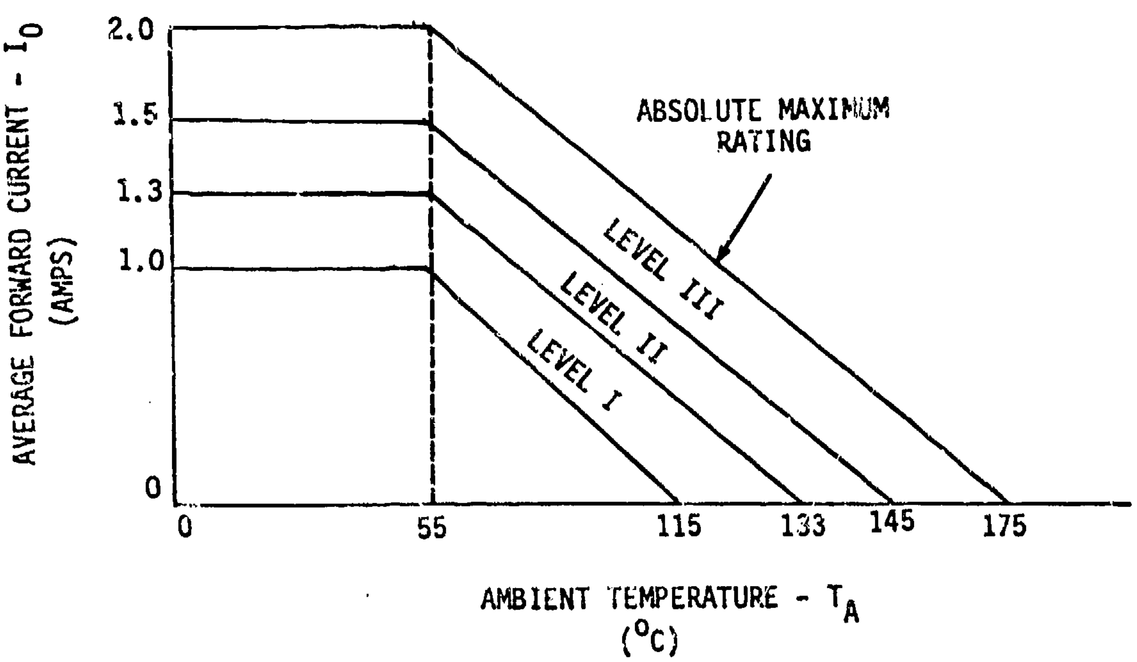


Figure 6-2: Ambient Temperature Derating For Rectifier Diode Types 1N5551-1N5554

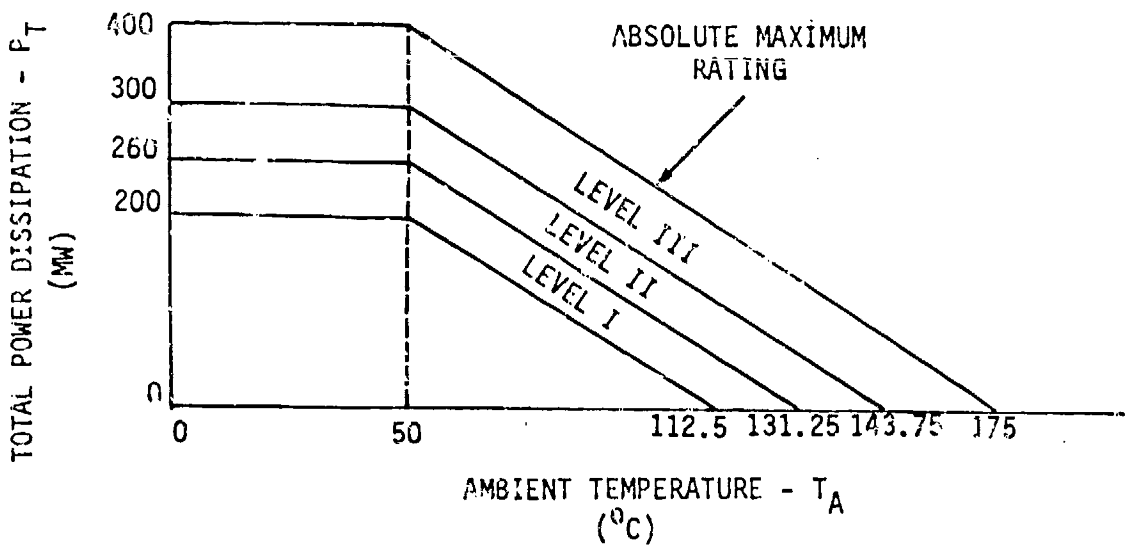


Figure 6-3: Ambient Temperature Derating For Voltage Regulator Diode Types 1N4370A-1N4372A/1N740A-1N759A

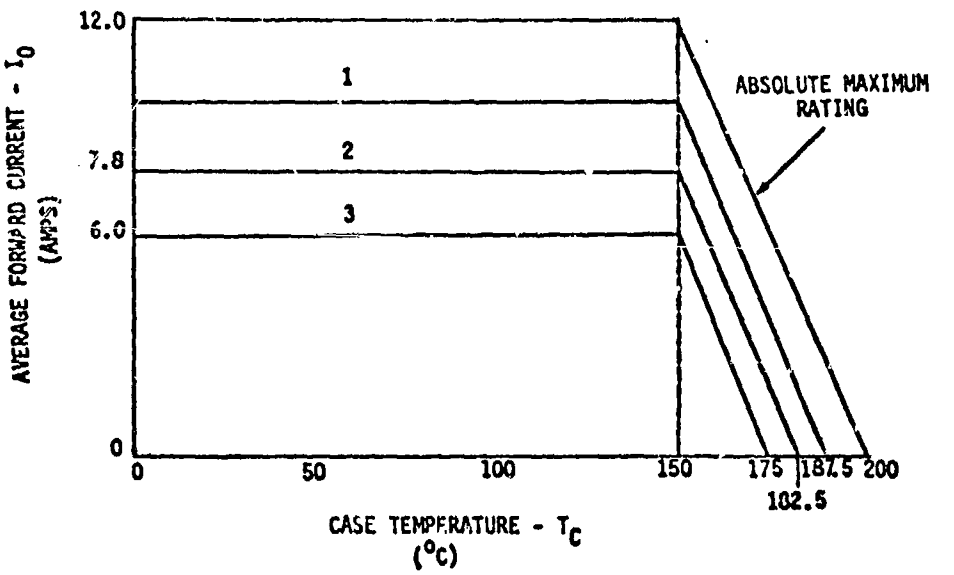


Figure 6-4: Case Temperature Current Only Derating For Rectifier Diode Types 1N1202A-1N1206A

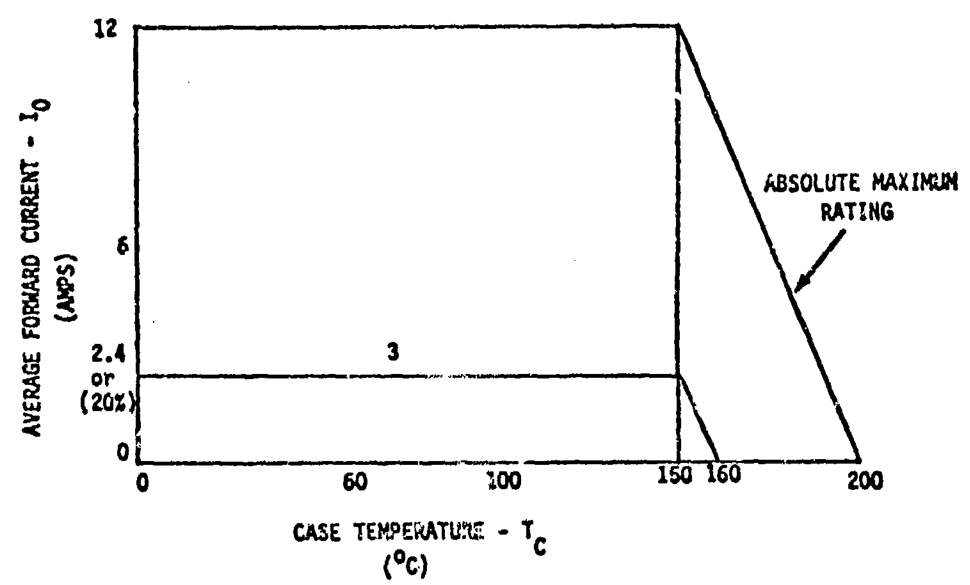


Figure 6-5: Case Temperature Junction Temperature Only Derating For Rectifier Diode Types 1N1202A -1N1206A

Junction temperature is the failure forcing stress function and therefore uncertainties should be resolved in favor of the lower junction temperature.

6.3.2 Microwave Diode Derating Limitations

In general, low frequency diodes offer almost the same electrical characteristics at various power levels which allows considerable design latitude for derating. This is not usually true for microwave types. Microwave design involves distributed constants and therefore the diode, package, parasitics, interconnections, and other components must be considered as a single unit. This often prevents consideration of derating as a separate variable.

While the design may require exceeding the recommended voltage, current, and power derating limits recommended for low frequency designs, the junction temperature limits defined in Table 6-1 should be observed. Use the failure rate model and prediction methods for microwave diodes defined in MIL-HDBK-217C to evaluate candidate designs for maximum reliability.

SECTION 7

THYRISTOR DERATING GUIDELINES

7.1 General

This section covers derating of rectifier devices which have additional junctions for controlling device turn-on, turn-off or both. The most common thyristor, sometimes called a silicon controlled rectifier (SCR), is a four layer (PNPN) semiconductor device. With voltage applied between anode and cathode, the device is normally non-conducting in either direction. The gate electrode when subjected to the appropriate current drive will trigger conduction between the cathode and anode. The cathode-anode voltage must be of a sufficient magnitude to maintain forward current above a minimum level known as the holding current. Once conduction is initiated, only a reduction of the forward current below the holding current can cause conduction to cease. Another class of thyristors, commonly known as triacs, has two gate elements which can both start and stop current flow through the rectifier. Of lesser usage, are light activated SCRs in which conduction is initiated by radiation.

The chief failure forcing functions for thyristors are excessive junction temperature (a function of forward current) and voltage breakdown.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

7.2 Application Guidelines

A. Allow as a minimum, the following degradation in the listed parameters over the service life of the design:

1. Forward voltage drop +/- 10%
2. Leakage Currents + 100%
3. Switching times + 20%

B. Design for "hard" gate turn-on (gate voltage and current well above minimum levels). Marginal or slow gate drive can cause device failure.

C. Gate transient pulses or noise can cause unwanted triggering and must be suppressed. Also fast (high dv/dt) anode voltage application can cause unwanted device turn-on.

D. Insure that for all "on" conditions the anode current is well above the minimum holding current level and for all "off" conditions the anode current is reduced well below the minimum specified holding current.

E. Never allow the gate to become more negative with respect to the anode than is allowed by the ratings as device damage will occur.

F. Voltages in excess of the forward and reverse blocking voltages can cause the device to break into unwanted conduction. Insure that "off" state voltages plus worst case transients do not exceed the rated blocking voltages.

G. When fusing for thyristor protection the I^2t rating of the fuse must be less than the I^2t of the thyristor.

7.3 Thyristor Derating Guidelines

A. Derate thyristor maximum junction temperatures to the limits shown in Table 7-1.

B. Derate thyristor voltages to the limits of Table 7-2.

C. Derate thyristor average forward currents to the limits of Table 7-3.

The method for applying the derating is the same as described for diodes in Section 6. Figure 7-1 shows the maximum rating curves for thyristor type 2N2324A as shown in specification MIL-S-19500/276A. Level II derating for the DC case is specified on this Figure.

TABLE 7-1: JUNCTION TEMPERATURE DERATING

MAXIMUM RATED TJ (DEG C)	MAXIMUM ALLOWABLE TJ (DEG C)		
	LEVEL I	LEVEL II	LEVEL III
200	115	140	160
175	100	125	145
150 OR LOWER	MAXIMUM RATED MINUS 65	MAXIMUM RATED MINUS 40	MAXIMUM RATED MINUS 20

TABLE 7-2: VOLTAGE DERATING

LEVEL	VOLTAGE PARAMETER	DESIGN MAXIMUM ALLOWABLE (VOLTS)
I	VDM, VRRM	0.6 MAXIMUM RATED
II	VDM, VRSM	0.7 MAXIMUM RATED
III	VDM, VRSM	0.8 MAXIMUM RATED

TABLE 7-3: FORWARD CURRENT DERATING

MAXIMUM ALLOWABLE FORWARD CURRENT		
LEVEL I	LEVEL II	LEVEL III
0.50 MAXIMUM RATED	0.65 MAXIMUM RATED	0.80 MAXIMUM RATED

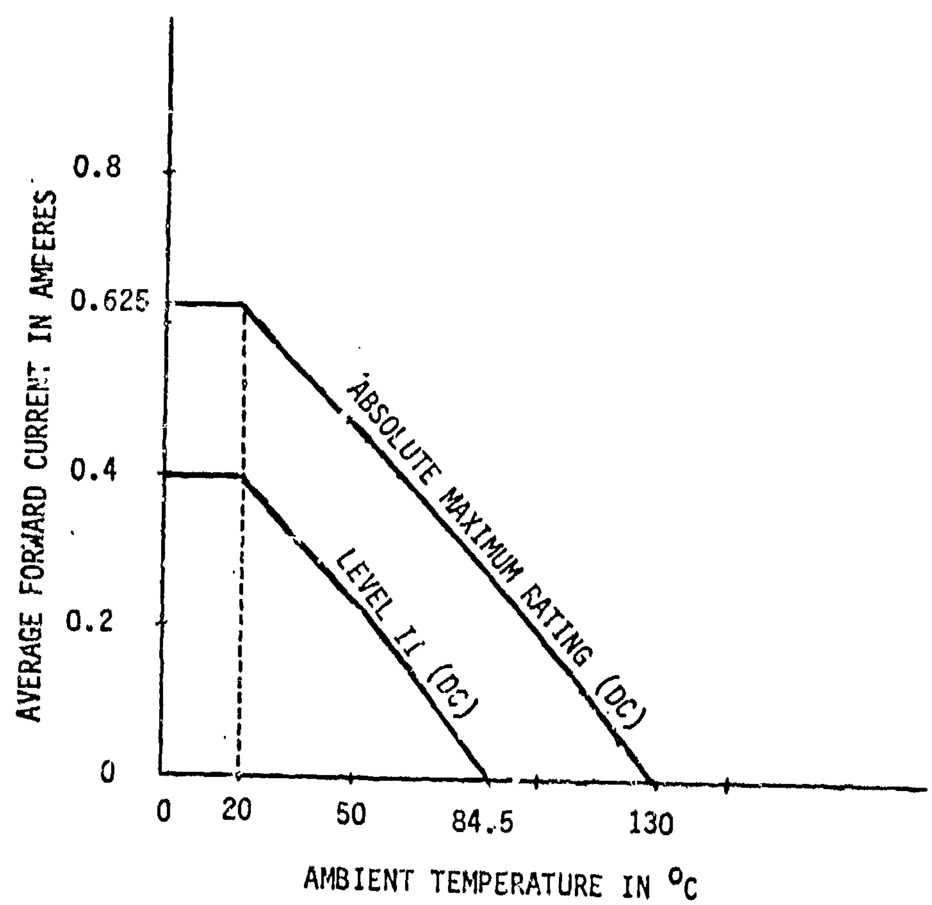


Figure 7-1: Ambient Temperature Curent Derating for Thyristor Type 2N2324A

SECTION 8

OPTICAL SEMICONDUCTOR DERATING GUIDELINES

8.1 General

There are three major classes of optical semiconductors. Those which emit radiation, those which collect radiation, and combinations of the two. The major type of emitters are light emitting diodes (LEDs) which are used for lamps and displays. The major collector types are optimized for visible light and include photodiodes, phototransistors, and light activated silicon controlled rectifiers. The most common combinational device is the optical isolator which contains a light emitting diode coupled with a collector, photo diode or phototransistor, and sometimes includes amplifying elements.

Generally, optical semeconductors are defined by the same parameters, (power, voltage, and current) as non optical devices with the addition of parameters defining the optical characteristics such as peak and dominant wavelength and axial luminous intensity of the radiation which is usually visible light.

In common with all other semiconductor, excessive junction temperature and junction voltage are the major failure forcing stress functions. Junction temperature is dependent on the current through the junction which is controlled by derating the operating current or power.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

8.2 Application Guidelines

A. A current limiting must be incorporated as part of the drive circuitry for LEDs. This is usually a series resistor.

B. Half or full-wave rectified ac sine wave is not recommended for LED drive current. If rectified ac is used to drive LEDs the peak value of the current must never exceed the allowable dc current maximum.

C. When operating a LED in the pulsed mode, the peak junction temperature, not the average, determines the time average power dissipation and light output.

D. Some LEDs can be operated at current levels significantly below (down to 50%) the maximum ratings without noticeable visual change in light output. This value is dependent upon the specific LED under consideration.

E. The dominant wavelength is a quantitative measure of the color of an LED.

F. To maintain opto isolator common mode rejection, optimize circuit board layout to reduce coupling by stray capacitance.

G. Many opto isolators incorporate very high gain circuitry (darlington) and require external bypassing to prevent damaging internal oscillation.

H. Allow for 15% degradation in opto isolator current transfer ratio (CTR) over the service life of the design. This degradation is especially prevalent at low drive current. The input drive current should be well above the turn-on point.

8.3 Optical Semiconductor Derating Guidelines

For all optical semiconductor devices derate junction temperature as shown in Table 8-1.

Optical semiconductors, in general, are rated at lower temperatures than other semiconductors. As a result it may be necessary for a specific design to exceed the recommended guidelines for maximum junction temperature. Since the desired radiation characteristics are dependent on operating voltage and current, general derating is not being recommended for these parameters. All design options should be analyzed using the failure rate prediction methods of MIL-HDBK-217 to determine the optimum reliability in an achievable design.

TABLE 8-1: JUNCTION TEMPERATURE DERATING

MAXIMUM RATED TJ (deg C)	MAXIMUM ALLOWABLE JUNCTION TEMPERATURE (TJ) (deg C)		
	LEVEL I	LEVEL II	LEVEL III
200	110	135	150
175	100	120	140
150 OR LOWER	MAXIMUM RATED MINUS 60	MAXIMUM RATED MINUS 50	MAXIMUM RATED MINUS 25

SECTION 9

RESISTOR DERATING GUIDELINES

9.0 Introduction

This section supplies the derating curves and application guidelines for fixed and variable resistors. The resistor types that will be covered in this section are defined by the following Military Specifications:

TYPE	SUBSECTION
COMPOSITION, FIXED	9.1.1
MIL-R-39008 Resistors, Fixed, Composition (Insulated), Established Reliability (ER), (Style RCR)	
FILM, FIXED	9.1.2
MIL-R-22684 Resistors, Fixed, Film, Insulated, (Style RL)	
MIL-R-39017 Resistors, Fixed, Film, Insulated, ER, (Style RLR)	
MIL-R-55182 Resistors, Fixed, Film, ER, (Style RNR)	
MIL-R-55342 Resistors, Fixed, Film, Chip, ER, (Style RM)	
NETWORK, FILM, FIXED	9.1.3
MIL-R-83401 Resistor Network, Fixed, Film, (Style RZ)	
WIREWOUND, FIXED	9.1.4
MIL-R-26 Resistors, Fixed, Wirewound (Power Type), (Style RW)	
MIL-R-18546 Resistors, Fixed, Wirewound (Power Type, Chassis Mounted), (Style RE)	
MIL-R-39005 Resistors, Fixed, Wirewound (Accurate), ER, (Style RBR)	
MIL-R-39007 Resistors, Fixed, Wirewound (Power Type), ER, (Style RWR)	
MIL-R-39009 Resistors, Fixed, Wirewound (Power Type, Chassis Mounted), ER, (Style RER)	
NON-WIREWOUND, VARIABLE	9.2.1
MIL-R-94 Resistors, Variable, Composition, (Style RV)	
MIL-R-22097 Resistors, Variable, Non-wirewound (Lead Screw Actuated), (Style RJ)	

MIL-R-39023	Resistors, Variable, Non-wirewound, Precision, (StyleRQ)
MIL-R-39035	Resistors, Variable, Cermet, or Carbon Film (Lead Screw Actuated) ER, (Style RJR)

WIREWOUND, VARIABLE 9.2.2

MIL-R-19	Resistors, Variable, Wirewound (Low Operating Temperature), (Style RA)
MIL-R-22	Resistors, Variable, Wirewound (Power Type), (Style RP)
MIL-R-12934	Resistors, Variable, Wirewound, Precision, (Style RR)
MIL-R-27208	Resistors, Variable, Wirewound (Lead Screw Actuated), (Style RT)
MIL-R-39002	Resistors, Variable, Wirewound, Semi-Precision, (Style RK)
MIL-R-39015	Resistors, Variable, Wirewound (Lead Screw Actuated), ER, (Style RTR)

THERMISTOR 9.3

MIL-T-23648	Thermistor (Thermally Sensitive Resistor), Insulated, (Style RTH)

Whenever two specifications define the same type resistor with the same temperature limits, the specifications are listed on the same derating curve; such as, MIL-R-22684 and MIL-R-39017 in Figure 9.1-4.

SECTION 9.1

FIXED RESISTOR GENERAL DERATING CONSIDERATIONS

The principal stress parameters in derating fixed resistors is the "hot spot temperature" (sum of the ambient temperature and the temperature due to the dissipated power). Therefore, decreasing the ambient temperature and/or the power dissipation factor will extend the lifetime.

All derating curves will reduce both ambient temperature as well as power.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

SECTION 9.1.1

FIXED COMPOSITION RESISTOR DERATING

9.1.1.1 General

The fixed composition resistor is defined by MIL-R-39008 (RCR). This type of resistor is small, inexpensive, and has good reliability when properly used. They do have poor resistance stability, high noise characteristic and appreciable voltage and temperature coefficients.

The resistance element consists of a mixture of carbon, insulating material, and suitable binders, either molded together or applied as a thin layer of conducting material on an insulated form. These resistors are covered by a molded jacket which is primarily intended to provide an adequate moisture barrier for the resistance element, as well as mechanical protection and strength for wire leads.

9.1.1.2 Application Guidelines

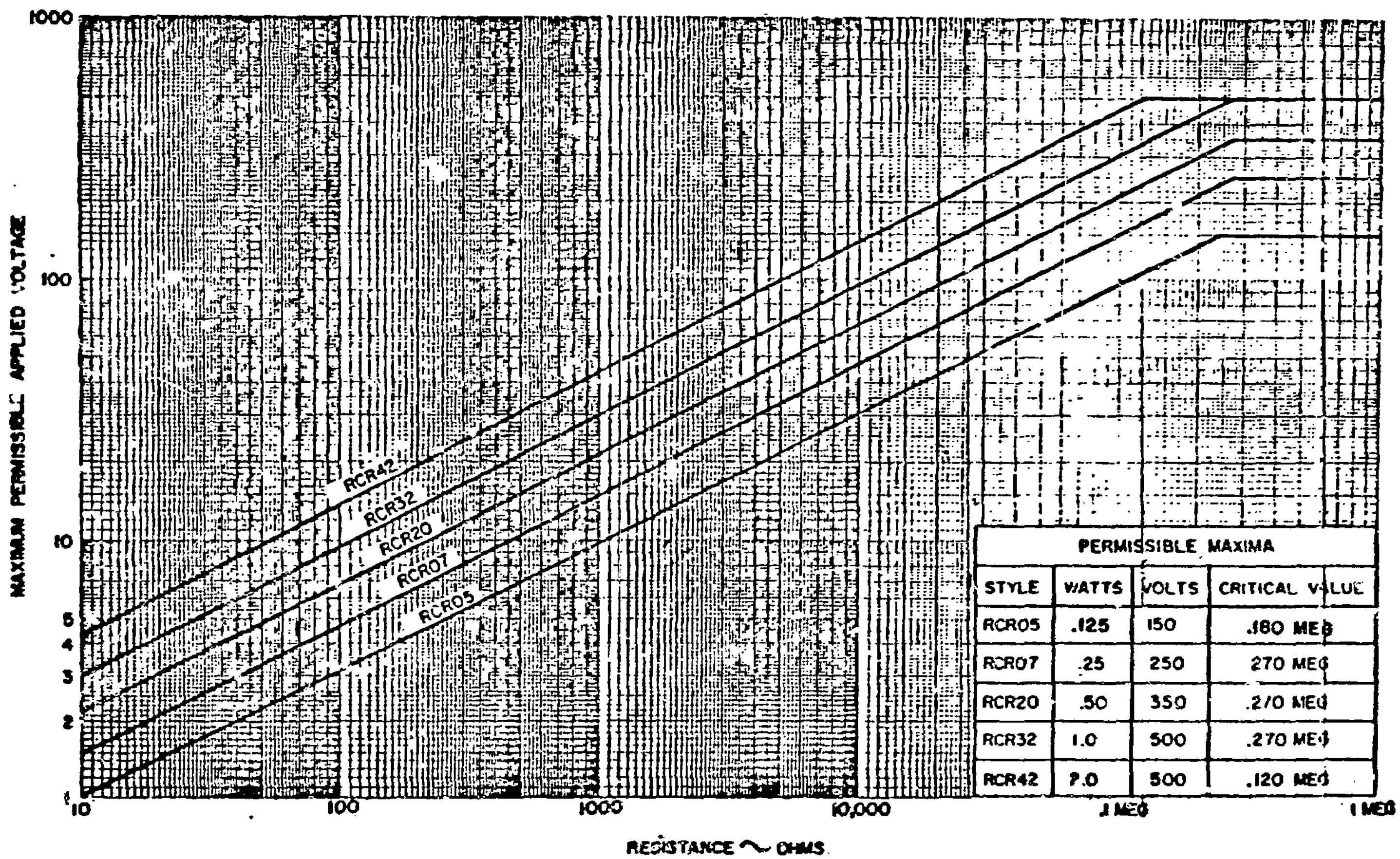
A. The voltage and power dissipations limits must not be overlooked. The resistance has a negative coefficent for both temperature and voltage and are very susceptible to burn-out. (See Figure 9.1-1 and MIL-STD-199 for applicable limits for voltage limitations.)

B. Exposure to humidity may cause surface leakage paths which lower resistance or absorption of moisture which may increase the resistance.

C. Resistor charcteristics can be permanently damaged by exposure of the resistive material to temperatures above 130 deg C.

9.1.1.3 Derating Guidelines

Ambient temperature and power are the principal derating stress parameters for fixed composition resistors. The recommended derating for the three application Levels are given in Figure 9.1-2.



PERMISSIBLE MAXIMA			
STYLE	WATTS	VOLTS	CRITICAL VALUE
RCR05	.125	150	.180 MEG
RCR07	.25	250	270 MEG
RCR20	.50	350	.270 MEG
RCR32	1.0	500	.270 MEG
RCR42	2.0	500	.120 MEG

Figure 9.1-1: Voltage Limitations by Style

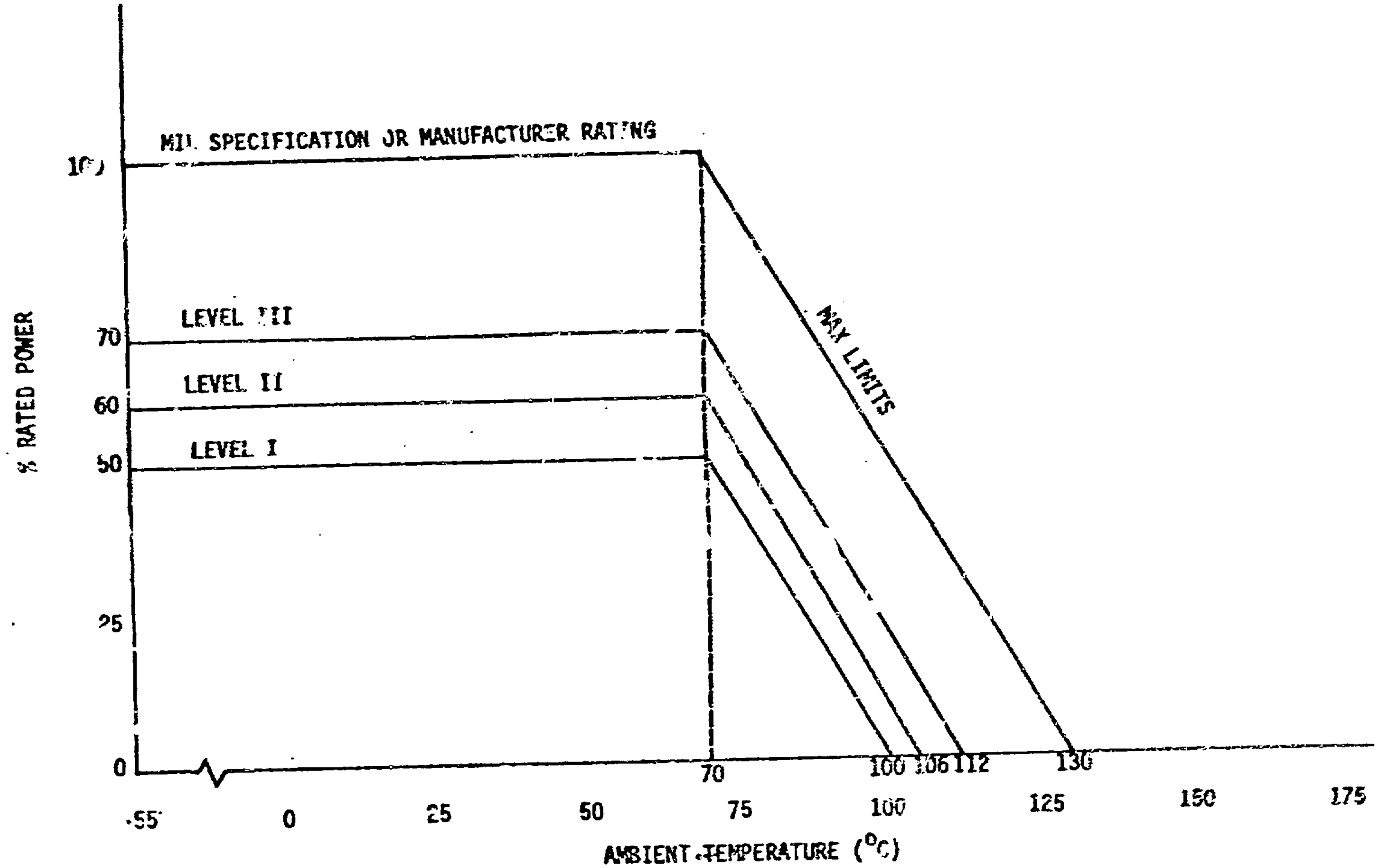


Figure 9.1-2: Derating Curves For Resistors, Fixed, Composition Defined by MIL-R-39008

SECTION 9.1.2

FIXED FILM RESISTOR DERATING

9.1.2.1 General

Fixed film resistors are defined by MIL-R-22684, MIL-R-39017, MIL-R-55182, and MIL-R-55342. This type is intended for high frequency applications and where high stability and close resistance tolerance is required.

For MIL-R-22684 (RL) and MIL-R-39017 (RLR) resistors, the resistance element consists of a film-type resistance element (tin oxide, metal glaze, etc.) which has been formed on a substrate by one of several processes depending upon the manufacturer. The element is spiraled to achieve ranges in resistance value and, after lead attachment the element is coated to protect it from moisture or other detrimental environmental conditions.

For MIL-R-55182 (RNR) resistor, the resistance element consists of a metal film element on a ceramic substrate. The element is formed by the condensation of a heated metal under vacuum conditions. Following spiralling to increase the available resistance values and the attachment of leads, the element is protected from environmental conditions by an enclosure.

The resistance element of MIL-R-55342 (RM) consists of a film element on a ceramic substrate. The element is formed either by deposition of a vaporized metal or the printing of a metal and glass combination paste which has then been fired at a high temperature. Resistance elements are generally rectangular in shape and calibrated to the proper resistance value by trimming the element by abrasion or a laser beam.

For detailed application and design guidelines, consult MIL-STD-199.

9.1.2.2 Application Guidelines

The application guidelines are defined for each Military type part.

A. For MIL-R-22684 and MIL-R-39017 type parts:

1. The maximum continuous working voltage specified for each style should not be exceeded, regardless of the calculated rated voltage on the basis of power rating.

2. Noise output is uncontrolled by the specification, but is considered a negligible quantity.

3. For MIL-R-39017 (only), the resistance value will change; 2% (average) per year (additive in subsequent years) under normal storage conditions. (25 deg +/- 10 deg C and humidity </- 90%).

4. The effective DC resistance will change when used at frequencies above 50 MHz (see Figure 9.1-3).

B. For MIL-R-55182 type parts:

1. The effective DC resistance for most values will remain fairly constant up to 100 MHz and decrease at higher frequencies. The larger resistance values are affected more by the high frequencies.

2. The tighter (0.1%) tolerance film resistors are susceptible to electrostatic damage (see Appendix C, DOD-STD-1686; DOD-HDBK-2630).

3. Peak power dissipation should not exceed four times the maximum rating of the resistor under any condition.

4. The design should be able to tolerate a +/- 2% shift in resistance to assure long life reliability.

C. For MIL-R-55342 type parts:

1. Film resistors with small dimensions and high sheet resistivity material may be subject to significant changes in resistance values (normally lower) and to changes in temperature coefficients due to a static discharge.

2. The effective resistance values will be reduced when used at frequencies of 200 MHz or above because of shunt capacitance between the resistance elements and the connecting circuits.

9.1.2.3 Derating Guidelines

Ambient temperature and power are the principal derating stress parameters for fixed film resistors. The recommended derating curves for the three Levels are given for each defined resistor type.

The derating curves for MIL-R-22684 and MIL-R-39017 types are given in Figure 9.1-4.

The derating curves for MIL-R-55182 types at 70 deg C and 125 deg C (ambient temperature) are given in Figure 9.1-5 and Figure 9.1-6, respectively.

The derating curves for MIL-R-55342 types are given in Figure 9.1-7.

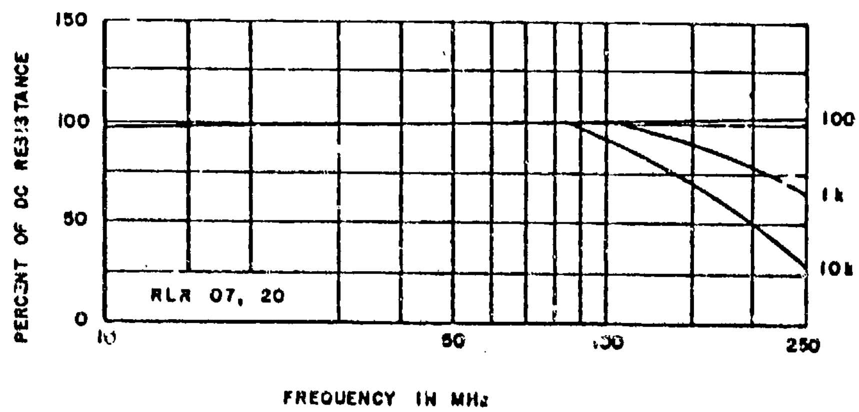


Figure 9.1-3: Frequency Response of Resistance

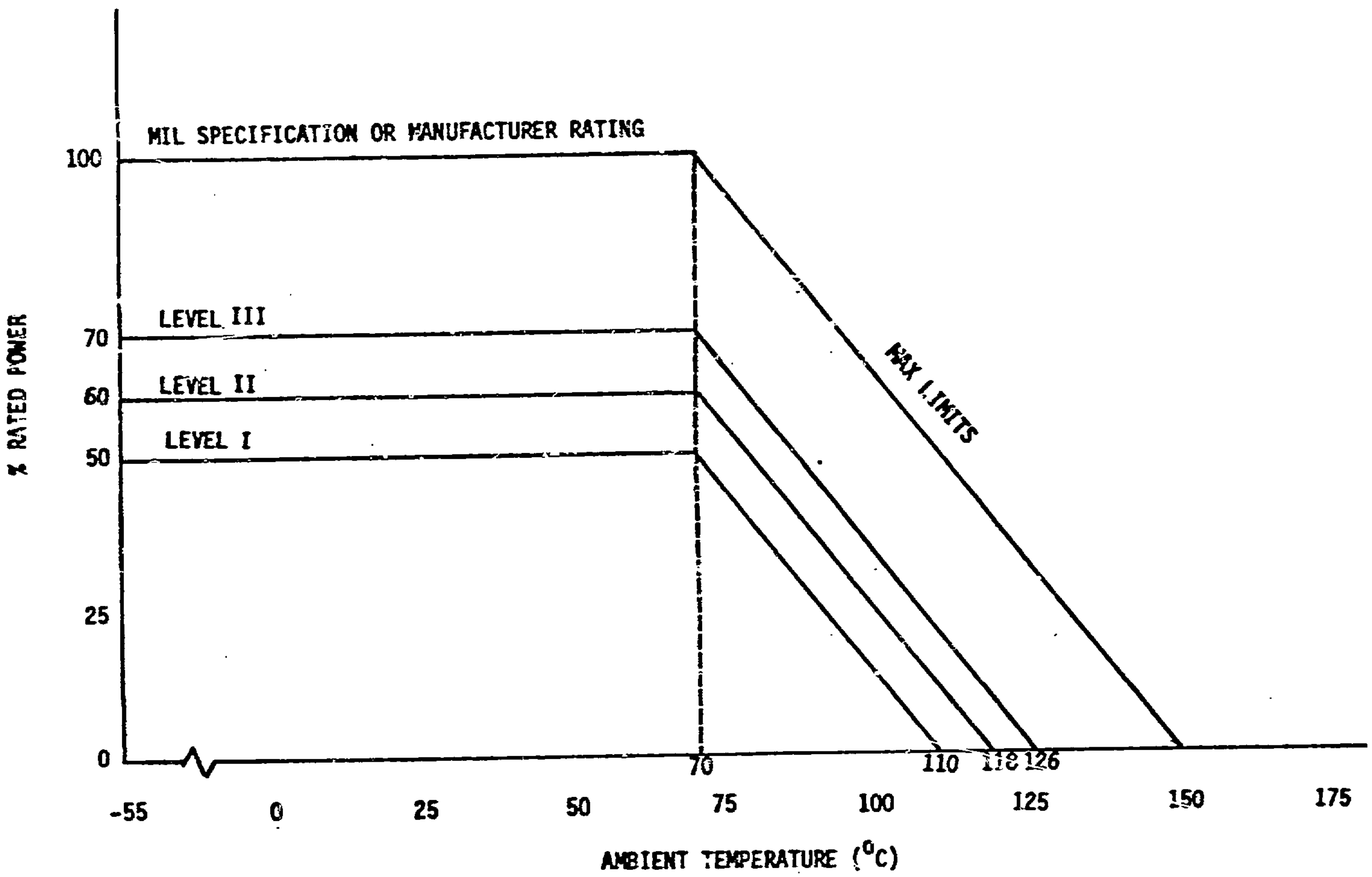


Figure 9.1-4: Derating Curves for Resistor, Fixed, Film Defined by MIL-R-22684 and MIL-R-39017

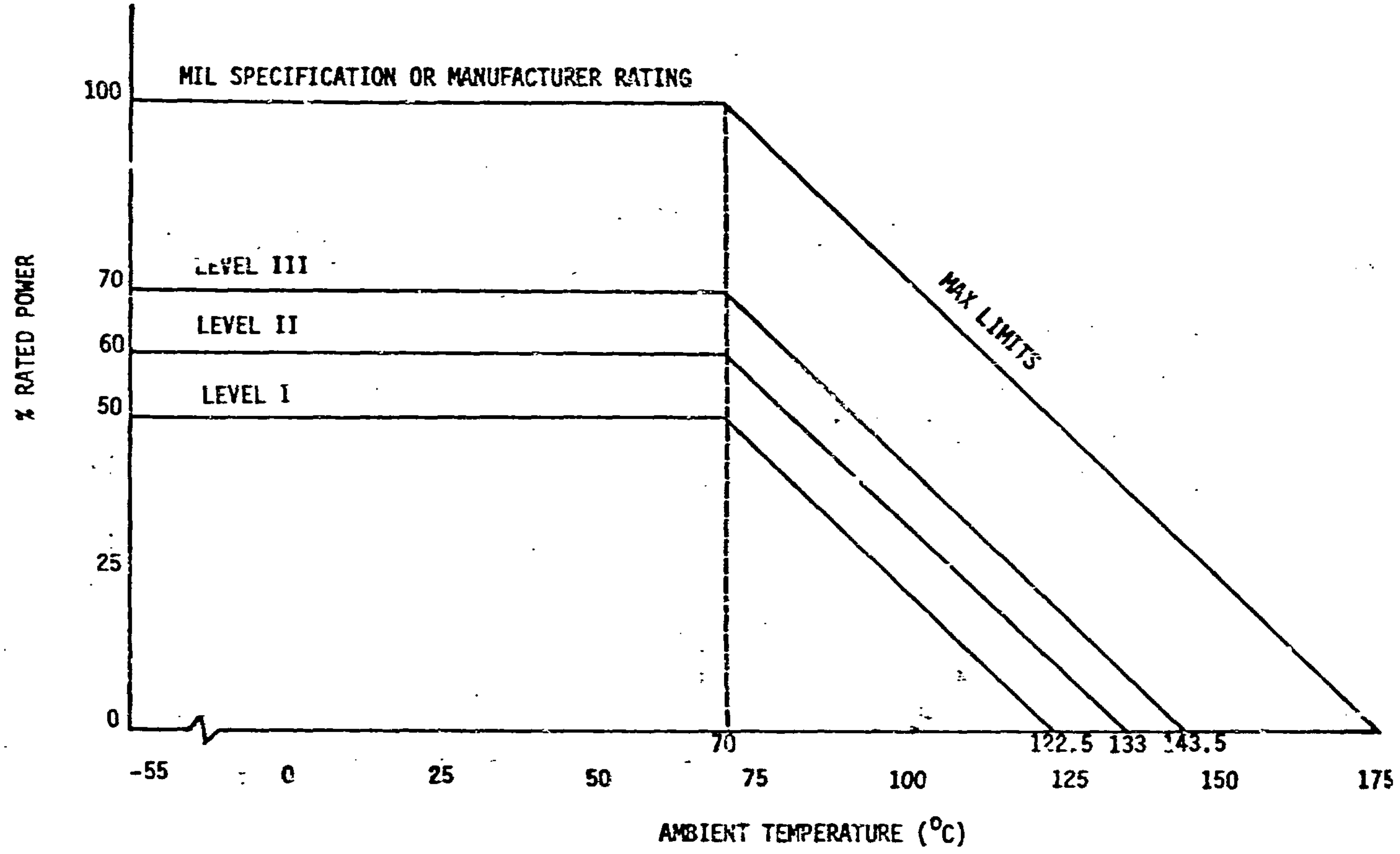


Figure 9.1-5: Derating Curves for Resistors, Fixed, Film Defined by MIL-R-55182 for Power Rating at 70C

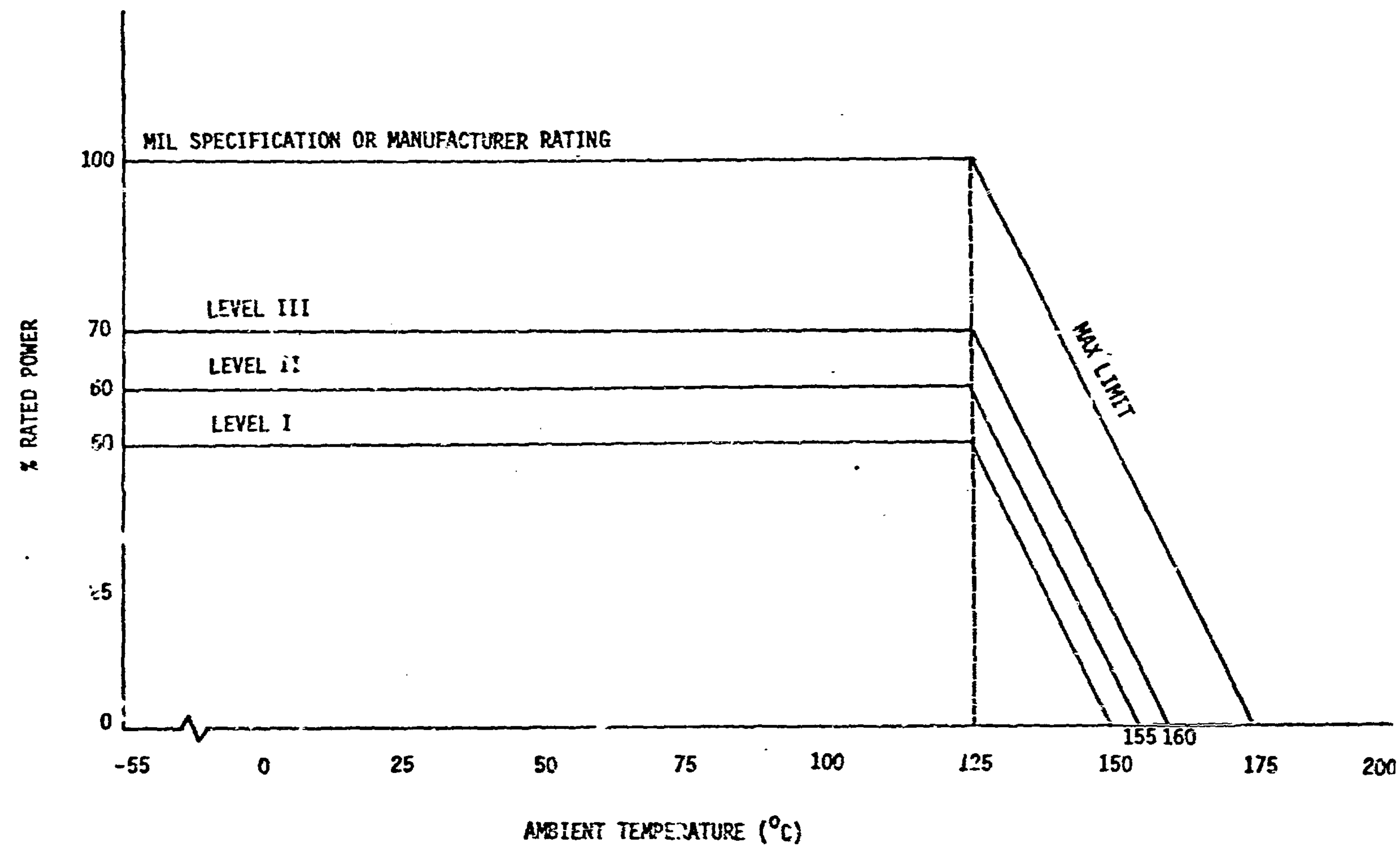


Figure 9.1-6: Derating Curves for Resistors, Fixed, Film Defined by MIL-R-55182 for Power Ratings at 125C

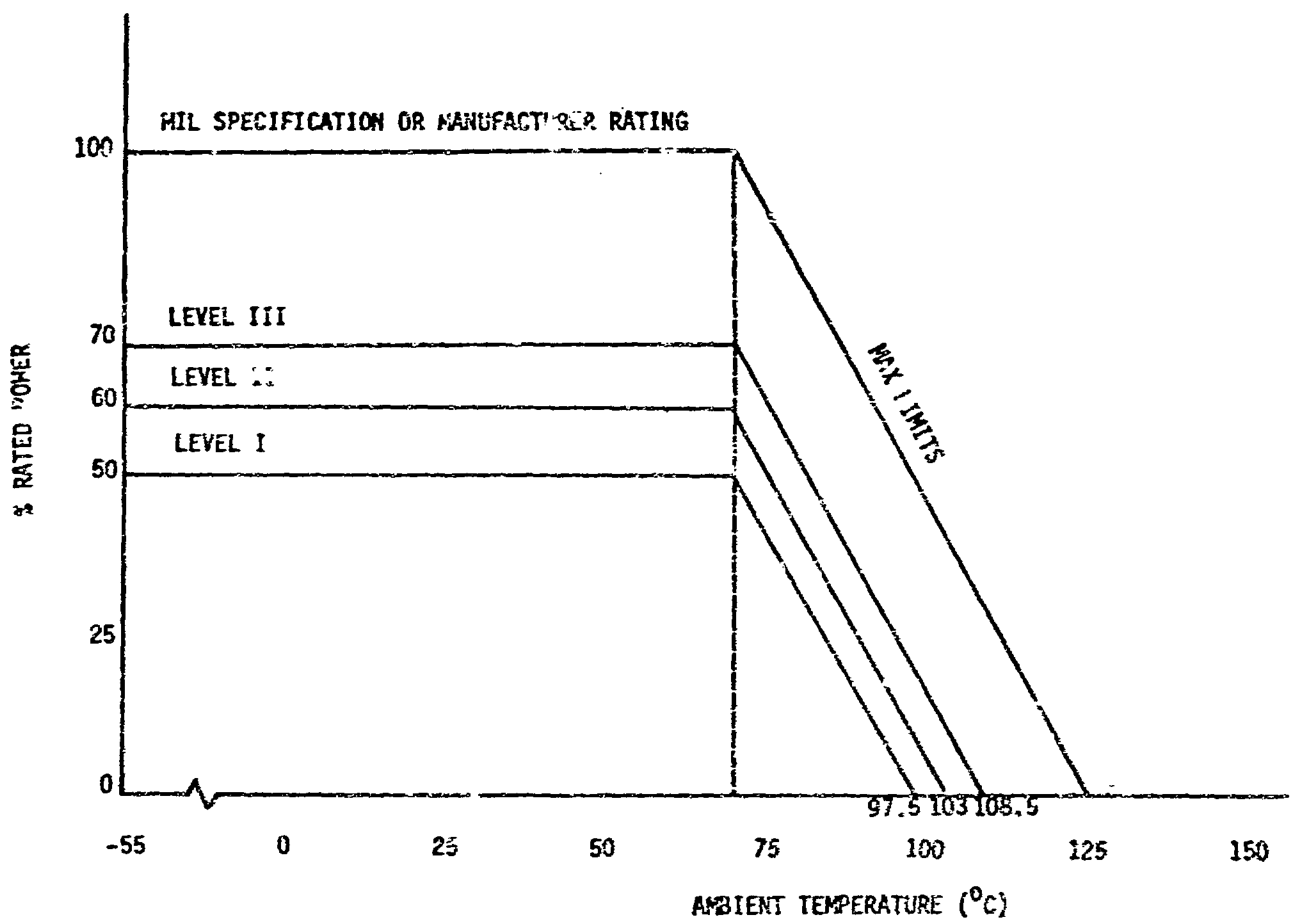


Figure 9.1-7: Derating Curves for Resistors, Fixed, Film Chip Defined by MIL-R-55342

SECTION 9.1.3

FIXED NETWORK FILM RESISTOR DERATING

9.1.3.1 General

The fixed network film resistors are defined by MIL-R-83401 (RZ). These resistors are fixed resistors in a resistor network configuration having a film resistance element and in a dual-in-line, single-in-line, or flat pack configuration. They are stable with respect to time, temperature, and humidity. These resistors are designed for use in critical circuitry where stability, long life, reliable operation and accuracy are of prime importance. They are particularly desirable for miniaturization and for ease of assembly.

The resistance element consists of a film element on a ceramic substrate. The element is formed either by deposition of a vaporized metal or the printing of a metal and glass combination paste which has then been fired at a high temperature. Resistance elements are generally rectangular in shape and calibrated to the proper resistance value by trimming the element by abrasion or a laser beam. After calibration, the resistance element is protected by an enclosure or coating of insulating, moisture-resistant material (usually epoxy or a silicone).

9.1.3.2 Application Guidelines

A. Maximum voltages are specified because of the very small spacing between the resistance elements and the connecting circuits. The maximum voltage for each network type is listed in MIL-R-33401 or MIL-STD-199.

B. The MIL spec or manufacturer listing gives two power ratings for the resistor network. They are individual element and total network package power ratings. The maximum power ratings is based on continuous, full-load operation at 70 deg C. If operated above 70 deg C, the resistors must be derated per Figure 9.1-8.

9.1.3.3 Derating Guidelines

Ambient temperature and power are the principal derating stress parameters for fixed network film resistors which is defined by MIL-R-83401. The recommended derating for the three Levels are given in Figure 9.1-8.

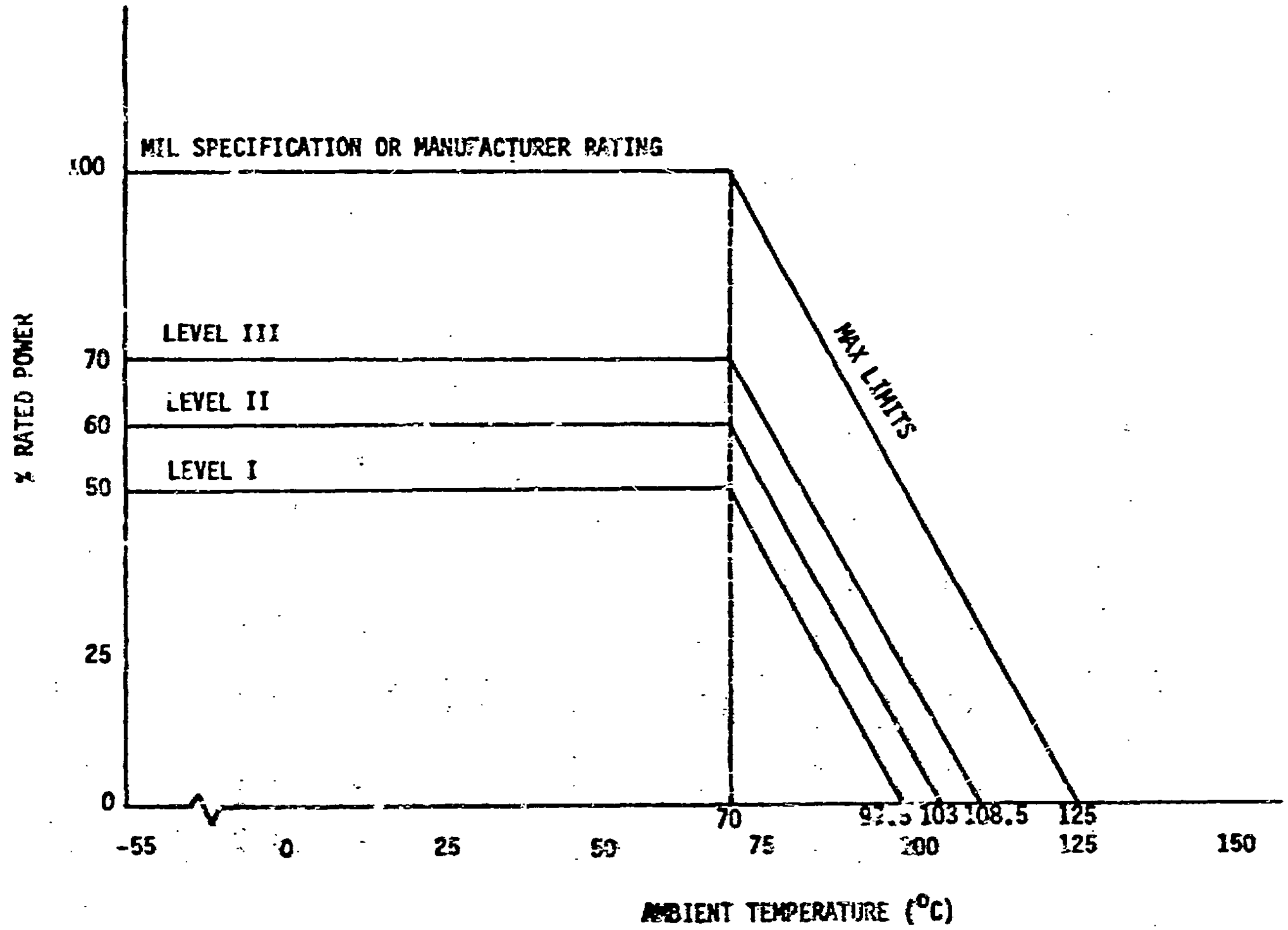


Figure 9.1-8: Derating Curves For Resistor Networks, Fixed, Film Defined by MIL-R-83401

SECTION 9.1.4

FIXED WIREWOUND RESISTOR DERATING

9.1.4.1 General

The fixed wirewound resistors are defined by MIL-R-26, MIL-R-18546, MIL-R-39005, MIL-R-39007, and MIL-R-39009.

The fixed wirewound resistor have high stability, medium temperature coefficeint, high reliability and negligible voltage coefficient characteristics and are normally unsuitable for usage above 50 KHz.

The construction of MIL-R-26 (RW) and MIL-R-39007 (RWR) type resistors employs a measured length of resistance wire or ribbon wound in a precise manner. The continuous length of wire is wound on a ceramic core or tube and attached to end terminations. The element is enclosed by inorganic vitreous or a silicone coating to protect it from detrimental environment conditions.

The construction of MIL-R-18546 (RE) and MIL-R-39009 (RER) type resistors are similar to MIL-R-26 as shown above. The continuous length of wire, the finished resistor element and element and termination caps are sealed by a coating material. The coated element is inserted in a finned aluminum alloy housing which completes the sealing of the element from detrimental environments and provides a radiator and a heat sink for heat dissipation.

The resistance element of MIL-R-39005 (RBR) consists of a precisely measured length of resistance wire, wound on a bobbin or core. The resistance wire is an alloy metal without joints, welds, or bonds, except for splicing at end terminals. In order to minimize inductance, resistors are wound reverse or bifilar. The element assembly is protected by an enclosure of moisture-resistant insulating material which covers the resistance element including connections and terminations.

9.1.4.2 Application Guidelines

The application guidelines are defined for each Military type part.

A. For MIL-R-26 type parts:

1. The use of a wire size less than 0.001 inch nominal diameter is not recommended for Levels I and II.

2. Resistors used in equipment should not exceed the rated operating temperature under any condition (i.e. high altitude, all enclosure in place, max power dissipation).

3. When mounted in rows or banks, the spacing of the resistors should be such that none of the resistors in the row or bank will exceed the maximum hot-spot temperature.

4. Where high voltages are present between resistor circuits and the grounded surface on which resistors are mounted, a secondary insulation capable of withstanding the voltage should be provided between resistors and mountings or between mountings and ground.

B. For MIL-R-18546 and MIL-R-39009 type parts:

1. The use of RE and RER resistors with a wire size less than 0.001 inch nominal diameter shall not be permitted for Levels I & II.

2. RER resistors can reliably withstand pulse voltages of much greater amplitude than permitted for steady state operation. Figure 9.1-9 illustrates the permissible pulse power applicable to the various power ratings. These curves must be derated if there is any steady state power applied. The indicated pulse power should be derated the same percentages as shown in the next section for Levels I, II, and III.

C. For MIL-R-39005 type parts:

1. Voltages in excess of the voltage ratings should not be used because it may cause insulation breakdown between the windings.

2. A secondary insulation between the resistor and its mounting, or between the mounting and grounded surface should be used where high voltages (250 volts or greater) are present between resistor circuit and the grounded surface.

3. Care should be used when soldering lower resistance values and tighter tolerance resistors to avoid causing increased contact resistance.

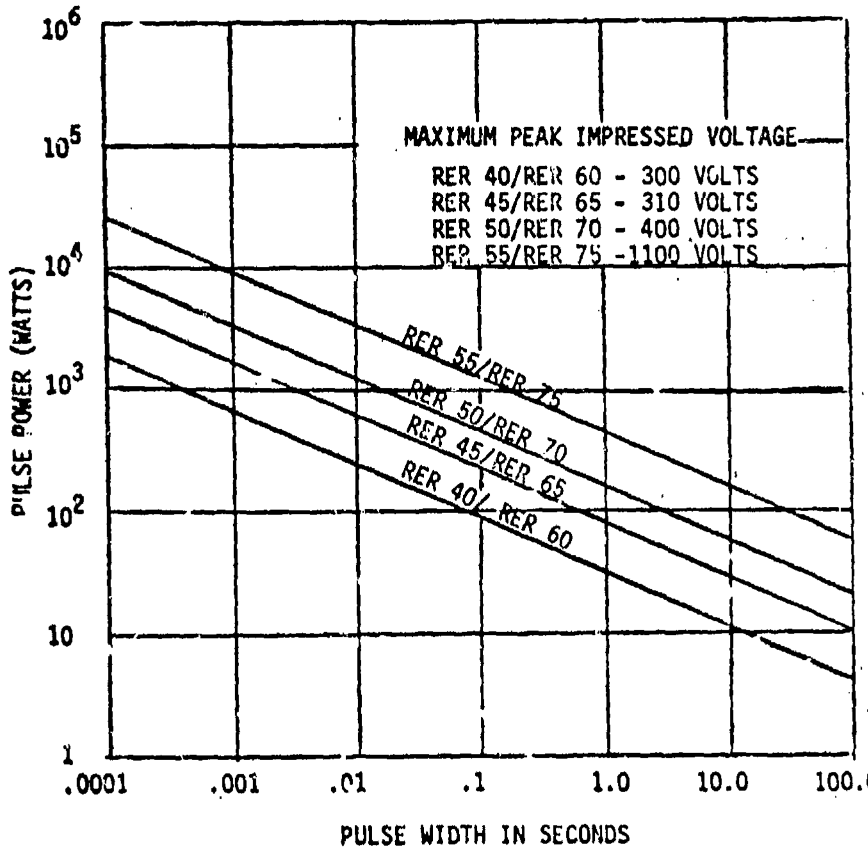
4. Lead length effects should be considered when using low resistance values and tight tolerance resistors (0.1% or less).

5. Wire size of less than 0.001 inch diameter is not recommended.

D. For MIL-R-39007 type parts:

1. Resistors used in equipment should not exceed the rated operating temperature under any condition (i.e. high altitude, all of the enclosures in place, the max power dissipation, etc.).

2. When mounted in rows or banks, the spacing of the resistors should be such that none of the resistors in the row or bank will exceed the maximum hot-spot temperature.



Example for use of the pulse rating curves:

1. Given:
   a) Ambient temperature at part location during operation = 55°C.
   b) Circuit requires nonrepetitive pulse of 50 volts, Pw = 100 msec.
   c) Required resistance value = 46.4 ohms; level equipment.
2. Find: Resistor type meeting pulse and power derating criteria.
3. Solution:
   a) Pulse power (P) = $E^2/R = 50^2/46.4 = 54$ watts.
   b) Plot intersection of 0.1 second and 54 watts on Figure 9.1-9.
   c) RER60 (5 watts) meets pulse criteria.
   d) However, from Figure 9.1-12, note that in this case, the permissible stress ratio is .5 of the maximum rating at 25°C. Accordingly, use RER65 (10 watts derated to 5 watts).

Figure 9.1-9: Pulse Ratings for RER Resistors

3. The use of a wire size of 0.001 inch nominal diameter is not recommended for Levels I and II.

4. RWR resistors can reliably withstand pulse voltages of much greater amplitude than permitted for steady state operation. Figure 9.1-10 shows the permissible pulse power applicable to the various power ratings. These curves must be derated if there is any steady state power applied. The indicated pulse power should be derated the same percentage as shown in the next section for Levels I, II, and III.

9.1.4.3 Derating Guidelines

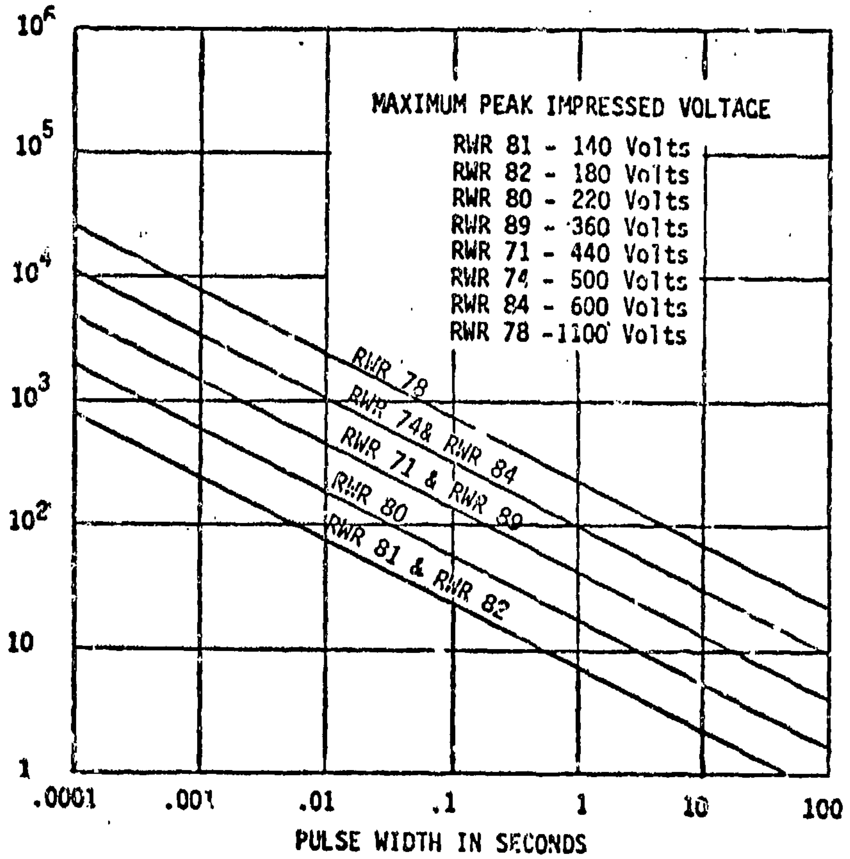
Ambient temperature and power are the principal derating stress parameters for fixed wirewound resistors. The recommended derating curves for the the three Levels are given for each MIL defined resistor type.

The derating curves for MIL-R-26 types are given in Figure 9.1-11.

The derating curves for MIL-R-18546 and MIL-R-39009 types are given in Figure 9.1-12. The chassis-area is another critical parameter for MIL-R-39009 types. With a reduction in the chassis-area, the power must be derated per Figure 9.1-13.

The derating curves for MIL-R-39005 types are given in Figure 9.1-14.

The derating curves for MIL-R-39007 types are given in Figure 9.1-15.



Example for use of the pulse rating curves:

1. Given:
   a) Ambient temperature at part location during operation = 75°C.
   b) Circuit requires nonrepetitive pulse of 100 volts, Pw = 10 msec.
   c) Required resistance value = 9.09 ohms; level equipment.
2. Find: Resistor type meeting pulse and power derating criteria.
3. Solution:
   a) Pulse power (P) = E^2/r = $100^2/9.09$ = 1100 watts.
   b) Plot intersection of .01 second and 1100 watts on Figure 9.1-10.
   c) Observe that a type RWR74 (5 watt) meets pulse criteria.
   d) However, from Figure 9.1-15, note that in this case, the permissible stress ratio is .5 of the maximum rating at 25°C. Accordingly use RWR78 (10 watts derated to 5 watts).

Figure 9.1-10: Pulse Ratings for RWR Resistors

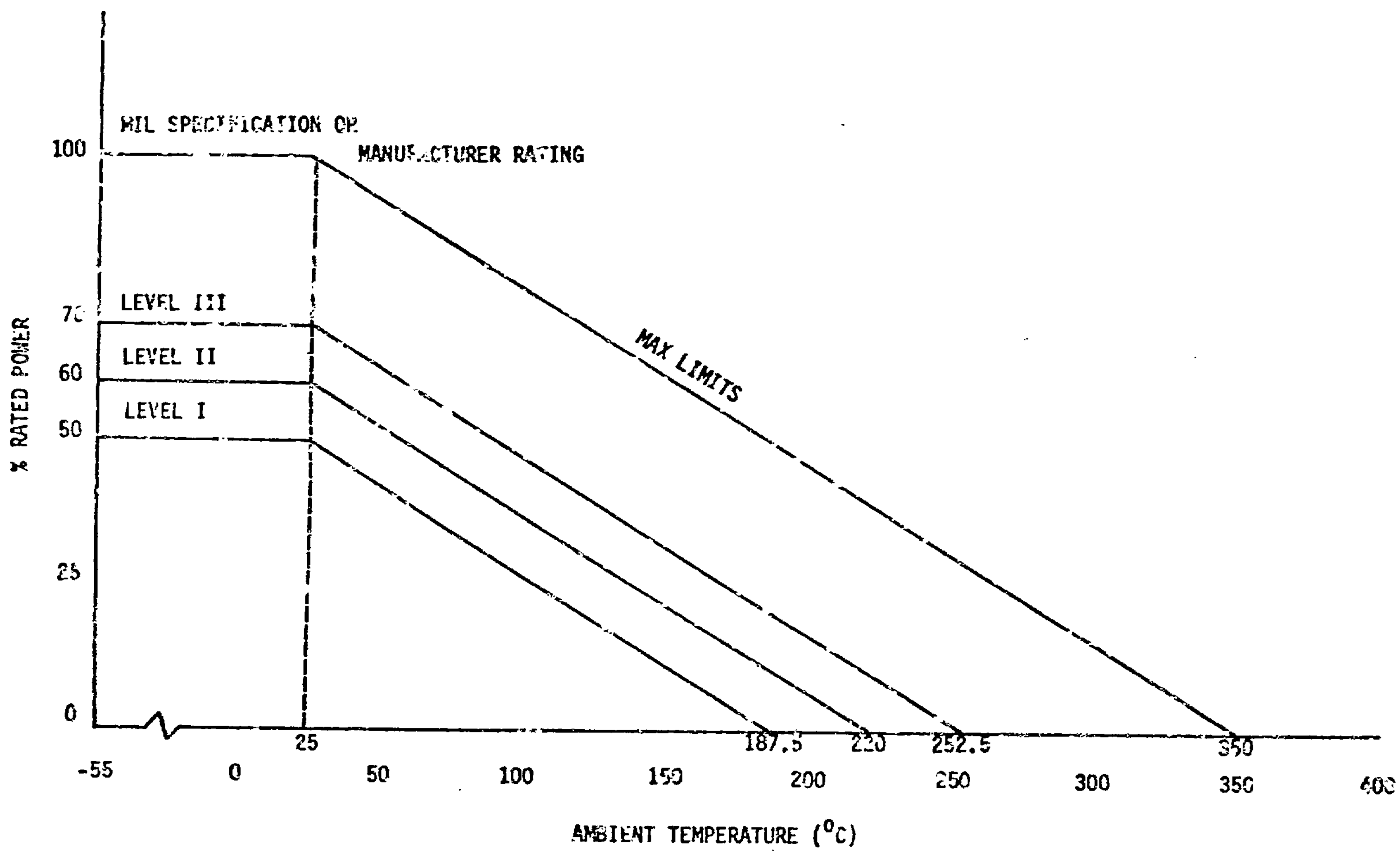


Figure 9.1-11: Derating Curves for Resistors, Fixed, Wirewound Power Defined by MIL-R-25

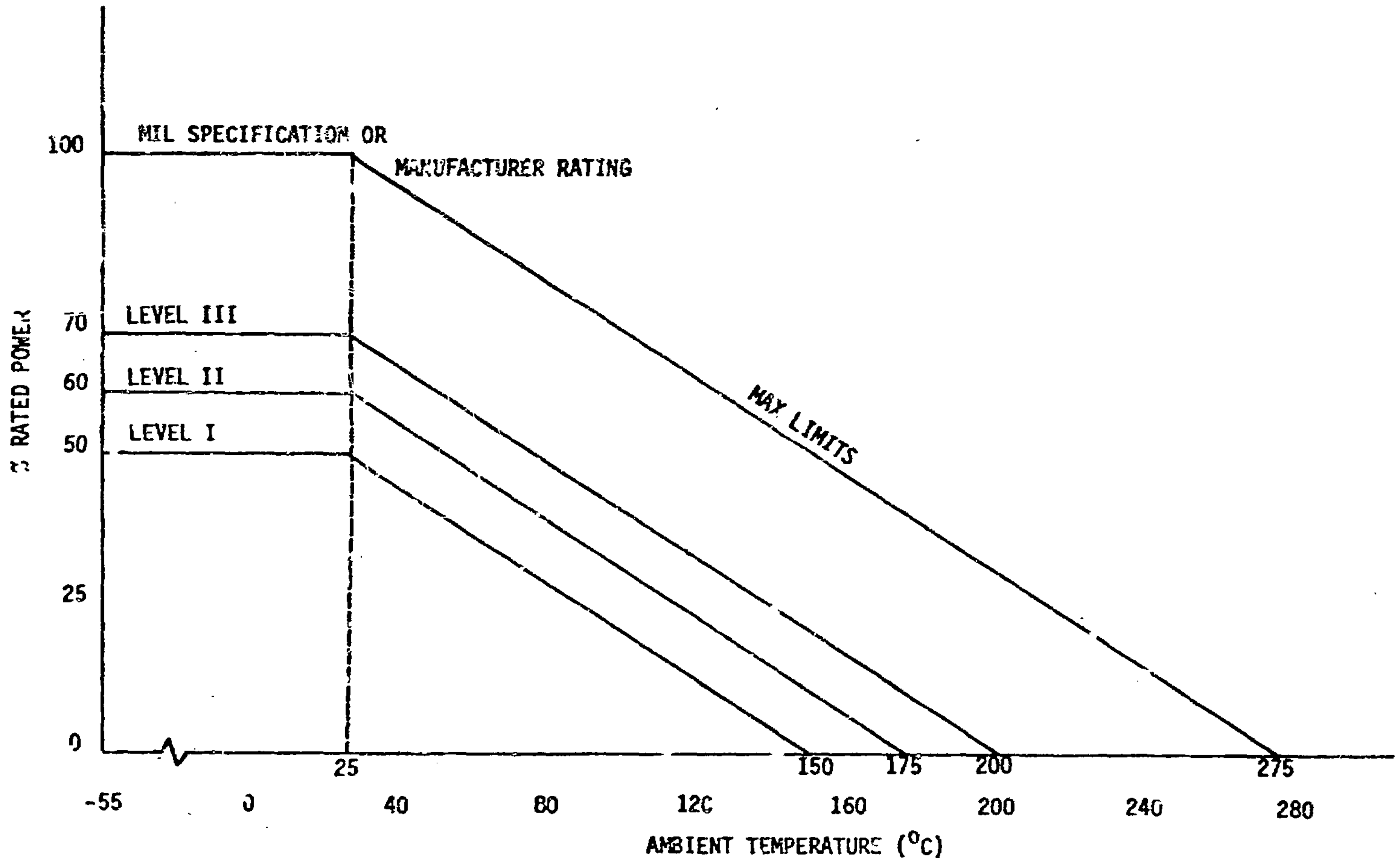
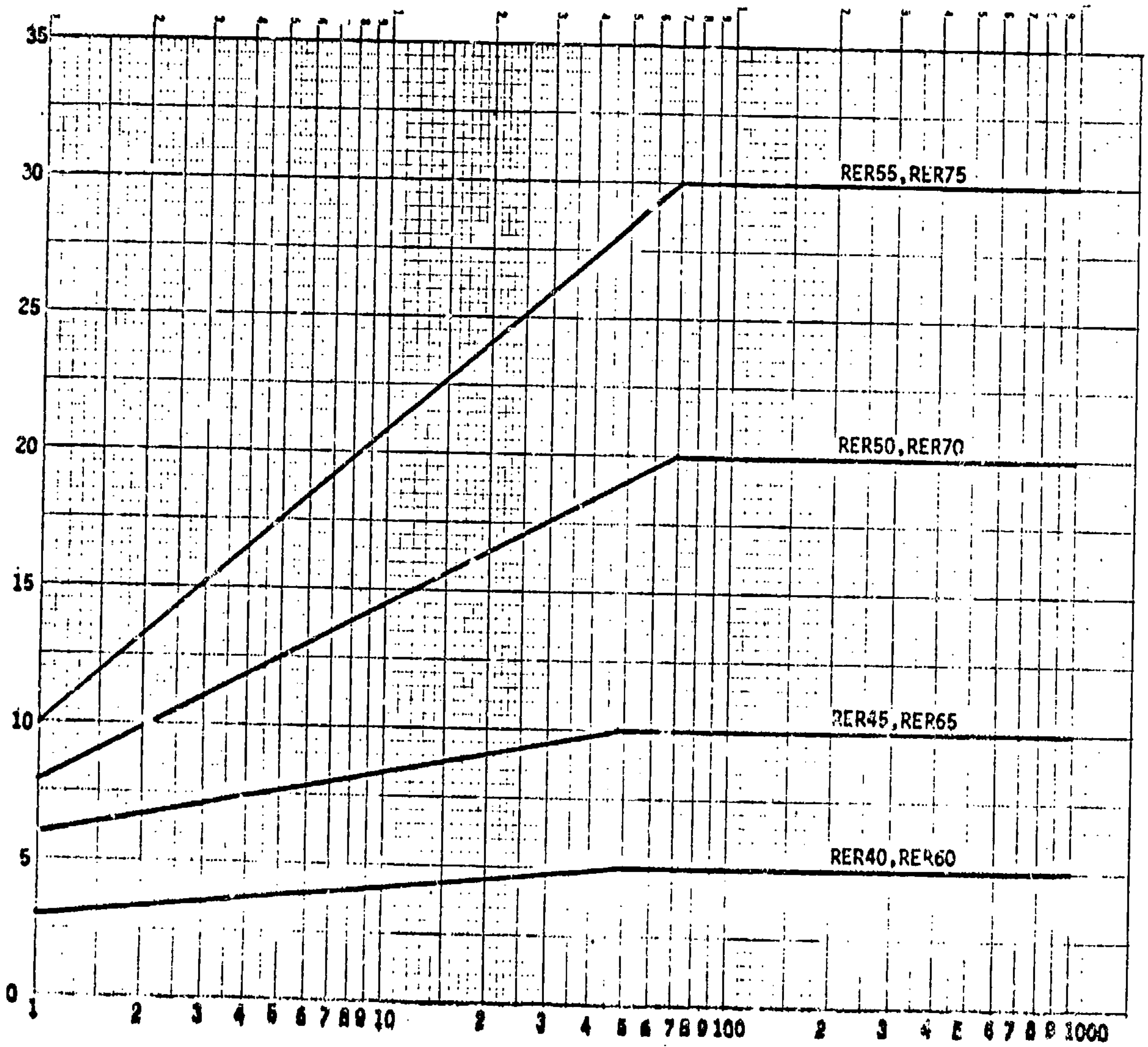


Figure 9.1-12: Derating for Resistors, Fixed, Wirewound Power and Chassis Mounted Defined by MIL-R-18546 and MIL-R-39009



NOTE: The chassis derating curves are based on the full power ratings at an ambient temperature of 25°C. These curves are independent of the temperature derating curves.

EXAMPLE: Styles RER45/RER65 have a power rating of 10 watts mounted on chassis of 48 square inches. In free air or no chassis, the styles are rated at 6 watts. If the chassis area is reduced to 10 square inches, then the wattage rating is reduced to 8.2 watts. This new value is then derated according to Figure 9.1-1[illegible]

Figure 9.1-13: Chassis-area Derating Curves

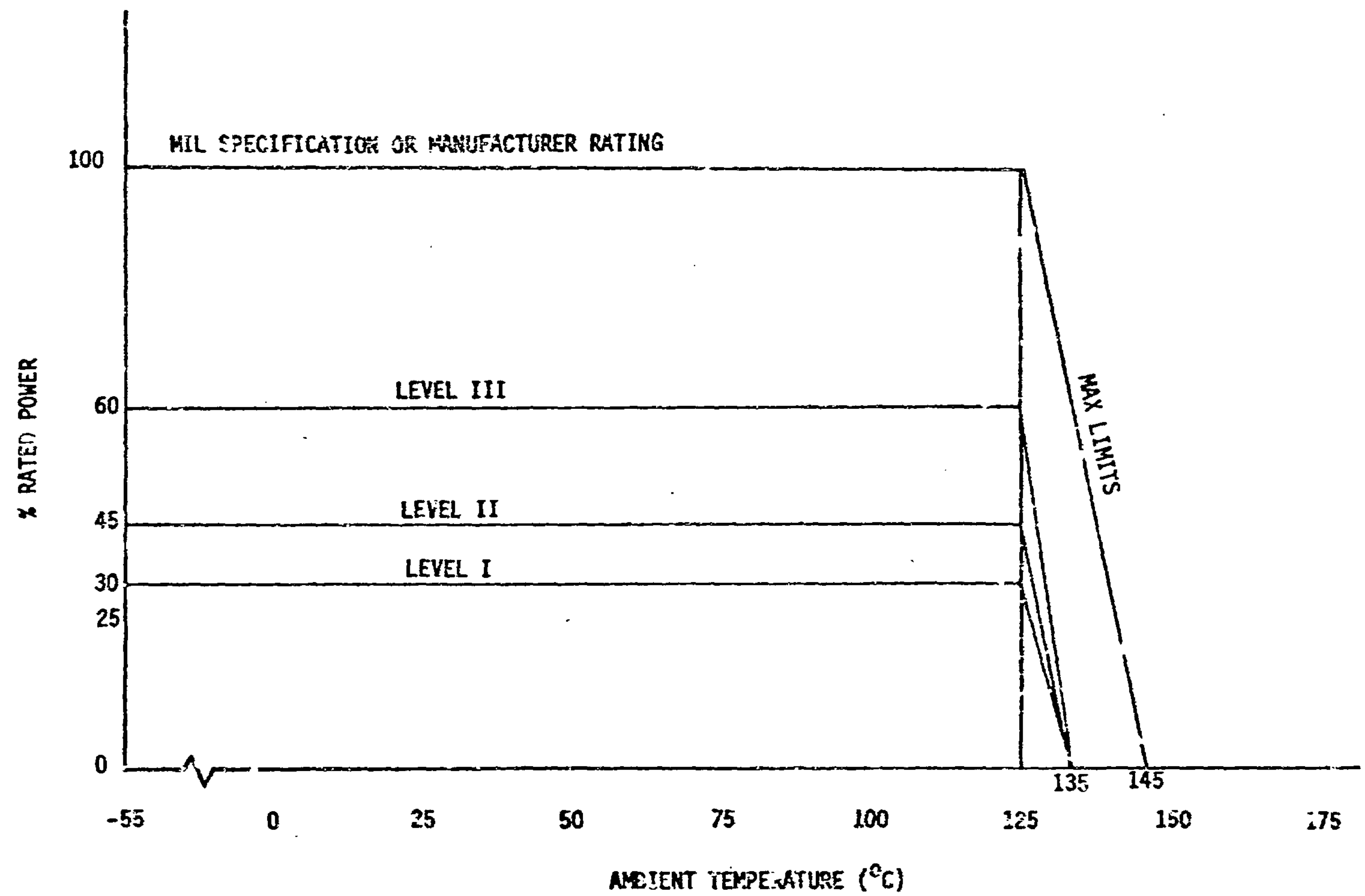


Figure 9.1-14: Derating Resistors, Fixed, Wirewound, Accurate Defined by MIL-R-39005

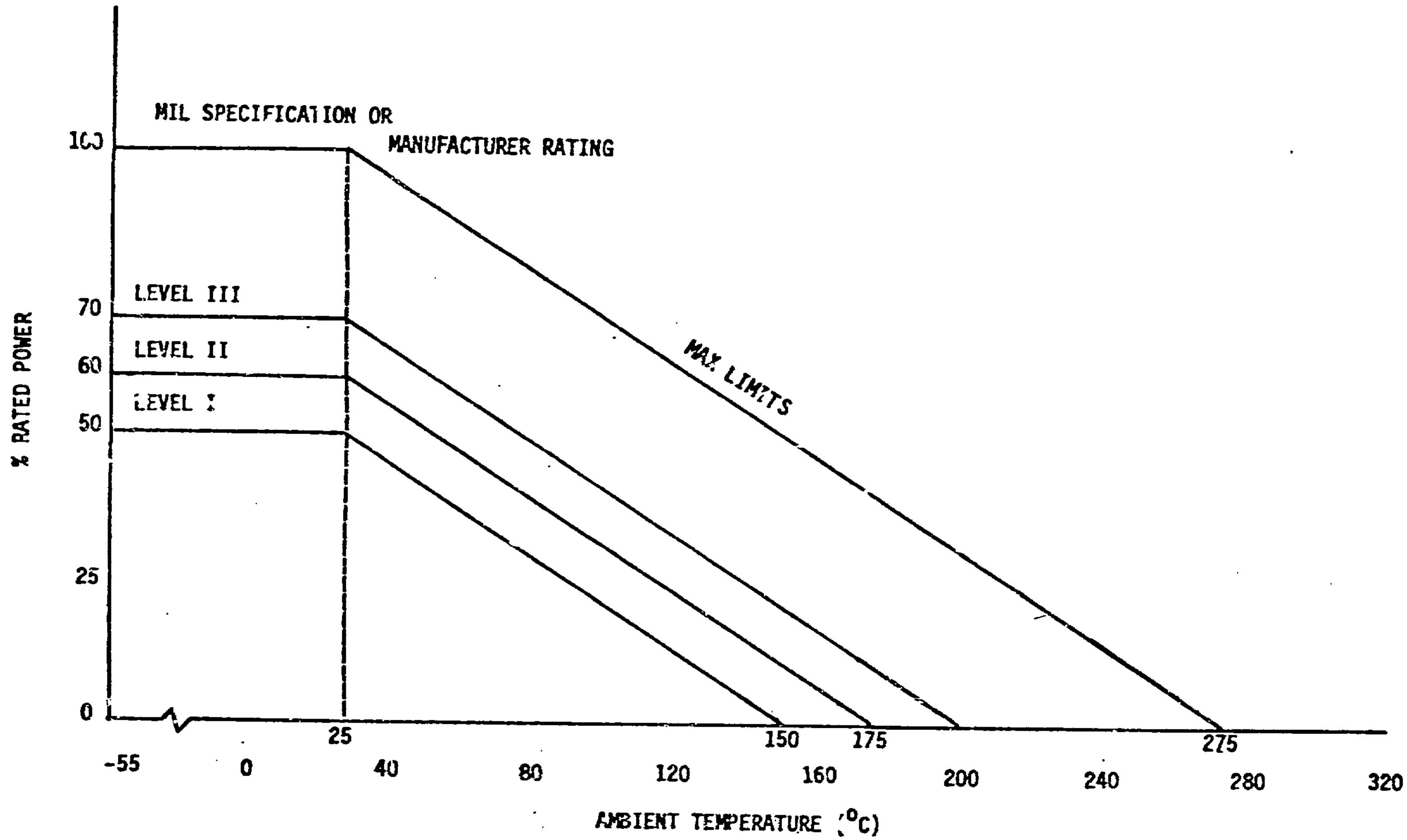


Figure 9.1-15: Derating for Resistors, Fixed, Wirewound, Power Defined by MIL-R-39007

SECTION 9.2

VARIABLE RESISTOR GENERAL DERATING CONSIDERATION

The principal stress parameter in derating variable resistors is the sum of the ambient temperature and the temperature rise from the power dissipated equaling the "hot-spot" temperature. Hence, lowering the maximum ambient temperature and derating the power reduces the "hot-spot" temperature In addition, derating power reduces the current through the contact and prevents its wearout. The total current (bleeder and element) cannot exceed that current indicated by the rated power. The wattage rating is decreased by that proportion which is removed from the circuit.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

SECTION 9.2.1

VARIABLE NON-WIREWOUND RESISTOR DERATING

9.2.1.1 General

The variable non-wirewound resistors are defined by MIL-R-94, MIL-R-22097, MIL-R-39023, and MIL-R-39035. The properties of this resistor group are determined by the resistive element being either a composition, carbon or metal film, cermet or conductive plastic. The conducting element also determines the maximum operating temperature and power ratings.

MIL-R-94 (RV) resistors have a composition resistive element shaped in an arc with a contact, controlled by a shaft, to give a linear change in resistance. The construction of the element is one of two types; a molded type which is a one-piece unit containing the resistance material, terminals, face plate, and the bushing, or a composition-film type constructed by spraying or painting a film of carbon resistance material onto the surface of a prepared form.

MIL-R-22097 (RJ) resistors have an element of metal, Cermet type or carbon film deposited upon a ceramic or glass base. Depending upon style, the element is rectangular or shaped in an arc and the sliding contact maintains continuous contact when traversing the element in a straight line or circular motion.

MIL-R-39023 (RQ) resistors have a resistance element consisting of carbon, cermet, or conductive plastic deposited on a plastic insulating bas . The moving contact is insulated from the operating shaft and maintains continuous electrical travel throughout the entire mechanical travel.

MIL-R-39035 (RJR) resistors have an element of continuous resistive material (cermet, metal film, etc.) on a rectangular or arc shaped core. depending upon the style. The sliding contact traverses the element in a circular or straight line.

All the above structures are housed in an enclosure to protect the conducting element and connections from environmental conditions.

For detailed application and design guidelines, consult MIL-STD-199.

9.2.1.2 Application Guidelines

The application guidelines are defined for each Military type part.

A. For MIL-R-94 type parts:

1. The wattage rating for these resistors are based on operation at 70 deg C, mounted on a 16 gauge steel plate, 4 inches square. This mounting technique should be taken into consideration when the wattage is applied during specific applications.

2. All properties of composition resistor may change when a soldering iron is applied directly to terminals for a long period of time. Heat sinking during solder operation should be considered.

3. These variable resistors should not be used at potentials to ground greater than 500V peak or 200V peak for aircraft equipment, unless supplementary insulation is provided.

4. The noise level is quite high for this type resistor. But, the thermal and mechanical noise level will normally decrease over the life.

B. For MIL-R-22097 and MIL-R-39035 type parts:

1. The wattage ratings of these resistors are based on operation at 85 deg C when mounted on 1/16 inch thick, glass base, epoxy laminate. The wattage rating is applicable when the entire resistance element is engaged in the circuit. When only a portion is engaged, the wattage is reduced directly in the same proportion as the resistance.

2. Where voltages higher than 250V rms are present between the resistor circuit and ground surface, a secondary insulation to withstand this condition should be provided.

3. When stacking resistors, the wattage must be reduced to compensate for the added temperature rise.

4. The resistance-temperature characteristic must be considered when operation may encounter a temperature rise due to neighboring components and/or ambient temperature rise.

C. For MIL-R-39023 type parts:

1. The wattage rating of these resistors are based on operation at 70 deg C, mounted on a 4-inch square 0.250 inch thick alloy aluminum panel. This mounting technique should be taken into consideration when the wattage is applied during specific application.

2. The resistance-temperature characteristics must be considered when operation may encounter a temperature rise due to neighboring components and/or ambient temperature rise. These characteristics are defined in MIL-R-39023.

9.2.1.3 Derating Guidelines

Ambient temperature and power are the principal derating stress parameters for variable non-wirewound resistors. The recommended derating curves for the three Levels are given for each MIL defined resistor type.

The derating curves for MIL-R-94 types are given in Figure 9.2-1.

The derating curves for MIL-R-22097 and MIL-R-39035 types are given in Figure 9.2-2.

The derating curves for MIL-R-39023 types are given in Figure 9.2-3. This derating only covers Levels II and III. This type is not recommended for use in Level I due to contact resistance variation and a failure rate higher than the fixed resistor replacements.

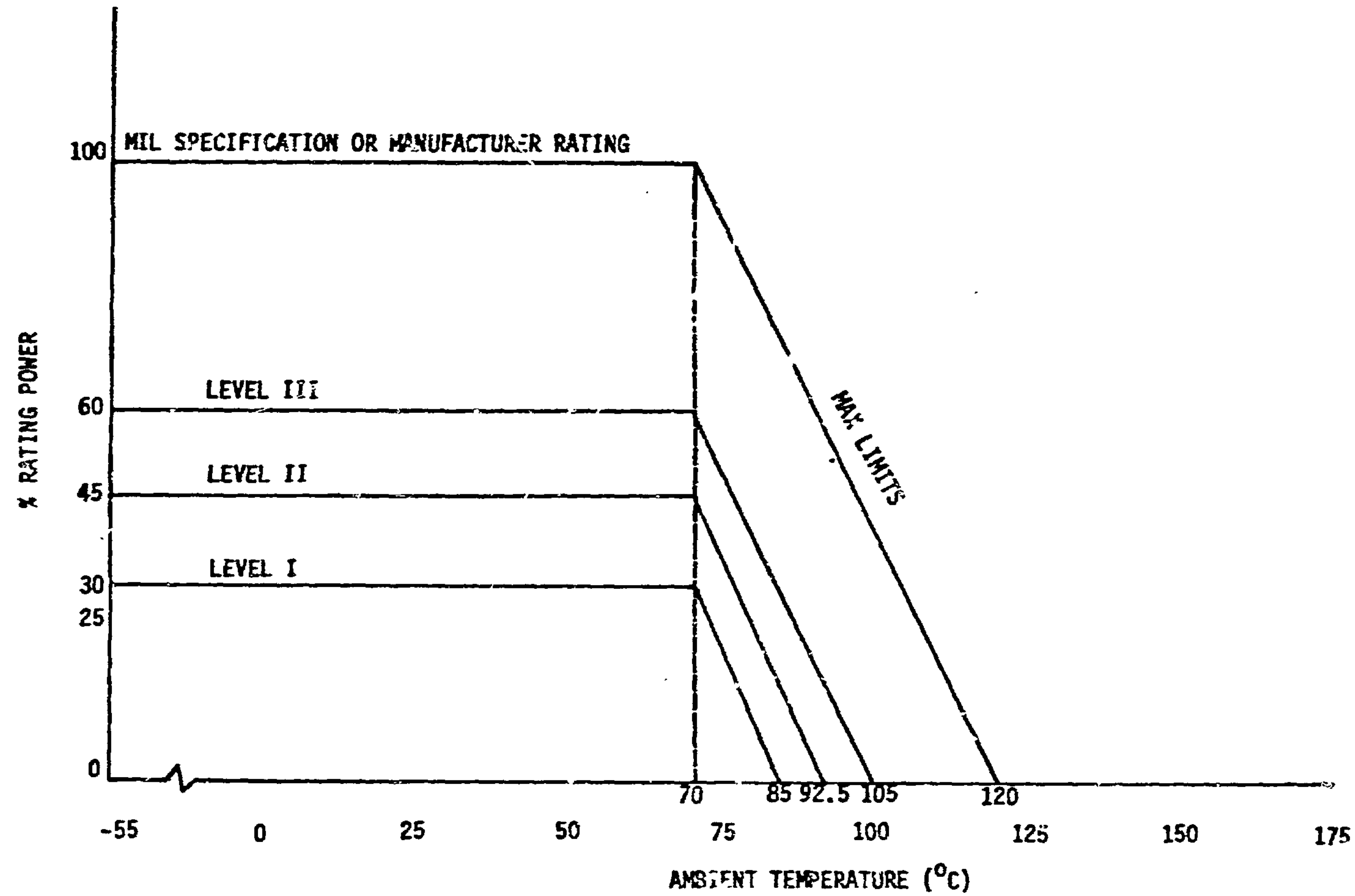


Figure 9.2-1: Derating Curves for Resistors, Variable, Composition Defined by MIL-R-94

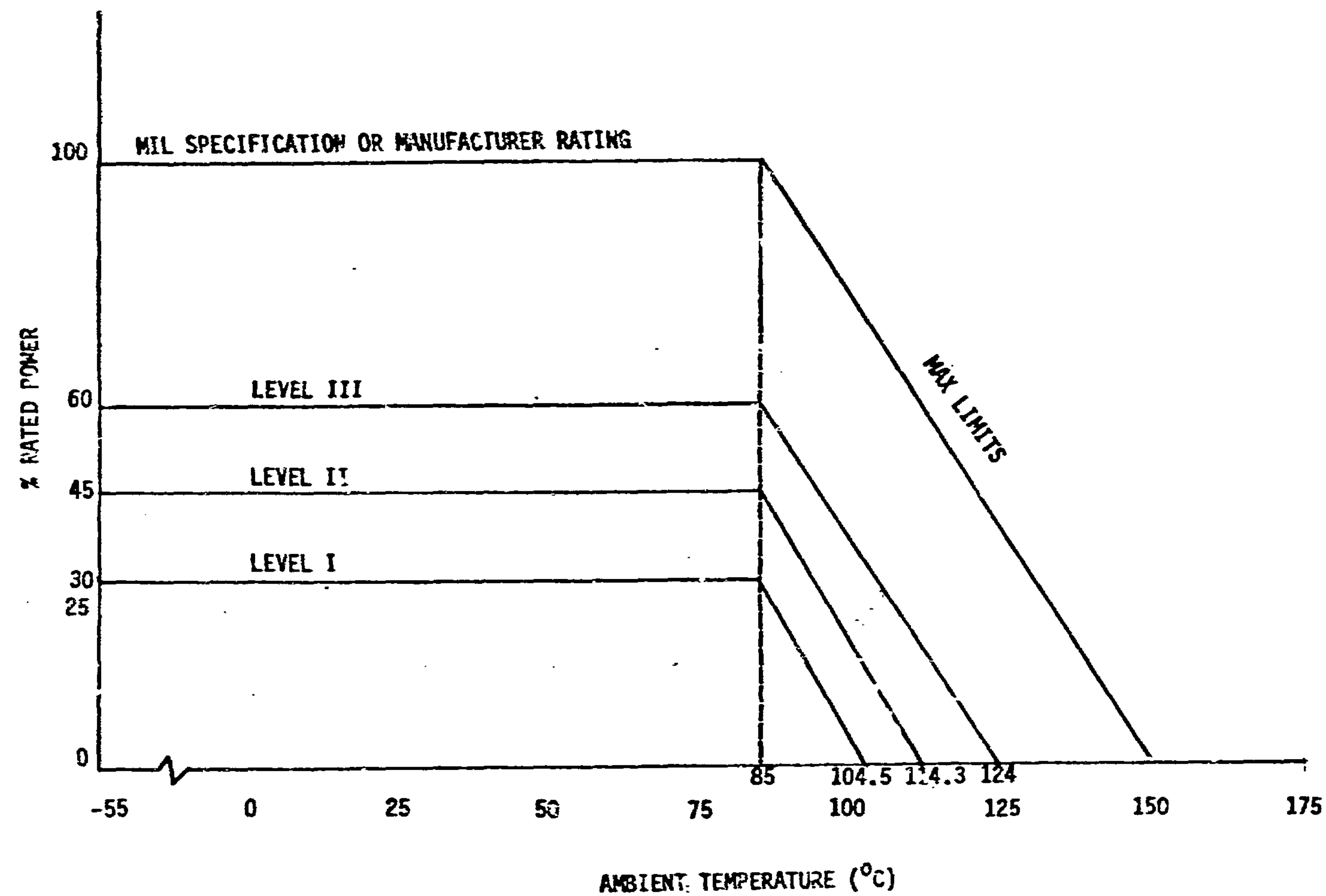


Figure 9.2-2: Resistor, Variable, Non Wirewound Defined by MIL-R-22097 and MIL-R-39035

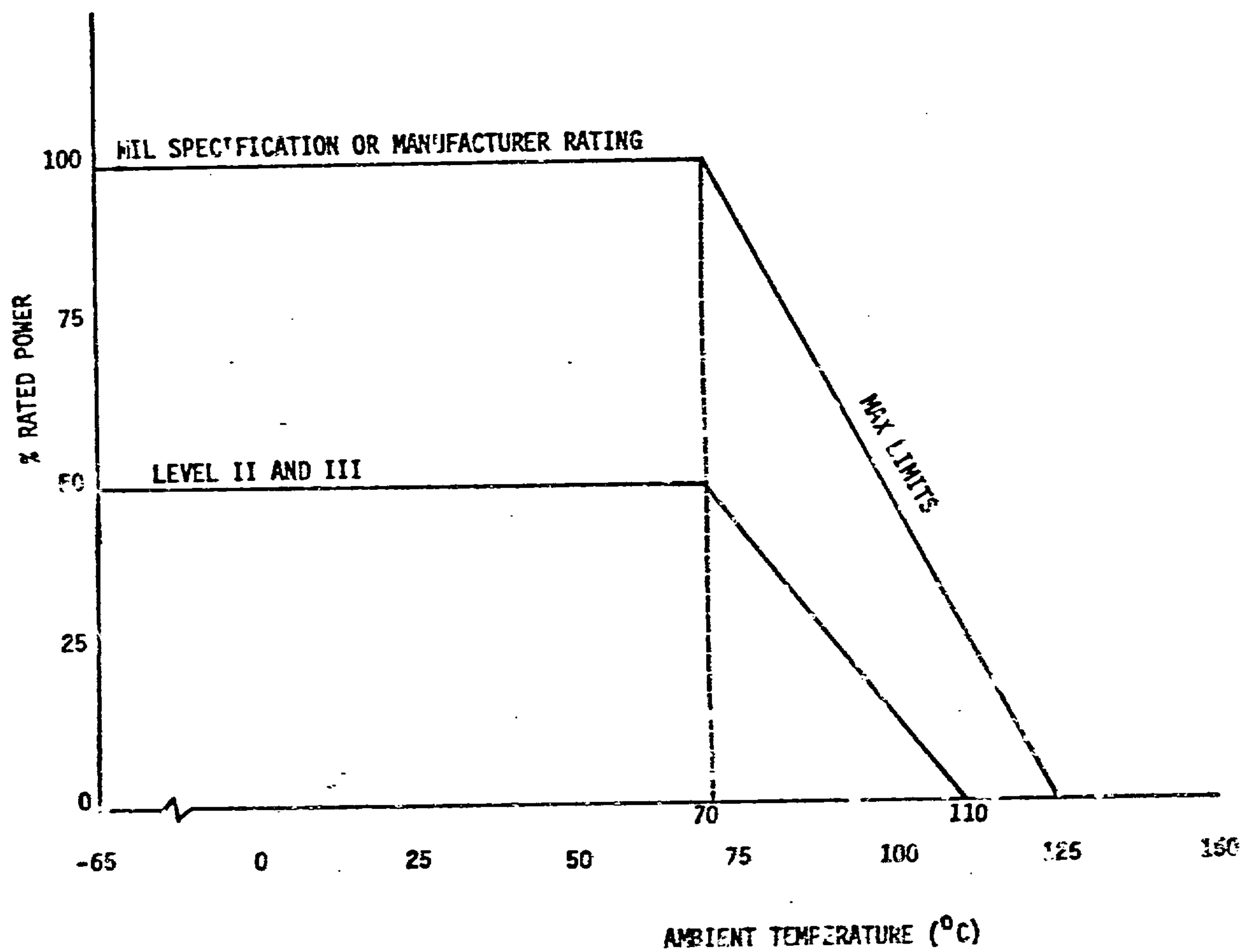


Figure 9.2-3: Derating Curves for Resistors, Variable, Non-Wirewound, Precision, Defined by MIL-R-39023

SECTION 9.2.2

VARIABLE WIREWOUND RESISTOR DERATING

9.2.2.1 General

The variable wirewound resistors are defined by MIL-R-19, MIL-R-22, MIL-R-12934, MIL-R-27208, MIL-R-39002, and MIL-R-39015. Based upon construction and power rating, these resistors are divided into two groups: MIL-R-19, MIL-R-22, and MIL-R-39002 form the larger power ratings, and MIL-R-27208, MIL-R-12934, and MIL-R-39015 comprise the lower power trimming units. All units are used basically as rheostats or voltage dividers.

MIL-R-19 (RA), MIL-R-22 (RP), and MIL-R-39002 (RK) resistors have a resistance element of continuous length wire, wound on an insulating strip or core and shaped in an arc so that a contact bears uniformly on the resistance element when adjusted by a control shaft. Various functions are available. The contact is insulated from the operating shaft and the resistor housing. The housing provides mechanical and environmental protection of the element. MIL-R-39002 is structured with more precision to provide improved linearity.

MIL-R-27208 (RT) and MIL-R-39015 (RTR) resistors have an element of continuous-length wire, wound linearly on a rectangular or arc-shaped core, depending upon the style. The sliding contact traverses the element in a circular or straight line, again dependent upon style. The element is protected from detrimental environmental conditions by a housing or enclosure. The lead screw head is insulated from the electrical portion of the resistor. MIL-R-12934 is similar except for addition of a helically wound resistance element.

For detailed application and design guidelines, consult MIL-STD-199.

9.2.2.2 Application Guidelines

The application guidelines are defined for each Military type part.

A. For MIL-R-19 type parts:

1. The wattage ratings of these resistors are based on operation of 40 deg C, mounted on 16 gauge steel plate, 4 inches square. This mounting technique should be taken into consideration when the wattage is applied during specific applications.

2. For linear types, the continuous wattage rating is directly proportional to the amount of resistance element in the circuit.

3. For taper type, the maximum permissible current for the high-resistance sections is 0.745 W/R and for the low- resistance sections is 2.24 W/R.

B. For MIL-R-22 type parts:

1. The wattage ratings of these resistors are based on operation at 25 deg C, mounted on 12-inch square steel panel, 0.063 inch thick (4-inch square X 0.50 inch for RP05 and RP06). This mounting technique should be taken into consideration when the wattage is applied during specific applications.

2. Operation of these resistors at ambient temperatures greater than 124 deg C can damage the resistor.

3. These resistors should not be used at potentials above ground greater than 500V (250V for styles RP05 and RP06) unless supplementary insulation is used.

4. When resistors are required to opporate in DC circuits having potentials in excess of 40V, care should be exercised in specifying an electrical off position.

C. For MIL-R-12934 type parts:

1. The wattage rating of these resistors are based on operation at 85 deg C, mounted on 4-inch squre, 0.250 inch thick alloy aluminum. This mounting technique should be taken into consideration when a wattage is dissipated during specific applications.

2. The resistance-temperature characteristic must be considered when operation may encounter a temperature rise due to neighboring components and/or ambient temperature rise. This characteristic is listed in MIL-R-12934.

D. For MIL-R-27208 and MIL-R-39015 type parts:

1. The wattage ratings of these resistors are based on operation at 85 deg C when mounted on a 1/16 inch thick, glass base, epoxy laminate. This wattage rating is applicable when the entire resistance element is engaged in the circuit. When resistance is reduced, the wattage rating will reduce by the same proportion.

2. When voltages higher than 250V rms is present between the resistor circuit and the grounded surface, a secondary insulation to withstand this condition should be provided.

3. Stacking resistors will cause an added rise in temperature. This rise must be considered in determining the total application temperature.

4. The resistance-temperature characteristic must be considered when operation may encounter a temperature rise due to neighboring components and/or ambient temperature rise.

5. Use of a wire size of less than 0.001 inch diameter is not recommended.

E. For MIL-R-39002 type parts:

1. The wattage rating of these resistors are based on operation at 85 deg C, mounted on a 4-inch square, 0.05-inch thick, steel panel. This mounting technique should be taken into consideration when the wattage is applied during the specific applications.

2. The resistance-temperature characteristic must be considered when operation may encounter a temperature rise due to neighboring components and/or ambient temperature rise.

3. When voltages higher than 250V rms are present between the resistor circuit and the grounded surface, a secondary insulation to withstand this condition should be provided.

4. When only a portion of the resistance element is engaged, the wattage rating must be reduced by the same proportion as the resistance.

9.2.2.3 Derating Guidelines

Ambient temperature and power are the principal derating stress parameter for variable wirewound resistors. The recommended derating curves for the three Levels are given for each MIL defined resistor types.

The derating curves for MIL-R-19 types are given in Figure 9.2-4.

The derating curves for MIL-R-22 types are given in Figure 9.2-5. Since the resistor is unenclosed, it can be effected by environmental conditions (such as moisture). Therefore, it is not recommended for Levels I & II.

The derating curve for MIL-R-12934 is given for Levels II and III in Figure 9.2-6. This type is not recommended for Level I due to contact resistance variation and a failure rate higher than the fixed resistor replacements.

The derating curves for MIL-R-27208 and MIL-R-39015 types are given in Figure 9.2-7.

The derating for MIL-R-39002 types are only given for Level II and III and are located in Figure 9.2-8. This type is not recommended for Level I due to contact resistance variation and a failure rate higher than the fixed resistor replacements.

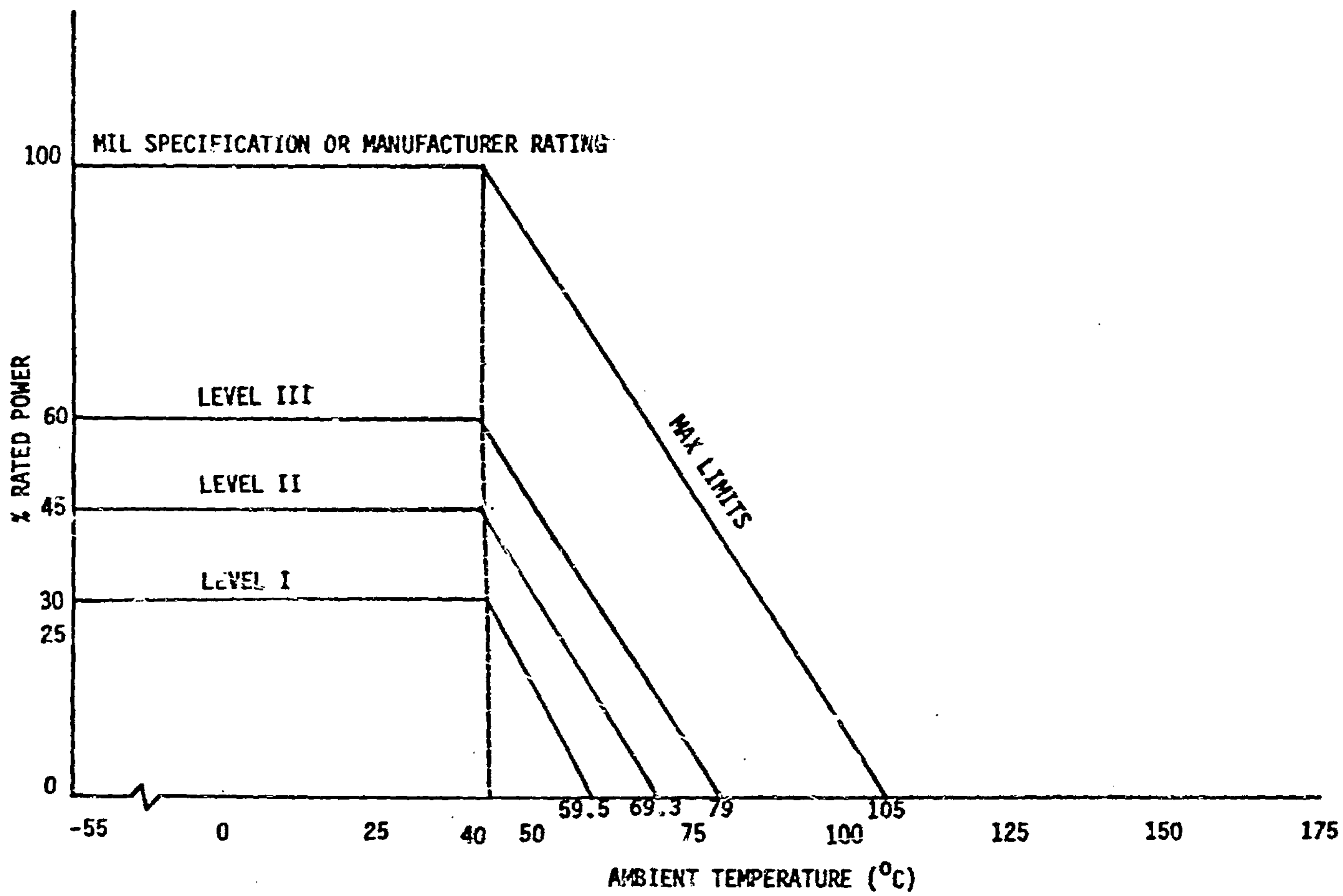


Figure 9.2-4: Derating Curves for Resistors, Variable, Wirewound (Low Temperature) Defined by MIL-R-19

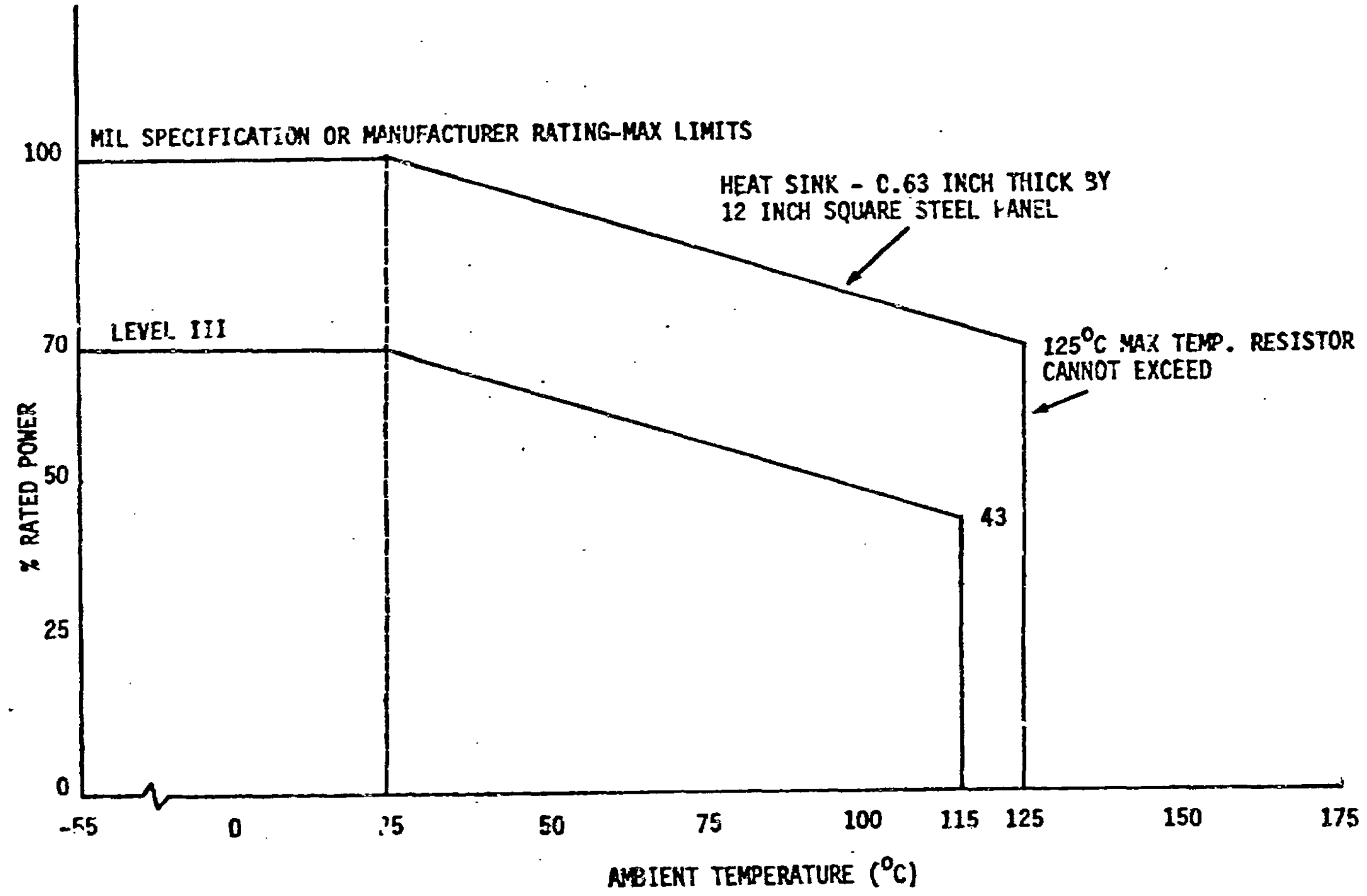


Figure 9.2-5: Derating Curves for Resistors, Variable, Wirewound Power Defined by MIL-R-22

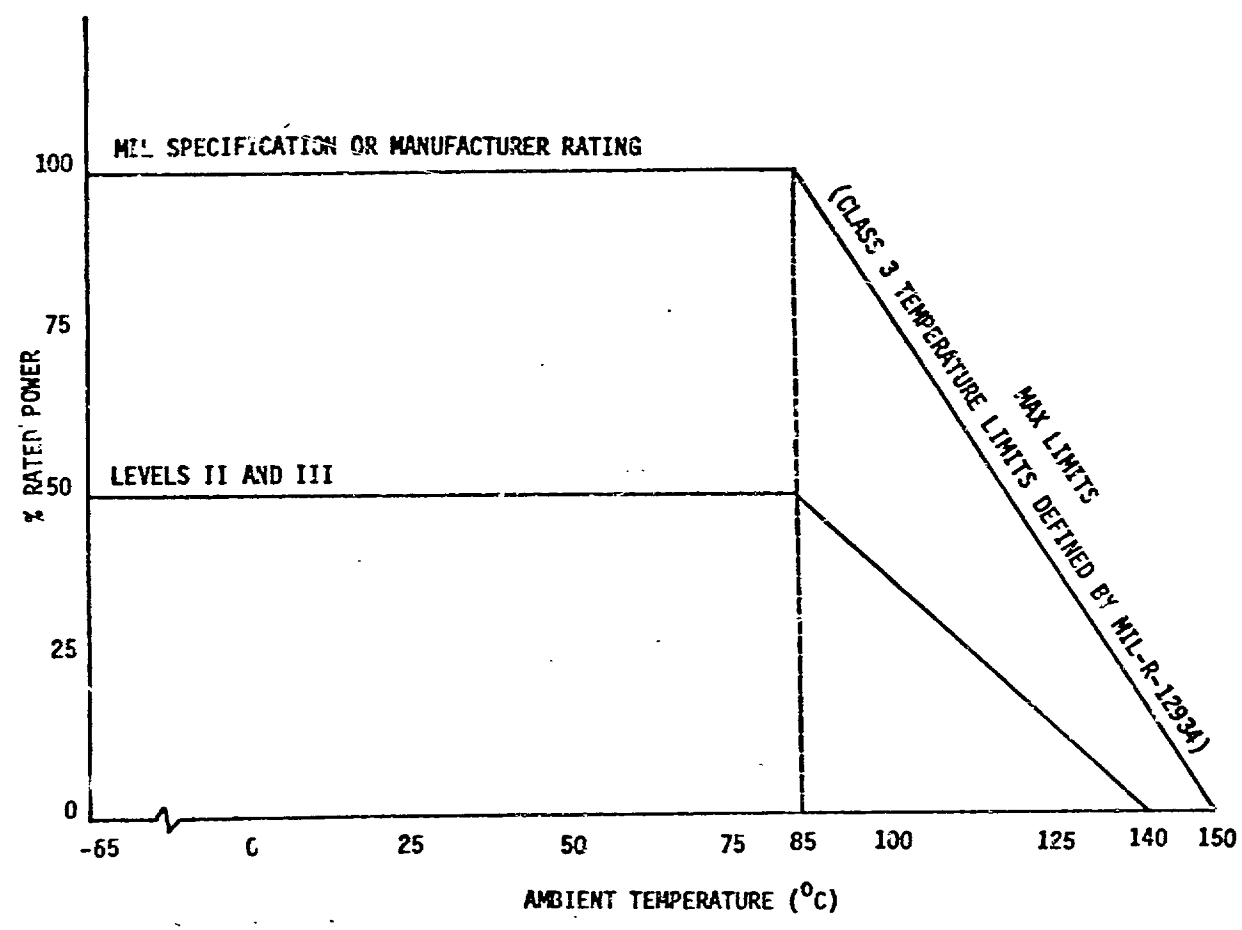


Figure 9.2-6: Derating Curves for Resistors, Variable, Wirewound, Precision Defined by MIL-R-12934

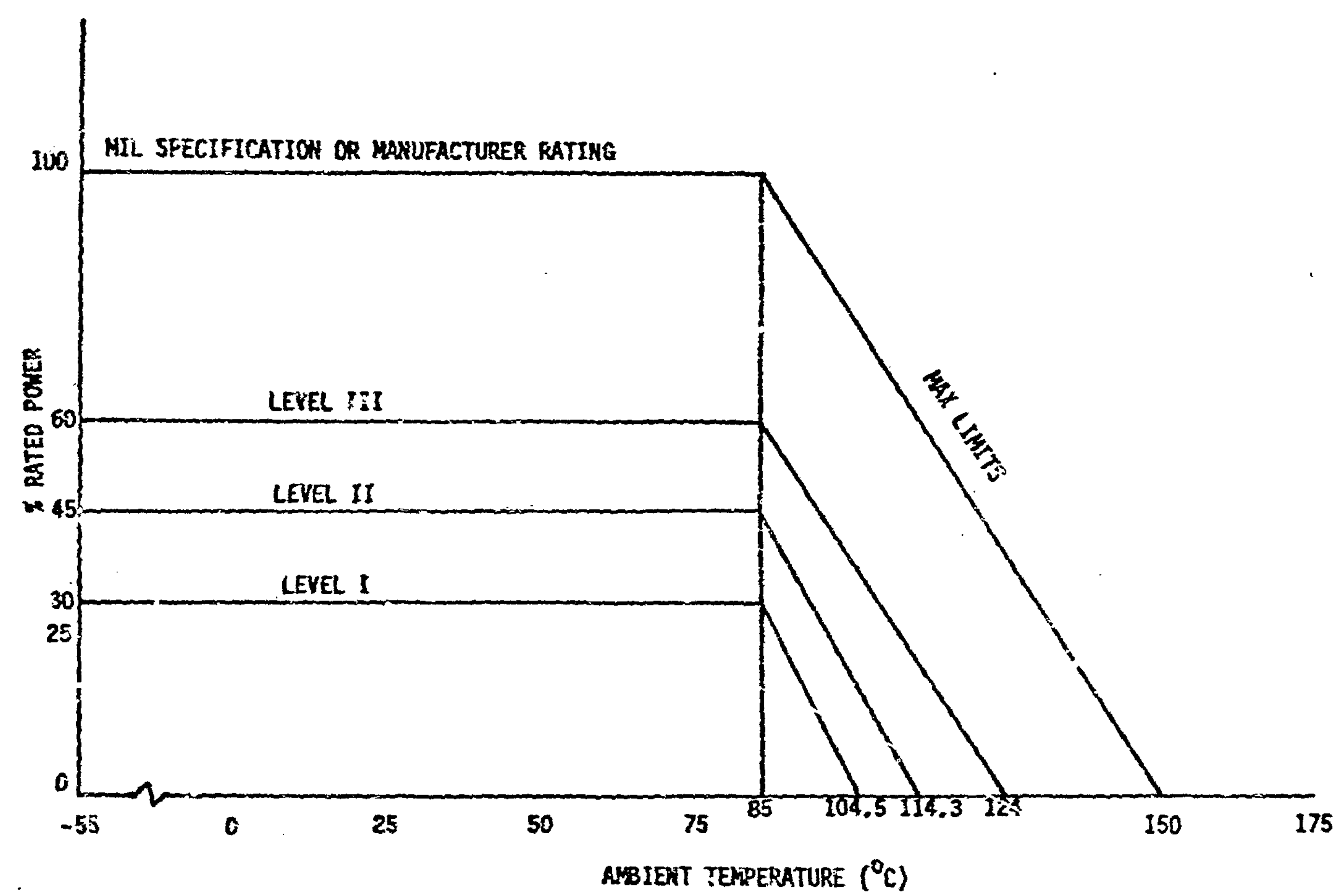


Figure 9.2-7: Derating Curves for Resistors, Variable, Wirewound Defined by MIL-R-27208, Non-ER and MIL-R-39015, ER

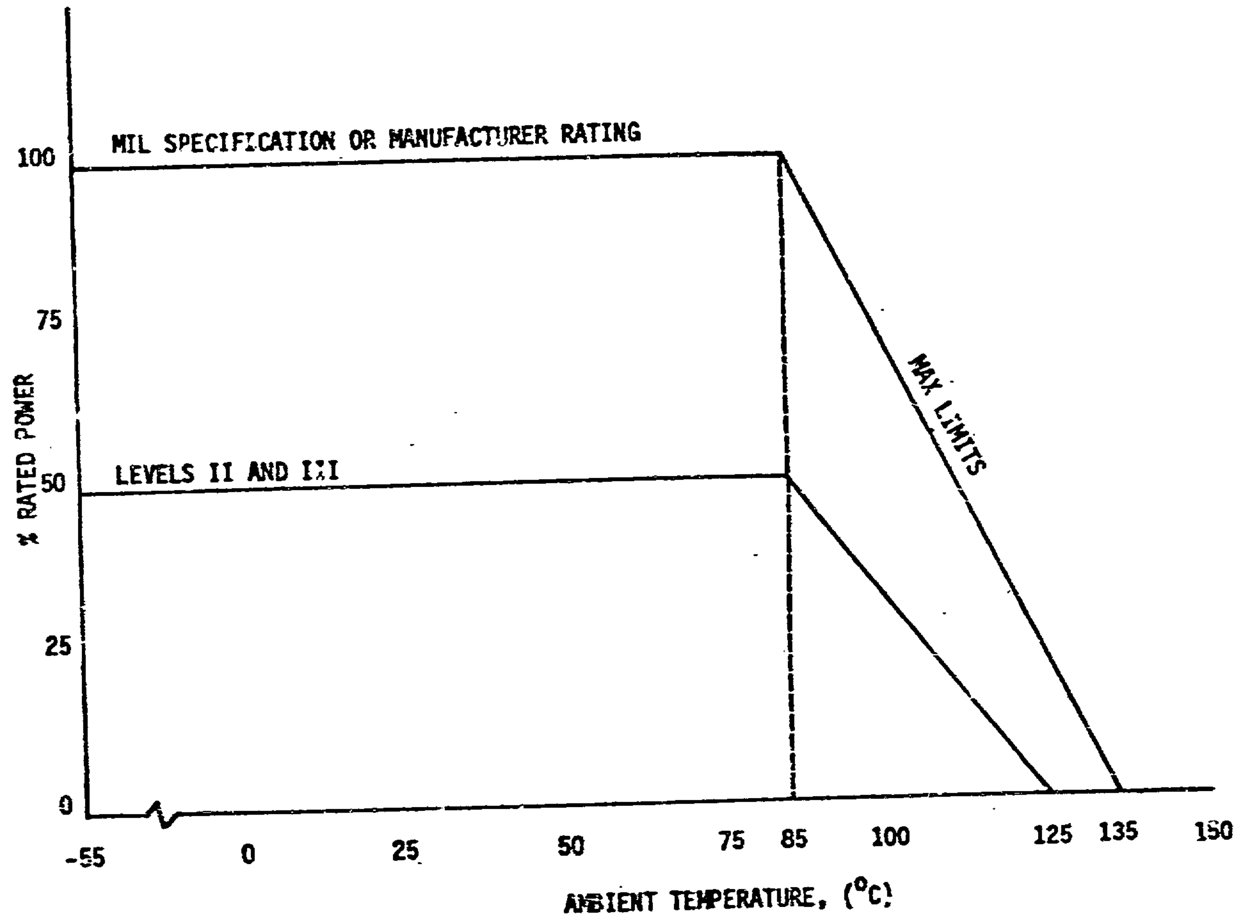


Figure 9.2-C: Derating Curves for Resistors, Variable, Wirewound, Semi-Precision Defined by MIL-R-39002

SECTION 9.3

THERMISTOR, (THERMALLY SENSITIVE RESISTOR), INSULATED DERATING

9.3.1 General

The principal stress parameter in derating thermistors, are the ambient temperature and the rated power.

The thermistor types are defined by MIL-T-23648 (RTH). The thermistor is a mixture of metal oxides fired at high temperatures to produce a sintered resistive element having an extremely high negative or positive temperature coefficients of resistance. The large temperature coefficients produce resistance ratios (values at 25 deg C compared to values at 125 deg C) of 0.5, 19.8, and 29.4.

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistent with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

9.3.2 Application Guidelines

A. Operation of thermistor above the maximum "hot spot" temperature will produce permanent resistance changes. In extreme cases, this can cause thermal runaway.

B. Use a current limiting resistor to prevent the negative coefficient type from going into thermal runaway.

C. Never exceed the maximum current or power rating, even for short time periods.

D. Never move a thermistor (self-heat mode) into a lower thermal conducting medium or environment without careful analysis in order to prevent thermal runaway conditions.

E. Accurate thermistors (+/- 1%) should not be operated beyond the specified test points given by the Mil-spec or manufacturer's listings.

9.3.3 Derating Guidelines

The principal derating stress parameters for thermistor, are the ambient temperature and the rated power. The recommended derating for the ambient temperature is 15 deg C below the maximum limits and the power is to be 50% of the rated (see Figure 9.3-1). These deratings will apply for all three Levels.

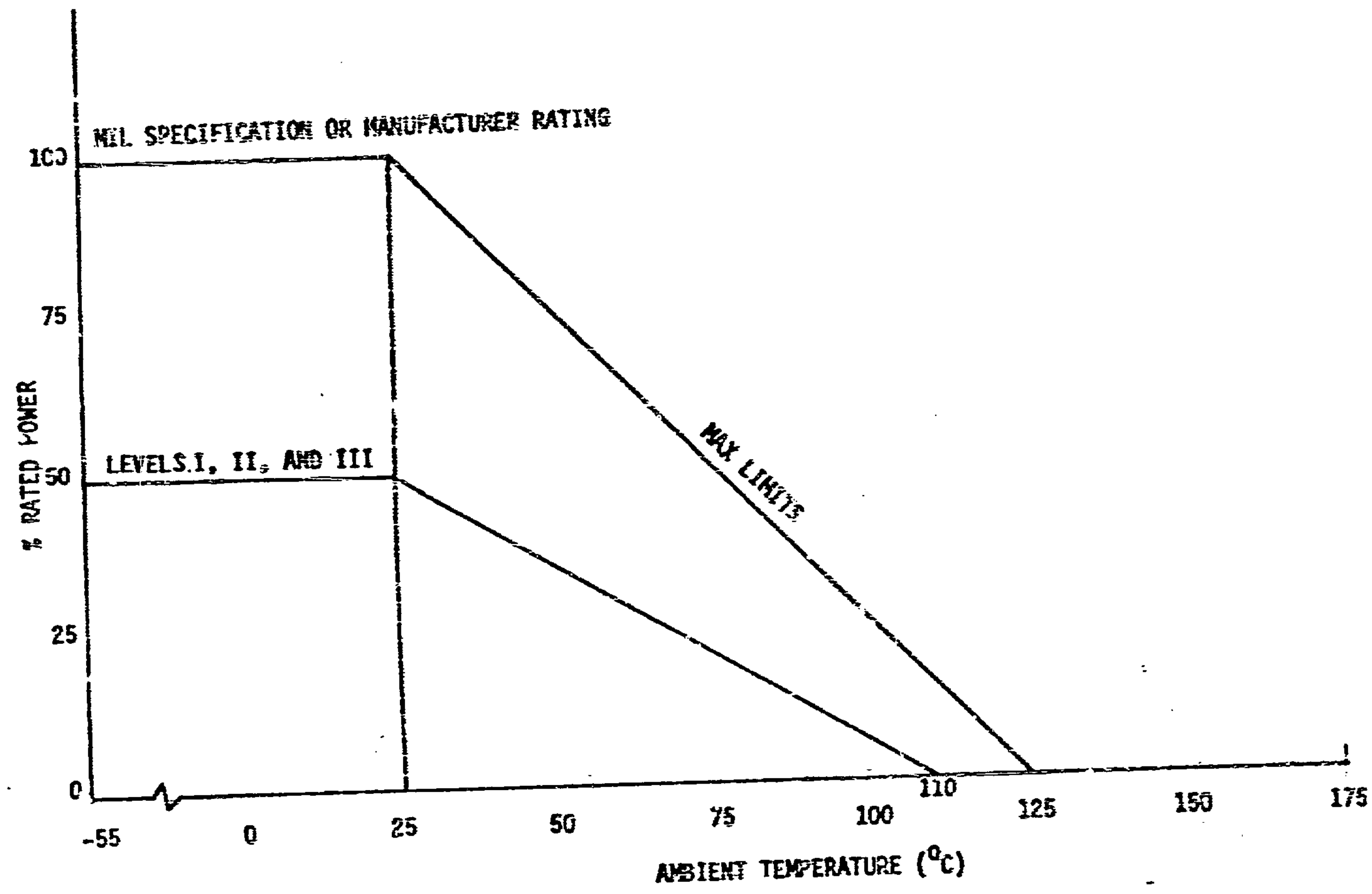


Figure 9.3-1: Derating Curves for Thermistor, Thermally Sensitive Resistor, Defined by MIL-T-23648

SECTION 10

CAPACITOR DERATING GUIDELINES

10.1 Introduction

This section covers the derating and application guidelines for fixed and variable capacitors. The capacitor types, selected are from MIL-HDBK-217C with the elimination of those types inactive for new design or where no suppliers are defined for the following Military specifications:

TYPE	SUBSECTION
PAPER/PLASTIC FILM	10.2
MIL-C-11693	Capacitors, Fixed, Paper, Metallized Paper, Metallized Plastic, RFI Feed-Thru, Established Reliability and Non-Established Reliability (Style CZR and CZ)
MIL-C-19978	Capacitors, Fixed, Plastic (or Paper-Plastic,) Established and Non-Established Reliability, (Style CQR and CQ)
MIL-C-39022	Capacitors, Fixed, Metallized, Paper-Plastic Film or Plastic Film Dielectric, Established Reliability, (Style CHR)
MIL-C-55514	Capacitors, Plastic, Metallized Plastic, Established Reliability, (Style CFR)
MIL-C-83421	Capacitors, Super-Metallized Plastic, Established Reliability, (Style CRH)
MICA	10.3
MIL-C-10950	Capacitors, Fixed, Mica, Button Style, (Style CB)
MIL-C-39001	Capacitors, Fixed, Mica, Established Reliability, (Style CMR)
GLASS	10.4
MIL-C-23269	Capacitors, Fixed, Glass, Established Reliability, (Style CYR)
CERAMIC	10.5
MIL-C-20	Capacitors, Fixed, Ceramic (Temperature Compensating), (Style CCR)
MIL-C-11015	Capacitors, Fixed, Ceramic (General Purpose), (Style CK)

TYPE		SUBSECTION
	MIL-C-39014	Capacitors, Fixed, Ceramic (General Purpose), Established Reliability, (Style CKR)
ELECTROLYTIC		10.6, 10.7, 10.8, And 10.9
	MIL-C-62	Capacitors, Fixed, Electrolytic (DC, Aluminum, Dry Electrolyte, Polarized), (Style CE)
	MIL-C-39003	Capacitors, Fixed, Electrolytic, Tantalum, Solid Electrolyte, Established Reliability, (Style CSR)
	MIL-C-39006	Capacitors, Fixed Electrolytic, Tantalum, Non-solid Electrolyte, Established Reliability, (Style CLR)
	MIL-C-39018	Capacitors, Fixed, Electrolytic, Aluminum Oxide, (Style CU)
VARIABLE CAPACITORS		10.10 And 10.11
	MIL-C-81	Capacitors, Variable, Ceramic, (Style CV)
	MIL-C-14409	Capacitors, Variable, Piston Type, Tubular Trimmer, (Style PC)

Wherever two or more specifications could be shown by one set of derating graphs, the specifications are listed together, such as MIL-C-10950 and MIL-C-39001 (see Figure 10.3-1).

Derating is that reduction of stress factors necessary to signifcantly extend the operational life. For capacitors, the factors are current, DC and/or AC voltage, and temperature (including the capacitor's case temperature rise from AC loading). There are two fundamental relations governing the derating of capacitors. The first relates voltage as follows:

Voltage DC Derated = Voltage DC (applied) + Peak AC voltage (applied).

The second relation is the total temperature of the capacitor being the sum of the ambient temperature and the rise in case temperature from the AC load. Methods of determining case temperature rise are outlined in MIL-STD-198.

Heat is generated in a capacitor by two mechanisms: (1) loss produced by leakage current through the dielectric and (2) loss due to the equivalent series resistance (ESR). ESR represents a combination of the effects of electrode resistance, electrolyte resistance, lead resistance, electrode eddy currents, and dielectric hysteresis.

That portion of heat generated by leakage current may usually be neglected since the temperature rise resulting therefrom seldom exceeds two or three degrees. ESR, however, contributes substantially to heating when an AC component is present, and this temperature rise consitutes an important limitation in capacitor application.

The maximum allowable AC component is that value which results in a case temperature rise above ambient such that the maximum temperature rating of the part is not exceeded.

Temperature capability is specification controlled at both high and low limits. The high-temperature limit may be exeeded only at the risk of degradation or thermal runaway. When energized after a period of storage or deactivation at temperature near the low limit, the nonsolid electrolyte types (MIL-C-39006) will exhibit a sizeable loss of capacitance until they warm up. If there is a substantial AC component, heating from the increased losses at low temperature will quickly restore the lost capacitance when the circuit is energized.

Dissipation factor (DF) is specified in capacitor specifications because it is more readily measureable than power factor, which is the characteristic of more interest to the designer. Frequency and capacitance are, of course, components of DF.

DC losses are specified in terms of leakage current (IL) for electrolytic capacitors and insulation resistance for non-electrolytic types. All capacitors have positive IL - temperature characteristics. Polarity has a negligible effect on IL of non-electrolytic and nonpolar electrolytic capacitors while polar electrolytics exhibit diode characteristics with respect to forward and reverse IL.

There is little evidence that age has any serious effect on leakage current although specifications allow 25% increase for nonsolid electrolytics, 50% for solid tantalum and 85% for ceramics at 10,000 hours life. Leakage current vs voltage is approximately linear belc. breakdown levels for all types.

Stray capacitance and resistance to case are negligible except for very low values of capacitance in metal cases, and except for foil electrolytics with floating cases (MIL-C-39003) which have an indeterminate resistance from cathode to case. Nonpolar types have an indeterminate resistance from both terminals to case.

Ripple and pulse currents affect temperature rise and consequently influence failure rate. Criteria for pulse current limits is not available in the specification or literature; the manufacturer's recommendations should be requested in the case of application requirements in excess of limits listed in the individual specifications.

The effects of voltage, temperature and ripple current are predictable but little information is available on the effect of voltage transients on failure rate.

Failure modes of capacitors may include shorts, opens, grounds to case, low capacitance, high capacitance, high dissipation factor, noisiness, leakage of electrolyte, and mechanical failure.

Noise in capacitors may be caused by scintillation, clearing, defects in bonds, and movement of electrodes caused by electrostatic force (audible noise).

The selected derating levels in this section are based upon analysis of a large historical body of user data and upon well understood relationships of stress and reliability. Generally the specified derating should be achievable with design constraints consistant with the enhanced reliability. Waivers to the specified derating should be considered on an item by item basis rather than broad changes to whole part categories.

SECTION 10.2

FIXED (PAPER/PLASTIC) FILM CAPACITOR DERATING GUIDELINES

10.2.1 General

The fixed paper-plastic film capacitors are defined by MIL-C-11693, MIL-C- 19978, MIL-C-39022, MIL-C-55514, and MIL-C-83421. This group of capacitors has high insulation resistance, low dielectric absorption or low loss factor over wide temperature ranges with the AC component of impressed voltage ranging from small to more than 50 percent of the DC voltage rating.

MIL-C-11693 (CZ and CZR) is a paper and metallized paper dielectric, radio inference reduction feed-through capacitor. This type of construction is essentially a three-terminal network in which the case constitutes a common or group terminal. This construction, which is analogous to a coaxial cable, requires a center conductor to carry rated line current, and a capacitor section disposed concentrically around the center conductor so that the path of RF currents flowing between the center conductor and the case is symmetrical.

Certain defects in feed-through-capacitor construction may cause the insertion-loss-characteristic to depart from the ideal. For example, resistance in the foils, or in the solder connections at the edges of the foils, may slow the rate of insertion-loss rise below that for the ideal capacitor and level out the curve in the high-frequency region. A downward slope in the insertion-loss curve at high frequency, beyond 100 megahertz (MHz), is usually indicative of incomplete or asymmetrical foil-to-ground connections.

Since a feed-through capacitor must carry all of the line current through its center conductor, it is rated not only in terms of the capacitance and the voltage it has to withstand, but also in terms of the current it can safely carry to the load.

MIL-C-19978 (CQ and CQR) defines an established reliability, plastic (or paper- plastic) dielectric, fixed capacitors, hermetically sealed in metal cases. These capacitors have high insulation resistance, low dielectric absorption, or low loss factor over wide temperature ranges with the AC component of the impressed voltage being small with respect to the DC voltage rating. These capacitors have foil electrodes with the thin paper plastic dielectric wound into cylindrical form. The foil extends beyond the body to reduce inductance and provide terminations. Sprayed metal is used to bond the foil to soldered leads. The unit is sealed hermetically in metal cases.

The major dielectrics are as follows:

Polyethylene terephthalate (characteristic M capacitors): Characteristic M capacitors are intended for high-temperature applications similar to those served by hermetically-sealed paper capacitors, but where high insulation resistance at the upper temperature limits is required.

Paper and polyethylene terephthalate (characteristic K capacitors): Characteristic K capacitors are intended for applications where high insulation resistance is necessary.

Polycarbonate (characteristic Q capacitors): Characteristic Q capacitors are intended for applications where minimum capacitance changes with temperature are required; these capacitors are especially suitable for use in tuned and precision timing circuits.

MIL-C-39022 (CHR) defines an established reliability, metallized dielectric (paper-plastic or plastic) fixed capacitors, hermetically sealed in-metal cases. The electrodes of metallized dielectric capacitors are formed by vapor deposition of aluminum or zinc on paper or plastic film, masked to provide insulation at one edge and exposed metal at the other. Pairs of metallized films (or papers) are wound into a roll which is connected to leads by metal spraying the ends and soldering. The rolls are enclosed in cylindrical metal cases and the leads are brought out to opposite ends through glass seals.

Metallized construction offers two advantages over foil construction for low voltage ratings. The vapor deposited metal is only 1 X 10E-6 inch thick compared to 250 x 10E-6 inch for foil, yielding considerable improvement in volume efficiency. The thinner electrode also makes it feasible to eliminate failure sites by using "clearing" techniques during fabrication. However, the thinner electrodes impose a limitation on current-carrying capacity and cause a slightly higher dissipation factor than that obtained with foil construction.

MIL-C-55514 (CFR) is the same type of capacitor as the MIL-C-39022 except the capacitor has a nonmetal case. The structure is similar with the metallized plastic dielectric. If used in moisture environments, the units should be encapsulated.

The major dielectrics are:

Polyethylene terephthalate: These capacitors are intended for high-temperature applications similar to those served by hermetically-sealed paper capacitors, but where high insulation resistance at the upper temperature limits is required.

Polycarbonate: These capacitors are intended for applications where minimum capacitance changes with temperature are required; they are especially suitable for use in tuned and preci on timing circuits.

These capacitors are designed for use in circuit applications requiring high insulation resistance, low dielectric absorption, or low loss factor over wide temperature ranges, and where the AC component of the impressed voltage is small with respect to the DC voltage rating.

MIL-C-83421 (CRH) is an established reliability, supermetallized plastic film dielectric, fixed capacitor having DC and AC ratings, hermetically sealed in metal cases. They are similar in construction to MIL-C-39022. An impregnant is used to reduce momentary breakdowns and a DC burn-in is conducted to remove defects requiring "clearing". These capacitors have high insulation resistance, controlled low dielectric absorption with a high stability temperature characteristic and low losses. Maximum DC rated voltages vary from 30 to 400 volts.

10.7.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-11693 type parts:

1. The derating curves are shown in Figure 10.2-1. Both temperature and voltage are ated for the three Levels. Line current is derated 80 percent of the rated value.

2. The ideal location for the feed-through capacitor in any suppression system is at the point of exit of the wiring from a chassis or housing surrounding the source of interference.

3. Selection of the optimum feed-through capacitance for any given application usually necessitates a compromise between capacitance sufficiently large to provide good insertion loss at the lowest RF to be suppressed, and capacitance not so large as to cause appreciable loading at 60 Hertz or other power frequencies. Generally, for the most practical suppression purposes, the range of capacitance values is from 0.01 to 2.0 microfarads (uF) inclusive.

4 Additional application data is found in MIL-STD-198.

B. For MIL-C-19978 type parts:

1. The derating curves for these capacitors are shown in Figure 10.2-2. Both temperature and voltage are derated for the three Levels.

2. These capacitors may be used where an AC component is present provided that (1) the sum of the DC voltage and the peak AC voltage does not exceed the DC voltage rating or (2) the peak AC voltage does not exceed 20 percent of the DC voltage rating at 60 Hz, 15 percent at 120 Hz; or 1 percent at 10,000 Hz. Where heavy transient or pulse currents are encountered, the requirements of MIL-C-19978 are not sufficient to guarantee satisfactory performance, and due allowance must therefore be made in the selection of a capacitor.

3. For addditional data, refer to MIL-STD-198.

C. For MIL-C-39022 type parts:

1. The derating curves for this capacitor are shown in Figure 10.2-3. Both temperature and voltage are derated for units with maximum temperatures of 85 and 125 deg C for the three Levels.

2. These capacitors may be used where an AC component is present provided that (1) the sum of the DC voltage and the peak AC voltage does not exceed the DC voltage rating, and (2) the AC voltage does not exceed 20 percent of the DC voltage rating.

3. For additional application data, see MIL-STD-198.

D. For MIL-C-55514 type parts:

1. The derating curves are shown in Figure 10.2-4. Both temperature and voltage are derated for the three Levels except that the capacitor is not used for space application where degassing is not permitted.

2. These capacitors may be used where an AC component is present provided that (1) the sum of the DC voltage and the peak AC voltage does not exceed the DC voltage rating or (2) the peak AC voltage does not exceed 20 percent of the DC voltage rating at 60 Hz; 15 percent at 120 Hz; or 1 percent at 10,000 Hz. Where heavy transient or pulse currents are encountered, the reqirements of MIL-C-55514 are not sufficient to guarantee satisfactory performance, and due allowance must therefore be made in the selection of a capacitor.

3. For additional application data, see MIL-STD-198.

E. For MIL-C-83421 type parts:

1. The derating curves for this capacitor are given in Figure 10.2-5. Both temperature and voltage are derated for the three Levels.

2. The AC ratings of voltage and urrent controlled by MIL-C- 83421, cannot be exeeded.

3. For additonal application data refer to MIL-C-39022 in MIL-STD-198 since this standard does not include MIL-C-83421.

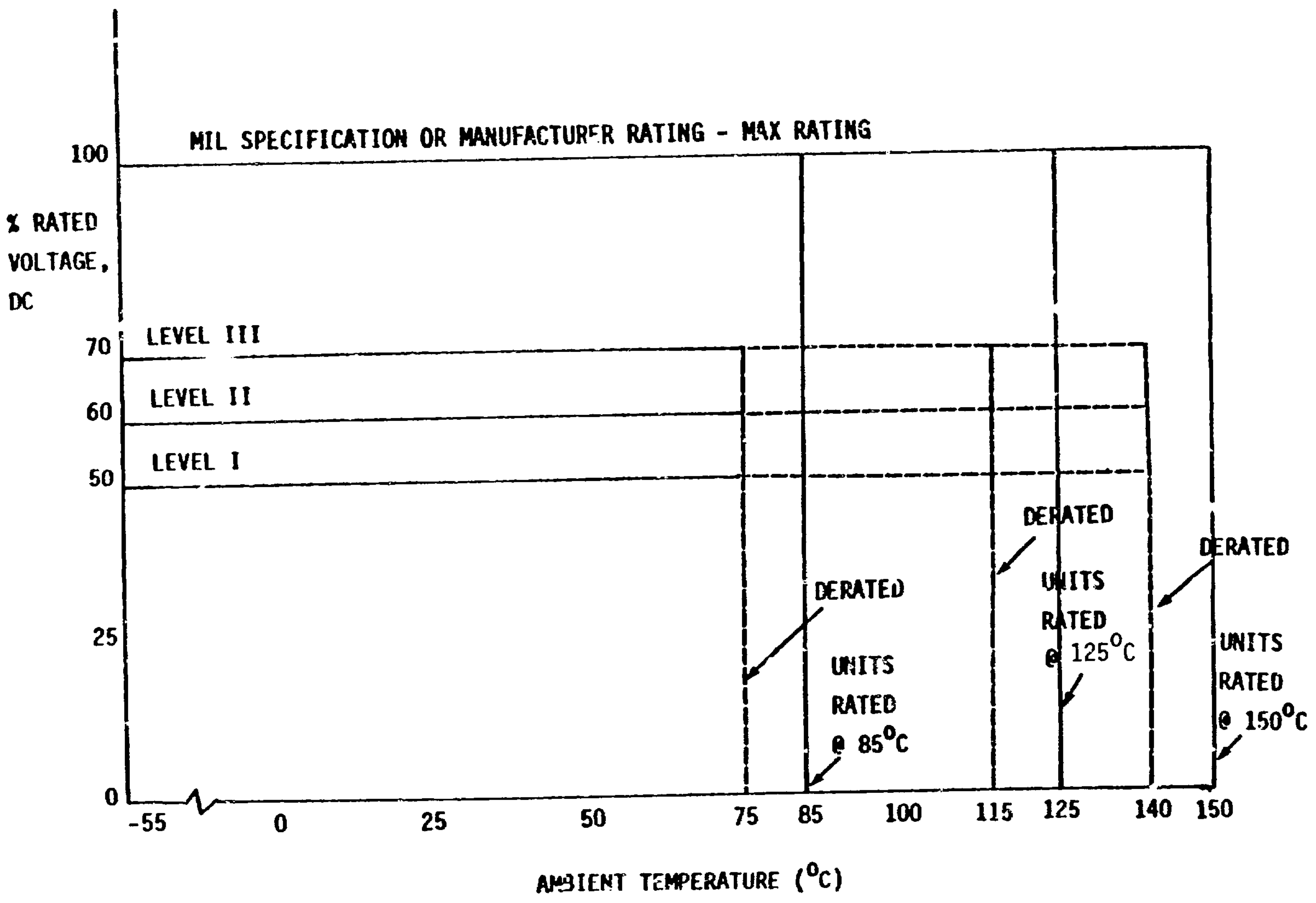


Figure 10.2-1: Derating Curves for Capacitors, Fixed, Metallized, Paper, Plastic, RFI Feed-thru Defined by MIL-C-11693

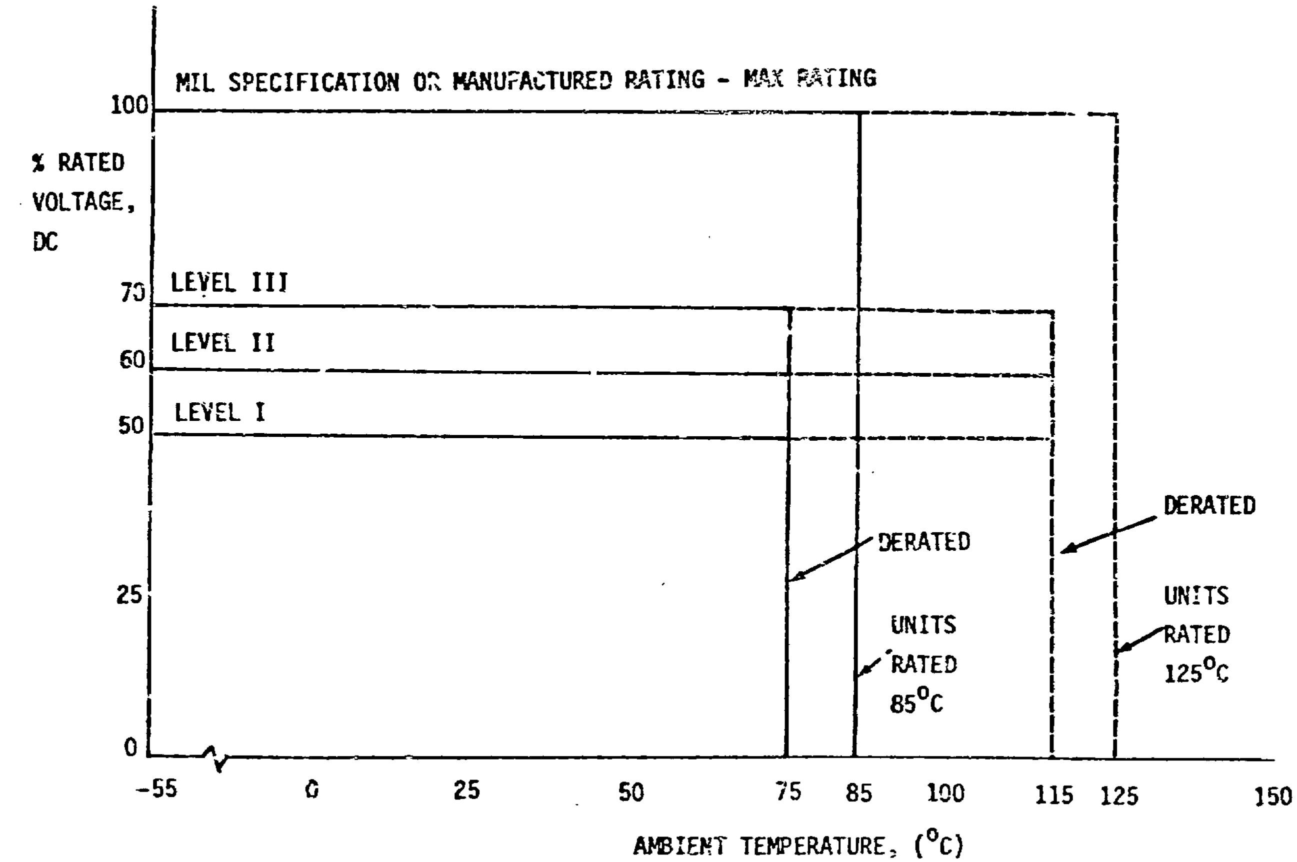


Figure 10.2-2: Derating Curves for Capacitors, Fixed, Plastic (Paper-Plastic), Defined by MIL-C-19978

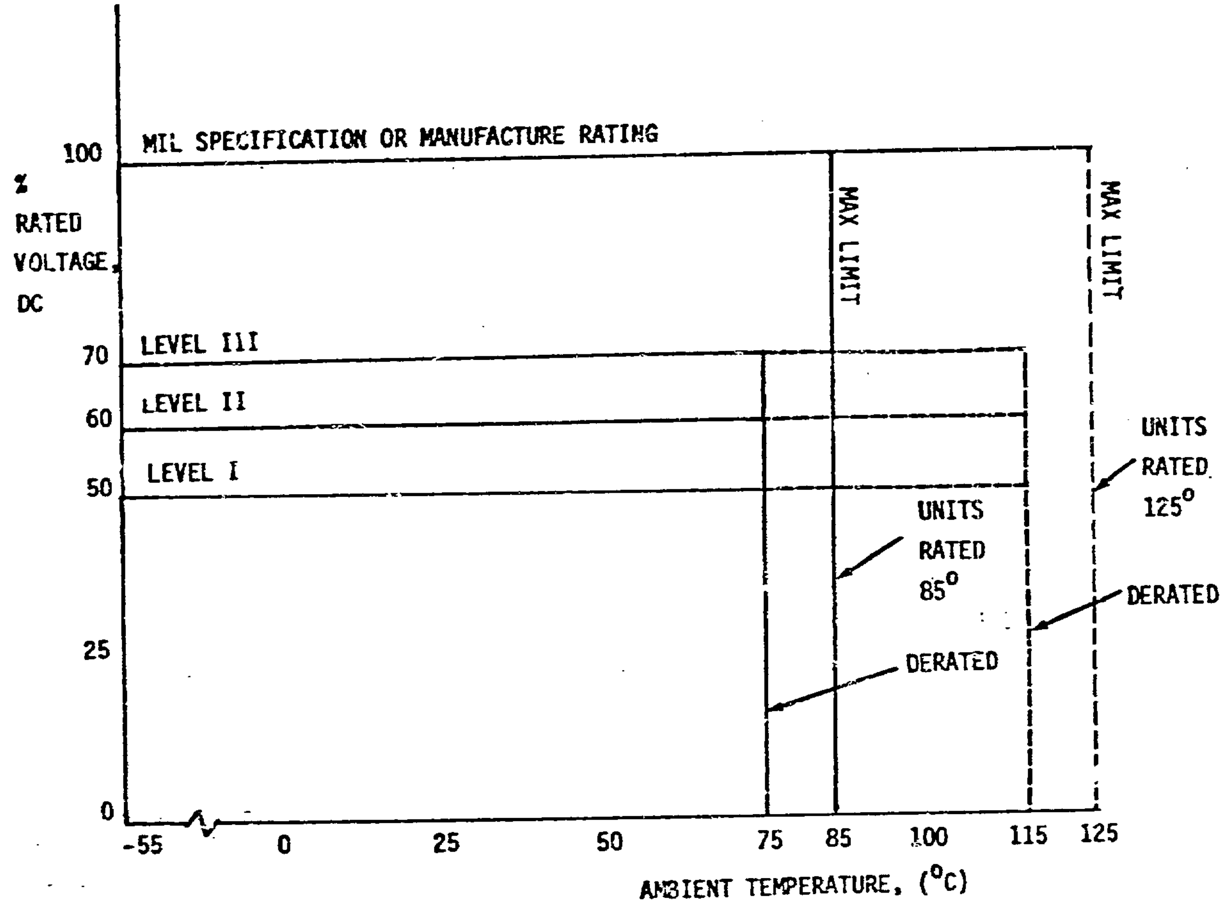


Figure 10.2-3: Derating Curves for Capacitors, Fixed, Metallized, Paper-Plastic, Plastic Film Dielectric Defined by MIL-C-39022

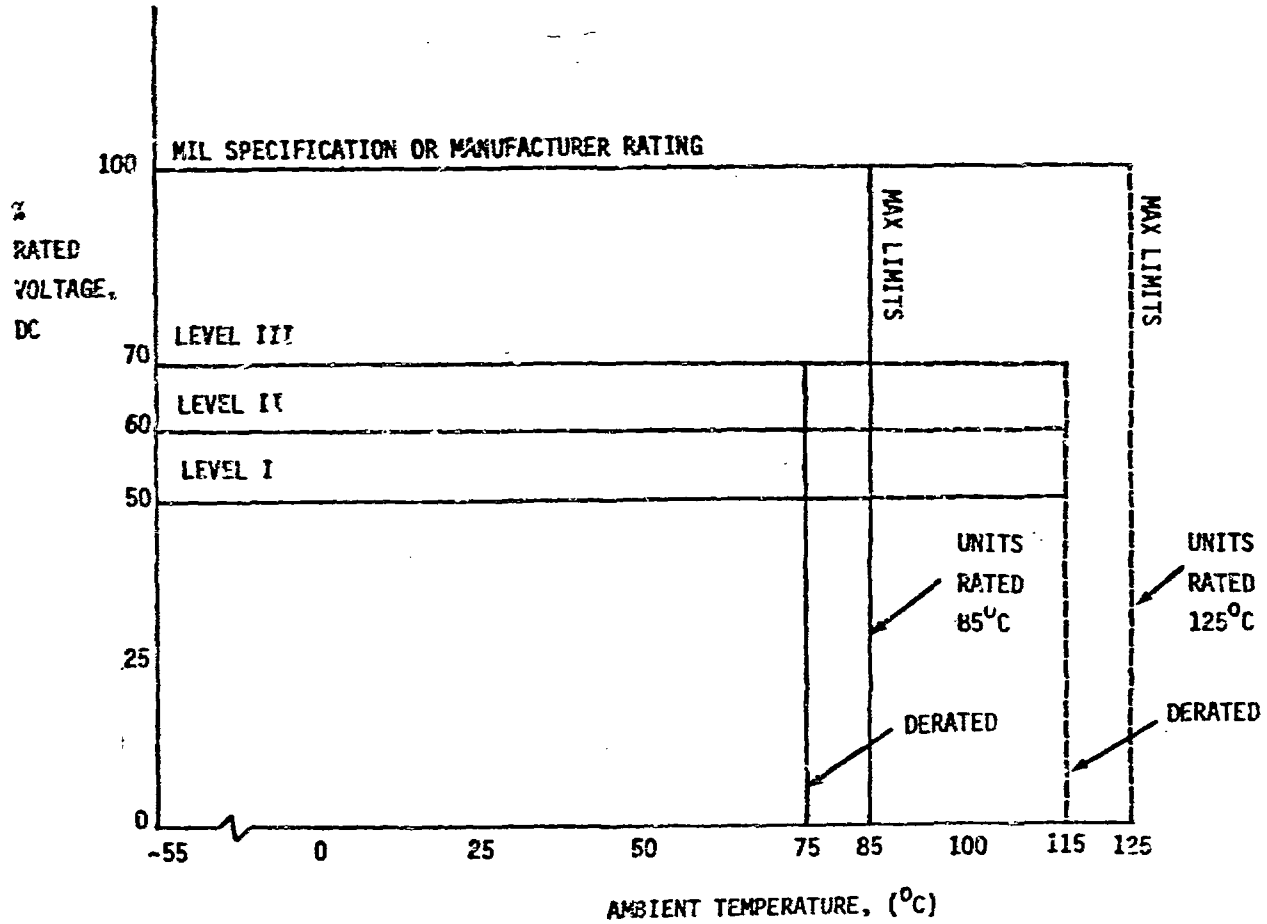


Figure 10.2-4: Derating Curves for Capacitors, Fixed, Metallized Plastic Dielectric, Defined by MIL-C-55514

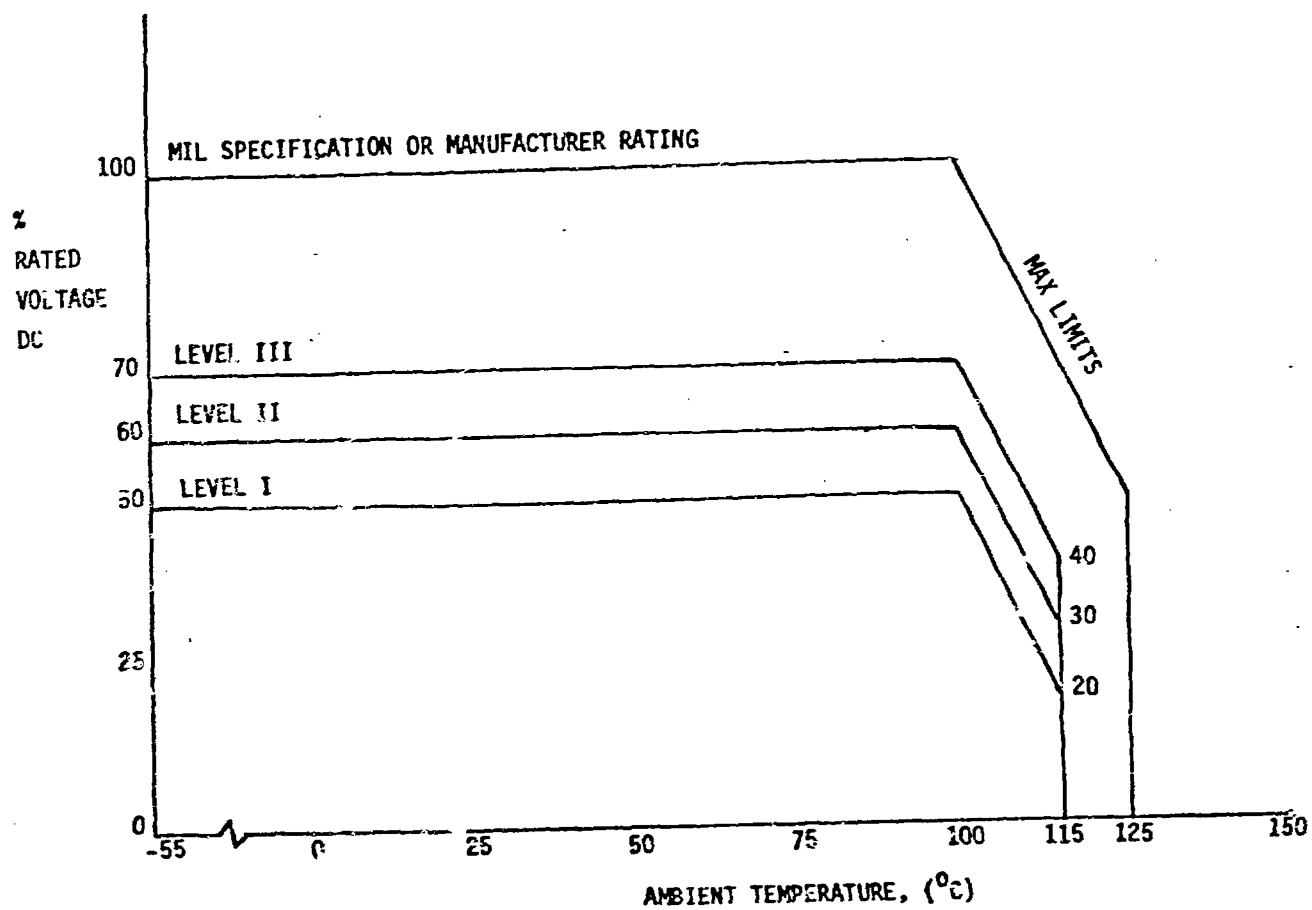


Figure 10.2-5: Derating Curves for Capacitors, Fixed Super-Metallized Plastic, Defined by MIL-C-83421

SECTION 10.3

FIXED MICA CAPACITOR DERATING GUIDELINES

10.3.1 General

MIL-C-39001 and MIL-C-10950 define the fixed mica capacitor. This capacitor approaches the ideal component by having a low dissipation factor (high Q), high temperature stability and high insulation resistance. They have good frequency stability up to 500 megahertz. They are used where close impedance limits are essential with respect to temperature, frequency, and aging.

MIL-C-39001 (CMR) is constructed with muscovite mica. It has a dielectric constant between 6.5 and 8.5 and can be split into thin sheets; it is nonporous and does not readily absorb moisture. Protection from moisture is provided to obtain high-capacitance stability and low losses. The two techniques used to form the capacitors covered in this section are by stacking the mica sheets through the silvered-mica process or by use of tin-lead foil to separate the mica sheets.

Terminals are attached to the mica stacks by the use of pressure clips which have been solder-coated for maximum mechanical strength.

The molded case is made of a polyester material which also exhibits high insulation resistance and high resistance to moisture absorption and transmission. The molded case also imparts rigidity to the capacitor in the event the capacitor is subjected to vibration or shock.

The MIL-C-10950 (CB) capacitors are composed of a stack of silvered-mica sheets connected in parallel. This assembly is enclosed in a metal case with a high potential terminal connected through the center of the stack. The other terminal is formed by this metal case connected at all points around the outer edge of the electrodes. This design permits the current to fan out in a 360-degrees pattern from the center terminal providing the shortest RF current path between the center terminal and chassis. The internal inductance is thus kept small. The use of relatively heavy and short terminals results in minimum external inductance associated permanently with the capacitor. The units are then welded and hermetically glass sealed with the exception of style CB50, which is resin sealed.

10.3.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-39001 and MIL-C-10950 type parts:

1. The derating curves are shown in Figure 10.3-1. Both temperature and voltage are derated for the three Levels.

2. Due to the inherent characteristics of the dielectric (i.e., high insulation resistance and high breakdown voltage, low power factor, low inductance, and low dielectric absorption), these mica capacitors are small and have good stability and high reliability.

3. MIL-C-39001 is an established reliability specification with failure rates available to R level (0.01 percent per thousand hours). They will experience failures at a rate depending almost exclusively upon the manner in which they are used; e.g., (1) with the temperature remaining constant, the capacitor life is inversely proportional to the 8th power of the applied DC voltage, or (2) with the DC voltage remaining constant, life decreases approximately 50 percent for every 10 deg C rise in temperature. These capacitors have a life expectancy of 50,000 hours at rated conditions.

4. MIL-C-10950 (only)

Capacitors are very stable with time and have high reliability in circuits where ambient conditions can be closely controlled to reduce failure from silver-ion migration. Silver-ion migration can occur in a few hours when silvered-mica capacitors are simultaneously exposed to DC voltage stresses, humidity, and high temperatures. For additional application data, refer to MIL-STD-198.

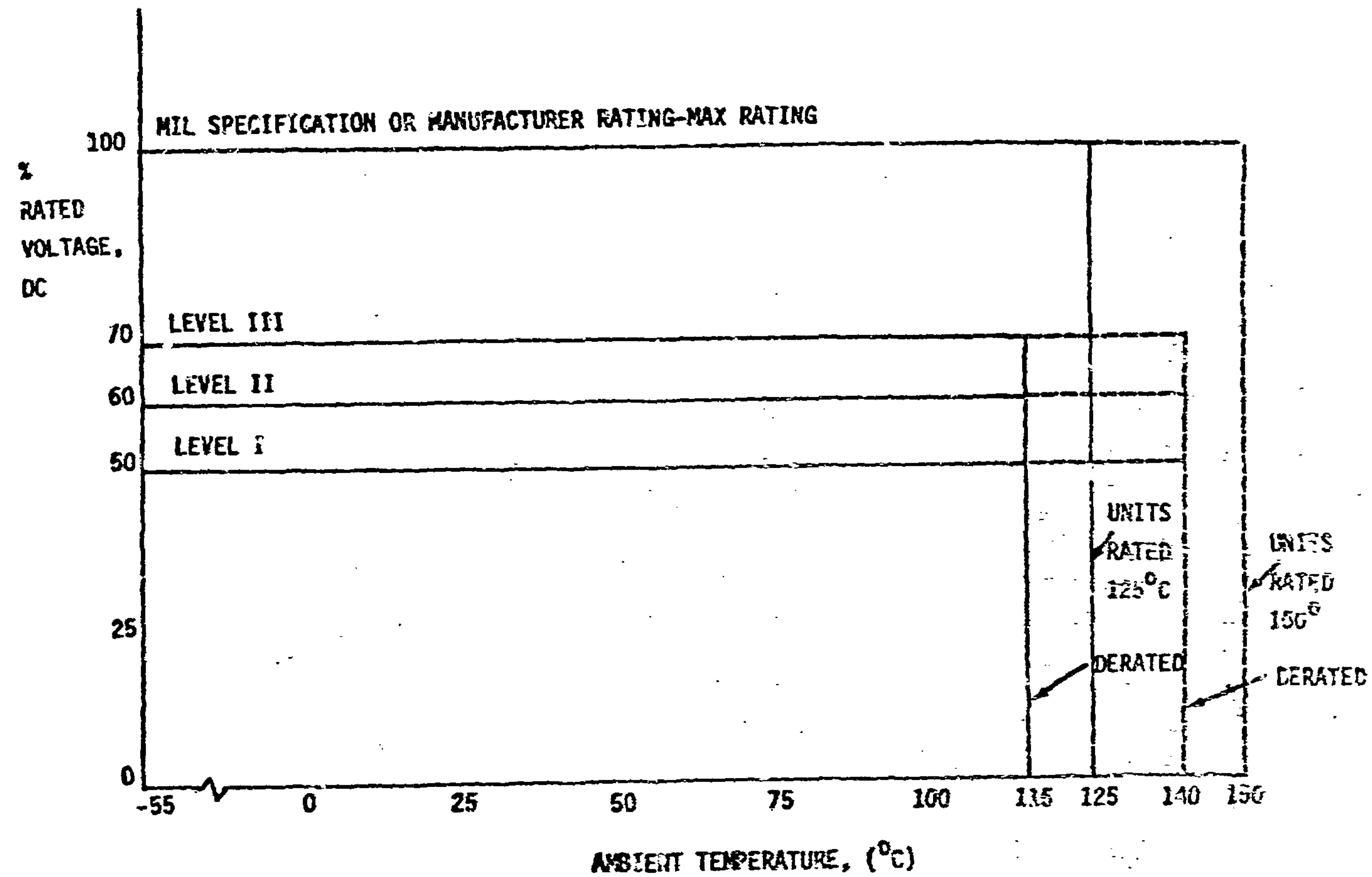


Figure 10.3-1: Derating Curves for Capacitors, Fixed, Mica Dielectric Defined by MIL-C-5, MIL-C-10950 and MIL-C-39001

SECTION 10.4

FIXED GLASS CAPACITOR DERATING GUIDELINES

10.4.1 General

MIL-C-23269 (CYR) specification defines the fixed, glass dielectric capacitor. It, like the mica capacitor, is ideal by having a low dissipation factor (high Q), high insulation resistance (low leakage) and high temperature stability. They are very stable with frequency up to 500 megahertz.

Glass-dielectric capcitors are composed of alternate layers of glass ribbon and the electrode material. After assembly, the units are sealed together by high temperature and pressure to form a rugged monolithic block. Since the terminal leads are fused to the glass case, the seal cannot be broken without destroying the capacitor.

10.4.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-23269 type parts:

1. The derating curves are shown in Figure 10.4-1 with both temperature and voltage drated for the three Levels.

2. For additional application data, refer to MIL-STD-198.

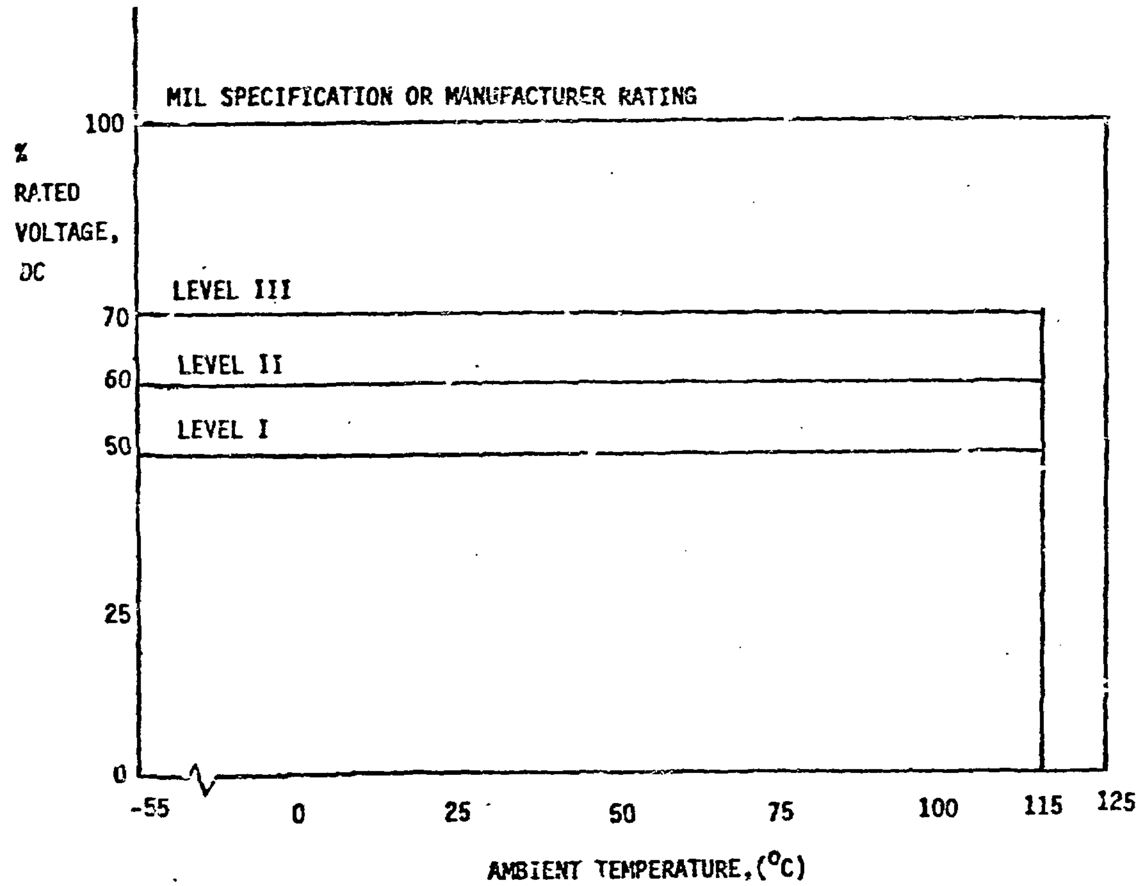


Figure 10.4-1: Derating Curves for Capacitors, Fixed, Glass Dielectric Defined by MIL-C-23269

SECTION 10.5

FIXED CERAMIC CAPACITOR DERATING GUIDELINES

10.5.1 General

MIL-C-39014 (CKR) defines an established reliability, general purpose ceramic capacitors. MIL-C-11015 (CK) is the non-established reliability unit. These capacitors are characteristically small physical size, high insulation resistance but with comparatively large capacitance values. The necessary large dielectric constant is subject to changes caused by temperature, voltage, frequency, and self aging.

This ceramic capacitor consists of a ceramic dielectric on which a thin metallic film, usually silver, has been fired at very high temperatures. Terminal leads are attached to the electrodes by a pressure contact or by soldering. Ceramic capacitors are encapsulated to protect the dielectric from the environment and to electrically insulate the capacitor. The disk types are covered by an insulating resin, plastic, or creamic; the thin-plated subminiature types may be dipped, molded, or preformed cases. The feed-through units are made of ceramic tubes modified for their required mounting. Because the constituent materials have molecular polar moments, the dielectric constants of some mixes reach hundreds (even thousands), of times the value of paper, mica, and plastic films. This results in ceramics having the largest capacitance-to-size ratios of all high-resistance dielectrics.

MIL-C-20 (CCR) defines an established reliability ceramic capacitor having controlled temperature characteristics. Control of capacitance change with temperature requires use of ceramics with different compositons producing low to high dielectric constants. The low dielectric constants (less than 10) produce very stable properties. As the dielectric constant increases, the temperature coefficient of capacitance decreases to negative values. Physically, the most common types of temperature-compensating, ceramic-dielectric capacitors are small monolithic tubular and rectangular types covered by insulating resin, plastic, or ceramic.

10.5.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-20, MIL-C-11015, and MIL-C-39014 type parts:

1. The derating curves for MIL-C-39014, MIL-C-20 and MIL-C- 11015 are shown in Figure 10.5-1. Both temperature and voltage are derated for units rated at 125 and 150 deg C.

2. Care ld be used in soldering the leads. Excessive heat may damage the encapsulation and weaken the electrode to terminal lead contact. Sudden changes in temperature such as those experienced in soldering, can crack the e capsulation or the ceramic dielectric. Leads should not be bent clo ... the case nor should any strain be imposed on the capacitor body to avoid fracturing the encapsulation or ceramic dielectric.

3. It is not intended that the case insulation be subjected to sustained voltage in excess of 150 percent of the DC rated voltage of the capacitor. Supplementary insulation should be provided where the case may come in contact with higher voltage.

4. When the silver electrodes in the ceramic capacitor are exposed to high humidities and high DC potentials, silver ion migration may take place and short circuit capacitors after relatively short periods of time. Excessive moisture during periods of storage should be avoided since the encapsulation material may absorb moisture and silver ion migration may occur when the capacitors are later put into service.

5. For additoual application data for each capacitor, refer to MIL-STD-198.

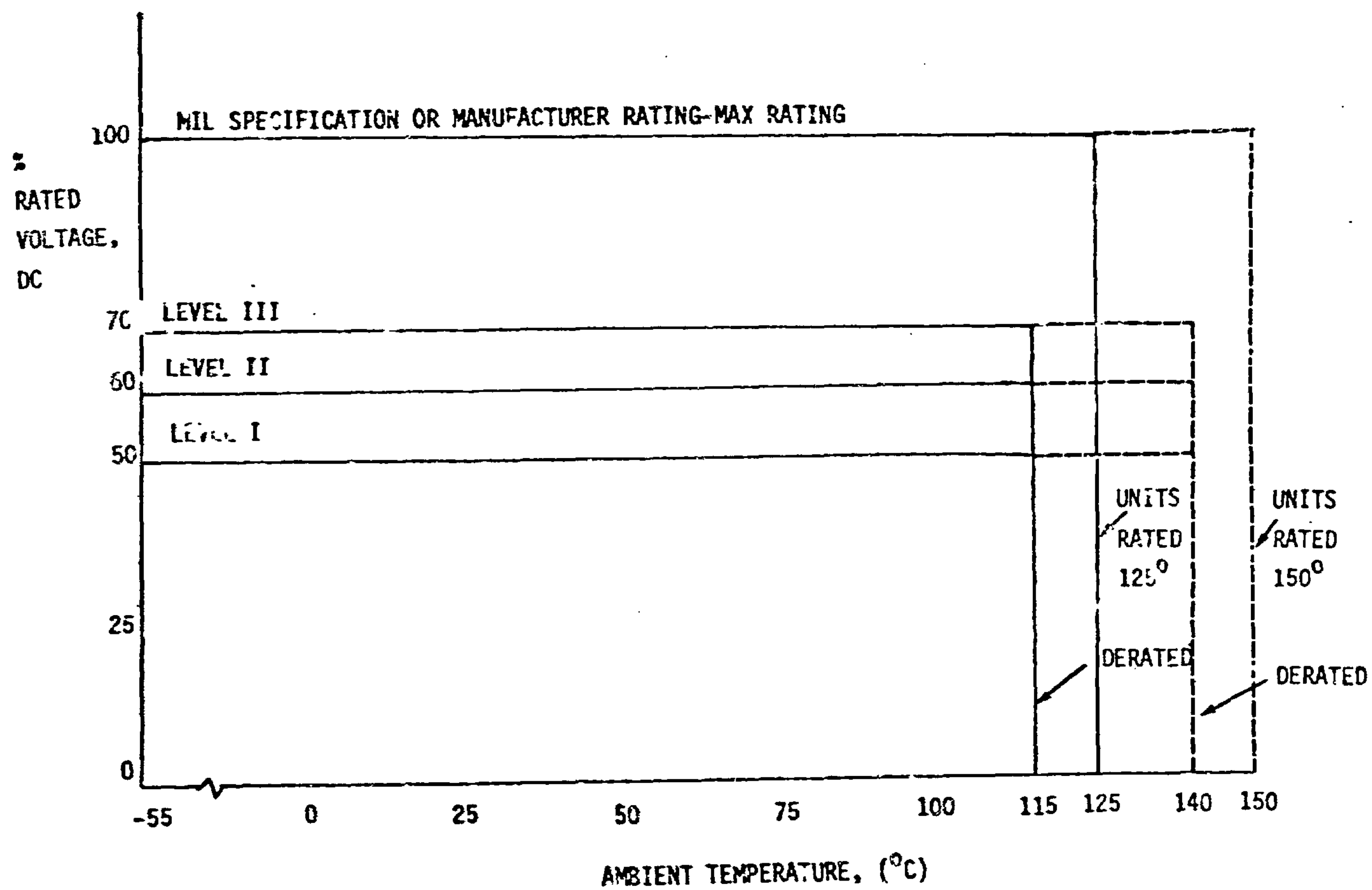


Figure 10.5-1: Derating Curves for Capacitors, Fixed, Ceramic, Dielectric Defined by MIL-C-20 and MIL-C-39014

SECTION 10.6

FIXED, ALUMINUM ELECTROLYTIC (DRY), CAPACITOR DERATING GUIDELINES

10.6.1 General

Aluminum electrolytic capacitors defined by MIL-C-62 (CE) provide the smallest volume, mass, and cost per microfarad of any type of capacitor with the exception of the tantalum electrolytic capacitor.

These capacitors are generally used where low frequency, pulsating, DC signal components are to be filtered out. These capacitors are designed for applications where accuracy of capacitance is relatively unimportant.

The capacitor consists of aluminum foil rolled onto a porous spacer. The foils are approximately 0.003 to 0.005 inch thick. The spacer is impregnated with an electrolyte and separates the anode and cathode. The electrolyte is usually an aqueous solution of ammonium borate, boric acid, and glycol.

The metal cases are provided with an insulating sleeve which has an insulation resistance of at least 100 megohms. It should be noted that the insulation resistance refers to the sleeve and not to the resistance between the terminals and the case.

10.6.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-62 type part:

1. The derating curves for MIL-C-62 are given in Figure 10.6-1. Both temperature and voltage are derated for Level III.

2. These capacitors are not suitable for airborne equipment applications since they should not be subjected to low barometric pressure and low temperatures at high altitudes. The aluminum electrolytic capacitors can be derated only for a short period since derating for any length of time may result in the necessity for re-forming. Even though they have vents designed to open at dangerous pressures, explosions can occur because of gas pressure or a spark ignition of free oxygen and hydrogen liberated at the electrodes. Provisions should be made to protect surrounding parts.

3. The thickness of the oxide film which is formed both initally on the foil and during the forming operations on the completed capacitor determines the maximum peak or surge voltage which may be applied. For maximum reliability and long life, the DC rated voltage should not be more than approximately 80 percent of full rating so that surges can be kept within the full-rated voltage. The time of surge- voltage application should not be more than 30 seconds every 10 minutes.

4. These capacitors should be used only in DC circuits with polarity properly observed. If AC components are present, the sum of the peak AC voltage plus the applied DC voltage must not exceed the DC rating. The peak AC value should also be less than the applied DC voltage in order that polarity may be maintained even on negative peaks. Capacitors which have been subjected to voltage reversal should be discarded.

5. When these capacitors are used for input-filtering purposes, the rms ripple (at +85 deg C and 120 Hz) should not exceed the value calculated from the following equation:

$$Ir = k\sqrt{C}$$

Where Ir = Maximum rms ripple current in milliamperes.
k = Value as specified in each slash sheet of MIL-C-62
C = Nominal capacitance in microfarads.

When operated at a frequency different from 120 Hz or at a temperature different from +85 deg C, the value obtained from the equation should be multiplied by the appropriate value supplied by each slash sheet of MIL-C-62.

6. For additional application data, refer to MIL-STD-198.

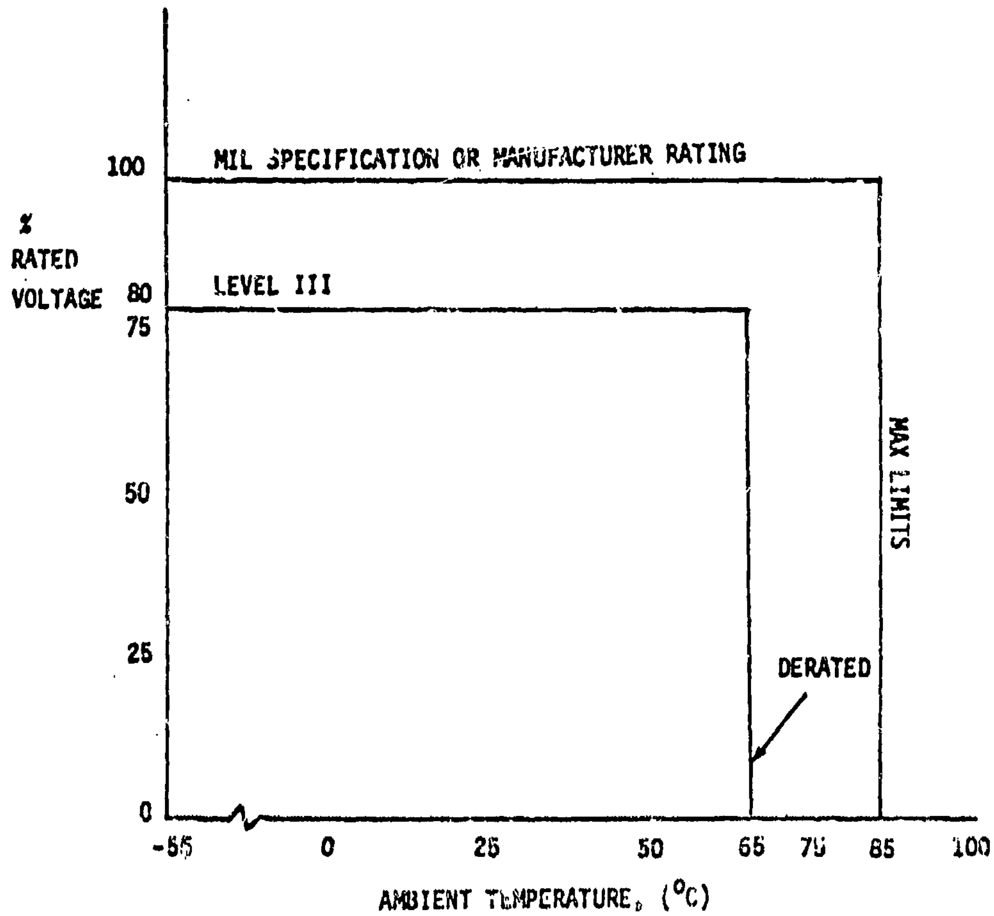


Figure 10.6-1: Derating Curves for Capacitors, Fixed, Aluminum Electrolytic Defined by MIL-C-62

SECTION 10.7

FIXED ELECTROLYTIC (ALUMINUM OXIDE), ER, CAPACITOR DERATING GUIDELINES

10.7.1 General

Aluminum electrolytic capacitors defined by MIL-C-39018 (CU) are intended for use in filter, coupling, and by-pass applications where large capacitance values are required in small cases and where excesses of capacitance over the nominal value can be tolerated.

Aluminum electrolytic capacitors provide the smallest volume, mass, and cost per microfarad of any type of capacitor with the exception of the tantalum electrolytic capacitor.

The capacitor consists of aluminum foil rolled onto a porous spacer. The foil is approximately 0.003 to 0.005 inch thick. The spacer is impregnated with an electrolyte and separates the anode and cathode. The electrolyte is usually an aqueous solution of ammonium borate, boric, acid, and glycol. Advancements in the manufacture of aluminum electrolytic capacitors have made possible an increased foil purity, improved oxide system, and an increase in etch ratios. Other contributing factors are an improved capacitor seal and the development of an electrolyte with a non-aqeous, non-acid base.

The metal cases are provided with an insulating sleeve which has an insulation resistance of at least 100 megohms.

It should be noted that the insulation resistance refers to the sleeve and not to the resistance between the terminals and the case.

10.7.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-39018 type parts:

1. The derating curves are given in Figure 10.7-1. Both temperature and voltage are derated for Level III. All styles, having maximum operating temperatures of 85, 105 and 125 deg C, are derated 20 degrees for long life.

2. For polarized capacitors, the applied AC peak voltage should never exceed the applied DC voltage; the sum of the applied AC peak and DC voltages should never exceed the rated DC working voltage.

3. The thickness of the oxide film which is formed both initially on the foil and during the forming operations on the completed capacitor determines the maximum peak or surge voltage which may applied. For maximum reliability and long life, the DC rated voltage should not be more than approximately 80 percent of full rating so that surges can be kept within the full-rated voltage. The time of surge- voltage application should not be more than 30 seconds every 10 minutes.

4. The surge voltage is the maximum voltage to which the capacitor should be subjected under any condition. This includes transients and peak ripple at the highest line voltage.

5. These capacitors are nonhermetically sealed and are not recommended for airborne equipment applications since they should not be subjected to low barometric pressure and low temperatures at high altitudes. These aluminum electrolytic capacitors can be derated only for a short period since derating for any length of time may result in the necessity for re-forming. Even though they have vents designed to open at dangerous pressures, explosions can occur because of gas pressure or a spark ignition of free oxygen and hydrogen liberated at the electrodes. Provisions should be made to protect surrounding parts.

6. Ripple current ratings are provided in each slash sheet of MIL-C-39018 for capacitor styles and are based upon a 10 degree rise in temperature.

7. For additional application data, refer to MIL-STD-198.

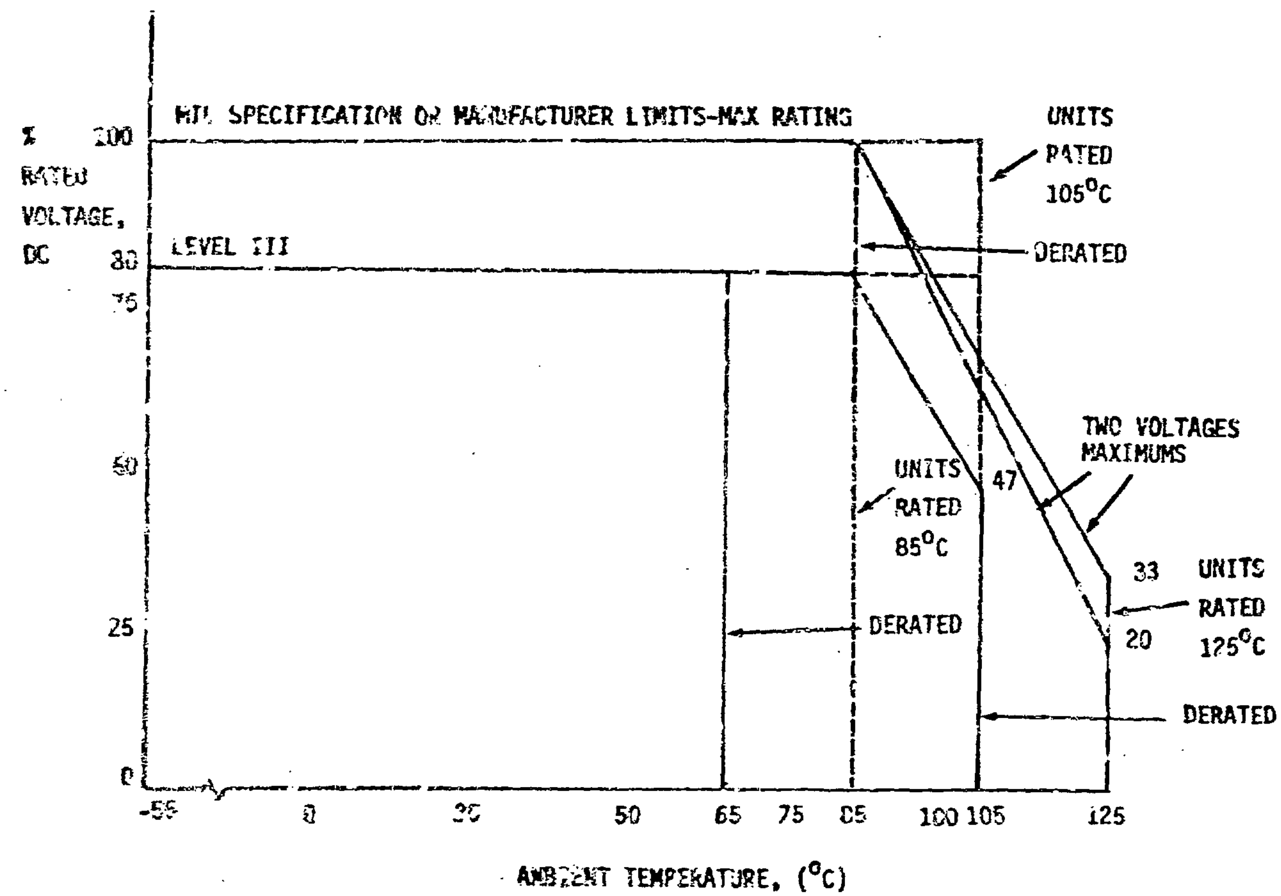


Figure 10.7-1: Derating Curves for Capacitors, Fixed, Aluminum Electrolytic Defined by MIL-C-39018

SECTION 10.8

FIXED, ELECTROLYTIC (SOLID ELECTROLYTE), TANTALUM, ER, CAPACITOR
DERATING GUIDELINES

10.8.1 General

These electrolytic capacitors defined by MIL-C-39003 (CSR) are the most stable and most reliable electrolytic available, having a longer life characteristic than any of the other electrolytic capacitors. Because of their passive electrolyte being solid and dry, these capacitors are not temperature-sensitive; they have a lower capacitance-temperature characteristic than any of the other electrolytic capacitors.

These capacitors are available as polarized and nonpolarized types. Polarized types should have their cases at the same potential as the negative lead; they should be used only in DC circuits with polarity observed. Nonpolarized types should be used where reversal of potential occurs.

A porous tantalum pellet or wire serves as the anode of a solid tantalum capacitor. The surfaces of the anode are electrochemically converted to an oxide of tantalum which serves as the dielectric. These surfaces are coated with an oxide semiconductor which is the working electrolyte in solid form. This oxide semiconductor establishes contact with all of the complex surfaces of the anodized pellet and is capable of healing imperfections of the tantalum oxide dielectric film.

10.8.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-39003 type parts:

1. The derating curves for these capacitors are shown in Figure 10.8-1. Both temperature and voltage are derated for Levels I, II, and III.

2. Failure rate is a function of temperature, applied voltage, and circuit impedance. Increased reliability may be obtained by derating the temperature and applied voltage and increasing circuit impedances.

3. DC leakage current increases when either voltage or temperature is increased; the rate of increase is greater at the higher values of voltage and temperature. A point can be reached where the DC leakage current will avalanche and attain proportions that will permanently damage the capacitor By increasing the circuit impedance, the leakage current is reduced. In high impendance circuits, momentary breakdowns (if present) will self-heal. It is recommended that a minimum circuit impedance of 3 ohms per applied volt be utilized to attain improved reliability.

4. These capacitors are not operated with reverse ripple current. They are capable of withstanding peak DC voltages in the reverse direction equal to 15% of their DC rating at +25 deg C; 10% at +55 deg C; 5% at +85 deg C; and 1% at +125 deg C.

5. For additional application data, refer to MIL-STD-198 including graphs for ripple voltage ratings as functions of temperature and frequency.

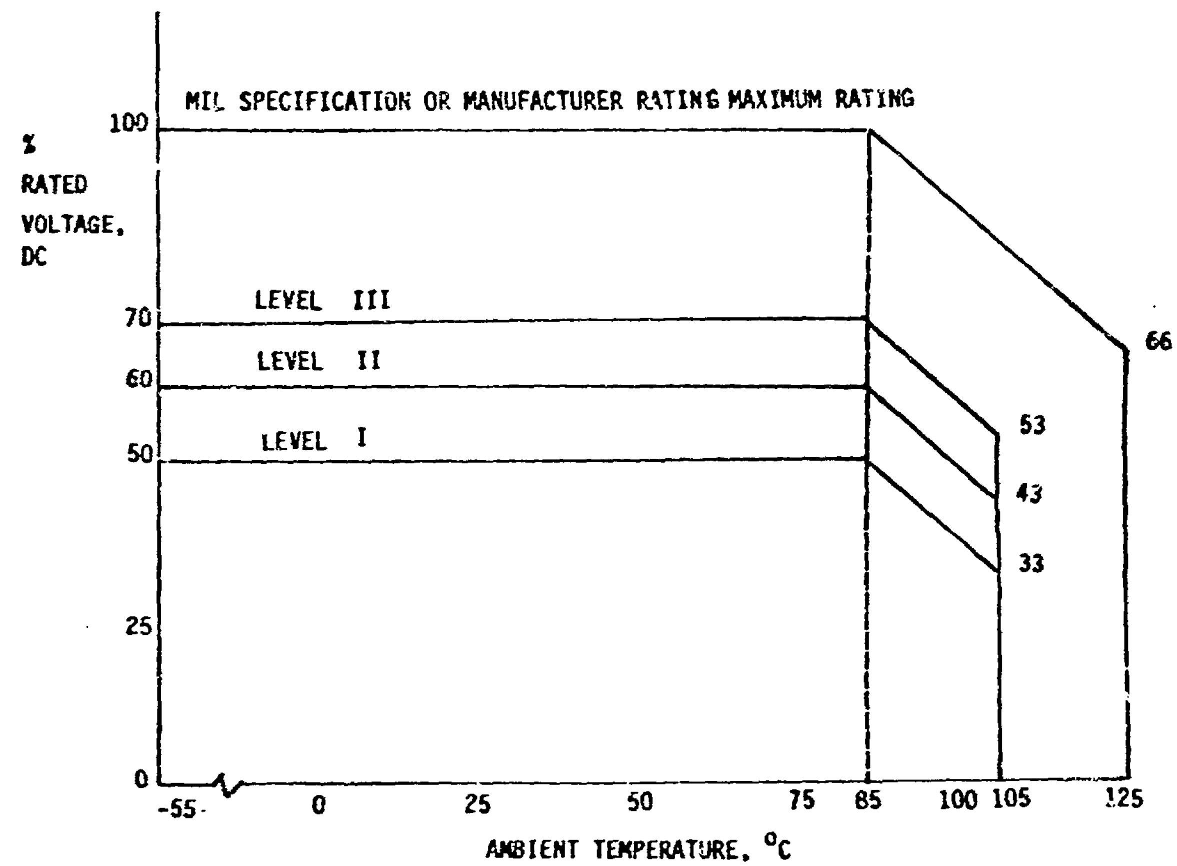


Figure 10.8-1: Derating Curves for Capacitors, Fixed Tantalum Solid Electrolyte Defined by MIL-C-39003

SECTION 10.9

FIXED, ELECTROLYTIC (NONSOLID ELECTROYTE), TANTALUM, ER, CAPACITOR DERATING GUIDELINES

10.9.1 General

The properties of MIL-C-39006 (CLR) capacitors are determined by the two basic types of tantalum (foil and sintered slug) employed in their construction.

Foil Types - The foil types are the most versatile of all electrolytic capacitors. They are available in plain or etched foil and in polarized or nonpolarized construction, which makes them suitable for many applications. The foil types are limited by their great variation of characteristics and design tolerances.

Polarized (Styles CLR25 and CLR 35) - The polarized foil types are essentially used where low-frequency pulsating DC components are to be bypassed or filtered out and for other uses in electronic equipment where large capacitance values are required and comparatively wide capacitance tolerances can be tolerated.

Nonpolarized (Styles CLR27 and CLR37) - The nonpolarized types are primarily suitable for AC applications or where DC voltage reversals occur. Examples of these uses are in (1) tuned low-frequency circuits, (2) phasing of low voltage AC motors, (3) computer circuits where reversal of DC voltage occurs, and (4) servo systems.

Sintered Slug Type (Styles CLR65 and CLR79) - These capacitors are limited to low voltage applications. Their primary use is in low voltage power supply filtering circuits. Their low leakage current (lowest of all the tantalum types) is not appreciable below +85 deg C and at ordinary operating temperatures is comparable to good quality paper capacitors, yet they are much smaller in size.

The structures of the foil and sintered slug capacitors are as follows:

Foil Types - These capacitors consist of a tantalum foil, acting as the anode, which is electromechanically treated to form a layer of tantalum oxide dielectric. Porous space material is used to form a conventional cylindrical capacitor section with axial tantulum wires on either end. The section is impregnated with a suitable electrolyte (usually a weak acid or base) and then sealed in a suitable container. Solderable leads are welded to the tantalum leads.

Sintered-Slug Types - These capacitors consist of a sintered-slug, acting as the anode, which is electrochemically treated to form a layer of tantalum oxide dielectric. The slug is placed in a suitable case (silver coated inside or for Style CLR79 a tantalum case with no silver applied) with a liquid electrolyte, such as sulphuric acid or lithium chloride. The can is then hermetically sealed.

10.9.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-39006 type parts:

1. The derating curves are given in Figure 10.9-1 for the three Levels. Both temperature and voltage are derated.

2. Because the more stable tantalum oxide film is less subject to dissolving the surrounding electrolyte than the film in an aluminum capacitor, the shelf life of the tantalum unit is much longer, and less re-forming is required. After storage for long periods, the re-forming current is low and the time is comparatively short; it may be expected to take less than 10 minutes. These properties are affected by the storage temperature to a significant degree, being excellent at temperatures from -55 deg to +25 deg C; good at +65 deg C; and relatively poor at +85 deg C.

Some Style CLR25 capacitors may exhibit capacitance change and dissipation factor changes when exposed to low DC bias levels (0 to 2.2 volts DC). Care should be exercised when applications require these voltage levels.

3. Although polarized styles may be rated for reverse voltages, it is recommended that no reversal is permitted. Reverse voltages produce large currents and removal of silver into solution. These actions are accumulative in breaking down the dielectric film by localized heating and filling pin holes with silver deposits.

4. Curves for controlling AC ripple voltages and currents are provided in MIL-STD-198. These ratings cannot be exceeded.

5. For additional application data, refer to MIL-STD-198.

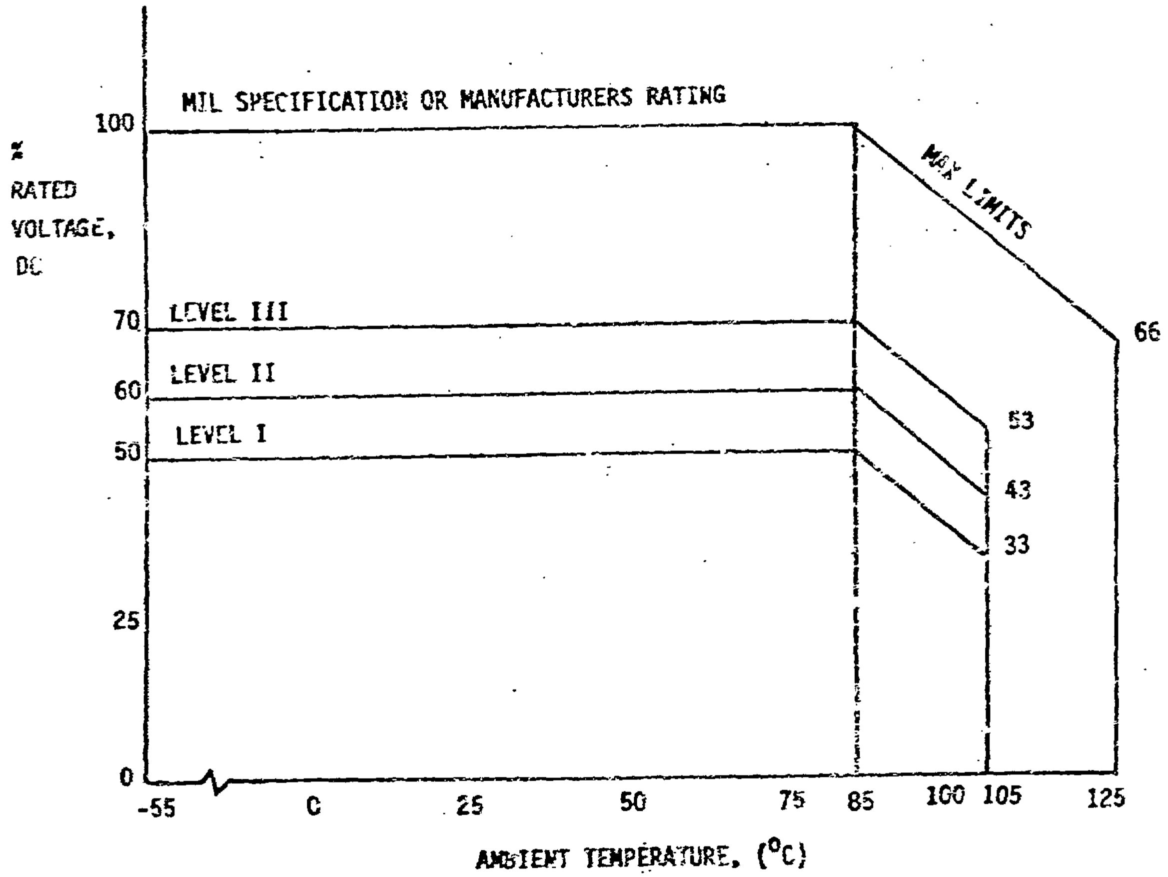


Figure 10.9-1: Derating Curves for Capacitors, Fixed, Tantalum, Non-Solid Electrolyte, Defined by MIL-C-39005

SECTION 10.10

VARIABLE (PISTON TYPE, TUBULAR TRIMMER) CAPACITOR DERATING GUIDELINES

10.10.1 General

These capacitors defined by MIL-C-14409 (PC) are small-sized, sealed, tubular trimmer, variable capacitors designed for use where fine tuning adjusments are periodically required during the life of the equipment. Normally they are used for trimming and coupling in such circuits as intermediate frequency, radio-frequency, oscillator, phase shifter, and discriminator stages.

Styles PC25 and PC26 capacitors are constructed of a series of concentric circular metal bands which interleaf and are variable by adjustment of the relative depth of the interface. All other style capacitors are constructed of glass- or quartz-dielectric cylinders and metal tuning pistons. A portion of the cylinder is plated with metal to form the stator and the metal piston, controlled by a tuning screw, acts as the rotor for these variable capacitors. The overlap of the stator and rotor determines the capacitance. The self-contained piston within the dielectric cylinder functions as a low inductance coaxial assembly.

10.10.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-14409 type parts:

1. The derating curves for these capacitors are given in Figure 10.10-1 for the three Levels.

2. For additional application data, refer to MIL-STD-198.

3. There are no application precautions perculiar to this device type over and above that discussed in the general section.

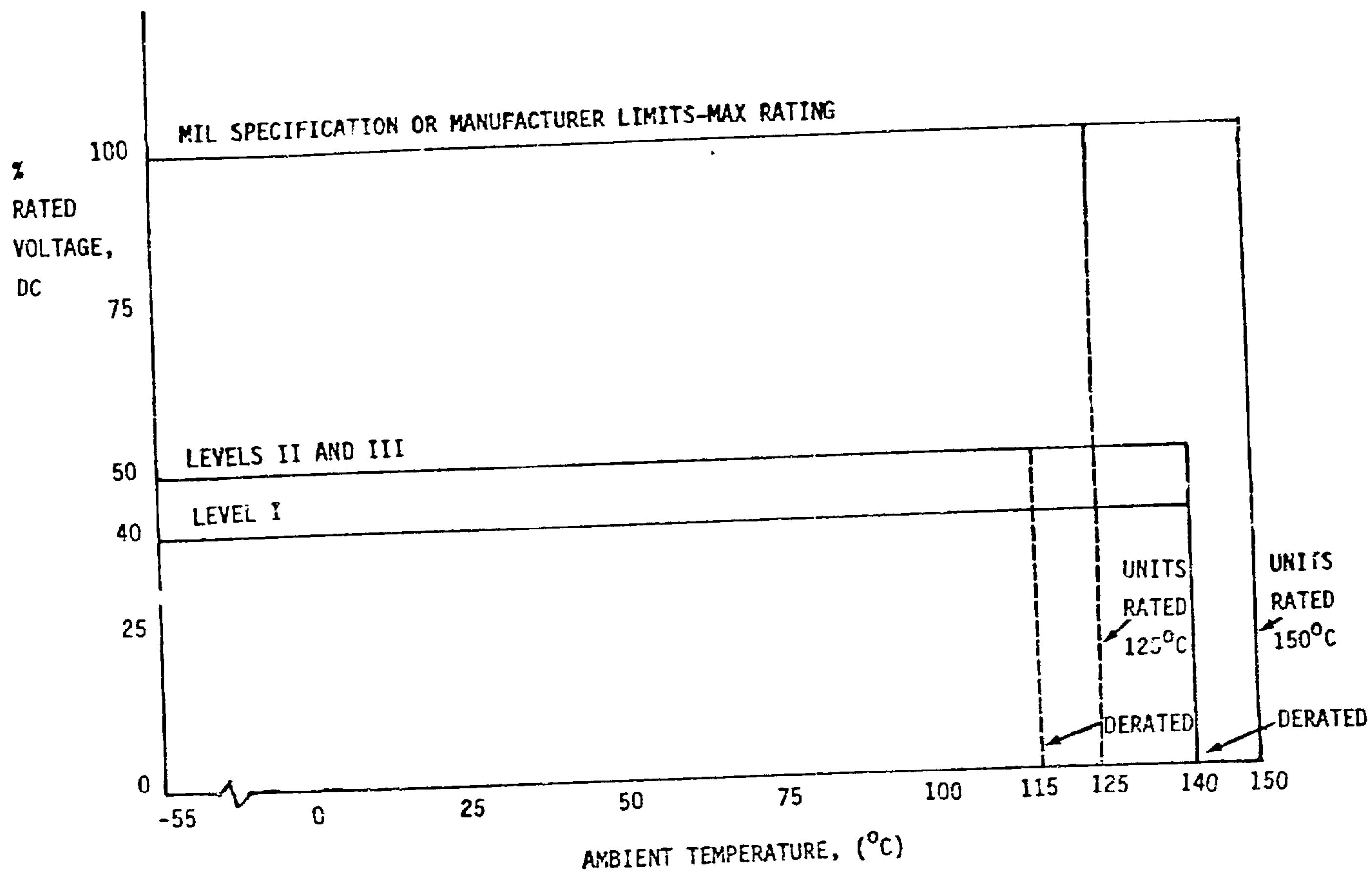


Figure 10.10-1: Derating Curves for Capacitors, Variable, Piston Type Tubular Defined by MIL-C-14409

SECTION 10.11

VARIABLE, CERAMIC, CAPACITOR DERATING GUIDELINES

10.11.1 General

These capacitors defined by MIL-C-81 (CV) are small-sized trimmer capacitors designed for use where fine tuning adjustments are periodically required during the life of the equipment. Normally they are used for trimming and coupling in such circuits as intermediate frequency, radio-frequency, oscillator, phase shifter, and discriminator stages. Because of their low mass, these units are relatively stable against shock and vibration which tend to cause changes in capacitance. Where a higher order of stability is required, air trimmers should be used.

Each unit consists of a single stator and a single rotor for each section, made of ceramic material impregnated with transformer or silicone oil. Pure silver is fired and burnished on the top of the base of the stator in a half-moon pattern. The rotor, usually of titanium dioxide, has pure silver contact points. The contact surfaces of both the stator and rotor are ground and lapped flat, thus eliminating air space variations with temperature.

The principle of operation is similar to that of an air-dielectric tuning capacitor where the overlap of the stator and rotor determines the capacitance; in these units, the ceramic dielectric replaces the air dielectric. Rotors may be rotated continuously: full capacitance change occurs during each rotation. The approximate maximum capacitance point is indicated on the capacitor.

Since the temperature sensitivity is nonlinear over the capacitance range and varies greatly between units, these capacitors should not be designed into circuits as temperature compensating units.

10.11.2 Application and Derating Guidelines

The application guidelines are defined for each military type part.

A. For MIL-C-81 type parts:

1. The derating curves are shown in Figure 10.11-1. Both temperature and voltage are derated for the three Levels.

2. For additional application data, refer to MIL-STD-198.

3. There are no application precautions for this device type over and above that discussed in the general section.

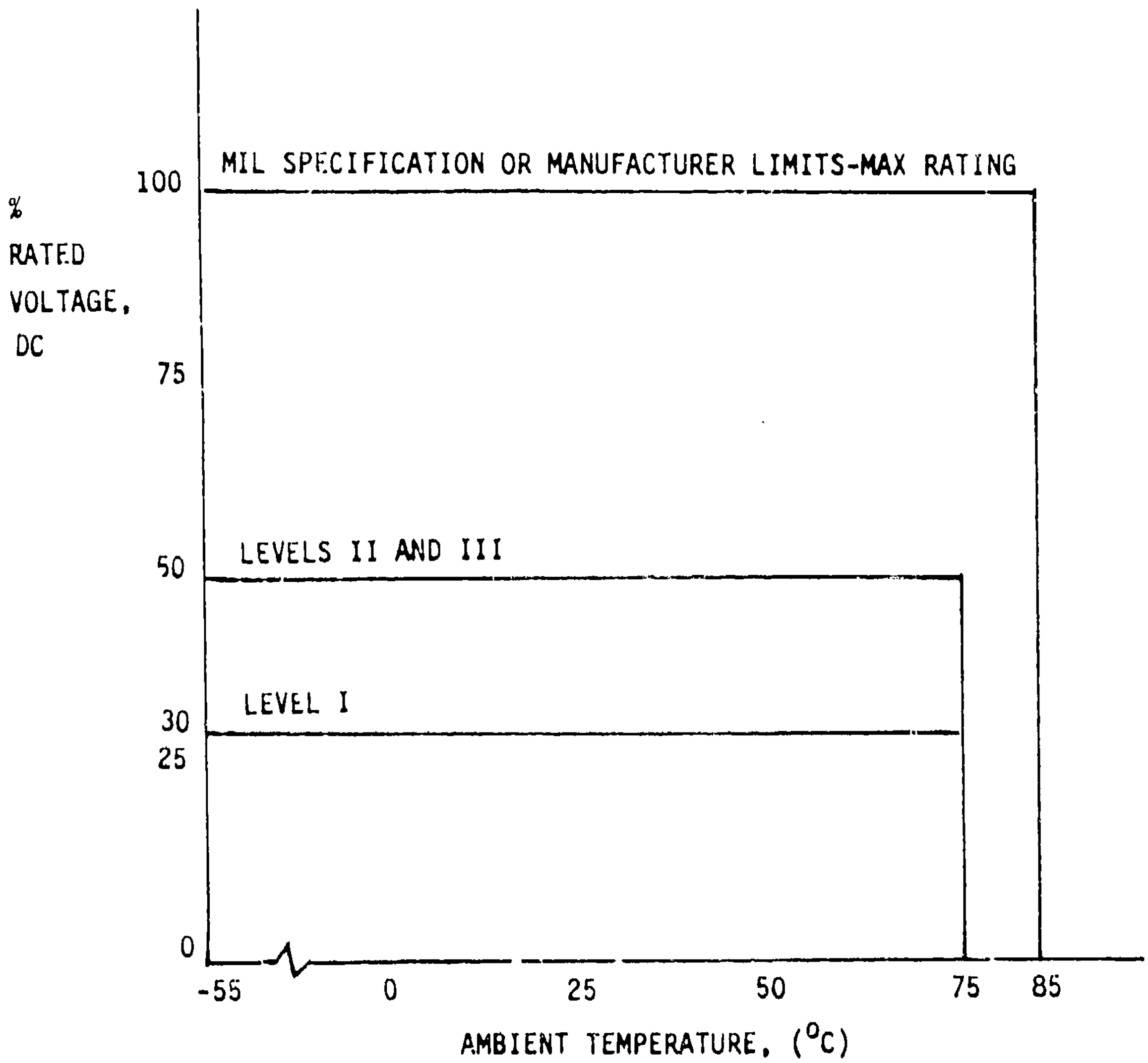


Figure 10.11-1: Derating Curves for Capacitors, Variable, Ceramic Dielectric Defined by MIL-C-81

SECTION 11

INDUCTIVE DEVICES DERATING GUIDELINES

11.1 General

Inductive devices create a magnetic field derived from the physical construction of the device and its electrical input. These devices include low and high frequency fixed coils, variable coils, audio and radio frequency transformers, power transformers, and low and high power pulse transformers.

Coils, the simplest of the inductive devices, are constructed with an insulated wire coil wound on a suitable support form which may or may not be inductive material. The inductance can be fixed or varied depending upon the physical construction. There are several types of transformers utilizing multiple coil windings with methods of coupling the magnetic field of the coils thru the physical relationship and the field-flux-coupling magnetic cores.

These construction features generally lead to closely spaced, multiple layered wraps of insulated wire over forms which may or may not be active in the device operation. This construction characteristic leads to heat generation deep within the wire coil and in the magnetic core. Large voltage differentials can exist between closely spaced elements seperated by a very thin insulation layer. Also, due to the multiplicity of coil wraps and a desire to constrain size and weight , the coil wire size tends to be marginal for the device current rating. All these construction elements are susceptable to insulation break down due to heat allowing electrical shorting between adjacent elements. Also, overheating can be caused by excessive currents (IR heating) or improper frequency of operation (core saturation or eddy current heating in the core).

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

11.2 Application Guidelines

A. Increased temperature degrades the insulation of the devices which, in turn, decreases the reliability and life span of the device.

B. Winding voltage is kept at the nominal value to prevent insulation break down.

C. Operation at a lower than designed frequency range results in overheating and possible core saturation, thus decreasing the life span.

11.3 Inductive Devices Derating Guidelines

The principal stress parameter for inductive devices is the operating hot spot temperature. The reliability of inductive devices is a function of operating hot spot temperature as it relates to the insulation capability , operating currents, in-rush transients, and dielectric stress. The method of computing the hot-spot temperature is given in MIL-HDBK-217C.

The critical parameters for inductive devices are listed as follows:

A. Winding voltages are fixed and are not derated to improve reliability.

B. Frequency operation at lower than the designed frequency range will result in overheating and possible core saturation. Therefore, frequency cannot be derated to improve reliability.

C. The derated values for hot-spot temperature, maximum current, inrush transients, and dielectric stress are derated as shown in Table 11-1.

TABLE 11-1: DERATING CRITERIA FOR TRANSFORMERS, INDUCTORS AND COILS

MILITARY TYPE DESIGNATION	FAMILY	APPLICATION	MAXIMUM HOT-SPOT TEMPERATURE (°C) LEVEL III											LEVEL II											LEVEL I											MAXIMUM PERMISSIBLE % OF MANUFACTURER'S RATING [1]		
		INSULATION CLASS	O	A	B	C	F	Q	R	S	T	U	V	O	A	B	C	F	Q	R	S	T	U	V	O	A	B	C	F	Q	R	S	T	U	V	OPERATING CURRENT	TRANSIENT VOLTAGE OR CURRENT	DIELECTRIC WITH-STANDING VOLTAGE
MIL-T-27	POWER XFMR/CHOKE AUDIO XFMR/CHOKE PULSE XFMR							70	90	115	155	170	140						60	80	105	145	160	130						45	65	90	130	145	115	70	90	60
MIL-T-21038	PULSE							70	50	115	140	165	180						60	80	105	130	155	170						45	65	90	115	130	155	60	70	60
MIL-T-55631	L.F. XFMR I.F. XFMR DISCRIMINATOR XFMR		70	90	110	130								60	80	100	120								45	65	85	105								60	90	50
MIL-T-15305	FIXED R.F. COIL VARIABLE R.F. COIL		70	90	110	135								60	80	100	125								45	65	85	110								70	90	50
MIL-C-39010	MOLDED R.F. & E.R. COILS			90	110		135								80	100		125								65	85		110							70	90	50

[1] Percentages given are for all three derating categories.

SECTION 12

RELAY DERATING GUIDELINES

12.1 General

The principal derating stress parameters for relays are the continuous contact current, coil operating voltage, coil drop out voltage, vibration limits, and temperature.

There are four major relay groups that will be covered. These groups are electromechanical relays, solid state relays, hybrid electromechanical relays, and hybrid solid state relays. Under these major groups, there are five relay types. These basic types are balanced armature, balanced-force, low level, magnetic latching, and polarized.

The electromechanical relays use an electrical input to create the motive force which mechanically moves the metallic contacts to open or closed positions. This type offer greater tolerances to overload conditions and usually better input to output isolation.

The solid state relays function by the use of electronic components which perform the relay operation. This type of relay does not contain moving parts, therefore it is not cycle life sensitive.

The hybrid electromechanical relay uses electromechanical and electronic devices to perform the switching functions with an electromechanical output.

The hybrid solid state relay use electronic devices and occasionally electromechanical devices to perform the switching functions with a solid state output. This type offers an increased sensitivity for operations at low energy input levels.

Under these four relay groups are five major functional types. These functional types are balanced armature, balanced-force, low-level, magnetic latching, and polarized types.

Balanced armature type relays has the armature pivoted at the center of the mass, which balances the armature with respect to static and dynamic external forces. This type works better than the other types in environments of extreme shock and vibration.

Balanced-force type relays have the same amount of force applied to the armature for both the energized and de-energized states.

Low level type relays are relays that will switch dry circuit or low level load. The low level loads are considered to be 100mV (open circuit voltage) or less and 10 mA or less. There is normally a gold or gold alloy plating on the surface of the contacts.

Magnetic latching type relays use a permanent magnet in conjunction with the normal soft iron circuit, so that the permanent magnet flux will hold the armature in the operated condition after the electromagnetic coil energy has been removed.

Polarized type relays have many relay styles including telegraph, crystal can, differential, ferreed, dry reed, magnetic latching, mercury- wetted contact, and armature type with a permanent core. This type usually has one or more permanent magnets to provide the polarizing magnetic flux that normally can flow in either of two symmetrical paths. It is necessary to observe the terminal polarity with this type of relay.

For a more detailed application and design guideline, consult MIL-STD-1346.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

12.2 Application Guidelines

There are many critical application guidelines to be considered for different relay applications. This section will call out critical application guidelines which apply to all of the relays.

A. Relays should not be energized for emergency operations. They should however be normally energized so that they will release under an emergency condition.

B. Never parallel contacts to increase the current capacity. Contacts will not make or break simultaneously, therefore one contact may end up carrying all of the load under worst case conditions.

C. Switching of circuit transient surges in excess of current ratings will seriously impair contact life. Note: surge current greater than ten times the steady state current can result when switching inductive, capacitive, and lamp loads.

D. Observe relay ratings

1. Relays tested and rated for single phase operations should not be used to switch polyphase circuits.

2. Use of relays to reverse motors should be avoided unless the relay is rated for this function or unless power is removed prior to reversal.

3. More power is needed to operate relays at elevated ambient temperatures due to the change in coil resistance.

4. Relays should be located and mounted in areas which will minimize the probability of contact chatter due to shock and vibration.

12.3 Relay Derating Guidelines

Continuous contact current, coil operating voltage, coil drop out voltage, vibration, and temperature are the derating stress parameters for all four of the relay groups.

The recommended derating for Level I is listed in table 12-1.

The recommended derating for Level II is listed in table 12-2.

The recommended derating for Level III is listed in table 12-3.

TABLE 12-1: RELAY DERATING FOR LEVEL 1

PARAMETER	DERATING PERCENTAGE (2)
CONTINUOUS CONTACT CURRENT	
LOW LEVEL (1)	DERATING NOT APPLICABLE
RESISTIVE LOAD	50% OF RATED RESISTIVE
CAPACITIVE LOAD MAXIMUM INRUSH CURRENT	50% OF RATED RESISTIVE
INDUCTIVE LOAD	50% OF RATE INDUCTIVE OR 35% OF RATED RESISTIVE
MOTOR LOAD	50% OF RATED MOTOR OR 15% OF RATED RESISTIVE
LAMP (FILAMENT) LOAD	50% OF RATED LAMP OR 7-8% OF RATED RESISTIVE
CONTACT POWER APPLICABLE TO REED, MERCURY WETTED OR OTHER LOADS RATED IN WATTS OR VOLT AMPERES	40% OF RATED VALUE
COIL OPERATE VOLTAGE MINIMUM CONTINUOUS DC OR RMS AC VOLTAGE	90% OF RATED NOMINAL VALUE
MINIMUM COIL VOLTAGE (3)	110% OF RATED PICKUP VOLTAGE
COIL DROP OUT VOLTAGE MAXIMUM ALLOWABLE	110% OF RATED DROPOUT
MINIMUM ALLOWABLE	90% OF RATED DROPOUT
VIBRATION LIMIT INCLUDING MOUNTING Q	60% OF MAX RATED
TEMPERATURE	20 DEG C LESS THAN MAX RATED

(1) Less than 100 mW of power
(2) Use derated resistive ratings when the inductive, motor, or lamp ratings are not given.
(3) Minimum short duration voltage, worst case limit. Transients of shorter duration than 10% of release time may be of lower voltage.

TABLE 12-2: RELAY DERATING FOR LEVEL II

PARAMETER	DERATING PERCENTAGE (2)
CONTINUOUS CONTACT CURRENT	
LOW LEVEL (1)	DERATING NOT APPLICABLE
RESISTIVE LOAD	75% OF RATED RESISTIVE
CAPACITIVE LOAD MAXIMUM INRUSH CURRENT	75% OF RATED RESISTIVE
INDUCTIVE LOAD	75% OF RATE INDUCTIVE OR 40% OF RATED RESISTIVE
MOTOR LOAD	75% OF RATED MOTOR OR 20% OF RATED RESISTIVE
LAMP (FILAMENT) LOAD	75% OF RATED LAMP OR 10% OF RATED RESISTIVE
CONTACT POWER APPLICABLE TO REED, MERCURY WETTED OR OTHER LOADS RATED IN WATTS OR VOLT AMPERES	50% OF RATED VALUE
COIL OPERATE VOLTAGE MINIMUM CONTINUOUS DC OR RMS AC VOLTAGE	90% OF RATED NOMINAL VALUE
MINIMUM COIL VOLTAGE (3)	110% OF RATED PICKUP VOLTAGE
COIL DROP OUT VOLTAGE MAXIMUM ALLOWABLE	110% OF RATED DROPOUT
MINIMUM ALLOWABLE	90% OF RATED DROPOUT
VIBRATION LIMIT INCLUDING MOUNTING Q	60% OF MAX RATED
TEMPERATURE	20 DEG C LESS THAN MAX RATED

(1) Less than 100 mW of power
(2) Use derated resistive ratings when the inductive, motor, or lamp ratings are not given.
(3) Minimum short duration voltage, worst case limit. Transients of shorter duration than 10% of release time may be of lower voltage.

TABLE 12-3: RELAY DERATING FOR LEVEL III

PARAMETER	DERATING PERCENTAGE (2)
CONTINUOUS CONTACT CURRENT	
LOW LEVEL (1)	DERATING NOT APPLICABLE
RESISTIVE LOAD	90% OF RATED RESISTIVE
CAPACITIVE LOAD MAXIMUM INRUSH CURRENT	90% OF RATED RESISTIVE
INDUCTIVE LOAD	90% OF RATED INDUCTIVE OR 75% OF RATED RESISTIVE
MOTOR LOAD	90% OF RATED MOTOR OR 75% OF RATED RESISTIVE
LAMP (FILAMENT) LOAD	90% OF RATED LAMP OR 30% OF RATED RESISTIVE
CONTACT POWER APPLICABLE TO REED, MERCURY WETTED OR OTHER LOADS RATED IN WATTS OR VOLT AMPERES	70% OF RATED VALUE
COIL OPERATE VOLTAGE MINIMUM CONTINUOUS DC OR RMS AC VOLTAGE	90% OF RATED NOMINAL VALUE
MINIMUM COIL VOLTAGE (3)	110% OF RATED PICKUP VOLTAGE
COIL DROP OUT VOLTAGE MAXIMUM ALLOWABLE	110% OF RATED DROPOUT
MINIMUM ALLOWABLE	90% OF RATED DROPOUT
VIBRATION LIMIT INCLUDING MOUNTING Q	60% OF MAXIMUM RATED
TEMPERATURE	20 DEG C LESS THAN MAX. RATED

(1) Less than 100 mW of power
(2) Use derated resistiveratings when the inductive, motor, or lamp ratings are not given.
(3) Minimum short duration voltage, worst case limit. Transients of shorter duration than 10% of release time may be of lower voltage.

SECTION 13

SWITCH DERATING GUIDELINES

13.1 General

The principal derating parameter for switches are the contact current, voltage, and power.

There are four major switch types that will be covered, they are toggle, sensitive, rotary, and pushbutton switches. Other switches like limit, proximity, thermal, etc. have many application considerations that must be followed, therefore, this derating may only apply to their contacts.

Toggle switches are used to perform a make-and-break action. They can be used in AC or DC circuits.

Sensitive switches are generally a plunger activated switch which performs a N. O. (normally open) or N. C. (normally closed) electrical swithching function. The plunger is spring loaded and can be activated be applying direct force (normally 5 once maximum) upon the top of the plunger or if there is a leaf pivotting arm attached to the plunger, by applying force to the arm which will in turn apply force to the plunger.

Rotary switches are generally used as a circuit selector for switching small signals, frequencies etc., and normally are not considered a power switching device. The switching is actuated by a rotary motion of the shaft for the selection of one or more circuits. They are suitable for use in AC or DC circuits.

Pushbutton switches are operated by the movement of a reciprocating plunger. These switches vary in complexity from a single circuit "on-off" switch to a multicircuit switch with a lighted display. These switches can be used in AC or DC circuits.

For detailed design and application guidelines, consult MIL-STD-1132.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

13.2 Application Guidelines

A. Switch contacts may be operated in parallel for redundancy but never to increase the current rating.

B. Switch application in digital circuits must be carefully reviewed to assure that contact bounce or chatter will not be interpreted as a circuit interruption which will produce logic errors.

C. Switches are subject to contact chatter in high shock and vibration environments, therefore they should be mounted in areas which will minimize shock and vibration.

D. Switches used in low level application, normally with noble metal contacts, must be rated for low level currents and voltages. Low level requirements are defined per MIL-STD-202 test method 311 as 10 mA maximum at 30 mV maximum open circuit voltage DC or peak AC.

E. Insulation resistance of switches must be considered when used in high impedance circuits.

F. Temperature and altitude variation must be considered because moisture condensation within the switch may occur during temperature/altitude changes. This moisture may cause contact contamination or short circuit.

G. It is usually necessary to use toggle or push button switches for high current levels. The rating of rotary switches is normally limited to 15 amperes. Positive break toggle switches per MIL-S-8834 are preferred types for heavy loads.

H. In humid or d[illegible] environments sealed switches should be used, although a larg[illegible] completely open switch is equally good in moist environments. A poorly sealed switch may allow condensation to accumulate but not provide for water drainage.

13.3 Derating Guidelines

The contact current, voltage, and power are the principal derating stress parameters. The recommended derating for Levels I, II, and III are listed in Table 13-1.

TABLE 13-1: SWITCH DERATING GUIDELINES

PARAMETERS	DERATING PERCENTAGE FOR LEVEL I (2)	DERATING PERCENTAGE FOR LEVEL II (2)	DERATING PERCENTAGE FOR LEVEL III (2)
CONTINUOUS CONTACT CURRENT			
LOW LEVEL (1)	DERATING NOT APPLICABLE	DERATING NOT APPLICABLE	DERATING NOT APPLICABLE
RESISTIVE LOAD	50% OF RATED RESISTIVE	75% OF RATED RESISTIVE	90% OF RATED RESISTIVE
CAPACITIVE LOAD (MAXIMUM INRUSH CURRENT)	50% OF RATED RESISTIVE	75% OF RATED RESISTIVE	90% OF RATED RESISTIVE
INDUCTIVE LOAD	50% OF RATED INDUCTIVE OR 35% OF RATED RESISTIVE	75% OF RATED INDUCTIVE OR 40% OF RATED RESISTIVE	90% OF RATED INDUCTIVE OR 50% OF RATED RESISTIVE
MOTOR LOAD	50% OF RATED MOTOR LOAD OR 15% OF RATED RESISTIVE	75% OF RATED MOTOR LOAD OR 20% OF RATED RESISTIVE	90% OF RATED MOTOR LOAD OR 35% OF RATED RESISTIVE
LAMP (FILAMENT) LOAD	50% OF RATED LAMP OR 7-8% OF RATED RESISTIVE	75% OF RATED LAMP OR 10% OF RATED RESISTIVE	90% OF RATED LAMP OR 15% OF RATED RESISTIVE
CONTACT POWER (3)	40% OF RATED	50% OF RATED	70% OF RATED
CONTACT VOLTAGE	40% OF RATED	50% OF RATED	70% OF RATED

(1) Less than 100mw of power.
(2) Use derated resistive ratings when the inductive, motor, or lamp ratings are not given.
(3) When contacts are rated for power or volt-ampere capacity such as with reed switches or mercury switch.

SECTION 14

CONNECTOR DERATING GUIDELINES

14.1 General

The primary factors affecting the failure rate of connectors are insert material, contact current, number of active contacts, mate/unmate cycling, and the environment in which it is operated. The rating of connectors is determined by the temperature of the insert material. This temperature is due to operating ambient temperature and the temperature rise caused by current through the contacts.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

14.2 Application Guidelines

A. When the number of active contacts is 100 or more in a single connector, the reliablity will be increased by using 2 connectors with the same total number of contacts as the single connector.

B. Using a 200 deg C rated insert over a 125 deg C rated insert will will lower generic failure rate an average of 85% (see Figure 14-1).

C. Scoop-proof connectors should be considered for designs susceptable to bent pin failures. Also, scoop-proof connectors must always be used for ordinance/explosive circuitry.

D. When pins are connected in parallel at the connector to increase the current capacity, allow for a mimimum of 25% surplus of pins over that required to meet the 50% derating for each pin, assuming equal currents in each. The currents will not divide equally due to variations in contact resistance. For example, it would require 5 pins rated at 1 ampere each to conduct 2 amperes under 50% derated conditions.

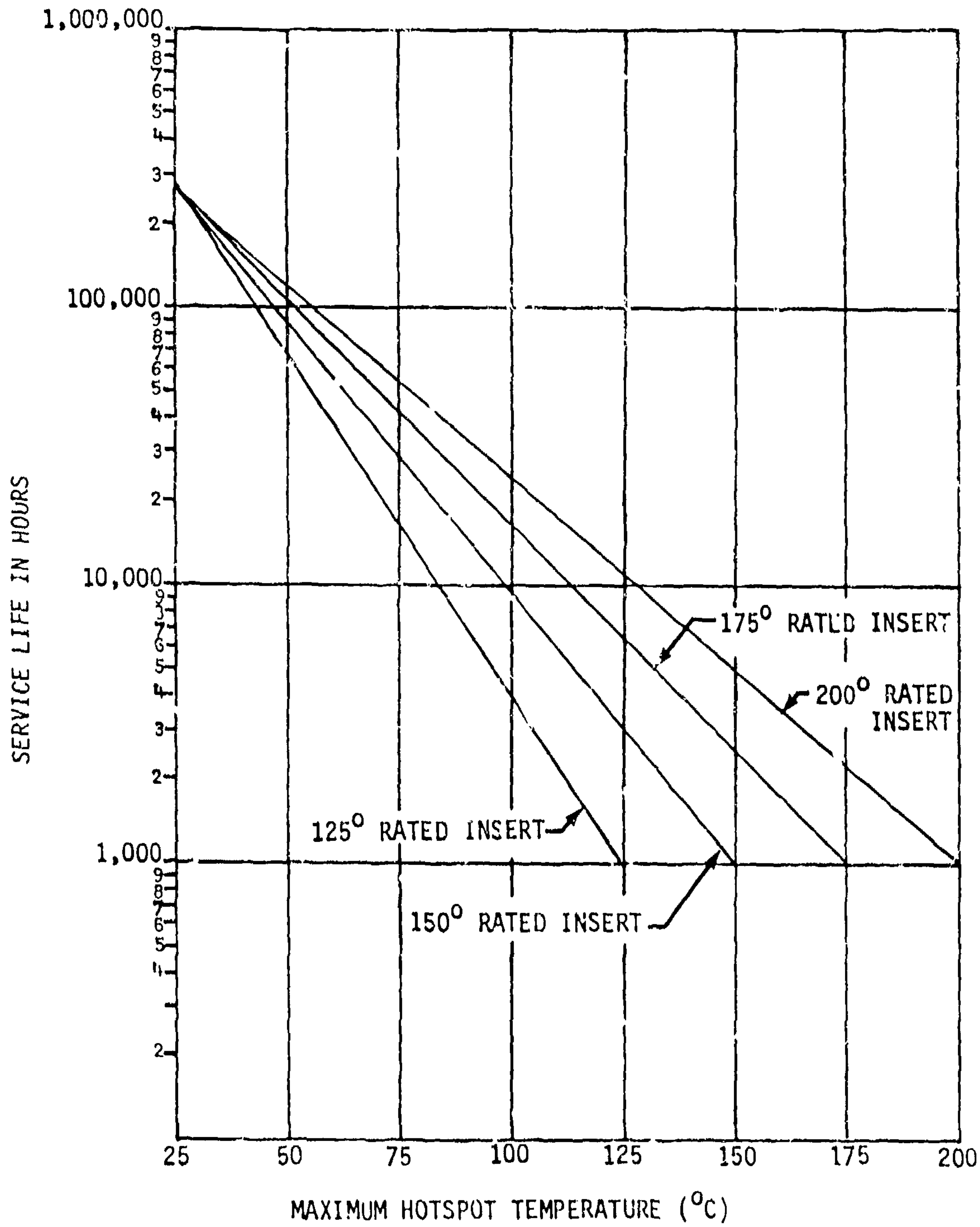


Figure 14-1: Service Life vs. Hotspot Temperature

14.3 Connector Derating Guidelines

Voltage, current, and temperature are the stress parameters that will be derated for connectors. The recommended derating for each Level is shown in Table 14-1. Also, the applied voltage must be derated for application in altitude as shown in Figure 14-2. The voltage derating of Table 14-1 and of Figure 14-2 is not additive. The lesser of the two voltages should be used.

The guidelines presented herein are applicable to all three classes of connectors, circular, printed wire board, and coaxial.

TABLE 14-1: RECOMMENDED CONNECTOR DERATING

PARAMETER	LEVEL I	LEVEL II	LEVEL III
Max Operating Voltage DC or AC Voltage	50% Rated Dielectric Withstanding Voltage	70% Rated Dielectric Withstanding Voltage	80% Rated Dielectric Withstanding Voltage
Max Operating Current	50% Rated Current	70% Rated Current	85% Rated Current
Max Insert Temperature (Ambient + Heating Factor) (1)	Max Rated Insert Temp less 50 degC	Max Rated Insert Temp less 25 degC	Max Rated Insert Temp less 20 degC

(1) Ambient temperature is that temperature in which the connector will operate. Heating factor is the temperature rise caused by power transmission through the contacts.

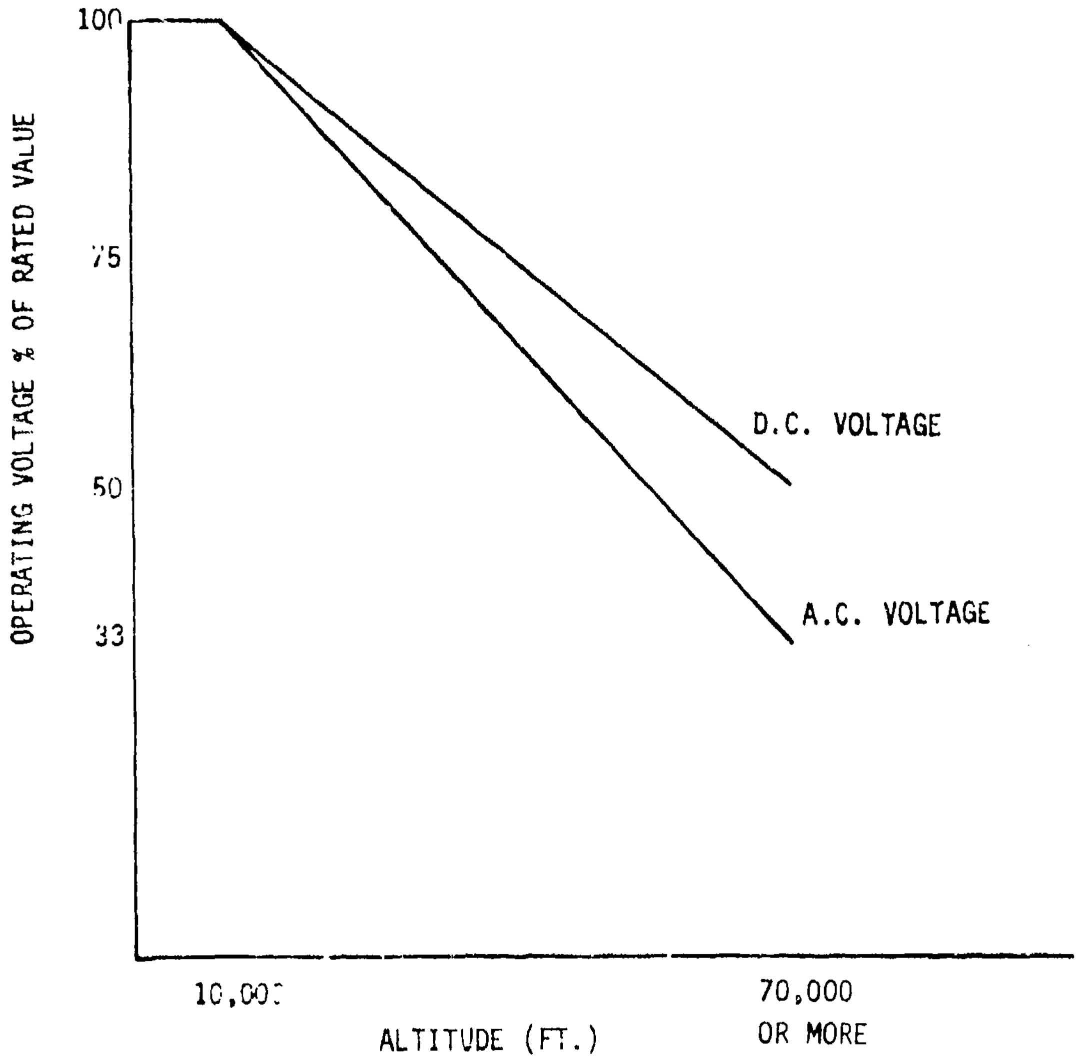


Figure 14-2: Voltage Derating For Altitude

SECTION 15

ROTATING DEVICES DERATING GUIDELINES

15.0 Introduction

The rotary device is an electromechanical device that will rotate in response to an electrical input or will produce an electrical output in response to rotation. Examples of this type of device are motors, generators, synchros, and time meters.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

SECTION 15.1

ELECTRICAL MOTOR DERATING GUIDELINES

15.1.1 General

The principal derating stress parameters for these devices are bearing loads, winding temperature, and the ambient temperature of operation.

The two major groups of electrical motors are alternating current (AC) devices and direct current (DC) devices.

AC motors are also divided into two major subgroups; synchronous and asynchronous devices. Synchronous devices run at a constant speed (as related to line frequency) regardless of load, while asynchronous devices run at a less than synchronous level (induction motor). The actual construction of the AC motor depends on the usage of the device, whether it be fractional horsepower or many horsepower. See Figure 15-1 for some examples. AC motors can be single phase or poly phase, but they are constructed and used in the same manner.

DC motors are widely used because the speed-torque relationship can be varied to many forms or for the regeneration application in either direction of rotation. They can be controlled smoothly down to zero rpms and immediately accelerated in the opposite direction. See Figure 15-1 for examples of DC motors.

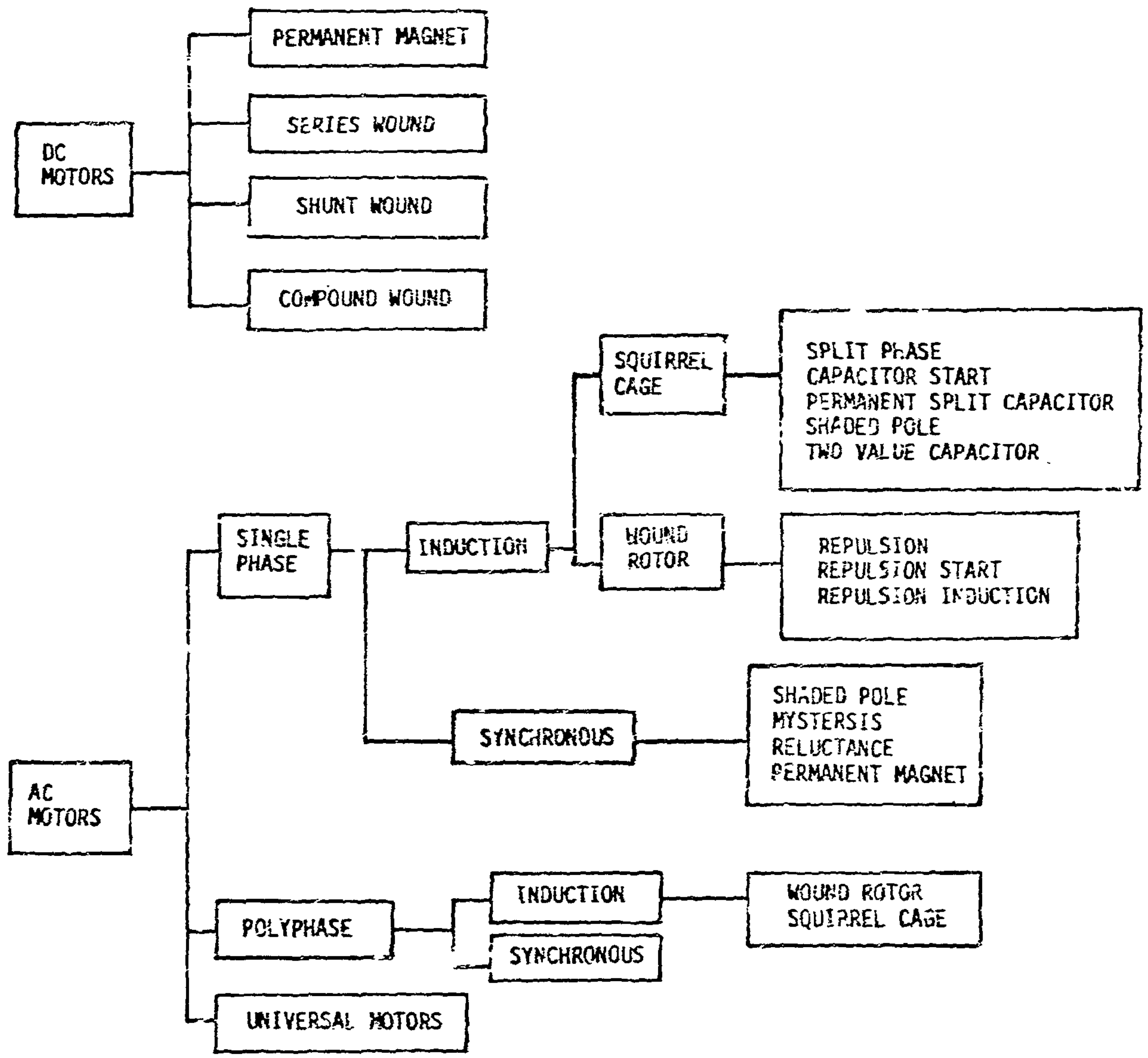


Figure 15-1: Motor Classifications

15.1.2 Application Guidelines

A. Temperature is the prime determining factor in motor life and efficiency. If the temperature of the device becomes too great, the windings insulation fails; if the temperature goes too low, the bearings fail. The preferred operating temperature range is between 0 degrees C and 30 degrees C.

B. Voltage must be maintained at the nominal level to achieve maximum efficiency and life span.

C. Moisture should be minimized to prevent corrosion, insulation degradation, and low resistance to electrical leakage.

D. Load and speed also affect efficiency and life span. Excessive loads or low speed can create high winding temperatures and excessive bearing loads.

15.1.3 Motor Derating Guidelines

The bearing load, winding temperature, and the ambient temperature of operation are the principal derating stress parameters for motors (AC and DC). The recommended derated values for all three Levels are listed below:

A. Temperature is the major stress factor for motors. Figure 15-2 graphs the relative effect of a change in the ambient temperature on the failure rate. Note that bearings fail at low temperatures while windings and insulation failure predominates at high temperature. Note that the failure rate plotted as a function of temperature (Figure 15-2) is relative since it will vary for different classes of motors and for various quality levels of motor construction. Note that the calculated failure rate (MIL-HDBK- 217C) plot shows a linear increase with temperaure (above 0 deg C). In actual practice, based upon typical chemical reaction rates, the failure rate probably increases faster than the calculation indicates. The maximum rated operating temperature should be derated as follows:

Level I; Max. rated less 40 deg C
Level II; Max. rated less 25 deg C
Level III; Max. rated less 15 deg C

Absolute upper temperature limits are not specified since this will vary with the class of insulation used in the device design. The lower temperature is limited to approximately 0 degrees C unless heating or precautions are taken due to bearing failures as shown in Figure 15-2.

B. Bearing load should be derated by 25% of rated load for Level I. For Levels II and III, the bearing load should be derated by 10% of the rated load.

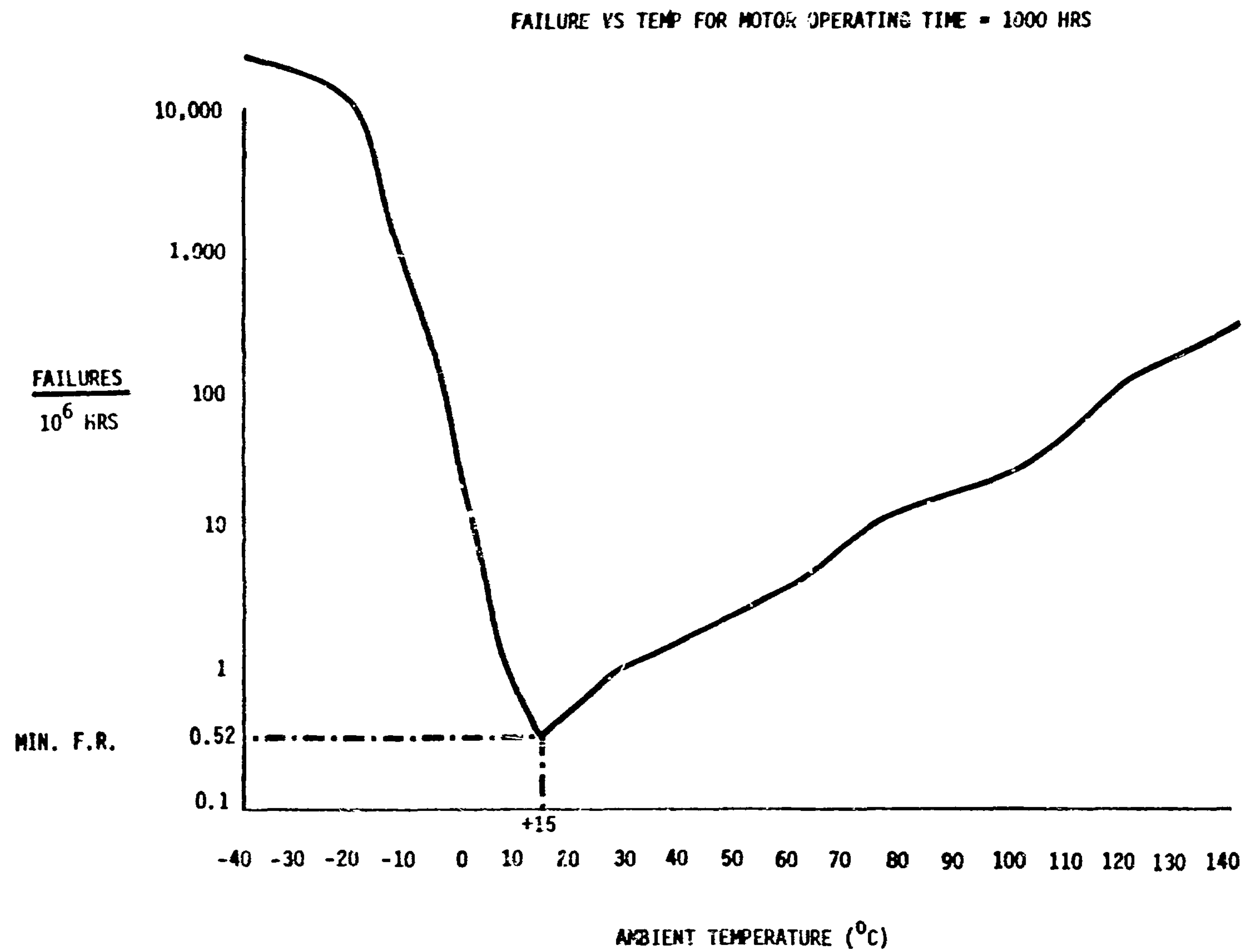


Figure 15-2: Effects of Temperature On Life Expectancy

SECTION 15.2

SYNCHROS AND RESOLVERS DERATING GUIDELINES

15.2.1 General

The principal derating stress parameters for synchros and resolvers are bearing loads and device winding temperature.

Synchros and resolvers are rotary devices that usually perform together to interpret mechanical angular displacement. The synchros measures physical angular position and transforms it into an electrical signal. The resolver converts an input electrical signal into an angular position displacement.

15.2.2 Application Guidelines

A. Temperature is the main factor in predicting the life span for synchros and resolvers. However, very little heat is internally generated and thus the ambient temperature is predominant. The preferred operating temperature range is between 0 degrees and 30 degrees C.

B. Voltage must be maintained at the nominal level to achieve maximum operation and life span.

C. Moisture should be minimized to prevent corrosion, insulation degradation, and low resistance electrical leakage.

D. Excessive load or speed are detrimental. These are normally low speed devices.

15.2.3 Synchros And Resolvers Derating Guidelines

The bearing load and winding temperature (or ambient temperature of operation) are the principal derating stress parameters for synchros and resolvers.

The bearing load should be derated by 25% of the rated load for Level I. For Level II and Level III, the bearing load should be derated by 10% of the rated load.

Figure 15-3 gives a relative effect of changes in the ambient temperature on the failure rate. At the lower ambient temperature, the failures are due to the bearings and at the higher ambient temperature, the failures are due to windings and insulation. The maximum rated temperature should be derated as follows:

Level I; Maximum Rated less 40 degrees C.
Level II; Maximum Rated less 25 degrees C.
Level III; Maximum Rated less 15 degrees C.

The absolute upper temperature limits are not specified since this will vary with the class of insulation used in the device design.

The lower operating temperature is to be limited to approximately 0 degrees C unless heating or other precautions are taken due to bearing failures shown in Figure 15-3.

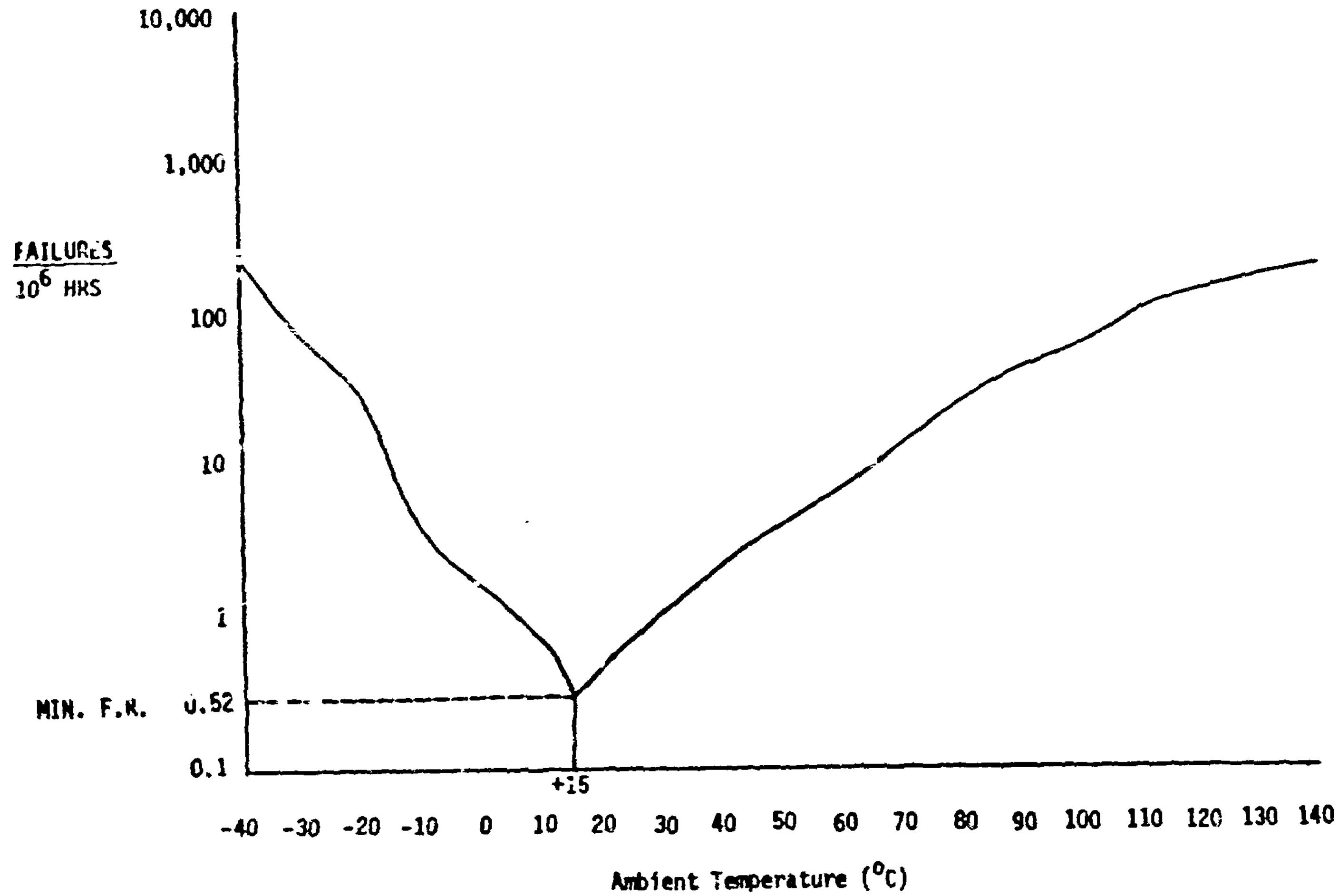


Figure 15-3: Effects of Temperature on Life Expectancy

SECTION 15.3

ELAPSED TIME METER DERATING GUIDELINES

15.3.1 General

The principal stress parameters for elapsed time meters is bearing temperature.

Most time meter devices use motor driven rotary components when the speed needs to be held constant. This is achieved either by the use of a governor (DC motor types) or by the use of a synchrous motor (AC motor types).

Most elapsed time meters provide a digital readout and may be resetable. Some time devices employ electronics or electrochemical operating principles. The load and speed of the mechanical elements is usually fixed, and therefore it can not be derated for improved reliability.

15.3.2 Application Guidelines

A. Temperature is the main factor in predicting the life span. If the temperature of the device becomes too great, the windings insulation fails; if the temperature goes too low, the bearings and other mechanical fuction characteristics can cause failures.

B. Voltage must be maintained at the nominal level to achieve maximum efficiency and life span.

C. Moisture should be minimized to prevent corrosion, insulation degradation, and low leakage resistance.

15.3.3 Elasped Time Meter Derating Guidelines (Motor Driven)

The bearing loads, winding temperature, and the ambient temperature of operation are the principal derating stress parameters for elapsed time meters. Time meter devices rely on the ability of the rotating motor to keep the speed constant. Therefore, the factors for maximum efficiency and life span are the same as for the motors. See Section 15.1.1 for the derating guidelines.

SECTION 16

LAMP DERATING GUIDELINES

This section will cover the derating for incandescent and gaseous (neon/argon) lamps.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

SECTION 16.1

INCANDESCENT LAMP DERATING GUIDELINES

16.1.1 General

The primary derating stress parameter for incandescent lamps is the applied voltage.

The incandescent lamp is made up of a filament sealed in an inert gas. This filament is normally made of tungsten and the operating temperature is between 1600 deg K and 3200 deg K for clear glass bulbs and between 1700 deg K and 6500 deg K for color coated bulbs. The application must protect against damages to the glass seal, mechanical stress (vibration or shock) to the filament and overheating of the filament.

The primary factor in predicting the life expectancy for incandescent lamps is the applied voltage. Figure 16-1 illustrates the relationship between the applied voltage, the life expectancy, and the light output. For example, operating the lamp at 94% of the rated design voltage will cause the candle power to be decreased by 16%, the current through the lamp to be decreased by 5%, and the average life to have multiplying factor of 2X or to be doubled. The life expectancy of an incandescent lamp is typically 1 to 2K hours, but may be shorter for high intensity types.

16.1.2 Application Guidelines

A. The lamp should not be exposed to extreme shock or vibration near the resonant frequency of the filament. If operated in this environment, probable damage to the filament will take place. Short filament lamps are not affected by shock or vibration as much as longer filament lamps.

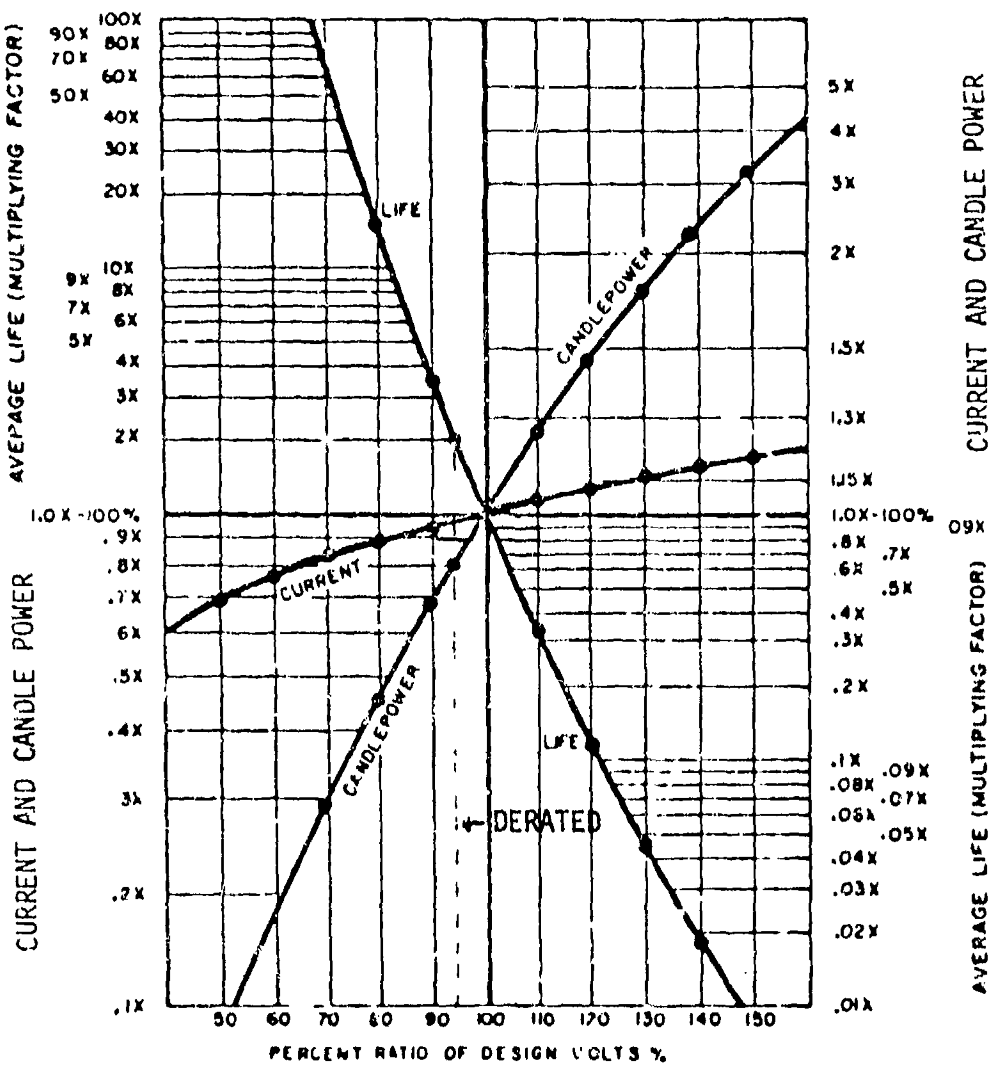


Figure 16-1: Percent Ratio of Design Volts Versus Average Life

B. If operating above 177 deg C, the solder on the base may soften and deform. Operating above 260 deg C, evolved gasses may attack the filament, or the glass envelope may soften or collapse.

C. Variation in applied voltage from the rated voltage level will significantly effect the light output and life expectancy (see Figure 16-1). The frequency of on/off cycling will also affect the life expectancy.

D. Incandescent lamps can be used with any color lens, however, the light output will be affected by the color of the lens (i.e. A light color lens, like yellow or straw, will have little affect on the light output. Where a green, red, or blue will decrease the light output.).

E. Temperature cycling is especially damaging to incandescent lamps. Also, the cold verses hot filament impedance ratio is typically 1:10 and causes high inrush current at turn-on. These life limiting factors can be minimized by application of stand-by power (1/2 voltage) and a series resistance (10% of the hot filament resistance).

F. The incandescent lamps will consume the most power for the given amount of light over the other lamp types.

G. DC operation of an incandescent lamp will greatly reduce life expectancy because the resistance in the lamp will increase with time and therefore cause a higher voltage drop across the lamp. There are other factors which may be encountered from DC operation, such as notching or uneven evaporation of the filament. These factors will also cause decreased life expectancy.

16.1.3 Incandescent Derating Guidelines

Voltage is the derating stress parameter for incandescent lamps. The recommended voltage level for all three Levels that will double the life expectancy with an acceptable drop in light output (16%) is 94% of the rated level, if operated in normal environments (i.e. no extreme shock, vibration or ambient temperature).

SECTION 16.2

NEON/ARGON LAMP DERATING GUIDELINES

16.2.1 General

The principal derating stress parameter for gaseous lamps are the current, the starting voltage, and maintaining voltage levels. Argon lamps will follow the same application and derating guidelines as neon lamps.

A neon lamp is a cold-cathode gas discharge type device and consists of two closely spaced electrodes in a gas filled glass envelope. The gas will ionize and glow when sufficient voltage is applied. The typical life expectancy for neon lamps is 10 to 15K hours.

The amount of light output from the lamp in directly proportioned to the current through the lamp. A resistor must be placed in series with the lamp to prevent instantaneous burnout from excessive current. With this series resistor and the combination of the sustaining voltage and lamp characteristics, the current level through the lamp can be determined. Therefore, the light output can also be determined.

The primary factors in predicting the life expectancy of a neon lamp are the current through the lamp and the starting voltage. Operation above rated current and starting voltage will cause a decrease in life expectancy.

16.2.2 Application Guidelines

A. The starting voltage, needed to start ionization, is normally 20% higher than the sustaining voltage level. Consult the appropriate specification for exact values.

B. Neon lamps can be operated in environments of shock and vibration.

C. Neon lamps should not be used in environments where the ambient temperature exceeds 150 deg C.

D. A variation from the rated current level will cause significant changes in the life expectancy and light output (i.e. an increase the current will increase the brightness and decrease the life expectancy). The current through the lamp, which is directly proportional to the required series resistor, is normally between 0.1mA and 5mA.

E. Dark colored lens (like green or blue) should not be used with neon lamps because the light output will be quite low.

F. The required starting and sustaining voltage will increase over the life of the part. A typical increase is about 5 to 10% from the initial values. This change may vary for different parts (consult the appropriate specification).

16.2.3 Neon Lamp Derating Guidelines

Current through the lamp is the principal derating stress parameter. The recommended current level for all three Levels is 94% of the rated current. With a derating of 94%, the life expectancy will double and the output will only be decreased by 16%.

The starting and sustaining voltage levels are lamp characteristics and cannot be derated. The starting voltage level can be increased for a quicker response time, but the life expectancy will be decreased.

SECTION 17

CIRCUIT BREAKER DERATING GUIDELINES

17.1 General

The principal derating parameter for circuit breakers is the current through the element.

There are three main types of circuit breakers that will be considered in this section. They are thermal, magnetic, and thermal compensated (thermal-magnetic). The type of circuit breaker is dependent on the following: wire protection, load requirements, interruption requirements, and environmental considerations. The trip characteristics will change slightly between operating with 60 Hz AC and DC currents.

The thermal circuit breaker responds only to temperature changes in the armature. The armature is normally bimetal and in series with the circuit it is to protect. The temperature change in the armature is generated by I^2R losses. The heat will cause the armature to bend, which causes it to unlatch (for a typical trip curve for this type, see Figure 17-1A). This type is normally unsealed.

Magnetic circuit breakers are made up of a solenoid coil with a dashpot time-delay element. The operation is dependent upon the magnetic flux generated from the current in the coil. The solenoid coil is wound such that the magnetic flux generated by rated current or less will not cause the spring armature to open. An increase in magnetic flux (due to an increase above the rated current) will cause the armature to pull open (for a typical trip curve for this type, see Figure 17-1B).

A thermal compensated circuit breaker operates in the same manner as thermal circuit breakers with the exception of the instantaneous tripping point. At the instantaneous tripping point, the magnetic feature either takes over to help it remain closed or will help the armature to open (for a typical trip curve for this type, see Figure 17-1C). This type of circuit breaker should be use in environments where the ambient temperature may vary.

For detailed design and application guidelines, consult MIL-STD-1498.

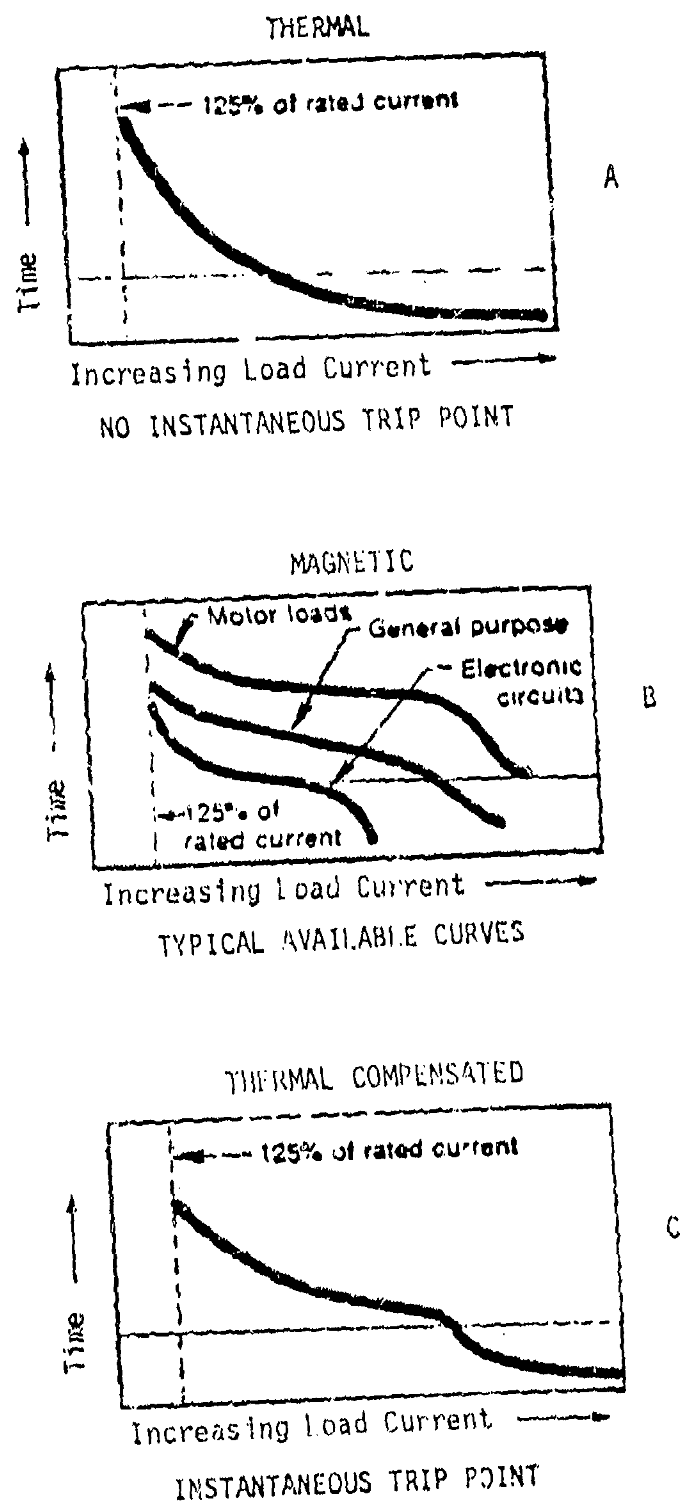


Figure 17-1: Circuit Breaker Types

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

17.2 Application Guidelines

A. The power capacity of the generating source is limited by the transformer and line impedances and must be considered.

B. The interrupt capacity of the circuit breaker must not be exceeded. The interrupting capacity is the maximum short circuit current that the circuit breaker can interrupt without failure occurring (normally 1000 A to 10000 A, consult the appropriate specification for precise values).

C. Thermal and thermal compensated relays do not have an instantaneous trip time. Instantaneous trip time is normally 15 msec or less (this value may vary between breakers, consult the appropriate specification).

D. A time delay trip characteristics should be used when the load may cause high inrush (high starting loads) currents.

E. Over the life of the breaker, the maximum ultimate trip current will increase by 10% and the minimum ultimate trip current will decrease by 10% (see Figure 17-2 for this example).

F. Environmentally sealed circuit breakers should be used when the application of the circuit breaker is in an environment where particles or gasses may cause failures.

17.3 Circuit Breaker Derating Guidelines

Current through a circuit breaker is the principal derating stress parameter. The recommended current derating for Levels I and II is 75% to 80% of the rated level and for Level III, use 90% of the rated level. At these levels, the ability to protect the circuit from a large overload is still available.

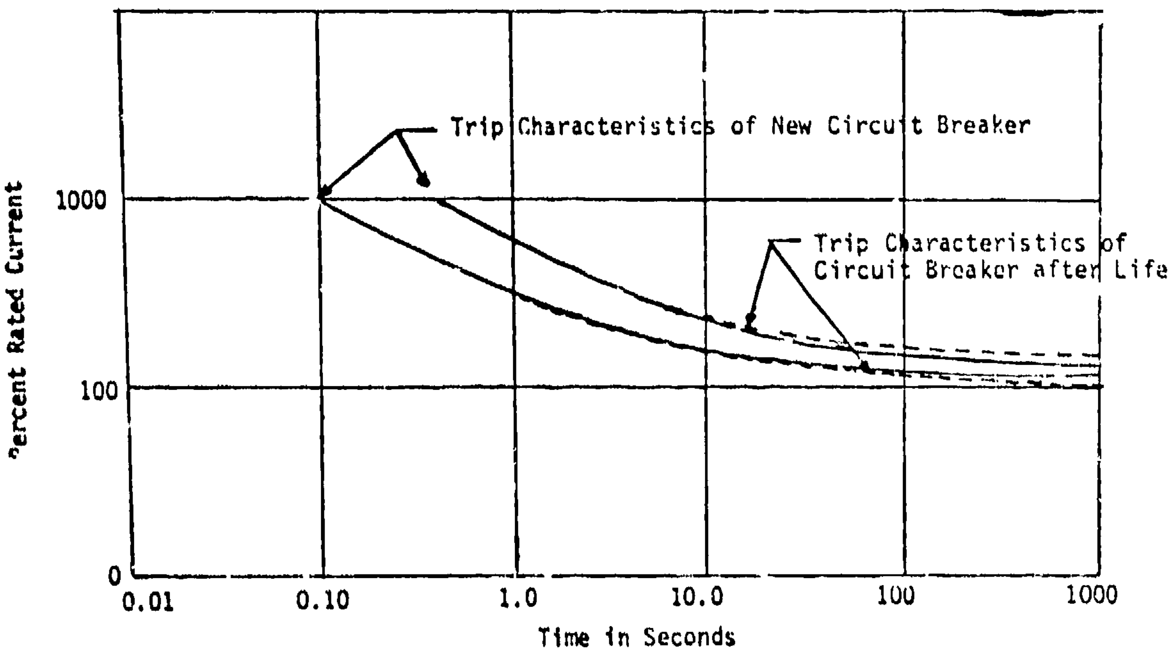


Figure 17-2: Circuit Breaker Trip Characteristics

SECTION 18

FUSE DERATING GUIDELINES

18.1 General

The principal derating stress parameter for fuses is current. The four basic types of fuses that are covered in this section are normal response, time-delay, fast-acting, and current limiting.

The normal-response fuses may or may not be current limiting. It has a fusing time which is normally faster than the trip time of a circuit breaker. Typically, the fusing time is 0 to 5 seconds at an overload of 200% or 0 to 0.1 seconds at an overload of 300%.

The time-delay fuse also may or may not be current limiting. It functions by the use of two elements: a thermal cutout with a high-time-lag characteristics and a short-circuit element. The thermal cutout operates under normal transient overloads and blows on continuous light overloads. The short-circuit elements will blow under heavy overloads and short-circuit conditions. The time-delay fuses can be used in conditions where a motor starting load or switching transients may cause normal-response fuses to blow.

The fast-acting fuses are designed to blow extremely fast under short-circuit conditions. The normal response time is a few msec for large overloads. These fuses may or may not be current-limiting. The fast-acting fuses can be used to provide some protection in semiconductor circuitry because of their fast response time to an overload.

The current-limiting fuses have the ability to limit the instantaneous peak current of a short circuit. It will not totally eliminate the effects of a short circuit, but it will lower the current to values much less than would exist if the fuse were not in the circuit. This type of fuse under a given short-circuit condition will clear the fault within one-half cycle under ac operation between 50 and 400Hz.

The selected derating levels in this section are based upon review of limited historical applications and/or upon engineering judgement to balance the increased reliability against the relative constraints placed upon design freedom. The device complexity and/or limited analytical relationship between applied stress and its reliability effects prevents precise selection of appropriate derating levels. Some flexability should be used in application of specific values of derating. In particular, one derated parameter can be traded off against another but the relief should not be granted all the way to the next level (i.e. Level I to Level II).

18.2 Application Guidelines

A. Current limiting fuses should not be used at frequencies higher than 400Hz if single cycle protection is desired.

B. The circuit voltage should not exceed the voltage rating of the fuse to protect from arcing.

C. Changes in ambient temperature will cause the rating of the fuse to change. For typical time-delay and normal response fuses, see Figure 18-1 and Figure 18-2, respectively.

D. Extreme caution should be observed when using fuses in a space applications (note: the characteristics may change in this environment).

E. Extreme shock or vibration may cause premature opening of fuses, consult the appropriate Spec for limits.

18.3 Fuse Derating Guidelines

Current is the derating stress parameter for fuses. The recommended current derating for fuses is 50% of the rated value for Levels I and II and 70% of the rated value for Level III. There is an additional derating of 0.5%/degC recommended for an increase in the ambient temperature above 25 deg C. It is also recommended that voltage rating of the fuse be derated 20-40% for fuse current ratings of 1/2 A or less.

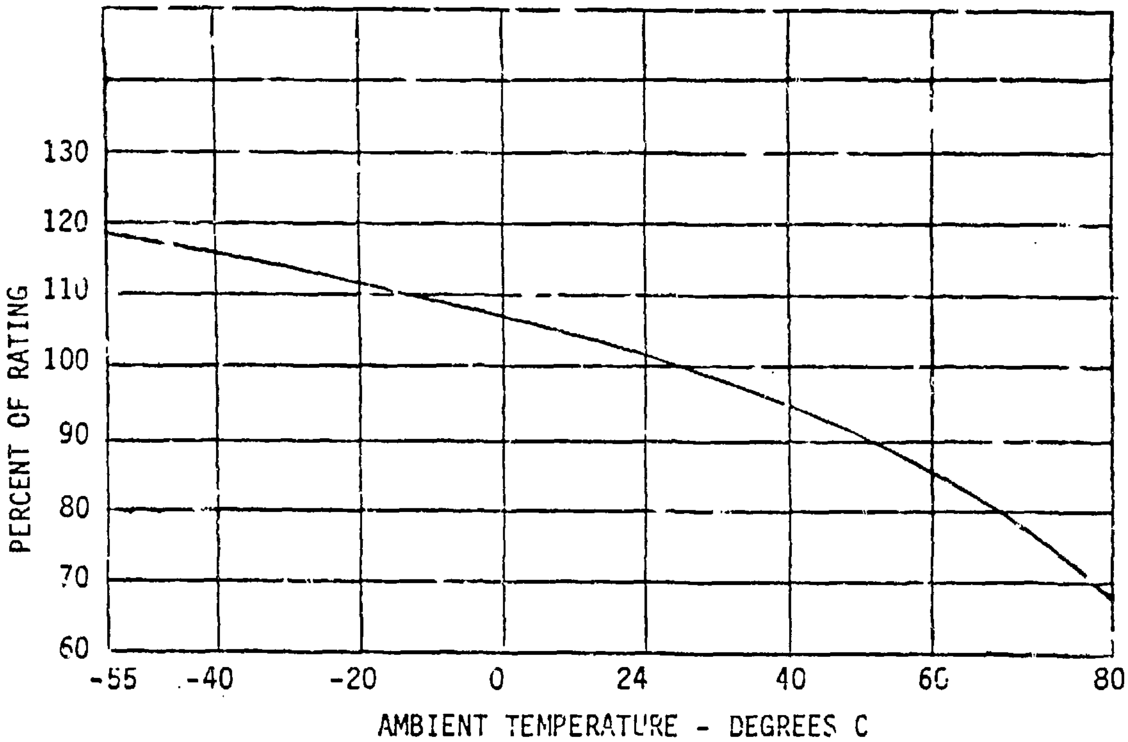


Figure 18-1: Effect of Ambient Temperature on the Current Carrying Capacity of Time-Delay Fuses

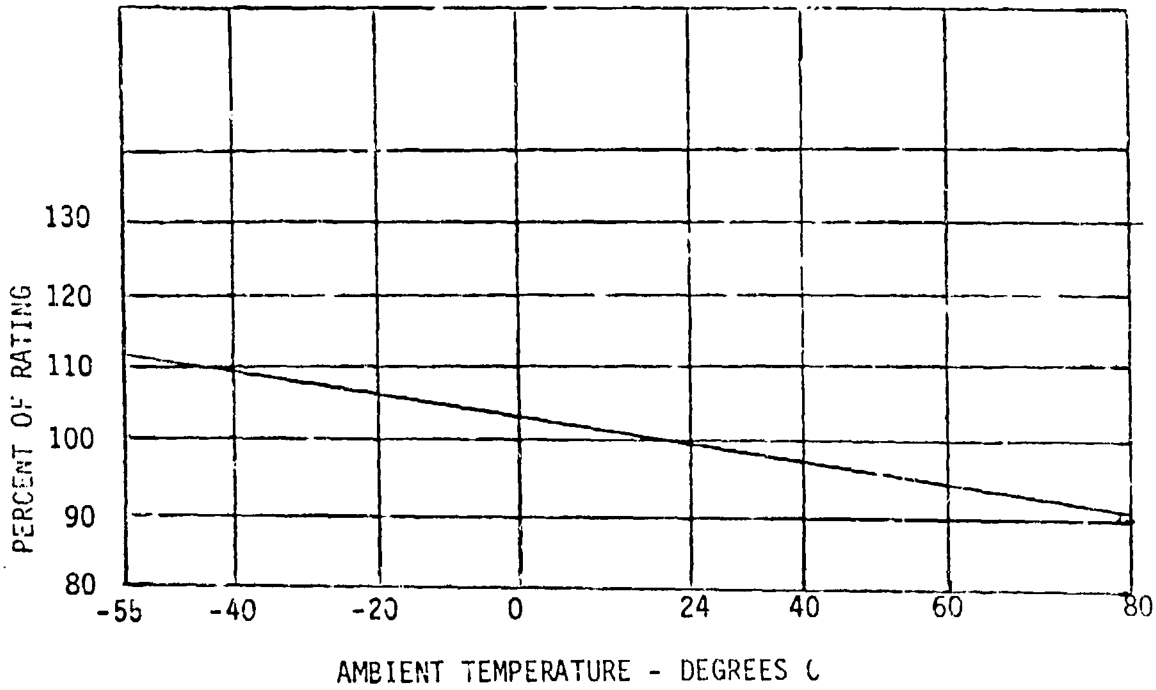


Figure 18-2: EFFECT OF AMBIENT TEMPERATURE ON THE CURRENT CARRYING CAPACITY OF NORMAL-RESPONSE FUSES

SECTION 19

CRYSTAL DERATING GUIDELINES

19.1 General

The crystal unit is generally made up of a quartz crystal mounted in a metallic holder. The size of the crystal is inversely proportional to the frequency of operation. The crystal unit may also contain a heating element which will help stabilize the crystal temperature.

The five important parameters of the crystal unit are frequency range, mode of oscillation, temperature range, load capacitance, and driving level. The principal stress parameters are the driving power and the temperature of operation. The rated power must be applied to achieve the rated frequency and output power.

MIL-C-3098 and MIL-STD-683 specifies military crystal units for frequencies of operation from 16 KHz to 125 MHz and operating temperature ranges from -55 deg C to +105 deg C and driving powers varying from 0.1 to 10.0 mW.

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their reliability contribution is well below that of the total system).

19.2 Application Guidelines

A. The frequency and frequency stability of a crystal is sensistive to high levels of moisture and temperature.

B. Environments of shock and vibration can damage the fragile crystal unit and lower the frequency of the larger types. Consult the appropiate specification for the recommended safe limits of shock and vibration.

C. While not normally considered electrostatic sensitive devices, most crystal units are susceptable to damage for electrostatic discharges greater than 4000 volts. This level of electrostatic voltage can be induced by improper handling. The damage often results in operational degradation rather than catastrophic failure.

D. With excessive drive voltage applied, crystal fractures can occur due to mechanical forces exceeding the elastic limits.

E. The input drive power tolerance (typically +/-1.0 %) can be tightened to assure frequency stability.

19.3 Crystal Derating Guidelines

The recommended driving power for most crystal units cannot be derated since the rated frequency may not be obtainable. Consult the appropiate specification or manufacturer's literature for possible exceptions.

The operating temperature of the crystal must be maintained between the maximum and minimum limits in order to achieve the rated frequency.

SECTION 20

TUBE DERATING GUIDELINES

20.1 Introduction

This section covers cathode ray tubes and microwave tubes of the following types; traveling wave tubes, magnetrons, and klystrons.

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their reliability contribution is well below that of the total system).

SECTION 20.2

CATHODE RAY TUBE DERATING GUIDELINES

The design of systems using cathode ray tubes is highly dependent on human factors such as visibility, size, color, readability,...,etc. Because of the specialized nature of the design field and of the data, it is not practical to establish generalized application and derating guidelines. However, with vacuum tube devices, the bulb, and the cathode temperatures are important for reliability. Consult specifications and manufacturer's literature for the optimum conditions for minimum failure rates. Also, consideration can be given to maintioning cathode temperature at a reduced temperate during "off" conditions. This will reduce effects of cold in-rush current and thermal cycling. Most failures are associated with cathode failure due to thermal effects or gun assembly failure due to mechanical stresses from vibration or shock.

SECTION 20.3

MICROWAVE TUBE DERATING GUIDELINES

20.3.1 General

Microwave tubes can be divided into two main classifications: linear beam types which include traveling wave and klystron tubes and crossed-field types which includes magnetrons.

In linear beam tubes, a magnetic field with coincident axis to the electron beam holds the beam together as it travels the length of the tube. Electrons receive potential energy from the dc beam voltage before they arrive in the microwave region. In the microwave region the electrons are accelerated or decelerated by the microwave field and then bunched as they drift. The bunched electrons give up kinetic energy to the microwave fields and induce current in the output structure.

In the crossed-field tubes, such as magnetrons, the dc magnetic field and the dc electric field are perpendicular to each other. The magnetic field has a direct part in the RF interaction process. The electrons emitted by the cathode are accelerated by the electric field. The higher the electron velocity the more their paths are bent by the magnetic field. With a RF field applied to the anode, electrons entering the retarding field are decelerated and give up energy to the RF field and the anode circuit. Those electrons entering during the accelerating field receive energy from the RF field and are returned back towards the cathode.

20.3.2 Microwave Tube Derating Guidelines

The design usage of microwave tubes is highly specialized and there is insufficient data to define generalized derating guidelines for all conditions. Use the failure rate prediction methods of MIL-HDBK-217C to optimize design and usage for minimum failure rate. The following recommendations are guidelines only and are not necessarily optimum for all devices under all conditions (see Table 20-1).

TABLE 20-1: MICROWAVE TUBE DERATING

PARAMETER	RECOMMENDED MAXIMUM
TEMPERATURE	20 deg C LESS THAN MAXIMUM RATING
POWER OUTPUT	80% OF MAXIMUM RATING
REFLECTED POWER	50% OF MAXIMUM RATING
DUTY CYCLE	75% OF MAXIMUM RATING

SECTION 21

LASER DERATING GUIDELINES

21.1 General

There are six major types of lasers in general usage which have failure rate prediction models defined by MIL-HDBK-217C.

A. Helium/Neon
B. Argon Ion
C. CO_2 Sealed
D. CO_2 Flowing
E. Solid State, Nd: YAG Rod
F. Solid State, Ruby Rod

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their raliability contribution is well below that of the total system).

21.2 Laser Application Guidelines and Derating

Laser system design is a specialized field where the operating parameters of each type are unique and interdependent. Limiting parameters by generalized derating is not practical or advisable. Develop designs for minimum predicted failure rate using the failure rate models of MIL-HDBK-217C and follow manufacturer's recommendations for operating parameters and conditions not defined by the failure rate models.

SECTION 22

VIBRATOR DERATING GUIDELINES

22.1 General

Vibrators are not recommended for use in electrical circuits because of limited cycling life. If a vibrator device is needed, the use of a solid state device like a high power switching transistor, is recommended.

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their reliability contribution is well below that of the total system).

22.2 Vibrator Derating Guidelines

The current through the contacts of the vibrator is the principal derating stress parameter. The recommended current derating for Levels I, II, and III are listed in Table 22-1. A reduction in the frequency of operation, if possible, will extend the life of the vibrator.

TABLE 22-1: VIBRATOR CURRENT DERATING

	LEVEL I	LEVEL II	LEVEL III
RESISTIVE LOAD	50% OF RATED RESISTIVE	75% OF RATED RESISTIVE	90% OF RATED RESISTIVE
CAPACITIVE LOAD (MAXIMUM INRUSH CURRENT)	50% OF RATED RESISTIVE	75% OF RATED RESISTIVE	90% OF RATED RESISTIVE
INDUCTIVE LOAD (1)	50% OF RATED INDUCTIVE OR 35% OF RATED RESISTIVE	75% OF RATED INDUCTIVE OR 40% OF RATED RESISTIVE	90% OF RATED INDUCTIVE OR 75% OF RATED RESISTIVE

(1) Use derated resistive ratings when inductive ratings are not given.

SECTION 23

SURFACE WAVE ACOUSTICAL DEVICE DERATING GUIDELINES

23.1 General

Surface wave acoustical (SAW) devices are designed as oscillators, filters, and delay lines operating at microwave frequencies to 1.0 GHz. Surface waves, known as Raleigh waves, are traveling disturbances on the surface of solids with the motion of the atoms mostly confined to a depth of a surface wavelength. Physically SAW devices consist of a piezoelectric crystal substrate over which the Raleigh waves propagate. The propagation velocity is much less than electronic propagation (and less than the crystal wave velocity) and thus signal delay and filtering can be achieved. The input and output electronic interface is achieved with surface deposited interdigitated conductors which creates crystal distortion with applied electrical potential. The crystal response is sensitive to temperature, surface condition, and the mounting characteristics. Since it is temperature stable over the full military range to one part in ten thousand, the most commonly used dielectric is Y-cut quartz crystal.

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their reliability contribution is well below that of the total system).

23.2 Application Guidelines

These devices are sensitive to surface conditions therefore it requires integrity of this hermetic package, changes in the surface environments such as gas, moisture, dirt, etc. all will degrade performance. Also the crystal mounting characteristics must not change from the original design. These sensitivities require design attention to minimize original stress to the package and mounting. Temperature cycling and mechanical stress should be minimized. Also exposure to excessive temperature over long periods will permanently degrade the crystal characteristics.

23.3 Saw Derating Guidelines

Derate input power by +10 dBm for devices operating above 100 MHz and +20 dBm for devices operating below 100 MHz. The design should not subject the SAW devices to the rated maximum of shock, vibration and temperature cycling.

SECTION 24

FIBER OPTIC COMPONENTS DERATING GUIDELINES

24.1 Introduction

The fiber optic components considered for derating criteria consist of the four major classes and their subclasses listed in Table 24-1. Particular items not considered, primarily because they are still in the developmental stage and are not mature enough to be classed as off the shelf components, include couplers, splitters, repeaters, splices and non-silicon detectors.

There are no prior established derating criteria for the four classes of fiber optic components. However, the major environmental and operating stress factors are known. Failure rates for these components are being developed.

The selected derating level in this section is based upon engineering judgement by consideration of the device construction and materials. Due either to the relative recent technology development and/or the manner in which the device is integrated into its surrounding system, no derating history is available. In many cases, due to the operative nature of the devices, derating itself is inappropriate. However, where practical, the design should strive to give the maximum stress margin (below maximum rated) practical when considered against the design difficulties thus incurred. Some analysis should be applied to assess the design difficulties thus incurred. These device types are generally low population devices in systems and thus have limited reliability contribution (if their reliability contribution is well below that of the total system).

SECTION 24.2

FIBER OPTIC LIGHT SOURCES DERATING GUIDELINES

24.2.1 General

The two major source types, light emitting diodes (LEDs) and injection laser diodes (ILDs), share most of the failure mechanisms and stress factors. Application choice of the two device types is dependent on two parameters: optical power and bandwidth. ILDs are capable of coupled power to the fiber in the range of a few milliwatts and bandwidths in the low gigahertz region while LEDs are generally capable of only a few hundred microwatts of coupled power and a bandwidth in the order of a few hundred megahertz.

TABLE 24-1: FIBER OPTIC COMPONENT CLASSES

CLASS	SUB CLASS
SOURCES	Injection Laser Diodes (ILD's) Light Emitting Diodes (LED's)
DECTECTORS	Pin Diodes Avalanche Photo Diodes
CABLES	One Single Fiber Multiple Single Fiber
CONNECTORS	Single Contact Multiple Contact

24.2.2 Application Guidelines

24.2.2.1 Electrical Factors

A. Power supplies for ILDs must be carefully designed to completely eliminate over current pulses which can cause catastrophic failure by facet damage.

B. Output power should be given a 3dB margin to account for gradual degradation of the device.

24.2.2.2 Mechanical Factors

A. Gradual degradation of optical power is caused by increased concentration of non radiative recombination centers and by point defects with energy levels deep in the forbidden gap. The rate of degradation is reduced only by reduction of the device temperature.

B. Mechanical stress, such as thermal or mechanical shock and vibration cause dark line defects (crystal lattice defects) to grow. These defects will reduce available output power. Stress screening can be used to eliminate devices with these defects.

C. Excess optical power of ILDs will damage facets and will destroy the device. Note that optical power output is strongly temperature dependent and must be monitored and controlled to assure safe operation. (See Figure 24-1).

24.2.3 Derating Guidelines

Primary stress factors for optical sources are temperature (for both ILDs and LEDs), voltage-current power dissipation for (LEDs and optical power dissipation for ILDs). The following parameters should be considered for derating:

A. Normalized failure rate versus temperature curves are given in Figure 24-2 for GaAs devices with 0.7Ev activation energy and for silicon devices with 1.1Ev activation energy.

B. A current derating curve for typical LED sources is included in Figure 24-3. It is based upon a maximum junction temperatures of Figure 24-2.

C. For ILDs, in addition to the maximum junction temperature limits of Figure 24-2 , the peak optical power output should be limited to 50% of rating.

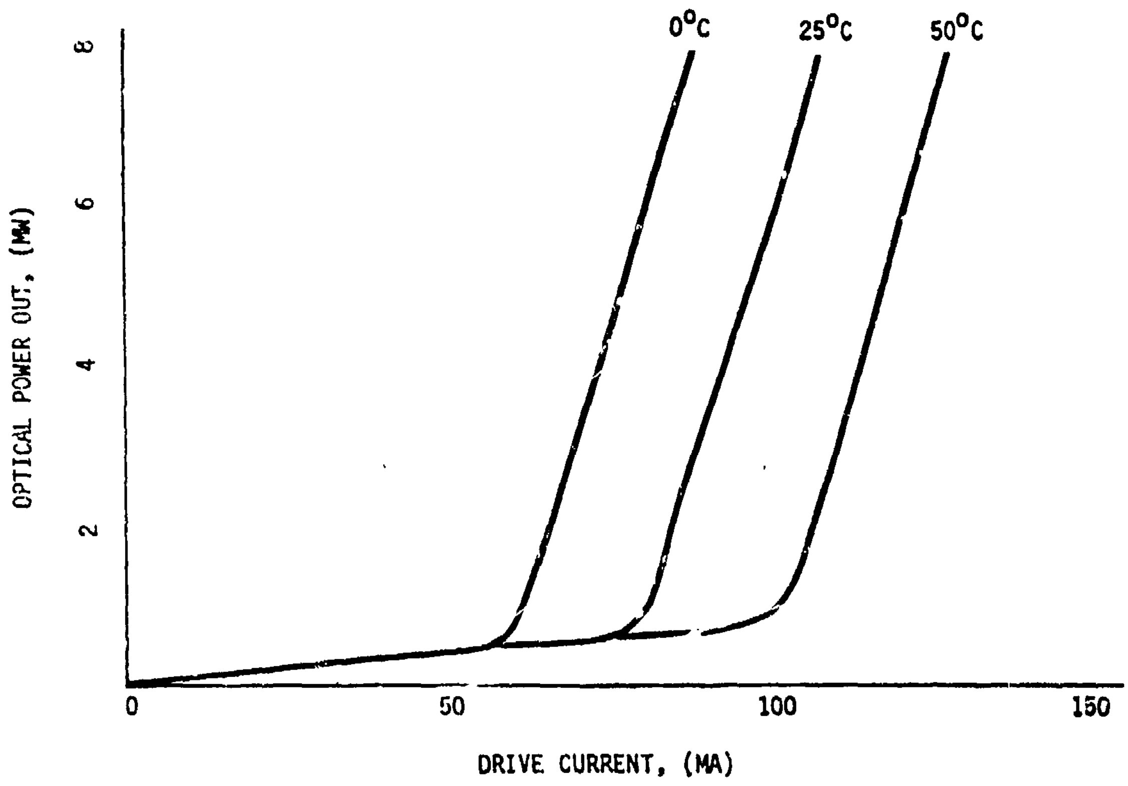


Figure 24-1: Typical ILD Operating Characteristics

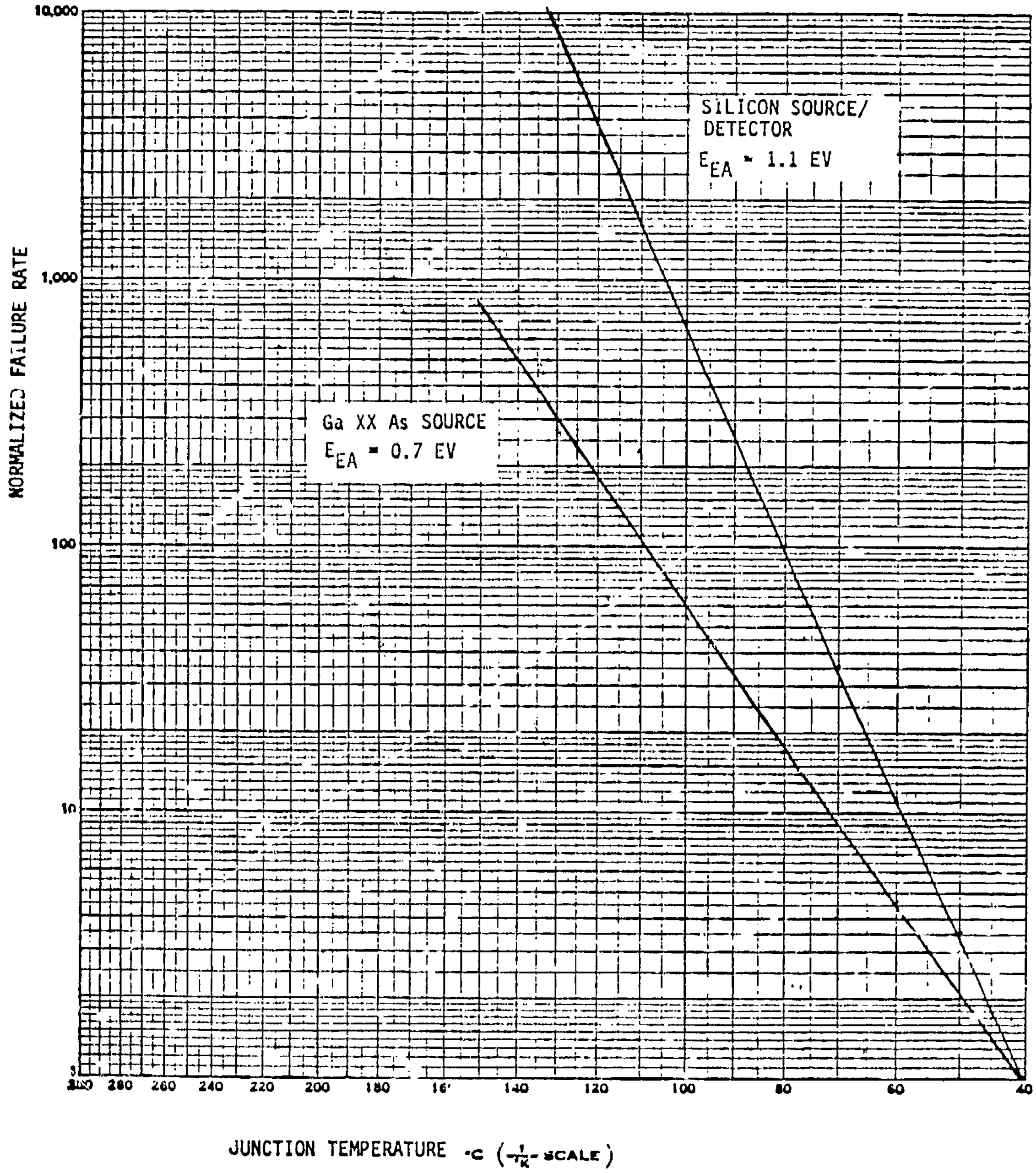


Figure 24-2: Activation Energies for Temperature Dependent Failure Mechanisms

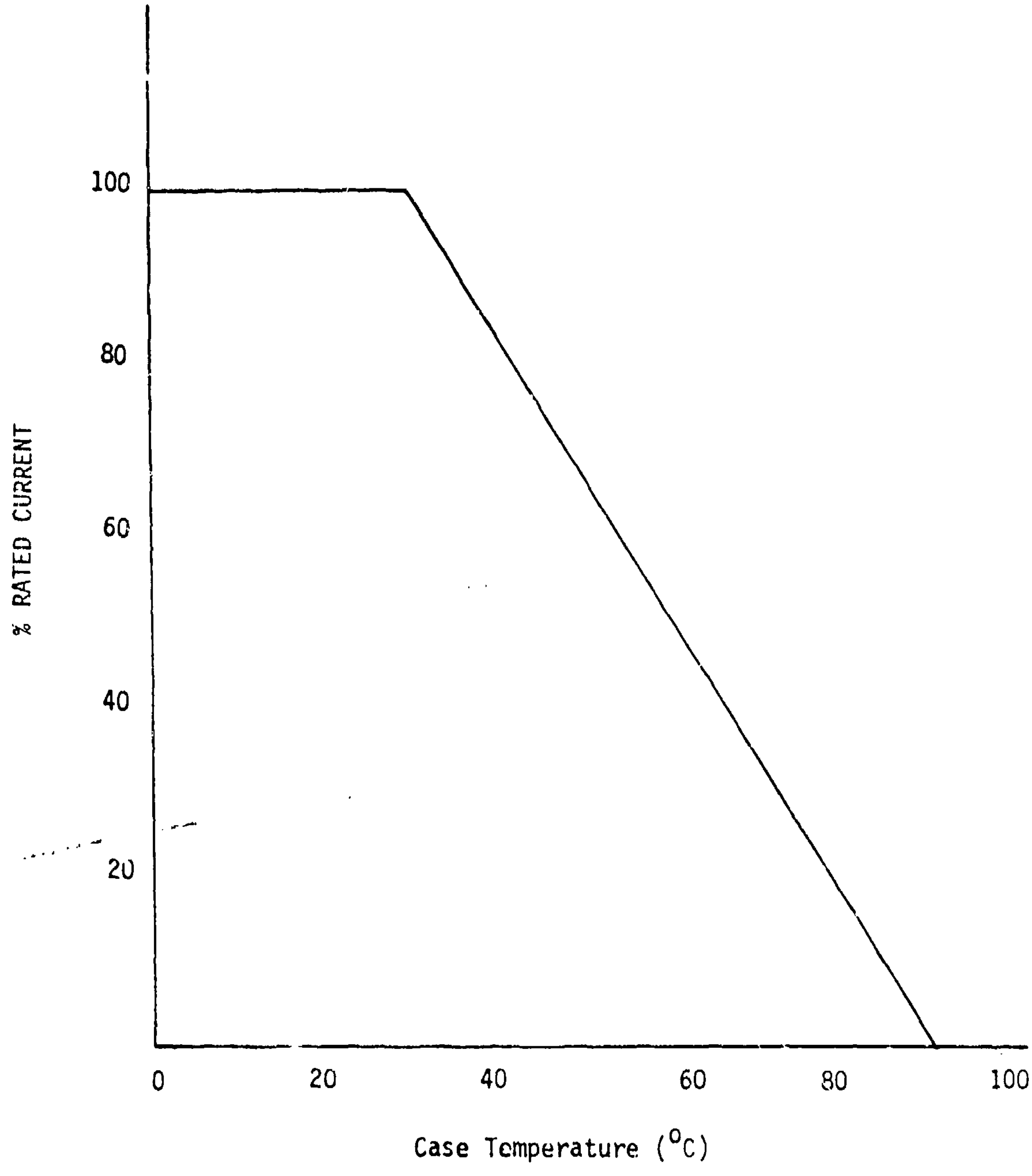


Figure 24-3: Ga As Led Source

SECTION 24.3

FIBER OPTIC DETECTOR DERATING GUIDELINES

24.3.1 General

The two major detector types used in present design are silicon diodes of PIN construction and APD (Avalanche Photo Diode) construction. PIN diodes are normally operated at a low reverse voltage (5V - 50V), whereas APDs are normally operated at high reverse voltage (200V to 400V). APDs are more subject to surface contamination and electrolytic corrosion.

Both detector types operate over the same wave length region (350-1100nM). The major difference in the two devices is that the APD is operated in the avalanche mode and has a net photo current gain. This gain may be up to 100 times that of a PIN diode whose output is in the range of 0.4 Amp per watt of incident optical power. The speed of APD is several times that of the PIN diode and extends into the low gigahertz region.

24.3.2 Application Guidelines

24.3.2.1 Electrical Factors

A. Gain of APDs should be derated by 3dB to account for gradual efficiency degradation and shifts in the operating point.

B. Reduction of junction temperature will reduce failure rate as shown in Figure 24-2.

C. Operation of PIN diodes at 60% of rated voltage (for all these criticality categories) will reduce stress and still provide an adequate drift field to assure low junction capacitance and quick turn off times.

24.3.2.2 Mechanical Factors

A. Lattice defects, and in the case of APDs, surface contamination are failure mechanisms which reduces the life span. The expected failure activation energy is estimated at 1.1Ev. The plot of failure rate versus case temperature for this energy is plotted in Figure 24-4.

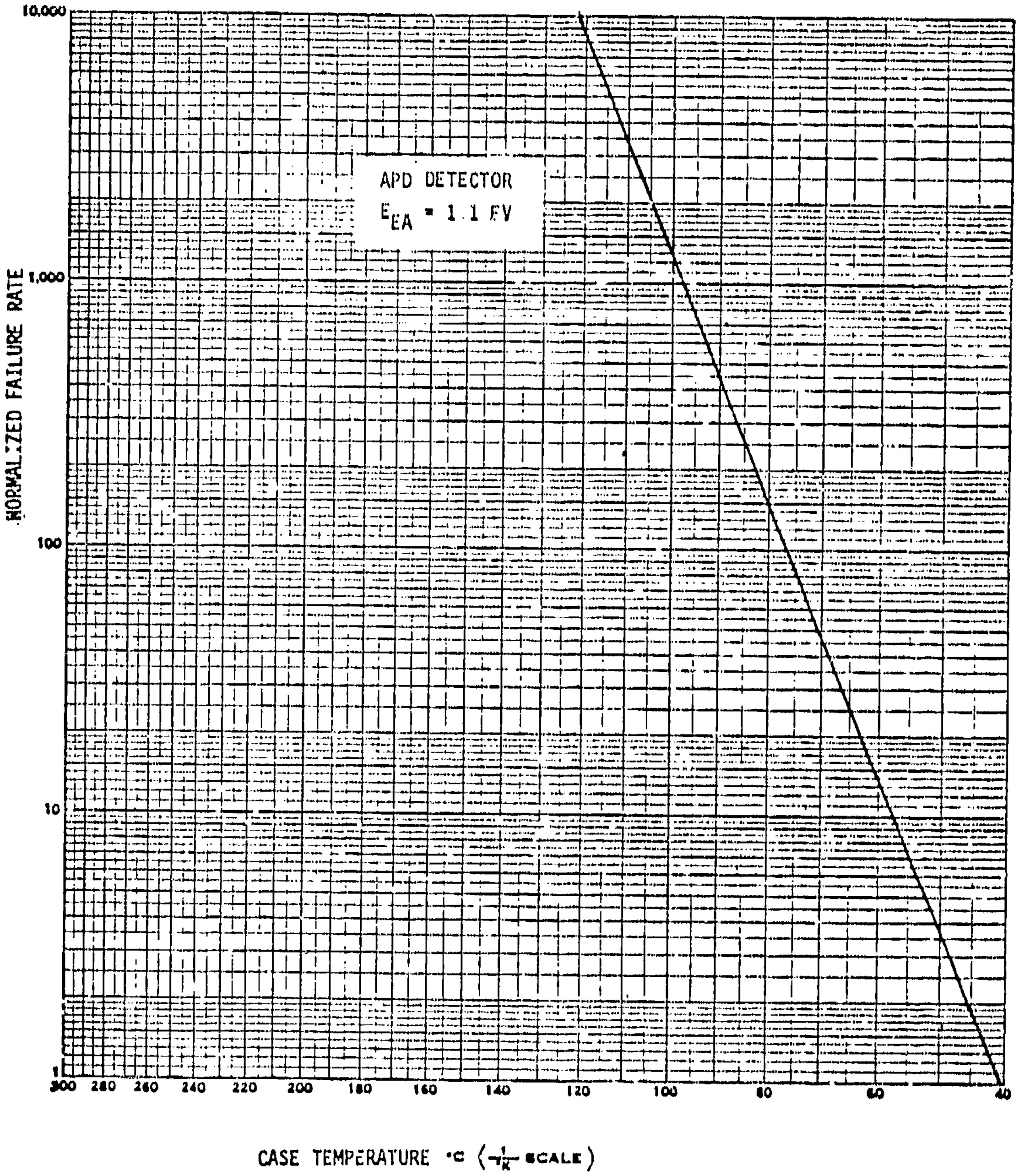


Figure 24-4: Activation Energy for Case Temperature vs Failure Rate

24.3.3 Derating Guidelines

A. Power derating is not necessary because internal dissipation is not significant.

B. Reduce junction temperature per Figures 24-2. Reduce PIN diode reverse voltage to 60% of rating for all three Levels. Reverse voltage cannot be derated for the APD as the voltage is used to set or adjust device gain and is typically set set slightly below the breakdown voltage.

SECTION 24.4

FIBER OPTIC CABLES/FIBERS DERATING GUIDELINES

24.4.1 General

The two primary cable configurations are the single fiber cable and a cable made up of a group of separately sheathed single fibers, (each fiber being a separate data channel). Two fiber types used in each of the cable configurations are the glass clad glass core type and the plastic clad glass core type. The second type is commonly abbreviated to PCS (Plastic Clad Silica). The all glass fiber is primarily used for "long line" (over 2 kilometer) applications, whereas the PCS fiber is used in "short haul" (less than 1 kilometer) applications.

24.4.2 Application Guidelines (Mechanical)

Failure modes encountered are catastrophic failure (fiber breakage) or attenuation. Both are caused by several stress factors: temperature, tension and nuclear radiation. The effects of the first two factors are a function primarily of cable fiber construction and installation, while the effects of radiation are determined entirely by the fiber (both core and cladding) material.

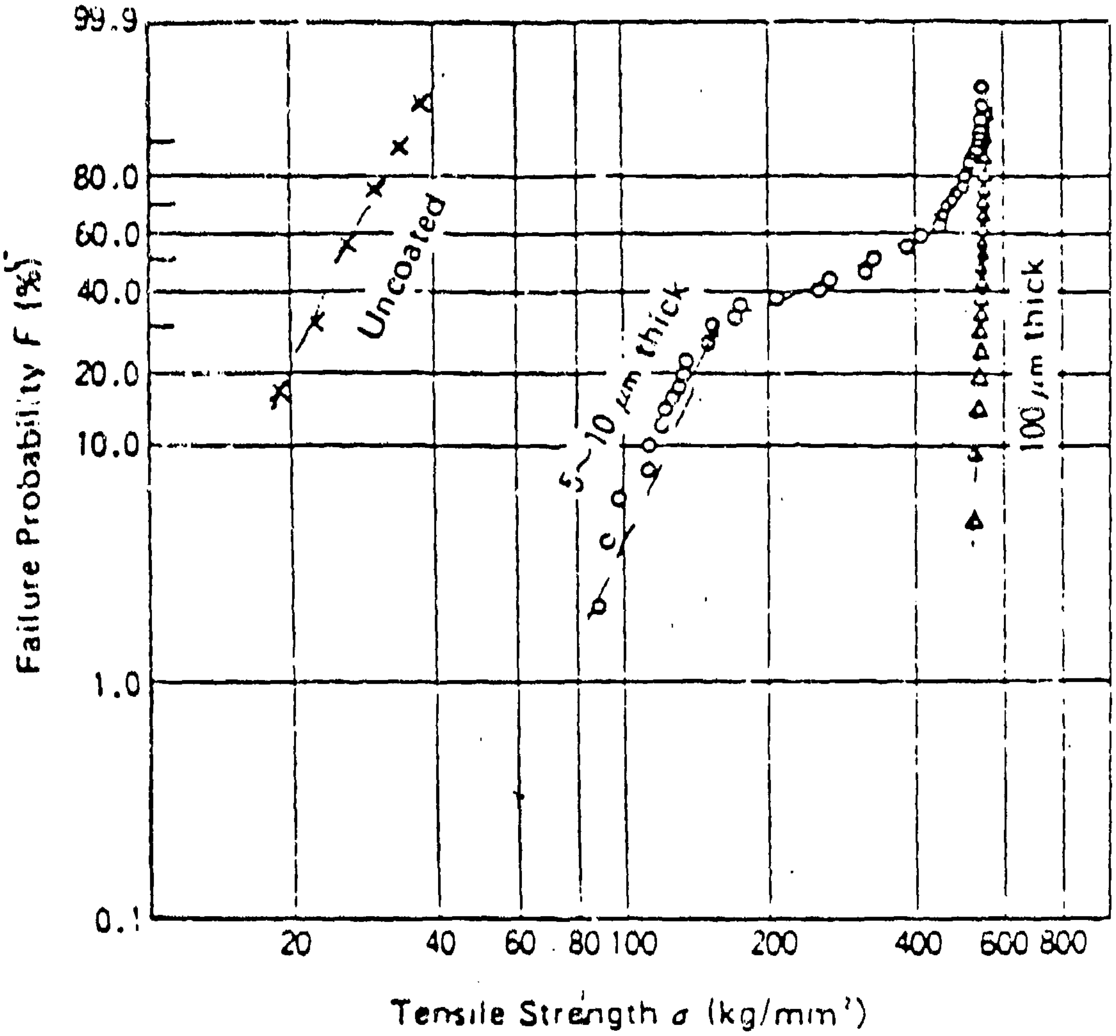
A. Temperature creates mechanical stress on the fiber due to temperature coefficients of expansion between the jacketing and the fiber and in the case of PCS fiber, between the core and the cladding. Proper cable design minimizes these stresses and assures longer life.

B. Temperature induced changes in cladding refractive index can also cause attenuation and extinction in PCS fibers.

C. The use of a buffer coating applied to the fiber, immediately after drawing, as a moisture barrier and a mechanical stiffener increases tensile strength of the fiber (see Figure 24-5).

D. Bend radius induced tension will ultimately cause a fiber to break even after up to 20 years of use. The stress relationship is non-linear and there are no real models upon which to base predictions of life span.

E. Radiation effects on fibers other than rate effects are primarily manifested by an increase in attenuation. Change is measured in units of dB/Km (see Figure 24-6). Low dose levels have to be allowed for so that the fibers are not rendered useless, particularly in "long line" applications.



× . Uncoated

○ : 5 ~ 10 μm thick polyurethane

△ : 100 μm thick silicone resin

Figure 24-5: Effects of Coating Thickness on Tensile Strength of Optical Fibers.
Sakaguchi, S., and M. Nakahara. Review of the Electrical Communication Laboratories, Vol. 27, no. 3-4, March-April 1979

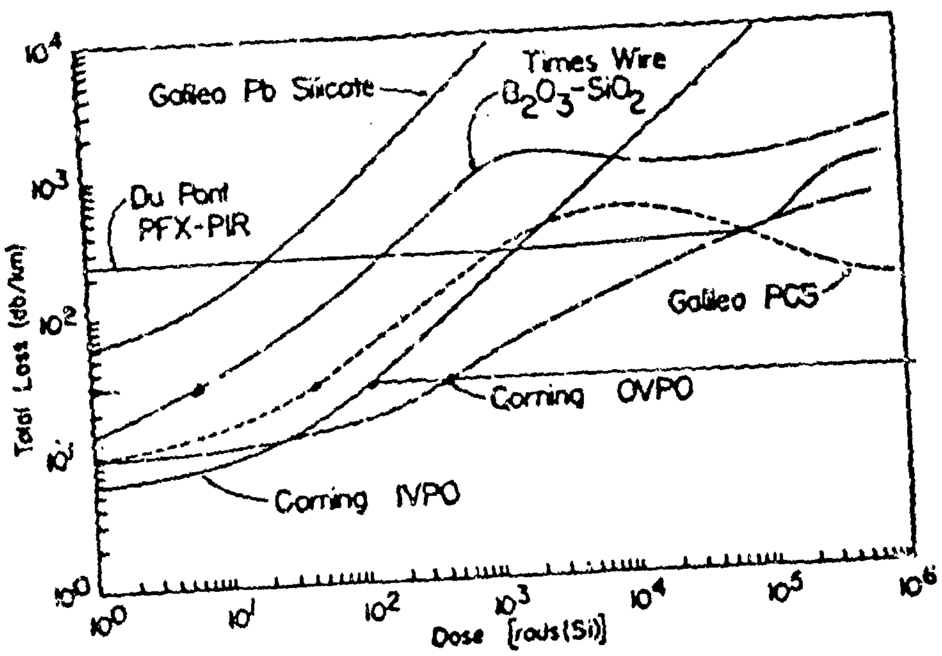


Figure 24-6: Total Optical Attenuation at 820 nm of Fiber-Optic Waveguides as a Function of Dosage during in situ "Co-irradiation." Friebele, E.J., et al. (U.S. Naval Res. Lab., Washington, DC). Laser Focus. Sept. 1978

24.4.3 Derating Guidelines

Cable construction is the key to high reliability in the particular applications of fiber optic cables. The use of strength members, buffers, jackets, and moisture barriers in the development of optimum cable designs is an emerging technology and little data is available on performance of present designs or of future products. New products procured under specification control for use outside of known performance levels should be qualified before use.

Primary stress factors should be derated as follows:

A. Temperature: 20 deg C inside both upper and lower limits.

B. Tension: For fiber - 20% of proof test. For cable - 50% of the rated tensile.

C. Bend radius: 200% of minimum.

D. Radiation - No criteria at this time (consult the supplier). See Figure 24-6 for radiation effects.

SECTION 24.5

FIBER OPTIC CONNECTOR DERATING GUIDELINES

24.5.1 General

Fiber optic connectors available today are primarily single contact type, although several multicontact types are in low volume use. Some available single connectors include the "SMA" derivatives, several plastic types and a few environmental types. The available multicontacts include the jack screw, rack and panel, and circular type, with a few ruggedized environmental versions in low volume production.

The primary purpose of a fiber optic connector is to hold two opposed fibers in proximity with axial, angular, and lateral alignment while protecting those fibers from the environment.

24.5.2 Application Guidelines (Mechanical)

A. Recommend 50% reduction in guaranteed mated/unmated cycles to reduce degradation.

B. Connector insertion loss performance parameter should be increased by 100% to account for fiber variation between fiber actually used in the design and the fiber used by the connector supplier when characterizing the connector, i.e. a 1.5dB loss connector should be considered a 3dB loss connector.

C. Stiffness transition at the cable/connector interface should be achieved by use of cable stiffeners or a heat shrinkable outer sheath.

D. Position adjustment should be available on at least one of the connector pairs to allow the mating of the two terminations as required. This design feature must be such that it is restrained after mating, and the mating position is not affected by outside stress.

E. To increase life, a cover is used to protect the fiber mating surfaces from contamination in the unmated condition.

24.5.3 Derating Guidelines

The primary degrading environment is temperature. This is true of conventional connectors as well. See derating for conventional connectors in Section 14 for derating guidelines.