FINAL REPORT

ANALYSIS OF SPECIFICATION SYSTEMS FOR THE PROCUREMENT OF HIGH-RELIABILITY PARTS

May 1964

Prepared for
National Aeronautics and Space Administration
under Contract NASw-831

ARINC RESEARCH CORPORATION
A SUBSIDIARY OF AERONAUTICAL RADIO, INC.

Publication No. 304-01-1-435

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

FINAL REPORT

ANALYSIS OF SPECIFICATION SYSTEMS FOR THE PROCUREMENT OF HIGH-RELIABILITY PARTS

May 1964

prepared under
Contract No. NASw-831

for
Office of Reliability and Quality Assurance
National Aeronautics and Space Administration
Washington, D. C. 20546

Bryce Sigmon

ARINC RESEARCH CORPORATION
a subsidiary of Aeronautical Radio, Inc.
1700 K Street, N. W.
Washington, D. C. 20006

Publication No. 304-01-1-435

ABSTRACT

21319

A qualitative analysis of six specification systems for the procurement of high-reliability components is presented. Related subject headings in the six systems are compared with regard to (1) cost, (2) delivery time, and (3) reliability assurance. Ratings are assigned to each of the subject headings on the basis of the relative effect each system has on these three factors.

In addition, the current status of procurement specifications for high-reliability devices is appraised. This appraisal covers some of the more serious problems associated with current procurement practice. A relatively new concept (Line Qualification) is presented as a means of alleviating these problems.

Author

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General Comments

The basic requirement of any specification is to provide a statement of the operational characteristics a device or system must possess in order to perform its intended function. It has been apparent for many years, however, that, in addition to this basic requirement, a procurement specification should provide a statement of required reliability.

The reliability requirements for a given part increase with the complexity of the systems in which it is used. Many military equipments have reached such a level of complexity that the reliability requirements of their various components merit as much attention as their operational characteristics. Practically all military procurement specifications in use today reflect an appreciation of this fact; and their effectiveness in the procurement of reliable parts is steadily improving.

To assure that the stated requirements have been met, the procurement document must specify various tests and inspections and set forth criteria for acceptance or rejection. Such an approach is generally sufficient to assure that the procured parts possess the required operational characteristics. However, by itself it is of limited use for assuring reliability. It is for this reason that in recent years procurement specifications for military parts have increased the controls over materials, processes, procedures, and administration of the manufacturing operation. In addition, the testing of parts has expanded considerably.

The increased scope of the procurement specification, necessitated by reliability considerations, is resulting in better, longer-lasting parts. At present, however, there is no concerted effort among consumers with high reliability requirements to standardize or consolidate their specification procedures. The application of specialized testing and process specifications to small-lot purchases of high-reliability parts causes severe penalties in cost and delivery schedules. Standardization could eliminate these penalties. Although technical problems and other factors frequently make the standardization of operating characteristics unfeasible, the standardization of reliability assurance programs -- including testing and processing -- is not generally subject to such limitation.

1.2 The Line Qualification Concept

The practice of qualifying a manufacturer to produce a particular part has been commonplace in military specifications for a number of years. Part qualification generally depends on standardization of operating characteristics, since such qualification is based on a particular end-use item. On the other hand, most specifications utilizing the part-qualification concept contain no provisions for the standardization of various tests and processes. In essence, this approach attempts to force standardization in areas where it is considered unfeasible and to omit standardization in areas where it is practical. In addition, for any qualification concept to acquire the desired result, it is necessary that a reasonably continuous production process be maintained. This implies a continuous demand for a specific item, if the individual-part qualification concept is to be successful. Technological innovations and economic factors usually prevent a long and reasonably constant demand for any specific item. Therefore, as standards or use patterns change, requalification or qualification for other items is required under the part qualification concept.

The concept of line qualification has the potential for eliminating, or at least minimizing, many of the undesirable aspects of part procurement that are attributable to qualification based on specific part types. It is based on the fact that most production lines produce a variety of end-use items that differ only in their operational characteristics. The quality and reliability of parts fabricated from the same basic materials and processes are essentially identical. For example, a typical transistor production line may produce a family of six devices that cover a broad range of forward-transfer characteristics. Each transistor type in this family will possess unique operational characteristics suited to a particular application. However, the inherent reliabilities of all six devices in this family are identical. In other cases, minor alterations in a production process make it feasible to produce thousands of part types all of which possess unique operating characteristics but are essentially identical with regard to quality and reliability. For example, a production line that produces integral electronic circuits on a standard substrate, and has as its only process variable the pattern of the deposited intraconnections, could produce over 100,000 devices which, though operationally unique, would possess the same reliability.

Line qualification would qualify a manufacturer to produce a class of parts on a single production line. Current qualification procedures and tests, with slight modifications, can be utilized for this purpose. Limits on the operational characteristics would be established in all instances in which there is a known relationship between the part failure rate and a particular operating characteristic. In other instances, limits would be necessary to provide a reference for quality assurance testing. Where such limits are established they would constitute a "window" at the end of the production process through which only the acceptable parts could pass.

Effective use of the concept of line qualification will require that the quality decision be made on the parts before unique operating characteristics are established. Therefore, the failure criteria for quality assurance testing cannot be established on end-use operating parameters. It is, however, feasible to use the delta-testing technique, in which failure criteria are based on a maximum allowable variation for a particular operating parameter.

An important condition in the concept of line qualification is that all quality- and reliability-assurance testing is performed before purchase orders are received. The parts are stored in controlled storage facilities (bonded warehouses) until subsequent screening is performed to select operational characteristics to a particular purchase order. Additional testing may be performed at the time of purchase to assure operation of the part in some unique application not covered by the established quality- and reliability-assurance program. Essentially, this additional testing, whether of an environmental or operational nature, will be in the form of screens. Controls are necessary to prevent return to the controlled storage area of parts that have been degraded by such screens.

Properly administered, the line qualification concept will provide the following advantages over qualification by individual part types:

(1) The cost of parts will be reduced, since qualification costs are amortized over a broad product base. In addition, the deletion of specialized testing and process specifications from the areas of manufacturing and quality-assurance testing would substantially increase the efficiency of these operations and further reduce cost.

(2) Delivery time will be shortened significantly. Under the part-qualification approach, which forces manufacturers to comply simultaneously with a large number of specialized testing and process specifications, delivery time often exceeds six months. Delivery time under the line-qualification approach is expected to be less than two weeks.

(3) The part manufacturer will be able to pace his production process at a reasonably steady rate and let the controlled storage area absorb the normally erratic influx of purchase orders. The degree of production control required to produce many types of parts -- to the requisite reliability level associated with their particular application -- is virtually impossible if the production and quality-assurance processes are not maintained at a continuous and steady rate.

Any approach to high-reliability procurement specifications must face the economic realities of industry. If manufacturers are to institute expensive qualification and reliability-assurance programs, there must exist a sufficient demand for the parts manufactured under these programs. Line qualification permits the manufacturer to associate a broad product base with a given program, thereby increasing his market. Since his production-line and quality-assurance investment is not dependent on the market for specific part types, he is able to operate at a considerably lower financial risk.

2. ANALYSIS PROCEDURES

This analysis involved a detailed study of six different specification systems for the procurement of high-reliability parts. Each of these systems comprises a group of documents. Four of the systems are capable of describing the requirements for all part types. Two of them are limited to generic classes of parts.

A system of procurement specifications usually consists of the following:

(1) General specification
(2) Generic specifications
(3) Specification sheets.

The general specification contains requirements that are common to all part types. It usually includes the reliability and quality-assurance program requirements, and the general requirements for qualification, data handling, lot acceptance, and sampling procedures. Requirements associated with specific parts or classes of parts are not included.

The generic specifications contain requirements that are common to a particular generic class of parts, such as semiconductors, relays, resistors, and other classes. These specifications elaborate on the requirements of the general specification to the extent that these requirements are applicable to a specific generic class. In addition, the generic specifications list requirements that are applicable only to a specific generic class and are therefore not stated in the general specification. These requirements may include test conditions and methods, definitions and abbreviations, and environmental factors.

Each generic specification is associated with as many specification sheets as there are part types in a particular generic class. The specification sheets contain requirements that are common to a particular part type, including test sequence and failure criteria for qualification and lot-acceptance testing, as well as required operational characteristics.

Figure 1 is a block diagram of a typical specification system. A complete procurement specification for a particular part type in such a system would consist of the appropriate generic specification and specification sheet, and the general specification. In addition, it is not uncommon for the general and generic specifications to cite as applicable documents a variety of additional specifications that deal with various specialized aspects of production, testing, marking, packaging, and related processes. These documents may refer to other documents, which, in turn, give further references -- all of which are part of the procurement contract unless specifically excepted in the procurement order, contract, or one of the specifications.

There are specification systems that are concerned only with a particular class of parts. In such cases the complete procurement specification usually consists of a general specification and a specification sheet -- the generic and general requirements having been combined into one document. Two of the systems involved in the analysis are of this type.

For purposes of simplification, the analysis described in this report was based on a set of specifications from each of the six systems that describes the total requirements for a particular part type. The part type selected to characterize five of the specification systems was a silicon transistor of the type commonly used in low-power, high-speed

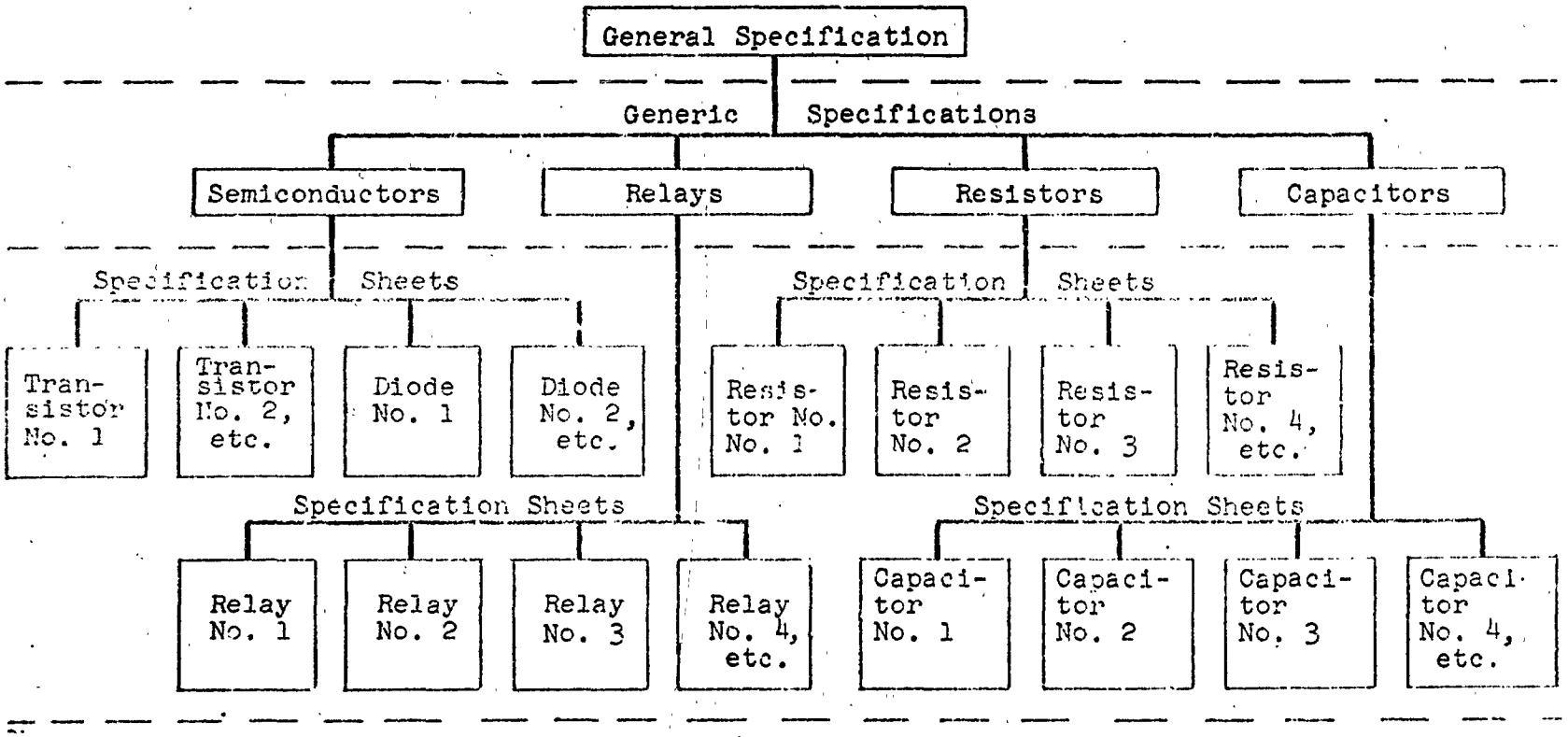


FIGURE 1

BLOCK DIAGRAM OF A TYPICAL SPECIFICATION SYSTEM

switching circuits. For the remaining system, the part type was a silicon semiconductor functional block. This device is fabricated in much the same manner as the selected transistor type. The selection of identical or similar part types was necessary to provide a common basis for comparing the test requirements of the six systems.

The specifications selected to characterize each system are shown in the following tabulation:

MIL-R-38100 System

MIL-R-38100A -- Reliability and Quality Assurance Requirements for Established Reliability Parts, General Specification for

MIL-S-38103A -- Military Specification, Semiconductor Device, Established Reliability, General Specification for

MIL-S-38103/508A -- Military Specification Sheet, Semiconductor Device Transistor, PNP, Silicon, Switch, Established Reliability

MIL-S-19500 System

MIL-S-19500C -- Military Specification, Semiconductor Devices, General Specification for

MIL-S-19500/69C -- Military Specification, Transistors, Types 2N337 and 2N338

MIL-M-23700 System

MIL-M-23700 -- Military Specification, Microelectronic Functional Devices, General Specification for

MIL-M-23700/1 -- Military Specification Sheet, Microelectronic Functional Device, Type ME1

NPC-200-3 System

NPC-200-3 (National Aeronautics and Space Administration) -- Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services

85M01643 (National Aeronautics and Space Administration) -- Screening Specification for Semiconductor Device S2N2412

NASA/UTC System

NASA-XXXXX (Preliminary) -- Electronic Parts for Aero-Space Systems, General Requirements for

NASA-XXXXX (Preliminary) -- NASA Specification for Semiconductor Devices for Aerospace Systems

NASA-XXXXX/2 (Preliminary) -- NASA Specification Sheet, Semiconductor Device, Transistor, Switching, PNP

Lockheed System

1415116A (Lockheed Aircraft Corporation) -- General Specification for High Reliability Devices

1415259 (Lockheed Aircraft Corporation) -- Generic Specification for High Reliability Semiconductors

1415259/1-2 (Lockheed Aircraft Corporation) -- High Reliability Specification, Transistor, Silicon, NPN, High Speed Switch

2.1 Analysis Procedure for General Quality and Reliability Assurance Requirements

The primary objective of the analysis is to provide a detailed comparison of the six separate approaches to the procurement of high-reliability parts. It was thus necessary to evolve a method by which similar or related statements in each of the specification systems could be readily extracted. The composite indices shown in Tables 1 and 2 proved to be the basis of a satisfactory technique for accomplishing this purpose.

Table 1 is a composite index of the general specification systems. Table 2 is a composite index of the four generic specifications that are associated with four of the six systems. Each of the charts was created by the selection of the most detailed specification within the general and generic groups and the insertion of the subject headings in a vertical column. The appropriate paragraph numbers were entered in an adjacent column.

A careful reading of the remaining documents in each group made it possible to associate the proper paragraph number in each of these documents with the appropriate subject heading. In cases where the original outline did not contain an appropriate subject heading, a heading was added from one of the remaining documents. The definition or concept associated with each heading in the outline was fixed by the specification from which it was extracted.

Care was taken not to lose the intended meaning of the paragraph taken out of context. For example, a paragraph relating to acceptance testing in one specification might be identical to a paragraph relating to qualification testing in another specification.

TABLE 1

COMPOSITE INDEX OF SUBJECT HEADINGS IN SIX GENERAL SPECIFICATIONS

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
1	SCOPE	1.0	1.0		1.0	1.0	1.0
	Statement of Scope	1.1	1.1 and 1.2		1.1 and 1.1.1	1.1	1.1
2	Classification					1.2 to 1.2.1.2	1.2 to 1.2.1.2
3	APPLICABLE DOCUMENTS	2.0 to 2.2	2.0 and 2.1		2.0 to 2.1	2.0 and 2.1	2.0 and 2.1
4	Order of Precedence	1.2	2.2			3.1	3.1
5	Specifications						
	MIL-S-19491, Semiconductor Devices, Preparation for Delivery					2.1	2.1
	MIL-C-45662, Calibration System Requirements	2.1					
	MIL-P-116, Preservation, Methods of				2.1		
	MIL-P-38105, Established Reliability Parts, Preparation for Delivery of	2.1					
	MIL-P-7936, Parts and Equipment, Aeronautical, Preparation for Delivery				2.1		
	MIL-Q-9858, Quality Control System Requirements		2.1		2.1		
	MIL-R-27542, Reliability Program Requirements, Aerospace Systems, Subsystems, and Equipments		2.1		2.1		
6	Standards						
	MIL-STD-202, Test Methods, Electronic Component Parts		2.1		2.1		2.1
	MIL-STD-706, Power Supply Voltages, Electronic Equipment						2.1
	MIL-STD-750, Test Methods for Semiconductor Devices					2.1	2.1
	MIL-STD-105, Sampling Procedures and Tables for Inspection by Attributes					2.1	
	MIL-STD-174, Colors for Coding Electronic Parts					2.1	
	MIL-STD-129, Marking for Shipment and Storage		2.1		2.1		
	MIL-STD-130, ID Marking for U. S. Government Property		2.1		2.1		
	MIL-STD-726, Packaging Requirements Code		2.1				
7	Other Publications						
	Air Force T.O.-00-203, Design of Clean Rooms	2.2			2.1		
	H4-1, Federal Supply Code for Manufacturer's Cataloging Handbook	2.2					

(continued)

TABLE 1 (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
	Other Publications (continued)						
	1412, Limits for Naturally Occurring Radiation with Wavelengths Below 100 Angstroms		2.1				
	1412815, X-Ray Inspection		2.1				
	LMSC-FB39, Dissimilar Metals, Protection of		2.1				
	LMSC-MD137, Nickel Wire, Gold Plate and Ribbon		2.1				
	LMSC-MD138, Dumet Wire, Gold Plated		2.1				
	LMSC-P200, Materials - Handling and Packaging Standards		2.1				
	LMSC-A050422, Supplier Quality Control System Requirements		2.1				
	NAVSHIPS-900 152, Manufacturer's Designating Symbols					2.1	2.1
	REQUIREMENTS	3.0			3.0		
8	General Requirements	3.1	3.2		3.1		
9	Detail Requirements	3.2	3.1	1.3		3.1.1	3.1.1
	Reliability Assurance Plan	3.3	4.1.5 and 4.7.1	1.4	4.2		
	Reliability Level Classification	1.3	6.2		3.3.1		
	Reliability Assurance Plan Documentation	3.3.1.5 and 3.15	4.1	2.4			
	Organizational Structure	3.3.1.1	4.1		3.4.4		
	Training Program	3.3.1.2					
	Description of Production Processes and Controls	3.3.1.3 and 3.3.1.5.1	4.1	3.7	3.4.2 to 3.4.2.2		
	Proprietary Processes and Procedures	3.3.1.3.1 to 3.5.1.1	4.1.2 to 4.1.3		3.4.1		
	Procurement, Production, and Control Documents	3.3.1.4.1, 3.3.1.4, 3.1.5.2, and 4.1.3	4.1.1.2 and 4.7.4	2.4, 3.1, and 3.4	3.4.2.1 to 3.4.2.2; 4.1.1		
	Documentation Responsibility	3.3.1.5.3	4.7.3.1.2				
	Availability and Review of Documentation	3.3.1.7	4.1				
	Yield	3.3.1.8					
	Manufacturer's Facilities	3.3.1.9, 3.3.4, 3.3.6, and 4.1.2	3.3.4, 4.7.3.1, and 4.10.3	3.4 and 3.9	3.4.7.3 and 4.3.4	4.4.1 and 6.3	4.4.1 and 6.5
	Quality Control Requirements	3.3.2	4.1.1	2.1 and 2.2; 3.5 and 3.6	4.1		
	Control of Nonconforming Parts and Material	3.6.2 and 3.3.5	4.5.5 and 4.5.6	3.8	4.6.4	3.7.1	
66	Calibration of Test Equipment	3.3.3 and 4.1.2	4.10.3	3.9 to 3.9.1	4.3.4	4.4.1	4.4.1

(continued)

TABLE 1 (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-E-5400	Lockheed	NPC-200-3	NASA/UPC	MIL-S-19500	MIL-M-23700
	Failure Analysis and Corrective Action	3.3.7 and 3.5.1.10	4.1 and 4.6.2		3.4.3		
	Failure Reporting	3.3.7.1, 4.1.5, and 3.3.7.6	4.1, 4.7.5, and 4.9.2		3.3.2.5		
	Failure Mode Identification and Audit	3.3.7.2; 3.3.7.3	4.9.2		3.4.3.1 and 6.7		
	Failure Analysis of Parts	3.3.7.4, 3.3.4, 3.3.7.7, 3.3.7.8	4.9.2		3.4.3.2		
	Failure Analysis Capabilities and Techniques	3.3.7.5					
	Corrective Action	3.3.8.1	4.1 and 4.7.5	3.14	3.4.3.3		
	Improved Prototype Parts	3.3.8.2					
	Evaluation of Corrective Action	3.3.8.3					
	Prototype Improved Parts, Evaluation Tests	3.3.8.4					
	Improved-Part Approval	3.3.8.5					
	Elapsed Time for Approval	3.3.8.5.1					
64	Test Data Transmittal	3.3.9 and 4.1.4	4.3.2, 4.7 to 4.7.3.1.4, and 6.7 to 6.7.3.3.1.3		3.5.2.3, 3.5.2.4, 3.3.2.3, 6.3, 3.5.2		
	Standardized Document Forms	3.3.9.1	3.10 to 3.10.3.2, and 4.8 to 8.2		3.3.2.3		
64	Application Data	3.4 to 3.4.2; 6.2			3.5.2 to 3.5.2.2; 6.3		
40	Qualification Requirements	6.9	6.1		4.4.3; 6.2 to 6.2.2	3.2 6.2	3.2; 6.2, 6.3
	Initial Qualification Requirements	3.5.1	4.7.1				
	Materials Design and Construction	3.5.1.1	3.3, 4.4.5, 4.4.6		3.4.1		
	Part Failure-Rate Level	3.5.1.4	4.6.4.4.1 and 6.2		3.3.2		
	Qualification Inspection Requirement	3.5.1.2	4.4.1		3.3.2.2 and 4.4	9.5 9.5.1, 9.5.4, and 9.5.5	4.5
	Qualification-Test Sample Parts	3.5.1.5	4.4.2		4.4.1 and 4.4.2	4.5.2 and 4.5.3	4.3.3

(continued)

TABLE I (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	NPC-200-3	NASA/GSFC	MIL-S-19500	MIL-M-23700
	Environmental Tests for Qualification	3.9.1.3	4.4.1		3.3.2.2		
	Initial Failure Rate Tests	3.9.1.7	4.4.1		3.3.2.2		
	Establishment of Failure-Rate-Level Goal	3.9.1.6					
	Qualification Test Data	3.5.1.8	4.7.2 to 4.7.3.1.4, and 6.7.2				
	Verification of Qualification Data	3.9.1.9	4.7.3.1.2		3.3.2.1		
	Qualification Maintenance	3.5.2 to 4.7	4.4.4		4.4.3		
	Requalification	3.9.3, 3.13, and 4.6	4.4.4		4.4.4		
	Failure-Rate Administration	3.7					
	Failure Rate Test Records	3.7.2 and 3.7.4.1	4.6.1, 4.6.2.1, and 4.6.2.2		3.3.2.3 and 3.3.2.5		
	Certification of Failure Rate Level	3.7.3	4.6.2		3.3.2.1		
	Exemption of Data	3.7.5	4.6.2.3		3.3.2.9		
	Reinitiation of Data Accumulation	3.7.4.2	4.6.2.1		3.3.2.6		
	Method of Changing a Qualified Failure Rate	3.7.6					
	Correction of Failure Rate Level	3.7.6.1			3.3.2.8		
	Certification to a Lower Failure Rate Level	3.7.6.2					
	Grouping of Part Designs	3.8			3.3.2.10	4.3.3	
	Homogeneity Requirements	3.9	3.4				
	Handling, Assembly, and Test Precautions	3.10			3.5.2.2		
45	Marking Requirements		3.8 to 3.8.3		3.5.1	3.7	
	Date Code	3.12.2	3.8.9		3.5.1.1	3.7.6	3.7.5
52	Prefix					3.7.1	3.7.2
46	Manufacturer's Identification	3.12.1	3.8.5, 3.8.6, and 3.8.8			3.7.7	
	Qualification Designating Code					3.7.2	3.7.4
	Country of Origin					3.7.5	3.7.6
	Terminal Identification						3.7.7 and 3.7.7.1
53	Color Code					3.7.3	
51	Polarity					3.7.4	
	Military Designator and Reliability Indicator	3.12.1				3.7.8 to 3.7.8.2	
47	Type Designation						
	Value	3.12.1					
	Tolerance	3.12.1					
48	Serialization		3.8.7 and 4.7.4		3.5.1.2		
50	Minimum Marking						3.7.1 to 3.7.1.2

(continued)

TABLE 1 (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
	Acceleration Factors	3.11 and 4.4.5			3.3.2.7		
11	Parts and Materials General Requirements	3.5.1.1	3.4		3.4.1		
12	Fungus Resistant Materials					3.5.1	3.5.1
14	Solder and Welds						
15	Soldering Flux						
16	Terminal Insulator						
17	Sleeving Insulation						
	Physical Condition of Materials		3.4.1				
13	Metals					3.5.2	3.5.2
	Unacceptable Materials		3.4.2				
	Dissimilar Metals		3.4.3				
18	Terminals and Leads		3.4.4				
	List of Materials		3.4.5				
10	Design and Construction General Requirements	3.5.1.1	3.3		3.4.1	3.6	3.6
	Soldering		3.3.1				
	Terminal and Leads		3.3.2 and 4.5.4				
	Threads		3.3.3				
	Standard Operating Voltages						3.6.3
	Fault-Location Test Points						3.6.2
	Physical Dimensions					3.6	3.6.1
44	Workmanship		3.9		4.8.1	3.8	3.8
54	QUALITY ASSURANCE PROVISIONS						
	Inspection by Manufacturer	4.1.1	4.1.6	2.3	4.3.2	4.1	4.1
	Witness of Inspection	3.1.6 and 4.1.1.1	4.1.4, 4.1.7	1.5, 3.2, and 3.2.1	3.3.2.1 and 4.3.5		
65	Inspection Conditions	4.1.2.1	4.10 to 4.10.2		4.3.3	4.4 and 4.4.1; 4.4.3	4.4 and 4.4.1
	Procedure in Case of Test Failure or Operator Error	4.1.2.2	4.6.2.3 and 4.7.3.1		3.3.2.9	4.4.1	4.4.2
			4.7.3.1				
55	Classification of Tests	4.1.6	4.2		4.3.1 and 4.7	4.3.1	4.3.1
	Inspection following Storage	3.6.1				4.2	4.2
55	Qualification Inspection (tests)	4.2	4.4.1		4.4	4.5.1	4.5
56	Sample	4.2.1, 4.4.3.1, 4.4.6, and 4.4.7	4.4.2 and 4.4.3		4.4.1	4.5.2 to 4.5.5	4.3.3
58	Screening		4.3 to 4.3.2		4.5		
35	Failure-Rate Testing (Life)	4.2.1; 4.4.1 and 4.4.1.1; 4.4.3 to 4.4.7; 6.6	4.6 to 4.6.2.3		4.7.1, 4.7.2.2, 3.3.2.2, and 3.3.2.4	4.6.5 to 4.6.5.2.2	4.5
57	Quality Assurance Inspection	4.2	4.4.1			4.5.4	4.5

(cont...)

TABLE 1 (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	MPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
42, 59, 62	Acceptance Inspection (tests)	3.6	4.5	3.6	4.6 and 4.6.2	4.6.2.1.2	4.6
	Classification of Acceptance Tests	4.3.1					4.6
61	Sample	4.3.2 to 4.3.3	4.5.4	3.5 and 3.12	4.6.1	4.6.2.1.3; 4.6.2 to 4.6.2.1.1	6.4
	Subgrouping of Parts	4.3.4					
	Group A Inspection	4.3.5 to 4.3.5.2				4.6.1	4.6.1 and 4.6.1.1;
	Group B Inspection	4.3.6				4.6.3 to 4.6.3.3	4.6.2 and 4.6.2.1
	Group C Inspection	4.3.7				4.6.4 to 4.6.4.4	4.6.3 to 4.6.3.3
35, 63	Life Test for Acceptance	3.7.1, 3.8.1.1, 6.7, 4.4.1.1, and 4.4.2	4.5.3		4.7.2 and 4.7.2.2	4.6.5 to 4.6.5.2.2	4.6
	Early Shipment	4.5 to 4.5.1.2	4.5.3.1		4.7.2.1	4.6.5.2.3 to 4.6.5.2.5	
	Resubmitted Lots	4.3.8			4.6.3 to	4.6.6	4.3.5
	Disposal of Sample Devices	4.3.9	4.5.5 and 4.5.6		4.6.3.4	4.6.7	4.3.4
39, 67	Methods of Examination, Inspection, and Test		4.11 and 4.12		4.8	4.4 and 4.4.1	4.4 and 4.4.1
37	Visual and Mechanical Inspection		4.11.16 and 4.11.14		4.8.1		
21	Environmental Testing and Requirements	3.5.1.3	3.5 and 4.5.2		3.2, 4.8.2, and 6.5		
22	Acceleration		4.11.1 to 4.11.1.4; 3.5.1				
26	Pressure		4.11.2 and 3.5.2		4.8.2.5		
33	Humidity (Moisture Resistance)		4.11.3 and 3.5.3		4.8.2.6		
29	Terminal and/or Lead Strength						
31	Fungus						
	Lead Fatigue		4.11.4 to 4.11.4.3				
27	Leak Detection		4.11.5 to 4.11.5.2.3				
34	Salt Atmosphere (Corrosion)		4.11.6 to 4.11.6.4; 3.5.8				
30	Radiation		4.11.7 and 3.5.4		4.8.2.7		
23	Shock		4.11.8 and 3.5.5		4.8.2.1		
24	Temperature		4.11.9 and 3.5.6		4.8.2.3		
	Torque		4.11.10 to 4.11.10.4				
28	Vibration		4.11.11 to 4.11.11.2; 3.5.7 to 3.5.7.2		4.8.2.2		
	Insulation Resistance		4.11.12				

(continued)

TABLE 1 (continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in General Specification					
		MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
	Dielectric Withstanding Voltage	4.11.13					
32	Effects of Soldering and Solderability	4.11.15					
	Acoustic Noise	3.5.9			4.8.2.4		
68	PREPARATION FOR DELIVERY	5.0 and 3.3.1.6		3.11			4.7
69	Packaging & Preservation		5.1.1		5.1 to 5.2	5.1	5.1
	Sealing		5.1.2				
71-79	Packaging for Shipment	3.3.1.10	5.1.3				
	Exterior Shipping Containers		5.1.4				
	Packaging Deviation		5.1.5				
70	Preservation & Packaging under Controlled Environment				5.1.1		
80	Marking		5.2.1				
	Unit & Intermediate Cont.		5.2.2		5.3.1		
	High-Reliability Marking		5.2.3		5.3.2 and 5.3.3		
	Reservations		5.3				
	Accessory Hardware		5.4				
	Packaging Area		5.5				
	Data		5.6; 6.7 to 6.7.3				
	NOTES	6.0	6.0		6.0	6.0	6.0
60	"Lot", Definition of	6.1	4.5.1.1 and 4.5.1.2, 6.3.11		3.6	4.3.2 to 4.3.2.1; 4.3.2.1.1	4.3.2
87	Definitions, Abbreviations, and Symbols	6.1	6.3 to 6.3.2.2	APPENDIX A		3.3 and 3.4	3.3 and 3.4
88	Ordering Data		6.4		6.1	6.1	6.1
	Changes Requested by Manufacturer		6.5				
	Changes Required by Procuring Activity		6.6	1.6			
82	Intended Use						
83	Storage Temperature						
84	Life Degradation						
85	Handling Precautions						
86	Vendor-Manufacturer						
	Confidence Level	6.3			6.4		
	International Standardization Agreements				6.5	6.4	
	Summary of Required Data				6.6		

TABLE 2

COMPOSITE INDEX OF SUBJECT HEADINGS IN FOUR GENERIC SPECIFICATIONS

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in Generic Specification*			
		NASA/UTC	NPC-200-3	Lockheed	MIL-R-38100
1	SCOPE	1.1	1.1	1.1 and 1.2	1.1
2	Classification	1.2 to 1.2.1.3	1.1	6.3.9.1	1.2 to 1.2.1.5
3	APPLICABLE DOCUMENTS	2.0 and 2.1	2.1	2.0 and 2.1	2.0 and 2.1
4	Order of Precedence		3.6	2.2	3.2
5	Specifications				
	NASA XXXX, Parts for Aerospace Systems, General Requirements	2.1			
	NASA XXXX/X, Item Specification	2.1			
	MIL-S-19491, Semiconductor Devices, Preparation for Delivery of	2.1			
	MIL-A-148, Aluminum Foil	2.1			
	MIL-F-22191, Films, Transparent, Flexible, etc.	2.1			
	MIL-S-19500C, Semiconductor Devices, General Specification for		2.1	2.1	2.1
	85MD1650, Radiographic Inspection of Electronic Parts		2.1	2.1	2.1
6	Standards				
	MIL-STD-202, Test Methods for Electronic Parts				2.1
	MIL-STD-750, Test Methods for Semiconductors	2.1	2.1	2.1	2.1
7	Other Publications				
	D-202 (ASTM Method), Methods of Sampling, etc.	2.1			
	PPP-T-76, Tape, Pressure-Sensitive, etc.	2.1			
	PPP-B-566, Boxes, Folding Paperboard	2.1			
	PPP-B-601, Boxes, Wood Cleated Plywood	2.1			
	PPP-B-636, Boxes 1, Fiber Board	2.1			
	PPP-B-665, Boxes, Paperboard Metal Stayed, etc.	2.1			
	PPP-B-676, Boxes, Set-up Paperboard	2.1			
	PPP-C-843, Cushioning Material, Cellulosic	2.1			
	1412815, X-Ray Inspection of Semiconductor Devices			2.1	
	1415259/0, Index to Item Specification			2.1	
	1415116, General Specification for High-Reliability Devices		2.1	2.1	
	NPC-200-3, Inspection System Provisions for Suppliers, etc.		2.1		
	STD-RS-236, EIA-NEMA Standards for Color Coding Semiconductor Devices				2.2
8	GENERAL REQUIREMENTS		3.6	2.2	3.2
9	Detail Requirements	3.1		3.1	3.2
10	Design and Construction	3.1.1 to 3.4.4	3.4	3.3 and 3.3.5	3.5 and 3.5.1
11	Materials			3.4	3.4
12	Fungus Resistance	3.4.1		3.4	
13	Metal	3.4.2			3.4.1
14	Solder and Welds	3.4.5	3.9	3.3.1 to 4.4.6	
15	Soldering Flux	3.4.6			

* Each generic specification is identified in this table by the name of the specification system of which it is a part.

(continued)

TABLE 2 (Continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in Generic Specification			
		NASA/UTC	NPC-200-3	Lockheed	MIL-R-38100
16	Terminal Insulator	3.4.7			
17	Sleeving Insulation				3.4.2
18	Terminals and Leads	3.4.2			3.6.5, 3.5.3, and 3.10.2.2
19	Semiconductor Material				3.5.2
20	Electrical Characteristics	3.10	3.3	3.6 to 3.7	3.7 to 3.8.34
21	Environmental Requirements and Tests	3.11 and 4.6.1		3.5, 3.7, and 4.11	3.6
22	Acceleration			3.5.1 and 4.11.1	3.6.13 and 4.4.13
23	Shock			3.5.5, 3.7.3, 4.11.8, and 4.11.2.2	3.6.19 and 3.6.20; 4.4.19 and 4.4.20
24	Temperature			3.4.6 to 3.4.6.2; 4.11.9	3.6.8, 6.2.2; 4.4.8 to 4.4.8.2; 4.4.22 and 4.6.17
25					
26	Pressure			3.7.9, 4.11.2, and 4.11.27	
27	Seal (Pressure)			3.7.7, 4.11.5, and 4.11.25	3.6.12; 4.4.12 to 4.4.12.4
28	Vibration			3.5.9, 3.7.4, 4.11.11, and 4.11.11.3	4.4.14 to 4.4.14.2; 3.6.14 to 3.6.17; and 4.4.15 to 4.4.17
29	Terminal and/or Lead Strength			4.11.4 and 4.11.10	3.6.6 to 3.6.7; 4.4.6 and 4.4.7
30	Radiation			4.11.7	
31	Fungus				3.6.2.4 to 4.4.2.4
32	Soldering and/or Welding		3.9	3.7.5 and 4.11.15	3.6.4, 3.6.23, 3.6.25, 4.4.4, 4.4.23, and 4.4.25
33	Moisture, Humidity, and Dew Point			3.7.2, 4.11.20, and 4.11.3	3.6.9 and 4.4.9
34	Corrosion (Salt Atmosphere)		3.4	3.7.1 and 4.11.6	3.6.18 and 4.4.18
35	Life			4.11.19, 4.11.21, and 4.11.26	3.6.10 to 3.6.11.1; 4.4.10 to 4.4.11.1
36	Examination				
37	Visual and Mechanical Examinations		4.10.1 and 4.10.2	3.7.6 and 4.11.14	3.6.1, 4.2.3, and 4.4.1
38	X-Ray Examination		4.10.5	3.7.8 and 4.11.16	3.6.2 to 4.4.2
39	Electrical Requirements and Tests	3.10 and 4.5.1	4.10.3 and 4.10.4; 4.10.8	3.6 to 3.6.2; 4.11.12, -13, -.18, -.28, -.28.4	4.5 to 4.5.56; 4.6 to 4.6.34
40	Qualification	3.6	3.1		3.1
41	Screening	3.7			
42	Lot Acceptance	3.8			
43	Reliability	3.9			
44	Workmanship			3.9	3.11

(continued)

TABLE 2 (Continued)

Generic Line Number	Subject Heading	Subject Location by Paragraph Number in Generic Specification			
		NASA/UTC	NPC-200-3	Lockheed	MIL-R-38100
45	Marking	3.5	3.8	3.8 and 3.8.13	3.10
46	Manufacturer's Identification	3.5	3.8.1		3.10.4
47	Type Designation		3.8.2		3.10.5
48	Serialization		3.8.3		
49	Date Code		3.8.4		3.10.3
50	Minimum Marking			3.8.9 and 3.8.10	3.10
51	Polarity			3.8.11 and 3.8.12	3.10.2
52	Prefix				3.10.1
53	Color Coding				3.10.5.1
54	QUALITY ASSURANCE PROVISIONS		4.1 to 4.4; 4.7	4.0 and 4.1	4.0 and 4.1
55	Qualification Inspection	4.1.1.1	4.8 to 4.8.3	4.4.1	
56	Samples for Qualification	4.1.1.2	4.8.1 and 6.2	4.4.2	
57	Inspection Routine	4.1.2	4.8.2	4.4.7	
58	Screening Tests and Inspection	4.2		4.3	
59	Lot Acceptance Testing and Inspection	4.3 to 4.3.2	4.9 to 4.9.1	4.5, 4.5.2, and 4.5.5 to 4.5.8	4.1.1
60	Lot Definition	4.3.1		4.5.1	4.1.1
61	Selection of Samples and Sample Size	4.3.3 to 4.3.3.3		4.2, 4.5.2, and 4.5.3	4.1.1
62	Lot Acceptability	4.3.4			
63	Life Tests	4.4.1		4.6 to 4.6.2.3; 4.5.3 and 4.5.3.1	
64	Test Documentation and Generation of Application Data		4.5 to 4.6.3	4.7 to 4.8.3	
65	Test Conditions			4.9 and 4.10	4.2 to 4.2.2
66	Test Equipment Calibration			4.10.4 and 4.10.5	4.3
67	Deviation from Test Method			4.12	
68	PREPARATION FOR DELIVERY	5.0	5.0	5.0	5.0
69	Preservation & Packaging	5.1			5.1
70	Preservation	5.1.1			5.1
71	Packaging	5.1.2	5.2		
72	Chipboard	5.1.2.1			
73	Plastic Blister	5.1.2.2			
74	Testing Provisions	5.1.2.3			
75	Removal Strip	5 and 5.1			
76	Electrical Shielding	5.1.2.4			
77	Intermediate Container	5.2			
78	Packing	5.3			
79	Level: "A", "B", "C"	5.3.1 to 5.3.3			
80	Marking	5.4	5.1		
81	NOTES			6.0 to 6.2; 6.5 to 6.7	
82	Intended Use	6.1			6.1
83	Storage Temperature	6.2			
84	Life Degradation	6.3			
85	Handling Precautions	6.4			
86	Vendor-Manufacturer	6.5			
87	Definitions, Abbreviations, Symbols	3.2 to 3.3	3.6	6.3, 6.3.9, and 6.3.23	
88	Ordering Data			6.4	6.2
89	Qualification Cost		6.1		

The general and generic indices were developed independently, primarily as a matter of convenience. However, before comparison of the six systems could be made, it was necessary to develop a means of merging the two indices, for the following reasons:

(1) Most current specification systems generally follow an outline form that has been recommended by the Department of Defense* and endorsed by the Electronic Industries Association. However, there are significant departures from standard procedure in all specification systems. The most important departure, with regard to the intended function of the composite indices, is that requirements contained in the general document of one system may be contained in the generic document of another, and vice versa.

(2) Many of the generic requirements are elaborations on statements made in the general document. In some cases, a general requirement is meaningless without the associated generic requirement, and vice versa.

(3) Two of the six systems involved in the analysis are two-document systems (MIL-S-19500 and MIL-M-23700). Their total requirements above the specification-sheet level (requirements that are contained in the general and generic documents in three-document systems) are all contained in a

---

* Department of Defense -- Proposed Outline of Form and Instructions for the Preparation of Design and Procurement Documentation for Military Components, 1958.

single specification. These two systems are referenced in the general composite index and, unless the general and generic indices (Tables 1 and 2) are merged, it is impossible to compare their generic requirements with those of the three-document systems. The same situation would exist if these two systems were referenced in the generic index. In this case, it would be impossible to compare their general requirements with those of the three-document systems.

A convenient method of merging the two indices was to number the generic subject headings in arithmetic sequence. The numbers appear in Table 2 in the first column; they are called "generic line numbers". Subsequently, the appropriate line number was entered in the first column of the general index (Table 1). For subject headings in the general index to which no generic information is applicable, the "Generic Line Number" column is blank. For subject headings in the generic index to which no general information is applicable, the generic subject heading and line number are inserted at the appropriate place according to the context of the general index, and the space for general-document paragraph numbers is left blank.

All paragraphs (in all six systems) that contain related requirements can be extracted in their proper context if one reads horizontally across the general composite index, Table 1. If a number appears in the "Generic Line Number" column, it is necessary to turn to the generic index (Table 2), locate the referenced line number, and note all paragraph numbers on this line.

In both indices, one paragraph number is frequently associated with several subject headings. This association occurs when a paragraph in a particular document contains information that is pertinent to more than one subject heading in one of the composite indices. When such multiple requirements are found in a paragraph, it is necessary to extract only those which are pertinent to the subject heading under consideration. This generally does not present a serious problem if the scope of the subject heading is well understood.

As an analytical aid, it was found convenient to arrange the paragraphs on large charts in their proper order according to the composite indices. By reading horizontally across these charts, one could make a rapid comparison of the requirements relating to a given subject for all six systems.

As pointed out previously, the sole function of specification sheets in the majority of systems is to state the type of tests, the test sequence, and the pass-fail criteria. Of the six systems analyzed, only one does otherwise. In this case [85M01643(NASA).] the generic requirements are contained in the specification sheet. These requirements were extracted and entered in the generic composite index.

2.2 Analysis Procedure for Test Requirements

The specialized test requirements associated with specification systems strongly influence the cost and delivery time of parts. Delivery time, which is often several months for certain part types, is almost exclusively determined by test requirements. Test cost is frequently several times the basic cost of a device. Both of these factors are affected directly and indirectly by test requirements. A significant portion of the delivery time consists of test equipment

scheduling and administrative delays (analysis of specifications, issuance of special instructions, data recording, conferences with purchaser for clarification, etc.). Part cost is affected significantly if the manufacturer is required to pre-screen his product rigorously in order to assure that it will not be rejected during lot-acceptance testing.

Lot-acceptance testing by sampling techniques provides an estimate of the quality and reliability level of a lot. However, the degree of confidence associated with the estimate varies radically depending on the degree of testing and type of sampling performed.

For these reasons, test requirements were given special attention. The flow charts in the appendix to this report indicate the types of tests, testing sequence, and sampling plans associated with the six specification systems. Although the test requirements called out by various specification sheets within a generic class of a particular system may vary; the specification sheets selected to characterize the six systems are thought to be typical of the majority of specification sheets in each of the systems. It is significant to note again that all the charts except one describe the test requirements for a silicon high-speed, low-power switching transistor. It is reasonable to assume that in the majority of instances, the application and environment to which any of these five devices is subjected will be essentially the same.

Tables 3 and 4 were developed from information extracted from the appendix flow charts for the purpose of summarizing significant points.

TABLE 3

ELECTRICAL-MEASUREMENT AND LIFE-TEST REQUIREMENTS FOR QUALIFICATION AND ACCEPTANCE TESTING

Specification System	Minimum Number of Measurements	Life Test Hours
Qualification Testing		
MIL-M-23700	1,984	1,000
MIL-R-38100	2,280	1,000
MIL-S-19500	4,780	1,000
NPC-200-3	5,896	2,000
NASA/UTC	8,865	2,000
Lockheed	10,841	2,000
Acceptance Testing		
MIL-S-19500	528	1,000
MIL-M-23700	1,241	1,000
MIL-R-38100	8,292	1,000
NASA/UTC	11,989	2,000
Lockheed	12,203	1,000
NPC-200-3	31,000	240

TABLE 4

COMPOSITE INDEX OF TEST REQUIREMENTS FROM SIX SPECIFICATION SHEETS

Type of Test	LTPD* and Screening Requirements for Qualification (Q) and Acceptance (A) Testing											
	MIL-R-38100		MIL-M-23700		MIL-S-19500		Lockheed		NASA/UTC		NPC-200-3	
	Q	A	Q	A	Q	A	Q	A	Q	A	Q	A
Operational Characteristics	2	S/2	3	5	S	10	1	4	5	5	S	S
Operating Life	10	4	15	20	8	10	6	10	10	3	8	
Storage Life	12		15	20	8	10	6		4			
Visual	2		15	20	S	8	1	4	S/2		S	S
Physical Dimensions			15	20	11	20			5			
High-Temperature Stabilization	2	S					S	S			S	S
Temperature Cycling	12	10	15	20	11	20	S	S	5		24	S
Burn-In	2	S					S	S	S	S	S	S
Thermal Shock			15	20			15	10				
High-Temperature Operation					11	20						
Low-Temperature Operation					11	20						
Soldering Heat	18		15	20								
Vibration (Constant)			15	20	11	20	5	10	5	5		
Vibration (Variable)	2	S	15	20	11	20	5	10	5		24	
Vibration (Random)	18						S/5	10				
Acceleration	18		15	20	11	20	5	S/10	S/5	S	24	S
Shock	18		15	20	11	20	5	10	S/5	S/5	24	S
Moisture Resistance	12	10	15	20	11	20	15	10	5	5		
Salt Atmosphere	18		11	20	15	10	5					
Dew Point							15					
Lead Fatigue	25	20	15	20	11	20	15	10	5		24	
Hermetic Seal	2	S					S/15	S/10	S/2	S	S/24	S
Radiation									5			
X-Ray							S	S	S/2	S		S
Solderability		20			11	20	15	10	5		24	
Intermittent Operation							6					

* Lot Tolerance Percent Defective

NOTES:
(1) Numbers represent LTPD's and indicate that sampling plan is used.
(2) "S" indicates that the entire lot is screened.
(3) "S" followed by a number (e.g., S/2) indicates that in addition to the screening, sampling is subsequently performed. The number is the LTPD.
(4) Each specification sheet is identified in this table by the name of the specification system of which it is a part.

Table 3 indicates the number of electrical measurements and life-test hours required for qualification and acceptance testing. The electrical measurements for qualification are based on the lowest reliability level allowable (typically, 1% per 1000 hours). Acceptance measurements are based on a lot size of 1000 units.

Electrical measurements add significantly to test costs. On a unit basis, the average cost of an electrical measurement, which includes individual handling and data recording, can be many times that of an environmental test, which is usually performed on bulk quantities of parts. The time required to conduct life tests represents the theoretical minimum delivery time and the minimum time required for qualification. However, for special test requirements these minimums are frequently exceeded by weeks or months, because of administrative delays, test equipment unavailability, and other delaying factors.

Table 4 is a composite tabulation of all the tests contained in the six specification sheets. From this chart, it can be determined whether or not a particular test is specified, and what the Lot-Tolerance Percent Defective (LTPD) number is. The letter "S" indicates that the entire qualification inspection lot or procurement lot is tested. A blank space indicates that the specification sheet does not require that the test be performed. This information may be used to indicate the relative effectiveness of a specification sheet's test requirements in assuring lot quality and reliability. The accuracy of such an analysis depends on the degree to which the following assumptions are valid:

(1) The test conditions specified for similar test requirements in each of the six specification sheets are reasonably identical.

This assumption is based on the fact that all environmental tests in all six specification sheets refer to MIL-STD-750, Test Methods for Semiconductor Devices. Variations in stress levels where such levels are called out by the specification sheet were held to be negligible. The applied voltages and current levels specified for the measurement of operating characteristics (electrical parameters) vary among specifications as well as among specific measurements. In each case, however, the conditions are typical of those the device would see in normal service. In addition, these conditions do not represent stress levels upon which any differentiation between the specifications can be based. It is concluded, therefore, that the first assumption is sufficiently true for the purposes of this analysis.

(2) The pass-fail criteria specified for a particular test requirement contained in two or more of the six specification sheets differ only with regard to differences in functional design between related parts. Example: Differences in maximum allowable junction capacity between transistor types is immaterial to the analysis if the difference is, in fact, attributable to differences in junction area as imposed by the device designers.

This assumption is considerably more difficult to justify. With few exceptions (visual inspection, physical dimensions, lead fatigue, solderability),

the pass-fail criteria are based on electrical measurements (end-point tests). The problem primarily concerns the number of electrical measurements made and the procedure used in making them, both of which elements vary considerably from one specification to the next. A detailed examination of the end-point tests indicated that variations in maximum or minimum limits among specifications for specific tests are negligible. Existing differences are attributable mostly to functional design.

The number of electrical measurements required for environmental end-point tests vary from two to fourteen between the six specifications. For life-test end points, the variation is from two to six measurements. It is reasonable to assume, however, that two measurements properly selected can be as effective as fourteen in detecting a failure attributable to any of the environmental or life-test conditions contained in these specifications. The specifications requiring only two measurements specify Collector Cutoff Current (I_{CBO}) and Static Forward-Current Transfer Ratio (h_{FE}). For the purpose of this analysis, these two measurements are held to be adequate, although additional measurements may be quite useful for specific applications.

Although all the specifications utilize attributes (go-no-go) testing, three of the six specifications specify a maximum allowable variation (delta testing) on selected measurements, in addition to specified maximum-minimum limits. Where such additional criteria occur, it becomes exceedingly difficult to appraise the severity of the pass-fail criteria. When delta testing is imposed, it becomes possible to detect

devices that are unstable to the point of being judged defective. Obviously, the pass-fail criteria increase in severity as the allowed variation is reduced. The effect of this increase in the severity of the criteria is impossible to appraise. Of the three specifications that incorporate delta testing in addition to maximum-minimum limits, one specification does so with regard to one out of three life-test end points; another does so with regard to three out of five life-test end points; and the remaining specification does so with regard to two out of two life-test end points. The latter specification also utilizes the delta procedure for a limited number of qualification and acceptance environmental tests.

The assumption that the failure criteria are sufficiently equal for the purposes of this analysis is exceptionally good for the environmental tests since only a limited number of the environmental tests from one of the six specifications are affected by the delta testing procedure. The assumption is less valid when applied to life tests, but it is considered sufficiently valid for purposes of the analysis.

Table 5 numerically rates the relative effectiveness of the test requirements called out in the six specification sheets with regard to the ability of each to assure a given level of quality and reliability. The ratings are based on the LTPD numbers stipulated in the specification sheets for the tests shown in Table 4. These tests were divided into three groups: (1) tests to assure that the devices possess the desired operational characteristics, (2) life tests, and (3) environmental tests.

The number of operational characteristics specified in the six specification sheets ranged from eight to fourteen. It is assumed that the number of characteristics specified

TABLE 5

RELATIVE-EFFECTIVENESS RATINGS OF TEST REQUIREMENTS IN SIX SPECIFICATION SHEETS

Specification Sheet	Test Requirement			
	Environmental Tests	Operating Characteristics Tests	Life Tests	Total Testing
Qualification Test Rating				
Lockheed	72	100	93	265
NASA/UTC	66	96	93	255
MIL-S-19500	60	100	93	253
MIL-R-38100	51	100	90	241
MIL-M-23700	48	96	84	228
NPC-200-3	39	100	45	184
Acceptance Test Rating				
MIL-S-19500	63	90	90	243
MIL-M-23700	51	96	81	228
Lockheed	75	96	45	216
NPC-200-3	39	100	51	190
MIL-R-38100	36	100	48	184
NASA/UTC	39	96	48	183

NOTES: (1) Best possible rating is 100 for particular test; 300 for total testing.

(2) Each specification sheet is identified in this table by the name of the specification system of which it is a part.

was immaterial and that all the specifications specified a sufficient number of characteristics adequately to describe the devices in relation to their application.

The rating listed in the "Operating Characteristics Tests" column of Table 5 is based solely on the LTPD stipulated for the "Operational Characteristics" test in Table 4.

The rating listed in the "Life Tests" column of Table 5 is based on the average of the LTPD numbers stipulated for "Operating Life" and "Storage Life" in Table 4.

The rating listed in the "Environmental Tests" column of Table 5 is based on the average of the LTPD numbers stipulated for environmental tests ("Visual" through "Intermittent Operation" in Table 4).

All ratings shown in Table 5 are based on the relationship of 100 minus the LTPD or average LTPD. As the LTPD or average LTPD approaches 100, the associated rating in Table 5 approaches zero.

In cases where a particular test was not specified, an LTPD of 100 was assigned. If the specification stipulated a 100% screen for an acceptance lot, an LTPD of zero was assigned.

Qualification tests were rated somewhat differently. With the exception of the visual examination and operational-characteristics tests, a screen was considered to be equivalent to an unspecified test, and was assigned an LTPD of 100. If the screen was followed or preceded by a sampling plan, the LTPD of the sampling plan was used. This procedure was based on the fact that screening tests provide negligible information regarding a manufacturer's fitness for qualification approval. In the case of the visual examination and

operational characteristics tests, this limitation does not apply. These tests and examinations assure that the devices on which qualification testing is being performed are, in fact, the devices for which qualification is being sought.

For both qualification and acceptance testing, a few of the tests were considered to be equivalent; in such cases the LTPD of the equivalent test was used if its counterpart was unspecified. Tests considered to be equivalent are as follows:

(1) Operating Life, equivalent to Burn-In at the same power level and ambient temperature,

(2) Storage Life, equivalent to High Temperature Stabilization at the same temperature,

(3) Thermal Shock, equivalent to Temperature Cycling between the same temperature extremes.

In addition, if the specified time for Burn-In exceeded 200 hours and a maximum allowable variation was imposed on the measured parameters, the Burn-In was considered equivalent to an Operating Life Test.

3. ANALYSIS RESULTS

The six specification systems listed in Section 2 are compared in this section with regard to the manner in which they affect the cost, delivery time, and reliability of the devices procured under them.

3.1 Rating Chart

The results of the comparative analysis are shown in the rating chart, Table 6. This chart consists of selected subject headings from the general composite index, with a relative rating assigned to each of the systems for each of the selected headings. Headings for paragraphs that contain only descriptive statements and instructions are not included in the rating chart. A subject heading in the general composite index must relate to a specific requirement or elaborate on the extent of a previously stated requirement in order to be included in the rating chart. Where a particular system provides no requirement or information pertinent to a given heading, no rating is assigned. In general, the ratings vary from 1 to 6. The ratings differ when, in the opinion of ARINC Research Corporation, a significant difference exists between two or more of the specification systems. The rating system makes no distinction as to the degree of difference that may exist. However, where radical differences are evident, an appraisal of such differences is given in the rating commentary, Section 3.2.

A separate rating is assigned to as many of the three factors (cost, delivery time, and reliability) as are affected by a particular subject heading.

In general, a numerically lower rating is indicative of lower cost, shorter delivery time, and greater reliability assurance. Numerically identical ratings indicate that no significant difference exists between specification systems so rated.

TABLE 6

RELIABILITY, COST, AND DELIVERY TIME RATINGS OF SIX SPECIFICATION SYSTEMS ACCORDING TO SUBJECT HEADINGS

Line Number	Subject Heading	Rated Factor*	Specification System Ratings**					
			MIL-R-38100	Lock-heed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
1	Reliability Assurance Plan	R	1	2	4	3	5	5
		C	5	4	2	3	1	1
2	Reliability Level Classification	R	1	2		1		
3	Reliability Assurance Plan Documentation	R	1	2	4	3		
		C	4	3	1	2		
4	Organizational Structure	R	1	1		1		
		C	1	1		1		
5	Training Program	R	1	1		1		
		C	1	1		1		
6	Description of Production Processes and Controls	R	1	3	2	2		
		C	3	1	2	2		
7	Proprietary Processes and Procedures	R	1	1		1		
		C	1	1		1		
8	Procurement, Production, and Control Documents	R	1	2	3	2		
		C	3	2	1	2		
9	Documentation Responsibility	R	1	2				
		C	2	1				
10	Availability and Review of Documentation	R	1	2				
11	Yield	R	1	2				
		C	1					
12	Manufacturers' Facilities	R	1	2	2	2	3	3
		C	3	2	2	2	1	2
13	Quality Control Requirements	R	3	1	2	1		
		C	1	3	2	3		
14	Control of Nonconforming Parts and Material	R	1	1	1	1	1	
		C	1	1	1	1	1	
15	Calibration of Test Equipment	R	1	2	3	3	3	3
		C	3	2	1	1	1	1
16	Failure Analysis and Corrective Action	R	1	3	4	2		
		C	4	2	1	3		
17	Failure Reporting	R	1	2	2	2		
		C	2	1	1	1		
18	Failure Mode Identification and Audit	R	1	2	2	1		
		C	2	1	1	2		
19	Failure Analysis of Discrepant Part	R	1	1	1	1		
		C	1	1	1	1		
20	Failure Analysis Capabilities and Techniques	R	1					
		C	1					
21	Corrective Action	R	1	1	2	1		
		C	2	2	1	2		

* R = Reliability; C = Cost; T = Delivery Time.

** See Section 3.1 of text for rating explanation.

(continued)

TABLE 6 (continued)

Line Number	Subject Heading	Rated Factor*	Specification System Ratings**					
			MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
22	Improved Prototype Parts	R	1					
		C	1					
23	Evaluation of Corrective Action	R	1					
		C	1					
24	Prototype-Improved-Parts Evaluation Tests	R	1					
		C	1					
25	Improved-Part Approval	R	1					
		C	1					
26	Elapsed Time for Approval	R	1					
		C	1					
27	Test Data Transmittal	R	2	1	2	1		
		C	1	2	1	2		
28	Standardized Document Forms	R	3	1		2		
		C	1	3		2		
29	Application Data	R	1			1		
		C	1			1		
30	Qualification Requirements	R	2	1	6	3	4	5
		C	3	3	1	2	2	2
31	Materials Design and Construction	R	1	1		1		
		C	1	1		1		
32	Part-Failure Rate Level	R	1	1		1		
33	Qualification Inspection Requirement	R	2	1	6	3	4	5
		C	2	6	4	5	3	1
34	Qualification-Test Sample Parts	R	1	1		1	1	1
		C	1	1		1	1	1
35	Initial Failure Rate Tests	R	2	1	4	1	1	3
		C	3	5	4	6	1	2
36	Qualification Test Data	R	1	1				
		C	2	1				
37	Verification of Qualification Data	R		1				
38	Qualification Maintenance and Requalification	R	1	2		2		
		C	1	2		2		
39	Failure Rate Administration	R	2	1		2		
		C	2	1		2		
40	Failure Rate Test Records	R	2	1		2		
		C	2	1		2		
41	Certification of Failure Rate Level	R	1	1		1		
		C	1	1		1		
42	Exemption of Data	R	1	1		1		
		C	1	1		1		
43	Reinitiation of Data Accumulation	R	1	1		1		
		C	1	1		1		
44	Correction of Failure Rate Level	R	1			1		
		C	1			1		

* R = Reliability; C = Cost; T = Delivery Time.

** See Section 3.1 of text for rating explanation.

(continued)

TABLE 6 (continued)

Line Number	Subject Heading	Rated Factor*	Specification System Ratings**					
			MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
45	Certification to a Lower Failure Rate Level	R C	1 1					
46	Homogeneity Requirements	R	1	1				
47	Handling, Assembly, and Test Precautions	R C	1 1			1 1		
48	Marking Requirements	R C	1 3	1 2	1 2	2 1	1 4	2 3
49	Date Code	R C	1 1	1 1	1 1	1 1	1 1	1 1
50	Prefix	C					1	1
51	Manufacturer's Identification	R C	1 1	1 1	1 1		1 1	
52	Qualification Designating Code	C					1	1
53	Country of Origin	C					1	1
54	Terminal Identification	C						1
55	Part Number	C	1	1	1	1	1	1
56	Polarity	C					1	
57	Military Designator and Reliability Indicator	C	1				1	
58	Value	C	1					
59	Tolerance	C	1					
60	Serialization	C		1	1	1		
61	Minimum Marking	C					1	
62	Parts and Materials, General Requirements	R	2	1	3	1	3	3
63	Fungus-Resistant Materials	R C	1 1	1 1	1 1	1 1	1 1	1 1
64	Solder	R C			1 1	1 1		
65	Soldering Flux	R C				1 1		
66	Terminal Insulator	R C				1 1		
67	Sleeving Insulation	R C	1 1					
68	Physical Condition of Materials	R C		1 1				
69	Metals	R C	1 1			1 1	1 1	1 1
70	Unacceptable Materials	R C		1 1				

* R = Reliability; C = Cost; T - Delivery Time.

** See Section 3.1 of text for rating explanation.

(continued)

TABLE 6 (continued)

Line Number	Subject Heading	Rated Factor*	Specification System Ratings**					
			MIL-R-38100	Lockheed	NPC-200-3	NASA/UTC	MIL-S-19500	MIL-M-23700
71	Dissimilar Metals	R		?				
		C		?				
72	Terminals and Leads	R	1	1		1		
		C	1	1		1		
73	List of Materials	R		1				
		C		1				
74	Design and Construction, General Requirements	R	3	1	3	3	3	2
		C	1	3	1		1	2
75	Soldering	R		1				
		C		1				
76	Terminals and Leads	R		1				
		C		1				
77	Threads	R		1				
		C		1				
78	Standard Operating Voltages	R						1
		C						1
79	Fault-Location Test Points	R						1
		C						1
80	Workmanship	R	2	1		?	2	2
		C	1	1		1	1	1
81	Witness of Inspection	R	1	1	1	1		
82	Inspection Conditions	R	2	1		1	1	1
		C	1	2		2	2	2
83	Inspection Following Storage	R	1				1	1
		C	2				1	1
84	Qualification Testing	R	?	1	6	2	3	5
		T	1	2	2	2	1	1
		C	2	6	4	5	3	1
85	Acceptance Testing	R	5	3	4	6	1	2
		T	2	2	1	3	2	2
		C	3	5	6	4	1	2
86	Early Shipment	R	2	1		1	2	3
		T	2	1		1	2	2
87	Disposal of Sample Devices	R	1	1		1	1	1
		C	1	2		2	1	1
88	Methods of Examination, Inspection, and Testing	R	1	1	1	1	1	1
		T	1	1	1	1	1	1
		C	1	1	1	1	1	1
89	Environmental Testing	R	5	1	4	4	2	3
		C	3	6	2	1	5	4
90	Preparation for Delivery	R	1	1	2	1	1	1
		C	2	2	1	2	2	2

* R = Reliability; C = Cost; T = Delivery Time.

** See Section 3.1 of text for rating explanation.

3.2 Rating Commentary

The following commentary discusses briefly the scope and meaning of the specification provisions indicated by the subject headings of the rating chart. In addition, where appropriate, the advantages and disadvantages are discussed and the assigned rating is explained.

The numbers to the left of the commentary are the line numbers of the rating chart, Table 6.

1 Stipulates the requirement for a reliability assurance plan. Detailed requirements for such a plan are given on lines 2 through 28. The ratings assigned to line 1 reflect a summary of the detailed requirements. The Lockheed and NASA/UTC documents reference MIL-R-27542, Reliability Program Requirements for Aerospace Systems Subsystems and Equipment, and the ratings assigned to these two documents are based on compliance with the referenced specification. Although MIL-S-19500 and MIL-M-23700 specify a few of the elements of a reliability assurance plan, neither document specifies a reliability assurance plan as such. The omission of a detailed reliability assurance program makes questionable the use of these documents for the procurement of high-reliability devices.

2 Specifies the maximum failure rate for which qualification will be granted. In addition, the various failure-rate levels for which qualification may be granted are defined. This concept makes it possible for a manufacturer to qualify at the lowest failure rate compatible with his capabilities and to receive

remuneration accordingly. Those specifications which provide for qualification only to a single failure rate or reliability level generally do not encourage a manufacturer to put forth his best effort to build high-reliability parts. Such encouragement is considered vital to a procurement specification for high-reliability devices.

3 Specifies the general requirement for documentation necessary for maintaining and administering the reliability assurance plan. The detailed requirements for such documentation are given on lines 4 through 11. The ratings assigned to line 3 reflect a summary of the detailed requirements.

4 Requires documentation delineating responsibility and authority of those personnel associated with the reliability assurance program.

5 Specifies the establishment of a training program involving all aspects of the production of devices under the specification. The requirement includes provisions for all documentation needed to conduct such a training program, in addition to reports to the qualifying activity describing the program. The Lockheed and NASA/UTC documents reference MIL-R-27542. The ratings assigned to these two documents are based on the assumption that the referenced specification, in its entirety, is a specific requirement.

The provisions for a comprehensive training program are considered vital to high-reliability specifications.

6 Requires that documentation be provided to describe all production processes and controls. The differences in assigned ratings are based on differences noted in the extent of documentation required.

7 Requires specifically that proprietary processes and procedures be documented. The extent to which this provision can be enforced is questionable since disclosure of such documentation to the procuring activity is not, and probably cannot be, a requirement.

8 Requires the identification of all documents pertinent to production, procurement, and test processes. The differences in assigned ratings are based on variations in the number of document types specifically detailed for identification, and on the extent to which identification must be carried. The Lockheed and NASA/UTC documents reference MIL-R-27542. The ratings assigned to these two documents are based on the assumption that the referenced specification, in its entirety, is a specific requirement.

9 Specifies that the qualifying agency be informed of personnel designated to maintain control of required documentation and that certain specific documentation be signed off by designated personnel.

10 Requires that all documentation be available for review.

11 Requires that yield information, presented in ratio form to protect proprietary interests, be submitted to the qualifying activity. Such information is an excellent indication of process control status.

Though the exact yield is unknown, yield variations over a time period are made evident. This concept is considered vital to procurement specifications for high-reliability parts.

12 Stipulates the minimum facilities that must be provided, as well as certain specific conditions under which facilities must be used. It may also require documentation of production and test equipment.

13 Requires that the manufacturer institute a quality control system for operations that affect the production of devices under the specification. The actual requirements regarding quality control vary widely. The Lockheed and NASA/UTC documents reference MIL-Q-9858 Quality Control System requirements. MIL-R-38100 simply requires that the manufacturer institute "a quality control system".

14. Requires that nonconforming parts, lots, and material used in the manufacturing process be identified and segregated from acceptable items.

15 Stipulates detailed requirements for test equipment calibration. MIL-R-38100 references MIL-C-45662, Calibration System Requirements.

16. States the general requirement for a failure-analysis and corrective-action plan. The assigned rating reflects the detailed requirements (stated on lines 17 through 26) for such a plan. The inclusion of such a plan is considered imperative for the procurement of high-reliability devices. Only through a detailed failure analysis program can improved reliability be attained. The Lockheed

and NASA/UTC documents reference MIL-R-27542. The ratings assigned these two documents are based, in part, on the assumption that the referenced specification, in its entirety, is a specific requirement.

17 Stipulates the extent to which failures are reported and the manner in which failure reports are made. Since such reporting provides the basis for the evaluation of failures and subsequent part improvement, this provision is vital to procurement specifications for high-reliability parts.

18 Stipulates that the manufacturer will establish a list of all known failure modes relevant to the devices procured under the specification. Various types of data related to failure modes are also required.

19 Stipulates when failure analysis is required, as well as the requirements for reporting the results of such analysis.

20 States the minimum facilities and equipment a manufacturer must possess for performing failure analysis. This requirement is advantageous in that it helps define the extent of failure analysis desired by the procuring activity. Such a provision reduces the possibility of minimal effort in an area vital to device reliability.

21 Requires the manufacturer to recommend a course of corrective action for the elimination of failure modes uncovered during the course of failure analysis. The requirement is vital for improved reliability, but it must be carefully administered.

Changes in the manufacturing process based on such corrective action can conceivably introduce more serious failure modesthan those they seek to eliminate.

22 Specifies the conditions under which prototype parts are to be fabricated. This provision is meant to assure that established production procedures will not be affected until the prototype parts have been evaluated.

23 Specifies the types of studies that shall be used to evaluate the prototype parts to determine that suggested corrective action is sufficient and without deleterious side effects.

24 Requires the testing of the prototype parts as part of the evaluation process.

25 Requires the submission of the results of the studies and tests performed on the improved parts to the qualifying activity. This provision enables the qualifying activity properly to administer and control suggested corrective action resulting from failure analysis.

26 Stipulates the maximum time required for approval of suggested corrective action. Provision is made for automatic approval after a specified time lapse.

27 Stipulates what test data are to be submitted, and the frequency of submission.

28 Stipulates the format to be used for submitted data. This provision is particularly important if data are to be processed automatically, which is generally the case.

29 Requires the manufacturer to submit application data on the devices procured under the specification. This provision is highly desirable from a reliability viewpoint: when properly administered it could reduce the occurrence of field failures attributable to device misapplication.

30 Summarizes the detailed requirements for qualification, which are contained on lines 31 through 36. The ratings assigned to line 30 reflect the ratings assigned to the detailed requirements. In certain specification systems, qualification approval may require prior establishment of a reliability assurance plan and advance submission of application data. The ratings assigned to this line reflect the total requirements for qualification, including testing.

31 Stipulates that the qualifying activity be informed as to the nature of the materials and the design and construction criteria used on the devices for which qualification is sought.

32 Applies only to specification systems that provide for qualification to more than one failure rate. The failure rate for which qualification is granted may be chosen by the manufacturer or stipulated by the procuring activity. In either case, this provision requires that the selected failure rate be established by test prior to qualification approval.

33 Stipulates the requirement for qualification testing. The assigned rating is based on the total requirements for qualification testing and it reflects the ratings assigned to lines 34 through 36 and line 84.

34 Stipulates the general conditions under which a sample for qualification testing may be selected.

35 Specifies the general conditions under which failure rate testing for qualification is to be performed. The reliability ratings assigned are based primarily on data presented in Table 5. The cost ratings are based primarily on the required number of electrical measurements. All data are based on a failure rate level of approximately 1% per 1000 hours.

36 Requires the transmission of various qualification test data to the qualifying activity. The differences in the assigned cost ratings are based on substantial differences in data requirements, which result in gross variations in the amount of data submitted.

37 Requires specific personnel to be responsible for the accuracy and completeness of qualification test data.

38 Outlines the conditions under which qualification will be withdrawn, and the procedures required for requalification. The difference in assigned ratings is attributable to the variation in the conditions under which qualification is withdrawn.

39 Stipulates the general requirements for establishing and maintaining qualification for various failure-rate levels. This provision is meant to assure that adequate records are kept regarding test data, parts tested, etc.; it is particularly desirable when data accumulation plans are used to establish qualification to lower failure-rate levels. The ratings assigned to this line are based on the ratings assigned to lines 40 through 43.

40 Stipulates the extent to which records will be maintained for failure rate testing. In some specification systems, a particular format for records is specified. When data accumulation plans are used, the procedures for such plans are stated in this provision.

41 Stipulates the records and data that must be submitted periodically to the procuring activity to assure that a particular failure rate is being maintained.

42 Requires the identification of questionable test data. Such data may result from faulty test equipment or operator error.

43 Stipulates detailed data-recording requirements for specification systems that allow data accumulation for failure-rate determination.

44 Requires that the procuring activity be informed if accumulated failure-rate test data indicate a reappraisal of the assigned (qualified) failure-rate level.

45 Specifies the procedures a manufacturer must follow if he desires to qualify for a lower failure rate.

46 Stipulates that all materials, processes, and procedures used to construct qualification-sample devices be the same as those normally used in the course of production of procurement lots. In addition, it may be stipulated that all materials used shall be of sufficient homogeneity to assure uniform lots.

47 Requires that procedures be instituted to safeguard the devices adequately from abuse during production and testing.

48 Stipulates the required marking of devices. The ratings assigned reflect the requirements of lines 49 through 61.

49-61 These provisions concern the marking that may appear on a device. Not all marking noted is mandatory. The extent of marking for a particular device type is generally contained in the item specification. Line 61 indicates minimum marking requirements for all devices procured under a particular specification system.

A reliability rating was assigned to lines 49 and 51 because the marking provisions indicated by these lines enable part traceability from field use back to device production. Such traceability is desirable as an aid to failure analysis.

62 Specifies the general requirements for parts and materials used in the construction of devices procured under the specification. The assigned ratings are based on the ratings assigned to lines 63 through 73, which contain specific requirements.

63 Specifies that materials will be non-nutrient to fungus.

64 Stipulates the use of specific solders. In addition, lead material must be suitably treated to facilitate soldering.

65 Stipulates the use of a specific soldering flux.

66 Stipulates the use of specific materials for terminal insulators.

67 Specifies that sleeving insulation be of the type material that shall withstand the stipulated temperature range. A statement describing the material used must be submitted prior to qualification.

68 Specifies that all materials used in device construction shall not fail in various stipulated ways when subjected to the environmental conditions called out in the specification.

69 Requires that metals used in device construction be treated to resist corrosion.

70 Requires that various stipulated materials not be used unless hermetically encased. Materials capable of supporting fungus or combustion shall not be used.

71 Specifies that dissimilar metals shall be protected against electrolytic corrosion.

72 Stipulates the use of specific material for terminals and leads. This material shall not exhibit various specified characteristics when viewed under magnification.

73 Specifies that a complete list of all materials used in device construction be submitted for approval.

74 Stipulates the general design and construction requirements. The ratings assigned to this line partially reflect the ratings assigned to lines 75 through 79, which contain additional detailed design and construction requirements.

75 Stipulates specific precautions that must be observed during any soldering operation. Limited criteria for appraising the adequacy of soldered connections are stated.

76 Specifies that terminals and leads be so constructed that their movement will not damage materials to which they are attached.

77 Specifies minimum thread engagement. Threaded connections are to have some form of locking device to prevent loosening during vibration.

78 Stipulates that specified standard operating supply voltages be used. This requirement is generally applicable only to systems; in this case it applies to a microelectronic circuit.

79 Stipulates that test points be made available on the device. This requirement is not generally applicable to discrete devices.

80 Stipulates the general requirement for quality workmanship. The difference in ratings is related to the degree of detail specified.

81 Stipulates that the manufacturer allow the qualifying or procuring activity access to production and test areas involving devices procured under the specification. The provision primarily concerns testing, and it generally contains special provisions for the protection of proprietary interests.

82 Stipulates specific environmental test conditions that must be maintained in the absence of a detailed environmental requirement. The provision is generally a definition of room ambient conditions, but it may specify certain restrictions regarding electric power, cyclic operation, and total operating time. MIL-R-38100 allows the manufacturer to perform acceptance testing at prevailing conditions of temperature and humidity if conditions are not otherwise specified.

83 Stipulates that devices may remain in storage a specified time before retesting is required. The cost ratings assigned are based primarily on length of storage time allowed prior to shipment without retesting. Variations in "maximum storage time before retesting is required" were held insignificant from the standpoint of reliability.

84 Stipulates the tests required to attain qualification for a particular end-use item. The assigned ratings are based on qualification tests required for a high-speed silicon switching transistor, except in MIL-M-23700. In MIL-M-23700, the rating is based on qualification-test requirements for a silicon semiconductor functional block. (See Section 2.2.) Failure-rate levels of 1% per 1000 hours were assumed in the evaluation of specification systems that provide for qualification to various failure-rate levels. This is approximately the same level of reliability as the level assured by the qualification test requirements of the remaining systems.

The assigned reliability ratings are based on an appraisal of how effective the specified tests are in assuring that a manufacturer possesses the desired capabilities for production. Qualification testing in itself, of course, adds nothing to the inherent reliability of the devices for which qualification is granted.

85 Stipulates the test requirements for lot acceptance of a particular end-use item. The assigned ratings are based on acceptance test requirements for the same type of devices described in line 84. (See Section 2.2.)

Reliability ratings are based on an appraisal of how effective the acceptance tests are in assuring a given level of quality and reliability.

For analysis purposes, testing requirements were separated into the three areas of (1) environmental testing, (2) operating-characteristics testing, and

(3) life testing. Each of these three areas was assumed to be equal to the others in importance. The assigned ratings are based on the total scores shown in Table 5. These scores are based on the extent of testing required and the LTPD associated with each test.

Delivery-time ratings are based primarily on the minimum initial time required for life tests. Provisions for early shipment were not considered. It is extremely difficult, if not impossible, to make an appraisal of relative delivery time since the factors of greatest influence are often outside the specifications. These factors include such items as test-equipment scheduling and administrative delays.

Cost ratings are based primarily on the number of electrical measurements required to substantiate the requisite operational characteristics and to provide for the end-point checks on environmental testing. A procurement lot of 1000 units was assumed for the computation of required electrical measurements.

The assigned ratings indicate, on the basis of the analysis techniques used, that those specifications which produce the highest test cost are not necessarily the most effective in assuring a given level of quality and reliability.

The overall test requirements of MIL-S-19500 are rated as the most effective and the least expensive. The test requirements of the NASA/UTC document are rated not only as the least effective but also as among the most expensive.

Specifications that require 100% acceptance screens increase test costs radically over costs of specifications that require lot sampling.

The degree to which the specifications differ with regard to the cost and effectiveness of test requirements can be determined by reference to Tables 3 through 5.

86 Stipulates the conditions under which procurement lots may be shipped before the completion of life tests on a selected sample. The differences in the assigned reliability ratings are based on the degree of control exercised over early-shipment provisions in each of the specifications. The delivery-time ratings are based solely on minimum test time required before shipment is possible.

87 Stipulates the disposition of sample devices that have undergone the various tests required by the specification. Except for devices subjected to destructive tests or devices that fail, this provision states that the devices are to be shipped as part of the purchased lot or are to be retained by the manufacturer. From the viewpoint of reliability assurance, there appears to be no material advantage in having these devices retained. The cost ratings are based on whether or not the manufacturer must retain devices that have not been subjected to destructive tests or that have not failed.

88 Stipulates the conditions and methods to be used when parts procured under the specification are being tested. Such provisions depend on the generic part type and, in some cases, on the individual part type

under consideration. The generic part type considered in this provision is the semiconductor group. All of the specifications under discussion refer to MIL-STD-750, Test Methods for Semiconductors.

89 Stipulates the environmental tests to be performed on devices procured under the specification. A composite list of the environmental test requirements of the six specifications under consideration is shown in Table 4 (lines 4 through 26) for a specific part type. The assigned reliability ratings are based on the environmental-tests-for-acceptance scores shown in Table 5. The cost ratings are based on the number of environmental tests required for acceptance.

90 Stipulates requirements for the preservation and packaging of devices for storage or shipment. In addition, this paragraph contains applicable requirements for the marking of containers and packaging. Special conditions under which packaging is to be accomplished may also be included.

The assigned ratings are based on the degree of detail specified.

APPENDIX

FLOW CHARTS FOR QUALIFICATION AND ACCEPTANCE TESTING

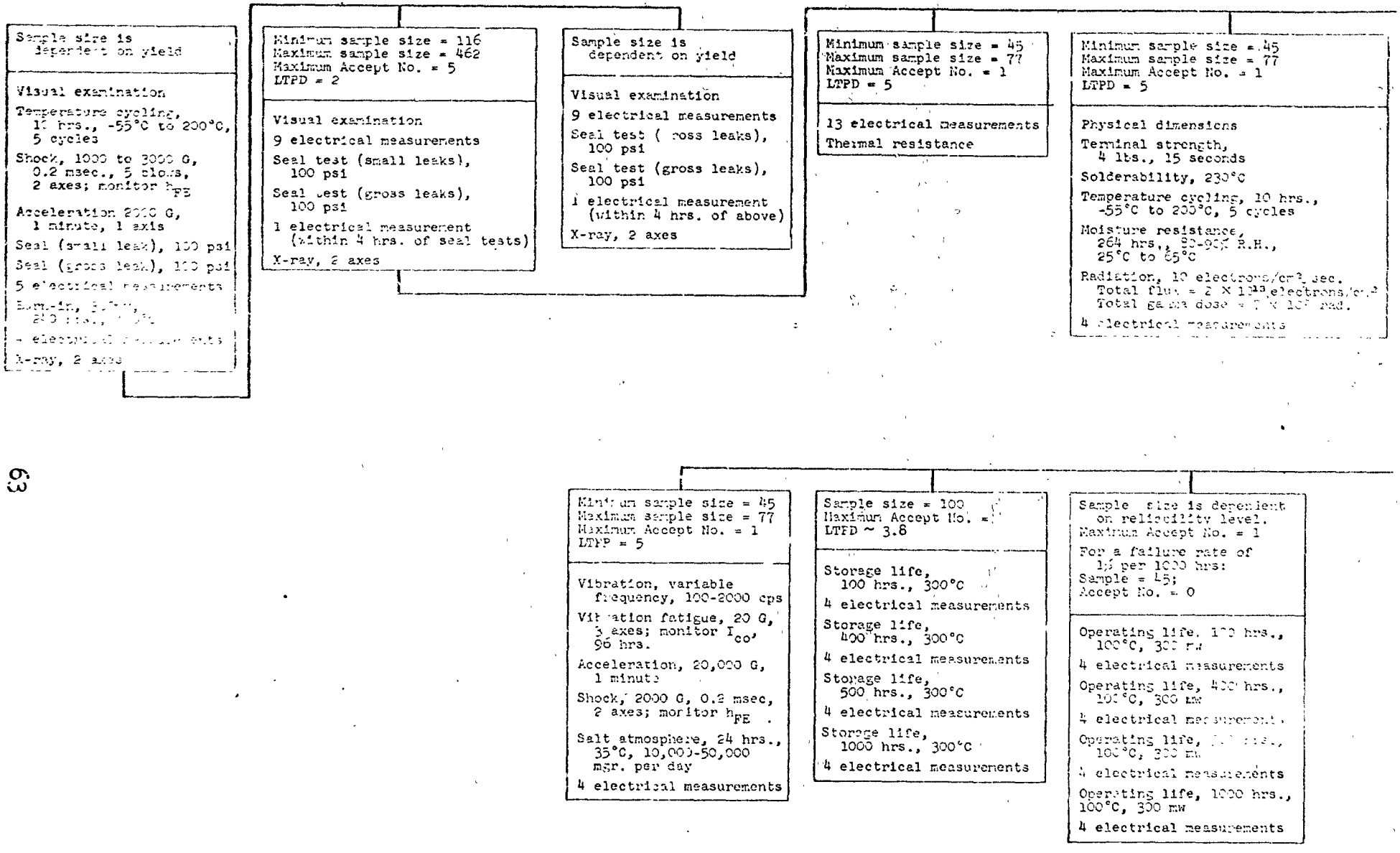
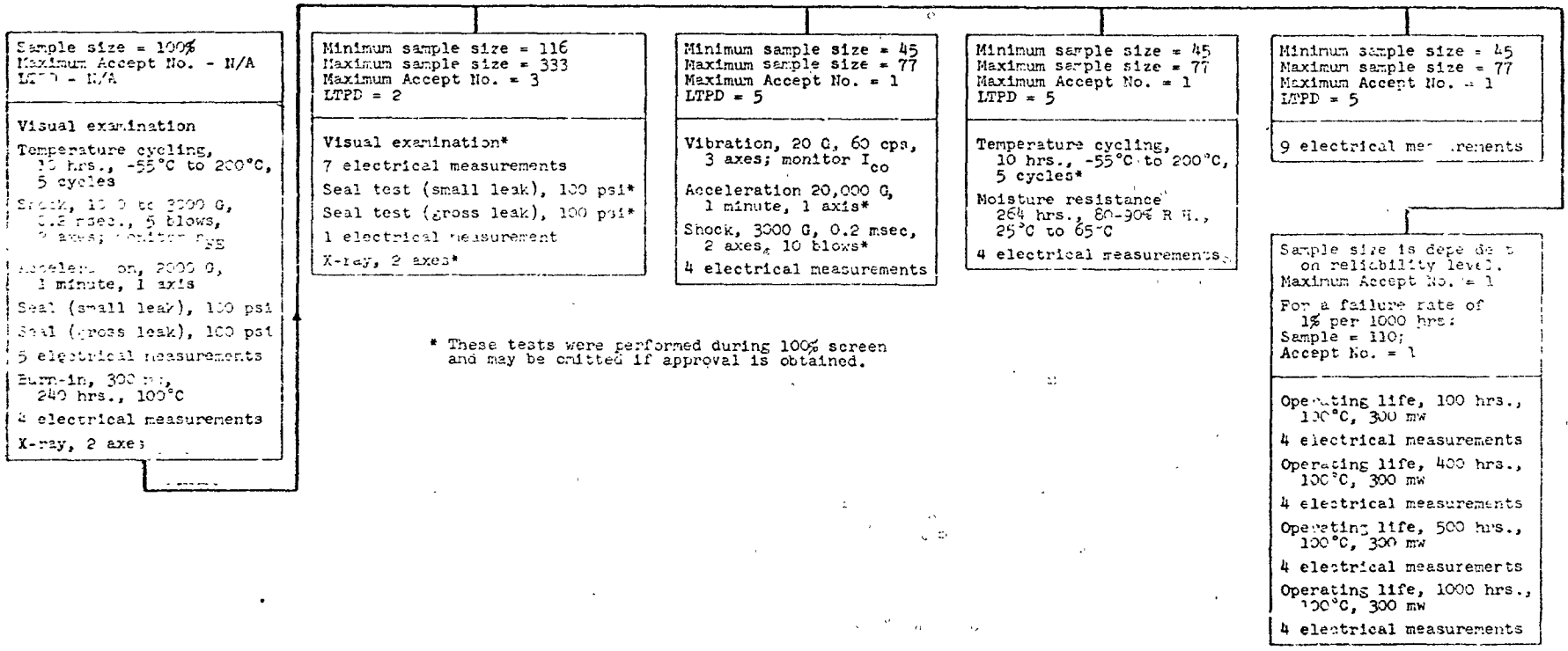


FIGURE A-1

FLOW CHART FOR QUALIFICATION TESTING:
NASA/UTC SPECIFICATION SYSTEM,
SILICON TRANSISTOR



* These tests were performed during 100% screen and may be omitted if approval is obtained.

FIGURE A-2

FLOW CHART FOR ACCEPTANCE TESTING:
NASA/UTC SPECIFICATION SYSTEM,
SILICON TRANSISTOR

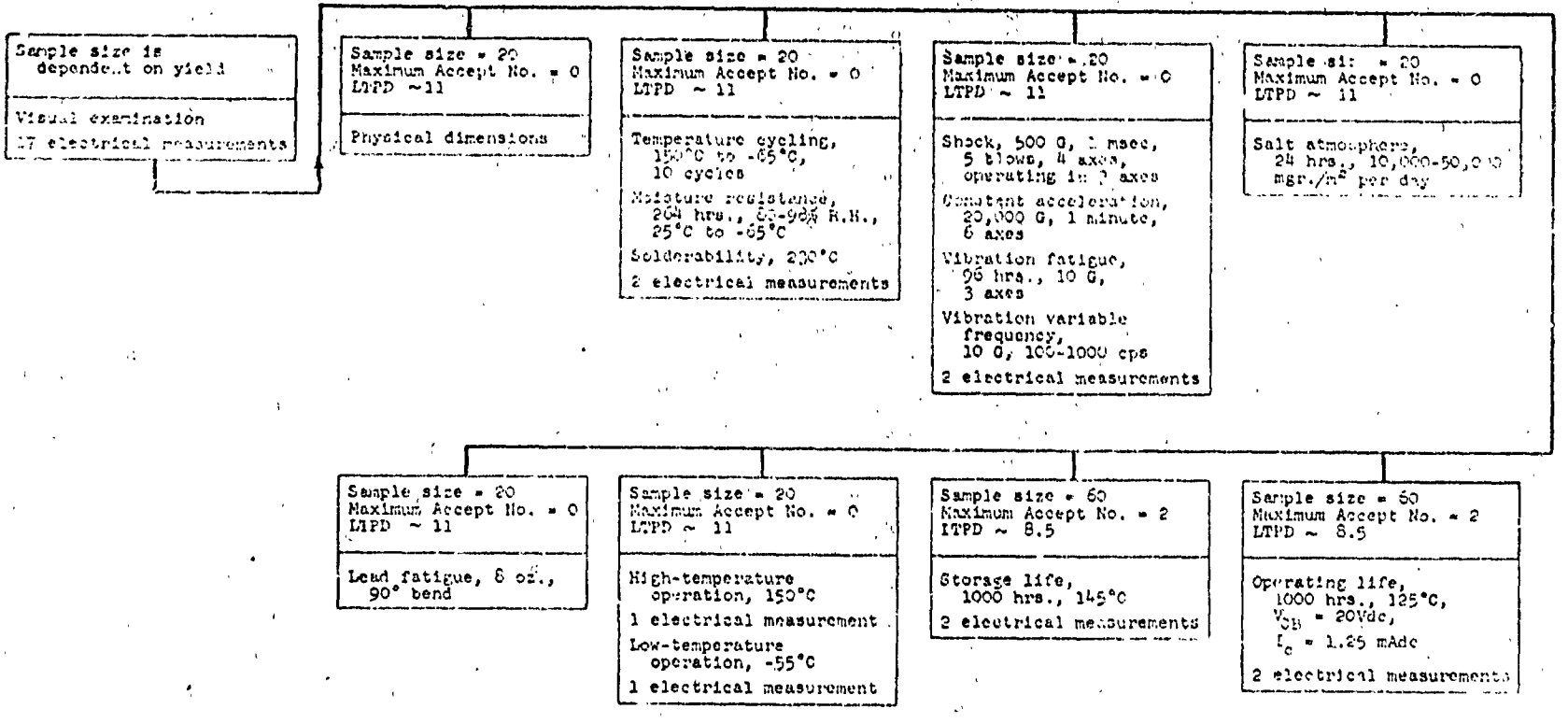


FIGURE A-3

FLOW CHART FOR QUALIFICATION TESTING: MIL-S-19500 SPECIFICATION SYSTEM, SILICON TRANSISTOR

Minimum sample size = 45 Maximum sample size = 158 Maximum Accept No. = 4 LTPD = 5
Visual examination (major)

Minimum sample size = 22 Maximum sample size = 91 Maximum Accept No. = 5 LTPD = 10
Visual examination (minor)

Minimum sample size = 22 Maximum sample size = 65 Maximum Accept No. = 3 LTPD = 10
6 electrical measurements

Minimum sample size = 22 Maximum sample size = 65 Maximum Accept No. = 3 LTPD = 10
5 electrical measurements

Minimum sample size = 22 Maximum sample size = 91 Maximum Accept No. = 5 LTPD = 10
3 electrical measurements

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
Physical dimensions

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
Shock, 500 G, 1 msec, 5 blows, 4 axes, 3 axes operating Contant acceleration, 20,000 G, 1 minute, 6 axes Vibration fatigue, 96 hrs., 10 G, 3 axes Vibration, variable frequency, 10 G, 100-1000 cps 2 electrical measurements

Minimum sample size = 22 Maximum sample size = 52 Maximum Accept No. = 2 LTPD = 10
Operating life, 1000 hrs., 125°C, V_{CB} = 20Vdc, I_c = 1.25 mVdc 2 electrical measurements

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
Temperature cycling, 150°C to -65°C, 10 cycles Moisture resistance, 264 hrs., 80-98% R.H., 25°C to 65°C Solderability, 230°C 2 electrical measurements

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
Lead fatigue, 8 oz., 90° bend

Minimum sample size = 22 Maximum sample size = 52 Maximum Accept No. = 2 LTPD = 10
Storage life, 1000 hrs., 145°C 2 electrical measurements

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
High-temperature operation, 150°C 1 electrical measurement Low-temperature operation, -55°C 1 electrical measurement

Minimum sample size = 11 Maximum sample size = 32 Maximum Accept No. = 3 LTPD = 20
Salt atmosphere, 24 hrs., 10-000-50,000 mgr./m² per day

Minimum sample size = 22 Maximum sample size = 91 Maximum Accept No. = 5 LTPD = 10
3 electrical measurements

NOTE: Tests within blocks must be performed in order shown; no block-to-block sequence is required.

FIGURE A-4

ACCEPTANCE TESTING REQUIREMENTS
FOR MIL-S-19500 SPECIFICATION SYSTEM,
SILICON TRANSISTOR

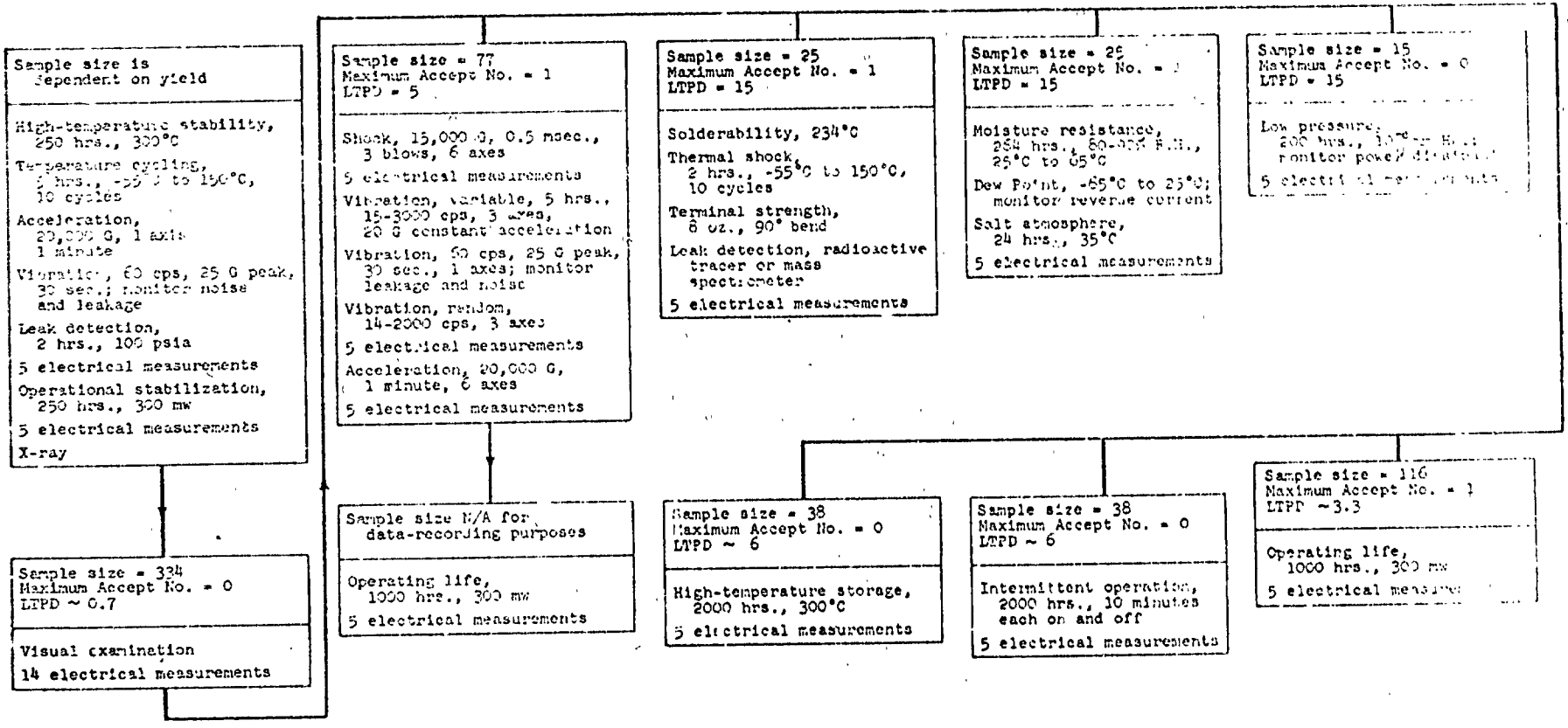


FIGURE A-5

FLOW CHART FOR QUALIFICATION TESTING: LOCKHEED SPECIFICATION SYSTEM, SILICON TRANSISTOR

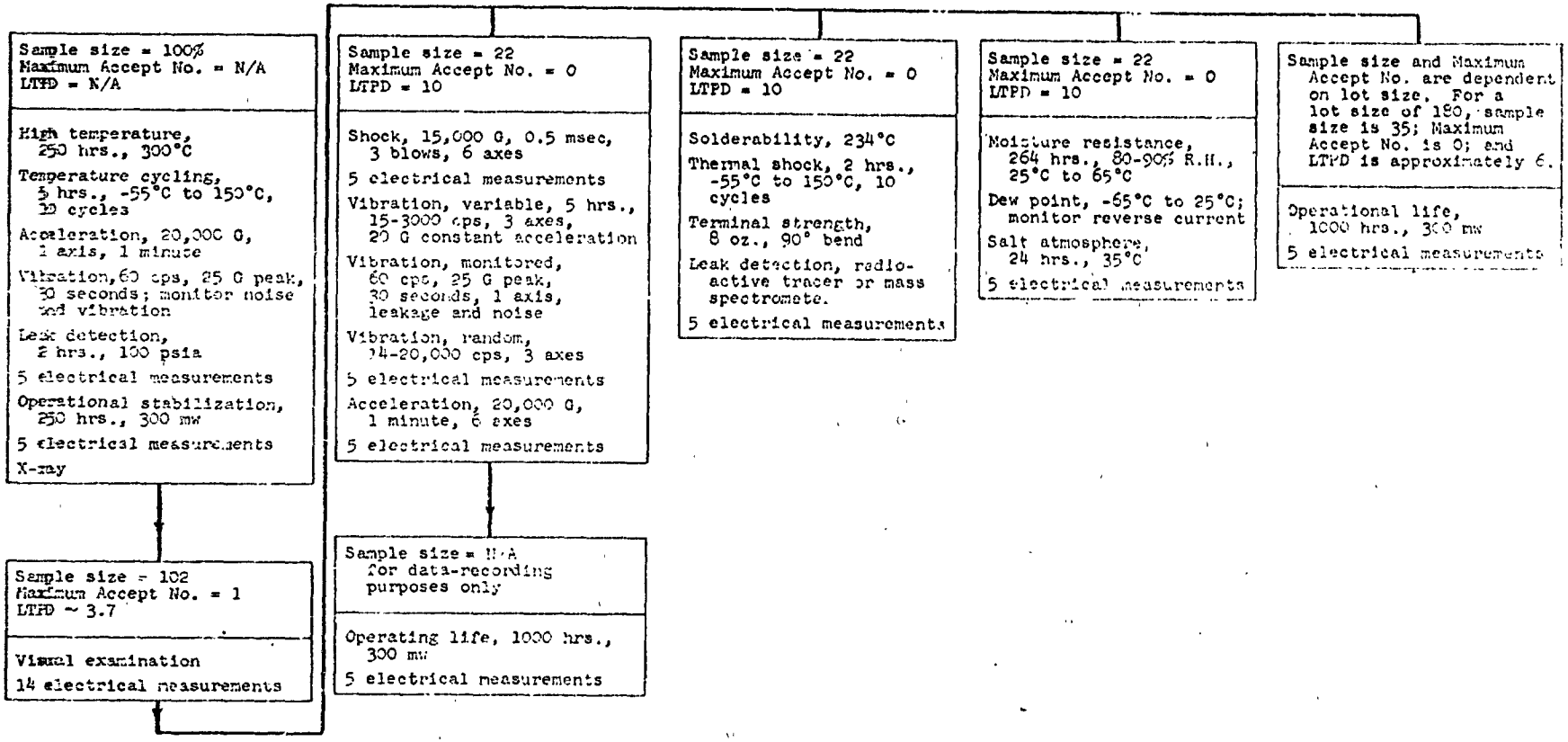
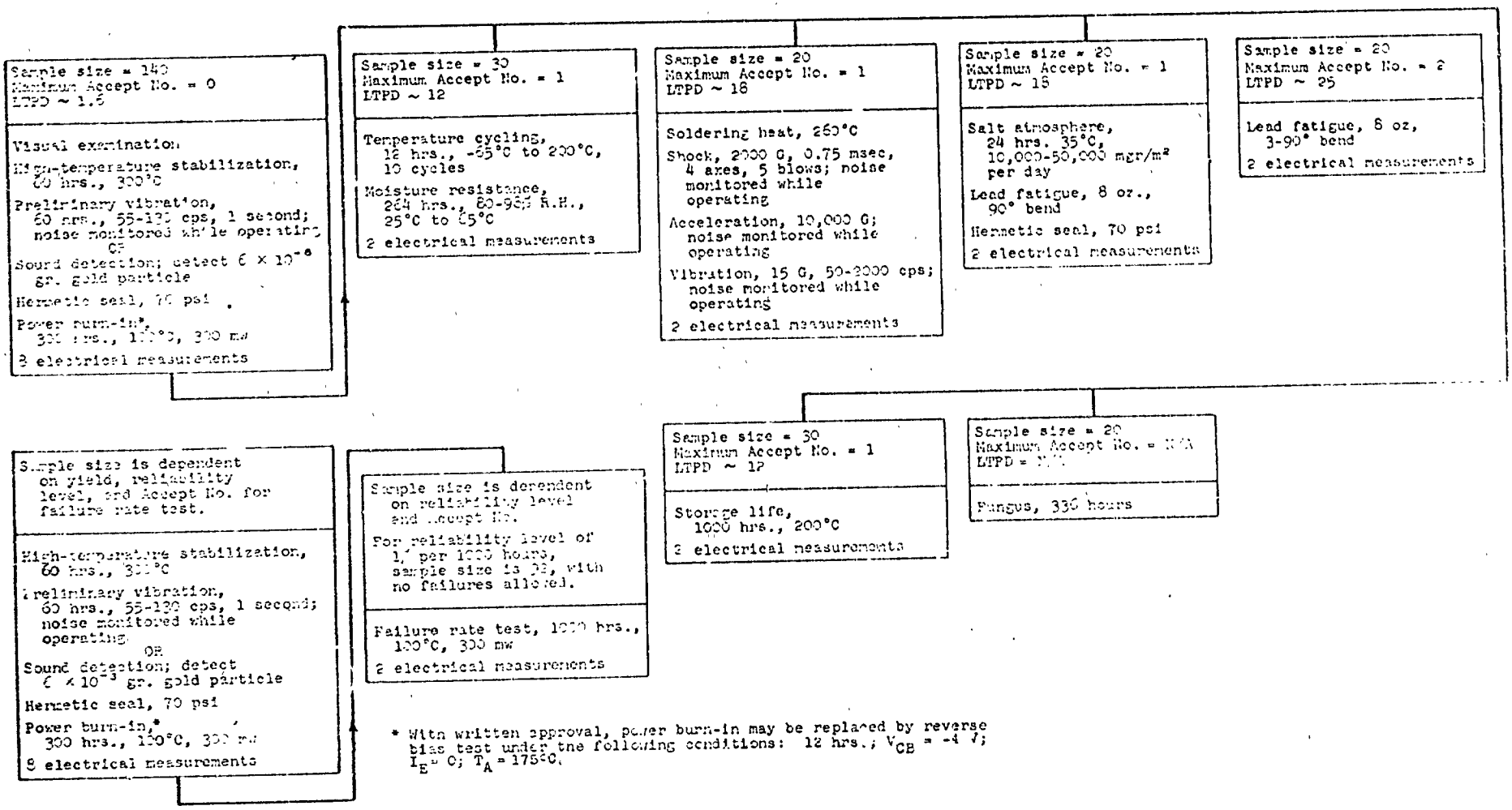


FIGURE A-6

FLOW CHART FOR ACCEPTANCE TESTING: LOCKHEED SPECIFICATION SYSTEM, SILICON TRANSISTOR



* With written approval, power burn-in may be replaced by reverse bias test under the following conditions: 12 hrs.; V_{CB} = -4 V; I_E = 0; T_A = 175°C.

FIGURE A-7

FLOW CHART FOR QUALIFICATION TESTING:
MIL-R-38100 SPECIFICATION SYSTEM,
SILICON TRANSISTOR

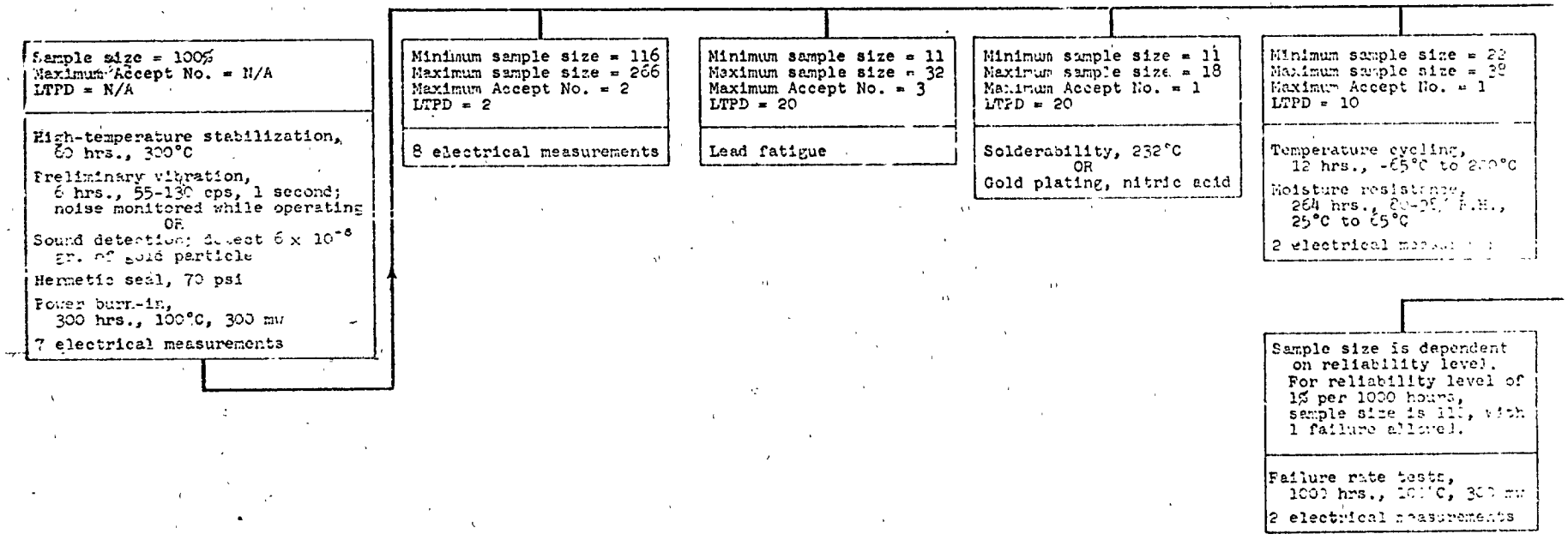


FIGURE A-8

FLOW CHART FOR ACCEPTANCE TESTING:
MIL-R-38100 SPECIFICATION SYSTEM,
SILICON TRANSISTOR

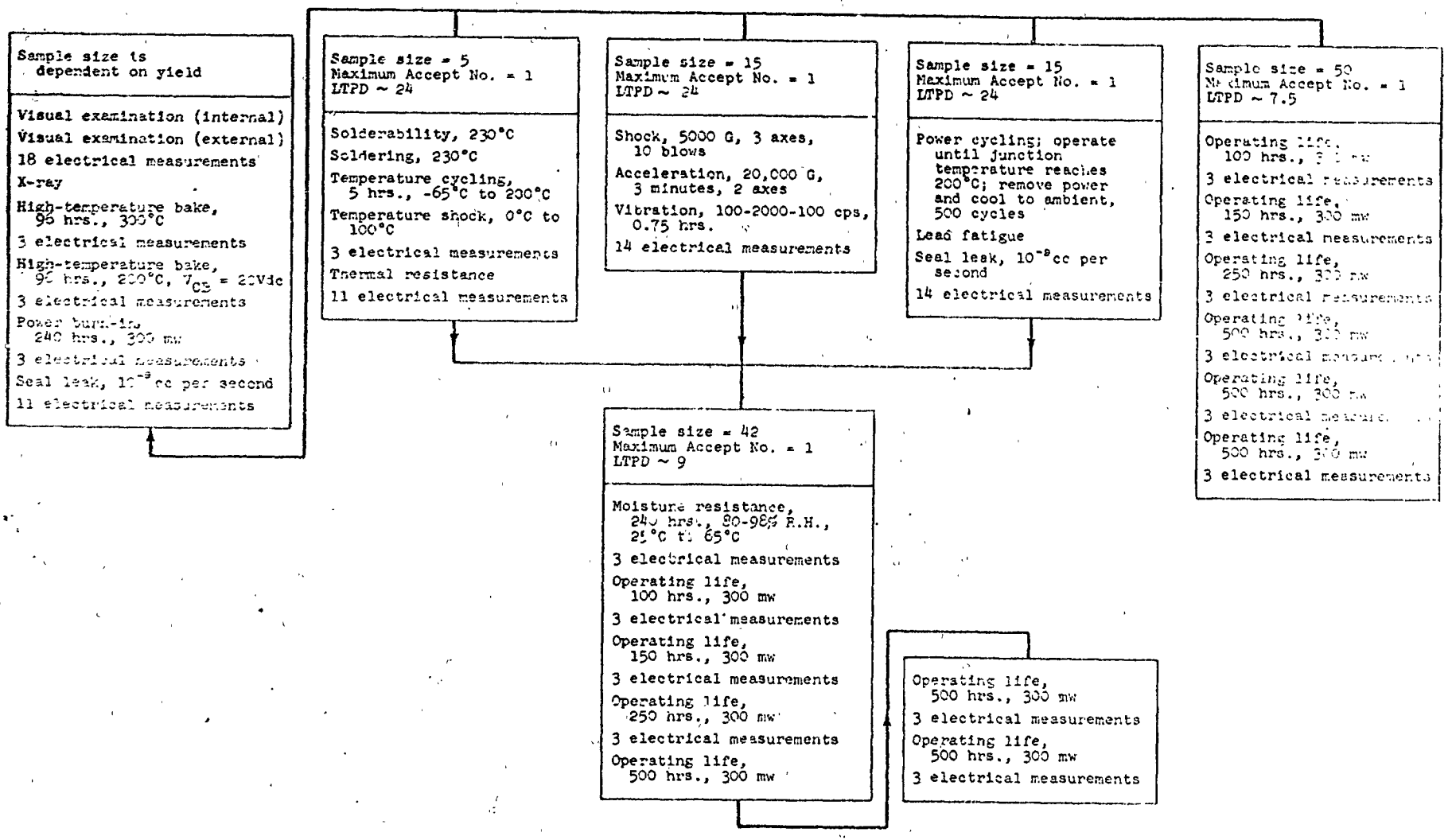
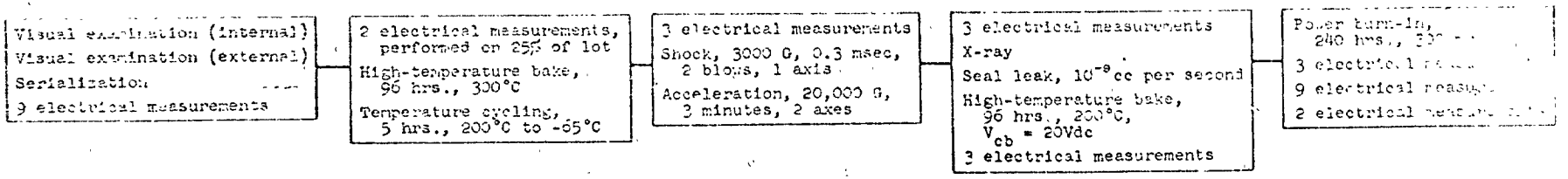


FIGURE A-9

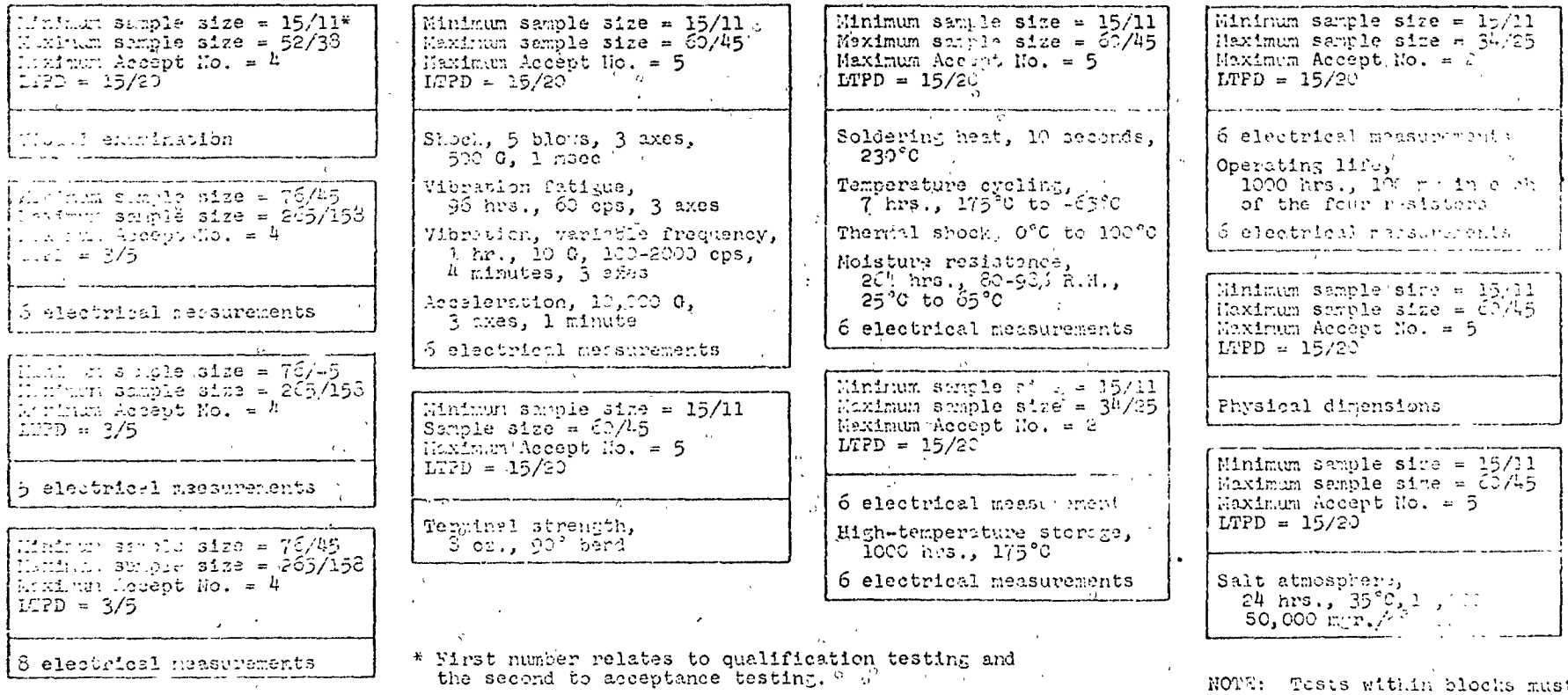
FLOW CHART FOR QUALIFICATION TESTING: NPC-200-3 SPECIFICATION SYSTEM, SILICON TRANSISTOR



NOTE: Sample size is 100%. Failed units are to be replaced.

FIGURE A-10

ACCEPTANCE TESTING REQUIREMENTS:
NPC-200-3 SPECIFICATION SYSTEM,
SILICON TRANSISTOR



* First number relates to qualification testing and the second to acceptance testing.

NOTE: Tests within blocks must be performed in order shown; no block-to-block sequence is required.

FIGURE A-11

FLOW CHART FOR QUALIFICATION AND ACCEPTANCE TESTING:
MIL-M-23700 SPECIFICATION SYSTEM,
SILICON DIODE GATE CIRCUIT