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SUMMARY REPORT

DEVELOPMENT OF AVIONICS INSTALLATION INTERFACE STANDARDS

August 1981

Prepared for
AERONAUTICAL SYSTEMS DIVISION
DEPUTY FOR DEVELOPMENT PLANNING (ASD/XR)
AND DEPUTY FOR AVIONICS CONTROL (ASD/AX)
WRIGHT-PATTERSON AIR FORCE BASE
DAYTON, OHIO 45433
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FOREWORD

Under Contract F04606-79-G-0082, ARINC Research Corporation adapted the Airlines Electronic Engineering Committee's ARINC Specifications 600 and 601 to meet the environment and constraints of military aircraft installations.

ARINC Research acknowledges the valuable contributions to this study provided by the Aeronautical Systems Division engineering staff (ASD/EN) and the many aircraft and avionics industry representatives who took time out to attend and support the open forum and other meetings described in this report, or who provided written comments in response to our circulation of draft documents.

This is a revision of ARINC Research Publication 2558-03-2-2447, June 1981. The revision includes the August 1981 complete update of "Strawman Air Force Control and Display Unit Installation Standard" in place of the previous version originally included as Attachment 2.

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CHAPTER ONE

INTRODUCTION

This report summarizes ARINC Research Corporation's efforts under Air Force Contract F04606-79-G-0082, "Standard Rack-Mounted and Panel-Mounted Avionics Interface Concepts Analysis." The period of performance was 29 August 1980 through 15 June 1981.

The technical areas addressed were the analysis and potential specification of rack-mounted avionics, cockpit-mounted control panels, and panel-mounted instruments. Contract tasks included conceptual studies of potential configurations of a Standard Avionics Integrated Control System (SAICS). The results of the SAICS analyses are reported separately in ARINC Research Publication 2258-02-1-2439, *Cost Benefit and Failure Criticality Analyses of the Standard Avionics Integrated Control System (SAICS) Concept,* June 1981.

The concepts-analysis project described herein continues a contractual effort initiated by the Air Force in 1979 to determine whether a comprehensive Packaging, Mounting, and Environmental (PME) avionics interface standard would benefit Air Force aircraft. Comprehensive findings of that effort are documented in ARINC Research Publication 1753-01-1-2124, *Standard Avionics Packaging, Mounting, and Cooling Baseline Study,* January 1980, which addresses the applicability of commercial airline avionics to military aircraft, the cost benefits associated with Air Force PME standards, and a possible implementation scenario with recommended activities and schedules. We recommend the perusal of that report to readers who are not familiar with this program. It forms the basis and justifications for continued Air Force efforts to pursue developments of a U.S. Air Force PME installation standard.

1.1 TASKS AND TECHNICAL APPROACH

The Air Force expressed the desire that the initial strawman rack-mounted and panel-mounted interface specifications conform as closely as possible to the applicable commercial (ARINC) specifications, since those documents represent the carefully considered product of a large segment of the potential supplier community.

We drew heavily on AEEC/ARINC experience and on commercial avionics and airframe manufacturing and integration experience, obtained from industry and consolidated during the study. We obtained this information by means of mailed surveys, visits, and an "open forum" meeting for the Air Force and industry, conducted in much the same manner as AEEC open-forum meetings to develop avionics specifications for the commercial carriers. Our work was organized in three tasks.

1.1.1 Task 1: Formulate and Assess Factors Influencing Standards for Rack-Mounted and Panel-Mounted Avionics

Task 1 addressed the planning factors relevant to the potential implementation of SAICS and PME standardization.

U.S. Air Force and DoD sources were surveyed for information on the planned and projected force structure for new aircraft and for modified aircraft that require new avionics subsystems. For each aircraft type, we determined the market size and projected IOC date for each new avionics requirement. The basic source of these data for the Air Force is the *Avionics Planning Baseline;* Navy information was obtained through the Naval Air System Command (Code: AIR 533); U.S. Army data were obtained from the U.S. Army's Aviation and R&D Activity (AVRADA). The data gathered were compiled and summarized to show the total market size for each subsystem in the period 1985 to 2000, and to show the grouping of aircraft by "windows of opportunity" for introducing production quantities of standard avionics subsystems that can be expected to be common to several aircraft types.

On the basis of this analysis and compilation, as well as the development, production, and modification-lead-time estimates, we developed times for the introduction of new or next-generation avionics subsystems and prepared a listing of candidate avionics LRUs to be built to each PME specification. Chapter Two and Three provide a summary of the analysis.

1.1.2 Task 2: Formulate Strawman Specifications and Standards

We circulated a preliminary draft Strawman PME Standard, prepared directly from the AEEC's ARINC Specification 600-2 word processor tapes, among industry, Air Force, and Navy avionics organizations. The purpose was to elicit comments on the use of commercial specifications for Air Force aircraft from the designers, installers, and users; and, where personal meetings could be arranged, to provide a focus for discussions. Meetings involving 13 companies and 5 Air Force agencies were arranged. Mailed comments were received from industry, Air Force, and Navy organizations.

1.1.3 Task 3: Determine the Accommodations Required for Acceptance of an Avionics PME Standard by Industry and Government Agencies

1.1.3.1 Identify Technical and Operational Issues

During the Task 2 trips, we collected and compiled data from pertinent Air Force, DoD (U.S. Navy and U.S. Army), and industry (avionics and airframe) sources concerning the following:

- Technical issues, requirements, and concepts for PME specifications for avionics

- Suitability of the technical content of ARINC Specifications 600 and 601 (with minimal tailoring) for a wide variety of air-cooled and convection-cooled military avionics
- Suggestions for modifying, augmenting, or deleting parts of ARINC Specifications 600 (Rack-Mounted Interfaces) and 601 (Panel-Mounted Interfaces) to accommodate use of a wide variety of military avionics

1.1.3.2 Evaluate Basis for Air Force Avionics PME Standards

Using the requirements, data, and opinions gathered, we developed a concept and rationale for avionics PME standardization that would be potentially acceptable to the Air Force using commands, logistics commands, and industry.

Following a briefing to ASD/AX/XR and review by ASD/EN representatives, Air Force approval was given for the updated versions of both draft standards to be distributed, with the agenda for and invitations to attend an Open Forum on Avionics Installation Standardization.

1.2 REPORT ORGANIZATION

This report is organized chronologically to provide a better understanding of the rationale leading to strawman standards and the conclusions drawn from the open forum.

Chapter Two describes our review of the future aircraft and avionics programs that may be candidates for the new installation standards. Chapter Three presents the rationale for the hierarchy of standards that was chosen and the applicability of these standards to different types of aircraft and avionics.

Chapter Four summarizes the comments on the strawman standards received from industry and Government prior to the open forum. Chapter Five describes the proceedings of the open forum and the consensus position on features of the avionics-bay installation standard. Chapter Six describes post-forum activities.

Chapter Seven describes the activities required for future implementation.

Chapter Eight presents our conclusions and recommendations on the general requirements for installation standards.

Supporting documentation is presented in a series of Appendixes:

- Appendix A lists the industry and Government contacts made during the development of the standards.
- Appendix B summarizes the mailed comments on the strawman standards.

- Appendix C presents considerations for the development of a High-Power Dissipation Addendum to the Avionics Installation Standard.
- Appendix D presents a draft Military Addendum to ARINC Specification 600.

A draft Avionics Installation Standard and a preliminary Strawman Control and Display Unit Standard are provided as Attachments 1 and 2, respectively.

CHAPTER TWO

AIRCRAFT AND AVIONICS EQUIPMENT PROJECTIONS

2.1 CANDIDATE AIRCRAFT FOR THE STANDARDS

We identified candidate aircraft, by mission designation series (MDS), that will exist in quantities greater than 20 in the period 1985 to 1990. The primary source document for this information was a computer projection by Headquarters, USAF (XO) for the FY 1982 Program Objective Memorandum (POM) "PA-82-3." That document was analyzed in detail to determine trends in force structure planning. The first conclusion reached was that the proportion of airframe types will remain fairly constant through 1995 as the Air Force replaces older aircraft (such as the F-4) with newer aircraft (such as the F-16).

Figure 2-1 demonstrates that the Air Force force structure in 1985 will comprise primarily high-performance airframes. The next two largest categories are cargo/transports and trainers.

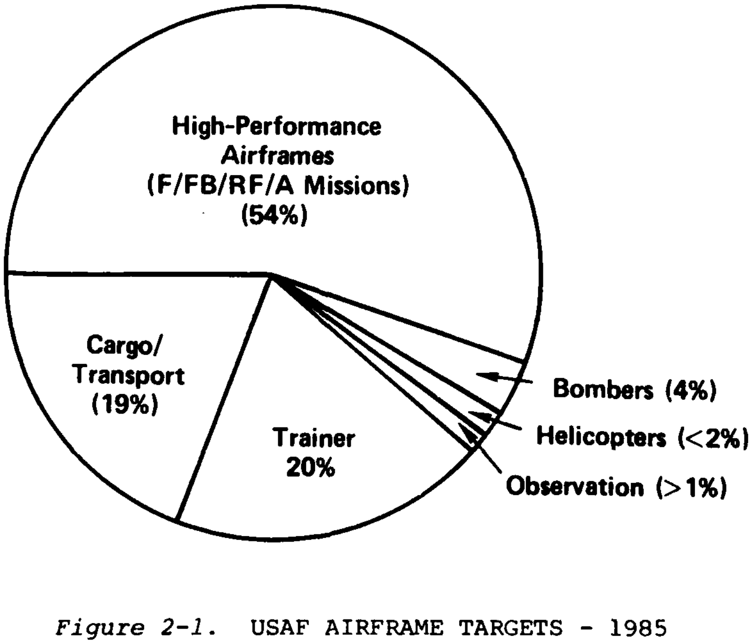

Figure 2-1. USAF AIRFRAME TARGETS - 1985

Since the current ARINC 600/601 commercial interface standards have been developed for cargo/transport-type airline aircraft, they may be directly applicable to less than 25 percent of the Air Force's 9,500 aircraft. A final observation to be drawn from Figure 2-1 is that, with respect to the total inventory, the proportion of bombers, helicopters, and observation aircraft is small. These classes of aircraft have some peculiar requirements with respect to environmental conditions of cooling, vibration, and electromagnetic pulse protection. To the extent possible, a PME standard should accommodate those requirements; however, the peculiarities of 6 percent of the force should not drive the concept for the remaining 94 percent. It may be necessary to have more than one installation standard or to allow broad exemptions for certain implementation.

2.2 WINDOWS OF OPPORTUNITY FOR THE STANDARDS

The Air Force projections of new aircraft production into the foreseeable future average about two percent of inventory per year. This means that in any given year, approximately 190 completely new avionics installations will be accomplished. However, not all new installations can be immediate candidates for the PME standard.

The commercial air transport industry, in arriving at ARINC 600/601, found that it will have taken approximately five years from the time the "new concept" installation standard was fairly well defined to the time it actually appears on the production aircraft. Basic decisions on dimensional multiples, form of cooling, racks, and holddowns were established in 1976 for the installations now being made on the Boeing 767.* There is no reason to suggest that the lead times for the military could be made much shorter. Thus 1985 is probably the earliest reasonable window for Air Force use of a new installation standard on its aircraft.

Figure 2-2 shows the new aircraft and major-retrofit aircraft on which firm planning information could be obtained. In addition to the AF/XO projections, our sources of information were the U.S. Army Aviation R&D Plan and individual program offices in the Air Force, Army, and Navy.

The year 1985 shows a number of new aircraft starts. The quantities planned for the period 1985 to 1990 are shown in parentheses; however, it should be noted that in the case of the Air Force aircraft, the F-16A/B** is already design-committed, thereby leaving 480 aircraft available as candidates for the installation standard. Similar situations exist for both Army and Navy aircraft as well. For example, both the F-18 and AV-8 are already design-committed, but more than 200 other Navy aircraft can be considered candidates.

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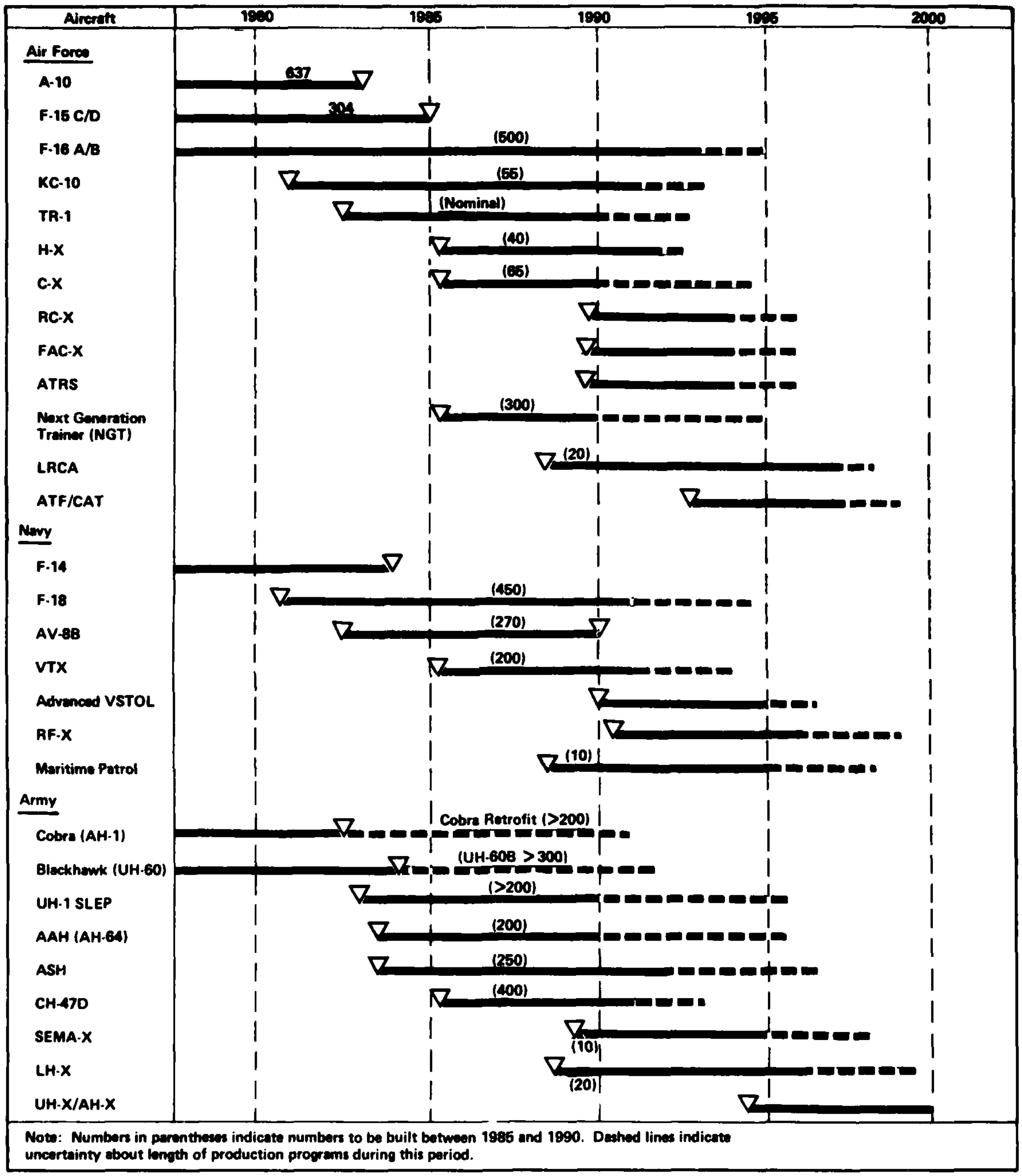
*Not all aspects were agreed upon at that time, however. For example, the final choice of the connector was not made until 1978.

**It may be possible to have a favorable impact on some portion of the avionics suite for Phase III of the Multinational Staged Improvement Program (MSIP). This program has not been fully defined, however.



Note: Numbers in parentheses indicate numbers to be built between 1985 and 1990. Dashed lines indicate uncertainty about length of production programs during this period.

Figure 2-2. NEW AIRFRAME OR MAJOR RETROFIT PROGRAMS

The Air Force candidate MDSs for implementation of this avionics installation standard appear to be:

MDS	1985-1990 Quantity	Remarks
KC-10	55	This aircraft is currently configured to receive ARINC 404A-specified avionics. To the extent that the future USAF standard adheres to commercial sizing, there should be little difficulty in accommodating the newer installation standards to the extent appropriate.
TR-1	--	
H-X	40	
C-X	65	Both of these aircraft are also expected to employ a significant amount of commercial avionics.
NGT	300	
LRCA	20	
Air Force Total	480	

The avionics "black box" count of those aircraft averages about 50 units. Thus, by 1990, more than 20,000 "new concept" avionics units could be in the Air Force inventory, providing benefits in lower LCC and retrofit costs.

We did not speculate on the numbers of aircraft in Air Force retrofit programs that might be included as candidates. All current major retrofit programs (EF-111A, B-52, OAS, F-15 Strike Eagle) have progressed too far to be influenced by a new installation standard. By 1985 the early A-10s and F-15s could be ready for a major retrofit, and this could add another 1,000 airframes as candidates for PME installations.

Other military services' use of the standard is contingent upon their agreement with the basic parameters of the specification. There is an increasing record of the employment of interservice avionics subsystems in the DoD. The ARN-118 TACAN and the APX-72 IFF Transponder are examples of equipments that are employed widely in all three services. The U.S. Air Force is looked upon as a primary developer of military avionics for DoD; thus the needs of the other services should be considered in developing the installation standard.

In the Navy, the advanced carrier trainer VT-X is the primary "window." Its requirements could be very similar to those of the Air Force's Next Generation Trainer (NGT). The driving requirements for new avionics in the Navy during the period 1985 to 1990, however, will be the F-18 program, which is design-committed (and which will probably have improvement programs similar to that planned under the F-16 MSIP) and piecemeal retrofit programs that are not shown on the chart.

The U.S. Army is planning major retrofit programs for the late 1990s. They are oriented to provide "Nap of the Earth" (NOE) capabilities for the current airframes, which are considered structurally and aerodynamically adequate. The major kinds of avionics involved are precision navigation sensors, night-vision devices, beyond-line-of-sight communications systems, and similar systems employed at low altitudes.

2.3 AVIONICS GFE PROGRAMS

An installation standard should encompass both GFE and CFE avionics; however, it is particularly important that the requirements for GFE avionics be understood, because these are normally installed in multiple aircraft types and have significant economic impact. A true test of the suitability of an Air Force installation standard would be its applicability to major GFE programs.

Our review of the major USAF initiatives to be implemented in 1985 and beyond produced the following list of GFE programs with production programs in excess of 3,000 units* by 1995. We have extended the "window" period by five years for this projection, because new-design avionics used in production installations tend also to be used as retrofit avionics for many more years, even though they may not be optimally designed for such programs.

2.3.1 Communications Equipments

2.3.1.1 Line-of-Sight Radios and Associated Crypto Units

The Air Force's tactical communications needs continue to be served by VHF, UHF, and L-Band communications systems. Secure jam-resistant systems, such as HAVE QUICK and SEEK TALK, will provide an initial capability. The Joint Tactical Information Distribution System (JTIDS) is proposed as a longer-term solution. Except for a few trainers, the entire Air Force fleet is to be outfitted with one or more of these systems, and the units tend to be upgraded for technology changes once each decade. Approximately 3,000 new JTIDS installations, 4,000 new VHF installations (SINCGARS-compatible units), and at least one fleetwide (10,000-unit) UHF swap-out are anticipated between now and 1995. Thus the total unit count could exceed 17,000.

2.3.1.2 Adaptive HF Radios

The potential vulnerability of satellites and other relay vehicles for beyond-line-of-sight communications has fostered a broad program to improve

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*The basic information for this survey is an earlier study by ARINC Research, *Air Force Avionics Standardization: An Assessment of System/Subsystem Standardization Opportunities*, Publication 1910-13-2-1722, March 1978, as updated with recent program information.

the reliability of HF communications, referred to generally as Adaptive HF Systems, with a potential Air Force market of some 3,800 units through 1995. The market for Army and Navy units is two or more times this number.

2.3.2 Navigation, Identification

2.3.2.1 Global Positioning System (GPS)

The GPS is planned to be introduced into the inventory early in the period 1985 to 1990. The Federal Radionavigation Plan has proposed this system as an alternative to radionavigation systems such as TACAN, Omega, LORAN, VOR/DME, and other externally referenced systems. Because of possible vulnerability of the space vehicles, it will not replace the need for inertial-reference units, however. It provides the largest new-capability avionics subsystem market potential for GFE units, approximately 9,000 units beyond 1985.

2.3.2.2 Inertial Navigation/Reference Units

Further employment of the standard F^3 INS is expected beyond 1985. Further, new technologies such as Ring Laser Gyros are expected to be introduced.

2.3.2.3 ILS/MLS

Instrument Landing System (ILS) units are currently installed in most Air Force aircraft. The Microwave Landing System (MLS) is the new ICAO system planned for the late 1980s. There will be a period of transition in which it may be necessary to have both systems installed in the aircraft, because some landing locations will not have one or the other system. A Navy program (Multi-Mode Receiver) is directed toward providing both ILS and MLS capabilities within the same "black box." The total market potential for MLS, ILS, or the combination of capabilities exceeds that of the GPS. We estimate 14,000 units by 1995.

2.3.2.4 IFF Systems

The Mark XII system, with improvements developed from the Technical Improvement Program (TIP), will continue to be used throughout most of the period 1980 to 1990. The TIP establishes backward-compatible internal modification options for the current DoD IFF units. The options for the next generation of NATO IFF systems have not been fully defined. The market potential for new-installation units for the current-technology equipment (APX-100 and APX-101) is approximately 1,500. The potential for retrofit in place of the older APX-64/72 units is of the same magnitude. Thus the total market is more than 3,000.

2.3.3 Mission Avionics and Flight Data

Embedded computer subsystems are becoming a reality for most of the newer mission-avionics systems, such as Multi-Role Radar (MRR) (1,200-system potential), LANTIRN (more than 1,000 pods), Digital Air Computer System (more than 1,000 units), and a number of newer Electronic Warfare Systems (EWS) epitomized by the New Threat Warning System (NTWS) (approximately 4,000 systems). Many of the processors for these units will be developed to the MIL-STD-1750A architecture and thus could be established as a standard package. Since there are multiple processor LRUs per system, the market impact is greater than for any of the standard programs individually. Using an average of two standard LRUs per system, we estimated the total demand through 1995 to be greater than 14,000 units.

2.3.4 Multifunction Displays and Controls

All of the subsystems discussed above will require controls and displays for the functions installed. Current integrated-control concepts propose controlling more than a dozen functions on one, two, or three controllers, depending on cockpit space. Depending on the extent of integration, up to 20,000 units could be required for new Air Force installations and retrofits alone. The probable characteristics of a Standard Avionics Integrated Control System (SAICS) are summarized in our companion report on this project.* Basically, SAICS is expected to perform in three different functional areas:

- Communication, radio-navigation, and identification
- Inertial navigation and electronic warfare
- Weapons control

2.4 FUTURE AVIONICS SYSTEMS AND ARCHITECTURES

2.4.1 Evolving Avionics Architectures

We reviewed future avionics systems and architectures with representatives of the Air Staff, the ASD Development Planning Organization, and the Air Force Wright Avionics Laboratory (AFWAL). Their suggested scenario for implementing a PME is discussed in the following paragraph and represented in Figure 2-3.

The PME standards being developed today will influence the internal accommodation for avionics in 1985 and beyond. Meanwhile, partitioning standards such as those developed by the Integrated Digital Avionics (IDA), Pave Pillar, and Modular Automatic Test Equipment (MATE) programs will determine the functional interfaces for the avionics subsystems for the same period.

LRU standards will establish box sizes for the functions established by the architectural standards discussed above. The component and shop-replaceable-unit (SRU) technologies packaged in the LRUs will be driven

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*ARINC Research Publication 2258-02-1-2439, *Cost-Benefit Failure-Criticality Analysis of the Standard Avionics Integrated Control System (SAICS) Concept*," April 1981.

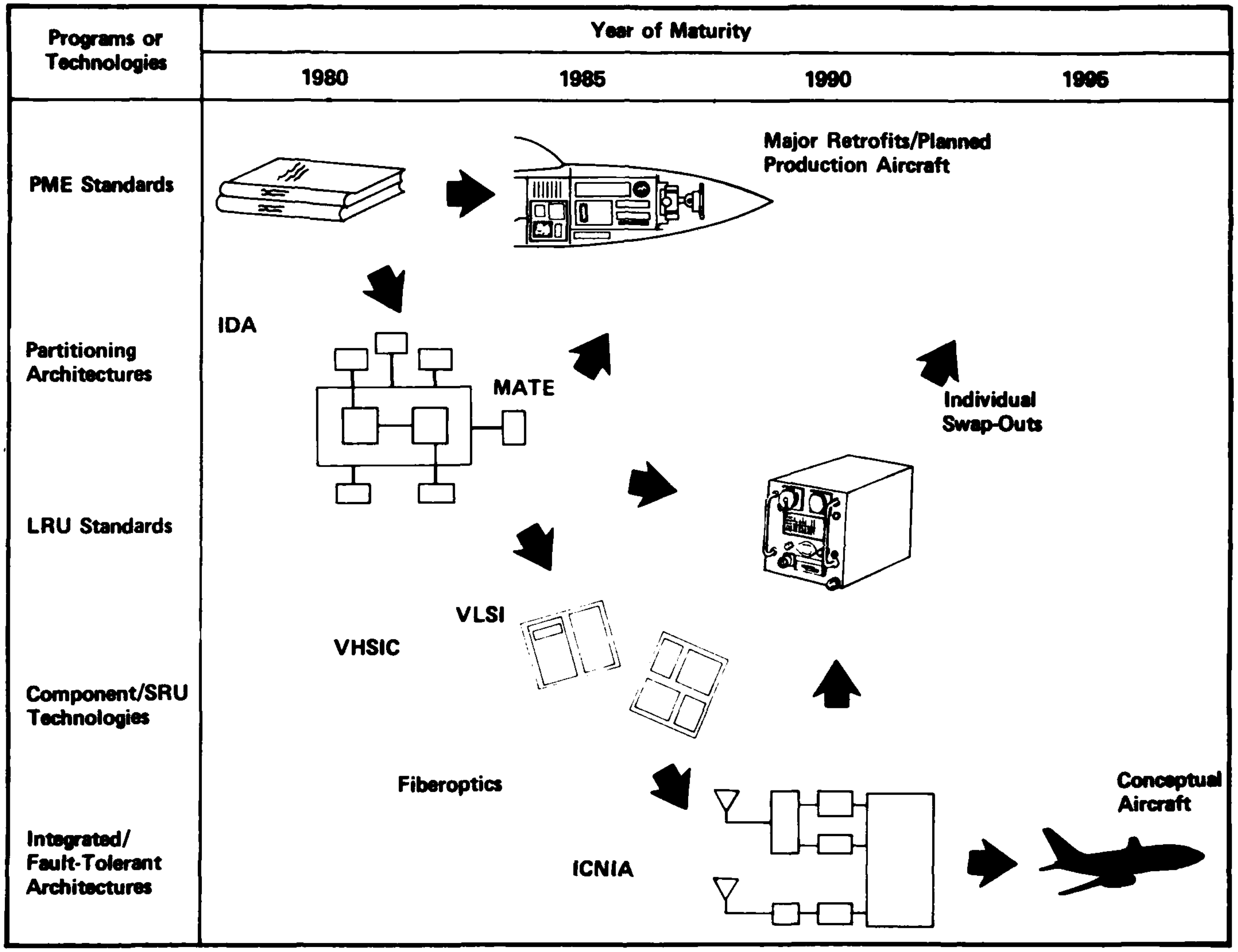


Figure 2-3. RELATIONSHIP OF THE PME STANDARD WITH OTHER AVIONICS ARCHITECTURE PROGRAMS

by the commercial marketplace, as well as by DoD-sponsored efforts such as the Very High Speed Integrated Circuit (VHSIC) program, and related programs in other services, such as the Navy's Standard Avionics Modules (SAMS) program.

The packaging densities of these component and SRU technology programs are expected to approach 120 pounds per cubic foot and establish a requirement to dissipate 2.5 kW per cubic foot for general-purpose processors that are part of radar, electronic warfare, and flight control architectures. The speeds with which information must be transferred within the architectures will require very-high-speed multiplex buses. This technology requirement is expected to be met with fiber-optic technologies.

With the advent of highly integrated, fault-tolerant architectures and very-high-speed buses, such as that proposed by the Integrated Communications, Navigation, and Identification Architectures (ICNIA), the concept of packaging a single function in a single box will be overtaken by technology. Nevertheless, the module sizes, their cooling concepts, the interconnection methods, and many other approaches to advanced architectures will be developed within the envelopes established by the PME standards in the early 1980s. Thus it is important that current standardization efforts consider the needs of the future advanced architectures and technologies.

2.4.2 Future Aircraft Avionics Interfaces

Because of the evolving nature of the avionics architecture programs that will become the standard avionics architecture in the period 1985 to 1990 and beyond, it is very difficult to establish firm functional interface characteristics at this time. In addition, there is a definite trend toward packaging more than one function within the same LRU, as evidenced by the Air Force's ARC-186 program (VHF AM and FM as a single box) and the Navy's Multi-Mode Receiver program (three different landing systems packaged together). For this reason, we recommended that the Air Force direct its initial efforts toward standardizing form, fit, and environment (F^2E) interfaces, allowing the functional interfaces to be determined individually as each functional subsystem becomes implemented in its new, PME-compliant configuration. If the ARINC 600 low-insertion-force (LIF) connector is accepted as a standard, there will be an opportunity at that time to establish standard pin-to-pin wiring for electrical power, power-up logic, multiplex data bus, video, and RF circuits.

There are, in addition, a number of standard interface concepts that have been directed by Headquarters USAF in the Program Management Directives (PMDs) for most new major weapon systems. These interfaces must be considered in developing the installation standard, to ensure that accommodations are provided in connectors for redundant power, multiplex data, fiber optics, and similar physical features. Among the key programs or standard interface concepts are the following:

- MIL-STD-1553B, Digital Multiplex Data Bus. This multiplex bus standard is being followed by all three services in the installation and retrofit of avionics for major aircraft programs. The chief impact of this standard on the PME standard is the potential reduction in the number of pins required and the corresponding reduction in the size of the wire bundles required to interconnect the avionics suite.

- Modular Automatic Test Equipment (MATE) Program. The ability of MATE to function effectively is dependent on the testability of each avionics LRU and the adequacy of the test access provided through the LRU's functional interface connector or through a dedicated, standard test connector.
- MIL-STD 1760 (Draft), Aircraft-to-Store Electrical Interface. This standard is evolving as a requirement for a MIL-STD-1553B Digital Multiplex Data Bus plus dedicated discrete and high-data-rate interconnections, with consequent additional functional interface requirements.
- MIL-STD-1750A, 16-Bit Computers Instruction Set Architecture. Any dedicated digital information transfer requirements arising from future distributed-processing concepts will have to be accommodated.

2.5 SUMMARY

The best potential for near-term application of the installation standard is (1) to establish repackaging programs for major GFE avionics that are expected to continue well into the late 1980s, and (2) to influence the development standards for programs that will reach production status during that period.

Table 2-1 lists typical avionics functions, any associated development or support programs, the actions needed to include each function in PME implementation, and estimated sizes (in MCUs), weights, and thermal dissipations that would have to be accommodated in each case. These estimates are based on our review of current packaging for the functions listed.

The "Action Needed" depends on the status of the "Associated Programs." Thus if an engineering development (ED) program phase is planned to replace or repackage existing and functional design or to provide for a new functional need, it is sufficient to specify compliance with the new installation standard. Cost trade-offs should be required for programs that are not compliant. If no such development is planned or needed, a repackaging initiative to furnish compatible avionics LRUs to "standardized" new aircraft or modernization programs should be considered.

To quality for implementation by "specified compliance," the Avionics Installation Standard must be approved and authorized for implementation before the applicable ED statement of work is published.

After 1990, newly developing avionics technologies will have interacted with and influenced the implementation and growth features of the standard. However, standardized mechanical and environmental interfaces will be maintained by evolutionary design adaptation. Thus swap-out

Table 2-1. POTENTIAL GFE PACKAGING EFFORTS

Avionics Functions	Associated Programs	Responsible Services	Action Needed	Approximate Projections		
				Size (MCUs Except Where Noted)	Weight (Pounds)	Heat (Watts)
Communications						
UHF	SEEK TALK	USAF	Specify	2	7	112
VHF	SINCGARS	USAF	Specify	6	15	25
HF	Adaptive HF	USAF	Develop	20	45	950
L-Band	JTIDS	Joint	Specify	20	125	1,500
Navigation/Identification						
ILS	ARN-127	USAF	Repackage	4	10	70
MLS	JTMLS	Joint	Specify	4	15	30
ILS/MLS	Multi-Mode Receiver	Navy	Specify	4	15	30
External Reference	GPS (RPU)	Joint	Specify	8	30	150
	(Antenna Control Electronics)	Joint	Specify	2	8	15
Inertial Reference	F^3 INS	USAF	Repackage	8	35	300
IFF Transponder	Mk XII TIP	DoD AIMS	Repackage	4	20	30
IFF Interrogator	Mk XII TIP	DoD AIMS	Repackage	6	19	70
IFF Computer	Mk XII TIP	DoD AIMS	Repackage	4	11	30
IFF Synchronizer	Mk XII TIP	DoD AIMS	Repackage	3	7	50
Mission Avionics/Flight Data						
Air Data Computer*			Specify	6	45	250
Flight Management Computer*			Specify	8	29	150
Flight Control Computer*			Specify	6	27	200
HUD Processor*			Specify	6	30	300
Radar Warning Receiver (NTWS)		USAF	Develop	3	8	30
ECM Processors (ASPJ)		Navy	Develop	8	40	500
Radar Processors (MRR)		USAF	Develop	12	30	200
Multifunction CDUs (SAICS)		USAF	Specify	5.75 × 8 × 6.5"	10	50
CDU Remote Indicator (SAICS)		USAF	Specify	5.75 × 4 × 6.5"	4	30

*While these equipments are often aircraft-unique, there is a possibility of the use of new-generation general-purpose 1760A boxes as part of the architecture.

interchangeability will be maintained between successive generations of like functional subsystems, even as these subsystems become more closely integrated into multifunctional LRUs.

CHAPTER THREE

FRAMEWORK FOR THE FORM AND APPLICABILITY OF THE INSTALLATION STANDARDS

3.1 BACKGROUND

One of the Air Force motivations for using the ARINC 600/601 installation specifications as a model for a military PME Standard is to permit continued use of commercial avionics in military aircraft where applicable. In the past, many ARINC 500 series analog equipments have been employed by the Air Force and the Navy, particularly in their larger aircraft, such as transports or maritime patrol. The commercial equipments used include inertial navigation sets, HF and VHF radios, radio altimeters, ground-proximity warning systems, and similar general-purpose avionics. These equipments were specified to the older commercial installation standards: ARINC 404A for avionics bay-mounted equipments, and ARINC 408 for avionics controls and instruments.

There are now three dozen Characteristics in the new 700 series, on which the AEEC began work in the fall of 1977. These Characteristics define standards for packaging the equipment and describe functional performance requirements and means for exchanging digital data between units and systems. Avionics systems described in the Characteristics include the following:

- Automatic flight control and auto-throttle computers
- Automatic navigation and fuel-management computers
- Primary instruments
- Attitude sensors
- Weather radar (doppler processing and color display)
- Air data computer
- Radio sensors for navigation and flight-path control
- VHF and HF radios, including data link interfaces

These ARINC 700 digital equipments are designed to comply with ARINC Specification 600, which requires improved cooling provisions, as well as connector and holddown concepts that are significantly different from those used in the military. Unless military practices in the installation of avionics are revised, the opportunities for use of commercially developed avionics will diminish.

3.2 SUITABILITY OF COMMERCIAL AVIONICS FOR MILITARY USE

A detailed review of selected commercial avionics for installation in Air Force aircraft was reported in our January 1980 report.* That review, which focused on the ARINC 500 series Characteristics, indicated that there was widespread use of commercial avionics in the military wide-body aircraft and that the equipment performed well in those aircraft.

The issue of how closely the Air Force installation standards should adhere to ARINC Specification 600 is linked to how extensively the military might employ commercial avionics in the future. To develop insight into this issue, we compared the functions defined by the 36 ARINC Characteristics now issued in the 700 series with those established for the five categories of candidate aircraft discussed in Chapter Two. The results of that review are shown in Figure 3-1. It is not surprising that the greatest number of

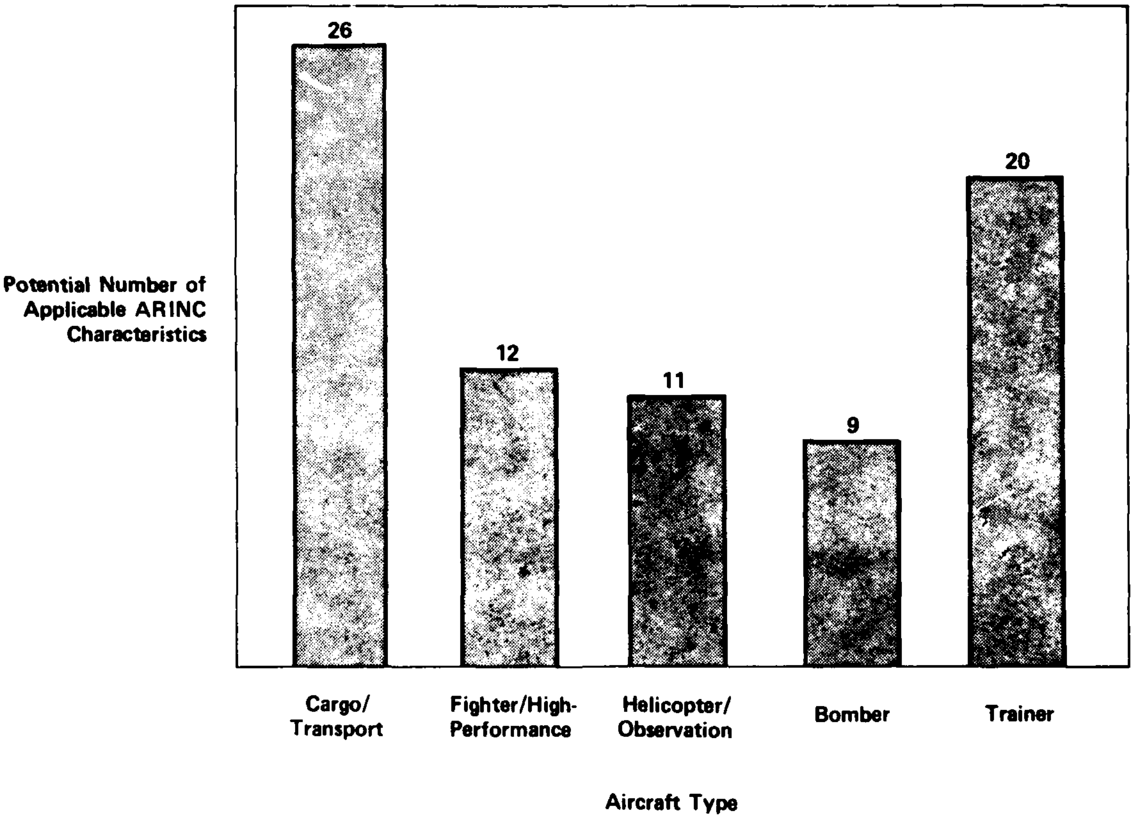


Figure 3-1. COMMERCIAL AVIONICS APPLICABILITY TO USAF AIRCRAFT

**Standard Avionics Packaging, Mounting, and Cooling Baseline Study,* ARINC Research Publication 1753-01-1-2124.

commercial and military avionics systems identical in function are those employed in military cargo/transport aircraft. The second greatest commonality of functions appears in trainer aircraft. These two categories of aircraft constitute approximately 40 percent of the Air Force fleet in 1985. Thus there would be significant benefit in assuring the continued use of commercial equipments for these two groups.

Relatively few commercial avionics systems could be employed in the remaining groups of tactical and strategic aircraft. Further, it is unlikely that there would be sufficient space or environmental provisions in fighter/attack aircraft, even where the avionics functions are similar. Therefore, it appears that perhaps more than one level of specification will be found to be necessary.

3.3 IMPLEMENTATION APPROACH TO CONTINUED USE OF COMMERCIAL AVIONICS

Because one of its missions, airlift, makes it a major air carrier, the U.S. Air Force is represented in the AEEC. Thus the Air Force is in a position to sponsor an addendum to existing commercial specifications to outline the additional requirements of the military.

The objective of an Air Force addendum to an ARINC Characteristic would be to ensure that military requirements are satisfied by identifying an acceptable degree of parts upgrading, added qualification testing, and increased testing stress levels that can reasonably be applied to military procurement of otherwise standard commercial items. Each supplier of commercial avionics could then evaluate the cost of complying with these requirements for any given military procurement from its commercial avionics product line, and can bid accordingly. If this approach found favor, the range of functional ARINC 700 Characteristics would probably also be augmented by an Air Force issue of parallel ARINC 600 compatible F^3 procurement specifications for noncommercial functions such as crypto units, Mk XII IFF, UHF Voice, and VHF-FM Voice.

The following principal benefits can be expected from this approach:

- Availability and interchangeability of the commercial equivalent for prototype-aircraft installation or for noncombat applications
- Quick-reaction modification potential, to supply avionics LRUs for prototyping
- Large- or small-lot competitive supply from an established commercial production base

3.4 USE OF AIR FORCE AVIONICS INSTALLATION STANDARD

Early in our analysis we recognized the fundamental differences between the overall military application of avionics and its commercial airlines

(ARINC) counterpart: Military constraints that cause these differences include the following:

- Shortage of regular avionics bay space, leading to the use of odd-shaped stowage spaces
- Severe vibration-shock-acceleration environment
- High ambient temperatures -- shortage of cooling capacity, leading to wide variations in operating temperatures
- High proportion of "mission avionics" functions not represented in commercial product lines
- Presence of high-power transmitting elements of radar systems and jammer systems that produce high internal heat and exacerbate electromagnetic interference and blanking problems

To accommodate to these constraints of the military environment, an Air Force avionics installation standard significantly different from the commercial ARINC 600 Specification would be required. Each, however, still has the same objective: to control the procurement of aircraft avionics and reduce the unneeded proliferation of similar systems.

It was therefore established that a new Air Force avionics installation standard should be modeled on ARINC 600 but could include substantial changes to ensure meeting the Air Force's military needs. These changes should be based on the widest possible consensus between the military users, the aircraft manufacturing industry as system integraters, and the avionics manufacturing industry as LRU designers and producers.

At the same time, it was established that the initial military standards would be limited in scope, to better assure their acceptance. The initial exclusions included the following:

- The standards would not apply to missile- or pod-mounted electronics.
- The basic standards would not address intrinsically high-heat-dissipation equipments such as radar transmitters or electronic warfare jamming equipments; however, addendums could be established to treat these cases.
- The standards would not be applied indiscriminately for LRU-by-LRU retrofits. Rather, they would be applied primarily for new-production programs, or to retrofits in which a completely new avionics suite was installed.
- There would be a continuing need for odd-size boxes to be mounted in the contours of smaller aircraft. Thus exemptions to some aspects of the standard might be required for high-performance designs.

The latter two exclusion areas gave rise to the concept of a MIL-PRIME rather than a MIL-STANDARD approach -- i.e., describe the installation standards in such a way that selected features of the standards could be specified in procurements in which total compliance would not be economically or operationally beneficial to the Air Force. For example, it might be possible to adhere to certain packaging aspects of the standard, but the connector and holddown provisions would require adaptation for a particular aircraft design. It was suggested, therefore, that the proposed military versions of the avionics-bay and cockpit-area installation standards be known as "MIL-PRIME-XXX" and "MIL-PRIME-YYY," respectively, during their development. The Air Force had not determined the final form of the specifications at this writing.

3.5 MIXED EMPLOYMENT OF COMMERCIAL AND MILITARY AVIONICS IN THE AIR FORCE

Inasmuch as the Air Force commonly buys avionics in large lots, there will be instances in which avionics specified to different installation standards must be jointly employed in a single aircraft. One way of controlling this apparent profusion of installation standards is depicted in the scenario shown in Figure 3-2.

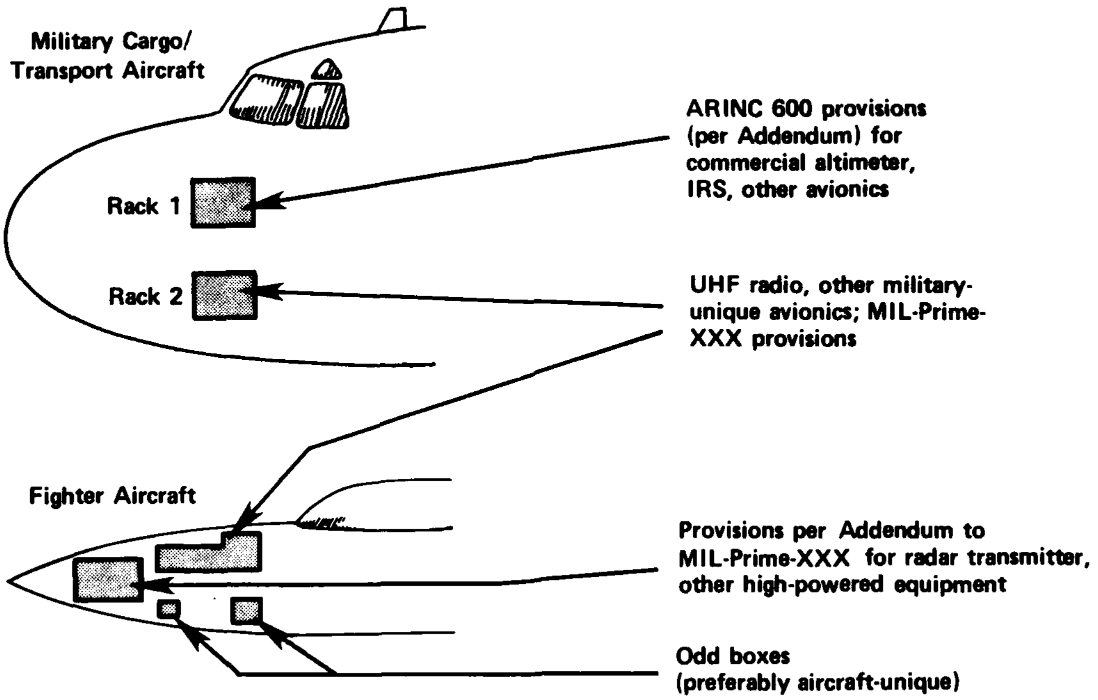


Figure 3-2. SCENARIO FOR MIXED USE OF INSTALLATION STANDARDS

The cockpit-area installation standard ("MIL-PRIME-YYY") has been omitted from the figure. A "strawman" for this standard patterned after ARINC 601 was circulated during the project; however, the Air Force decided to place emphasis on standards for the avionics bay. Thus the details of implementation for the cockpit standard were not considered further during this open forum development. Both the old and the new commercial cockpit-area installation standards follow military practices closely. It is very likely that a single standard could be developed to meet the needs for all classes of aircraft.

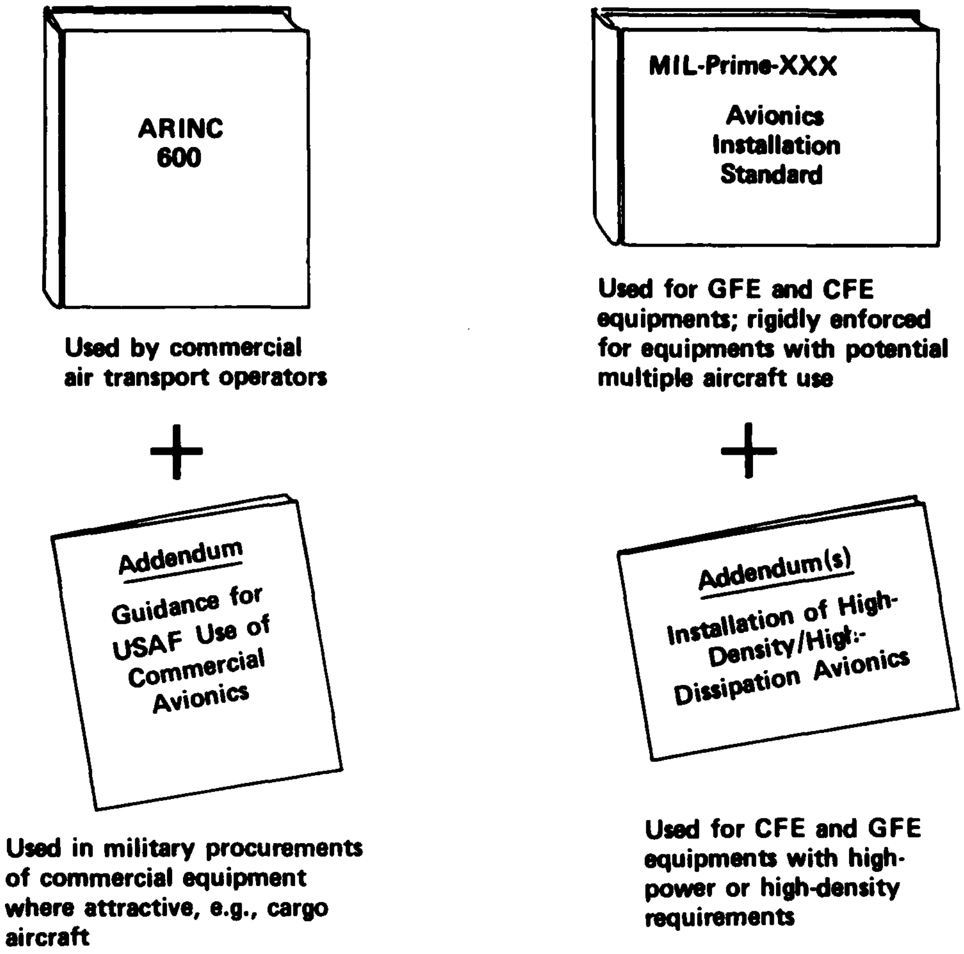
In the scenario, the military transport has employed commercially available avionics built to ARINC Characteristics (some with military addendums). A second rack (or portion of rack) has been added to accommodate military-unique equipment such as cryptographic units and UHF radios built to MIL-PRIME-XXX specifications. Accommodations have also been made in the fighter for this latter class of equipments, which would be interchangeable among aircraft types. The scenario also recognizes the need to accommodate the higher-power equipment, such as radar transmitters, which would be built to MIL-PRIME-XXX specifications with addendums. Because of space constraints, some aircraft-unique boxes may also be required, to fit into the contours of the aircraft. The extent to which the latter are used would be carefully controlled, and these boxes would be limited to aircraft-unique functions.

3.6 SUMMARY

A method was developed to address the conflicting avionics standardization objectives of high-performance aircraft and aircraft that provide a more benign environment. The proposed method of documenting these standards is summarized in Figure 3-3. It requires three basic steps:

1. Develop pertinent information on the changes required to ARINC 600 for a prospective Air Force purchase. This information should be attached to ARINC 600 by the action of the AEEC in response to a formal request made through the Air Force member(s). This proposed document is referred to as the ARINC 600 Military Addendum.
2. Prepare a military avionics installation requirements document paralleling ARINC 600, but fully addressing the environment and needs of high-performance, space-critical aircraft. This document is referred to tentatively as MIL-PRIME-XXX; it is the document that was subjected to the first open forum review.
3. Develop an addendum to MIL-PRIME-XXX, issued to address the adaptation of the military avionics standard to the installation of high-heat-dissipation avionics LRUs, including liquid-cooled and "boil-off" types of systems.

With respect to the cockpit-area installation standards, there are two possibilities: (1) establish a conventional MIL-PRIME or MIL-STD document, or (2) handle the additional military requirements by means of an addendum to ARINC 601. It is planned to discuss these at the second open forum to be held in the fall of 1981.



Used by commercial air transport operators

Used for GFE and CFE equipments; rigidly enforced for equipments with potential multiple aircraft use

Used in military procurements of commercial equipment where attractive, e.g., cargo aircraft

Used for CFE and GFE equipments with high-power or high-density requirements

Figure 3-3. APPROACH TO STANDARDS DOCUMENTATION

CHAPTER FOUR

GOVERNMENT AND INDUSTRY CONTRIBUTIONS TO THE STRAWMAN STANDARDS

With ARINC Specifications 600 and 601 being used as baseline documents, strawman Air Force MIL-STANDARD drafts were prepared and given wide circulation to industry and Air Force groups for initial critique. The purpose of this distribution was to provide an indication of the purpose and direction of the present effort and to stimulate agreement, disagreement, and constructive comment on what each reviewer might view as relevant issues. This chapter synopsizes the responses received prior to the open forum.

4.1 GOVERNMENT PARTICIPATION IN FORMULATING THE PRELIMINARY STRAWMAN STANDARD

4.1.1 U.S. Air Force -- Aeronautical Systems Division and Acquisition Logistics Division

On the basis of projections for the continued numerical preponderance of fighter/attack aircraft (as discussed in Chapter Two), the Air Force sponsors determined that the strawman standards must emphasize the requirements of F, R/F, FB, and A Mission Design Series aircraft types. The rationale was that if the worst-case installation requirements could be met, the needs of other aircraft types would also be accommodated.

It was also determined that the standard avionics cooling medium would be forced air (as in ARINC 600/601). Although benefits of efficiency and overall aircraft performance are seen in the potential application of liquid cooling to avionics, these are outweighed by Air Force concerns over the vulnerability of a liquid-coolant system to battle damage, deterioration of integrity in service, and the impact on avionics maintainability of measures necessary to avoid loss or contamination of the contained fluid. Some individual mission equipments must continue to use high-capacity cooling methods.

Preliminary briefings were presented to ASD on 6 October and 17 November to determine the extent of the changes to ARINC Specification 600 the Air Force considered necessary to accommodate it to general service use and to identify the issues that would arise in obtaining agreement on the definition and implementation of these changes. A "paste up" draft of the altered specification was reviewed at the 17 November meeting, and final Air Force additions and changes were approved.

This preliminary draft included the recommendations that reduced-height LRUs would be preferred for the majority of Air Force aircraft (54 percent are fighter/attack types). It was proposed that the LRU height be set to 6.0 inches and that the requirements for the uppermost connector insert on the back of the LRU be deleted so that the connector shell's overall height could be reduced to 5-1/2 inches. The resulting signal-pin limit of 150 pins for the 2-MCU size and larger was considered adequate for all known requirements, especially since if the equipment is 3 MCUs or larger, the signal-pin limit increases to 300. No change in the lower insert would be necessary, and the keying function for blind mating would be retained. This change was considered possible because the use of digital data buses has reduced the number of signal pins required. Digital messages are now being used to transmit the status of discretes, thus reducing the number of individual wires from that previously needed. The 1-MCU case size was also eliminated; it was considered impractical for military use, because it would be structurally unstable.

4.1.2 U.S. Air Force -- Air Logistics Centers

We visited all of the Air Logistics Centers. We elicited from the System Managers and Item Managers logistics problems arising from the methods of installing avionics in the aircraft. We obtained the following information:

- Methods of achieving adequate cooling in retrofit situations represent the primary problem at the ALCs.
- The Air Force has had experience with both rear-mounted and front-mounted connectors. They have had both good and bad experiences with each type.
- Finding cockpit space for retrofits is more difficult than finding avionics-bay space.
- The Air Force experience with commercial avionics has been very satisfactory.

4.1.3 U.S. Army

We briefed interested parties at the U.S. Army Aviation and R&D Activity (AVRADA) and Navigation and Control (NAVCON) offices at Fort Monmouth, New Jersey, on the scope of the program. The Army attendees commented that they often used avionics systems developed by one of the other military services and therefore have an interest in following the Air Force PME program. They did not provide detailed comments at that time; however, they arranged to have a representative at the open forum held in Annapolis.

4.1.4 U.S. Navy

We briefed personnel at the Naval Avionics Center (NAC), Indianapolis, on the progress of the program and obtained valuable insight based on their experience in the Modular Avionics Packaging Program. NAC also provided detailed comments on the strawman standards (see Appendix B).

The NAC is currently conducting a study of integrated racks to house a family of standard modules. One of the recent investigations was a conceptual design study conducted by Grumman in which the design of the rack was optimized for 80°C junction temperature, with the maximum power dissipation of each module held to 10 watts. In the design of the rack, two principal thermal design approaches to meeting these requirements were examined: conductive cooling and direct air impingement. Conductive-cooling concepts were found to be more effective.

Of particular interest for the Air Force PME program is the Navy standard enclosure program at Boeing. This program will provide accommodation for the NAC Improved Standard Electronic Module (ISEM) in a 1/4-ATR housing and in a 1/2-ATR housing. Modular combinations provide for 3/4-ATR and 1-ATR widths. The double-sided ISEM comes in two sizes: 5.7" × 1.6" and 5.7" × 3.7", and in two styles: conduction-cooled or heat-pipe-cooled, and flow-through forced-air-cooled. The hollow-core heat-exchanger, flow-through design can transfer heat to the coolant air at a rate equivalent to 1 kilowatt per ATR enclosure. From the Navy's point of view, it would be desirable if the Air Force developed dimension and cooling provisions in their standard to be compatible with the Navy's standard enclosure concept.

4.2 INDUSTRY PARTICIPATION IN FORMULATING THE STRAWMAN STANDARDS

4.2.1 West Coast "Mini Forum" (Santa Ana, 1/19/81)

Because of a concentration of industry addresses in Southern California and indications of willing cooperation from several groups in that area, an informal meeting with ten companies on the West Coast was arranged. The following views were expressed at this meeting:

- It would be difficult to enforce an avionics installation standard. Each aircraft program would attempt to impose individual form, fit, and environmental constraints on avionics LRUs, to solve aircraft interface problems.
- ARINC 404 might be more suitable than ARINC 600, because there is field experience to draw on.
- Cooling-air flow from rear to front is a better alternative to vertical flow. Direct-impingement cooling should not be permitted in the military environment.
- ARINC 600 connector design remains to be proven in actual service. Mating tolerances are still being refined. Transient open circuits under vibration testing are causing problems.
- The standard should address avionics LRU installation in the unpressurized bays of military aircraft.
- The standard should be structured to assure compatibility with new technology, particularly VLSIC and VHSIC.

This "around the table" discussion gave expression to many of the concerns and reservations of knowledgeable individuals and groups about wide applicability of the preliminary draft installation standard to military programs. However, there was general support for the provision of some guidance document. It was generally believed that each program must retain the responsibility for mounting methods and environmental standards in its own aircraft. Nonetheless, most of the comments were constructive, and the overall indication was that efforts to develop a generic standard would receive support from industry.

4.2.2 Other Industry Visits

We visited General Dynamics in Fort Worth, Sperry Flight Systems in Phoenix, Collins Radio in Cedar Rapids, and several of the Boeing facilities in the Seattle area. We also met with Grumman Aircraft representatives at our facility in Annapolis. Representation at these meetings is reported in Appendix A. The points of view were very much the same as those heard from other military avionics installers and suppliers:

- Volume constraints and unique form constraints for a particular aircraft will probably conflict with any particular standardization constraints.
- Individually optimized cooling interfaces are often needed (none located bottom or top).
- Avionics installation usually cannot be concentrated in one convenient location.
- Environmental specifications are unique to the aircraft type and to location in the aircraft.
- Hard-mounted avionics LRUs may be required.
- Direct-impingement air cooling may be unacceptable.

4.2.3 Mailed Comments on Avionics Standard

The replies to our mailed circulation of the draft strawman standards received from industry are collated in Appendix B. Generally similar to the industry views described in Section 4.2.2, they are synopsized as follows:

- The standard should be limited to avionics-bay installations.
- The ARINC 404-style boxes should also be included.
- A height limit, rather than a fixed height, should be specified.
- All MCU sizes except 1 MCU should be retained.
- The cooling-air ports should be positioned on the back of the LRU and should be self-closing when the LRU is removed.
- Connectors should be positioned on the front of the LRU.
- Circular "MIL" connectors should be used.
- Convection cooling should be allowed.

- Environmental requirements should be left to the individual equipment specification.
- A hard-mount capability or vibration isolation internal to each LRU should be required.
- EMI should be addressed more fully, and EMP requirements should be added.
- Environmental seals on all connectors should be specified.
- Cable routing and isolation from EMI effects should be added.

4.2.4 Mailed Comments on the Control and Display Unit (CDU) Installation Strawman

The CDU preliminary strawman was circulated with the avionics LRU strawman. The response from industry groups is presented in Appendix B. It was observed that individual design predominates in military cockpit layouts. Although existing standards for console-mounted control panels and individual instrument case sizes are widely used, the design of the principal weapon-delivery, navigation, and status displays, as well as the way in which they are all integrated into an efficient weapon-system-management configuration, is very much the purview of each aircraft design group. Military CDU cooling is addressed on a case-by-case basis only where it is seen to be essential for the reliable operation of high-dissipation units. It was noted by several participants that until recently, most control panels (i.e., MS 25212 form factor units) contained intrinsically low-dissipation avionics components and the major heat source was the standard integrally lit (incandescent lamp) plastic-lighting faceplate. Other military-driven concerns were:

- MIL-STD-1553 data bus in lieu of DITS
- More rigorous physical and electromagnetic environment
- Problem of direct sunlight on displays, and solar heating of displays and controls "in situ"
- Rain penetration of open canopies when aircraft is parked
- Shortage of cooling and cockpit-pressurization air

Concurrent study of new technology CDUs* suggested that standardized interfaces and standardized form-factor components could be developed in conjunction with the implementation of the advanced military cockpit concepts now being developed in industry. Several CDU update programs that are now being implemented in the separate Air Force, Army, and Coast Guard aircraft programs have followed Collins Radio and Grumman Aerospace participation in the Army's IACS development program.

**Cost Benefit and Failure Criticality Analyses of the Standard Avionics Integrated Control System (SAICS) Concept*, ARINC Research Publication 2258-02-1-2439, 15 June 1981.

No further work was undertaken on the CDU standard, other than to incorporate the comments on the CDU strawman. At the request of the sponsors, emphasis was placed on the rack-mounted installation standards in the preparations for and organization of the open forum.

4.3 GOVERNMENT REVIEW AND COMMENT

In parallel with the industry distribution and opportunity to comment, both preliminary draft strawmen were more widely distributed within military agencies by ASD/AX. The replies received from interested Government agencies in some respects paralleled those received from industry (see Appendix B). A summary of military comments on the Avionics Installation Standard follows:

- Application to fighters, as written, is highly questionable.
- High-dissipation avionics should also be included.
- Testability requirements and MATE compatibility should be added.
- Avionics power standards should be addressed.
- Standard BITE requirements should be addressed, or relevant document referenced.
- Blind-mated connectors are not favored. The user should be consulted.
- Environmental specifications have to be "missionized."
- Cooling-air entry should be in backplate.
- New electronics technology will sharply increase power density.
- EMP and lightning strike, as well as EMI, should be addressed.
- Cable routing and cable stress-relief precautions should be addressed.

4.4 SUMMARY

Prior to our solicitation of opinion and comments from industry and military organizations, the text of the ARINC 600-2 Specification was edited technically to rectify obvious discrepancies with military practice and rearranged into sections more in conformance with DoD style. Further changes were based on consensus views represented in responses received up to 6 March 1981. Because of a lack of consensus, some suggested changes were held in abeyance pending the outcome of the planned open forum proceedings. An Air Force briefing was held on 17 February 1981 to discuss with ASD engineers the changes we proposed to make in the draft Air Force Avionics Installation Standard and obtain their views before submitting the two strawmen to ASD/AX/XR for approval. Changes were incorporated into the draft to be distributed, together with the schedule, agenda, and data package prepared for the April 21-23 open forum.

Because the initial open forum was intended to address only the equipment-bay LRU standard, the CDU strawman was not updated; it was included in the open forum documentation as preliminary information only. A second open forum is planned to address this subject.

CHAPTER FIVE

THE OPEN FORUM

Task 3 of the contract Statement of Work required ARINC Research to develop a management framework for open forum activities patterned after commercial standardization activities. We were also to outline key issues for resolution at the open forum and conduct the initial forum on the installation standard.

5.1 APPROACH

Early in the project we made presentations to the sponsors on the commercial standardization process, the documentation of its products, the support staff required, and recommendations for implementing a similar process for the Air Force. The recommended process is described in Chapter Seven. Our work in this area was closely coordinated with an Air Force ad hoc group examining a similar issue for the Standardization Panel of the Avionics and Armament Planning Conference.

5.2 CONDUCT OF THE OPEN FORUM

This section summarizes the results of the open forum conducted from 21 April through 23 April 1981 at Annapolis, Maryland. Figure 5-1 is a reproduction of the meeting schedule, which follows the format of the AEEC forums. Figure 5-2 shows the working group organization and the major issues chartered for each. The progress made by the working groups was reported in the closing general session on 23 April 1981.

5.3 CONSENSUS REACHED BY THE WORKING GROUPS

After the initial introductions and definition of the intended scope and objectives of the open forum, each of the working groups met, discussed their issues, and, where possible, established a consensus position on each. Some periods of joint discussion among groups were initiated where there was obvious interaction of issues, but these were held to a limited duration to prevent impeding more general progress. Minutes of the initial conclusions of the planning group were prepared and supplied to the other working groups at the end of the first day.

USAF AVIONICS INSTALLATION STANDARDS FORUM
Annapolis, Maryland

MEETING SCHEDULE

	Monday, April 20	Tuesday, April 21	Wednesday, April 22	Thursday, April 23
MORNING		General Session (Open) 9:00 AM - 5:00 PM Hilton Inn Introductions Scope Objectives Working Group Charters Issues Summary ARINC Building #1 Working Groups 2:00 PM - 5:00 PM 1) Form & Fit Group 2) Cooling Interface Group 3) Connector Group 4) Environmental Standards Group	ARINC Building #1 Working Groups 1) Form & Fit Group 2) Cooling Interface Group 3) Connector Group 4) Environmental Standards Group 5) Planning Group	General Session (Open) 9:00 AM - 4:30 PM Hilton Inn Reports from Working Groups Changes to Strawman User's Viewpoint Floor Discussion Summing Up "The Next Moves"
AFTERNOON	Administrative Session (USAF Only) USAF Steering Group 2:30 PM - 5:00 PM			

PRIORITY TIME SCHEDULE FOR SPECIFIC ITEMS*

DAILY SCHEDULES	Tuesday, April 21	Wednesday, April 22	Thursday, April 23
Morning 9:00 AM	Introductions		Working Group Reports
After Break 10:45 AM	Working Group Charters		Strawman Changes
After Lunch 2:00 PM	Issues		
After Break 3:45 PM	Summary		Summing Up

* These Agenda Items will be taken up at the times shown. Other Agenda Items will be taken up on a non-scheduled basis in the numerical order used in this Agenda unless otherwise announced.

Figure 5-1. OPEN FORUM MEETING SCHEDULE

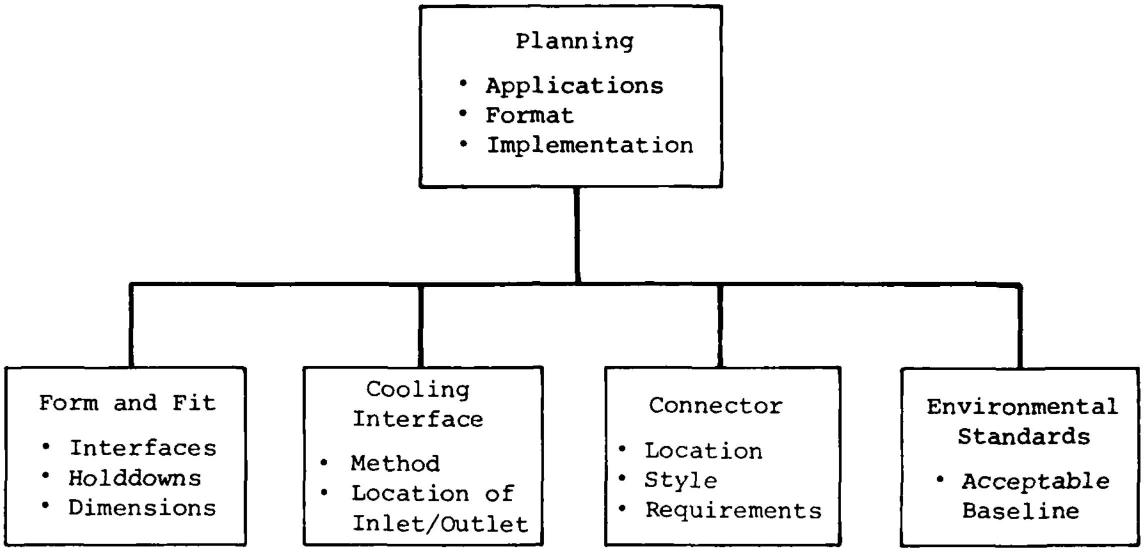


Figure 5-2. OPEN FORUM WORKING GROUP STRUCTURE AND ISSUES

5.3.1 Planning Group Results

The Air Force Avionics Installation Standards should be usable for actual hardware products of planned programs such as the C-X and later stages of ongoing programs such as the F-15E Strike Eagle, the F-16 Multinational Staged Improvement Program (MSIP), and the Long-Range Combat Aircraft (LRCA). The priority order of applying the standards is as follows:

1. New aircraft programs
2. Major avionics retrofit programs
3. Line replaceable unit (LRU) programs (where shown to be cost-effective)

The major issues should be addressed early and tentative decisions made, to provide a signal to the avionics community that the Air Force is serious about the standards. Easier issues should be resolved immediately in order to provide guidance to ongoing hardware design; however, the schedule problems of these programs must be acknowledged.

The Air Force has been relatively successful in previous LRU standardization efforts, on an LRU-by-LRU basis, in such programs as the ARN-118 TACAN and the ARC-164 UHF Communications Set, but each of these programs has developed unique sizing, mounting, connector, and cooling provisions. The principal purpose of the current PME standards is to permit common installation interchangeability and ease of retrofit.

5.3.1.1 PME Standards Family

The product applicability of the PME standards family was reviewed, and there was consensus that the market for the PME standards family was as follows:

- MIL-PRIME-XXX for the avionics in all Air Force aircraft, including the difficult fighter and attack environment
- High-density and/or high-dissipation addendum to MIL-PRIME-XXX for selected avionics
- MIL-PRIME-YYY for cockpit equipments to be worked on in the future
- Addendum to ARINC 600 for commercial avionics usable on Air Force transport, cargo, and other aircraft, as appropriate

5.3.1.2 Compatibility with Navy Standards

To the extent possible, MIL-PRIME-XXX should accommodate the Navy's Modular Avionics Packaging (MAP) modules, which are based on a 7 5/8" LRU height rather than the 6" height specified in the strawman specification. The solution suggested was to build the LRUs for either upright or "on the side" installation to permit an LRU 7 5/8" H × 6" W to be installed in a 6" high shelf space on its side.

Since the Navy's packaging approach makes it difficult to introduce cooling-air entry or exit from the sides or bottom, front and rear cooling would be desirable. This approach was favored by Air Force engineers as well.

5.3.1.3 Compatibility with Airline Standards

It was agreed that it would be desirable to use commercial airline avionics in Air Force aircraft. It was recognized that in many Air Force aircraft installations, this would not be possible. Therefore, MIL-PRIME-XXX should not be forced to accommodate commercial airline avionics built to the ARINC 600 specification. However, an Air Force addendum to ARINC 600 would leave the door open to realizing the cost and schedule savings afforded by commercial boxes wherever feasible.

5.3.1.4 Excess Cooling Capacity

A major issue raised was the heat dissipation called out in the strawman specification; comments were that this should be increased. In the discussion it was determined that this issue needs to be more carefully considered to avoid imposing undue design penalty on aircraft, with associated cost/performance impacts, which would turn program directors or airframe manufacturers away from the PME standards. Therefore, it appeared appropriate to plan for an addendum to MIL-PRIME-XXX to cover high-dissipation avionics at a later date.

5.3.2 Results of Combined Cooling Interface/Environmental Standards Working Groups

The Cooling Interface Working Group combined with the Environmental Standards Working Group because of the similarity of issues under discussion.

5.3.2.1 Baseline Environment: Fighter Aircraft

It was agreed that MIL-PRIME-XXX should serve as the baseline environmental standard for all military aircraft and therefore must reflect the worst-case conditions of high-performance fighter aircraft, Class 2X. (The strawman specification used Class 1 as the baseline environment.)

5.3.2.2 Heat Dissipation Limit: 1 kW for 8 MCU

There was a consensus on increasing the strawman specification's heat-dissipation limit for forced-air cooling to 1 kW for an 8-MCU LRU (100 watts for an 8-MCU LRU without forced-air cooling). Other LRU sizes would be scaled linearly at 125 watts per MCU: 250 watts for 2 MCU to 1.5 kW for 12 MCU.

The working group further recognized the potential need for even higher heat-dissipation limits in future military avionics packaging. These higher limits should be accommodated in the high-dissipation/density addendum to MIL-PRIME-XXX.

5.3.2.3 Forced-Air Cooling Using Heat Exchanger

There was a consensus that heat exchangers should be used in forced-air cooling. Direct air impingement was ruled out because of the possibility of condensation due to temperature and altitude changes. It was agreed that even with indirect cooling, humidity control of the forced-air supply is still required.

5.3.2.4 Rear Air Inlet, Front Outlet

After considerable discussion, the working group decided to depart from the ARINC 600 cooling method of bottom entry, because this was ruled out by the Navy standards and because it was felt that rear air entry is more efficient for fighter aircraft. It was decided to specify forced-air entry from the rear of the LRU and exhaust from the front of the LRU in MIL-PRIME-XXX, even though this rules out direct interchangeability of military avionics with commercial avionics built to ARINC 600. However, it was believed that the improved cooling efficiency obtainable in fighter aircraft with severely limited Environmental Control System (ECS) capacity should be the governing criterion. Military applications have favored forced-air inlet through the backplate, with free exhaust from the front of each LRU (B-1, F-111, F-16 are recent examples). The following rationale supports this preference:

- The soft air seal is simply compressed on final engagement and does not suffer from sliding damage as LRUs are inserted and removed.

- All the air-supply ducting is located at the rack backplate.
- LRU internal-ducting/heat-exchanger arrangements do not reduce the height available for circuit boards and components.
- Exhaust air does not impinge on adjacent LRUs.

No solution was suggested at this time for aircraft without an ECS (such as the A-10), in which only ram air or cockpit exhaust air is available.

The working group discussed the conflict between rear air inlet and rear-mounted connectors, which were recommended by the connector working group. A recommendation was made against using part of the connector shell for air inlet on the grounds that this would cause jurisdictional disputes between the ECS designer and electrical connector designers for each aircraft installation. A recommendation was made to consider using a half-size connector for 2-MCU and 4-MCU LRUs.

> NOTE: In a revision to the strawman subsequent to the open forum, a design proposal was included to permit separate cooling air and connector territory on the rear of each size of box. While this proposal requires further analysis and feasibility testing, it may offer a solution to the dilemma of cooling/connector location. This approach is addressed in Chapter Six.

5.3.2.5 Cooling Air of 2.37 lb/min/kW at 15.5°C

The fighter aircraft ECS limitations were discussed, and it was agreed that the limit on the cooling-air supply available should be lowered to 2.37 lb/min/kW at 15.5°C for a 71°C, Class 2 environment.

5.3.2.6 Integrated Cooling, Thermal, and Reliability Analyses

There was consensus that the specific numbers to be included in the installation standard should be supported by careful integrated analysis of the thermal, cooling, and reliability criteria. In addition, the values chosen should be based on cost-effective solutions.

The installation standard should include a uniform cooling evaluation test to be run on all installation designs to provide data on cooling adequacy, ECS loading, and the environmental impact on reliability.

The working group recommended that temperature limits should be specified in terms of electronic device junction temperatures rather than case temperatures. The specific values suggested were junction temperature limits of 105°C for microcircuits and 120°C for power devices, in order to assure reasonable reliability performance. The working group did not discuss methods for measuring junction temperatures.

5.3.3 Results of Connector Working Group

5.3.3.1 Connector Location and Type

The Connector Working Group consensus after one and one-half days of intense discussions was to recommend a rear-mounted ARINC 600 connector. Table 5-1 was compiled by the working group as a summary of the pro and con issues entering into the recommendation. While it was not possible to quantify the advantages of the ARINC 600 connector, it was generally believed that the advantages outweighed the disadvantages.

The working group summarized the following rationale for the choice of the proposed low insertion force, blind-mated ARINC 600 type connector.

- Standard state-of-the-art connector for all ARINC 700 boxes
- Commercial standard
- Positive mating
- Low mating forces
- Multiple procurement sources (also European sources)
- High pin density and flexibility of assembly methods
- Availability of replaceable inserts, e.g., waveguide and coaxial inserts
- Protected cable harness
- Load-carrying member (400 lbs maximum, all sizes)
- Easier LRU installation
- Uses standard MIL-Specification tools in repair
- Front-mounted and front removable rack connector
- Reinforced sockets, protected pins

Agreement on the connector recommendation was difficult to reach, primarily because of the blind-mating problem and because of past unfavorable experiences with previous-generation rear-mounted connectors on military transport aircraft that resulted in unreliable avionics performance. In addition, it was pointed out that the ARINC 600 connector had not been proved in commercial service. However, the ARINC 600 connector has been under development for approximately five years, all of the shortcomings of previous-generation rear-mounted connectors have been addressed, and the commercial avionics and airframe industry has the confidence to invest money in the connector.

Two issues regarding the connector recommendations could not be resolved by the working group:

- The rear-mounted connector may not leave adequate area for cooling-air entry from the rear for the 2-, 3-, and 4-MCU size LRUs. The Connector Working Group suggested using one of the connector

Table 5-1. CONNECTOR CONSIDERATIONS

Item	ARINC 600 (NIC) Connector		MIL-81659 (or 83733 USAF) Connector		Front-Mounted Circular Connector	
	Pro	Con	Pro	Con	Pro	Con
Load Capability	400 lb minimum for all three sizes				N/A	
Rear Air		Use one connector insert		Same as 600	Good access	
Reliability	• Good contact lead in • Protected pins • Hooded sockets • Positive mating • No cable motion • Protected cable harness	Not in service	Same as 600 In service		Existing design In service	Cable motion Exposed cables Cable abuse
Maintainability		Difficult access		Same as 600	Good access	
Flexibility	• High pin count • Power contacts • Waveguide • Individual [illegible] inserts		Same as 600		High pin count Power contacts	
Installation	Excellent		Same as 600			Average
EMC	TBD		In service		In service	
Environmental Seal	[illegible]		In service			
Cost	TBD		TBD		TBD	
Modification of Aircraft	Good		Good		Good	
Availability						
Now		TBD	Total		Total	
5 Years		TBD	Total		Total	
Specification		MIL spec required	81659		38999	
Blind Mating	Excellent		Average		N/A	
Vibration	MIL-STD-1344A, Method 2005.1, Condition V		MIL-STD-1344A, Method 2005.1, Condition V			
Commercial Compatibility			No		No	

inserts for air entry, but the combined Cooling Interface/ Environmental Standards Working Group recommended against this (see Note in Section 5.3.2.4).

- The ARINC 600 connector is a load-carrying member that is required to withstand a 400-pound maximum shear load and a 1,000-pound compressive load. There was concern that the attachment of the connector to the LRU would not withstand the required loading, particularly since the Form and Fit Working Group recommended increasing the allowable LRU weight. It was pointed out that there is a Navy equipment requirement for 35 g's for carrier catapult launch and arrested landings.

5.3.3.2 Qualification Status of the ARINC 600 Connectors

Boeing Commercial Aircraft Company has completed qualification tests of the ARINC 600 connector sizes 1, 2, and 3 for the commercial environment, including vibration tests at 17 g's.

The McDonnell Douglas DC-9 Super 80 and the F-15 fuselage disconnect were cited as applications of connector inserts comparable with the ARINC 600 connector inserts.

Environmental sealing is on one side only for the commercial environment. The connector manufacturer representatives stated that they thought that the connectors could be sealed on both sides. Qualification tests are needed to verify environmental sealing on both sides for military applications.

The Connector Working Group could not identify available data on electromagnetic compatibility or on shielding, bonding, and grounding. Further investigation is required. EMP requirements must also be investigated for military applications.

5.3.3.3 Pin Capacity

One reason for recommending the ARINC 600 connector was the high pin count available, up to 120, 300, and 600 signal contacts in shell sizes 1, 2, and 3, respectively. The working group gave examples of contemporary equipments requiring up to 400 pins. The estimated pin-count requirement for the A-6 GPS is 300 pins on 5 connectors. The F-16 nose radar uses 267 pins distributed between two connectors. However, it was also pointed out that the increasing use of MIL-STD-1553 type multiplexed buses should reduce the pin count in the future. The commercial airline equipment with the ARINC 600 connector already results in an average use of only 34 percent of the signal pins.

No consensus was reached on the desired pin capacity except for the recommendation to specify all three connector shell sizes.

5.3.4 Form and Fit Working Group

5.3.4.1 Equipment Form Factor

The Form and Fit Working Group endorsed the ARINC 600 avionics LRU form factor, except that the 1-MCU size provision was eliminated. Thus the strawman specification height was changed back to the original 7 5/8" (from 6"). The rationale for the 7 5/8" height was that this had been chosen as both the Navy MAP standard and the commercial avionics standard and a large component and tooling investment was at stake.

It was decided to require mounting-orientation flexibility, to permit interchanging the height and width dimensions routinely in order to accommodate space-availability variations in fighter-type aircraft installations.

It was recommended that an investigation of alternate front-panel holddown methods be undertaken to support this requirement. This investigation should also consider means for providing two holddown hooks for the 2-MCU size instead of the single hook now specified.

The front-panel protrusion allowed by ARINC 600 and the strawman specification (2.5") was considered appropriate to accommodate handles, test connectors, and optional connectors, and to provide for forced-air exit. The Form and Fit Working Group agreed with the forced-air rear-entry/front-exit recommendation made by the Cooling/Environmental Working Group and also agreed that study was needed to provide for a rear cooling-air entry and a rear-panel electrical connector (see Note in Section 5.3.2.4).

5.3.4.2 Weight Limits

Recognizing the trends to higher-density packaging, the working group recommended a 50 percent increase in the ARINC 600 individual LRU weight limits (an 8-MCU LRU weight limit was changed from 44 to 66 pounds). At the same time, it was necessary to define the total installation weight to be supported by each equipment rack, although the maximum LRU weight limit would not be expected for all LRUs in a particular rack. The maximum weight of the largest unit should be limited to 90 pounds, and the rack attachments should be reviewed. The working group suggested an investigation of the methods of attaching the load-bearing connector shell to the LRU rear panel that would support high stresses. MIL-STD-1472 (Human Factors) limitations would also apply to the larger units. The rack design should support an average load of 7.5 pounds per MCU under dynamic load conditions.

5.3.4.3 Heat Dissipation and Indirect Cooling

The Form and Fit Working Group agreed with the recommendations made by the Cooling/Environmental Working Group for increased heat-dissipation allowance. It was also agreed that an addendum should be worked out to accommodate future high-dissipation equipment designs.

The group agreed that direct air impingement should be ruled out to avoid the effects of condensation caused by pressure and temperature changes in flight.

5.3.5 Open Forum General Session

The considerations discussed in the preceding paragraphs were developed in open discussion within the working groups, with limited communications between groups. The final day's proceedings represented consensus positions taken before the entire industry/Government body. Therefore, they are summarized and presented here, even though some material from the preceding sections is repeated. Questions and responses to the questions raised during this session are also described.

The working groups convened in a final joint session on 23 April 1981. The working group spokesmen presented the consensus reached.

5.3.5.1 Report of the Combined Cooling Interface/Environmental Standards Working Groups

The working group chairman reviewed the ground rules for his group's position, i.e., that MIL-PRIME-XXX was to address the needs of new fighter-class aircraft (Class 2X environment). In that way, the needs of other aircraft classes would be met, although perhaps somewhat overspecified. The following technical points were addressed:

- Both convection cooling and forced-air cooling should be permitted. (Thresholds for requiring forced-air cooling were established.)
- Direct impingement cooling should be prohibited; however, air quality must still be controlled (particularly entrained moisture and condensation).
- Rear air inlet and front exhaust are preferred. The rationale for these locations is as follows:
  - Access to cards would be easier.
  - Sliding damage to a bottom seal would be obviated.
  - Extra ducting would be required if top and bottom locations were selected.
  - Top location of exhaust would allow dripping water and other contaminants to enter.
  - Most fighter LRUs today have rear inlets.
- Limited cooling air on fighters will lead to higher exhaust temperatures.
- Cooling, thermal, and reliability analysis and requirements should be incorporated into the text of the standard.
- There should be growth provisions for higher-density packaging. (The values in the standard now should be good for the next five years.)

Several areas of required future work were addressed. Appendix I of the standard, the cooling evaluation test in particular, needs work to bring it into line with the revised environmental and cooling specifications. The working group supported a standardized approach; however, the specific values (cooling-air temperature and volume, and pressure drop) should be studied further. It is also necessary to determine if there is sufficient room for the air inlet with a rear-mounted connector.

Questions raised by the forum participants, and the responses, were as follows:

Q. How about dynamic tests?

A. We have cross-referenced other documents. These probably should be added to this standard later.

Q. How does this differ from business as usual?

A. Cooling values have been tailored to the latest ECS state of the art. Better control over the reliability of avionics will be achieved. An integrated testing concept and junction temperature limits have been imposed. These limits would be imposed for specific aircraft types.

5.3.5.2 Report of the Connector Working Group

The Connector Working Group favored the ARINC 600 low-insertion-force, rear-mounted connector (three shell sizes). While this connector was not the unanimous choice, the following reasons favor the selection:

- The connector is state-of-the-art.
- It is a commercial standard.
- Positive mating is assured.
- Low mating force is required.
- There are multiple sources for the connector.
- The connector has high pin density.
- The cable harness is protected.
- The shell is load-bearing (400 pounds for all three shell sizes).
- LRU insertion is easier.
- Repair is accomplished with standard MIL-Specification tools.
- Front-removable rack connectors are mandatory.
- The pins are protected.

Insufficient requirements information was available to address the following issues:

- Electromagnetic compatibility
- Electrical bonding and grounding
- Power quality

The following questions and responses arose:

Q. Can you use flat ribbon cable with the connector?

A. Yes.

Q. Were the connector load-bearing requirements and capabilities coordinated with the form/fit group?

A. Yes, but actual ultimate loading for each connector size needs to be determined.

Q. Can fiberoptics interface be accommodated?

A. Yes, with an appropriate connector insert; however, the fiberoptics cable must be standardized first. There is activity under way to do the latter.

5.3.5.3 Report of the Form and Fit Working Group

The group categorized its findings into consensus areas, tentative areas, and hard issues:

- Consensus Areas
  - Box height should be 7 5/8".
  - MCU sizing should be as stated in ARINC 600.
  - Rear-air inlet is preferred (need to find way to handle this for smaller box sizes if ARINC 600 connector is used).
  - Front-panel protrusions must be permitted (e.g., handles, test plugs).
  - Mounting orientations other than vertical should be allowed to accommodate installation in fighters.
- Tentative Areas
  - The holddown design needs more review. The Navy is concerned that air exits may be obstructed.
  - The heat limits must be substantially increased. Values that are reasonable to handle 95 percent of the cases must be sought. A choice of front or back connector should be permitted (for retrofit modifications).
- Hard Issues
  - The weight density will surely go up. Actual connector shell strengths must be determined. The strength of the attachment of the shell to the backplate will probably be even more critical. This will affect both the rack designs and the LRU designs.

The discussion that followed highlighted the following points:

Q. Where do we put the drain hole if more than one mounting orientation is allowed?

A. Probably more than one drain hole is needed.

Q. If the connector location is optional, front or rear, how do we handle the rear holddown of the box?

A. Use either a dummy connector or dagger pins.

5.3.5.4 Report of the Planning Working Group

A representative of the Planning Working Group outlined future plans. The overall Air Force program will continue on schedule, as planned (see Chapter Seven for the program schedule). The areas requiring further studies and tests will be examined in more detail this year. The Air Force intends to keep industry informed of the progress on the standard. Points of contact in ARINC Research and the Air Force Aeronautical Systems Division were given.

5.3.5.5 Closing Remarks

The open forum chairman presented closing remarks. He thanked members of the industry and the Government for their hard work during the forum. He asked them to spread the word on the plan for implementing the standard:

- An addendum to ARINC 600 to be used as guidance for procuring commercial avionics for military purposes
- MIL-PRIME-XXX and MIL-PRIME-YYY as primary standards for avionics for general use
- Addendum(s) to MIL-PRIME-XXX for higher-power or higher-dissipation equipments

The classic pitfalls of standards implementation were recalled:

- There isn't one when we need it.
- It's so restrictive we can't apply it.
- It's so flexible that it's really not a standard.

The meeting was adjourned with the request that Government and industry work together to avoid these pitfalls.

CHAPTER SIX

POST-FORUM ACTIVITIES

In the limited time after the first open forum and before the submission of this report, we were able to develop additional information on certain of the unresolved issues raised by the participants. This chapter provides our preliminary findings.

6.1 HIGH POWER/HIGH DISSIPATION ADDENDUMS TO MIL-PRIME-XXX

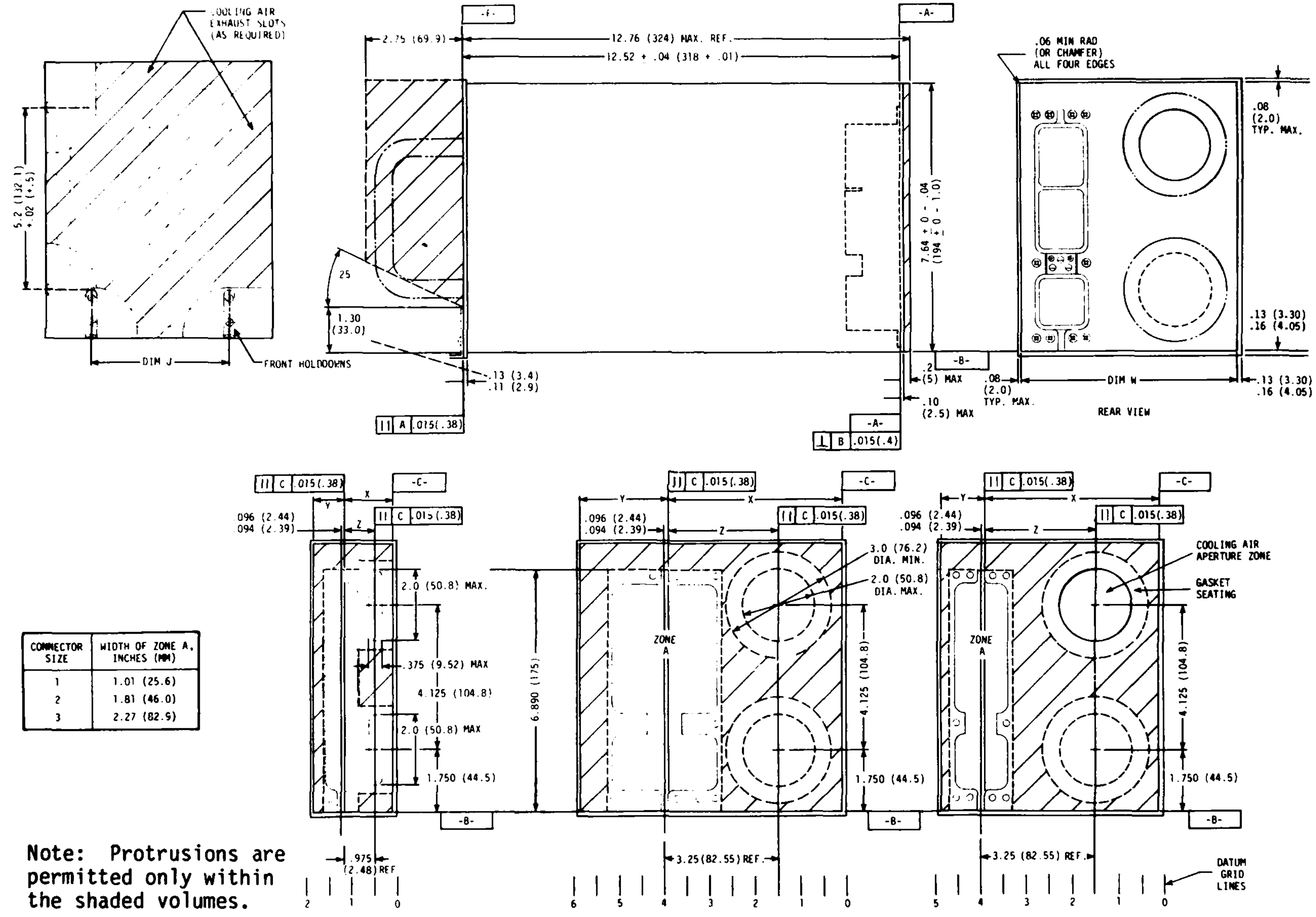
The current version of MIL-PRIME-XXX has heat-dissipation values greatly increased over the initial "strawman" values. It was the opinion of the forum participants that these values would accommodate conventional avionics packaging technologies for the next five years. We have addressed the installation design considerations for high-powered equipments such as radar transmitters. This information is provided in Appendix D.

6.2 ACCOMMODATION OF COOLING AIR INLETS

The open forum recommended ARINC 600 rear-mounted connectors and rear entry of forced-air cooling. It was recognized by the open forum that the restricted area available for cooling-air entry for small LRUs needed additional investigation.

The approach adopted in the revised draft Avionics Installation Standard is to offset the connector from the LRU centerline, making backplate areas available for both connector and cooling-air-inlet ports for small LRUs, as shown in Figures 6-1 and 6-2. Two types of air-inlet ports were incorporated into the draft standard:

- Small air-inlet ports with either two or four ports per LRU. Each inlet is oval, 2 inches by 3/8 inch, giving a gross inlet area of 0.72 square inch per port.
- Large air-inlet ports with two or four ports per LRU. Each inlet is 2 inches in diameter, giving a gross inlet area of 3.14 square inches per port.



CONNECTOR SIZE	WIDTH OF ZONE A, INCHES (MM)
1	1.01 (25.6)
2	1.81 (46.0)
3	2.27 (82.9)

Note: Protrusions are permitted only within the shaded volumes.

Figure 6-1. STANDARD LRU FORM FACTORS

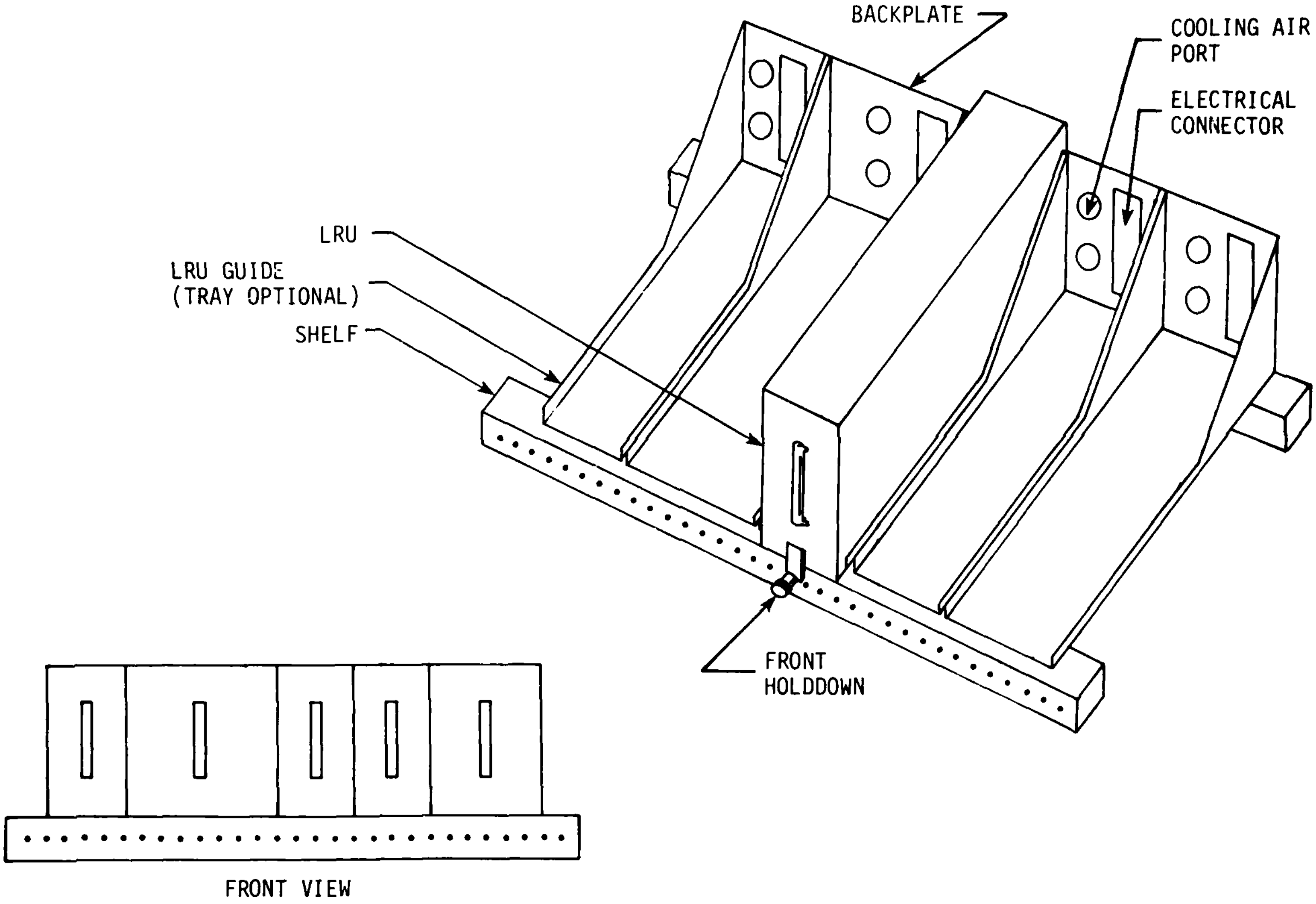


Figure 6-2. PICTORIAL OF TYPICAL EQUIPMENT RACK, SHOWING POSITIONS OF TRAYS, CONNECTOR, AND COOLING-AIR-ENTRY PORT

The standard also provides for free convection cooling, without any air-inlet ports. Table 6-1 gives the minimum LRU size as a function of connector size, air-inlet-port size, and number of inlet ports.

Table 6-1. MINIMUM LRU SIZE AS A FUNCTION OF SIZE OF CONNECTOR AND NUMBER AND SIZE OF AIR PORTS

Connector Size	Minimum LRU Size				
	No Air Port*	2 Small Ports	4 Small Ports*	2 Large Ports	4 Large Ports*
3	3 MCU	4 MCU	5 MCU	6 MCU	8 MCU
2	2 MCU	--	3 MCU	5 MCU	7 MCU
1	--	2 MCU	3 MCU	4 MCU	7 MCU

*Electrical connector on LRU centerline.

Figure 6-3 shows the locations for the air-entry ports and connector cutouts on the ARINC 600 rack datum grid for typical LRU sizes. Note that each element is shown centered on a *grid* line with the exception of the size 1 connector. The size 1 receptacle could be mounted on a datum line at the extreme edge of the LRU backplate (as shown by the ARINC 600 1-MCU design), thereby allowing the width of the small-size air-entry ports to be increased from 0.375 to 0.70 inch.

Figure 6-4 shows a typical arrangement of the backplate for a single LRU, mounted in an individual tray.

Table 6-2 provides the dimensional locations of the connector and cooling apertures for the full range of LRU sizes.

6.3 ACCOMMODATION OF ORIENTATION FLEXIBILITY

The open forum recommended flexibility in installation orientation. That is, there should be provisions for mounting LRUs vertically or laying on their sides. Figure 6-5 shows the additional provisions for front hold-down locations made in the revised strawman. Provisions are required for moving the holddown hooks to the left-hand, normally vertical edge of the LRU front panel to provide for field reconfiguration for horizontal mounting in a low-profile tray, as shown in Figure 6-6.

In addition, revisions have been made to the appropriate figures of the strawman standard to illustrate the use of mounting trays (see Figures 6-2, 6-4, and 6-6 of this chapter). The trays may be arranged together on structural members to form a shelf (as is done in the Boeing 767 and

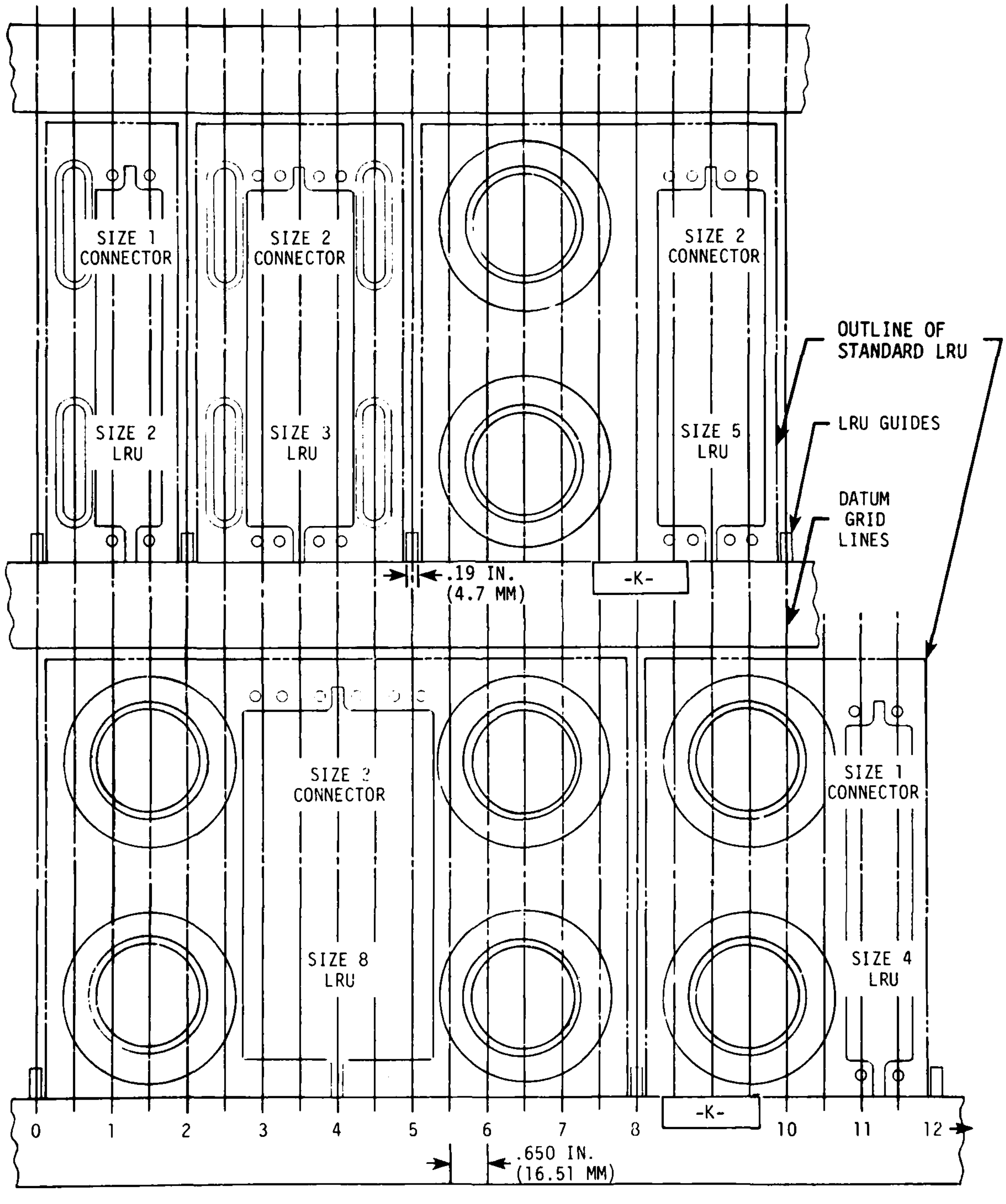


Figure 6-3. REPRESENTATIVE CONNECTOR AND COOLING-AIR-ENTRY LOCATIONS ON RACK DATUM GRID

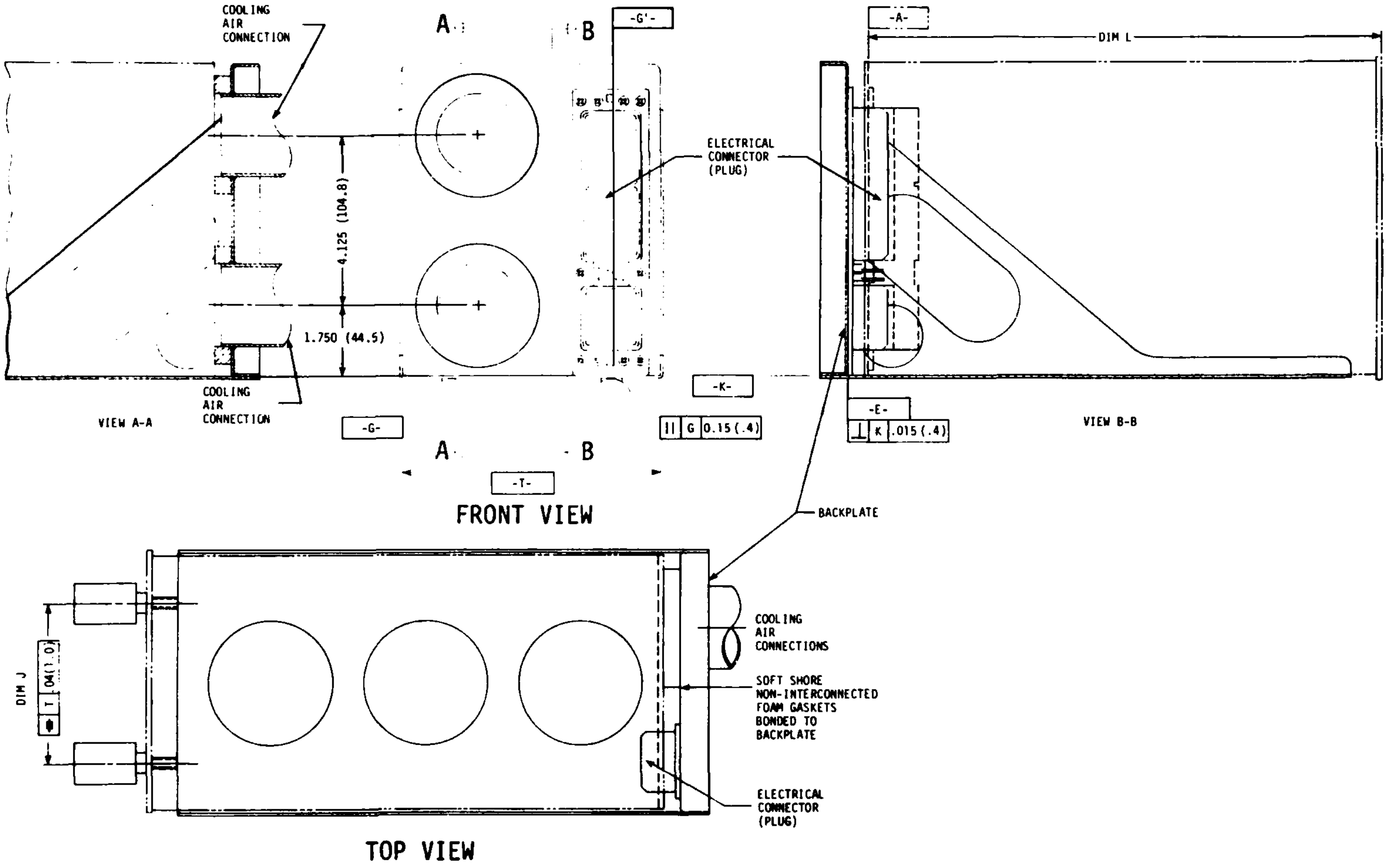
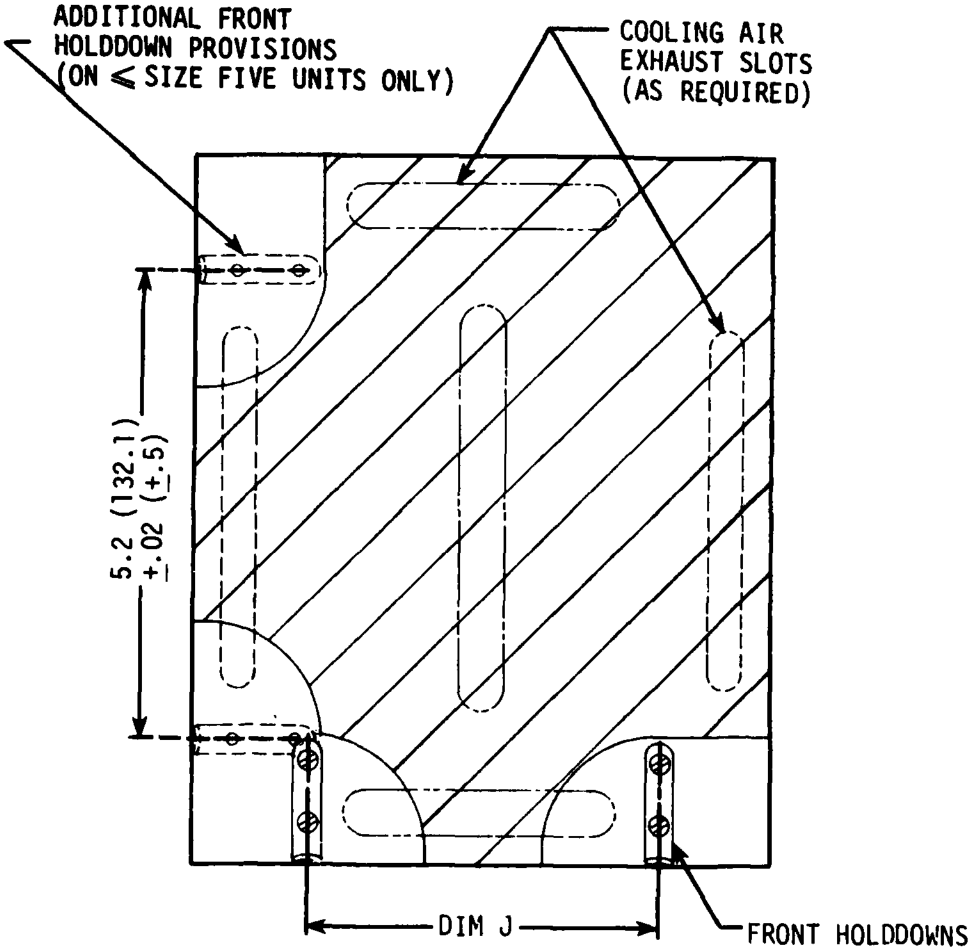


Figure 6-4. MOUNTING TRAY - CONNECTOR AND COOLING AIR SUPPLY PORTS

Table 6-2. LOCATION OF CONNECTOR AND COOLING APERTURES

LRU Size	Connector Size	Cooling Ports	Rear Panel Position Dimensions, Inches (Millimeters)			
			W ±.02 (.5)	X ±.005 (.13)	Y (Ref)	Z ±.01 (.25)
2	1 or 2	None	2.25 (57.2)	1.030 (26.2)	1.220 (31.0)	--
2	1	2 Small	2.25 (57.2)	1.460 (37.1)	0.790 (20.0)	.880 (22.4)
3	1, 2, or 3	None	3.56 (90.4)	1.685 (42.8)	1.875 (47.6)	--
3	1 or 2	4 Small	3.56 (90.4)	1.685 (42.8)	1.875 (47.6)	1.205 (30.6)
4	1	2 Large	4.88 (124.0)	3.970 (100.8)	0.910 (23.2)	3.155 (80.1)
4	1, 2, or 3	2 Small	4.88 (124.0)	3.000 (76.2)	1.880 (47.8)	2.505 (63.6)
4	1 or 2	4 Small	4.88 (124.0)	2.345 (59.6)	2.535 (64.4)	1.205 (30.6)
5	1 or 2	2 Large	6.19 (157.2)	4.300 (109.2)	1.890 (48.0)	3.155 (80.1)
5	1, 2, or 3	4 Small	6.19 (157.2)	3.000 (76.2)	3.190 (81.0)	2.505 (63.6)
6	1, 2, or 3	2 Large	7.50 (190.5)	4.963 (126.1)	2.537 (64.4)	3.155 (80.1)
6	1, 2, or 3	4 Small	7.50 (190.5)	3.655 (92.8)	3.845 (97.7)	2.505 (63.6)
7	1 or 2	4 Either	8.79 (223.3)	4.300 (109.2)	4.490 (114.2)	3.155 (80.1)
8	1, 2, or 3	4 Either	10.09 (256.3)	4.95 (125.7)	5.14 (130.6)	3.155 (80.1)
9	1, 2, or 3	4 Either	11.39 (289.3)	5.60 (142.2)	5.79 (147.1)	3.805 (96.6)
10	1, 2, or 3	4 Either	12.69 (322.3)	6.25 (158.7)	6.44 (163.6)	4.455 (113.2)
11	1, 2, or 3	4 Either	13.99 (355.3)	6.90 (175.2)	7.09 (180.1)	5.105 (129.7)
12	1, 2, or 3	4 Either	15.29 (388.4)	7.55 (191.8)	7.74 (196.6)	5.755 (146.2)



FRONT VIEW

Figure 6-5. ADDITIONAL FRONT HOLDDOWN LOCATION PROVISIONS

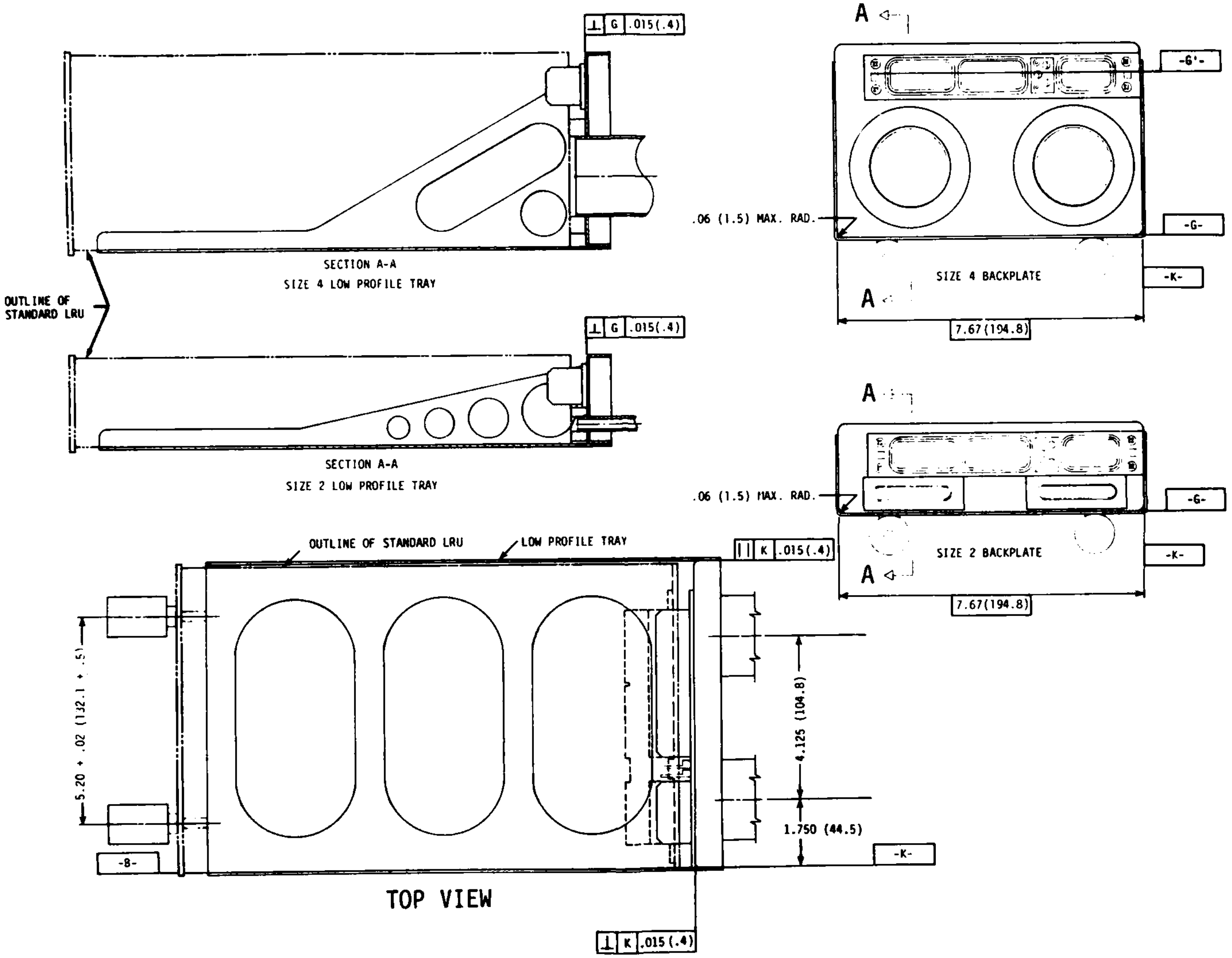


Figure 6-6. TYPICAL LOW-PROFILE TRAYS

Douglas DC-9 avionics-equipment bays) or individually in other locations in an aircraft. For example, an ARINC 600 form-factor maintenance recorder is installed in a wheel well of the Boeing 767. Where necessary, individual trays may be mounted on vibration isolators.

6.4 REVISED VIBRATION REQUIREMENT

As a result of the open forum recommendations, the vibration-environment requirements were revised to state that the avionics rack location and design should control vibration input not to exceed 0.04 G^2/Hz from 20 Hz to 1,000 Hz, as shown in Figure 6-7.

6.5 AMBIENT TEMPERATURES

On the basis of recommendations made by the open forum, the ambient temperatures for design and test purposes were revised as follows:

- Ground Survival Temperature: -62°C to 95°C
- Short-Term Operating Temperature: -40°C to 85°C
- Operating Temperature: -15°C to 71°C

6.6 MAXIMUM PERMISSIBLE THERMAL DISSIPATION

The open forum consensus was to increase the allowed thermal dissipation for LRUs qualified for operation with forced-air cooling (MIL-E-5400, Class 2X), as shown in Table 6-3, column 2. The allowed thermal dissipation for LRUs qualified for operation without externally supplied cooling air (MIL-E-5400, Class 2) was left unchanged.

6.7 ENVIRONMENTAL CONTROL SYSTEM (ECS) REQUIREMENTS FOR COOLING-AIR-MASS FLOW AS A FUNCTION OF INLET TEMPERATURE

The open forum recommended clarifying ECS design requirements. It was considered necessary to specify a schedule of mass flow versus inlet bulk air temperature to ensure that the ECS can deliver sufficient cooling flow to maintain avionics LRU exhaust temperatures below 71°C. The required relationships are shown in Figure 6-8.

The pressure drop through the LRU was changed to 2 inches water gauge, static, for a flow rate of 2.37 lb/min/kW.

6.8 COOLING-AIR HUMIDITY

On the basis of the open forum recommendation, the strawman standard was changed to state that the cooling air can contain up to 154 grains of water per pound of dry air under ECS fault conditions.

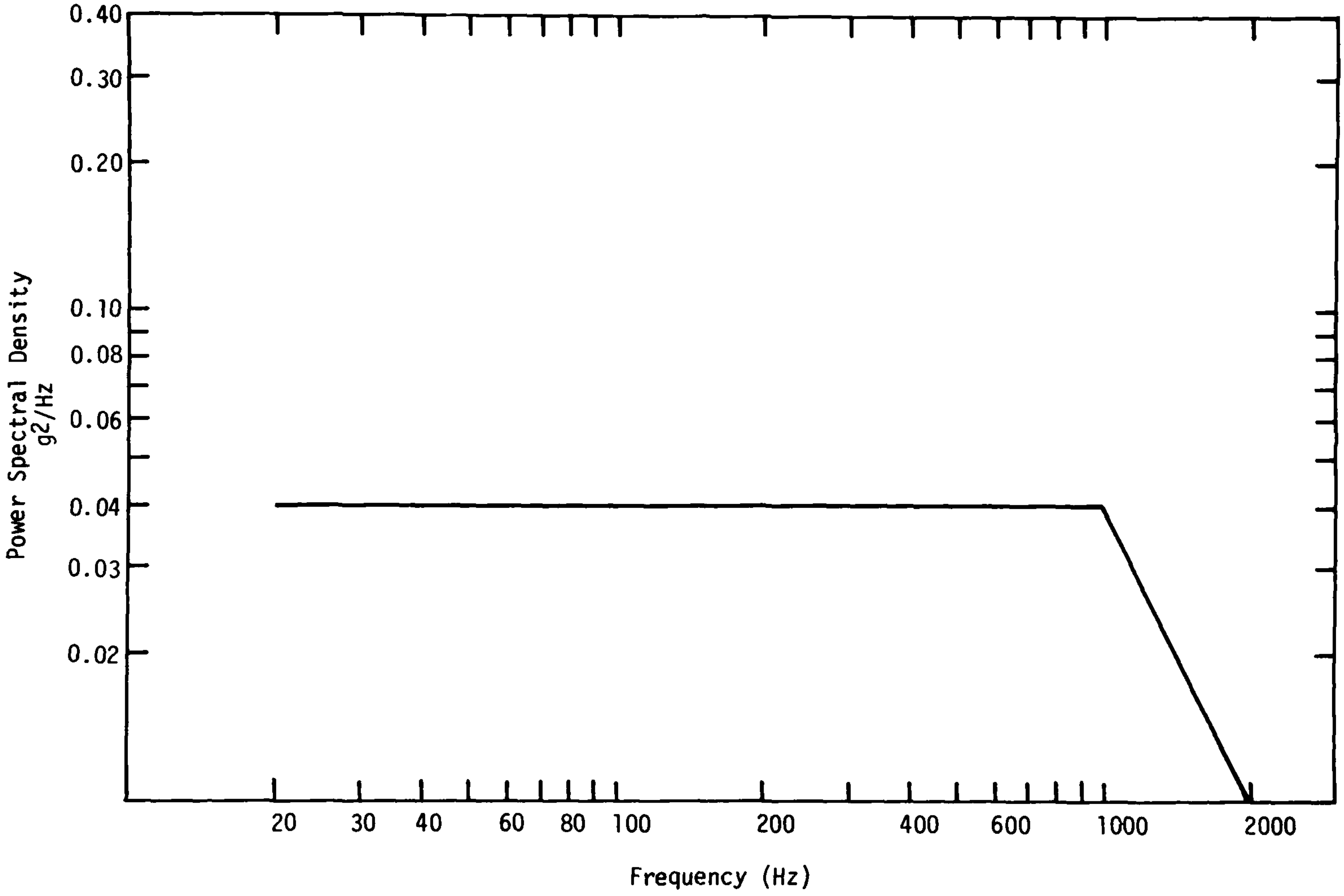


Figure 6-7. REVISED VIBRATION SPECTRUM

Table 6-3. **MAXIMUM LRU THERMAL DISSIPATION**

LRU Case Size	Maximum Permissible Power Dissipation (Watts)	
	With Cooling Air	Without Cooling Air
2	250	10
3	375	12
4	500	15
5	625	17
6	750	20
7	875	22
8	1,000	25
9	1,125	27
10	1,250	30
11	1,375	32
12	1,500	35

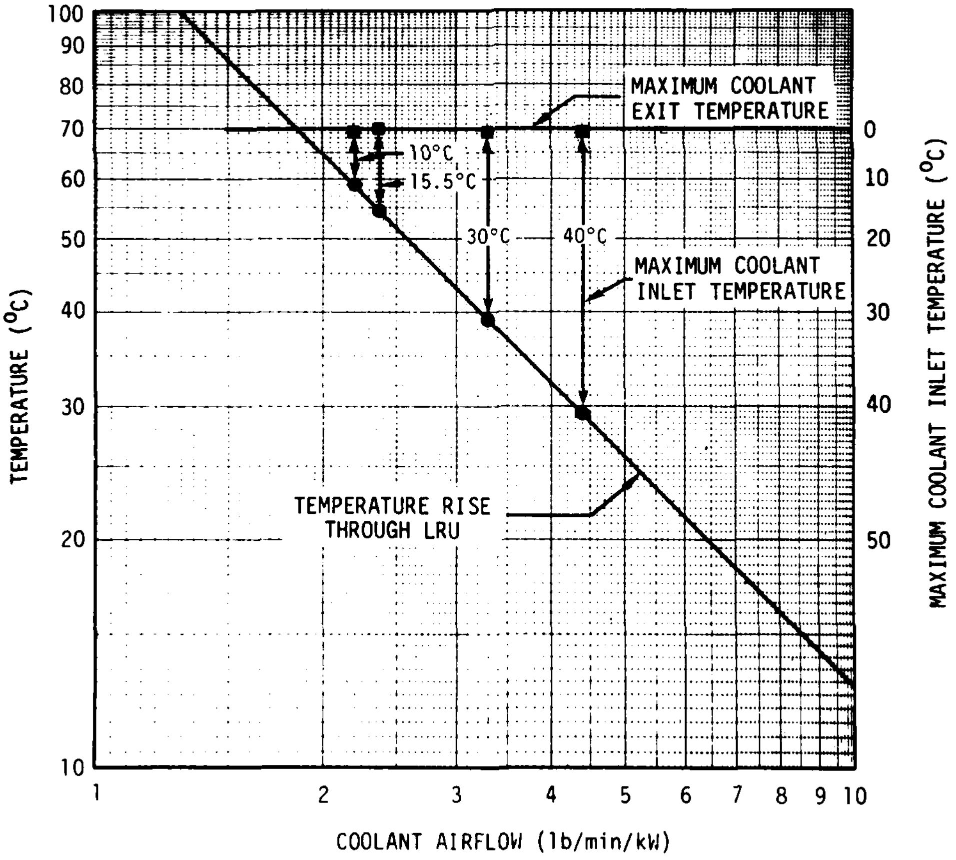


Figure 6-8. COOLING AIR FLOW REQUIREMENTS FOR ALTERNATE COOLING AIR BULK INLET TEMPERATURES

6.9 COOLING EVALUATION TEST

The Cooling/Environmental Working Group at the open forum suggested modification of the cooling evaluation test, Appendix I of the strawman standard. The working group noted that for microcircuit and semiconductor devices, the critical operating parameter for reliability is the operating temperature at the device junction. However, the junction temperature is not directly measurable by thermal appraisal methods at installation. It is for this reason that the installation and control data for each LRU should include the maximum allowable surface temperatures of critical components, specified by the equipment supplier as a result of his thermal appraisal testing. Therefore, at least at this point, the Cooling Evaluation Test (Appendix I) was not modified to add junction-temperature criteria.

6.10 LRU HOT SPOTS

To be consistent with the average LRU sidewall temperature of 71°C suggested by the open forum, the specification now limits LRU sidewall hot spots to 80°C.

6.11 WEIGHT LIMITS FOR LRUs

The open forum recommended a 50 percent increase in the allowable LRU weights on the basis of the observation that contemporary avionics systems approach packaging densities of 100 pounds per cubic foot. At the same time, it was recommended that the maximum weight of an LRU supported by a rack should not exceed 90 pounds in order to maintain a realistic rack design for high g loads. Therefore, the strawman standard has been revised as shown in Table 6-4.

The open forum also noted that more conservative human-factors constraints, imposed by MIL-STD-1472, would be applied appropriately in the LRU design specifications.

6.12 LRU HOLDDOWN DEVICE

On the basis of the open forum recommendation, the maximum axial force applied by the LRU holddown device remains "not to exceed 125 pounds per holddown hook."

6.13 ELECTROMAGNETIC COMPATIBILITY AND ELECTRICAL BONDING

The open forum left unresolved the issues of EMC and EMP. No resolution has been reached on these issues since the open forum.

The specification requirement on electrical bonding has been relaxed to read that the resistance of equipment case to rack to ground shall not exceed 2.5 milliohms at maximum short-circuit fault current.

Table 6-4. LRU MAXIMUM WEIGHT

LRU Case Size	Maximum Permissible Weight	
	Pounds	Kilograms
2	22	10
3	30	14
4	38	17
5	46	21
6	52	24
7	59	27
8	65	30
9	72	33
10	78	36
11	84	39
12	90	41

6.14 CONNECTOR STRENGTH AND ATTACHMENT

The open forum recommended that the structural integrity of the connector shell be validated, together with the methods of attaching the connector to the LRU. No action has been taken on this recommendation. However, the Boeing specification control drawing for the connector, paragraph 3.2.6, requires the connector shell to withstand vertical and side loads of 400 pounds and a connector mating impact force of 1,000 pounds, without regard to connector size.

6.15 SUMMARY

We have formulated tentative approaches for most of the major decisions resulting from the open forum. These approaches require further development and discussion with the industry and Government organizations concerned with subjects on which the decisions were made. Some decisions will require tests before further progress can be made, particularly concerning the suitability of the rack attachments for the larger LRUs, the cooling inlets for the smaller LRUs, and the ARINC 600 electrical connector in the MIL-SPEC environment.

CHAPTER SEVEN

IMPLEMENTATION ACTIVITIES

Task 3 of the contract Statement of Work required ARINC Research to develop an implementation framework for the PME standards and to establish future activities that would be needed to resolve technical uncertainties in the standard. This chapter reviews the results of Task 3.

7.1 IMPLEMENTATION FRAMEWORK

Figure 7-1 shows the recommended implementation framework for the new PME standard. The process begins with a developed PME standard, shown in the upper left. The major aspects of the process, as depicted in the figure, are described in the following subsections, which are keyed to the elements of Figure 7-1.

7.1.1 New Aircraft ①

For each aircraft manufactured in the future, the PME standard should be incorporated to the extent necessary. As a minimum, it will have avionics bays, shelves, racks, mounting provisions, connectors, and cable runs that conform to the standard. An electrical power system standard could be implemented separately but, preferably, would be included in production design. Incorporation of an environmental control system (ECS) should be based on a cost/performance trade-off study for the specific aircraft.

7.1.2 Older Aircraft ②

A large portion of the Air Force fleet, including current new first-line aircraft like the F-15, F-16, and A-10, will be older aircraft by the time a PME standard can be introduced. These aircraft will not be amenable to the incorporation of a new standard for avionics boxes, racks, and mounting. Incorporating equipments designed to PME standards into these older aircraft would cost at least as much as -- and probably a great deal more than -- incorporating such equipments in a production-line aircraft designed for PME. Cost savings are thus made suspect and practicality doubtful. Further, since these aircraft are older, there will be less opportunity for future retrofits, further restricting payback potential. An exception to this reasoning would be an aircraft, such as the B-52, that has been singled out for an entirely new suite of avionics. If a decision were made to strip

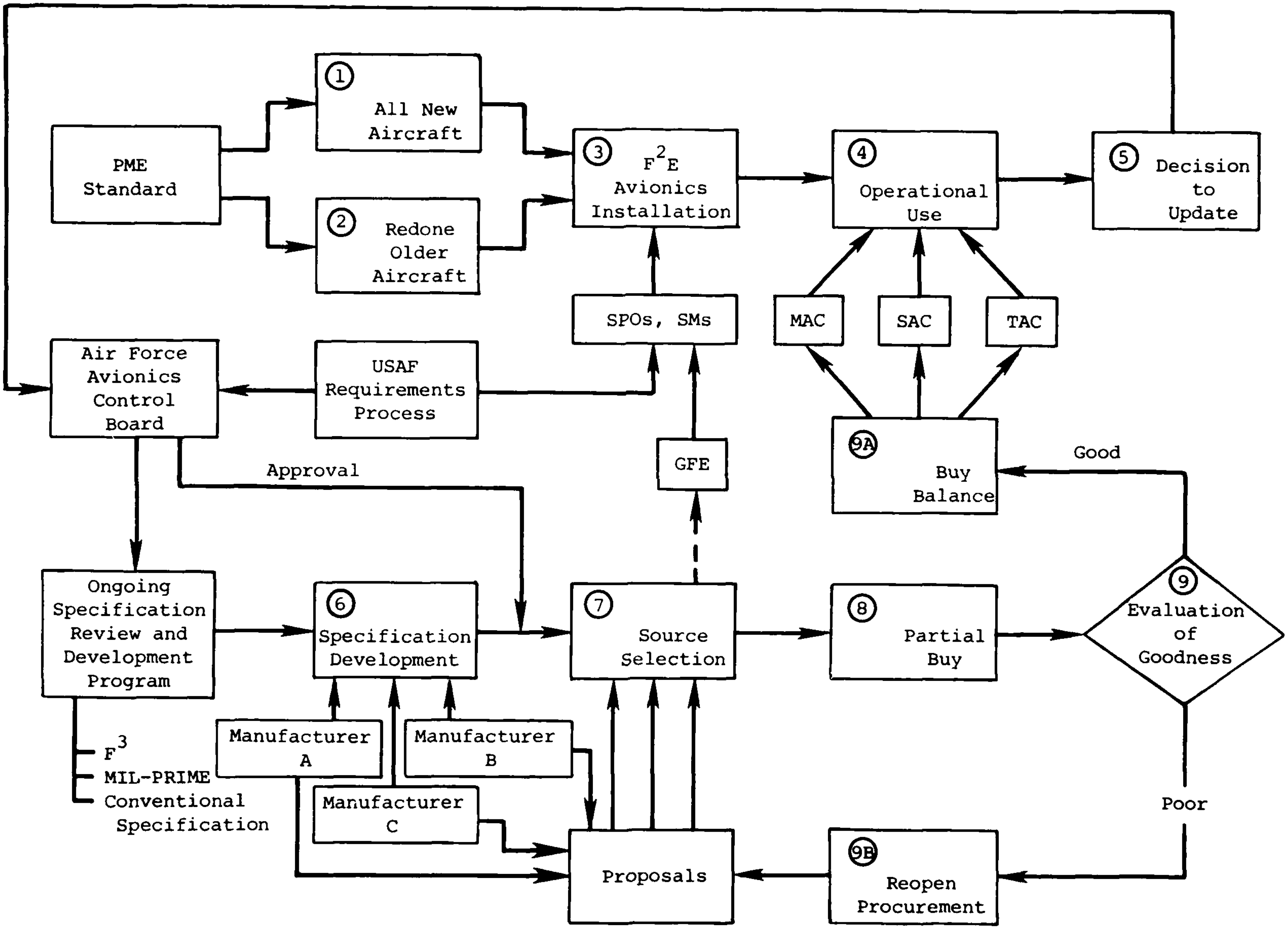


Figure 7-1. PME STANDARD IMPLEMENTATION SCENARIO

out old avionics and install a new suite, PME standardization might very well be advised as a convincing rationale for that decision.

7.1.3 Installation of Form-Fit-Environment (F^2E) Avionics ③

Unless compelling arguments can be found for exemptions, aircraft SPOs and SMs should be required to specify the new PME standard when procuring CFE or GFE avionics. The performance characteristics of the avionics could be established through airframe/avionics cost trade-offs against the requirements established by the current Air Force process.

7.1.4 Operational Use ④

The aircraft and avionics will enter the fleets of the major users and remain until it is determined that they should be replaced with higher-performance or lower-support-cost equipment.

7.1.5 Decision to Update ⑤

At some time in the life of the aircraft, avionics modernization begins to take place. We are now dealing with an aircraft in which all of the avionics are in PME boxes and the PME standard has been implemented to varying degrees. At this point, the equipment in question probably is well defined. It has been used for a long period in an operational environment, and its performance, cost, and maintenance characteristics are well known.

7.1.6 Specification Development ⑥

The experience with and knowledge of the avionics system that have been gained at the time of the update decision contribute to the preparation of better specifications for the modernizing equipment, particularly if the specification is developed in an environment similar to the Airlines Electronic Engineering Committee (AEEC) open forum process. Functional (F^3) standardization can be accommodated at this point if desirable.

7.1.7 Source Selection ⑦

Procurements can be structured to create a win-win situation for the Air Force and the contractor and to assuage the logistics community's major concern of spares proliferation. Several competitors involved in developing the specification would be expected to bid on the procurement.

7.1.8 Partial Buy ⑧

To ensure that the source-selection process ends with selection of the best source, only a small increment of the total buy is procured initially to verify the equipment's performance.

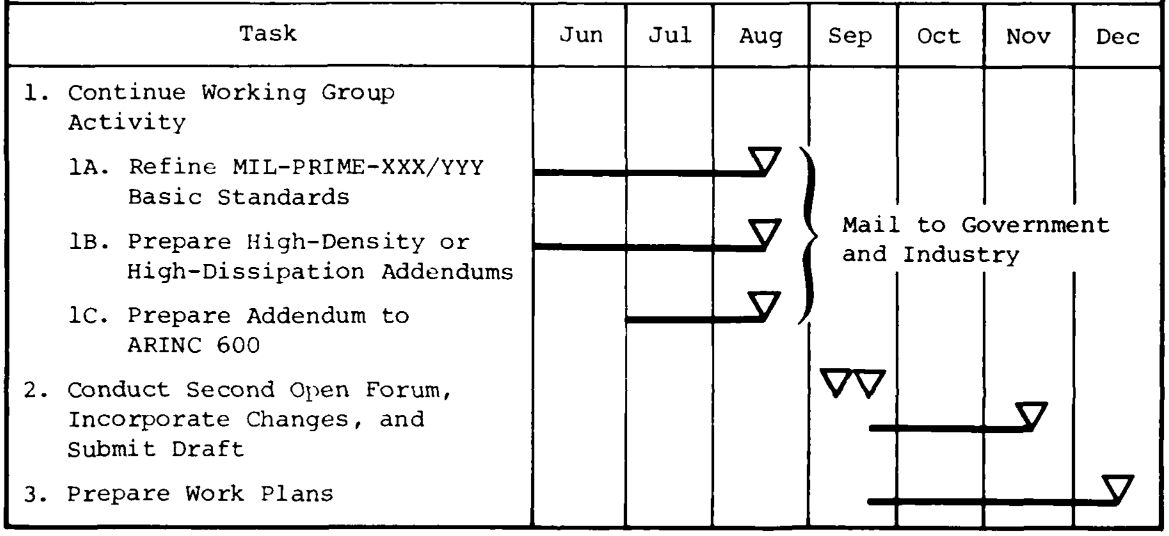
7.1.9 Evaluation of Goodness ⑨

If the product has proved itself in operational conditions, the balance of the procurement is purchased. If not, the procurement can be reopened.

7.2 NEAR-TERM IMPLEMENTATION ACTIVITIES

The work schedule for the near-team future is shown in Figure 7-2.

Figure 7-2. NEAR-TERM IMPLEMENTATION SCENARIO



7.2.1 Task 1: Continue Working Group Activity

7.2.1.1 Refine MIL-PRIME-XXX/YYY

The changes to the strawman avionics installation standard that resulted from the first open forum have been incorporated in the new draft. This draft should be circulated to industry well in advance of the second open forum.

The unresolved issue of the co-location of electrical and cooling air connections on the rear face of the box requires review of the options now illustrated in the strawman standard and definition of the air connector configuration. This latter area should take account of the data provided by McDonnell Douglas concerning operating avionics equipment interchangeability between fighters and transport aircraft, which have significantly different environmental control system parameters. The strawman CDU standard requires additional refinement by Government and industry prior to the next open forum. In particular, the Aeronautical Systems Division Control and Display Working Group should review the current strawman and provide comments.

7.2.1.2 Prepare High-Power-Dissipation LRU Standard

A strawman addendum to the draft MIL-PRIME-XXX Avionics Installation Standard should be circulated for comment prior to the second open forum. Some initial considerations for this addendum are presented in Appendix C to this report. These considerations are based on comments received from industry and Government during the initial circulation of the installation standard.

7.2.1.3 Prepare Military Addendum to ARINC Specification 600

Industry recommendations as to what should be added to ARINC 600 for military transport applications should be reviewed, augmented as necessary by the Air Force, and presented to the open forum. A strawman version, based on discussion of its probable contents at the first open forum, is included as Appendix D of this report. If there is a consensus that the content of this addendum is acceptable and useful, the Air Force members of the AEEC could elect to sponsor its approval by the AEEC at the next meeting.

7.2.2 Task 2: Conduct Open Forum(s) and Submit Draft

Our recommendations for the issues to be addressed at the second open forum and subsequent forums are presented in Figure 7-3. We have also indicated the probable organization of the working groups and the paths for submission of the products of the open forum.

7.2.3 Task 3: Develop Future Work Plans

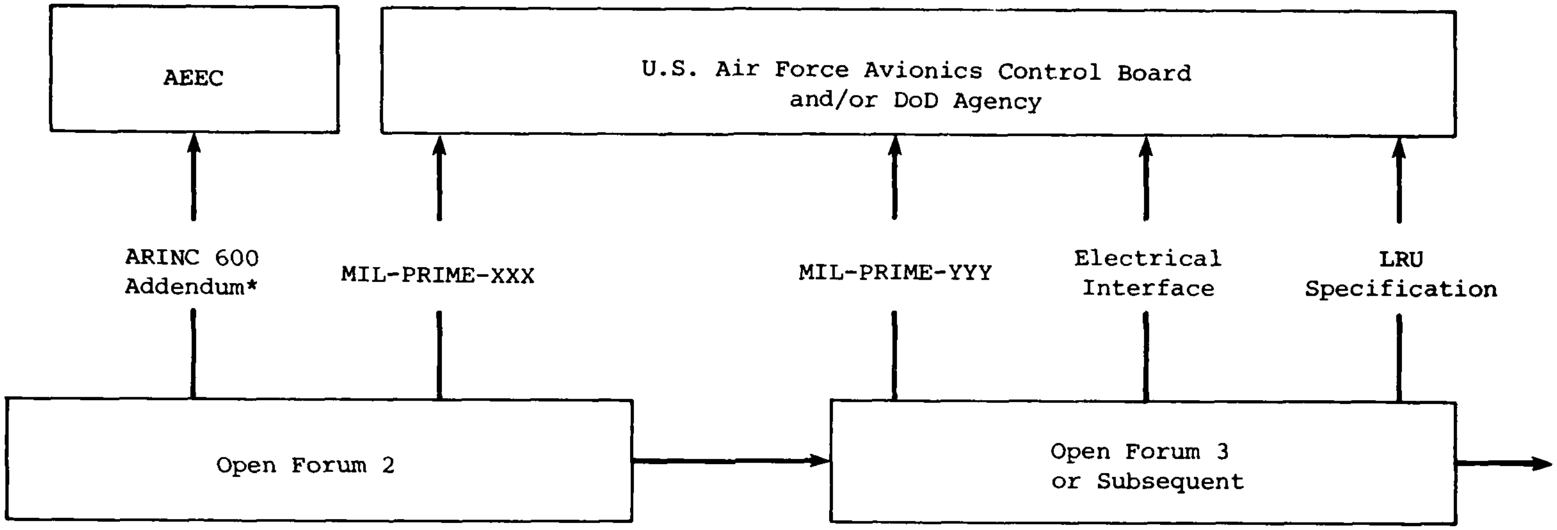
Firm work plans should be developed as the standard evolves and necessary activities are determined. The following subsections present the activities that must be undertaken to verify assumptions and design judgments made in the definition of the avionics installation standards and to initiate the correction of any discrepancies that may become apparent.

7.2.3.1 LRU Mass/Rack and Holddown Load Factor/Ultimate Stress Tests

As now defined, the LRU is held against dynamic loads by standard front holddown hooks and the rear connector shell, and the permitted LRU mass has been increased significantly over present commercial and military limits. Analysis, mechanical testing, and possible respecification of the standard rack configuration should be accomplished under this subtask. Testing the sheer load capacity of the electrical connector should be accomplished as soon as possible, as this is critical to the PME concept.

7.2.3.2 Cooling System Effectiveness

The requirements and theoretical relationships assumed for the cooling-air mass flow, entry and exit temperatures, heat exchanger/heat-sink interface temperature, and critical component temperatures (e.g., junction temperatures) should be investigated experimentally to validate or correct the specification values.



- Achieve consensus on PME Standard
- Address CDU Standard
- Select candidate LRUs
- Address High-Power LRU Standard

Working Groups

- PME Standard
- Control-Panel Cooling
- Instrument-Panel Cooling
- CRT-Display Form and Fit
- CRT-Display Cooling
- High-Dissipation LRUs

- Achieve consensus on CDU Standard
- Address F^2E or F^3E specification of selected LRUs as appropriate

Working Groups

- CDU Standard
- High-Dissipation LRU Addendum
- Standard Electrical Interface
- Candidate LRU Specifications (Air Force-selected GFE avionics programs)

*To Air Force AEEC representatives for AEEC action.

Figure 7-3. RECOMMENDED NEAR-TERM AIR FORCE ACTIVITIES FOR AVIONICS STANDARDIZATION OPEN FORUM

7.2.3.3 Electrical Connector Environmental Performance Tests

In order to qualify a "militarized" version of the ARINC 600 service connector, the electrical connector should be subjected to temperature, vibration, and altitude testing; humidity and drip testing; sand and dust testing; and EMI/EMP performance evaluation.

7.2.3.4 Development of Functional Interface Standards

Specification or interface control drawings (ICDs) should be developed for each avionics functional LRU selected as appropriate for multiaircraft application in conformance with the avionics installation standards and current military requirements. These ICDs should include avionics interface features that will be common to most avionics LRUs, e.g., power, power-up logic, multiplex data bus, RF and digital data coaxial, and future fiber optics connections. Where LRU functional architectures can be established, standard functional characteristics for selected multiapplication avionics LRUs should be developed.

7.2.3.5 Schedule Development

Schedules for the above-described activities should be developed as the details of the final draft standards become known. The Air Force objective is to implement a military PME standard in time to influence avionics installations and major retrofits occurring after 1985. Considering production lead times and procurement delays, it will be necessary to start the testing and certification of selected equipments by 1983.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The initial objectives of the PME standardization activity have been fulfilled. The major factors influencing the selection of Standards for Rack-Mounted and Panel- or Console-Mounted avionics installations were identified. Strawman standards have been submitted to Government and industry scrutiny to determine the accommodations needed for mutual acceptance. Industry has indicated that formal installation standards would be welcomed, provided that appropriate applications were chosen. A basis for agreement on the major attributes of the avionics standard has been found. Specific conclusions on key issues are presented in the following subsections.

8.1.1 Application of Commercially Specified Avionics

An adaptation of the ARINC Characteristic 700 series of commercial avionics is an attractive option for most transport and trainer aircraft. The particular additional features generically required by the military should be described in an addendum to ARINC 600 for the information of prospective suppliers and military purchasing agents. This information should be attached to ARINC 600 by the action of the AEEC in response to a formal request made through the Air Force member(s). This proposed document is referred to as the ARINC 600 Military Addendum. Provision for ARINC 700 series boxes will allow use of up to 24 commercially developed avionics in the appropriate military classes of aircraft.

8.1.2 Application of an Air Force Avionics Installation Standard

The basic form and fit and the electrical connector developed for the commercial airlines is a strong contender as an Air Force standard. Changes are required in the cooling air interface and cooling parameters to meet the environmental constraints of high-performance combat aircraft. This document is referred to tentatively as MIL-PRIME-XXX; it is the document that was subjected to the first open forum review. The configurations supported by open forum consensus provide a standard basis for installing avionics units of moderate size and power dissipation in the range from the smallest unit (1/8 cu ft, 15 lb, 250 watts) to the largest unit (3/4 cu ft, 90 lb, 1,500 watts), with cooling-air attachments and the electrical connector located on the rear panel.

8.1.3 High-Density/High-Power Avionics Units

The Air Force installation standard that evolved during the open forum addresses significantly higher densities and powers than the current commercial standard. Nevertheless, there are units, such as radar transmitters and electronic jammers, that could not be accommodated within the values recommended. Therefore, the additional provisions needed for the installation of these units could be specified in an addendum to MIL-PRIME-XXX. This document requires further development.

8.1.4 Implementation of the Standards

The earliest implementation of the PME standards would be for post-1985 production aircraft or major retrofits. Therefore, avionics repackaging efforts or modifications to current development programs must be initiated no later than 1983. The initial effort should be oriented toward establishing the Form, Fit, and Environmental (F^2E) common baseline of high-volume GFE programs that will continue late into the 1980s. Avionics programs currently in development will establish a de facto functional baseline as well; however, this baseline is expected to evolve as the trend toward multifunctional avionics units continues.

8.1.5 Cockpit Installation Standards

With respect to the cockpit-area installation standards, there are two possibilities: (1) establish a conventional MIL-PRIME or MIL-STD document, or (2) handle the additional military requirements by means of an addendum to ARINC 601. It is planned to discuss these at the second open forum to be held in the fall of 1981.

8.2 RECOMMENDATIONS

8.2.1 Near-Term Activities

The following activities should be initiated as soon as possible:

- The revised drafts of the installation standards should be recirculated to Government and industry, and a second open forum should be scheduled. Technical "clean up" of the drafts should be continued prior to the open forum.
- A preliminary testing program should be undertaken to establish the suitability of the rear-mounted connector as a load-bearing structure. Closely related to this issue is the need to determine the adequacy of the cooling-inlet space available in the rear of the smaller LRU sizes to support moderate-power units.

8.2.2 Far-Term Activities

The following activities should be initiated after consensus on the draft standards has been achieved:

- Post-1985 candidate aircraft and avionics GFE programs should be formalized by PMD revision. The revised installation standards should be called out in PMDs for all of the aircraft and avionics programs that do not have finalized avionics architectures. Those programs which have proceeded further in design should be required to provide rationale as to why the new installation standards cannot be accommodated. The following are the candidate aircraft and avionics programs recommended for PMD revision:

Candidate Aircraft	Candidate Avionics GFE Programs
C-X	1750A Computers
LRCA	Post-1985 Line-of-Sight Radios
NGT	Adaptive HF Programs
Post-MSIP F-16s	GPS
	MLS
	NATO IFF
	Common-Cockpit CDUs

- The participation of the Navy and Army in establishing the installation standard should be formalized by including the program in the list of potential joint programs for the Joint Services Review Committee on Avionics Components and Subsystems Standardization.
- After consensus for either a DoD installation standard or a USAF installation standard is achieved, the task of functional LRU standardization should be undertaken. This task can be approached in the same way as the installation standards -- i.e., open forum development by Government and industry.
- A rigorous testing program should be undertaken to qualify certain aspects of the standards for military use -- attachment methods, cooling provisions, and suitability for high-speed multiplex bus applications.

8.3 CONCLUDING OBSERVATIONS

It has taken the commercial air transport industry more than 30 years to achieve its current high level of avionics interchangeability across aircraft types. The Air Force has shown that it can benefit from that experience.

An important element of achieving the success ascribed to commercial avionics standards is to avoid abitrary changes to commitments made in open forum discussion. The Government must, in the end, decide on the final characteristics of the standards. However, the rationale for the decisions should be discussed openly with the participants who have contributed to its makeup. The momentum established by the first open forum should be sustained by means of frequent exchanges between Government and industry until the standards are formalized.

APPENDIX A

REPRESENTATION AT INDUSTRY VISITS AND OPEN FORUM MEETINGS

This appendix lists the individuals who took part in the principal industry visits and open forum meetings that were arranged by ARINC Research to develop the draft Avionics Installation Standard.

1. Mini-Forum, Santa Ana, CA -- 19 January 1981

Representative	Organization
Jim Viviani	Gould NAVCON Systems
Louis Zaragoza	Gould NAVCON Systems
Mike Saba	Air Research, Torrance
W. D. O'Hirok	ITT Cannon
Dave Goodman	ITT Cannon
Peter Chyzinski	ITT Cannon
John Marcin	Douglas Aircraft
Otto Wendel	Lockheed California Company
Don Sevier	Hollingshead International Corp.
Jim McCracken	Hollingshead International Corp.
Bob Hollingshead	Hollingshead International Corp.
Bill Fuqua	McDonnell Douglas
Mike Kocin	TRW, Redondo Beach
Dick Maher	TRW, Redondo Beach
Frank Hogancamp	Rockwell International (NAAD)
Tom Logan	Rockwell International (NAAD)
Roger Robinson	Barry Controls
Major G. Schopf USAF	ASD/XRS
Gary O'Bryan	ARINC Research, Santa Ana

Representative	Organization
Hal N. Buchanan	ARINC Research, Santa Ana
Neil Sullivan	ARINC Research, Annapolis

2. Sperry Flight Systems, Phoenix, AZ -- 21 January 1981

Richard Therrien	Engineering Department Head
Richard Gohman	Engineering Section Head
H. J. McGann	Engineering Section Head
Randall Gaylor	Engineering Department Head
A. Haines	Marketing
Joe I. Durant	Marketing
N. Sullivan	ARINC Research Corporation

3. General Dynamics Corporation, Fort Worth, TX -- 22 January 1981

Grant Grumbine	Group Engineer, Systems Installation
John Turner	Installation Group
D. L. Massey	Electrical Systems
R. D. Brown	Crew Station Design
N. Sullivan	ARINC Research Corporation

4. The Boeing Companies, Seattle, WA -- 17, 18, 19 March 1981

Dale Snell	Packaging Supervisor
Alex Taylor	BCAC
William H. Weaver	Design Engineering
Ted J. Kramer	Thermal/Fluid Systems
James L. Franklin	Thermal/Fluid Systems
Adam Lloyd	
Bruce E. Lawrenson	Hardware Manager, Electronic Support
S. Baily	ARINC Research Corporation
N. Sullivan	ARINC Research Corporation
Major G. Schopf USAF	ASD/XRS

5. Avionics Installation Standards Open Forum, Annapolis, MD -- 21-23 April 1981

Representative	Organization
Col. Dave Teal	AF/RDPV
Ken Ricker	ASD/AXP
Bernard Schneider	ASD/AXA, USAF Project Management
Col. George Botbyl	ASD/AX, WPAFB, OH
Col. Walt Larimer	HQ, ASD/AX, WPAFB, OH
Major Jerry Schopf	ASD/XRS, USAF Project Management
Glen Babb	AFALD/PTSP, Chairman, Connector Working Group
Walter Detert	ASD/ENES, Co-Chairman, Cooling/Environmental Working Group
James Verdier	ASD/ENASA, Chairman, Form-Fit Working Group
John Wafford	ASD/ENFSL, Co-Chairman, Cooling/Environmental Working Group
Bob Berger	ASD/ENFEE, Co-Chairman, Cooling/Environmental Working Group
Bobby Jones	ASD/ENO, Chairman, Planning Working Group
R. Ittelson	ASD/XRE, Conference Chairman
Murray Tepper	Fairchild Weston Systems, Inc.
Philip Baris	Fairchild Republic Company
Bob Hollingshead	Hollingshead International Corp.
Roland Hade	Hamilton Standard
Roger Saunders	Rockwell Collins
Norman Wright	Rockwell Collins
Mohamed Shakil	Rockwell Collins
William Rupp	Bendix Air Transport, Avionics Division
D. T. Engen	Bendix Air Transport, Avionics Division
J. C. Hoelz	Bendix Air Transport, Avionics Division
Walter Boronow	Douglas Aircraft
John Marcin	Douglas Aircraft
Louis Zaragoza	Gould NAVCOM Systems
John Reilly	USA ERADCOM, Fort Monmouth, NJ
Joe McGann	Sperry Flight Systems
J. Maxwell Moore	ITT Cannon

Representative	Organization
Dick Yada	ITT Cannon
Joe Wilkinson	IBM Corporation
M. Donegan	IBM Corporation
Ted Kramer	Boeing
Michael Kocin	TRW, Redondo Beach
Otto Wendel	Lockheed California Company
William Gully	Delco Electronics
David Wilson	General Electric ACSD
Phelps Hurford	McDonnell Aircraft
Peter Gibson	Ferranti, Ltd.
Gustav Hagman	Simmonds Precision
Roald Horton	Westinghouse DESC
John Kitwell	Naval Avionics Center
Art Scheidecker	AMP, Inc.
Michael Evans	AMP, Inc.
Joseph Saylor	AMP, Inc.
Roy Malarik	Lear-Siegler, Inc.
Ed Kazmarek	Lear-Siegler, Inc.
Ralph Blair	Control Data Corporation
Roger Robinson	Barry Controls
John Turner	General Dynamics, Fort Worth
John Pizzuto	Singer Kearfott
Denis Perry	LFE
Ed Ramirez	Grumman Aircraft Company
Vincent Cirrito	Grumman Aircraft Company
Bruno Lijoi	Grumman Aircraft Company
Stu Baily	ARINC Research Corporation
Noel Smith	ARINC Research Corporation
Ed Straub	ARINC Research Corporation
Atso Savisaar	ARINC Research Corporation
Neil Sullivan	ARINC Research Corporation
Stan Munson	ARINC Research Corporation

Representative	Organization
Dave Featherstone	Aeronautical Radio, AEEC Assistant Chairman
Rick Climie	Aeronautical Radio, AEEC Chairman

APPENDIX B

INDUSTRY AND GOVERNMENT COMMENTS ON PRELIMINARY DRAFT INSTALLATION STANDARDS

This appendix summarizes the detailed comments of industry and Government representatives on the preliminary draft installation standards. The comments are referenced to the paragraph numbers of the preliminary draft standards that were circulated.

1. Replies from Industry on Avionics Installation Standard (December 1980)

Draft Paragraph No.	Comment
Astronautics Corp. of America, Milwaukee, WI; H. J. Sandberg	
5.1.3	Prefer convection cooling, which the specification does not allow.
Bendix Corp., Flight Systems Division, Teterboro, NJ	
5.1.1	Keep size 10 MCU. 6 in. height is a hardship for rear-inserted vertical cards.
Figure 2	Adjacent 3-MCU holddown devices interfere.
Table 2	44-lb limit not practical for 12 MCU.
5.1.2	Vibration is hard on small MCUs; test duration should be specified.
5.3.1.2	3-amp signal pins would be enough.
5.3.1.6	Make inserts interchangeable between manufacturers.
5.3.1.7	Front release and removal of pins is desirable also.
5.3.3	Have all connectors with environmental seals.
5.3.5.1	Second paragraph, first sentence "depends on connector designer."
5.3.5.2	"Low insertion force" not so low any more.

<table>
<tr><th>Draft Paragraph No.</th><th>Comment</th></tr>
<tr><td colspan="2">General Electric Co., Aerospace Control Systems Division,
Binghamton, NY; G. W. Daniels</td></tr>
<tr><td>3.1</td><td>Keep 10-MCU size.</td></tr>
<tr><td>3.4.1</td><td>Where are data supporting unified-power-supplies objective?</td></tr>
<tr><td>3.6</td><td>Clarify required direction(s) of air flow.</td></tr>
<tr><td>5.1.1</td><td>Note 2. Height reduction would heavily penalize internal module design, particularly when associated with vertical cooling air flow.</td></tr>
<tr><td>5.1.2</td><td>Requirements insufficiently defined.</td></tr>
<tr><td>5.1.3.2</td><td>Power dissipation allowed without cooling openings could be increased by 25 percent.</td></tr>
<tr><td>5.3.1.7</td><td>Add "round posts for flexible printed wiring."</td></tr>
<tr><td>5.7</td><td>Specify deflection and bending appraisal and vibration appraisal?</td></tr>
<tr><td colspan="2">General Electric Co., Aerospace Electronic Systems Division,
Utica, NY; A. N. Mondo</td></tr>
<tr><td>3.4</td><td>Recommend front-mounted connectors (per McClellan AFB maintenance people).</td></tr>
<tr><td>3.6</td><td>Clarify air-flow direction(s) required to be tested.</td></tr>
<tr><td>5.1.1</td><td>Reduced height (to 6 in.) would force design of long, narrow boards with few pins.</td></tr>
<tr><td>5.1.3.1</td><td>Cooling-air holes top and bottom permit dirt and metal chips to enter LRU.</td></tr>
<tr><td>5.2.3.2.2</td><td>Where is extractor?</td></tr>
<tr><td>5.2.5.2</td><td>Must block cooling-air flow when LRU is removed from rack. Also preclude entry of tools, hardware, and dirt into ducts.</td></tr>
<tr><td>5.3.1</td><td>Add connector EMI shielding requirement.</td></tr>
<tr><td>5.3.5.1.1,
5.3.5.2</td><td>Datum E appears only on Figure 9.</td></tr>
<tr><td>5.5.4.2</td><td>"... shall contain no entrained condensate."</td></tr>
</table>

Draft Paragraph No.	Comment
International Business Machines Corp., Owego, NY; G. T. Ho	
5.1.2	Shock and acceleration data missing; vibration duration not given. Different applications (e.g., helo, aircraft) need different specification limits.
5.1.3.1	Vertical-cooling flow is prone to clogging.
5.1.3.2	Table 3. Suggest all power-dissipation levels be increased 50 percent.
5.2	Unclear how connector "holddown" provides structural integrity.
Appendix I	Appears overly detailed. How does it fit in with MIL-STD requirements?
General Comment	Any implementation plan should consider existing hardware, retrofit impacts, orderly (gradual) introduction, and flexibility to accommodate future technology developments.
McDonnell Douglas Aircraft Co., St. Louis, MO; H. K. Decker	
General Comments	As written, the strawman standards contain characteristics of both military specifications and military handbooks. They are much too broad and create the potential for conflict with other existing specifications and standards such as MIL-E-5400, MIL-I-8700, MIL-E-38453, MIL-E-87145, MIL-STD-454, and MIL-STD-890. If the Air Force wishes to change the requirements set forth in existing specifications and standards, those documents should be revised. Another layer of documents should not be added. The relationship of the proposed standards to the Air Force MIL-PRIME documents should also be considered. The proposed standards must be revised so that they fit into the military specification and standards program. Briefly, the proposed standards need to be revised extensively before they can be applied to fighter/attack aircraft. The standards must fit into the military specification and standards program, and they must provide the packaging and installation flexibility needed to design fighter aircraft that are superior to the opposition's. The revision process should make full use of the experience of members of the fighter aircraft industry.

Draft Paragraph No.	Comment
McDonnell Douglas Co. (continued)	
1.0	Consider liquid cooling.
3.1	Do not fix size and shape.
3.2	"Cabinet," "rack," "shelf" not to be assumed in fighter aircraft.
3.3	LRU guides can also align cooling-air interface.
3.4	Multiplex bus, video, double-shielded wiring, and fiber optics should be included.
3.4.1	Design goal only.
3.5	Wire integration areas: no space in fighter aircraft (also applies to 5.4.1, 5.6).
3.6	Ducting may be integral with structure -- allow fore and aft air flow in LRU (also applies to 5.5.4.6, 5.5.6.2).
3.9	2° in one hour is "stable."
3.12	Critical operating condition may not be "ground operation" (also applies to 5.5.1).
4.1	Add objectives given in cover letter and MIL-E-87145 (USAF).
4.2	Add: "minimal penalties to aircraft performance and LCC."
5.1.1	Do not fix shape and size; changes to rack and panel installations are the most difficult to implement; front round connectors are the most efficient and easy to repair, replace, or modify.
Figure 2	Reduce lower lip dimension from 0.142 ± 0.016 to 0.06 ± 0.03.
5.1.2	Vibration performance will be in Equipment Specification; reference MIL-I-8700A, paragraph 3.3.12.
5.1.3	Cooling: address liquid cooling also. Prohibit direct air impingement on components. Don't have openings on top surface of LRU. Greater heat dissipations than "Table 3" are possible, and needed. Recommend air inlet at rear, exhaust at front. Pressure drop at rated flow is better at 1 1/2 inches (38 mm) of water, with lower inlet temperatures (4.5°C ± 2°C) and lower rated flow (54 kg/hr/kW) (also 5.5.1 and 5.5.4.5).

Draft Paragraph No.	Comment
McDonnell Douglas Co. (continued)	
5.1.4	50,000 feet altitude is too low.
5.1.5	Reduction in cooling air: LRU should withstand X minutes unharmed. Loss of cooling air: LRU should not fail for Y minutes.
5.1.6 to 5.1.10	Environmental requirements are an LRU specification item.
5.1.11	EMC requirements are an aircraft specification item.
5.2	Collecting exhaust cooling air is not necessary and often not practical.
Figure 8	Holddown angle of 45 degrees provides equal "down" and "in" restraint.
5.2.5	Any improvement (increase in efficiency) within an LRU that reduces the demand on environmental control thereby reduces the aircraft performance penalties and LCC. Use heat pipes.
5.2.5.1	Vibration attenuation at all frequencies is difficult. Shock and acceleration are not addressed.
5.2.5.2	Ensure shut-off of cooling-air leak when an LRU is removed.
5.2.7	Access to back side of rack not usually feasible in fighter aircraft.
5.3	Reference to Boeing drawing is not acceptable; MIL-STD required.
5.3.1	Add wire-support and strain-relief requirements (also applies to Figure 12).
5.3.2	Mounting pins, not the connector, should react loads at rear of LRU.
5.3.3	Add environmental "pin to socket" seals to connector requirement.
5.5.1(d)	71°C ambient representative of fighter aircraft (also applies to 5.5.1(i)).
5.5.1(e)	An external cooling air flow may be provided.
5.5.1(f)	DC-10 investigation of 21°C cooling air. B-767 offers option of 21°C cooling air on the ground. Some fighters reduce airflow to 40 kg/hr/kW and temperature to -18°C ± 2°C.

Draft Paragraph No.	Comment
McDonnell Douglas Co. (continued)	
5.5.1(g)	Add maximum allowable flow rate.
5.5.3	Ground survival temperature: -62°C to 95°C for fighters. Minimum operating: -54°C.
5.5.4.1(b)	Minimum continuous ground or flight operation: -20°C to -26°C.
5.5.4.1(c), (d)	Normal continuous operation depending on design cooling-air inlet temperature, chosen from trade-off study results in accordance with MIL-E-87145 (page 89).
5.5.4.4	MIL-E-87145 (USAF) recommends much cleaner air: solid contaminants not exceeding 50 microns, 95 percent less than 20 microns, total less than 0.0005 gram per kilogram.
5.5.5	Average sidewall temperature 71°C representative of fighter aircraft.
5.5.6	Add paragraph "Equipment thermal analysis" from CDU Standard paragraph 5.6.3.1.
5.8	Additional. Add requirement to prevent avionics operation if adequate cooling is not provided on the ground.
10.1	Add evaluation of thermal transient responses for avionics in fighter aircraft.
10.4	Figure 10-7. Test also at other flow rates and temperatures. Add transient tests. Add low-ambient-pressure (high-altitude) tests.
Kaman Aerospace Corp., Bloomfield, CT; G. Matheas	
5.1.1.1	Are holddowns to be stressed for crash loads? This would be 440 lb or more.
5.1.2	Recommend MIL-STD-810 reference.
5.2.5.1	Recommend hard mounting for avionics.
3.4.1	Stay with MIL-STD-704.
General Comment	In smaller air vehicles, the avionics represents an appreciable percentage of vehicle gross weight. The airframe manufacturer must give careful consideration to avionics location in order to maintain aircraft balance. It is sometimes necessary to install

Draft Paragraph No.	Comment
Kaman Aerospace Corp. (continued)	
General Comment	equipment in locations less than optimum from a service standpoint in order to achieve balance. Adoption of this concept would require that all of the avionics be congregated in one or perhaps two locations, and these locations would be severely restricted by the size, form-factor, and access requirements of the concept. It is ideal from the avionics access and maintainability standpoint, but the price for this is not easy to assess. It diminishes the airframe contractor's ability to seek the optimum overall configuration, which is always a mass of compromises.
MITRE Corporation, Bedford, MA; H. T. Cervantes	
3.3	Add "and mechanical tie-downs."
3.6	Air distribution and interfacing could become a real problem if many small heat-producing LRUs were in a rack.
3.10	Add to end of sentence: "with equipment operating at steady-state conditions."
3.12	The thermal design condition as defined should also include the performance at altitude for the particular aircraft in which the LRU will be installed.
5.1.1.2 & 5.1.1.3	References to Figures 1 and 3 are too vague; i.e., in 5.1.1.3 the third sentence refers to limits in Figure 1 for connector mounting screw heads. It is not evident in Figure 1 what these limits are.
5.1.2	The frequencies used are 40 and 800 Hz with roll-offs at 6 dB/octave from $W_O = 0.04$. MIL-STD-810C Method 5.14.1 uses 100 Hz and 1,000 Hz with roll-offs to 20 Hz and 2,000 Hz. Both the frequencies for W_O and the extremes (20 Hz and 2,000 Hz) should be used.
5.1.3	Commentary: Add a comma after "cold plates" and after "pipes."
5.1.3.1	The mechanical aspects of the cooling-air interfaces can be a problem since air leakage must be minimized (first sentence). Unless some secondary operation is involved in the insertion of an LRU into its rack/ cabinet, the design could require substantially tight tolerances to assure proper mating and sealing of the upper and lower air openings. Would it be possible to place the air inlet and exhaust on the rear panel?

Draft Paragraph No.	Comment
MITRE Corporation (continued)	
5.3 (all)	Are any proprietary problems being raised by specifying a Boeing drawing (10-61953) in this specification?
5.5.4.2	The statement only refers to entrained condensate. A limit should be placed on the relative humidity (RH) allowable, since saturated air could easily condense on cold surfaces.
5.7	In the first and third paragraphs add "and" after "analysis."
Appendix 1	
10.2.2.2e	The relative humidity value of ±15% appears high. It ought to be either ±5% or ±10%.
Rockwell International, Cedar Rapids, IO; R. A. Saunders	
3.6	Clarify direction of airflow.
5.1.1	Keep the additional box sizes. The reduced height might exclude commonality with pertinent subassemblies as well as ARINC 600 units.
Figures 1, 2, 3	Clarify datum planes and units of measure.
5.1.1.3	Rear mounting thickness too restrictive.
5.1.1.5	Who is custodian of indexing?
5.1.3	Is cooling air allowed over components?
Table 3	Heat-dissipation limits too restrictive.

2. Replies from Industry on CDU Installation Standard

Draft Paragraph No.	Comment
Bendix Corp., Flight Systems Division, Teterboro, NJ	
4.4 Figure 2	Larger CRT display units need a different housing truncation for each new installation. Tray-mount form factors and handle/cam mechanism need to be better defined.
5.3.9	Water contamination is a problem with "flow through" cooling. Humidity monitor and shutdown of high-voltage circuits is desirable.
Figures 20-1, -5, -6, -8	These tables are difficult to read.
Douglas Aircraft Co., Los Angeles, CA	
5.3.2 Figure 4	Illustrates general approach: permit variations.
5.3.3 Table 1	"Cooler is better" should refer to the component temperatures.
5.3.3(c)	More leeway may be needed.
5.3.5.1	Flow could be lower yet, if air temperature is below 30°C.
5.3.5.2	ARINC 408A calls out 275 kg/hr.
5.3.6	Specified pressure drop is an excessive penalty. Fan limitations should be more flexible.
5.3.7	Contamination limits should be much tighter; smaller particle size, lower initial and final filter-pressure drop. Suggest folded filter.
5.3.8(c)	Design temperature should be for "maximum continuous operation" (65° in this case) not "normal continuous operation 40°C." (Also applies to 3.11.)
5.3.9	The specific humidity of the cooling air should be controlled so that no internal condensations can form during warm-up from "cold cruise" to "warm moist ground" condition.
5.3.10	Why are 5.3.10 conditions more severe than 5.3.8 design conditions?
5.3.11	Equipment may start operation under these conditions, but should rapidly cool to acceptable steady-state temperatures.

Draft Paragraph No.	Comment
Douglas Aircraft Co. (continued)	
5.3.12.1	Minimum orifice size of 0.050 in. should also be specified to eliminate bridgeover from contamination. (Hughes 1 RAM computer development tests.)
5.3.12.3	Specify soft-shore closed-cell foam with 20-year life expectancy.
5.3.12.4	Maximum screen-mesh opening size should be specified.
5.4.2	Derating factors should be subject to periodic review.
5.4.3	Commentary: A more positive design to eliminate "immediate" effect of abnormal operation on reliability is needed.
5.5.1	Commentary: Type B should be designed to "not fail" without cooling air, but have improved performance reliability with this cooling.
5.5.4	Moist air may be allowed in isolated cold plate or blow-by passages.
5.5.5	Noise criteria should be specified.
5.6.4C	Data should cover full range of pressures, temperatures, and flow rates.
10.2.3	Similar points for reverse flow should be specified if suction or blowing systems are used interchangeably.
Page 25	Flagnote 1: humidity 0.017 lb/lb or 119 grains appears excessive.
Flagnote 5	Time constant or ramp should be specified. Already operationally heated components should be specified.
Page 32	Figure 10-6. Why eliminate measurements T10 and Q1 during qualification?
Page 35	Some combined thermal-mechanical stress evaluation should be specified (burn in) during manufacturing as well as procurement.
General Dynamics Corp., Fort Worth, TX; R. D. Brown	
5.2.1	Are we ready to be this specific?
5.2.4	Clarify meaning of "forward of the datum."
5.3.11	Ground survival -65°F to 203°F required for F-16.

Draft Paragraph No.	Comment
General Dynamics Corp. (continued)	
5.3.12.2	Design constraints are too specific.
Appendix II	Include MS 33556, Reference ANSI Y1405-1973 (ASME publication).
Figure 20	Connectors should be specified on detail item specification only.
General Electric Co., Aerospace Control Systems Division, Binghampton, NY; G. W. Daniels	
3.6	Change "class" to "cooling type."
4.2.1	Reference to Paragraph 5.1.12 is incorrect.
4.2.2	Reference to Paragraph 5.2.2.2 should be 5.2.2.
5.3.3 & Table 1	"Attachment 1" is incorrect. Table 1 appears to be redundant.
Figure 5	Clarify definition of ordinate ΔT.
5.3.5.2 & Figure 5A	Remove degrees F and watts/cm^2 scales and reference. "Attachment 9" is incorrect.
5.3.7.2	"... at the point of delivery to the equipment being cooled."
5.3.7.3	Use units consistently, mm of water.
5.4	Electronic design and internal thermal survey exceed the scope of an installation standard.
5.5.1	The third sentence is incomplete.
10.2.3	(T4): Change (T5A) and (T5B) to (T4A) and (T4B); (T9): change existing to exiting; (T11): change Section 4.4 to Section 5.6.2. Note 1: change "show" to "shown."
Flagnotes, Figure 10-4	"Duct-D" belongs to Figure 10-5.
Figure 10-6	Shows no Type B cooling arrangements.
Flagnotes, Figures 10-5 to 10-8	Flags and notes do not agree. Flagnote 11: change Class A to Type A.
10.5	Change 10.7.2 to 3.2; 10.7.7 to 3.7; 10.7.10 to 3.10; 10.7.14 to 3.14. "Section 2" is incorrect.

<table>
<tr><th>Draft Paragraph No.</th><th>Comment</th></tr>
<tr><td colspan="2">General Electric Co., Aerospace Control Systems Division (continued)</td></tr>
<tr><td>10.5.2</td><td>Temperature Variation Test. This test will require more than 4 days of 24 hours per day continuous testing. Modification of the requirements to shorten the time or allow breaks in the test cycle would be desirable.</td></tr>
<tr><td>20.2</td><td>Protrusions on the case. The information in this paragraph repeats Paragraph 5.2.4.</td></tr>
<tr><td>20.3</td><td>Connectors. MIL-C-38999 connectors are high-reliability, environmentally protected connectors with higher connection density (smaller physical size for the same number of contacts) and are well accepted for Air Force avionics use. Suggest that requirements be changed from MIL-C-26482 to MIL-C-38999.</td></tr>
<tr><td>20.4</td><td>Clamp Mounting. A section number is missing in the second paragraph.</td></tr>
<tr><td>20.4.2</td><td>Flangeless Round. Screw type should be "flat head" rather than "countersunk."</td></tr>
<tr><td colspan="2">General Electric Co., Aerospace Electronic Systems Division,
Utica, NY; A. N. Mondo</td></tr>
<tr><td>5.3.9</td><td>"The coolant air shall contain no entrained condensate."</td></tr>
<tr><td>5.4.2</td><td>Component-case-temperature limitations exceed the scope of an installation standard.</td></tr>
<tr><td colspan="2">McDonnel Douglas Aircraft Co., St. Louis, MO; H. K. Decker</td></tr>
<tr><td>5.5.3 &
Table 1</td><td>Type A (Flow-Through). Current fighter aircraft contain equipment using Type A cooling which dissipates more than 0.35 watt/in.^{3}. This can be accomplished with efficient internal thermal design.
Type B (Flow-By). Studies by Douglas Aircraft and by the Boeing Company (Reference AGARD CP-196, Paper No. 11, June 1976) indicate that directed flow of air over display units can allow the units to dissipate more than 0.2 watt/in.^{2}. Airflow rates, air temperatures, and flow patterns for flow-by cooling need to be defined more fully.</td></tr>
</table>

Draft Paragraph No.	Comment
McDonnell Douglas Co. (continued)	
	Type C (No Cooling). Ambient-air-cooled control and display units can dissipate more than 0.05 watt/in.^{2} with efficient thermal design. Inefficient thermal design reduces aircraft performance and increases aircraft cost. Since there is cooling by natural convection and other means, it is suggested that the name be changed to Ambient Cooling.
5.3.5.1, 5.3.5.2, 5.3.8, 5.5.1, 5.6.4	The airflow rate and temperature should be selected on the basis of trade studies, as is described in MIL-E-87145 (USAF), 21 February 1980, p. 89.
5.3.6	A maximum pressure drop of 38 mm of water, at the flow rate and temperature based on trade study results, is representative of units in fighter aircraft.
5.3.7.2	The particle-size limits described in MIL-E-87145 (USAF), p. 93, are suggested.
5.3.10(b)	A low ambient temperature of -40°C is representative of fighter aircraft.
5.3.10(c) & (d)	Normal ground or flight operating temperature as low as 30°C may be considered.
5.3.11	Ground survival temperatures range from -62°C to 95°C for fighter aircraft.
5.3.X	Addition. An item about local environmental pressure seems needed. The lower cockpit pressures in fighter aircraft, relative to cargo or transport aircraft, should be considered.
5.4.2	Units for the temperatures used in the equations should be defined.
5.5.1	See comment on Paragraph 5.3.5.1 regarding cooling-air temperature.
	It should not be objectionable to use cabin conditioning air, since this air source also may be used to cool other avionics. Cabin exhaust air may provide adequate cooling, but air obtained from the refrigeration system directly can provide better cooling than cabin exhaust air.
5.5.5	Acceptable levels of noise must be specified.

AD-A116 852 ARINC RESEARCH CORP ANNAPOLIS MD F/G 1/3
DEVELOPMENT OF AVIONICS INSTALLATION INTERFACE STANDARDS, REVIS--ETC(U)
AUG 81 S BAILEY, N SULLIVAN, A SAVISAAR F04606-79-G-0082
UNCLASSIFIED 2258-03-2-2477R NL

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<table>
<tr><th>Draft
Paragraph No.</th><th>Comment</th></tr>
<tr><td colspan="2">McDonnel Douglas Co. (continued)</td></tr>
<tr><td>5.6.4(c)</td><td>Pressure-drop information should be supplied for flow rates and temperatures based on comment on Paragraph 5.3.5.1.</td></tr>
<tr><td>Figs. 10-1, 10-2, & 10-3</td><td>Temperatures should be consistent with previous comments. Environmental pressure should be considered as a test parameter.</td></tr>
<tr><td>Appendix II</td><td>No provisions are made for EMI grounding of instruments to instrument panel.</td></tr>
<tr><td>20.3</td><td>Connectors should be in accordance with MIL-C-38999.</td></tr>
<tr><td colspan="2">Rockwell International, Cedar Rapids, IO; R. A. Saunders</td></tr>
<tr><td>3.8, 3.9, & 3.15</td><td>"...ground and flight operation."</td></tr>
<tr><td>5.1</td><td>Do not restrict to Air Force.</td></tr>
<tr><td>5.2.4</td><td>Front protrusions to 1.5 inches are more typical of military units.</td></tr>
<tr><td>5.4.2</td><td>We prefer the derating approach defined in the Avionics Installation Standard, Paragraph 5.5.2.</td></tr>
<tr><td>5.6.1</td><td>Commentary: 5,000 hours between maintenance actions would be realistic goal.</td></tr>
<tr><td>Appendix I</td><td>Testing should include high-altitude, free-convection conditions.</td></tr>
<tr><td colspan="2">Westinghouse Electric Corp.,
Defense & Electronic Systems Center,
Baltimore, MD; R. N. Horton</td></tr>
<tr><td>4.3</td><td>Cooling-air-aperture locations severely restrict equipment design.</td></tr>
<tr><td>Figure 2</td><td>Form factor conflicts with standard CRT sizes. Blind mating connectors and cooling ports are not recommended for tray-mounted units.</td></tr>
<tr><td>Figure 5</td><td>Needs clarification.</td></tr>
<tr><td>5.3.6</td><td>Much larger pressure drop required to provide the desired flow rates.</td></tr>
<tr><td>5.3.12.4</td><td>What is "robust"?</td></tr>
</table>

<table>
<tr><th>Draft Paragraph No.</th><th>Comment</th></tr>
<tr><td colspan="2">Westinghouse Electric Corp. (continued)</td></tr>
<tr><td>5.6.1</td><td>Commentary: Goal of 10,000 MTBF is very difficult to meet.</td></tr>
<tr><td>5.6.4(d)</td><td>Seems unnecessary.</td></tr>
<tr><td colspan="2">MITRE Corporation, Bedford, MA; H. T. Cervantes</td></tr>
<tr><td>Appendix 10.2.2(5)</td><td>"Specific" humidity ±15% ought to be "relative" humidity and the tolerance ±5%.</td></tr>
</table>

3. Replies from Government on Avionics Installation Standard

3.1 U.S. Air Force Review and Comment

Organization	Comment
HQ, Ogden ALC (AFLC) Hill AFB, UT 84056 Ed Fowers, MMSRW	Concur with objective. See difficulties in small fighter-type aircraft. Recommend using standard connectors and compensating ballast when LRU is removed from aircraft.
HQ, Ogden ALC (AFLC) Hill AFB, UT 84056 Joseph Cronin F-16 Acquisition Div.	Concur.
HQ, San Antonio ALC (AFLC) Kelly AFB, TX 78241 J. Johnson, MMIMP	Should address "Avionics Testability" and reference the "Design Guide" to be published by ASD/AEGB (G. Wolanski). Recommend reference to computer-aided thermal design concepts of AFFDL (Dr. Arnold Meyer).
HQ, Oklahoma City ALC (AFLC) Tinker AFB, OK 73145 Norman Davis, XRX	Do not exclude any LRUs that can logically and practically fit the constraints outlined in the standard. Retain EMI and EMP.
HQ, Sacramento ALC (AFLC) McClellan AFB, CA 95652 W. T. Spratt, MMMMT	Clarify acronyms. Define "zero or low insertion force."
HQ, Aeronautical Systems Div. Wright-Patterson AFB, OH 45433 Bobby Jones, ASD/EN	Change "must" and "should" to "shall" throughout. Spell out "ATR" (3.1). Change "permitted" to "required" (5.1.1.6). Delete "when possible" (5.1.3.1). Sand and Dust Test is applicable (5.1.10). Delete "where applicable" (5.3.5.1). Delete "care should be taken in," and change "to" to "shall" (2 places) (5.6.2). Revise so as to be compatible with MIL-PRIMEs: Environmental Control, EMC, Materials Electrical Power; per EN01-81-1 (1 February 1980) and AFSCR 800-10 "Lessons Learned Program."

Organization	Comment
HQ, Aeronautical Systems Div. Wright-Patterson AFB (continued)	Concept is only suitable for cargo and bomber aircraft. Power-dissipation limits are a severe handicap. Needs could reach 1,000 watts per ATR. Specify environmental requirements elsewhere: in equipment design specification. Restate the vibration level as an installation location constraint.
Wright Aeronautical Laboratory Wright-Patterson AFB, OH 45433 C. J. Feldmanis	Allowed cooling-air temperature range (-15°C to +55°C, paragraph 5.5.4) is too wide for avionics reliability. Specify maximum equipment or component case or junction temperatures. Consider other coolants. Outline component mounting techniques and parameters. Provide guidance to computer-aided thermal analysis.
HQ, Air Force Logistics Command Wright-Patterson AFB, OH 45433 Jill Levy, LOWWC	Emphasize functional interchangeability. Address testing: BITE and "Off-Line." Reference MATE and "Avionics Testability Design Guide." Provide valid, accessible test points. Follow up stated BITE objective. Ensure circuit integrity through interfaces. Coordinate with test-fixture design activities.
HQ, Air Force Acquisition Logistics Division (AFLC) Wright-Patterson AFB, OH 45433 Code: PTEE	Identify nonpreferred MCU sizes clearly in 3.1.1, and reference throughout text. Clarify that Thermal Stabilization is intended in 3.9 title.
HQ, Warner Robins ALC (AFLC) Robins AFB, GA 31098 L. A. Wright, MMMLA	Are other connector styles being considered? Should guide pins be specified? Cable routing and stress relief should be included.

Organization	Comment
HQ, Warner Robins ALC (AFLC) Robins AFB (continued)	Are signal or power standards to be added? Avoid protrusions and cables that can be used as handles. Can BITE flag or elapsed-time indicators be mounted on rack front? Vibration is not realistically specified. Thermal characteristics and vibration will depend on location in aircraft. Loss of cooling air: 10 minutes is not enough. Address blind-RF-connector problem. Address weight and human factors - Air Force HDBK DH-1-3. Address "use of materials" requirements.
HQ, Air Force Systems Command Andrews AFB, D.C. 20334 Lt. Charles L. Houston, III	Add SAC, MAC, and TAC to distribution. BITE call out (4.1(d)) not necessary in packaging standard. Addresses modular enclosures, not modular electronics (4.2(a)). Part "location" intended (5.5.6.1(c)).
HQ, Electronic Systems Command Hanscom AFB, MA 01731 LTC D. Busse, ESD/DCB	"Upward" airflow direction depends on orientation of the LRU in the airframe. No mention is made of lightning protection. Appendix I belongs in a "Test Standard."

3.2 U.S. Navy Review and Comment

The Navy comments are grouped into six major areas:

- Physical Considerations
- Thermal Considerations
- Environmental Considerations
- Structural Considerations
- Electrical Considerations
- Miscellaneous Considerations

The comments under these major areas are listed by topic and refer to the appropriate Air Force Standard page/paragraph numbers for easy reference. Reasons are presented where Navy requirements may vary from those of the Air Force.

3.2.1 Physical Considerations

Topic	Reference	Comments and Reasons
Internal Configuration	Page 3, para. 5.1	Internal box configurations, as this standard is written, would not be specified or controlled. The Navy believes that module-level standardization should be implemented. Two module sizes are being adopted for Naval avionics -- the ISEM-2A and the 1/2 ATR. (NOTE: The 1/2 ATR is 2.15" taller than, but otherwise the same as, the ISEM-2A.)
Vertical Airflow	Page 2, para. 3.6 Page 8, para. 5.1.3	Cooling-air apertures in the top and bottom of the enclosure define a vertical airflow. While vertical airflow may be an efficient use of space for new aircraft designs, many existing Navy aircraft require horizontal (back-to-front) airflow. New standards must consider retrofit application to existing aircraft as well as use in new aircraft. The Boeing Aerospace Company is investigating standard enclosure designs and air ducting locations on Navy aircraft. Their findings and recommendations will be available in June 1981.

Topic	Reference	Comments and Reasons
6" Height of Enclosures	Page 5, note 2	The Navy disagrees with the option for a 6"-high enclosure because of inefficient application of standard module sizes. There does not seem to be sufficiently documented justification for the deviation from the 7.64" standardized height.
Reduced Height Connector	Page 5, note 3	The reduced height connector is only necessary if the enclosure height is reduced to 6". This change in the connector size would require much new tooling for connector shells and inserts.
MCU Size Exclusion	Page 5, note 1	Modular Container Unit (MCU) size 12 should be excluded along with those listed for exclusion, i.e., 1, 5, 7, 9, 10, and 11. The recommended sizes are 2, 3, 4, 6, and 8.
Weight	Page 8, para. 5.1.1.4, and Page 9, Table 2	Table 2 specifies the maximum weights for different sized enclosures. The problem with Table 2 is demonstrated by the following hypothetical example. Given two designs (with the same functional performance), Table 2 would reject the lighter, more compact design. For example:

Design	Device Technology	Case Size	Weight
1	Dual-In-Line Package (DIP)	6 MCU	30 lb
2	Leadless Ceramic Chip Carrier (LCCC)	2 MCU	12 lb

Topic	Reference	Comments and Reasons
Weight (continued)		The following suggested note should be added to the table: "Every effort should be made to design to the lowest weight and smallest case size, even if the weight for that smaller case might be exceeded."

3.2.2 Thermal Considerations

Component Part Temperature	Page 29, para. 5.5.2	(1) The introductory note outlining the advisory nature of this section should be deleted. (2) This standard, as written, defines "part temperature" as the part surface temperature. In the case of semiconductors, the junction temperature is directly related to component reliability, whereas the surface temperature is only indirectly related. Information on maximum allowable junction temperatures should be added.
Power Dissipation	Page 10, Table 3	Increasing circuit complexity and density requirements are increasing avionics power dissipation levels, possibly faster than packaging innovations can offset them. To prepare for this possibility, the Navy has contracted the Boeing Aerospace Company to investigate avionic forced-air cooling techniques at the following thermal dissipation levels:

Enclosure Case Size	Power Dissipation (Watts)
2 MCU	250
4 MCU	500
6 MCU	750
8 MCU	1,000

Topic	Reference	Comments and Reasons
Power Dissipation (continued)		Using these levels as requirements may stifle development of power-efficient devices by allowing a system developer to use older, less efficient devices. Therefore, industry input should be sought to determine how much adjustment to the Table 3 (thermal dissipation) levels is needed to result in a good balance between dense circuitry and power efficiency.
Air Pressure	Page 8, para. 5.1.3.1	Increased coolant flow rates may be required to permit increased packaging density with greater heat dissipation. Consequently, the pressure drop should be increased to 37 ±5 mm of water.
Cooling	Page 8, para. 5.1.3	As written, cooling air directly impinging on components is allowed. Requirement 52 of MIL-STD-454F (called out in MIL-E-5400) does not permit direct air impingement cooling because of contamination and moisture problems encountered with this form of cooling. References to MIL-E-5400 and MIL-STD-454F should be incorporated in this requirement.

3.2.3 Environmental Considerations

Ambient Temperature	Page 29, para. 5.5.3	The temperatures specified are not consistent with MIL-E-5400, Class 1, Class 2, Class 1(X), or Class 2(X). The MIL-E-5400 requirements are preferred.
Vibration, Shock, and Acceleration	Page 8, para. 5.1.2	(1) Acceleration requirements are not specified in this standard, nor are they specified in MIL-E-5400. (2) Shock loads as specified in MIL-E-5400 should

Topic	Reference	Comments and Reasons
Vibration, Shock, and Acceleration (continued)		be required. (3) In addition, a requirement to cover the rigors of catapult launch and arrested landing should be added such as: "Shock: MIL-STD-810C, Method 516.2, Procedure IV, high intensity test flight vehicle equipment, Figure 516.2-1." (4) The random vibration spectrum should be extended to 2 kHz and sine vibration should be added, and required to be in accordance with MIL-E-5400T, Figure 2, curve IVa.
Sand and Dust	Page 12, para. 5.1.10	The Navy does not concur that sand and dust requirements are "not applicable to equipment installed inside compartments or electronic bays."

3.2.4 Structural Considerations

Topic	Reference	Comments and Reasons
Backplate Deflection	Page 18, para. 5.2.3.1.2	The worst-case force for backplate deflection is believed to be caused by the 250-pound extractor mechanism force. The backplate deflection requirement should include this worst-case load.
Connector Engaging Force	Page 21, para. 5.3.2.4	The engaging force has been updated by Boeing specification SCD 10-61953, revision D, and should be 100 pounds for the full (7.64") height enclosure.
Connector Index Key Strength	Page 21, para. 5.3.2.6	The key must be capable of withstanding the 250-pound force produced by the extractor mechanism.

3.2.5 Electrical Considerations

Topic	Reference	Comments and Reasons
EMC	Page 12, para. 5.1.11	MIL-STD-461 has been updated to revision B, which includes a table listing the tests necessary for various equipment classes. The suggested class is Alb. An EMP specification should be prepared and, when available, should be referenced in this standard.
Electrical Power Supplies	Page 1, para. 3.4.1	Voltage levels should be standardized (as stated in the commentary); however, the Navy does not agree that complete elimination of power converters in black boxes will occur.
Connector Installation Considerations	Page 24, para. 5.3.5	For new installations, consideration should be given to use of MIL-STD-1553B data bus interconnection systems.

3.2.6 Miscellaneous Considerations

Dimensional Units	Throughout	Either Standard International (SI) units or English units should be decided upon and used throughout. The use of SI units with English units following in parentheses is recommended.
Indexing	Page 8, para. 5.1.1.5	An agency should be established for allocation and control of indexing key codes to preclude duplication and promote interchangeability of enclosures among different aircraft.
Air Leakage	Page 50, para. 5.5.4.7	A limit for air leakage should be negotiated. As a starting point, "1 percent maximum" is proposed.
Undefined Dimensions	Page 4, Figure 1, Table 1	The back view of Figure 1 shows dimensions "M" and "N." These dimensions are not listed in Table 1.

4. Replies from Government on Strawman AF CDU Standard

Organization	Comment
HQ, Ogden ALC (AFLC) Hill AFB, UT 84056 Joseph Cronin F-16 Acquisition Div.	Concur.
HQ, Air Force Logistics Command Wright-Patterson AFB, OH 45433 Jill Levy, LOWWC	Does not address issues on the use of "smart" or "intelligent" CDUs. Does not address off-line-test requirements or interfaces.
HQ, Air Force Systems Command Andrews AFB, MD 20334 Lt. Charles L. Houston, III	If cooling-air supply fails (5.4.3, Abnormal Operation), nonessential heat loads might be shut down.
HQ, Electronic Systems Command Hanscom AFB, MA 01731 LTC D. E. Busse, ESD/DCB	Load factors and crash safety are not addressed. Human factors and operator interface are not addressed.
Wright Aeronautical Laboratory Wright-Patterson AFB, OH 45433 Gary Brown, AAAS-3	Why restrict use of internal fans? A standard flow rate is not valid; component density and cold wall bonding influence cooling efficiency. DZUS form factor not applicable for CRT devices. What is the cost impact of required documentation?
HQ, Space Division (AFSC) P. O. Box 92960 Los Angeles, CA 90009 Col. James W. Reynolds	GPS has used MIL-C-6781 (Para 3.0), MIL-E-16400G (Para 3.7.8), and MS 25212 designs for CDUs. GPS would use cooling air for CDU if it was available.
HQ, Aeronautical System Div. Wright-Patterson AFB, OH 45433 Bobby Jones, ASD/EN	Change "must" and "should" to "shall." There are also Air Force standard instrument sizes, and STANAG-3319 should be considered. MS-28042 defines mounting clamps. Length of instruments (9 in. maximum) can exceed available space in some aircraft. Move environmental specification requirement to the individual equipment specifications.

APPENDIX C

DESIGN CONSIDERATIONS FOR HIGH-POWER/ HIGH-HEAT-DISSIPATION LRUs

1. INTRODUCTION

In addressing a potential standard configuration for high-powered avionics LRUs such as radar transmitters and jammers, it is important to take note of their inherent differences from ordinary low-power avionics LRUs. The high-powered LRUs have:

- Greater size
- Greater weight
- Need for high rate of heat removal
- Need for immediate shutdown if cooling means is interrupted

The avionics PME standard under consideration for rack-mounted or tray-mounted avionics now provides for LRUs of up to 90 lb weight, 3/4 ft^3 volume, and 1.5 kW heat dissipation by forced air cooling. This appendix therefore addresses LRUs in which these values must be exceeded. Such an LRU will usually require an individual installation location in relation to its associated antenna(s) and an individually tailored cooling system.

It is convenient to classify high-power avionics employing alternate cooling techniques as follows:

Type A: High-heat-dissipation avionics equipment located in the avionics bay and cooled by forced air.

Type B: High-heat-dissipation avionics equipment located in the avionics bay and cooled by liquid.

Type C: High-heat-dissipation avionics equipment located remotely (including unpressurized areas) and liquid-cooled by cold-plate mounting structures or integrated liquid heat exchangers.

Type D: High-heat-dissipation avionics equipment located remotely (including unpressurized areas) and cooled by ram-air induction during high-power operational modes.

Type E: High-heat-dissipation avionics equipment, located in avionics bay or remotely, that uses supplemental cooling by boil-off during high-power operational modes.

2. HIGH-POWER LRU DESIGN REQUIREMENTS

2.1 General

This section includes basic design standards and desired system interfaces for each of the types of high-heat-dissipation equipment described. Equipments requiring cooling to cryogenic temperatures are not excluded, but only the thermal and mechanical interfaces with the aircraft cooling system will be addressed.

2.2 Heat Exchangers

It is highly desirable that the air passages in the heat exchanger be no smaller than 0.1 inch minor dimension, to preclude the collection of dust and other particles carried by the cooling air. It is expected that filters in the environmental control system will eliminate all particles greater than 50 microns in diameter. All foreign matter smaller than 50 microns should easily pass through the heat exchanger without appreciable accumulations. The use of turbulent flow to increase the heat exchanger's efficiency is encouraged. Where forced-air cooling is derived primarily from ram-air sources, dust may be present in combination with water in the liquid form. Air manifolds that control the distribution should be accessible for inspection and cleaning if necessary.

2.3 Cold-Plate Mechanical/Thermal Interfaces

The design of the mechanical/thermal interface between the cold plate permanently attached to the aircraft structure and the LRU heat-sink surface should permit the maintenance of at least 90 percent of the heat-transfer capability after five years of service use. Typical service use consists of at least 10 removals and replacements of the LRU per year, with humidity exposure between each removal.

3. TYPE A EQUIPMENT

Type A equipment includes any forced-air-cooled equipment located in the avionics bay that dissipates heat at a rate greater than 1 watt/cu in or greater than 1.5 kW total.

3.1 Suggested Air-Pressure Drop

The pressure drop through the equipment as measured at the line replaceable unit (LRU) should not exceed 100 mm of water with a flow rate of 73 kg/hr/kW at 15°C. The pressure drop shall not exceed 300 mm of water at a flow rate of 220 kg/hr/kW at 55°C.

3.2 Exhaust-Air Temperature

The temperature of the exhaust air should not exceed 232°C under any condition of operation, because of the fire hazard associated with fuels, oils, and hydraulic fluid that may be present. If it is necessary to make maintenance adjustments in the vicinity of the air exhaust, the exhaust-air temperature should be limited to 71°C. If electrical wiring is present in the compartment, the maximum exhaust-air temperature for the highest-temperature insulation is 175°C.

3.3 Exhaust Air Ducts

Ducts carrying high-temperature exhaust air to exit ports should not exceed 120°C unless materials used for ducts, gaskets, seals, coatings, and insulation adhesives are specifically designed for higher temperatures and have been proven to withstand these temperatures for long-term exposures without degradation.

3.4 Overtemperature Protection

To preclude the possibility of overtemperature-stressing of the equipment, appropriate sensors must be included at the cooling-air inlet to detect air-flow conditions directly, or to detect excessive heat-exchanger surface temperatures. Automatic power-down of the equipment should occur and caution circuits must be activated under such conditions.

3.5 Air Inlet Design

The seal between the cooling-air source and the equipment should be designed to permit removing the LRU without disconnecting separate retainers at the cooling air interface. Leakage at the cooling-air interface should not exceed 5 percent of the rated flow. Insertion of the LRU and tightening of the holddown devices should provide the force necessary to complete air-inlet coupling.

4. TYPE B EQUIPMENT

Type B equipment includes any liquid-cooled equipment located in the avionics bay.

4.1 Disconnects

All LRUs using integral liquid-cooling loops should have self-sealing disconnects. It should not be necessary to have to refill any bled liquid loops as a result of routine maintenance actions such as LRU replacement. Quick disconnects are preferred over valves because disconnects provide for instantaneous sealing of hoses or liquid-cooled components without appreciable loss of coolant.

4.2 Maximum Coolant Temperature

All equipments that use liquid coolant should be designed to prevent overtemperature of the liquid in any part of the coolant loop. Transient conditions that cause the coolant to rise above the maximum operating temperature of the coolant should be avoided to prevent overpressure, coolant breakdown, corrosion, and possible coagulation. Operating procedures should be designed to prevent coolant overtemperatures that may occur during low-flow or no-flow conditions, where residual heat fluxes from high-power operation may be present following equipment turn-off.

4.3 Suggested Line Pressures

The liquid-cooling loops within the equipment (or within a cold plate mounting base) should be designed for a normal operating pressure of 50 psig.

4.4 Suggested Coolant-Inlet Temperature

The following coolant temperatures are considered typical of aircraft environmental control systems using liquid-coolant loops:

Start-Up	-40°C (cold soak)
Ground Operation	30°C
Engine Idle	50°C
Flight Conditions	25°C
Descent and Landing	30°C

4.5 Suggested Coolant Flow Rate

The nominal flow rate for liquid-cooling loops is 4 lb/min/kW. This flow rate is based on the specific heats of "Flo-cool 180" or "Coolanol 25." Flow rates for other coolants must be adjusted for specific heat, viscosity, maximum operating temperatures, and other properties of the coolant selected.

4.6 Coolant Residues

The coolant selected must not be corrosive, toxic, or offensive to maintenance personnel when small residues are present during maintenance either in the aircraft or on the test bench.

4.7 Coolant Cost

High-cost coolants should be avoided unless the specific properties of a high-cost coolant are absolutely necessary to achieve the required coolant performance.

4.8 Coolant Contamination Within the LRU

The internal design of the LRU and the liquid-cooled heat exchanger should preclude the contamination of major portions of the electronic circuitry if internal seals leak. The use of individual cooling loops in modules should be avoided to reduce the number of internal disconnects.

4.9 Minimum Liquid-Coolant Temperatures

Equipment designs requiring the use of liquid coolants below 30°C should be avoided.

5. TYPE C EQUIPMENT

Type C equipment includes high-heat-dissipating avionics located remotely from the avionics bay in an unpressurized area.

5.1 Environmental Considerations

Typical ambient temperatures at remote equipment locations range up to 95°C, and cooling may have to be instituted prior to equipment turn-on to prevent overstress of electronic components. Typical vibration environments may exceed 10 g because of engine-induced or aerodynamically induced vibrations. Other environmental ambients such as fuel fumes, hydraulic fluids, and water must be assumed to be present, unless specific means are adopted to remove them.

5.2 Design for Reduced Heat Absorption from Ambient

Liquid-cooled equipment designed for remote locations in an unpressurized, uncontrolled environment should be specifically designed to reduce heat absorption from the environment, including conduction through mounting structures, to reduce to the minimum the total heat load placed on the environmental control system. All high-thermal-resistance materials used shall be fireproof and of sufficient structural strength to withstand repeated removals for maintenance.

6. TYPE D EQUIPMENT

Type D equipment includes high-power equipment located remotely from the avionics bay and using ram-air cooling when operating in high-heat-dissipation modes.

6.1 Ram-Air Quality

Because of excessive pressure drop, it is usually not practical to incorporate water separators in ram-air ducts: the quality of ram air may be degraded by water, ice, and corrosive gun-blast gases and residues. While ram-air ports may possess a de-icing capability, ice fragments may enter the equipment cooling air inlet. Dust and foreign matter may be present in the ram-air ducts after periods of storage or ground operation.

6.2 Ram-Air Pressure Drop

The pressure available at the ram-air inlet is relatively low, 3 to 10 psi. The pressure is further reduced by the ducting before the air reaches the equipment. Therefore, all equipment should be designed to accept low-pressure, high-volume air at the inlet port.

6.3 Ram-Air Temperature Range

Ram air is considered suitable for cooling electronic equipment as long as it remains below 50°C. A severe temperature transient can be expected when the air scoops are opened into the air stream, which can be at any temperature down to -50°C.

6.4 Ground Operation of Ram-Air-Cooled Equipment

Where ground operation for checkout of equipment is mandatory, fans must be provided to provide flow to the equipment inlets. However, neither the flow rate nor the pressure head can be expected to equal that available in flight. Operational checkout procedures must take this into account, and appropriate limits should be placed on the duration of high-power tests.

7. TYPE E EQUIPMENT

Type E equipment uses the heat of vaporization of a liquid to carry away large amounts of heat over specified periods while maintaining an essentially constant temperature of the heat exchanger as long as the liquid supply lasts.

7.1 Coolant

Water is an excellent heat sink because of its high latent heat. However, there is a potential for serious problems in the use of water, and a number of design features are necessary to reduce such potential.

7.2 Constraints

Type E equipment should be specified only when all other methods have been proven impractical and a decision has been made to accept the operational difficulties inherent in the use of liquid-boiler-type heat exchangers. A number of serious development and operational problems have resulted from the use of water boilers and water storage tanks, including excessive water consumption, rupture of heat-exchanger cores, leakage of ducting joints, and corrosion of the water storage tank.

7.3 Freezing

The high freezing point of water requires that the boiler and storage tank not be adversely affected by repeated freeze and thaw cycles. Propylene glycol is frequently added to the water to prevent "hard" feezing. The concentration is usually 10 to 20 percent, resulting in a "slush" at low temperatures (-40°F to -65°F). Even with propylene glycol mixtures, the freeze-thaw test should be conducted. Three freeze-and-thaw test cycles are a good basis for evaluation, because damage is most likely to occur on the first cycle.

7.4 Loss of Coolant

Excessive water consumption occurs as the result of violent boiling action, which causes water carryover as the steam is vented overboard. Leakage has occurred because of submerging of the duct and other connections in the water; thus any leakage will result in entry of water into the air-side when the system is off (unpressurized), "slugging" water through the air-side when the system is turned on.

7.5 Corrosion

By far the most serious difficulty encountered is corrosion. A means of access shall be provided for inspection of water-boiler heat exchangers and storage tanks while they are installed in the aircraft. The water storage tank shall not be an integral part of the aircraft structure, and it shall be a readily replaceable low-cost item.

7.6 Installation Review

The water storage tank shall have a readily accessible water fill port and overboard drain. There shall be no joints submerged in the water, and the replaceability of the tank must be fully established. The corrosion-prevention/control provisions should also be fully reviewed.

APPENDIX D

DRAFT MILITARY ADDENDUM TO ARINC SPECIFICATION 600
ENVIRONMENTAL REQUIREMENTS FOR MILITARY AIRCRAFT

This addendum describes the additions to ARINC Specification 600 that are necessary and sufficient to facilitate application of commercial avionics to military aircraft. For reference purposes, the specific paragraph of ARINC 600 that is affected is shown in parentheses immediately following the title.

VIBRATION, SHOCK, AND ACCELERATION (3.1.2)

In addition to the requirements stated in Attachment 13 to ARINC Specification 600 concerning vibration, the following shall apply: Vibration: All equipment shall be tested to random vibration inputs of 0.04 g^2/Hz over the frequency range of 20 to 1,000 Hz without the use of vibration-isolation devices.

POWER DISSIPATION (3.1.3.2)

The power dissipated within the LRU shall be limited to the values shown in Attachment 12 to ARINC Specification 600. Level 2 cooling-air pressure drop (25 mm water gauge) shall apply.

THE EQUIPMENT RACK (3.2)

The requirements of this paragraph shall apply except for the requirement (in paragraph 3.2.5.2) to collect exhaust air from each shelf mounted on a rack. The installed equipment and rack shall meet the electromagnetic compatibility requirements of MIL-E-6051 as a total system.

ELECTRICAL BONDING INTERFACE (3.2.4)

In addition to the requirements stated in paragraph 3.2.4 of ARINC 600, the requirements of MIL-B-5087, paragraphs 3.3.2 and 3.3.5.1, shall apply.

THERMAL DESIGN CONDITIONS (3.5.1.6)

This requirement applies except for subparagraph (g), which is changed as follows: "Coolant air flow rate of 165 kilograms per hour per kilowatt based on actual heat dissipation at condition (b) above. Commentary: The lower coolant flow is specified in recognition of the situation in which 220 kilograms per hour per kilowatt air flow available in a civil configuration requires redistribution among the additional mission-related avionics for military use and it is not feasible to increase the capacity of the aircraft environmental control system."

COOLANT AIR FLOW RATE (3.5.4.3)

This requirement applies except that the design air-flow rate shall be 165 kilograms per hour per kilowatt at sea level (inlet temperature 40°C). This air flow shall be reduced to 102 kilograms per hour per kilowatt when an inlet temperature of 30°C is supplied by the aircraft environmental control systems.

THERMAL INTERFACE INFORMATION (3.5.7)

The flow rates stated in paragraph 3.5.7, subparagraph (c), shall be changed to agree with the rate changes to 3.5.1.6 and 3.5.4.3 stated above.

POWER QUALITY (3.6.1)

The requirements of MIL-STD-704C shall govern power quality.

SEVERE HUMIDITY ENVIRONMENT (RTCA DO-160, SECTION 6.0)

Because of the deployment conditions encountered by military aircraft, all avionics equipments shall be qualified (i.e., tested) for Category B, Level I humidity environment.

TEMPERATURE/ALTITUDE TESTS (RTCA DO-160, SECTION 4)

Avionics equipment for general military use shall withstand the condition stated for Category E1 for temperature/altitude, except for high operating temperatures.

HIGH OPERATING TEMPERATURE (RTCA DO-160, SECTION 4)

The high operating temperatures of Category B1 shall apply.

ATTACHMENT 1

DRAFT AIR FORCE AVIONICS INSTALLATION STANDARD

JUNE 1981

PROPOSED MIL-STD-XXX
15 JUNE 1981

NOTE: This draft, dated 15 June 1981 prepared by AFSC, ASD/AXA/XRS has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL

DRAFT AIR FORCE AVIONICS INSTALLATION STANDARD

(Superseding Strawman Standard dated April 1981)

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APPENDIX

DRAFT

June 1981

AIR FORCE AVIONICS INSTALLATION STANDARD

1.0 SCOPE. This Standard defines the packaging, mounting, and cooling concept to be used for military avionics equipment, together with the specific dimensions and environmental characteristics of a set of standard avionics packaging modules which shall govern the exterior design of new and repackaged avionics equipment that is intended to be installed in the avionics bays of Air Force aircraft. This Standard will not be applied to pod-mounted avionics, to missiles, or to intrinsically high dissipation components or to units necessarily installed near the extremities of the airframe structure. Present industry experience has demonstrated the need for new concepts to avoid problems resulting from the growing complexity of electrical/electronic avionic equipment. Concepts which address these needs form the basis of this Standard.

This Standard sets forth:

(a) The definition, guidance, and appraisal for design and acceptance of the electrical connector, mechanical and environmental interfaces between LRUs and the racks or trays in which they are installed.

(b) The definition, guidance, and appraisal for design and acceptance of the mechanical and environmental interfaces between racks or trays and the aircraft in which they are installed.

It is intended that this Standard shall be provided for use by using commands, avionics development agencies, airframe manufacturers, and avionics manufacturers. It is strongly desired that this Standard be used by all military organizations for aircraft avionic equipment installations, and that all system and subsystem developers are required to adhere to these requirements when specifying and developing new avionics systems.

2.0 REFERENCED DOCUMENTS

2.1 Documents. The following documents, of the exact issue listed, form a part of the specification to the extent specified herein. Copies of specifications, standards, handbooks, drawings, and publications required should be obtained from the procuring activity or as directed by the contracting officer.

2.2 Precedence of Documents. In the event of a conflict between the contract, this standard, or the referenced documents, the following precedence shall apply:

(a) The contract and its attachments shall have precedence over any specification or reference document.

(b) This standard shall have precedence over all referenced documents. Any deviation from, or exception to any portion of the standard, shall be approved in writing by the contracting activity.

2.3 List of Documents

SPECIFICATIONS

Military

MIL-B-5087B Amend. 2	31 Aug 70	Bonding, Electrical, and Lighting Protection, for Aerospace Systems
MIL-E-6051D	5 Jul 68	Electromagnetic Compatibility Requirements, Systems
MIL-C-81659B Supp. 1	16 Dec 71	Connector Electrical, Rectangular Crimp Contacts, General Specification for

Commercial

10-61953 Rev G The Boeing Co.	14 Nov 80	Specification Control Drawing for Connector, Electric, Low Insertion Force, Rectangular

STANDARDS

Military

MIL-STD-461B	1 Apr 80	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-704C	30 Dec 77	Aircraft Electric Power Characteristics
MIL-STD-1472B	31 Dec 74	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

Commercial

NAS 622 Rev 1	31 Oct 61	Hook, Support, Electronic Equipment Clamp

3.0 NOMENCLATURE AND DEFINITIONS

3.1 The Line Replaceable Unit (LRU). The basic Line Replaceable Units (LRUs) around which the entire packaging and installation concept is constructed are of uniform length and height. The width shall be selected (or specified) from a range of modular sizes numbered 2 through 12. Any combination of LRUs installed side by side, occupy shelf space equal to the sum of their size numbers multiplied by 1.3 inches (33 mm). The individual LRU widths are given in Table I.

TABLE I - LRU DIMENSIONS

LRU Size	Width - W Inches ± 0.020	MM ± 0.5
12	15.29	388.4
11	13.99	355.3
10	12.69	322.3
9	11.39	289.3
8	10.09	256.3
7	8.79	223.3
6	7.50	190.5
5	6.19	157.2
4	4.88	124.0
3	3.56	90.4
2	2.25	57.2

Lengths L_1 = 12.51 ± 0.04 in. (318 ± 1.0 mm)

L_2 = 12.76 max. (REF) in. (324 mm)
See Figure 1

Height H = $7.64\,^{+.00}_{-.04}$ in. ($194\,^{+0.0}_{-1.0}$ mm)

When a deviation above the standard length is unavoidable, the value of 19.74 inches (502 mm) shall be used.

The correlation between the LRU sizes and Air Transport Racking (ATR) box sizes is as follows:

- The height is the maximum allowed for ATR
- The length is approximately equivalent to ATR short
- The width equivalencies are:

Size 12	1 1/2 ATR
Size 8	1 ATR
Size 6	3/4 ATR
Size 4	1/2 ATR
Size 3	3/8 ATR
Size 2	1/4 ATR

3.2 The Equipment Rack and Shelf. The designation "equipment rack" pertains to the structure on which a number of LRUs are installed. The equipment rack shall be designed so best use can be made of the available space, often resulting in more than one tier of equipment. The structure upon which any one tier of equipment is mounted is designated a shelf. Shelves provide the support points which mechanically locate the LRU. The rack electrically interfaces the LRU with the aircraft wiring and other LRUs, and interfaces the LRU with the equipment cooling system. An equipment rack may be open or partially enclosed, or it may be entirely enclosed to meet specific requirements.

3.3 LRU Guides and Holddowns. LRU guides and holddowns on the shelf, or coordinated into the design of a mounting base or tray, provide dimensional control between the LRU, the rack connector, and the cooling air interface.

3.4 The Electrical Interface. The electrical interface between the LRU and the aircraft wiring is provided by a low insertion force rack and panel connector. The metal or structural component on which the rack half of the connector is mounted to the rack is designated as the backplate.

> COMMENTARY: The words "low insertion force" (LIF) will be used throughout to describe the connector. The limits of these forces are discussed in 5.3.2.4.

3.5 Electrical Power Supply. The characteristics of the electrical power supplied to the equipment racks are usually described/controlled by the airframe manufacturer's specification for the particular aircraft. MIL-STD-704 describes the limits of deviation of the power quality from nominal under steady-state, normal, abnormal and emergency conditions of operation in the aircraft electrical system.

3.6 *Cooling Air Ducts and Plenums.* Ducting and plenums are members built into or mounted on the rack or adjacent structures to direct the flow of cooling air to the LRU. Mating apertures in the LRU provide for passage of the cooling air through the unit.

3.7 Electronic Part. An electronic part, for the purpose of this document, is defined as an item not subject to further disassembly which is utilized in the fabrication of avionic equipment. For example: resistors, capacitors, filters, circuit breakers, switches, connectors (electrical), relays, coils, transformers, piezoelectric crystals, electron tubes, transistors, diodes, microcircuits, waveguides, synchros, and resolvers.

3.8 Temperature-Critical Parts. Temperature-critical parts are electronic parts whose operating temperatures are most likely to approach their maximum allowable temperature.

3.9 Thermal Stabilization. A stabilized thermal condition has been attained when the indicated temperature of all temperature sensors internal to the test chamber (including the instrumented test unit electronic parts) have varied no more than 2°C over a continuous one-hour exposure period.

3.10 Maximum Steady-State Heat Dissipation. Maximum steady-state heat dissipation is the condition wherein the equipment is operated at the maximum steady-state supply voltage level through the normal operational duty cycle which will yield the maximum heat dissipation.

3.11 Ambient Temperature. Ambient temperature is the air temperature immediately surrounding the equipment rack.

3.12 Thermal Design Condition. The thermal design condition is the environmental and electrical operating mode to be used as the basic design condition for the equipment.

4.0 GENERAL REQUIREMENTS

4.1 Objectives. Application of this Standard will provide:

(a) A system of modularized avionics boxes.

(b) A system of modularized installation in racks or mounting bases.

(c) A standard means to guard against LRUs being inadvertently placed in the wrong rack location.

(d) A family of low insertion force electrical connectors to provide the electrical interface between the equipment and the aircraft wiring.

(e) A system for effective environmental control of the equipment.

5.0 DETAILED REQUIREMENTS

5.1 The LRU. This Standard specifies the interfaces between the LRUs and the electrical wiring, environmental control systems, and supporting structures. The internal configuration of the LRUs is the responsibility of the equipment developing agency. However, the specific limits of interfaces which are required for physical interchangeability, discussed in the following sections, shall be observed in each LRU design.

5.1.1 Form Factor and Case Dimensions. The LRU is a right parallelpiped. The height and length dimensions are fixed. Variations in LRU sizes are accounted for by modular increments in case width. The smallest LRU is designated "Size 2," and others are designated "Size n" where n is the number of modular units that would occupy the same shelf width as the case in question. The dimensions associated with each case size are shown in Figure 1 and Table I.

NOTE: The case sizes are derived from the short ATR boxes which have been the industry standard for black box design.

5.1.1.1 LRU Holddowns. The LRU shall have NAS 622 Type T holddown hooks installed as shown on Figure 2 or structurally equivalent projections from the box lip. Provisions shall be made for the optional attachment of NAS 622 Type T holddown hooks on the lefthand 7.625 inch (194 mm) edge of the front panel. The LRU shall be capable of withstanding:

(a) The compressive forces exerted between the holddown hooks on the front of the box and the connector on the rear of the box.

(b) The vertical forces resulting from the downward component of the holddown devices, installed as shown on Figure 2, in addition to the specified flight loads (see 5.2.3.3).

(c) The tensile forces resulting from pulling the LRU out of its mating connector. The maximum values of the compressive and tensile forces shall be as follows:

LRU Size	2	3-12
Maximum axial force to be applied by hold-down or other insertion device	125 lbs	250 lbs (Equally divided between two hooks.)

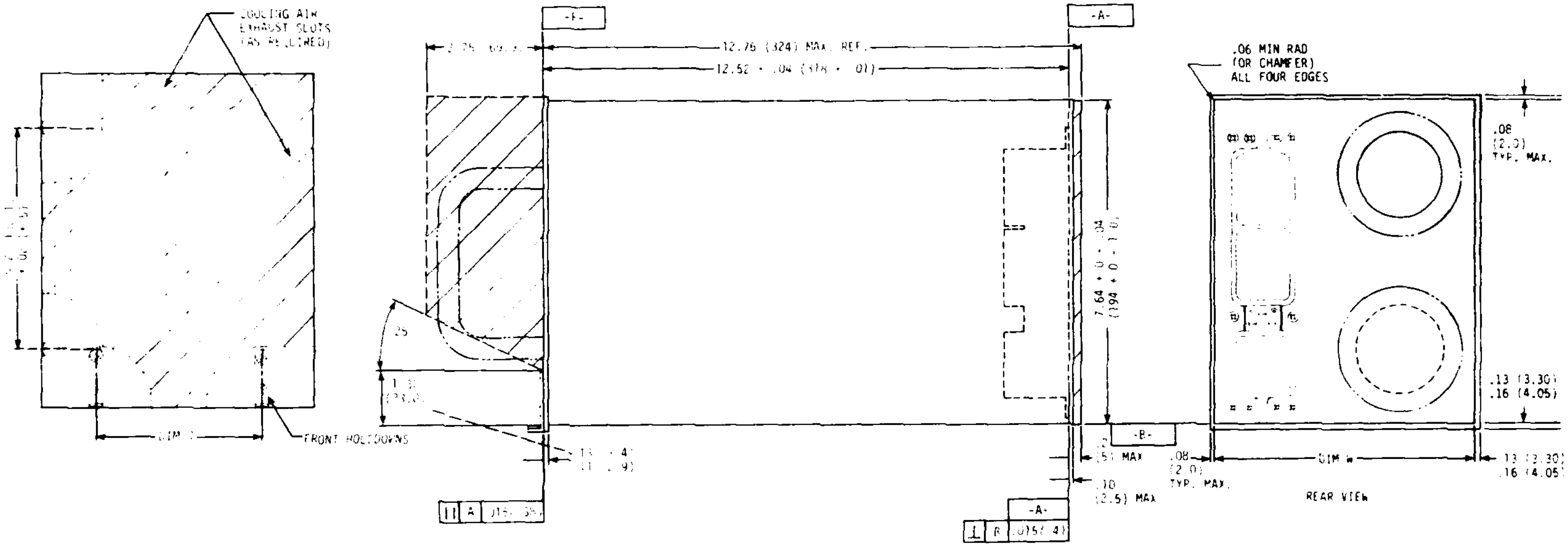
5.1.1.2 Front Panel Protrusions. All protrusions such as holddowns, carrying handles, switches, knobs, test connectors, and indicators shall lie within the outline envelope shown shaded in Figure 1.

5.1.1.3 Rear Panel. The primary purpose of the back of the LRU is for connecting to the cooling air supply and mounting the electrical connector. Any other use shall not interfere with the interfacing of the LRU with the rack. Connector-mounting screw heads shall lie within the limits shown in Figure 1. The rear mounting surface shall have a maximum thickness of 0.1 inch in the connector mounting area, ZONE 'A'.

The connector position on a LRU shall be as specified in Figure 3.

COMMENTARY: Projections on the LRU backplate surface are permitted provided there is no interference with the rack backplate, as provided by the dimensioning and tolerancing specified in Figures 1 and 12A.

5.1.1.4 Maximum Weight. Maximum weight limits shown in Table II are assigned to enable adequate structural design of racks and shelves which must carry the loads. In no case shall a unit having a weight of more than the amount given in Table II be installed. A lower maximum weight is imposed upon the larger LRUs for handling purposes by the requirements of MIL-STD-1472. These constraints shall apply to the extent specified by the design specification of each individual LRU.



FRONT VIEW

SIDE VIEW

REAR VIEW

NOTE: Protrusions are permitted only within the shaded volumes (see para. 5.1.1.2).

FIGURE 1 - STANDARD LRU CASE

LRU SIZE	3 MCU	4 MCU	5 MCU	6 MCU	7 MCU	8 MCU	9 MCU	10 MCU	11 MCU	12 MCU
DIM J ± .02 IN.	2.60	2.60	3.90	5.20	6.50	7.80	9.10	10.40	11.70	13.00
DIM J ± .5 MM	66.0	66.0	99.1	132.1	165.1	198.1	231.1	264.2	297.2	330.2

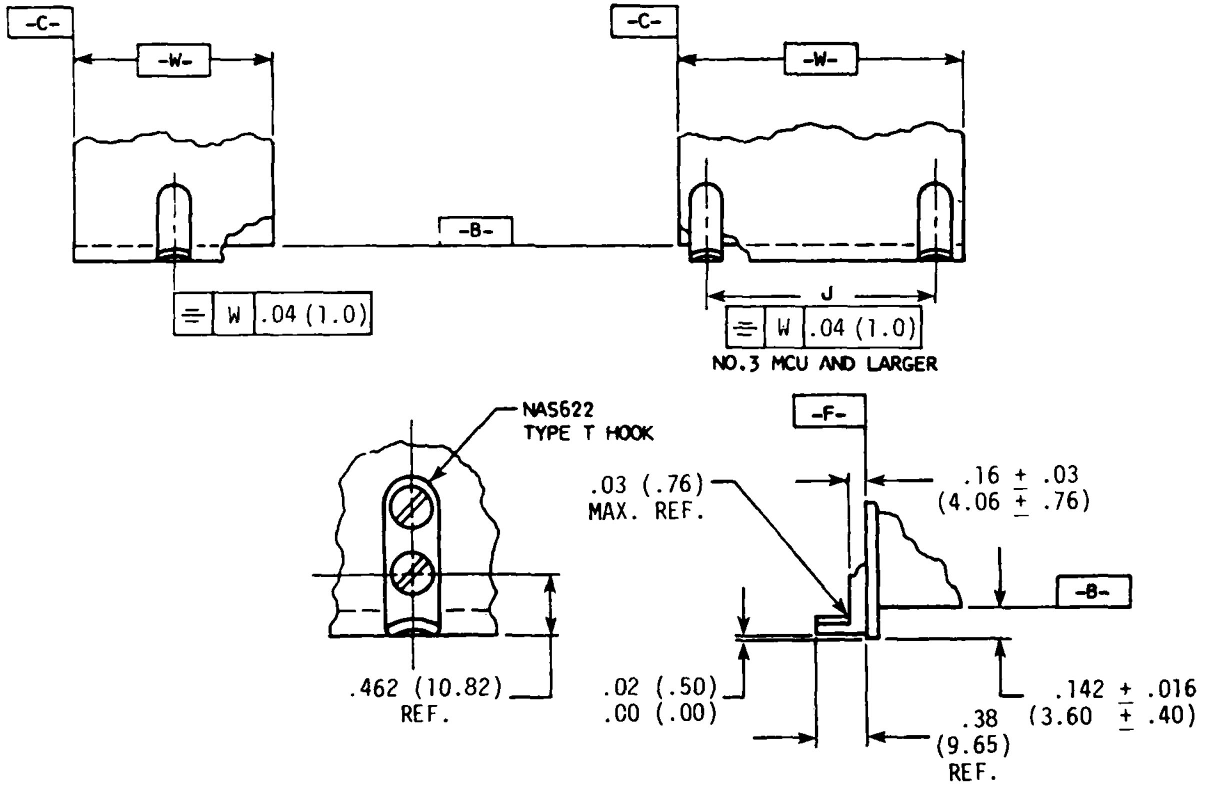
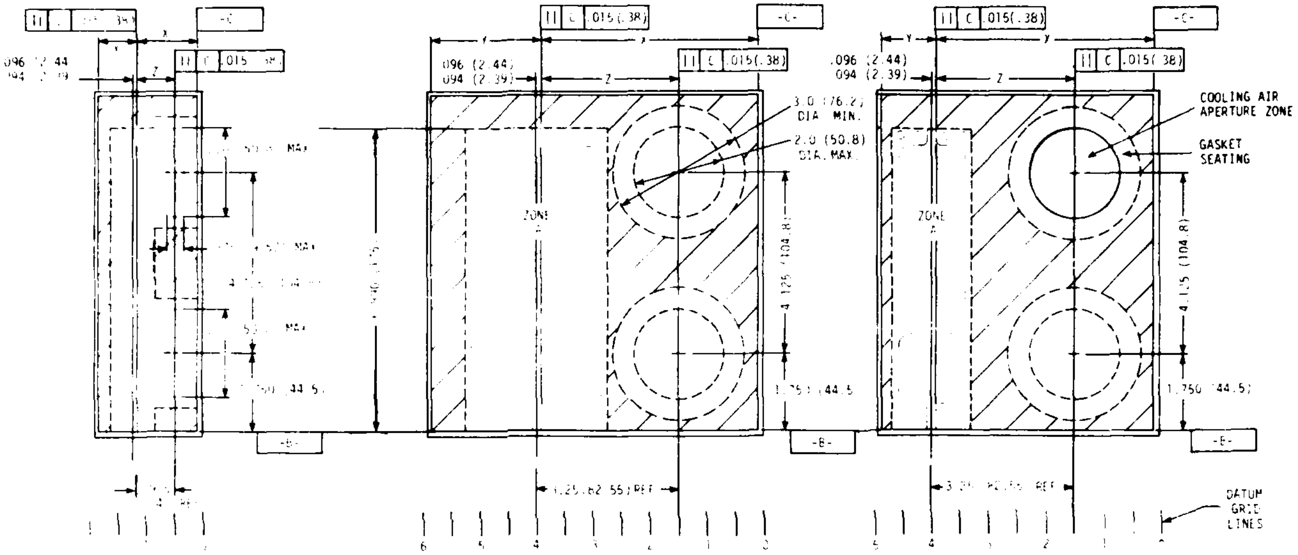


FIGURE 2 - LRU HOLDDOWN MECHANISM

CONNECTOR SIZE	WIDTH [illegible] ZONE A, INCHES (MM)
[illegible]	[illegible]



REAR VIEW OF LRU

LRU Size	Connector Size	Cooling Ports	Rear Panel Position Dimensions, Inches (Millimeters)							
			W ±.02 (.5)		X ±.005 (.13)		Y (Ref)		Z ±.01 (.25)	
2	1 or 2	None	2.25	(57.2)	1.030	(26.2)	1.220	(31.0)	--	
2	1	2 Small	2.25	(57.2)	1.460	(37.1)	0.790	(20.0)	.880	(22.4)
3	1, 2, or 3	None	3.56	(90.4)	1.685	(42.8)	1.875	(47.6)	--	
3	1 or 2	4 Small	3.56	(90.4)	1.685	(42.8)	1.875	(47.6)	1.205	(30.6)
4	1	2 Large	4.88	(124.0)	3.970	(100.8)	0.910	(23.2)	3.155	(80.1)
4	1, 2, or 3	2 Small	4.88	(124.0)	3.000	(76.2)	1.880	(47.8)	2.505	(63.6)
4	1 or 2	4 Small	4.88	(124.0)	2.345	(59.6)	2.535	(64.4)	1.205	(30.6)
5	1 or 2	2 Large	6.19	(157.2)	4.300	(109.2)	1.890	(48.0)	3.155	(80.1)
5	1, 2, or 3	4 Small	6.19	(157.2)	3.000	(76.2)	3.190	(81.0)	2.505	(63.6)
6	1, 2, or 3	2 Large	7.50	(190.5)	4.963	(126.1)	2.537	(64.4)	3.155	(80.1)
6	1, 2, or 3	4 Small	7.50	(190.5)	3.655	(92.8)	3.845	(97.7)	2.505	(63.6)
7	1 or 2	4 Either	8.79	(223.3)	4.300	(109.2)	4.490	(114.2)	3.155	(80.1)
8	1, 2, or 3	4 Either	10.09	(256.3)	4.95	(125.7)	5.14	(130.6)	3.155	(80.1)
9	1, 2, or 3	4 Either	11.39	(289.3)	5.60	(142.2)	5.79	(147.1)	3.805	(96.6)
10	1, 2, or 3	4 Either	12.69	(322.3)	6.25	(158.7)	6.44	(163.6)	4.455	(113.2)
11	1, 2, or 3	4 Either	13.99	(355.3)	6.90	(175.2)	7.09	(180.1)	5.105	(129.7)
12	1, 2, or 3	4 Either	15.29	(388.4)	7.55	(191.8)	7.74	(196.6)	5.755	(146.2)

FIGURE 3 - LOCATION OF CONNECTOR AND COOLING APERTURES

TABLE II - LRU MAXIMUM WEIGHT

LRU Case Size Number	Maximum Permissible Weight	
	Pounds	Kilograms
2	22	10
3	30	14
4	38	17
5	46	21
6	52	24
7	59	27
8	65	30
9	72	33
10	78	36
11	84	39
12	90	41

5.1.2 Cooling. When the LRU heat dissipation exceeds the values allowed for free convection and radiation cooling given in Table III, column 3 "Without Cooling Air" the active cooling medium shall be forced air (as described in 5.5.4) moving through passages in the LRU. In all cases, the LRU designer shall make efficient use of the cooling air supplied to the unit. To this end, internal air distribution systems, baffles, heat exchangers, cold plates, heat pipes, etc., shall be judiciously employed to avoid hot spots. Cooling by air impinging directly on electronic components is not permitted. Particular attention shall be directed to avoiding air leaks that allow coolant to bypass heat transfer surfaces. Units which do not require forced air cooling shall not have openings on any surface other than small drain holes appropriately positioned. The maximum permissible power dissipation for equipment with cooling is defined in Table III, Column 2.

> COMMENTARY: Only if units can pass the thermal appraisal tests set forth in 5.5.6 with no air at all may the manufacturer state that his LRU requires no forced cooling air. The use of the term "convection-cooled" is discouraged. Units not requiring forced air cooling shall pass appraisal test with no air provided to the unit.

5.1.2.1 Cooling Air Interface. The interface with the equipment cooling system the shall be designed to minimize leakage. The interface with the cooling system is via apertures in the LRU in accordance with the details shown in Figure 3. The quantity and condition of cooling air flow through the unit is described in 5.5.4. The pressure drop at the design flow rate for 15.5°C cooling air, ground operation, from inlet to exhaust shall be 50.5 ± 5 mm of water. The methods used to manage heat flow within the unit and to prevent temperature build-up at the power dissipating elements are not controlled by this standard. However, the results of that design shall be proven in the evaluation tests outlined in Section 5.5. See Section 5.5.4.3 on cooling pressure drop.

5.1.2.2 Power Dissipation. The power dissipated within the LRU shall be limited to the values shown in Table III.

TABLE III - MAXIMUM LRU THERMAL DISSIPATION

LRU Case Size	Maximum Permissible Power Dissipation (Watts)	
	With Cooling Air	Without Cooling Air*
2	250	10
3	375	12
4	500	15
5	625	17
6	750	20
7	875	22
8	1000	25
9	1125	27
10	1250	30
11	1375	32
12	1500	35

---

*Equipment not requiring forced air cooling shall pass the thermal appraisal test set forth in Appendix I.

5.1.2.3 LRU Cooling Evaluation. Each LRU design shall be proved by appraisal tests per Appendix I to demonstrate the unit's capability to perform and survive under the conditions set forth in this standard.

5.1.3 Ambient Pressure. When supplied with cooling air at the rates specified in 5.5.4.3, each LRU shall provide specified performance at altitudes up to 70,000 feet. Non-operating exposures to ambient air at altitudes up to 70,000 feet shall not cause damage to the LRU.

5.1.4 Loss of Cooling Air Supply. Under any operating condition specified herein, loss of or reduction in the flow rates of cooling air, or reversion to emergency ram air due to malfunction of the Environmental Control System, for a period of time not exceeding 10 minutes shall not cause degradation of LRU performance below specified limits, or damage to the LRU.

5.1.5 Electromagnetic Compatibility. Although the rack is required (see 5.2.5.4) to protect LRUs mounted within it from radiated and conducted noise originating external to the rack, it cannot protect its LRUs from each other, or from outside interference conducted in on RF signal lines. Consequently, LRUs shall be designed to comply with the requirements of MIL-STD-461, Part 2, Class A1b.

5.1.6 Environmental Considerations

5.1.6.1 Temperature/Altitude. Each LRU shall be capable of operating in the temperature/altitude environment shown in Figure 4. Curve A defines the expected normal ambient temperature, curve B defines the extreme or short-term expected environment.

5.1.6.2 Vibration. Each LRU shall be capable of function in and withstanding the rack interface environment given in 5.2.5.1 for its intended life.

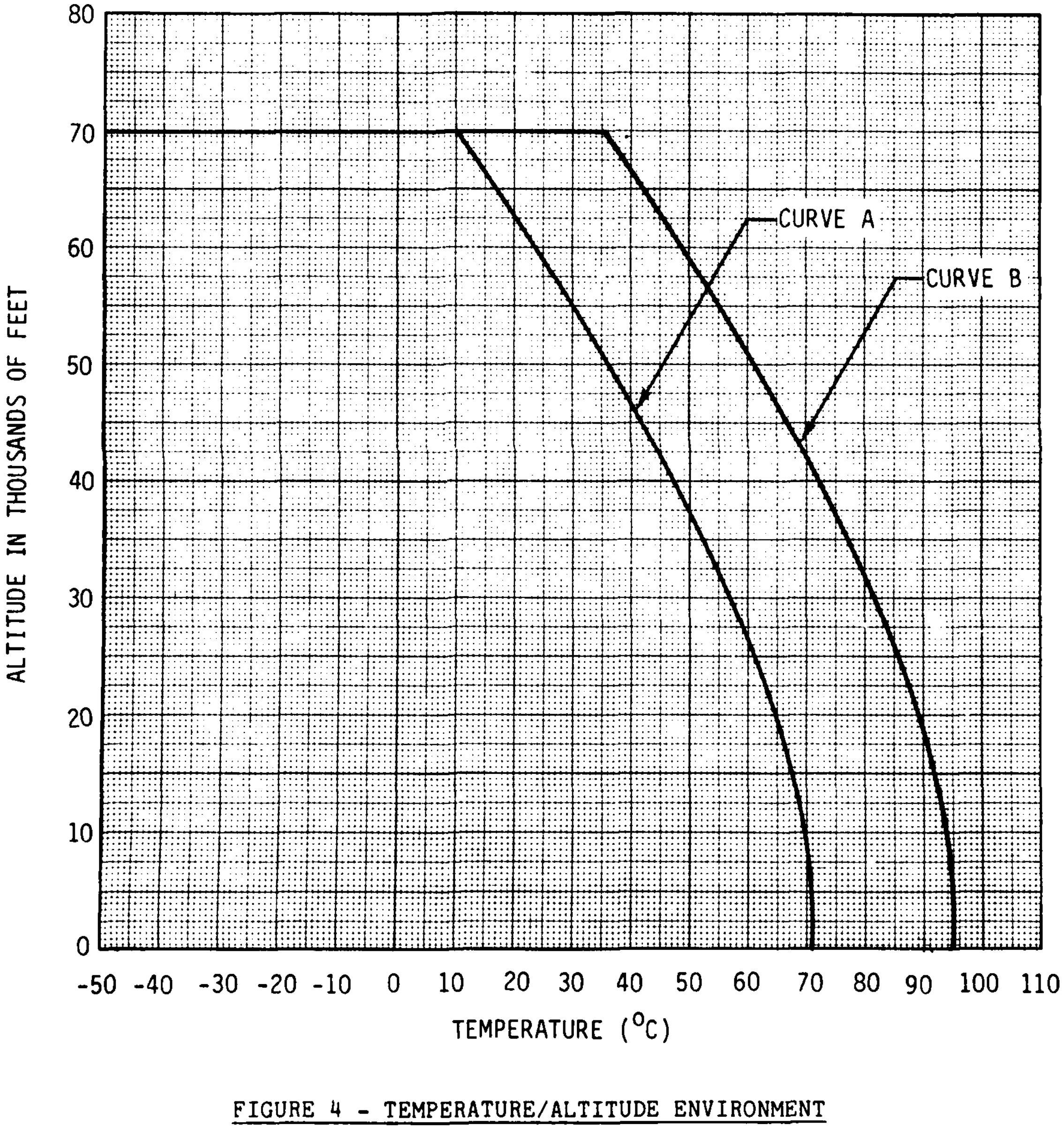


FIGURE 4 - TEMPERATURE/ALTITUDE ENVIRONMENT

5.2 The Equipment Rack. An equipment rack provides a method of installing a number of LRUs in any particular location in the aircraft. Individual shelves and trays are used to provide a mounting platform for the equipment. The equipment rack provides a means of interfacing the LRU with aircraft wiring, equipment cooling system, and other equipment in the aircraft.

Rack structure will vary depending on aircraft constraints such as available space, equipment required, and mechanical considerations. The rack may be of open construction, or it may be partially or entirely enclosed to meet specific environmental or EMI requirements.

The overall form factor of the rack is optional, to allow each airframe manufacturer to best accommodate the required LRUs within the volume available. The general arrangement of a typical rack assembly is shown in Figure 5.

5.2.1 Datum and Method of Dimensioning. Dimensional control is established by use of datums which are physical features from which other locations can be measured. (Datums are as shown in Figures 1, 2, 3, 6, 7, 8, 9, 12, and 13.)

5.2.2 LRU Spacing on Rack Shelf. Shelves shall be designed to accommodate any combination of LRU trays or guides. Figure 6 shows a typical shelf arrangement.

The spacing between LRU guides on a shelf is given in Figure 7. These guides direct and position the LRU so that the connector on the rack or backplate and the connector on the LRU will align for mating.

The spacing between the guide surface of one LRU guide and the adjacent guide surface on the next LRU guide and the application of these dimensions to a shelf is shown on Figure 6. The use of the term "LRU guides" as defined in this specification (ref. para. 3.3, as opposed to the term "tray") is not to imply trays cannot be used as LRU guides but is to emphasize the option of the airframe manufacturer to select either trays or rails as LRU guides. Interguide spacing and LRU tray widths are equal.

For all LRU sizes and combinations of LRUs the total assembled width of any other group of LRUs (including spacing) is equal to the width of any other group of LRUs (including spacing) having the same arithmetic sum of modular sizes.

5.2.3 Mechanical Interface with the LRU. The rack shall be designed such that individual LRUs can be installed in or removed from the rack without disturbing any other LRU. The rack shall provide the mechanical attachment points required by each LRU, i.e., the electrical connector shell at the backplate, and the attachment points for holddowns. The location of holddown attachments shall be as shown in Figure 7.

5.2.3.1 Back Plate Assembly. The assembly of the backplate to the shelf, tray, or rack structure, shall be designed to meet the tolerance requirements shown in Figure 8.

The backplate deflection during the period when the LRU is installed, is being installed, or is being removed from the rack shall not exceed the dimensions specified in Figure 8 (see 5.3.2.4 for allowable LRU insertion forces).

> COMMENTARY: One of the objectives of this specification is to overcome the problem of deflection forces applied to the rack due to high density electrical connectors --thus the use of low insertion force connectors (see Section 5.3). It should be recognized, however, that even with low insertion force connectors, it is still necessary to apply some force to engage the connector. The rack trays and backplates shall be designed to be compatible with these forces. Gauging of the shelf backplate is considered essential to establish the perpendicularity of the shelf connector mounting face relative to the plane of the shelf load-bearing surface.

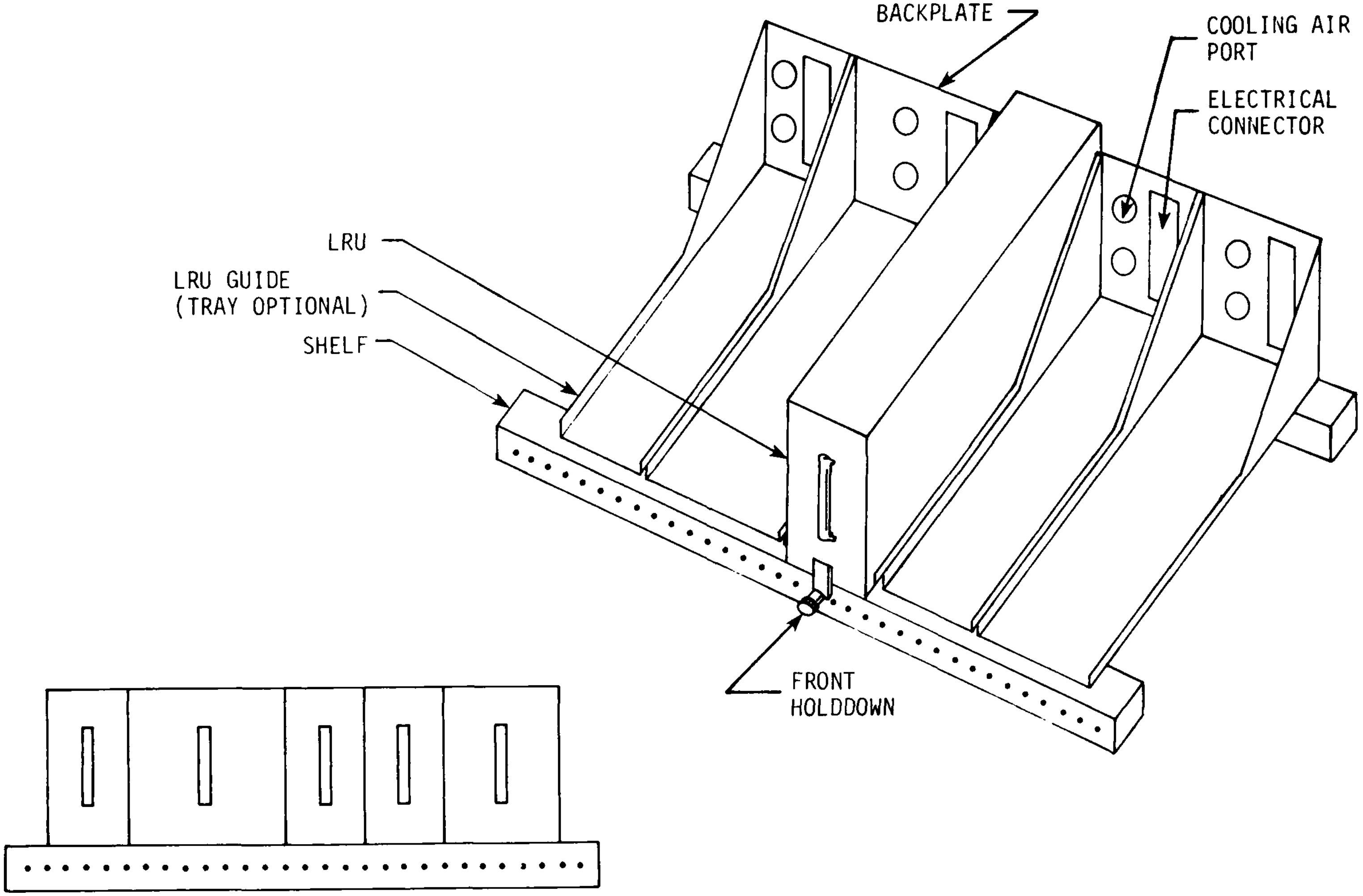
5.2.3.2 Cooling System Interface. The rack will serve as the interface between the electrical/electronic equipment cooling system and the LRU. The racking shall include ducting so arranged that the cooling medium can be delivered to the LRU through the openings shown in Figure 8.

Metering plates shall be used to control the air flow as required by each LRU. (See 5.5.4.2.)

Prevention of loss of cooling air at the LRU is controlled by provisions at the mechanical interface between the LRU and the tray or rack.

5.2.3.3 Front Retainer. The shelf, rack, or tray shall provide a force-limiting, manually-operated means of pushing the LRU into its mating connector, means of holding the LRU in place, and a means for extracting the LRU from its connector. A protective barrier or top shelf shall be provided to prevent the front of an unlatched LRU being raised more than 0.2 inches when being inserted in or extracted from the rack.

5.2.3.3.1 LRU Holddown Details. The means for inserting and holding down the LRU to the shelf are as shown on Figure 7. The line of application of the insertion force shall be inclined to the horizontal as shown. The resultant horizontal component of the force applied by each holddown shall be limited to 125 lbs by a mechanism which prevents over stressing the LRU. The interface of the LRU with the shelf/rack holddown is the NAS 622 T hook. Forces on Sizes 3 through 12 LRUs are to be provided by two holddown devices as shown on Figure 7. The resulting maximum forces on the LRU are as given in 5.2.3.3.2.



FRONT VIEW

FIGURE 5 - TYPICAL RACK ASSEMBLY

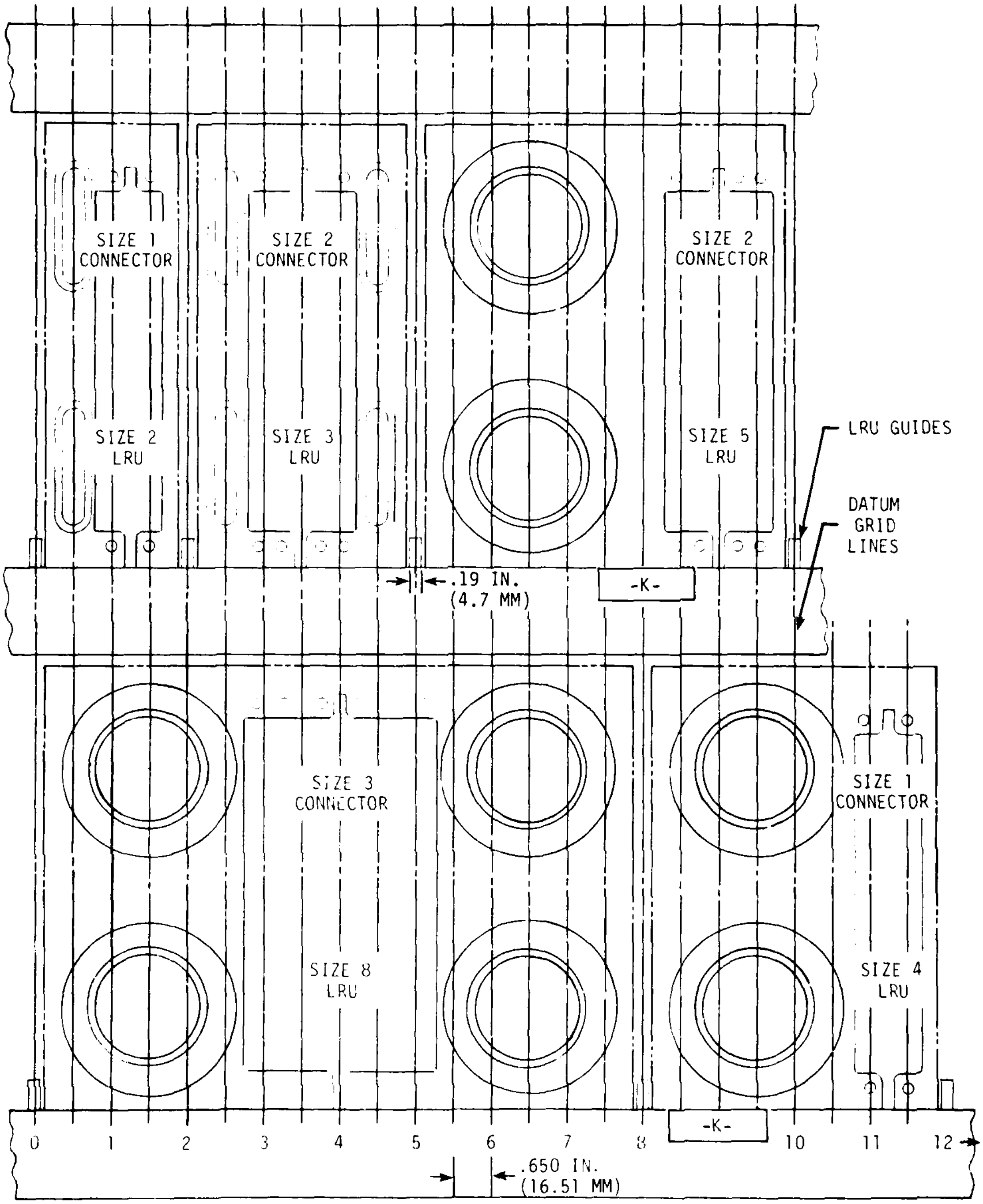
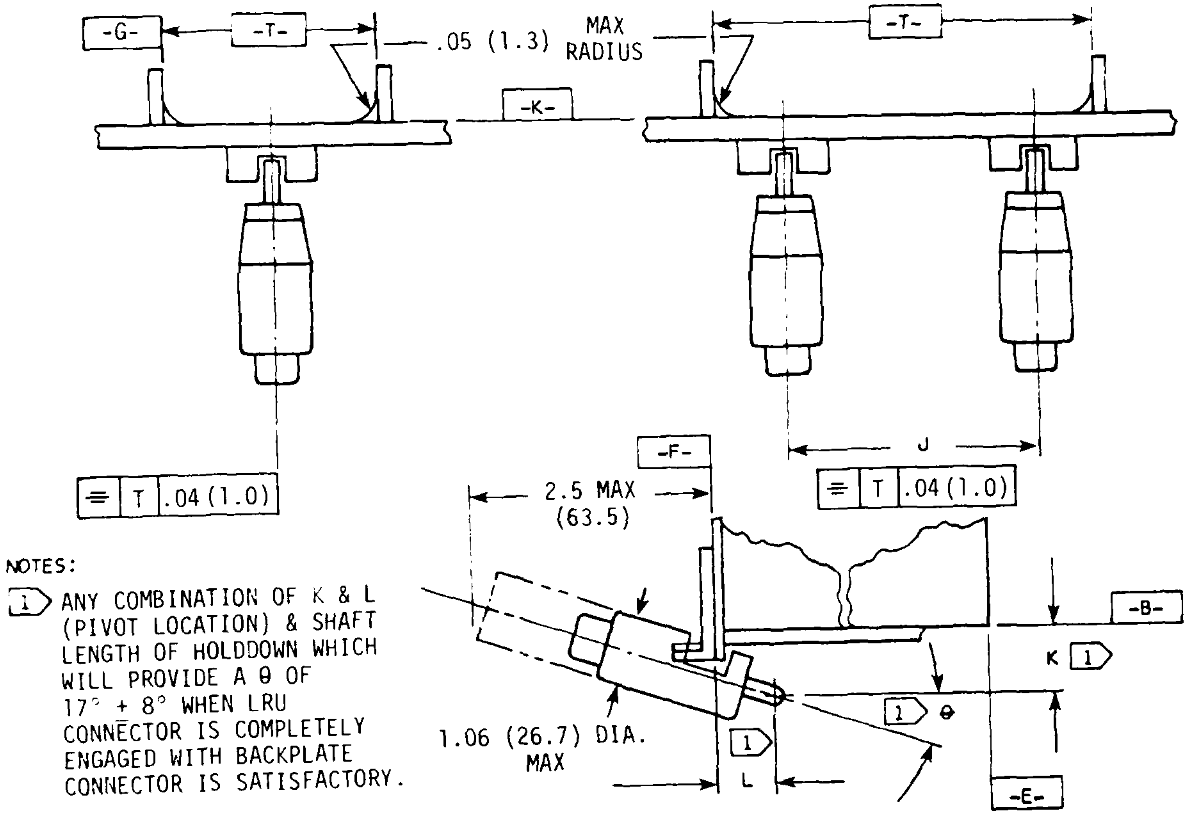


FIGURE 6 - STANDARD SHELF DATUM LINE GRID AND LRU LOCATION

UNIT SIZE (MCU)	2	3	4	5	6	7	8	9	10	11	12
DIM J ± .02 IN.	0.00	2.60	2.60	3.90	5.20	6.50	7.80	9.10	10.40	11.70	13.00
DIM J ± .5 MM	0.00	66.0	66.0	99.1	132.1	165.1	198.1	231.1	264.2	297.2	330.2
DIM T + .010 IN.	2.39	3.69	5.01	6.31	7.61	8.91	10.21	11.51	12.81	14.11	15.41
DIM T ± .3 MM	60.7	93.7	127.3	160.3	193.3	226.3	259.3	292.4	325.4	358.4	391.4



NOTES:

1 ANY COMBINATION OF K & L (PIVOT LOCATION) & SHAFT LENGTH OF HOLDDOWN WHICH WILL PROVIDE A θ OF 17° + 8° WHEN LRU CONNECTOR IS COMPLETELY ENGAGED WITH BACKPLATE CONNECTOR IS SATISFACTORY.

FIGURE 7 - LRU RACK GUIDES (OR TRAY) AND HOLDDOWN MECHANISM

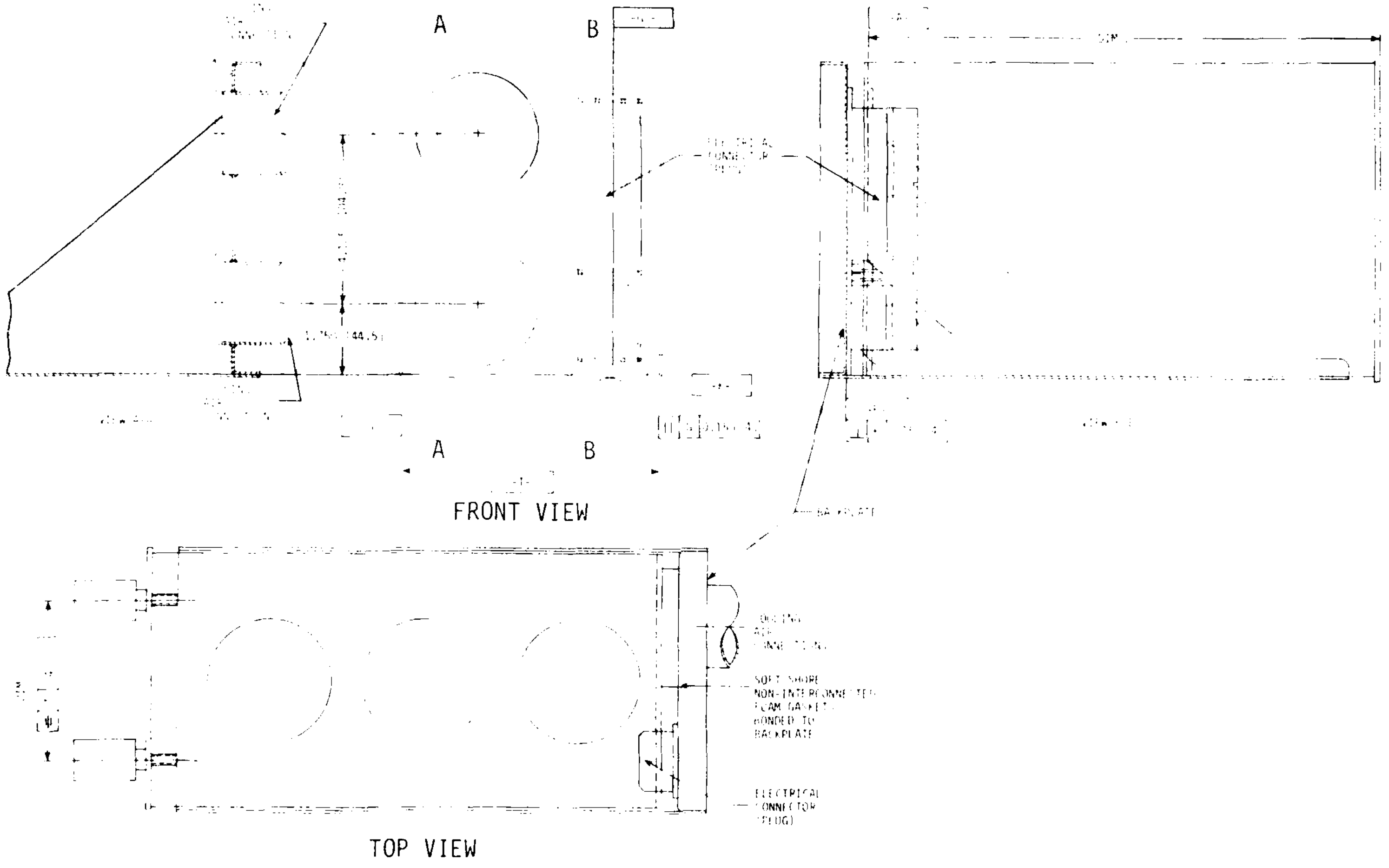


FIGURE 8 - RACK DATUMS AND COOLINNG AIR SUPPLY PORTS

Additional requirements of the LRU holddowns are as follows:

(a) The front of the LRU must be securely held to the shelf.

(b) The LRU connector must be retained in the fully mated position with the rack-mounted connector.

(c) The attachment must absorb tolerances of the shelf, and of the LRU length as given in Table I.

(d) Release and removal of an LRU with a failed holddown shall be readily accomplished.

(e) The holddown force is limited by means supplied with the rack or tray. The values of force exceed the contact insertion force by allowances for misalignment of the LRU with the rack during initial engagement, location of the box on the shelf, and securing of the holddown devices.

5.2.3.3.2 LRU Extractor Details. The shelf, rack, or tray shall provide an extractor mechanism which gives mechanical advantage to assist in removing the LRU from the rack. The extractor may operate against the front lip as shown on Figures 1 and 8. The extractor shall conveniently apply forces as follows:

LRU Size	2	3-12
Minimum Extractor Force	125 lbs	250 lbs

5.2.3.3.3 Low Profile Mounting Tray. Where necessary, any LRU can be mounted on its side in a specially adapted tray such as that illustrated in Figure 9, unless a specific mounting attitude is required for functional reasons.

5.2.3.4 Load Factor. Avionics, shelves, and racks shall be designed to withstand the following load factor (steady acceleration) requirements. Shelves and racks shall support the maximum mass shown in Table II. The orientation of axes is relative to the applicable aircraft installation.

(a) Avionics, shelves, and racks shall remain within alignment tolerances of Figures 8 and 9, shall not suffer damage, or fail to operate during or subsequent to sequential application of the following load factors.

Horizontal plane:	two mutually perpendicular axes ± 6.1 g
Vertical axis:	Up 4.1 g Down 10.4 g

(b) Avionics, shelves, and racks shall remain intact and restrained when exposed to the following load factors applied sequentially.

Horizontal plane:	two mutually perpendicular axes ± 9.15
Vertical axis:	Up 6.15 Down 15.6

5.2.4 Electrical Bonding Interface. All metal parts of the rack and shelves shall be maintained at airframe potential by the application of suitable bonding and grounding techniques. The ground path provided shall be capable of conducting the maximum fault (short circuit) current to which the rack may be exposed. Under such conditions, the resistance of the ground path shall not exceed 2.5 milliohm in accordance with MIL-B-5087, para. 3.3.5.1. The ground path shall provide the greatest surface area possible to allow a low impedance ground path for radio frequency currents.

5.2.5 Environmental Considerations. Environmental control requirements are discussed in this section.

5.2.5.1 Vibration Environment. The avionics installation concepts and design approaches employed shall address the location of the standard avionics, and the design of the racks, shelves, and trays, to control the vibration inputs that are transmitted to the avionics equipment to no more than 0.04 g^2/Hz between frequency limits shown in Figure 10.

> COMMENTARY: While most locations in the avionics bays of fighter aircraft can meet this requirement without any special design considerations, some locations may be affected by more severe vibrations such as gunfire. The aircraft procuring activity shall verify by actual test that vibration inputs are properly controlled. This requirement is needed to facilitate the wide use of standard avionics equipment, without imposing worst case environmental requirements on all Air Force avionics, which would not be cost effective.

5.2.5.2 Humidity and Contamination. See 5.5.4.5 and 5.5.4.6.

5.2.5.3 Temperature/Altitude. The rack or tray shall be designed to operate in the temperature/altitude environment shown in Figure 4.

5.2.5.4 Electromagnetic Interference. The rack, tray, and connector design shall incorporate means to exclude radiated or conducted EMI originating outside the rack. The avionics and rack assembly, as installed in the aircraft, shall meet the requirements of MIL-E-6051.

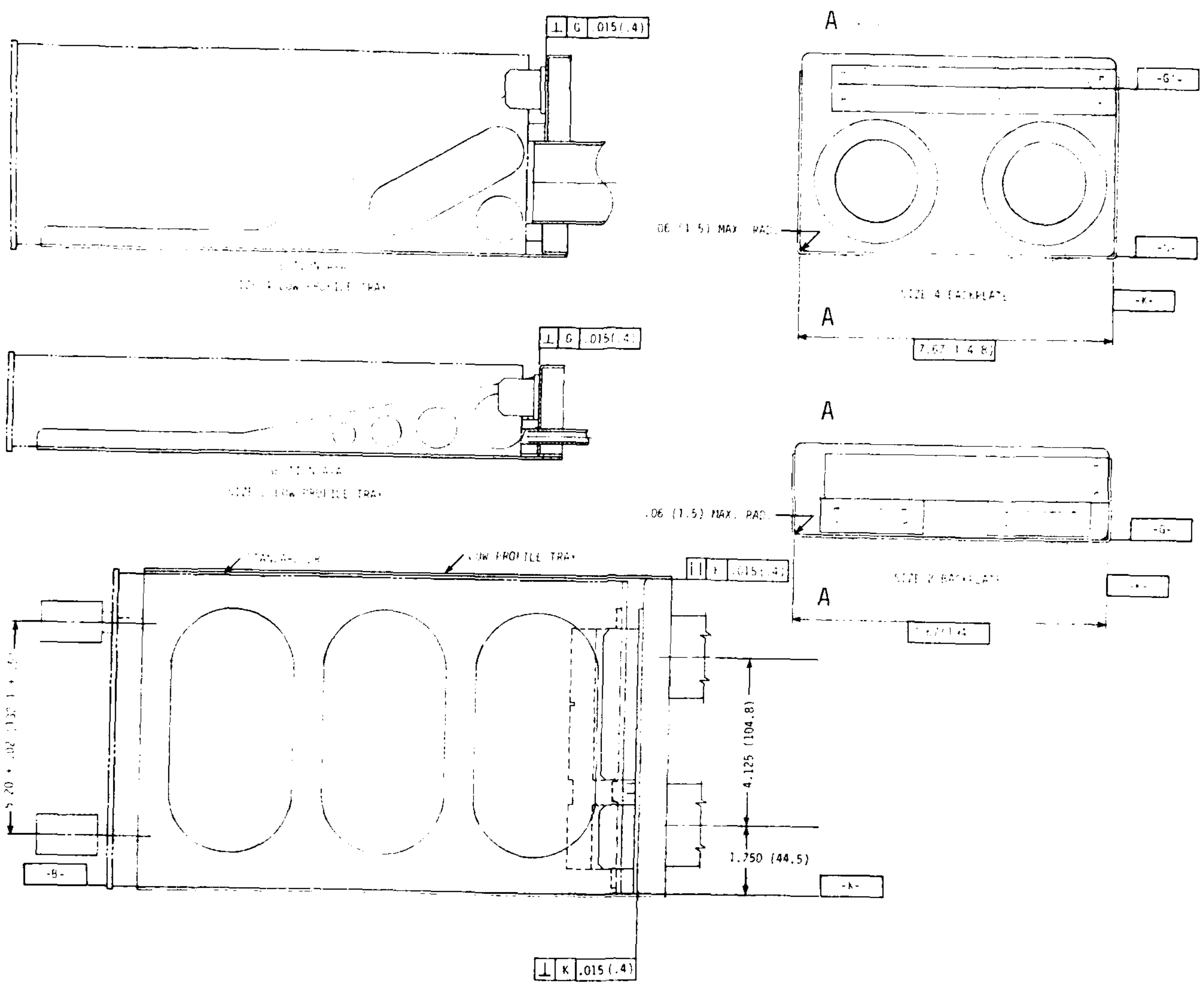


FIGURE 9 - LOW PROFILE TRAY ASSEMBLY

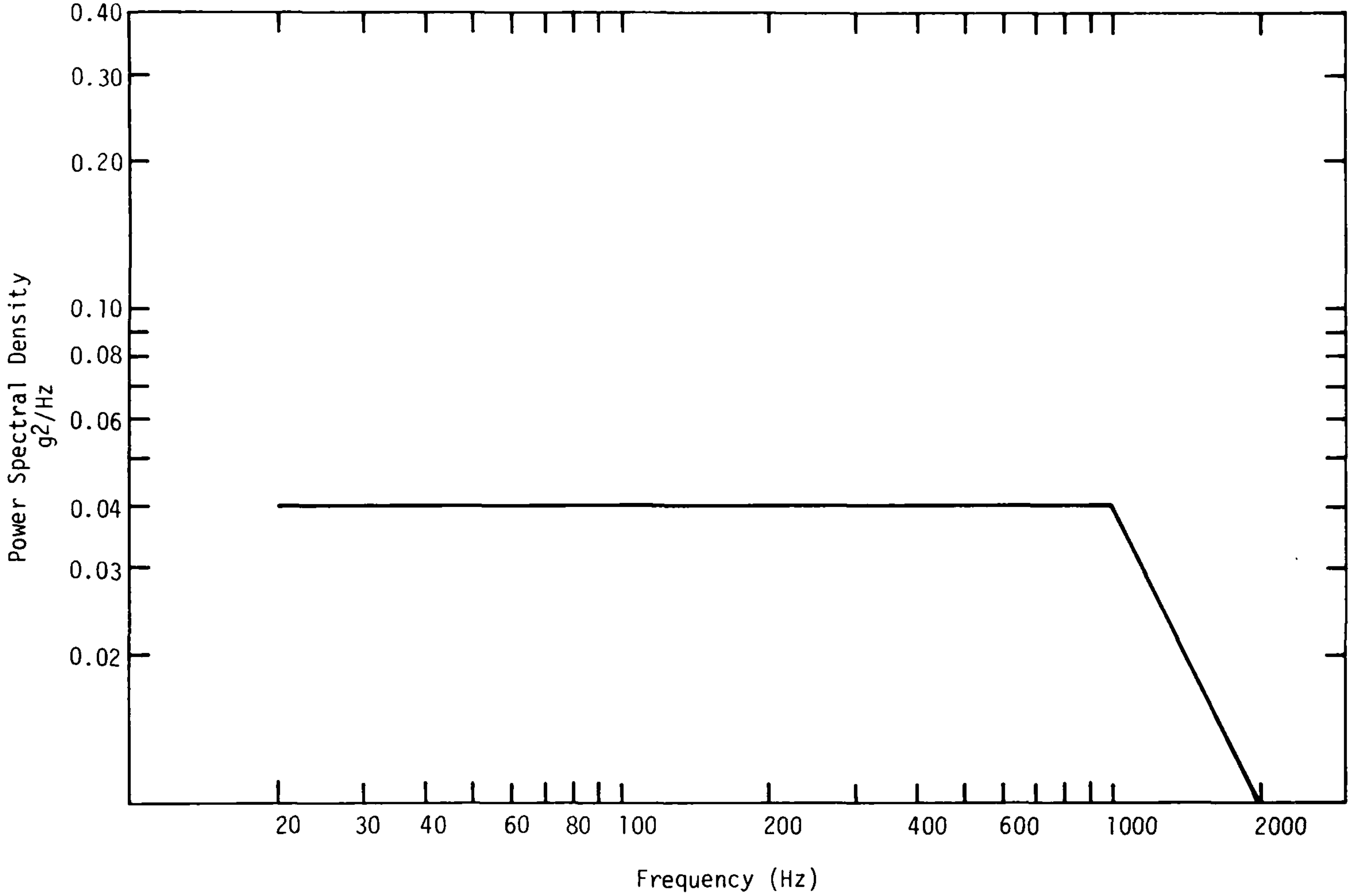


FIGURE 10 - VIBRATION ENVIRONMENT

5.2.6 Rack Maintenance and Accessibility. Easy access is required to allow maintenance and modification work on wiring, wire integration, connectors, mechanical devices, environmental control facilities, etc. The rack shall be so designed that normal hand tools may be used in maintenance, and space for the use of those tools shall be adequate.

5.2.7 Equipment Rack Design Evaluation. The rack shall be evaluated in accordance with the thermal management mechanical and structural considerations procedures defined in 5.5 and 5.7 to ensure that it meets the design criteria established above.

5.3 The Rack and Panel Connector. The rack and panel connector used for equipment designed to meet this specification shall utilize low insertion force technology. The connector shall provide the electrical and rear mechanical interface between the LRUs and the aircraft equipment rack.

The rack and panel connector shall meet the requirements of Boeing Drawing Number 10-61953, "Connector, Electric, Low Insertion Force, Rectangular".

> COMMENTARY: Until such time as an industry standard for the connector can be established, (e.g., MIL-SPEC, SAE Standard) the Boeing drawing will be used as the definition of the requirements for the connector. However, for those who do not have immediate access to the Boeing drawing, the following are some of the general characteristics of the connector.

5.3.1 Connector Electrical Considerations

5.3.1.1 The rack and panel connector shall accommodate combinations of the following contacts:

(a) Low insertion force "signal" contacts with a 5 ampere, 115 volt RMS continuous duty rating.

(b) Conventional power contacts to include sizes 8, 12, 16 and 20.

(c) Conventional coaxial contacts as required in MIL C-81659A.

(d) Waveguide

> COMMENTARY: Fiber optic and pneumatic connections to LRU will be required in the immediate future.

5.3.1.2 The connectors shall accommodate interfacing of electrical circuits ranging from 0 amps (dry circuits) to 50 amps. The signal section shall carry currents up to 5 amps maximum on any one pin. Currents higher than 5 amps shall be carried by conventional round pins and sockets in the power insert.

5.3.1.3 A family of rack and panel connectors is shown in Boeing Drawing Number 10-61953. The rows of contacts shall be numbered in accordance with Figures 11A and 11B.

5.3.1.4 The shell of the connector shall include provisions for physical barriers between inserts required to satisfy circuit separation requirements. Contacts shall not protrude beyond the connector shell.

5.3.1.5 Connector inserts shall be individually replaceable in the field.

5.3.1.6 Connectors shall be intermateable between manufacturers.

> COMMENTARY: This does not imply that inserts of different manufacturers shall be interchangeable.

5.3.1.7 The contact-to-wire interface designs shall be compatible with the use of either stranded or solid conductor wire including flat conductor cable. The electrical contacts shall be available with crimp barrels, and round and rectangular posts.

Wire termination contacts are to be intermateable, interchangeable, and replaceable between manufacturers.

Crimp contacts shall be all rear release and rear removable. Contacts shall be positively retained by the insert.

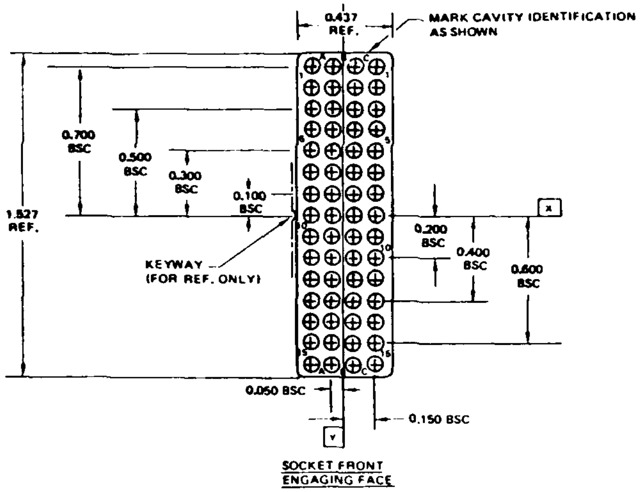
The connector contacts shall not be used as a switch to apply and remove power to LRUs.

> COMMENTARY: This means that some procedural method shall be used to ensure that power is removed before the LRU is installed in or removed from the rack, e.g., the circuit breaker shall be opened.

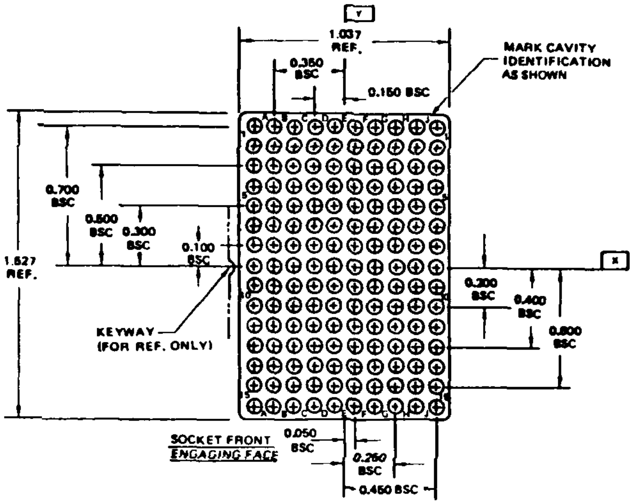
5.3.2 Connector Mechanical Considerations. The connector shell will serve as the mechanical interface between the rear of the LRU and the equipment rack. Engagement of the connector contacts shall be automatically achieved through the action of inserting the LRU in the rack. The connector shell shall be designed to accommodate a LRU/shelf lateral misalignment of 2.5 mm (0.1 in.).

5.3.2.1 The mated shells of the connector shall be of sufficient strength to retain the LRU in position in all three axes when subjected to axial, vertical, and side loads under flight load factors and shock loads of para. 5.2.3.4. This requires that the holddowns used to restrain the front of the box are properly secured and are also capable of meeting this three-axis requirement. The force required to keep the connector halves mated shall be provided by the front mounted retainers (holddowns).

SIGNAL CONTACT ARRANGEMENT 01,
SHELL SIZE 1 CONNECTOR–SCD 10-61953/4A



SIGNAL CONTACT ARRANGEMENT 02,
SHELL SIZE 2 AND 3 CONNECTORS–SCD 10-61953/4B



CONTACT ARRANGEMENT 05, SIGNAL CONTACTS WITH SIZE 1 COAXIAL,
SHELL SIZE 2 AND 3 CONNECTORS–SCD 10-61953/4C

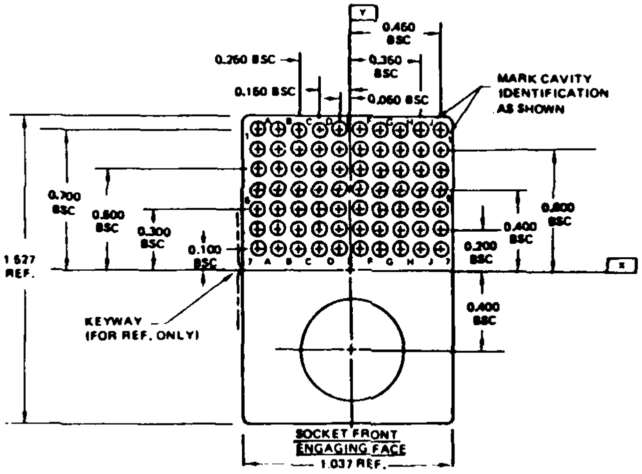
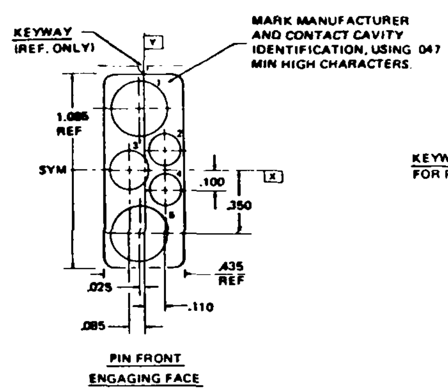


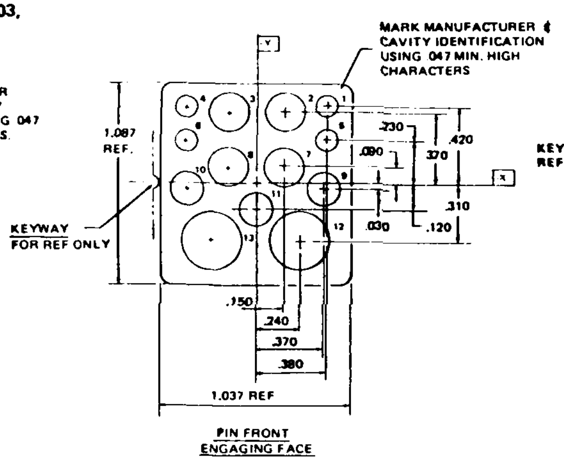
FIGURE 11A - UPPER CONTACT POSITION IDENTIFICATION INSERT

POWER/COAXIAL CONTACT ARRANGEMENT 03,
SHELL SIZE 1–SCD 10-61953/5A



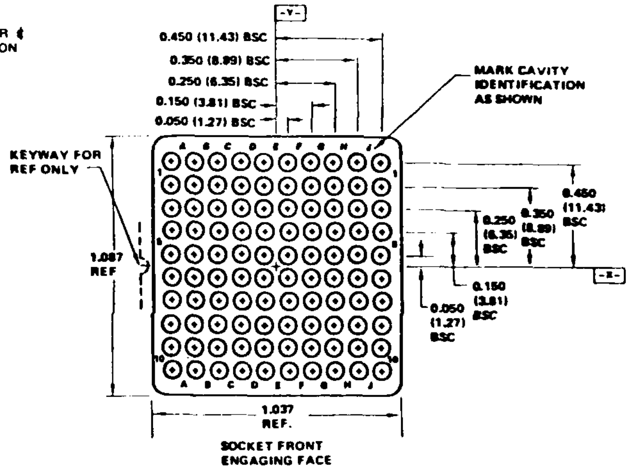
SIZE	CAVITY
5	1 & 5
12	3
16	2 & 4

POWER/COAXIAL CONTACT ARRANGEMENT 04,
SHELL SIZE 2 AND 3–SCD 10-61953/5B



SIZE	CAVITY
8	12 & 13
12	2, 3, 7, & 8
16	9, 10, & 11
20 HD	1, 4, 5, & 6

SIGNAL CONTACT ARRANGEMENT 07,
SHELL SIZE 2 AND 3 CONNECTORS–SCD 10-61953/5C



INDEX PIN CODING

NOTES 1. Darkened portion indicates extended part of post in plug. Light portion indicates key hole in receptacle.
2. Mating faces shown with top up.

FIGURE 11B - LOWER CONTACT POSITION IDENTIFICATION INSERT SIZE AND INDEX PIN CODING

5.3.2.2 The connector shell shall act as a stop or limit for LRU insertion into the rack. The shells shall be designed to withstand an axial compressive force of 1,000 lbs.

5.3.2.3 The connector and its engaging sequence are shown in Figures 12A through 12C.

5.3.2.4 The force to fully engage and disengage the mated pair shells and contacts shall not exceed 27 lbs for size 1, 60 lbs for size 2, and 105 lbs for size 3.

5.3.2.5 The signal contact center-to-center spacing is 0.100 inches on a 0.025-inch square grid pattern. All other contacts shall also be located on this same 0.025-inch square grid pattern.

5.3.2.6 The rack and panel connector shell shall provide for indexing capability to ensure that the LRUs are not inadvertently placed in wrong locations. The indexing shall be accomplished by means of three index pins located within the connector shell.

5.3.2.7 Indexing of connectors shall be numbered using the three index pins in the sequence LEFT; CENTER; RIGHT, each pin having the six possible positions shown in Figure 11B. Each index position shall be accomplished without disturbing the electrical contacts of the contact portion.

5.3.3 Connector Environmental Considerations. Rack and panel connectors shall last the life of the aircraft (typically 100,000 hours operating time).

The rack and panel connectors shall provide environmental protection, and shall prevent moisture from ingressing to the contacts either via the wire or at the connector-to-connector interface. Further, the connector shall be designed to prevent the ingress of sand, dust, or other contamination into the connector when mated.

5.3.4 Connector Tooling and Maintenance Considerations. All techniques and processes used to connect electrical wires to the contacts and the means of inserting contacts in the insert, shall be compatible with automatic and semiautomatic installation techniques, but must also be capable of being accomplished by a flight line technician using inexpensive hand tools.

> COMMENTARY: While automated wire termination processes may become economically justifiable for the airframe and equipment manufacturers, they may not be justifiable for maintenance operations. Therefore, any process which uses automatic or semiautomatic tools in the factory shall be backed up by inexpensive and easily operated hand tools and processes.

All contacts and connector components shall be marked permanently to identify the manufacturer.

5.3.5 Connector Installation Considerations

5.3.5.1 The LRU Electrical Interface. The connector will serve as the electrical interface between the rear of the LRU and the equipment rack. To ensure connector mateability the use of more than one connector is not permitted.

The connector shell is installed on the inside surface (Datum A, Figure 1) of the back, and projects into but not through the opening in the rear of the LRU. Connector mounting hardware shall be within the limits shown in Figure 12A to avoid possible interference with the mating rack connector support (see Paragraph 5.3.5.2).

Where applicable, exposed sockets shall be located on the LRU receptacle while the more protected pins shall be located on the rack mounted plug. The number of electrical circuits allocated to the LRU connector shall take into account both test requirements and the operational function. Test requirements to be considered include airborne, on-board, and shop. Where a dedicated connector is required for on-board and/or shop testing it shall be located on the front of the LRU.

5.3.5.1.1 Connector Position. The connector position is as shown in Figure 3.

Close tolerance guides designed into the connector shell are used to accurately position the connector on the LRU backplate (see Figure 3). The locator bosses on the plane of the connector control the horizontal position and location feet control its vertical position, with reference to Datum C' and Datum B shown on Figures 13A, 13B, and 13C.

The use of locator bosses permits replacement of a damaged connector in the field with the same accuracy as achieved in the original factory installation and is not dependent on accurately located connector mounting holes.

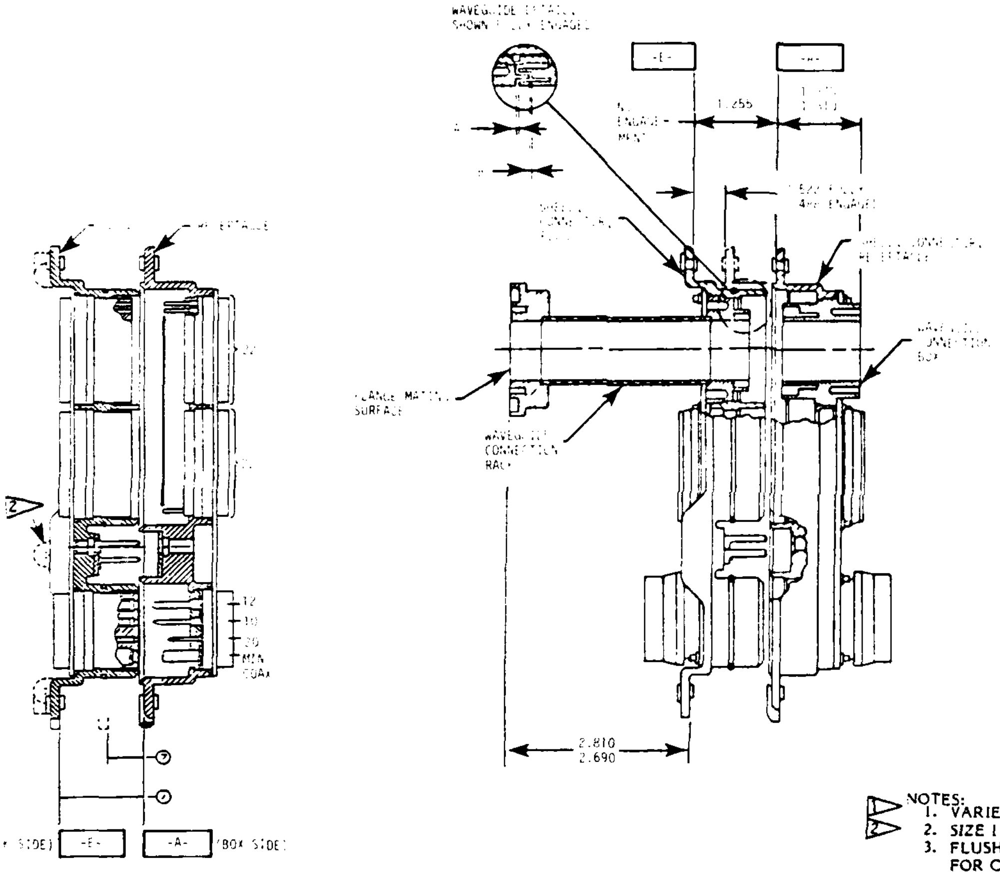
5.3.5.1.2 Bonding and Grounding. The impedance from any point of the LRU chassis to the connector shell, when measured at a direct current equivalent to the maximum supply current of the LRU, shall not exceed 2.5 milliohms.

A primary ground is defined as a ground providing the low impedance path necessary to meet this requirement.

All electrical circuits inclusive of secondary ground connections will be via connected contacts.

AC and DC supply input grounds shall be routed through separate dedicated pins in the LRU connector.

> COMMENTARY: A secondary ground connection is defined as a circuit wire only required to maintain a current path in unlikely failure of the main primary ground.



STANDARD

WITH WAVEGUIDE INSERT

MATING SEQUENCE	FLANGE POSITION WITH:	FLANGE SPACING
①	NO ENGAGEMENT	1.245 (31.62) NOM.
②	SHELLS INITIALLY ENGAGED	1.110 (28.19) 1.073 (27.25)
③	POLARIZING PINS ENTERING KEYS	1.073 (27.25) 1.023 (25.98)
④	CONTACTS ENTERING MATING INSULATOR	
	# 22	.800 (20.32) .748 (18.99)
	# 20	.805 (20.45) .741 (18.82)
	# 16	1.012 (25.70) .949 (24.10)
	# 12	1.008 (25.60) .953 (24.20)
	MINIATURE COAX	▷1
⑤	CONTACTS ELECTRICALLY ENGAGED	
	# 22	.642 (16.30) .547 (13.89)
	# 20	.648 (16.46) .533 (13.54)
	# 16	[illegible] (8.49) .818 (20.77)
	# 12	.772 (19.60) .692 (17.57)
	MINIATURE COAX	▷1
⑥	PERIPHERAL SEAL ENGAGEMENT (BKAE ONLY)	.209 (5.30) .578 (14.68)
⑦	SHELLS FULLY MATED	.483 (12.26) .488 (12.40)

NOTES:

▷1 1. VARIES: SEE MIL SPEC

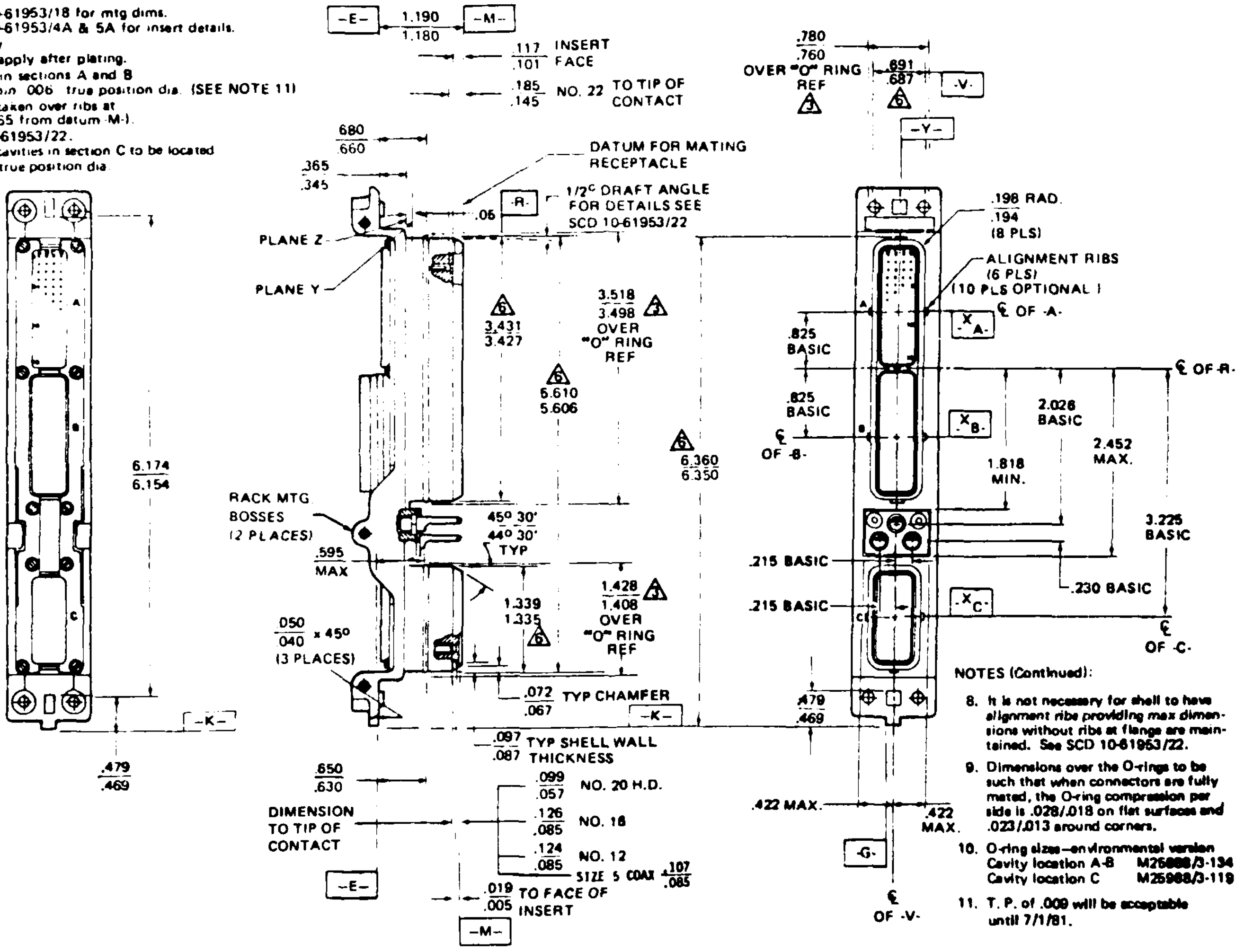
▷2 2. SIZE 1 ONLY

3. FLUSH HEAD SCREWS ARE NOT PERMITTED FOR CONNECTOR MOUNTING AS THEY WOULD POSITION CONNECTOR INCORRECTLY
4. DIMENSION 7 WAS CALCULATED TO PROVIDE CLEARANCE FOR
   - MCU BACKPLATE MAT'L THICKNESS OF 2.5 MM(.10 in) (Sec.3.1.1.3)
   - RACK BACKPLATE MAT'L THICKNESS OF 2.5 MM(.10 in)
   - CONNECTOR MOUNTING PAN HEAD SCREWS,MCU 2.0 MM (.08 in) RACK 2.0 MM (.08 in)
   - TOLERANCE ALLOWANCE - 3.2 MM (.13 in) (See "Commentary" under Section 3.1.1.3 Rear Panel)

   TOTAL - 12.2 MM (.50 in) (minimum)

FIGURE 12A - THE CONNECTOR AND ITS ENGAGING SEQUENCE

1. See SCD 10-61953/18 for mtg dims.
2. See SCD 10-61953/4A & 5A for insert details.
3. Class B only
4. Dimensions apply after plating.
5. All cavities in sections A and B located within .006 true position dia. (SEE NOTE 11)
6. Dimension taken over ribs at plane N (.165 from datum -M-). See SCD 10-61953/22.
7. All contact cavities in section C to be located within .020 true position dia.



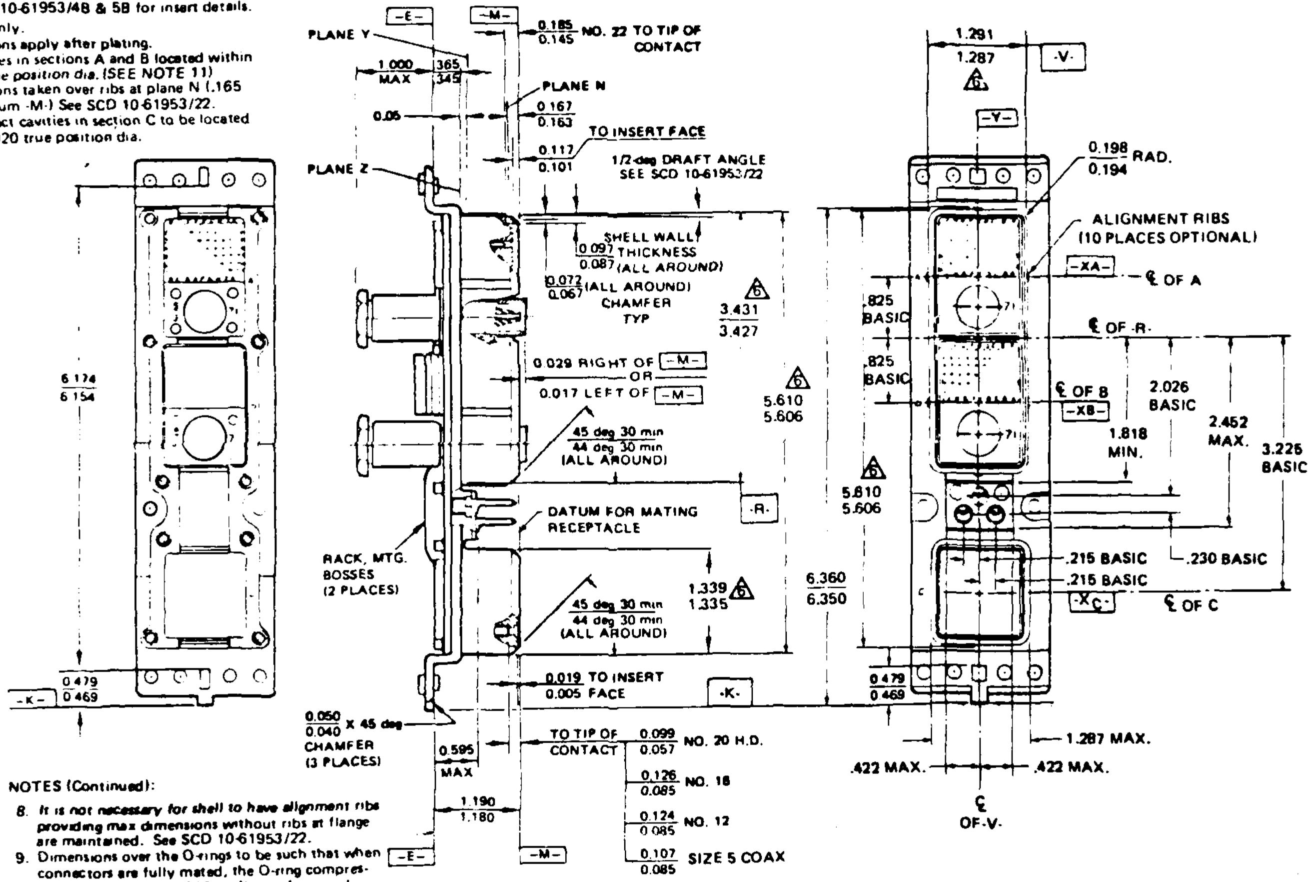
NOTES (Continued):

8. It is not necessary for shell to have alignment ribs providing max dimensions without ribs at flange are maintained. See SCD 10-61953/22.
9. Dimensions over the O-rings to be such that when connectors are fully mated, the O-ring compression per side is .028/.018 on flat surfaces and .023/.013 around corners.
10. O-ring sizes—environmental version
    Cavity location A-B M25988/3-134
    Cavity location C M25988/3-119
11. T. P. of .009 will be acceptable until 7/1/81.

FIGURE 12B - SIZE 1 CONNECTOR PLUG

NOTES

1. See SCD 10-61953/28 for mtg dims.
2. See SCD 10-61953/48 & 58 for insert details.
3. △ Class B only.
4. Dimensions apply after plating.
5. All cavities in sections A and B located within .036 true position dia. (SEE NOTE 11)
6. △ Dimensions taken over ribs at plane N (.165 from datum -M-) See SCD 10-61953/22.
7. All contact cavities in section C to be located within .020 true position dia.



NOTES (Continued):

8. *It is not necessary for shell to have alignment ribs providing max dimensions without ribs at flange are maintained.* See SCD 10-61953/22.
9. Dimensions over the O-rings to be such that when connectors are fully mated, the O-ring compression per side is .028/.018 on flat surfaces and .023/.013 around corners.
10. O-ring sizes—environmental version

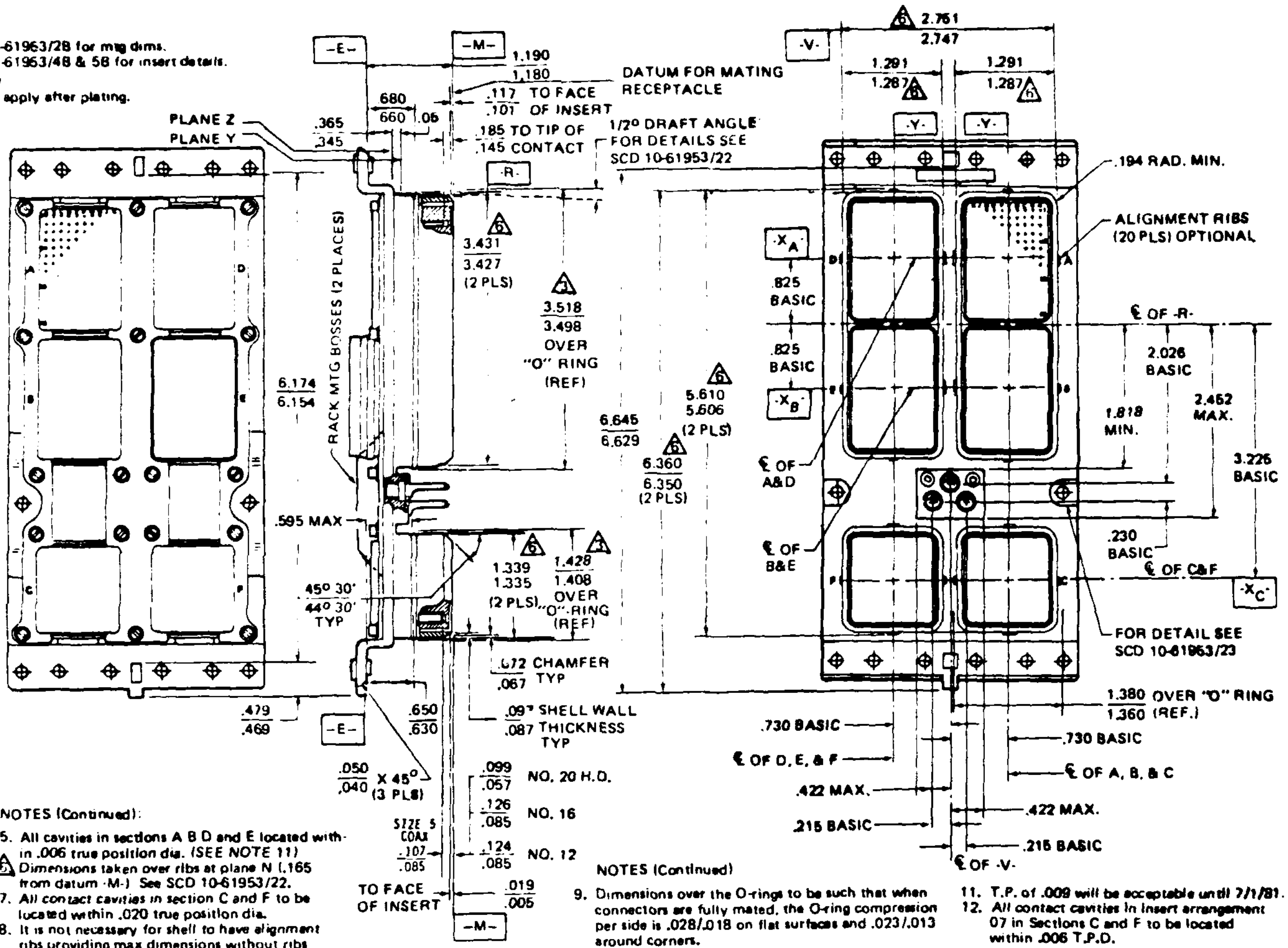
Cavity location A-B	M25988/3-142
Cavity location C	M25988/3-124

11. T. P. of .009 will be acceptable until 7/1/81.

FIGURE 12C - SIZE 2 CONNECTOR PLUG

NOTES.

1 See SCD 10-61963/28 for mtg dims.
2 See SCD 10-61963/48 & 58 for insert details.
△3 Class B only
4 Dimensions apply after plating.



NOTES (Continued):

5. All cavities in sections A B D and E located within .006 true position dia. (SEE NOTE 11)
△6 Dimensions taken over ribs at plane N (.165 from datum -M-) See SCD 10-61953/22.
7. All contact cavities in section C and F to be located within .020 true position dia.
8. It is not necessary for shell to have alignment ribs providing max dimensions without ribs at flange are maintained. See SCD 10-61953/22.

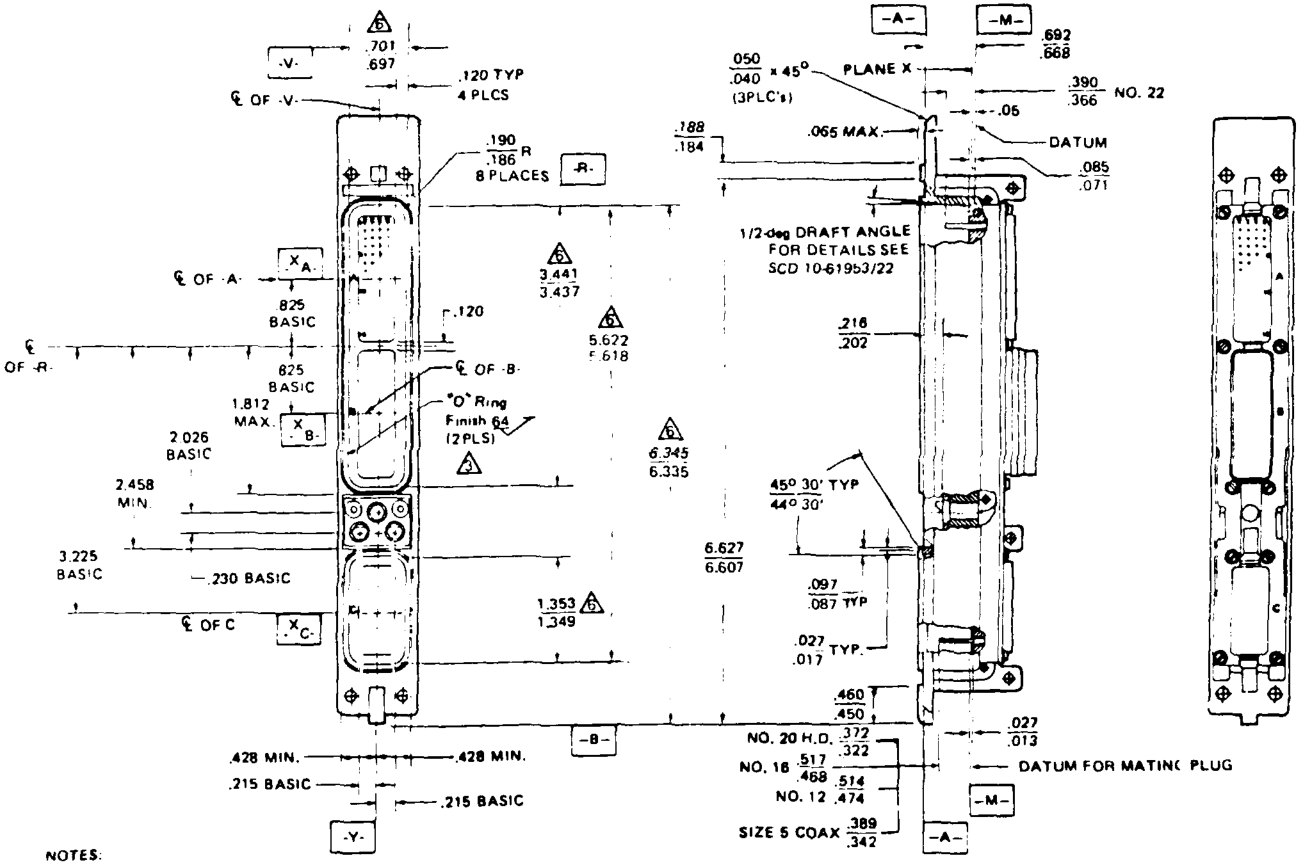
NOTES (Continued)

9. Dimensions over the O-rings to be such that when connectors are fully mated, the O-ring compression per side is .028/.018 on flat surfaces and .023/.013 around corners.
10. O-ring sizes—environmental version

Cavity location A-B	M25988/3-142
Cavity location C	M25988/3-124

11. T.P. of .009 will be acceptable until 7/1/81.
12. All contact cavities in insert arrangement 07 in Sections C and F to be located within .006 T.P.D.

FIGURE 12D - SIZE 3 CONNECTOR PLUG



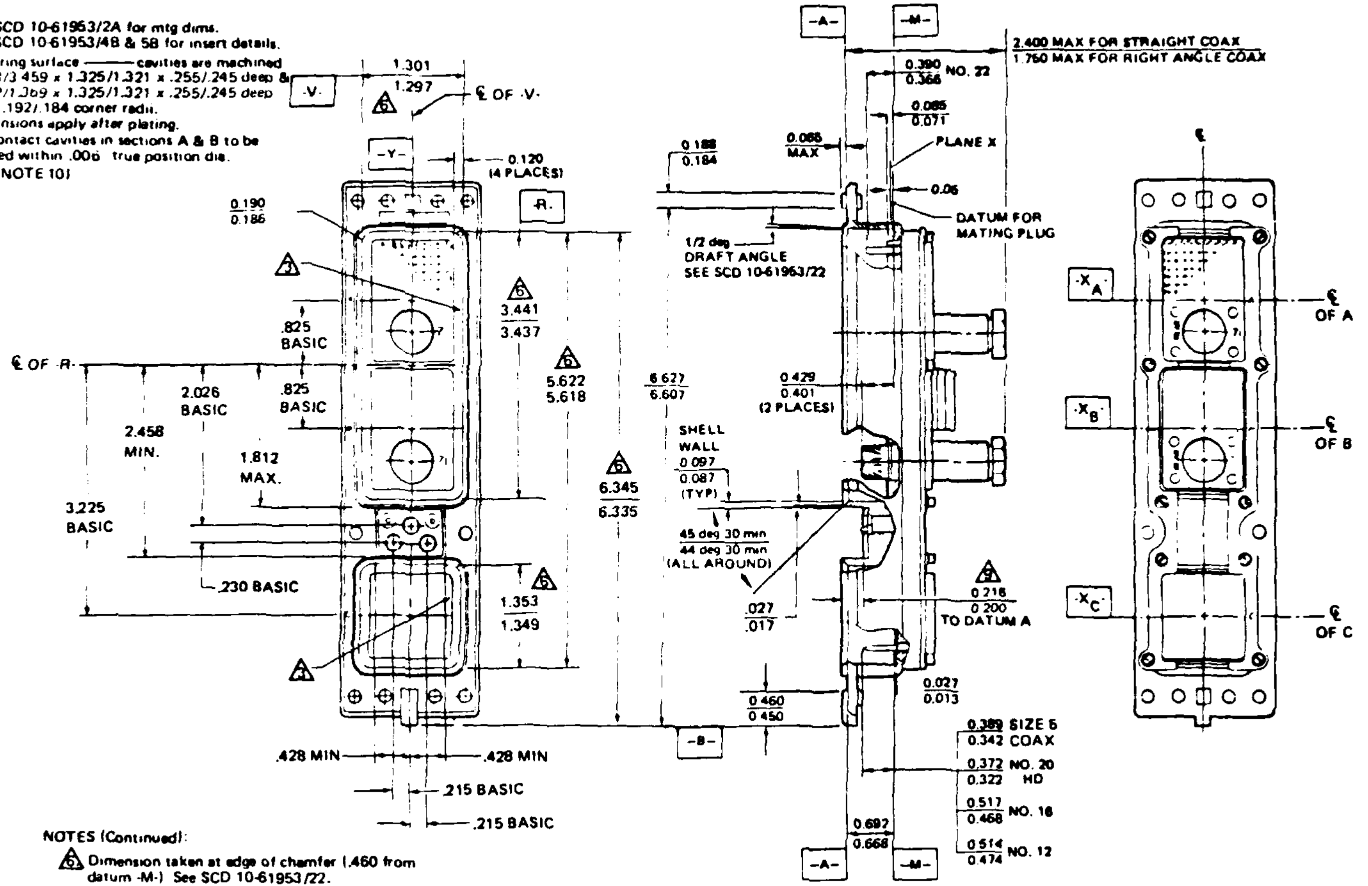
NOTES:

1. See SCD 10-61953/1A for mtg dims.
2. See SCD 10-61953/4A & 5A for insert details.
3. "O" ring surface ______ cavities are machined 3.463/3.459 x .725/.721 x .255/.245 deep & 1.372/1.369 x .725/.721 x .255/.245 deep with .192/.184 corner radii
4. Dimensions apply after plating.
5. All contact cavities in sections A & B to be located within .006 true position dia. (SEE NOTE 9)
6. Dimension taken at edge of chamfer (.460 from datum -M-) See SCD 10-61953/22.
7. Splay of #22 sockets shall be .006 max. at tip of socket.
8. All contact cavities in section C to be located within .020 true position dia.
9. T. P. of .009 will be acceptable until 7/1/81.

FIGURE 12E - SIZE 1 CONNECTOR RECEPTACLE

NOTES

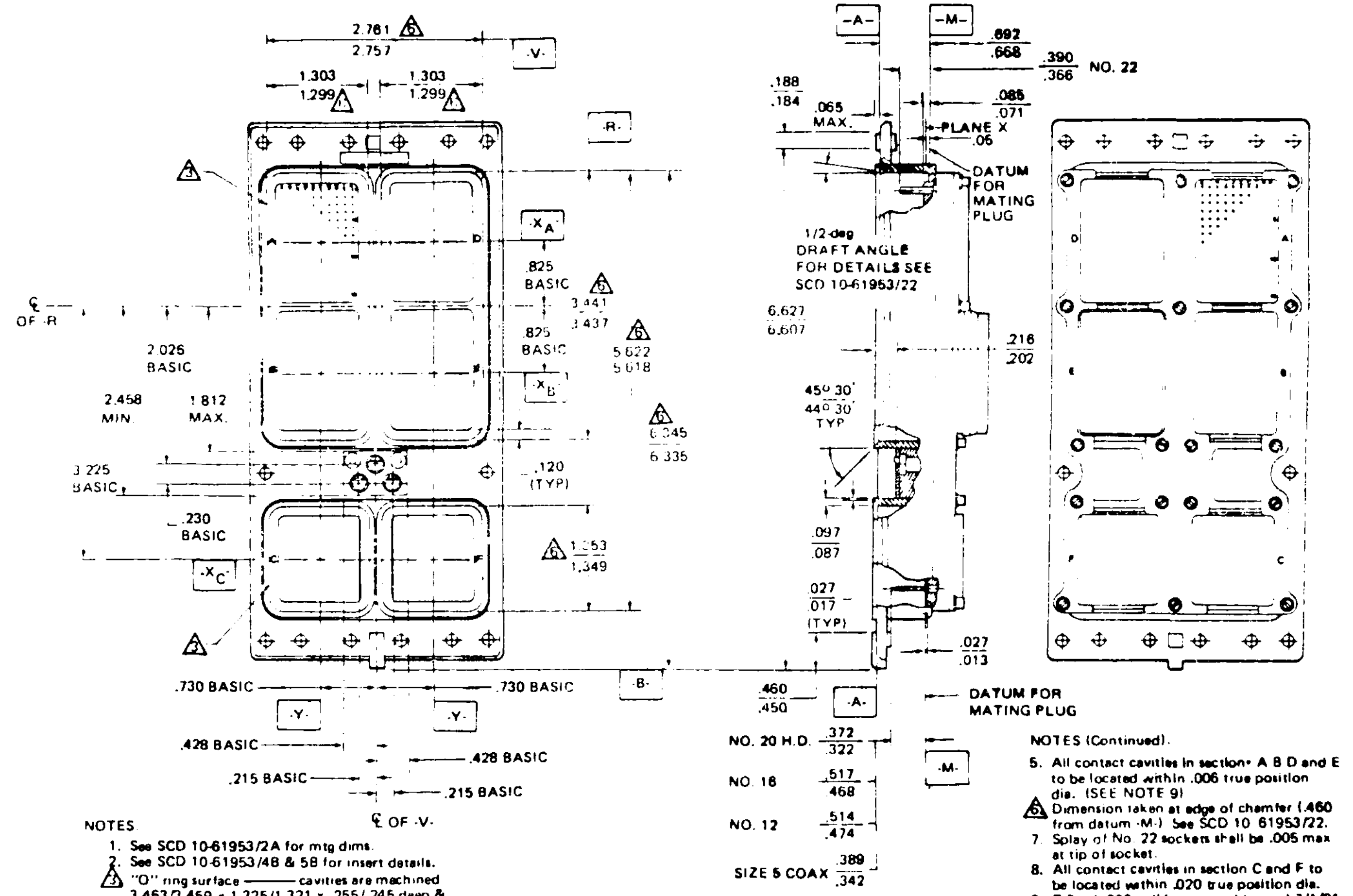
1. See SCD 10-61963/2A for mtg dims.
2. See SCD 10-61953/4B & 5B for insert details.
3. △ "O" ring surface ——— cavities are machined 3 463/3 459 x 1.325/1.321 x .255/.245 deep & 1.372/1.369 x 1.325/1.321 x .255/.245 deep with .192/.184 corner radii.
4. Dimensions apply after plating.
5. All contact cavities in sections A & B to be located within .006 true position dia. (SEE NOTE 10)



NOTES (Continued):

6. △ Dimension taken at edge of chamfer (.460 from datum -M-) See SCD 10-61953/22.
7. Splay of #22 sockets shall be .005 max. at tip of socket.
8. All contact cavities in section C to be located within .020 true position dia.
9. △ For shell size 3 connector, use 0.216/0.202—all other dimensional information on center view identical for shell size 3 connector.
10. T. P. of .009 will be acceptable until 7/1/81.

FIGURE 12F - SIZE 2 CONNECTOR RECEPTACLE



NOTES.

1. See SCD 10-61953/2A for mtg dims.
2. See SCD 10-61953/4B & 5B for insert details.
3. "O" ring surface ——— cavities are machined 3.463/3.459 x 1.325/1.321 x .255/.245 deep & 1.372/1.369 x 1.325/1.321 x 255/.245 deep & .192/.184 corner radii.
4. Dimensions apply after plating.

NOTES (Continued).

5. All contact cavities in sections A B D and E to be located within .006 true position dia. (SEE NOTE 9)
6. Dimension taken at edge of chamfer (.460 from datum -M-) See SCD 10 61953/22.
7. Splay of No. 22 sockets shall be .005 max at tip of socket.
8. All contact cavities in section C and F to be located within .020 true position dia.
9. T P. of .009 will be acceptable until 7/1/81.
10. All contact cavities in insert arrangement 07 in sections C and F to be located within 006 T.P.D.

FIGURE 12G - SIZE 3 CONNECTOR RECEPTACLE

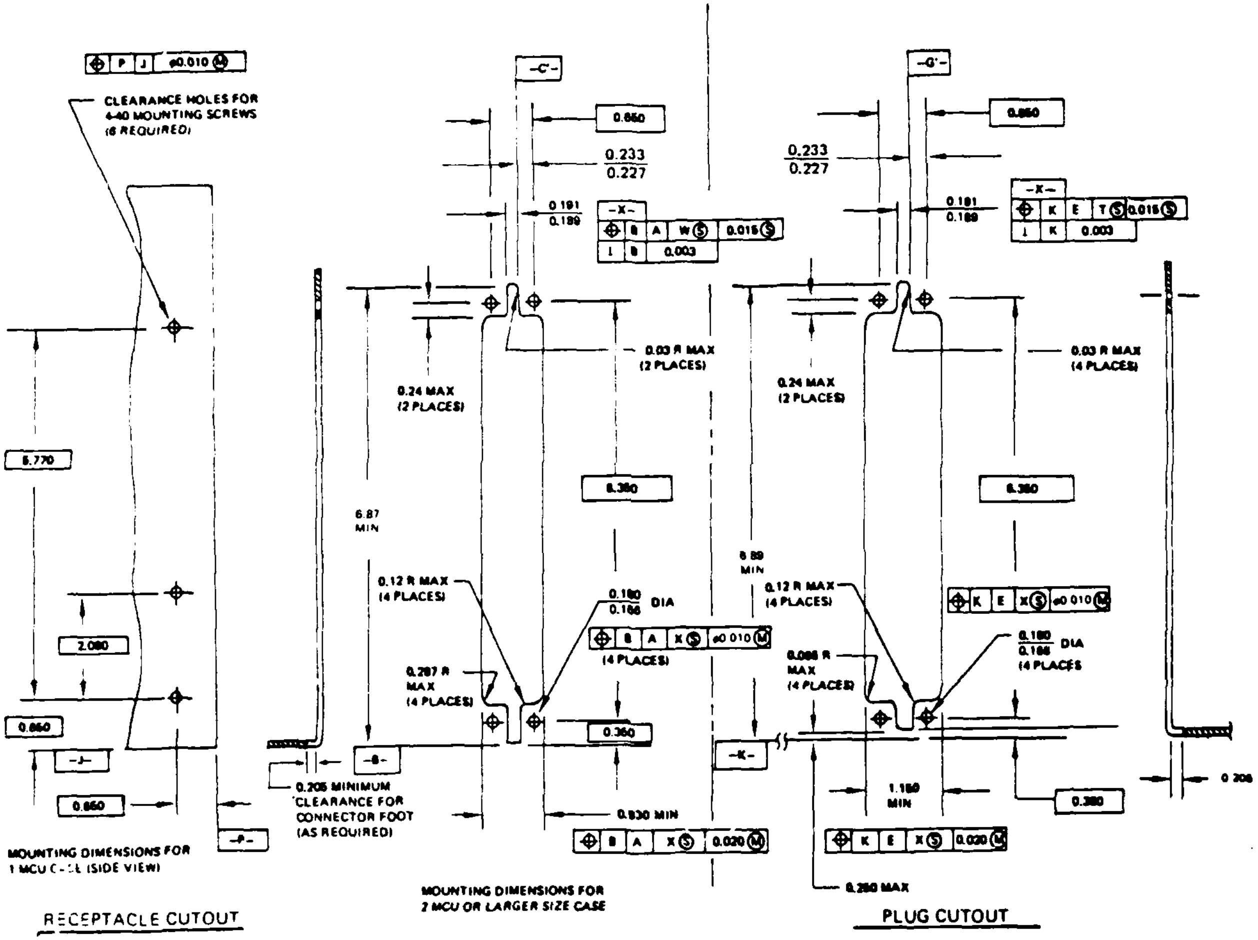
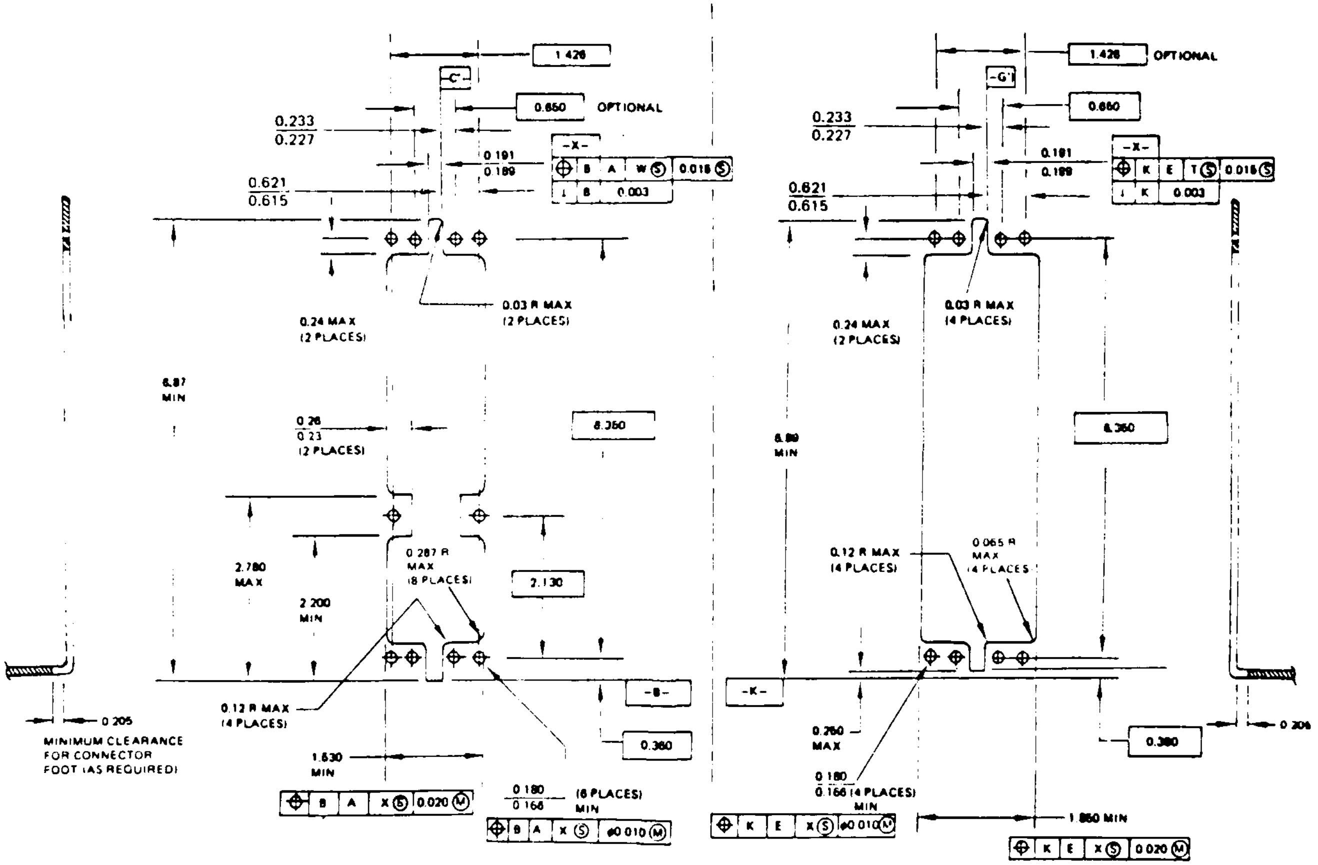


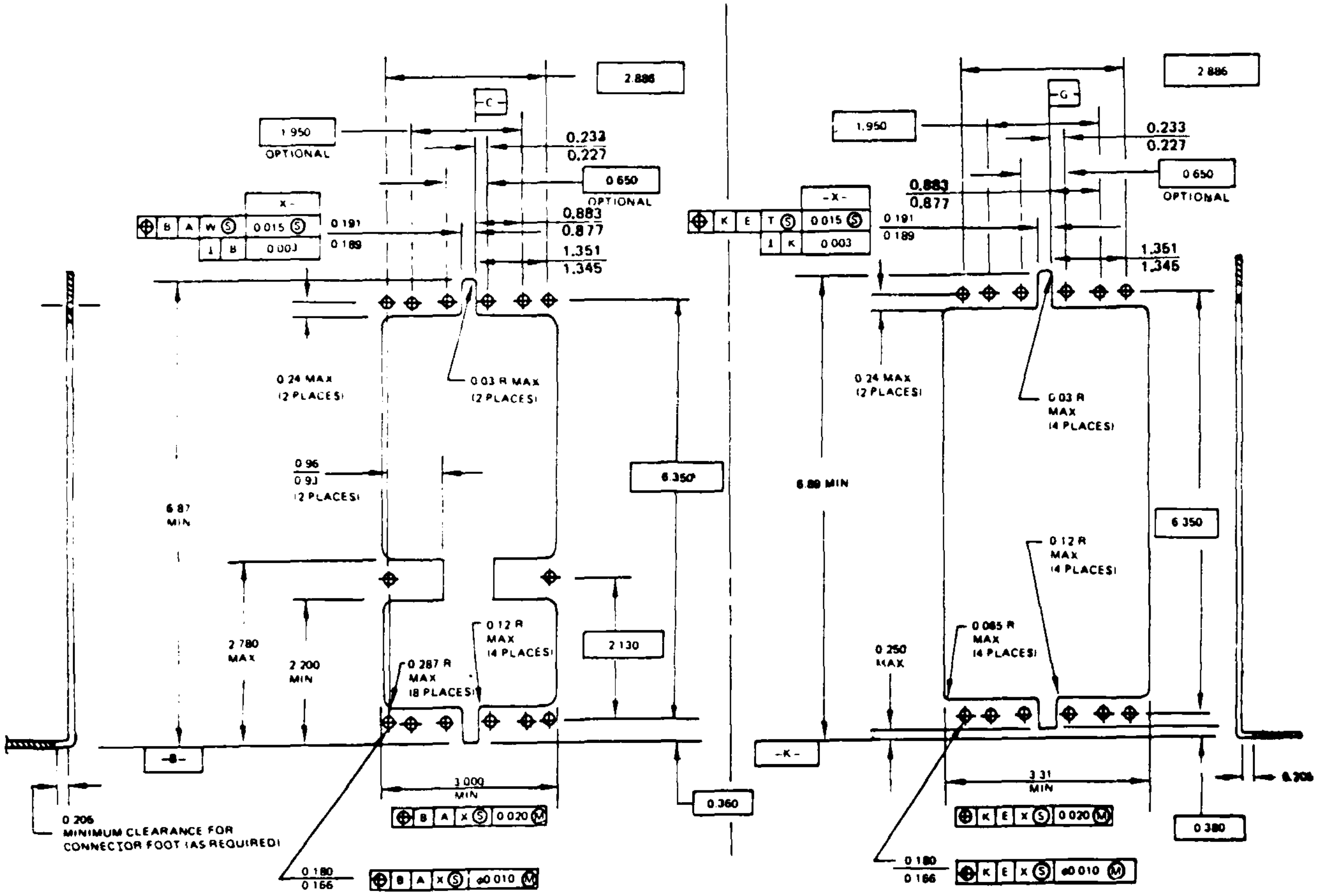
FIGURE 13A - SIZE 1 CONNECTOR CUTOUTS



RECEPTACLE CUTOUT

PLUG CUTOUT

FIGURE 13B - SIZE 2 CONNECTOR CUTOUTS



RECEPTACLE CUTOUT

PLUG CUTOUT

FIGURE 13C - SIZE 3 CONNECTOR CUTOUTS

5.3.5.2 The Rack/Tray Electrical Interface. The electrical interface between the rack/tray and the LRU shall be accomplished through a low insertion force connector mounted on the backplate of the shelf or LRU tray.

The connector shell is installed on the back surface (Datum E, Figure 8) of the backplate. Connector mounting hardware shall be within the limits shown in Figure 12A to avoid possible interference with the mating LRU connector (see Paragraph 5.3.5.1).

5.3.5.2.1 Backplate Connector Positions. The connector position shall be as shown in Figures 8 and 9, as defined by Datum G' and Datum K. The backplate connector cutouts are shown in Figures 13A, 13B, and 13C. (Refer to Paragraph 5.3.5.1.1 for description of connector mounting.) The spacings between connectors mounted on a common backplate is given in Figure 6. The connector spacing is selected to allow connector contacts to be located on a 0.025-inch grid (see Paragraph 5.3.2).

5.3.5.2.2 Backplate Deflection. The perpendicularity requirements of Figures 8 and 9 shall be met when all equipment is installed.

5.4 Wire Integration. Wire integration is a function rather than a specific separate item of hardware. It is implemented as a part of the airframe wiring and the specific form it takes depends largely on the wiring techniques employed by the airframe manufacturer. However, some aspects of wire integration are discussed below.

5.4.1 Mechanical Interface Considerations

5.4.1.1 The wire integration center shall be located on the rack or airframe structure in such a way that it is accessible for test, checkout, repair, removal, and retrofit without removal of any other equipment or pieces of the aircraft.

5.4.1.2 The electrical terminations used for the wire integration center shall be protected from inadvertent contact with foreign materials and liquids which create unwanted electrical circuits. An easily removable protective cover shall be provided. Fluid drainage shall be provided.

5.4.1.3 Wire integration shall not impede the ability to replace the connector on a rack backplate. When a defective backplate connector is being replaced, there shall be minimal disturbance of the circuits not directly associated with that connector (includes need for removal of adjacent LRUs).

5.4.1.4 Connectors which are associated with wire integration shall be indexed or keyed to prevent inadvertent misconnection.

5.4.2 Electrical Interface Considerations

5.4.2.1 The wire integration center shall not use customized connectors and contact systems.

5.4.2.2 Each circuit which goes through the wire integration center shall be individually identifiable and accessible so that it can be intercepted for repair, test, reassignment, etc., with minimum disturbance to any other circuit.

5.4.2.3 The wire integration center shall be designed to accommodate a mixture of "straight through" circuits and "fanned out paralleled" circuits.

5.4.2.4 The wire integration center shall include provision for physical barriers required by circuit separation.

5.4.2.5 Where the wire integration is accomplished on a separate removable unit, provision shall be made to ensure that proper grounding of circuits can be accomplished and that, when there is a current of 10 Amps DC, a voltage drop of less than 2.5 millivolts between the ground part and structure is achieved.

5.4.3 Tooling and Maintenance Considerations. All of the tooling and maintenance considerations of Section 5.3.4 apply to the wire integration unit.

5.5 Thermal Management

5.5.1 Thermal Design Condition. The thermal design condition is the environmental and electrical operating mode to be used as the basic design condition for the equipment.

The thermal design condition represents normal operation of the equipment as installed in a military aircraft. For the test and design computational purposes herein, the thermal design condition is defined as follows:

(a) Equipment in the steady-state thermal condition (see Stabilization, 3.9).

(b) Equipment in the electrical operating mode which will yield the maximum steady-state heat dissipation.

(c) Ambient pressure at 101.3 kPa (1013.25 mbar). The local ambient pressure is acceptable provided it is noted in the test report.

(d) Ambient temperature, except for variations caused by (e) below, at 71°C.

(e) Air velocities immediately surrounding the equipment not greater than those caused by air movement due to natural (free) convection effects.

(f) Coolant air bulk inlet temperature at 15.5°C.

(g) Coolant airflow rate at 65 kg.hr.$^{-1}$ kW^{-1} based on actual heat dissipation at condition (b) above.

(h) Inlet coolant air relative humidity not greater than 40 percent.

(i) Equipment located in surrounding and supporting structure which simulates standard in-service usage including adjacent units with surface temperatures of 80°C and minimum emissivities of 0.85 (see also Appendix I).

5.5.2 Electronic Part Application. This section is advisory in nature to caution the manufacturers of avionics equipments regarding the problems associated with electrical and electronic parts applications. To achieve electro/thermal stress levels consistent with desired performance and reliability, electronic part temperature shall be limited as follows:

(a) Electronic part temperatures for any anticipated operational mode shall not exceed the component manufacturer's maximum operating curve. (This temperature limit is usually expressed as a function of power dissipation but it may be a function of voltage, current, or other parameter of operation or combination thereof.) Anticipated operational modes include the startup transient following a high temperature soak, the high continuous operating temperature, and continuous operation at reduced coolant flow rate (see 5.5.3 and 5.5.4). It is expected that all of these conditions may be encountered during the equipment lifetime but they do not represent normal operations and therefore are not the basis for a conventional reliability assessment. However, the probability of occurrence is considered high enough that electronic parts shall be able to survive these operating conditions without a drastic reduction of equipment life (as would be expected to occur when the component manufacturer's absolute maximum is exceeded).

(b) During normal operation of equipment, defined by the thermal design condition (see 3.12 and 5.5.3(d)), electronic part temperature shall not exceed a limit determined by the reliability number apportioned to that part based on the reliability number assessed against the equipment. MIL-Handbook 217 shall be used as the basis of determination that the applied electrical stresses and the maximum predicted part temperature are in accordance with the reliability apportionment for the part. (It should be noted that "part temperature" actually means part surface temperature and that measurement or calculation shall relate to surface temperatures and not internal operating temperatures.)

COMMENTARY: The maximum predicted part temperature shall also take into account the effect of temperature of adjacent parts as well as the ambient air. It is no good to calculate the maximum predicted power/operating temperature of, say, a transistor based on the apportionment and then place it physically next to a wire wound resistor whose maximum predicted power/operating temperature is also based on the reliability data for the resistor. Either the maximum power dissipated by the transistor shall be derated to take into account the ambient created by the resistor or the resistor shall be rerated to create an environment which does not have a deleterious effect on the transistor.

5.5.3 Ambient Temperature. This is the ambient air temperature immediately surrounding the equipment rack. For test purposes, ambient temperature is measured 75 mm in front of the LRU.

(a) Ground Survival Temperature

-62°C to 95°C

NOTE: These are the lowest and highest ground temperatures expected to be experienced by equipment during aircraft storage or exposure to climatic extremes with power off. Equipment is not expected to be capable of operation at these temperatures, but to survive them without damage.

(b) Short Term Operating Temperature, 30 Minutes Duration -40°C to 85°C

(c) Low and High Operating Temperature, Ground or Flight

-15°C to 71°C

5.5.4 Coolant Air. Coolant air shall be supplied to LRUs installed in an aircraft in accordance with the design requirements of MIL-E-87145. The coolant air characteristics shall be as follows:

5.5.4.1 Coolant Air, Bulk Temperature at the LRU Inlet, Minimum to Maximum

(a) Short-Time Operation, Equipment Startup, One Minute Duration.

-40°C to 70°C

(b) Normal Continuous Flight Operation

15.5°C to 30°C

NOTE: This is the design temperature selected for electrical component derating in accordance with the part application guidelines of 5.5.2.

(c) Normal Continuous Ground Operation

15.5°C to 40°C

5.5.4.2 Coolant Air Flow Rate. Cooling air is to be supplied to each equipment in proportion to the equipment's steady-state heat dissipation, defined per 3.10. The design airflow rate shall be in accordance with the mass flow versus inlet bulk temperature relationships shown in Figure 14.

5.5.4.3 Coolant Air Pressure Drop Through the Equipment. The coolant air static pressure drop through the equipment shall be 50.5 ± 5 mm of water at the rated flow rate. This pressure drop does not include the drop through a metering orifice when such orifice is located external to the equipment case; e.g., in a rack-mounted equipment tray. (For test purposes, at laboratory ambient pressure other than standard, corrections are allowed.)

5.5.4.4 Coolant Air Leakage from the Equipment. There shall be no air paths into or out of the equipment other than the back and front of the units, except for the drain holes (5.1.2).

5.5.4.5 Coolant Air Humidity. Under ECS fault conditions the coolant air can contain up to 154 grains of water per pound of dry air.

5.5.4.6 Coolant Air Contamination. The cooling air shall not contain contaminant particles in excess of 400 m (microns).

5.5.4.7 Coolant Air Inlet and Outlet Locations. The coolant air shall enter the equipment through the rear surface only. This shall be accomplished by blowing the air. The exhaust cooling air shall exit via ports in the front face of the LRU.

5.5.5 Equipment Sidewall Temperature. Under the thermal design conditions specified in 5.5.4.1 (b), the average temperature of any LRU equipment vertical sidewall (including front and back vertical surfaces) shall not exceed 71°C. There shall be no sidewall hot spot temperatures in excess of 60°C.

5.5.6 LRU Thermal Appraisal. The LRU shall meet the minimum standards of thermal design defined in Appendix I. This shall be demonstrated and documented in a thermal appraisal report intended to show that temperatures remain within the limits set forth in that appendix.

5.5.6.1 Identification and Data Tabulation for Heat Dissipating and Temperature Critical Parts

(a) Description. Identification of the part type shall be presented under a column headed "description"; e.g., RL07 resistor, 2N2484 transistor, IN746 diode, CKR05 capacitor, etc. The term part shall include encapsulated assemblies.

(b) Schematic Identification. The tabulated data shall include the schematic symbol for each part; e.g., R105, C127, Z701, etc.

(c) Location. A general description of the part shall be provided.

(d) Manufacturer's Maximum Rated Operating Dissipation. May be the absolute maximum recommended by the part manufacturer or may be some upper limit less than the absolute maximum operating dissipation established by the equipment manufacturer.

(e) Heat Dissipation. The value for the rate of energy, in watts, being dissipated by the part during operation at the thermal design condition (as defined in 5.5.1) shall be tabulated. Preferably this value shall be the result of measured data, but it may be determined through calculations.

(f) Maximum Surface Temperature (T_M). This is the absolute maximum surface temperature allowable in the above (e) mode of operation as determined by the component manufacturer's specification.

(g) Design Surface Temperature (T_C). The design surface temperature is defined as the maximum external surface temperature that can be tolerated consistent with the part's function and system or equipment specified reliability requirement at the thermal design condition. The value for this temperature and its location on each part shall be tabulated for each part. For electrical parts, the design surface temperature shall be determined as outlined in 5.5.2 (b), Electronic Part Application.

NOTE: Parts which are encapsulated assemblies of basic component parts shall have their maximum and design surface temperatures tabulated. The thermal relationship between the parts in the encapsulation and the encapsulated assembly surface shall be reported in sufficient detail to allow the prediction of the internal part temperatures from the measured encapsulated assembly surface temperature.

5.5.6.2 Thermal Evaluation Test. A thermal evaluation test shall be conducted on one representative production unit in accordance with the procedures of Appendix I. The evaluation shall determine for operation at elevated temperature (1) the equipment total heat dissipation, (2) the pressure drop versus airflow relationship, and (3) the temperature of equipment sidewalls and selected internal parts.

The LRU design shall meet or exceed the minimum standards of thermal performance when tested for coolant airflow as outlined in the Thermal Evaluation Test Acceptance Criteria of Appendix I.

5.5.7 Thermal Interface Information. The following information shall be supplied with the Equipment Installation and Control Drawing:

a) Total wattage input and actual heat dissipation for all modes of electrical operation for which the equipment was designed; e.g., standby, receiving, transmitting, etc.

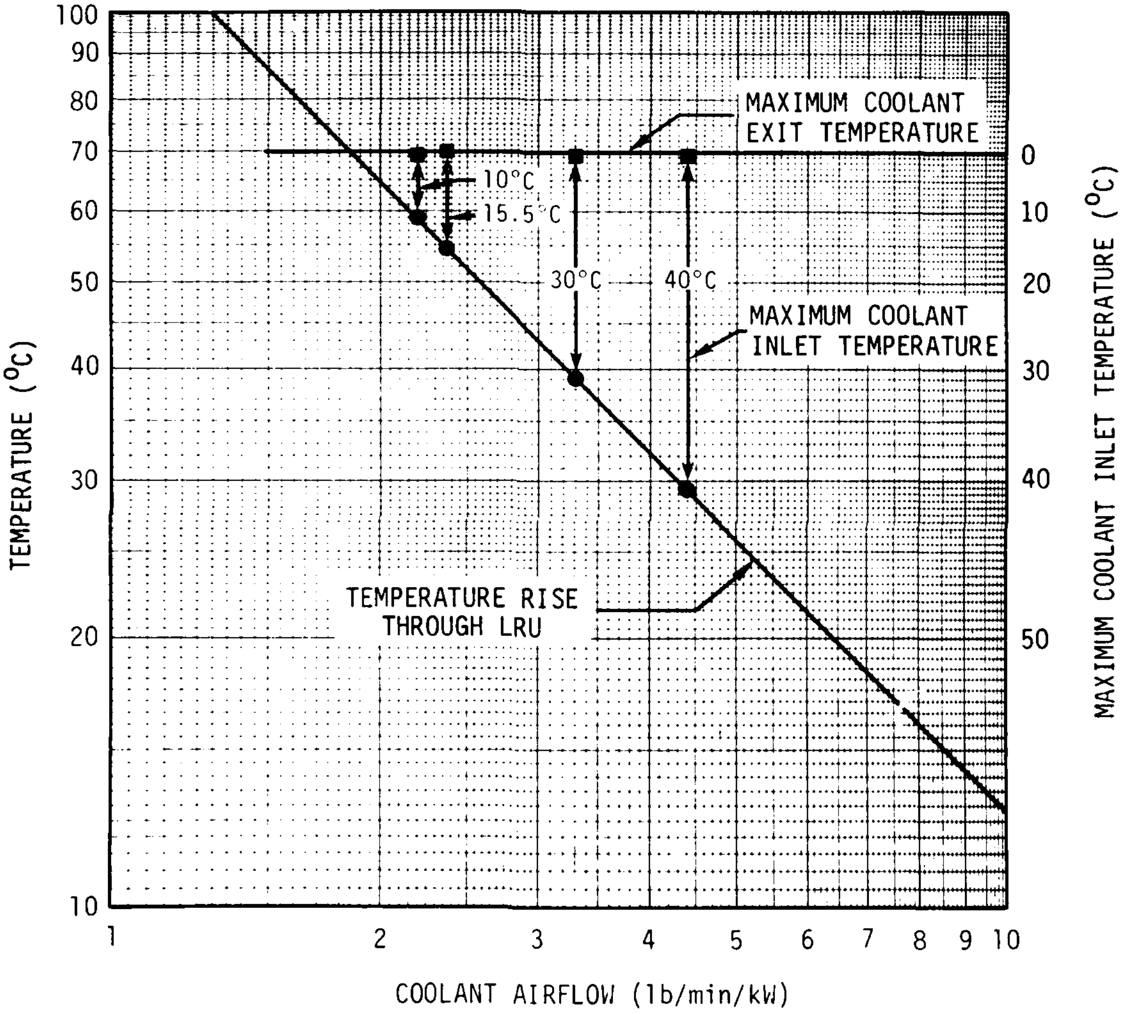


FIGURE 14 - COOLING AIRFLOW REQUIREMENTS

(b) Estimated in-flight and ground maximum duty cycle (when specified).

(c) Pressure drop through the unit in mm of water when the ambient pressure is 101.3 kPa and,

  (1) Coolant inlet temperature is 40°C at a flow rate of 120 kg hr^{-1} . kW^{-1}.

  (2) Coolant inlet temperature is 15.5°C at a flow rate of 65 kg hr^{-1} . kW^{-1}.

  (3) Coolant inlet temperature is -18°C at a flow rate of 40 kg hr^{-1} . kW^{-1}.

(d) Average temperature of equipment sidewalls at the thermal design condition.

(e) Effect of dry contamination on unit cooling performance and recommended unit service intervals required to maintain cooling performance, if applicable.

(f) Effect on the subsystem reliability prediction (reference MIL-STD-785A, para. 5.2.2) of a variation in the coolant inlet temperature and rate of flow from 50% to 150% of the design cooling capacity.

5.6 <u>Power Quality and Power Conditioning</u>. An electrical interface section is included in this specification to provide guidance information to the equipment engineer regarding

(a) The characteristics of the aircraft electrical power available to the LRU at the equipment rack, and

(b) Conversion and conditioning of this power for use within the LRU.

5.6.1 <u>Power Quality</u>. Each aircraft electrical power quality specification may vary slightly with regard to specific parameter being observed and values assigned to that parameter under various operating conditions. However, it is generally accepted that, in the vast majority of aircraft, no problems due to input power quality will be encountered by LRUs/equipment which have been designed to meet MIL-STD-704C plus the voltage spike conducted tests of MIL-STD-461.

Therefore, for the purpose of this specification, the electrical power interface at the equipment rack will be considered as defined by the details of MIL-STD-704C.

5.6.2 <u>Power Conditioning</u>. All conversion and/or conditioning of power to obtain desired frequency, level of voltage, or quality of power will be accomplished within the LRU or by the subsystem of which the LRU is a part. Design of the power conditioning section shall minimize the thermal losses, and control the effect of conducted and radiated interference.

5.7 <u>Mechanical and Structural Evaluation</u>. The rack, tray, or mounting base manufacturer shall show by analysis and/or test that the rack will meet the deflection and bending requirements under specified conditions of load, and that the rack has required strength to resist all operational stresses, in accordance with 5.2.2.

The aircraft cooling system shall be tested to demonstrate that the required airflow rates are achieved at the specified inlet temperatures, in accordance with 5.5.4.

The LRU manufacturer shall show by analysis and/or test that the unit meets required weight, vibration, shock, and acceleration load limits, in accordance with 5.1.1.4, 5.1.6.2, and 5.2.3.4.

COOLING EVALUATION TEST

APPENDIX I

10.1 PURPOSE. This test is conducted on the LRU to determine:

(a) The total wattage input and actual heat dissipation for all modes of electrical operation.

(b) The temperature of equipment sidewalls at the thermal design condition.

(c) Pressure drop through the equipment versus coolant airflow rate.

(d) Temperature characteristics at the thermal design condition and other anticipated environmental operating conditions (see Figure 10-7).

10.2 APPARATUS

10.2.1 Test Chamber and Aircraft Mounting Simulation. For the cooling evaluation test, a test facility capable of producing the environmental conditions of Figure 10-7, shall be employed. A suitable test chamber and aircraft mounting simulation is depicted in Figure 10-1. It is recommended that airflow be ducted in accordance with Figure 10-2 to ensure the proper airflow distribution and ambient temperature surrounding the LRU.

10.2.2 Instrumentation

10.2.2.1 Accuracy of the Test Apparatus. All instruments and test equipment used in conducting the test shall conform to laboratory standards whose calibration is traceable to the appropriate national prime standards.

10.2.2.2 Measurement Tolerances. The maximum allowable tolerances on measurements (excepting those required for a heat balance) shall be as follows:

(a)	Temperature	±2 degrees C
(b)	Coolant Flow	± .45 kg hr^{-1} or ± 3 percent of the test unit flow rate, whichever is greater.
(c)	Pressure: Differential	± 5%
	Atmospheric	± 1%
(d)	Power	± 2 watts or 3 percent of the test unit power dissipation, whichever is greater.
(e)	Relative Humidity	± 15%

10.2.2.3 Measurements for Cooling Evaluation Test. Suitable instrumentation shall be provided to measure the items below, as applicable, during testing. (For temperature measurements "suitable instrumentation" techniques are defined in Paragraph 10.3.2.2.) Figure 10-3 delineates the instrumentation layout with respect to the test chamber and other apparatus. The encircled numerals in Figure 10-3 correspond to the following measurements:

T1 Ambient temperature external to the test chamber

T2 Bulk temperature of the coolant entering the test chamber

T3 Bulk temperature of the coolant entering the test unit (coolant inlet temperature) 6 mm from the bottom surface of the test unit and centered with respect to the coolant opening in the equipment tray. (Several measurements may be required where gradients exist.)

T4 Bulk temperature of the bypass flow entering the test chamber.

T5 Ambient temperature surrounding the equipment rack as determined by the air temperature centered with respect to and 76 mm forward of the front face of the test unit (excluding such projections as handles and knobs).

T6 Bulk temperature of the bypass airflow exiting the test chamber.

T7 Test unit's vertical external surface temperatures; viz., front, back, and sides. (Measurement to be representative of the average surface temperature. Several measurements may be required on a surface where gradients exist.)

T8 Temperature of simulated unit surfaces facing the test unit (simulated unit working surfaces).

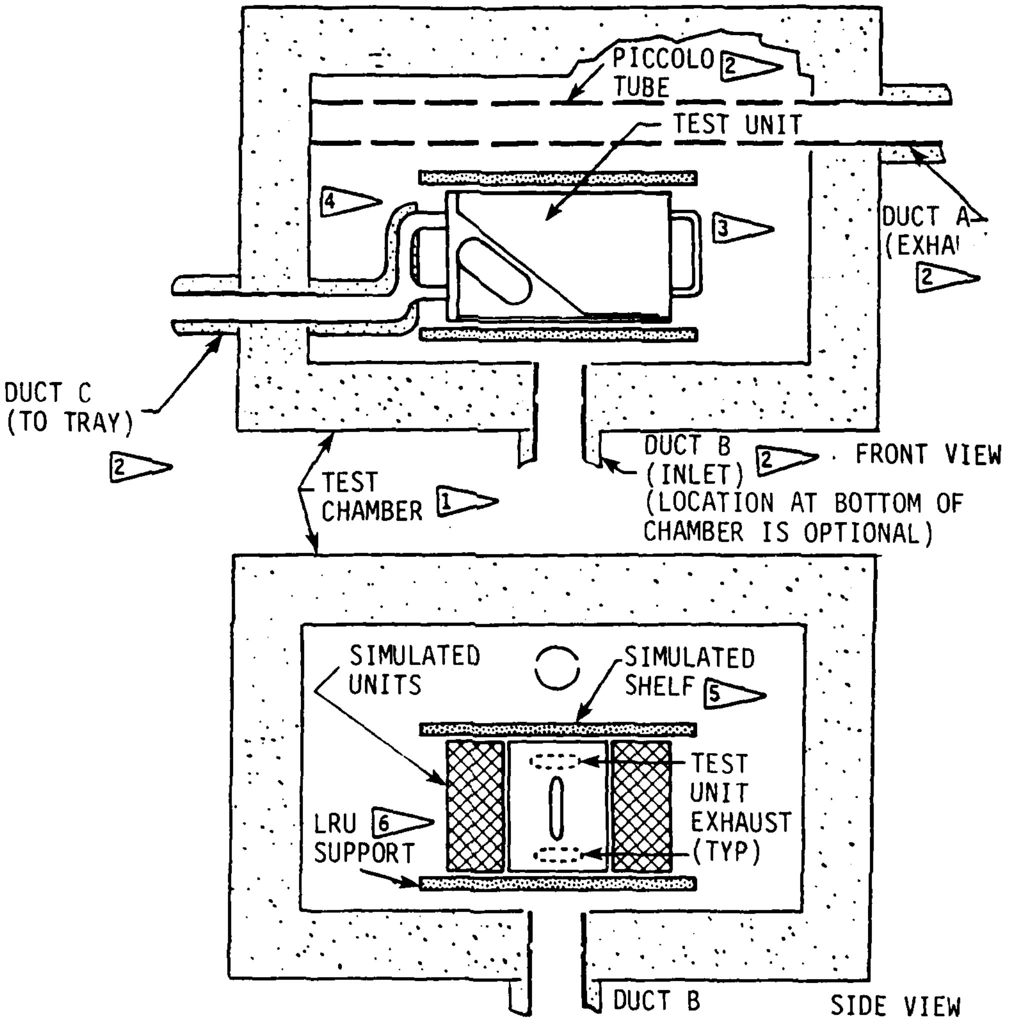


FIGURE 10-1 - STANDARD TEST CHAMBER

Figure 10-1 Flag Notes

1 Test Chamber. The test chamber's internal dimensions shall enclose a space approximately 0.9m square by 0.5m high. The test chamber (and associated inlet and exit ducting) shall be airtight and thermally insulated to the extent necessary.

Ambient temperature surrounding the equipment rack T5, see Figure 10-3, is the standard for test chamber control. The means for maintaining this temperature constant shall be additional airflow (bypass flow) through the test chamber other than that required for dedicated coolant flow through the test unit. Flow control provisions shall be capable of maintaining the T5 temperatures constant within ±2°C of any selected test temperature. To ensure that ambient velocities surrounding the test unit remain comparable to those which would occur from natural convection effects; bypass flow rate M2 shall be limited to 80 kg of air per hour maximum, and the temperature differential between T4 and the T5 ambient temperature shall be limited to ±5°C. Airflow through the test chamber and through the test unit shall be produced by positive pressure. The inlet and exhaust ducts shall not be coupled into a closed-loop system.

2 Air Inlet and Exhaust Ducts. Airflow ducts shall be provided in the locations shown. Their functions are shown schematically in Figure 10-2.

Duct A shall function as an exhaust duct. It shall be connected to a piccolo tube located above the simulated shelf.

Duct B shall function as an inlet duct. It may penetrate the test chamber through the bottom or lower sidewall with air delivery effected below the level of the test unit. By location, or by the use of a baffle or distributor, the duct shall be arranged to preclude direct impingement of air upon the test unit.

Duct C shall be coupled to the plenum as shown in Figure 10-1 or to the equipment shelf cooling-aperture when the plenum shelf is simulated by a solid piece of material. It shall be thermally insulated from the test chamber ambient air and the duct B entrance airflow.

3 Plenum Shelf. The plenum shelf (equipment shelf) is used to support the equipment and simulated units and to act as a baffle to deflect the airflow entering the test chamber through duct B. It represents the plenum shelf in the aircraft, but does not have to be an actual plenum in the test setup. It shall be 320 to 500 mm deep and 635 ± 25 mm long, including insulation if required. Thickness is optional. There shall be no holes that might allow passage of air through the plenum shelf except as required to couple the cooling aperture with duct C. The plenum shelf is not intended to act as heat sink. Where an actual plenum (as depicted in Figure 10-1) is employed, it shall be thermally insulated from the test chamber ambient and the duct B entrance airflow. An alternate approach is to use a solid shelf fabricated of some low-conductivity non-metallic material (such as a fiberglass laminate or wood) and to couple duct C to the equipment shelf cooling-aperture.

4 Simulated Unit. (Two required, one each side of the test unit.) The simulated unit shall be 320 ± 5 mm deep by 194 ± 2 mm high. The plane of the simulated unit facing the test unit (working surface) shall be parallel to and $8.9 \pm {}^{0.0}_{1.3}$ mm from the test unit sidewall. The simulated unit back-vertical edge shall be aligned with the back edge of the unit under test. Temperature of the working surface T8 is the standard for simulated unit control. It is recommended that the working surface be fabricated of aluminum or copper plate and heated by electrical resistance heaters evenly distributed over the plate side opposite the working surface to achieve a uniform temperature distribution. The working surface shall be smooth and solid (no holes that might allow the passage of air through the plane). The minimum emissivity of the working surface shall be 0.85. The working surface should be thermally insulated from the plenum shelf to preclude the existence of a conduction path from the working surface to the test unit. The side opposite the working surface shall be insulated to minimize heat transfer to the test chamber ambient. Balsa is a satisfactory thermal insulation for the plate side opposite the working surface (the plate edges do not need to be insulated except from the plenum shelf).

5 Simulated Shelf. A solid shelf 320 to 500 mm deep by 635 ± 25 mm long. Thickness is optional. The shelf shall be mounted 12.7 ± 1.3 mm above the simulated units and aligned to cover the full length and width of both simulated units when viewed from above. The shelf shall be fabricated from some low-conductivity non-metallic material, such as a fiberglass laminate or balsa wood.

6 LRU Support. An equipment mounting surface with guide rails and cooling air aperture shall be used which is representative of the aircraft installation. It will provide flow control openings, a backplate for electrical connector mounting, and usually the mounting surface for the holddown mechanism. The installation shall be aligned so that the back vertical surface of the test unit (excluding projections) is flush with the back vertical surfaces of the simulated units. The equipment mounting surface may be installed as part of the top surface of an air plenum as shown in Figure 10-1. Alternatively, the coolant airflow may be ducted directly from duct C to the cooling aperture but, in either case, the airflow path shall be thermally shielded from the duct B entrance airflow.

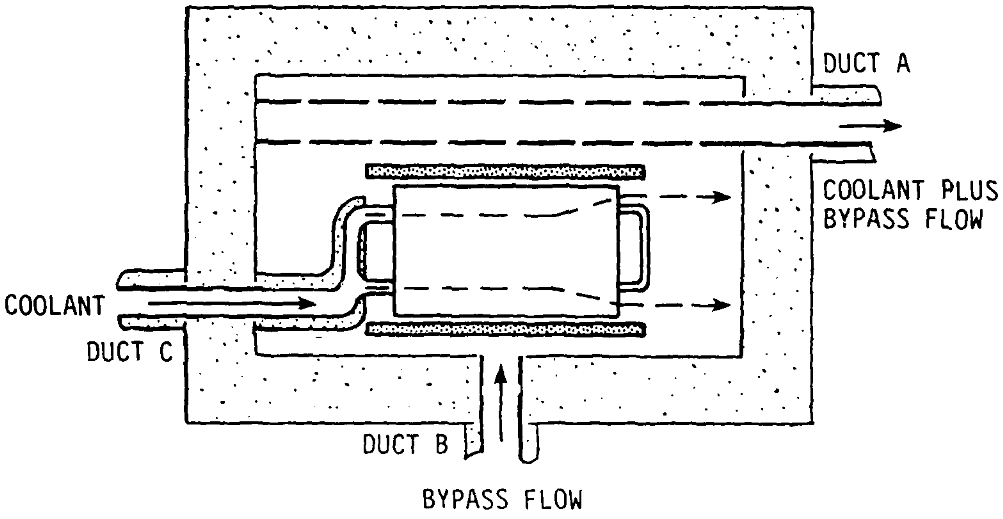
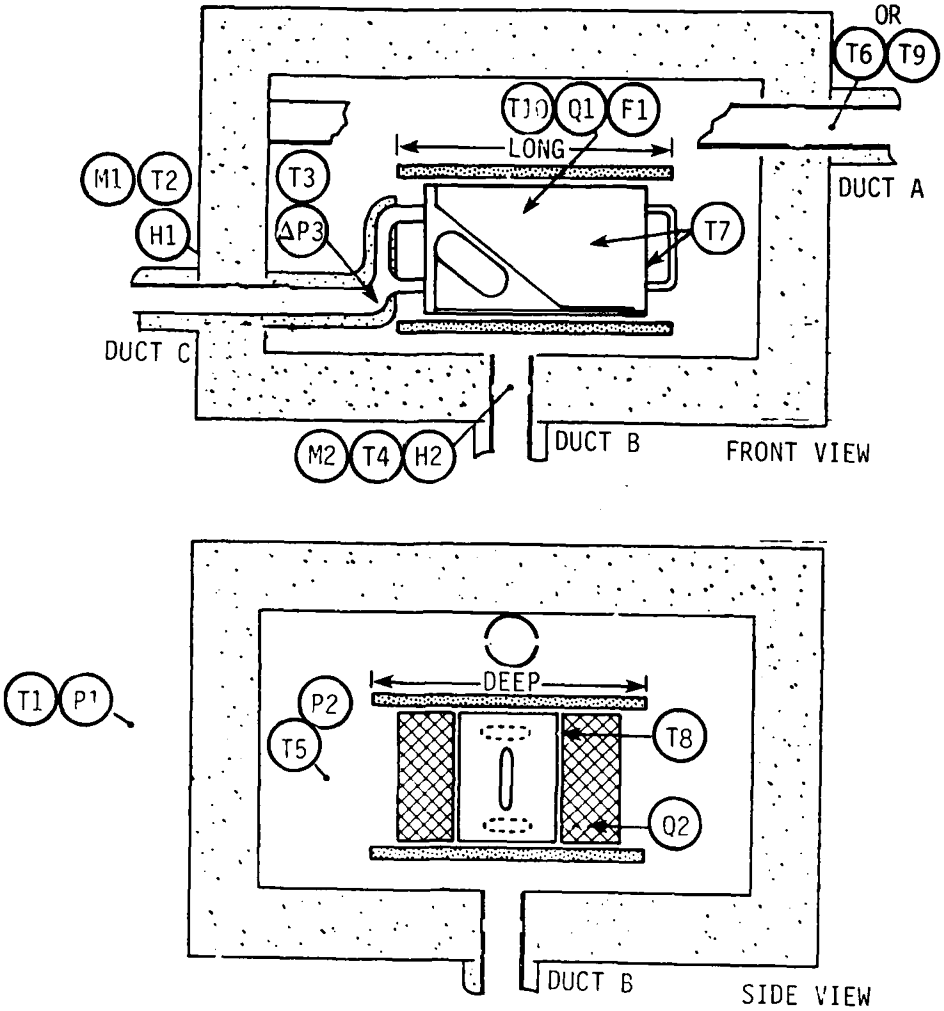


FIGURE 10-2 - AIRFLOW SCHEMATIC



NUMBERS COINCIDE WITH PARAGRAPH 1.2.2.3

LETTERS: F = FUNCTIONAL
H = SPECIFIC HUMIDITY
M = MASS FLOWRATE
P = PRESSURE
Q = POWER DISSIPATION
T = TEMPERATURE
Δ = DIFFERENTIAL

FIGURE 10-3 - INSTRUMENTATION SCHEMATIC, TEST CHAMBER

T9	Bulk temperature of the coolant exiting the test chamber.
T10	Surface temperature of temperature critical parts inside the test unit where the number of parts instrumented shall be 10 parts or 10% of the total, whichever is greater, up to a total of 50 parts. It is recommended that there shall be at least one measurement per printed circuit board. Additional part monitoring could be performed provided the temperature monitoring does not significantly alter the data of the critical part monitoring.
P1	Ambient pressure external to the test chamber.
P2	Ambient pressure external to the test unit.
P3	Differential pressure, total to total (in mm of H_2O) from the test unit coolant inlet to outlet. Determine using a separate pressure drop test setup. The pressure drop shall not include the drop across the metering orifice or other miscellaneous losses, external to the LRU.
M1	Mass flow rate of the coolant through the test unit.
M2	Mass flow rate of the bypass flow through the test chamber (separate from the test unit's coolant flow).
H1	Relative humidity of the coolant entering the test unit. (This may be calculated from measurements made at the air source.)
H2	Relative humidity of the bypass flow entering the test chamber. (This may be calculated from measurements made at the air source.)
Q1	Test unit's heat dissipation. (Equal to power input to the test unit minus power output from the test unit not dissipated as heat.)
Q2	Simulated unit's power input.
F1	Test unit's functional performance characteristics.

10.2.2.4 Temperature Measurement Techniques. Thermocouples will be the standard temperature sensors for this testing. They shall be constructed of a wire size equal to or smaller than 30 AWG.

(a) *Surface Temperature.* The temperature sensor shall be located so as to make good thermal contact with the surface to be measured and yet minimize the error due to the presence of the sensor. Where necessary, the sensor leads shall be insulated electrically from the surface, but shall be held in intimate thermal contact with the surface for at least 6 mm measured from the thermocouple junction. Where an adhesive bond is employed, its thickness, total amount, and distribution shall be commensurate with the requirements of good thermal contact and a minimum disturbance of the normal temperature distribution. Figure 10-4 shows an acceptable thermocouple installation on a test unit case.

Surface temperature measurements on electronic parts shall be located, if possible, at the point which will yield the maximum surface temperature. Figures 10-5 and 10-6 depict satisfactory thermocouple attachment methods for several common part types. Whenever the application of the thermocouple may appreciably affect the temperature field on a part, particular consideration shall be given to using smaller gauge thermocouples and to the method of installation.

(b) Ambient Temperature. Ambient temperature thermocouples shall have at least 50 diameters of bare wire exposed in each leg of the thermocouple junction.

(c) Bulk Airflow Temperature. The measurement of bulk coolant temperature and/or airflow entering or exiting the test chamber is complicated by the fact that at any station in the moving airstream gradients exist. To determine a bulk temperature, either mechanical mixing shall be supplied or a study of the temperature profile shall be made. When adequate mixing of the airflow is employed, one temperature sensor in the air would be a sufficient indication of bulk temperature. As with ambient temperature measurements, at *least 50 diameters of bare* wire shall be exposed to the airflow in each leg at the thermocouple junction. At the test unit's coolant inlet, several thermocouple measurements may be required to establish the mean inlet temperature.

COMMENTARY: When air flows in a duct, bulk temperature shall be calculated because of the inherent thermal and velocity gradients. One method of determination of the bulk temperature involves measuring the air temperature at the centerline of the duct and the duct wall temperature at the same station. The duct shall be sized to yield a Reynolds number in the neighborhood of 10,000 when the flow rate is in the expected range. The duct shall be well insulated in order to minimize the temperature difference between the air and the duct. The centerline thermocouple shall be located at a point of well developed flow. With the preceding configuration, the following equation will give the bulk temperature at the station where the measurements were made:

$$t_b = 0.81\ t_{cl} + 0.19\ t_d$$

where:

t_b = bulk temperature

t_{cl} = temperature at the centerline of the duct

t_d = temperature of the duct wall.

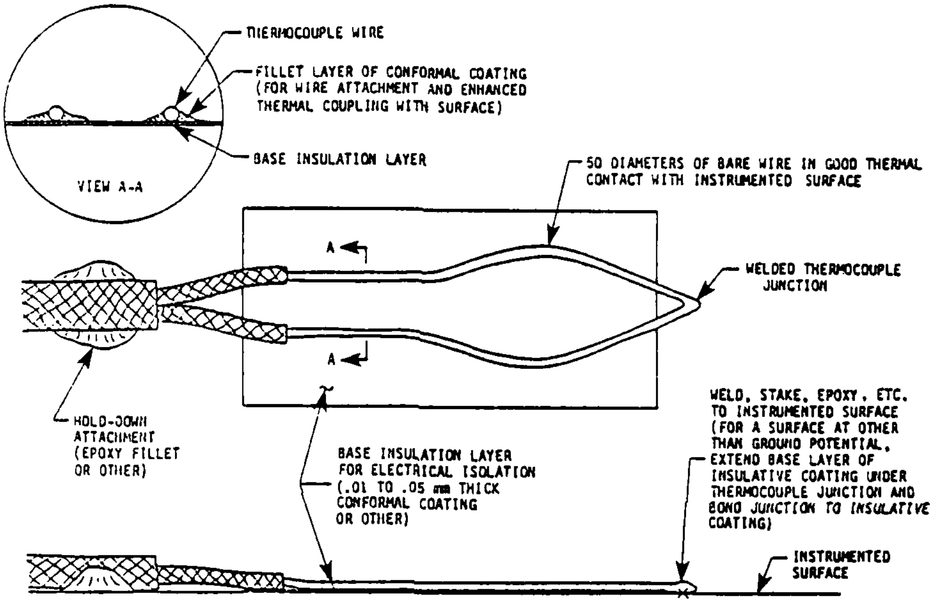


FIGURE 10-4 - THERMOCOUPLE INSTALLATION
ON A TEST UNIT CASE

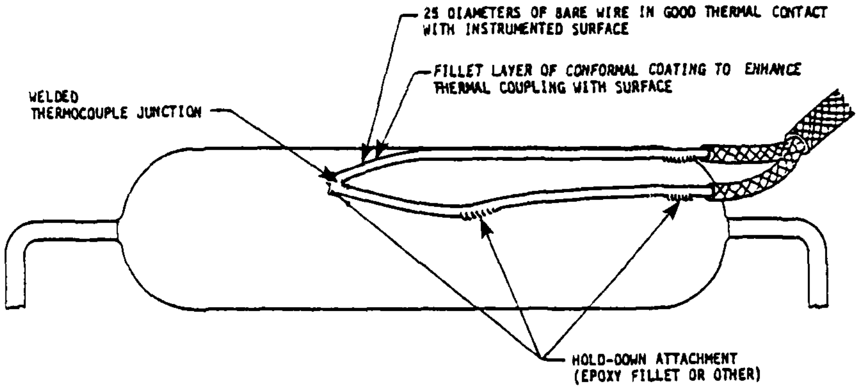
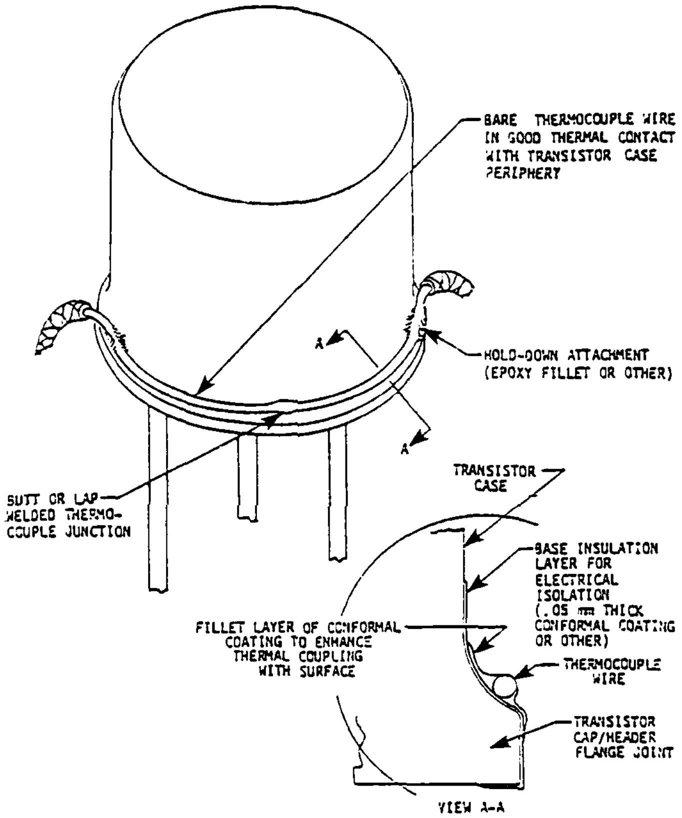


FIGURE 10-5 - THERMOCOUPLE INSTALLATION ON A RESISTOR OR DIODE



<u>FIGURE 10-6 - THERMOCOUPLE INSTALLATION ON A TRANSISTOR PACKAGE</u>

10.3 <u>TEST REPORT</u>. The test report will contain the details and results of the cooling evaluation test. The data shall include the actual test sequence used, and test conditions and results recorded as required during the test. The test record shall contain a signature and date block for certification of the test data by the test engineer.

The test data shall include a complete description of all test equipment and accessories. The test apparatus shall be adequately documented by photographs, schematics, or line drawings. All stimulus and measurement equipment shall be identified by make and model and the latest calibration date recorded.

10.4 <u>TEST PROCEDURE</u>. Figure 10-7 shows the correspondence between environmental operating conditions and test requirements.

Step (1) <u>Pre-Test Performance Record</u>. Prior to instrumentation of the test unit it shall be operated and a record made of all data necessary to determine that the test unit complies with the applicable equipment performance standards. These data will provide the criteria for checking the validity of the test regarding satisfactory performance of the test unit during and at the conclusion of the test.

Step (2) <u>Heat Dissipation</u>. Measure the total wattage input and determine the actual heat dissipation in watts for all modes of electrical operation for which the equipment was designed; e.g., standby, receiving, transmitting, etc. These measurements are to be made at the laboratory ambient temperature which shall be recorded.

Identify the electrical operating mode corresponding to maximum steady-state heat dissipation (see Paragraph 3.10).

Step (3) <u>Instrumentation</u>. Instrument the test unit.

Step (4) <u>Installation</u>. Install the test unit in the test facility.

Step (5) <u>Normal Continuous Operation</u> (Thermal Design Condition). With the test unit operating at maximum steady-state heat dissipation, stabilize the equipment at the conditions representing normal operation as given in Figure 10-7.

Record the Paragraph 10.2.2.3 data. Determine that the part temperature limits, test unit sidewall temperatures, and pressure drop meet the requirements of Figure 10-7.

> <u>COMMENTARY</u>: A heat balance made using the step 5 data and other measurements as necessary will check the performance of the test facility and associated instrumentation. The measured total heat dissipation of the test unit and simulated units shall equate to the net heat tranferred through the test chamber walls and the heat transferred to the airflows (coolant airflow through the test unit and bypass airflow through the test chamber). A heat balance which equates the heat inputs with the heat outputs within 10 percent shows that the test facility is functioning properly with all significant heat paths accounted for.

Step (6) <u>High Temperature Startup</u>. With the test unit and simulated units turned off and no coolant flow through the test unit, stabilize the equipment at the ambient temperature given in Figure 10-7 for high temperature startup.

Operate the test unit at maximum steady-state heat dissipation for 30 minutes beginning with the "ON" cycle for equipment designed for intermittent power peaks. Test conditions shall conform to the data representing high temperature startup in Figure 10-7. Cooling airflow through the test unit is turned on at the same time as the test unit. (Note that the simulated units are also turned on and their power adjusted as required to maintain the temperature of the simulated unit working surface equal to the average temperature of the adjacent test unit sidewall ± $2^{\circ}C$.) The test chamber's ambient temperature is held constant. Record the data of 10.2.2.3 at the beginning and end of the test. Record measurements: T3, T4, T5, T7, T10, M1, M2, and Q1 at 10-minute intervals throughout the 30-minute test. Determine that the part temperatures remain less than the manufacturer's maximum allowable temperature during the 30 minute test (see Figure 10-7, Requirements).

Step (7) <u>Normal Flight Operation</u>. With the test unit operating at maximum steady-state heat dissipation, stabilize the equipment at conditions representing normal flight operation as given in Figure 10-7.

Record the data of 10.2.2.3.

Determine that part temperature limits and test unit sidewall temperatures meet the requirements of Figure 10-7.

Step (8) <u>Post-Test Checkout</u>. Return the equipment to laboratory ambient and stabilize. Operate the test unit recording the pre-test performance data, Step (1).

Determine if the test unit complies with applicable equipment performance standards.

Inspect the test unit recording all damage or deterioration resulting from the test.

ENVIRONMENTAL OPERATING CONDITION	TEST CHAMBER ENVIRONMENT					TEST UNIT REQUIREMENTS		
	(H1) (a) COOLANT AIRFLOW RATE (b) $\frac{kg}{hr-kW}$	(T3) COOLANT TEMPERATURE AT EQUIPMENT INLET °C	(T5) AMBIENT AIR SURROUNDING EQUIPMENT RACK (c) °C	(T8) TEMP OF SIMULATED UNIT WORKING SURFACE °C	(P2) AMBIENT PRESSURE KPa	(T10) PART TEMPERATURE LIMIT	(T7) MAXIMUM EQUIPMENT SIDEWALL TEMPERATURE AVG./HOTSPOT °C	(ΔP3) MAXIMUM TOTAL PRESSURE DROP MM. OF WATER
FIGHTER CONTINUOUS	60	10	71	71	37.6	DESIGN	71/80	--
OTHER CONTINUOUS	89	30	55	71	75.3	DESIGN	71/80	--
REFRIGERATED GROUND	65	15.5	71	71	101.3	DESIGN	--	55.5
GROUND HOT STARTUP	117	40	85	WITHIN 2°C OF TEST UNIT	101.3	MAXIMUM	71/80	--
TRANSPORT	220	40	50	60	101.3	DESIGN	60/65	150

NOTES, SPECIFIC:

(a) See paragraph 10.2.2.3 and Figure 10-3 for definition and location of instrumentation.
(b) The maximum allowable relative humidity is 40%.
(c) Air velocities immediately surrounding the test unit shall not be greater than those caused by air movement due to natural convection effects.

NOTES, GENERAL:

(d) Test unit shall be operating at Maximum Steady-State Heat Dissipation.
(e) Equipment thermal status shall be steady-state except during High Temperature Startup.
(f) The test unit shall demonstrate acceptable functional performance in all Environmental Operating Conditions.

FIGURE 10-7 - OPERATING CONDITIONS AND TEST REQUIREMENTS

ATTACHMENT 2

STRAWMAN AIR FORCE CONTROL AND DISPLAY UNIT INSTALLATION STANDARD

AUGUST 1981

PRELIMINARY DRAFT PREPARED FOR DISCUSSION PURPOSES

August 1981

STRAWMAN AIR FORCE CONTROL AND DISPLAY UNIT INSTALLATION STANDARD

1. SCOPE. This standard establishes mechanical and cooling interface requirements for avionics equipment and instruments mounted on instrument panels, side consoles, overhead panels, and flight engineer's panels of military aircraft. Mechanical interfaces are not defined for controls and displays mounted on glare shields and side panels, usually unique to the aircraft type. For fighter and other aircraft which conventionally use standard consoles, the console standards specified herein shall apply. This Standard sets forth:

a. BASIC DESIGN STANDARDS for avionic equipment and its installation to assure suitable thermal interfaces (5.1).
b. DESIGN CRITERIA AND GUIDANCE TO provide further details concerning the equipment and installations (5.2)
c. COOLING APPRAISAL to provide data which should be utilized by users or equipment and aircraft manufacturers to confirm the equipment thermal design and to show compatibility with the aircraft environment (5.3).

This Specification is provided for use by the industry, the military operators, the airframe manufacturers and the equipment manufacturers. Specification developers for systems and subsystems should adhere to the guidance provided herein when creating Specifications for new systems.

2. REFERENCED DOCUMENTS. To be determined

3. NOMENCLATURE AND DEFINITIONS

3.1 Type of Cooling.

Type A - Cooling air FLOWS THROUGH the unit.

Type B - Cooling air FLOWS BY, over the external surfaces of the unit.

Type C - No cooling air flow is provided for the individual unit, but the general ambient temperature is controlled.

3.2 Electrical Operating Mode. A particular functional mode (or identifiable duty cycle) for which the equipment was designed; e.g., standby, receiving, transmitting, etc.

3.3 Environmental Operating Condition. An identifiable set of environmental boundary conditions anticipated in service and for which the equipment is designed (see Appendix I - Fig. 10-1, 10-2 and 10-3).

3.4 Equipment Surface Area. The equipment surface area is defined as the surface area of a rectangular box or cylinder with ends, whichever is the smaller of the two, which will completely enclose the unit excluding the flange used for mounting panel-mounted equipment and/or such projections as handles, knobs, and connectors. The equipment surface area is used for calculating the heat flux, in watts/in^2.

3.5 Equipment Volume. The equipment volume is the actual enclosed volume within the major planar or cylindrical surfaces of the unit. Handles, knobs, connectors, cooling fins, etc., are not included in the calculated volume. The equipment volume is used in the calculation of equipment heat dissipation density in watts/in^3.

3.6 Ground Survival Temperature. These are the lowest and highest ground temperatures experienced by the equipment during aircraft storage or exposure to climatic extremes. Equipment is not normally expected to be capable of operation at these temperatures. Ground survival temperatures are stated in Appendix I in accordance with the equipment cooling type.

3.7 Heat Dissipation. The thermal energy which is generated within or on the equipment and dissipated by heat transfer from the external surfaces of, or to coolant flowing through, the equipment. Heat dissipation is commonly determined by measuring power input minus power output from the unit.

3.8 High Operating Temperature. The maximum environmental operating temperature which is expected to be encountered during ground or flight. The environmental conditions for High Operating Temperature are defined in Appendix I in accordance with the equipment cooling type.

3.9 Line Replaceable Unit (LRU). As applied herein, the LRU is the instrument control panel or display unit, designed to be readily disconnected, removed, and replaced by first line maintenance organization.

3.10 Installation Standards. The mechanical and cooling interfaces between the aircraft mounting and the LRU (e.g., the electrical connector, cooling provisions and attachment method) are defined by this Specification.

3.11 Low Operating Temperature. The lowest environmental operating temperature which is expected to be encountered during ground or flight. The environmental conditions for Low Operating Temperature are defined in Appendix I in accordance with the equipment cooling type.

3.12 Maximum Duty Cycle. The electrical operating mode (3.2) for the equipment which will yield the maximum steady-state or average transient heat dissipation (3.7) when:

Normal maximum voltage is applied,

Normal frequency is applied,

The aircraft is in a straight and level flight path,

Indicator lights within the equipment are powered at maximum voltage,

For equipment that is cycled periodically it shall deliver rated power for the maximum specified time and to deliver a lower power level (or off power) for the minimum specified time. When intermittent operation is not periodic, Maximum Duty Cycle shall be as defined in the appropriate equipment specification.

3.13 Normal Operation. Normal Operation is defined as the environmental operating condition to be used as the design condition for the equipment. The environmental conditions for Normal Operation are defined in Appendix I in accordance with the equipment cooling type.

3.14 Short-Time Operation. These are the maximum and minimum temperature conditions in which equipment could be expected to be started and operated for short time periods (up to 30 minutes). The environmental conditions for short-time operation are defined in Appendix I in accordance with the equipment cooling type.

3.15 Thermal Stabilization. Stabilization or stabilize means to achieve the steady-state thermal condition; i.e., constant temperature operation. Criterion for adequate stabilization, for the tests herein, is that the subject equipment (test unit or peripheral apparatus within the test chamber as applicable) should not vary more than $2^{o}C$ over a period of one hour and a minimum period of one hour should be employed to accomplish temperature stabilization.

3.16 Temperature Critical Part. Parts whose operating temperatures are most likely to approach their design temperature limit or their maximum temperature limit.

3.17 Temperature Variation. Temperature excursions between the operating extremes which may be encountered during ground or flight. The range of environmental conditions for Temperature Variation are defined in Appendix I, for each equipment cooling type.

4. GENERAL CONSIDERATIONS

4.1 Installation Locations.

4.1.1 Instrument Panel Mounted Equipment. Instruments, Control Units, Display Units and combined Control/Display units are installed in the instrument panels of aircraft: These equipments are included in that the thermal characteristics are specified but the electrical interfaces are not. Appendix II gives the preferred standard configurations and dimensions for panel mounted instruments. In addition, recent developments have added CRT Instruments as a new equipment in the instrument panel area. CRT Instrument mechanical and thermal interface needs are covered herein.

COMMENTARY

The control and display units which are designed into the instrument panel have been unique to the aircraft in most instances.

Electronic flight instruments and engine instruments (CRT Instruments) shall be common to many aircraft for the future and therefore require one or more standard tray mounting/form factor configurations, as well as controlled thermal characteristics.

The mechanical characteristics for CRT instrument cases are described in 5.2.1.

4.1.2 Console Overhead and Flight Engineer's Panel. Units used in the console, overhead, and Flight Engineer's panels traditionally have used the Military Standard MS25212 (DZUS) form factor and passive cooling. This document uses the DZUS mechanical interface and defines three categories of cooling. The equipment thermal interface described in Section 5 of this document applies.

COMMENTARY

The use of the cockpit side and center consoles for simple controls has been traditional. Recently, however, more active electronic circuitry has been included in control units. The increased thermal dissipation has resulted in increased operating temperatures and decreased reliability. It is the intent of this document to provide the cooling standards needed to assure an optimum reliability level without imposing undue design limits.

4.1.3 Glare Shield and Side Panel Mounted Equipment. Controls and displays mounted in the Glare Shield and Side Panels traditionally have been unique designs for each aircraft configuration. This document does not define the mechanical interface, but guidance is provided for cooling these units.

4.2 Installation Design. Instrument panels, trays, and other mounts will, be custom designed in most cases to match the space available in a particular aircraft and the temperature, shock, vibration and other environmental factors. The design of the mounting facilities is therefore, of necessity, the responsibility of the airframe manufacturer.

Ducting and plenums should be provided as an integral part of the aircraft equipment mounting, or on adjacent structure, to direct the flow of cooling air through or around the LRU. Apertures are defined for each LRU to to provide for passage of the cooling air through the unit where flow-through cooling is provided.

The standard aircraft installation should accommodate any manufacturer's CDU designed to an Equipment Specification compatible with this standard, with complete mechanical cooling interface compatibility.

5. DESIGN STANDARDS

5.1 General. *This section defines the basic* standards which form the foundation for achieving the levels of unit interchangeability and maintenance free operating life desired by the Air Force.

The Standard instrument and CDU form factors are intended to minimize the multiplicity of sizes and shapes, to afford the installer standard space envelopes and panel cutouts, to simplify changes in the field, and to reduce logistics problems.

5.1.1 Load Factor. Instrument panel assemblies and independently mounted CDUs shall not suffer damage, or fail to operate during or subsequent to sequential application of the following load factors.

Horizontal plane:	Two mutually perpendicular axes ±6.1 g.
Vertical axis:	Up 4.1 g Down 10.4 g

They shall remain intact and restrained when exposed to the following load factors applied sequentially.

Horizontal plane:	Two mutually perpendicular axes ±9.15 g
Vertical axis:	Up 6.15 g Down 15.1 g

5.1.2 Vibration Environment. The CDU installation concepts and the design of the panels and trays shall control the vibration inputs that are transmitted to the equipment to no more than 0.04 g^2/Hz between frequency limits shown in Figure 1. The aircraft procuring activity shall verify by actual test that vibration inputs are properly controlled.

5.1.4 Temperature/Altitude. The CDU shall be designed to operate in the temperature/altitude environment shown in Figure 2.

5.1.5 Electrical Bonding Interface. All metal parts shall be maintained at airframe potential by the application of suitable bonding and grounding techniques. The ground path provided shall be capable of conducting the maximum fault (short circuit) current. Under such conditions, the resistance of the ground path shall not exceed 2.5 milliohm in accordance with MIL-B-5087, para. 3.3.5.1.

5.2 Physical Characteristics.

5.2.1 Instrument Panel Mounted Instruments. The philosophy has been to maintain as small a number of different bezel sizes and incremental case lengths as possible for the indicators to be mounted in instrument panels. See Appendix II.

5.2.2 Larger, Integrated Display Units. Tray mounted CRT displays should use the form factor and mounting means described in Figure 3.

5.2.3 Console Mounted Units. All units mounted in the consoles, overhead, or Flight Engineers panels shall conform to MS25212. Many such units will continue to need only the ambient or area cooling. Units with thermal dissipation levels higher than that described for Type C cooling should utilize either the Type A or B cooling as described in 5.3.2.

5.2.4 Other Mounting Area. The needs of other mounting areas may be aircraft unique.

5.2.5 Protrusions on the Case. It is extremely important that protrusions on the front of the units be so positioned as to permit the unit to be installed without the necessity of removal of knobs, lights, etc. If it is deemed impractical to meet this requirement, the knobs, etc., must be easily removable and replaceable by some positive locking, quick disconnect method.

These protrusions should not extend more than one and one-half inches in front of the datum or reference plane of the instrument.

Protrustions on other faces of the case are prohibited except for connectors specified in the following sections. The length dimensions should include any rear protrusions other than these connectors.

No protrusions on the sides of the case shall extend outside of the case envelope as defined in this document.

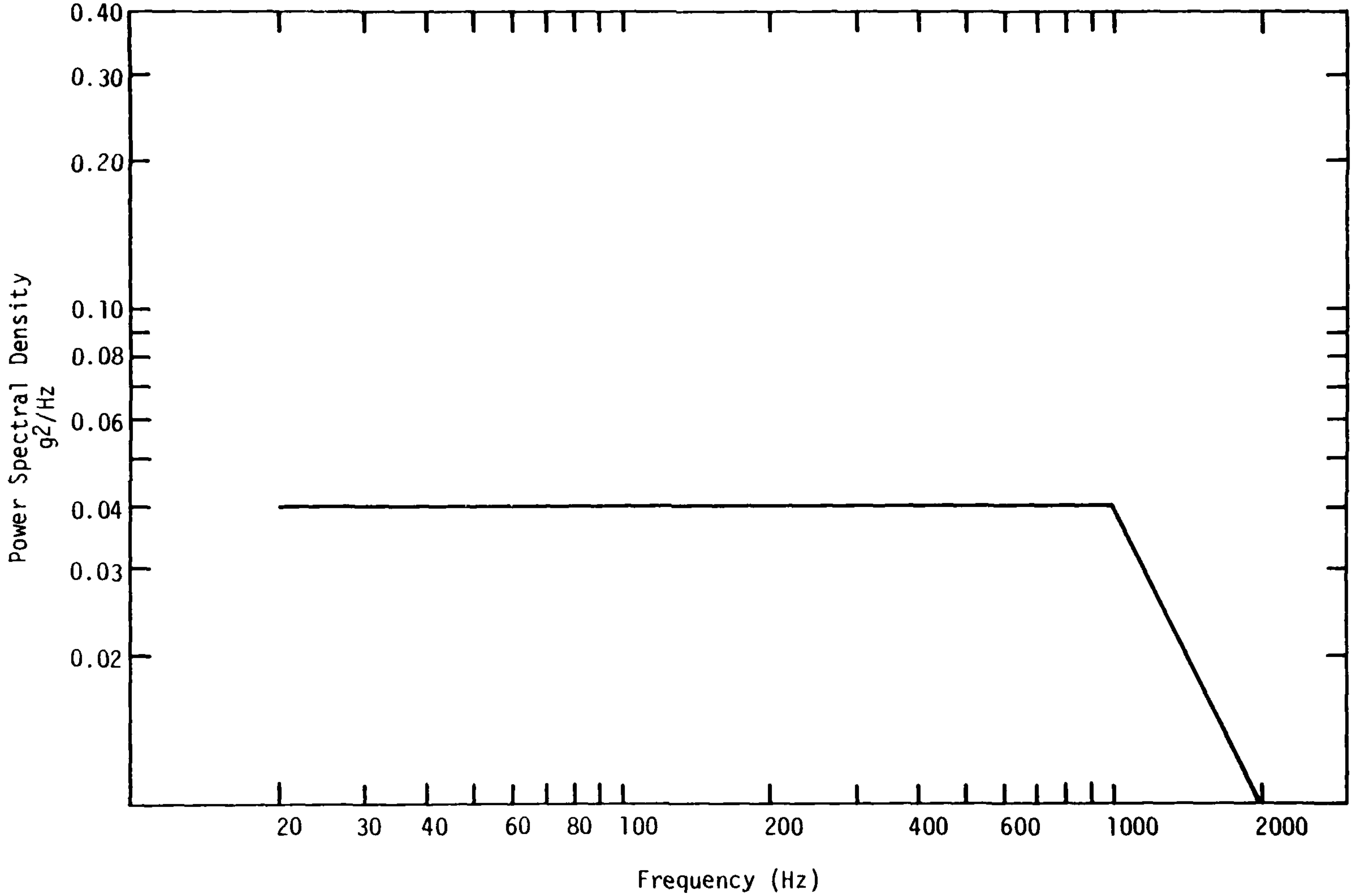


FIGURE 1 - VIBRATION ENVIRONMENT

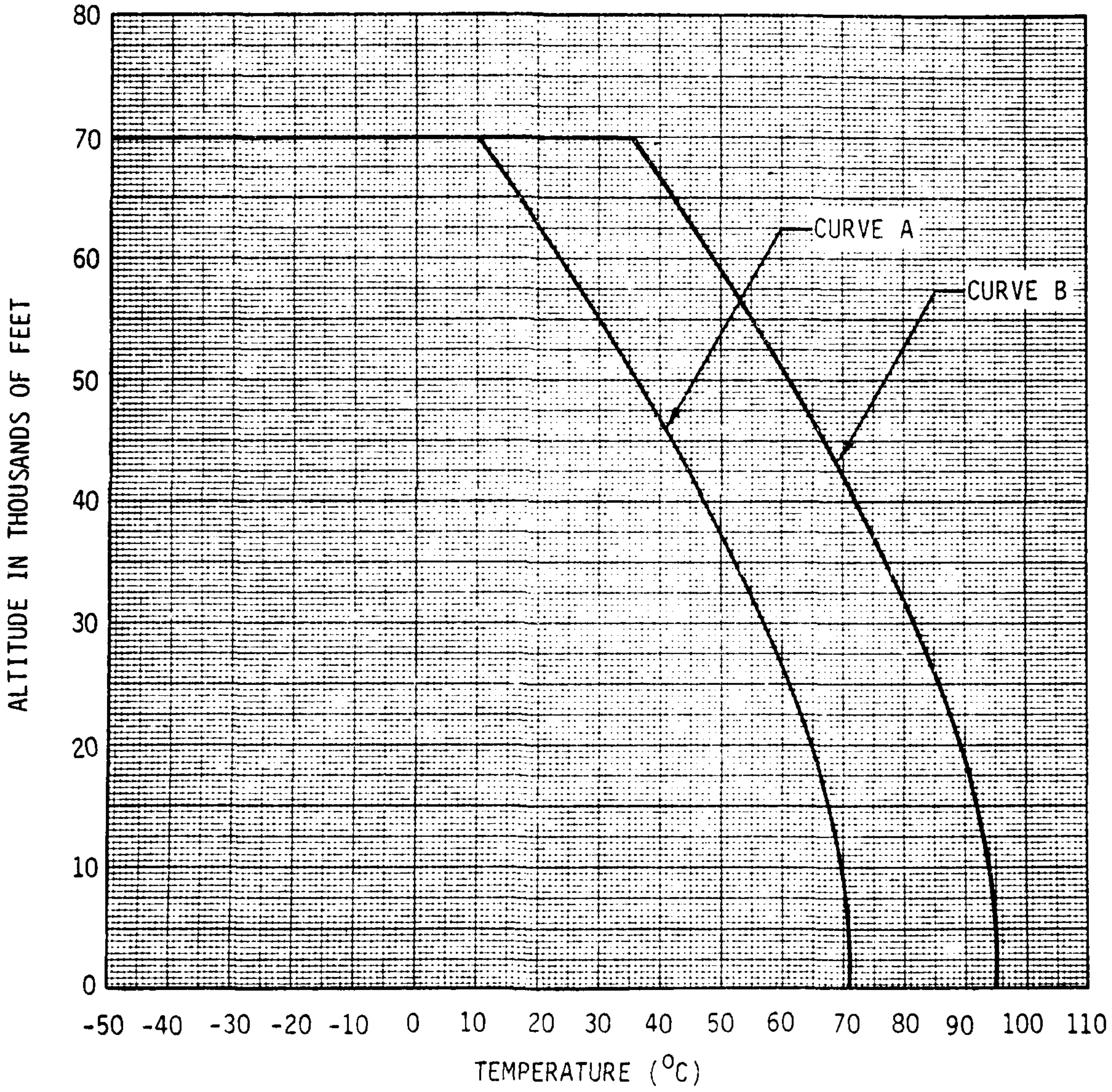
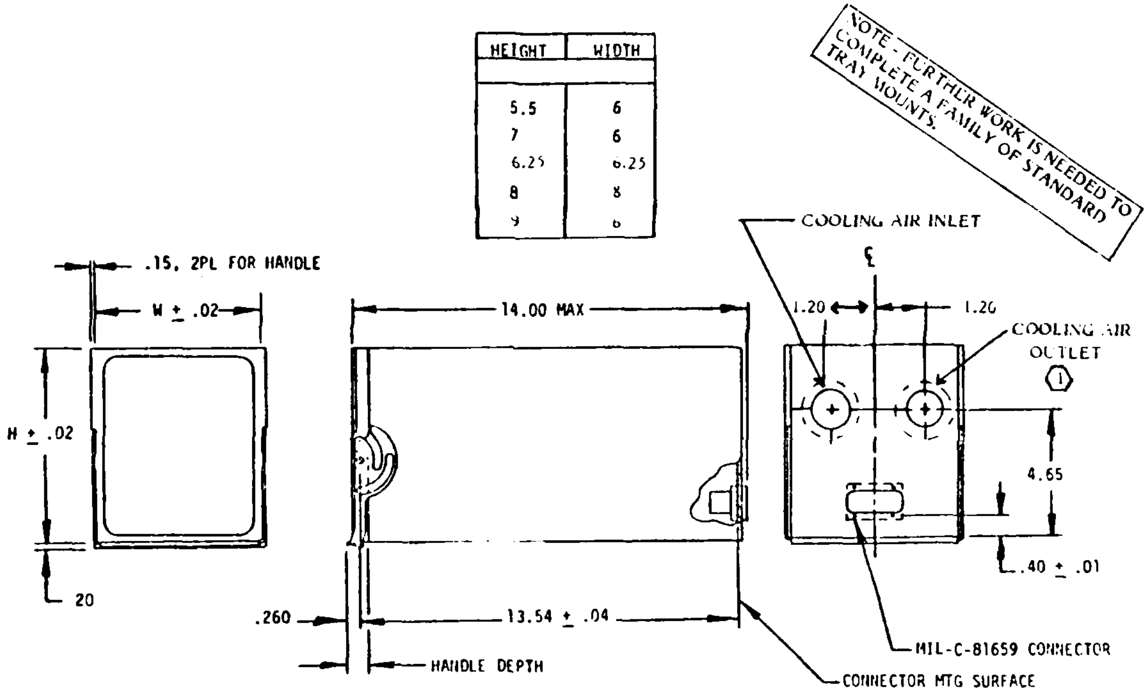


FIGURE 2 - TEMPERATURE/ALTITUDE ENVIRONMENT



HEIGHT	WIDTH
5.5	6
7	6
6.25	6.25
8	8
9	6

NOTE - FURTHER WORK IS NEEDED TO COMPLETE A FAMILY OF STANDARD TRAY MOUNTS.

NOTE: Surface surrounding the cooling air inlet and outlet should mate with a donut type air seal on the mounting tray.

FIGURE 3 - TYPICAL TRAY MOUNTED FORM FACTOR

5.3 Thermal Management. The purpose of cooling systems is to maintain the internal components of electronic/electromechanical equipment at temperatures which will achieve a long and predictable service life. This goal can only be achieved by a cooperative effort of both the equipment and airframe manufacturers to produce compatible equipment and installation cooling system designs. Proper maintenance and operation of cooling systems in service is also needed.

This section provides guidance for the provision of equipment cooling. The equipment thermal evaluation described in this document provides verification of the equipment design for general aircraft application. The standard cooling interfaces are described in Section 5.

COMMENTARY

> The Air Force has found in recent years an increase in failures attributed to inadequate thermal management. A first concern with such failures is the potential impact upon the operational availability of the aircraft. A second conern, is the logistic support cost impact, when equipment fails to achieve an optimum service life between maintenance actions. This document provides thermal design STANDARDS (standard cooling interfaces) needed for equipment inter changeability, and, standard equipment thermal evaluation methods aimed at ensuring better equipment service life.

5.3.1 Cooling Medium. The cooling medium shall be air supplied in accordance with the design requirements of MIL-E-87145 and moving through or around each LRU. The interface between the LRU and the thermal environment provided by the avionic cooling system is defined for each type of equipment. Units which do not require Flow-Through cooling shall not have openings on any surface. The maximum permissible power dissipation levels are defined in 5.3.3.

There shall be no air paths into or out of the equipment other than the designated inlet and the exit of the units.

COMMENTARY

> In all cases, the LRU designer should make efficient use of the cooling air supplied to the unit. To this end, internal air distribution systems, baffles, heat exchangers, cold plates etc., should be judiciously employed to avoid hot spots. Particular attention should be directed to avoiding air leaks that allow coolant to bypass heat transfer surfaces.

5.3.2 Cooling Methods. This specification establishes three thermal interface configurations (three types of heat transfer boundaries between the equipment and the aircraft installation). These environments are generally applicable to any instrument, indicator, control or display unit. Since cooling needs vary greatly among the different types of control, display and indicator units, this document defines three separate categories or types of cooling as follows:

Type A - Flow-Through provides a prescribed quantity and quality of cooling air which the LRU designer should circulate through the LRU, using the interface configuration shown in Figures 3, 4, or 5.

Type B - Flow-By defines a range of maximum case temperatures to be maintained by cooling air which the installation designer should circulate over the external surfaces of the LRU, using the interface configuration shown in Figures 6 or 7.

Type C - No cooling air is provided for the individual LRU, but the general ambient temperature is controlled as set forth in 5.3.7.

NOTE: A summary of cooling limits and applications is provided in Table 1.

COMMENTARY

> Air movement through and/or around the equipment is produced by the application of cooling air supplied by the aircraft environmental control system.
>
> The design goals for Type A equipment include optimization of coolant paths and expenditure of available pressure drop in a way that will maximize cooling of temperature sensitive parts. Internal fans shall not be used unless so described in the applicable equipment specification.
>
> Units that do not need forced air cooling must pass appraisal test with no air provided to the unit.

5.3.3 Thermal Dissipation Limits (Maximums). Because of limited heat transfer area and cooling air flows, it is necessary that equipment internal power dissipation limits be specified which are consistent with the thermal limits specified herein.

The unit average power surface flux or power density should not exceed either of the limits set forth in this Section as given in watts per square inch (W/in^2) of surface or in watts per cubic inch (W/in^3) of volume. Average unit power density is defined as:

$$\frac{\text{Heat Dissipation}}{\text{Surface Area}} \quad \text{or} \quad \frac{\text{Heat Dissipation}}{\text{Volume}}$$

Heat Dissipation, Surface Area and Volume are defined in Section 3. The heat dissipation to be used is that which occurs during the Maximum Duty

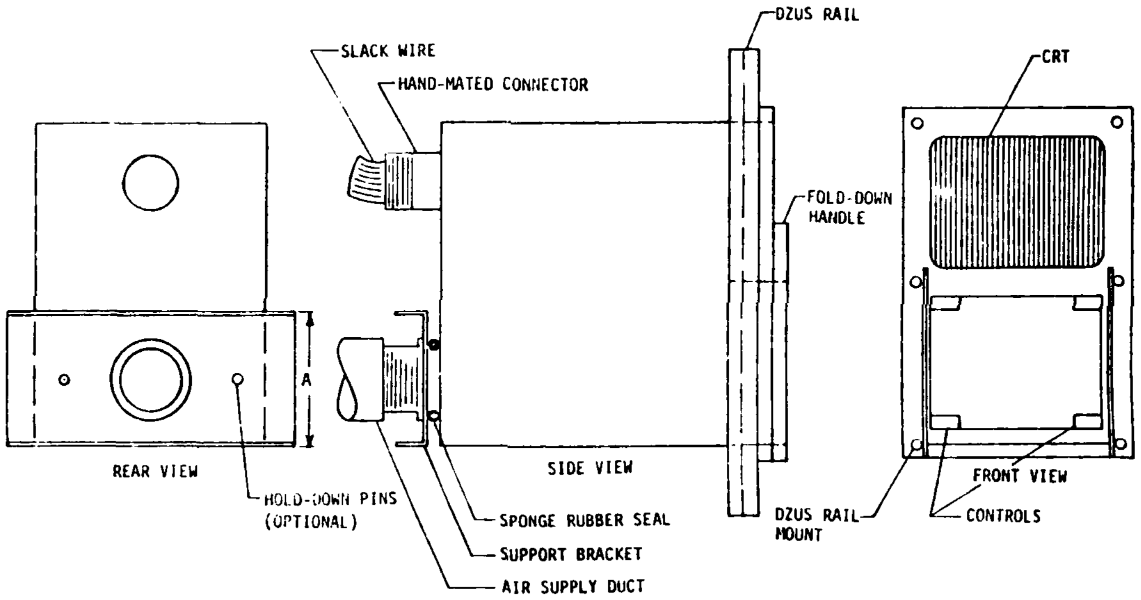


FIGURE 4 - STANDARD FLOW-THROUGH COOLING FOR MS25212 (DZUS) RAIL MOUNTED UNITS

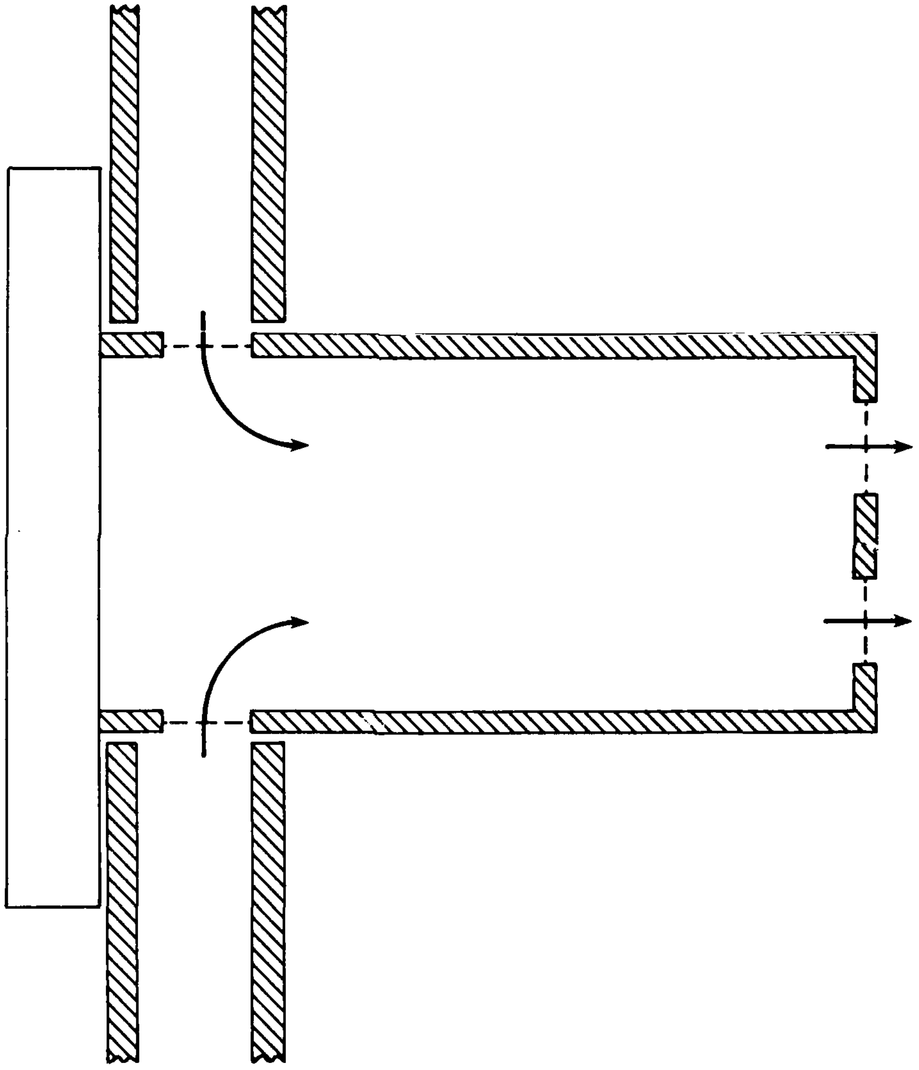


FIGURE 5 - PANEL MOUNTED FLOW-THROUGH COOLING

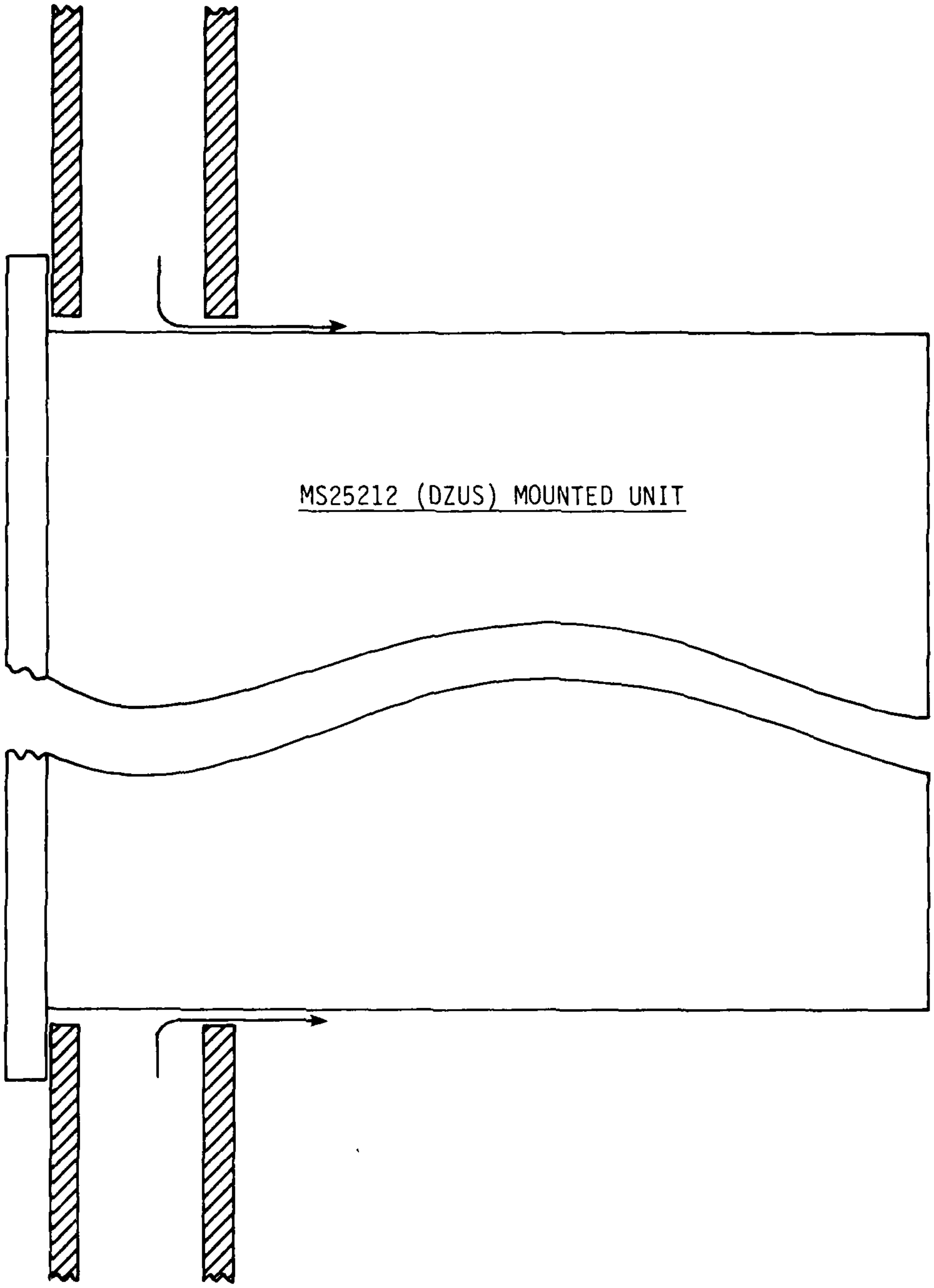


FIGURE 6 - PANEL MOUNTED FLOW-BY COOLING

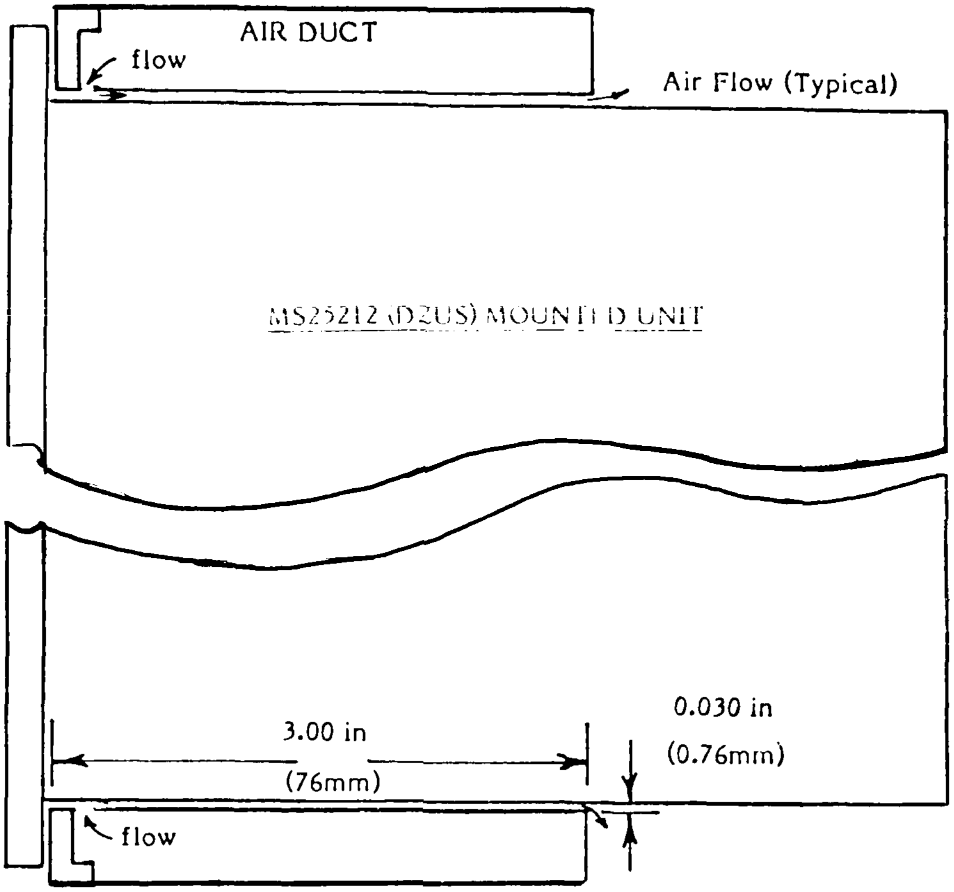


FIGURE 7 - DZUS RAIL MOUNTED FLOW-BY COOLING

Cycle (average heat dissipation for the maximum duty cycle during steady-state flight operation) as defined in Section 3.10.

Experience has shown the user can realize the desired maintenance cycle times only where the thermal dissipation is limited for each type of cooling. These limits are defined in Table 1 in terms of thermal flux density for both the case area (See Section 3.4) and unit volume as follows.

Table 1. MAXIMUM THERMAL DISSIPATION

Type of Cooling	Surface Area Watts/In^2	Volume Watts/In^3
Type A (Flow-Through)	N/A	1.0
Type B (Flow-By)	0.15	0.20
Type C (Ambient)	0.05	N/A

Notes:

a. N.A. indicates limit is "Not Applicable."

b. The lower of the limits, for area or volume, is the controlling factor. The Type A Flow-Through shall be used in any equipment where either limit of 0.15 Watts/In^2 or 0.20 Watts/In^3 is exceeded.

COMMENTARY

COOLER IS BETTER!

The users are convinced that the number of failures of avionic equipment can be reduced by providing more effective cooling. Obviously this would not apply if carried to the extreme, but over any range likely to be encountered on the flight deck or cockpit of aircraft, THE COOLER THE BETTER!

5.3.4 Surface Temperature Limits

5.3.4.1 Face Temperature. In normal operations test, the equipment face temperature (excluding the knobs, etc. which are limited by Section 5.3.4.2) should not be greater than 15°C above the ambient temperature in front of the unit.

5.3.4.2 Control Surface Temperature. In the normal and emergency operating conditions control surfaces which are manipulated by hand (such as knobs, buttons, pushbutton switches, etc.) should not exceed the limits shown in Figure 8. The limit (maximum control surface temperature) is a function of the contact coefficient which is calculated using the thermal conductivity, density and a specific heat of the material. The limit is given as an allowable rise (delta T) above the ambient temperature in front of the unit.

5.3.4.3 Case Temperature Limits (Type A Equipment Only). For Type A equipment, the design shall be such that for the normal ground or flight conditions described in Appendix I, when the cooling airflow set forth in 5.3.5 is provided, the average temperature of any one of the equipment's four side surfaces should not exceed 60°C and there shall be no surface hot spot temperatures in excess of 65°C.

5.3.4.4 Hot Spot Case Temperature (Type B Equipment Only). For Type B equipment, the design should be such that the equipment case hot spot temperatures should not be greater than 5°C above the average case sidewall (four sides exclusive of the front and rear surfaces) temperature schedule defined in Figure 10-2 for the normal operation or Thermal Design Condition.

5.3.5 Cooling Air Flow Rate. The equipment should be designed to efficiently use (and the standard aircraft installation should supply) cooling air in proportion to the equipment's steady-state heat dissipation defined in 3.7.

5.3.5.1 Flow-Through (Type A) Cooling. The air flow rate should be 220 $kg.hr^{-1} \cdot kW^{-1}$ when the coolant air inlet temperature is 40°C, at sea level pressure, or in accordance with Figure 9 when the inlet cooling air temperature is reduced. The airflow rate can be reduced proportionally down to a minimum airflow rate of 82 $kg.hr^{-1} kW^{-1}$ at a coolant air inlet temperature of 10°C in ground or flight operation.

5.3.5.2 Flow-By (Type B) Cooling. The air flow rate and its movement with respect to the unit should be such that the average case surface temperatures do not exceed the limits shown in Figure 10 for the average case surface flux (watts/in^2) set forth for the unit in the applicable Equipment Specification.

COMMENTARY

The thermal "interface" for Type B (Flow-By) equipment is defined as an average case side temperature limit. This "interface" is so stated because it is necessary to establish an effective heat transfer rate in each installation design. The coolant airflow rate necessary to achieve this "interface" limit depends upon the geometry of the equipment installation and the specified method of air delivery.

The thermal appraisal in Appendix I utilizes this "interface" to define Normal Ground Operation test conditions.

5.3.6 Air Pressure Drop Through Type A Equipment. The coolant air pressure drop through the equipment should be 50.8 ± 5 mm of water at a temperature of 40°C and the standard flow rate. The pressure drop does not include the drop through a metering orifice when such orifice is located external to the equipment case; e.g., in a

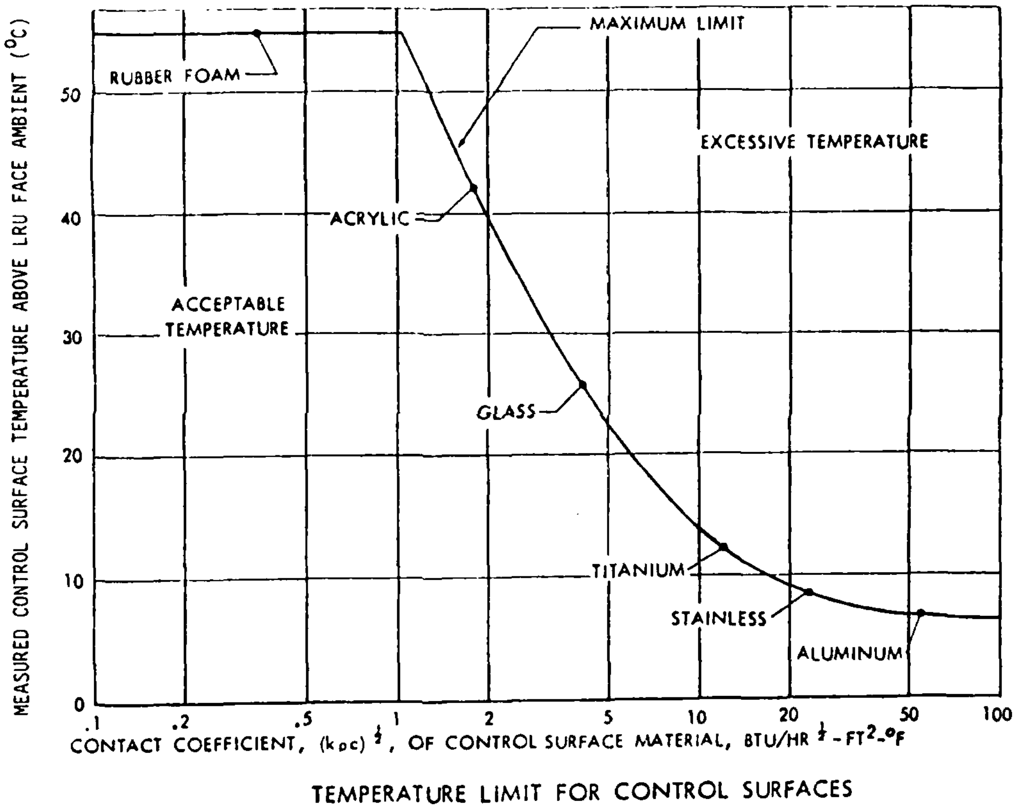


FIGURE 8 - TEMPERATURE LIMIT FOR CONTROL KNOBS

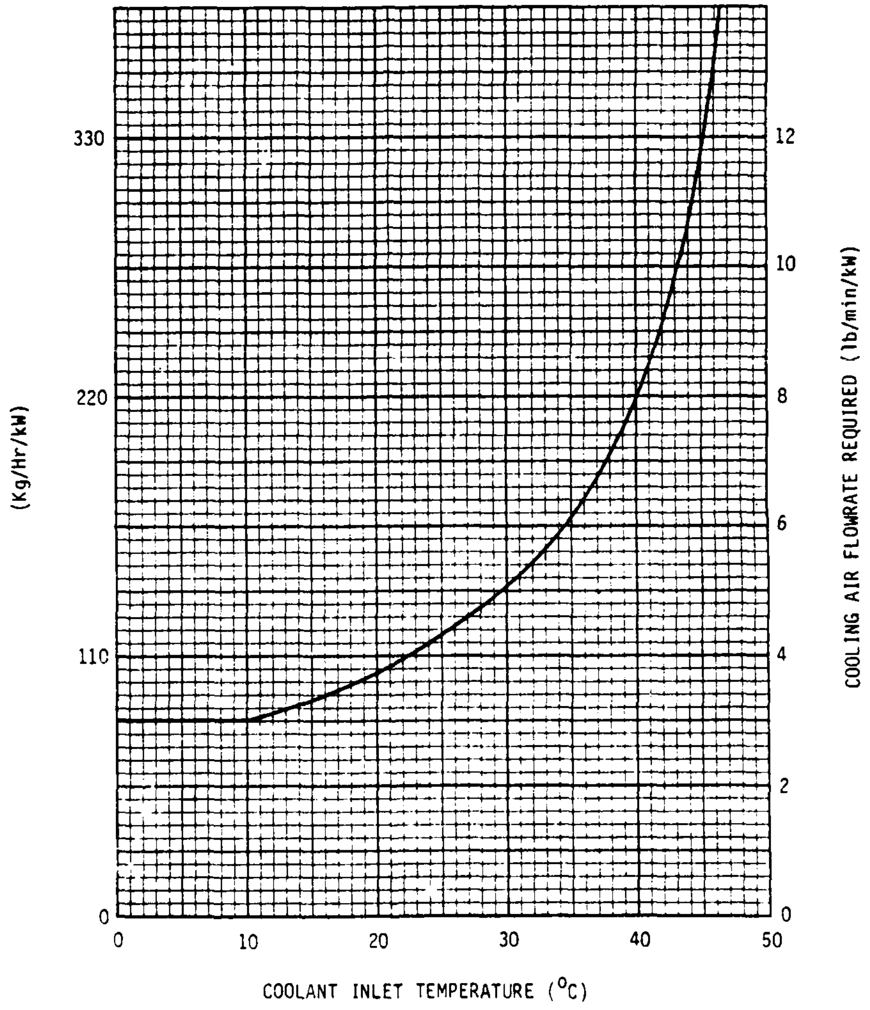


FIGURE 9 - COOLING AIRFLOW REQUIREMENTS

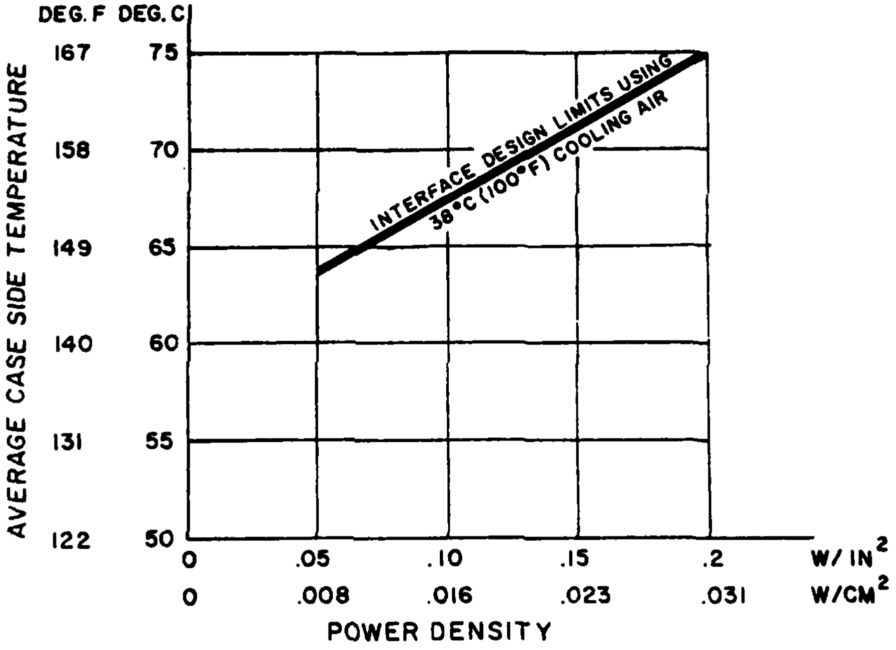
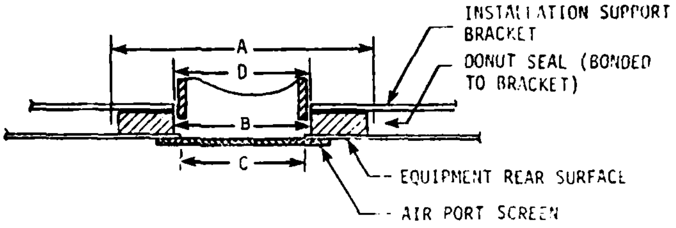


FIGURE 10 - MAXIMUM CASE TEMPERATURE



DIMENSION	DEFINITION
A = D + 1.125" (+ 28.58 MM)	DIAMETER OF UNOBSTRUCTED FLAT MATING SURFACE ON LRU
B = D + .125" (+ 3.17 MM)	INSIDE DIAMETER OF DONUT SEAL (UNCOMPRESSED)
C = D - .070" (- 1.78 MM)	INSIDE OPENING DIAMETER
D	AIR CONNECTION SIZE

D OUTSIDE DIAMETER TUBE SIZE		UNIT DUTY CYCLE HEAT DISSIPATION ~ WATTS
INCH	MM	
.50	12.70	0 to 20
.75	19.05	21 to 50
1.00	25.40	51 to 80
1.25	31.75	81 to 120
1.50	38.10	121 to 180
1.75	44.45	181 to 250

FIGURE 11 - AIR CONNECTION INTERFACE

equipment mount tray. (For test purposes, corrections may be made where the laboratory ambient pressure is other than 1 standard atmosphere. When internal blowers are used, the flow resistance should not exceed the above limits.

In some special cases an internal blower may decrease the flow resistance to zero or below, causing reduced airflow through other equipment. This shall not be permitted to exist except intermittently (i.e., not to exceed 30 seconds each two minutes).

5.3.7 Ambient Air Temperature. The ambient air temperature behind the panel or within the console shall be controlled by the installation design to within the following limits:

a. Short Term Operating Temperature, 30 Minutes Duration

-40°C to 85°C

NOTE: These are startup conditions where equipments are turned on immediately following a ground soak. It is expected that these conditions will be of short duration since cooling or heating air circulation or other means of controlling compartment temperature would be enabled concurrently with (or preferably preceeding) avionic equipment startup.

b. Continuous Low and High Operating Temperature, Ground or Flight

-15°C to 70°C

c. Normal Ground Operating Temperature

55°C

d. Normal Continuous Flight Operation

45°C

5.3.7.1 Ground Survival Temperatures. The equipment shall be designed for a ground survival temperature range of

-62°C to 95°C

NOTE: These are the lowest and highest ground temperatures expected to be experienced by equipment during aircraft storage or exposure to climatic extremes with power off. Equipment is not expected to be capable of operation at these temperatures, but must survive them without damage.

5.3.8 Coolant Air Temperature (Types A and B). The bulk temperature of the supply coolant air should be as follows:

a. Short-Time Operation, Equipment Startup, 30 Minutes Duration.

-40°C to 70°C

b. Normal Continuous Flight Operation

15.5°C to 40°C

c. Normal Continuous Ground Operation

15.5°C to 40°C

5.3.9 Coolant Air Relative Humidity. The coolant air shall contain no entrained condensate.

5.3.10 Cooling Air Interface. A standard mechanical and cooling air transfer interface shall be used by equipment and installation designers to assure the degree of equipment interchangeability desired by the users. This document describes the basic configurations applicable to each type of unit.

5.3.10.1 Minimum Hose/Duct Sizes. All cooling air inlet and outlet hoses and/or ducts should be sufficiently large to carry the volume of air set forth in 5.3.5.1 at a conservative velocity (see 5.5.5). The minimum sizes which are recommended for circular hoses connected to ducts with a wall thickness of 0.035 in. (0.9 mm) are set forth in Figure 11.

5.3.10.2 Panel Mounted Displays. Figure 3 shows a typical configuration for the location of the cooling air inlet and outlet connections for tray mounted display units, including those with a CRT. The applicable equipment specification shall provide specific dimensions and tolerances selected from a family of standard tray mounts.

5.3.10.3 Standard for DZUS Mounted CDU. Figure 4 shows the standard configuration for the supply and evacuation of Type A cooling air in an MS25212 (DZUS) rail type installation. The air is supplied through the standard air connection interface shown in Figure 11 from a hose located behind the unit.

COMMENTARY

The installation designer should select the type of material and thickness of the seal which will determine the clearance between the aircraft interface and the unit rear face. The equipment designer should assure sufficient rigidity of the rear surface of the unit to prevent air leakage or other problems that might result from a deflection of that surface when the unit is installed.

All air shall be exhausted through the rear surface or rear portion of the side panels of the CDU. The front 3 inch area of the side panels may be used for the cooling air supply configuration shown in Figures 5, 6, and 7. The heated air shall be removed by the environmental control system.

COMMENTARY

Equipment designers are encouraged to make optimum use of the rear surface of the CDU as a heat exchanger since it normally provides the greatest freedom for air flow, unrestricted by adjacent units. The use of the top and bottom panels (those sides perpendicular to the rails) should not be used to exhaust air since the space between adjacent units is seldom more than an eighth inch. If it is essential to use the top and/or bottom panels for air exhaust the subject surface(s) should be recessed to provide adequate air passage.

5.3.10.4 Foreign Object Screen. All cooling air inlets and outlets shall incorporate a suitable means of preventing the intrusion of foreign objects.

5.4 Electronic Design

5.4.1 Equipment Component Parts Application. This section is advisory in nature to caution the manufacturers of avionics equipments regarding the problems associated with electrical and electronic parts applications. To achieve electro/thermal stress levels consistent with desired performance and reliability, electronic part temperature shall be limited as follows:

a. Electronic part temperatures for any anticipated operational mode shall not exceed the component manufacturer's maximum operating curve. (This temperature limit is usually expressed as a function of power dissipation but it may be a function of voltage, current, or other parameter of operation or combination thereof.) Anticipated operational modes include the startup transient following a high temperature soak, the high continuous operating temperature, and continuous operation at reduced coolant flow rate (see 5.5.3 and 5.5.4). It is expected that all of these conditions may be encountered during the equipment lifetime but they do not represent normal operations and therefore are not the basis for a conventional reliability assessment. However, the probability of occurrence is considered high enough that electronic parts shall be able to survive these operating conditions without a drastic reduction of equipment life (as would be expected to occur when the component manufacturer's absolute maximum is exceeded).

b. During normal operation of equipment, defined by the thermal design condition (see 3.12 and 3.13), electronic part temperature shall not exceed a limit determined by the reliability number apportioned to that part based on the reliability number assessed against the equipment. MIL-Handbook 217 shall be used as the basis of determination that the applied electrical stresses and the maximum predicted part temperature are in accordance with the reliability apportionment for the part. (It should be noted that "part temperature" actually means part surface temperature and that measurement or calculation shall relate to surface temperatures and not internal operating temperatures.)

COMMENTARY: The maximum predicted part temperature shall also take into account the effect of temperature of adjacent parts as well as the ambient air. It is no good to calculate the maximum predicted power/operating temperature of, say, a transistor based on the apportionment and then place it physically next to a wire wound resistor whose maximum predicted power/operating temperature is also based on the reliability data for the resistor. Either the maximum power dissipated by the transistor shall be derated to take into account the ambient created by the resistor or the resistor shall be rerated to create an environment which does not have a deleterious effect on the transistor.

5.4.3 Abnormal Operation

Equipment designers should give due regard to the need for Types A and B equipment to continue to operate when the flow of coolant air is interrupted due to a failure of the cooling system or the other abnormal conditions set forth in 5.5.2. This consideration may, in fact, prove to be the pacing consideration in the thermal design of some equipment.

COMMENTARY

The equipment designers should consider both the potential impact of abnormal conditions and the operational needs for the subject equipment during and following such conditions. In some equipment a temporary degradation in performance may be acceptable. The users also recognize that failure of the cooling system may degrade the maintenance action interval without compromise of immediate system reliability.

5.5 Environmental Control System (ECS)

5.5.1 General. Coolant air shall be supplied to the cockpit control and display units in accordance with the design requirements of MIL-E-87145. The ECS shall provide sufficient cooling to meet the equipment environmental control parameters (i.e., airflow rate, ambient temperature, case temperature, etc.) defined for each equipment cooling type defined in 5.3.2. The normal design conditions are predicated on a flight deck ambient temperature of 40°C and a cooling system supply air temperature of 40°C. The equipment cooling system should provide the equipment environment parameters when using 40°C air (i.e., without supplemental air conditioning).

COMMENTARY

Type B equipment needs pressure driven cooling air, washing the surfaces of the equipment behind the panel surface. The cooling method is not specified, to allow flexibility of the cooling system and equipment installation design.

An exhaust system, in addition to the blowing system, is usually needed for Types B and C cooling.

The cooling system should not utilize the cabin conditioned supply air as the basic source, because this air often is heated to a high temperature during cold ambient conditions both in flight and on the ground. The temperature extremes encountered in the cabin conditioned supply air, due to the "bang-bang" servo system, can result in more avionic equipment failures rather than the expected improvement from providing such "cooling". However, it may be used for emergency or other abnormal operations.

5.5.2 Abnormal In-Flight Operation. Maximum case temperature for emergency operation (such as failure of the primary cooling system) shall not exceed either of the limits of the Short-Time Operating Temperature, High (30 minutes duration), the High Operating Temperature (continuous), or the Emergency Operation (30 minutes duration) conditions shown in Appendix I.

5.5.3 Indication of Airflow. The cooling system shall provide a means to alert flight and/or maintenance personnel to a loss of airflow, whenever the avionic equipment is powered. This indication should permit appropriate action to be taken prior to equipment overheat when such a condition exists, and should be displayed for both flight and ground crew alert.

COMMENTARY

Installation designers should consider automatic shutdown of nonessential equipment when loss of airflow is detected.

5.5.4 Supplemental Cooling. Supplemental air conditioning may be used to increase equipment life. Such air shall be free of entrained moisture. If moisture is present, then the air must not be allowed to impinge directly on the equipment.

COMMENTARY

The use of conditioned air to provide additional equipment environment temperature control during severe ambient conditions may be necessary for aircraft which operate frequently in these severe environments.

5.5.5 Acoustic Noise. The equipment and installation designers should take adequate precautions to preclude generation and/or transmission of acoustic noise beyond the LRU and air ducts. The ambient acoustic background noise due to cooling airflow as measured at each crew station shall not exceed 45 dB(A).

5.6 Design Verification. Each CDU design should be proved by the appraisal tests detailed in Appendix I to demonstrate the unit's capability to perform and survive under the conditions set forth in this document.

5.6.1 Equipment Design Limits. The equipment thermal environments are tabulated in Appendix I, Figures 10-1 through 10-3. The equipment design limits are as described for the "normal" or "normal ground" and "normal flight" environmental conditions.

The equipment is expected to meet the design limits defined in this section when the interface control parameters defined in Appendix I, as applicable, are provided. A Cooling Evaluation Test, shall be performed to determine that the equipment is in compliance with the design limits and interface standards defined in this document.

The test environmental control parameters and performance requirements are referenced to the standard test setup of Appendix I, Figures 10-4 through 10-8. Several test setups are necessary to define the test configuration for all the cooling types defined herein. The letters and numbers within the circles are test measurement points defined in the instrumentation section of Appendix I. The first three columns of Figures 10-1, -2, and -3 identify the equipment thermal environment control parameters and the applicable design limits.

Appendix I also defines the environmental extremes to which the equipment is expected to be subjected in-service. Testing to only a part of these environmental conditions is included in the Cooling Evaluation Test. However, the equipment is expected to be designed for these extremes.

COMMENTARY

The users strongly encourage the equipment designers to optimize the cooling for maximum service life between maintenance actions. It is not considered acceptable to design only to meet the equipment certification environmental tests. The objective for avionic equipment should be not more than one maintenance actions per 5,000 flight hours.

5.6.2 Identification and Data Tabulation for Heat Dissipating and Temperature Critical Parts. A thermal analysis should be performed prior to finalization of the equipment design, to assure that the equipment is designed in accordance with the required standards of thermal design. This analysis should include a parts data tabulation and should predict the parts temperature for selected critical parts to assure the parts will operate at reliable limits. This procedure will help eliminate potential thermal problems at an early stage in the design.

a. Description. Identification of the part type should be presented under a column headed "description;" e.g., R107 resistor, 2N2484 transistor, 1N746 diode, CDR05 capacitor, etc. The term part should include encapsulated assemblies.

b. Schematic Identification. The tabulated data should include the schematic symbol for each part; e.g., R106, Q127, V701, etc.

c. Location. A general description of the location of the part should be provided.

d. Manufacturer's Maximum Rated Operating Dissipation. May be the absolute maximum recommended by the part manufacturer or may be some upper limit less than the absolute maximum operating dissiption established by the equipment manufacturer.

e. Heat Dissipation. The value for the rate of energy, in watts, being dissipated by the part during operation at the Maximum Duty Cycle shall be tabulated. Preferably this value should be the result of measured data, but it may be determined through calculations.

f. Maximum Surface Temperature (T sub M). This is the absolute maximum surface temperature allowable in the above, (e), mode of operation as determined by the component manufacturer's specification.

g. Design Surface Temperature (T sub C). The design surface temperature is defined as the maximum external surface temperature that can be tolerated consistent with the part's function and system or equipment specified reliability requirement at the Thermal Design Condition. (See Figures 10-1, 10-2 and 10-3, Note 9). The value for this temperature and its location on each part should be tabulated for each part. For electrical parts, the Design Surface Temperature should be determined.

NOTE: Parts which are encapsulated assemblies of basic component parts should have their Maximum and Design Surface Temperatures tabulated. The thermal relationship between the parts in the encapsulation and the encapsulated assembly surface should be reported in sufficient detail to allow the prediction of the internal part temperatures from the measured encapsulated assembly surface temperature.

5.6.3 Equipment Thermal Appraisal. The thermal appraisal procedure defined in Appendix I should be performed for all equipment to demonstrate that the design thermal limits required by 5.3.3 and Appendix I are complied with. Measurement of internal part temperatures should be included in order to conduct a comprehensive thermal appraisal.

5.6.4 Reference Surface Temperature (All Equipment). A location anywhere on or within the LRU should be selected and designated by the vendor as a reference surface temperature. The surface temperature at this location should be representative of the thermal behavior of the electrical/electronic parts complement. An equipment case or chassis temperature measurement from the T7 group is preferred for the reference, provided it can be used to predict the general part temperature levels internal to the equipment.

COMMENTARY

There are conflicting needs in the location of the reference surface temperature. The primary need is for the equipment designer to select the most appropriate or significant thermal point. Often this is a component within the unit. However, the installation designer would like to have the reference point on the outside of the unit to provide convenient access without opening the unit.

5.6.5 Thermal Documentation. The following information shall be supplied as applicable:

a. Total wattage input and actual heat dissipation for all modes of electrical operation for which the equipment was designed; e.g., standby, receiving, transmitting, etc.

b. Estimated in-flight and ground maximum duty cycle.

c. Pressure drop through the unit in mm of water when the ambient pressure is 1013 mbars and,

   (1) Coolant inlet temperature is 40°C at a flowrate of 220 kg hr^{-1} kW^{-1}.

   (2) Coolant inlet temperature is 10°C at a flowrate of 82 kg hr^{-1} kW^{-1}.

d. Location of reference surface temperature measurement point and the corresponding maximum allowable temperature to maintain the unit within design limits.

to maintain the unit within design limits.

e. Effect on the subsystem reliability prediction (reference MIL-STD-785A, para. 5.2.2) of a variation in the coolant inlet temperature and rate of flow from 50% to 150% of the design cooling capacity.

5.7 Mechanical and Structural Evaluation. The tray or mounting base manufacturer shall show by analysis and/or test that the rack will meet the deflection and bending requirements under specified conditions of load, and that the rack has required strength to resist all operational stresses, in accordance with 5.1.1.

The aircraft cooling system shall be tested to demonstrate that the required airflow rates are achieved at the specified inlet temperatures, in accordance with 5.3.8.

The CDU manufacturer shall show by analysis and/or test that the unit meets required vibration and acceleration load limits in accordance with 5.1.1.

APPENDIX I

COOLING EVALUATION TEST

10.1 Purpose. This attachment describes procedures and facilities that may be used to evaluate the thermal performance of equipment in order to provide uniformity in the evaluation process. The evaluation procedures are intended to provide the means of determining that the equipment cooling interface design limits are satisfied, and to allow evaluation of the performance of the equipment in the aircraft, throughout its range of operating and nonoperating environmental conditions. See Figures 10-1, 10-2 and 10-3.

10.2 General Instrumentation. This section defines standard instrumentation from which measurements are selected for the specific test setups shown in 10.4, Figures 10-4 through 10-8.

10.2.1 Accuracy of the Test Apparatus. All measurements should be made with instrumentation and methods whose accuracies have been verified. All instruments and test equipment should conform to laboratory standards whose calibration is traceable to the prime standards at the U. S. National Bureau of Standards.

10.2.2 Measurement Tolerances for Cooling Tests. The accuracy of measurements should be as follows:

a.	Temperature	±2°C
b.	Airflow Rate	±.45 kg/hr or ±3% of the test unit flowrate, whichever is greater
c.	Pressure:	
	Differential	±5%
	Atmospheric	±1%
d.	Power	±2 watts or 3% of the actual test unit power dissipation, whichever is greater
e.	Specific Humidity	±15%

10.2.3 Measurements. Suitable instrumentation should be provided to measure the parameters below, as applicable, during testing. Only a portion of the measurements may be required for a particular test setup and those required measurements are designated on test setup Figures 10-5 through 10-8. The circled numerals in the test setup figures correspond to the following measurements:

(T1)	Ambient temperature external to the test chamber.
(T2)	Bulk temperature of the coolant entering the test chamber as measured at the plane of the inner wall of the test chamber.
(T3)	Bulk temperature of the coolant entering the test unit (coolant inlet temperature).
(T4)	Bulk temperature of the bypass flow entering the test chamber. Two measurements, (T4A) and (T4B) are required. Locate these measurements in line and one-half of the distance between the termination of each inlet duct and its associated flow deflecting baffle.
(T5A)	The temperature of the air centered with respect to, and three inches forward of, the front face of the test unit, excluding such projections as handles and knobs.
(T5B)	The temperature of the air centered with respect to, and eight inches aft of, the back face of the test unit, excluding such projections as the equipment electrical connector.
(T5)	The mean value of the above two measurements.
(T6)	Bulk temperature of the bypass airflow exiting the test chamber as measured at the plane of the test chamber inner wall.
(T7A)	Test unit's side surface temperatures. There should be two measurements per side, centered with respect to the front half and back halves of the side. There are four sides for all equipment. (Measurement to be representative of the average surface temperature. More measurements may be needed on a surface where gradients in excess of 5°C exist).
(T7B)	Test unit's front-face surface temperature. (Measurement to be representative of the average surface temperature. Several measurements may be needed on a surface where gradients in excess of 5°C exist).
(T7C)	Test unit's back-face surface temperature. (Measurement to be representative of the average surface temperature. Several measurements may be needed on a surface where gradients in excess of 5°C exist).
(T7)	Equipment surface temperature average composed of four (T7A) measurements.

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		ENVIRONMENTAL CONTROL PARAMETERS					PERFORMANCE REQUIREMENTS				
ENVIRONMENTAL OPERATING CONDITION	TEST SETUP FIGURE #	(M1) COOLANT AIRFLOW RATE ▷1 KG HR-KW	(T3) COOLANT TEMP AT EQUIPMENT INLET °C	(T5A) AMBIENT AIR TEMPERATURE IN FRONT OF PANEL ▷2 °C	(T5B) AMBIENT AIR TEMPERATURE BEHIND PANEL °C	(TR) TEMP OF SIMULATED UNIT SURFACE °C	(T7) EQUIPMENT SIDEWALL TEMP LIMIT AVG/HOT SPOT °C	(T7B) FACE TEMP LIMIT °C	(T10) PART TEMP LIMIT	(T12) CONTROL SURFACE TEMP LIMIT ▷3 °C	(ΔP) TOTAL PRESSURE DROP MM H_2O
NORMAL GROUND OPERATION ▷9	10-5	226	40	40	50	60	60/65	(T5A) +15	DESIGN	(T5A) +ΔT	20 to 30
NORMAL FLIGHT OPERATION ▷9	10-5	[illegible]	30	30	40	60	60/65	(T5A) +15	DESIGN	(T5A) +ΔT	
GROUND SURVIVAL TEMP., HIGH		0		85	85						
SHORT-TIME ▷4 OPERATING TEMPERATURE, HIGH ▷10	10-5	201	70/55	70/55	70	SUS OFF			MAXIMUM		
HIGH OPERATING TEMPERATURE ▷10	10-5	204	65	55	70	75			MAXIMUM		
EMERGENCY OPERATION ▷5		[illegible]	30	30/45	40/70	60/ ▷6				(T5A) +ΔT	
GROUND SURVIVAL TEMP., LOW		0		-55	-55						
LOW TEMPERATURE STARTUP		295	40	-40	-40						
LOW OPERATING TEMPERATURE		270	-15	-15	-15						
TEMPERATURE VARIATION	10-8	270 ▷7	-15 to 65	-15 to 65	-15 to 65						

CIRCLED PARAMETERS ARE DEFINED IN PARAGRAPH 10.2.3

FIGURE 10-1 TEST PARAMETERS FOR TYPE A COOLING (FLOW-THROUGH)

ENVIRONMENTAL OPERATING CONDITIONS	TEST SETUP FIGURE #	ENVIRONMENTAL CONTROL PARAMETERS			PERFORMANCE REQUIREMENTS			
		(T5A) AMBIENT AIR TEMPERATURE IN FRONT OF PANEL ▷2	(T5B) AMBIENT AIR TEMPERATURE BEHIND PANEL ▷2	(T7) AVERAGE CASE SIDEWALL TEMPERATURE ▷8	(T7A) CASE SIDEWALL HOT SPOT LIMIT °C	(T7B) FACE TEMPERATURE LIMIT °C	(T10) PART TEMPERATURE LIMIT °C	(T12) CONTROL SURFACE TEMPERATURE LIMIT °C ▷3
NORMAL OPERATION ▷1	10-5	40	N.A.	60 + (75 (Q1) + A)	(T7) + 10°C	(T5A) + 15°C	DESIGN	(T5A) + ΔT
GROUND SURVIVAL TEMPERATURE, HIGH		85	85	N.A.				
SHORT-TIME OPERATING TEMPERATURE, HIGH ▷10	10-5	▷4 70/55	70/55	N.A.			MAXIMUM	
HIGH OPERATING TEMPERATURE ▷10	10-5	55	N.A.	75 + (75 (Q1) + A)			MAXIMUM	
EMERGENCY OPERATION ▷5		30/45	N.A.	50+(75-(Q1)+A)/75+(150-(Q1)+A)				(T5A) + ΔT
GROUND SURVIVAL TEMPERATURE, LOW		-55	-55	N.A.				
LOW TEMPERATURE STARTUP		-40	-40	N.A.				
LOW OPERATING TEMPERATURE		-15	-15	N.A.				
TEMPERATURE VARIATION	10-8	-15 to 70	-15 to 70	N.A.				

CIRCLED PARAMETERS ARE DEFINED IN PARAGRAPH 10.2.3

N.A. MEANS NOT APPLICABLE.

FIGURE 10-2 TEST PARAMETERS FOR TYPE B COOLING (FLOW-BY)

ENVIRONMENTAL OPERATING CONDITION	TEST SETUP FIGURE #	ENVIRONMENTAL CONTROL PARAMETERS		PERFORMANCE REQUIREMENTS			
		T5A AMBIENT AIR TEMPERATURE IN FRONT OF PANEL [2] °C	T5B AMBIENT AIR TEMPERATURE BEHIND PANEL [2] °C	T7B FACE TEMPERATURE LIMIT °C	T10 PART TEMPERATURE LIMIT °C	T11 REFERENCE SURFACE TEMPERATURE MEASUREMENT °C	T12 CONTROL SURFACE TEMPERATURE LIMIT °C [3]
NORMAL OPERATION [9]	10-7	40	55	T5A + 15°C	DESIGN	RECORD	T5A + ΔT
GROUND SURVIVAL TEMPERATURE, HIGH		85	85			RECORD	
SHORT-TIME OPERATING TEMPERATURE, HIGH [4] [10]	10-7	70/55	70/55		MAXIMUM	RECORD	
HIGH OPERATING TEMPERATURE [10]	10-7	55	70		MAXIMUM	RECORD	
EMERGENCY OPERATION [5]		30/45	40/70			RECORD	T5A + ΔT
GROUND SURVIVAL TEMPERATURE, LOW		-55	-55			RECORD	
LOW TEMPERATURE STARTUP		-40	-40			RECORD	
LOW OPERATING TEMPERATURE		-15	-15			RECORD	
TEMPERATURE VARIATION	10-8	-15 to 70	-15 to 70			RECORD	

CIRCLED PARAMETERS ARE DEFINED IN PARAGRAPH 10.2.3

FIGURE 10-3 TEST PARAMETERS FOR TYPE C COOLING (NO COOLING)

FLAG NOTES FOR FIGURES 10-1, 10-2 AND 10-3

1 Coolant airflow is allocated on the basis of the equipment's heat dissipation when operating at maximum duty cycle. Use the mass airflow rate specified regardless of the laboratory ambient pressure. The maximum allowable specific humidity is .017 lb of water per lb of dry air, and there shall be no entrained condensation.

2 Mass flowrate and temperature limits on the bypass airflow used to control (T5) are defined in Figure 10-1, notes. The maximum allowable specific humidity of the bypass airflow is .017 lb of water per lb of dry air and there should be no entrained condensation.

3 The control surface temperature limit is calculated by adding the maximum allowable control surface temperature differential from to the measured (T5A) temperature in °C.

4 At the supplier's option, the (T3) and/or (T5) test parameter can be varied with time during the 30 minute test period provided the parameter is maintained at or above a linear curve connecting beginning and end points denoted by the values of the left and right, respectively, of the slash mark (/).

5 This test condition defines operation with a failed cooling system. For the emergency operation, values to the left of the slash define the initial test parameters prior to when the cooling airflow to the test unit is shut off. The values to tne right of the slash define the final test parameters at the end of the 30 minute test period. Between the end points note 3 above, applies. The step function sign ( ) indicates the termination of coolant airflow rate as specified in the test procedure for Type A equipment.

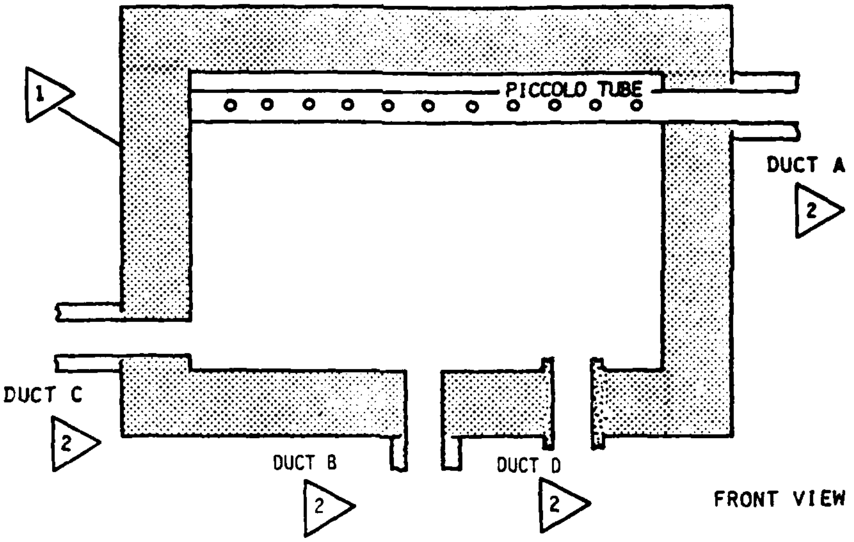
6 The power input required to stabilize the simulated unit prior to cooling air shutoff is to be maintained constant after the cooling airflow is terminated.

7 For the temperature variation test, adjust the coolant airflow rate to the specified value at the low temperature condition of the cycle. Coolant airflow rate does not have to be adjusted for other conditions of the cycle, but may be allowed to vary in response to temperature change of the coolant.

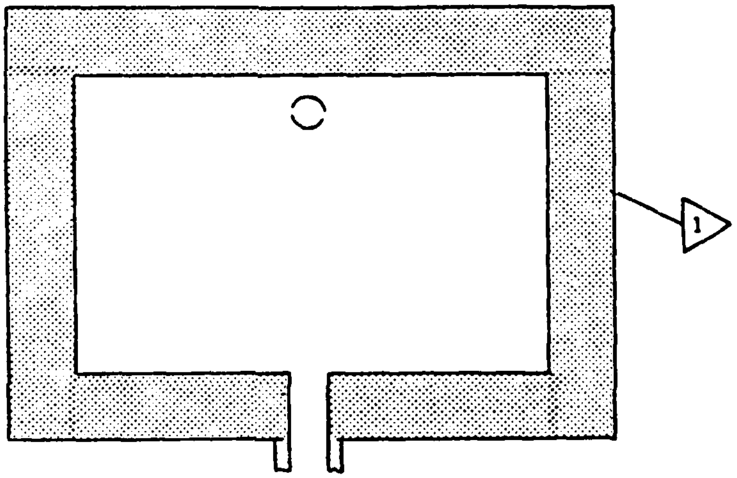
8 The (T7A) control temperature is to be calculated using the value of (Q1)/A which is the heat dissipation (watts) measured at maximum duty cycle (see 3.10) divided by the equipment surface area (square inches) as defined in 3.4. For the cooling evaluation test, (Q1) is measured per step (3) of 10.5.1.

9 Thermal Design Condition (See Section 5.3.7). .

10 The environmental operating condition at which the maximum component part temperatures (T sub M) apply (See Section 5.6.2f).



FRONT VIEW



SIDE VIEW

FIGURE 10-4 RECOMMENDED TEST CHAMBER

FLAG NOTES FOR FIGURE 10-4

1 Test Chamber

It is recommended that the test chamber's internal dimensions enclose a space approximately 3 feet square by 1-3/4 feet high. The test chamber (and associated inlet and exit ducting and wiring access ports) should be airtight and thermally insulated. It is recommended that the effective overall thermal conductivity of the test chamber walls not exceed .05 Btu/(hr ft^2 °F). As an option, the test chamber outline shown can be located in a larger environmental chamber. In this case, the inner test chamber would not need to be well insulated, serving primarily as a fluid boundary so the airflow rate through the inner test chamber can be measured and controlled.

2 Air Inlet and Exhaust Ducts

Flow control provisions should be capable of maintaining ambient and/or coolant temperatures within $\pm 2^{\circ}$C of any selected test temperature. The means of controlling the (T5) ambient temperature should be by providing bypass airflow (air that is not dedicated to go through the test unit).

Airflow through the test chamber may be produced by either positive or negative pressure.

Recommended duct functions and airflow direction for tests are defined in Figures 10-5 through 10-8. In general:

Duct A should function as an exhaust duct and should be connected to a piccolo tube (running the length of the test chamber near the ceiling) with tube ports in the horizontal plane.

Duct B and C should function as inlet ducts to handle bypass air for test chamber ambient temperature control. To minimize temperature gradients, entering airflow temperature should be maintained with $\pm 5^{\circ}$C of the (T5A) or test (T5B) chamber ambient temperature. To insure that ambient air velocities surrounding the test unit remain comparable to those which occur from natural convection, the bypass airflow rate should not exceed 3 air changes per minute based on the test chamber interior volume. Baffles and/or piccolo tubes should be employed to preclude the direct impingement of entrance velocities on the test unit. Ducts B and C should enter the test chamber near the floor or through the lower portion of a sidewall (near the floor) or in the floor. Ducts B and C should provide bypass to air control (T5A) and (T5B), respectively, to the required ambient temperature.

Duct D should be coupled to the test unit as shown in Figure 10-5. Its purpose is to supply coolant air to Type A cooled units.

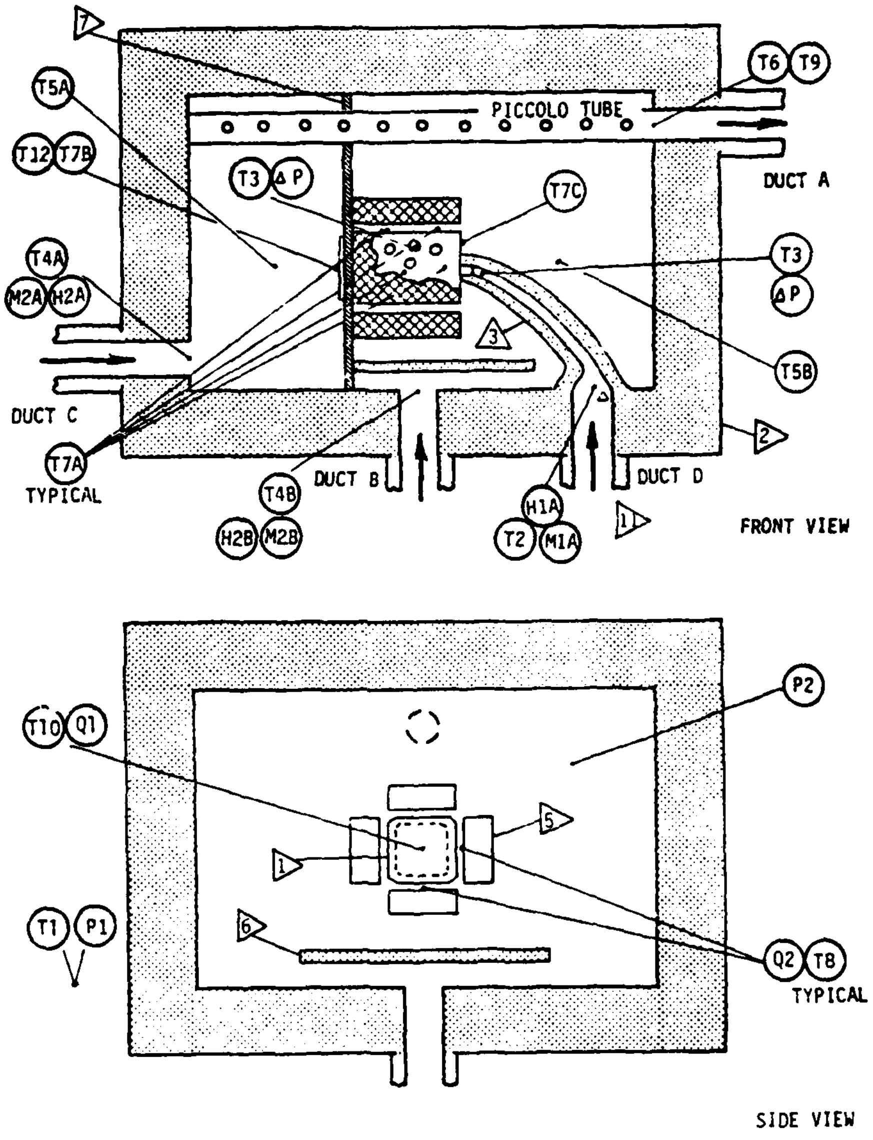
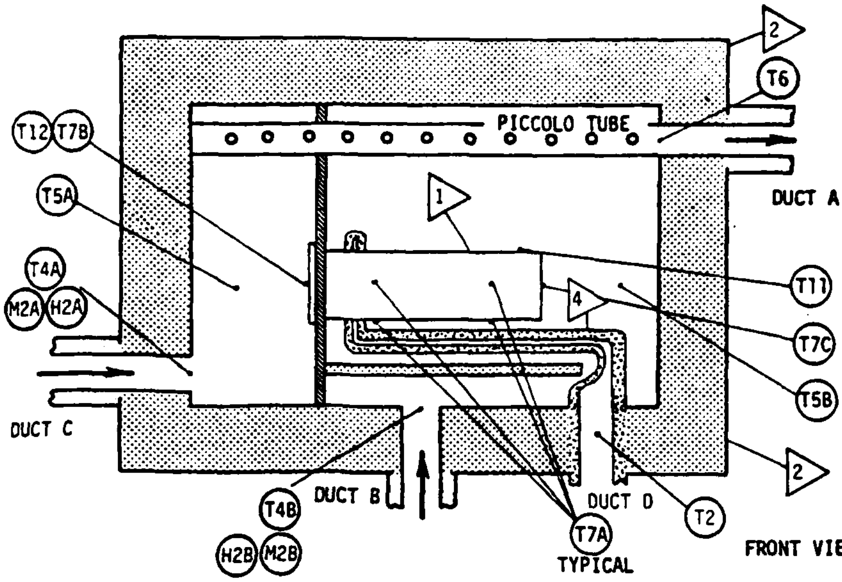
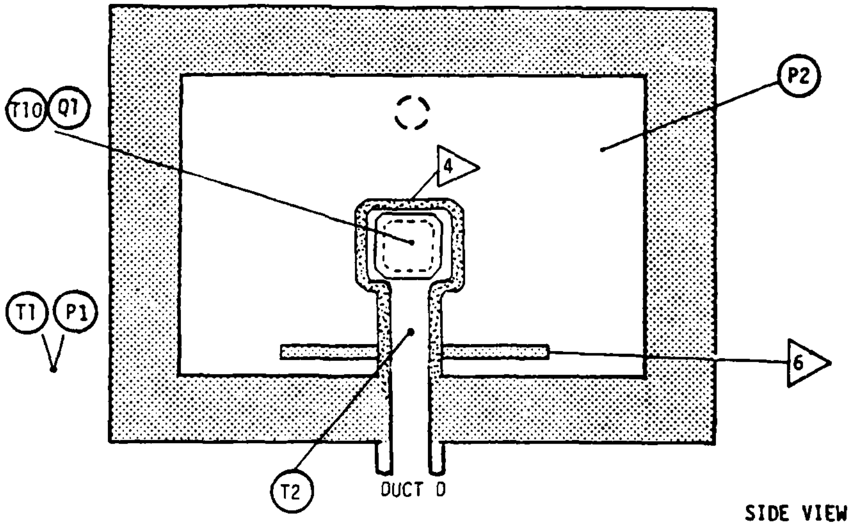


FIGURE 10-5 TEST SETUP - TYPE A EQUIPMENT

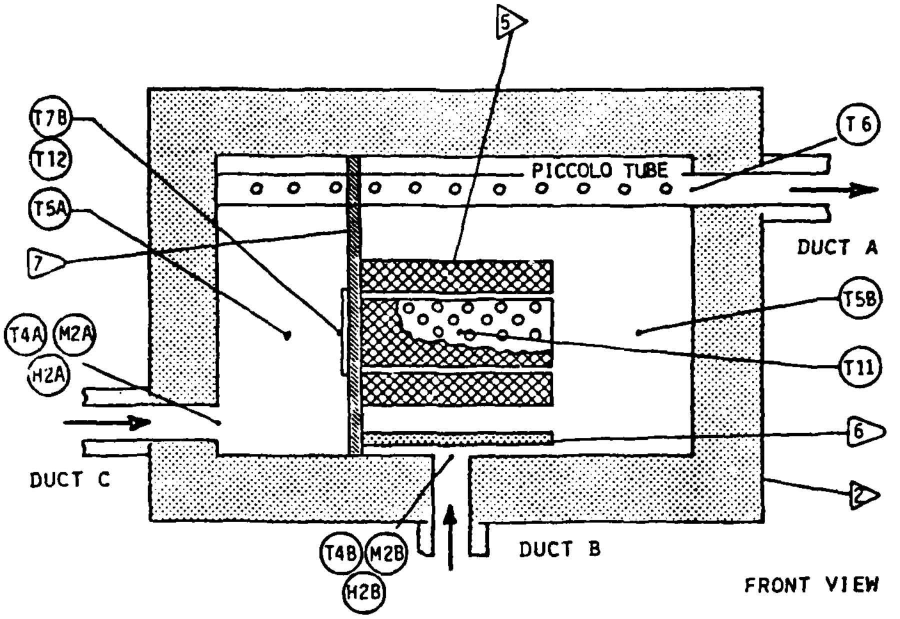


FRONT VIEW



SIDE VIEW

FIGURE 10-6 TEST SETUP - TYPE B EQUIPMENT



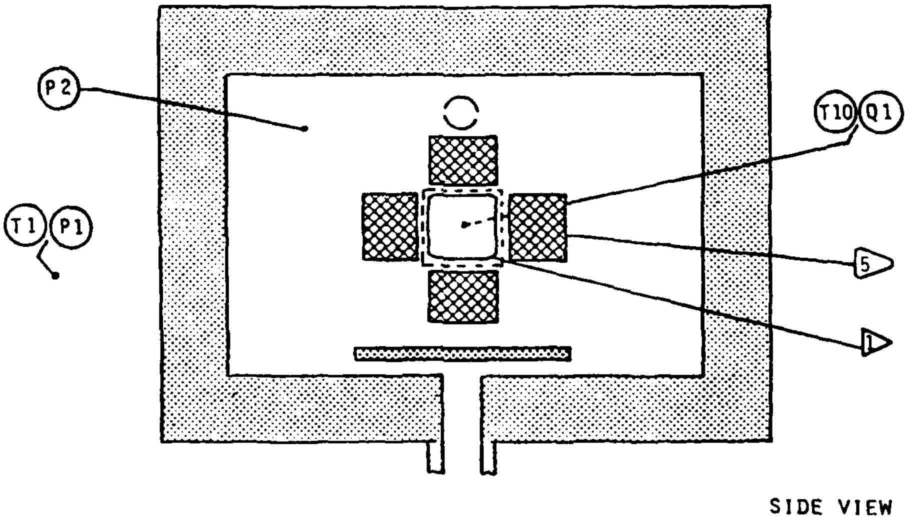
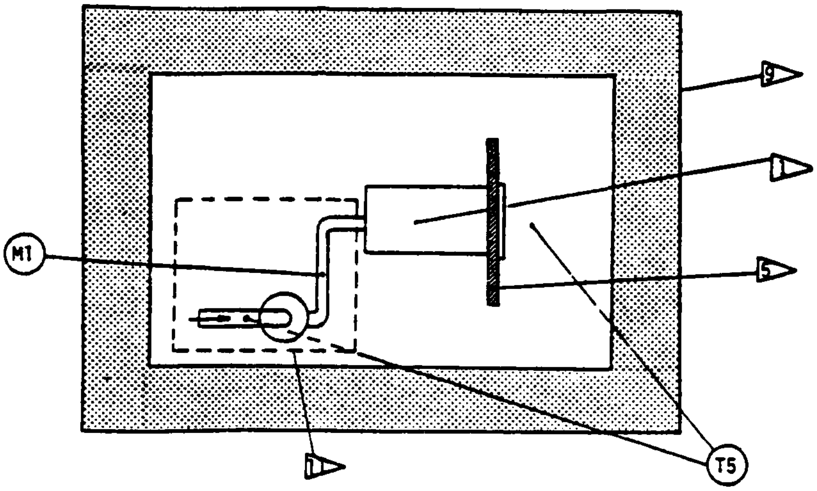


FIGURE 10-7 TEST SETUP - TYPE C EQUIPMENT



NOTE: THIS TEST IS INTENDED FOR ACCELERATED LIFE EVALUATION WHERE SO DESIRED.

FIGURE 10-8 TEST SETUP - GENERAL

FLAG NOTES FOR FIGURES 10-5 through 10-8

1 Test Unit

2 Test Chamber

3 Flow-Through Coolant Air Coupling

4 Flow-By Coolant Air Coupling

The coolant air couplings should not act as heat sources or sinks for the test unit or the test chamber ambient air; i.e., it should be thermally insulated from the test chamber ambient.

5 Simulated Unit (Four required, one on each side of the test unit).

Each simulated unit should be sized to match the adjacent side of the test unit. The width should be the same as the width (or diameter) of the adjacent test unit side and the length should be the same as the test unit length, or 9 inches minimum. The simulated units should be mounted parallel to and .25 ±.03 inches from the adjacent test unit sidewall.

Temperature of the heated surface (T8) is the standard for simulated unit control. It is recommended that the heated surface be fabricated of aluminum or copper plate and heated by pad-type electrical resistance heaters evenly distributed over the plate side opposite the heated surface. The heated surface should be smooth and solid (no holes that might allow the passage of air through the plane). The minimum emissivity of the heated surface should be 0.85, and it should be constructed so as to have a uniform temperature distribution. The surfaces of the simulated unit which do not face the test unit should be thermally insulated from the test chamber ambient air (except the heated plate edges which may be uninsulated).

6 Phenolic Panel

The test unit and simulated units should be installed on a .25" thick phenolic panel. There will be no openings (other than the cutout for the test unit), which might allow flow of air through the panel. The panel should span the entire cross-section of the test chamber so the ambient temperatures on either side of the panel can be controlled independently.

7 Baffle

8 Inactive Simulated Unit (Four required, one each side of the test unit).

Each simulated unit should be sized to match the adjacent side of the test unit. The width should be the same as the width (or diameter) of the adjacent test unit side and the length should be the same as the test unit length, or 9 inches minimum. The thickness should be 2.0 ±.5 inches. The simulated units should be mounted parallel to and .25 ±.03 inches from the adjacent test unit sidewall. It should be fabricated of some low thermal conductivity non-metallic material to minimize its heat transfer capability. Heaters are not required.

9 Any Test Chamber

10 Baffle Box

A baffle box, to preclude forced air circulation from impinging on the test unit, is required. A suitable box may be constructed of .25" peg board having .25" diameter holes on one inch centers.

11 Equipment Cooling System

Apparatus for providing cooling airflow through a small blower, which may be mounted in the test chamber and ingesting air from the test chamber at the (T5) temperature, should be used.

(T8)	Temperature of the simulated unit surfaces facing the test unit (simulated unit heated surfaces).
(T9)	Bulk temperature of the coolant exiting the test chamber as measured at the plane of the test chamber inner wall.
(T10)	Surface temperatures of temperature critical parts inside the test unit.
(T11)	Test unit reference surface temperature for Type C equipment.
(T12)	Surface temperature of control surfaces which are manipulated by hand; i.e., knobs, keys, push switches, etc. Several measurements may be needed to measure all representative control surface temperatures considering location, temperature gradients and material type.
(P1)	Test chamber external ambient pressure.
(P2)	Test chamber internal ambient pressure.
(P)	Differential pressure, total to total from the test unit coolant inlet to outlet.
(M1)	Mass flowrate of the coolant through the test unit.
(M2A) and (M2B)	Mass flowrate of the bypass flow (separate from the test unit's coolant flow).
(H1)	Specific humidity of the coolant entering the test unit. (This may be calculated from a measurement made at the air source).
(H2A) and (H2B)	Specific humidity of the bypass flow entering the test chamber. (This may be calculated from a measurement made at the air source).
(Q1)	Test unit's heat dissipation. (Equal to power input to the test unit minus power output from the test unit not dissipated as heat).
(Q2)	Simulated unit's heat dissipation.

NOTES:

1. Reference numbers which appear within circles on drawings are show within parenthesis and underscored in the text of this document e.g., (T5).
2. Measurement of equipment performance (functional checks) will require instrumentation additional to the above. This instrumentation will be provided for the functional checks.

10.3 Selection of Instrumented Parts. Parts operated near their limits should be instrumented for this appraisal. Such parts may be identified by preliminary checks to locate hot spots on circuit cards, etc., prior to instrumentation. Parts selected should include representative samples of all components with emphasis on the following:

a. Components whose stress level exceeds 75% of the allowable derated level.
b. High power dissipators.
c. Components located adjacent to high power dissipators.
d. Components with large mass for determination of thermal stability.

When this appraisal is used to evaluate the design, 10 parts or 10% of the total part count, whichever is greater, up to a limit of 30 parts should be identified and instrumented for the test. There should be at least one part surface temperature measurement per printed-circuit-board regardless of part count.

10.4 Test Setups. This section contains figures which show the test setups used in the cooling. The test setups show:

a. The ducts for airflow control and the airflow direction.
b. The simulation apparatus required inside the test chamber.
c. The required measurements for the test (other than those necessary for functional performance checks).

For all test setups, the test unit should be positioned in approximately the same attitude as when the airplane is on the ground. To allow most installations to be tested either horizontally or vertically, the nearest major axis of 0, 45 or 90 degrees of angle with respect to the earth's surface, and which simulates the airplane installation attitude, can be selected for the test setup. The test unit should be mounted using the same method as used in the aircraft (using appropriate panel fasteners, clamp devices, tray, or DZUS rails).

The test setups shown are based on use of a test chamber shown in Figure 10-4 herein. Use of this particular chamber is not required.

10.5 Cooling Evaluation Test. The Cooling Evaluation Test Procedure is intended to demonstrate that the equipment thermal interface requirements, and part temperature limits, have been achieved in the test article. Additionally, a temperature cycling test is included as a means to demonstrate that the equipment will operate satisfactorily in the extreme aircraft temperature environment. This test can be extended in time and be used as an accelerated life test.

Figures 10-1, 10-2 and 10-3 define the Environmental Parameters for the tests.

For all steps of the test procedure requiring the test unit to be energized, the unit shall be operated at the maximum duty cycle (3.10). When equipment is designed for intermittent duty, and the procedure calls for startup, it should be started at the beginning of the "on" cycle.

For all tests herein, the term stabilize or stabilization is as described in 3.13.

10.5.1 Thermal Interface Appraisal (Cooling Evaluation Test)

Product Examination, Visual

Step (1) For Type A equipment, the test article shall be inspected to verify compliance with paragraph 5.3.10.

Pre-Test Performance Record

Step (2) Prior to instrumentation of the test unit it shall be operated and a record made of all data necessary to determine that the test unit complies with the applicable equipment performance standards. This data may be taken at laboratory ambient conditions with full cooling as specified by the equipment manufacturer. Record ambient temperature, pressure and humidity; and for Types A and B equipment, coolant inlet temperatures, humidity and flowrate.

Step (3) Measure the test unit Heat Dissipation for all Electrical Operating Modes (see 10.7.2). Heat dissipation (10.7.7) may be determined by power (watts) input minus power output, or by any suitable method which achieves the required accuracy. These measurements may be made at laboratory ambient conditions. Indicator lights within the equipment are to be powered at the maximum continuous operating voltage for all electrical operating modes. Record ambient temperature, pressure and humidity and if the equipment is Type A or Type B, coolant conditions of inlet temperature, humidity and flowrate.

Instrumentation

Step (4) Instrument the test unit per the applicable test setup figure.

Installation

Step (5) Install the test unit in the applicable test setup.

Normal Operation

Step (6) With the equipment energized, adjust the test control parameters to those specified for the normal operating condition and stabilize the equipment. Record the measurements shown on the applicable test setup figure. Determine compliance with the applicable equipment performance standards.

NOTES:

(a) For Types A and B equipment, perform step (6) for both normal ground operation and normal flight operation.

(b) When the thermal characteristics of the equipment vary with different electrical operating modes in such a manner that different parts become temperature critical (3.14) in different electrical operating modes, repeat step (6) for each such mode.

Short-Time Operating Temperature, High

Step (7) Adjust the test control parameters to those specified for the high temperature, short-time operating condition. Stabilize the equipment in the non-operating mode. Record the measurements shown on the applicable test setup figure.

Step (8) Engergize the equipment for 30 minutes maintaining the (T5) ambient air (and (T2,T3) coolant temperatures) at or above the temperature limit curve specified in the Table. Record the measurements shown on the test setup figure at 10 minute intervals and at the end of the 30 minute period. In the last 5 minutes of the 30 minute period, determine compliance with the applicable equipment performance standards.

High Operating Temperature

Step (9) Adjust the test control parameters to those specified for the high operating condition. Stabilize the equipment in the operating mode. Record the measurements shown on the applicable test setup figure. Determine compliance with the applicable equipment performance standards.

Post-Test Checkout

Step (10) Return the equipment (de-energized) to laboratory ambient temperature and stabilize. Energize the equipment repeating the step (6) procedure. Inspect the test unit, recording all damage or deterioration resulting from the test.

NOTE: The equipment may be removed from the test chamber for this performance check.

10.5.2 Temperature Variation Test

Pre-Test Performance Record

Step (1) Perform a pretest performance check per 10.5.1, step (2).

NOTE: This step may be omitted if the Temperature Variation Test follows the 10.5.1 test and no modifications were made to the test unit.

Installation

Step (2) Install the equipment in the applicable test setup.

Test Preparation

Step (3) With the equipment not operating, reduce (T5,T3) for Type A equipment and (T2) for Type B equipment, to the specified low temperatures and stabilize the equipment. Record the measurements specified on the applicable test setup figure.

NOTE: For Type A and Type B equipment, the (T2) and (T3) coolant flow is active through all subsequent steps of this test procedure. (For Type C equipment, (T2,T3) is not applicable).

Step (4) Operate the equipment for a period of 15 minutes.

Temperature Cycling

Step (5) Immediately following step (4), increase (T5) and (T2,T3) to the high temperature specified at a rate not exceeding 10°C per minute.

During the transient from low to high temperature, check for proper functional performance. Record the (T5) and (T2,T3) temperatures at least every five minutes.

Step (6) Maintain (T5) and (T2,T3) at the high temperature level for one hour. Record the measurements shown on the test setup figure.

Step (7) De-energize the equipment for 2 minutes. Maintain (T5) and (T2,T3) constant. Energize the equipment and check for proper functional performance.

Step (8) Reduce (T5) and (T2,T3) to the low temperature level at the transition rate used in step (5). Record (T5), and (T2,T3) at the step (5) intervals.

Step (9) Maintain (T5) and (T2,T3) constant at the low temperature level for one hour. Record the measurements shown on the test setup figure.

Step (10) De-energize the equipment for 30 minutes. Maintain (T5) and (T2,T3) constant at the low temperature level. At the end of 30 minutes, energize the equipment and check for proper functional performance.

Step (11) Increase (T5) and (T2,T3) to the high temperature level at the transition rate used in step (5). Record (T5) and (T2,T3) at the step (5) intervals.

Step (12) Steps (6), (8), (9), and (11) constitute one complete cycle. Repeat this sequence of steps continuously for a total of 24 cycles. Determination of proper functional performance, step (7) and step (10) shall be included every third cycle. Recording measurements shown on the test setup figure shall be accomplished every third cycle except for (T5) and (T2,T3), which should be recorded every cycle at the timing sequence established in the initial cycle.

Step (13) Repeat steps (6) and (7).

Post-Test Checkout

Step (14) Return the equipment, de-energized, to laboratory ambient temperature and stabilize. Energize the equipment and repeat the measurement of all data taken in 10.5.1, Step (2). Inspect the test unit. Record all damage or deterioration resulting from the test.

NOTE: The equipment may be removed from the test chamber for this performance check.

10.6 Test Report. The test report shall contain the details and results of the test, including a chronological record of the actual test sequence used, test conditions and results recorded as required during the test. The test record shall contain the signature and date of certification of the test data by the test engineer.

The test data shall include a complete description of all test equipment, instrumentation and accessories. The test apparatus and measurement locations shall be adequately documented by photographs, schematics, or line drawings. All stimulus and measurement equipment shall be identified by make and model and the latest calibration date recorded.

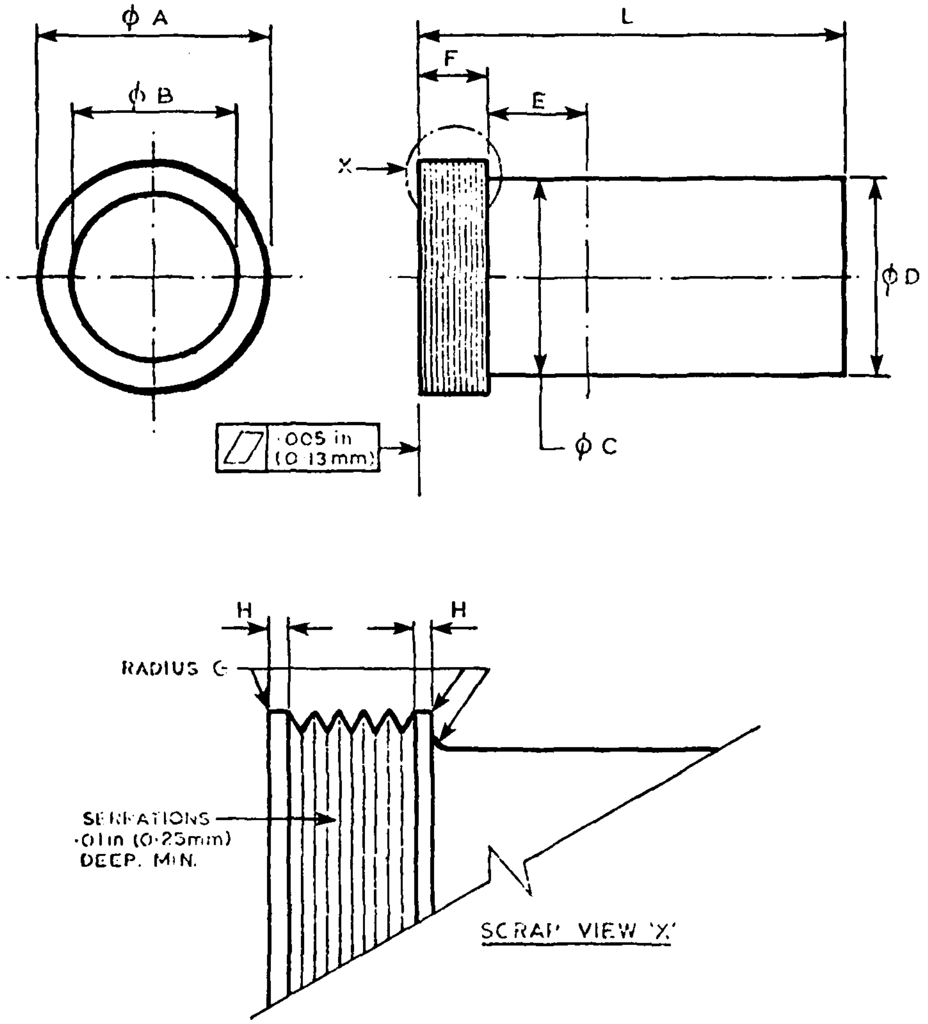
APPENDIX II

STANDARDIZATION OF INSTRUMENT CASE DIMENSIONS

The USAF has implemented NATO Standardization Agreement -- STANAG 3319 (Edition 4) defining the following types of aircraft instrument cases.

Type A: Flangeless round
Type B: Square flanged, round
Type C: Square flanged, octagonal
Type D: Rectangular flanged, octagonal
Type E: Rectangular flanged, octagonal for vertical scales

The corresponding Annexes to STANAG 3319 are reproduced in this appendix.

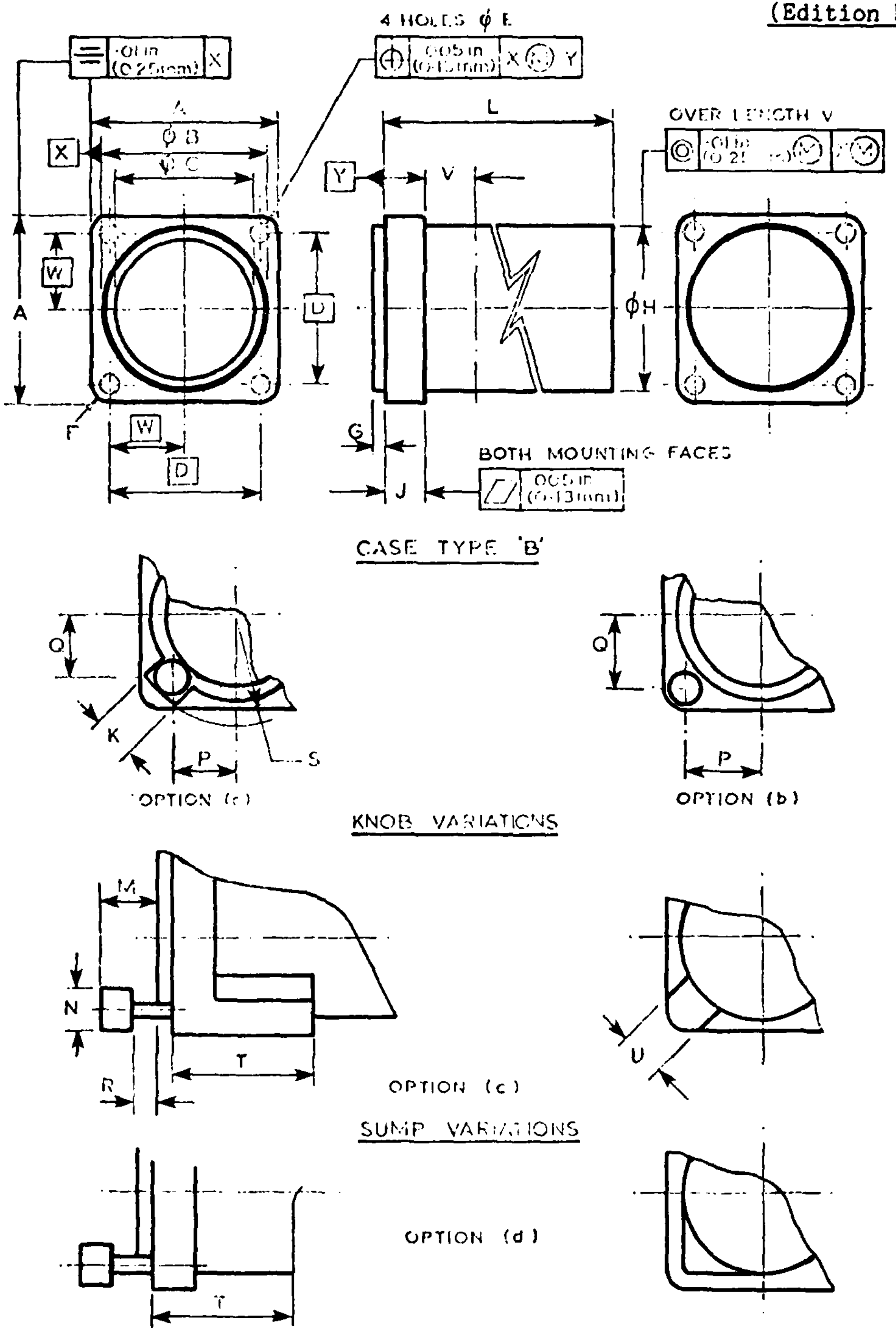


STANDARD DIMENSIONS FOR CASES TYPE A, FLANGELESS ROUND

TABLE OF DIMENSIONS - ANNEX A

Case Type		Type A1		Type A2		Type A3		Type A4		Type A5	
Dimension		in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
ØA	max min	1.068 1.058	27.13 26.87	1.192 1.182	30.28 30.02	1.568 1.558	39.83 39.57	2.010 1.990	51.05 50.55	3.240 3.220	82.30 81.79
ØB	min	0.950	24.13	1.131	28.73	1.375	34.93	1.810	45.97	2.950	74.93
ØC	max min	1.000 0.995	25.40 25.27	1.130 1.125	28.70 28.57	1.500 1.495	38.10 37.97	1.940 1.930	49.28 49.02	3.130 3.120	79.50 79.25
ØD	max	1.000	25.40	1.130	28.70	1.500	38.10	1.940	49.28	3.130	79.50
E	min	1.250	31.75	▨	▨	▨	▨	▨	▨	▨	▨
F	max min	0.230 0.210	5.84 5.33	▨	▨	▨	▨	▨	▨	▨	▨
G	max	0.010	0.25	▨	▨	▨	As Type A1		▨	▨	▨
H	max min	0.047 0.015	1.19 0.38	▨	▨	▨	▨	▨	▨	▨	▨
L		See Instrument Specification									

NOTES: 1. For installation, clearance shall be allowed for the maximum overall dimensions shown on the drawing, to render the instrument compatible for mounting with instrument mounting clamps detailed in SDM(A) IS 362.



STANDARD DIMENSIONS FOR CASES TYPE B, SQUARE FLANGED, ROUND

TABLE OF DIMENSIONS - ANNEX B

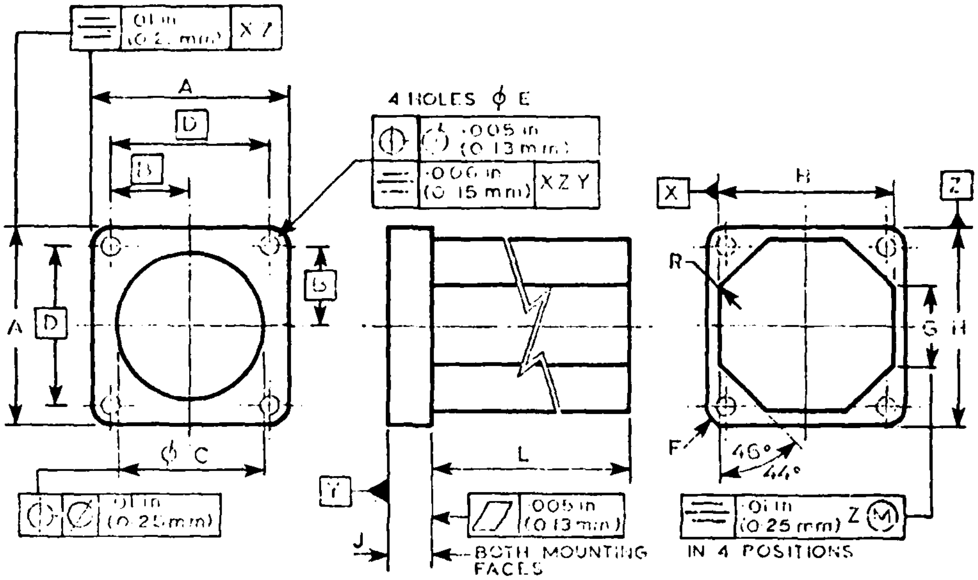
Case Type		Type B1		Type B2		Remarks
Dimension		in.	mm	in.	mm	
A	max	2.418	61.42	3.260	82.80	Incl. Finish
ØB	max min	2.255 2.235	57.28 56.77	3.130 3.110	79.50 78.99	See Note 4
ØC	min	1.875	47.63	2.750	69.85	Aperture
D		1.856	47.14	2.475	62.87	
ØE	max min	0.172 0.168	4.37 4.27	0.172 0.168	4.37 4.27	See Note 2
F	min	0.060	1.52	0.060	1.52	Radius
G		0.125	3.18	0.125	3.18	See Note 4
ØH	max	2.271	57.68	3.146	79.91	Incl. Pin & Labels
J		0.375	9.53	0.375	9.53	
K				1.062	26.97	
L						See Inst. Spec.
M	max min	1.000 0.500	25.40 12.70	1.000 0.500	25.40 12.70	See Inst. Spec.
N	max min	0.600 0.375	15.24 9.53	0.600 0.375	15.24 9.53	See Inst. Spec.
P						See Inst. Spec.
Q						See Inst. Spec.
R	max min	0.187 0.125	4.75 3.18	0.187 0.125	4.75 3.18	
S	min			1.938	49.23	Radius
T						See Inst. Spec.
U	max	0.625	15.88	1.562	39.67	
V	min	0.250.	6.35	0.250	6.35	
W		0.928	23.57	1.238	31.45	

NOTES:

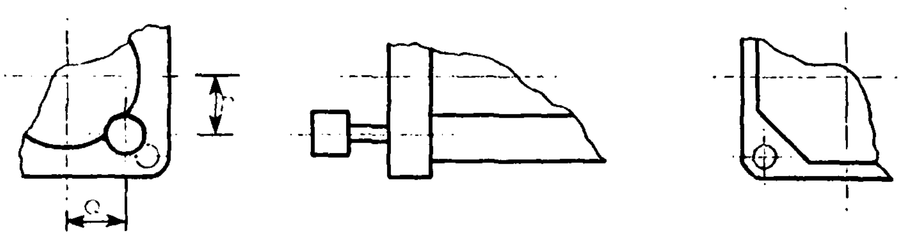
1. Unless otherwise specified, linear tolerances shall be ±0.016 in. (±0.40 mm).
2. For cases to be mounted from the rear of a panel, fixing holes may be replaced by integral nuts with 6-32 UNC thread.
3. All screws and nuts shall be flush with the mounting face.
4. For cases mounted from the front of a panel, ØB dimensional spigot may be omitted with max flange thickness incrasing to J + G.
5. The mounting flange profile may vary from that shown provided that it lies within the maximum overall dimensions A.

   Note: The preferred alternative flange for case Type B2 is specified as follows: "Each corner of the flange shall be clipped to form an included angle of 76° which shall be equally disposed about the 45° flange diagonals and the flange overall diagonal dimension after clipping shall be within 3.970 to 3.905 in. (108.36 to 99.19 mm).

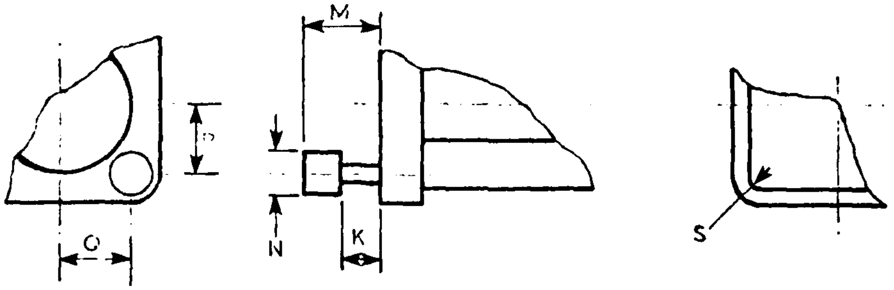
6. The knob may be on the right and/or left hand side. (See Inst. Spec.).
7. Electrical bonding shall be in accordance with the Inst. Spec.
8. For installation, clearance shall be allowed for the maximum overall dimensions.



CASE TYPE 'C'



OPTION (a) KNOB WITHOUT SUMP



OPTION (b) KNOB WITH SUMP

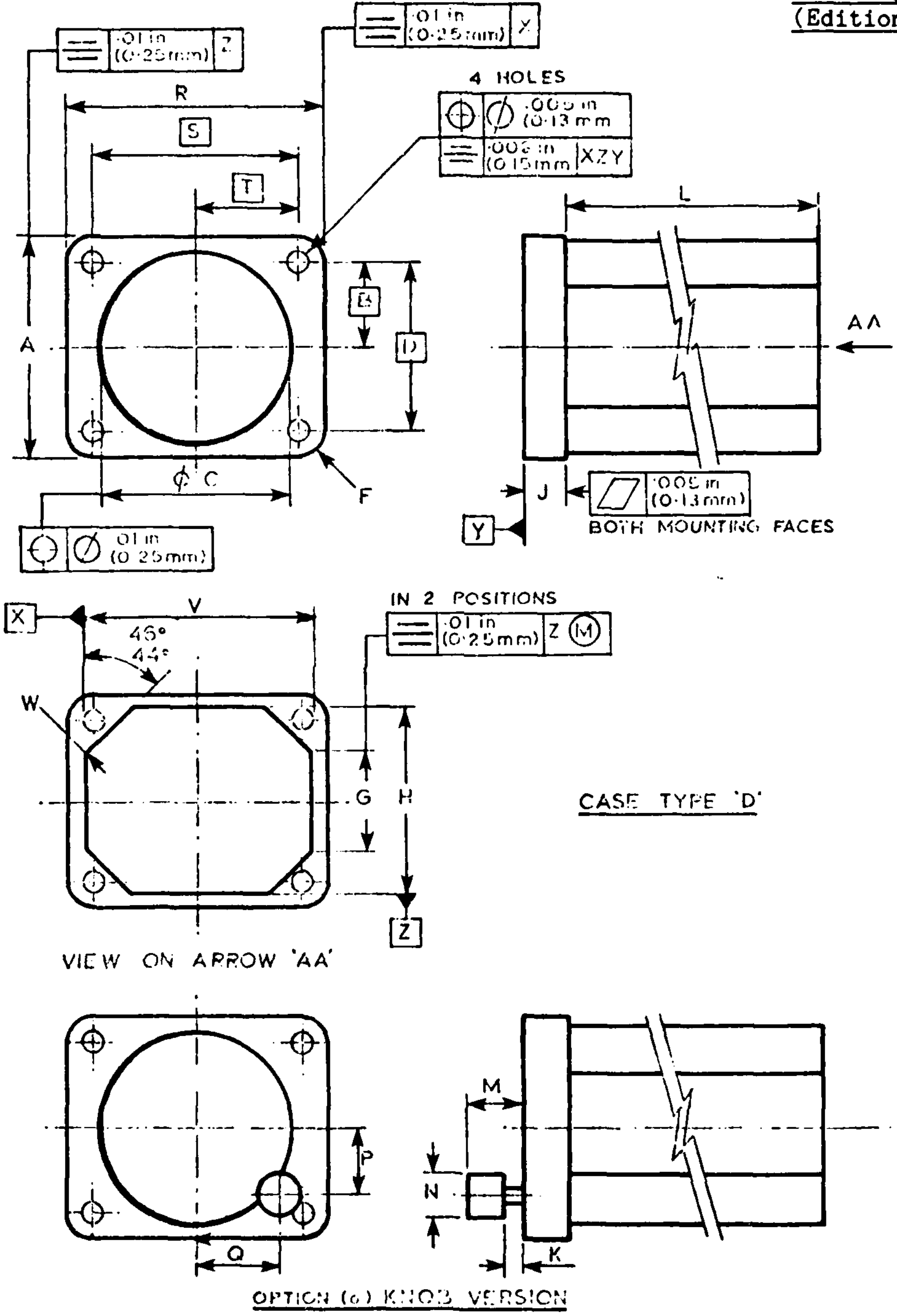
STANDARD DIMENSIONS FOR CASES TYPE C, SQUARE FLANGED, OCTAGONAL

TABLE OF DIMENSIONS - ANNEX C

Case Type		Type C1		Type C2		Type C3		Remarks
Dimension		in.	mm	in.	mm	in.	mm	
A	max	2.418	81.42	3.266	82.96	4.016	102.01	Incl. Fin
B		1.063	27.00	1.500	38.10	1.875	47.63	
ØC	min	1.938	49.23	2.875	73.03	3.500	88.90	
D		2.125	53.98	3.000	76.20	3.750	85.25	
ØE	max min	0.172 0.168	4.37 4.27	0.172 0.168	4.37 4.27	0.172 0.168	4.37 4.27	See Note 2
F	min	0.080	1.52	0.060	1.52	0.060	1.52	Radius
G	max	1.440	36.58	2.326	59.08	2.840	72.14	
H	max	2.255	57.28	3.191	81.05	3.885	98.68	
J	max	0.406	10.31	0.391	9.93	0.391	9.93	
K	max min	0.187 0.125	4.75 3.18	0.167 0.125	4.75 3.18	0.187 0.125	4.75 3.18	See Inst. Spec.
L								See Inst. Spec.
M	max min	1.000 0.500	25.40 12.70	1.000 0.500	25.40 12.70	1.000 0.500	25.40 12.70	See Inst. Spec.
N	max min	0.600 0.375	15.24 9.53	0.600 0.375	15.24 9.53	0.600 0.375	15.24 9.53	See Inst. Spec.
P								See Inst. Spec.
Q								See Inst. Spec.
R	min	0.060	1.52	0.060	1.52	0.060	1.52	Radius
S	min	0.102	2.59	0.102	2.59	0.102	2.59	Radius

NOTES:

1. Unless otherwise specified, linear tolerances shall be ±0.016 in. (±0.40 mm).
2. For cases to be mounted from the rear of a panel, the fixing holes may be replaced by integral nuts with 6-32 UNC thread.
3. All screws and nuts shall be flush with the mounting faces.
4. For cases to be mounted from the rear of a panel, a flange spigot, not protruding more than 0.125 in., conforming to the dimensions H and G to datums X and Y, may be employed.
5. The knobs may be on the right and/or left hand side. (See Inst. Spec.).
6. Electrical bonding shall be in accordance with the Inst. Spec.
7. For installation, clearance shall be allowed for the maximum overall dimensions.



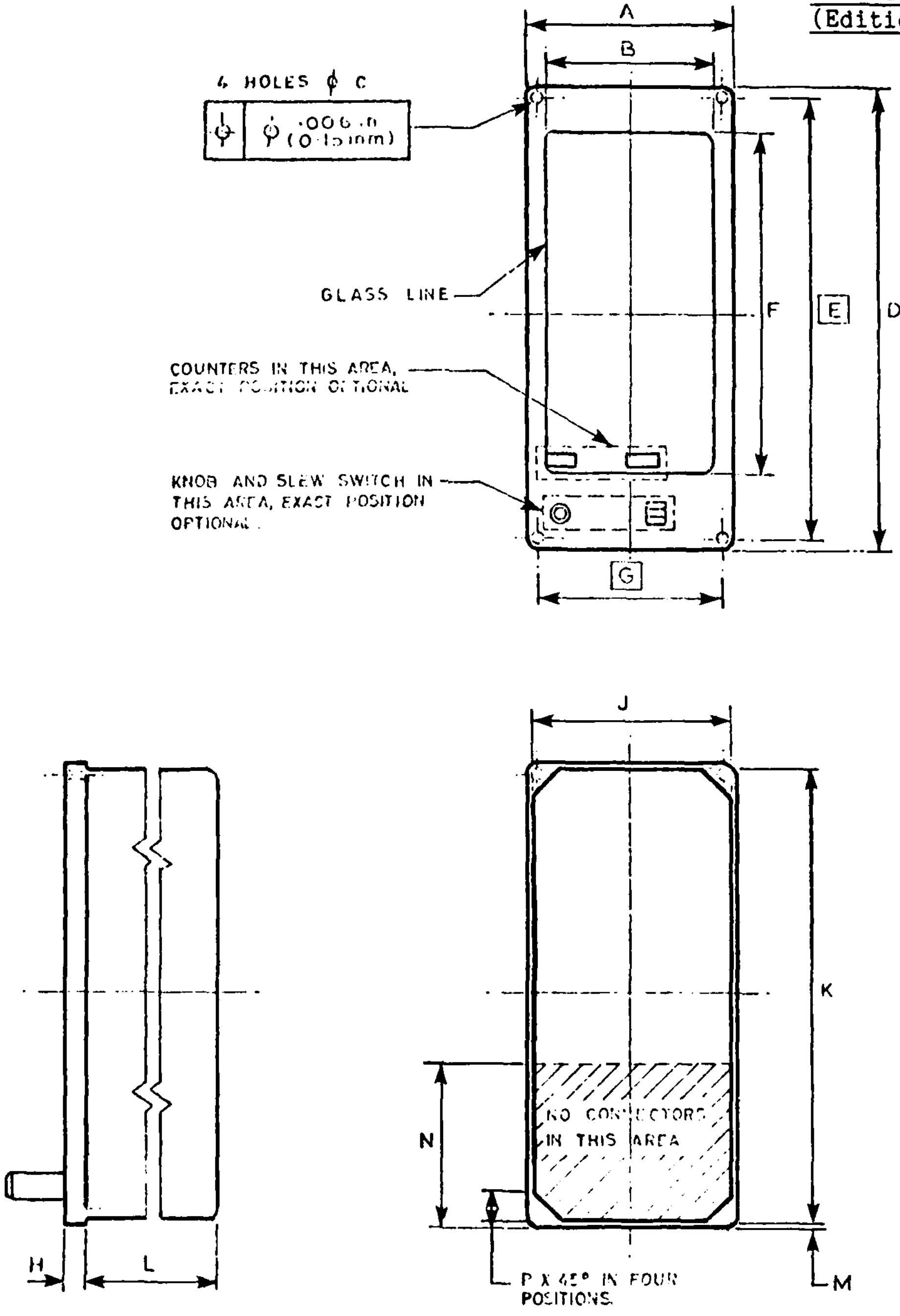
STANDARD DIMENSIONS FOR CASES TYPE D, RECTANGULAR FLANGED, OCTAGONAL

TABLE OF DIMENSIONS - ANNEX D

Case Type		Type D1		Type D2		Remarks
Dimension		in.	mm	in.	mm	
A	max	5.016	127.41	5.016	127.41	Incl. Pin
B		2.250	57.15	2.250	57.15	
ØC						See Inst. Spec.
D		4.500	114.30	4.500	114.30	
ØE						See Note 2
F	min	0.060	1.52	0.060	1.52	Radius
G	max	3.559	90.40	3.559	90.40	
H	max	4.875	123.83	4.875	123.83	
J		0.391	9.93	0.391	9.93	
K	max	0.187	4.75	0.187	4.75	See Inst. Spec.
	min	0.125	3.18	0.125	3.18	
L						See Inst. Spec.
M	max	1.000	25.40	1.000	25.40	See Inst. Spec.
	min	0.500	12.70	0.500	12.70	
N	max	0.600	15.24	0.600	15.24	See Inst. Spec.
	min	0.375	9.53	0.375	9.53	
P						See Inst. Spec.
Q						See Inst. Spec.
R	max	4.266	108.36	5.266	133.76	Incl. Pin
S		3.750	95.25	4.750	120.65	
T		1.875	47.63	2.375	60.33	
V	max	4.125	104.78	5.125	130.18	
W	min	0.060	1.52	0.060	1.52	Radius

NOTES:

1. Unless otherwise specified, linear tolerances shall be ±0.016 in (±0.40 mm).
2. Four holes 0.209 in. (5.31 mm) diameter counter-bored 0.375 in. (9.53 mm) diameter to a depth of 0.156 in. (3.96 mm).
3. For cases mounted from rear of the panel the holes may be replaced by integral nuts with 10-32 UNF thread, the counter-bore may be omitted.
4. All screws and nuts shall be flush with the mounting face.
5. For cases mounted from the rear of a panel a front of flange spigot, not protruding more than 0.125 in., conforming to dimensions H, G, and V to datums X and Y, may be employed.
6. The knob may be on the right and/or left hand side. (See Inst. Spec.)
7. Electrical bonding shall be in accordance with the Inst. Spec.
8. For installation, clearance shall be allowed for the maximum overall dimensions.



STANDARD DIMENSION FOR CASES TYPE E, RECTANGULAR FLANGED, OCTAGONAL, FOR VERTICAL SCALES

TABLE OF DIMENSIONS - ANNEX E

Case Type	Type E1		Remarks
Dimension	in.	mm	
A	3.500	88.90	
B	2.937	74.60	
C	0.170	4.32	
D	7.750	196.85	
E	7.375	187.33	
F	5.750	146.05	
G	3.125	79.38	
H	0.375	9.53	
J	3.375	85.73	
K	7.625	193.68	
L			See Inst. Spec.
M	0.062	1.57	
N	2.750	69.85	
P	0.500	12.70	

NOTES: 1. Unless otherwise specified, linear tolerances shall be ±0.010 in. (±0.250 mm) and angular tolerances ±2 degrees.

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