ORDER

SO 6000.14A

F&E Construction and Electronics Handbook

December 21, 1990

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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FOREWARD

This Directive contains specific guidelines, information, and examples of activities associated with the Southern Region's Facilities and Equipment (F&E) program. This handbook instructs FAA F&E engineers and technicians of the administrative and technical aspects of their activities within the Establishment Engineering Branch, ASO-450.

for C. R. Pinkerton
Manager, Airway Facilities Division

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CHAPTER 1. GENERAL INFORMATION

SECTION 1. INTRODUCTION, EMPLOYMENT, AND SAFETY

1. PURPOSE. This order provides technical information useful to electronic and construction field personnel. Installation of complete facilities are accomplished by the Establishment Engineering Branch. However, each "sub-branch" has duties which are unique to them. Therefore, as you use this handbook, remember to refer to your appropriate work area when the information is split "construction" and "installation" information.

a. Field employees, administrative duties, training opportunities, telephone policy, and safety practices are defined in this section of the order.

b. Section 2 covers a brief description of the following: FAA Directives System, work orders, engineering packages, weekly reports, construction reports, time reporting, travel, F&E coding, and purchases.

c. A description of FAA facilities and systems is briefly contained in Chapter 2, Section 1, of this order.

d. Electronic installation standards and procedures are outlined in Chapter 2, Section 2, of this order.

e. A description of construction standards and procedures is contained in Chapter 2, Section 3.

f. Electronic symbols, charts, technical installation reference, electronic formulas, and materials most commonly used are contained in Appendix I of this order.

2. DISTRIBUTION. This order is distributed to the regional Airway Facilities Division, section level; all Establishment Engineering Branch, ASO-450, Category IV employees; and to all Airway Facility sectors and sector field offices.

3. CANCELLATION. This order cancels Southern Region Orders SO 6000.14, dated February 24, 1977, and SO 6900.5, dated July 28, 1980.

4. INTRODUCTION. This handbook is issued to all field employees so that they may better understand the construction/installation work activity and the duties and responsibilities of Construction and Installation Units. This publication should be carried to all project assignments, thereby being available as a ready reference in performance of construction and installation work.

5. EMPLOYMENT. Employment as a field engineer/technician is governed by the FAA policies and regulations contained in Agency orders and directives. Each employee is bound by these regulations as management is in providing employee benefits and career opportunities.

a. Conduct and Discipline. Each employee must conduct himself, both on and off duty, in such a manner that reflects credit on the Federal Government and the FAA. Rules of conduct are contained in Handbook 3750.4 and DOT Regulations, Part 99 - Employee Responsibilities and Conduct. Each year a copy of DOT Regulations, Part 99, is circulated to all employees for reading and signature.

b. Recognition and Awards. The FAA Award Program gives recognition to employees for superior achievements by offering honorary recognition through letters of commendation or appreciation and cash awards such as Quality Step Pay Increase or Sustained Performance Awards. An award may be given to an individual or to several employees as a Group Award (Reference Handbook 3450.7).

c. Suggestion Award. Suggestion awards are given to employees who recognize problems in the agency operation and propose solutions to that problem. Suggestions on how to improve the construction/installation effort, such as use of tools which make the job safer and more efficient, are encouraged by management. Awards for suggestions are usually cash, based on the cost vs. benefits. Suggestions should be submitted on FAA Form 2333.

d. Career Development. The Establishment Engineering Branch offers an employee the opportunity to develop technical skills on many types of FAA systems. His abilities may be developed on one or more of the following specialities: navigational aids, radar systems, communication systems, or data processing equipment. The combination of these technical skills, along with the training programs offered by FAA, give the employee an opportunity for career progression.

6. TRAINING PROGRAM. The objective of the FAA Training Program is to develop, improve, and increase the knowledge and skills of its employees in order to increase economy and effectiveness of the agency's operation and to raise the quality of performance by its employees to the maximum possible level of proficiency. The program design encourages employee self-development. The types of training offered are:

a. Directed study. The Directed Study Program is a series of correspondence courses administered by the FAA Academy. Enrollment in this program can be voluntary or may be mandatory to fulfill prerequisite training requirements prior to academy resident training.

b. Resident Training. Resident training is the formal training conducted by the FAA Academy. Selection of courses and employees to

attend is made by the Installation Unit Supervisor. Early notification (three weeks or more) of scheduled training is normally given so that an employee can plan his personal affairs. F&E Training is given a lower priority by the FAA. Maintenance personnel requiring equipment certification credentials to perform their job are given training priority over F&E personnel. On occasion a training slot will become available on short notice because maintenance personnel cannot fill the quota, and this quota is offered to F&E.

c. On-the-job Training. Most of the knowledge and skills necessary for installation work are developed while actually working on F&E projects and observing the techniques of other installers. As stated earlier, installation projects are diversified in several areas which aid employee development.

d. Out-of-agency Training. This is training offered by private industries, other government agencies, or the military. These courses are primarily equipment or civil engineering and construction in nature. Very little academy training is offered for construction or civil engineering training.

7. SAFETY/INJURY ON THE JOB.

a. Each employee has a responsibility for safety of himself as well as others. In this regard, employees are expected to report all unsafe conditions to the work order carrier and/or to their supervisor. All employees are expected to observe all safety regulations. If an accident does occur, the employee should immediately seek first aid and report the accident to his supervisor as soon as practical. Employees should recognize that even when on TDY, injuries off the job and/or after duty hours should be reported.

b. Accident Reporting. Details for reporting of all accidents are contained in Orders 3900.24, Accident and Fire Reporting, and 4670.2, Motor Vehicle Management. General information only will be provided here, so every one should become familiar with the above-mentioned orders. Some orders specify certain forms be prepared by the employee's supervisor. However, due to the remoteness of the supervisor in our organization, it is necessary that all the required forms be completed to whatever degree possible by the employee, then forwarded to his supervisor. The supervisor will then complete the forms and forward them to the appropriate officials. Accidents occurring in POV's used on official business should be reported the same as accidents occurring in GOV's.

c. If you are injured, you must fill out form CA-1 and CA-2, Federal Employees Notice of Injury or Occupational Disease. Items 1 through 16 of this form must be completed by the injured employee or some one acting for him whenever an injury is sustained in the performance of duty. It will also be the responsibility of the employee or some one acting in his behalf to obtain the information required by items 17, 18, and 19. The

completed form is to be forwarded to the employee's supervisor within 48 hours following the injury. The supervisor will complete the "Receipt of Notice of Injury" portion of the form and return that portion to the employee. The back of the form will be completed by the employee's supervisor.

d. A Form CA-16 is completed by the supervisor, work order carrier, or local sector field office manager when it has been determined that an injury has occurred in the performance of duty and the supervisor is authorizing the payment of medical bills by the Government. In this instance, Item 6, Block A, would be checked. However, if there is doubt that the injury was sustained in the performance of duty, then Item 6, Block B, would be completed.

e. When, after returning to work, you stop work as a result of the original injury, a Form CA-2a, "Notice of Recurrence of Disability" must be completed and forwarded to your supervisor.

8. TELEPHONE.

a. The FAA Southern Region Office operates the Regional Communications Control Center 24 hours a day. Telephone numbers of all supervisors are on file at the Communications Control Center. In case of emergency after hours, during weekends, and holidays, the center will provide the employee with telephone numbers and switch telephone calls to a supervisor. The Regional Communications Control Center telephone numbers are 246-7541 (FTS) and (404) 763-7541 (commercial).

b. When an F&E employee is in a travel status for two or more consecutive nights, other than academy training, that individual will be authorized one brief call to his/her residence each day during nonduty periods on FTS service if available. If FTS is not available, each employee will be reimbursed on his travel voucher for no more than two calls to his/her residence over commercial long distance network per week (or each seven (7) day period).

c. Brief. Brief telephone calls should be interpreted to be calls that do not exceed $3 on commercial lines or five minutes if on FTS lines.

d. F&E personnel are encouraged to use the Government-provided telephone service to report their arrival and departures to their respective office when changing job assignments, i.e., departing Mobile, AL, and arriving Jackson, TN.

e. Calls must be between places within the United States (the 50 states and the District of Columbia). See Order DOT 1500.6.

9. TRANSPORTATION BY POV. The majority of field employees use their own automobile on project assignments due to the restrictions on use of

Government vehicles after duty hours. An employee electing to use his POV must keep the vehicle in good mechanical condition and otherwise use the vehicle under the same conditions he would a Government car.

9-1. PERSONAL MAIL

a. Personal mail will not be received in the regional office for employees of this Division. The only exception to this will be mail for F&E Category IV (field) employees who are in a continuous travel status and do not have a permanent home address. The correct address to be used by these employees is: John J. Doe, FAA, ASO-450A or ASO-450B (as appropriate), P. O. Box 20636, Atlanta, Georgia 30320.

(1) The majority of mail being received in the regional office for F&E Category IV (field) employees has the correct address with the appropriate routing symbol; however, some are still being received without this information. This creates an additional workload on employees in the Mail Room and in the branch offices. All F&E Category IV (field) employees receiving personal mail in the regional office are responsible for reviewing all mail received to insure that the correct address, as outlined above, is being used. Action will be taken immediately to change incomplete and/or incorrect addresses with all companies, personnel, etc., to conform to the above.

(2) All first-, second-, and fourth-class mail, and third-class mail of obvious value, addressed to F&E Category IV (field) employees will be forwarded to addressee by ASO-450A or ASO-450B as appropriate. This mail so forwarded will be endorsed by the forwarding office, "Change of Address Due to Official Orders." Third-class mail that is not of obvious value cannot be reforwarded without additional postage. Therefore, this type mail, received in this office, will be held until it is personally picked up or appropriate arrangements are made to furnish postage for reforwarding.

(16) 6500 Communications and Flight Assistance Facilities.

(17) 6600 Communication Equipment.

(18) 6700 Navigational Aids.

(19) 6900 Plants and Structures.

(20) 8200 Flight Inspections and Procedures.

c. FAA Directives. Some specific directives which list procedures, standards, tolerances, and other information, some of which is directive in nature, are listed below. These directives (handbooks) contain information which installation personnel will find very useful. All personnel should become familiar with these handbooks. These directives are available for your reference at the airways facilities sectors and sector field offices throughout the region. It is common practice for the region to supplement FAA (Washington) directives. The supplements normally provide more details and reflect the Southern Region's operating guidelines. The supplements are just as directive as the basic orders and must be followed. Always check the current edition of the Southern Region Directives Checklist for the latest version of a supplement or order.

d. General.

(1) 1500.14, Travel (transmits DOT 1500.6)

(2) SO 6000.10, Preparation of Weekly Report of Expenditures, SO Form 6000-2.

(3) 6000.15, General Maintenance Handbook for Airway Facilities.

(4) 6000.20, Waiver of Criteria for Establishment and Maintenance of Airway Facilities.

(5) 6030.45, Facility Reference Data File.

(6) OAP 8200.1, United States Standard Flight Inspection Manual.

e. Communications.

(1) 6000.22, Maintenance of Two-Point Private Lines.

(2) 6550.2, Maintenance of Weather Broadcast and Information Service Equipment.

(3) 6560.13, Maintenance of Aviation Meteorological Systems and Miscellaneous Aids (LLWAS).

(4) 6580.5, Maintenance of Remote Communication Facility (RCF) Equipments.

(5) 6600.21, Maintenance of Communications Transceivers.

(6) 6640.2, Maintenance of Audio and Speech Equipment.

(7) 6670.4, Maintenance of Multichannel Recorder Equipment.

f. Radar.

(1) 6300.6, Five-Channel Video Mapper, FA-8970

(2) AF P 6310.1, Radar Facilities and Equipment Modification Handbook - ASR.

(3) 6310.2, Maintenance of Airport Surveillance Radar (ASR) Facilities.

(4) 6310.3, ASR-8/ATCBI-5 Implementation.

(5) SO 6310.5, Operating Policy for Airport Surveillance Radar (ASR) Systems.

(6) SM P 6330.1, Maintenance of Airport Surface Detection Equipment Facilities.

(7) AF P 6340.1, Radar Facilities and Equipment Modification Handbook Long Range Surveillance.

(8) 6340.8, Maintenance of Air Route Surveillance Radar (ARSR) Facilities.

(9) SO 6340.4, Cable Testing by Time Domain Reflectometry.

(10) 6360.1, Maintenance of Air Traffic Control Beacon Interrogator Equipment.

(11) AF P 6360.1, Radar Facilities and Equipment Modification Handbook - Radar.

(12) SO 6360.1, SECRA Power Reduction Procedures.

(13) 6360.2, Air Traffic Control Radar Beacon System Interrogator Usage and Power Reduction Procedures.

(14) IM P 6360.2, Installation Instructions for ATC Radar Beacon, Type ATCBI.

(15) IM P 6360.3, Installation Instructions for Radar Beacon Equipment Used with FAA, ADC, and Navy Radars.

(16) T.I. 6410.18, DBrite Operations and Maintenance Instructions.

(17) T.I. 6410.19, DBrite Systems Circuit Diagrams.

(18) T.I. 6130.6, Flight Data Input/Output (FDIO) System.

(19) T.I. 6130.7, Flight Data Input/Output (FDIO) System.

g. Navaids.

(1) 6560.8, Maintenance of Runway Visual Range (RVR) Equipment.

(2) 6730.2, Maintenance of Distance Measuring Equipment (DME) Facilities.

(3) 6740.2, Maintenance of Nondirectional Beacons.

(4) 6740.4, Nondirectional Beacon (NDB) Installation Standards Handbook.

(5) AF P 6750.1, Navigational Aids Facilities and Equipment Modification - ILS.

(6) 6750.6B, Installation Instructions For Category I and Category II ILS Glide Slopes.

(7) 6750.16, Siting Criteria for Instrument Landing Systems.

(8) 6750.35, Installation Instructions for Category I Localizer, Marker Beacon, and Compass Locator Facilities.

(9) 6750.47, End-Fire Glide Slope Antenna Installation Drawings.

(10) 6750.49, Maintenance of Instrument Landing System (ILS) Facilities.

(11) SO 6750.9, Vector Voltmeter Applications for ILS Technicians.

(12) TI 6820.2, Instruction Book VORTAC, VOR/DME, VOR, DVOR Equipment.

(13) 6820.7, Maintenance of Navigational Aids Facilities and Equipment VOR, VOR/DME, VORTAC.

(14) 6820.10, VOR, VOR/DME, and VORTAC Siting Criteria.

h. Automation.

(1) 6100.1, Maintenance of NAS Enroute Stage A - Air Traffic Control System.

(2) 6190.1, EEM Handbook - ARTS System Equipment.

(3) 6190.6, Maintenance of Automated Radar Terminal and Tracking System.

11. WORK ORDER AND ENGINEERING PACKAGE.

a. Installation Unit work order, FAA Form 6030-4, (figure 1-1, following page) will be issued for all projects. In almost all cases, the work order will be part of an engineering package. The engineering package is a set of documents consisting of the work order, which is the authorization for work, the plans and specifications that provide the installation details necessary for the accomplishment of F&E and maintenance projects, and the supplementary work order instructions. The work order provides a brief description of work, the local coordination contacts, an estimated completion date, the authorized mandays/dollars, and the appropriation codes for the project. The plans and specifications include detailed scope of the project, suggested installation procedures, parts lists, drawings, and other information pertinent to the completion of the project. The supplementary work order instruction provides guidance for the completion of documentation required during the course of the project. The engineering package should be adhered to as much as possible. If a change is necessary which conflicts with the engineering package, prior approval from an installation unit supervisor must be obtained and the change documented on the appropriate drawing. Though the engineering package is issued to the work order carrier, the other members of the installation crew should read it to be familiar with the total project. Detailed guidance on the content of the engineering package is provided in Branch Operational Procedure No. 2. Work orders are usually prepared by the responsible project engineer, assigned by the installation unit supervisor, requested by the engineering unit supervisor, and authorized by the section supervisor.

b. Construction Unit Work Order, FAA Form 6030-4, makes the specific job assignment and provides local contacts, estimated completion date, authorized mandays/dollars, and the appropriation code. Generally attached to the work order are several sets of plans and specifications, a copy of the contract, and the coordination designation letter.

c. The amount of mandays authorized in the work order shall not be exceeded. The unit supervisor should be advised as soon as it becomes apparent the authorized amount is insufficient. The unit supervisor is required to increase the mandays by written amendment to the work order or request the field engineer/technician be reassigned to another job when the mandays authorized by the work order are depleted. Within one week

FIGURE 1-1. FAA FORM 6030-4

WORK ORDER - COST DATA

JOB NO. 60861
WORK ORDER NO. ASO-453-90-013
SUPPLEMENT NO. 4
DATE 1/19/90

TO: John Q. Cat, IV

FROM: Supervisor, Installation Unit

You are authorized to proceed to Huntsville, AL, on or about 1/30/90 for the purpose of changing the insulators on the DVOR. Detailed instructions are provided in the attached plans and specifications.

LOCAL PROJECT COORDINATION. You shall coordinate your work schedule and other important aspects of this project with the following personnel prior to starting and, as necessary, during implementation of this project.

Manager, Airway Facilities Sector, Memphis, TN
Manager, Airway Facilities Sector Field Office, Huntsville, TN

The Sector Manager or Sector Field Office Manager (as appropriate) will be kept informed of project progress throughout the duration of the project.

JOINT ACCEPTANCE INSPECTION. The JAI is tentatively scheduled for 2/2/90.

ESTIMATED				DELIVERY SCHEDULE		
	PREVIOUS	ADDITIONAL	FIRST OR TOTAL	DATE FIRST UNIT REQUIRED IN FIELD		
MAN HOURS				THEREAFTER	NO. UNITS	PER ☐ WEEK ☐ MONTH
COST						

FISCAL PROGRAMMING					
1ST QTR.	2ND QTR.	3RD QTR.	4TH QTR.	CARRYOVER	FINAL COST (Provided by FMD on Completion of Work)

NOTE TO BUDGET	WITHDRAW FROM	ALLOCATE TO	AMOUNT
	7/482.0/8093/810/442/60861/2112 (Travel) 7/082.0/8093/440/60861/2630 (Purchases)		20 Mandays $200 Funding

REQUESTED BY (Signature)		AUTHORIZED BY (Signature)	
Jane Doe		John Doe	
TITLE	REF. NO.	TITLE	REF. NO.
Supervisor, Engineering Unit	ASO-453.10	Supervisor, Elec. NAVAIDS Section	ASO-453

FAA Form 6030-4 (7-71) FORMERLY FAA FORM 1196
U. S. GOVERNMENT PRINTING OFFICE: 1982 - 373-879

after completion of an assignment, the work order carrier should fill out the final charges (mandays and funds) on the work order and so note on the weekly report of expenditures that it is the final report.

d. The amount of funds authorized are to be used for local purchases and are not to be exceeded without prior approval of an installation supervisor.

12. THE WEEKLY REPORT OF EXPENDITURES. SO Form 6000-2 is to be prepared by the work order carrier (WOC) in accordance with the current Order SO 6000.10. The report is to be prepared and mailed each Friday and at the completion of the project. Although it is the WOC's responsibility for preparation, all personnel assigned to the project should become familiar with the contents of the weekly report.

a. On the following pages are examples of the proper format to use in the preparation of the weekly report. Examples vary as to how the front pages are completed. The back of the form should be completed as instructed on the form.

b. Example One is the format to be used when the project is covered by PCB&T/Activity 8 (personnel compensation, benefits, and travel) funding (see figure 1-2, PCB&T, following page). This example is for the vast majority of our jobs.

c. Example Two is the format to be used on a reimbursable project where our costs are being paid by an airport authority, military, etc., and a strict accounting of funds spent is needed for proper payment to the FAA. A quick method to determine if a project is reimbursable is to check the job number (see figure 1-3, Reimbursables, following page).

(1) If the fifth digit of the appropriation code is a 9, this denotes reimbursable funding.

(2) If the second digit of the five digit job number is a 7 or 8, this denotes reimbursable funding also.

Example: x/xxx.9/xxxx/xxxx8xxx/xxx

(3) Example One preparation:

(a) Routing block: Check for appropriate section supervisor.

(b) Week Ending: Saturday's date. Week runs from Sunday to Saturday.

(c) Report Number: Starting at 1, number sequentially until end of project where the last report should have, in addition to the number, the word "Final."

FIGURE 1-2. PCB&T

WEEKLY REPORT OF EXPENDITURES

TO [X] Chief, Environmental Engineering Br. [ ] Chief, Electronic Engineering Br.

WEEK ENDING	REPORT NO.	JOB ORDER NO.	WORK ORDER NO.
01/25/90	01	7/482.0/8095/810/330/C06	03 ASO-455-90-3

PROJECT NAME

Construction of MALSR, Rwy 34, Asheville Regional Airport, Asheville, NC

DATE PROJECT STARTED	PERCENT COMPLETED TO DATE	ESTIMATED COMPLETION DATE
01/18/90	22% by cost	03/18/90

I. PROJECT EXPENDITURES

ITEMIZED DATA	PERSONNEL				CONTRACT PURCHASE	VEHICLE CHARGES	TOTAL
	MAN HRS	SALARY (140%)	PER DIEM	TA'S			
Total this week	76.5				17.23		
Total previous week	0				0		
Total to date	76.5				17.23		
TOTAL WORK ORDER AMOUNT →	$1,000.00		TOTAL WORK ORDER BALANCE →				$982.77

II. NARRATIVE REPORT

See Construction Report #1 for narrative report.

Percent complete to date was figured by including structural steel onsite in a cost analysis, so it may be misleadingly high. Any other method is just as questionable this early in the job.

The pictoral record attached is primarily of road conditions at start of job to allow enforcement of Note 8, SO-D-100810-C01.

Joe P. Cat, IV, RE, ASO-455

Supplemental: Contract purchases were for film and developing, etc. Can expect cost of $600 (approximate) by SF-44 through SFO for components to build landline control unit and panel.

SO FORM 6000-2 (03-88) (Supersedes previous edition)

FIGURE 1-3. REIMBURSABLES

WEEKLY REPORT OF EXPENDITURES

TO ☐ Chief, Environmental Engineering Br. ☒ Chief, Electronic Engineering Br.

WEEK ENDING	REPORT NO.	JOB ORDER NO.	WORK ORDER NO.
9 May 87	5	88353	ASO-453-87-016

PROJECT NAME
Relocate VOR and convert to DVOR, Augusta, GA

DATE PROJECT STARTED	PERCENT COMPLETED TO DATE	ESTIMATED COMPLETION DATE
6 April 87	40%	26 June 87

I. PROJECT EXPENDITURES

ITEMIZED DATA	PERSONNEL				CONTRACT PURCHASE	VEHICLE CHARGES	TOTAL
	MAN HRS	SALARY (140%)	PER DIEM	TAXES			
Total this week	120	2,029.38	762.21	-	383.89	41.94	3,217.43
Total previous week	340	5,761.38	2,159.00	-	362.11	276.48	8,558.97
Total to date	460	7,790.76	2,921.21	-	745.99	318.42	11,776.40
TOTAL WORK ORDER AMOUNT →		17,000.00	TOTAL WORK ORDER BALANCE →				5,223.60

II. NARRATIVE REPORT

Mandays Alloted 30 Mandays Used 57.5

III. Personnel Assigned

	Hours this week	Hours total
J. Doe	40	200
T. Engineer	40	137
R. Technician	40	112
S. Anybody	-	11

IV. Work This Week

1. Bolted down 50 antenna pedestals.
2. Mounted antenna braces.
3. Installed equipment drawers in racks.
4. Began interconnect wiring of VORTAC equipment.
5. Mounted carrier antenna.

V. Work Next Week

1. Align pedestals, carrier antenna, and VOR monitor antenna.
2. Mount 50 antennas and radomes.
3. Transport new TACAN antenna to new site.
4. Continue interconnect wiring of VORTAC equipment.

VI. Remarks

Had to purchase new hardware for antenna braces because the bolts that were shipped were too long.

SO FORM 6000-2 (03-88) (Supersedes previous edition)

(d) Job Number: From the work order accounting block (withdraw from). x/xxx.x/xxxx/xxx/xxx/93904/xxxx.

(e) Work order number: From the work order job number block (example: ASO-453-90-10).

(f) Project name: Short description of job and location. Example: Install LLWAS, Bristol, TN.

(g) Date project started: Date of departure for the project.

(h) Estimate of work completed on project: Quick check of progress vs. mandays used: Divide mandays used by total mandays allotted, and compare to your estimate of percentage of work completed.

(i) Estimated completed date: As titled.

(j) Man Hrs.: Weekly total of manhours for all personnel assigned to project. Regular, overtime, and comp. all count the same.

(k) Total Previous Week: If this is weekly report one, then there would be no entry; for later reports, it would have the data from "Total to Date" of the previous week's report.

(l) Total to Date: Running total of manhours used.

(m) Total Work Order Amount: Total number of manhours allocated for project (Mandays X 8).

(n) Contract Purchase This Week: Amount of funds spent during the week for local purchase items (nuts, bolts, wire, etc.).

(o) Contract Purchase Total Previous Week: Running total of local purchases.

(p) Contract Purchases Total to Date: As stated.

(q) Total Work Order Balance: Total amount of funds allotted for project.

(r) Personnel Assigned: A listing of all F&E personnel assigned to project, with their weekly hours charged to project, and total hours charged to project. If several people have been reassigned to other projects, instead of listing their names and total manhours each week, a statement such as "Personnel from previous reports" and their total manhours as a group will be sufficient.

(s) Mandays Allotted: Total Mandays allotted from work order.

(t) Mandays Used: Time charged to project in mandays.

(u) Work Performed This Week: A brief summary of work performed during the week. Any problems concerning the project such as missing material, etc., should be noted.

(v) Work To Be Performed Next Week: Brief outline of work planned to be performed during the next week.

(w) Remarks: As stated.

(4) Example Two preparation:

(a) Preparation of a Weekly Report for a reimbursable project varies only in the reporting of expenditures. All charges to the project must be accounted for. In addition to keeping track of manhours and contract purchases, the salary for each individual assigned to the project must be figured, along with per diem and vehicle charges.

(b) Salary: Salary charts showing overhead charges added to base rates are distributed each January from the branch. These charts breakdown the costs to a hourly, daily, and weekly rate.

(c) Per Diem: A dollar amount of all per diem charges being charged to the project.

(d) Vehicle Charges: All POV mileage charges must be accounted for.

13. WEEKLY CONSTRUCTION REPORT AND DIARY (Construction Unit Only).

a. Weekly Construction Report, SO Form 6900-5 (Figure 1-4, following pages). This report should be prepared at the end of every work week. The report serves as communications between the resident engineer, the project engineer, and the contracting officer. The report should indicate progress made, conditions encountered, and construction planned for the following week.

b. The weekly construction report is used to monitor construction progress, provide information for coordination with other organizational elements in the agency, and, when necessary, by the contracting officer to initiate corrective action to avoid or reduce delays in completion of construction. This report may also be used to resolve disputes and claims arising from the construction contracts. Therefore, it is important that the report be a complete and accurate synopsis of the daily construction diary entries.

c. Three copies of the report should be made by the resident engineer. The original should be addressed in the top right hand corner to ASO-55. One copy should be marked to the attention of the project

FIGURE 1-4. WEEKLY CONSTRUCTION REPORT

WEEKLY CONSTRUCTION REPORT

1. REPORT NO.	2. WEEK ENDING (FRIDAY)
01	01/17-25/90
3. CONTRACT NO.	**4. WORK ORDER NO.**
DTFA06-89-30049	N/A

TO: Chief, Environmental Establishment Engineering Branch, ASO-440 — DATE: 01/26/90

5. JOB NAME: Construction of MALSR, Rwy 34	6. JOB LOCATION: Asheville, North Carolina
7. CONTRACTOR: Home Menders, Inc.	8. WEATHER: Clear and warm at first, then rain began.
9. CONTRACTOR'S SUPERINTENDENT: A. B. Foreman	10. GROUND CONDITIONS: Frozen crust in a.m., slightly muddy in p.m.

11. CONTRACT TIME USED	12. WORK COMPLETED	13. CONTRACT TIME (DAYS)	14. CONTRACT TIME USED (DAYS)
13 %	22% by cost %	60	08

15. ITEMS OF WORK BEHIND SCHEDULE	16. REASON FOR DELAY
Based on schedule provided by contractor, the fabrication of the towers is slightly behind schedule but not by much. The foundation work is progressing slowly though.	Contractor's work force is not as large as expected. Rain on 01/20 and 01/25 hampered progress.
17. SHORTAGE OF GOVERNMENT FURNISHED MATERIALS BY ITEM NUMBER	**18. ACTION TAKEN REGARDING DELAYED MATERIALS**
1g, 3, 4, 5, 6, 10, 16, 18, 19, 20, 22, 26, 31, 32, 33, 34, 35, 36, 39, 40, 42 (11 is available from SFO)	Informed project engineer, ASO-455. He is arranging acquisition.
19. TIME LOST THIS WEEK (DAYS & HOURS)	**20. REASONS FOR TIME LOST**
1 day, 5 hours	01/20 - rain 1:00 to 6:00 p.m. 01/15 - Rain all day

ITEM (IF EXPLANATION NECESSARY, REFER TO ITEM NO. AND EXPLAIN IN "REMARKS" ON REVERSE)	YES	NO
21. ARE THE CONTRACTOR - FURNISHED MATERIALS ON ORDER OR PRESENTLY ON SITE; OR OTHERWISE QUICKLY AVAILABLE FOR USE WHEN SCHEDULED?	X	
22. ARE THE WORKING FORCE AND EQUIPMENT ADEQUATE TO ACCOMPLISH SCHEDULED COMPLETION?	Questionable at this time.	
23. ARE YOU POSTING AND MAINTAINING THE CONSTRUCTION PROGRESS SCHEDULE?	X	
24. ARE THERE ENOUGH DIFFERENT ITEMS OF WORK BEING ACCOMPLISHED SIMULTANEOUSLY TO ASSURE SCHEDULED COMPLETION?	Difficult to evaluate this early in job.	
25. IS CONTRACTOR'S SUPERVISION ADEQUATE?	X	
26. IS CONTRACTOR'S SUPERVISION CONTINUOUS?	X	
27. IS THE CONTRACTOR INITIATING AND ACCOMPLISHING WORK ITEMS IN CONFORMANCE WITH THE CONSTRUCTION PROGRESS SCHEDULE? (EXPLAIN)	X	

28. ITEMS OF WORK SUSPENDED BY REASON OF WEATHER OR GROUND CONDITIONS. (EXPLAIN)
Contractor intended to layout, excavate, form, and place concrete at all stations with GP-1 towers and MG towers first. To date, he has only 2 complete compared to 4 or 5 expected. Rain and work force has contributed to the slower productivity.

29. VISITORS, OFFICIAL, AND CONTRACTOR'S PRINCIPAL
Onsite: Bob Technician (AVL SFO), R. C. Watts (CP&L) plus PRECON Attendants.

30. SPECIAL INSTRUCTIONS GIVEN OR RECEIVED
Jane Doe will pay invoice for structural steel onsite per inspection after PRECON. Special provisions to Airport Road Easement revised to reflect installation of 4-inch dia. conduit at 48 inches depth. RE instructed to obtain price for extra 23 feet of duct required by same. Suzy Secretary (Real Estate) to handle expired application for service by CP&L.

SO FORM 6900-5 (3-82) (Supersedes previous edition) *(See reverse)*

FIGURE 1-4. WEEKLY CONSTRUCTION REPORT (CONT'D)

31. PRINCIPAL ITEMS OF WORK THIS WEEK (CHECK YES OR NO)

ITEM	UNDER CONSTRUCTION YES	UNDER CONSTRUCTION NO	COMPLETED YES	COMPLETED NO
A. EARTH WORK	X			X
B. BUILDING		X		X
C. MECHANICAL Not applicable				
D. ELECTRICAL		X		X
E. CABLE LAYING		X		X
F. ENGINE GENERATOR Not applicable				

32. THIS WEEK'S ROLL OF FILM
☐ IS ENCLOSED ☒ FORWARDED to ASO-455
☐ WILL BE FORWARDED

33. HAVE YOU RECEIVED CURRENT PAYROLLS?
☐ YES ☒ NO (NOTE DISCREPANCIES)

Should receive next Monday, will include in next report.

	YES	NO
34. REQUISITION FOR FORMS - FORM FAA-192.1 ENCLOSED		X
35. REQUISITION FOR OFFICE SUPPLIES - FORM FAA-542 ENCLOSED		X

36. LIST BY NAMES SUB-CONTRACTORS ON PROJECT DURING THE WEEK

Big and Small (Land Surveyors)

37. REMARKS

Attached: GEM Transfer List with status of missing items. (2 pages)
Digest of Meeting with NC DOT Representative--changes Special Provisions of Airport Road cable crossing agreement. (1 page)

Daily Notes:

01/17 PRECON held. Site inspected, structural steel acknowledged as onsite, new cable betweem P&C Station and Localizer 16 was suggested.

01/18 Coordinated and accomplished layout survey of base line and elevation off of runway centerline. RE inventoried GFM.

01/19 Surveyor continued layout, RE reported GFM status and transferred material on hand to contractor. Contractor began tying reinforcement steel for tower foundations.

01/20 Contractor built temporary rain shelter, repaired trencher. Rain in afternoon lost 5 hours work time.

01/21 Contractor continued work on rain shelter and reinforcement steel.

01/22 Contractor built forms for Sta. 4, 6, 8 foundations, continued rein. steel work, lost rain shelter to wind. RE coordinated efforts for landline units, GFM, reinf. steel inspection, etc.

01/23 Contractor excavated, formed, and placed concrete at Sta. 8. RE arranged meeting with NC DOT, witnessed concrete placement.

01/24 Contractor excavated, formed, and placed concrete at Sta. 6. RE witnessed it. Slow mist/drizzle did not stop work but did slow productivity.

01/25 RE met with NC DOT. Contractor did piddly work, all-day rain stopped progress.

NAME OF FAA REPRESENTATIVE (TYPE & SIGN)	TITLE	DATE
Joe P. CAT IV Joe P. Cat, IV	Resident Engineer, ASO-455	01/26/90

engineer, and the third copy should be retained by the resident engineer until final payment is made to the construction contractor.

d. Construction Diary.

(1) Accurate and factual entries shall be made in the construction diary as events occur, but no later than the end of each working day. The construction diary is an official record and may be used to resolve disputes and claims arising out of the construction project. It is most important that the entries be complete so as to permit reconstruction of all events and conditions from this written record.

(2) Preprinted, bound construction diaries (figure 1-5, following page) are usually furnished to the resident engineer at the beginning of each construction job. In the event the preprinted diaries are not available, a bound notebook shall be used and the information shown in the following sample, "Construction Diary Daily Entry Data Format" used as an outline and checkoff sheet. Loose leaf notes or binders are not acceptable for construction diaries.

(3) At the completion of the construction job, the construction diary or diaries shall be given to the project engineer for review and transmittal to the contracting officer.

FIGURE 1-5. CONSTRUCTION DIARY DAILY ENTRY DATA FORMAT

a. Day/Date: _____.

b. Work Started: _____. Work Stopped: _____.
(Time)

c. Contract time used: _____ _____days.

d. Weather:

(1) Temperature: High_____°F Low_____°F

(2) Rainfall measured for the 24 hours: _____inches.

(3) Time of rainfall_____.

e. Conditions affecting work.

f. Number and type of major equipment that the contractor has on project site. Indicate if equipment is in use or not.

g. Number and classification of employees the contractor or subcontractors have on project site and hours worked at job site for payroll review purposes.

h. Brief description of work accomplished this date.

i. Description of any accidents and injuries.

j. Special instructions or decisions given to contractor, interpretations of drawings, and specifications.

k. List of visitors to project site and purpose of visit.

l. Government-Furnished materials (GFM) received.

m. List of major construction materials received by contractor.

n. Materials or shop drawings received, approved or disapproved.

o. Contract correspondence (issued and received).

p. Telephone calls (time, person, title, subject matter.

q. Instructions received from regional office.

r. List of subcontractors.

s. Supplemental record.

14. PERIODICAL ESTIMATE, FAA FORM 3669 (figure 1-6, following page). Periodical estimates usually are prepared by the resident engineer on the twenty-fifth (25th) day of each month or on the last working day before the 25th of each month and at the completion of the construction job. The original of the periodic estimate should be sent to the responsible project engineer for review and a copy retained in the job files at the site. The certification on the estimate shall be signed and dated by the resident engineer. The resident engineer shall discuss the periodic estimate with the contractor's representative before submitting it.

a. The contractor can be given credit for materials that are at the job site but not installed if invoices are furnished. This amount should be included in the "Work performed or materials installed to date - amount, Column 8," in the appropriate line item. Planned change orders or contract amendments should not be included in the periodical estimate.

b. A copy of the final construction acceptance inspection report should be enclosed with the final periodical estimate submitted through the project engineer to the construction contracting section for payment.

FIGURE 1-6. PERIODICAL ESTIMATE

PAGE 1 OF 1

PERIODICAL ESTIMATE

ESTIMATE No.: 2
PERIOD ENDING: November 25, 1975
PROJECT NAME: XYZ Facility
DATE PREPARED: November 25, 1975
LOCATION: Anytown (Fliers Field)
STATE: Georgia
SITE No.:
PROJECT No.:
ALLOTMENT:
APPROPRIATION: 027.0/08061/330/54321
PROPOSAL No.:
DESCRIPTION OF WORK: Construct XYZ facility building, antenna tower, and access road.
CONTRACT No.: DOT-FA76SO-9598
CONTRACT AMOUNT: $46,400
CONTRACTOR (NAME AND ADDRESS): ACE Construction Company, 1234 N. Main Street, Atlanta, GA 30301
LUMP SUM: UNIT PRICE: FORCE ACC'T.
CONTRACT TIME: 90 DAYS
PROCEED NOTICE EFFECTIVE: 10/1/75
WORK COMMENCED: October 3, 1975
DUE DATE:
ESTIMATED OR ACTUAL COMPLETION DATE: January 13, 1976
CONTRACTOR IS NOW 5 DAYS BEHIND SCHEDULE.
ESTIMATED PERCENTAGE OF PHYSICAL COMPLETION 62%

ITEM CODE No. (1)	DESCRIPTION OF ITEM (2)	LATEST REVISED DETAILED ESTIMATE QUANTITY (3)	UNIT (4)	UNIT PRICE (5)	AMOUNT (6)	WORK PERFORMED OR MATERIALS INSTALLED TO DATE QUANTITY (7)	AMOUNT (8)	Percent complete (9)
1.	SCHEDULE I							
	Building, antenna towers, and access road	1	JOB		40,000		24,000	60
2.	SCHEDULE II							
	Concrete piling	800	LF	8.00	6,400	600	4,800	75
						Subtotal	28,000	
3.	CHANGE ORDER #1							
	Additional culvert	1	JOB		600		600	100
						Total	29,400	

CERTIFICATE

I HEREBY CERTIFY that the work performed or the materials installed to date, as shown hereon, were accomplished in accordance with plans, specifications, and contract provisions, and that the quantities were determined from official field measurements and are correct.

(Signature)

Date _____ Engineer in Charge _____

REMARKS:

APPROVED

DATE | SIGNATURE OF CONTRACTING OFFICER

FAA Form 3669 (11-64) OBSOLETE PREVIOUS EDITION 0052-637-1000 4452

15. APPROVAL OR DISAPPROVAL OF CONTRACTOR'S MATERIALS OR SHOP DRAWINGS, SO FORM 4445-1 (figure 1-7, following page). Once the resident engineer is on the job site, all submittals and shop drawings should be submitted to him for approval or disapproval. Whether the resident engineer reviews the submittals depends on information available for proper review, his experience, and other factors such as availability of engineering assistance. The project engineer and the resident engineer should establish procedure for handling the submittals prior to the start of the construction job.

a. Usually, all submittals the resident engineer is capable of reviewing are approved or disapproved by him. Some exceptions will be made on high cost facilities and where more than one facility of the same type is being built. Submittals the resident engineer considers controversial, technically complex, or highly specialized are forwarded to the project engineer and reviewed by appropriate specialists at the regional office. All submittals reviewed in the regional office will be returned to the contractor through the resident engineer to assure proper coordination and project management.

b. The resident engineer shall compile and maintain a log on submittals required, submitted, approved, or disapproved. He shall routinely review this log to assure that all required submittals are submitted and processed in a timely manner. Time allowed for submittals and the review, as well as the number of copies and the format of submittals, is usually noted in the construction contract. It is critical that submittals be reviewed and returned to the contractor within the contract time allowed.

c. Review and comment on the submittals shall refer to specific contract drawings and/or specifications which apply. Care should be exercised in the review of shop drawings to assure compliance with the contract conditions, compatibility with related items, physical space, maintainability, etc.

FIGURE 1-7. SO FORM 4445-1

APPROVAL OR DISAPPROVAL OF CONTRACTOR'S MATERIALS OR SHOP DRAWINGS

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
SOUTHERN REGION

1. TO:

ACE Construction Company
1234 N. Main Street
Atlanta, GA 30301

2. DATE January 16, 1990

3. GOV'T TRANS. NO. RE-03

4. CONTRACTOR'S TRANS. NO. #5

5. DATE CONTRACTOR'S TRANSMITTAL RECEIVED January 15, 1990

6. PROJECT NAME XYZ Facility, Anytown, Georgia

7. CONTRACT NUMBER DOT-FA91SO-9598

8. TRANSMITTAL REFERENCE TO CONTRACT DRAWINGS and/or SHOP DRAWINGS

SO-D-9876-S1 through S3

9. TRANSMITTAL REFERENCE TO CONTRACT SPECIFICATIONS AND PARAGRAPH NUMBER and/or CHANGE ORDER

FAA-SO-789, Divisions 3 and 5

10. FACTS: Gentlemen:
We are returning herewith the following Submittal Data:

A. ITEM NO.	B. NO. COPIES	C. NAME OF SUPPLIER	D. TYPE OF MATERIAL OR EQUIPMENT	E. APPROVAL AS SUB'TD	E. APPROVAL AS NOTED	E. APPROVAL AS TO MFGR. ONLY	F. NOT APPROVED
1	1	Atlas Steel	Building reinforcing steel		x(1)		
2	1	Atlas Steel	Tower foundation reinforcing steel				
3	1	Strong Bolt Co.	Tower anchor bolts				x(2)

G. SUBMITTED MATERIAL OR EQUIPMENT FOR USE AS reinforcing steel for building and tower foundation. Tower anchor bolts.

H. REMARKS (1) Reinforcing steel for pile caps shown on Atlas Steel shop drawing No. 123-sheet 2, detail C, is incorrect size, see drawing SO-D-9876-S2, detail 3/S2; #6 x 4'-5" rebars required.
(2) Anchor bolts not correct material and galvanized coating; see specification FAA-SO-789, paragraphs 5.2.3. and 5.4.6.

I. STIPULATIONS

Data marked "Approved *as Noted*" is satisfactory, contingent upon contractor acceptance of corrections and/or notations, and if accepted does not require re-submittal. Data marked "Approved *as to Mfgr. Only*" will be acceptable, provided re-submittal is made with revised selection, according to specifications. Data marked "Not Approved" does not meet job requirements, and contractor must re-submit on proper basis. Approval of Data does not obivate Contractor Responsibility for correct quantity take-off or installation clearances.

Sincerely.

Carbon Copies Transmitted To:

Contracting Officer, ASO-55A
Project Engineer, ASO-441

SO Form 4445-1 (1-73)(Supersedes SO Form 460)

16. EXCESS PROPERTY REPORT, FAA FORM 4800-1 (figure 1-8, following page). The resident engineer and the electronic installation work order carrier should be aware at all times of the availability, usage, and excess of government-furnished materials, especially cable. He is responsible for preparing a list of excess property. The list of excess property is given to the property custodian for proper action.

REPORT OF EXCESS PROPERTY

PAGE 1 OF 1

1. PREPARING OFFICE: AFSFO, Anytown, Georgia
2. SUPPLY SUPPORT/ADDRESS CODE: 4251 - Anytown, GA, XYZ Facility
3. DOCUMENT NO.: To be filled in by ASO-52C
4. REPORT APPROVED BY (Name and title): Leave blank
5. SIGNATURE: Leave blank
6. DATE OF APPROVAL: Leave blank

ITEM NO. (7)	FEDERAL STOCK NUMBER (FSN) (8)	NOMENCLATURE (9)	CONDITION CODE (10)	UNIT OF ISSUE (11)	QUANTITY (12)	ACQUISITION COST UNIT PRICE (13)	ACQUISITION COST TOTAL VALUE (12 X 13) (14)	APPROVED ACTION (15)	DATE AVAILABLE (If material cannot be screened until) (16)
1.	6145-00-765-6736	Cable, 25 pr #19A 1 reel continuous length	N-1	FT	200	.39	78.00		
2.	6145-00-867-4628	Cable 2/c #8, 2 each 50' length, coiled	N-1	FT	100	.89	89.00		
Excess to Job N. 54367,		XYZ Facility, Anytown,	Georgi						

Chief, AFSFO, Anytown, Georgia
Cost Center Code - 08570
Location Identifier - ANT

FIGURE 1-8. FAA FORM 4800-1

17. TIME REPORTING: Time and attendance reports (T&A's) are submitted to the Payroll Branch electronically via the Electronic Time and Attendance Management System (ETAMS). All F&E field personnel shall submit the following information to their T&A clerks once each week (time to be designated by each section and/or unit): Daily hours of work, job number to charge those hours to, and all leave taken. This should be the first order of business to insure proper submission of the T&A's. When there are several members of an installation crew, this should be done as a group effort with only one phone call, not several individual calls throughout the day. An example of how it should be called in follows:

> "On the first Monday of the first week, I worked from 8:00 a.m. to 4:30 p.m. regular hours; and from 4:30 p.m. to 6:00 p.m., overtime. These hours are charged to job number 87444."

a. Leave. All leave taken, regardless of type (annual, sick, or comp.) or amount, must be documented by submission of an Application for Leave Form (SF-71).

b. Annual Leave. Your supervisor should be notified as soon as possible when you need to take time off; however, eight hours or less can be approved by your work order carrier, who in turn will notify the supervisor at the earliest possible moment. Annual leave in excess of three days requires that an SF-71 be completed and submitted to your supervisor for his signature/approval. Application for annual leave (submittal of SF-71) should be made as far in advance of the start of the leave period as practical to allow for revision of work schedules.

c. Sick Leave. Sick leave up to four days can be taken without having an SF-71 signed by a doctor. Sick leave in excess of four days, however, requires submission of a completed SF-71, signed by a doctor, to your supervisor. At the supervisor's discretion, a completed SF-71, signed by a doctor, can be required for sick leave of less than four days. In all cases of sick leave, you should notify your supervisor or work order carrier as soon as practical. If the work order carrier is notified, he in turn is to notify the supervisor.

18. TRAVEL REIMBURSEMENT. Employees traveling on official business away from their headquarters are paid a daily allowance to compensate them for expenses incurred for meals, lodging, tips, laundry, and dry cleaning. A standard mileage rate is also paid to employees for their vehicles on official business. The Travel Manual, 1500.14, appendix 1, establishes basic travel policies and procedures for all DOT employees. This manual is not always readily available to field personnel; therefore, the following information from the manual may be used in preparation of the employee's travel voucher.

a. Glossary of travel terms:

(1) Constructive cost. Cost of travel by common carrier which would have been incurred had travel been performed as authorized by the travel authorizing official and the travel manual.

(2) Government Quarters. Sleeping accommodations in a facility (other than that provided by carriers) operated under United States Government control or supervision, or furnished under the terms of a Government contract, or on a complimentary basis. Government quarters include homes owned by the Government and permanently occupied by Government employees, guest houses, clubs, hotels, bachelor quarters, visiting officers' quarters, or similar facilities.

(3) Local Travel. Official travel (not involving per diem) performed by bus, streetcar, taxi, or other conveyance within the local travel area as defined by the official delegated authority to define local travel.

(4) Mileage Allowance. The rate allowed per mile in lieu of actual expenses for operation of a privately-owned conveyance or in connection with towing a mobile home.

(5) Mobile Home. All types of house trailers and dwellings constructed for use as residences and designed to be moved overland, either self-propelled or towed.

(6) Per Diem. A daily allowance for employees or other persons while traveling or while on temporary duty assignments on official business. It is intended to compensate for the necessary subsistence costs of travel not otherwise reimburseable. It is intended to compensate for all subsistence expense, including meals, lodging, personal use of a room during daytime, baths, all fees and tips to waiters, porters, baggage men, bellboys, hotel maids, dining room stewards, and others on vessels, hotel servants in foreign countries, telegrams, and telephone calls reserving hotel accommodations, laundry, cleaning and pressing of clothing, fans and fires in rooms, and transportation between places of lodging or business and places where meals are taken. The term "lodging" does not include accommodations on airplanes, trains, or steamers; and these expenses are not subsistence expenses.

(7) Permanent Change of Station (PCS) or Official Change of Station Travel. Travel of an employee in connection with a transfer to a different duty station on other than a temporary basis.

(8) Privately-owned Conveyance. A privately-owned aircraft, automobile, or motorcycle used by a traveler other than on a for-hire or rental basis. Actual ownership may or may not exist.

(9) Privately-owned Conveyance (POC) or Vehicle (POV). Any self-propelled wheeled motor conveyance that is primarily for use as a passenger-carrying vehicle, jeeps, motorcycles and motor scooters, pick-up and panel trucks and such trucks when converted to "campers," small autobuses of the Volkswagen, Micro, and similar types (not to exceed nine-passenger capacity) and other passenger-carrying or multipurpose motor vehicles designed for overland ground transportation which, while not specifically mentioned herein, may be found to qualify as privately owned motor vehicles on the basis of the employee's written certification that the vehicle is for his personal use as a passenger-carrying vehicle.

(10) Temporary Duty Travel (TDY). Travel to one or more places away from an official station to perform temporary assignments and, upon completion thereof, return to the official station or assignment to another temporary assignment.

(11) Training. A formally planned and systematically conducted routine of instruction and practice as distinguished from a meeting which is for the purpose of exchanging information and discussing problems with others inside official station.

(12) Travel, Official. Authorized travel solely in connection with business of the DOT. Official travel may be performed within the vicinity of a permanent duty station; to or from place of actual residence; to, from, or between permanent duty stations; and to, from, at, and between places of temporary assignment. The term "travel" relates not only to movement from place to place but also includes entitlement to the use of quarters facilities, allowances, and certain transportation and reimbursable expenses incident to travel, subject to conditions and limitations in the travel manual.

(13) Travel Advance. A travel advance is intended to provide the traveler with funds before and during the period his travel voucher is being processed. A Government-issued Diners Club Card is available, and all travelers are encouraged to use the card. If the traveler is a member of the PASS BARGAINING UNIT, that individual may obtain a $3,600 advance; however, if he elects to use the Diners Club Card, he will be limited to an advance of only $2,500. All travelers who are not members of the bargaining unit are limited to the $2,500 advance. A cash advance of up to $600 may be obtained from an imprest fund.

b. Travel Order. Authorization in writing for official travel by a designated travel authorizing official. Travel orders include authorizations, approvals, limitations, instructions, and special conditions relating to travel and assignment.

c. Travel Status. The elapsed period of time from the beginning to the ending of official travel in compliance with the authority in a travel order. This includes incidental waiting time enroute for transportation connections and delays enroute beyond the control of the traveler.

d. Composition of Per Diem Allowance.

(1) Per Diem Allowance at Official Station. Per diem will not be allowed an employee either at his official duty station or at his placeof abode from which he commutes daily to his official or temporary duty station.

(2) Lodging With Friends or Relatives. When an employee obtains lodging from friends or relatives (including members of the immediate family) with or without charge, no part of the per diem allowance will be allowed for lodging unless the host actually incurs additional costs in accommodating the traveler and these costs are substantiated. Costs may include rental of a bed or sleep sofa and increased utility expenses. These costs need to be supported by rental receipts and, if appropriate, copies of utility bills for periods before, during, and after a visit which document the increased costs. The additional documented costs may be allowed as a lodging expense when determined to be reasonable by approving officials. Neither costs based on room rates for comparable conventional lodging in the area nor flat "token" amounts will be considered reasonable.

(3) For Situations Involving Double Occupancy. If the lodging receipt shows a charge for double occupancy, such fact shall be shown on the travel voucher with the name and employing agency or office of the person sharing the room if such person is a Government employee on official travel. One-half of the double occupancy charge will be allowable for each employee. If the person sharing the room is not another Government employee on official travel, identification of the person sharing the room is not required; and the employee may be allowed the single room rate.

(4) Lodging Not Available at Temporary Duty Location. In certain circumstances, lodging accommodations may not be available at the temporary duty location, and the employee must obtain lodging in an adjacent locality where the prescribed maximum per diem rate is higher than the maximum per diem rate for the location of the temporary duty point. In such instances, the authorizing official may make an administrative determination on an individual case basis to authorize or approve the higher maximum per diem rate. If the higher maximum rate is not justified and authorized in advance, the employee must furnish a statement with the travel voucher satisfactorily explaining the circumstances which required the use of lodging in an area other than that of the temporary duty point designated in the travel authorization.

e. Lodging Receipt Requirements. Receipts shall be required to support all lodging costs for which an allowance is claimed under the lodgings-plus per diem system except that a written statement instead of a receipt may be accepted for the fee or service charge incurred for the use of Government quarters. Receipts are not required when a specific or reduced rate has been authorized in advance of the travel.

f. Beginning and Ending of Entitlement. For computing per diem allowances, official travel begins at the time an employee leaves home, office, or other authorized point of departure and ends when the employee concludes travel at home, office, or other authorized point. Travel from the regional office to a temporary duty station shall not commence after 2 p.m. except in emergency situations. Emergency cases must have the verbal approval of the section supervisor.

g. Rules For Computing Number of Days of Per Diem.

(1) TDY Travel of 24 hours or Less. In computing the amount of per diem for periods of TDY of 24 hours or less, the actual number of hours of the trip are counted and computed as if they fell entirely within one calendar day. For example, TDY status from 4 p.m. of one day to 2 p.m. of the following day is counted as falling within one calendar day for the purpose of computing per diem. For each six hours or fractional part of a six hour period, per diem is allowed at the rate of one-fourth of the daily rate. In the example, the 22-hour temporary duty would be considered as one full day. No per diem will be allowed when the travel period is 10 hours or less during the same calendar day, except when the travel period is six hours or more and begins before 6 a.m. or terminates after 8 p.m.

(2) Travel of More than 24 Hours. The calendar day (midnight to midnight) will be the unit for a full day's per diem in computing per diem for continuous travel of more than 24 hours. Fractional days of travel status will be computed at the rate of one-fourth of the per diem allowance for each period of six hours or fractional period based on the standard six-hour quarters of the calendar day.

h. Interruptions of Per Diem Entitlement, Leave and Nonworkdays.

(1) General. Except as otherwise provided, if the time that leave of absence begins or terminates is within the traveler's prescribed hours of duty, per diem in lieu of subsistence expenses will terminate at the beginning of the next quarter day or begins with the quarter day during which the leave of absence terminates. If leave of absence does not begin or terminate within the traveler's prescribed hours of duty, the traveler will be entitled to per diem in lieu of subsistence expenses until midnight of the last day preceding the leave of absence and from 12:01 a.m. of the day following the leave of absence.

(2) Nonworkdays. A traveler will be considered to be in a subsistence status on nonworkdays unless he returns to his official station or place of abode from which he commutes daily to his official station, or unless he is in a leave status at the end of the workday preceding the nonworkday(s) and at the beginning of the workday following the nonworkday(s) and the period of leave on either of those days exceeds one-half of the prescribed working hours for that day: Provided that

subsistence may not be paid for more than two nonworkdays where the leave of absence is immediately preceded and followed by nonworkday(s).

(3) Leave Within One Day. Leave of absence for part of a workday not extending into the next workday, where for one-half of the prescribed working hours or less, will be disregarded for subsistence purposes; where leave for part of a workday exceeds one-half of the prescribed working hours, one half of the subsistence for that day may be allowed.

i. Part-day Leave Extending Between Successive Workdays. Leave of absence for the last part of one workday, which extends into leave of absence the beginning of the next workday and there are no intervening nonworkdays, will be disregarded for subsistence purposes if the leave of absence on both days combined does not exceed one-half of the prescribed working hours for one day.

j. Annual Leave on Friday Followed by Sick Leave on Monday. If, while in a travel status, an employee takes annual leave on Friday afternoon and sick leave on the following Monday, he is not entitled to per diem after 6 p.m. on Friday unless a certification is included on the voucher stating when the illness began and indicating that it continued through Monday. Payment of per diem is then authorized from the quarter of the day in which the illness began.

k. Per Diem for Indirect-Route or Interrupted Travel. Where, for the traveler's personal convenience or through the taking of leave, there is interruption of travel or deviation from the direct route, the per diem allowance may not exceed that which would have been incurred for interrupted travel by a usually traveled route.

l. Sick Leave While in Travel Status. Whenever a traveler takes leave of absence because of being incapacitated due to his illness or injury, not due to his own misconduct, the prescribed per diem in lieu of subsistence will be continued for periods not to exceed 14 days (including fractional days) in any one period of absence unless, under the circumstances in a particular case, a longer period is approved. The employee must certify on the travel voucher that the illness or injury was not due to misconduct and that no hospitalization or reimbursement was received under federal statute (other than Government Health Insurance). Reimbursement of per diem while on sick leave must be approved by an official authorized to approve travel. If, while in travel status, the traveler receives hospitalization (or is reimbursed for hospital expenses) under any federal statute, other than the Federal Employees Health Benefits Act, he is not entitled to a travel allowance for the period involved.

m. Use of Mobile Dwelling During Temporary Duty.

(1) Per diem allowances are authorized for employee's privately owned trailers, campers, and mobile homes during periods of travel and temporary duty. The allowances will consist of a flat rate of $55 per day. This per diem rate is specifically limited to facilities and equipment (F&E) field personnel and must be indicated specifically on the applicable travel order covering the individual's travel.

(2) Authorization for flat rate per diem must be approved by the division manager in writing.

n. Cost comparison - Lodging - Plus Per Diem System (see figure 1-9 for computation samples).

(1) Voluntary return to permanent duty station or place of abode is shown in figure 1-9.

(2) Sample request for cost comparison - enroute travel is found in figure 1-9.

(3) Constructive cost formulas are shown in figure 1-9.

FIGURE 1-9. COMPUTATION EXAMPLES

(1) Voluntary return to permanent duty station or place of abode.

7/3 Thursday - Depart TDY @ 4:30 p.m.

7/4 Friday - Holiday.

7/5 Saturday - RDO.

7/6 Sunday - RDO arrive TDY @ 4 p.m.

TDY location is the standard CONUS rate, maximum lodging of $40 plus $26 for M&IE.

Per Diem up to Point of Deviation	Cost to Go	Cost to Stay
7/3 3/4 M&IE	1/4 M&IE + transportation	1/4 M&IE + lodging
7/4 0	0	M&IE + lodging
7/5	0	M&IE + lodging
7/6 1/2 M&IE + lodging	1/2 M&IE + transportation	1/2 M&IE

Lodging costs for constructive cost purposes will be determined by the cost of the previous night's lodging.

FIGURE 1-9. COMPUTATION EXAMPLES (CONT'D)

(2) Cost Comparison - Enroute Travel.

Actual Enroute Travel

8/2	8:30 a.m.	Dep Orlando, FL, via POV	
	5:15 p.m.	Arr Atlanta, GA	
		POV MILEAGE 431 MILES @ .24	$103.44
		3/4 DAY @ $34 = $24.75	25.50
		LODGING $55.29	55.29
8/3		At TDY location, Atlanta, GA	89.29
		1 day @ $34 plus lodging, $55.29.	
		Attended meeting beginning at 2 p.m.	
8/14	10:30 a.m.	Dep Atlanta, GA	
	7:45 p.m.	Arr residence, Orlando, FL	
		1 day @ $34	34.00
		POV mileage 431 miles @ .21	103.44
TOTAL ACTUAL TRAVEL			$410.96

(3) Constructive Cost

8/3	7 a.m.	Dep residence for office - POV		
		22 miles @ .24		5.28
		Dep office for airport - POV		
		5 miles @ .24		1.20
	12.05 p.m.	Dep Orlando via EA 336		
	1:35 p.m.	Arr Atlanta, GA		
		Round trip airfare		156.00
		Taxi to regional office		5.00
		3/4 day @ $34		25.50
		Lodging - $55.29		55.29
		Attending meeting beginning at 2 p.m.		
8/14	10:30 p.m.	Dep. regional office by taxi		5.00
	12:30 p.m.	Dep Atlanta via EA 337		
	2:06 p.m.	Arr Orlando, FL		
	3 p.m.	Arr office via POV		
		5 miles @ .24		1.20
		Parking, Orlando Airport		24.00
		Mileage, office to residence - POV		
		22 miles @ .24		5.28
		3/4 day @ $34		25.50
		TOTAL CONSTRUCTIVE COST		$309.25
LESSER AMOUNT CLAIMED				$309.25

NOTES.

The lesser amount should be placed in Column M.

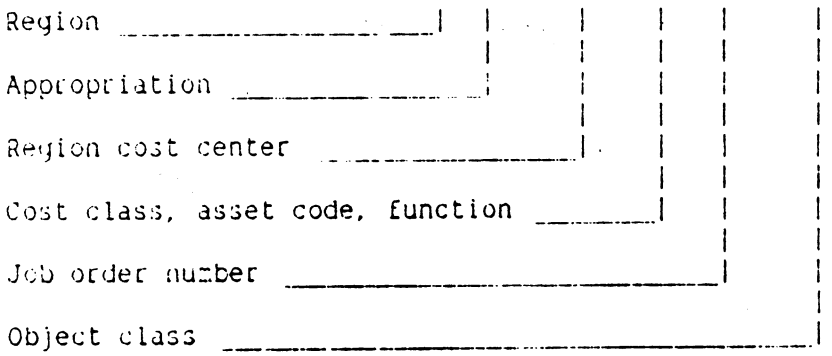
Transportation to and from carrier terminals, office, residence, and parking must be the usual methods based on traveler's prior trips.

Parking at carrier terminals must be reasonable when claimed in constructive cost. Rule of thumb: Parking and mileage can not exceed round trip taxi fare.

19. F&E CODING AND PURCHASES. All documents where funds are deducted from the general ledger account must be coded with a sequence of numbers which the agency's data processing equipment will identify. Some of the documents which are coded are travel vouchers, LDR's, Form 44's, and imprest fund purchase receipts.

a. Coding Format. The complete code is made up of several number groups which identify the appropriation, region, cost class, job order number, and object of the charge. The code sequence is:

x/xxx.x/xxxx/xxx xxxxx/xxxx



b. Coding Examples.

Hardware purchased for use on a specific project.

Example: 7/182.0/8093/440/71427/2630

c. Object class Codes. The last four numbers of the code make up the object class. This identifies the nature of the goods or services purchased. Order SO 2700.1 lists description and illustrations of purchases and specifies the object class to use. A few codes which field personnel use are given below:

(1) 2112 Subsistence (per diem) claim and reimbursement for use of POV on travel voucher.

(2) 2630 Includes all hardware items, hand tools, power tools, paint, lumber, electrical goods, and electrical parts.

(3) 2541 Rental, miscellaneous equipment, with operator.

(4) 2543 Repair of equipment.

(5) 2391 Rental, miscellaneous equipment, without operator.

(6) 2231 Rental, truck, GSA or commercial.

(7) 2211 Transportation of government supplies/material by commercial carrier.

(8) 2639 Film, photographic supplies, developing.

(9) 2370 Waste disposal, continuous service contract.

20. FIELD PURCHASES. Supervisors and project engineers are to insure that all local purchases are limited to the needs of the project or are required to perform day-to-day installation/construction activities. Purchase of logistics center stocked items is to be limited to the immediate needs of the project, with further procurement through F&E Engineering Support Services, ASO-454.

21. PAYING FOR PURCHASES. Four payment options may be used in purchasing supplies in the field.

a. Visa Card. GSA has contracted with Rocky Mountain Bank Card System to provide a Government Visa Card to be used for small purchases. Employees who have been authorized small purchase authority are eligible for a Visa Card. The card is issued in the employee's name. An approving official is identified for each card holder. A card holder may purchase up to $1000 for a single purchase. The FAA is then billed once a month for all purchases made by its card holders. The card holder receives a statement monthly of his/her purchases. He/she then attaches all the sales slips for the month, annotating the accounting classification for each purchase, and forwards it to the approving official. The approving official then certifies that the purchases were for official business and forwards to Accounting for payment. Accounting then pays Visa once a month as opposed to each individual vendor. The result is that the vendor gets his money anytime he turns the purchases over to Visa, daily if he wants. The Visa Card specifically states that the purchase is tax exempt. Vendors who previously did not want to sell to the Government due to delays in payment will be more willing to do business with us.

b. Imprest Fund. Cash purchases using imprest fund money is another method of paying for field purchases. Imprest funds are usually established at all facility sector and sub-sector offices. Except for purchases made by credit card, all small purchases shall be supported by

an authorized procurement request (PR). A Standard Form (SF) 1164 completed by hand and signed by the AFS or SFO manager may be used as a PR for purchases reimbursed from the imprest fund. The original completed SF-1164 will be retained by the imprest fund cashier. For small purchases of less than fifteen dollars, a cash register receipt is required for proof of purchase. Larger purchases require an original invoice marked "paid" and the seller's full signature. All receipts must be F&E coded before payment by the imprest fund cashier. The region issues small purchase authority on an individual basis and issues a Small Purchase Authority Card, FAA Form 4405-2, (figure 1-10, following page) to be presented to imprest fund cashiers when payment is requested.

c. Travel Voucher Reimbursement. Local purchases can be claimed on the employee's monthly travel voucher. This method of reimbursement can be used when working at locations where imprest funds are small or not available. SF-1164 should be used for miscellaneous purchases that total more than fifty dollars. Less than fifty dollars will be paid on your regular voucher.

d. SF-44, Purchase Order. Another method for paying bills is with a Standard Form 44 (SF-44). This method has many restrictions. One of the essential criteria that must be met before a SF-44 can be used to make a purchase is that only one delivery and one payment will be made. It is not appropriate to split what should be a single purchase into smaller purchases in order to avoid competition or other limitations or restrictions. Do not make monthly payments to avoid exceeding your SF-44 limit authority. When issuing a SF-44 to an individual, include his/her tax ID number or social security number on the SF-44.

e. Restricted Purchase Items (excerpted from SO Order 4402.3, Chg. 3).

(1) Unauthorized Acquisition of Expendable Supplies. All offices shall refrain from purchasing expendable supplies for personal consumption.

(2) Restrictions. The following items may not be purchased using imprest fund, SF-44's, or blank purchase authorities (BPA) except as noted.

(a) Advertising in newspapers or trade journals.

(b) Annual agreements for maintenance, repair and reconditioning of typewriters, office machines, or other office equipment. However, one time repair of typewriters, office machines and other office equipment may be accomplished, provided that the cost of repair does not exceed the mandatory use threshold in any applicable GSA Supply Schedule contract. Contact ASO-55 for contract information on repairs not specifically identified in Paragraph "Y."

FIGURE 1-10. SO FORM 4406-2

LAST NAME	FIRST NAME	MIDDLE INITIAL	OFFICE & ROUTING SYMBOL
Cat, IV,	John	Q.	ASO-453

SMALL PURCHASE AUTHORITY
SOUTHERN REGION

U.S. Department of Transportation
Federal Aviation Administration

No. _____

John Q. Cat, IV

Whose signature appears below is delegated small purchase authority as described on the reverse of this form.

John Q. Cat, IV — Signature of Designee
10-1-90 — Expiration Date

Signature of Contracting Officer — Date

SO Form 4406-2 (12/89)

INSTRUCTIONS: Designee shall sign and return ALL copies to the Procurement Branch, ASO-55

TYPE: ☐ Full ☒ Restricted

☒ Supplies not to exceed $ 500
☐ Non-personal services not to exceed $ _____
☐ Rental of aircraft not to exceed $ _____
☐ Emergency Repairs to agency aircraft not to exceed $ _____
☐ Other _____

(c) Automated data processing hardware, software, and services. Prior approval must be obtained from the Regional Information Resource Manager, ASO-60.

(d) Books, magazines, periodicals and publications.

(e) Carpets, rugs, linoleum, tile and other floor coverings.

(f) Clothing (or personal apparel of any description). Requirements for special type clothing are to be coordinated with the Procurement Branch, ASO-55.

(g) Commercial or short-term rental of motor vehicles - See Handbook 4670.2A, with SO Supplements, for more information.

(h) Covers, seat, truck and/or passenger cars.

(i) FAA Logistics Center support items, except as authorized by paragraphs 7 and 8 of Order 4650.12B, Local Purchases. SHOW BASIS FOR PURCHASE ON INVOICE OR SF-44.

(j) GSA Stores Stock Catalog except that purchases not exceeding $100 may be made if the item customarily obtained from GSA stock is not readily available. A STATEMENT THAT THE ITEM PURCHASED WAS NOT AVAILABLE FROM GSA STOCK MUST ACCOMPANY THE WHITE AND GREEN COPIES OF THE SF-44 OR IMPREST FUND SUBVOUCHER.

(k) Handling employee's household effects. Specific instructions covering packing, crating, drayage, wharfage, handling, and storage of employee's personal effects shall be obtained from the Materiel Management Branch, ASO-52.

(l) Office furniture and equipment. This restriction includes all items in Federal Supply Classification Code Group 71, regardless of cost.

(m) Payment of salaries or wages.

(n) Personal services. Descriptive elements that should be used in assessing whether or not a proposed contract is personal in nature are listed in the Federal Acquisition Regulations (FAR), Subpart 37.104(d) and include (1) performance onsite; (2) principal tools and equipment furnished by the Government; (3) services are applied directly to the integral effort of agencies or an organization subpart in furtherance of assigned function or mission; (4) comparable services, meeting comparable needs, are performed in the same or similar agencies using civil service personnel; (5) the need for the type of service provided can reasonably be expected to last beyond one year; (6) the inherent nature of the service,

or the manner in which it is provided reasonably requires directly or indirectly, Government direction or supervision of contractor employees.

(o) Printing and binding. Requirements for printing or binding must be coordinated in advance with the Regional Printing Specialist, Materiel Management Branch, ASO-52. WHEN THE PRINTING SPECIALIST AUTHORIZES OUT-OF-AGENCY PURCHASING OR PRINTING SERVICES, THE PURCHASE DOCUMENT SHALL MAKE REFERENCE TO SUCH AUTHORIZATION.

(p) Purchases from DOT employees.

(q) Rental of real property (including storage space, buildings, land, easements, right-of-ways, etc.). This does not preclude the use of the small purchase method to obtain temporary storage of equipment and materials received at a site prior to the time actual installation can begin. HOWEVER, THE CIRCUMSTANCES SHALL BE EXPLAINED ON THE ORIGINAL AND GREEN COPIES OF THE SF-44 OR INVOICE.

(r) Repairs or alterations to leased premises. Approval of the Real Estate and Utilities Branch, ASO-56, is required prior to the repair or alteration of leased premises.

(s) Space (including short-term use of conference and meeting facilities) without prior approval of the Real Estate and Utilities Branch, ASO-56.

(t) Transportation charges when services are ordered on a Government bill of lading or a commercial bill of lading to be converted to a Government bill of lading.

(u) Transportation of personnel or a combination of personnel and freight. A transportation request must be used in these instances.

(v) Utility services such as electrical energy, water, gas, etc., except by special authorization from the Real Estate and Utilities Branch, ASO-56.

(w) Water for drinking and coolers except at locations where there is no water available at the site. Show this fact on invoices or SF-44's.

(x) Purchase of automotive repair parts and maintenance or repair of FAA vehicles in excess of $300 must have prior approval of the Motor Fleet Manager, ASO-52C5. In no event shall purchases for automotive repair parts exceed any limitation that may be listed in Paragraph "Z."

(y) The purchase of telephones is restricted. Contact the Telecommunications Operations and Administration Section, ASO-481, FTS

246-7387 or Commercial 763-7387, to obtain approvals for purchase of telephones.

(z) Other supplies or services as follows:

Appliances, all types
Batteries, all types over $300
Brooms, brushes over $100
Calculators, desk top and handheld, over $50
Cameras, projectors, and accessories
Canvas articles
Chains, tires over $300
Drinking cups
Drugs, medicinal (except as authorized under current labor agreement)
Duck, cotton
Envelopes, all types
Equipment (test and facility administrative and other equipment)
Explosives and caps over $100
Food preparation and serving equipment
Ladders over $100
Lamps, electric and photographic, over $300
Modifications to contracts
Padlocks for personal use
Recreation and athletic equipment
Repair of typewriters over $300
Repair of copiers over $500
Shelving, steel
Spark plugs (more than one set)
Tires and tubes over $100
Water coolers and dispensers

f. Emergencies. When the need for supplies or services is of such an unusual or compelling urgency that the delay in award would result in serious injury, financial or other, to the Government, the foregoing restrictions may be waived. In such cases, the purchaser shall attach to the original and green copies of the SF-44 or to the invoice a signed statement, in memorandum form, giving full details of the events leading to the emergency situation. "Emergency purchase" or other nonexplanatory words or phrases will not be acceptable. The original copy of the SF-44 or invoice shall be routed through the Procurement Branch for review and approval prior to being submitted to the Accounting Division for payment. This paragraph shall not relieve the purchaser from seeking prior approval from the Procurement Branch if time permits.

g. Preparation of SF-44's. Suppliers will be paid with a minimum of delay if SF-44's are prepared in the following manner:

(1) All copies are legible.

(2) Monetary limitations are not to exceed $1,000 without bids.

(3) No purchase of restricted items is made.

(4) The complete name, address, and zip code of seller is shown.

(5) A description of each item, the unit price, and total amount appears for each line item. A seller's invoice may be attached but not in lieu of the above description.

(6) The seller signs the white copy of the SF-44 in the seller's signature block.

(7) Competitive quotations are shown on the back side of the pink and green copies for purchases that exceed $1,000.

(8) The purchase order number appears on the top of the SF-44.

(9) Agency name and billing address block is indicated as follows:

Federal Aviation Administration
ASO-22
P.O. Box 20636
Atlanta, Georgia 30320

CHAPTER 2. INSTALLATION OF FACILITIES

SECTION 1. DESCRIPTION OF FACILITIES

22. AIR ROUTE TRAFFIC CONTROL CENTER (ARTCC) (See figure 2-1). The ARTCC is the agency's largest facility, both in physical size and magnitude of operation. Its primary duty is to provide separation of aircraft passing through its geographic boundaries. The center building is very large and contains a number of special purpose rooms. The equipment rooms for radar, communication, telco, and data equipment are in the basement. The control room is directly above the equipment rooms. The control room can contain as many as 60 positions (sectors), each having radar, communications, and data equipment. Most of the center's communications is conducted over telephone lines to remote RCAG sites, and radar data from remote ARSR sites is received on telephone lines. The amount of wiring within a center building is larger than many city telephone exchanges.

23. AIR TRAFFIC CONTROL TOWER (ATCT) (See figure 2-2). The ATCT directs movement of aircraft in the vicinity of the airport, including all ground traffic on the runways and taxiways. Aircraft under the control of the ARTCC are directed to the airport control zone where they are "handed off" to the ATCT for landing directions. Aircraft taking off are directed to the airport zone limits where the ARTCC assumes responsibility. The ATCT uses radio and radar for directing aircraft. The complexity of equipment and number of controller positions at ATCT's vary with the amount of airport traffic. Many small towers are established without radar facilities and with all radio equipment located in the tower structure.

24. AUTOMATED FLIGHT SERVICE STATIONS (AFSS) (See figure 2-3). The AFSS's, 61 nationwide, primary functions are: pilot briefings, weather observations, search and rescue procedures, emergency services mainly through direction finder equipment, processing flight plans, hazardous inflight weather advisory services (HIWAS), enroute flight advisory service (EFAS), and inflight services, primarily to VFR aircraft. The AFSS functions depend on maintaining a complete nationwide weather gathering system and monitoring the operation of navigational aids (VORTAC's and NDB's) used for enroute air traffic movement in order to provide these services.

25. REMOTE COMMUNICATIONS AIR/GROUND (RCAG). RCAG'S are remotely operated air/ground radio facilities providing coverage for a specific sector of air space. RCAG facilities have a varying number of channels, with each channel consisting of a UHF frequency, a VHF frequency, or both. The UHF and VHF transmitters may be configured through the digital radio control equipment (RCE) as paired (keyed simultaneously) or split (keyed individually). The RCE provides the interface to the specially engineered 4-wire telephone circuit that connects each RCAG channel to the ARTCC. At selected RCAG facilities, an AC generator provides emergency power for the continued operation of environmental/lighting systems while the RCE

FIGURE 2-1. AIR ROUTE TRAFFIC CONTROL CENTER

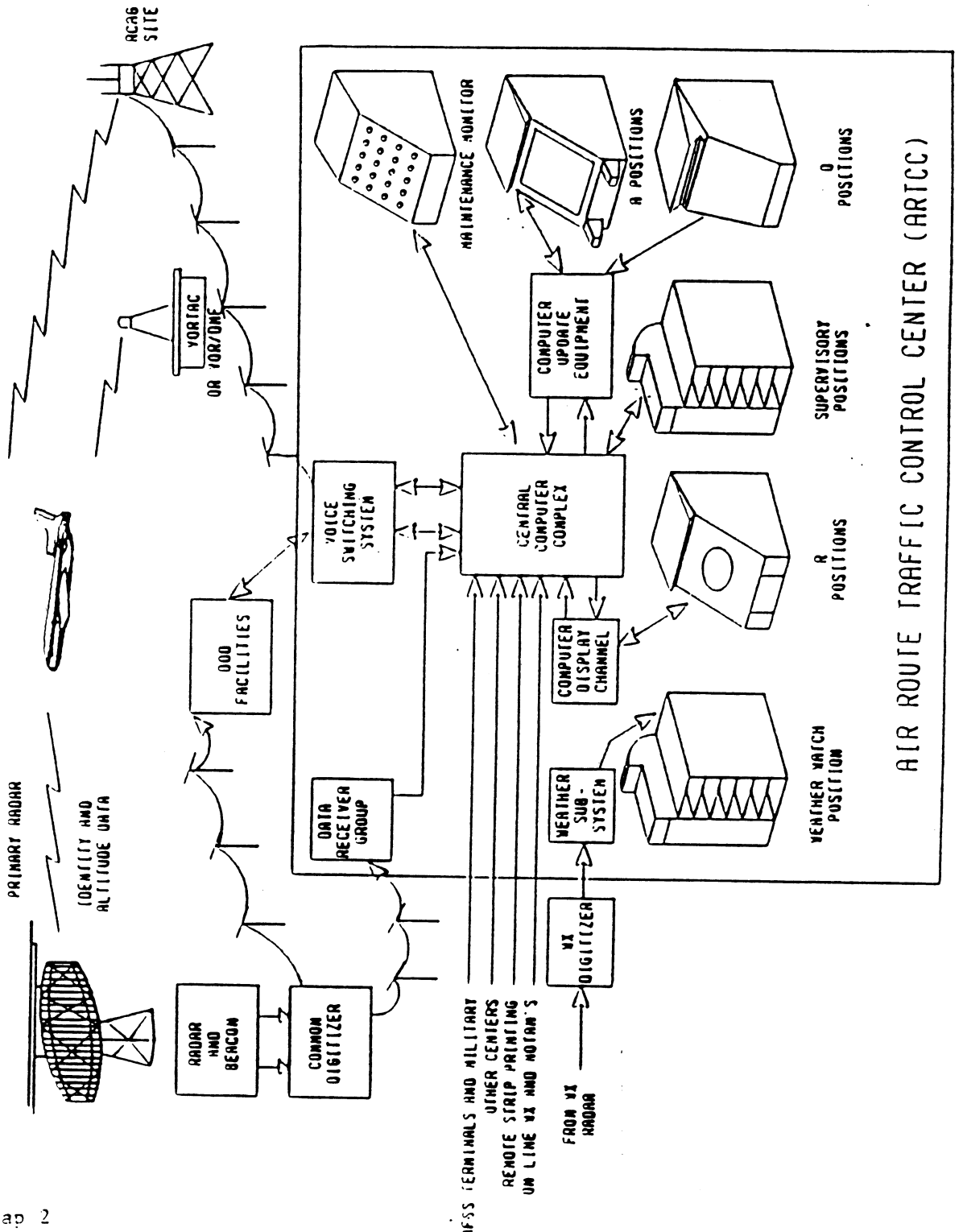


FIGURE 2-2. AIR TRAFFIC CONTROL TOWER

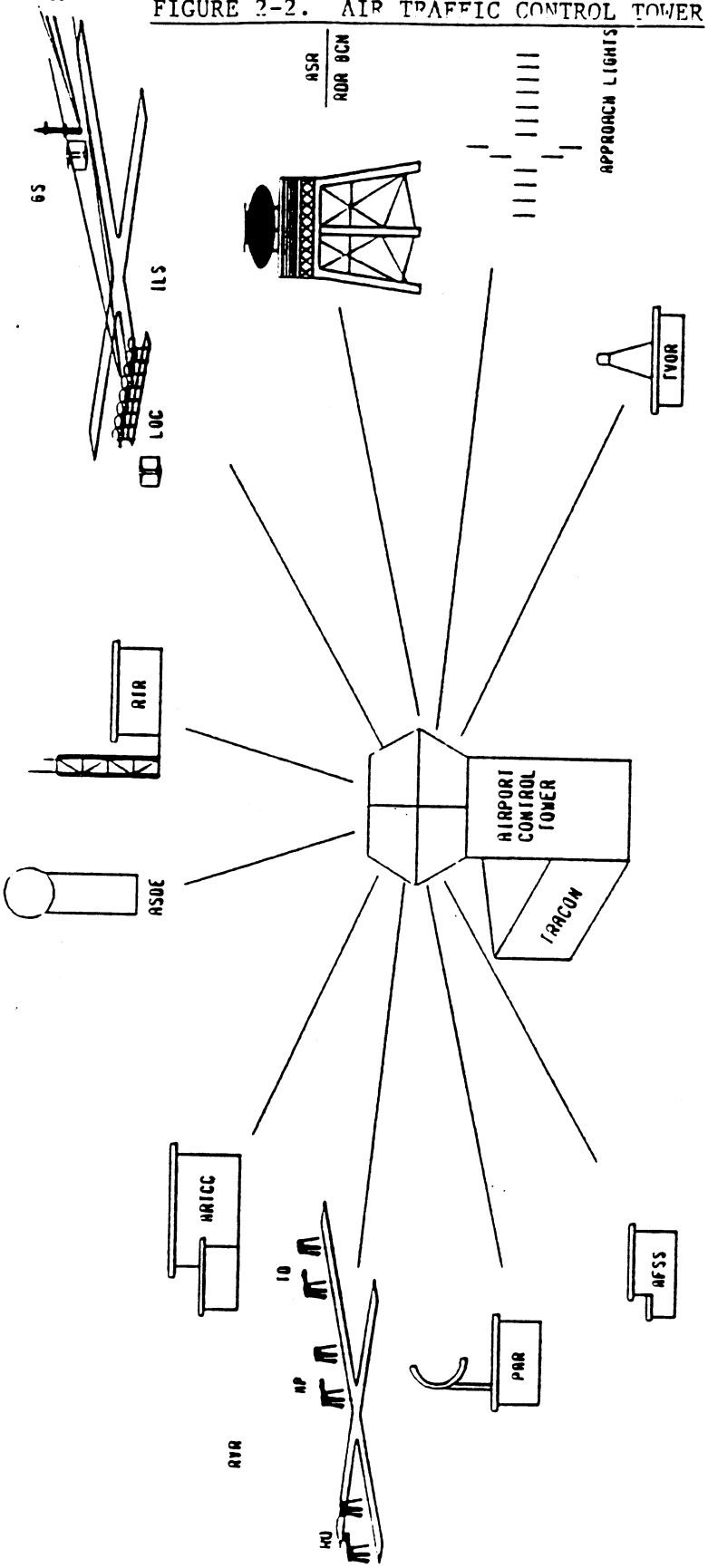
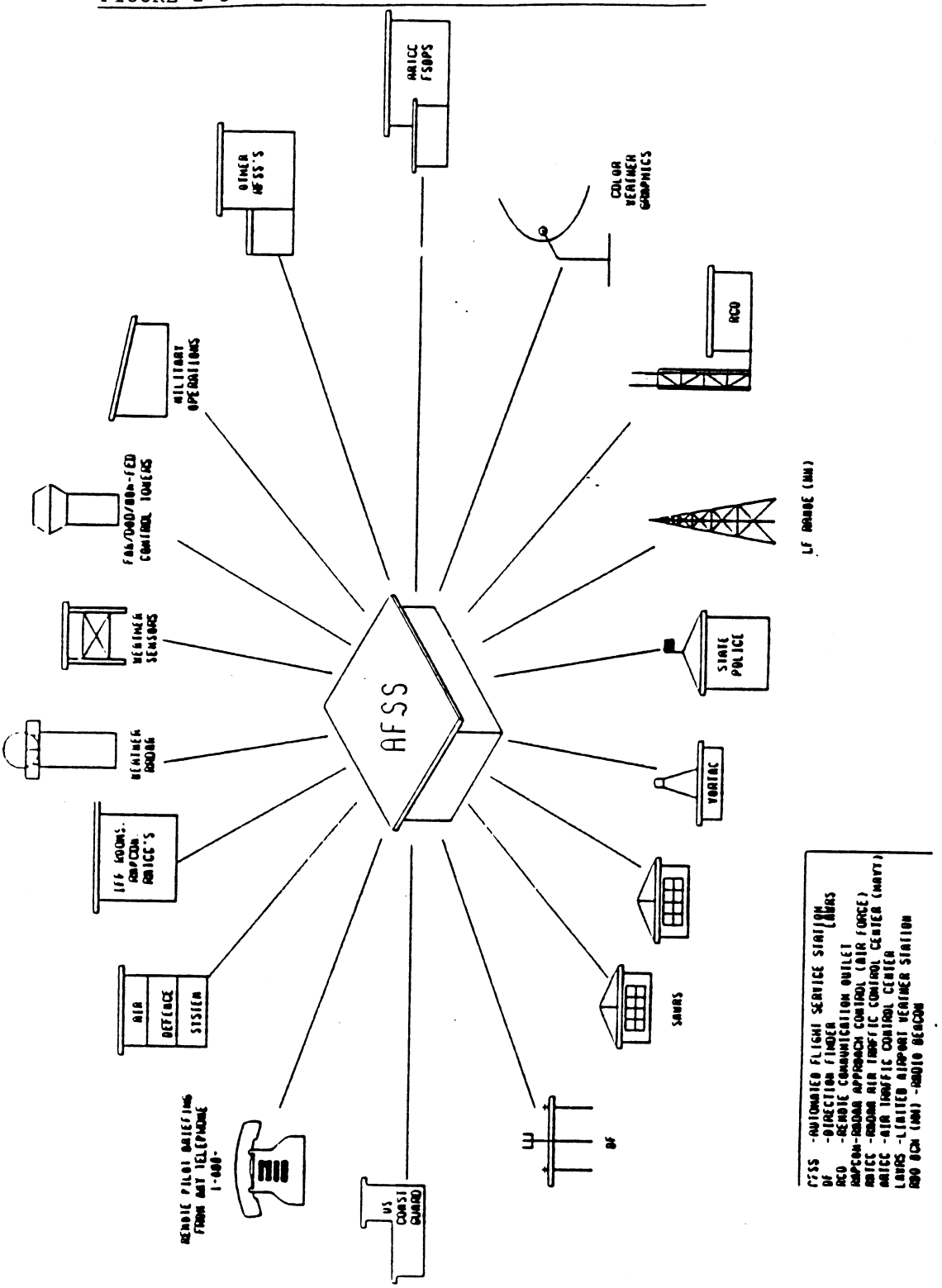


FIGURE 2-3. AUTOMATED FLIGHT SERVICE STATIONS



system provides maintenance and environmental monitoring and provides DC back-up power to the radio transmitters and receivers. These systems, coupled with a main and standby radio transmitter and receiver for each frequency, ensure controller to aircraft communication.

26. REMOTE TRANSMITTER/RECEIVER (RTR). Remote transmitter/receiver sites serve the air/ground communications needs of the ATCT's. In many cases, the receivers are located in the tower equipment room with transmitters only at remote sites. Keying and audio signals are transmitted over buried cables from the ATCT to the remote site. In most cases, complete one-for-one backup equipment is provided, with changeover to standby equipment accomplished by a control panel in the tower cab. An RTR site may contain as many as 12 air/ground channels. An RTR site can be located some distance from the controlling facility with keying and audio signals transmitted over telephone lines.

27. REMOTE CONTROL OUTLET (RCO). An RCO is an RTR located some distance from the controlling facility. The control of the equipment is similar to an RCAG with keying and audio signals being transmitted over telephone lines. RCO's are installed in areas lacking reliable communications due to terrain or obstructions. A RCO provides communication coverage controlled by an AFSS.

28. LIMITED REMOTE CONTROL OUTLET (LRCO). LRCO equipment consists of one or two receivers installed at a VOR. They share the same telco line with the VOR monitor tones to the controlling AFSS. Two-way communication to an aircraft is provided when the AFSS operator transmits on the VOR transmitter.

29. INSTRUMENT LANDING SYSTEM (ILS). The ILS helps pilots to safely land an aircraft at an airport under conditions of low ceilings and limited visibility. The use of the system reduces interruptions of service at airports resulting from bad weather by allowing operations to continue at lower weather minimums. The ILS also increases the traffic capacity of the airport under all weather conditions. The ILS consists of a localizer, glide slope, and from one to three marker beacons plus necessary monitor and control equipment. Other radio facilities installed for use in conjunction with an ILS may include compass locators and distance measuring equipment (DME).

a. Localizer. The localizer provides a course directed along the center line of the runway toward the direction of the approaching aircraft. The localizer provides right and left guidance of the aircraft by horizontal deflection of a needle in the cross pointer instrument of the aircraft. The localizer channel frequencies (108 MHz to 112 MHz) are in the VHF frequency range.

b. Glide Slope. The glide slope transmits a signal pattern that provides a glide path along the approach course (defined by the localizer). This facility provides above and below path guidance to the

pilot by vertical deflection of another needle in the cross pointer instrument of the aircraft. The glide slope channel frequencies (329 MHz to 335 MHz) are in the UHF frequency band.

c. Marker Beacons. The 75 MHz ILS marker beacons are located along the approach course at distances from the runway identified on the pilot's approach procedure charts. Indication is provided to the pilot via appropriate tone and lights when the aircraft passes over the marker beacon. The marker indication is received only when the aircraft is over the marker.

d. Compass Locator. The compass locator (non-directional beacon NDB), is usually collocated with the 75 MHz outer marker beacon. The pilot "homes-in-on" the nondirectional NDB signals in order to find the localizer course. The compass locator operates in the 200 to 415 KHz frequency band.

30. MICROWAVE LANDING SYSTEM (MLS). The MLS provides precision navigation guidance for exact alignment and descent of aircraft on approach to a runway. It provides azimuth, elevation, and distance. MLS has improved signal accuracy over ILS. During flight testing, MLS has been proven to consistently satisfy the high accuracy standards set for Category III operations. The MLS has the capability to fulfill a variety of needs in the departure, landing, missed approach, and transition phases of flight. Other features of the MLS are the ability to provide curved and segmented approaches, selective glide path angles, accurate 3-D positioning of the aircraft in space, and the establishment of boundaries to insure clearance from obstructions in the terminal area. MLS will eventually replace ILS as the standard landing system in the United States for civil, military, and international aviation.

31. VHF OMNI-DIRECTION RANGE (VOR). The conventional VOR system and the doppler VOR system provide properly equipped aircraft with azimuth information for enroute navigation. Both types of VOR's provide aircraft with compatible azimuth information but in different ways. Conventional VOR stations transmit two rf signals. The first, a constant phase 30 Hz reference signal, is transmitted as frequency modulation (FM) of a 9960-Hz subcarrier, which in turn amplitude modulates the conventional VOR transmitter. The second, a 30 Hz variable phase signal, is produced in space by amplitude modulation (AM) of the radiated rf carrier. In the aircraft receiver, the FM signal is detected and output as a 30-Hz reference signal, which has a constant phase at all azimuths around the VOR station. The AM signal is also detected and output as a 30 Hz variable signal with a phase angle that changes one degree for each degree change in azimuth around the conventional VOR station. Conventional VOR stations are designed so that at 0 degree magnetic or north bearing from the VOR the detected 30-Hz reference and the 30-Hz variable signals are in phase. As the receiver moves clockwise around the conventional VOR station, the detected 30-Hz variable phase signal lags the detected 30-Hz reference signal one degree for every degree of clockwise movement.

Doppler VOR stations also transmit AM and FM signals, but the 30-Hz reference is now carried on the AM signal and the 30-Hz variable is carried on the FM signal. Additionally, the frequency modulation and amplitude modulation are derived differently from that in the conventional VOR. The 30-Hz carrier amplitude modulation, which is the reference in the doppler VOR, is done at the transmitter and not in space. The FM signal is a result of the doppler effect, which is the change in frequency of an audio or rf signal caused by a change in distance between the transmitting and receiving points for the wave energy. The doppler effect applies to the DVOR system in two ways. One, the source of transmitted energy moves as the 50 antennas in the array are fed in sequence; and two, the aircraft is moving. However, in practice, the speed and heading of the aircraft have little appreciable effect and can be considered to be stationary. The commutation of the antenna array is similar to moving a radiating source continuously around a circle. This circular motion shifts the frequency upward when the moving source is approaching the receiver and downward when the source is moving away from the receiver. This frequency deviation occurs at a 30-Hz rate, the rate of antenna array commutation. To retain compatibility with existing aircraft receivers, the detected 30-Hz variable phase signal from a doppler VOR station begins to lead the detected 30-Hz reference one degree in phase for every degree of clockwise movement around the site. It is assumed that the distance from the antenna array to the aircraft receivers is much larger than the diameter of the array and that, at the beginning of antenna commutation, the antenna at the northern most point of the array is radiating an upper sideband signal 9960-Hz greater than the carrier frequency. A lower sideband signal is also being transmitted from the southern most point of the antenna array at the same time, but its effect is similar to that of the upper sideband. The antenna array is commutated counterclockwise; and the carrier antenna, located at the center of the array, transmits the 30-Hz reference AM signal.

32. DISTANCE MEASURING EQUIPMENT (DME). DME's are collocated in selected VOR or localizer facilities to give the pilot of an aircraft a direct readout of his distance from the navigational aid. A DME is collocated with a localizer where siting problems prohibit the installation of 75 MHz outer marker beacons. The DME ground equipment is interrogated by the aircraft. The DME transmits a reply signal back to the aircraft. Circuits in the airborne equipment measure the time elapsed between interrogation pulse and the reply pulse and converts the time to a distance measurement. The DME frequencies lie within the 960 to 1215 MHz UHF band.

33. TACTICAL AIR NAVIGATIONAL EQUIPMENT (TACAN). The TACAN facility combines azimuth information and distance measuring on one system. Distance data is computed in the aircraft by measuring the time for interrogation pulse pairs to be returned via the TACAN reply frequencies. There are 126 receiver frequencies and 126 reply frequencies in the TACAN transponder equipment. As many as 100 aircraft may simultaneously obtain navigational information from a single transponder installation. The

azimuth information received by an aircraft from a TACAN is the result of rotation of either the facility antenna's mechanical or electronic rotation. Fundamental frequencies radiated are 15-Hz and 135-Hz which are detected in the aircraft's receiver. The 15-Hz course phase measurement establishes the initial location of the aircraft indicator within a 40 degree sector, and the 135-Hz fine phase measurement establishes the exact position within the 40 degree sector. This concept indicates that a small azimuth change will appear as a nine-fold electrical phase angle, which is the factor which makes the TACAN navigation system very accurate.

34. VOR AND TACAN (VORTAC). The VORTAC facility has two air navigational systems installed in a single building. The VOR system was developed to provide the necessary enroute navigational data for civil aviation. TACAN was developed by the military to provide a navigational system suitable to military needs. With the advent of the unified air traffic control concept, it was decided that the two navigational systems would be collocated. Thus, military aircraft can use the TACAN frequencies for azimuth and distance data, while civil aircraft may use the VOR for bearing data from the same facility.

35. RADAR. Many classes of radar systems are used in the FAA for detection of aircraft movements and measurement of the "target" range. In the basic radar system, the transmitter sends out short bursts of radio energy. The voltage is then switched off while the system waits for echoes to be received. The system uses a common antenna which rotates 360 degrees of azimuth. The speed of rotation varies with the operational range of the system. The position of the antenna with respect to magnetic north is fed to the indicator so that targets presented may be seen in their relation to magnetic north. Radar systems are now combined with alphanumerics data systems for identity of targets on the indicator. The controller can insert any data pertaining to the aircraft, and it will be displayed in alphanumerics alongside the corresponding radar target as it progresses across the radar display. FAA designated radar systems are:

a. Air Route Surveillance Radar (ARSR). ARSR radars are located in geographically selected areas to provide the ARTCC's with complete surveillance of the nation's air route structure. The echoes returned to the remotely located radar sites are transmitted to the ARTCC over microwave link (RML) TELCO lines and satellite systems. At the ARTCC, the information is presented on the controller's display. The ARSR transmitter RF output is approximately four mega watts, and the surveillance range is 200 miles.

b. Airport Surveillance Radar (ASR). The ASR system radar is installed at busier airports and serve the ATCT controllers directing approaches and departures from the airport. They operate at an RF output of approximately 500 Kilowatts to 1 mega watt and have a range of 50 miles.

c. Airport Surface Detection Equipment (ASDE). The ASDE system is especially designed to provide surveillance of the ground features at an airport. The ASDE system allows the controller to direct ground movement of aircraft under very low visibility conditions.

36. AIR TRAFFIC CONTROL BEACON INTERROGATOR (ATCBI). The ATCBI functions similar to the DME and TACAN facilities except in reverse form. The aircraft is interrogated from the ground by the controller. A transponder in the aircraft responds by sending replies back to the ground. The controller uses separate codes to obtain aircraft identification and altitude data. The automated radar terminal system (ARTS) facilities beacon-derived identification is automatically displayed adjacent to the aircraft target. The beacon system eliminates much of the need for voice communication between controllers and pilots.

37. DIGITAL BRIGHT RADAR INDICATOR TOWER EQUIPMENT (DBRITE). The DBRITE is a tower display system that provides a raster scan presentation of both primary and beacon radar videos and alphanumeric (A/N) data from an air traffic control (ATC) automation system.

38. RADIO COMMUNICATIONS LINK (RCL). The RCL is used to carry radar data from long range radar facilities to air route traffic control centers (ARTCC's). The system is made up of line of site hops that range in distance from 15 to 25 miles, depending on terrain, and has a frequency range of 7 to 8 giga hertz. Each link has an operational capability of 180 channels and is also used to carry radio communications air to ground (RCAG) and back up emergency communications (BUEC) from remote sites to the ARTCC.

39. BACKUP EMERGENCY COMMUNICATIONS (BUEC). The BUEC system provides redundant remote center air/ground (RCAG) very high-frequency (vhf) and ultra-high-frequency (uhf) communication channels that are available to the air route traffic control centers (ARTCC's) for immediate use if one or more primary RCAG frequencies fail. BUEC channels are completely independent of the normal transmission paths (telephone lines) between ARTCC and RCAG. They use alternate radar microwave link (RML) voice channels or alternate-route telephone circuits to link the ARTCC and the remote sites (usually long-range radars (LRR) at which the BUEC vhf/uhf transmitter-receivers (transceivers) are installed). Air traffic controllers manning normal air/ground channels may, within seconds, access any of up to 10 uhf and 10 vhf transceivers at a single radio position, dramatically reducing the impact of unexpected or catastrophic communication failures between controller and aircraft. The BUEC system is intended not to augment but rather to supplement the existing air traffic control communication system. It may be employed only in emergencies; it is not to be used as the primary communication system.

40. AUTOMATED RADAR TERMINAL SYSTEM (ARTS). Many of the functions performed in the terminal radar environment are incorporated in the automated radar terminal display systems. These are semi-automatic air

traffic control display systems suitable for application to radar terminal facilities with varying traffic densities and complexities. The functional capability of the systems can be tailored to meet increases in air traffic volume and complexity.

a. ARTS III Beacon Tracking Level System. The primary function of the ARTS III, as currently installed, is to track selected targets giving the controller a positive target identification and a positive indication of the anticipated motion of the target. To accomplish this, the ARTS III is used in conjunction with the airport surveillance radar and the air traffic control beacon interrogator as a video processor and computer. The computer functions of the ARTS III additionally furnish flight plan and hand-off data to the nearby air route traffic control center and allow for data to be entered locally by that ARTCC.

b. ARTS II Beacon Non-tracking Level System. The ARTS II system is designed to serve the automation needs of low-to-medium level air traffic control terminals providing radar service from either an IFR room (TRACON) or a tower cab (TRACAB) facility. The system provides raw and decoded broadband beacon video on the air traffic controller's display as currently provided on operation displays. In addition, the system provides an associated alpha numeric identification for aircraft equipped with 4096 code transponders and numeric beacon readouts on all beacon-equipped aircraft.

41. RUNWAY VISUAL RANGE (RVR). The runway visual range system provides the air traffic controller with an instrumentally derived value based on standard calibration and runway light intensity setting, giving the horizontal distance a pilot will see down the runway. The RVR system is comprised of visibility sensors, an ambient light sensor, runway light intensity monitors, sensor interface electronics, a data processing unit, displays, and a system console. RVR's are installed beside runways for touchdown information; but on CAT II and CAT III runways, additional RVR's are installed in the midpoint and roll-out positions.

42. APPROACH LIGHTING SYSTEM WITH SEQUENCED FLASHERS, CAT II (ALSF-2). This is the only high intensity (high voltage) approach lighting system that the agency installs. It is comprised of 247 "steady-burning" incandescent lamps arranged in groups of 3, 4, or 5 (called bars) over a distance of 2,400 feet, extending from the end of the runway along the extended runway centerline. The 49 lights at the end of the runway have green filters on them, and the inner 1,000 feet of the system also has some red filters. Fifteen additional lights flash in sequence toward the runway, beginning 2,400 feet from the end of the runway and ending 1,000 feet from the runway. This configuration of lights is designed to be used in Category II weather conditions; however, systems installed since 1983 have the ability to be switched into a simplified configuration similar to the MALS/RAIL. This is called a simplified short approach lighting system with runway alignment indicator lights (SSALSR) and can be used in Category I weather. Both configurations have five levels of intensity.

43. MEDIUM INTENSITY APPROACH LIGHTING SYSTEM WITH RUNWAY ALIGNMENT INDICATOR LIGHTS (MALS/RAIL). This system has two components. One is comprised of 63 steady-burning incandescent lamps, arranged into a configuration of 18 green lights at the runway end and groups of 5 at 200-foot intervals from the runway for a distance of 1,400 feet from the end of the runway; and the other is comprised of 5 lights flashing in sequence toward the runway, beginning 2,400 feet from the runway and ending 1,600 feet from the runway. This system is used for approaches in Category I weather and has three levels of intensity.

44. RUNWAY END IDENTIFIER LIGHTS (REIL). This system consists of two lights located on each side of the end of the runway which flash twice per second simultaneously. The system is used to locate the end of the runway visually and does not lower landing minima.

45. PRECISION APPROACH PATH INDICATOR (PAPI). This system consists of four "lamp housing assemblies" which house three lamps apiece. These lamps appear either red or white, depending on the viewer's elevation relative to the LHA's. The system provides a visual landing path for pilots and does not lower landing minima.

SECTION 2. INSTALLATION PROCEDURES

46. PROJECT WORK ASSIGNMENTS. Installation personnel are assigned to work sites by the Installation Unit when the construction activity, in conjunction with the project, is finished or has proceeded to the point that installation of equipment can proceed. The size of the installation force is determined by the workload and time demands of the project.

47. PRELIMINARY PROJECT ACTIVITY. Before actual work begins on the project, several preliminary actions are required of the work order carrier.

a. Review Engineering Package. The engineering package, consisting of the project drawings and transmittals, is to be reviewed in detail. Particular attention should be given to floor plans and antenna placement. Any noted discrepancy between the proposed location of equipment and the existing equipment location is to be reported to the installation office. The total number of racks, transmitters, receivers, control boxes, etc., are to be counted when reviewing the drawings.

b. Equipment Inventory. Equipment for scheduled projects is usually sent to the project site in advance of the arrival of the installation personnel and is in the custody of the local maintenance office. All boxes are to be uncrated and the contents inventoried against the project needs. The installation office is to be advised of any shortage or damaged equipment.

c. Planning Project Work. The actual workload of the project is to be analyzed and scheduled so one task flows into another without any delay. Consideration of environment and whether work is proceeding around in-service equipment are factors in job planning. Outside antenna installations are to be made during good weather periods if possible. The normal installation will start with rack placements, followed by electrical wiring, electronic component installation, and electronic wiring. The final phase consists of tune-up, complete FRDF forms, flight check, and the joint acceptance inspection.

48. ELECTRONIC CABINET PLACEMENT. The number of electronic cabinets per installation varies with the type of facilities. An RCO or ILS trailer may contain only one cabinet while a large center has two hundred. Engineering drawings will specify the area where cabinets are to be placed. In multiple cabinet installations, the units are bolted together to form a bay. An installation may consist of several bays.

49. ANCHORING ELECTRONIC CABINETS. All single cabinet installations are to be anchored at each corner of the cabinet base. Where several cabinets are together in a bay, two anchors per rack in diagonal corners is sufficient. The method of anchoring equipment cabinets is dependent upon the type of floor construction. On concrete floors an anchor with threaded studs or inserts must be set in the floor beneath the cabinet.

Many types of masonry anchors can be found in local hardware outlets. Most require drilling a hole with a masonry bit and drill to the depth and diameter of the anchor body. Where many anchors are required, the installation should be made secure in the concrete. Anchoring in wooden floors is made with lag screws. Equipment installation on walls are to be made using toggle bolts or molly bolts.

50. ELECTRICAL WIRING. FAA power wiring installations must conform to the National Electrical Code in all respects. In this respect, all receptacles and equipment power cords are to be 3-wire grounding type. Other FAA electrical requirements are:

a. Ducts, Conduits, and Raceways. All electrical wires from circuit breaker boxes to equipment cabinets must be concealed in approved ducts, conduits, or raceways. At junction points of conduit to duct or conduit to electrical outlet boxes, bushings are to be installed to protect wires from physical damage. On cable tray systems, dividers must be provided if power and audio signaling conductors share the cable tray. Outside electrical installations are to use moisture-proof conduits and fittings.

b. Electrical Conductors. Single conductor wiring concealed in conduits or raceways is made with thermoplastic covered wire, type THW or THWN. The size wire is determined by the drain of the circuit. Most branch circuits used for FAA equipment are protected with 20 amp breakers, which in accordance with NEC, requires use of No. 12 wire. Other capacity and wire size demands are:

15 amp	No. 14	65 amp	No. 6
20 amp	No. 12	85 amp	No. 4
30 amp	No. 10	100 amp	No. 3
45 amp	No. 8	115 amp	No. 2

Any wire splices are to be made with approved splicing connectors and be in accessible areas such as junction boxes and square ducts with covers.

c. Color-Coding (See Specification FAA-C-1217). All branch circuits and feeder conductors shall be color-coded. The color-coding shall be continuous throughout the facility on each phase conductor to its point of utilization so that the conductor phase connection is readily identifiable in any part of the installation. The equipment grounding conductor shall be covered with green insulation or shall be bare copper. Conductors covered with green insulation with a yellow tracer shall be used for other grounding systems. Neutral conductors shall be continuous white unless more than one system is run in the same raceway, box, or other type enclosure. The neutral of the other systems shall be white with identifiable colored tracers (not green). Where color-coding is not available in the larger size conductors, the conductors shall be color-coded by use of color-coded tape, half lapped for a length of three inches. Where conductors are color-coded in this manner, they shall be color-coded in all junction and pull boxes, accessible raceways, panel

boards, outlets, and switches as well as at all terminations. Conductors in accessible raceways shall be coded in such a manner that by removing or opening any cover, the coding will be visible. AC electrical wires, either single conductor or 3-wire cord types, are to be color-coded as follows:

White - Neutral
Green - Ground
Black - 115V AC

Phase conductors shall be coded as follows:

Single Phase	Three Phase	
120/240 Volts	120/208 or 240 Volts	277/480 Volts
Line A - Black	Phase A - Black	Phase A - Yellow
Line B - Red	Phase B - Red	Phase B - Brown
	Phase C - Blue	Phase C - Orange

d. Receptacle Wiring. Most of the branch circuit wiring will terminate at equipment rack receptacles or to plug-in strips. The receptacles must be 3-wire type with proper identification of hot, neutral, and ground terminals. AC strips are usually wired in the field so that they can be made adaptable to the electrical needs of the rack. Receptacles installed outdoors must be weather-proof types and have ground-fault protectors.

e. DC Wiring Systems. Wire size of DC systems will conform to the same ampere rating as AC systems. Grounding of the negative side of the circuit will be made at the supply station.

51. MOUNTING ELECTRONIC COMPONENTS. Installation of electronic equipment in various facility locations will be indicated on the project drawings. Much of the tower cab equipment requires control panels and monitor equipment mounted on consoles at operating positions.

a. Rack Mounting. Electronic equipment mounted in racks is spaced from top to bottom in an order which allows dissipation of heat and leaves room for future additions. All openings are to be closed off with standard size blank panels when the installation is complete.

b. Console Mounting. The individual components to be mounted in an operating position should be so arranged to provide easy access by the controller working the position. Any opening made in a console will be cut to provide support for the flange around the equipment to be mounted. The flange will be secured to the wood or metal console with pan head Phillips screws.

52. SYSTEM WIRING. The wiring provides a keying circuit and audio circuit to each transmitter on a frequency and also an audio circuit for each receiver. This basic concept is repeated many times in large facilities. Demarcation points provide interface terminations between various systems, either local or remote. Each provide a communication link between the controller and aircraft.

a. Cable Installation. A cable trough or tray system is installed for cable runs between the control positions and the equipment room. Cables are installed on the tray in a systematic order with as few crossovers as possible. Where the number of cables requires stacking, the cables traveling the farthest are to be on the bottom of the intervals, using plastic tie-wraps. Second, third, and succeeding stacks of cables are tied to those below.

b. Dressing of Cables. It is very important that cable dressing be carried out in a uniform manner throughout the installation and that the general appearance be of a professional manner. All cables entering or leaving a building should terminate on the right side of the blocks. If Siemon-type blocks are used in a rack, then all cables entering or leaving the rack should be terminated on the right side of the block. The drain wires on shielded pairs should be grounded on one end only. Sufficient slack should be provided in wiring for termination on any block in an established row of blocks.

c. Terminating Wires. After dressing of the cables is completed to the intended terminating point, the individual cable pairs are separated in accordance with the FAA Standard Color Code. Actual terminating technique depends on the type of connector or block wired; however, on all installations, some slack is to be left in the terminated wire in the event that removal and retermination become necessary. It is apparent that termination of the facility wiring is probably the most important operation of the installation and should be carried out with professional technique. The care and attention exercised on this phase will pay off when the equipment is placed in operation and when the facility is inspected during the JAI.

d. Wiring Check Out. Every connection made during the installation is to be verified for circuit continuity before energizing the system. When testing small equipment plug wiring, the adjacent terminals to the connection being checked should be tested for possible shorts caused by the cramped wiring in the connector housing. Underground cables extending to remote facilities are to be tested for continuity also.

e. Handling of Shields. Cables having shielded pairs used for audio signal wiring are to have their shield grounded at one end only. The shielded pairs normally have an aluminum foil wrapping with a bare wire (drain wire) under the foil. In such cases, only the drain wire is terminated to ground. The best installation is achieved by removing the foil from all the cable pairs at the same point and then twisting their

drain wires together to form a braid. All the drain wires can be lugged together and attached to ground.

53. GROUNDING OF EQUIPMENT. It is extremely important that FAA installations be properly grounded. Among the reasons for this are the prevention of safety hazards to personnel, electronic noise reduction, and lightning protection. Grounding in FAA facilities exceeds the requirements set forth by the National Electric Code (NEC). FAA grounding essentially consists of two separate systems; one for power and one for electronics. The FAA system of grounding is described below briefly and in greater depth in Order SO 6950.8.

a. Power Grounding. The power grounding consists of the green wire system required by the NEC. This system provides a safe working environment for FAA employees, contractors, and visitors. This system is connected to the FAA earth electrode system (EES) through the insulated grounding electrode conductor at the ground bus in the service disconnect means (SDM). This system has sometimes been referred to as the "Station Ground." All metal frames, racks, cable ladders, junction boxes, ducts, and raceways associated with wiring other than electronic signal and control installed in the facility are to be grounded to the power grounding system.

b. Electronic Grounding. In order for electronic equipment to work properly, a proper electronic grounding system must be established. There are two types of electronic grounding systems. These two types are based on the frequency at which the equipment operates or the manufacturer's design requirements. The electronic single point ground system is designed to provide a ground system without ground loops and is best for equipment operating below about 100 kHz. The electronic multipoint ground system creates an interconnected grid so as to reduce the high frequency impedance of the grounding system. These two systems are described below:

(1) Electronic Single Point Grounding. The single point grounding (SPG) system is normally of a tree or star construction and is isolated from all other grounds except through the main ground plate and the EES. The SPG system provides isolation between noise sources. This system is constructed using isolated plates and insulated wires color-coded green and yellow. The SPG system is only installed in those facilities which require it.

(2) Electronic Multipoint Grounding. The multipoint grounding (MPG) system is designed to incorporate the maximum number of parallel paths. These parallel paths reduce the overall impedance of the grounding system to high frequency noise signals. The multipoint system incorporates all racks, cable ladders, junction boxes, ducts, and raceways used for electronic signal and control wiring as well as building steel (where available). An insulated #6 wire, color-coded green and orange, bonded to each section of raceways, cable ladders, etc., will insure

continuity. Alternatively, a bare stranded bonding jumper may be used across joints to ensure electrical continuity.

(3) Transient Protection Grounding. High energy transient protection devices are grounded directly to the earth electrode system (EES) with insulated cable. This cable is color-coded green with a red tracer and sized in accordance with FAA-STD-019. It runs between bulkhead plates or "A" buses and the EES.

c. External Grounding. Outside antennas, antenna towers, junction boxes, and equipment enclosures are to be grounded to the facility EES. Grounding is accomplished in accordance with the requirements of FAA-STD-019.

54. ANTENNA AND COAXIAL CABLES. Installation of antennas and assembly of the coaxial feed lines is to be accomplished as early as possible on the project during good weather periods. Antenna installation for communication facilities are made on top of conduit supports atop free standing towers or on ATCT or AFSS roofs. Placement of NAVAIDS antennas is critical due to their course-forming characteristics. The handling and assembly of coaxial connectors, like many other installation practices, can best be learned "on the job" through repeated experience. Some of the precautions and standards of working with coaxial cables are:

a. Handling Cable. Coaxial cable falls in the category of semi-rigid construction and appears to be quite rugged; however, if treated improperly, physical damage and electrical deterioration will result. Sharp bends and twists, especially when the cable is cold, are to be avoided. On antenna towers, the cables should be firmly secured to the railing structure and not allowed to flap in the breeze.

b. Connector Installation. The performance of an RF line depends to a great degree on the assembly technique of the connectors. Trimming of the jacket, braid, and dielectric material must be precise for the connector body to seat properly over the cable end. Care must be taken that heat does not deform the dielectric when the pin is being soldered to the center conductor. When assembling crimp-on type connectors, the exact tool prescribed by the manufacturer must be used for crimping the center pin and outer ferrule.

c. Cable Check-Out. All coaxial cables are to be checked for shorts and/or leakage between center conductor and shield. Tests are made using a megger testing instrument connected to the conductor and shield at one end of the feed line. With the antenna end open, the DC resistance will read infinite or greater than 50M on a good line. If the line resistance is low, the defective area must be isolated and either repaired or replaced. A possible cause may be due to improper connector assembly.

55. TUNE-UP. Individual electronic components, such as transmitters and receivers, are to be adjusted as soon as possible during the installation

project in order to detect defective components or out of tolerance conditions. The equipment tolerance, as well as the overall facility performance standards, are given in the 6000 Series of FAA Orders and Directives. A list of these publications is found in Section 2 of this order. FAA tolerance is indicated by three conditions. They are defined as follows:

a. Standard. The optimum obtainable performance or standard at which the equipment was designed to operate.

b. Initial. The maximum deviation from the standard which is acceptable or permissible at the time of installation and which will be allowable after any modification or modernization.

c. Operating. The maximum deviation from the standard within which normal functioning can continue without readjustment or corrective maintenance and beyond which remedial action by maintenance personnel is mandatory. The installations made by personnel of the Installation Section must meet the initial category and, in most cases, will approach the standard tolerance.

56. FLIGHT CHECK. All facilities used for navigational purposes must have a flight inspection before being placed in service. The inspection aircraft has recording equipment which presents a graphic record of the received navigation signals from the ground equipment. To perform an effective flight check, reliable communication must be established between personnel in the aircraft and those on the ground. The operating limits of the facility is established, and much of the FRDF data is acquired during the flight check.

57. FACILITY REFERENCE DATA FILE (FRDF) (Order 6030.45). Many FAA facilities require adjustment data, including meter readings, voltage measurements, RF power output, and mathematical computations, be documented at the time of installation. This information is entered on the FRDF Forms. The FRDF data must be complete and a copy furnished to the local maintenance office at the time of the JAI.

58. AS-BUILTS. Each drawing included in the original engineering package must be reviewed. Where actual wiring or equipment location varied from the original plan, the change is indicated on the print with a red pencil. Two sets of red-lined drawings are necessary, one left at the facility for maintenance use, and the other returned to the regional office for permanent updating of the facility file.

59. JOINT ACCEPTANCE INSPECTION. All installation work, at a new facility or modifications to an old facility, requires a joint acceptance inspection. The JAI consists of a joint evaluation of the installation between the installation representative, usually the work order carrier, and the maintenance sector which will have responsibility for operating the facility. At the time of the JAI, the work order carrier shall

present to maintenance one copy of the appropriate FRDF Forms 6030-17 and a set of drawings which have been red-lined.

60. FINAL SITE WORK. Final work on an installation project includes clean up of the work area. All debris, including boxes, crates, and packing material, is to be removed from the work site. Much of this material can be burned at remote areas where there are no restrictions on open fires. Where restrictions do exist, arrangements are to be made for transporting the debris to the local municipal trash dump.

61. NOTICE TO AIRMEN (NOTAM). NOTAM's provide information to pilots concerning changes to published information that may affect operations. Examples are closed runways or taxiways, navigational aids out of service, and changes to operational hours of control towers. NOTAM's are issued by flight service stations and may be initiated by many people, including Airway Facilities regional office and field personnel, flight inspection personnel, and Air Traffic regional and field personnel. Installation personnel must always coordinate with local Airway Facilities personnel to ensure that appropriate NOTAM's are issued when necessary. Installation personnel frequently are involved in projects which require NOTAM's.

a. Operational Facilities. Projects to modify or relocate operational facilities require that a NOTAM be issued. Examples are relocation of an ILS facility, modification of a RADAR facility that requires it to be shut down, and conversion of a VOR to doppler. If the facility must be removed from service for an extended period of time, the shutdown must be coordinated and scheduled well in advance of the shutdown.

b. Changes to airport operations. When equipment or vehicles are in areas that impact airport (flight) operations, a NOTAM is required. Examples are vehicles blocking or near runways or taxiways, such as a crane removing a glide slope tower or construction personnel working on runway lighting systems.

c. Commissioning New Facilities. When a facility such as an ILS or approach light system are installed at a location, a commissioning NOTAM is required. These NOTAM's usually are issued some time after the installation is completed. Normally, the NOTAM is issued in response to a message sent by regional office Airway Facilities personnel; and it is sent to several other organizations for actions related to the commissioning. NAVAIDS are commissioned coincident with the publication of charts and approach plates. These publications occur on cycles of 28 days for terminal facilities and 56 days for enroute facilities. Some projects may require two or more NOTAM's. An example is installation of lighting components at the end of a runway. Because personnel and equipment are near or on the runway, aircraft operations must be kept clear of the area. If there is a localizer at that end of the runway, it must be removed from service if the vehicles are in the critical zone since they may significantly affect the signals.

62. SOLDERING.

a. Soldering is a process which involves joining two metals (wire and terminal) by applying solder and flux in a molten state at the junction of wire and terminal. The quality and reliability of a soldered electrical termination is dependent to a great degree upon proper technique, soldering iron, and solder.

b. The most commonly used solders are alloys of tin and lead combined in various proportions to give the solder different characteristics. Popular combinations have the following proportions: 40/60, 50/50, and 60/40. The first figure represents the tin content of the solder, and the second figure indicates the lead content. Thus, an 60/40 solder contains 60 percent tin and 40 percent lead. Each metal contributes to the overall properties of the solder. For example, a large quantity of tin in relation to the lead content will make the solder easy to use. It has excellent flowing properties. If the lead content is much greater than the tin content, the solder may be more difficult to apply. The tin-lead ratio also affects the freezing (solidification) properties of the solder. The 60/40 solder freezes almost instantly after the heat has been removed while the 40/60 solder remains partially liquefied for a few seconds longer. A slow freezing solder will form very smooth joints but only if the metals being soldered are held rigidly until the solder has frozen. Otherwise, a defective joint will result. Therefore, a fast freezing solder such as 60/40 is used when metals being joined cannot be held in place for any length of time. the 50/50, 60/40, and 63/37 with rosin core flux are normally used to solder joints in electronic equipment with the 60/40 being the most popular. They have low melting points and excellent flowing properties, and they solidify quickly. The 70/30 solder is used for special applications, such as soldering semiconductors, where a high tin content is desirable.

c. Solder is available in various diameters (gauges). Available standard diameters vary from approximately .093 inch (13 gauge) to .025 inch (23 gauge). The size of the solder used depends on the size of the job. Small (21 or 23 gauge) solder would normally be used for small terminations such as transistor terminals. Large solder (13 or 16 gauge) would be used for larger terminations such as connecting #6 copper wire to lugs. The most popular and usable size of solder is 18 gauge. This size of solder can be used for most all connections. It must be emphasized, however, that it is important to use the proper size solder; i.e., do not use 13 gauge to solder transistors.

d. Soldering can seldom be accomplished without a flux. The only acceptable flux for electronic soldering is a noncorrosive type such as rosin. Almost all solder used will have the flux within the solder such as rosin core solder. The primary function of a soldering flux is to prevent formation of oxides on metallic surfaces while they are being heated to soldering temperature. Fluxes have some cleaning ability, but they should not be expected to remove heavy surface oxides from metals.

When using the rosin core solder, the joint must be sufficiently heated to dissolve the rosin completely so that it does not become part of the joint.

e. Various soldering tools are available. The most widely used tools are soldering irons and pistol-type, trigger-operated guns. These tools come in various sizes and wattages to suit requirements generated by different sizes, gauges, and types of terminals and conductors. Soldering iron or gun size and wattage should be selected to fit the job requirement. Irons or guns of excessive wattage should not be used since damage to wire insulation and other components may occur. Heat sensitive components such as semiconductors and printed circuit boards require low wattage irons, usually with a maximum rating of 35 to 60 watts, to prevent damage. For light work requiring intermittent operation of soldering tools, the use of a soldering gun is recommended.

f. Tips for electric soldering irons are usually copper and are available in various shapes, diameters, and lengths to suit different applications. On most electric soldering irons, the tip is removable. For good soldering, it is essential that all copper tips be properly tinned. This also applies to soldering guns. To tin a new tip, heat the iron or gun and apply rosin core solder to the sides of the tip. Make sure the rosin comes in contact with the tip or the solder will not stick. Cover the surface of the tip completely with solder. Wipe off the excess solder with a clean, damp cloth. The soldering iron tip should now have a smooth, thin coating of solder. Used tips should be heated to remove the old solder and, if necessary, filed and dressed to remove the old solder, pits, and tarnish and to restore tip surfaces and shape. They should then be tinned as above.

g. Another type of soldering tip is armorclad copper. The armor coating is tinned during manufacture and is designed for longer life without pitting than ordinary tips. These tips should never be filed unless the armor coating has been completely worn away as this will shorten the life of the tip. When oxide or foreign matter accumulates on the tinned portion of the tip, restore the luster by alternately wiping on a clean, damp cloth and applying rosin core solder until a satisfactory surface is obtained.

h. When soldering, the metals to be joined must be free of foreign materials and tinned with a light coat of solder. The surface to be soldered must be thoroughly cleaned of enamel, grease, dirt, and oxides, or the solder will not adhere and a cold connection will result. Rosin flux will carry off small amounts of oxides upon vaporization; but for all practical purposes, the surfaces should be bright and shiny.

i. Apply a small amount of solder to the tip before putting the iron aside between connecting operations. This will prevent formation of oxides on the tinned area. Wipe the tip with a cloth or canvas pad before use and occasionally thereafter to remove accumulated particles of flux or

foreign material. It is permissible, however, for a small globule of molten solder to be carried to successive connections on the iron tip to aid in the heating process.

j. The preferred and universally accepted method of making soldered electrical and electronic connections is to use an external source of heat (soldering iron) to raise the temperature of the metals (terminals and conductors) to be joined to the degree at which the solder will melt. Then flow solder over the junction in the presence of a rosin flux. Heat application is maintained during the solder-flowing process, then withdrawn to allow the connection to cool. This completes the connection. Care must be taken to avoid movement of the connection until the solder solidifies to prevent a faulty joint.

k. When desoldering, many vacuum-type devices are available to remove molten solder after the connection has been heated. Another method is to use copper braid. The braid is treated with rosin flux. The braid is then placed against the connection and the braid heated with a soldering iron. The hot solder will be drawn into the braid as the solder melts. Cut off the solder-saturated end and repeat as necessary.

l. The following general practices are applicable to most soldered connections:

(1) Connect conductors to terminals in a manner which will provide the greatest amount of contact between the surfaces of the two while providing a secure electrical and mechanical joint.

(2) Extend the insulation of wires connected to terminals close to the joint of soldering, but exclude them from the holes of perforated and tubular terminals, the notches of notched terminals, and from under the screwhead of screw-type terminals. In no case should any of the insulation be allowed to extend through the hole in perforated terminals or around the notch of notched terminals in a manner which would prevent a good soldered connection.

(3) Connect wire so that the length of bare portion of wire between the point of connection to the terminal and the end of the insulation is not greater than the clearance between the adjacent terminals at that point. In no case should it be permitted to extend one-sixteenth of an inch.

(4) Insulation should not be unduly frayed, burned, or otherwise damaged at the point of stripping or along the bare wire.

(5) Wires should not be pulled taut around terminals to which they are not connected.

(6) Holes of perforated terminals having terminations should be filled with solder except when the hole size is excessive or when otherwise impracticable.

(7) All soldered terminations should be secure and free of foreign substances such as enamel, rosin, etc.

(8) Keep rubber and synthetic insulations slightly away from terminals (approximately 1/32 inch) to avoid damage to the insulation when soldering the connection. Do not pull wire taut around terminals to the extent that the insulations may be broken.

SECTION 3. CONSTRUCTION PROCEDURES

63. GENERAL.

a. The resident engineer on construction projects serves as the engineering representative of the Establishment Engineering Branch and as the onsite representative of the contracting officer. Through inspections and observations, he administers the construction contract in accordance with instructions and authority delegated to him by the contracting officer. The resident engineer provides interpretation of contract plans and specifications, coordinates construction activity with other affected organizations or individuals, and performs general duties as described in this handbook and as outlined in his work order.

b. At the job site, the resident engineer is the only person authorized to issue instructions or interpretations of the contract to the contractor's superintendent or to the contractor when he acts as his own superintendent. The contractor is expected to perform no more or no less than specified in the construction contract. Only the contractor to whom the contract is awarded is responsible for all work in the contract; therefore, all instructions and interpretations should be issued only to the contractor's superintendent. This does not preclude representatives of subcontractors or vendors from participation in any discussion at the contractor's option. The resident engineer shall not issue direct instructions to the contractor's workmen or act as the contractor's superintendent. The resident engineer shall be fully aware of all activities that occur on the job site and should be fully aware of schedules, plans, and methods that the contractor is planning to use during the performance of the contract.

64. DUTIES. The duties and responsibilities of the resident engineer are as prescribed by directives, this handbook, work order, letter of authorization issued by the contracting officer, and instructions from the supervisor. Specific duties will vary depending on the type and location of the construction job. Instructions or advice peculiar to a certain type of facility or a specific location will be written in the work order and should be discussed with the project engineer. The resident engineer should understand the functions, basic criteria, and/or peculiar requirements of the facility he is constructing or at which he is working. General instructions described in this handbook are applicable to all resident engineers at all construction jobs unless specifically exempted in the work order.

65. FAMILIARIZATION. The resident engineer shall familiarize himself completely with all construction contract documents prior to the preconstruction conference or start of construction, whichever occurs first. He shall make sure that he or she has one complete set of all contract documents, such as general provisions, special provisions, wage rates, list of specifications and drawings, etc., and not only the specifications and drawings.

66. COORDINATION. Upon arrival at the temporary duty station, the resident engineer shall contact the local Airway Facilities sector manager, sector field office manager, or sector field unit supervisor. The resident engineer should brief the local Airway Facilities sector manager, supervisor, and airport manager or property owner of the assigned construction project. Other officials who are affected by the construction project should also be contacted upon the recommendation of the local Airway Facilities sector manager or when instructed by the project engineer.

67. LOCATOR. Upon arrival at the temporary duty station, the resident engineer should inform the nearest Airway Facilities sector or sector field office of the address and telephone numbers where he can be reached during duty and off-duty hours. Within 24 hours after arrival at a temporary duty station, the address and off-duty telephone numbers should be transmitted by telephone or dispatch to the appropriate section. The resident engineer's mail is usually forwarded to the nearest Airway Facilities office unless otherwise requested. "Checking-out" at the nearest Airway Facilities office at the completion of the job is just as important to assure that mail and messages will be promptly and properly forwarded.

68. CONSTRUCTION SCHEDULE. At the beginning of a construction contract, the contractor is usually required to submit a proposed construction schedule and cost breakdown. In some contracts, submittal of the construction schedule with associated time frames is described in detail. The resident engineer shall review the contractor's proposed construction schedule and cost breakdown, consult with the project engineer on the subjects, and provide comments and recommendations to the project engineer. The contractor's construction schedule is approved by the contracting officer based on comments and concurrence by the project engineer. Construction progress, in respect to the construction schedule, should be monitored on a daily basis. Should it become apparent to the resident engineer that the contractor is getting behind schedule, the resident engineer should inquire from the contractor's superintendent as to corrective action planned to get the job back on schedule. The resident engineer should inform the contracting officer and project engineer verbally and in writing of any delays that may have an impact on the construction completion date or beneficial occupancy date. More details and information on delinquent performance by the contractor than is usually reported in the weekly construction report may be required by the project engineer and contracting officer. The contracting officer may instruct the contractor verbally and in writing to undertake actions to avoid or reduce delays in contract completion. The contracting officer's decision will depend on information furnished by the resident engineer and recommendations made by the Establishment Engineering Branch.

69. CONSTRUCTION MATERIALS. Most construction materials are usually furnished by the contractor; however, some materials such as engine

generators, cables, and special visual navigation aid fixtures are furnished by the government.

a. The resident engineer shall review the "List of Government-Furnished Materials" in the contract documents and assure himself through inspection and accounting that all government-furnished materials are on hand at the delivery point designated in the construction contract. It is important that the materials are of the correct type, size, and quantity required in the construction contract; therefore, the resident engineer should personally verify the materials required by drawings and specifications. The resident engineer should notify the project engineer verbally and notify the contracting officer and project engineer in writing as promptly as possible of any material deficiencies.

b. The government-furnished materials that are required in a construction job are transferred from the government's custodian to the contractor's custody at the beginning of the construction job, usually during the first ten days. These materials usually remain in the custody of the contractor until the completed construction job is accepted by the government. The government's custodian, usually the supply specialist or sector field office/unit supervisor, will require the contractor to acknowledge receipt of materials in writing. At the completion of the job, any excess government-furnished materials shall be returned by the contractor to the government's custodian. It is the resident engineer's responsibility to monitor the installation of these materials and to provide the custodian a complete listing (see Chapter 1, Section 1, paragraph 14).

c. The resident engineer shall make sure that the contractor-furnished materials conform to all the contract requirements. The resident engineer should also assure himself, through observations and discussions with the contractor, that all necessary materials are available or have been ordered to arrive at the job site in time to avoid any delays. Timely submittal of shop drawings, test data, diagrams, and other submittals, where required, should be monitored and requested from the contractor's superintendent by the resident engineer. "Shop drawing" procedures are described in Chapter 1, Section 2, paragraph 15.

70. ACCESS AND SECURITY. Access and security requirements vary at different facility construction sites; therefore, specific guidance will be furnished by the project engineer in the work order and may be noted in the construction contract. In general, special access and security requirements exist when the construction work is performed at an operating facility, within the secured area on an airport, or at a military installation. Regardless of the security classification, contract work shall not be performed at an operating facility or near runways on an airport without the presence of an FAA employee. Security procedures on airports are established by the airport managers based on FAA regulations and guidelines. The resident engineer should obtain these special local rules directly from the airport manager when the construction job is

within the airport security area. These special local rules should also be discussed at the preconstruction conference. Security and access at operating remote facilities are controlled by the responsible Airway Facilities office and at manned operating facilities, such as ARTCC, ATCT, and FSS jointly with the local Air Traffic facilities manager. Procedures at these locations should be discussed with the local managers and strictly adhered to. Keys assigned to the resident engineer shall not be transferred or loaned to any other person (Order 1600.6B). For access to facilities that require a security clearance, the necessary clearance shall be obtained through your supervisor on the earliest date possible.

71. UTILITIES. The resident engineer is responsible for coordinating the installation of utilities, such as electric service, telephone, water, sewer, or gas. Information pertaining to utility contracts that have been issued prior to the start of construction and the names of local contacts should be obtained from the project engineer. Installation of these utilities should be coordinated and discussed at the job site with representative of the utility companies to assure proper coordination, connections, and timing and to avoid conflicts or changes between the utilities or with the construction contract. This coordination should be performed prior to the start of construction, but no later than during the first week of construction. Temporary utilities are usually the responsibility of the contractor and at the contractor's expense, unless otherwise noted in the contract. Installation or changes of utilities at an operating facility should also be coordinated with the local Airway Facilities manager, and on airports, with the Airway Facilities manager and the airport manager. Any changes or problems should be promptly reported to the project engineer for appropriate action by the Real Estate and Utilities Branch.

72. LAYOUT AND SURVEYS. The resident engineer is responsible for assuring that a facility is being constructed at the correct location and elevation. Usually some site surveying has been performed at the proposed construction site during the preliminary engineering phase of the project, and some survey monuments or stakes may have been left in place. Upon arrival at the site, the resident engineer shall verify the location of the survey monuments and check the construction drawings against actual site condition. Any discrepancies shall be promptly reported verbally and in writing to the project engineer for resolution. Any discrepancies that affect the contract shall also be promptly reported to the contracting officer. Correct location of survey stakes should not be assumed; distances, angles, and elevations should be checked with surveying equipment. Usually the contract documents prescribe the government's responsibility to provide the contractor base lines and benchmarks as indicated on drawings. It is the contractor's responsibility to lay out the construction work from base lines and benchmarks that are on or within the boundaries of the construction site. The resident engineer should check the contractor's layouts and advise the contractor promptly of any deviation from prescribed location or elevation.

73. CONTRACT DRAWINGS AND SPECIFICATIONS. The drawings and specifications that are included in the construction contract are checked and reviewed before approval and printing; however, some conflicts or mistakes may exist. The resident engineer shall be completely familiar with these contract documents. Upon discovery of any conflicts or mistakes, corrective action should be promptly recommended to the project engineer and contracting officer. Changes shall not be made in the contract drawing or specifications without approval of the project engineer and the contracting officer. Changes in drawings or specifications may require contract change orders or contract amendments. Approval of major changes or changes that affect contract value or performance time must be in writing from the contracting officer.

74. CONSTRUCTION CONTRACT ADMINISTRATION. The contracting officer designates the resident engineer as his authorized representative at the construction site. The letter of authorization also provides instructions on contract administrative tasks that should be performed. Usually administrative tasks are the following:

a. Preparation and submittal of weekly construction reports (Chapter 1, Section 2, paragraph 11).

b. Approval or disapproval of contractor's materials or shop drawings (Chapter 1, Section 2, paragraph 13).

c. Conducting labor standards interviews. Receive and certify contractor's payrolls. Inspect that wage rates and WH 1321 poster are properly posted at job site.

d. Administration of government-furnished materials.

e. Preparation and submittal of periodical estimates.

f. Issuing of stop orders under emergency conditions.

g. Issuing of work directives and field changes in emergency conditions.

h. Conducting routine compliance review of the contractor's Equal Employment Opportunity policies and practices.

i. Reporting accidents (3900.24A, transmitting DOT 3902.6).

75. CONSTRUCTION INSPECTION. The inspection of the construction job by the resident engineer shall be timely, thorough, objective, fair, and reasonable. Interpretations of drawings, specifications, and other contract documents shall be made as promptly as possible. Confirmation by or guidance from the contracting officer or project engineer is necessary on complex or controversial matters. The decisions or interpretations made shall be promptly documented in the diary and with a letter to the

contractor when necessary. Knowledge of various codes and standards referred to in the contract, normal trade practices, and the design criteria for the facility is necessary to perform proper construction inspection. Certain inspection requirements are mandated in some construction contracts to assure that the installation of these materials is inspected before they are covered up. The resident engineer shall inspect all materials before they are buried, encased in concrete, or covered up with subsequent construction and all placement of concrete. Special inspection procedures have to be followed during the installation of cables. Quality control type material tests, such as compaction and concrete compressive strength test, are sometimes optional at the resident engineer's discretion unless specifically mandated by the contract. Tests should be made by a qualified independent testing laboratory when the quality of workmanship or material is questionable. A supervisor representing the local Airway Facilities sector shall inspect, along with the resident engineer, the initial splicing of cables, checking materials, workmanship, and finished splice prior to being buried.

76. REPORTS AND RECORDS. The resident engineer is required to prepare timely and accurate records and reports on the construction job. Preparation of basic records and reports such as the construction diary, weekly construction report, and other reports are described in detail in this handbook. The records and reports should be continuous from the beginning to the completion of the job. There is no substitute for complete, factual, accurate records on a construction job. In addition to reports prescribed in this handbook, the contracting officer or the supervisor may request additional reports or records.

77. PHOTOGRAPHIC RECORDS. The resident engineer should take pictures of the job site prior to construction, during the job to indicate progress or special construction problem areas, and at the completion of the job. The pictures will assist the resident engineer in communications with others and will be useful as part of the project records. Frequency of picture taking will vary depending on size or complexity of the job. Cameras are furnished by the Establishment Engineering Branch. Services for development of film and prints while on travel status should be obtained from local sources that offer competitively reasonable prices and reimbursement for those expenses claimed on the travel voucher. Pictures should not be made of installations that have security restrictions. Each picture should be identified as to location, type of facility, date, description of view, and name of person making the picture. These pictures and associated negatives should be sent to the project engineer. Film for official pictures is available at the regional office through the appropriate project engineer.

78. "AS-BUILT" DRAWINGS. The resident engineer shall keep one set of construction contract drawings and specifications current and marked-up during the duration of the construction job. The above set and associated contract documents shall be readily available to the resident engineer at the construction job site. Prior to completion of the construction

contract, the resident engineer shall prepare three "as-built" sets of drawings. One set of drawings should be given to the local Airway Facilities sector office and one to the sector field office at the time of joint acceptance inspection and the other set of drawings forwarded through the project engineer to the Drafting Section for revisions and preparation of permanent record drawings. Red pencil shall be used to note all revisions and changes on the drawings, including words "as-built" with date and resident engineer's initials in the revision area of the title block. The drawings and notes on the drawings should be carefully reviewed to indicate actual conditions at the completion of the job. Words such as "remove, relocate, construct, and install" may not be appropriate in the notes upon completion of the job.

79. ACCEPTANCE INSPECTION, 6030.45. Final inspection and acceptance of a construction project is usually accomplished in two phases: final construction acceptance inspection (CAI) and joint acceptance inspection (JAI).

a. The final construction acceptance inspection is performed at the end of the job on a date when all construction and cleanup is to be completed by the contractor. The date should be mutually agreed to as far in advance as possible by the contractor and the resident engineer. The contractor may request this final inspection of the contracting officer without the concurrence of the resident engineer; however, should a follow-up final inspection be required, the contractor may be required to pay for the cost of this additional inspection. The contracting officer or his designated representative accepts the completed construction project from the contractor at the time of the final construction inspection. The contract performance time also ends at the CAI. Should it become apparent during an inspection that the job is not complete and cannot be accepted, the inspection should be considered a periodic construction inspection, not a CAI; and a detailed "punchlist" should be provided in writing to the contractor. It should be made clear to all concerned, and especially in written reports, whether the inspection performed was a CAI or only a periodic inspection. The local Airway Facilities supervisors and/or technicians are not required by directives to participate in the CAI, but their review of the construction prior to the CAI and comments thereon should be solicited and encouraged by the resident engineer and project engineer. The resident engineer should make a "punchlist" when the job is nearing completion, keep it current, and provide a copy to the contractor when the CAI is requested. The final "punchlist" developed during the CAI must be submitted in writing to the contracting officer within 24 hours of the CAI. The contracting officer will forward this final "punchlist" to the contractor. Items on the "punchlist" should make reference to the appropriate contract document, such as paragraph in specification, detail on specific drawings, etc.

b. The resident engineer should be fully familiar with the directive (6030.45) detailing the requirements and procedures of the joint acceptance inspection. Advance notification for the JAI is required by

the directive; the prescribed time factors should be considered in advance to avoid any delays in completing the job. The local Airway Facilities sector office accepts the construction job from the contracting officer, including the Environmental Engineering Branch, at a joint acceptance inspection. Depending on the size and quality of the construction job, the CAI and JAI can be held consecutively on the same day or several days apart. The resident engineer should make every effort possible to complete the construction job without any exceptions.

c. Beneficial occupancy of part of a facility that is under construction may be required to permit installation of electronic, telephone, or other equipment. Careful inspection must be made of any areas of a facility which are made available for beneficial occupancy before they are accepted. Any contract work remaining in these areas shall be listed and the list transmitted in writing to the contractor, contracting officer, and project engineer.

80. DESIGN IMPROVEMENTS AND RECOMMENDATIONS. The resident engineer should observe construction methods, materials, and techniques used on the job. Based on observations, experience, initiative, and ingenuity, the resident engineer is encouraged to suggest improvements in the design, drawings, and specifications. These suggestions should be submitted through the DACT or EATIM process.

81. DOCUMENTATION OF CLAIMS. During the performance of a contract, a contractor will indicate that certain directives or site conditions are different than anticipated or from what is in the contract. In such event, the matter shall be immediately referred to the contracting officer and project engineer. A detailed record of the contractor's claim, including the time and material used in performing the alleged extra work, should be kept. This information will be used by the contracting officer in rendering a decision.

82. CONSTRUCTION AT OPERATING FACILITIES.

a. Modifications, modernizations, and improvements are made at various types of operating facilities. The local Airway Facilities offices are responsible for operating facilities; therefore, all work performed at an operating facility must be coordinated with the responsible local Airway Facilities sector manager. Coordination may also be required with the local Air Traffic facility chief when the work affects area, equipment, or facilities used or monitored by Air Traffic personnel. Usually only the local Airway Facilities sector manager has the authority to remove a facility from operational status and then only after proper coordination. In some case, a Notice to Airmen (NOTAM) will have to be initiated by the local Airway Facilities office prior to removing a facility from operation. Some outages must be scheduled as much as a week in advance. Lengthier outages over 24 hours must be prescheduled and coordinated about 60 days in advance in the regional office by the project engineer. Any removal of a facility from operation,

including disconnecting of electric power, should be performed by the engineer or technician who is responsible for the facility or has proper authorization from the local Airway Facilities sector manager. An FAA employee must be present when a contractor works at an operating facility.

b. Performance of some facilities may be affected by work performed in their vicinity. Before proceeding with any type of work, surveying, or construction near an existing facility, the proposed work should be discussed with the local Airway Facilities manager. Special precautions and coordination are required when work is to be performed in the vicinity of radar antennas, ILS glide scope and localizer facilities, or VOR, VORTAC, or TVOR facilities. Approval of the local Airway Facilities sector manager is required before proceeding with any work that might affect the performance of an operating facility. Visits to unmanned facilities will be prearranged to coincide with technician's trips whenever possible. Visits to unmanned facilities on airports will not be permitted unless accompanied by personnel from the responsible Airway Facilities office. Only responsible maintenance personnel may make entries in the facility log.

c. Work that affects operation of an existing facility may have to be performed during time periods when the disturbance of interruption to operations has the least impact. This time period at ARTCC, ATCT, TRACON, FSS, and other facilities is variable but is usually late at night to early in the morning or sometimes only during weekends. This time period should be coordinated and approved by all the facility managers who are affected. In formal construction contracts, this time period may be specified and should be reiterated during the preconstruction conference.

83. CONSTRUCTION ON AIRPORTS.

a. Most airports at which the FAA constructs or maintains airway facilities are owned and operated by cities, counties, or local airport authorities. Leases or permits for the land to be used must be obtained from the airport sponsors. Any surveying or construction on an airport must be coordinated with the airport management (airport manager, director of aviation, commissioner of aviation, or other local officials responsible for operations and planning of the airport). When work is to be performed on or near runways, taxiways, or ramps, or when a facility is to be taken out of service, coordination with the Air Traffic facility manager is required in addition to the usual coordination with the Airway Facilities sector manager.

b. Safety and security requirements as prescribed by the airport owner and the Federal Aviation Administration shall be complied with. For safety purposes, radio communications shall be required in vehicles, flags and/or yellow beacons may be required on vehicles, and clearances will have to be obtained from the air traffic control tower when driving near or crossing any surfaces used by aircraft. General conditions applicable to the construction contractor are usually noted in the construction

contract's "Special Precautions for Work at Operating Airports" and "Airport Security Requirements"; however, local details and conditions should be discussed and resolved during the preconstruction conference. Security requirements may necessitate obtaining badges and keys through the local Airway Facilities office from the airport management. Any special conditions or procedures established on safety, security, or work schedules should be summarized in writing as minutes of the meeting or by exchange of letters.

c. Most exterior work on airports should also be inspected by the airport manager at the completion of the job to assure that the grounds or exteriors of leased buildings have been restored by the contractor to the satisfaction of the airport management. Usually the resident engineer is required to obtain a letter of approval at the completion of the job from the airport manager.

84. INSTALLATION OF UNDERGROUND CABLES. One of the important parts of construction is the installation of cables. Basically, the following three types of cables are installed: Power, high or low voltage electrical cables; control, telephone type of cables used for monitoring, remote control of facilities or transmission of radar, communications or other signals; and coaxial cables. Usually most of the cables are obtained from the FAA Logistics Center's stock of project materials and made available from the nearest local storage place to the construction contractor as "government-furnished materials" (GFM). Type and quantities of cables furnished by the agency are specifically listed on the "List of Government-Furnished Materials" in the construction contract. Any cable left over from the job remains government property. The planning, inspection, and special procedures to be followed in the installation of cables are as follows:

a. The resident engineer shall review the contract drawings, specifications, and actual site conditions at the beginning of the job to verify the cable requirement, type of cables, and quantities.

b. All cables in storage or being received for the job should be visually inspected in person by the resident engineer at the beginning of the job or at any time a shipment is received during construction for factory defects or shipping damage. The quality of the cables should be inspected and any damages promptly reported to the project engineer. The type of cable received should be verified and compared with the construction job requirements. (Are the cables armored or unarmored, shielded, individual pairs shielded, correct number of pairs or conductors, correct conductor size, etc.?) The quantities of cables received should be compared with the job requirements and record made of all types of lengths, per reel or coil, of cables available for the job. Unusual number of short pieces of cables that would require excessive number of splices should be promptly reported to the project engineer for resolution. The cables should be megged and also inspected jointly with

the contractor when the materials are transferred to the contractor. The cable ends should be left sealed after any inspections or cuttings.

c. The layout, sequence of installation, and use of the cables should be planned and coordinated with the contractor to keep splicing of cables to the minimum. Specific cable reels or coils should be designated at this time for use at specific locations. Locations of splices should also be considered. Whenever possible, splices should be made in manholes and at least 200 feet from the edge of any runways 75 feet from edge of taxiways, always in a location that is accessible without closing of runways or taxiways.

d. The cable route alignment should be approved by the resident engineer. All underground cables, utilities, and other structures that the cable routes will cross or be in close proximity to should be located and marked with the assistance from the owners of the utilities (power, telephone, pipeline, gas, water, and sewage companies or authorities) and the airport owner. The airport owner should also assist in locating duct banks and in marking the locations of airport lighting cables, airport lighting control cables, and drainage pipes in the job area. Other federal agencies, such as the National Weather Service and Air National Guard, may have cables on an airport and should be consulted when their cables may be affected by the planned cable installation job. The local Airway Facilities office is required to keep records on the location of agency-owned cables and will assist the resident engineer in locating these cables. Hand excavation and identification of other installations that the cables will cross is advisable before proceeding with excavation by mechanical equipment such as trenchers or backhoes in these areas. The location of other installations in the cable installation areas should be marked with survey hub and guard stakes. The expected depth and alignment of the utility to be crossed should be marked at the job site. In the event an underground installation is damaged during the cable installation job, the owner of the installation should be promptly notified and circumstances completely described in construction records and reports. Some utility companies may require the presence of their representative when excavation work is performed near their installation; this request should be honored.

e. The resident engineer shall be present during the laying of any cables, splicing of cables, and during placement of initial cover over of the cables. The resident engineer shall also inspect the counterpoise and associated ground rods above the cable before they are covered up with backfill. Prior to the installation of cables, the trenches and excavations should be measured to assure proper depth and cover after installation. During laying of cables, the resident engineer should observe that the cables are not stretched, skinned, nicked, or otherwise damaged. The cable shall not be unreeled by being pulled along the ground from the back of a truck. The reel must be turned so that the cable is not subjected to stress by its own weight or abrasive action. During the cable unreeling operation, the resident engineer should station himself

near the cable reel and personally inspect the cable continuously for any defects. Locations and diameters of cable loops and length of cables at splices should also be observed. The cable shall be megged before placement of backfill. At locations where rock is encountered, sand bedding for the cables is usually specified in the construction contract. Complete records and pictures are also required when rock excavation is encountered. The backfill material should be inspected to assure that rocks or other sharp objects will not damage the cable during the backfilling and associated compaction. Proper spacing between power and control or other cables, as noted in the contract specifications, should be maintained. Cables under paved areas, under driveways where vehicular traffic is expected, under drainage ditches, and when crossing power cables are usually installed in conduits or ducts.

f. The resident engineer shall inspect splicing of cables when performed by the construction contractor to assure that the splices are made in accordance with contract requirements, instructions furnished by the manufacturer of splicing kits, and regional cable splicing standards described in FAA-SO-STD-71. The resident engineer shall notify the local Airway Facilities office as soon as possible and no later than one day prior to the start of cable splicing of the planned work. The resident engineer, together with the local Airway Facilities office representative, shall make a joint inspection of all cable splices prior to backfilling. Inspection shall be scheduled and conducted so that open cable pits or trenches may be closed during normal working hours to prevent delays to the construction contractor unless the delay in inspection of splice will have undue restriction on the airport. If so, the inspection will be accomplished outside normal working hours. Record of splices shall be made in accordance with 6030-45. Good workmanship is essential, and any defects in splicing shall not be accepted. Defective splices shall not be covered up or backfilled. The interior of cables must be dry when splices are made. Suggested practice is to test the cable with megger and ohmeter before proceeding to the next splice or covering up the splice. Proper protection of the splice and splicer should be provided when splicing is performed during inclement weather conditions. Specifications also require a cable marker at the location of the splice. Location of splices should be indicated and dimensioned on "as-built" drawings. Some splicing of cables as indicated in the construction contract is performed by the Southern Region's field maintenance party, and coordination with the above may be required by the resident engineer.

g. Compaction of the cable trenches and other excavations shall be inspected by the resident engineer. Restoration of surfaces such as paving, grassing, or sodding should be inspected as work progresses. Cable markers should be installed at the proper locations and elevations in respect to finished grade, inscribed with identifying description and correct directional arrows. All terminations of cables should be in accordance with contract requirements. Cables not terminated should be properly sealed. Before the completion of the contract, the cables should be tested in the presence of the contractor and a representative of the

local Airway Facilities office. The cable test results must be recorded on FAA Form 6030.17. Termination of all grounding conductors, shield, and counterpoise at terminals and in manholes shall be inspected.

85. INSTALLATION OF ENGINE GENERATORS (SO 6980.1). Procedures to be followed during installation of engine generators by the resident engineer and the local Airway Facilities sector's maintenance mechanic are outlined in "Installation Acceptance Test for Engine Generators" (Order SO 6980.1). Scope of work for installation of engine generators by a contractor is defined in the construction contract. The resident engineer should make sure that all the required government-furnished materials are "on-hand" at the beginning of the job and that all concerned understand which materials are to be furnished by the government and which materials the contractor is expected to furnish. The engine generator should be checked out and started only by the local Airway Facilities office maintenance mechanic. Usually the fuel tank is filled during the engine generator installation. Fuel needed to test the engine generator (about 50 to 100 gallons, depending on the size of the fuel tank) is charged to the F&E project, and fuel required to fill the entire tank is paid for by the local Airway Facilities sector out of its operation budget. Coordination with the local sector field office manager during order of fuel is recommended to permit delivery of all fuel at one time, avoiding unnecessary delivery costs. At the completion of the engine generator installation, the resident engineer should complete "Engine Generator Installation Record" (SO Form 6900-6) and provide two copies of this record to the local Airway Facilities office and one copy to the responsible project engineer.

86. GROUND RESISTANCE AND LIGHTNING PROTECTION. Proper electrical grounding, lightning protection, electrical surge protection, and low ground resistance are most important for proper operation of the electronic equipment at the facilities and for safety. Ground resistance at the "facility ground" for solid-state electronic equipment should be 10 ohms or less unless otherwise approved by the project engineer. Test equipment to measure the ground resistance is available on loan basis to the resident engineers from the Establishment Engineering Branch or from the Airway Facilities sector manager's office. Definitions and procedures to be followed in earth ground resistance testing are described in Order 6980.18, SO SUP 1, and associated Drawing SAH4XX0005. Record of ground resistance readings, including written and/or graphic description of the ground resistance testing, shall be transmitted by the resident engineer to the responsible Airway Facilities office prior to the joint acceptance inspection. In the event that the ground resistance exceeds the maximum specified in the contract requirements for the facility, the resident engineer should obtain advice and instructions from the responsible electrical engineer in the Establishment Engineering Branch. All connections on the grounding system shall be completely inspected to assure that proper contact is made, paint that may serve as an insulator is removed, and all connections are made with prescribed connectors and are tight.

APPENDIX 1. SYMBOLS, CHARTS, AND ILLUSTRATIONS

FIGURE 1. INTERNATIONAL MORSE CODE

A	. -
B	- ...
C	- . - .
D	- ..
E	.
F	.. - .
G	-- .
H	....
I	..
J	. ---
K	- . -
L	. - ..
M	--
N	- .
O	---
P	. -- .
Q	-- . -
R	. - .
S	...
T	-
U	.. -
V	... -
W	. --
X	- .. -
Y	- . --
Z	-- ..
1	. ----
2	.. ---
3	... --
4	.... -
5	.....
6	- ....
7	-- ...
8	--- ..
9	---- .
0	-----

FIGURE 2. BINARY NUMBERS

	16	8	4	2	1		16	8	4	2	1		16	8	4	2	1
0					0	11		1	0	1	1	22	1	0	1	1	0
1					1	12		1	1	0	0	23	1	0	1	1	1
2				1	0	13		1	1	0	1	24	1	1	0	0	0
3				1	1	14		1	1	1	0	25	1	1	0	0	1
4			1	0	0	15		1	1	1	1	26	1	1	0	1	0
5			1	0	1	16	1	0	0	0	0	27	1	1	0	1	1
6			1	1	0	17	1	0	0	0	1	28	1	1	1	0	0
7			1	1	1	18	1	0	0	1	0	29	1	1	1	0	1
8		1	0	0	0	19	1	0	0	1	1	30	1	1	1	1	0
9		1	0	0	1	20	1	0	1	0	0	31	1	1	1	1	1
10		1	0	1	0	21	1	0	1	0	1						

DECIMAL-TO-BINARY CONVERSION RULES

(a) Write number n + 0 if even or (n-1) + 1 if odd.
(b) Divide even number obtained in (a) by 2.
Write answer (m) below in same form:
m + 0 if even, (m-1) + 1 if odd.
(c) Continue until m or (m-1) becomes zero.
(d) Column of ones and zeros as obtained is binary equivalent of n with least significant digit at the top.

EXAMPLE: n = 327

326 + 1
162 + 1
80 + 1
40 + 0
20 + 0
10 + 0
4 + 1
2 + 0
0 + 1

Therefore the binary equivalent of 327 is 101000111

BINARY-TO-DECIMAL CONVERSION RULES

(a) Start at left with first significant digit - double it if the next digit is a zero or "dibble" it (double and add one) if the next digit is a one.
(b) If the 3rd digit is a zero, double value obtained in (a), if it is a one dibble value obtained in (a).
(c) Continue until operation indicated by least significant digit has been performed.
(d) Result is the decimal equivalent of the binary number.

EXAMPLE: 101101

The sequence of numbers obtained in following the above procedure is:

1	5	22
2	11	45

So 45 is the decimal equivalent of 101101

FIGURE 3. ELECTRONICS SYMBOLS

AMPLIFIER (2)

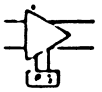
general

with two inputs

with two outputs

with adjustable gain

with associated power supply



with associated attenuator

with external feedback path

Amplifier Letter Combinations (amplifier-use identification in symbol if required)

BDG	Bridging
BST	Booster
CMP	Compression
DC	Direct Current
EXP	Expansion
LIM	Limiting
MON	Monitoring
PGM	Program
PRE	Preliminary
PWR	Power
TRQ	Torque

ANTENNA (3)

general

dipole

loop

counterpoise

ARRESTER, LIGHTNING (4)

general

carbon block

electrolytic or aluminum cell

horn gap

protective gap

sphere gap

valve or film element

multigap

ATTENUATOR, FIXED
(see PAD) (37)
(same symbol as variable attenuator, without variability)

ATTENUATOR, VARIABLE (5)

balanced

unbalanced

AUDIBLE SIGNALING DEVICE (6)

bell, electrical; ringer, telephone

buzzer

horn, electrical; loudspeaker; siren; underwater sound hydrophone, projector or transducer

Horn, Letter Combinations (if required)

*HN	Horn, electrical
*HW	Howler
*LS	Loudspeaker
*SN	Siren
‡EM	Electromagnetic with moving coil
‡EMN	Electromagnetic with moving coil and neutralizing winding
‡MG	Magnetic armature
‡PM	Permanent magnet with moving coil

Identification replaces (*) asterisk and (‡) dagger)

sounder, telegraph

BATTERY (7)

generalized direct current source; one cell

multicell

CAPACITOR (8)

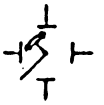
general

polarized

adjustable or variable

continuously adjustable or variable differential

phase-shifter



split-stator

feed-through

CELL, PHOTOSENSITIVE (Semiconductor) (9)

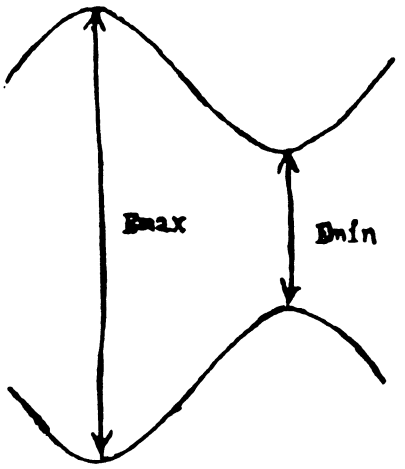
asymmetrical photoconductive transducer

symmetrical photoconductive transducer

FIGURE 4. ELECTRONICS FORMULAS

Modulation % from oscilloscope:

$$\text{Modulation \%} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100$$



$$VSWR = \frac{\sqrt{P1} + \sqrt{P2}}{\sqrt{P1} - \sqrt{P2}}$$

P1 = Forward Power
P2 = Reverse Power

Series Resistance:

$$Rt = R1 + R2 + R3..etc.$$

Parallel Resistance:

$$Rt = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} ..etc}$$

Two Resistors in Parallel:

$$Rt = \frac{R1 \times R2}{R1 + R2}$$

Wavelength in space:

$$\lambda \text{ in meters} = \frac{300}{f\ (MHz)}$$

Wavelength of RG- cable:

$$\lambda \text{ in feet} = \frac{984V}{f}$$

$$\tfrac{1}{4}\lambda \text{ in inches} = \frac{492V}{f} \times 12$$

$$\tfrac{1}{2}\lambda \text{ in inches} = \frac{246V}{f} \times 12$$

where: 984 = 300 X 3.281
V = RG- cable Velocity
f = Frequency in MHz

Capacitance in Parallel :

$$Ct = C1 + C2 + C3...ect.$$

Capacitance in Series :

$$Ct = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} ...etc}$$

Two Capacitors in Series :

$$Ct = \frac{C1 \times C2}{C1 + C2}$$

FIGURE 4. ELECTRONICS FORMULAS (CONTINUED)

Ohm's Law for D-C Circuits

$$I = \frac{E}{R} = \frac{P}{E} = \sqrt{\frac{P}{R}}$$

$$R = \frac{E}{I} = \frac{E^2}{P} = \frac{P}{I^2}$$

$$E = IR = \frac{P}{I} = \sqrt{PR}$$

$$P = EI = \frac{E^2}{R} = I^2R$$

Resistors in Series

$$R_T = R_1 + R_2 + \cdots$$

Resistors in Parallel

Two resistors

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

More than two

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

RL Circuit Time Constant

$$\frac{L \text{ (in henrys)}}{R \text{ (in ohms)}} = t \text{ (in seconds), or}$$

$$\frac{L \text{ (in microhenrys)}}{R \text{ (in ohms)}} = t \text{ (in microseconds)}$$

Inductors in Series

$$L_T = L_1 + L_2 + \cdots \text{ (No coupling between coils)}$$

Inductors in Parallel

Two inductors

$$L_T = \frac{L_1 L_2}{L_1 + L_2} \text{ (No coupling between coils)}$$

More than two

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots \text{ (No coupling between coils)}$$

Inductors in series with fields aiding:

$$L_a = L_1 + L_2 + 2M$$

Inductors in series with fields opposing:

$$L_o = L_1 + L_2 - 2M$$

Inductors in parallel with fields aiding:

$$L_a = \frac{1}{\frac{1}{L_1 + M} + \frac{1}{L_2 + M}}$$

Inductors in parallel with fields opposing:

$$L_o = \frac{1}{\frac{1}{L_1 - M} + \frac{1}{L_2 - M}}$$

where: L_a = total inductance with aiding fields
L_o = total inductance with opposing fields
L_1, L_2 = self-inductance of coil

Inductive Reactance

$$X_L = 2\pi fL$$

Q of a Coil

$$Q = \frac{X_L}{R}$$

Impedance of an RL Circuit (Series)

$$Z = \sqrt{R^2 + (X_L)^2}$$

Quantity of electricity stored in a capacitor:

$$Q = CE$$

where: Q = quantity stored in coulombs
E = potential across the capacitor in volts
C = capacitance in farads

Capacitance of a parallel plate capacitor:

$$C = 0.08842 \frac{KA(n-1)}{d}$$

where: C = capacitance in pmf
K = dielectric constant
A = area of one plate in square centimeters*
n = number of plates
d = thickness of the dielectric in centimeters*
* If the A and d values are given in inches, change constant 0.08842 to 0.2244.

Capacitors in Series

Two capacitors

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

More than two

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

Capacitors in Parallel: $C_T = C_1 + C_2 + \cdots$

Capacitive Reactance: $X_C = \frac{1}{2\pi fC}$

Impedance in an RC Circuit (Series)

$$Z = \sqrt{R^2 + (X_C)^2}$$

RC Circuit Time Constant

R (ohms) x C (farads) = t (seconds)

R (megohms) x C (microfarads) = t (seconds)

R (ohms) x C (microfarads) = t (micro-seconds)

R (megohms) x C (micromicrofarads) = t (microseconds)

Impedance with R, C, and L in Series

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Parallel Circuit Impedance

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

Sine-Wave Voltage Relationships

Average value

$$E_{ave} = \frac{2}{\pi} \times E_{max} = 0.637 E_{max}$$

Effective or r.m.s. value

$$E_{eff} = \frac{E_{max}}{\sqrt{2}} = \frac{E_{max}}{1.414} = 0.707 E_{max}$$
$$= 1.110 E_{ave}$$

Maximum value

$$E_{max} = \sqrt{2}(E_{eff}) = 1.414 E_{eff}$$
$$= 1.570 E_{ave}$$

Voltage in an a-c circuit

$$E = IR = \frac{P}{I \times P.F.}$$

Current in an a-c circuit

$$I = \frac{E}{R} = \frac{P}{E \times P.F.}$$

FIGURE 4. ELECTRONICS FORMULAS (CONTINUED)

Power in A.C. Circuit

Apparent power: $P = EI$

True power: $P = EI\cos\theta = EI \times P.F.$

Power factor

$$P.F. = \frac{P}{EI} = \cos\theta$$

$$\cos\theta = \frac{\text{true power}}{\text{apparent power}}$$

Transformers

Voltage relationship

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \text{ or } E_s = E_p \times \frac{N_s}{N_p}$$

Current relationship

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$

Induced voltage

$$E_{eff} = 4.44 \times BAfN \times 10^{-8}$$

Turns ratio

$$\frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}}$$

Secondary current

$$I_s = I_p \times \frac{N_p}{N_s}$$

Secondary voltage

$$E_s = E_p \times \frac{N_s}{N_p}$$

Conductance

Conductance in a d-c circuit is the reciprocal of resistance and is expressed by

$$G = \frac{1}{R}$$

conversely

$$R = \frac{1}{G}$$

where
G = conductance in mhos
R = resistance in ohms

When resistors are connected in a parallel d-c circuit, the total conductance is given by

$$G_t = G_1 + G_2 + G_3 + G_4 \ldots$$

and the total current by

$$I_t = EG_t$$

In terms of conductance, Ohm's Law may be stated as follows:

$I = EG$ and

$$E = \frac{I}{G}$$

Susceptance

The susceptance of an a-c series circuit is expressed by

$$B = \frac{X}{R^2 + X^2}$$

where
B = susceptance in mhos
R = resistance in ohms
X = reactance in ohms

Admittance

The admittance of an a-c circuit is expressed by

$$Y = \frac{1}{\sqrt{R^2 + X^2}}$$

Since admittance is the reciprocal of impedance:

$$Y = \frac{1}{Z}$$

also

$$Y = \frac{I}{E}$$

where
Y = admittance in mhos
R = resistance in ohms
E = potential in volts
I = current in amperes
X = reactance in ohms
Z = impedance in ohms

Mutual Inductance

The mutual inductance between two coupled r-f coils is given by

$$M = \frac{L_a - L_b}{4}$$

where
M = mutual inductance
L_a = total inductance of L_1 and L_2 with aiding fields
L_b = total inductance of L_1 and L_2 with opposing fields

Inductance of Small Air-core Coils

For single-layer wound coils:

$$L = \frac{(rN)^2}{9r + 10l} \text{ and}$$

$$N = \frac{\sqrt{L(9r + 10l)}}{r}$$

For multi-layer wound coils:

$$L = \frac{0.8(rN)^2}{6r + 9l + 10b}$$

For single-layer pancake coils:

$$L = \frac{(rN)^2}{8r + 11b}$$

where
L = self-inductance in microhenries
N = total number of turns
r = mean radius in inches
l = length of coil in inches
b = depth of coil in inches

Coupling Coefficient

When two r-f coils are inductively coupled, the coefficient of ling is given by

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

where
K = coupling coefficient (K x 100 = coupling coefficient in %
M = mutual inductance
L_1, L_2 = self-inductance of coil

Resonance

When X_L is equal to X_C, the circuit is resonant at a particular frequency. Combining the two reactance formulas, the formula for resonant frequency is found to be

$$f_r = \frac{1}{2\pi\sqrt{LC}} \text{ or } f_r = \frac{.159}{\sqrt{LC}}$$

also

$$L = \frac{1}{4\pi^2 f_r^2 C}$$

and

$$C = \frac{1}{4\pi^2 f_r^2 L}$$

where
f_r = resonant frequency in cycles
L = inductance in henries
C = capacitance in farads

Wavelength and Frequency

To convert from frequency to wavelength:

$$\lambda = \frac{3 \times 10^8}{f} \text{ (meters)}$$

where
f = frequency in cycles also

$$\lambda = \frac{3 \times 10^5}{f} \text{ (meters)}$$

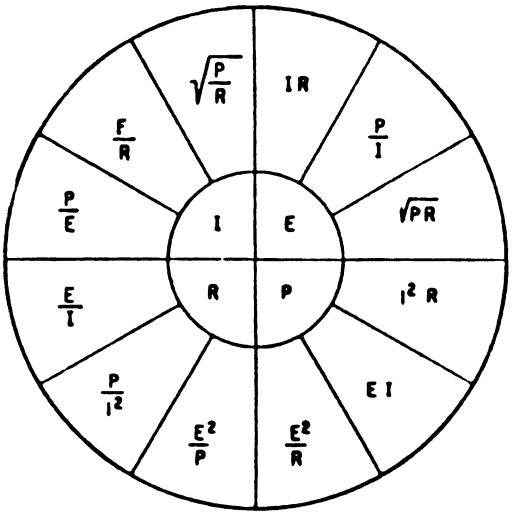
where
f = frequency in kilocycles and

$$\lambda = \frac{300}{f} \text{ (meters)}$$

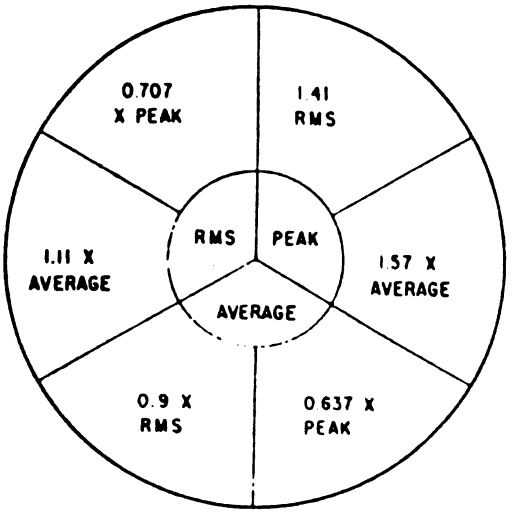
where
f = frequency in megacycles

FIGURE 5. ELECTRICAL/MATHEMATICAL RELATIONSHIP

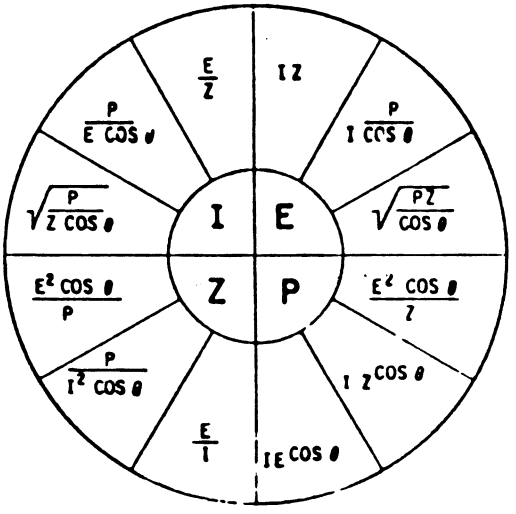
OHMS LAW FOR D-C CIRCUITS



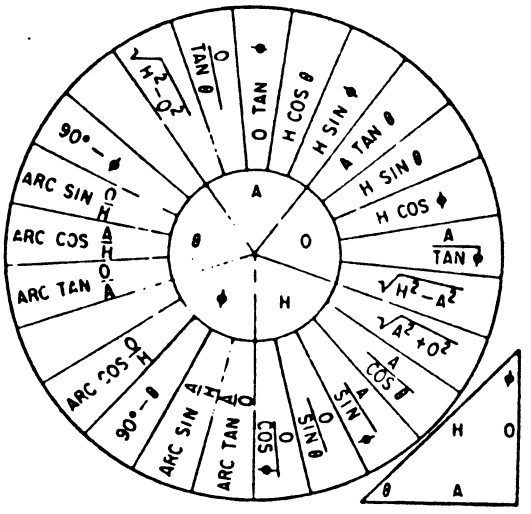
A-C VOLTAGE RELATIONS



OHMS LAW FOR A-C CIRCUITS



FUNCTIONS OF A RIGHT ANGLE



POWER FACTOR $\frac{E\,i\cos\theta}{EI}$

RATIO $\frac{\text{NAUTICAL MILE}}{\text{STATUTE MILE}} = \frac{7.60}{6.60}$

CIRCULAR MILS = $\frac{\text{SQ MILS}}{0.7854}$

ONE RADIAN = $\frac{360°}{2\pi} = 57.3°$

RADIANS = DEGREES x 0.0175

SECONDS OF ARC = 206265 = $\frac{360° \times 60' \times 60''}{2\pi}$

MINUTES OF ARC = 3438 = $\frac{360° \times 60'}{2\pi}$

FIGURE 5. ELECTRICAL/MATHEMATICAL RELATIONSHIP (CONTINUED)

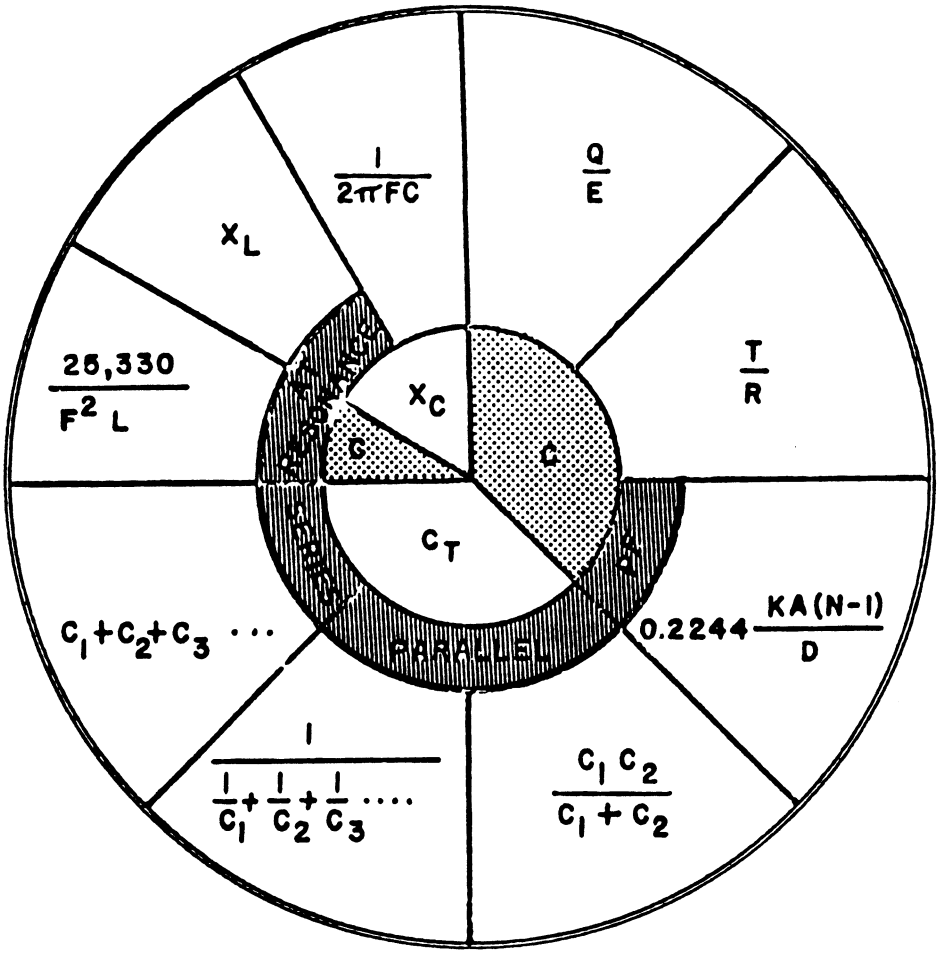
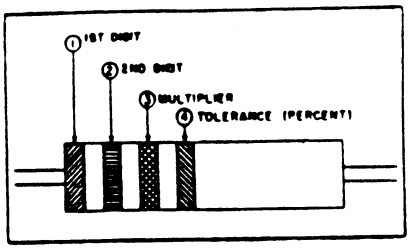
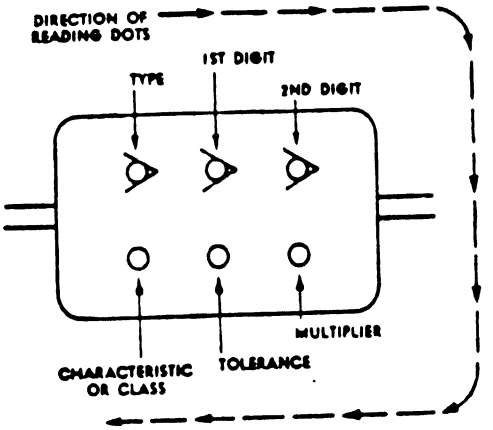


FIGURE 6. ELECTRONICS COLOR CODING

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (percent)
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Gold			.1	5
Silver			.01	10
No color				20



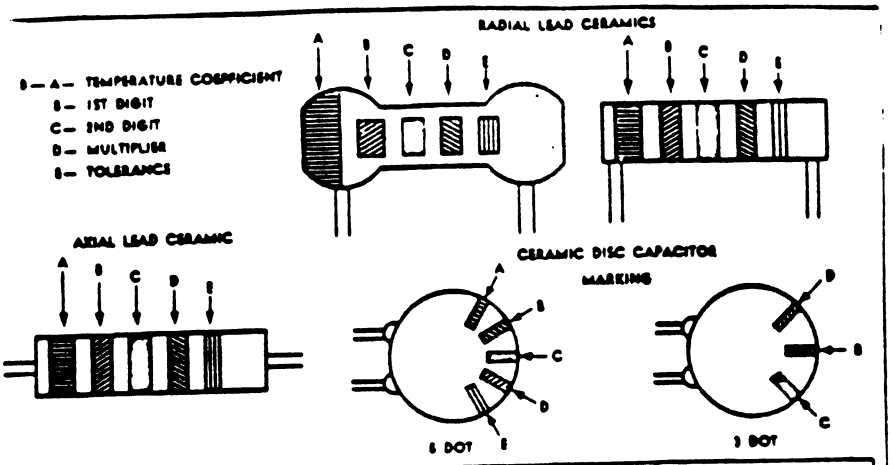
Resistor Color Code



TYPE	COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	CHARACTERISTIC OR CLASS
JAN, MICA	BLACK	0	0	1.0		APPLIES TO
	BROWN	1	1	10	± 1	TEMPERATURE
	RED	2	2	100	± 2	COEFFICIENT
	ORANGE	3	3	1,000	± 3	OR METHODS
	YELLOW	4	4	10,000	± 4	OF TESTING
	GREEN	5	5	100,000	± 5	
	BLUE	6	6	1,000,000	± 6	
	VIOLET	7	7	10,000,000	± 7	
	GRAY	8	8	100,000,000	± 8	
EIA, MICA	WHITE	9	9	1,000,000,000	± 9	
	GOLD			.1		
MOLDED PAPER	SILVER			.01	±10	
	BODY				±20	

6-Dot Color Code For Mica And Molded Capacitors

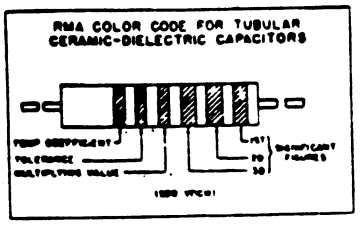
FIGURE 6. ELECTRONICS COLOR CODING (CONTINUED)



COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE: MORE THAN 10 pF (IN PERCENT)	TOLERANCE: LESS THAN 10 pF (IN pF)	TEMPERATURE COEFFICIENT *
BLACK	0	0	1.0	±20	±2.0	0
BROWN	1	1	10	± 1		−30
RED	2	2	100	± 2		−80
ORANGE	3	3	1,000			−150
YELLOW	4	4	10,000			−220
GREEN	5	5		± 5	±0.5	−330
BLUE	6	6				−470
VIOLET	7	7				−750
GRAY	8	8	.01		±0.25	+30
WHITE	9	9	.1	±10	±1.0	+120 TO −750 (EIA)
						+500 TO −330 (JAN)
SILVER						+100 (JAN)
GOLD						BYPASS OR COUPLING (EIA)

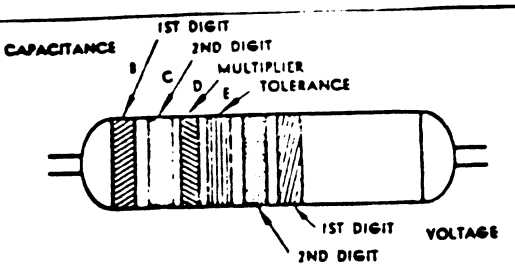
* PARTS PER MILLION PER DEGREE CENTIGRADE.

Identifications For Ceramic Capacitors



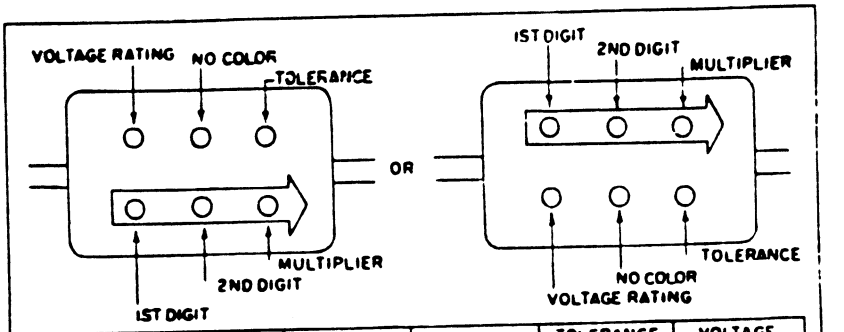
(PRESENTLY OBSOLETE - FOUND ON OLDER EQUIPMENT)

FIGURE 6. ELECTRONICS COLOR CODING (CONTINUED)



COLOR	CAPACITANCE			TOLERANCE (PERCENT)	VOLTAGE RATING	
	1ST DIGIT	2ND DIGIT	MULTIPLIER		1ST DIGIT	2ND DIGIT
BLACK	0	0	1	±20	0	0
BROWN	1	1	10		1	1
RED	2	2	100		2	2
ORANGE	3	3	1,000	±30	3	3
YELLOW	4	4	10,000	±40	4	4
GREEN	5	5	100,000	± 5	5	5
BLUE	6	6	1,000,000		6	6
VIOLET	7	7			7	7
GRAY	8	8			8	8
WHITE	9	9		±10	9	9

6-Band Color Code For Tubular Paper Dielectric Capacitors

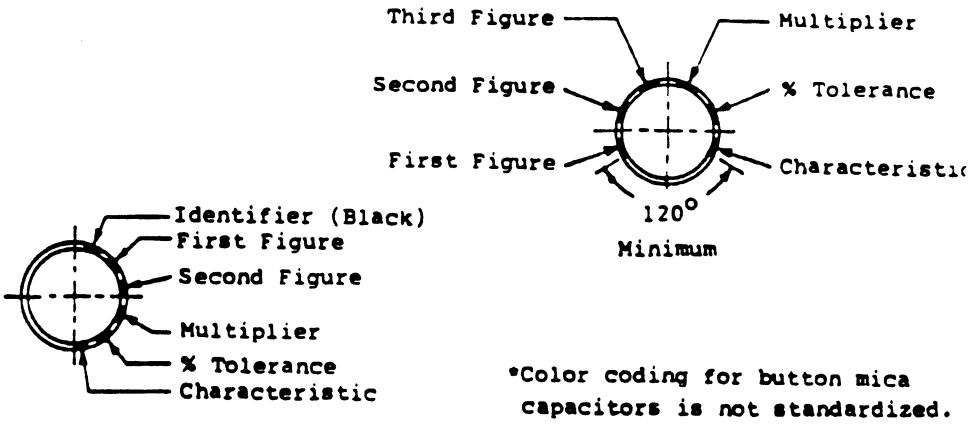


COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	VOLTAGE RATING
BLACK	0	0	10		
BROWN	1	1	10	± 1	100
RED	2	2	100	± 2	200
ORANGE	3	3	1,000	± 3	300
YELLOW	4	4	10,000	± 4	400
GREEN	5	5	100,000	± 5	500
BLUE	6	6	1,000,000	± 6	600
VIOLET	7	7	10,000,000	± 7	700
GRAY	8	8	100,000,000	± 8	800
WHITE	9	9	1,000,000,000	± 9	900
GOLD			1		1000
SILVER			.01	±10	2000
BODY				±20	*

* WHERE NO COLOR IS INDICATED, THE VOLTAGE RATING MAY BE AS LOW AS 300 VOLTS.

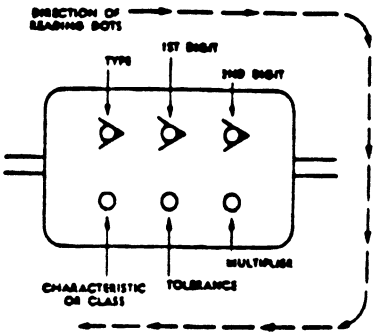
3, 4, & 5 Dot Capacitor Code (Mica)

FIGURE 6. ELECTRONICS COLOR CODING (CONTINUED)



*Color coding for button mica capacitors is not standardized.

Color Coding of Button Mica Capacitors*

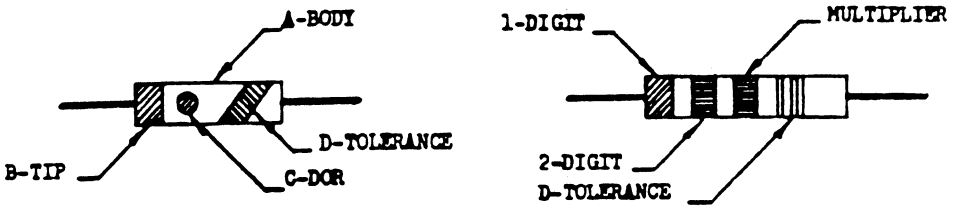


TYPE	COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	CHARACTERISTIC OR CLASS
JAN, MICA	BLACK	0	0	1.0		APPLIES TO
	BROWN	1	1	10	± 1	TEMPERATURE
	RED	2	2	100	± 2	COEFFICIENT
	ORANGE	3	3	1,000	± 3	OR METHODS
	YELLOW	4	4	10,000	± 4	OF TESTING
	GREEN	5	5	100,000	± 5	
	BLUE	6	6	1,000,000	± 6	
	VIOLET	7	7	10,000,000	± 7	
	GRAY	8	8	100,000,000	± 8	
EIA, MICA	WHITE	9	9	1,000,000,000	± 9	
	GOLD			.1		
MOLDED PAPER	SILVER			.01	±10	
	BODY				±20	

6-Dot Color Code For Mica And Molded Capacitors

FIGURE 6. ELECTRONICS COLOR CODING (CONTINUED)

RNA COLOR CODE RESISTORS



COLOR	1 ST. DIGIT	2 ND DIGIT	MULTIPLIER
SILVER	-	-	0.01
GOLD	-	-	0.1
BLACK	-	0	1
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
PURPLE	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	1,000,000,000

D--TOLERANCE CODE

GOLD-5%	SILVER-10 %	NO COLOR-20 %

FIGURE 6. ELECTRONICS COLOR CODING (CONTINUED)

Cylindrical RF Choke Coil Color Code

A..Mil. Identifier (Silver)

B..First Significant Figure

C..Second Significant Figure Or Decimal Point Indication (Gold Band)

D..Multiplier Or Second Significant Figure (If Decimal Was Used)

E..Tolerance

Standard Resistor Color Code Is Used, Except For Decimal Indicator

Neon Lamps

NO.	A-C STARTING VOLTS	BASE*	B
NE-2	65.0	Wire Term.	T
NE-14	75.0	Cand Screw	T
NE-16	67.0	Cand Bayonet	T
NE-17	55.0	Cand Bayonet	T
NE-34	60.0	Edison	S-
NE-40	60.0	Edison	S-
NE-45	65.0	Cand Screw	T-
NE-48	65.0	Cand Bayonet	T-
NE-51	65.0	Min Bayonet	T-
NE-57	55.0	Cand Screw	T-
NE-58	65.0	Cand Screw	T-

* Neon types with screw base ha resistor for 105 - 125 volt oper tion. Other types require extern series resistor.

EIA PREFERRED VALUE SYSTEM

TOLERANCE:	5%	10%	20%
VALUES:	10	10	10
	11	-	-
	12	12	-
	13	-	-
	15	15	15
	16	-	-
	18	18	-
	20	-	-
	22	22	22
	24	-	-
	27	27	-
	30	-	-
	33	33	33
	36	-	-
	39	39	-
	43	-	-
	47	47	47
	51	-	-
	56	56	-
	62	-	-
	68	68	68
	75	-	-
	82	82	-
	91	-	-

(BASE VALUES SHOWN - MULTIPLY BY POWERS OF TEN FOR OTHER VALUES)

FIGURE 7. TRANSISTOR OUTLINES

Physical size and shapes of transistors vary greatly with manufacture and types. Below are the most common transistor types with leads identified. Where only two leads are shown, the case is used as the third element or terminal.

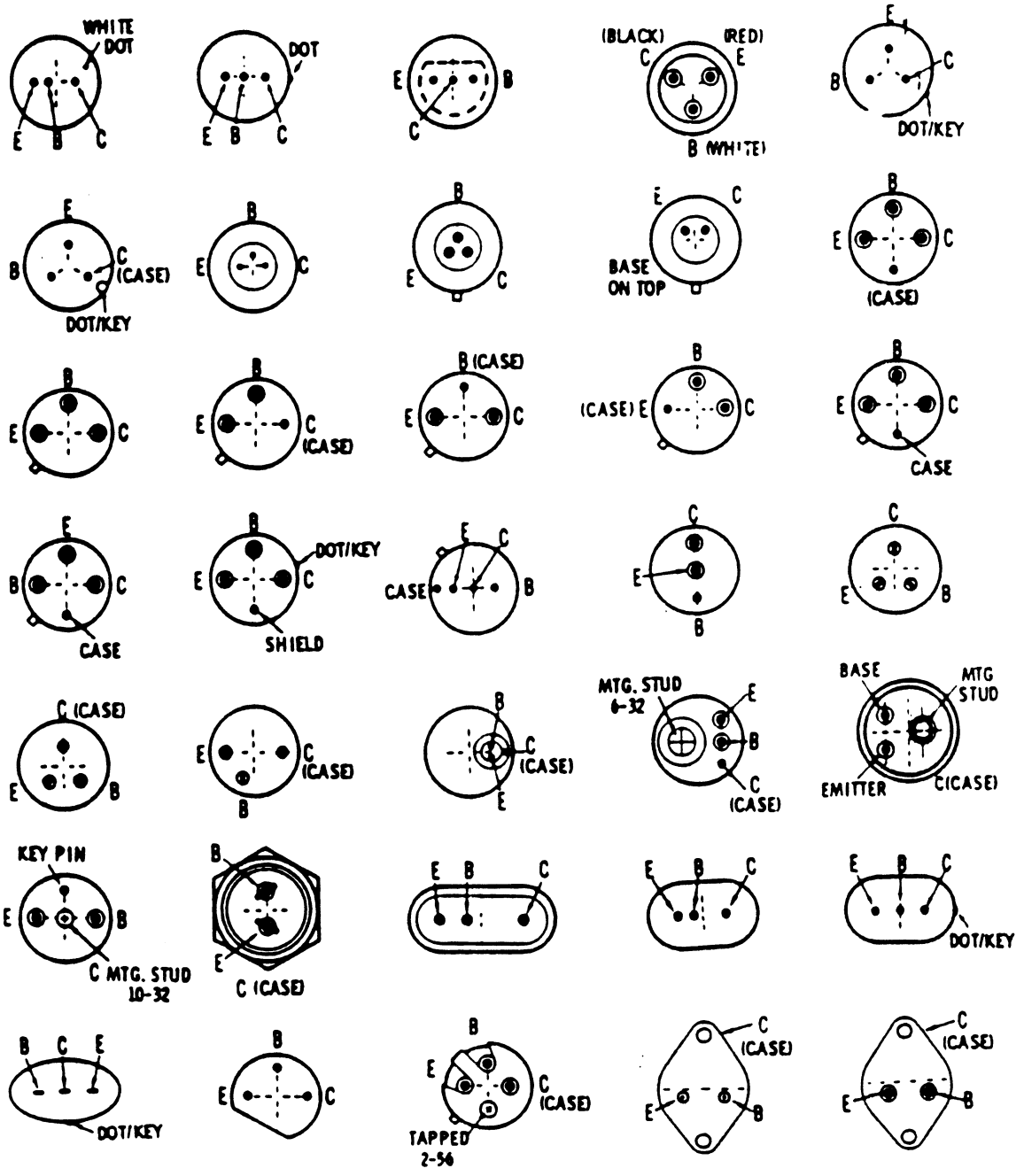


FIGURE 7. TRANSISTOR OUTLINES (CONTINUED)

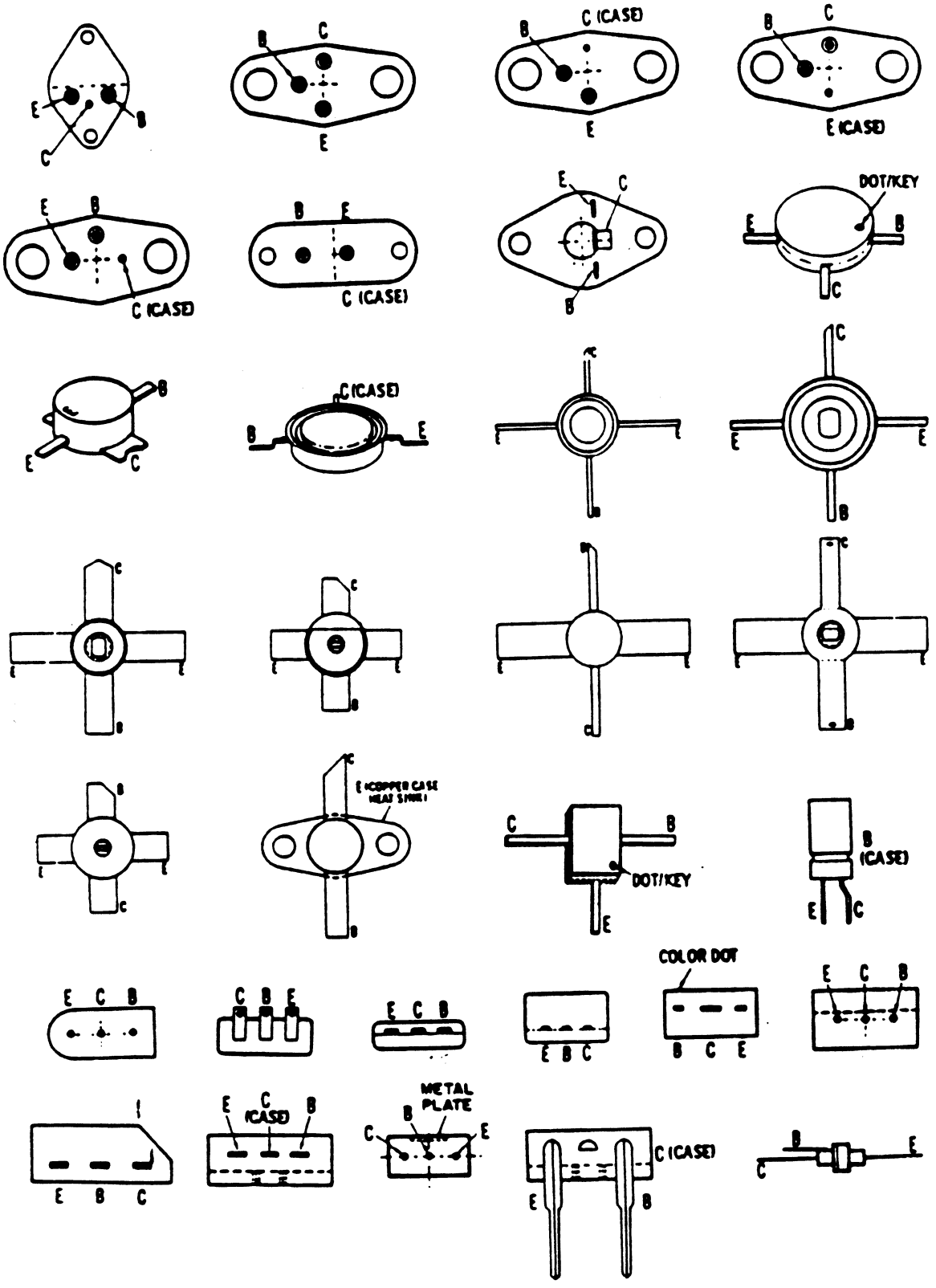


FIGURE 7. TRANSISTOR OUTLINES (CONTINUED)

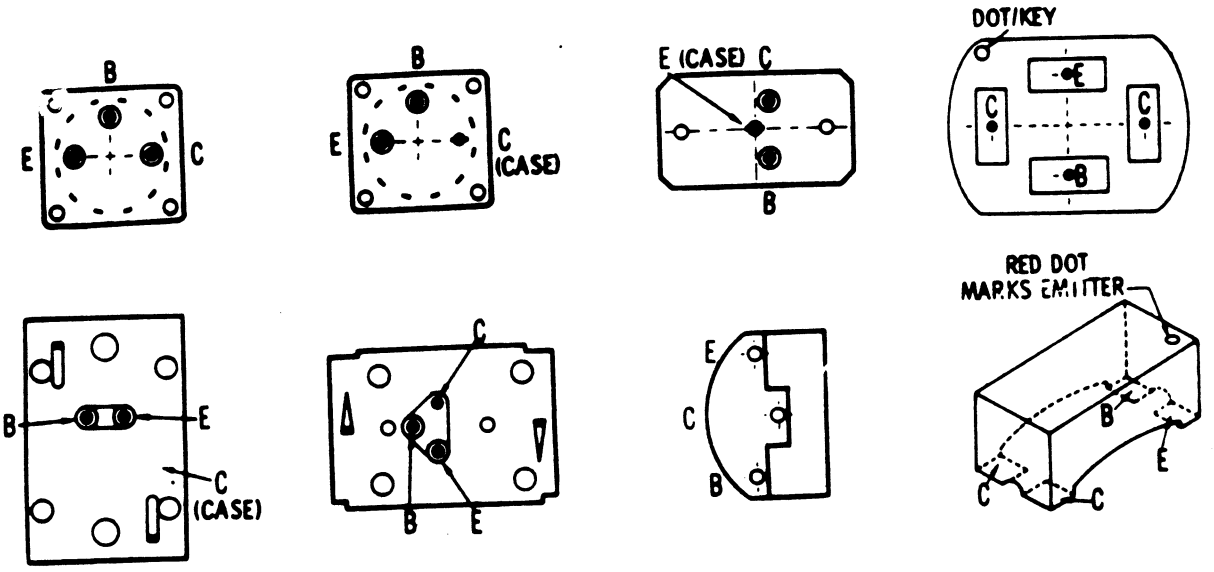


FIGURE 8. COLOR CODING FOR MULTICONDUCTOR CABLE

COLOR CODING FOR MULTICONDUCTOR CABLE

(a) Basic Color Code. 1-20 Conductors

1.	Blue	11.	Orange/White
2.	Orange	12.	Orange/Green
3.	Green	13.	Orange/Brown
4.	Brown	14.	Orange/Slate
5.	Slate	15.	Green/White
6.	Blue/White	16.	Green/Brown
7.	Blue/Orange	17.	Green/Slate
8.	Blue/Green	18.	Brown/White
9.	Blue/Brown	19.	Brown/Slate
10.	Blue/Slate	20.	Slate/White

(b) Color Combinations, Single Wires. 1-60 Conductors using Red, Black and Red/Black Traces

Conductor	Basic Color	Trace Color
1-20	1-20	Red
21-40	1-20	Black
41-60	1-20	Red/Black

(c) Color Combinations, Paired Wires

Pair	Trip Color	Ring Color
1-20	White	Basic Colors 1-20
21-40	Red	Basic Colors 1-20
41-60	Black	Basic Colors 1-20
61-80	Red/White	Basic Colors 1-20
81-100	Black/White	Basic Colors 1-20
101-120	Red/Black	Basic Colors 1-20
121-140	White	Basic Colors with Red Tracer
141-160	Red	Basic Colors with Red Tracer
161-180	Red	Basic Colors with Black Tracer
181-200	Basic Colors with Red/White Tracer	Basic Colors

FIGURE 9. CABLE COLOR CODES

Color Code of 12 Pair Control Cable

Pair No.	Tracer	Color
1.	Black	Brown
2.	Black	Red
3.	Black	Orange
4.	Black	Yellow
5.	Black	Green
6.	Black	Blue
7.	Black	White
8.	Red	Yellow
9.	Red	Green
10.	Red	Blue
11.	Red	White
12.	Red	Brown

Red Jacket 10 Pair Shielded Cable

Pair No.	Tracer	Color
1.	White	Blue
2.	White	Orange
3.	White	Green
4.	White	Brown
5.	White	Slate
6.	Red	Blue
7.	Red	Orange
8.	Red	Green
9.	Red	Brown
10.	Red	Slate

Yellow Jacket 26 Pr. Control

Pair No.	Tracer	Color
1.	White	Blue
2.	White	Orange
3.	White	Green
4.	White	Brown
5.	White	Slate
6.	White	bl/wht
7.	White	bl/org
8.	White	bl/grn
9.	White	bl/brn
10.	White	bl/slt
11.	White	or/wht
12.	White	or/grn
13.	White	or/brn
14.	White	or/slt
15.	White	gr/wht
16.	White	gr/brn
17.	White	gr/slt
18.	White	br/wht
19.	White	br/slt
20.	White	sl/wht
21.	Red	Blue
22.	Red	Orange
23.	Red	Green
24.	Red	Brown
25.	Red	Slate
26.	Red (spare)	bl/wht

FIGURE 9. CABLE COLOR CODES (CONTINUED)

100 PAIR CONTROL CABLE

Four Bundles - 25 Pair Per Bundle - Coded with Twine

Bundle	Color Coded Twine	Pair Nos.
1st	Blue	1 thru 25
2nd	Orange	26 thru 50
3rd	Green	51 thru 75
4th	Brown	76 thru 100

Color Code Per Bundle

Pair No.	Tracer	Color
1.	White	Blue
2.	White	Orange
3.	White	Green
4.	White	Brown
5.	White	Slate
6.	Red	Blue
7.	Red	Orange
8.	Red	Green
9.	Red	Brown
10.	Red	Slate
11.	Black	Blue
12.	Black	Orange
13.	Black	Green
14.	Black	Brown
15.	Black	Slate
16.	Yellow	Blue
17.	Yellow	Orange
18.	Yellow	Green
19.	Yellow	Brown
20.	Yellow	Slate
21.	Purple	Blue
22.	Purple	Orange
23.	Purple	Green
24.	Purple	Brown
25.	Purple	Slate

FIGURE 9. CABLE COLOR CODES (CONTINUED)

25 PAIR YELLOW JACKET CONTROL CABLE

Pair No.	Tracer	Color
1.	White	Blue
2.	White	Orange
3.	White	Green
4.	White	Brown
5.	White	Slate
6.	Red	Blue
7.	Red	Orange
8.	Red	Green
9.	Red	Brown
10.	Red	Slate
11.	Black	Blue
12.	Black	Orange
13.	Black	Green
14.	Black	Brown
15.	Black	Slate
16.	Yellow	Blue
17.	Yellow	Orange
18.	Yellow	Green
19.	Yellow	Brown
20.	Yellow	Slate
21.	Purple	Blue
22.	Purple	Orange
23.	Purple	Green
24.	Purple	Brown
25.	Purple	Slate

FIGURE 9. CABLE COLOR CODES (CONTINUED)

40 SINGLE CONDUCTOR

1. BLACK
2. RED
3. GREEN
4. WHITE
5. BROWN
6. BLUE
7. ORANGE
8. YELLOW
9. PURPLE
10. GRAY
11. PINK
12. TAN
13. RED/GREEN
14. RED/YELLOW
15. RED/BLACK
16. WHITE/BLACK
17. WHITE/RED
18. WHITE/GREEN
19. WHITE/YELLOW
20. WHITE/BLUE
21. WHITE/BROWN
22. WHITE/ORANGE
23. WHITE/GRAY
24. WHITE/VIOLET
25. WHITE/BLACK/RED
26. WHITE/BLACK/GREEN
27. WHITE/BLACK/YELLOW
28. WHITE/BLACK/BLUE
29. WHITE/BLACK/BROWN
30. WHITE/BLACK/ORANGE
31. WHITE/BLACK/GRAY
32. WHITE/BLACK/PURPLE
33. WHITE/BLACK/BLACK
34. WHITE/RED/BLACK
35. WHITE/RED/RED
36. WHITE/RED/GREEN
37. WHITE/RED/BLUE
38. WHITE/RED/BROWN
39. WHITE/RED/PURPLE
40. WHITE/GREEN/BLACK

32 SINGLE CONDUCTOR

1. BLUE
2. WHITE/BLUE
3. RED/BLUE
4. BLACK/BLUE
5. WHITE/BLACK/BLUE
6. ORANGE
7. GREEN/ORANGE
8. RED/ORANGE
9. BLACK/ORANGE
10. GREEN/BLACK/ORANGE
11. WHITE/BLACK/ORANGE
12. GREEN
13. WHITE/GREEN
14. BLACK/GREEN
15. ORANGE/BLACK/GREEN
16. WHITE/BLACK/GREEN
17. WHITE
18. RED/WHITE
19. BLACK/WHITE
20. GREEN/RED/WHITE
21. RED/BLACK/WHITE
22. RED
23. GREEN/RED
24. WHITE/RED
25. BLACK/RED
26. GREEN/BLACK/RED
27. WHITE/BLACK/RED
28. BLACK
29. WHITE/BLACK
30. RED/BLACK
31. GREEN/RED/BLACK
32. WHITE/RED/BLACK

FIGURE 9. CABLE COLOR CODES (CONTINUED)

CABLE RUNNING SHEET
FROM 25 PR CABLE # _____ TO

W BLU
W OR
W GR
W BR
W SL
R BLU
R OR
R GR
R BR
R SL
BK BLU
BK OR
BK GR
BK BR
BK SL
Y BLU
Y OR
Y GR
Y BR
Y SL
P BLU
P OR
P GR
P BR
P SL

SO Form 6012-2 (8-75)

FIGURE 9. CABLE COLOR CODES (CONTINUED)

CABLE RUNNING SHEET

FROM 10 PR CABLE #_____ TO

W BLU
W OR
W GR
W BR
W SL
R BLU
R OR
R GR
R BR
R SL

10 PR CABLE #_____

W BLU
W OR
W GR
W BR
W SL
R BLU
R OR
R GR
R BR
R SL

SO Form 6012-J (8-75)

FIGURE 10. ATTENUATOR (PAD) NETWORKS, FORMULAS, AND TABLES

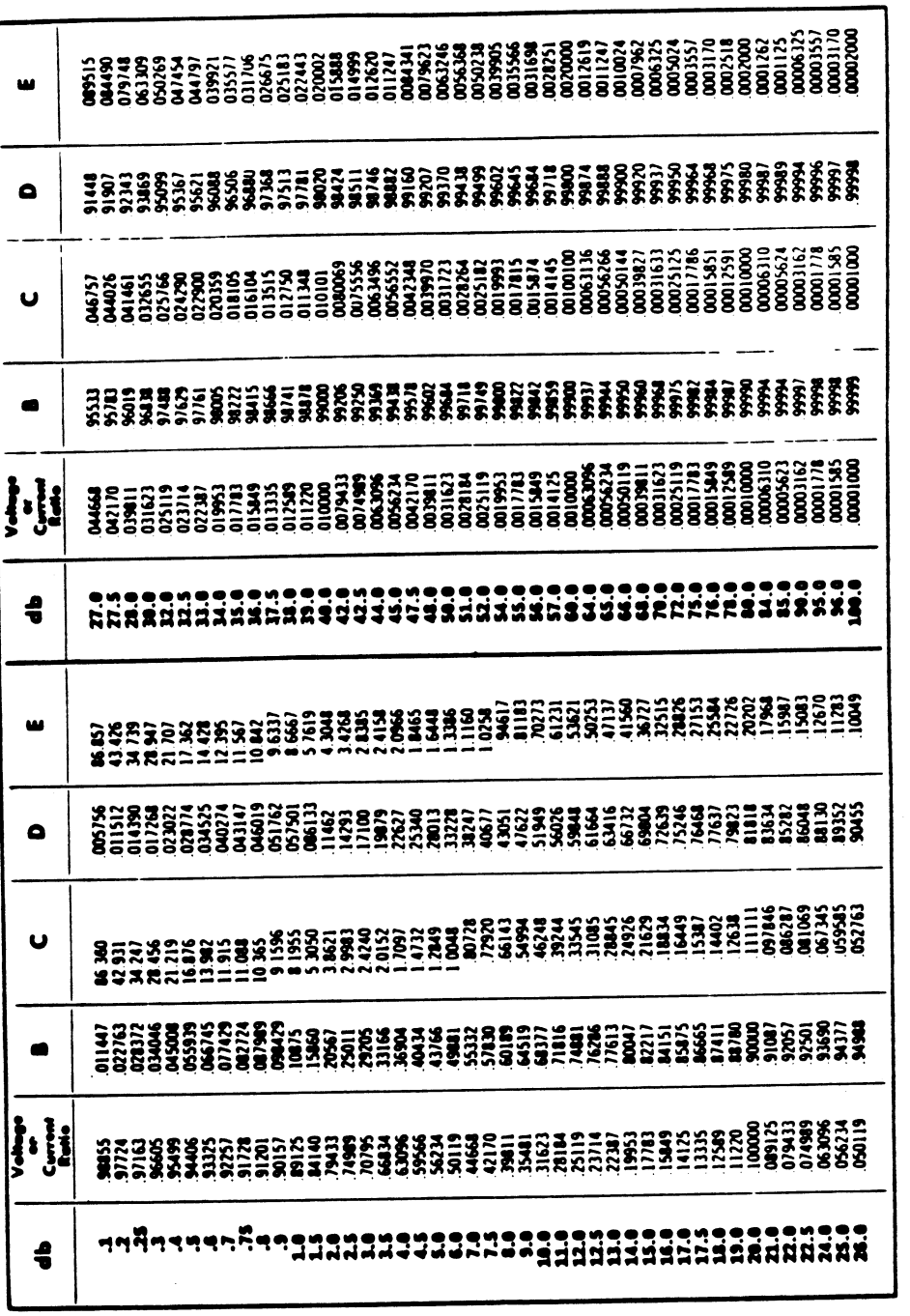


Table of Values for Attenuator Network Formulas

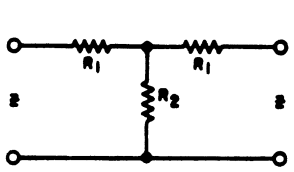
db	Voltage or Current Ratio	B	C	D	E	db	Voltage or Current Ratio	B	C	D	E
.1	.98855	.011447	86.360	.005756	86.857	27.0	.044668	.95533	.046757	.91448	.089515
.2	.97724	.022763	42.931	.011512	43.426	27.5	.042170	.95783	.044026	.91907	.084490
.25	.97163	.028372	34.247	.014390	34.739	28.0	.039811	.96019	.041461	.92343	.079748
.3	.96605	.034046	28.456	.017268	28.947	28.5	.037584	.96438	.039055	.93069	.075277
.4	.95499	.045008	21.219	.023022	21.707	30.0	.035481	.96438	.036798	.93469	.071067
.5	.94406	.055939	16.816	.028774	17.362	31.0	.033497	.96628	.034683	.93829	.067106
.6	.93325	.066745	13.982	.034525	14.428	32.0	.031623	.96807	.032655	.94159	.063386
.7	.92257	.077429	11.915	.040274	12.395	33.0	.029853	.96977	.030759	.94458	.059888
.75	.91728	.082724	11.088	.043147	11.567	34.0	.028184	.97138	.028905	.94738	.056577
.8	.91201	.087989	10.365	.046019	10.842	35.0	.026607	.97292	.027106	.94999	.053477
.9	.90157	.098429	9.1596	.051762	9.6337	36.0	.025119	.97415	.025360	.95240	.050577
1.0	.89125	.10875	8.1955	.057501	8.6667	37.5	.023335	.97666	.023515	.95513	.046675
1.5	.84140	.15860	5.3050	.086133	5.7619	38.0	.022589	.97741	.022750	.95621	.045183
2.0	.79433	.20567	3.8621	.11462	4.3048	39.0	.021220	.97878	.021348	.95781	.042443
2.5	.74989	.25011	2.9983	.14293	3.4268	40.0	.020000	.98000	.020101	.96070	.040002
3.0	.70795	.29205	2.4240	.17100	2.8385	42.0	.017989	.98206	.018069	.96424	.035888
3.5	.66834	.33166	2.0152	.19879	2.4158	42.5	.017783	.98250	.017876	.96511	.035577
4.0	.63096	.36904	1.7097	.22627	2.0966	44.0	.016104	.98369	.016180	.96746	.032620
4.5	.59566	.40434	1.4732	.25340	1.8465	45.0	.015849	.98438	.015924	.96882	.031747
5.0	.56234	.43766	1.2849	.28013	1.6448	47.5	.014170	.98578	.014234	.97160	.028441
6.0	.50119	.49881	1.0048	.33228	1.3386	48.0	.013970	.98602	.013911	.97207	.027923
7.0	.44668	.55332	.80728	.38247	1.1160	49.0	.013623	.98684	.013723	.97370	.027463
7.5	.42170	.57830	.72920	.40677	1.0258	51.0	.012884	.98718	.012964	.97438	.025938
8.0	.39811	.60189	.66143	.43051	.94617	52.0	.012589	.98749	.012682	.97499	.025368
9.0	.35481	.64519	.54994	.47622	.81183	54.0	.011953	.98800	.012043	.97602	.024105
10.0	.31623	.68377	.46248	.51949	.70273	55.0	.011783	.98822	.011873	.97645	.023566
11.0	.28184	.71816	.39244	.56026	.61231	56.0	.011549	.98842	.011638	.97684	.023098
12.0	.25119	.74881	.33545	.59848	.53621	57.0	.011425	.98859	.011514	.97718	.022851
12.5	.23714	.76286	.31085	.61664	.50253	58.0	.011000	.98900	.011100	.97800	.022000
13.0	.22387	.77613	.28845	.63416	.47137	64.0	.010063	.98937	.010136	.97874	.020126
14.0	.19953	.80047	.24926	.66732	.41560	65.0	.009962	.98944	.010037	.97888	.019924
15.0	.17783	.82217	.21629	.69804	.36727	66.0	.009811	.98950	.009887	.97900	.019624
16.0	.15849	.84151	.18834	.72639	.32515	70.0	.009623	.98964	.009699	.97920	.019246
17.0	.14125	.85875	.16449	.75246	.28826	72.0	.008511	.98975	.008577	.97937	.017020
17.5	.13335	.86665	.15387	.76468	.27153	75.0	.008318	.98982	.008382	.97964	.016635
18.0	.12589	.87411	.14402	.77637	.25584	76.0	.008511	.98984	.008585	.97968	.017170
19.0	.11220	.88780	.12638	.79823	.22726	78.0	.007943	.98987	.008012	.97975	.015886
20.0	.10000	.90000	.11111	.81818	.20202	80.0	.007943	.98990	.008012	.97980	.015886
21.0	.089125	.91087	.097846	.83634	.17968	84.0	.006310	.98994	.006366	.97987	.012620
22.0	.079433	.92057	.086287	.85282	.15987	85.0	.005623	.98994	.005674	.97989	.011247
22.5	.074989	.92501	.081069	.86048	.15083	90.0	.003162	.98997	.003192	.97994	.006325
24.0	.063096	.93690	.067345	.88130	.12670	95.0	.001778	.98998	.001794	.97996	.003557
25.0	.056234	.94377	.059585	.89352	.11283	96.0	.001585	.98998	.001600	.97997	.003170
26.0	.050119	.94988	.052763	.90455	.10049	100.0	.001000	.99995	.001000	.99998	.002000

FIGURE 10. ATTENUATOR (PAD) NETWORKS, FORMULAS, AND TABLES (CONTINUED)

Attenuator Networks

For Insertion Between Equal Impedances

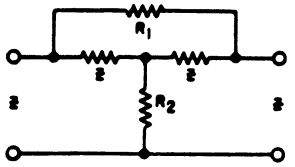
See table on page 25 for values of B, C, D, and # used in the following attenuator network formulas.



T

$R_1 = ZD$

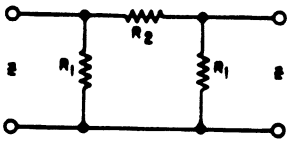
$R_2 = ZE$



Bridged T

$R_1 = \frac{Z}{C}$

$R_2 = ZC$

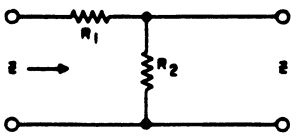


π

$R_1 = \frac{Z}{D}$

$R_2 = \frac{Z}{E}$

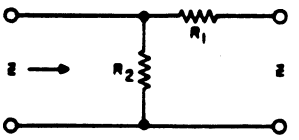
In the case of L and U networks where only the input or output can be matched, as required, the matched side is indicated by an arrow pointing toward the pad. On all other networks, both the input and output circuits are matched.



L

$R_1 = ZB$

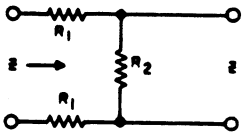
$R_2 = ZC$



L

$R_1 = \frac{Z}{C}$

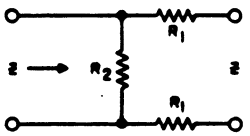
$R_2 = \frac{Z}{B}$



U

$R_1 = \frac{ZB}{2}$

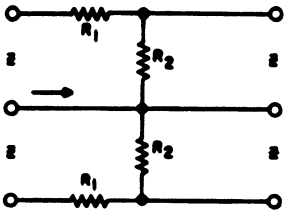
$R_2 = ZC$



U

$R_1 = \frac{Z}{2C}$

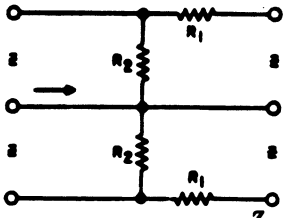
$R_2 = \frac{Z}{B}$



Balanced U

$R_1 = \frac{ZB}{2}$

$R_2 = \frac{ZC}{2}$



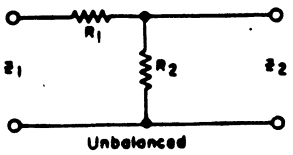
Balanced U

$R_1 = \frac{Z}{2C}$

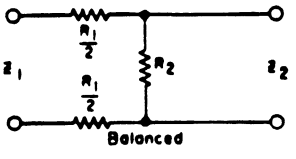
$R_2 = \frac{Z}{2B}$

FIGURE 10. ATTENUATOR (PAD) NETWORKS, FORMULAS, AND TABLES (CONTINUED)

Minimum Loss Pads



Unbalanced



Balanced

For Matching Two Impedances where $Z_1 > Z_2$

$$R_1 = \sqrt{Z_1 (Z_1 - Z_2)}$$

$$R_2 = \frac{Z_1 Z_2}{R_1}$$

$$db \text{ loss} = 20 \log_{10} \left(\sqrt{\frac{Z_1}{Z_2}} + \sqrt{\frac{Z_1}{Z_2} - 1} \right)$$

Where Only One Impedance is to be Matched

If the larger impedance only is to be matched, use a resistor R_L in series with the smaller impedance such that

$$R_L = Z_1 - Z_2$$

$$db \text{ loss} = 20 \log_{10} \sqrt{\frac{Z_1}{Z_2}}$$

If the smaller impedance only is to be matched, use a resistor R_S in shunt across the larger impedance such that

$$R_S = \frac{Z_1 Z_2}{Z_1 - Z_2}$$

Here also db loss $= 20 \log_{10} \sqrt{\frac{Z_1}{Z_2}}$

Tables of R_1 and R_2 Values

When Z_1 is 600 ohms and Z_2 is less than 600 ohms.

Z_2	500	400	300	250	200	150	100	75	50	40	30	25
R_1	245	346	424	458	490	520	548	561	575	580	585	587
R_2	1,225	694	425	328	245	173	110	80.2	52.2	41.4	30.8	25.6
db Loss	3.8	5.7	7.6	8.7	10.0	11.4	13.4	14.8	16.6	17.6	18.9	19.7

When Z_2 is less than 25 ohms,

$$\text{let } R_1 = 600 - \frac{Z_1}{Z_2}$$

$$\text{and } R_2 = Z_2$$

Where Z_2 is 600 ohms, and Z_1 is greater than 600 ohms.

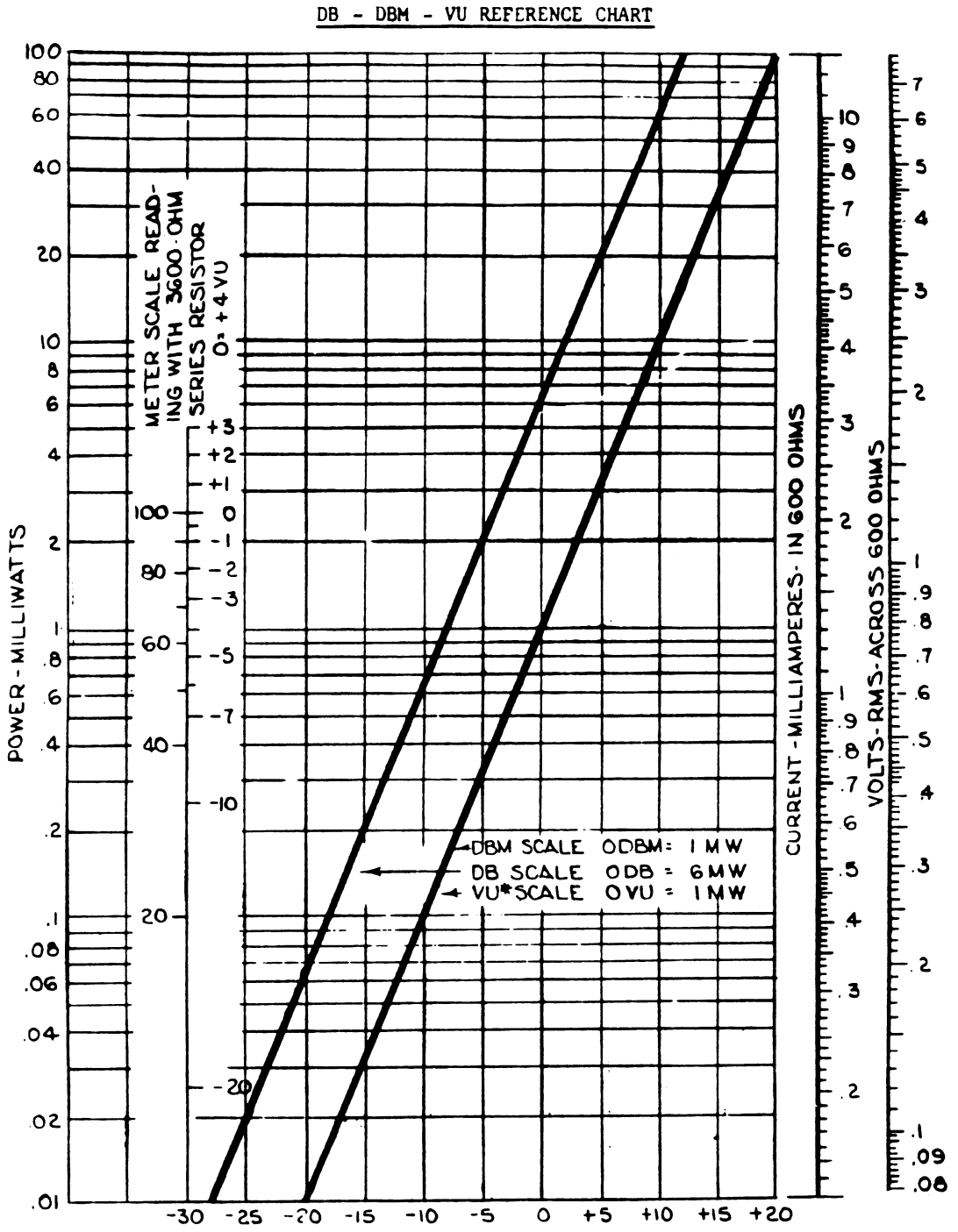
Z_1	800	1,000	1,200	1,500	2,000	2,500	3,000	3,500	4,000	5,000	6,000	8,000	10,000
R_1	400	632	849	1,162	1,673	2,180	2,683	3,186	3,688	4,690	5,692	7,694	9,695
R_2	1,200	949	849	775	717	688	671	659	651	638	633	624	619
db Loss	4.8	6.5	7.6	9.0	10.5	11.6	12.5	13.3	13.9	15.0	15.8	17.1	18.1

When Z_1 is greater than 10,000 ohms,

$$\text{let } R_1 = Z_1 - 300$$

$$\text{and } R_2 = 600$$

FIGURE 10. ATTENUATOR (PAD) NETWORKS, FORMULAS, AND TABLES (CONTINUED)



* THE SCALE READING IN VU WILL CORRESPOND TO DBM WITH REFERENCE TO ONE MILLIWATT ONLY IN THE CASE OF STEADY-STATE SINE WAVE VOLTAGES AT 1000 CYCLES.

FIGURE 11. CHARACTERISTICS OF COMMONLY-USED TRANSMISSION LINES

TYPE RG /U	IMPEDANCE OHMS	VELOCITY CONSTANT %	ATTENUATION PER 100FT 100MHz	200MHz	400MHz
8, 8A	52	66	2.0db	3.0db	4.7db
Belden #8214 8/U	50	78	1.8db	2.6db	3.3db
9, 9B	50	66	1.9db	2.8db	4.1db
11, 11A	75	66	2.0db	2.9db	4.2db
17	52	66	1.0db	1.7db	2.5db
58	53.5	66	4.1db	6.2db	9.5db
58A, 58C	50	66	5.3db	8.2db	12.6db
Belden #8219 58A	50	78	4.8db	6.9db	10.1db
59	73	66	3.4db	4.9db	7.1db
59B	75	66	3.4db	4.9db	7.1db
62, 62B	93	84	3.1db	4.4db	6.3db
71B	93	84	3.1db	4.4db	6.3db
213	50	66	2.0db	3.0db	4.7db
214	50	66	2.0db	3.0db	4.7db
218	50	66	1.0db	1.7db	2.5db
223	50	66	4.8db	7.0db	10.0db
FOAM					
331 1/2in	50	81	.9db	1.5db	2.0db
333 7/8in	50	81	.5db	.85db	1.4db

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA

LEGEND

C—Copper
TC—Tinned Copper
S—Silvered Copper
CW—Copperweld
SCW—Silvered Copperweld
N—Nichrome
K—Karma

AL—Aluminum
ST Steel—Stainless Steel
GS—Galvanized Steel
Poly—Polyethylene
SS Poly—Semi-Solid Polyethylene
Rub.—Synthetic Rubber
HDP—High Density Polyethylene

Copo—Copolene
Mag. Ox—Magnesium Oxide
C.S—Cannot Supply
SCB—Silvered Cadmium Bronze
*—Armored Cable
**—Do not manufacture at present time will supply if quantity warrants.

Jacket Types Described on Page 13

RG/U Number	Impedance	Capacitance MMF/FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
1				Rectangular Wave Guide					
2				Rectangular Wave Guide					
3				Rectangular Wave Guide					
4	50	30.0	Poly	20C	I	CC	.226	2.5	Replaced by 58/U
5	52.5	28.5	Poly	16C	I	CC	.332	8.6	Replaced by 58/U
5A	50	29	Poly	16S	II Grey	SS	.328	8.3	Replaced by 58/U
5B	50	28.5	Poly	16S	IIa	SS	.328	8.3	Replaced by 212/U
6	76	20	Poly	21 CW	II Grey	SC	.332	8.0	Replaced by 6A/U
6A	75	20	Poly	21 CW	IIa	SC	.332	8.0	
7	97	12.5	SS Poly	19C	I	C	.370	8.0	
8	52	29.5	Poly	7/21C	I	C	.405	10.5	
8A	52	29.5	Poly	7/21C	IIa	C	.405	10.3	Replaced by 213/U
9	50	30	Poly	7/21S	II Grey	SC	.420	12.8	
9A	50	30	Poly	7/21S	II Grey	SS	.420	12.8	
9B	50	30	Poly	7/21S	IIa	SS	.420	12.7	Replaced by 214/U
10	52	29.5	Poly	7/21C	II Grey*	C	.475	12.9	Replaced by 10A/U
10A	52	29.5	Poly	7/21C	IIa*	C	.475	12.9	Replaced by 215/U
11	75	20.5	Poly	7/26TC	I	C	.405	9.2	
11A	75	20.5	Poly	7/26TC	IIa	C	.405	9.0	
12	75	20.5	Poly	7/26TC	II Grey*	C	.475	11.6	Replaced by 12A/U
12A	75	20.5	Poly	7/26TC	IIa*	C	.475	11.4	11A/U with Armor
13	74	20.5	Poly	7/26TC	I	CC	.425	12.1	
13A	74	20.5	Poly	7/26TC	IIa	CC	.420	12.1	Replaced by 216/U
14	52	29.5	Poly	10C	II Grey	CC	.545	20.6	Replaced by 14A/U
14A	52	29.5	Poly	10C	IIa	CC	.545	20.0	Replaced by 217/U
15	76	20	Poly	15 CW	I	CC	.545	19.6	Replaced by 11A/U, 12A/U
16	52	29.5	Poly	125 C Tube	I	C	.630	25.4	
17	52	29.5	Poly	188C	II Grey	C	.870	46.3	
17A	52	29.5	Poly	188C	IIa	C	.870	46.0	Replaced by 218/U
17B	52	29.5	Poly	188C	IIa	SS	.940	—	Cancelled Same as 177/U
18	52	29.5	Poly	188C	II Grey*	C	.945	51.9	Replaced by 18A/U
18A	52	29.5	Poly	188C	IIa*	C	.945	51.5	Replaced by 219/U
19	52	29.5	Poly	250C	II Grey	C	1.120	74.5	Replaced by 19A/U
19A	52	29.5	Poly	250C	IIa	C	1.120	74.0	Replaced by 220/U
20	52	29.5	Poly	250C	II Grey*	C	1.195	80.7	Replaced by 20A/U

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
20A	52	29.5	Poly	250C	IIa*	C	1.195	80.0	Replaced by 221/U
21	53	29	Poly	16N	II Grey	SS	332	8.3	Replaced By 21A/U
21A	53	29	Poly	16N	IIa	SS	332	8.0	Replaced by 222/U
22	95	16	Poly	Two 7/.0152C	I	TC	405	10.3	
22A	95	16	Poly	Two 7/.1052C	II Grey	TC-TC	420	11.9	Replaced by 22B/U
22B	95	16	Poly	Two 7/.0152C	IIa	TC-TC	420	12.0	
23	125	12	Poly	Two 7/21C	I	CC	650 x 945	38.0	Replaced by 23A/U
23A	125	12	Poly	Two 7/21C	IIa	CC	650 x 945	36.0	
24	125	12	Poly	Two 7/21C	I*	CC	735 x1.034	43.0	Replaced by 24A/U
24A	125	12	Poly	Two 7/21C	IIa*	CC	735 x1.034	41.0	23A/U with Armor
25	48	50	Rub.	19/.0117TC	IV	TC-TC	565	20.5	Pulse Cable
25A	48	50	Rub.	19/.0117TC	IV	TC-TC	505	20.5	Pulse Cable
26	48	50	Rub.	19/.0117TC	IV*	TC	525	18.9	Pulse Cable
26A	48	50	Rub.	19/.0117TC	IV*	TC	505	18.9	Pulse Cable
27	48	50	Rub.	19/.0185TC	I*	TC	675	30.4	Pulse Cable
27A	48	50	Rub.	19/.0185TC	IV*	TC	670	30.4	Pulse Cable
28	48	50	Rub.	19/.0185TC	IV	TC-GS	805	37.0	Pulse Cable
28A	50	50	Rub.	19/.0185TC	Rub.*	TC	805	37.0	Pulse Cable
28B	48	50	Rub.	19/.0185TC	IV	TC-GS	750	37.0	Pulse Cable
29	53.5	28.5	Poly	20C	Poly	TC	.184	2.2	
30	58	27	Copo.	7/26C	I	C	250	—	Replaced by 58/U
31	51	31	Copo.	7/21C	I	C	405	10.6	Replaced by 8/U
32	51	29	Copo.	7/21C	I*	C	465	—	Replaced by 10A/U
33	51	30	Poly	10C	Lead	—	470	39.0	
34	71	21.5	Poly	7/21C	I	C	.625	22.9	Replaced by 34B/U
34A	75	21.5	Poly	7/.0249C	IIa	C	.630	22.4	Replaced by 34B/U
34B	75	21.5	Poly	7/.0249C	IIa	C	630	22.4	
35	71	21.5	Poly	9C	II Grey*	C	.945	45.8	Replaced by 35B/U
35A	71	21.5	Poly	9C	IIa*	C	.945	45.4	Replaced by 35B/U
35B	75	21	Poly	.1045C	IIa*	C	.945	45.4	
36	69	22	Poly	162C	I*	C	1.180	80.5	
37	52.5	38	Rub.	20TC	Poly	TC	.210	4.0	Replaced by 58/U
38	52.5	38	Rub.	17TC	Poly	TC-TC	312	11.0	Replaced by 5/U
39	72.5	28	Rub.	22CW	Poly	TC-TC	312	10.0	Replaced by 6/U. 59/U
40	72.5	28	Rub.	22CW	IV	TC-TC	420	15.0	Replaced by 6/U
41	67.5	27	Rub.	16/30TC	IV	TC	425	15.0	
42	78	20	Poly	21N	II Grey	SS	342	5.0	Replaced by 21A/U
43	95	17	Copo.	Two 7/21C	I	C	617	—	Replaced by 57A/U
44				Stub Supported Coaxial Line					
45				Stub Supported Coaxial Line					

continued on next page

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
46				Stub Supported Coaxial Line					
47				Stub Supported Coaxial Line					
48				Rigid Rectangular Wave Guide					
49				Rigid Rectangular Wave Guide					
50				Rigid Rectangular Wave Guide					
51				Rigid Rectangular Wave Guide					
52				Rigid Rectangular Wave Guide					
53				Rigid Rectangular Wave Guide					
54	58	27	Poly	7/26C	I	C	275	—	Replaced by 54A/U
54A	58	26.5	Poly	7/.0152C	Poly	TC	.250	4.0	
55	53.5	28.5	Poly	20C	Poly	TC-TC	.206	3.6	Replaced by 55B/U
55A	50	29.5	Poly	035S	IIa	SS	216	3.6	Replaced by 223/U
55B	53.5	28.5	Poly	20S	IIIa	TC-TC	206	3.4	
56	—	—	Rub	19/.0117C	I	CC	535	—	Pulse Cable
57	95	16	Poly	Two 7/21C	I	TC	625	24.8	Replaced by 57A/U
57A	95	16	Poly	Two 7/21C	IIa	TC	.625	24.1	
58	53.5	28.5	Poly	20C	I	TC	195	2.7	
58A	50	30	Poly	19/.0071TC	I	TC	195	2.7	
58B	53.5	28.5	Poly	20C	IIa	TC	195	2.5	Deleted
58C	50	30	Poly	19/.0071TC	IIa	TC	195	2.5	
59	73	21.5	Poly	22 CW	I	C	.242	3.7	
59A	75	21	Poly	.023 CW	IIa	C	.242	3.5	Replaced by 59B/U
59B	75	21	Poly	023 CW	IIa	C	242	3.5	
60	50	—	Rub.	Copper	IV	C	.425	—	Pulse Cable
61		—		Special 500 Ohm Line					
62	93	13.5	SS Poly	22 CW	I	C	242	3.6	
62A	93	13.5	SS Poly	22 CW	IIa	C	242	3.5	
62B	93	13.5	SS Poly	7/32 CW	IIa	C	242	3.0	
62C	93	13.5	SS Teflon	22 SCW	V	S	242	4.0	Reassigned 210/U
63	125	10	SS Poly	22 CW	I	C	405	8.8	
63A	125	—	Poly	22 C	I	C	.415	—	Replaced by 63B/U
63B	125	10	SS Poly	22 CW	IIa	C	405	8.4	
64	48	50	Rub.	19/.0117TC	IV	TC-TC	.495	20.5	Pulse Cable
64A	48	50	Rub.	19/.0117TC	IV	TC-TC	.475	20.5	Pulse Cable
65	950	44	Poly	32 Formex F	I	C	.405	9.6	Delay Cable
65A	950	44	Poly	32 Formex F	IIa	C	.405	9.6	Delay Cable
66				Rigid Rectangular Wave Guide					
67				Rigid Rectangular Wave Guide					
68				Rigid Rectangular Wave Guide					
69				Rigid Rectangular Wave Guide					
70				Unassigned					

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
71	93	13.5	SS Poly	22 CW	Poly	C-TC	250	4.3	Replaced by 71B U
71A	93	13.5	SS Poly	22 CW	I	C-TC	245	4.3	
71B	93	13.5	SS Poly	22 CW	IIIa	C-TC	250	4.3	
72	150	–	SS Poly	22 CW	I	C	.630	–	
73	25	–	Poly	20C	None	CC	.275	–	
74	52	29.5	Poly	10C	II Grey*	CC	615	23.4	Replaced by 74A/U
74A	52	29.5	Poly	10C	IIa*	CC	.615	23.6	Replaced by 224/U
75				Rigid Rectangular Wave Guide					
76				Stub Supported Coaxial Line					
77A	48	50	Rub.	19/.0117TC	IIa	TC-TC	.415	–	Pulse Cable
78A	50	50	Rub.	19/.0117TC	IIa	TC	.385	–	Pulse Cable
79	125	10	SS Poly	22 CW	I*	C	.475	11.4	Replaced by 79B/U
79A	125	–	Poly	22 CW	I	C	.415	–	Replaced by 79B/U
79B	125	10	SS Poly	22 CW	IIa*	C	.475	11.1	63B/U with Armor
80	51	–		Bead Supported Coaxial Line					
81	50	37	Mag. Ox.	.0625C	C Tube	–	.375	17.2	
82	50	36	Mag. Ox.	.125C	C Tube	–	.750	69.8	
83	35	44	Poly	10C	I	C	.405	12.2	Deleted
84A	75	21.5	Poly	9C	Lead*	C	1.000	132.5	35/U with Lead Armor
85A	75	21.5	Poly	9C	Lead*	C	1.565	291.0	84/U with Special Armor
86	200	7.8	Poly	Two 7/.0285C	None	–	.650x .300		Twin-Lead
87	50	29.5	Teflon	7/21S	V	SC	.425	–	Replaced by 87A/U
87A	50	29.5	Teflon	7/20S	V	SS	.425	17.4	Replaced by 225/U
88A	48	50	Rub.	19/.0117TC	IV	TC-TC-TC-TC	.515		Pulse Cable—Formerly 88B/U
89	125	10	Poly	22 CW	I	C	.632	20.0	Deleted
90	50	–	Poly	7/24TC or S	IIa	CCC	.425	–	Exp. Video Cable
91				Rigid Rectangular Wave Guide					
92	46		SS Teflon	.375C	Tubing				Teflon Bead Dielectric
93	50	29	Tef. Tape	19 Strands .200 Dia. C	V	C	.710	47.5	Replaced by 117/U
94	50	27	Tef. Tape	19/23S	V	CC	.445	–	
94A	50	27	Tef. Tape	19/22S	V	CC	.500	24.7	Reassigned 226/U
95				Rigid Rectangular Wave Guide					
96				Rigid Rectangular Wave Guide					
97				Rigid Rectangular Wave Guide					
98				Rigid Rectangular Wave Guide					
99				Rigid Rectangular Wave Guide					
100	35	44	Poly	19/.0147C	I	C	.242	–	
101	75	–	Rub.	14C	–	TC	.588	–	
102	140	–	Rub.	Two 12C	–	TC	1.088	–	
103				Rigid Rectangular Wave Guide					

continued on next page

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
104				Rigid Rectangular Wave Guide					
105				Rigid Rectangular Wave Guide					
106				Rigid Rectangular Wave Guide					
107				Rigid Rectangular Wave Guide					
108	78	23.5	Poly	Two 7/28TC	I	TC	.245	3.1	Replaced by 108A/U
108A	78	23.5	Poly	Two 7/28TC	IIa	TC	.235	2.9	
109				Rigid Rectangular Wave Guide					
110				Rigid Rectangular Wave Guide					
111	95	16	Poly	Two 7/0152C	II Grey*	TC-TC	.490	14.5	22A/U with Armor
111A	95	16	Poly	Two 7/0152C	IIa*	TC-TC	.490	14.5	22B/U with Armor
112				Rigid Rectangular Wave Guide					
113				Rigid Rectangular Wave Guide					
114	185	6.5	SS Poly	33 CW	I	C	.405	8.7	
114A	185	6.5	SS Poly	33 CW	IIa	C	.405	8.7	
115	50	29.5	Tef. Tape	7/21S	V	SS	.375	13.9	
115A	50	29.5	Tef. Tape	7/21S	V	SS	.415	15.9	
116	50	29.5	Teflon	7/20S	V*	SS	.475	22.4	Replaced by 227/U
117	50	29	Teflon	.188C	V	C	.730	45.0	Replaced by 211/U
118	50	29	Teflon	.188C	V*	C	.780	60.0	Replaced by 228/U
119	50	29	Teflon	.102C	V	CC	.465	22.5	
120	50	29	Teflon	.102C	V*	CC	.525	28.2	119/U with Armor
121				Rigid Rectangular Wave Guide					
122	50	29.5	Poly	27/36TC	IIa	TC	.160	2.0	
123					Unassigned				
124	73	20.3	Tef. Tape	22 CW	V	TC	.240	—	Replaced by 140/U
125	150	7.8	SS Poly	26 CW	IIa	C	.600	18.0	
126	50	28.5	Teflon	7/24K	V	K	.280	7.6	
127				Rigid Rectangular Wave Guide					
128	50		SS Teflon	.644	C Tubing		1.625		Teflon Bead Dielectric
129				Flexible Wave Guide					
130	95	17	Poly	Two 7/21C	I	TC	.625	22.0	
131	95	17	Poly	Two 7/21C	I*	TC	.710	29.5	130/U with Armor
132				Rigid Rectangular Wave Guide					
133	95	16.2	Poly	21C	I	C	.405	9.4	
134	185	6.5	SS Teflon	28C	Brass		.450	—	
135				Rigid Rectangular Wave Guide					
136				Rigid Rectangular Wave Guide					
137				Rigid Rectangular Wave Guide					
138				Rigid Rectangular Wave Guide					
139				Rigid Rectangular Wave Guide					
140	75	21	Teflon	.025 SCW	V	S	.233	4.5	

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
141	50	28.5	Teflon	.0359 SCW	V	S	.190	3.5	
141A	50	28.5	Teflon	.039 SCW	V	S	.190	3.5	
142	50	28.5	Teflon	.0359 SCW	V	SS	.206	4.5	
142A	50	28.5	Teflon	.039 SCW	V	SS	.206	4.5	
143	50	28.5	Teflon	.057 SCW	V	SS	.325	10.2	
143A	50	28.5	Teflon	.059 SCW	V	SS	.325	10.2	
144	75	20.5	Teflon	7/25 SCW	V	S	.410	12.0	
145	75	14.6	SS Poly	Two 13C	Lead—Tar	C Tube	—	—	
146	190	6.0	SS Teflon	.007 CW	V	C	.375	—	Obsolete
147	52	29.5	Poly	.250C	I*	C	1.937	—	19/U with Spiral Armor
148	52	29.5	Poly	7/21C	I*	C	.800	—	8/U with Spiral Armor
149	75	20.5	Poly	7/26TC	I	TC	.405	9.2	11/U Low Noise
150	75	20.5	Poly	7 26TC	I*	TC	.475	11.6	149/U with Armor
151	90	—	—	.125C	C Tubing	—	.375	—	
152	50	—	—	2.88C Tube	C Tubing	—	6.125	—	
153	50	—	—	.664C Tube	C Tubing	—	1.625	—	
154	50	—	—	1.315C Tube	C Tubing	—	3.125	—	
155	50	—	—	.341C Tube	C Tubing	—	.875	—	
156	50	30	Conductive Poly	7/21TC	IIa	TC-GS-TC	.540	—	Pulse Cable
157	50	30	Conductive Poly	19/24TC	IIa	TC-GS-TC	.725	—	Pulse Cable
158	25	78	Conductive Poly	37/21TC	IIa	TC-GS-TC	.725	—	Pulse Cable
159	50	29.0	Tef. Tape	20S	V	S	.195	—	Replaced by 142/U
160	125	12.0	Poly	2 19/27TC 2 19/27C	I	C	1.055	—	Flexible 4 Conductor Twinax
160A	125	12.0	Poly	2 19/27TC 2 19/27C	IIIa	C Ribbon	1.055	—	Flexible 4 Conductor Twinax
161	70	20	Teflon	7/30 SCB	Black Nylon	S	.082	—	
162	175	—	SS Teflon	.156C Tube	C Tubing	—	3.065	—	
163				Rigid Rectangular Wave Guide					
164	75	21.0	Poly	.1045C	IIa	C	.870	—	35B/U Less Armor
165	50	29.5	Teflon	7/.032S	V	S	.410	—	
166	50	29.5	Teflon	7/.032S	V*	S	.460	—	165/U with Armor
167				Rigid Rectangular Wave Guide					
168				Rigid Rectangular Wave Guide					
169				Rigid Rectangular Wave Guide					
170				Rigid Rectangular Wave Guide					
171				Rigid Rectangular Wave Guide					
172				Rigid Rectangular Wave Guide					
173				Rigid Rectangular Wave Guide					
174	50	29.5	Poly	7/.0063CW	I	TC	.100	.075	
175				Bead Supported Coaxial Line					

continued on next page

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
176	2.240	49	Poly	.135 Helix	I	C	405	–	Delay Line
177	50	30	Poly	195C	IIa	SS	895	–	
178	50	28.5	Teflon	7/38SCW	Kel-F	S	.075	–	
178A	50	28.5	Teflon	7/38SCW	Kel-F	S	075	–	
179	70	19.5	Teflon	7/38SCW	Kel-F	S	.090	–	
179A	75	19.5	Teflon	7/38SCW	Kel-F	S	105	–	
180	93	15.5	Teflon	7/38SCW	Kel-F	S	.141	–	
180A	95	15.0	Teflon	7/38SCW	Kel-F	S	145	–	
181	125	12	Poly	Two 7/26C	IIa	CC	640	–	
182	125	12	Poly	19/27C 19/27TC 19/.0066C 19/.0066TC	I	C	1.055	–	Replaced by 160/U
183	50	23	Tef. Tape	.025IC	–	Al. Tube	.750	–	
184					Wave Guide				
185				Special Time Delay Cable					
186				Special Time Delay Cable					
187	75	19.5	Teflon	7/38 SCW	VII	S	110	–	
188	50	29.0	Teflon	7/.0067 SCW	VII	S	110	–	
189	50	23.0	Helix	.251C	IIIa	S	.875	–	
190	50	50	Rubber	19/.0117TC	VIII	GS. TC	.700	–	Pulse Cable
191	25	–	Rubber	Copper Braid	VIII	GS. TC	1.460	–	Pulse Cable
192	–	–	–	–	Pulse Cable	–	–	–	
193	–	–	–	–	Pulse Cable	–	–	–	
194	–	–	–	–	Pulse Cable	–	–	–	
195	95	15.0	Teflon	7/38 SCW	VII	S	155	–	
196	50	28.5	Teflon	7/38 SCW	VII	S	080	–	
197	50	–	–	–	–	–	875	–	Rigid Line
199	70	–	–	–	–	–	.875	–	Rigid Line
200	70	–	–	–	–	–	1.875	–	Rigid Line
209	50	26.5	SS Teflon	19/.037BS	VI	SS	.750	–	
210	95	13.5	SS Teflon	22 SCW	V	S	242	4.0	Formerly 62C/U
211	50	29	Teflon	.190C	V	C	.730	–	Formerly 117/U
212	50	29.5	Poly	.055GS	IIa	SS	.332	8.3	Formerly 5B/U
213	50	29.5	Poly	7/.029GC	IIa	C	.405	10.3	Formerly 8A/U
214	50	29.5	Poly	7/.029GS	IIa	SS	.425	12.7	Formerly 9B/U
215	50	29.5	Poly	7/.029GC	IIa*	C	.475	12.7	Formerly 10A/U
216	75	20.5	Poly	7/26TC	IIa	CC	.425	12.1	Formerly 13A/U
217	50	29.5	Poly	.108C	IIa	CC	.545	20.0	Formerly 14A/U
218	50	29.5	Poly	.195C	IIa	C	.870	46.7	Formerly 17A/U
219	50	29.5	Poly	.195C	IIa*	C	.945	51.5	Formerly 18A/U
220	50	29.5	Poly	.260C	IIa	C	1.120	–	Formerly 19A/U
221	50	29.5	Poly	.260C	IIa*	C	1.195	–	Formerly 20A/U

FIGURE 12. R.F. CABLE AND WAVEGUIDE DATA (CONTINUED)

RG/U Number	Impedance	Capacitance MMF./FT.	Dielectric Material	Center Conductor	Jacket Type	Shield	Over-all Diameter	Weight 100 Ft.	Remarks
222	50	29	Poly	0556N	IIa	SS	332	8 4	Formerly 21A/U
223	50	29 5	Poly	035S	IIa	SS	216	3 6	Formerly 55A/U
224	50	29 5	Poly	.106C	IIa*	CC	615	23 6	Formerly 74A/U
225	50	29 5	Teflon	7/ 0312S	V	SS	430	17 4	Formerly 87A/U
226	50	29 5	Tef Tape	19/ 0254S	V	CC	500	24 7	Formerly 94A/U
227	50	29 5	Teflon	7/ 0312S	V*	SS	490	22 4	Formerly 115/U
228	50	29	Teflon	190C	V*	C	795	–	Formerly 17A/U
229	50	29 5	Teflon	7 .032S	V*	S	480	–	Replaced by 155/U
230	25	–	–	–	–	–	–	–	Pulse Cable
231	50	–	Foam Poly	.162C Tube	Al. Tube	–	500	–	
232	50	–	–	–	–	–	875	–	Rigid Line
233	50	–	–	–	–	–	1 625	–	Rigid Line
234	50	–	–	–	–	–	3 125	–	Rigid Line
235	50	29 5	Tef Tape	7/21S	VI	SS	470	–	Similar to 115A/U
236	50	–	–	–	–	–	500	–	Rigid Line
237	50	–	–	–	–	–	–	–	Rigid Line
238	–	–	–	–	–	–	–	–	Cancelled—Same as 197/U
239	50	–	–	–	–	–	–	–	Rigid Line
240	50	–	–	–	–	–	1 625	–	Rigid Line
241	50	–	–	–	–	–	–	–	Rigid Line
242	50	–	–	–	–	–	3 125	–	Rigid Line
243	50	–	–	–	–	–	–	–	Rigid Line
244	75	–	–	–	–	–	500	–	Rigid Line
245	75	–	–	–	–	–	–	–	Rigid Line
246	75	–	–	–	–	–	875	–	Rigid Line
247	75	–	–	–	–	–	–	–	Rigid Line
248	75	–	–	–	–	–	1 625	–	Rigid Line
249	75	–	–	–	–	–	–	–	Rigid Line
250	75	–	–	–	–	–	3.125	–	Rigid Line
251	75	–	–	–	–	–	–	–	Rigid Line
252	50	24	HDP	–	None	AL	530	17 5	Rigid Line
253	50	24	HDP	–	IIIa	AL	630	19.	Rigid Line
254	50	24	HDP	–	IIIa	AL	1 093	69.	Rigid Line
255	50	24	HDP	–	None	AL	953	55.5	Rigid Line
256	50	24	Teflon	–	None	AL	953	55 5	Rigid Line
257	50	24	HDP	–	None	AL	1 785	120.	Rigid Line
258	50	24	HDP	–	IIIa	AL	1 926	134	Rigid Line
259	50	24	HDP	–	None	AL	390	10	Rigid Line
260	50	24	HDP	–	IIIa	AL	450	11	Rigid Line
264	40	38	4-Poly	4 19/27C	I	2C, 2TC	750	–	Quad Cable
268	50	23	Spiral	162C	Flex. Tube	–	500	–	
269	50	22 2	Spiral	355C Tube	Flex. Tube	–	.795	–	
270	50	22.3	Spiral	667 C Tube	Flex. Tube	–	1 570	–	

FIGURE 13. COAXIAL CONNECTOR/CABLE CROSS-REFERENCE

RG/U no.	remarks	series
5	Replaced by 58/U	C, N, Term
5A	Replaced by 58/U	
5B	Replaced by 212/U	
6	Replaced by 6A/U	BNC, C, N, Term
6A		
8		BNC, C, HN, LT, N, Splices, Term, UHF
8A	Replaced by 213/U	
9		BNC, C, HN, LT, N, Splices, Term, UHF
9A		
9B	Replaced by 214/U	
10	Replaced by 10A/U	C, HN, N, UHF
10A	Replaced by 215/U	
11		N, Splices, Term, UHF
11A		
12	Replaced by 12A/U	C, HN, N, UHF
12A	11A/U with Armor	
13		C, N, Splices, Term, UHF
13A	Replaced by 216/U	
14	Replaced by 14A/U	C, HN, N
14A	Replaced by 217/U	
15	Rep. by 11A & 12A/U	
17		C, HN, LC, N, Splices, Term, UHF
17A	Replaced by 218/U	
17B	Replaced by 177/U	
18	Replaced by 18A/U	C, HN, LC, N
18A	Replaced by 219/U	
20	Replaced by 20A/U	
20A	Replaced by 221/U	
21	Replaced by 21A/U	C, N, Term
21A	Replaced by 222/U	
22		Twin
22A	Replaced by 22B/U	
22B		
25		Pulse
25A		
26		Pulse
26A		

RG/U no.	remarks	series
29	Replaced by 58/U	
34	Replaced by 34B/U	UHF
34A	Replaced by 34B/U	
34B		
35	Replaced by 35B/U	N
35A	Replaced by 35B/U	
35B	164/U with Armor	
42	Replaced by 21A/U	
54	Replaced by 54A/U	HN, MHV
54A		
55	Replaced by 55B/U	BN, BNC, C, HN, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
55A	Replaced by 223/U	
55B		
57	Replaced by 57A/U	Twin
57A		
58		BN, BNC, C, HN, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
58A		
58B		
58C		
59		BN, BNC, C, MB, MC, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
59A	Replaced by 59B/U	
59B		
62		BN, BNC, C, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
62A		
62B		
62C	Superseded by 210/U	
63		C, N, UHF
63A	Replaced by 63B/U	
63B		
71	Replaced by 71B/U	BN, BNC, C, MHV, N, Plug-in, SM, Splices Term, TNC, UHF
71A		
71B		
74	Replaced by 74A/U	C, HN, N
74A	Replaced by 224/U	
79	Replaced by 79B/U	C, HN, N, UHF
79A	Replaced by 79B/U	
79B	63B/U with Armor	

FIGURE 13. COAXIAL CONNECTOR/CABLE CROSS-REFERENCE (CONTINUED)

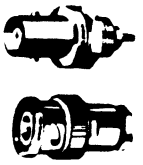
RG/U no.	remarks	series
87	Replaced by 87A/U	C, HN, LT, N, Splices, Term, UHF
87A	Replaced by 225/U	
93	Replaced by 117/U	
108	Replaced by 108A/U	Twin
108A		
111	22A/U with Armor	
111A	22B/U with Armor	
114		BNC, C, N
114A		
115		UHF
115A		
116	Replaced by 227/U	C, HN, N
117	Replaced by 211/U	C, LT
117A		
118	Replaced by 228/U	C
118A	Replaced by 228A/U	
122		BNC, MB, Plug-in, SM, TNC
140		BN, BNC, C, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
141		BN, BNC, C, HN, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
141A		
142		BN, BNC, C, HN, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
142A		
142B		
143		C, N, Term
143A		
144		N
149		N, Splices, Term, UHF
150	149/U with Armor	
161		BNC
164	35B/U Less Armor	Term
174		BNC, MB, SM, SUB. 27, SUB. 5116, Term, TNC
178	Replaced by 178B/U	BNC, MB, SM, SUB. 27, SUB. 5116
178A	Replaced by 178B/U	
178B		

RG/U no.	remarks	series
179	Replaced by 179B/U	BNC, MB, SUB. 27, SUB. 5116, Term, TNC
179A	Replaced by 179B/U	
179B		
180	Replaced by 180B/U	BNC, MB, Plug-in, SUB. 27, SUB. 5116, Term, TNC
180A	Replaced by 180B/U	
180B		
187		BNC, MB, SUB. 27, SUB. 5116, Term, TNC
187A		
188		BNC, MB, SUB. 27, SUB. 5116, Term, TNC
188A		
195		BNC, MB, Plug-in, SUB. 27, SUB. 5116, Term, TNC
195A		
196		BNC, MB, SM, SUB. 27, SUB. 5116
196A		
210		BN, BNC, C, MB, MHV, N, Plug-in, SM, Splices, Term, TNC, UHF
212		C, N, Term
213		C, HN, LT, N, Splices, Term, UHF
214		C, HN, LT, N, Splices, Term, UHF
215	213/U with Armor	C, HN, N, UHF
216		N, UHF, Splices, Term
217		C, HN, N
218		HN, N, Term, UHF
219	218/U with Armor	C, HN, N
222		C, N, Term
223		BN, BNC, C, MHV, N, Plug-in, TNC, UHF
224	217/U with Armor	C, HN, N
225		C, HN, LT, N, Splices, Term, UHF
227	225/U with Armor	C, HN, N
—		BNC, MB, Plug-in SUB. 27, Term, TNC
—		HN, N
—		HN, N
—		HN, N
—		BNC

FIGURE 14. COAXIAL CONNECTOR DATA

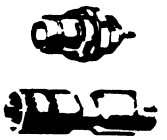
RADIO FREQUENCY CONNECTORS

SERIES BN



Military Number	AMPHENOL Number	Description	For RG-/U Cables
UG-88 U	31-002	Plug	55, 58
UG-88B U	31-018	Plug	55, 58
UG-88C U	31-202	Plug	55, 58
UG-89 U	31-005	Jack	55, 58
UG-89A U	31-019	Jack	55, 58
UG-89B U	31-205	Jack	55, 58
CW-123 U	31-006	Cap and Chain	--
CW-123A U	31-026	Cap and Chain	--
CW-155 U	31-007	Cap	--
CW-155A U	31-027	Cap	--
CW-159 U	31-017	Shorting Plug	--
UG-254A U	31-016	Receptacle Press.	--
UG-260 U	31-012	Plug	59, 62, 71
UG-260A U	31-021	Plug	59, 62, 71
UG-260B U	31-212	Plug	59, 62, 71
UG-261 U	31-015	Jack	59, 62, 71
UG-261A U	31-022	Jack	59, 62, 71
UG-261B U	31-215	Jack	59, 62, 71
UG-262 U	31-011	Panel Jack	59, 62, 71
UG-262A U	31-023	Panel Jack	59, 62, 71
UG-262B U	31-211	Panel Jack	59, 62, 71
UG-274 U	31-008	Adapter, Tee	--
UG-274A U	31-208	Adapter, Tee	--
CW-282 U	31-210	Cap and Chain	--
UG-290 U	31-003	Receptacle	--
UG-290A/U	31-203	Receptacle	--
UG-291 U	31-001	Panel Jack	55, 58
UG-291A U	31-020	Panel Jack	55, 58
UG-291B U	31-201	Panel Jack	55, 58
UG-306 U	31-009	Adapter, Right-Angle	--
UG-306A U	31-209	Adapter, Right-Angle	--
UG-447 U	31-817	Receptacle	--
UG-491A U	31-218	Adapter	--
UG-492A/U	31-220	Adapter, Press.	--
UG-657/U	31-102	Receptacle, Press.	--
UG-909/U	31-208	Jack, Bulkhead	55, 58
UG-910/U	31-207	Jack, Bulkhead	59, 62, 71
UG-913/U	31-204	Plug, Right-Angle	55, 58
UG-914/U	31-219	Adapter, Straight	--
UG-1094/U	31-221	Receptacle, Bulk.	--
UG-1098/U	31-222	Receptacle, Right Angle	--
--	31-759	Shield Grounding Lug	--
--	31-842	Receptacle	--
--	31-850	Plug, Right Angle	59, 62, 71
--	31-851	Cable Feed-Thru	55, 58

SERIES BN



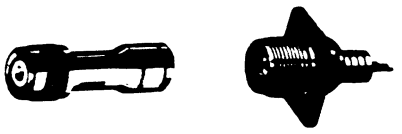
Military Number	AMPHENOL Number	Description	For RG-/U Cables
UG-85/U	82-21	Plug	55,58,59,62,71
UG-87/U	82-42	Receptacle	--
UG-114/U	82-25	Panel Jack	55,58,59,62,71
UG-115/U	82-26	Jack	55,58,59,62,71
UG-206/U	31-101	Receptacle, Bulk. Gold Plated	--
--	31-759	Shield Grounding Lug	--

SERIES C

UG-566A/U	82-536	Adapter, Tee	--
UG-567A/U	82-535	Adapter, Right-Angle	--
UG-568/U	82-504	Receptacle	--
UG-569/U	82-505	Receptacle Bulk.	--
UG-570/U	82-502	Jack, Bulkhead	8, 9, 10
UG-571, U	82-501	Panel Jack	8, 9, 10
UG-572/U	82-503	Jack	8, 9, 10
UG-573A/U	82-530	Plug	8, 9, 10
UG-628A/U	82-532	Plug, High-Voltage	8, 9A
UG-632/U	82-521	Jack, Bulkhead, High-Voltage	8, 9A
UG-634/U	82-515	Receptacle, Bulk. High-Voltage	--
UG-643/U	82-514	Adapter, Straight	--
UG-705/U	82-511	Receptacle, Bulk. Pressurized	--
UG-707A/U	82-533	Plug	14, 74
UG-709A/U	82-534	Plug	55, 58
UG-710A/U	82-531	Plug, Right-Angle	8, 9
UG-937/U	82-522	Jack, Bulkhead	10, 12
UG-938/U	82-523	Panel Jack	10, 12
UG-939/U	82-524	Jack, Bulkhead, High-Voltage	10, 12
UG-942A/U	82-539	Plug, High-Voltage	10, 12
UG-943A/U	82-538	Plug	10, 12
UG-944/U	82-526	Jack	10, 12
UG-945A/U	82-537	Plug, Right-Angle	10, 12
MX-1142/U	82-512	Cap and Chain for Jacks	--
MX-1143/U	82-513	Cap and Chain for Plugs	--
MX-1286/U	82-517	Armor Clamp	10, 12
--	82-510	Hood	8, 9, 10
--	82-519	Adapter, Tee	13 (74Ω)

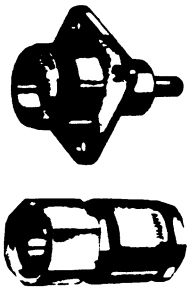
FIGURE 14. COAXIAL CONNECTOR DATA (CONTINUED)

SERIES HN



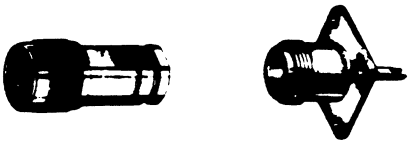
UG-59A U	82-38	Plug	8, 9, 10
UG-59B U	82-804	Plug	8, 9, 10
UG-60A U	82-39	Jack	8, 9, 10
UG-60B U	82-814	Jack	8, 9, 10
UG-61A U	82-40	Panel Jack	8, 9, 10
UG-61B U	82-815	Panel Jack	8, 9, 10
MX-103 U	103-301	Tapering Tool	8, 9, 10
UG-212A U	82-91	Adapter, Right-Angle	--
UG-212C U	82-115	Adapter, Right-Angle	--
UG-333/U	82-56	Jack	17, 18
UG-333A U	82-107	Jack	17, 18
UG-334 U	82-57	Panel Jack	17, 18
UG-334A U	82-108	Panel Jack	17, 18
UG-495A U	82-111	Plug	17, 18
UG-496 U	82-92	Receptacle	--
UG-560 U	82-805	Receptacle	--
MX-564 U	82-48	Armor Clamp	10
MX-564A/U	82-109	Armor Clamp	10
UG-929/U	82-114	Panel Jack	10, 116
--	82-91A	Adapter, Right Angle	--
--	82-130	Cap & Chain-Jacks	--
--	82-320	Plug, Cap. Con.	8,9,10,87A, 115, 115A
--	82-321	Jack, Cap. Con.	8,9,10,87A, 115, 115A
--	82-324	Panel Jack, Cap. Con.	8,9,10,87A, 115, 115A
--	82-816	Plug	54A
--	82-833	Angle Plug	8, 9, 10
--	82-836	Receptacle, Press.	--
--	82-843	Receptacle, Press., High-Voltage	--
--	82-856	Angle Plug	8, 9, 10

SERIES LC



UG-154/U	82-59	Plug	17, 18
UG-352/U	82-80	Receptacle	--
UG-352A/U	82-110	Receptacle	--

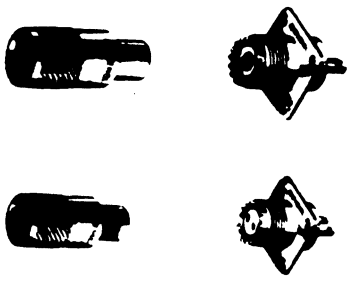
SERIES N



UG-18B/U	82-86	Plug	5, 6, 21
UG-18C U	82-203	Plug	5, 6, 21
UG-19B U	82-87	Panel Jack	5, 6, 21
UG-19C/U	82-207	Panel Jack	5, 6, 21
UG-20B U	82-88	Jack	5, 6, 21
UG-20C U	82-210	Jack	5, 6, 21
UG-21B U	82-61	Plug	8, 9, 10
UG-21C/U	82-96	Plug	8, 9, 10
UG-21D/U	82-202	Plug	8, 9, 10
UG-22B/U	82-62	Panel Jack	8, 9, 10
UG-22C U	82-95	Panel Jack	8, 9, 10
UG-22D/U	82-208	Panel Jack	8, 9, 10
UG-23B/U	82-63	Jack	8, 9, 10
UG-23C/U	82-94	Jack	8, 9, 10
UG-23D U	82-209	Jack	8, 9, 10
UG-27A/U	82-64	Adapter, Right-Angle	--
UG-27B/U	82-98	Adapter, Right-Angle	--
UG-27C/U	82-213	Adapter, Right-Angle	--
UG-28A/U	82-99	Adapter, Tee	--
UG-29A/U	82-65	Adapter, Straight	--
UG-29B/U	82-101	Adapter, Straight	--
UG-30/U	82-66	Adapter, Bulk. Pressurized	--
UG-30C/U	82-201	Adapter, Bulk. Pressurized	--
UG-57B/U	82-100	Adapter, Straight	--
UG-58/U	82-24	Receptacle	--
UG-58A/U	82-97	Receptacle	--
UG-94A/U	82-84	Plug	11, 12, 13
UG-95A/U	82-89	Jack	11, 12, 13
UG-96A/U	82-90	Panel Jack	11, 12, 13
UG-106/U	83-1H	Hood	8,9,10,11,12,13
UG-107A/U	82-36	Adapter, Tee	--
UG-107B/U	82-102	Adapter, Tee	--
UG-160A/U	82-67	Jack, Bulkhead	8, 9, 10
UG-160B/U	82-93	Jack, Bulkhead	8, 9, 10
UG-167A/U	82-104	Plug	17, 18
UG-167D/U	82-215	Plug	17, 18
UG-204A/U	82-105	Plug	14, 74
UG-204B/U	82-205	Plug	14, 74
UG-204C/U	82-214	Plug	14, 74
MX-564/U	82-48	Armor Clamp	10, 12
MX-564A/U	82-109	Armor Clamp	10, 12
UG-680/U	82-811	Receptacle, Bulk. Herm., Press.	--
MX-913/U	82-106	Cap and Chain	--
UG-935A/U	82-211	Panel Jack	10, 12
UG-940A/U	82-212	Jack	10, 12
UG-941A/U	82-204	Plug	10, 12
UG-1185/U	82-312	Plug, Cap. Con.	8, 9, 10, 87A, 115, 115A
UG-1186/U	82-313	Jack, Cap. Con.	8, 9, 10, 87A, 115, 115A
UG-1187/U	82-314	Panel Jack, Cap. Con.	8, 9, 10, 87A, 115, 115A
--	82-835	Angle Plug	8, 9, 10
--	82-849	Adapter, Straight, Pressurized	--
--	82-1275	Shield Grounding Lug	--
--	83-1H	Hood	8,9,10,11,12,13
--	83-1BC	Cap and Chain	--

FIGURE 14. COAXIAL CONNECTOR DATA (CONTINUED

SERIES UHF



Small Single Contact Connectors

UG-106 U	83-1H	Hood	8, 9, 10, 11, 12, 13, 63, 65
UG-111 U	83-750	Plug	59, 62, 71
UG-175 U	83-185	Adapter, Reducing	58
UG-176 U	83-168	Adapter, Reducing	59, 62, 71
UG-177 U	83-765	Hood	29, 55, 58
UG-203 U	83-776	Plug	55, 59, 62, 71
SO-239	83-1R	Receptacle	— —
SO-239A	83-798	Receptacle	— —
PL-258	83-1J	Adapter, Straight	— —
PL-259	83-1SP	Plug	8, 9, 10, 11, 12, 13, 63, 65
PL-259A	83-1SPN	Plug (Mica-Filled Bakelite)	8, 9, 10, 11, 12, 13, 63, 65
PL-259A	83-756	Plug (Teflon)	8, 9, 10, 11, 12
PL-274	83-1F	Adapter, Bulk.	— —
M-358	83-1T	Adapter, Tee	— —
M-359	83-1AP	Adapter, Right-Angle	— —
M-359A	83-58	Adapter, Right-Angle	— —
M-360	83-1H	Hood	8, 9, 10, 11, 12, 13, 63, 65
UG-363 U	83-1F	Adapter, Bulk.	— —
UG-372 U	83-1HP	Hood	8, 9, 10, 11, 12, 13, 63, 65
UG-646 U	83-1AP	Adapter, Right-Angle	— —
49190	83-1SP	Plug	8, 9, 10, 11, 12, 13, 63, 65
49191	83-1J	Adapter, Straight	— —
49192	83-1AP	Adapter, Right-Angle	— —
49192A	83-58	Adapter, Right-Angle	— —
49193	83-1H	Hood	8, 9, 10, 11, 12, 13, 63, 65
49194	83-1R	Receptacle	— —
49195	83-1SPN	Plug (Mica-Filled Bakelite)	8, 9, 10, 11, 12, 13, 63, 65
49195	83-756	Plug (Teflon)	8, 9, 10, 11, 12
49199	83-1T	Adapter, Tee	— —
49482	83-776	Plug	55, 59, 62, 71
491049	83-1F	Adapter, Bulk	— —
— —	83-1AC	Cap and Chain	— —
— —	83-1BC	Cap and Chain	— —
— —	83-1RTY	Receptacle	— —
— —	83-59	Plug, Right-Angle	8, 9, 10, 11, 12, 13, 63, 65
— —	83-716	Receptacle, Pressure Proof	— —
— —	83-786	Hood & Gang Nut	29, 55, 58
— —	83-812	Receptacle	— —
— —	83-822	Plug	8, 9
— —	83-850	Plug, Solderless	11
— —	83-851	Plug, Solderless	8, 9, 10, 11, 12, 13, 63, 65

Small Twin Contact Connectors

UG-102 U	83-22SP	Plug	22
UG-103 U	83-22R	Receptacle	— —
UG-104 U	83-22AP	Adapter, Right-Angle	— —
UG-105 U	83-22J	Adapter, Straight	— —
UG-106 U	83-1H	Hood	22
UG-196 U	83-22T	Adapter, Tee	— —
SO-264	83-22R	Receptacle	— —
PL-275	83-22F	Adapter, Straight, Bulkhead	— —
PL-284	83-22SP	Plug	22
PL-285	83-22J	Adapter, Straight	— —
PL-293	83-22AP	Adapter, Right-Angle	— —
M-360	83-1H	Hood	22
49193	83-1H	Hood	22
— —	83-1AC	Cap and Chain	— —
— —	83-1BC	Cap and Chain	— —
— —	83-65	Adapter, Reducing	250 Diam.
— —	83-821	Plug	22

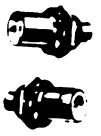
Large Single Contact Connectors

UG-357 U	83-21R	Receptacle	— —
UG-358 U	83-21SP	Plug	34
M-365	83-2H	Hood	34
49208	83-2H	Hood	34
— —	83-787	Plug	14

Large Twin Contact Connectors

SO-265	83-2R	Receptacle	— —
PL-295	83-2SP	Plug	57, 130
PL-305	83-2J	Adapter, Straight	— —
M-365	83-2H	Hood	57, 130
49188	83-2SP	Plug	57, 130
49189	83-2J	Adapter, Straight	— —
49196	83-2R	Receptacle	— —
49208	83-2H	Hood	57, 130

PUSH ON



Military Number	AMPHENOL Number	Description	For RG- U Cables
— —	82-830	Plug	58
— —	82-831	Receptacle, Bulk.	— —
— —	82-832	Plug	59, 62
— —	82-841	Receptacle, Bulk.	— —
— —	82-842	Plug	58
— —	82-845	Plug, Bulk.	58
— —	82-846	Jack, Bulk.	58

FIGURE 14. COAXIAL CONNECTOR DATA (CONTINUED)

SUBMINAX—50 OHM

	AMPHENOL Number	Description	For RG-/U Cables
Push-on	27-1	Plug	174, 21-596
	27-2	Jack	174, 21-596
	27-3	Receptacle	--
	27-4	Jack, Bulkhead	174, 21-596
	27-5	Cable Feed-Thru	--
	27-6	Plug, Right Angle	174, 21-596
Screw-on	27-7	Plug	174, 21-596
	27-8	Jack	174, 21-596
	27-9	Receptacle	--
	27-10	Jack, Bulkhead	174, 21-596
	27-11	Cable Feed-Thru	--
	27-12	Receptacle, Herm.	--
	27-26	Plug, Right Angle	174, 21-596

SUBMINAX—75 OHM

Push-on	27-13	Plug	21-597
	27-14	Jack	21-597
	27-15	Receptacle	--
	27-16	Jack, Bulkhead	21-597
	27-17	Cable Feed-Thru	--
	27-18	Plug, Right Angle	21-597
Screw-on	27-19	Plug	21-597
	27-20	Jack	21-597
	27-21	Receptacle	--
	27-22	Jack, Bulkhead	21-597
	27-23	Cable Feed-Thru	--
	27-24	Receptacle, Herm.	--
	27-25	Plug, Right Angle	21-597

BETWEEN SERIES ADAPTERS

		Mates With
UG-201/U	31-830	N Female and BNC Male
UG-201A/U	31-216	N Female and BNC Male
UG-273/U	31-028	BNC Male and UHF 49194 or Equivalent
UG-349A/U	31-217	N Male and BNC Female
UG-564/U	82-508	C Male and N Female
UG-565A/U	82-540	C Female and N Male

CABLE TRANSITION

		From RG- U Cable	To RG- U Cable
	82-150	17, 18	8, 9 or 10

CABLE SPLICE

			For RG-/U Cables
	82-152		35, 164

CABLE END SEAL

			For RG- U Cables
	152-201		8-11

FIGURE 14. COAXIAL CONNECTOR DATA (CONTINUED)

FOR RG-8, -9, -213, AND -214 CABLE
SERIES N CONNECTORS

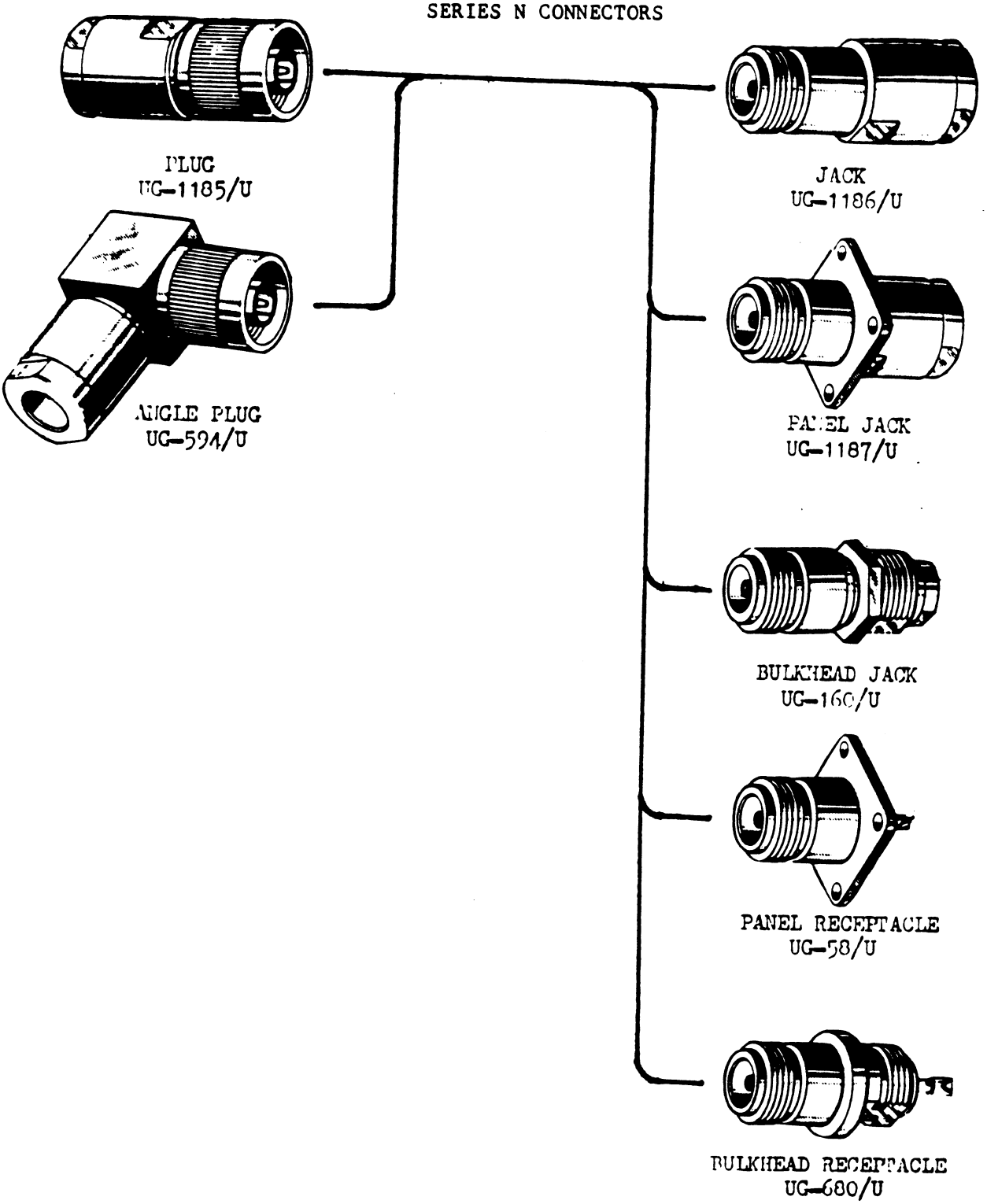
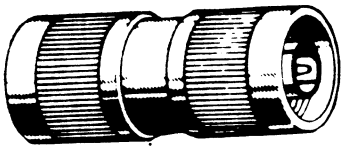
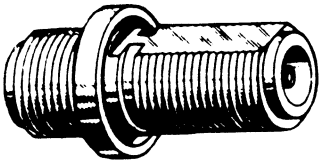


FIGURE 15. SERIES N ADAPTERS

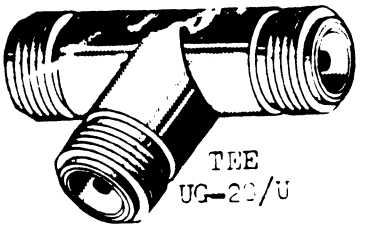


STRAIGHT
UG-57/U

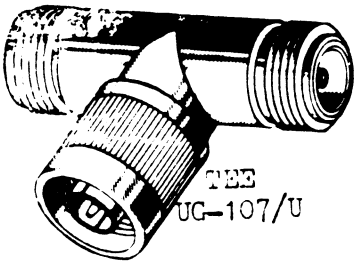
STRAIGHT
UG-29/U



BULKHEAD
UG-30/U



TEE
UG-29/U



TEE
UG-107/U

FIGURE 16. BNC CONNECTORS

FOR RG-58 and -223 CABLE

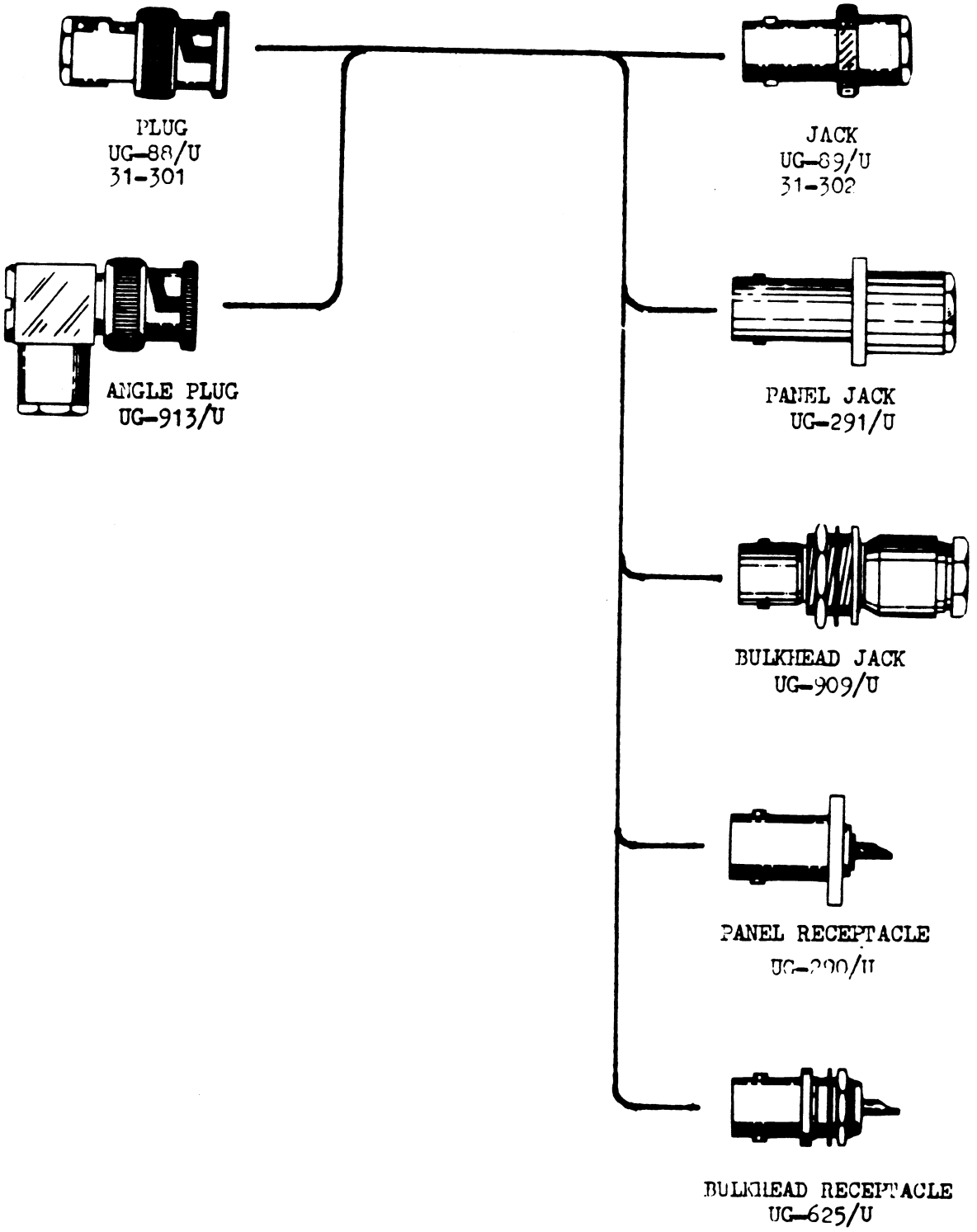


FIGURE 16. BNC CONNECTORS (CONTINUED)

FOR RG-59, -62 AND -71 CABLE

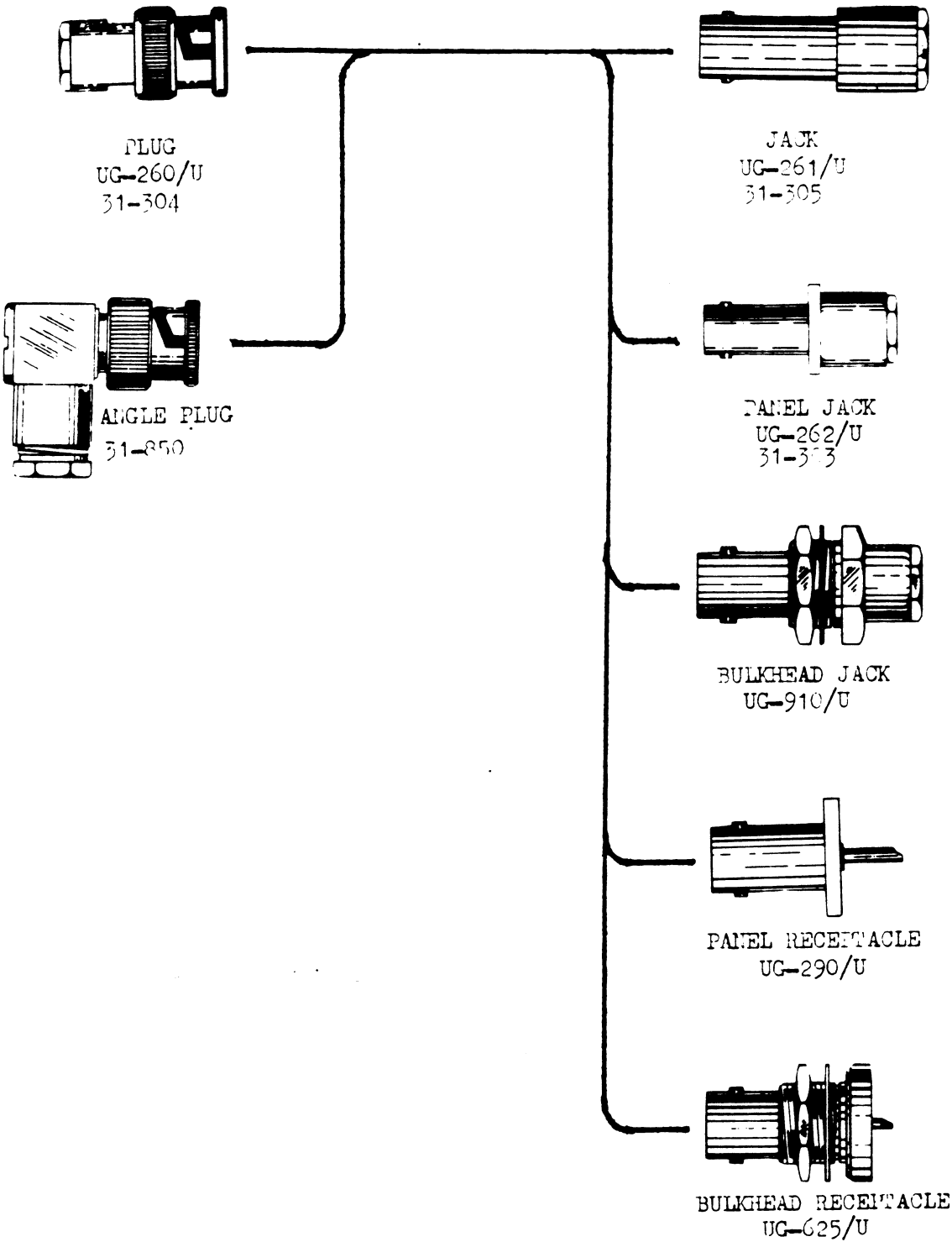
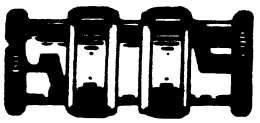
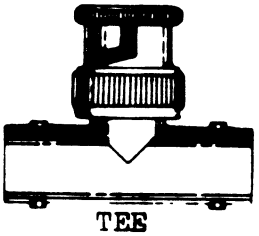


FIGURE 17. BNC ADAPTERS

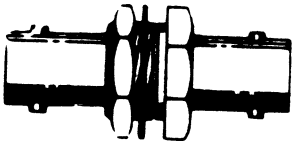


STRAIGHT
UG-491/U

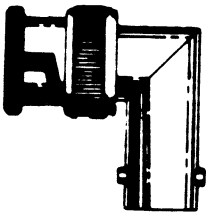
STRAIGHT
UG-914/U



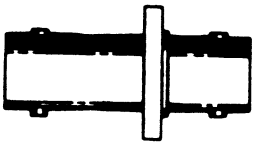
TEE
UG-274/U



BULKHEAD
UG-492/U



ANGLE
UG-306/U



STRAIGHT FLANGE
UG-414/U

FIGURE 18. TNC CONNECTORS

FOR RG-58 AND 223 CABLE

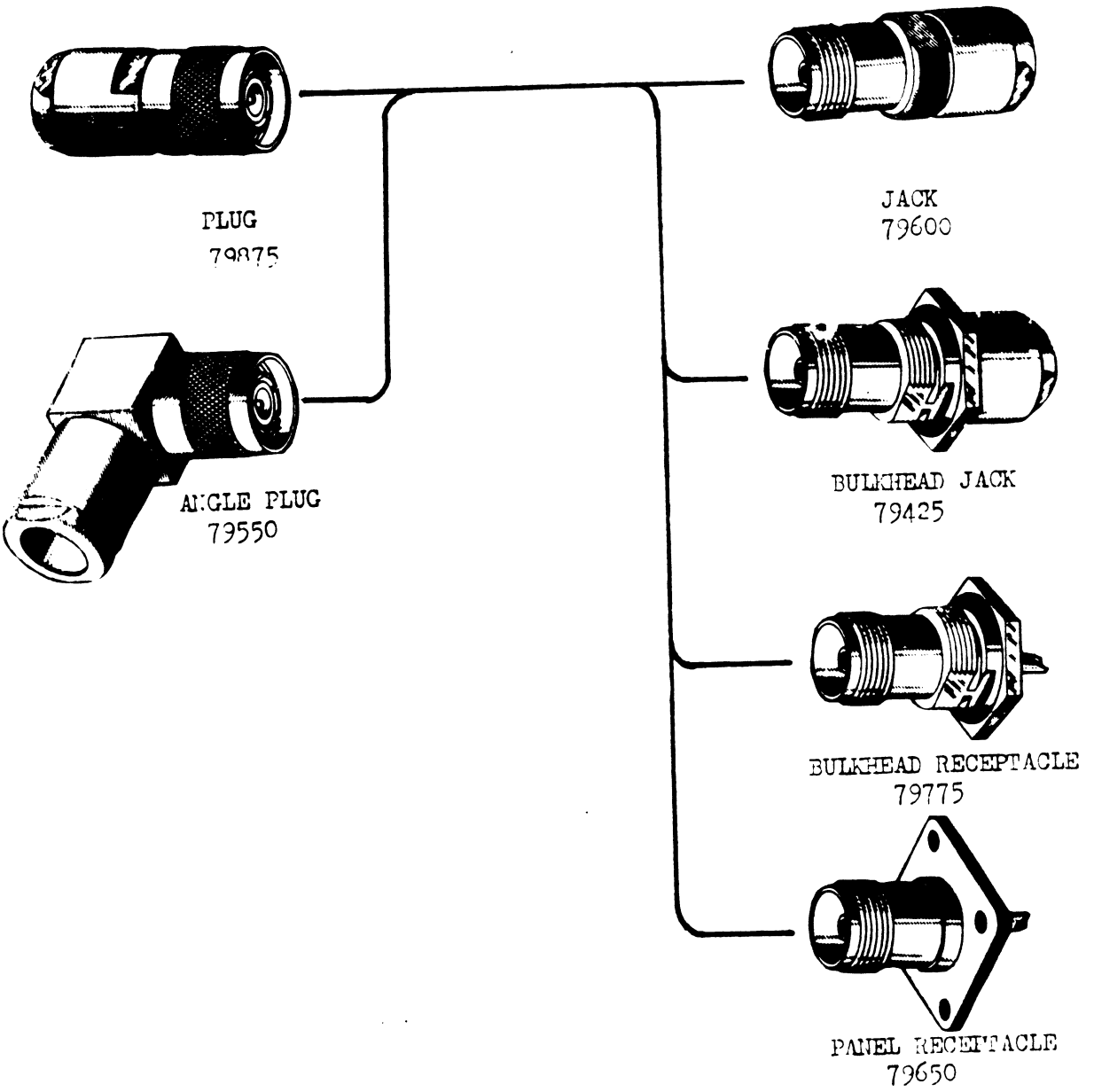


FIGURE 18. TNC CONNECTORS (CONTINUED)

FOR RG-59, 62 AND 71 CABLE

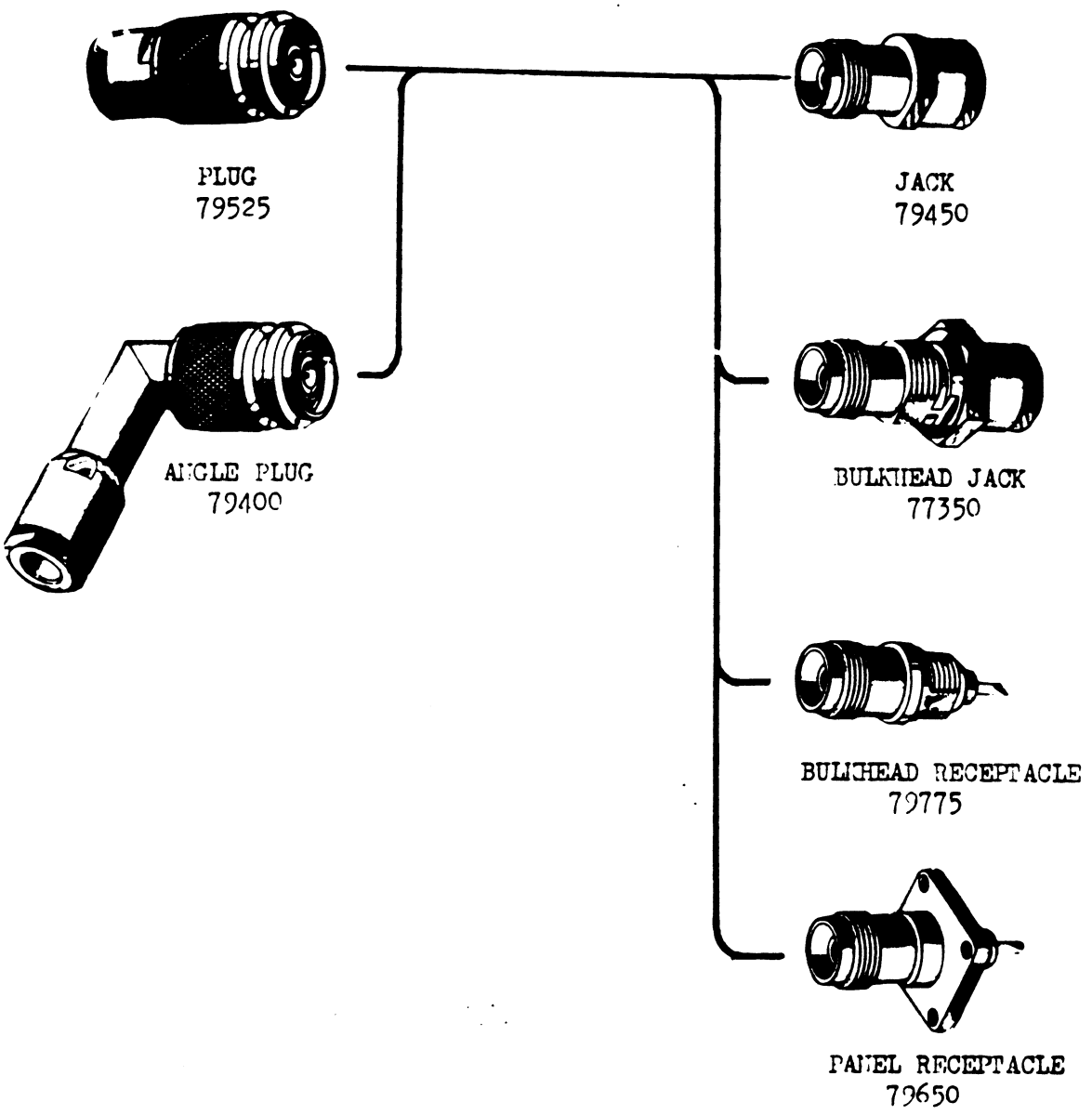
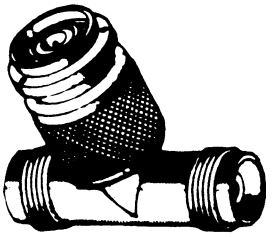
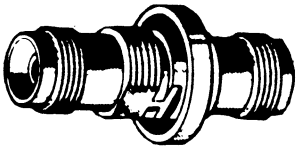


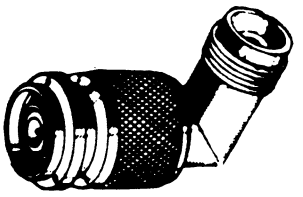
FIGURE 19. TNC ADAPTERS



TEE ADAPTER
79700



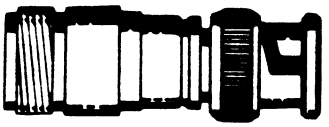
BULKHEAD ADAPTER
79100



ANGLE ADAPTER
79125

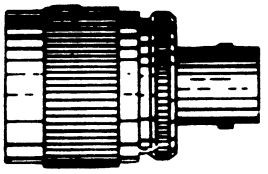
FIGURE 20. ADAPTERS BETWEEN SERIES

N JACK — BNC PLUG



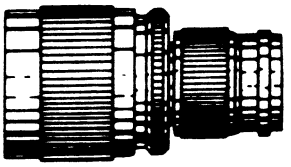
UG-349/U

N PLUG — BNC JACK



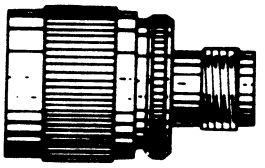
UG-201/U

N PLUG — TNC PLUG



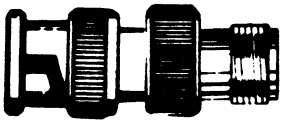
79850

N PLUG — TNC JACK



78800

BNC PLUG — TNC JACK



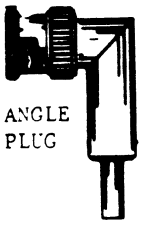
79025

FIGURE 21. CRIMP-ON CONNECTORS

BNC TYPES

STRAIGHT PLUG

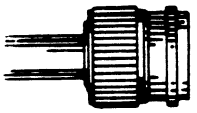
JACK



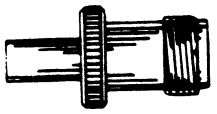
Δ ANGLE PLUG

MFR.	PART NO.	TYPE	USE ON RG- /U	CRIMPING TOOLS - See groups below: CENTER PIN	BRAID
1	36775	Plug	58	A	B
1	36800	Jack	58	A	B
1	95600	ΔPlug	58	A	B
1	36875	Plug	223	A	B
1	36900	Jack	223	A	B
1	95575	ΔPlug	223	A	B
1	68175	Plug	59, 62	A	C
1	68150	Jack	59, 62	A	C
1	95625	ΔPlug	59, 62	A	C
1	34625	Plug	71	A	C
1	34650	Jack	71	A	C
1	95650	ΔPlug	71	A	C
2	331350	Plug	59, 62	D	D
2	331351	Jack	59, 62	D	D

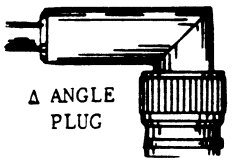
TNC TYPES



STRAIGHT PLUG



JACK



Δ ANGLE PLUG

MFR.	PART NO.	TYPE	USE ON RG- /U	CRIMPING TOOLS - See groups below: CENTER PIN	BRAID
1	36825	Plug	58	A	B
1	36850	Jack	58	A	B
1	97900	ΔPlug	58	A	B
1	36925	Plug	223	A	B
1	36950	Jack	223	A	B
1	97875	ΔPlug	223	A	B
1	69350	Plug	59, 62	A	C
1	69375	Jack	59, 62	A	C
1	97925	ΔPlug	59, 62	A	C
1	34825	Plug	71	A	C
1	34875	Jack	71	A	C
1	97950	ΔPlug	71	A	C

CRIMPING TOOL NUMBERS

GROUP A	GROUP B	GROUP C	GROUP D
MS-3191A	MS-M55619/1-04	MS-M55619/1-03	69477-1
227-932-1	227-350	227-375	(69710 with
227-927	227-921	227-921	(69669-1 Die)
227-1189	227-150	227-175	
	227-50	227-75	
	615031	615030	

FIGURE 22. SEMI-RIGID COAX AND CONNECTORS

(FOAMFLEX)

The attenuation loss of standard RG cables is too great on some FAA transmission systems, especially where low powered transistor equipment is used. For this reason Foamflex cables, RG-331/u and -333/u are being used more frequently in FAA installations. Connectors for these cables are not interchangeable between cable manufactures. For this reason the cable manufacture must be known before the proper connectors can be furnished. The most commonely used cable and their connector part numbers are:

CABLE
RG-331 = 1/2 in. dia.
RG-333 = 7/8 in. dia.

Type	Manufacture	Part No.
RG-331/u	Prodelin	54-500
RG-333/u	Prodelin	54-875
RG-331/u	Cablewave	FXA-12-50
RG-333/u	Cablewave	FXA-78-50

CONNECTORS
Type N, 50 Ohm, Male

Cable Type	Manufacture	Part No.
RG-331/u	Prodelin	76-580
RG-331/u	Cablewave	FX-12-50-NM
RG-333/u	Prodelin	76-880
RG-333/u	Cablewave	FX-78-50-NM

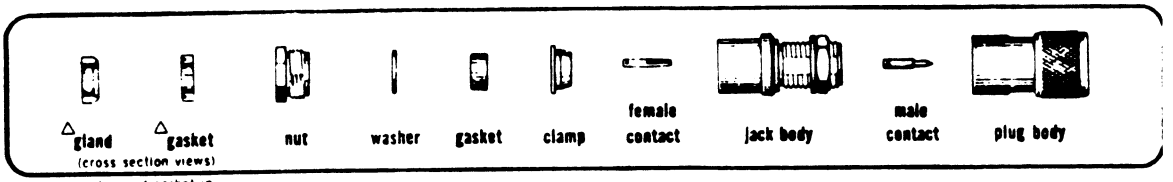
CONNECTORS
Type N, 50 Ohm, Female

Cable Type	Manufacture	Part No.
RG-331/u	Prodelin	75-580
RG-331/u	Cablewave	FX-12-50-NF
RG-333/u	Prodelin	75-880
RG-333/u	Cablewave	FX-78-50-NF

NOTE: **Cablewave was formerly Phelps Dodage Corp.**

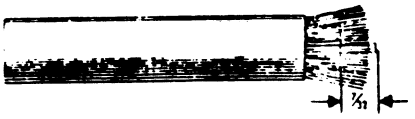
FIGURE 23. ASSEMBLY INSTRUCTIONS

Type N, Amphenol, Standard Connector

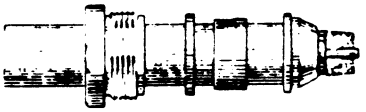


△replace washer and gasket in:
UG-21C U (82-96) UG-23C U (82-94)
UG-27C U (82-95) UG-1608/U (82-93)

Remove 1/16" of vinyl jacket. When using double shielded cable, remove 3/16".

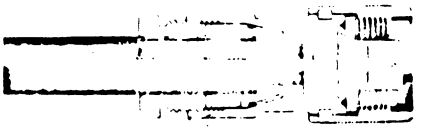


Comb out copper braid as shown. Cut off dielectric 1/32" from end. Tin center conductor.

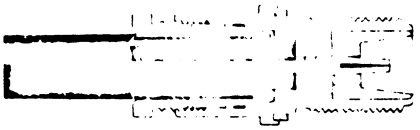


Taper braid as shown. Slide nut, washer and gasket over vinyl jacket. Slide clamp over braid with internal shoulder of clamp flush against end of vinyl jacket. When assembling connectors with gland, be sure knife edge is toward end of cable and groove in gasket is toward the gland.

Smooth braid back over clamp and trim. Soft solder contact to center conductor. Avoid use of excessive heat and solder. See that end of dielectric is clean. Contact must be flush against dielectric. Outside of contact must be free of solder.



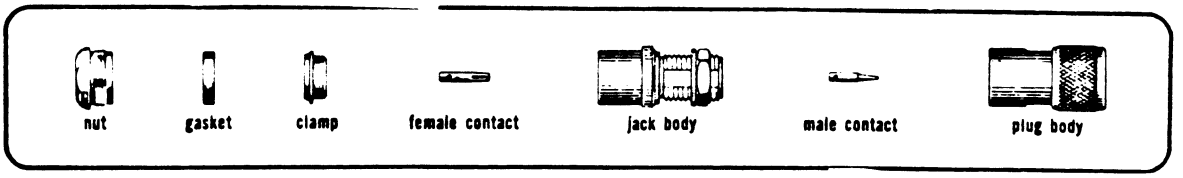
Slide body into place carefully so that contact enters hole in insulator. Face of dielectric must be flush against insulator. Slide completed assembly into body by pushing nut. When nut is in place, tighten with wrenches. In connectors with gland, knife-edge should cut gasket in half by tightening sufficiently.

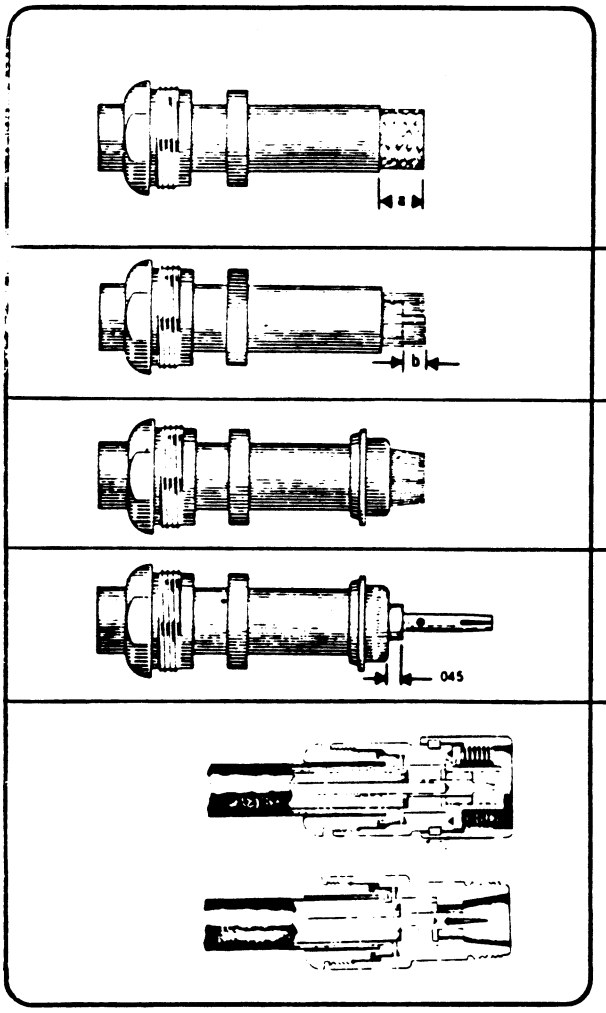


note: For armored cable slide cap over armor first. Push armor and cap back out of way and proceed with assembly as directed above using armor clamp in place of standard clamp nut. When assembly is complete straighten bulge in armor and trim so it can be clamped between nut and cap.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type N, Amphenol, Improved Connector





Improved	
a	b
9/32	5/32

Place nut and gasket, with "V" groove toward clamp, over cable and cut off jacket to dim. a.

Comb out braid and fold out. Cut off cable dielectric to dim b as shown.

Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.

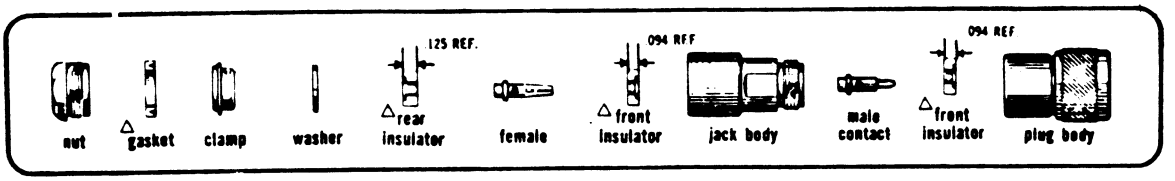
Fold back braid wires as shown, trim to proper length and form over clamp as shown. Solder contact to center conductor.

Insert cable and parts into connector body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut.

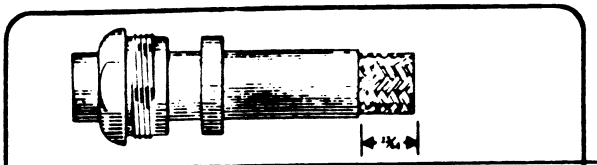
note: For armored cable slide cap over armor first. Push armor and cap back out of way and proceed with assembly as directed above using armor clamp in place of standard clamp nut. When assembly is complete straighten bulge in armor and trim so it can be clamped between nut and cap.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

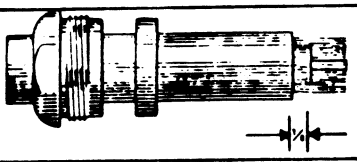
Type N, Amphenol, Captivated Contacts Connector



△cross section views

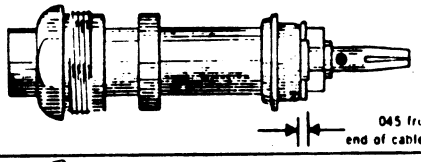


Cut end of cable even. Place nut and gasket, with "V" groove toward clamp, over cable and cut off jacket 7/64" from end.

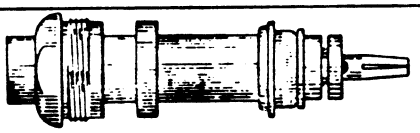


Comb out braid as shown. Cut off cable dielectric 1/8" from end of jacket.

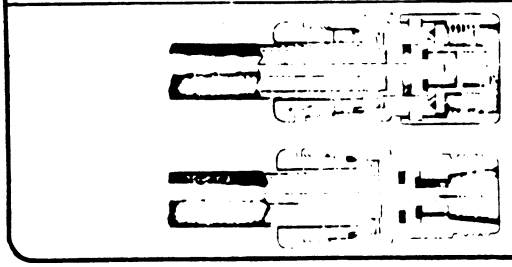
Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.



Fold back braid wires as shown, trim to proper length and form over clamp as shown. Tin exposed center conductor using minimum amount of heat.* Slide on washer, rear insulator and contact. Contact shoulder, insulator, and cable core must butt as shown. Solder contact to center conductor*



Slide front insulator over contact. Be sure to place counter bore end of insulator toward mating end of contact.



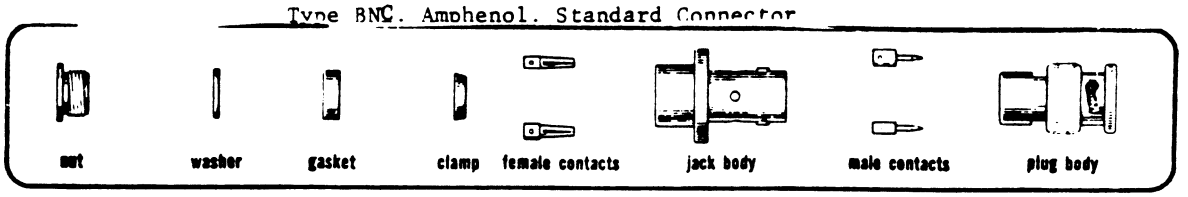
Insert prepared cable termination into connector body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut, holding body stationary.

note: For armored cable slide cap over armor first. Push armor and cap back out of way and proceed with assembly as directed above using armor clamp in place of standard clamp nut. When assembly is complete straighten bulge in armor and trim so it can be clamped between nut and cap.

*Use Divco #276 (or other high temp. alloy) solder for high temp applications.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type BNC, Amphenol, Standard Connector

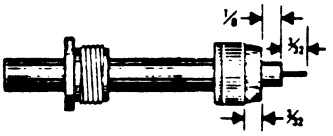


Cut jacket to correct dimension.

RG-/U cable	dimension a
55, 71, 142	1/16
58, 140, 141	5/32
59, 62, 210	1 3/64

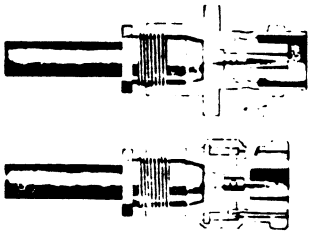
Fray shield and strip inner dielectric 3/32". Tin center conductor.

Taper braid and slide nut, washer, gasket and clamp over braid. Clamp is inserted so that its inner shoulder fits squarely against end of cable jacket.



With clamp in place, comb out braid, fold back smooth as shown and trim 3/32" from end.

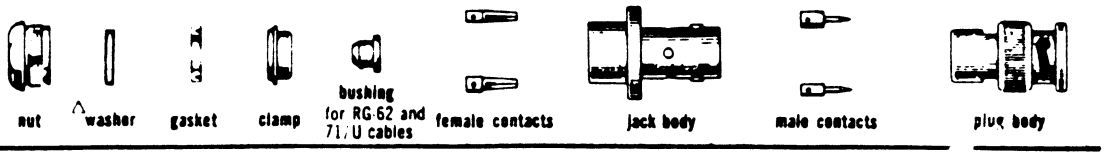
Slip contact in place, butt against dielectric and solder. Remove excess solder from outside of contact. Be sure cable dielectric is not heated excessively and swollen so as to prevent dielectric from entering into connector body.



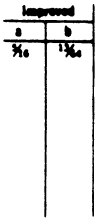
Push assembly into body as far as it will go. Slide nut into body and screw in place with wrench until tight. For this operation, hold cable and shell rigid and rotate nut.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

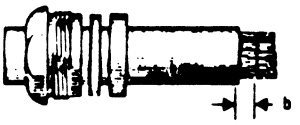
Type BNC, Amphenol, Improved Connector



△only the 31-2XXX and 31-3XXX connectors contain this washer

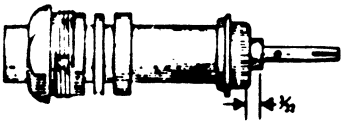


Place nut, washer and gasket over cable and cut jacket to dimension shown.

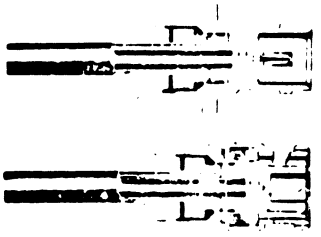


Comb out braid and fold out. Cut cable dielectric to dimension shown. Tin center conductor.

Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.



Fold back braid wires as shown, trim to proper length (1/8") and form over clamp as shown. For RG-62 and 71/U cable, trim to 3/32" dimension as shown and add bushing. Solder contact to center conductor.

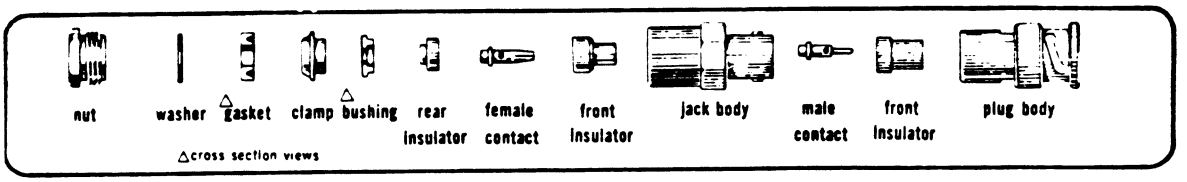


Insert cable and parts into connector body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut.

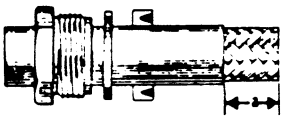
note: For RG-141/142 type copper jacketed cables replace connector's standard clamping components with contents of accessory adapter kit 31-885. Cut metal jacket back 9/32 ± 1/64. Cut dielectric so that .120 ± .005 is exposed. Place the kit's components over the cable jacket in the following order: clamp nut, gasket, compression clamp (with fingers toward cut end of cable), and compression bushing (with smaller diameter toward cut end of cable in line with jacket). Follow conventional assembly instructions disregarding references to cable braid. Tighten nut applying a torque of up to 100 inch-pounds max. while holding body stationary.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type BNC, Amphenol, Captivated Contacts

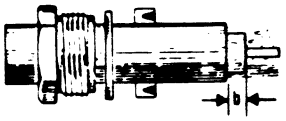


cables RG-55/U, RG-55B/U, RG-58/U, RG-58A/U, RG-58C/U, RG-141/U, RG-142/U, RG-223/U



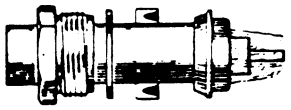
Cut end of cable sharp and square. Slide nut, washer and gasket, with "V" groove toward clamp over jacket, and cut off jacket to dimension a shown below.

dimension	plugs	all others
a	11/64"	3/8"

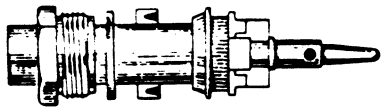


Comb out braid and fold out. Cut off cable dielectric to dimension b shown below. Cut to be sharp and square. Do not nick center conductor.

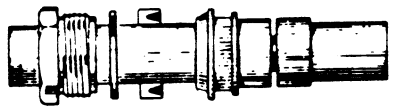
dimension	
b	1/16"



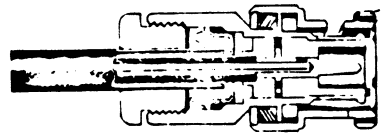
Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.



Fold back braid wires as shown, trim to proper length and evenly form over clamp as shown. Tin exposed center conductor using minimum amount of heat. ■ Do not distort dielectric so as to prevent proper mating with bushing and rear insulator.
Slide on bushing, rear insulator and contact. These parts must butt, as shown. Solder contact to center conductor.■ Remove flux and excess solder from contact O.D.



Slide front insulator over contact and butt against contact shoulder as shown. Do not reverse direction of insulator.



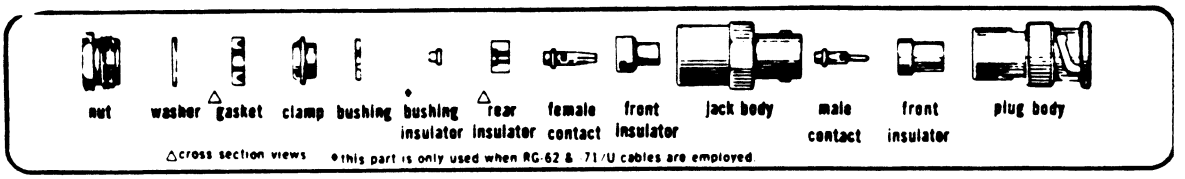
Insert prepared cable termination into conductor body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut, holding body stationary.

■ Use Divco #276 (or other high temp. alloy) solder for high temp. applications.

note: For RG-141/142-type copper jacketed cable, see assembly instructions for Improved Type connectors.

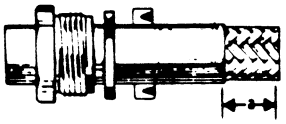
FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type BNC, Amphenol, Captivated Contacts



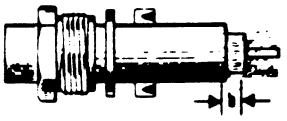
△cross section views • this part is only used when RG-62 & -71/U cables are employed.

cables RG-59/U, RG-59A/U, RG-59B/U, RG-62/U, RG-62A/U, RG-62C/U, RG-71/U, RG-71B/U, RG-140/U



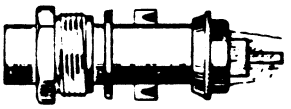
Cut end of cable sharp and square. Slide nut, washer and gasket, with "V" groove toward clamp over jacket, and cut off jacket to dimension a shown below.

dimension	plugs	all others
a	11/64"	1/8"

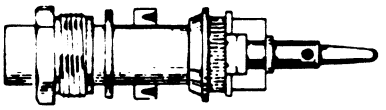


Comb out braid and fold out. Cut off cable dielectric to dimension b shown below. Cut to be sharp and square Do not nick center conductor.

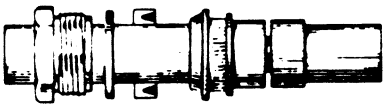
dimension	RG-59/U, RG-59A/U, RG-59B/U, RG-140/U	RG-62/U, RG-62A/U, RG-62C/U, RG-71/U, RG-71B/U
b	1/4"	1/8"



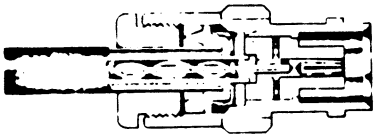
Pull braid wires forward and taper toward center conductor Place clamp over braid and push back against cable jacket.



Fold back braid wires as shown, trim to proper length and evenly form over clamp as shown. Tin exposed center conductor using minimum amount of heat. ■ Do not distort dielectric so as to prevent proper mating with bushing and rear insulator
Slide on bushing, (for RG-62 & -71/U cable, add insulator bushing), rear insulator and contact. These parts must butt, as shown. Solder contact to center conductor. ■ Remove flux and excess solder from contact O.D.



Slide front insulator over contact and butt against contact shoulder as shown. Do not reverse direction of insulator.



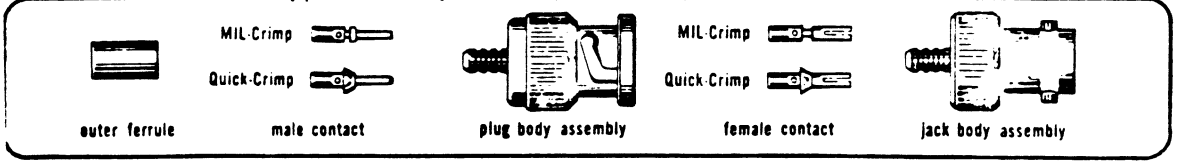
Insert prepared cable termination into conductor body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut, holding body stationary.

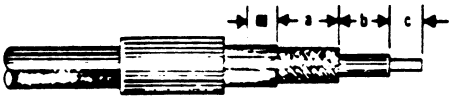
■ Use Divco #276 (or other high temp. alloy) solder for high temp. applications.

note: For RG-141/142-type copper jacketed cable, see assembly instructions for Improved Type connectors.

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

ASSEMBLY INSTRUCTIONS
Type BNC, Amphenol, Quick Crimp Connector



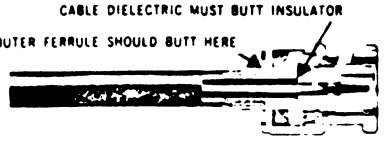


■ For RG-174, 179, 187, 188 U cables only, slit jacket back 100 ± 015 as shown. Before attaching center contact, slide metal spacer and Teflon sleeve (not shown) over cable dielectric. The center contact should butt against the dielectric and Teflon sleeve.

CONTACT MUST BUTT AGAINST CABLE DIELECTRIC

CABLE DIELECTRIC MUST BUTT INSULATOR
OUTER FERRULE SHOULD BUTT HERE

CABLE DIELECTRIC MUST BUTT INSULATOR
OUTER FERRULE SHOULD BUTT HERE



Strip cable jacket, braid, and dielectric to dimensions shown in table. All cuts are to be sharp and square. Important: Do not nick braid, dielectric and center conductor. Tinning of center conductor is not necessary if contact is to be crimped. For solder method: tin center conductor avoiding excessive heat. Slide outer ferrule onto cable as shown.

	MIL-Crimps			Quick-Crimps			M39012 MIL Crimps		
stripping dims. (±1/64)	a	b	c	a	b	c	a	b	c
plugs & jacks	1/4	13/64	1/8	1/4	7/32	11/64	11/32	9/32	5/32
right angle plugs	1/4	13/64	1/8	1/4	9/16	11/64	11/32	9/32	5/32
bulkhead jacks	1/4	13/64	1/8	1/4	1/4	11/64	11/32	9/32	5/32

Flare slightly end of cable braid as shown to facilitate insertion onto inner ferrule. Important: Do not comb out braid.

Place contact on cable center conductor so that it butts against cable dielectric. Center conductor should be visible through inspection hole in contact. Crimp or solder the contact in place as follows:

crimp method. Use center contact crimp tool indicated in table below with appropriate end of nest bushing or positioner inserted into the tool.

tool no.	center contact crimp tool nest bushing or positioner
227-932-1 or 227-927•	227-1157 nest bushing (supplied with tool) end "P" for male (pin), end "S" for female (socket)
MS-3191-A	MIL-Crimp male contact positioner 227-918, female 227-919. Quick-Crimp male and female positioner 227-1156. Order positioners separately.

•economy version

solder method. Soft solder contact to cable center conductor. Do not get any solder on outside surfaces of contact. Avoid excessive heat to prevent swelling of dielectric.

Install cable assembly into body assembly so that inner ferrule portion slides under braid. Push cable assembly forward until contact snaps into place in insulator. Slide outer ferrule over braid and up against connector body. Crimp outer ferrule with tool specified in table.

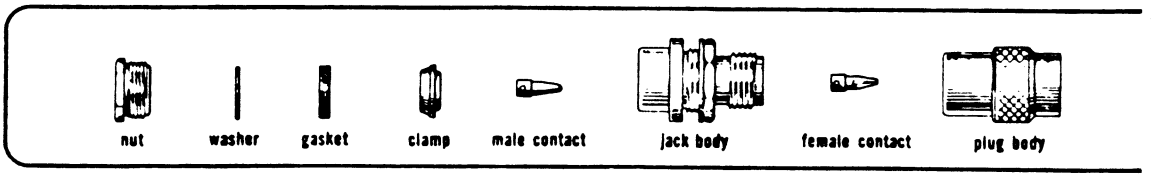
Amphenol hex crimp tools for use with RG-/U cable	Amphenol tool no.▲	Amphenol die no.	die cavity designation
55, 58, 141, 142, 223	227-350	227-920-1	A
59, 62, 140, 210	227-375	227-920-2	D
71	227-375	227-920-2	C
122, 174, 179, 180, 187, 188, 195	227-350	227-920-1	B

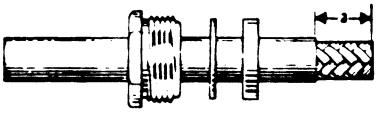
▲Includes basic tool frame (227-921) and die no. indicated

FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

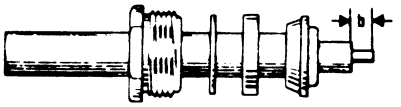
ASSEMBLY INSTRUCTIONS

Type TNC, Amphenol, Standard Connector



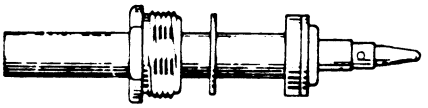


Slide nut, washer and gasket over cable; "V" in gasket should face toward cable end. Cut off outer jack to dimension a (see table below).

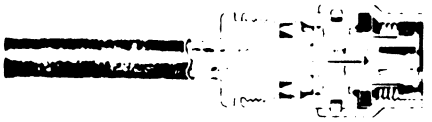


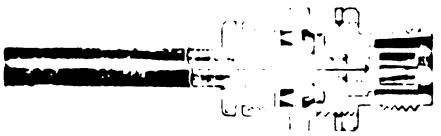
Slide on braid clamp and push back against cable jacket. Trim properly and fold braid back over clamp, making sure the braid is evenly distributed. Cut cable dielectric to dimension b; make cut sharp and square. Do not nick center conductor.

	a ± 1/64	b ± 1/64
jack	1 9/64	1/4
plug	1 9/32	1/4



Tin center conductor using minimum heat and tin and solder contact to conductor. Remove any excess solder. Important: do not apply excessive heat in these operations.

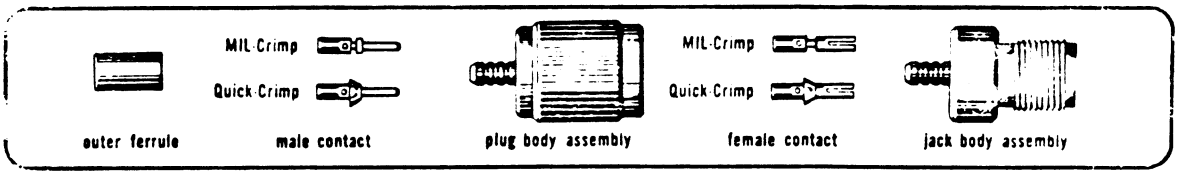




Insert prepared cable termination into connector body. (Check that sharp edge of braid clamp is properly seated in the clamp gasket.) Tighten clamp nut, holding body stationary.

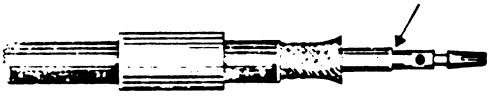
FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type TNC, Amphenol, Quick Crimp Connector



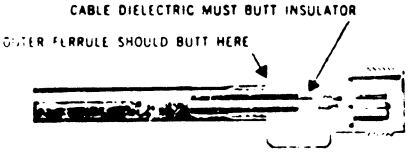
■ For RG-174, 179, 187, 188 U cables only, slit jacket back 100 ± 015 as shown. Before attaching center contact, slide metal spacer and Teflon sleeve (not shown) over cable dielectric. The center contact should butt against the dielectric and Teflon sleeve.

CONTACT MUST BUTT AGAINST CABLE DIELECTRIC



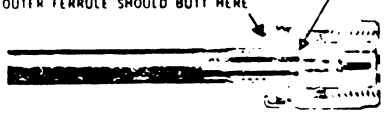
CABLE DIELECTRIC MUST BUTT INSULATOR

OUTER FERRULE SHOULD BUT HERE



CABLE DIELECTRIC MUST BUTT INSULATOR

OUTER FERRULE SHOULD BUTT HERE



Strip cable jacket, braid and dielectric to dimensions shown in table. All cuts are to be sharp and square. Important: Do not nick braid, dielectric and center conductor. Tinning of center conductor is not necessary if contact is to be crimped. For solder method, tin center conductor avoiding excessive heat. Slide outer ferrule onto cable as shown.

	MIL Crimps			Quick Crimps		
stripping dims. (± ⅛₄)	a	b	c	a	b	c
plugs & jacks	¼	¹³⁄₆₄	⅛	¼	⁹⁄₆₄	¹⁷⁄₆₄
right angle plugs	¼	¹³⁄₆₄	⅛	¼	⁹⁄₆₄	¹⁷⁄₆₄
bulkhead jacks	¼	¹³⁄₆₄	⅛	¼	¼	¹⁷⁄₆₄

Flare slightly end of cable braid as shown to facilitate insertion onto inner ferrule. Important: Do not comb out braid.

Place contact on cable center conductor so that it butts against dielectric. Center conductor should be visible through inspection hole in contact. Crimp or solder the contact in place as follows:

crimp method. Use center contact crimp tool indicated in table below with appropriate end of nest bushing or positioner inserted into the tool.

tool no.	center contact crimp tool nest bushing or positioner
227-932-1 or 227-927●	227-1157 nest bushing (supplied with tool) end "P" for male (pin) end "S" for female (socket)
MS-3191-A	MIL-Crimp male contact positioner 227-918, female 227-919 Quick-Crimp male and female positioner 227-1156. Order positioners separately

●economy version

solder method. Soft solder contact to cable center conductor. Do not get any solder on outside surfaces of contact. Avoid excessive heat to prevent swelling of dielectric.

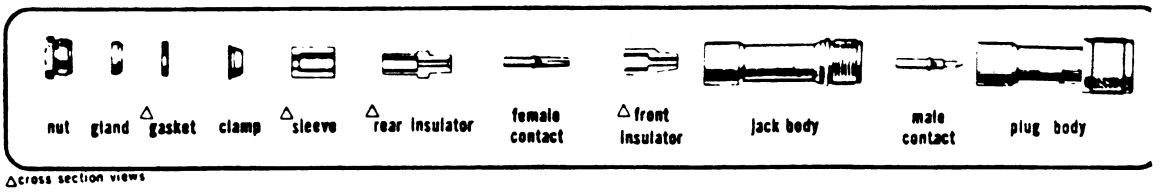
Install cable assembly into body assembly so that inner ferrule goes on slides under braid. Push cable assembly forward until contact snaps into place in insulator. Slide outer ferrule over braid and up against connector body. Crimp outer ferrule with tool specified in table.

Amphenol hex crimp tools for use with RG-/U cable	Amphenol tool no ▲	Amphenol die no.	die cavity designation
55, 58, 141, 142, 223	227-350	227-920-1	A
59, 62, 140, 210	227-375	227-920-2	D
71	227-375	227-920-2	C
122, 174, 179, 180, 187, 188 195	227-350	227-920-1	B

▲Includes basic tool frame (227-921) and die no. indicated

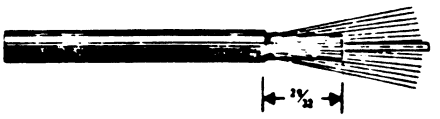
FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Type HN, Amphenol UG-1214/u Captivated Contact Connector



△cross section views

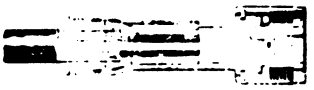
Cut end of cable even. Strip off vinyl jacket 1⅛" as shown.



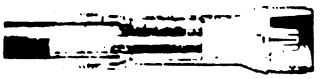
Comb out braid as shown. Cut off dielectric ²⁹⁄₃₂" from end of jacket.

Taper braid wires forward and slide nut and gland onto jacket. Make certain knife edge of gland is toward end of cable. Then slide gasket onto jacket with "V" groove toward gland. Clamp is now pushed over braid so that internal shoulder butts flush against cable jacket.

Fold braid back over clamp and trim. Tin exposed center conductor using minimum amount of heat.▲ Slide sleeve and rear insulator over cable dielectric. Soft solder contact to center conductor.▲ Rear insulator must seat against cable dielectric and contact shoulder must be flush with insulator face as shown. Coat cable dielectric and insulator mating surfaces with AMPHENOL 53-307 Silicone Compound to achieve 5KV peak rating under operating conditions. For jacks only, install front insulator (dotted outline).



Slide prepared cable termination carefully into body. Be sure knife edge of gland remains in groove of gasket. Tighten nut with wrench holding body stationary. Gasket should be cut in half during tightening.



▲Use Divco #276 (or other high temp. alloy) solder for high temp. applications.

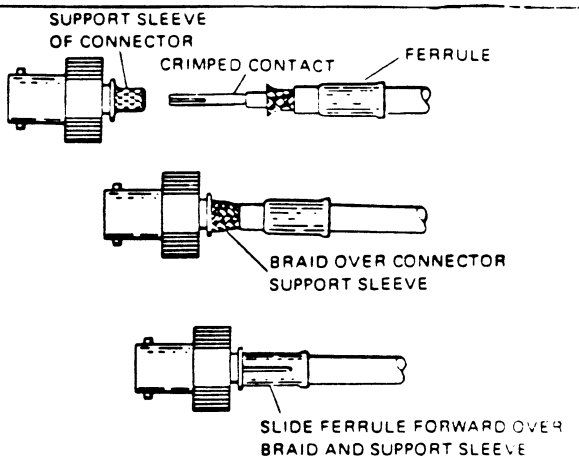
FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

ASSEMBLY INSTRUCTIONS

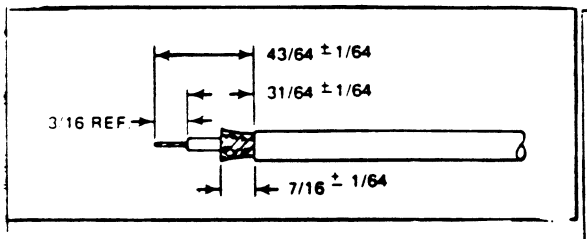
Amp 331350 and 331351 Connectors

TYPICAL ASSEMBLY PROCEDURE JACK

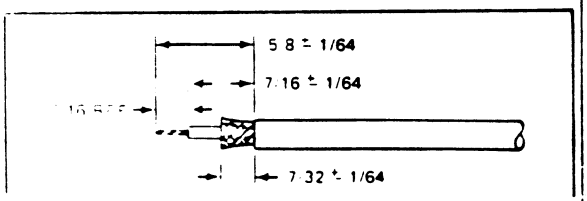
1. Slide ferrule on cable, then strip cable. Crimp center contact (See tool instructions referenced in table)
2. Insert contact into connector with braid over support sleeve
3. Slide ferrule over braid and crimp ferrule. (See tool instructions referenced in table.)



JACK CABLE STRIP



PLUG CABLE STRIP



TYPICAL ASSEMBLY PROCEDURE PLUG

1. Slide ferrule on cable, then strip cable. Crimp center contact (See tool instructions referenced in table).
2. Insert contact into connector with braid over support sleeve.
3. Slide ferrule over braid and crimp ferrule. (See tool instructions referenced in table.)

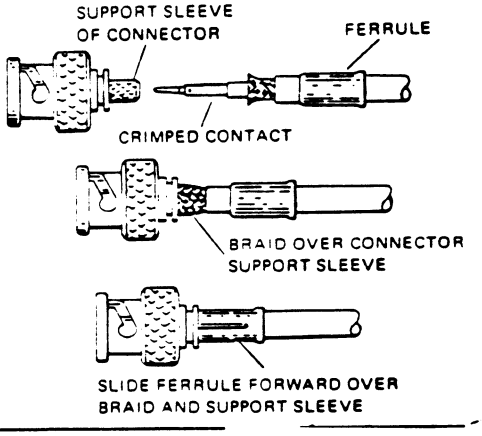
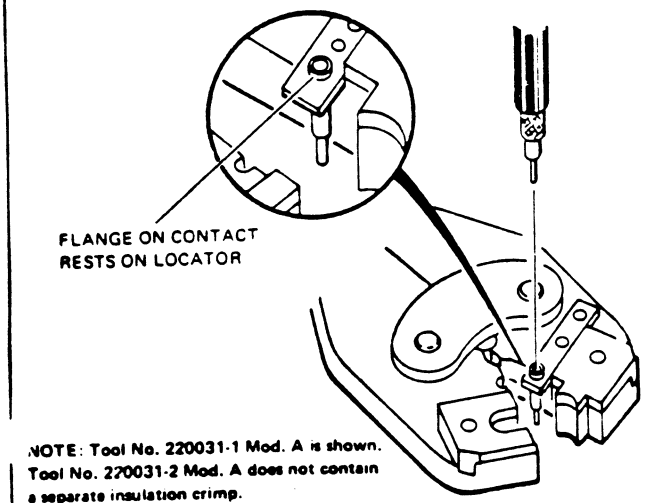


FIGURE 23. ASSEMBLY INSTRUCTIONS (CONTINUED)

Amp Crimping Tool Use

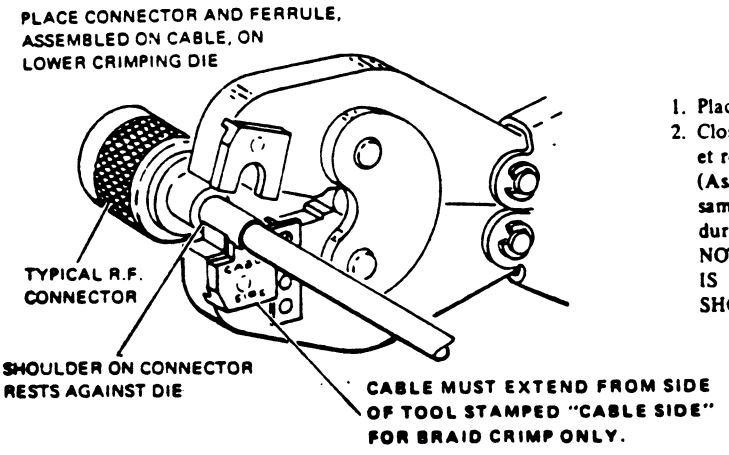
CRIMPING CENTER CONTACT



1. Slip Ferrule on Cable, then strip cable.
2. Place Contact in Tool Head as shown. Close Tool Handles just enough to hold Contact in place without deforming Wire Barrel.
   (Crimping Dies on Tool are opened by closing Handles until CERTI-CRIMP™ Ratchet releases. Once Ratchet is engaged, Handles cannot be opened until fully closed.)
3. Insert Conductor into Contact Wire Barrel until Cable Dielectric butts against Contact.
4. Close handles until Ratchet releases to complete crimp.

NOTE: Tool No. 220031-1 Mod. A is shown. Tool No. 220031-2 Mod. A does not contain a separate insulation crimp.

CRIMPING FERRULE



1. Place Assembly in Tool as shown.
2. Close Handles until CERTI-CRIMP Ratchet releases to complete crimp.
   (Assemble and crimp all connectors in the same manner as Plug shown in this procedure.)
   NOTE: MAKE SURE THAT CONNECTOR IS LOCATED IN TOOL EXACTLY AS SHOWN TO ASSURE PROPER CRIMP.

FIGURE 24. DUCT, LAY-IN

WIREWAY & WIRING TROUGH
SQUARE-Duct & RAINTIGHT

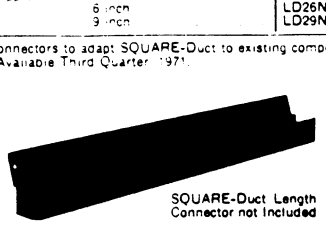
SQUARE-Duct

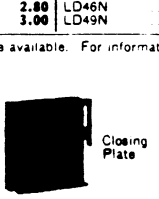
SQUARE-Duct combination wireway is usable as either Hinge Cover or Screw Cover Duct. It provides full lay-in features throughout its entire installation, eliminating threading and pulling of conductors. Hinge covers are quickly removed and replaced by pressing spring tabs. The same cover has keyhole slots to accept captive screws locking the cover securely closed. The entire run may be sealed. All SQUARE-Duct components are UL listed, File No. 6625 as steel enclosed wireway and auxiliary gutter. Knockouts match other Square D switches, breakers, service equipment, contactors and starters. Finish—Gray baked enamel.

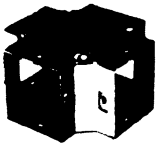
NO CONNECTORS ARE FURNISHED WITH LENGTHS OR FITTINGS

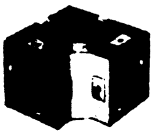
Component	Description	2½"x2½" Catalog Number Knockouts	2½"x2½" Catalog Number Without Knockouts	2½"x2½" Price	4"x4" Catalog Number Knockouts	4"x4" Catalog Number Without Knockouts	4"x4" Price	6"x6" Catalog Number Knockouts	6"x6" Catalog Number Without Knockouts	6"x6" Price	8"x8" Cat. No. Without Knockouts	8"x8" Price	12"x12" ‡ Cat. No. Without Knockouts	12"x12" ‡ Price
Length	1 Foot	LD21	LD21WK	$ 2.70	LD41	LD41WK	$ 3.30	LD61	LD61WK	$ 7.20	LD81	$12.10	LD121	$18.50
	2 Foot	LD22	LD22WK	4.20	LD42	LD42WK	5.40	LD62	LD62WK	9.40	LD82	18.60	LD122	36.00
	3 Foot	LD23	LD23WK	7.20	LD43	LD43WK	8.70	LD63	LD63WK	13.00	LD83	27.00	LD123	53.00
	4 Foot	LD24	LD24WK	9.80	LD44	LD44WK	11.70	LD64	LD64WK	17.70	LD84	33.00	LD124	64.00
	5 Foot	LD25	LD25WK	11.60	LD45	LD45WK	13.00	LD65	LD65WK	21.90	LD85	38.00	LD125	74.00
	10 Foot	LD210	LD210WK	23.90	LD410	LD410WK	26.70	LD610	LD610WK	45.20				
Cut-off Fitting	3 foot screw cover for cutting odd dimensions	LD23CF		7.20	LD43CF		8.70	LD63CF		13.00	LD83CF	27.00	LD123CF	53.00
Elbow	90 degrees	LD290L		7.00	LD490L		8.10	LD690L		11.20	LD88L	17.40	LD1290L	35.20
	90 degree sweep bend				LD490LS		17.10	LD690LS		23.70				
	45 degrees	LD245L		5.40	LD445L		6.80	LD645L		9.40	LD845L	17.40	LD1245L	52.00
	22½ degrees	LD225L		5.40	LD425L		6.80	LD625L		9.40				
Tee	Branch from runs	LD2T		9.90	LD4T		11.60	LD6T		13.10	LD88T	37.00	LD12T	54.00
Junction Box	For T, L or Cross 4 sides—1 opening each	LD2J		11.10	LD4J		13.10	LD6J		13.10	LD88J	37.00	LD12J	82.00
Pull Box	For T, L or Cross 2 sides—1 opening; 2 sides—2 openings				LD4PB		36.00	LD6PB		73.00				
Telescope Transposition	Slide Adjustment	LD2TF		10.10	LD4TF		10.10	LD6TF		42.00				
Section	Rotates wireway 90°	LD21TS		4.60	LD41TS		5.80	LD61TS		12.70				
*Connector	Couples lengths and fittings	LD2C		.70	LD4C		.70	LD6C		1.40	LD88C	2.00	LD12C	5.00
Hanger	Universal—drop or side	LD2H		1.20	LD4H		1.50	LD6H		4.60	LD88H	6.40	LD12H	19.20
Closing Plate	Seals openings	LD2CP	LD2CPWK	.70	LD4CP	LD4CPWK	.70	LD6CP	LD6CPWK	1.40	LD88E	2.00	LD12CP	5.90
Wire Retainer	Snap-in spring steel strap	LD2WR		.20	LD4WR		.30	LD6WR		.30				
Adaptor	Connects to panel square duct, etc.	LD22A		2.30	LD44A		2.70	LD66A		4.00	LD88A	5.80	LD12A	19.40
Reducer	4"x4" to 2½"x2½"				LD42R		5.40							
	6" x 6" to 4" x 4"							LD64R		11.00				
	8" x 8" to 6" x 6"										LD86R	12.70	LD128R	21.00
Gusset Bracket	Mount for vertical wall No hanger required	LD2GB		1.20	LD4GB		1.50	LD6GB		4.60				
Nipple	4 inch	LD23N		3.00	LD43N		3.50	LD63N		7.20				
	6 inch	LD26N		2.80	LD46N		3.50	LD66N		7.20				
	9 inch	LD29N		3.00	LD49N		3.50	LD69N		7.20				

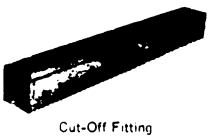
*Connectors to adapt SQUARE-Duct to existing competitive duct are available. For information contact your nearest Square D field office. Dimensions, Page 42
‡Available Third Quarter 1971.











RAINTIGHT TROUGHS

Raintight troughs are for ganging meter devices, panels, switches, etc. Each length is a completely enclosed section with a removable cover that has a provision for sealing. Two sizes of concentric knockouts (one ½, ¾, 1, 1½ and two 1¼, 1½, 2, 2½ per foot) are located along the bottom of the troughs on 3" centers. These knockouts provide easy ganging of service equipment. **Lengths without knockouts** are available at standard price—add WK suffix to Cat. No. Finish: Gray baked enamel.

Description	4" x 4" Cat. No	4" x 4" Price	6" x 6" Cat. No.	6" x 6" Price
1 Foot Length	RD41	$ 7.50	RD61	$15.70
2 Foot Length	RD42	11.20	RD62	19.40
3 Foot Length	RD43	16.20	RD63	27.00
4 Foot Length	RD44	20.00	RD64	35.00
5 Foot Length	RD45	24.30	RD65	42.00

SQUARE-Duct is a Registered Trademark of Square D Company.

FIGURE 24. DUCT, LAY-IN (CONTINUED)

WIREWAY & WIRING TROUGH
TYPE JIC

Type JIC Sectional Oiltight Wireway and fittings are used to protect runs of electrical wiring from oil, water, coolants, dirt or dust as well as physical damage, and may be used either indoors or outdoors. This wireway is manufactured to JIC and NMTBA standards for Industrial Control Equipment. It is available in four standard sizes 2½" x 2½", 4" x 4", 6" x 6" and 8" x 8". Lengths and fittings are made of 14 gauge steel with 10 gauge welded flanges. Straight lengths have hinged covers with sponge neoprene gasket all around and are held closed with external clamps. A ⅛" solid neoprene gasket is provided for placing between flanges when sections and fittings are bolted together. All lengths and fittings are without knockouts. Finish is a gray prime coat over a phosphated surface.

JIC WIREWAY

Type JIC Sectional Wireway and Enclosed wiring troughs are generally used in conjunction with industrial machinery and consequently have never been submitted for UL listing.

Description	No. of Gaskets Furnished	2½" x 2½" Cat. No.	2½" x 2½" Price	4" x 4" Cat. No.	4" x 4" Price	6" x 6" Cat. No.	6" x 6" Price	8" x 8" Cat. No.	8" x 8" Price
Straight Length — 1 foot	1	JD-21	$15.10	JD-41	$18.30	JD-61	$ 22.40	JD-81	$35.00
2 foot	1	JD-22	22.10	JD-42	25.00	JD-62	30.00	JD-82	49.00
3 foot	1	JD-23	27.00	JD-43	30.00	JD-63	40.00		
4 foot	1	JD-24	30.00	JD-44	35.00	JD-64	51.00		
5 foot	1	JD-25	33.00	JD-45	40.00	JD-65	63.00	JD-85	83.00
10 foot	1	JD-210	61.00	JD-410	69.00	JD-610	106.00		
90° Elbow	1	JD-290L	17.70	JD-490L	21.90	JD-690L	27.00	JD-890L	40.00
45° Elbow	1	JD-245L	17.70	JD-445L	21.90	JD-645L	27.00	JD-845L	40.00
Cross	2	JD-2X	29.00	JD-4X	37.00	JD-6X	49.00	JD-8X	65.00
Tee	2	JD-2T	23.30	JD-4T	27.00	JD-6T	37.00	JD-8T	54.00
Telescope Fitting	1	JD2TF	21.70	JD-4TF	23.10	JD-6TF	29.00	JD-8TF	43.00
Cut-off Fitting	1	JD-2CF	10.90	JD-4CF	15.10	JD-6CF	18.80	JD-8CF	30.00
Box Adaptor	1	JD-2A	3.90	JD-4A	5.50	JD-6A	7.10	JD-8A	8.90
Closure Plate	1	JD-2CP	2.20	JD-4CP	3.90	JD-6CP	4.80	JD-8CP	7.00
Drop Hanger	0	JD-2DH	3.50	JD-4DH	4.80	JD-6DH	6.30	JD-8DH	12.30
Bracket Hanger	0	JD-2BH	2.30	JD-4BH	3.20	JD-6BH	4.50	JD-8BH	12.00
Reducer Bushing—									
4" to 2½" Center Hole	1			JD-42RC	9.20				
4" to 2½" Edge Hole	1			JD-42RE	9.20				
6" to 4" Center Hole	1					JD-64RC	18.80		
6" to 4" Edge Hole	1					JD-64RE	18.80		
8" to 6" Center Hole	1							JD-86RC	14.40
8" to 6" Edge Hole	1							JD-86RE	14.40
Gasket & Screws (Extra)		JD-2G	.80	JD-4G	1.10	JD-6G	1.40	JD-8G	2.00

Dimension Page 42.

Elbow

Drop Hanger

Wiring Trough

Tee

Bracket Hanger

Sectional Wireway

Type JIC Totally Enclosed Wiring Troughs are dustproof and water-tight. They are used to house electrical wiring where protection against oil, coolants, water, dust or dirt, as well as physical damage, is required. This wireway is manufactured to JIC specifications. It is made of 14 gauge steel with welded seams ground and polished. A removable cover, with a sponge neoprene gasket, is attached to the trough by a chain at each end and is latched securely with external clamps. Troughs have external mounting feet and are without knockouts or openings. Finish is a baked gray enamel over a phosphated surface.

JIC WIRING TROUGHS

Description	2½" x 2½" Cat. No.	2½" x 2½" Price	4" x 4" Cat. No.	4" x 4" Price
1 Foot Length (12")	JT-21	$12.80	JT-41	$15.40
1½ Foot Length (18")	JT-2018	15.80	JT-4018	18.80
2 Foot Length (24")	JT-22	18.80	JT-42	22.20
2½ Foot Length (30")			JT-4030	25.00
3 Foot Length (36")	JT-23	21.70	JT-43	28.00
4 Foot Length (48")	JT-24	24.90	JT-44	32.00
5 Foot Length (60")	JT-25	30.00	JT-45	41.00
6 Foot Length (72")			JT-46	47.00

Note: 6" x 6" and 8" x 8" Troughs available on special order. Consult factory.

Dimension Page 42.

CONDUCTOR TABLE — NO DERATING NECESSARY UP TO 30 CONDUCTORS OR 20% FILL — N.E.C. 362-5

***NOTE:** The 1968 National Electrical Code limits installations to 30 conductors in one wireway except where derated according to tables 310-12 through 310-15, N.E.C., or where special permission has been obtained from the local authority enforcing the Code or where conductors in excess of 30 are for signalling circuits or are control wires between a motor and its starter and used only for starting duty, and other exceptions as noted in 520-5 (theaters) and 620-32 (elevators).

†Areas for Type RWH & RHH are .0327 & .0384 for sizes 14 & 12 respectively.

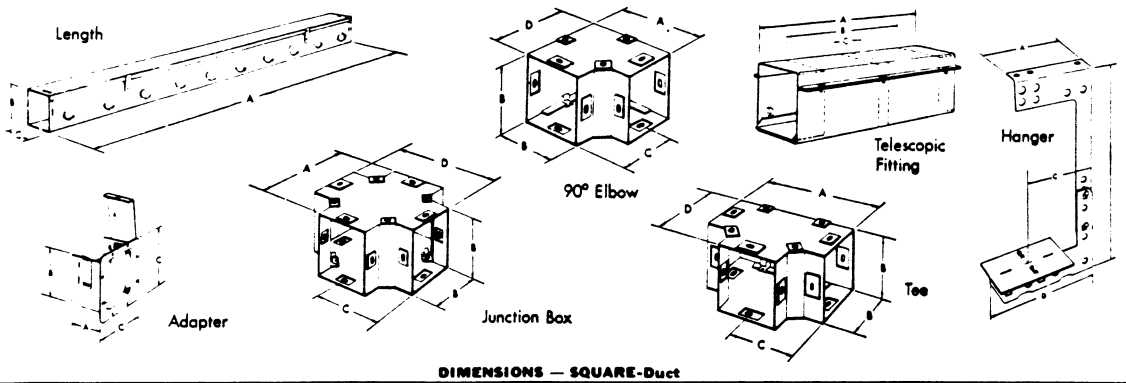
●Areas for Type THW are .0206, .0251, .0311 and .0526 for sizes 14, 12, 10 & 8 respectively.

A — Type RH, RWH & RHH
B — Type T, TW & THW
Areas given in square inches.

Conductor Size	Area of Conductor: Type RH, RWH & RHH — A	Area of Conductor: Type T, TW & THW — B	Maximum Number of Conductors All of One Size: 2½" x 2½" Duct A	2½" x 2½" Duct B	4" x 4" Duct A	4" x 4" Duct B	6" x 6" Duct A	6" x 6" Duct B	8" x 8" Duct A	8" x 8" Duct B
14	.0230†	.0135●	*54	*92	*139	*237	*313	*533	*557	*950
12	.0278†	.0172●	*45	*72	*115	*186	*259	*428	*461	*744
10	.0460	.0224●	27	*55	*64	*142	*156	*321	*278	*570
8	.0760	.0408●	16	30	*42	* 78	*94	*176	*168	*314
6	.1238	.0819	10	15	25	* 39	*58	* 87	*103	*158
4	.1605	.1087	7	11	19	29	*44	* 66	*79	*107
3	.1817	.1263	6	9	17	25	*39	* 57	*70	*101
2	.2067	.1473	6	8	15	21	*34	* 48	*61	* 87
1	.2715	.2027	4	6	11	15	26	* 35	*47	* 63
0	.3107	.2367	4	5	10	13	23	30	*41	* 54
00	.3578	.2781	3	4	8	11	20	25	*35	* 46
000	.4151	.3288	3	3	7	9	17	21	30	* 39
0000	.4840	.3904	2	3	6	8	14	18	26	* 32
250,000	.5917	.4877	2	2	5	6	12	14	21	26
300,000	.6837	.5581	1	2	4	5	10	12	18	22
400,000	.8365	.6969	1	1	3	4	8	10	15	18
500,000	.9834	.8316	1	1	3	3	7	8	13	15
600,000	1.1940	1.0260	..	..	2	3	6	7	10	12
700,000	1.3360	1.1580	..	..	2	2	5	6	9	11
750,000	1.4020	1.2250	..	..	2	2	5	5	9	10

FIGURE 24. DUCT, LAY-IN (CONTINUED)

WIREWAY DIMENSIONS
SQUARE-Duct & TYPE JIC



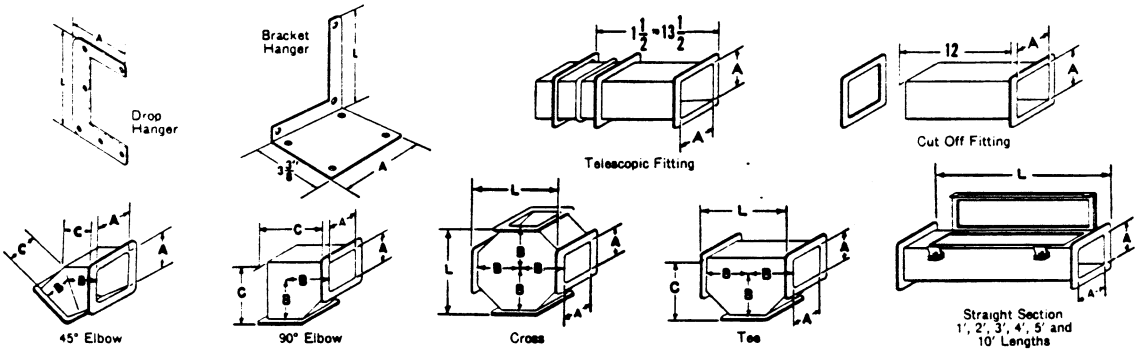
DIMENSIONS — SQUARE-Duct

2½" x 2½" — Knockouts ½, ¾, 1, 1¼				
Cat. No.	A	B	C	D
LD21	12	2⅝	2⅝	
LD22	24	2⅝	2⅝	
LD23	36	2⅝	2⅝	
LD24	48	2⅝	2⅝	
LD25	60	2⅝	2⅝	
LD210	120	2⅝	2⅝	
LD290L	4⅝	2⅝	3 5/16	4⅝
LD245L	2⅞	2⅝		2⅞
LD225L	2 5/16	2⅝		2 5/16
LD2T	6⅝	2⅝	3 5/16	4⅝
LD2J	6⅝	2⅝	3 5/16	6⅝
LD2TF	15	11½	½	
LD2H	4 5/16	10	3¼	4⅜
LD22A	3¼	2⅝	3⅝	

4" x 4" — Knockouts ½, ¾, 1, 1¼				
Cat. No.	A	B	C	D
LD41	12	4⅛	4⅛	
LD42	24	4⅛	4⅛	
LD43	36	4⅛	4⅛	
LD44	48	4⅛	4⅛	
LD45	60	4⅛	4⅛	
LD410	120	4⅛	4⅛	
LD490L	5⅛	4⅛	4 1/16	6⅛
LD490LS	9 7/16	4⅛	7⅜	9 7/16
LD445L	3½	4⅛		3½
LD425L	2⅝	4⅛		2⅝
LD4T	8 1/16	4⅛	4 1/16	6⅛
LD4J	8⅛	4⅛	4 1/16	8⅛
LD4PB	14 7/16	4⅛		14 7/16
LD4TF	15	11½	½	
LD4H	4 5/16	11⅝	3 15/16	6
LD44A	3¼	4⅛	5⅛	

6" x 6" — Knockouts ½, ¾, 1, 1¼, 1½, 2				
Cat. No.	A	B	C	D
LD61	12	6⅛	6⅛	
LD62	24	6⅛	6⅛	
LD63	36	6⅛	6⅛	
LD64	48	6⅛	6⅛	
LD65	60	6⅛	6⅛	
LD610	120	6⅛	6⅛	
LD690L	8¾	6⅛	5 11/16	8¾
LD690LS	14 1/16	6⅛	11	14 1/16
LD645L	5	6⅛		5
LD625L	3⅝	6⅛		3⅝
LD6T	11⅜	6⅛	5 11/16	8¾
LD6J	11⅜	6⅛	5 11/16	11⅜
LD6PB	19 11/16	6⅛		19 11/16
LD6TF	15	11½	½	
LD6H	5 7/16	17	5¼	8⅛
LD66A	4 7/16	6⅛	7⅝	

8" x 8" — No Knockouts				
Cat. No.	A	B	C	D
LD81	12	8	8	
LD82	24	8	8	
LD83	36	8	8	
LD84	48	8	8	
LD85	60	8	8	
LD88L	10¾	8⅛	6 11/16	10¾
LD845L	5⅞	8⅛		5⅞
LD88T	13¾	8⅛	6 11/16	10¾
LD88J	13⅜	8⅛	6 11/16	13⅜
LD88H	5 7/16	16⅞	5⅛	9½
LD88A	2	8⅛	9⅞	



DIMENSIONS — JIC WIREWAY

2½" x 2½"				
Cat. No.	A	B	C	L
JD21	2½			12
JD22	2½			24
JD23	2½			36
JD24	2½			48
JD25	2½			60
JD210	2½			120
JD290L	2½	4¼	5½	
JD245L	2½	2	2½	
JD2X	2½	4¼		8½
JD2T	2½	4¼	5½	8½
JD2TF	2½			
JD2CF	2½			
JD2DH	4½			9¼
JD2BH	3⅞			4⅝
JT21	2½			12
JT2018	2½			18
JT22	2½			24
JT23	2½			36
JT24	2½			48
JT25	2½			60

4" x 4"				
Cat. No.	A	B	C	L
JD41	4			12
JD42	4			24
JD43	4			36
JD44	4			48
JD45	4			60
JD410	4			120
JD490L	4	5	7	
JD445L	4	2¾	3¼	
JD4X	4	5		10
JD4T	4	5	7	10
JD4TF	4			
JD4CF	4			
JD4DH	6			11⅜
JD4BH	5⅜			6⅛
JT41	4			12
JT4018	4			18
JT42	4			24
JT4030	4			30
JT43	4			36
JT44	4			48
JT45	4			60
JT46	4			72

6" x 6"				
Cat. No.	A	B	C	L
JD61	6			12
JD62	6			24
JD63	6			36
JD64	6			48
JD65	6			60
JD610	6			120
JD690L	6	6	9	
JD645L	6	3	4¼	
JD6X	6	6		12
JD6T	6	6	9	12
JD6TF	6			
JD6CF	6			
JD6DH	8¼			15¼
JD6BH	7⅜			8⅜

8" x 8"				
Cat. No.	A	B	C	L
JD81	8			12
JD82	8			24
JD85	8			60
JD890L	8	8	12	
JD845L	8	4	5¾	
JD8X	8	8		16
JD8T	8	8	12	16
JD8TF	8			
JD8CF	8			
JD8DH	10¼			18¼
JD8BH	9⅜			10⅜

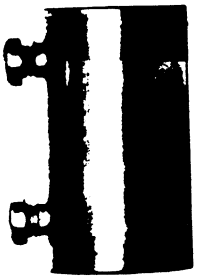
SQUARE-Duct is a Registered Tradmark of Square D Company.

FIGURE 25. CONDUIT FITTINGS

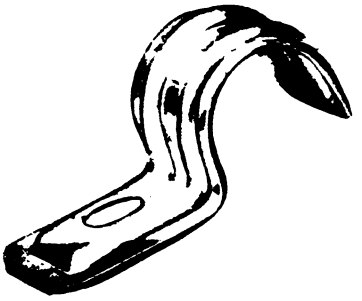
For Electrical Metallic Tubing (Thinwall)

Pipe Straps
(malleable iron)

Set Screw
Coupling



Pipe Straps (steel)

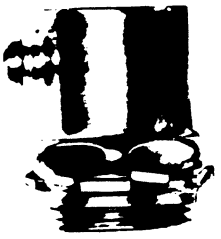


Raintight Box
Connector

Raintight
Coupling

Insulated Raintight
Box Connector

Set Screw
Connector

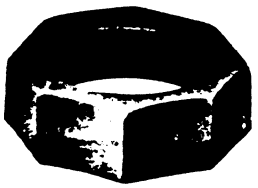


Insulated Raintight
Short Elbows

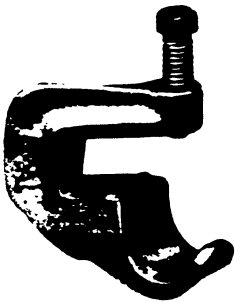
FIGURE 23. CONDUIT FITTINGS (CONTINUED)

For Standard Rigid Conduit

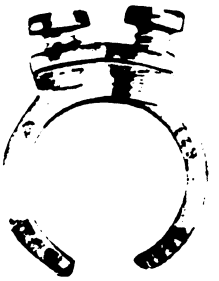
Insulated Bushings



Conduit Support

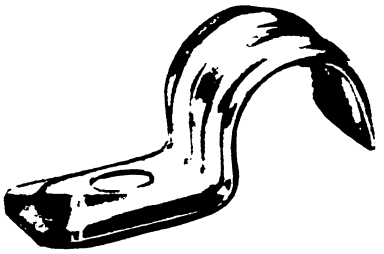


Grounding Wedges



Pipe Straps
(malleable iron)

Pipe Straps
(steel)



Insuliner
Sleeves

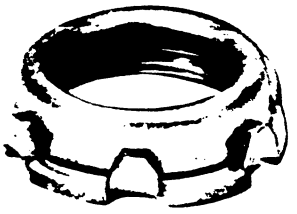
Insulated
Grounding Bushing

FIGURE 25. CONDUIT FITTINGS (CONTINUED)

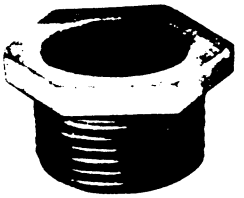
For Standard Rigid Conduit (continued)

Locknuts

Bushings

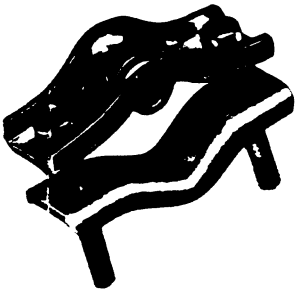


Chase Nipples

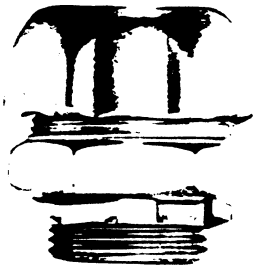


Heavy Duty
Ground Fittings

All Purpose
Ground Clamp



Threadless Connectors



Erickson Coupling

Threadless Couplings

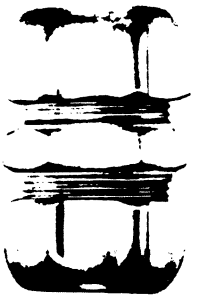


FIGURE 25. CONDUIT FITTINGS (CONTINUED)

For Standard Rigid Conduit (continued)

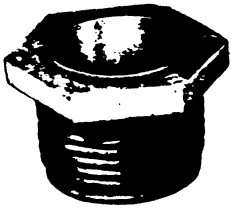
Spacer

Push-Penny Plugs

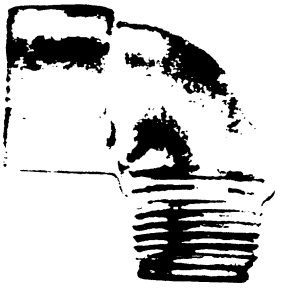
Insulated Threadless Connectors

Offset Nipples

Insulated Chase Nipples



Insulated Short Elbows



Insulated Metallic Bushings

FIGURE 25. CONDUIT FITTINGS (CONTINUED)

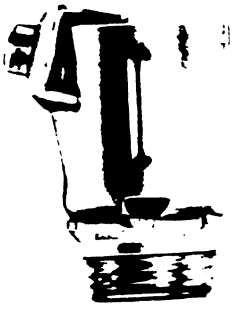
For Armored Cable and Flexible Conduit

Squeeze Connector
Straight

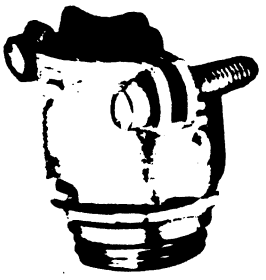
Squeeze Connector
90° Angle

Squeeze Connector
45° Angle

Insulated Tite-Bite
Straight Connector



Squeeze Connector
Two Screw



Insulated Tite-Bite
90° Angle Connector

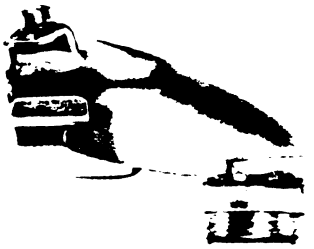
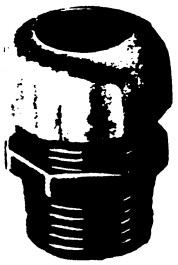


FIGURE 25. CONDUIT FITTINGS (CONTINUED)

For Drop Cords

Watertight Strain Relief Connector Straight



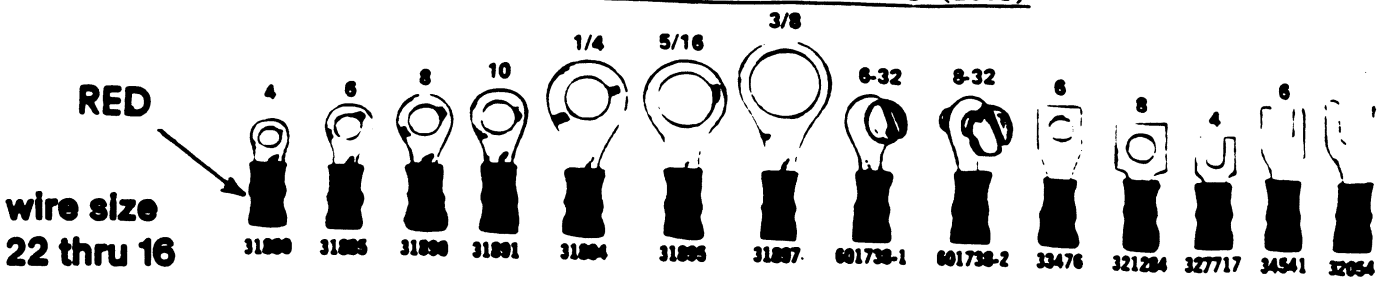
Watertight Strain Relief Connector 90° Angle

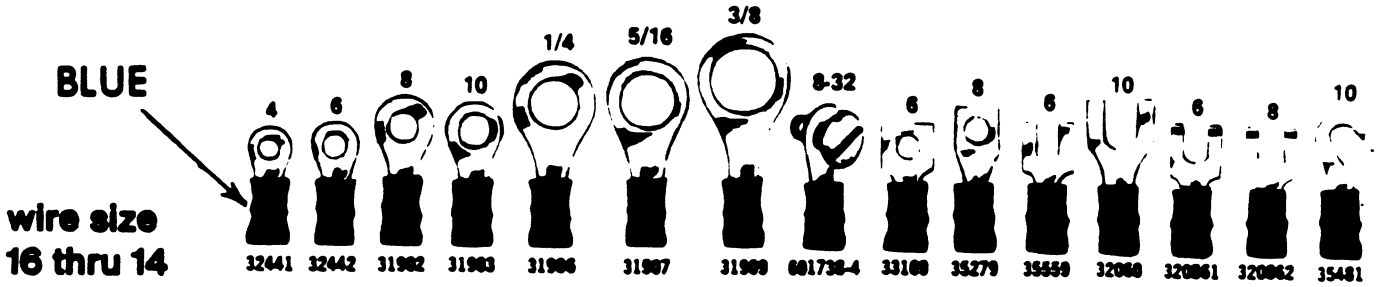
For Non-Metallic Cable

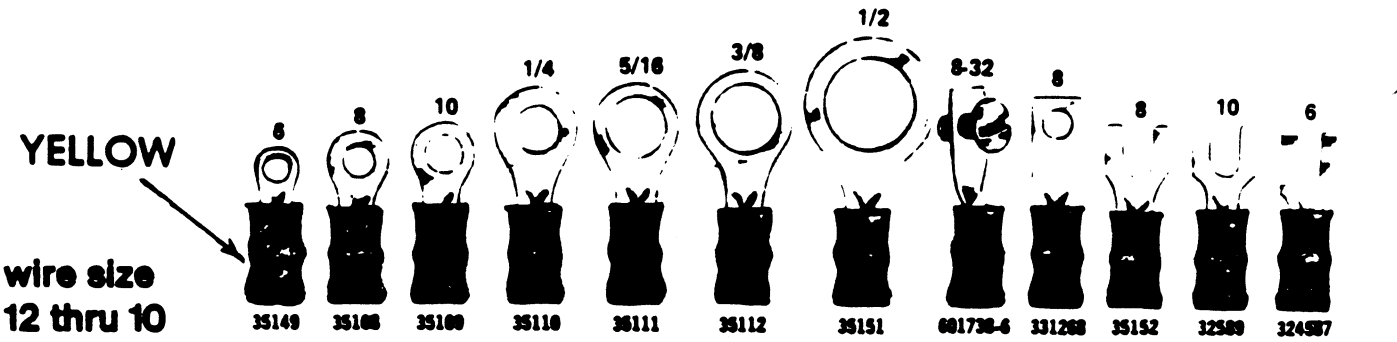
Two Screw Connectors

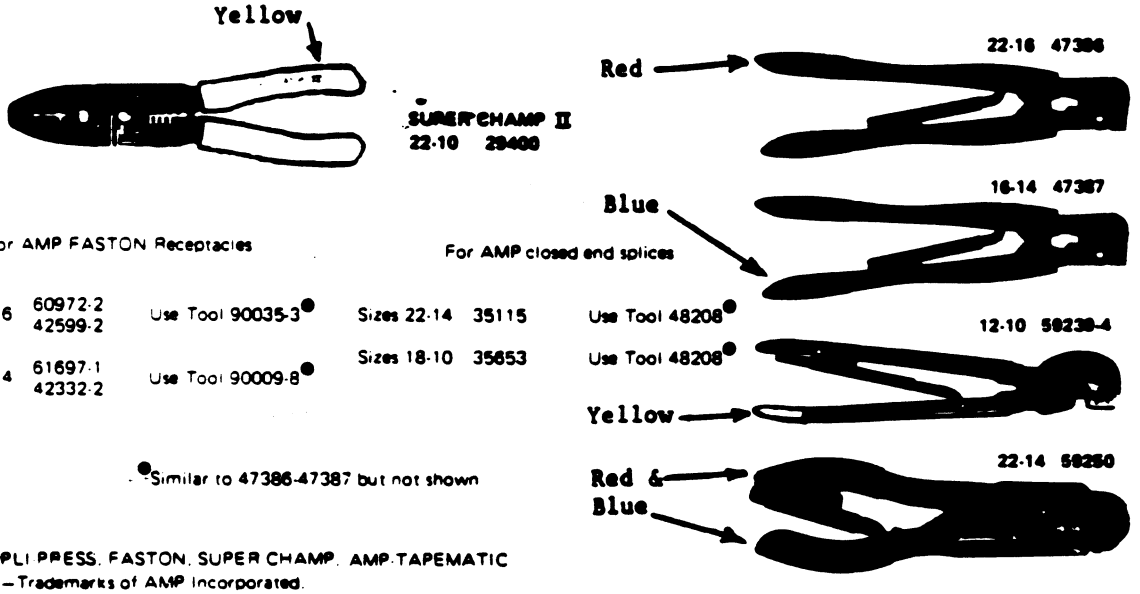
This page is reserved.

FIGURE 26. WIRE TERMINAL CONNECTORS (LUGS)









For AMP FASTON Receptacles

Sizes 22-16	60972-2 42599-2	Use Tool 90035-3●	
Sizes 16-14	61697-1 42332-2	Use Tool 90009-8●	

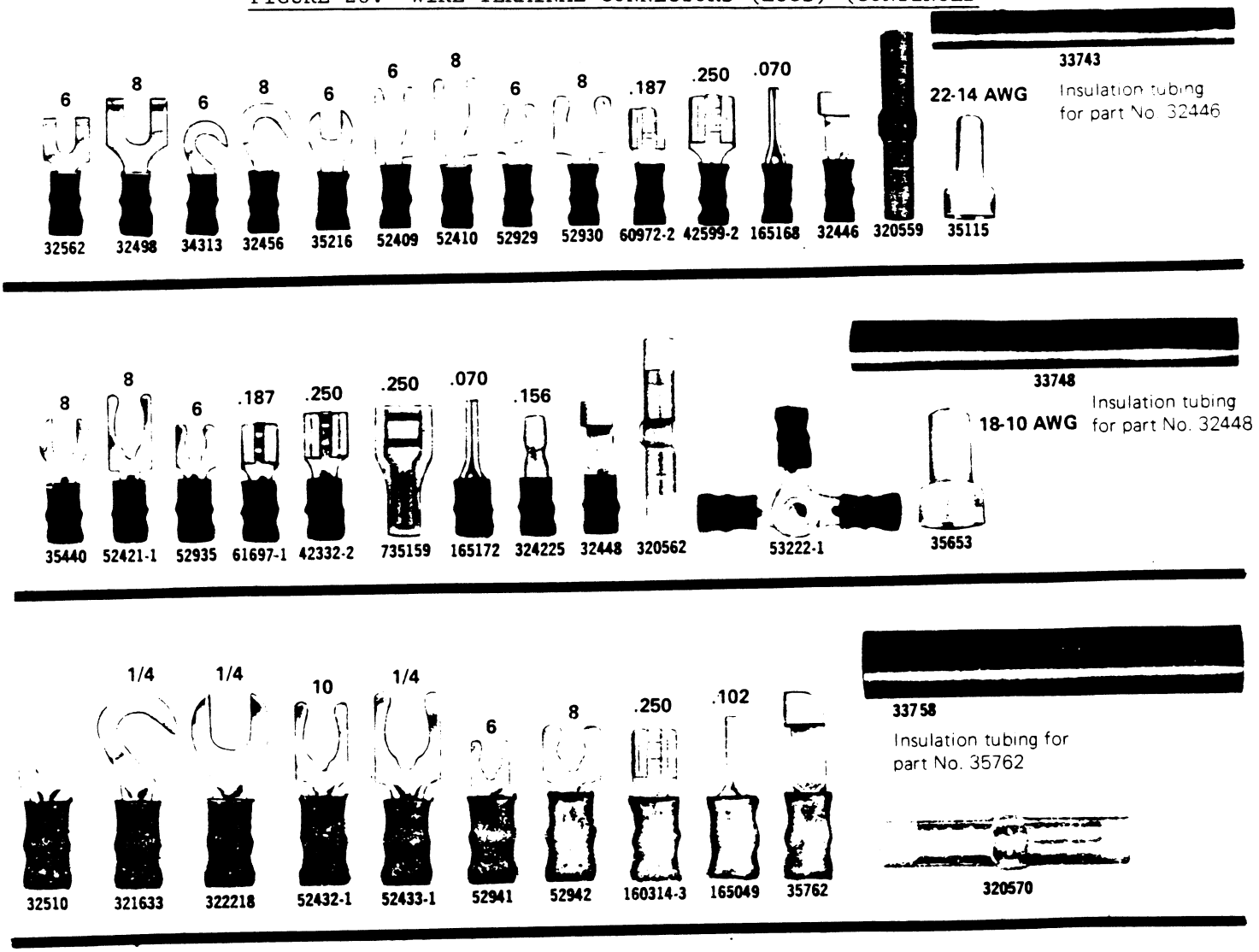
For AMP closed end splices

Sizes 22-14	35115	Use Tool 48208●
Sizes 18-10	35653	Use Tool 48208●

●Similar to 47386-47387 but not shown

AMP, AMPLI PRESS, FASTON, SUPER CHAMP, AMP-TAPEMATIC and PIDG—Trademarks of AMP Incorporated.

FIGURE 26. WIRE TERMINAL CONNECTORS (LUGS) (CONTINUED



STUD SIZE	METRIC SIZE MM
4	2.8
6	3.5
8	4.2
10	4.8
14	6.1
1/4	6.4

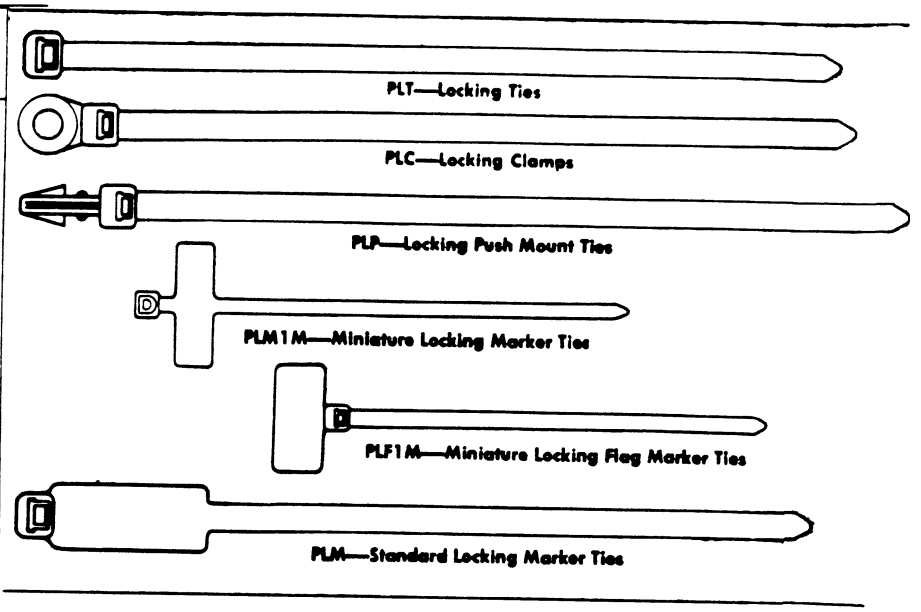
STUD SIZE	METRIC SIZE MM
5/16	7.9
3/8	9.5
1/2	12.7

FIGURE 27. CABLE TIES, TIE MOUNTS, AND SPIRAL WRAP

PAN-TY® ONE PIECE CABLE TIES, CLAMPS, PUSH MOUNT TIES & MARKERS

PL Self-Locking Ties — Tool or Hand Installed

Part Number†	Max. Bundle Dia.	Approx. Length (Inches)
PLT1M-CP	¾"	4
PLT1.5M-CP	1¼"	5½
PLT1.5I-CP	1¼"	5½
PLT2M-CP	2"	8
PLT2I-CP	2"	8
PLT2S-CP	1¾"	7¼
PLT3I-CP	3"	11½
PLT3S-CP	3"	11½
PLT4I-CP	4"	14½
PLT4S-CP	4"	14½
PLT4H-LP	4"	14½
PLT8H-LP	9"	30⅝
PLC1M-S4-CP	¾"	4⅜
PLC1.5I-S8-CP	1¼"	6⅜
PLC2S-S6-CP	1¾"	7½
PLC2S-S10-CP	1¾"	7½
PLC4H-S25-LP	4"	15¼
PLP1.5I-CP	1¼"	6
PLP2S-CP	1¾"	7¾
PLM1M-CP	¾"	4
PLF1M-CP	¾"	4⅜
PLM2S-CP	1¾"	7¼
PLM4S-CP	4"	14½



STA-STRAP® CABLE TIES, CLAMPS & MARKERS

Hand or Tool Installed — Releasable Prior to Tightening

Part Number†	Max. Bundle Dia.	Approx. Length (Inches)
SST1M-CP	¾"	4
SST1.5M-CP	1¼"	5½
SST1.5I-CP	1¼"	5½
SST1.5S-CP	1¼"	5¾
SST2I-CP	2"	8⅛
SST2S-CP	1¾"	6¾
SST2H-LP	2"	8
SST3I-CP	3"	11
SST3S-CP	3"	11
SST4I-CP	4"	14¾
SST4S-CP	4"	15
SST4H-LP	4"	14¾
SST8H-LP	8"	27½
SSC2S-S6-CP	1¾"	7⅞
SSC2S-S10-CP	1¾"	7⅞
SSC4S-S6-CP	4"	15⅞
SSC4S-S10-CP	4"	15⅞
SSC4H-S25-LP	4"	15⅞
SSM2S-CP	1¾"	6¾
SSM4S-CP	4"	14¾
SSB2S-C	‡	6¾

‡ Any two bundles up to approximately total diameter of 1¼".

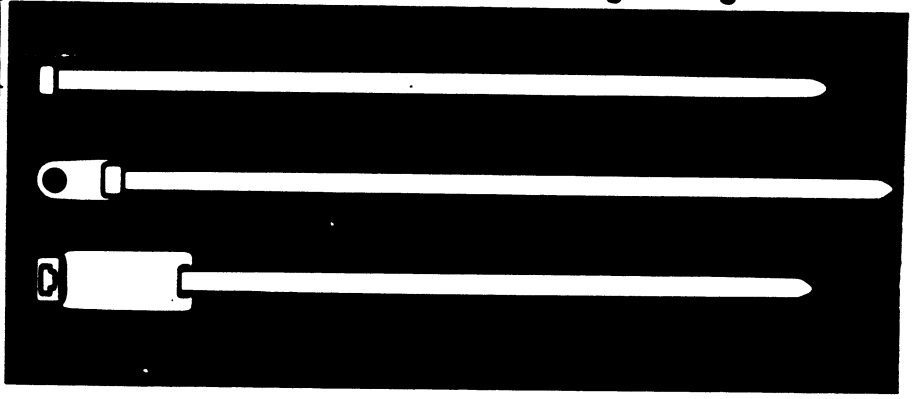


FIGURE 27. CABLE TIES, TIE MOUNTS, AND SPIRAL WRAP (CONTINUED)

PANDUIT CABLE TIE MOUNTING DEVICES

TM Mount

TMEH Mount

TA1 Mount

Part Number	Used With These Cable Ties†	Screw Hole Size
TM1S4-C TM1S6-C TM1A-C	M M M	#4 #6 Ad-hesive▲
TM2S6-C TM2S8-C TM2R6-C TM2A-C	M, I, S M, I, S M, I, S M, I, S	#6 #8 #6 Rivet Ad-hesive▲
TM3S8-C TM3S10-C TM3S25-C TM3R6-C TM3A-C	M, I, S, H● M, I, S, H● M, I, S, H● M, I, S, H● M, I, S, H●	#8 #10 ¼" #6 Rivet Ad-hesive▲
TMEH-S8-QO TMEH-S10-QO TMEH-S25-QO	All All All	#8 #10 ¼"
TA1S8-C TA1S10-C	M, I, S M, I, S	#8 #10

TA2 Mount

TP Mount

CR Connector Ring

CROS Connector Ring, Open

PM2H25 Push Mount

SCMS-P Swivel Clip-on Mount

TA2-C	M, I, S	—
TP2-C TP4H-C	M, I, S M, I, S, H●	#10 ¼"
CR2-C CR4H-C CROS-C◆	I, S H● M, I, S	— — —
PM2H25-C‡	S	—
SCMS-P-X††	M, I, S	—

SPIRAL WRAPPING — SPIRALLY CUT PLASTIC TUBING

(Package Includes Spiral Wrapping Tool at No Additional Cost)

SPIRAL WRAPPING

SPIRAL WRAPPING TOOL

Part Number System

T12 F

Type & Size — Material

Materials: F — Polyethylene (Clear)
R — Flame Retardant Polyethylene (White)
N — Nylon, Heat Stabilized (Clear)

Part Number
T12F T12R T12N

⅛" O.D. SPIRAL WRAPPING Bundle Range 1/16" to ½" Diam.

Part Number
T25F T25FM T25R T25RM T25N T25NM

¼" O.D. SPIRAL WRAPPING Bundle Range 3/16" to 2" Diam.

Part Number
T50F T50R T50N

¾" to 4" Diam. SPIRAL WRAPPING Bundle Range ½" O.D.

FIGURE 28. MACHINE SCREWS, HEAD STYLES

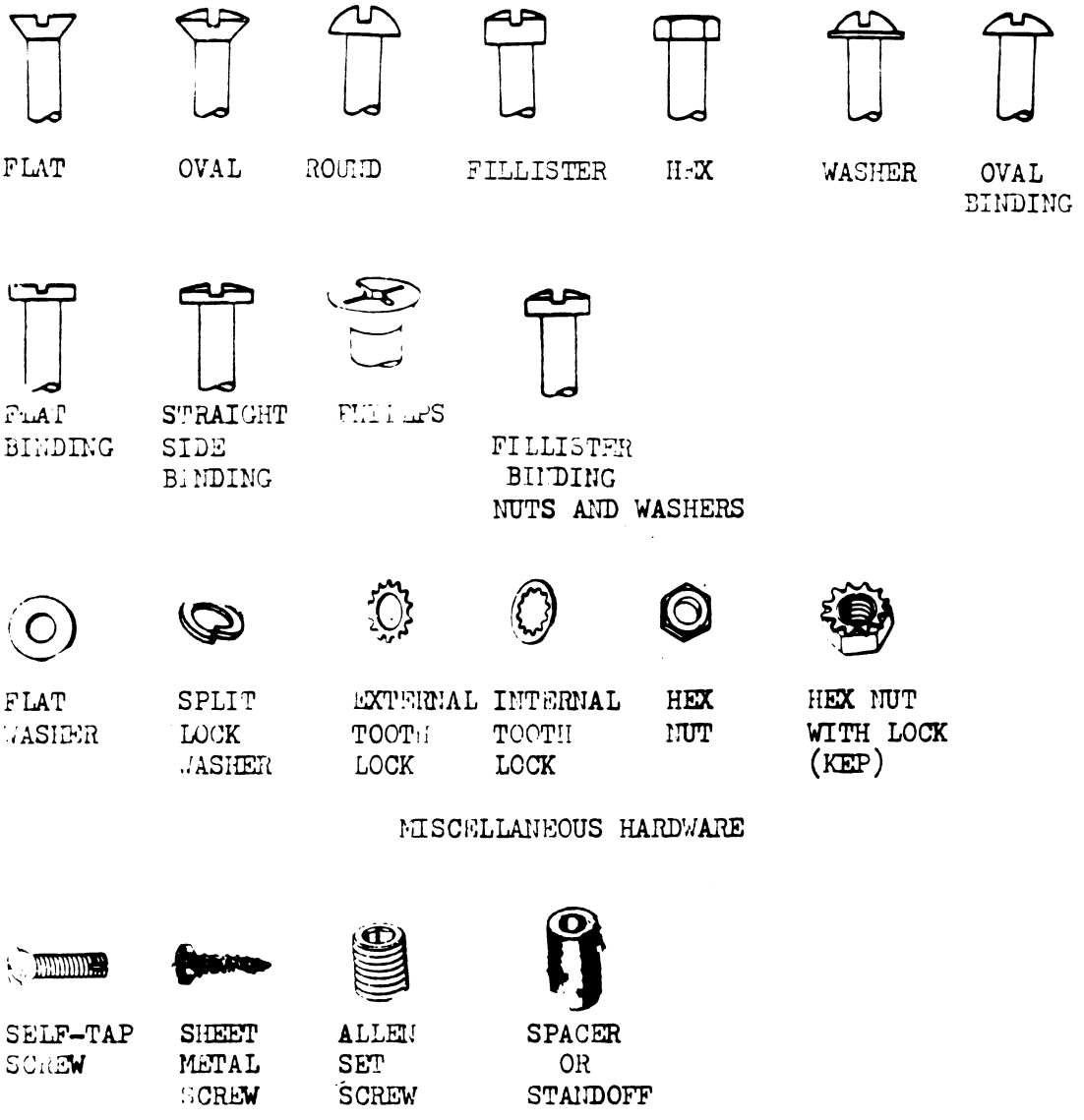
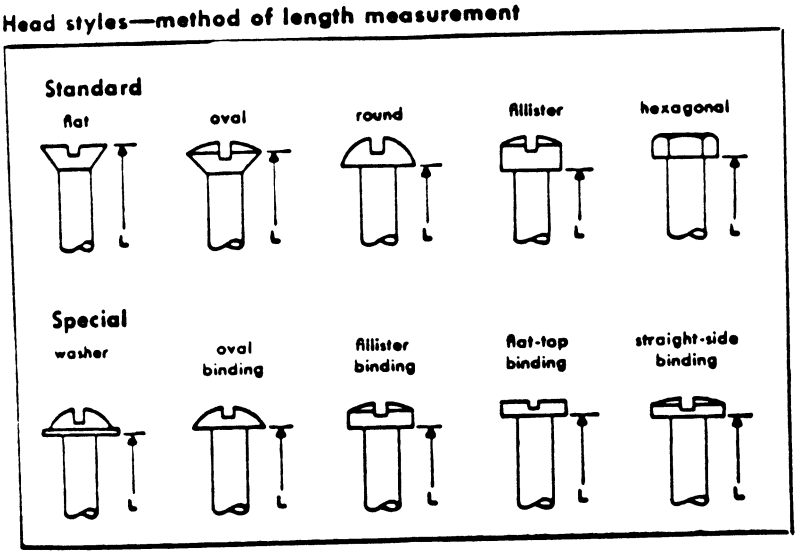


FIGURE 28. MACHINE SCREWS, HEAD STYLES (CONTINUED)

Head styles—method of length measurement



Dimensions and other data

screw		threads per inch		clearance drill*		tap drill†			head						hex nut			washer	
							diameter		round		flat	fillister							
no	dia	coarse	fine	no	dia	no	inches	mm	max OD	max height	max OD	max OD	max height	across flat	across corner	thick-ness	OD	ID
0	0.060	—	80	52	0.064	56	0.047	1.2	0.113	0.053	0.119	0.096	0.059	0.156	0.171	0.046	—	—
1	0.073	64	72	47	0.079	53	0.060	1.5	0.138	0.061	0.146	0.118	0.070	0.156	0.171	0.046	—	—
2	0.086	56	64	42	0.094	50	0.070	1.8	0.162	0.070	0.172	0.140	0.083	0.187	0.205	0.062	1/4	0.093
3	0.099	48	—	37	0.104	47	0.079	2.0	0.187	0.078	0.199	0.161	0.095	0.187	0.205	0.062	1/4	0.105
		—	56			45	0.082	2.1										
4	0.112	40	—	31	0.120	43	0.089	2.3	0.211	0.086	0.225	0.183	0.107	0.250	0.275	0.093	5/16	0.125
		—	48			42	0.094	2.4										
5	0.125	40	—	29	0.136	38	0.102	2.6	0.236	0.095	0.252	0.205	0.120	0.312	0.344	0.109	3/8	0.140
		—	44			37	0.104	2.6										
6	0.138	32	—	27	0.144	36	0.107	2.7	0.260	0.103	0.279	0.226	0.132	0.312	0.344	0.109	5/16	0.156
		—	40			33	0.113	2.9									3/8	
8	0.164	32	—	18	0.170	29	0.136	3.5	0.309	0.119	0.332	0.270	0.156	0.344	0.373	0.125	3/8	0.186
		—	36			29	0.136	3.5									7/16	
10	0.190	24	—	9	0.196	25	0.150	3.8	0.359	0.136	0.385	0.313	0.180	0.375	0.413	0.125	7/16	0.218
		—	32			21	0.159	4.0									1/2	
12	0.216	24	—	2	0.221	16	0.177	4.5	0.408	0.152	0.438	0.357	0.205	0.437	0.488	0.156	1/2	0.250
		—	28			14	0.182	4.6									9/16	
¼	0.250	20	—	—	17/64	7	0.201	5.1	0.472	0.174	0.507	0.414	0.237	0.437	0.488	0.203	9/16	0.281
		—	28			3	0.213	5.5						0.500	0.577	0.250	5/8	

All dimensions in inches except where noted.

* Clearance-drill sizes are practical values for use of the engineer or technician doing his own shop work.

† Tap-drill sizes are for use in hand tapping material such as brass or soft steel. For copper, aluminum, Norway iron, cast iron, bakelite, or for very thin material, the drill should be a size or two larger diameter than shown.

FIGURE 29. SHEET METAL GAUGES

Systems in use

Materials are customarily made to certain gauge systems. While materials can usually be had specially in any system, some usual practices are shown below.

material	sheet	wire
Aluminum	B&S	AWG (B&S)
Brass, bronze, sheet	B&S	—
Copper	B&S	AWG (B&S)
Iron, steel, band and hoop	BWG	—
Iron, steel, telephone and telegraph wire	—	BWG
Steel wire, except telephone and telegraph	—	W&M
Steel sheet	US	—
Tank steel	BWG	—
Zinc sheet	"Zinc gauge" proprietary	—

Comparison of gauges

The following table gives a comparison of various sheet-metal-gauge systems. Thickness is expressed in decimal fractions of an inch.

gauge	AWG B&S	Birmingham or Stubs BWG	Wash. & Moen W&M	British standard NBS SWG	London or old English	United States standard US	American Standard preferred thickness
0000000	—	—	0.490	0.500	—	0.50000	—
000000	0.5800	—	0.460	0.464	—	0.46875	—
00000	0.5165	—	0.430	0.432	—	0.43750	—
0000	0.4600	0.454	0.3938	0.400	0.454	0.40625	—
000	0.4096	0.425	0.3625	0.372	0.425	0.37500	—
00	0.3648	0.380	0.3310	0.348	0.380	0.34375	—
0	0.3249	0.340	0.3065	0.324	0.340	0.31250	—
1	0.2893	0.300	0.2830	0.300	0.300	0.28125	—
2	0.2576	0.284	0.2625	0.276	0.284	0.265625	—
3	0.2294	0.259	0.2437	0.252	0.259	0.250000	0.224
4	0.2043	0.238	0.2253	0.232	0.238	0.234375	0.200
5	0.1819	0.220	0.2070	0.212	0.220	0.218750	0.180
6	0.1620	0.203	0.1920	0.192	0.203	0.203125	0.160
7	0.1443	0.180	0.1770	0.176	0.180	0.187500	0.140
8	0.1285	0.165	0.1620	0.160	0.165	0.171875	0.125
9	0.1144	0.148	0.1483	0.144	0.148	0.156250	0.112
10	0.1019	0.134	0.1350	0.128	0.134	0.140625	0.100
11	0.09074	0.120	0.1205	0.116	0.120	0.125000	0.090
12	0.08081	0.109	0.1055	0.104	0.109	0.109375	0.080
13	0.07196	0.095	0.0915	0.092	0.095	0.093750	0.071
14	0.06408	0.083	0.0800	0.080	0.083	0.078125	0.063
15	0.05707	0.072	0.0720	0.072	0.072	0.0703125	0.056
16	0.05082	0.065	0.0625	0.064	0.065	0.0625000	0.050
17	0.04526	0.058	0.0540	0.056	0.058	0.0562500	0.045
18	0.04030	0.049	0.0475	0.048	0.049	0.0500000	0.040
19	0.03589	0.042	0.0410	0.040	0.040	0.0437500	0.036
20	0.03196	0.035	0.0348	0.036	0.035	0.0375000	0.032
21	0.02846	0.032	0.03175	0.032	0.0315	0.0343750	0.028
22	0.02535	0.028	0.02860	0.028	0.0295	0.0312500	0.025
23	0.02257	0.025	0.02580	0.024	0.0270	0.0281250	0.022
24	0.02010	0.022	0.02300	0.022	0.0250	0.0250000	0.020
25	0.01790	0.020	0.02040	0.020	0.0230	0.0218750	0.018
26	0.01594	0.018	0.01810	0.018	0.0205	0.0187500	0.016
27	0.01420	0.016	0.01730	0.0164	0.0187	0.0171875	0.014
28	0.01264	0.014	0.01620	0.0148	0.0165	0.0156250	0.012
29	0.01126	0.013	0.01500	0.0136	0.0155	0.0140625	0.011
30	0.01003	0.012	0.01400	0.0124	0.01372	0.0125000	0.010
31	0.008928	0.010	0.01320	0.0116	0.01220	0.01093750	0.009
32	0.007950	0.009	0.01260	0.0108	0.01120	0.01015625	0.008
33	0.007080	0.008	0.01180	0.0100	0.01020	0.00937500	0.007
34	0.006305	0.007	0.01040	0.0092	0.00950	0.00859375	0.006
35	0.005615	0.005	0.00950	0.0084	0.00900	0.00781250	—
36	0.005000	0.004	0.00900	0.0076	0.00750	0.007031250	—
37	0.004453	—	0.00850	0.0068	0.00650	0.006640625	—
38	0.003965	—	0.00800	0.0060	0.00570	0.006250000	—
39	0.003531	—	0.00750	0.0052	0.00500	—	—
40	0.003145	—	0.00700	0.0048	0.00450	—	—

FIGURE 30. WIRE (STRANDING AND OTHER DATA)

STANDARD WIRE STRANDINGS

A. W. GAUGE	O. D.	STRANDING
22	030	7/30
22	030	27/36
21	.034	19/.0071
20	037	7/28
20	035	10/30
18	046	7/ 0152
18	048	7/26
17	.054	7/25
16	.060	7/24
16	060	7/ 020
16	058	19/ 0117
16	058	26/30
15	067	7/.022
14	073	19/ 0147
13	085	7/21
12	096	7/20
7	162	7/ 054

WIRE CHART

Table of Standard Annealed Bare Copper Wire Using American Wire Gauge (B & S)

Gauge (AWG) or (B & S)	DIA.	AREA	WEIGHT	LENGTH	RESISTANCE AT 68° F		
	Inches (Nom.)	Circular Mils	Pounds per M'	Feet per Lb.	Ohms per M'	Feet per Ohm	Ohms per Lb.
0000	4600	211600	640 5	1 561	04901	20400	00007652
000	4096	167800	507 9	1 968	06180	16180	0001217
00	3648	133100	402 8	2 482	07793	12830	0001935
0	3249	105500	319 5	3 130	09827	10180	0003076
1	2893	83690	253 3	3 947	1239	8070	0004891
2	2576	66370	200 9	4 977	1563	6400	0007778
3	2294	52640	159 3	6 276	1970	5075	001237
4	2043	41740	126 4	7 914	2485	4025	001966
	250	62500	189 1	5 286	1659	6025	000877
5	1819	33100	100 2	9 980	3133	3192	003127
6	1620	26250	79 46	12 58	3951	2531	004972
7	1443	20820	63 02	15 87	4982	2007	007905
8	1285	16510	49 98	20 01	6282	1592	01257
	188	35344	106 98	9 425	2934	3407	00276
9	1144	13090	39 63	25 23	7921	1262	01999
10	1019	10380	31 43	31 82	9989	1001	03178
11	09074	8234	24 92	40 12	1 260	794	05053
12	08081	6530	19 77	50 59	1 588	629 6	08035
13	07196	5178	15 68	63 80	2 003	499 3	1278
14	06408	4107	12 43	80 44	2 525	396 0	2032
15	05707	3257	9 858	101 4	3 184	314 0	3230
16	05082	2583	7 818	127 9	4 016	249 0	5136
17	04576	2048	6 200	161 3	5 064	197 5	8167
18	04030	1624	4 917	203 4	6 385	156 5	1 299
19	03589	1288	3 899	256 5	8 051	124 2	2 065
20	03196	1022	3 092	323 4	10 15	98 5	3 283
21	02846	810 1	2 452	407 8	12 80	78 11	5 221
22	02535	642 4	1 945	514 2	16 14	61 95	8 301
23	02257	509 5	1 542	648 4	20 36	49 13	13 20
24	02010	404 0	1 223	817 7	25 67	38 96	20 99
26	01790	320 4	9699	1031	32 37	30 90	33 37
26	01594	254 1	7692	1300	40 81	24 50	53 06
27	01420	201 5	6100	1639	51 47	19 43	84 37
28	01264	159 8	4837	2067	64 90	15 41	134 2
29	01126	126 7	3836	2607	81 83	12 22	213 3
30	01003	100 5	3042	3287	103 2	9 691	339 2
31	008928	79 7	2413	4145	130 1	7 685	539 3
32	007950	63 21	1913	5227	164 1	6 095	857 6
33	007080	50 13	1517	6591	206 9	4 833	1364
34	006305	39 75	1203	8310	260 9	3 833	2168
35	005615	31 52	09542	10480	329 0	3 040	3448
36	005000	25 00	07568	13210	414 8	2 411	5482
37	004453	19 83	06001	16660	523 1	1 912	8717
38	003965	15 72	04759	21010	659 6	1 516	13860
39	003531	12 47	03774	26500	831 8	1 202	22040
40	003145	9 888	02993	33410	1049	0 9534	35040
41	00280	7 8400	02373	42140	1323	7559	55750
42	00249	6 2001	01877	53270	1673	5977	89120
43	00222	4 9284	01492	67020	2104	4753	141000
44	00197	3 8809	01175	85100	2672	3743	227180
45	00176	3 0976	00938	106600	3348	2987	356890
46	00157	2 4649	00746	134040	4207	2377	563900

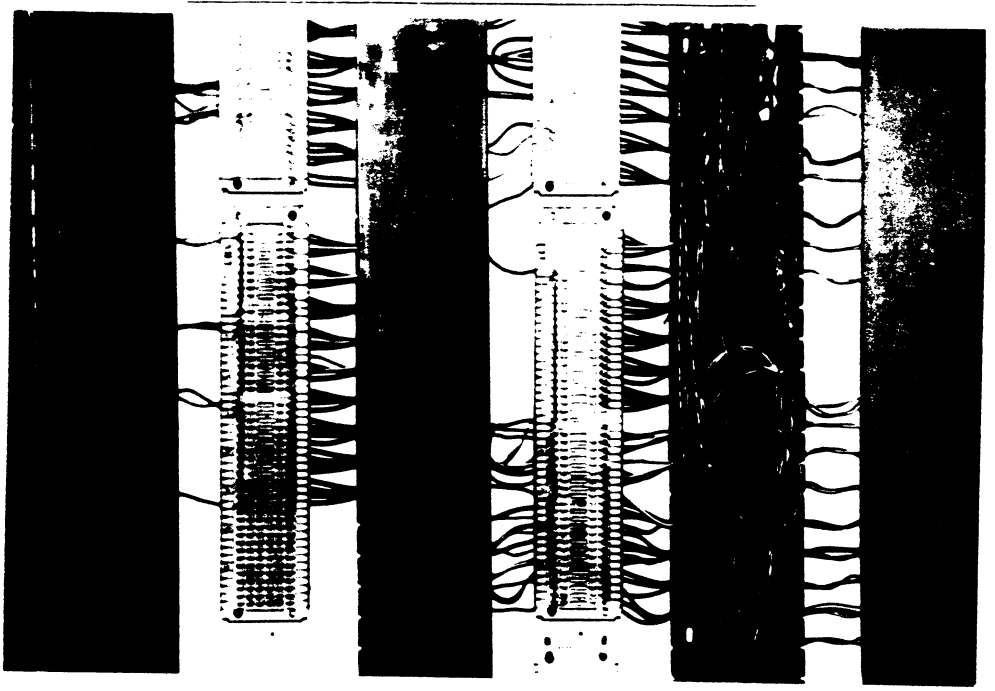
FIGURE 31. DRILL SIZES

drill	inches	drill	inches	drill	inches	drill	inches	drill	inches
0.10 mm	0.003937	1.75 mm	0.068897	4.30 mm	0.169291	7.40 mm	0.291338	15.00 mm	0.590550
0.15 mm	0.005905	no 50	0.070000	no 18	0.169500	ltr M	0.295000	15/64 in	0.593750
0.20 mm	0.007874	1.80 mm	0.070866	11/64 in	0.171875	7.50 mm	0.295275	39/64 in	0.609375
0.25 mm	0.009842	1.85 mm	0.072834	no 17	0.173000	19/64 in	0.296875	15.50 mm	0.610235
0.30 mm	0.011811	no 49	0.073000	4.40 mm	0.173228	7.60 mm	0.299212	5/8 in	0.625000
no 80	0.013000	1.90 mm	0.074803	no 16	0.177000	ltr N	0.302000	16.00 mm	0.629920
no 79 1/2	0.013500	no 48	0.076000	4.50 mm	0.177165	7.70 mm	0.303149	41/64 in	0.640625
0.35 mm	0.013779	1.95 mm	0.076771	no 15	0.180000	7.75 mm	0.305117	16.50 mm	0.649605
no 79	0.014000	5/64 in	0.078125	4.60 mm	0.181102	7.80 mm	0.307086	21/32 in	0.656250
no 78 1/2	0.014500	no 47	0.078500	no 14	0.182000	7.90 mm	0.311023	17.00 mm	0.669290
no 78	0.015000	2.00 mm	0.078740	no 13	0.185000	5/16 in	0.312500	43/64 in	0.671875
1/64 in	0.015625	2.05 mm	0.080708	4.70 mm	0.185039	8.00 mm	0.314960	11/16 in	0.687500
0.40 mm	0.015748	no 46	0.081000	4.75 mm	0.187007	ltr O	0.316000	17.50 mm	0.688975
no 77	0.016000	no 45	0.082000	3/16 in	0.187500	8.10 mm	0.318897	45/64 in	0.703125
0.45 mm	0.017716	2.10 mm	0.082677	4.80 mm	0.188976	8.20 mm	0.322834	18.00 mm	0.708660
no 76	0.018000	2.15 mm	0.084645	no 12	0.189000	ltr P	0.323000	23/32 in	0.718750
0.50 mm	0.019685	no 44	0.086000	no 11	0.191000	8.25 mm	0.324802	18.50 mm	0.728345
no 75	0.020000	2.20 mm	0.086614	4.90 mm	0.192913	8.30 mm	0.326771	47/64 in	0.734375
no 74 1/2	0.021000	2.25 mm	0.088582	no 10	0.193500	21/64 in	0.328125	19.00 mm	0.748030
0.55 mm	0.021653	no 43	0.089000	no 9	0.196000	8.40 mm	0.330708	3/4 in	0.750000
no 74	0.022000	2.30 mm	0.090551	5.00 mm	0.196850	ltr Q	0.332000	49/64 in	0.765625
no 73 1/2	0.022500	2.35 mm	0.092519	no 8	0.199000	8.50 mm	0.334645	19.50 mm	0.767715
no 73	0.023000	no 42	0.093500	5.10 mm	0.200787	8.60 mm	0.338582		
0.60 mm	0.023622	3/32 in	0.093750	no 7	0.201000	ltr R	0.339000	25/32 in	0.781250
no 72	0.024000	2.40 mm	0.094488	13/64 in	0.203125	8.70 mm	0.342519	20.00 mm	0.787400
no 71 1/2	0.025000	no 41	0.096000	no 6	0.204000	11/64 in	0.343750	51/64 in	0.796875
0.65 mm	0.025590	2.45 mm	0.096456	5.20 mm	0.204724	8.75 mm	0.344487	20.50 mm	0.807085
no 71	0.026000	no 40	0.098000	no 5	0.205500	8.80 mm	0.344476	13/16 in	0.812500
no 70	0.027000	2.50 mm	0.098425	5.25 mm	0.206692	ltr S	0.348000	21.00 mm	0.826770
0.70 mm	0.027559	no 39	0.099500	5.30 mm	0.208661	8.90 mm	0.350393	53/64 in	0.828125
no 69 1/2	0.028000	no 38	0.101500	no 4	0.209000	9.00 mm	0.354330	27/32 in	0.843750
no 69	0.029000	2.60 mm	0.102362	5.40 mm	0.212598	ltr T	0.358000	21.50 mm	0.846455
no 68 1/2	0.029250	no 37	0.104000	no 3	0.213000	9.10 mm	0.358767	55/64 in	0.859375
0.75 mm	0.029527	2.70 mm	0.106299	5.50 mm	0.216535	27/64 in	0.359375	22.00 mm	0.866140
no 68	0.030000	no 36	0.106500	7/32 in	0.218750	9.20 mm	0.362204	7/8 in	0.875000
no 67	0.031000	2.75 mm	0.108267	5.60 mm	0.220472	9.25 mm	0.364172	22.50 mm	0.885825
1/32 in	0.031250	7/64 in	0.109375	no 2	0.221000	9.30 mm	0.366141	57/64 in	0.890625
0.80 mm	0.031496	no 35	0.110000	5.70 mm	0.224409	ltr U	0.368000	23.00 mm	0.905510
no 66	0.032000	2.80 mm	0.110236	5.75 mm	0.226377	9.40 mm	0.370078	29/32 in	0.906250
no 65	0.033000	no 34	0.111000	no 1	0.228000	9.50 mm	0.374015	59/64 in	0.921875
0.85 mm	0.033464			5.80 mm	0.228346	3/8 in	0.375000	23.50 mm	0.925195
no 64	0.035000	no 33	0.113000	5.90 mm	0.232283	ltr V	0.377000	15/16 in	0.937500
0.90 mm	0.035433	2.90 mm	0.114173	ltr A	0.234000	9.60 mm	0.377952	24.00 mm	0.944880
no 63	0.036000	no 32	0.116000	15/64 in	0.234375	9.70 mm	0.381889	61/64 in	0.953125
no 62	0.037000	3.00 mm	0.118110	6.00 mm	0.236220	9.75 mm	0.383857	24.50 mm	0.964565
0.95 mm	0.037401	no 31	0.120000	ltr B	0.238000	9.80 mm	0.385826	31/32 in	0.968750
no 61	0.038000	3.10 mm	0.122047	6.10 mm	0.240157	ltr W	0.386000	25.00 mm	0.984250
no 60 1/2	0.039000	1/8 in	0.125000	ltr C	0.242000	9.90 mm	0.389763	63/64 in	0.984375
1.00 mm	0.039370	3.20 mm	0.125984	6.20 mm	0.244094	25/64 in	0.390625	1 in	1.000000
no 60	0.040000	3.25 mm	0.127952	ltr D	0.246000	10.00 mm	0.393700		
no 59	0.041000	no 30	0.128500	6.25 mm	0.246062	ltr X	0.397000		
1.05 mm	0.041338	3.30 mm	0.129921	6.30 mm	0.248031	ltr Y	0.404000		
no 58	0.042000	3.40 mm	0.133858	ltr E	0.250000	13/32 in	0.406250		
no 57	0.043000	no 29	0.136000	1/4 in		ltr Z	0.413000		
1.10 mm	0.043307	3.50 mm	0.137795	6.40 mm	0.251968	10.50 mm	0.413385		
1.15 mm	0.045275	no 28	0.140500	6.50 mm	0.255905	27/64 in	0.421875		
no 56	0.046500	9/64 in	0.140625	ltr F	0.257000	11.00 mm	0.433070		
1/16 in	0.046875	3.60 mm	0.141732	6.60 mm	0.259842	7/16 in	0.437500		
1.20 mm	0.047244	no 27	0.144000	ltr G	0.261000	11.50 mm	0.452755		
1.25 mm	0.049212	3.70 mm	0.145669	6.70 mm	0.263779	29/64 in	0.453125		
1.30 mm	0.051181	no 26	0.147000	17/64 in	0.265625	15/32 in	0.468750		
no 55	0.052000	3.75 mm	0.147637	6.75 mm	0.265747	12.00 mm	0.472440		
1.35 mm	0.053149	no 25	0.149500	ltr H	0.266000	31/64 in	0.484375		
no 54	0.055000	3.80 mm	0.149606	6.80 mm	0.267716	12.50 mm	0.492125		
1.40 mm	0.055118	no 24	0.152000	6.90 mm	0.271653	1/2 in	0.500000		
1.45 mm	0.057086	3.90 mm	0.153543	ltr I	0.272000	13.00 mm	0.511810		
1.50 mm	0.059055	no 23	0.154000	7.00 mm	0.275590	33/64 in	0.515625		
no 53	0.059500	5/32 in	0.156250	ltr J	0.277000	17/32 in	0.531250		
1.55 mm	0.061023	no 22	0.157000	7.10 mm	0.279527	13.50 mm	0.531495		
1/16 in	0.062500	4.00 mm	0.157480	ltr K	0.281000	35/64 in	0.546875		
1.60 mm	0.062992	no 21	0.159000	9/32 in	0.281250	14.00 mm	0.551180		
no 52	0.063500	no 20	0.161000	7.20 mm	0.283464	9/16 in	0.562500		
1.65 mm	0.064960	4.10 mm	0.161417	7.25 mm	0.285432	14.50 mm	0.570865		
1.70 mm	0.066929	no 19	0.166000	7.30 mm	0.287401	37/64 in	0.578125		
no 51	0.067000	4.25 mm	0.167322	ltr L	0.290000				

Installation of Demarcation

Completed Demarcation

FIGURE 32. DEMARCATIONS (CONTINUED)



Installation of Demarcation

Completed Demarcation

FIGURE 32. DEMARCATIONS (CONTINUED)

ICSS Equipment Racks and DEMARC Wall

SELMAN Block Installation Inside Racks

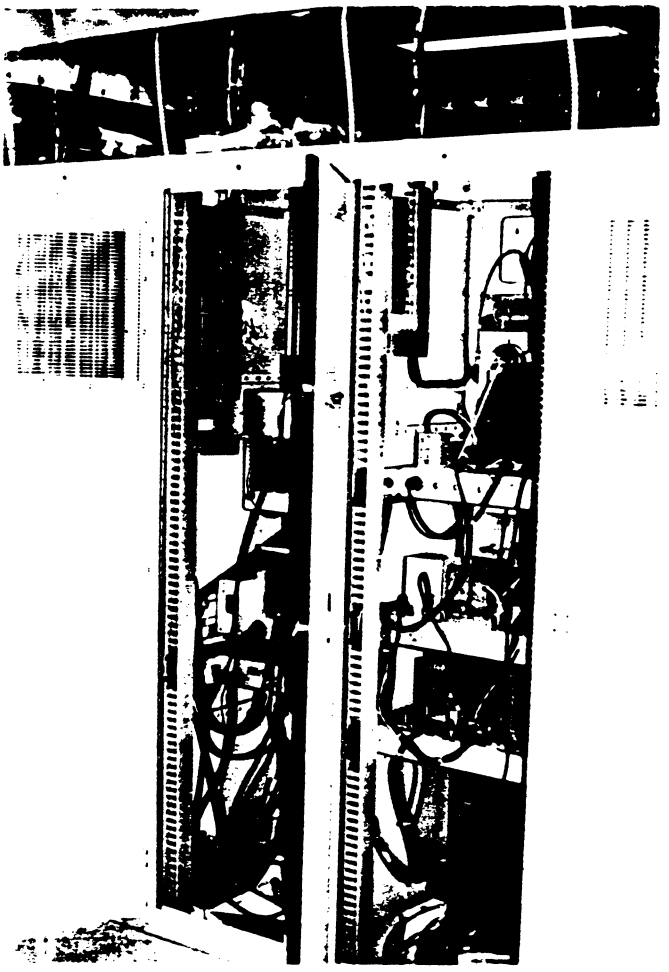
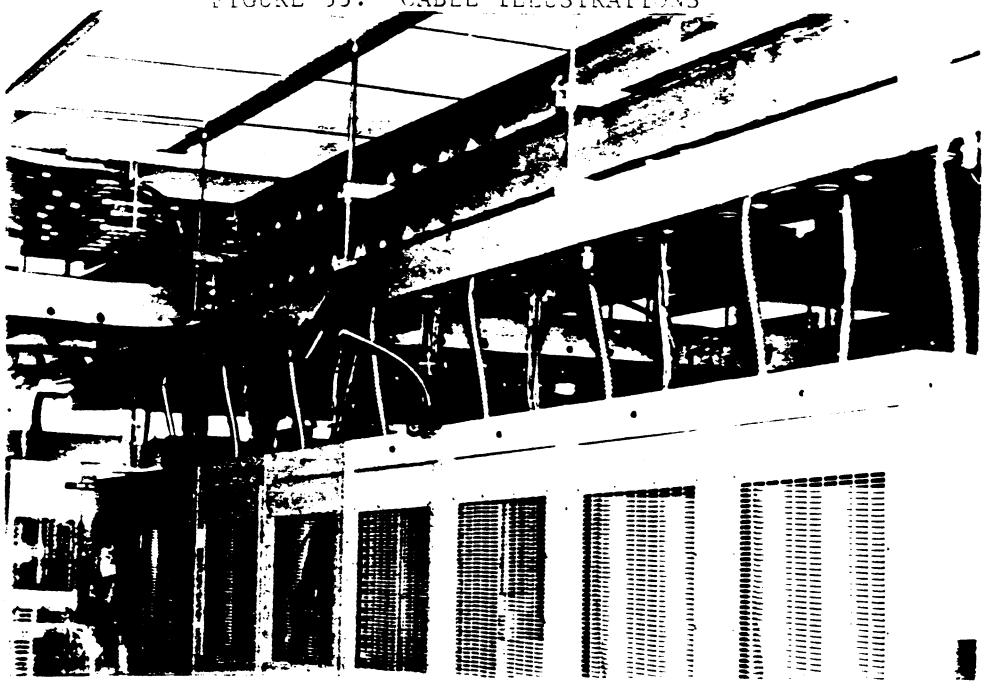
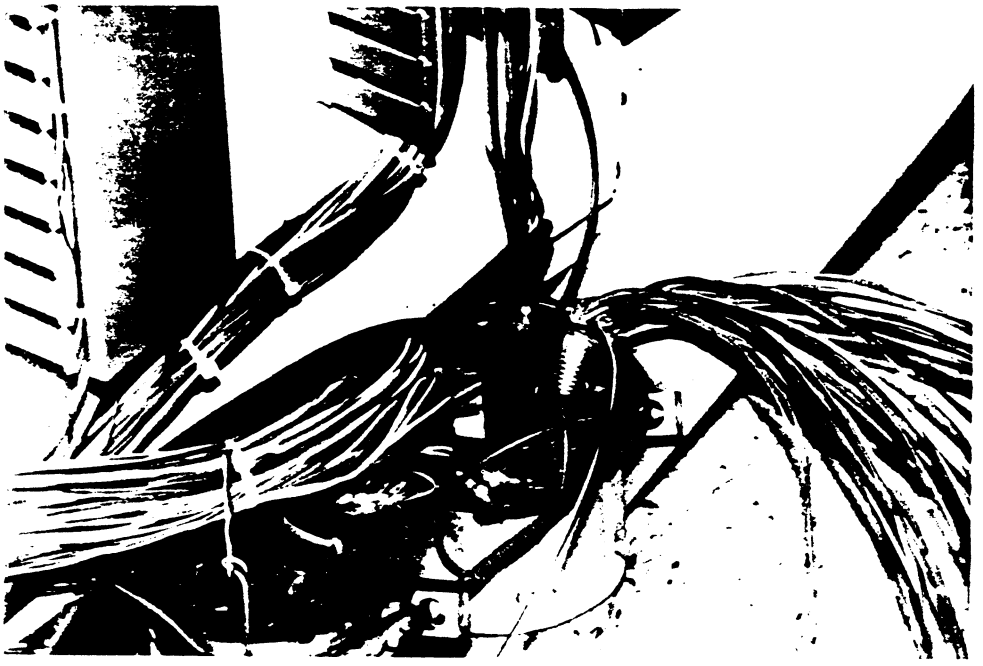


FIGURE 33. CABLE ILLUSTRATIONS



Square Duct - Rack Cable Interconnect



Field Cable Entrance (into building)

FIGURE 33. CABLE ILLUSTRATIONS (CONTINUED)

Bottom Views of Overhead Cable Trays