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MIL-HDBK-116
30 JUNE 1989

# MILITARY HANDBOOK

# ENVIRONMENTAL CONTROL OF SMALL SHELTERS

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Environmental Control of Small Shelters

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3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: USA Belvoir Research, Development and Engineering Center, ATTN: STRBE-TSE, Fort Belvoir, VA 22060-5606 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

# FOREWORD

It is essential that environmental control requirements be considered in conjunction with the planning for all other equipment to be installed in a shelter. Just two important examples of this are: planning the use of shelter space that the ECU and ducting must share with operational equipment and the need to assure compatibility of demands for electrical power for the ECU and other equipment in terms of voltage, phase, and frequency.

This handbook is intended to assist with the proper inclusion of environmental control considerations in overall shelter utilization planning by providing a quick and easy method of estimating cooling and heating requirements and selecting from the military standard environmental control units the unit most suited to the purpose.

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# CHAPTER 1

# INTRODUCTION

1.1 Introduction. This handbook provides the non-heating and air conditioning engineer basic information needed to determine cooling and heating equipment requirements for standard military shelters.

1.2 Scope. The content addresses procedures for determining the type and size of environmental control units (ECU) required, methods for installing ECU's, and distribution of conditioned air in shelters. Nuclear, biological, and chemical (NBC) equipment and its use with the ECU and steps that might help the ECU to survive and function in an NBC environment are also addressed briefly.

1.3 General parameters. Coverage of the handbook is defined by:

a. Shelters considered. The Standard Family of Tactical Shelters (appendix A, reference 15) was used to determine ECU requirements. Table I includes examples covering a representative range of sizes and structural types of shelters extracted from reference 15.

b. ECU's considered. Only standard military compact ECU's, four Navy adaptations of commercial ECU's and an Air Force ECU are recommended. The military compact units are included in MIL-A-52767 and MIL-STD-1408; the Navy ECU's are in Navy Technical Manual NAVAIR 19-60-83; and the Air Force unit in MIL-A-83216. ECU descriptive data from these references are in Table II.

c. Climatic conditions and categories. Table III provides the world temperatures and humidities by the climatic categories agreed to in QSTAG-360 (appendix A, reference 8). The locations of the world in which these conditions are found are shown in figure 1-1. These data are necessary in determining the required ECU capacity.

1.4 Referenced documents. Appendix A lists major source documents, including all documents referenced in the text of the handbook.

1.5 Definitions. Definitions, explanations, and illustrations of terms used in the handbook are included in appendix B.

1.6 Use of handbook. This handbook is a guide. It contains the basic information needed to determine heating and air conditioning requirements for military shelters, with supplemental and supporting information in appendices. However, you may encounter complex problems which will require professional assistance or reference to appropriate technical publications. The handbook attempts to highlight where these instances might arise. If you should need help, appendix A, reference 2 is recommended as an initial source of information on environmental control. Specific points of contact for questions and assistance:

a. Relating to any aspect of this handbook:

Commander
U.S. Army Belvoir Research, Development and Engineering Center
Attention: STRBE-FES
Fort Belvoir, VA 22060-5606
Autovon: 345-3433; Commercial: (703) 664-3433.

b. Relating to mobile shelters and nuclear hardening of shelters:

Commander
U.S. Army Natick Research, Development and Engineering Center
Attention: STRNC-UST
Kansas Street
Natick, MA 01761-5107
Autovon: 256-5248; Commercial: (508) 651-5248.

c. Relating to NBC protective equipment and its applications:

Commander
U.S. Army Chemical Research, Development and Engineering Center
Attention: SMCCR-PPS
Aberdeen Proving Ground, MD 21010-5423
Autovon: 584-8427; Commercial: (301) 671-8427.

TABLE I. Standard small military shelters considered in this handbook.

| Designation | Service Sponsor | Nominal Outside Dimensions (HxWxL) (ft) | Inside Dimensions (HxWxL) (ft/in.) |
|---|---|---|---|
| Nonexpandable | | | |
| S250 | Army | 6 x 6½ x 7 | H: 5'4" in aisle<br>: 3'10" at side wall<br>W: 6'3" at top<br>: 3'8" at floor<br>L: 6'6" |
| S280 C/G | Army | 7½ x 7½ x 12 | 6'5" x 6'10" x 11'6" |
| ISO GP | Army | 8 x 8 x 20 | 7'1" x 7'7" x 19'1" |
| MF ISO [2] | Navy | 8 x 8 x 20 | 7'1" x 7'6" x 19'4" |
| Expandable | | | |
| S-530 A/G | Air Force | 7½ x 7½ x 12 (unexpanded) | Unexpanded:<br>6'9" x 6'7" x 11'5"<br>Expanded:[3]<br>6'9" x 19'9" x 11'5" |
| ISO, one side expandable | Army | 8 x 8 x 20 (Unexpanded) | Unexpanded:<br>7'1" x 6'5" x 19'1"<br>Expanded:<br>7'1" x 14'6" x 18'4" |
| ISO, two sides expandable | Army | 8 x 8 x 20 (Unexpanded) | Unexpanded:<br>7'1" x 6'0" x 19'1"<br>Expanded:<br>7'1" x 21'6" x 18'4" |

[1]The S280 B/G configuration has the same dimensions except for the height: nominal outside is 7-1/4' and inside is 6'2".

[2]The Navy MF ISO has three configurations:

1. Single unit basic mobile facility.
2. Side joining units A and B which join into a double unit.
3. Integration unit to which up to six single basic units can be attached, end on: one to each end and two to each side.

All MF ISO units have the same dimensions and the same thermal characteristics.

[3]Two shelters joined.

TABLE II. Standard military environmental control units.[1]

| Nominal Capacity (Btuh) | Rating (Btuh) | | Dimensions H x W x L (Inches) | Weight (lb) | Power | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Requirement | | | | | | | | | Consumption (KW) | |
| | | | | | Voltage | | | Phase | | Freq. (Hz) | | Wires | | | |
| | Cooling[2] | Heating | | | 115 | 208 | 230 | 1 | 3 | 50/60 | 400 | 3 | 4 | 50/60 Hz | 400 Hz |
| **Horizontal Configuration (Army)** | | | | | | | | | | | | | | | |
| 9,000 | 10,000 | 7,000 | $16\frac{1}{8} \times 23\frac{7}{8} \times 26\frac{1}{2}$ | 200 | X | | | X | | X | | X | | 3.2 | |
| | | | | | | | X | X | | X | | X | | 3.2 | |
| | | | | | | X | | | X | X | | | X | 3.0 | |
| | | | | | | X | | | X | | X | | X | | 3.1 |
| 18,000 | 18,500 | 14,300 | 20 x 30 x 28 | 290 | | | X | X | | X | | X | | 6.5 | |
| | | | | | | X | | | X | X | | | X | 6.5 | |
| | | | | | | X | | | X | | X | | X | | 6.5 |
| 36,000 | 41,000 | 31,200 | $29\frac{1}{8} \times 38\frac{1}{16} \times 35\frac{3}{16}$ | 435 | | X | | | X | X | | | X | 13.5 | |
| | | | | | | X | | | X | | X | | X | | 13.5 |
| 60,000 | 62,000 | 45,000 | $27\frac{1}{8} \times 44\frac{1}{8} \times 41\frac{3}{4}$ | 600 | | X | | | X | X | | | X | 14.0 | |
| | | | | | | X | | | X | | X | | X | | 18.0 |
| **Vertical Configuration (Army)** | | | | | | | | | | | | | | | |
| 6,000 | 6,300 | 4,500 | $28\frac{1}{4} \times 17 \times 17$ | 180 | X | | | X | | X | | X | | 2.2 | |
| | | | | | | X | | | X | | X | | X | | 2.6 |
| 9,000 | 9,350 | 6,000 | 32 x 17 x 17 | 200 | X | | | X | | X | | X | | 3.6 | |
| | | | | | | | X | X | | X | | X | | 3.4 | |
| | | | | | | X | | | X | X | | | X | 3.4 | |
| | | | | | | X | | | X | | X | | X | | 3.6 |
| 18,000 | 19,300 | 12,000 | $45\frac{5}{8} \times 17\frac{3}{4} \times 20$ | 270 | | X | | | X | X | | | X | 5.0 | |
| | | | | | | X | | | X | | X | | X | | 5.7 |
| 36,000 | 37,800 | 28,600 | $55\frac{1}{4} \times 30\frac{5}{8} \times 21\frac{1}{2}$ | 460 | | X | | | X | X | | | X | 8.5 | |
| | | | | | | X | | | X | | X | | X | | 10.5 |
| 60,000 | 60,000 | 47,000 | $65\frac{13}{16} \times 34\frac{5}{8} \times 23\frac{7}{8}$ | 620 | | X | | | X | X | | | X | 15.5 | |
| | | | | | | X | | | X | | X | | X | | 18.6 |
| **Vertical Configuration (Navy)[3]** | | | | | | | | | | | | | | | |
| 22,000 (HB022) | 22,000 | 21,000[4] | $72\frac{1}{4} \times 31\frac{1}{4} \times 12\frac{1}{2}$ | 270 | | 208/230 | | X | | 60 | | | | 10.6 | N/A |
| 34,000 (HB036) | 33,400 | 35,000[4] | $72\frac{1}{4} \times 39\frac{1}{4} \times 15$ | 432 | | 208/240 | | | X | 60 | | | | 16.0 | N/A |
| **Sleeve Mounted Configuration (Navy)[3]** | | | | | | | | | | | | | | | |
| 22,000 (HE022R &S) | 22,000 | 21,000[4] | $24\frac{1}{4} \times 31\frac{1}{4} \times 22\frac{1}{2}$ | 275 | | 208/230 | | X | | 60 | | | | 10.6 | N/A |
| 34,000 (HE036R &S) | 33,400 | 35,000[4] | $44 \times 39\frac{1}{4} \times 28\frac{1}{2}$ | 423 | | 208/240 | | | X | 60 | | | | 16.0 | N/A |
| **Ground Mounted (Air Force)** | | | | | | | | | | | | | | | |
| 54,000 | 54,000 | 32,400 | 32 x 48 x 67 | 940 | | 208/230 | | | X | | | | | 10.0 | |

[1]Sources of data are: MIL-A-52767 for Army ECU's; Navy TM, NAVAIR 19-00-83 for Navy units; and MIL-A-83216 for USAF unit.

[2]Cooling ratings for ECU's were determined under conditions specified in source documents cited in above footnote.

[3]See "Heat Pump" in appendix B.

[4]For installed supplementary heaters, see MIL-STD-1407.

TABLE III. High and low temperatures and relative humidities from characteristic diurnal cycle during hottest or coldest month of the year.[1]

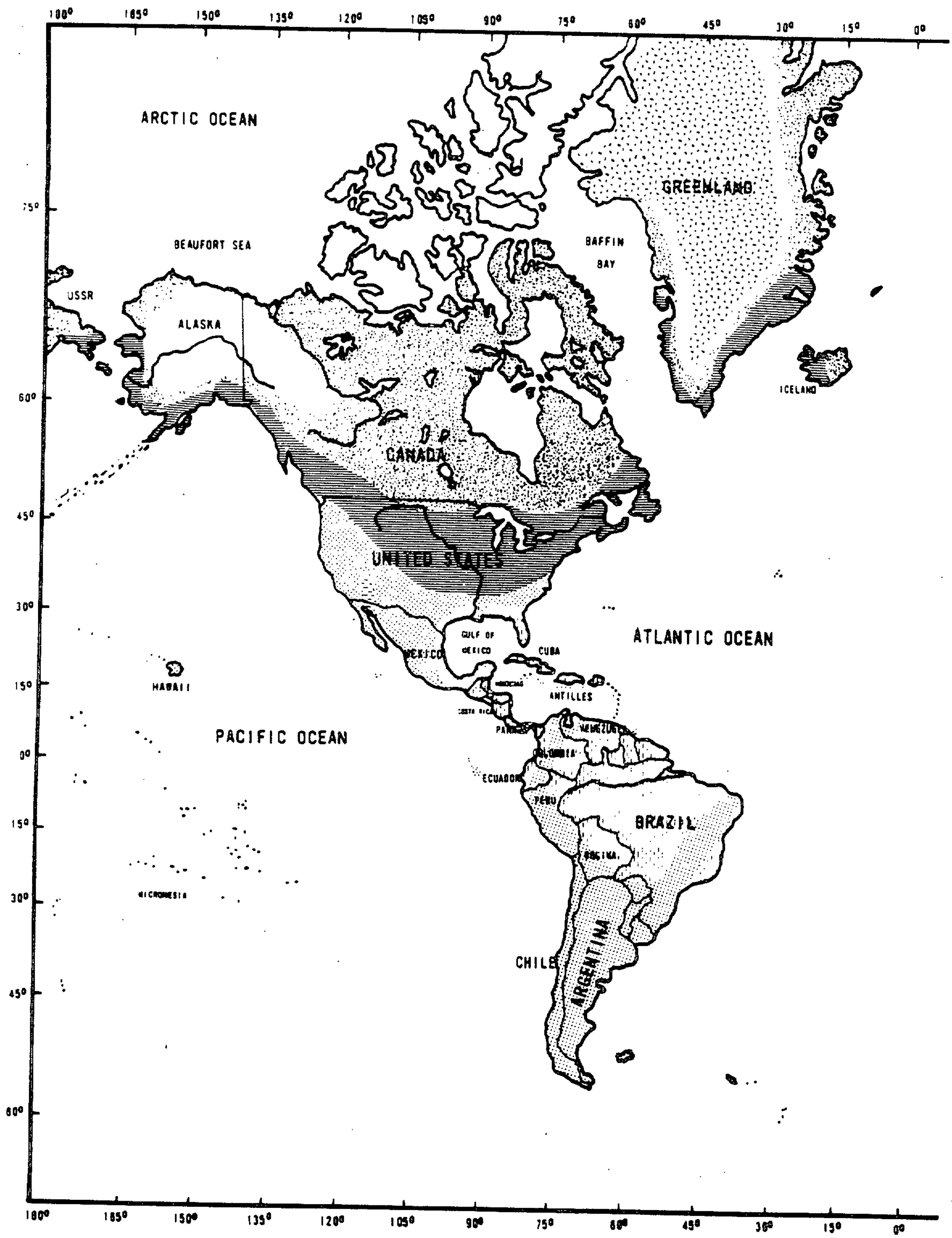
| Climatic Category[2] | Ambient Air Temperatures, °F (°C)[3] | | | Relative Humidity |
|---|---|---|---|---|
| | High | Low | Highest/Lowest Ever Recorded[4] | |
| A1 Hot dry | 120 (49) | 90 (32) | 136 (58) | 3% - 8% |
| A2 Intermediate hot dry | 111 (44) | 86 (30) | 127 (53) | 8% - 40% |
| B1 Wet warm | Nearly constant at 75 (24) throughout the 24 hours | | - | 95% - 100% |
| B2 Wet hot | 95 (35) | 79 (26) | - | 74% @ 95° (1500 hrs) 100% @ 79° (2400 - 0600 hrs) |
| B3 Humid hot coastal desert | 106 (41) | 88 (31) | - | 60% @ 106° (1500 hrs) 88% @ 88° (2400 - 0600 hrs) |
| CO Mild cold | 21 (-6) | -2 (-19) | -11 (-24) | Tending to saturation |
| C1 Intermediate cold | -6 (-21) | -24 (-31) | -44 (-42) | Tending to saturation |
| C2 Cold | -35 (-37) | -51 (-46) | -69 (-56) | Tending to saturation |
| C3 Severe cold | Nearly constant at -60 (-51) throughout the 24 hours | | - | Tending to saturation |
| C4 Extreme cold | Nearly constant at -71 (-57) throughout the 24 hours | | -96 (-71) | Tending to saturation |

[1]From appendix A, reference 8.

[2]See figure 1-1.

[3]For categories A1, A2, and CO through C4, temperature is the principal consideration. For categories B1, B2, and B3, humidity is the principal consideration. All temperatures are dry bulb readings.

[4]Highest temperature where heat is principal consideration and lowest where cold is principal consideration.


ARCTIC OCEAN
BEAUFORT SEA
USSR
ALASKA
GREENLAND
BAFFIN BAY
ICELAND
CANADA
UNITED STATES
GULF OF MEXICO
MEXICO
CUBA
ANTILLES
ATLANTIC OCEAN
PACIFIC OCEAN
HAWAII
MICRONESIA
VENEZUELA
COLOMBIA
ECUADOR
PERU
BRAZIL
BOLIVIA
CHILE
ARGENTINA

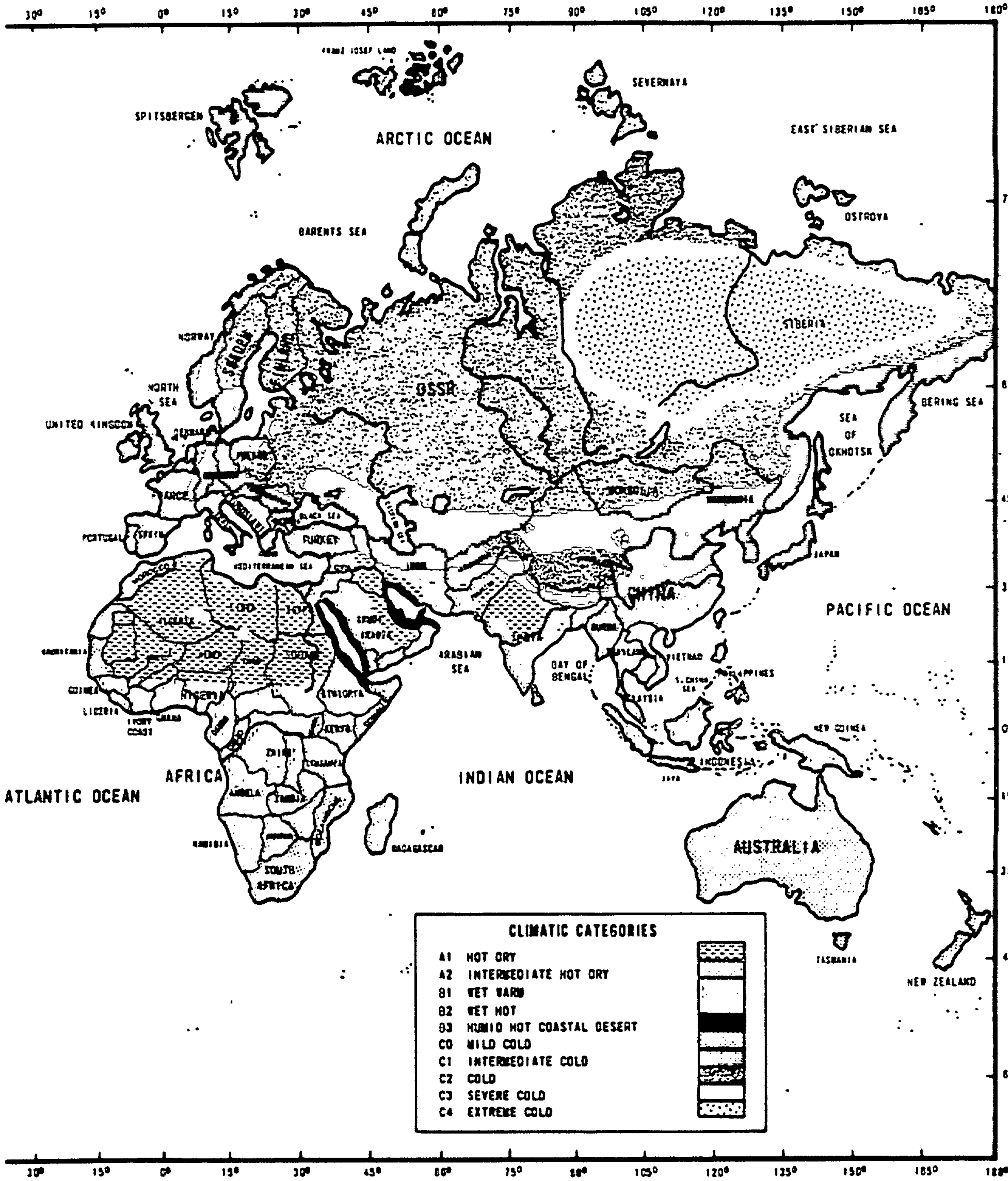



FIGURE 1-1. Location of climate categories. (includes facing page)

# CHAPTER 2

## SELECTION OF ENVIRONMENTAL CONTROL UNITS

2.1 Introduction. This chapter provides simple steps for selecting ECU's for standard, small, military shelters. These steps assist the user in:

a. Estimating the summer cooling requirement.

b. Estimating the winter heating requirement.

c. Selecting an adequate ECU.

d. Selecting an auxiliary heater, if one is needed.

This method will give acceptable results for most military systems under normal conditions. If the requirement calls for special conditions, such as precise humidity control, special engineering help may be needed.

2.2 Estimating the cooling requirement. Reproduce the Worksheet Part I-Cooling Requirement Estimate from appendix C. Fill in the data at the top of the sheet and follow steps 1 through 5 of the instructions. If planning for a B1 region (see figure 1-1) anticipating a worldwide (as opposed to a regional) application or planning that CB collective protection equipment will be required, read 2.3, 2.4, and 2.5 before starting on the worksheet.

2.3 Humidity control. Military ECU's are sometimes not satisfactory as dehumidifiers under conditions of high humidity. When confronted with a situation of very high humidity and not much cooling to be done, such as climatic category B1 with a nearly constant temperature of 75 °F, they cannot always handle the problem. This is reflected in table IV.

2.3.1 Dehumidifying incidental to cooling. Military ECU's are designed not for humidity control but primarily for sensible (dry) cooling. They cannot dehumidify unless they are also cooling; what dehumidification is accomplished is only incidental to the cooling process. Also, in a related problem, in high humidity the ECU evaporator coils, especially on some vertical configurations, experience water carryover problems and tend to throw water out of the return air louvers.

2.3.2 Adding humidity control capability. Humidity control needs humidistat control of cooling, a reheat capability roughly equal to cooling, and a reheat temperature control. Military ECU's do not have these. They would have to be provided by the user as add-ons, as required, and adding them to military ECU's is a difficult job. It requires extensive knowledge of psychrometrics, a familiarity with the internal circuitry of the equipment, precise load evaluation, and design experience with the necessary add-on features. All this is well beyond the scope of this handbook to cover. The job should be undertaken only by someone with the necessary expertise and a full and proven capability, ideally, the ECU's original manufacturer. If you need humidity control, it is recommended that you contact the U.S. Army Belvoir Research, Development and Engineering Center[1] or one or more of the leading manufacturers of air conditioners to discuss in specific terms any problems and requirements you may have with regard to the matter.

TABLE IV. Estimating data for cooling and heating requirements.

| A | B | C | D |
|---|---|---|---|
| STANDARD SHELTER DESIGNATION | SHELTER SIZE (HxWxL) (FT.) | SUMMER SOLAR & CONDUCTION HEAT GAIN (BTUH) | WINTER CONDUCTION HEAT LOSS (BTUH) |
| Non-Expandable: | | | |
| Army S-250 | 6x6½x7 | 3,750 | 6,200 |
| Army S-280[1] | 7½x7½x12 | 7,060 | 11,580 |
| Navy MF ISO[2] (Single) | 8x8x20 | 8,272 | 13,440 |
| Navy MF ISO (Double) | 8x16x20 | 12,984 | 21,280 |
| ISO Army CP | 8x8x20 | 11,630 | 18,820 |
| Expandable: | | | |
| Air Force S-520 | 7½x22x12 | 15,830 | 25,430 |
| ISO Army 1 side expandable | 8x15x20 | 17,580 | 28,420 |
| ISO Army 2 sides expandable | 8x22x20 | 23,640 | 38,020 |

| E | F | | G | H |
|---|---|---|---|---|
| SUMMER COOLING FACTOR | WINTER HEATING FACTOR | CLIMATIC CATEGORIES | SUMMER VENTILATION HEAT GAIN (BTUH/CFM) | WINTER VENTILATION HEAT LOSS (BTUH/CFM) |
| 1.49 | 1.00 | A1 HOT DRY | 46 | 76 |
| 1.31 | 1.00 | A2 MOD HOT DRY | 34 | 76 |
| NA | 1.00 | B1 WET WARM | NA | 76 |
| 1.00 | 1.00 | B2 WET HOT | 100 | 76 |
| 1.26 | 1.00 | B3 HUMID HOT | 124 | 76 |
| 1.31 | 1.00 | C0 MILD COLD | 39 | 76 |
| 1.00 | 1.36 | C1 MOD COLD | 39 | 104 |
| 1.00 | 1.71 | C2 COLD | 39 | 131 |
| 1.00 | 1.86 | C3 SEVERE COLD | 39 | 141 |
| 1.00 | 2.00 | C4 EXTREME COLD | 39 | 152 |

Notes: a. Baseline temperatures inside shelters: summer, 78 °F; winter, 70 °F.

b. The heat transfer coefficient (U factor) for both unhardened and hardened Army and AF shelters is taken as 0.35 Btu/hr/ft$^2$/°F and 0.25 for Navy shelters. The table therefore applies to both unhardened and hardened units.

[1] Cooling and heating data apply on both S280 configurations (see table I).

[2] When single MF shelters are attached to an integration unit (see footnote 1 to Table I), each shelter, including the integration unit, is treated as a separate unit for determination of cooling and heating requirements.

[1] See 1.6.

2.3.3 Additional power requirement. A major consideration in using humidity control is the power requirement. Because of the need for full constant cooling plus about equal reheat, humidity control imposes a high power demand which must be met. This could result in as much as twice the normal cooling power consumption.

2.4 Worldwide application. The cooling requirement determination of Worksheet Part I and as illustrated in the sample problem of 2.8 is for a specific climatic category applying to a certain region of the world. In cases where there is a need for systems capable of worldwide use, complete two worksheets using the climatic categories (see figure 1-1) which provide the most extreme conditions: A1 and B3. Using table IV, column E and G values of 1.49 and 46 for A1 and 1.26 and 124 for B3, compute the total cooling requirement. Use the one which gives the larger requirement.

2.5 Nuclear, biological and chemical (NBC) protection equipment and ECU's. NBC protection equipment will add to the cooling load of an ECU. The CB filter-blower unit blows air into the shelter at 10 to 15 °F above outside temperature. This added heat factor must be considered when computing ECU requirements. Chapter 5 (5.10), explains how to do this.

2.6 Estimating heating requirements. Reproduce Worksheet Part II - Heating Requirement Estimate from appendix C. Fill in the data at the top of the sheet and then follow steps 6 through 12 of the instructions.

2.7 How to select an ECU. Selecting an ECU which will adequately control the environment without unnecessarily oversizing the unit is important. This will also require consideration of other factors explained in 2.9 through 2.12. MIL-A-52767 and MIL-STD-1408 list (as does table II of this handbook) a number of categories of units available. However, the horizontal compact and vertical compact units are the best designs for most shelters. The Worksheet Part II addresses these two ECU designs. Other ECU designs may be considered if there is a special requirement. Reproduce both pages of Worksheet Part III - Selection of ECU from appendix C, fill in the top portion, and then follow steps 13 and 14 of the instructions and, if appropriate, steps 15, 16 and 17.

2.8 Sample problem. The following sample problem provides an illustration of how the procedures offered in 2.2, 2.6 and 2.7 will work.

a. The following input data are assumed for the purpose of the sample problem. For an actual integration requirement, the input would be provided or available.

(1) Shelter: Navy MF ISO (single)

(2) Location: Ramstein, Federal Republic of Germany

(3) Occupants: 3 people

(4) Design inside temperature: 75 °F (desired inside temperature)

(5) Electrical equipment/lights: Maximum at any one time - 6,000 watts; minimum - 0 watts

(6) Available power: 208 volts ac, 3 phase, 50/60 Hz, 4 wires

b. From the completed Worksheet Part I (figure 2-1), the cooling requirement is 33,091 Btu/hr. Note that the solar conduction heat gain was adjusted because the desired interior temperature is different from the 78 °F on which the values in column C of table IV, are based. Figure 2-4 was used to determine the correction factor, in this case 1.07.

c. From the completed Worksheet Part II (figure 2-2), the heating requirement is 24,518 Btu/hr.

d. From the completed Worksheet Part III (figures 2-3 and 2-4):

(1) Steps 13 and 14 show that adequate cooling requires a standard ECU with a nominal capacity of 36,000 Btu/hr. The actual rating of the horizontal unit is determined in the example to be 38,335 Btu/hr and for the vertical unit it is 35,343. Both units are well above the requirement so you may select the configuration best suited to your needs. Notice that the final ECU ratings are adjusted (derated). This derating is done because in table II the ECU is rated for an interior temperature of 80 °F at outdoor temperatures up to 105 °F. At lower indoor temperatures, in this case 75 °F, it is necessary to derate the air conditioner. Had you been selecting a system for a climatic area with outdoor design temperatures above 105 °F, the derating factor would have been 0.805. These factors are obtained from figure 2-5. Before proceeding, read 2.9 and 2.10.

(2) Step 17 (figure 2-4) determined that a pair of horizontal units with a combined capacity of 34,596 Btu/hr or a pair of vertical ECU's at 36,466 Btu/hr will be adequate and reasonably sized. It also shows that the combined heating capacities are close enough to the requirement to be acceptable in view of the fact that heat generated by personnel and electrical equipment was not considered in the Worksheet Part II computations.

e. Final selection will depend upon any adjustments made after considering 2.9 through 2.12 and the mounting method required.

2.9 Proper sizing. The ECU selected should be adequate but not oversized for the cooling load calculated on Worksheet Part I. Sizing the cooling unit as closely as possible to the requirement is important because of the dehumidification process. An oversize ECU will cool the shelter quickly, switch to a non-cooling mode and remain in a non-cooling mode until it is needed to cool again. While in the non-cooling mode, it is not dehumidifying the shelter. A smaller ECU will cool more slowly and, because its capacity is close to the requirement, will cool almost constantly; it therefore will be also constantly dehumidifying the shelter. By contrast, oversize of the heating capacity does not create a similar problem. Actually, heating oversize may be beneficial in overcoming heat loss because of doors opening and also for bringing an unused shelter up to the desired temperature more quickly before sensitive equipment is turned on.

2.10 Multiple units. The use of two or more ECU's to satisfy a single requirement offers several potential advantages:

a. It may be possible to size closer to the requirement.

WORKSHEET PART I - COOLING REQUIREMENT ESTIMATE

Shelter Designation NAVY MFO 150 (SINGLE)

Shelter Location RAMSTEIN, FRG

Shelter Occupants (Avg. No. of Persons) 3

Required (Design) Inside Temperature 75 °F

(If only heating is required, skip steps 1 through 5 and go to Worksheet II)

STEP

1. Solar/conduction heat gain: 8,272 (1a) Btuh x 1.00 (1b) x 1.07 (1c) = 8,851 (1) Btuh

2. Heat gain from electrical equipment/lights: 6000 (2a) watts x 3.4 Btuh/watt = 20,400 (2) Btuh

3. Heat gain from personnel: 3 (3a) persons x 500 Btuh/person = 1,500 (3) Btuh

4. Heat gain from ventilation: 39 (4a) Btuh/cfm x 3 (4b) persons x 20 cfm/person = 2,340 (4) Btuh

5. Total cooling requirement: (1) + (2) + (3) + (4) = 33,091 (5) Btuh

Where to find (1a): Table IV, column C
(1b): Table IV, column E
(1c): Figure 2-5
(2a): Equipment and lights in shelter
(3a): Top of worksheet
(4a): Table IV, column G
(4b): Top of worksheet

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INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 1 - SOLAR/CONDUCTION HEAT GAIN

- Find the shelter you want to cool in column A of table IV.
- For this type of shelter pick out the summer cooling load from column C and put it in worksheet space (1a).
- Find the location of the shelter on the map, figure 1-1, and note the pattern.
- Match the pattern with column E. Pick out the proper cooling factor and put it in worksheet space (1b).
- With your design inside temperature, turn to figure 2-5 and, using the solar conduction heat gain curve, find the correction factor and put it in space (1c).
- Perform multiplication and put the result in space (1).

STEP 2 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of all electrical equipment and lights to be used in the shelter.
- Put the sum in space (2a) and multiply it by 3.4.
- Put the result in space (2).

STEP 3 - HEAT GAIN FROM PERSONNEL

- Put the number of people to occupy the shelter in space (3a).
- Multiply by 500 and put the result in space (3).

STEP 4 - HEAT GAIN FROM VENTILATION

- With the same climatic category pattern used in Step 1, find the summer heat gain factor from table IV, column G and put it in worksheet space (4a).
- Put the number of people in the shelter in space (4b).
- Perform the multiplication indicated on the worksheet and write the result in space (4).

STEP 5 - TOTAL COOLING REQUIREMENT

- Perform the addition and put the sum in space (5). This is the cooling requirement for selecting the ECU.

FIGURE 2-1. Sample problem - worksheet part I.

WORKSHEET PART II - HEATING REQUIREMENT ESTIMATE

Shelter Designation NAVY MFO ISO (SINGLE)

Shelter Location RAMSTEIN, FRG

Shelter Occupants (Avg. No. of Persons) 3

STEP

6. Conduction heat loss: 13,440 (6a) Btuh x 1.36 (6b) = 18278 (6) Btuh

7. Vent heat loss: 104 (7a) Btuh/cfm x 3 (7b) pers x 20 cfm/pers = 6,240 (7) Btuh

8. Heating requirement: (6) + (7) = (Read step 8 of instructions, below) (PRE-HEATING ASSUMED REQUIRED) 24,518 (8) Btuh

9. Heat gain from elec equip/lights: ______ (9a) watts x 3.4 Btuh/watt = ______ (9) Btuh

10. Heat gain from personnel: ______ (10a) pers x 500 Btuh/pers = ______ (10) Btuh

11. Total heat gain: (9) + (10) = ______ (11) Btuh

12. Net heating requirement: (8) - (11) = ______ (12) Btuh

Where to find (6a): Table IV, column D; (7b): Top of worksheet

(6b): Table IV, column F; (9a): Equipment and lights in shelter

(7a): Table IV, column H; (10a): Top of worksheet

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 6 - CONDUCTION HEAT LOSS

- Find the shelter you want to cool in column A of table IV.
- For this type of shelter, pick out the winter heating load from column D and put it in worksheet space (6a).
- Find the location of the shelter on the map, figure 1-1, and note the pattern.
- Match the pattern with column F, table IV. Pick out the proper heating factor and put it in worksheet space (6b).
- Perform the multiplication and put the result in space (6).

STEP 7 - VENTILATION HEAT LOSS

- With the climatic category pattern used in step 6, find the winter heat loss factor in column H, table IV, and put it in space (7a).
- Put the number of people in the shelter in space (7b).
- Perform the multiplication and put the result in space (7).

STEP 8 - HEATING REQUIREMENT

- Add (6) and (7) and put the sum in worksheet space (8). This is your heating requirement if your operational equipment must be warmed before it can be safely started. In this case, use this figure in Worksheet Part III. If you do not require preheating for the equipment, your energy requirements can be reduced by recognizing the heat gained from electrical equipment and personnel in the shelter and following steps 9 through 12.

STEP 9 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of minimum electrical equipment and lights to be used during shelter operation.
- Put the sum in space (9a) and multiply it by 3.4.
- Put the results in space (9).

STEP 10 - HEAT GAIN FROM PERSONNEL

- Put the number of people in space (10a) and multiply by 500.
- Put the result in space (10).

STEP 11 - TOTAL HEAT GAIN

- Add (9) and (10) and put the sum in space (11).

STEP 12 - NET HEATING REQUIREMENT

- Subtract (11) from (8) and put the difference in space (12). This is the heating requirement for selecting the ECU.

FIGURE 2-2. Sample problem - worksheet part II.

WORKSHEET PART III - SELECTION OF ECU (Page 1 of 2)

Shelter Designation: NAVY MFO 150 (SINGLE); Location: RAMSTEIN, FRG

Cooling Requirement: 33,091 Btuh; Heating Requirement: 24,518 Btuh

Design Inside Temperature: 75 °F; Climatic Category: C1

Power Source Available: AC 208 volts, 3 phase, 50/60 Hertz, 4 wires

Reference table II and MIL-A-52767 for ECU data.

| STEP | HORIZONTAL COMPACT | VERTICAL COMPACT |
|---|---|---|
| SINGLE ECU | | |
| 13. Nominal capacity (Btuh): | 36,000 (13a) | 36,000 (13b) |
| 14. Actual rating (Btuh): | | |
| Cooling: | 41,000 (14a) x 0.935 (14b) = 38,335 (14c) | 37,800 (14d) x 0.935 (14e) = 35,343 (14f) |
| Heating: | 31,200 (14g) | 28,600 (14h) |

INSTRUCTIONS FOR COMPLETING WORKSHEET

SINGLE ECU

STEP 13 - NOMINAL ECU CAPACITY

- From table II, select a horizontal and a vertical ECU each with a nominal capacity equal to the next size larger than the cooling requirement. Put these sizes in spaces (13a) and (13b).

STEP 14 - ACTUAL RATING AND SELECTION

- From table II, find the cooling and heating "Rating Btuh" for these two ECU's. Put these into spaces (14a) and (14g) for the horizontal ECU and (14d) and (14h) for the vertical ECU.
- With your climatic category and desired interior temperature (design inside temperature), turn to figure 2-5. Using curve A or curve B, as determined by your climatic category, find the correction factor and put it into spaces (14b) and (14e). Multiply to determine the ECU actual rating.
- If cooling rating of either or both of these is equal to or slightly larger than the cooling requirement, you have completed the preliminary selection process and steps 15 and 16 may be skipped.
- If the heating rating is equal to or larger than the requirement, no supplementary heater will be required and 2-12 may be skipped. If the heating rating is smaller than the requirement, go to 2-12.
- You should complete steps 15 and 16 if the units in step 14 are smaller or much larger than the requirement.

FIGURE 2-3. Sample problem - worksheet part III (1 of 2).

WORKSHEET PART III - SELECTION OF ECU (Page 2 of 2)

DUAL ECU'S

15. Nominal capacities (Btuh):

18,000 (15a) x 2 = 36,000 (15b)  18,000 (15c) x 2 = 36,000 (15d)

16. Actual ratings (Btuh):

Cooling: 18,500 (16a) x 0.935 (16b) = 17,298 (16c)  19,500 (16d) x 0.935 (16e) = 18,233 (16f)

Heating: 14,300 (16g)  12,000 (16h)

17. Closest combination:

Cooling: 2 X (16a) or (16f) = 34,596 (17a) OR 36,466 (17b)

Heating: 2 X (16g) or (16h) = 28,600 (17c) OR 24,000 (17d)

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INSTRUCTIONS FOR COMPLETING WORKSHEET

DUAL ECU'S

STEP 15 - NOMINAL CAPACITIES

- From table II, select the smallest pair of nominal capacities that satisfies the cooling requirement. Put these ratings in spaces (15a) and (15c). Multiply them by 2 and put the results in spaces (15b) and (15d). If the pair looks close, proceed with Step 16; if not, select another pair.

STEP 16 - ACTUAL RATINGS

- From table II, find the cooling and heating ratings for the vertical and horizontal ECU's picked in step 15; enter these in spaces (16a), (16d), (16g) and (16h). Enter in spaces (16b) and (16e) the correction factor used in (14b) and (14e). Multiply and put the results in spaces (16c) and (16f).

STEP 17 - CLOSEST COMBINATION OF ECU'S

- If a pair of ECU's satisfies and is closer to the cooling requirement than the single units of step 14, the pair, shelter space permitting, should be your preliminary selection. Heating consideration is the same as for step 14.

FIGURE 2-4. Sample problem - worksheet part III (2 of 2).

b. The flexibility of mounting at two or more points on the shelter might permit a solution to the distribution problem without the need for ducting.

c. The calculated cooling requirement is based on the anticipated worst case. During times that the worst case does not exist, the cooling requirement would be reduced.

(1) Use of a single oversized unit could result in the dehumidification problem discussed in 2.9. Multiple units provide a flexibility which might avoid this problem.

(2) Much of the time when the load is less than the maximum computed, one of the pair of ECU's may meet the cooling requirement. Less power would then be consumed. Further, with two or more units, there would be a backup ECU during the periods of lower requirements.

As a rule, when two or more ECU's are used, it is a good idea to make them all the same. This will not only ease the logistical support burden but will also improve the backup flexibility. In a technical sense, however, there is no significant drawback to mixing types and capacities (as long as power requirements are compatible) and there may be an occasional good reason for doing so. For example, there could be a case in which normally operating mission equipment generates a moderate amount of heat but where installed special mission equipment, which operates only infrequently, is a big heat producer. In this case, a small ECU may cool adequately for normal operations but a larger ECU may be a necessity when special equipment is in use.

2.11 Reducing oversize. The ECU size and power usage increase significantly as rated cooling capacity increases. Since shelters are usually cramped for space and power is often at a premium, consideration should be given to using the lowest capacity ECU that reasonable comfort and equipment requirements will permit. For example, if:

a. An inside temperature of 85 °F, instead of 78 °F, is tolerable, considering the benefits to comfort that the dehumidification by the ECU will provide, and

b. A reduced ventilation requirement is acceptable, considering that since the onset of the emphasis on energy conservation, a more conservative value of 5 cfm per person has been established by appendix A, reference 4, then --

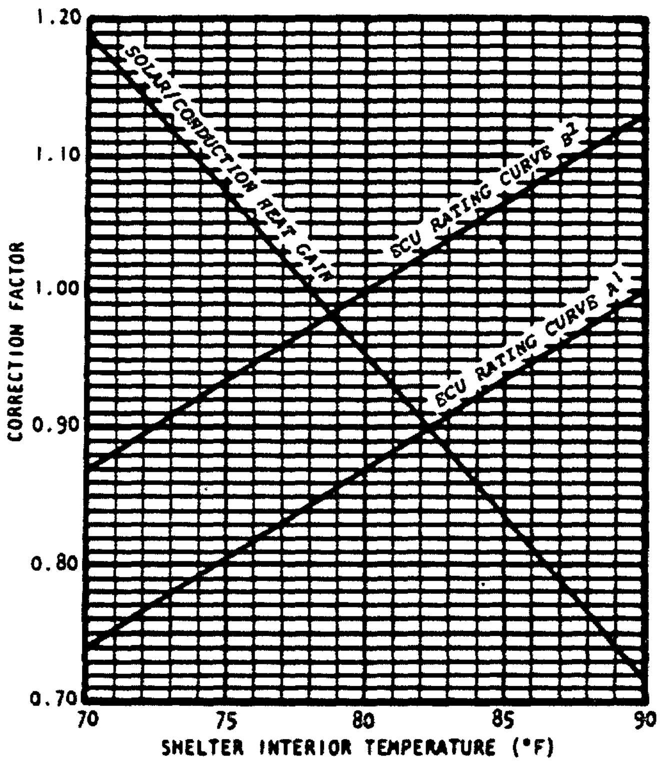
The selection process of chapter 2 would include the following adjustments:

(1) Reduce the solar/conduction cooling load (table IV, column C). Select from figure 2-5 the solar/conduction correction factor for 85 °F (0.835). Recompute Worksheet step 1 by multiplying the value in Worksheet space (1) by the correction factor, 0.835.

(2) Reduce the ventilation requirement from 20 cfm per person to 5 cfm per person and recompute Worksheet step 4.

(3) Retotal spaces (1) through (4) to obtain an adjusted cooling requirement.

(4) Increase the rated cooling capacity of the next smaller ECU. Using curve B of figure 2-5 (if outside temperature were over 105 °F, you would use curve A), select the ECU rating correction factor (1.064 or 1.06). Multiply the rated cooling capacity of the ECU by the factor 1.06 to obtain the adjusted cooling rating. Compare the adjusted rating with the adjusted requirement. If the smaller ECU now meets the cooling requirement, it may be selected. This procedure may be used in the same manner for other interior shelter temperatures within the range of figure 2-5.




[1] Curve A for design outside temperatures over 105 °F. (Climate categories A1, A2, and B3; see figure 1-1.)

[2] Curve B for design outside temperatures up to 105 °F. (All climate categories other than A1, A2, and B3; see figure 1-1.)

FIGURE 2-5. Correction factor for adjusting from shelter interior design temperature.

2.12 The value of shading the shelter. A significant source of heat which the ECU must handle is solar radiation subsequently conducted through the shelter walls and roof. The heat gain from this source can be reduced by approximately 45% if the shelter is shaded. To reach this reduction, the shade should be complete, that is, no sun filtering through. Adequate shade can be provided by dense tree foliage or a rectangular canvas cover, perhaps combined with camouflage netting. The canvas should be as shown in figure 2-6. The overhang should be the same on all four sides of the shelter. The distance of the canvas above the shelter should always be at least 1 foot.

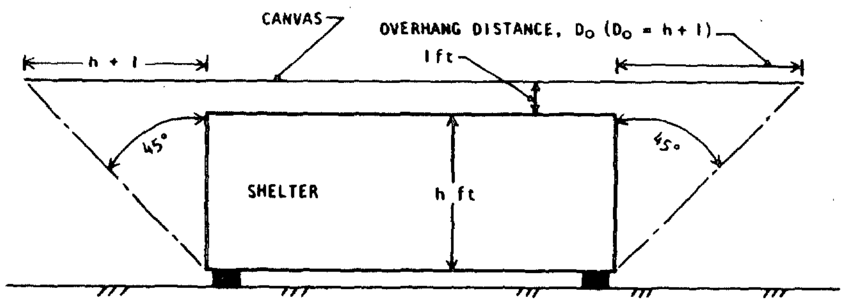



FIGURE 2-6. Shading the shelter.

There is no noticeable advantage to making it higher than this; but, if some consideration requires that it be, the overhang distance should then become the height of the shelter plus the distance between the canvas and the shelter roof.

2.13 How to select a supplementary heater. Cooling is the primary concern in selecting an ECU. In most of the cases, the ECU which was sized for cooling will be adequate also for heating. However, if the net heating requirement determined in step 12 of the worksheet exceeds the rated heating capacity of the selected ECU (or ECU's), then a supplemental heater will be needed. Heaters applicable for use in shelters are listed in MIL-STD-1407 under the heading: "Heating, Space, Blower Type." The heater selected will depend on the heating requirement, for example:

a. If the temperature in the entire shelter needs to be kept fairly uniform, a fuel burning space heater with a blower may be required. The heating requirement would be that determined on Worksheet Part II.

b. If heat is needed for the space around an individual occupant, a small portable electric space heater or a small fuel burning heater may be adequate.

c. If floor space is at a premium, outside mounting of a duct type heater may be needed.

d. Electric heaters increase power consumption but all fuel burning heaters require an exhaust to the outside.

e. In short, identifying potential heaters from MIL-STD-1407 is a relatively simple matter but selecting one depends upon the requirement.

2.14 A caution on ventilation. Instructions should be included in the operating procedures for the shelter not to exceed the ventilation specified in Worksheet steps 4 and 7. When the fresh air damper is manually adjusted open to provide additional fresh air for ventilation to exceed 20 cfm, there results a substantial penalty in air conditioner cooling load in hot and humid conditions and in heater load in colder climatic conditions.

# CHAPTER 3

# INSTALLATION

3.1 Introduction. This section suggests ways to install ECU's. The concepts offered are designed to fit a variety of shelter applications. Select the concept which best meets the need. Installation must be done in consideration of the ECU, the shelter or facility, and all other equipment to be mounted or placed in the shelter.

3.2 Limiting factors affecting installation of ECU's in shelters. There are a number of practical considerations which affect installation options:

a. Side walls of all shelters are excluded from permanent exterior installation. The maximum envelope dimensions for shipment preclude permanent exterior projections from the sides.

b. Exterior permanent installations on the end walls of all shelters, except the S250 and S280-type, also are precluded by the shipping envelope constraints.

c. Permanent fixtures must be limited in expandable shelters. In one-side expandables, the expandable side and a portion of each end wall are excluded from any permanent fixture by the very narrow spacing between folded panels. Because of center of gravity considerations during lifting and moving, there should be restrictions also on the weight of equipment permanently installed on the non-expandable side unless the shelter is permanently mounted on a truck or trailer. Both side walls and portions of both end walls in two-side expandables are excluded from use for permanently installed equipment.

d. Exterior installation of the ECU on the entrance end of the S280 is to be carefully considered because of the potential requirement for a protective entrance (PE) (see 5.5.1.3). Accomodation of both the PE and ECU on the entrance end may require a special design to strengthen the end panel.

e. Permanent end-wall installation of any ECU heavier than the 36,000 Btu/hr units is risky because of the limited strength of the shelter wall panel, which could fail during road or rail movement.

f. All ECU installations, when in shipping configuration, must withstand railroad humping loads (up to 6 G's in the vertical and lateral directions and 10 G's in the longitudinal direction) and survive the nuclear conditions described in chapter 7. These requirements have resulted in much heavier mountings than would be required for a shelter which can remain static and not be subjected to tactical stresses.

g. The requirement for setup or takedown/packup to be accomplished within 30 minutes by two men with little or no mechanical lifting assistance dictates:

(1) Permanent installations where practicable: slide-in/slide-out and inside-fixed or exterior-fixed wall mountings.

(2) The exclusion of mountings which require manual lifting of the ECU more than a few inches off the ground in order to mount it.

(3) That remote mountings be designed as self-contained units. The ECU should be transported on its mounting pallet so that only positioning relative to the shelter, connecting, and turning on are all that are required upon arrival at the operating site. All hardware necessary for putting the unit into operation must accompany the ECU and be readily available and accessible. The possibility of separation or loss during storage, shipment, and use must be at a minimum.

h. Installation should permit ready access for routine servicing and minor maintenance without removal of the ECU from its mounting position. If slight shifting must be done, it should be possible without the need for mechanical lift assistance. This requires that both sides, front, back, and top be exposed or easily exposable.

3.3 Recommended matchups. As an aid in narrowing installation considerations, a table of recommended shelter-ECU matchups is shown in table V. Types of mounts suitable for these matchups are discussed in 3.4 through 3.7, below.

3.4 Retractable mounting installation.

3.4.1 Description of a retractable mount. The distinguishing feature of the retractable mounting is its ability to move out of and back into the shelter through a hole in the shelter wall. In the design presented here, this movement is made possible by the commercially available supporting ball bearing slides, or tracks. The recommended position of the mount is at floor level where it requires the least amount of space-consuming bracing and reinforcing to withstand the dynamic loading of rail shipment. A type of retractable mount is illustrated at figure 3-1; a design drawing is at appendix D. figure D-1.

3.4.2 Benefits of retractable system.

(1) The retractable mount is the best system for installing ECU's in shelters planned for use in non-NBC environments. It keeps the noise and heat outside the shelter during operation while allowing for rapid deployment. In non-CB and non-NBC environments, the ECU can be retracted for redeployment with little time and effort and then pushed out again into operating position upon arrival at the new site.

(2) When retracted, this mounting method leaves no significant exterior projections to violate the shipping envelope. This benefit is most notable with shelters larger than the S250 and S280. (The S250 and S280 can fit into a shipping container with their ECU's still mounted on the front end.)

(3) The ECU is protected during shipment since it is inside the shelter.

3.4.3 Drawbacks of retractable installation.

TABLE V. Recommended shelter-ECU matchups.[1]

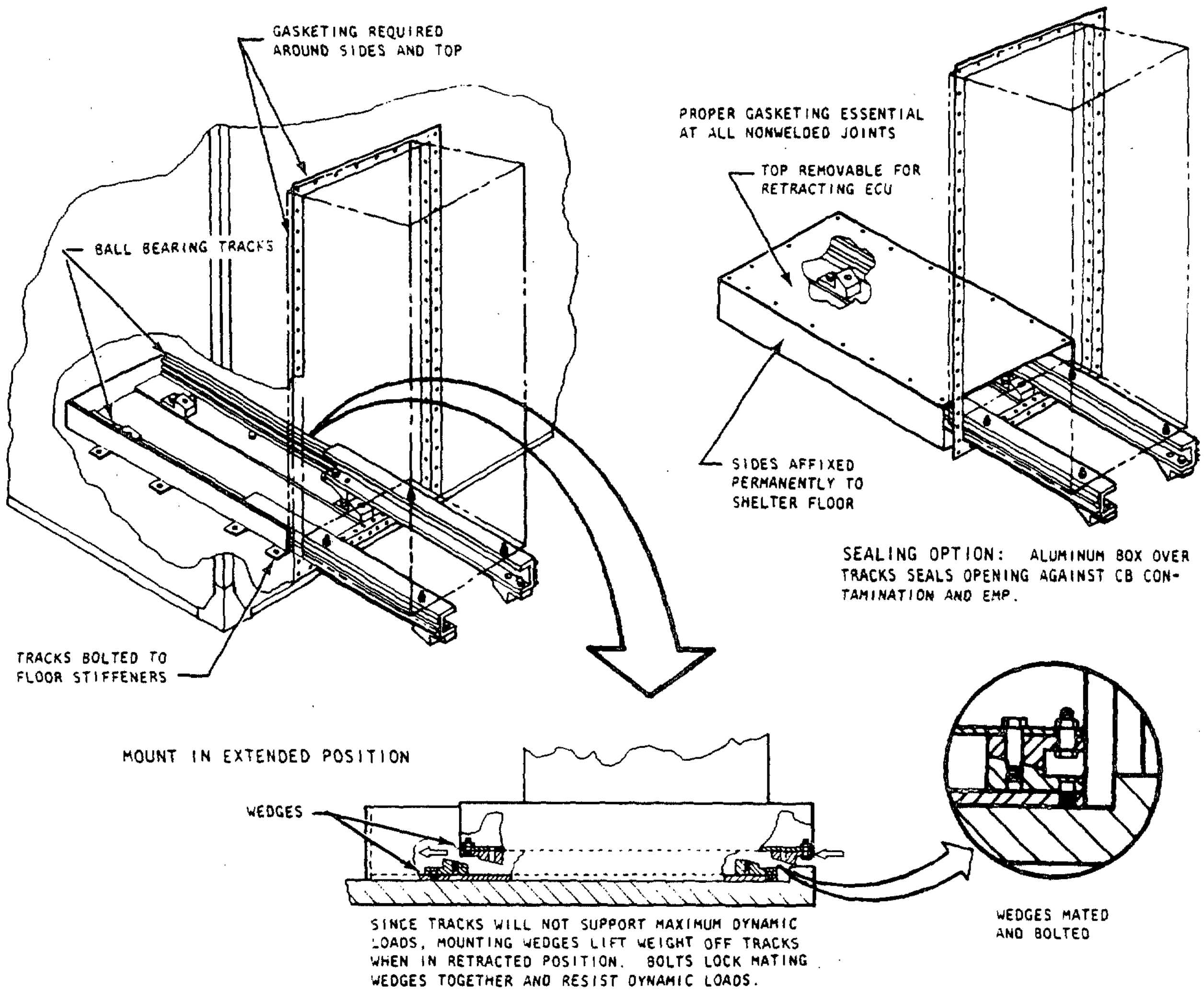
| SHELTER | HORIZONTAL ECU | VERTICAL ECU | MOUNTING POSITION OPTIONS |
|---|---|---|---|
| *NONEXPANDABLE* | | | |
| S250 | | 6,000 | Rear[2] exterior wall |
| | | 9,000 | Rear exterior wall |
| S280 | | 6,000 | Front[2] or rear exterior wall |
| | | 9,000 | Front or rear exterior wall |
| | 9,000 (Single or Double) | | Front exterior wall[3] |
| | 18,000 (Single or Double) | | Front exterior wall[3] |
| | | 18,000 | Front exterior wall |
| | 36,000 | 36,000 | Front exterior wall[3] |
| | All above, plus 60,000 | All above, plus 60,000 | Ground: remote or flush; entry through any wall |
| | | | Retractable: any wall |
| ISO, Army, GP | Same as S280 | | Any wall: mount should be retractable, fixed interior or ground type |
| Navy | Same as S280 | | Any wall: mount should be retractable, fixed interior or ground type |
| *EXPANDABLE* | | | |
| All | 36,000 and 60,000 (Below 36,000, vertical ECU's present a more suitable matchup) | 6,000, 9,000 and 18,000 (Above 18,000, horizontal ECU's present a more stable package and a smaller envelope) | Remote ground mount with flexible ducting<br>Flush ground mount with boot to eliminate flexible ducting |

[1]See tables I and II

[2]Rear - shelter entrance end
Front - end opposite from shelter entrance

[3]Fixed or retractable mount

3.4.3.1 Maintaining is difficult. The stringent sealing requirements for an NBC (including EMP) environment are very difficult to meet and to maintain with a retractable mount. The irregular surfaces asound the tracks supporting the ECU constitute an exceptionally difficult interface joint to seal. A concept for this is shown in figure 3-1. Reference 34 shows a concept for closure used with the Navy ECU's. Further, when seals must be repeatedly broken and reestablished, there is a serious doubt that they will continue to be effective in:




Major actions to place into operation: Remove plug from wall opening; push ECU into operating position; attach bracing as required; place cover plate over tracks inside shelter (for sealing); attach power and control cables; attach any ducting required; start ECU.

CHARACTERISTICS OF RETRACTABLE MOUNTING

- ECU mounted on ball-bearing slides. For shipping, ECU locked in retracted position inside the shelter (sketch illustrates concept). For humping, ECU also requires bracing at top. Bolthole in upper rear of ECU provided for this purpose. For operation, ECU pushed through opening in shelter wall into extended position.
- To withstand nuclear overpressure in extended position mount and ECU require removable external bracing against movement in all three planes (not shown on sketch).
- Mounting shown uses vertical ECU which generally is a more suitable configuration. Mounting is adaptable to a horizontal ECU.

FIGURE 3-1. Mount for retractable ECU.

(a) Maintaining the positive air pressure necessary for NBC protection without an undue loss of air from leakage and the resultant increased demand on the ECU and the gas particulate filter unit (see chapter 5).

(b) Sealing against NBC contaminants during brief moments when outside pressure may be greater than inside pressure. Such reverses in pressure may be from a number of causes to include a gust of wind or a passing truck.

(c) Maintaining the seal against EMP, which is critical if solid-state equipment is to survive.

3.4.3.2 Mounting weak when extended. The best ball bearing tracks available are strong and durable but, when extended, cannot be relied upon to withstand significant dynamic loading while supporting the weight of the ECU. Therefore, to survive significant nuclear overpressure (see 7.2 and 7.3), the mounting would need reinforcing with outside bracing comparable to the wall mount designs presented in 3.6. Since projections outside the shipment envelope are unacceptable, the bracing would have to be removed for transit, stowed during transit, and reinstalled upon setup. This would detract from the quick setup and takedown benefits of the retractable mount. Further, there would be little gain, if any, in survivability since the current shelter, itself, is rather weak in this respect (see 7.2).

3.4.3.3 No space gain. There is no gain in interior space when the mount is in the extended position. The area vacated by the ECU when it is extended (and into which it retracts) is not available for other uses. This area must remain clear to prevent blocking the air passage (unless detachable ducting is provided, which would further complicate the takedown and setup process by adding to the number of pieces to be disconnected, stowed, and reconnected).

3.4.3.4 Location selection restricted. Structurally, the best position to place the retractable mounting is on the floor. The best position from an air distribution viewpoint is near the ceiling.[2] The dynamic loading of railroad humping would make a structure for putting the ECU near the ceiling rather space-consuming. (Note the comment on use of equipment racks in 3.5, below.). The problem could be overcome by use of a riser duct from the air supply outlet of the ECU to a point near the ceiling. But this would require space (up to 8 inches from the wall as wide as the ECU air supply discharge). Also, as noted above, ducting would complicate the takedown and setup process.

## 3.5 Inside fixed mounting installation.

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[2]Provided there are no obstructions to block the air flow (see chapter 4), cooling can probably be accomplished in the shelters addressed by this handbook with a floor-mounted ECU, although somewhat less efficiently and effectively. Because of their height, the vertical ECU's are more suited to floor mounting than are the horizontal models and can probably be used satisfactorily without ducting. A floor-mounted horizontal ECU, on the other hand, should probably have its supply air ducted to near the ceiling.

3.5.1 Description of inside fixed mounting. The ECU must be fixed into place firmly enough to withstand rail shipment dynamic loadings and insulated to reduce both heat and noise (the heat being that which radiates from the ECU housing). The rear of the ECU faces outside through a hole in the shelter wall so that air used for cooling the condenser is discharged directly outside without entering the shelter compartment.

3.5.1.1 Mounting at the floor. For floor mounting, since the mounting bolt spacing of the ECU probably will not coincide with the floor stiffener spacing, a plate or beams will have to be used to span and be bolted to the stiffeners. The ECU can then be bolted to the plate or beams. It is advisable also to use a reinforcing backplate beneath the floor, on the outside, which can be connected to the baseplate or beams by bolts through the shelter floor. One way to deal with the problem of noise and heat from the inside-mounted ECU, and at the same time provide the vertical ECU with the necessary bracing against overturning, is to fabricate a rigid, insulated enclosure for the ECU (see Figure 3-2). The enclosure should attach to the shelter floor and wall and be removable to permit access to the ECU for repair and maintenance.

3.5.1.2 High mounting. Mounts near the ceiling would require structure inside the shelter which, depending upon its design, may reduce space for other purposes. A supporting structure, such as equipment racks of the type provided by shelter manufacturers, if adequately anchored, can support the ECU near the ceiling and might permit better space utilization by allowing the space beneath the ECU to be used for other purposes.

3.5.2 Benefits of inside installation. For inside, fixed installation:

a. The ECU is fixed and braced in place and ready to turn on almost immediately upon arrival at the operating site. Further, there are no requirements to remove hardware in preparation for a move, to stow it during transit and to replace it upon arrival, so takedown and setup time are minimal.

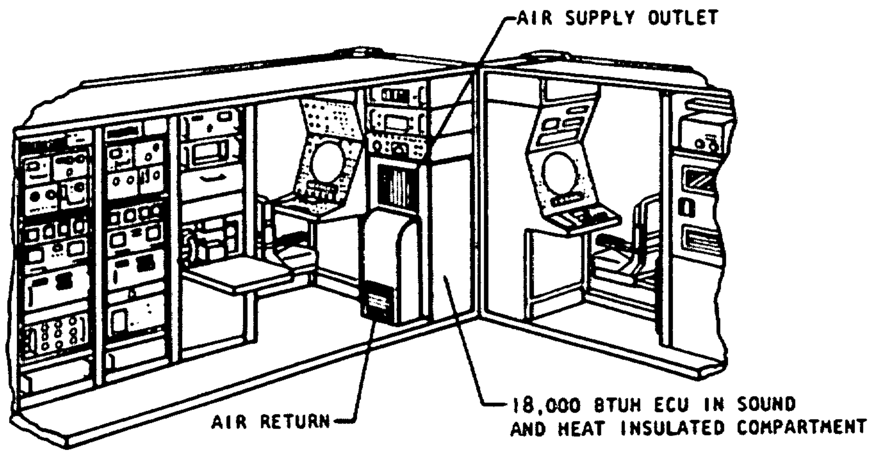
b. Sealing is comparatively easy since gaskets are compressed between the relatively even surfaces of the rim of the ECU's rear face and the frame around the hole in the wall panel. Additionally, the seals should be more effective than with most other mounts since there is no requirement to break them for moves; the floor mounting should permit maintaining a rigid joint with a constant pressure on the seals.

c. The ECU is protected at all times to the same degree as other interior-mounted equipment.

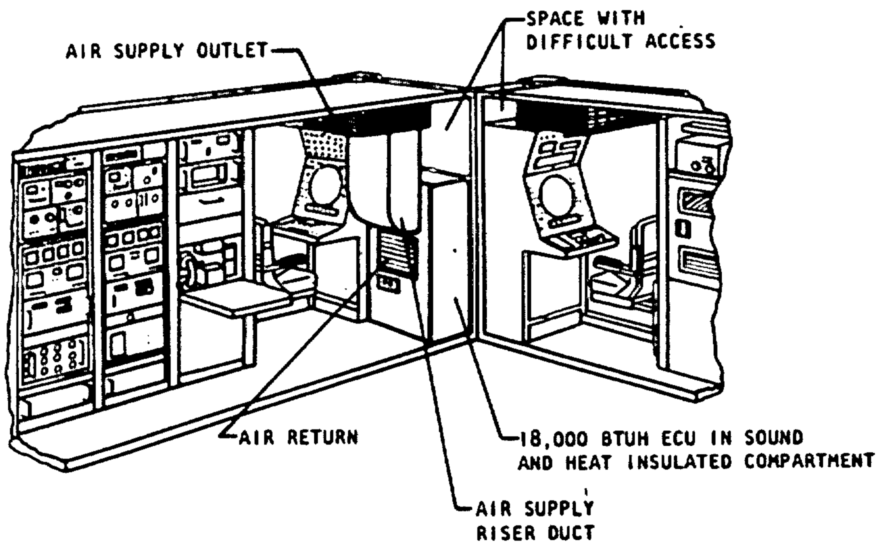
d. Mounting is less expensive and more quickly accomplished than for all others considered.

3.5.3 Problems with inside installation. Problems associated with inside, fixed mounting:

a. Military ECU's are designed primarily for outside installation, so the condenser sections of the ECU's are not insulated. As a consequence, they are heat producers in summer and cold producers in winter. Further, they are




VERTICAL ECU WITH DUCTING TO SEPARATE AIR SUPPLY AND AIR RETURN




VERTICAL ECU WITH AIR SUPPLY DUCTED TO CEILING-LEVEL OUTLETS

FIGURE 3-2. Inside mounted ECU's illustrating characteristic space requirements.

noisy, especially the vertical configurations, although newer models have been improved somewhat in this respect. Adequate insulation can reduce the heat problem to a manageable level but may help less effectively with noise. A good, solid job of mounting should be some help with vibration and noise.

b. For structural reasons, the shelter floor is the best place to mount the ECU, but this position is not the best for air distribution.[3] Adequate bracing inside the shelter, to support the ECU near the ceiling and meet the railroad humping load requirement, would be very space-consuming and is not recommended unless standard equipment racks can be made suitable. The ducting necessary to raise the air supply outlet from the floor to the ceiling would also consume space. To rise vertically from the ECU air supply discharge, the ducting would be 20 to 30 inches from the wall (a little more than the distance from front to back of the ECU) and, unless adjacent equipment can lend support, would be freestanding and require special bracing. Some appreciation of the space requirement may be gained from the sketches in figure 3-2.

c. Access for maintenance and repair can become a problem unless care is taken in locating adjoining equipment. There must be clearance for hands and the use of appropriate wrenches for demounting and remounting the ECU.

3.6 <u>Outside wall mounting installation</u>.

3.6.1 <u>Description of outside wall mount concept</u>. The ECU is wall mounted outside the shelter on a rack affixed to the end panel of the shelter. The conditioned air supply and return face into the shelter through a hole in the wall. The mountings must be designed to withstand railroad humping; an incidental benefit from this is an ability to survive an estimated nuclear-free field overpressure of 4 psi (ref to 20.1.2, 20.1.4, and 20.2.3.2). Since the structural design of shelter wall panels, according to the leading manufacturers, varies widely even within the same shelter type, the design cannot rely solely on end panel strength. Instead, it transfers a major portion of the load from the end panel to the corners and into shear stresses in the side and roof panels. The thin-skinned sandwich panels are much stronger in shear than in moment. Sample design drawings are at appendix D. Wall mountings are illustrated in figures 3-3 and 3-4.

3.6.2 <u>Benefits of outside wall mounting</u>.

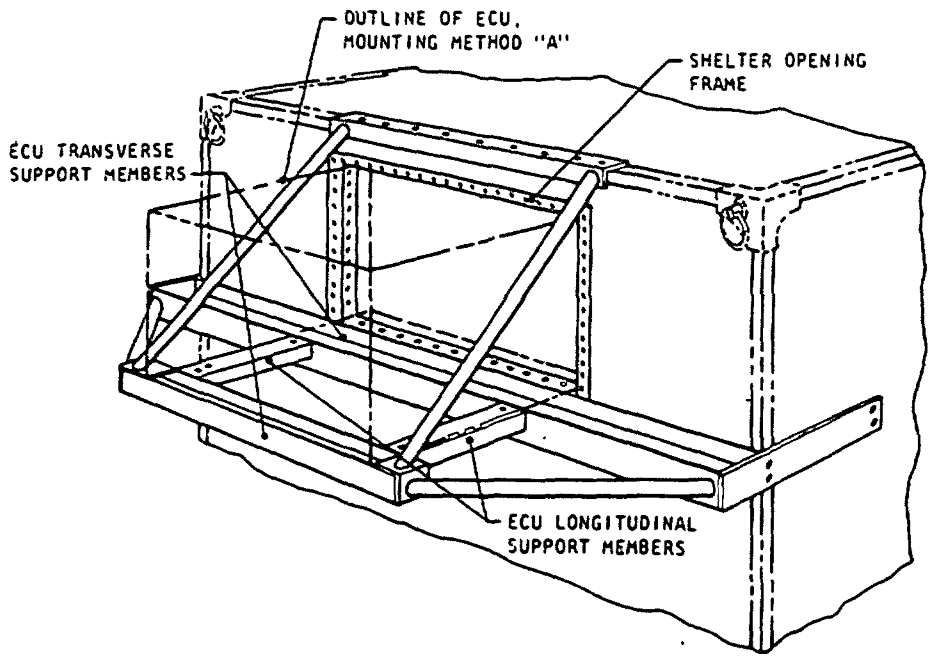
a. There is no requirement for setup and takedown for relocations.

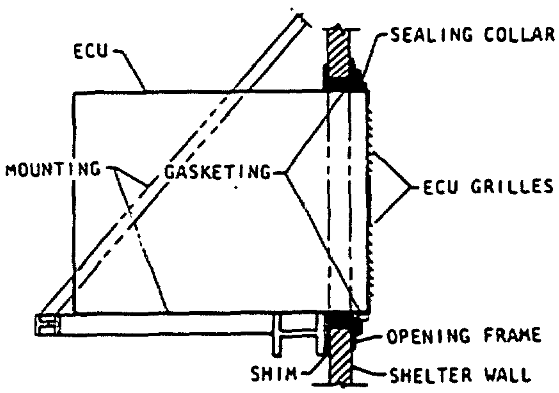
b. Noise and radiated heat are outside the shelter.

c. There is a saving of space by not having the ECU and its mounting structures inside the shelter.

3.6.3 <u>Problems of outside wall mounting</u>.

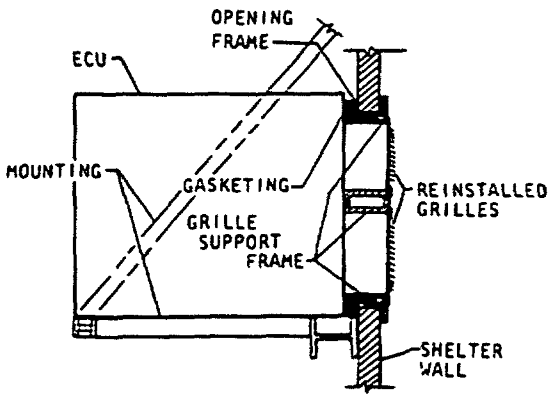
[3]See footnote to 3.4.3.4.




MOUNTING METHOD "A"

ECU fits through opening into shelter. This is simpler of two methods but it is a little more difficult to seal.



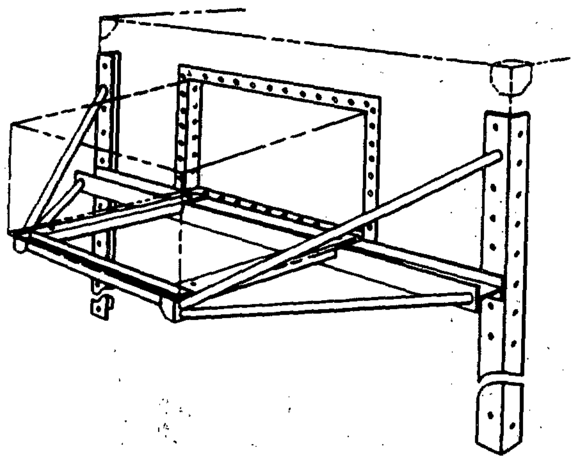

MOUNTING METHOD "B"

ECU is completely outside shelter. Supply and return grilles and control panel are removed and reinstalled onto a grille support frame which must be fabricated. Grille support frame must include ducts to keep supply and return air separated in space between ECU and remounted grilles.

CHARACTERISTICS OF FIXED MOUNTINGS

- Permanently attached to shelter; permits shipping shelter with ECU in place (ECU mounted using normal boltholes in bottom of unit).
- Designed for rail humping loadings of 6G in vertical and transverse directions and 10G in longitudinal direction.
- Rated for nuclear overpressures up to 4 psi.
- Fabricated from standard aluminum extruded shapes or from shapes built up from aluminum sheets. Welded construction.

FIGURE 3-3. Typical wall mounting.

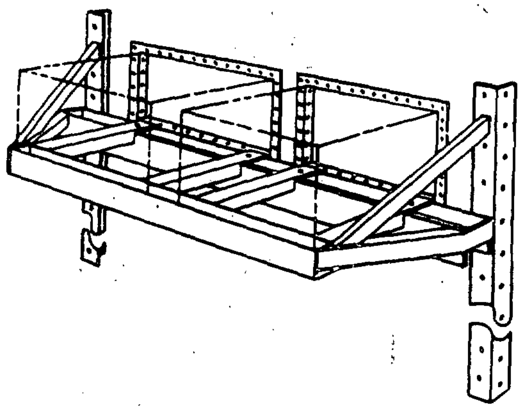


WALL MOUNT #1

Applicable ECU: 9,000 Btuh; 18,000 Btuh

Approximate Weight: 113 pounds

Design Drawing: Appendix D Figure D-2

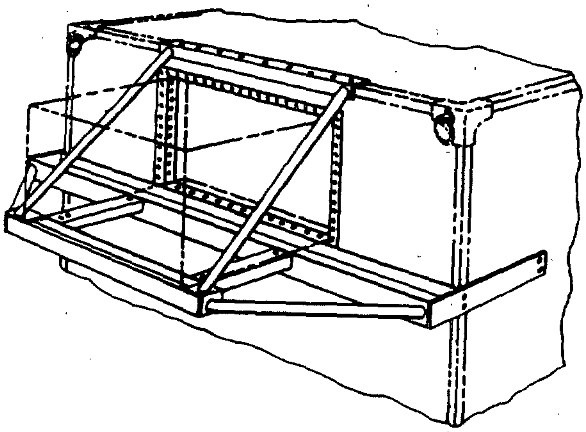


WALL MOUNT #2

Applicable ECU: (2) 9,000 Btuh; (2) 18,000 Btuh

Approximate Weight: 118 pounds

Design Drawing: Appendix D Figure D-3



WALL MOUNT #3

Applicable ECU: 36,000 Btuh

Approximate Weight: 133 pounds

Design Drawing: Appendix D Figure D-4

FIGURE 3-4. Wall mountings for horizontal ECU.

a. The use of the outside fixed mounting is limited to the S250 and S280 shelters. These mounts would be applicable also to other shelters of similar width if their use were not precluded by the shipping envelope constraints.

b. Because of their exposed position, the outside mounted ECU's are subject to damage by flying fragments as well as nuclear blast and thermal effects.

c. The outside wall mounts assume that the shelter will be truck mounted and therefore are designed to overhang the truck cab. The designs are intended to allow adequate clearance between the mounting frame and the truck cab. However, the height of the cab top above the truck bed can vary several inches not only between truck types but also within the same type. Therefore, the vertical distance between the cab top to the bed level must be determined and checked against the mounting design for each truck used to see if the mount will clear the cab. If there is insufficient clearance, it may be possible to achieve clearance by raising the entire shelter with the use of blocks between the truck bed and the shelter bottom.

3.7 Ground mounting.

3.7.1 Description of two types of ground mounts. The two types of mountings described below should satisfy nearly all ground mounting requirements.

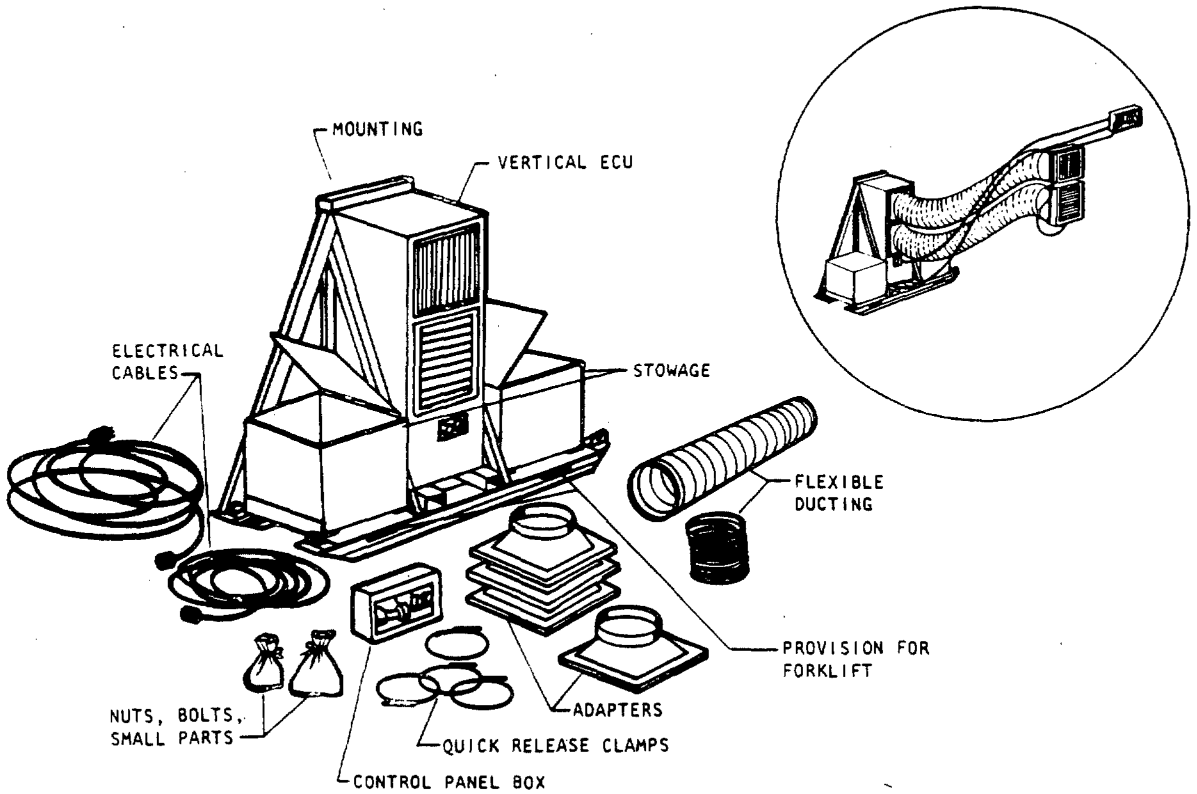
3.7.1.1 Remote mounting. The ECU is mounted and braced on an aluminum frame pallet (see figure 3-5). Also on the pallet is space for stowing the hardware necessary to put the ECU into operation. The ECU is shipped on its mount, separate from the shelter. When tied down to prevent tipping, the mount is designed to survive rail hump loadings as well as the nuclear overpressure up to 7.3 psi. A sample design drawing is at appendix D. In operation, the mount is located 4 to 8 feet from the shelter and the conditioned air is carried to the shelter by flexible ducting.

3.7.1.2 Flush mounting. The main conceptual difference between this and the remote mount is that the flush mounting is almost touching the shelter as illustrated in figure 3-6. Shelter and ECU are connected by a short, heavy duty boot made of high heat-resistant material. The boot is accordioned to absorb a small amount of independent movement between the shelter and ECU. It is strong enough to provide a degree of support to the ECU so that it can use a simpler mounting than that required of the remote concept. The mounting illustrated in figure 3-6 is a suggested type but any mounting which would hold the ECU at the desired level and prevent its tipping over should be acceptable.

3.7.2 Benefits of remote and flush ground mounting.

3.7.2.1 Remote approach.

a. Since the conditioned air supply and return are carried in 10-foot long, flexible ducts, this mounting method offers the most flexibility of all the mounts for locating the supply and return opening(s) in the shelter wall. They may be located separately or together, positioned to avoid obstructions and prevent a short circuit (see definition in appendix B), and openings may be placed to make most effective use of available air passages inside the



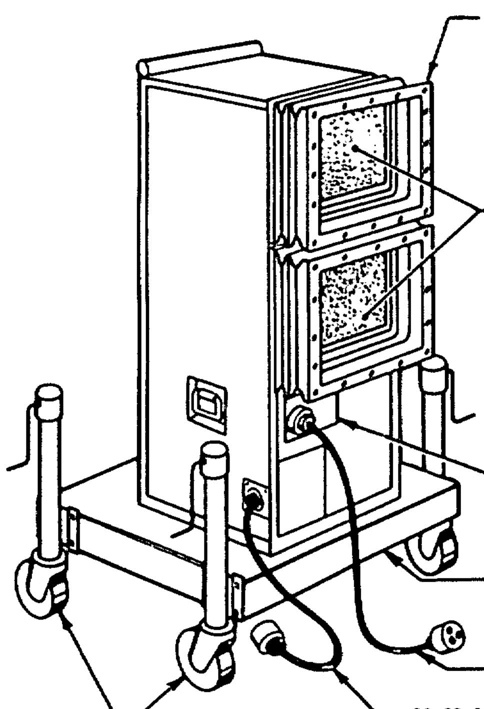

REMOTE-MOUNTED ECU WITH ESSENTIAL ACCOMPANYING PARTS

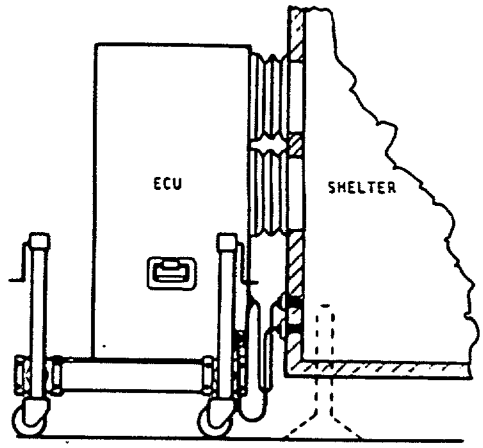
Major actions to place into operation: locate and level mount, remove supply and return grilles from ECU and install on grille support frame (permanently installed on inside of shelter), mount control box in shelter, install adapters and flexible ducting, connect power cables.

CHARACTERISTICS OF REMOTE MOUNTINGS

- Located away from shelter.
- ECU bolted to skid-mounted pallet, using normal ECU boltholes, for shipment and operation.
- Includes stowage for all necessary hardware.
- Designed for rail humping loadings of 6G vertically and transversely and 10G longitudinally.
- Designed for nuclear overpressures up to 7.3 psi.
- Fabricated from standard aluminum sheets and extruded shapes. Welded construction.

FIGURE 3-5. Typical remote ground-mounted ECU.




RELATIONSHIP OF ECU TO SHELTER

Major actions to place into operation: Remove grilles from ECU; attach boot to ECU; attach power cables; push ECU into position close to shelter; attach necessary gasketing; attach boot to shelter; attach necessary filters; attach grilles to opening inside shelter; attach necessary tiedowns.

CHARACTERISTICS OF FLUSH MOUNTING

- ECU mounted on simple pallet to provide stability for shipment and operation. For railroad shipment and when nuclear overpressure loadings are expected, tiedowns, from the top, should also be provided. Pallet has light duty, rolling crank jack (several types are commercially available) on each corner for adjusting height up to 12 inches and for leveling. Wheels on jacks permit short moves at very slow speeds and manually shifting position of unit.
- ECU located approximately 6 inches from shelter and attached to shelter by custom made, commercial heavy, flexible, high heat ducting, or boot. Boot has metal flanges bonded to ducting. Small access space between ECU and shelter dictates that flange and bolt holes be accessible from the inside of boot. Boot is connected to ECU first. ECU is then pushed against shelter. Access to bolts is from inside of shelter through hole in wall panel to inside of boot.
- Suggested means of transporting boots, bolts, and wrench is canvas pouch, or pouches, which can be strapped to ECU.
- Vertical ECU is shown in illustration but concept is adaptable to horizontal units.

FIGURE 3-6. Typical flush ground mounting.

shelter, thus reducing the space that must be dedicated solely to this purpose.

b. The sealing of the interface between the ECU and the shelter is comparatively simple to achieve and maintain.

c. There is practically no stress on the wall panel from the mounting.

d. The remote mounting can be used with any size ECU and with any shelter.

e. There is full accessibility for maintenance and repair of the ECU.

f. The shelter is isolated from the vibration and noise of the ECU.

3.7.2.2 Flush approach.

a. Sealing the ECU/shelter interface is a comparatively easy task since fairly even surfaces meet each other and gaskets can be uniformly compressed.

b. The short boot which connects the ECU and the shelter is relatively hard. It is much shorter (and therefore less exposed) and much tougher than the long flexible ducting of the remote mount. Also, it is between the ECU and the shelter and thereby somewhat shielded from thermal radiation.

c. There is no constraint on matching ECU's and shelters.

d. During normal operation, there is little stress on the shelter panel from the mounting.

e. The shelter is separated from the ECU by the length of the boot (approximately 6 inches). This serves to isolate the shelter from the vibration and noise of the ECU.

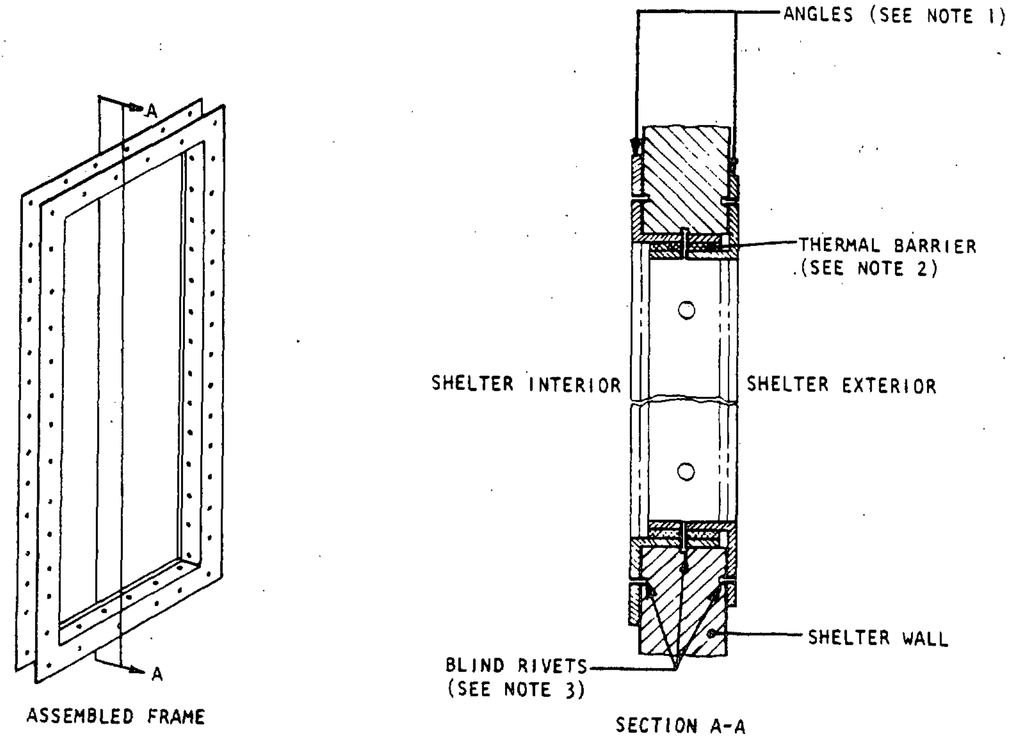
3.7.3 Problems for ground mounting. Because of their height, both remote and flush mounts are subject to tipping when hit by the blast wave or subjected to railroad humping. They should therefore be tied down during both movement and operation.

3.7.3.1 Remote mounting problems. The ECU and ducting are vulnerable to fragments, blast pressures, and thermal radiation; the ducting should not be expected to survive. The weight of the ECU and the mount requires mechanical lifting equipment and transporting equipment to move the system to the site and to place it where it will be used. If materials handing equipment, cranes or wreckers are available, this is no problem. A system shipped by sea would require transport to move it to its site and plans would probably be in place for this. One shipped by air may require a dolly or other means of short-range transport to move it from the aircraft to its on-base site. Long distances would require major transport means in any event.

3.7.3.2 Flush mounting problems. Although less vulnerable than the remote mounting, the fact that the ECU is in the open renders the flush mount, also, susceptible to damage by fragments, blast pressures, and thermal radiation. However, the boot duct should survive in cases in which the ECU and shelter survive. The weight of the ECU presents the same requirement for moving and handling as does the remote mounting.

3.8 Frames. For all mounts, the necessary holes or openings in the walls must be adequately framed both to restore and reinforce the strength and rigidity of the panel and to protect the edges of the hole. A framing concept which is commonly used and which has proven to be satisfactory is illustrated on figure 3-7. The frame can be modified in size and strength to accommodate having other structural members bolted to it.

3.9 Summary. For convenience, "Considerations for selecting ECU mountings", summarizing the discussions of 3.2 and 3.4 through 3.7, are included at table VI.




NOTES:

1. ALUMINUM ALLOY 6061-T6: EXTRUDED OR FABRICATED ANGLES, MINIMUM 1/8 IN. THICK. LEG LENGTHS TO ACCOMMODATE SHELTER WALL THICKNESS AND ANY STRUCTURAL ATTACHMENTS (E.G., MOUNTING FRAMES).

2. THERMAL BARRIER, 1/8 IN. THICK:
   - LAMINATED PLASTIC - MIL-P-15035, TYPE FBM <u>OR</u>
   - TEFLON STRIP - MIL-P-22242 <u>OR</u>
   - PLYWOOD, EXTERIOR TYPE, COMMERCIAL STANDARD PS-1-74

3. RIVETS SHOULD BE DIPPED IN CONDUCTIVE SEALANT PRIOR TO INSERTING INTO HOLES.

FIGURE 3-7. Shelter opening frame.

TABLE VI. Considerations for selecting ECU mountings.

| CONSIDERATION | EXTERIOR FIXED WALL MOUNTINGS | RETRACTABLE & FIXED INSIDE MOUNTING | GROUND MOUNTINGS (REMOTE & FLUSH) |
|---|---|---|---|
| Which shelters are applicable? | S250 and S280 only (all others precluded by shipping constraints). | All nonexpandable shelters (no permanent fixtures in walls of expandable shelters). | All shelters. |
| What ECU sizes can be mounted? | Up to: Two 18,000 Btuh, or One 18,000 Btuh plus 1 GPFU, or One 36,000 Btuh | Up to one 36,000 Btuh per mounting. Vertical ECU's present better space utilization in most cases. | No restrictions. (But for ECU's of 36,000 Btuh and above, horizontals present a smaller envelope. Verticals are preferred below 36,000 Btuh.) |
| Any restrictions on mounting locations? | • Restricted to:<br>- Rear end wall of S280. Front (entrance) end precluded by need to preserve option to use CB protective entrance.<br>- Front (entrance) end of S250.<br>• Shipping considerations preclude use of:<br>- All side walls of all shelters.<br>- All shelters larger than S280.<br>- All expandable shelters. | • Should be restricted to floor level only.<br>• All two-side expandable shelters cannot use mounts which are not dismantled before shelter is prepared for movement. | No restrictions. |
| What clearances are required inside shelters? | Sufficient to prevent blocking of air supply and return flow. Refer to figure 4-1 of this handbook. | Requires space for entire ECU, plus riser air duct; also space sufficient to prevent blocking of air supply and return flow (see chapter 4). | Sufficient to prevent blocking of air supply and return flow (see figure 4-1. Supply and return can be close together or separated when flexible ducting is used for carrying air to shelter. |
| Any exterior ducting required? | None required. | None required. | Normal remote mounting requires flexible ducting. The ground flush mounting uses a boot which allows ECU virtually to be attached to shelter yet permits small independent movement and isolates shelter from ECU vibration. |
| What set-up tasks are required at the operational site? | None. | Retractable: Unplug wall opening; remove bolts, emplace ECU in out position; affix external bracing, install air duct connections, seal around opening.<br>Fixed Inside: Unplug wall opening. | Minor leveling of ECU pallet, unplug wall opening(s), connect adapters and ducting, connect control cables, and connect power cables. (Assumes pallet-mounted ECU was satisfactorily located when delivered. ECU and pallet can be manhandled for small adjustments in position.) |

TABLE VI. Considerations for selecting ECU mountings. (continued)

| CONSIDERATION | EXTERIOR FIXED WALL MOUNTINGS | RETRACTABLE & FIXED INSIDE MOUNTING | GROUND MOUNTINGS (REMOTE & FLUSH) |
|---|---|---|---|
| How is the access for servicing and minor repairs? | Good. | Retractable: Good.<br>Fixed Inside: Good to poor. | Excellent. |
| Can mounting, with ECU affixed, withstand shipping? | Designed to withstand rail humping loadings (6 G in vertical and transverse directions and 10 G in longitudinal direction). NO TESTING HAS BEEN DONE. | Retractable: When in retracted position only.<br>Fixed Inside: Proper floor mounting should stand up to hump loads. | Mounting pallet is designed to withstand rail humping loadings with ECU in mounted position. NO TESTING HAS BEEN DONE. |
| What is extent of nuclear hardening? | Overpressure up to 4 psi. ECU may be vulnerable to fragments. NO TESTING HAS BEEN DONE. | Retractable: Can withstand only in retracted position (if shelter has been hardened). NO TESTING HAS BEEN DONE.<br>Fixed Inside: Same as above. | Mounting will take 4 psi with ECU on it but will need anchoring to prevent moving or tipping over. Flexible ducting is extremely vulnerable. Boot used with flush mounting is expected to be equal to mounting. NO TESTING HAS BEEN DONE. |
| What is difficulty of sealing the ECU openings in the shelter against air loss and NBC contamination? | Moderate. | Retractable: High.<br>Fixed Inside: Moderate. | Minimal. |
| Is transportation separate from shelter required? | No. ECU and mount are permanently attached to shelter. | No. ECU and mount are permanently attached to shelter. | Yes. ECU is separately mounted and transportation arrangements for it are required. This includes long distance and short distance moves. Also, mechanical help for loading and unloading from transporting vehicle is required. |

# CHAPTER 4

## DISTRIBUTING AIR IN THE SHELTER

4.1 Introduction. Most heating and air conditioning manuals are aimed at buildings that require considerably more complex air distribution systems than do tactical shelters. Fortunately, most of the factors which impact heavily on air flow in long, complicated systems have drastically less impact on the types of short, compact systems needed for military shelters. For these small systems, simplifications can be introduced to permit easier and quicker design without appreciably degrading effectiveness. To resolve more complex problems, consult appropriate handbooks (appendix A, references 2, 3 and 9, for example) or an air conditioning engineer for assistance.

4.2 Free-flow or ducted distribution. There are two ways to distribute air within a shelter. One is free-flow, that is, direct discharge of the conditioned supply air into the shelter with sufficient velocity and direction so that the air, in effect, distributes itself. The other way is to carry the air through ducts directly to the point or points where it is needed. In a combination of these two methods, you may duct the supply, only. It is unlikely that there would be a need for a return air duct in small shelters. Free-flow distribution will be adequate in most cases covered by this handbook. It has the advantages of being cheaper, quicker, and easier to install than ducted distribution and it takes up less space inside the shelter.

4.3 Planning the distribution system. Obtain scale drawings of the plan and elevation of the shelter interior. Then follow the planning steps 18 through 26 of figure 4-1 (Steps 1 through 17 are in chapter 2, Selection of Environmental Control Units). If ducting is needed, two points should be kept in mind:

a. In some system designs there will be a need to change the duct's cross-sectional dimensions, change direction, direct some of the air to intermediate points, or maybe all of these. These changes need not have a great impact on system effectiveness if they are handled properly. If and when you encounter these needs, refer to 4.4 through 4.7 for advice.

b. When ducting is to be used for both cooling and heating, it is normally designed for cooling with the knowledge that it will work also for heating. Auxiliary heaters in a shelter will probably be unducted or, if ducting is necessary, separately ducted.

4.4 Reductions and expansions. As long as the volume of air being carried remains the same (no takeoffs or outlets and no significant leaks), the cross-sectional dimensions should remain the same for the length of the duct. If space does not permit this, then a reduction in size or a change in shape becomes unavoidable. Any change should be made in a straight stretch of duct, if possible, and made with a thought to keep the aspect ratio[4] as low as possible. When a dimension must decrease or increase, the gentler the rate of change, the less the loss of efficiency. Try to limit the angle of increase

[4] See "Aspect Ratio" in appendix B.

| STEP NO. | STEP DESCRIPTION AND EXPLANATION | COMPLETED |
|---|---|---|
| | Steps 1 thru 17 are in Chapter 2 - Selecting the ECU | |
| 18 | Determine what needs cooling:<br>• Personnel<br>• Equipment<br>• Both | |
| 19 | Accurately locate on the scale drawings personnel stations and all installed equipment, cabinets, or other objects which might cause an obstacle to straight airflow. Identify the position of electrical equipment. | |
| 20 | Determine where the ECU supply and return will be. You may not have much choice in this; the location of a wall-mounted ECU is dictated largely by the shelter wall structure and the mounting structure design. The ducted supply and return from an ECU on a remote mount provide more flexibility for locating the entry into the shelter. But even here, you may find yourself restricted by the arrangement of interior-mounted mission equipment. If you have a choice:<br>• Position the supply and return to avoid a short circuit.[1]<br>• Locate the supply so that the air stream is afforded a straight path to the primary area to be cooled.<br>• Locate the supply so that the conditioned air reaches personnel stations first and electrical equipment second.<br>• For horizontal ECU's, locate the supply entry into the shelter in the upper part of the wall. If the ceiling is free of obstructions, a location near the ceiling should be selected. If there is an obstruction on the ceiling, the supply should be lowered to where a straight air stream will miss the obstruction. In most cases the supply air outlet of a vertical ECU mounted at floor level will be high enough to permit free flow distribution without<br><br>[1] See definition in appendix B. A short circuit can defeat your system so avoiding it is important. | |

FIGURE 4-1. Air distribution system planning instructions.

| STEP NO. | STEP DESCRIPTION AND EXPLANATION | COMPLETED |
|---|---|---|
| | ducting unless there is an obstruction to proper flow. The location of the return is less critical but should not be blocked or positioned to cause a short circuit (see next page). It is desirable that the return be in the lower part of the wall, even near the floor if this is an easy option. | |
| 21 | Accurately locate on the drawings the conditioned air supply and return outlets. | |
| 22 | Determine by using the drawings if there is a direct, unobstructed view, at least as wide as the supply outlet, from the air supply to points to be cooled. If not, an unsatisfactory condition for free-flow distribution exists. See step 25. | |
| 23 | Determine by using the drawings if a short circuit condition exists or is likely to exist. A good rule of thumb to follow is: if it seems likely that there will be a short circuit, assume there will be. If there seems to be a short circuit condition, an unsatisfactory condition for free-flow distribution exists. See step 25. | |
| 24 | Determine if free-flow air will pass heat generating electrical equipment enroute to personnel. If so, multiply the wattage of the equipment by 3.4 Btuh per watt. If the result is 35%[2] or more of the ECU-rated cooling capacity, an unsatisfactory condition exists for free-flow distribution. See step 25. | |
| 25 | If all conditions examined in steps 22, 23, and 24 are satisfactory, ducting is not required; you may use free-flow air distribution, and the remainder of this step and all of step 26 may be omitted. If any condition is unsatisfactory, ducting is necessary.<br><br>• If more than one condition is unsatisfactory, any ducting planned must satisfy all conditions.<br><br>• On the drawings, sketch the route of the ducting and the location(s) of outlet(s) to overcome the problem(s). Keep in mind that:<br><br>[2] The 35% is another rule of thumb and is based upon considered judgement; it is believed close enough for your purposes in this handbook. | |

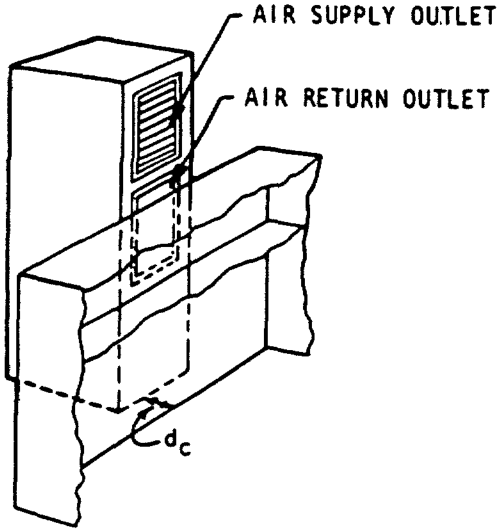
FIGURE 4-1. Air distribution system planning instructions - continued.

| STEP NO. | STEP DESCRIPTION AND EXPLANATION | COMPLETED |
|---|---|---|
| | •• Only the supply needs to be ducted except in unusual circumstances. | |
| | •• The duct should be as short as the requirement will allow. | |
| | •• Changes in direction and size or cross-sectional shape of ducts should be minimized and curves should be as gentle as space will permit. | |
| | •• High velocity air (50 fps or higher) blowing directly on a person will be uncomfortable. The best approach for air at acceptable[3] velocities is directly from the front. The next best is from the side or from overhead. The least desirable, from the viewpoint of comfort, is from behind the person.[3] | |
| | •• While comfort is not to be ignored, these systems are for use under field conditions where comfort must take second place to operational and logistical considerations. If in extreme weather conditions the temperature occasionally becomes a little warmer or a little cooler than desired, the occupants can dress accordingly. If there are times when the breeze from the ECU is blowing directly on an occupant and is either too strong or too cool, the occupant can change the louver setting to deflect the airflow. | |
| 26 | Once you have decided upon the location of the duct and the outlets, the size and cross-sectional shape of the duct should be determined. These may be controlled to some extent by the space available but you should try to keep them as close as you can to the dimensions of the supply discharge. The aspect ratio, that is the ratio of the cross-sectional long dimension to the short should be as close to that of the supply discharge as practicable or else as close to 1:1 as practicable.[4] If the duct must be over walkways, there may be some constraint on the depth of the duct so that there will be sufficient head room. In this case, the vertical dimension will be the short one and the | |
| | [3] Reference 3, p. 2-65. Acceptable velocities are between 18 fps and 50 fps; most favorable is around 25 fps. | |
| | [4] See "Aspect Ratio" in appendix B. | |

FIGURE 4-1. Air distribution system planning instructions - continued.

## Clearance for Air Return

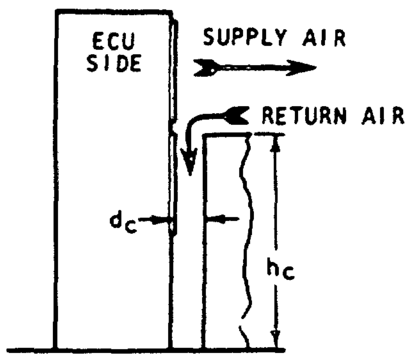
The following is a rule of thumb and not a hard-and-fast requirement. You may vary from it if the equipment in the shelter cannot be arranged to permit the recommended clearances. But you must keep in mind that the more you squeeze the air flow clearances, the greater the risk to the effectiveness of the environmental control system.




The clearance ($d_c$) in front of return intake of the ECU should be at least 2 inches or that necessary to provide a cross-section of air flow equal to twice the area of the ECU return intake opening, whichever is greater.

Example:

A = Area of ECU air return intake opening
= 15 in. x 16 in. = 240 sq in.
$w_c$ = Width of clearance = 16 in.
$h_c$ = Height of clearance = 30 in.




FIND: Required depth of clearance, $d_c$

$$2A = d_c\ (2h_c + w_c)$$

Notice that since obstruction is sitting on the floor, air flow is around three sides only.

$$d_c = \frac{2 \times 240}{2(30) + 16} = 6.3 \text{ inches}$$

NOTE: If the air flow from the sides of the ECU is lessened by reducing the clearance or adding more obstructions, the more will be the air that must come over the top of the obstruction. This path will impinge on the flow space of the air from the supply outlet and create conditions that could result in a short circuit. If this becomes a problem, the supply air outlet should be relocated by ducting.

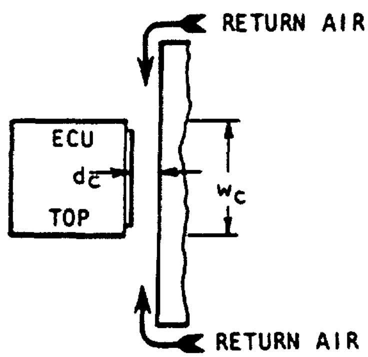



FIGURE 4-1. Air distribution system planning instructions - continued.

| STEP NO. | STEP DESCRIPTION AND EXPLANATION | COMPLETED |
|---|---|---|
| | aspect ratio will be considerably more than 1:1. On the other hand, if the duct passes over cabinets, there may be room to make the aspect ratio approach 1:1. In any event, you should try to avoid an aspect ratio over 5:1. Determine the controlling dimension and, using the cross-sectional area of the supply discharge, determine the other dimension. You must accept that adequate may have to be good enough. Shelters are usually cramped for space with a number of valid needs competing for that which is available. Also, the small spaces sometimes dictate practices that would not be followed if more room were available. So, you do the best you can and take what you get. | |

FIGURE 4-1. Air distribution system planning instructions - Continued.

or decrease to not more than that shown in figure 4-2. If it is impossible to stay within the limits shown in figure 4-2, the disadvantages of the wider angles can be lessened somewhat by the use of splitters to guide the flow generally along a less angular path (see figure 4-3).

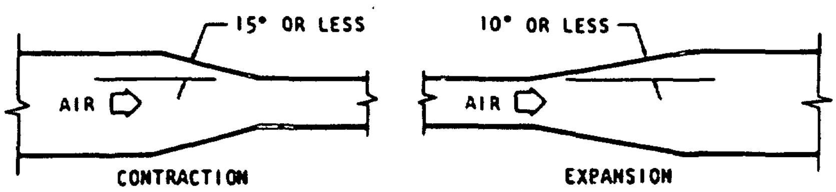



FIGURE 4-2. Maximum desirable contraction and expansion angles.

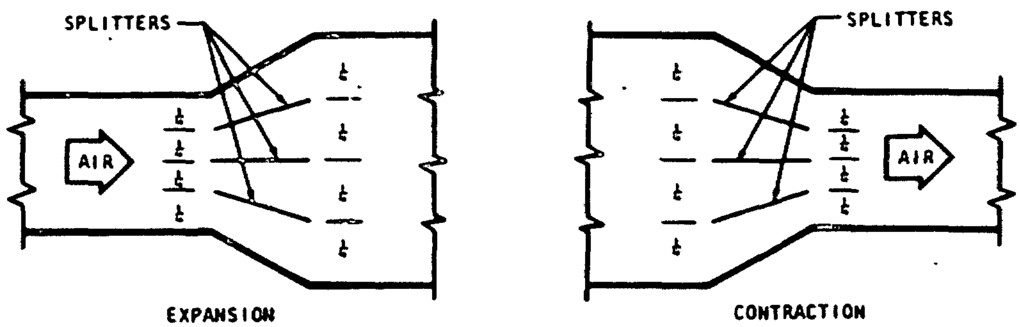



FIGURE 4-3. Splitters in expansion and contracting fittings.

4.5 Bends. Several types of bends, or elbows, which may be useful are illustrated on figures 4-4 and 4-5 (only rectangular ducting is shown since rectangular shapes are more adaptable). Referring to figure 4-4:

a. The full radius elbow, which by definition has an R/D ratio of 1.25, is considered optimum.

b. Because of the limited space available in shelters, short radius (anything with $R_t$ less than 3/4D, including $R_t$ equal to zero) or square elbows are generally used. In order of efficiency and reverse order of overall costs, elbows rank: full radius, short radius, and square.

(1) To improve their lower efficiency, short radius and square elbows normally require turning vanes. For curved elbows, the vanes should run the full length of the curvature and only two or three will be necessary.

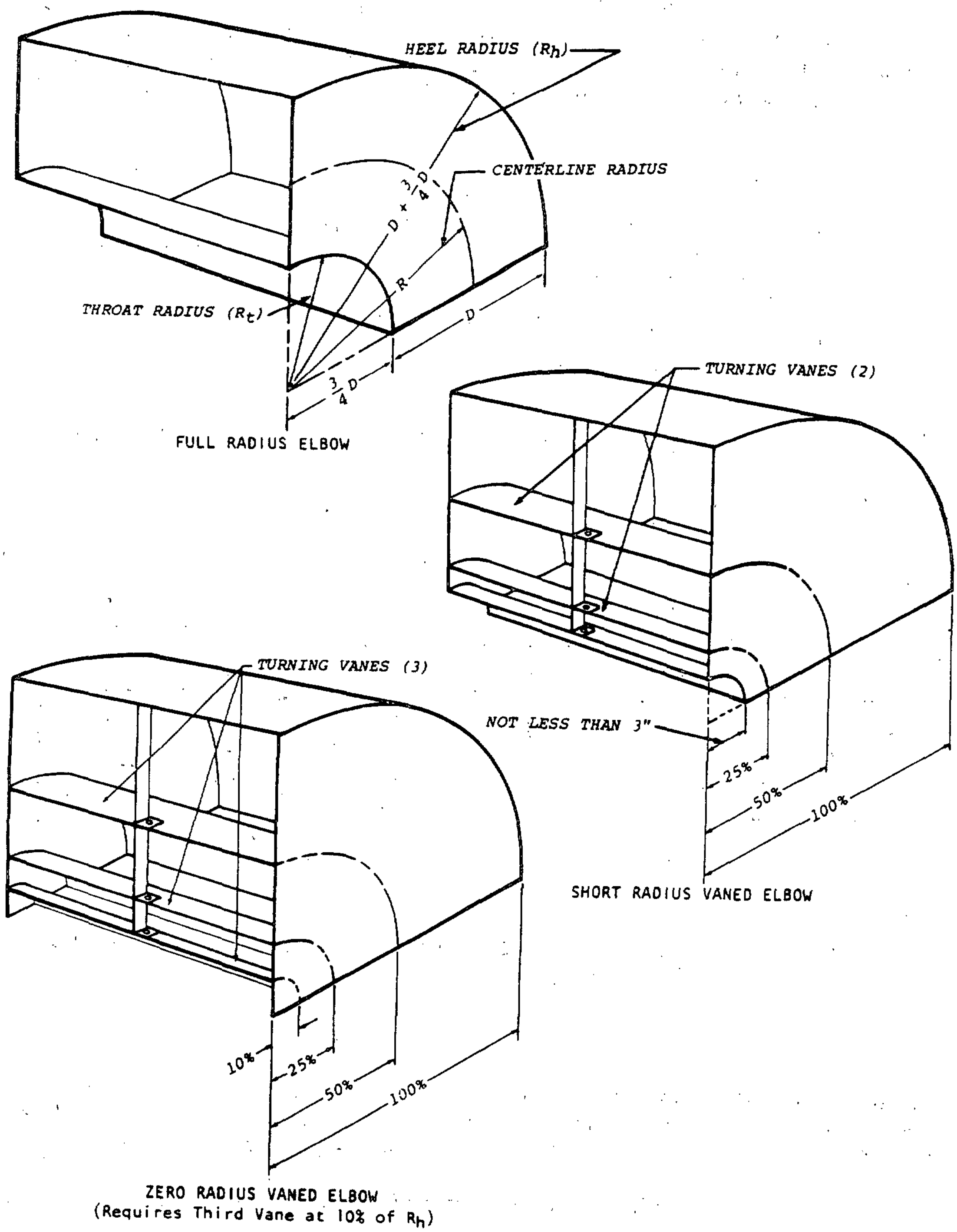



FIGURE 4-4. Curved elbows for rectangular ducting.

(2) The square elbow, as shown in figure 4-5, requires numerous small vanes, the number depending upon the size of the elbows. There are two types of vanes: single thickness, which are the thickness of the sheet metal used to fabricate them, and double thickness configured to an aerodynamic shape. The double thickness vanes are considerably more efficient and are preferable. A reliable heating and air conditioning contractor can probably supply these. The sketches in Figure 4-5 show the location and spacing of vanes for both types of elbows.

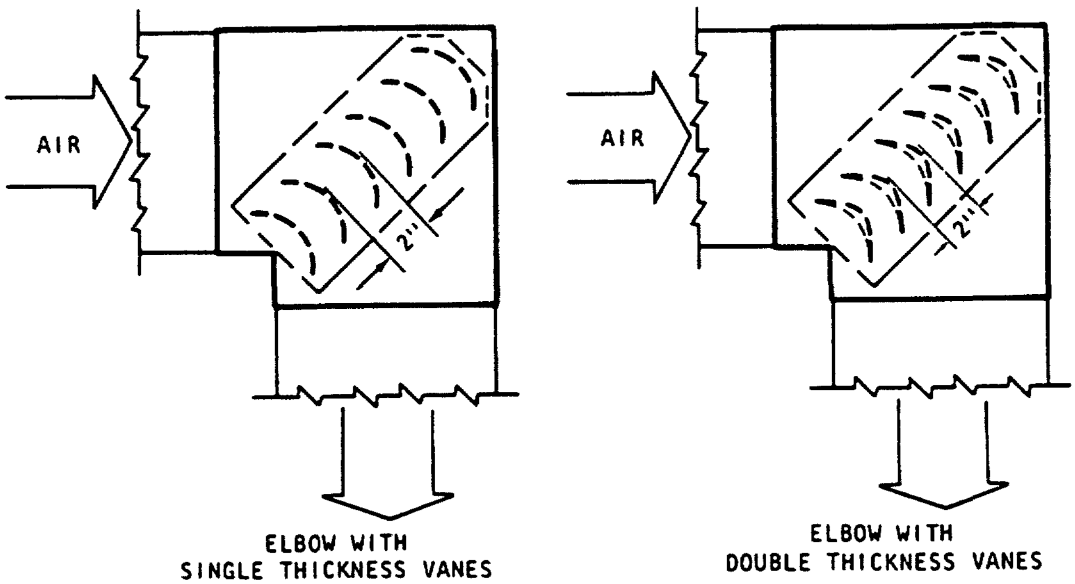



FIGURE 4-5. Vaned square elbows.

4.6 Takeoffs. Takeoffs are needed to channel some of the air from the main stream to a second destination. Two types should be considered for application: the diverging wye, which is the preferred takeoff, and the diverging tee for use where space prevents the use of a wye (see Figure 4-6). When diverting air from the main flow, you will need to know how much air is taken off and how much remains in the main duct for other destinations. For the small systems dealt with here, an acceptably accurate way to estimate flow of air in the main and branch ducts is direct proportion to the duct cross-sectional areas. For example, the flow of air in the main duct beyond the takeoff plus the flow in the branch must equal the flow approaching the takeoff. The lower part of figure 4-6 provides a graphic means of making these estimations.

4.7 Outlets.

4.7.1 Functions. Outlets are important elements of the distribution system even though they are at the end of the line. Their primary functions are to:

a. Direct the air in desired directions.

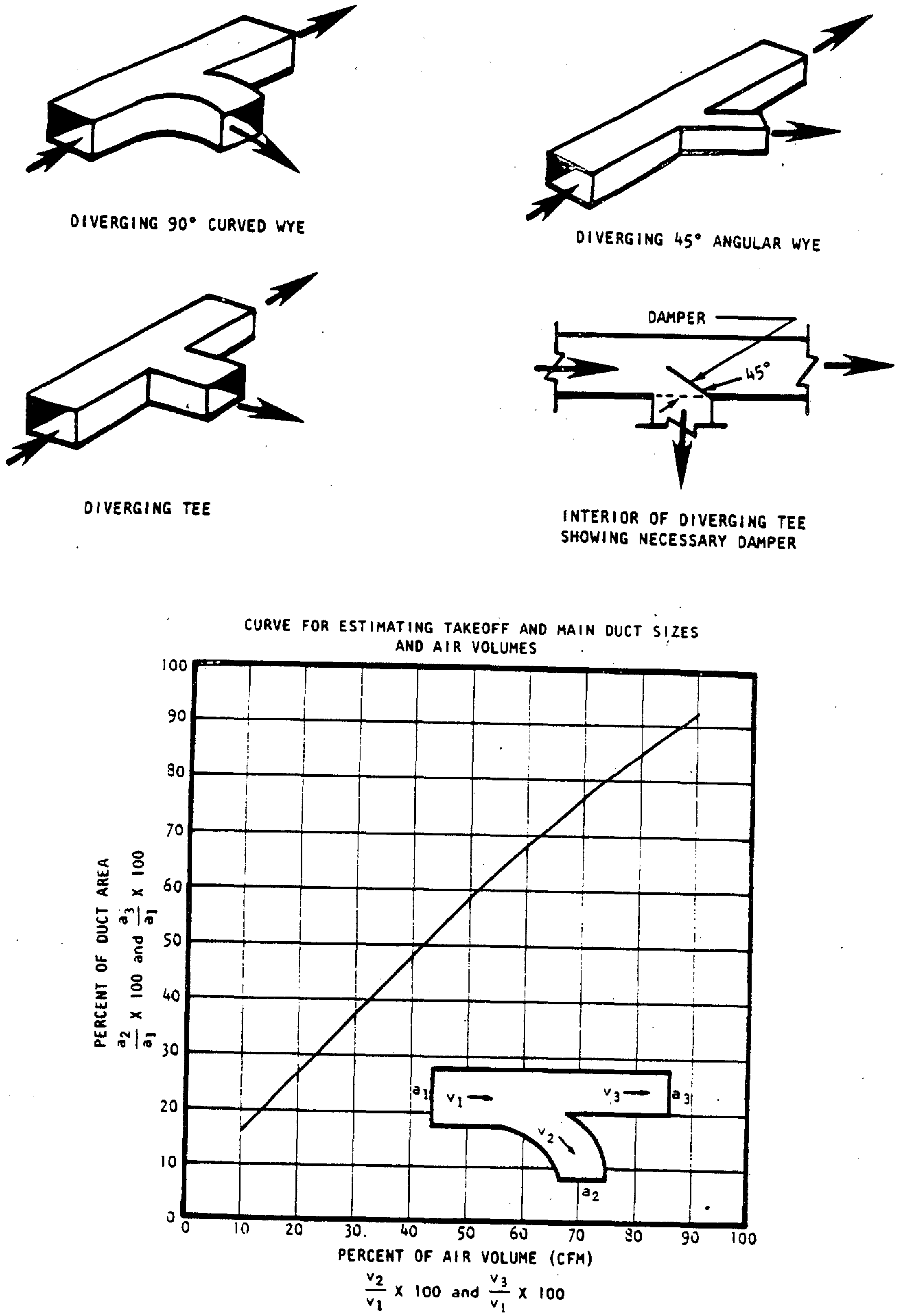



FIGURE 4-6. Takeoffs.

b. Regulate the spread of the conditioned air stream and the resultant entrainment of room air into the conditioned air stream.

c. Achieve entrainment at the desired rate; the higher the entrainment rate, the shorter the throw distance for the air stream and the more quickly the objectional air velocities are reduced.

4.7.2 Wall outlets. Grilles with individually adjustable louvers, such as those with the ECU, are the most desirable type of wall outlet. They can satisfy the above three functional requirements in most cases. Louvered grilles are available commercially in a variety of sizes. In some instances, however, the air can enter the compartment with such a velocity that it creates a high level of noise and draws complaints about uncomfortable breezes. In these cases a long, narrow outlet as illustrated in figure 4-7 may be needed (as close to the width of the shelter as available space will allow and only 2 or 3 inches high). With this, the velocity will be reduced, cutting down the noise and the breeze.

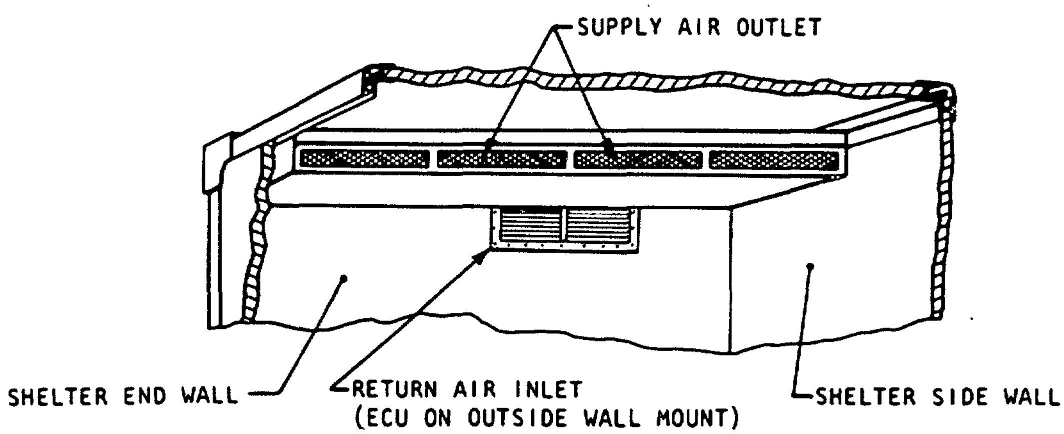



FIGURE 4-7. Outlet for reducing air velocity and noise.

4.7.3 Ceiling outlets. The two types of ceiling outlets are diffusers and perforated ceilings:

(1) As their name implies, diffusers disperse the air into the compartment. The approach of the air to the diffuser is a factor in its effectiveness. Two methods of achieving a satisfactory approach are illustrated in figure 4-8.

(2) The perforated ceiling is a form of plenum and is rarely used in shelters.

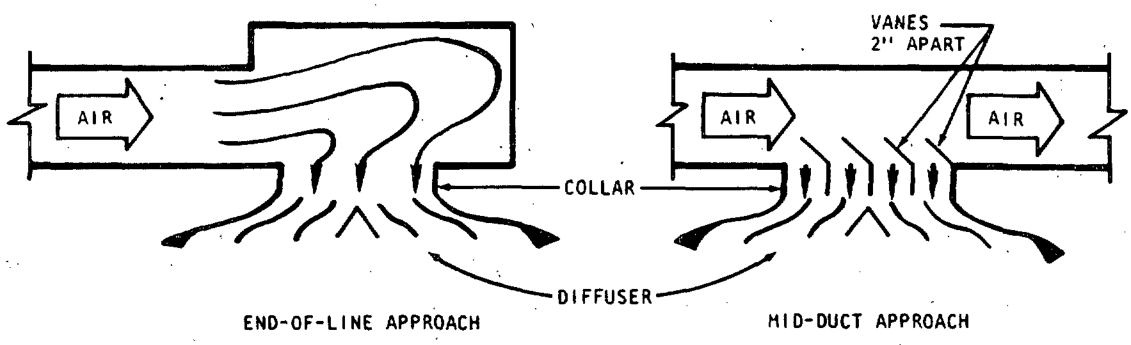



FIGURE 4-8. Approaches to diffusers.

4.8 Material. Weight and safety considerations lead to the recommendation that ducts be fabricated from 22-gauge aluminum[5] and that all joints, seams, and connections be made airtight.

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[5]Appendix A, Reference 3, Table 14.

# CHAPTER 5

# PROTECTING AGAINST CHEMICAL, BIOLOGICAL, AND RADIOACTIVE FALLOUT CONTAMINATION

5.1 Introduction. Previous chapters of this handbook provided information on environmental control in shelters during peacetime operations. In wartime, the potential hazards of nuclear, biological, and chemical (NBC) contamination of the environment are a serious threat. Against this threat, personnel protection and environmental control equipment in shelters must be capable of working effectively to ensure the safety of personnel and mission achievement. This chapter provides information on NBC protective equipment and its relationship to and impact on ECU's.

5.2 Effects of CB agents and radioactive particulates. The effects of CB agents or radioactive particulates on personnel are extremely serious. Addtionally, the effects on equipment are serious. Electronic equipment is particularly vulnerable. Protection of both personnel and equipment is recommended. Therefore, proper installation of ECU and modular collective protection equipment (MCPE) is critically important.

5.3 Personnel protection. Personnel can obtain protection from NBC effects by using a mask and protective clothing or by staying inside a properly sealed shelter equipped with MCPE. However, due to the physiological burden experienced when wearing the mask and protective clothing, operational effectiveness of the individual is degraded. This degradation has been measured and data are available from the Chemical Research Development and Engineering Center[6]. The MCPE provides clean, filtered air with sufficient positive pressure to prevent penetration of NBC contaminants from outside so that the individual can function without psychological burden.

5.4 Modular collective protection equipment. The MCPE provides sufficient, clean, filtered air to maintain a small positive pressure of 0.7 inch of water inside the shelter or enclosure to prevent penetration of contaminants from the outside. The system includes a gas particulate filter unit (GPFU), an integrated protective entrance (IPE), a system control module (SCM) and, for 200 cfm and 400 cfm capacity (GPFU's), a motor controller (MC). Flexible ducting and electrical cables are not provided. MCPE components are discussed below in the context of the interfaces between the GPFU, ECU, PE, and shelter.

5.5 Interfaces.

5.5.1 MCPE-shelter interface.

5.5.1.1 GPFU. Three sizes (capacities) of GPFU are available: 100 cfm, 200 cfm, and 400 cfm (see figure 5-1). Paragraph 5.9 explains how to select the size needed.

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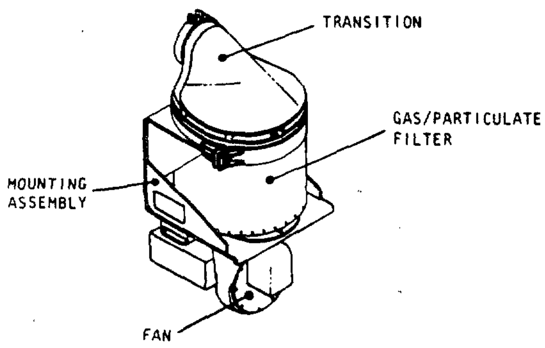
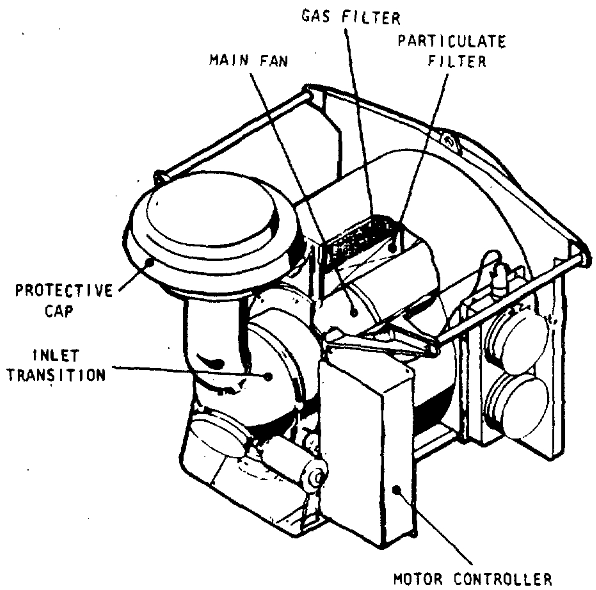
[6] See 1.6




XM93 100 CFM GAS PARTICULATE FILTER UNIT




XM95 OR XM96 GAS PARTICULATE FILTER UNIT

| UNIT | DIMENSIONS IN INCHES | | | WEIGHT (LB) | POWER CONSUMPTION (KW) |
|---|---|---|---|---|---|
| | HEIGHT | WIDTH | LENGTH | | |
| XM93 100 cfm | 28.0 | 14.0 | 14 | 61 | 0.51 |
| XM95 200 cfm | 32.9 | 35.5 | 35 | 165* | 1.10 |
| XM96 400 cfm | 32.9 | 35.5 | 45 | 215* | 1.70 |

*Add 45 lbs when used with ground mount stand.

FIGURE 5-1. Gas particulate filter units.

5.5.1.1.1 Mounting.

a. 100 cfm GPFU. The 100 cfm GPFU is designed to be mounted directly to the shelter wall. There is no requirement for direct GPFU-ECU interface, but the possibility that both may have to be mounted on the same wall should be kept in mind.

b. 200 cfm and 400 cfm GPFU's. In most cases, the GPFU's should be mounted on the ground using the stand available for this purpose (see appendix A, reference 12). In cases where wall mounting is required, care should be taken not to overload the shelter wall. ECU wall mount number 2 (see figure 3-4) with some adaptation can accommodate the GPFU and one 18,000 Btu/hr ECU within the limits of the wall capability. If an individual wall mounting option is required, the Physical Protection Directorate, U.S. Army Chemical Research Development and Engineering Center (see 1.6) has a design which should be examined for its applicability before initiating effort to design another mount.

5.5.1.1.2 Ducting. Air from the ground-mounted GPFU is carried to the shelter through flexible ducting. This ducting, like several other components, is very vulnerable to blast and fragments.

5.5.1.1.3 Power. The 100, 200, and 400 cfm GPFU's can operate using 120V, single phase, 60 or 400 hz input power, or 208V, three phase, 60 or 400 hz input power. The maximum power consumptions of these units are 510W, 1100W, and 1700W, respectively. The actual power used depends on the fan speed required to maintain the 0.7 inches of water positive pressure inside the shelter. Good sealing of the shelter, therefore, will minimize power consumption. The motor contoller must be used in the 200 cfm and 400 cfm applications. The motor controller weighs 47 pounds and is 16 inches tall, 9 inches wide, and 7.5 inches deep. It should be mounted vertically, to facilitate cooling, and may be mounted on the GPFU or directly on the shelter wall or floor. Since the motor controller uses solid-state devices, which are very vulnerable to electromagnetic pulse, consider mounting it inside the shelter or, if mounted outside, assure adequate shielding is provided.

5.5.1.1.4 Optional applications. The GPFU may prove useful in non-NBC situations where an effective capability to remove dust and supply a quantity of clean, fresh air is required. Conversely, in situations where dust will not be a problem, the GPFU may be used without the dust separator. However, since the GPFU can add 10 to 15 °F to ambient air temperature, it may be necessary to use it in conjunction with an ECU.

5.5.1.2 System control module. This automatically regulates the shelter air pressure relative to ambient and must be mounted on the inside of the shelter. It is connected to the GPFU by a power cable which will require an entry provision in the shelter wall. (Note that all MCPE cables are unique to the system. Obtain information on cables and connections from the Chemical Research Development and Engineering Center, see footnote to 5.3.) When pressure falls below a safe level, a horn in the module sounds to warn personnel to don protective masks and equipment. At the same time, an indicator on the control module labeled "MASK" lights.

5.5.1.3 Integrated protective entrance (IPE).

5.5.1.3.1 Description. IPE's are collapsible entries designed to fit S250 and S280 shelters; they come already attached to the shelter doors (as shown in figure 5-2). To install the IPE, replace the shelter door with the IPE-door assembly. If a shelter other than the S250 or S280 is used, modifications of the IPE probably will be required. The IPE for the S280 shelter is available in two models: one mounts on the outside of the shelter door, the other mounts on the inside. The IPE for the S250 shelter is available in only one model and mounts on the outside of the shelter door. An IPE can be erected by one man in a few seconds and can be struck and remain attached to the shelter door during the non-NBC mode. IPE's are self-supporting and platforms are not required.

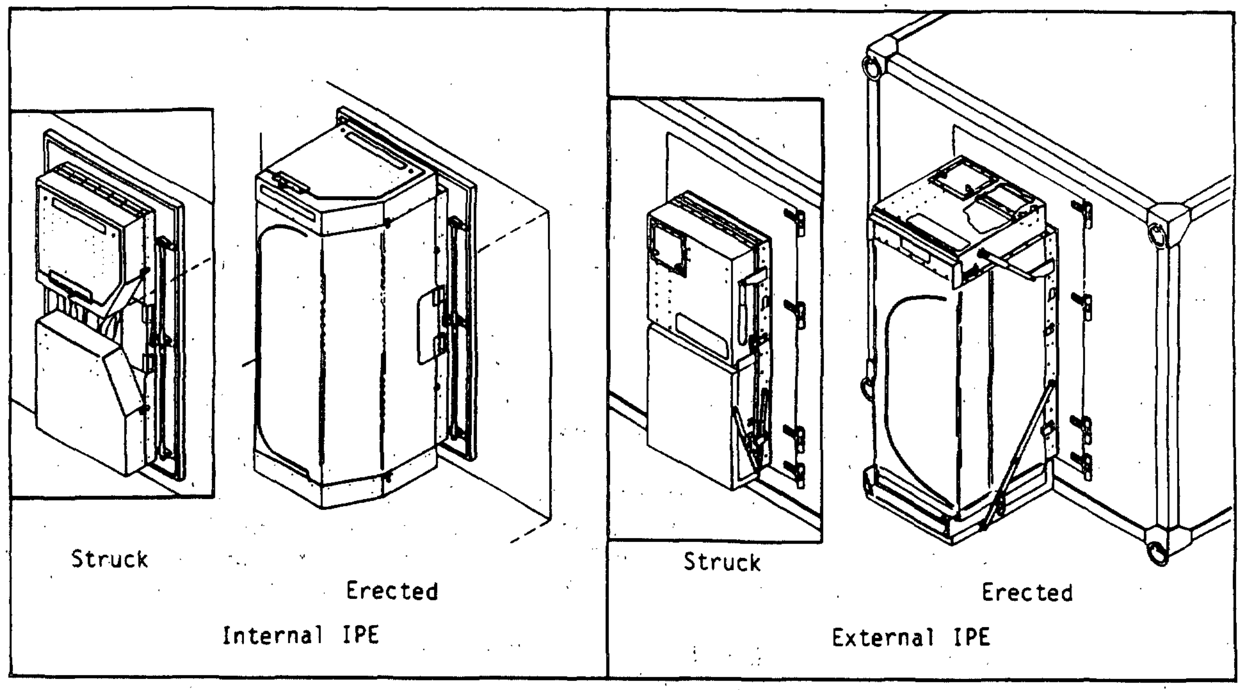



FIGURE 5-2. Integrated protective entrances (IPE).

5.5.1.3.2 Function. The IPE is a pressurized transitional compartment. In it, personnel coming in from a contaminated atmosphere can be subjected to a recommended 5-minute air wash and can perform personal decontaminating operations before entering the shelter, itself. Space inside the IPE limits occupancy to one person at a time. Positive air pressure within the IPE assures an outward leakage to prevent entry of contamination. The IPE receives air for the air wash through an opening in the IPE/shelter interface. The opening is sized to control the air flow rate from the shelter to the IPE so that the IPE pressure of 0.4 inches of water is lower than the shelter pressure of 0.7 inches of water. This pressure differential ensures that air in the IPE does not enter the shelter, but the differential is low enough to minimize loss of shelter pressure when people enter or leave. This pressure level is monitored by means of a protective entrance module which is located inside the IPE.

5.5.1.3.3 Vulnerability. IPE's are unhardened and very vulnerable to fragments and blast waves, and will likely be lost to blast and fragments. Replacements should be kept available. The IPE module meets nuclear hardness requirements, primarily EMP.

5.5.2 MCPE-ECU interface. The ECU interfaces with the shelter and, in that the shelter is a part of the MCPE system, it also interfaces with the MCPE. An effective seal between the ECU (air supply and return openings and power and control cable entries) and the shelter is essential. Included in this seal is the closing of the ECU fresh air intake during operations under NBC conditions (see appendix B, figure B-1).

5.6 Summary of concerns regarding the MCPE.

a. Although the basic MCPE system has passed several nuclear hardening, EMI and EMP tests, the unhardened shelter, the flexible ducting, and the external IPE are very vulnerable to blast and fragments. Anticipate that the ducting and the IPE will require replacement following a conventional or nuclear attack; for this reason, spares should be available.

b. Exterior ducting is also subject to heat transfer from ambient conditions to filtered air. Because of this and the vulnerability of exterior ducting to blast and fragments, consider the use of wall-mounted GPFU's.

c. The ECU-MCPE (shelter) interface must be sealed against entry of contaminants.

d. When the ECU operates in conjunction with the MCPE, the initial ECU selection should be reassessed. Filtered air from the GPFU comes out 10 to 15 °F warmer than it goes in; this adds to the cooling load of the ECU. The additional heat load may exceed the cooling capacity of the ECU which was initially selected in chapter 2. Guidance for reassessing the ECU requirements is provided in 5.10.

e. The shelter must be sealed well enough to permit the GPFU to maintain the necessary positive pressure without undue loss of air. Good sealing is necessary also to prevent a momentary reverse flow of air due to greater outside pressure, such as can be created by a blast wave or a passing truck. Additionally, when the MCPE is operating in an actual NBC atmosphere, the ECU fresh air intake must be closed or contaminated air will enter the shelter and air leakage will prevent adequate pressurization.

f. Sealing material used to reduce air leakage and protect against NBC agent infiltration must be impermeable to air; resistant to CB agents, environmental extremes, and decontamination fluids; be easy to install; and be compatible with requirements for protection against EMP (see chapter 6).

g. More detailed information on the MCPE may be found in appendix A, references 4, 7 and 12.

5.7 Integration of GPFU and ECU. In current applications, the MCPE and the ECU are not integrated into a single unit. Although there are components of similar purpose in each (e.g., blowers and, with the new multiple input power ECU, the motor controller) the components cannot perform each other's functions in their present configurations. Further, there are so many components dedicated to each unit's specific function that little can be eliminated through integration of the two units into a single package. The separate units offer certain advantages:

a. There is more flexibility in mounting arrangements.

b. The ECU can function alone when CB attacks are not imminent, thus saving power.

c. In the event of a breakdown, one can be replaced without having to replace the other as well.

5.8 Caution. None of the filters in the equipment discussed above or in the GPFU will protect against carbon monoxide or ammonia fumes.

5.9 Determination of GPFU size. The ECU requirement is based on the cooling load, which is increased by the heat added to the shelter air by the GPFU. This is addressed in 5.10. Additionally, the size and weight of the GPFU must be considered in cases where both the GPFU and the ECU share the same mounting system. For this reason, it is useful to be able to find the size of the GPFU that will be used. The determination of GPFU size is based upon the air flow requirement. There are several factors to be considered.

5.9.1 Shelter leakage. This is incidental leakage as opposed to deliberate venting. Although MIL-STD-907 specifies a maximum allowable leakage, actual leakage can be determined only by test since it is largely dependent on how well the shelter is sealed against leaks. It should be measured at the positive pressure under which the system will function/ Some leakage, either incidental or deliberate, is required if ventilation requirements are to be met.

5.9.2 Ventilation. Personnel health and comfort require ventilation. Multiply the average number of people occupying the shelter at any one time by 20 cfm per occupant to determine the ventilation air requirement. If in chapter 2 (refer to 2.11.b) a smaller figure than 20 cfm per person is used, then that figure should be used. If incidental leakage is insufficient to provide for the required ventilation, a means of deliberate venting must be provided. (The GPFU and ECU, after a certain pressure is reached, can input only as much air as can be leaked or vented.) Adjustable dampers are available for this purpose; examples are illustrated in appendix A, reference 14, pages 235 and 237. Also, most shelter manufacturers have workable dampers.

5.9.3 Integrated Protective entrance. The IPE must exhaust contaminated air after air-washing people who are entering the shelter. It therefore has a deliberate leakage of 50 cfm.

5.9.4 ECU makeup air. This requirement is not a factor in determining the GPFU capacity. When the shelter and MCPE are used in an NBC environment, one of two situations exists relative to the ECU makeup air (fresh air) intake (see figure B-1). In one case, part of the GPFU output is passed through the ECU for conditioning before entering the shelter; in this case, it is ducted directly to the ECU makeup air intake. In the other case, the GPFU air enters the shelter first and then is taken into the ECU, through the return air inlet, for conditioning. In this latter case, the ECU fresh air inlet damper must be closed to prevent loss of shelter air pressure. In either case, the makeup air is not an air flow requirement for the GPFU.

5.9.5 Air flow requirement determination. This can best be explained with the following illustrative example.

a. Shelter leakage. For the purpose of the example, it is assumed that the shelter leakage is the maximum allowed by MIL-STD-907: 240 cfm

b. Ventilation. Three people are assumed to be in the shelter. At 20 cfm/person, the requirement is: 60 cfm

c. Protective entrance. The IPE is assumed to be at 1.5 cfm and requires: 50 cfm

d. Analysis.

(1) The shelter leakage (200 cfm) exceeds the ventilation requirement (60 cfm), so ventilation is satisfied through incidental leakage; deliberate venting will not be required.

(2) The total of the leakage to be made up plus the IPE requirement is 250 cfm (200 cfm plus 50 cfm). This is too large for the 200 cfm filter size so the 400 cfm unit will be required.

(3) If the leakage can be reduced by better sealing, to where the loss is only 150 cfm, then the total would be 200 cfm and the GPFU of that capacity can be used. This is an advantage if it will prevent having to go to a larger ECU. Besides the drawback of an oversized ECU mentioned in 2.9, a larger ECU would use more power, as also would the larger GPFU.

5.10 Reassessment of ECU size based upon use of the GPFU. If a GPFU and IPE are added to the air system of the shelter, the ECU size determination must be reevaluated. As mentioned in 2.5, ambient (outside) air temperature is raised by 10 to 15°F when it passes through the GPFU. Further, as shown above, the use of the GPFU greatly increases the volume of air being introduced into the shelter over that needed for ventilation. These two make it necessary to recompute step 4, Worksheet Part I (figure 2-1), and step 7, Worksheet Part II (figure 2-2), to determine the increased cooling and descreased heating loads. The wording of these steps should be revised as follows:

"4. Heat from ventilation: _______ Btuh/cfm x _______ cfm = _______ Btuh."
(4a-rev) (4b-rev) (4-rev)

"7. Vent heat loss: _______ Btuh/cfm x _______ cfm = _______ Btuh."
(7a-rev) (7b-rev) (7-rev)

a. Blanks (4a-rev) and (7a-rev). The values in these spaces are normally taken from columns G and H of Table IV. When the GPFU and PE are used, these values should be taken, instead, from columns I and J of Table VII, for the same climate category.

b. Blanks (4b-rev) and (7b-rev). The ventilation air requirement is exceeded by the shelter leakage and the PE air requirements. The air volumes of blanks (4b-rev) and (7b-rev) should therefore be determined as shown in 5.9.5, above.

c. Example. These steps are illustrated by revising step 4 of figure 2-1 (step 7 of figure 2-2 is revised similarly):

TABLE VII. Ventilation factors when GPFU is used.

| CLIMATIC CATEGORIES | I SUMMER VENTILATION HEAT GAIN (BTUH/CFM) | J WINTER VENTILATION HEAT LOSS (BTUH/CFM) |
|---|---|---|
| A1 HOT DRY | 62 | 66 |
| A2 MOD HOT DRY | 50 | 66 |
| B1 WET WARM | NA | 66 |
| B2 WET HOT | 116 | 66 |
| B3 HUMID HOT | 140 | 66 |
| C0 MILD COLD | 55 | 66 |
| C1 MOD COLD | 55 | 94 |
| C2 COLD | 55 | 120 |
| C3 SEVERE COLD | 55 | 130 |
| C4 EXTREME COLD | 55 | 141 |

(1) For blank (4a-rev), the new summer ventilation heat gain is 55 Btuh/cfm (table VII, column G).

(2) For blank (4b-rev), the total air input air volume is 250 cfm (from 5.9.5.a(2), above).

(3) The heat from ventilation is 4a x 4b or 55 Btuh/cfm x 250 cfm, which equals 13,750 Btuh, to be placed in blank (4 rev).

(4) Returning to figure 2-1, replace the "2,340 Btuh" in blank (4) with the "13,750 Btuh" from blank (4 rev) and redetermine the total cooling requirement in blank (5). This now totals 44,501 Btuh.

(5) Reevaluate the ECU selection made in figures 2-3 and 2-4.

5.11 Decontamination. Once NBC contaminants have been deposited on equipment, sooner or later they must be removed or neutralized. Decontaminating agents are highly corrosive and can damage rubber, certain plastics, and metal. For this reason, you should avoid the use of the standard decontaminating agents on the ECU and shelter seals if less stringent means are available. If they must be used, these agents should be applied as prescribed but should be washed off, as soon as instructions for use of the decontaminant permit, with soapy water and a clean water rinse; the soapy water and rinse are effective also in removing (but not neutralizing) contaminants. When using decontaminating agents, avoid applying them to areas not touched during maintenance, closed compartments not contaminated, and areas where it will be difficult to rinse after decontamination. The following subparagraphs discuss the standard agents for decontaminating equipment and alternatives which might be available.

5.11.1 Decontaminating agent, supertropical bleach (STB). STB is a mixture of chlorinated lime and calcium oxide that can be used against all liquid chemical agents and some biological agents. It is available in powder form in 8-gallon drums. It is applied as a powder or as a slurry. It is recommended that STB not be used on equipment covered in this handbook. It is highly corrosive to most metals and injurious to most fabrics. It is toxic and flammable. . Under development is the M12A1, truck-mounted, power-driven decontaminating apparatus which includes a capability to dispense STB and wash vehicles. This would permit decontaminating with STB, followed with a good cleaning, thus overcoming some of the objectionable features of STB. For further information, refer to appendix A, reference 4, pages 103 and 131.

5.11.2 Decontaminating agent, DS2. DS2 is 70 percent active agent (diethylenetriamine), 28 percent solvent (ethylene glycol monomethyl ether), and 2 percent active agent booster (sodium hydroxide). It is available in liquid form in either 1-1/3-quart cans or 5-gallon drums. DS2 is effective against all known chemical agents if allowed to remain in contact to a maximum of 30 minutes. It is effective against the nerve agent CB and mustard gas HD within 5 minutes. As with STB, avoid use of DS2 on the ECU and its ancillary equipment. However, if a choice between STB and DS2 must be made, DS2 is more effective in most cases. Characteristics pertinent to use on ECU's:

a. DS2 has a low flashpoint and can be a fire hazard if used on heated equipment.

b. It is irritating to the eyes and skin and the vapor is harmful if inhaled.

c. DS2 removes and softens new paint, except polyurethane paint, and can discolor old paint and polyurethane. It will also soften leather and rubber products.

More information is in appendix A, reference 4, page 111.

5.11.3 Alternatives to STB and DS2. The following alternatives are primarily means of removing the contamination from the equipment rather than neutralizing it. An exception is the heat method which can evaporate most chemical agents and destroy biological agents. Remember that if an agent is just removed, as in washing, it still remains a potential danger even in the wastewater.

5.11.3.1 Heat. Heat will vaporize most chemical agents and permit them to be dispersed by evaporation into the air in non-injurious concentrations. The temperature necessary for heat alone to do the job is a minimum 180 °F. How this might be achieved is a question which greatly limits its application at present.

5.11.3.2 Soap and water. Washing with a strong alkaline soap (e.g., GI soap) and hot water will likely remove CB decontamination as well as radioactive particles and achieve a small degree of decontamination. This is fairly easy for small, outside surfaces but it may be difficult to reach some interior sections of the ECU.

5.11.3.3 Plain water. Rinsing with plain water may not neutralize the agents but it will probably remove enough to reduce their chances of causing injury. An item recently adopted by the U.S. Army is the M17, lightweight, decontaminating system. This unit, called the NBC Sanator, provides a hot water rinse for shelters, vehicles, and equipment. It draws water from any source, heats it, and delivers it at 100 psi at controlled temperatures up to 248 °F. Additional information is in appendix A, reference 8, page 135.

5.11.3.4 Steam. Steam cleaning is a very effective means of removing and perhaps neutralizing contaminants without damage to the ECU or protective equipment. A mobile steam generator would be a very handy piece of equipment to have for this.

5.12 Additional information. This chapter has provided those who need to integrate environmental control equipment into a shelter system as appreciation of the NBC considerations that must be addressed. For additional information concerning the NBC protective equipment and procedures, contact the U.S. Army Chemical Research Development and Engineering Center (see 1.6).

# CHAPTER 6

## PROTECTION AGAINST ELECTROMAGNETIC PULSE

6.1 Introduction. Electro-Magnetic Pulse (EMP) is a product of all nuclear explosions. In the case of a high altitude explosion (20-60 km), a high intensity, short duration, downwardly travelling 50 kV/m electromagnetic wave can cause damage or upset to sensitive circuits over an area roughly bounded by the line of sight distance from the point of detonation to the earth, potentially for hundreds of miles around. Within this area, all metallic conductors become antennas and collect energy from the EMP field. This energy can be conducted for large distances and put sensitive electronics at risk of EMP-induced damage. Mission-essential equipment must be protected against such risk. AM EMP "shield" can provide this protection through isolation of a particular environment from the EMP field by means of an electrically contiguous enclosure. For C3I systems, for example, this is typically achieved using a tactical shelter which employs one or more aluminum electromagnetic shields. To prevent the energy of the field from being conducted into the shielded shelter via power and signal cables, line filters are used. This chapter offers guidance on how to maintain or restore the EMP shield across penetrations and apertures resulting from the integration of ECU's with an EMP-protected shelter.

6.2 Attenuation requirement. The level of protection from the threat of electromagnetic pulse required by U.S. Army systems is determined by the U.S. Nuclear and Chemical Agency (USANCA). Systems with "low risk" requirements may provide 80 dB of shielding effectiveness of a specified range of frequencies. "Moderate risk" systems must provide a 40 dB primary EMP shield with a second shield. Most frequently cited is the requirement of 60 dB shielding efffectiveness over the electromagnetic frequency range of 150 kHz to 10 GHz. The nuclear hardened shelters cited in Chapter 7 of this document bear this 60 dB requirement.

6.3 ECU and MCPE vulnerabilities.

6.3.1 ECU. The ECU has a number of components which are particularly vulnerable to EMP.[7] The two chief causes of concern are the solid-state rectifier, the solid-state time delay relay, and, in the multiple input power ECU, the motor controller. EMP can cause damage and even total failure in these components. Other elements which may also be weak links in the chain are the capacitors, the filters for DC current, and the starters. While these are not solid-state, the very high currents and voltages induced by the EMP could cause component upset even if they do not cause permanent damage. Additionally, EMP-induced currents and voltages may cause circuit breakers to open or fuses to blow.

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[7]The only exceptions at present are the 18,000 Btuh split-pack ECU, developed for the PATRIOT system, and the 208 volt, 3-phase, 50/60 Hertz version of the 18,000 Btuh compact horizontal ECU, which was hardened to meet a Regency Net requirement. These are believed to be protected to an adequate EMP attenuation level although this is yet to be confirmed by testing.

6.3.2 MCPE. The MCPE has passed basic EMP testing and the version being used for the PATRIOT system, for example, has been modified to provide even greater resistance to EMP. The modifications include part of what will also have to be done with the ECU: the elimination of all solid-state circuitry and the provision of shielding and filtering in the electrical cables.

6.4 Remedy for ECU weaknesses. There are two actions which can be followed in overcoming the ECU's vulnerabilities.

a. The best course is to request the DOD proponent agency[8] to supply ECU's that have the requisite protection. This would provide a basis in demand for the establishment of a program to develop protected ECU's over the range of unit sizes required. Eventually, it would also place EMP-protected ECU's into the DOD procurement system and make future acquisition of these units simpler and quicker.

b. The other alternative is to modify existing ECU's, during production, as was done with the Regency Net unit. This may possibly produce quicker short-term results and might warrant consideration in conjunction with the above course. Modification is sufficiently complicated to warrant doing it at the factory in accordance with performance specifications, to include the required EMP attenuation (see 6.2)[9]. The work should include at least the following and might include other items if the retrofit modifying facility shows them to be necessary to meet the required performance:

(1) Replacement of solid-state components with vacuum tubes or mechanical components or the placement of solid-state circuitry in EMP-shielded enclosures.

(2) The shielding of all other sensitive components (e.g., capacitors, circuit breakers) perhaps by placing them also in EMP-shielded enclosures. Consider the possibility of remote mounting the circuit breakers inside the shelter. This would provide shielding as well as safe access for resetting during attack without having to go outside the shelter.

(3) Conductive sealant at all seams after all aluminum surfaces have been cleaned to bare metal and treated with a chromate conversion coating prior to sealant application. Immediately following the application of all

[8]Commanding General
U.S. Army Troop Support and Aviation Materiel Readiness Command
ATTN: DRSTS-WX
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798
(Procedures for placing a development requirement are contained in DARCOM Regulation 700-5)

[9]The requirement for all EMP protective materials to withstand CB agents, thermal radiation, temperature extremes, corrosive effects of the atmosphere, galvanic corrosion, and air pressures (from within the shelter as well as external nuclear overpressure) also should be spelled out in some detail in the performance specification.

conductive compounds a topcoat of chemical agent resistant coating (CARC) paint should be applied; because of corrosion, no conductive compound should be exposed to air.

(4) Conductive gasketing on all doors and access panel enclosures.

(5) Filtering at control and power cable entries.

(6) Conductive honeycomb barriers on all uncovered openings.

(7) Shielded cables.

(8) All bolts and rivets solidly seated with clean metal-to-metal contact and installed after dipping in conductive sealant and sealed against the environment.

6.5 ECU-shelter interface. The principle EMP shield of a shelter system is made up of the aluminum shelter skins, electrically connected across each panel interface. This electrically contiguous metal enclosure isolates the interior environment from the exterior EMP field. Seam openings and penetrations, however, cause electrical discontinuities across the EMP shield resulting in EMP leakage and reduction of shielding effectiveness. It is imperative that electrical continuity be provided across all apertures to maintain shielding effectiveness. Some means of achieving electrical continuity are discussed below.

6.5.1 Types of gasketing. Some ECU's and MCPE are, themselves, designed to be EMP "hardened", or shielded. This equipment can be mounted directly to the EMP shield of the shelter, with its equipment cabinet in contact with the shelter skin. To ensure contact around the resulting interface seam, EMI/EMP gaskets are used. There are a number of types of this gasketing on the market which can provide the shielding effectiveness (EMP attenuation, air pressure seal, and resistance to chemicals and climatic extremes). Examples of some which may be acceptable:

a. A metal mesh of knitted, springy, resilient, interlocking wire loops (see figure 6-1(a), (b) and (c)). Metal mesh cannot, by itself, provide a pressure or environmental seal; it must be used in conjunction with an elastomer as illustrated in figure 6-1(a). A type of gasket not shown is an elastomer core surrounded by wire mesh. It is claimed that this can provide an environmental as well as an EMP seal although to be of questionable reliability as a pressure seal; this, also, should probably be used in conjunction with an elastomer.

b. A solid or sponge silicone elastomer with embedded, conductive shielding wires oriented perpendicular to the mating surfaces (figure 6-1(d)).

c. A solid silicone elastomer with continuous metal conductive paths throughout the gasket with many surface contact points (figure 6-1(e)).

6.5.2 Gasketing considerations.

a. The oriented wires and the contact points of the conductive paths protrude from the surface of the gasket and, under compression, cut through

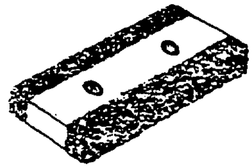
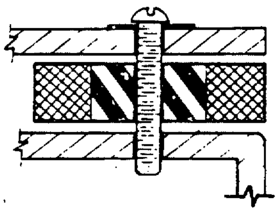
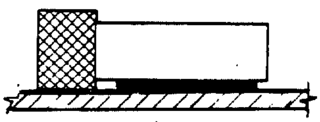
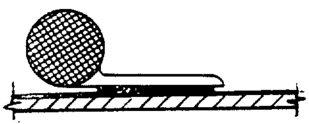
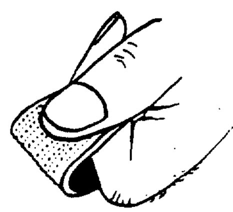
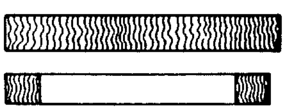
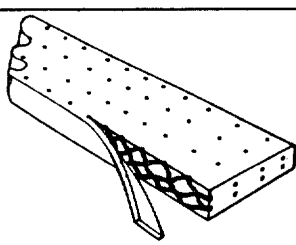
| | |
|---|---|
| KNITTED WIRE MESH |  |
| (a)  | Two formed or compressed mesh strips in parallel with sponge elastomer strip. Affixed with bolt through bolthole. Can be affixed also with adhesive. Thicknesses available: 0.062 to 0.375 inch. |
| (b)  | Formed mesh strip in parallel with mesh attaching strip. Affixed with conductive or nonconductive adhesive. May be obtained with boltholes in attaching strip. Thicknesses available: 0.04 to 0.375 inch. |
| (c)  | Round mesh strip with extruded metal attaching fin. Affixed with conductive or nonconductive adhesive. May be obtained with boltholes in fin. Thicknesses available: 0.062 to 0.500 inch. |
| METAL CONDUCTORS EMBEDDED IN ELASTOMER |  |
| (d)  | Shielding wires in matrix of solid or sponge silicone elastomer. Wires oriented perpendicular to mating surfaces. Affixed with conducting elastomer. Provides composite EMP and pressure seal. Thicknesses available: 0.030 to 0.500 inch. |
| (e)  | Multiple layers of solid copper conductive paths in solid or sponge elastomer. Contact points coated with special tin alloy. Thicknesses available: 0.125 to 0.625 inch. |

FIGURE 6-1. Some examples of EMP gasket materials.

any buildup of nonconductive oxidation to establish good electrical contact with the mating surfaces. The solid elastomer will probably provide a better pressure seal than will the sponge but achieving and maintaining adequate compression pressure will be more difficult than with the sponge elastomer. In designing a gasket, the sponge elastomer compresses into a smaller space while the solid elastomer does not compress but rather deforms and flows while maintaining a constant volume. Space must be allowed in your joint design for this.

b. Most knitted wire mesh and embedded elastomer gaskets are fabricated using Sn/Cu/Fe or Sn/Phosphor Bronze wire. These materials are used to provide a high degree of electrical continuity and minimal corrosion. Since the EMP shield surfaces of most shelters are made of aluminum, corrosion (oxidation) can occur at the shelter/gasket interface due to the dissimiarity of metals. Oxidation can greatly reduce electrical continuity and consequently the shielding effectiveness. It is important, therefore, to apply a chromate conversion coating (in accordance with MIL-C-5541) to aluminum surfaces in contact with the mesh gasket to retard the oxidation process. Electrical contact surfaces that are exposed to weather or subject to wear (such as doors and door jambs) should be flame-sprayed or arc-sprayed with a coating of tin.

c. The service life of the gasket is another factor to consider. The gasket material should be resistant to or protected from abrasion, moisture, chemicals, and thermal radiation. Also, close attention should be paid to manufacturers' specifications, since some elastomers change under temperature extremes, becoming hard and brittle in extreme cold and soft and foamy in extreme heat. In either case, reduction in shielding effectiveness can result.

d. Compression pressure (to compress the seal between the mating surfaces) is important in developing the full EMP shielding and pressure/environmental seal effectiveness of the gasket.

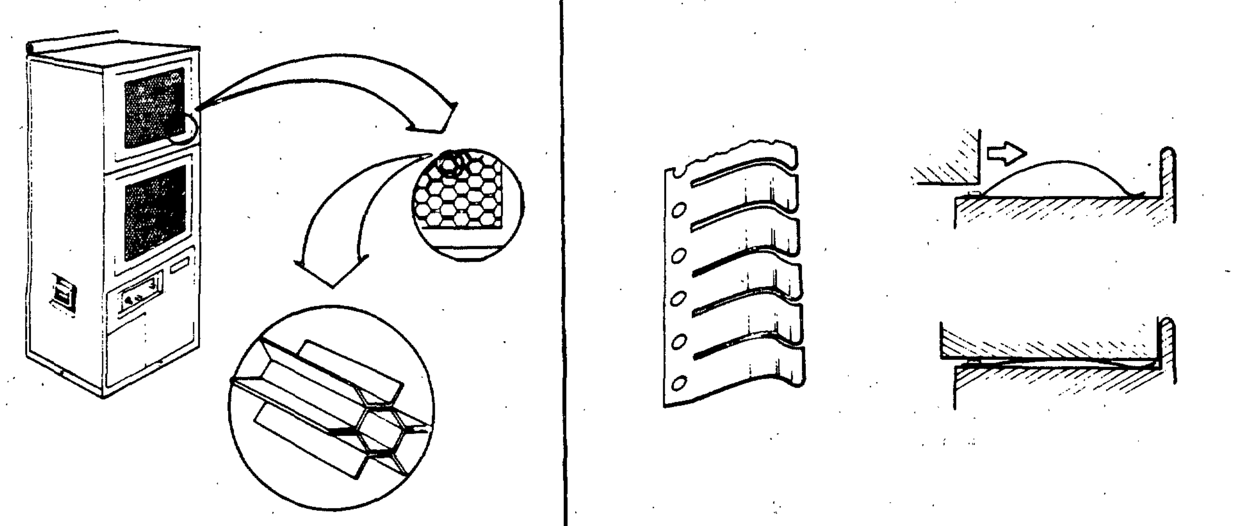
(1) The sponge or solid elastomer must be compressed or deformed sufficiently to fill all the unevenness between the two mating surfaces and to force the wire tips or contact points through any oxidation buildup. Depending upon the situation and the material, a compression pressure of 20 to 100 psi will be needed.

(2) The concern in this respect is primarily with wall mountings, since the seal between the heavy ECU and the shelter might be broken if the mounting should flex during transport.

6.5.3 Sealing. Systems with MCPE are designed also to protect against a chemical/biological (CB) threat. In order for the MCPE to function, the shelter must be capable of being pressurized to 0.8 inches of water pressure, gage. For such systems, it is imperative that the ECU/shelter and the MCPE/shelter interfaces be air tight. When properly installed, both the solid and sponge silicone elastomer gaskets already mentioned are rated very highly in this respect: up to 30 psi. This should also withstand the overpressures generated by a nuclear blast at a level which the shelter, itself, would survive.

6.5.4 Weather protection. Weather gaskets or sealants must be used around interface seams to prevent the intrusion of moisture into the shelter and to minimize corrosion of EMI/EMP gaskets. Sealants must be subsequently coated with CARC paint for systems designed to protect against a CB threat.

6.5.5 Screening air passages. Usually, the installation of an ECU or GPFU results in a hole in the EMP shield to permit air flow between the shelter exterior and interior. A honeycomb EMI filter is normally used to provide electrical continuity across such an opening. The flexible ducting, or connecting boot, of the ECU and GPFU ground mounts is unshielded; therefore, an EMP gasket at the interface of the duct and the ECU or GPFU would be of no benefit (CB sealing is still vital, however). In the case of ground mounts, EMP protection for the shelter interior must be provided by conductive honeycomb barriers in the air passages through the shelter wall. An illustration of a honeycomb barrier is at figure 6-2(a).



(a) *HONEYCOMB AIR PASSAGE SHIELD*

(b) *SPRING FINGER DOOR CLOSURE SHIELD*

FIGURE 6-2. Examples of EMP shielding for air passages and door closures.

6.5.6 Spring finger strip. A useful non-gasket type of shield for doors which are repeatedly opened and closed is the metallic spring finger strip, an example of which is illustrated in figure 6-2(b). This type of shield provides no pressure seal or environmental seal and must be used with environmental and pressure seals such as elastomer gaskets. Careful and proper installation of the spring finger strips is necessary to reduce damage from normal use and traffic. A type of damage that often occurs is that in which a finger is snagged on a passing object, a person's clothing for example, and broken. This would likely negate the effectiveness of the shield. For best effect, the installation should be such that the fingers scrape the contact surface during closing to assure that nonconductive oxides, which may have formed, are wiped off.

6.5.7 Seek expert advice. This handbook does not attempt to designate the specific shielding materials or procedures to be used. For advice or guidance on specific problems, a recommended starting point is the Natick Research, Development, and Engineering Center (see 1.6). Consultation with manufacturers of EMP shielding materials may yield a range of possible options for the latest materials and effective procedures for installation. When presented with specific requirements, a manufacturer may be able to propose combinations of sealing materials and methods tailored to the need and to guarantee the required results.

# CHAPTER 7

## BLAST AND THERMAL PROTECTION

7.1 Introduction. A nuclear detonation generates several adverse effects which can damage or upset sensitive mission essential equipment. These nuclear weapons effects (NWE) include air blast, ground shock, thermal radiation, ballistic fragmentation and electromagnetic pulse (EMP). The last of these, EMP, has been addressed in Chapter 6 of this handbook. This chapter addresses actions that can be taken to reduce the vulnerability of ECU's, MCPE and associated equipment to nuclear air blast and thermal radiation.

7.2 Nuclear effects of concern. Air blast effects are comprised of an overpressure phase and a drag phase.

7.2.1 Overpressure. Blast overpressure is the air pressure at the front of the shock wave resulting from a nuclear detonation. Overpressure includes two components: 1) the direct wave and 2) the wave reflected off of the ground. Nuclear blast overpressure can result in wall distortion/crushing, equipment shock, rupture of the EMP shield and antenna damage.

7.2.2 Drag. The drag phase of air blast is a longer duration, lower intensity consequence of a nuclear detonation. Immediately succeeding the initial shock wave, the drag phase can cause further damage to an already weakened system resulting in overturning and damage to external system interfaces.

7.2.3 Thermal. Thermal radiation is the high intensity, short duration flash of heat emmanating from a nuclear explosion. This "thermal pulse" can arrive several seconds before air blast, degrading adhesives and structural materials, and resulting in high thermal stresses.

7.2.4 Fragments. Protection from the threat of ballistic fragmentation is essential to prevent cracking or penetration of the EMP shield and the air tight seal essential to CB protection.

7.3 Outlook for protection. A series of near- and long-term efforts have been underway to provide nuclear survivable tactical shelters for mission-essential systems. For the near term, four "fully hardened" and two "intermediate hardened" shelters have been developed. Lighter weight, composite shelters are currently under development to provide long-term nuclear survivability solutions. These are addressed further in the context of the discussion of threat levels, below. The shelters described below have been successfully tested to their respective threat levels for protection from the combined nuclear weapons effects. These represent near term solutions to the nuclear survivability problem at the three threat levels defined by the nuclear community.

7.4 Threat levels. Three threat levels are associated with the design of hardened tactical shelters (HATS). These are most readily described by the degree of blast overpressure defined for each level: 10 psi, 7 psi and 4 psi. Corresponding thermal and ballistic threats are associated with each overpressure level. The threat levels for each of the nuclear survivable shelters are described below.

7.4.1 Fully hardened (10 psi). The fully hardened shelters were designed to survive a peak free-field overpressure of 10 psi with a pressure positive (drag) phase of 1.0 seconds and a 110 cal/cm$^2$ total fluence. The shelters also were required to provide ballistic fragment protection such that there were no cracks or penetrations of the EMI shield by a 60 grain, hard right cylinder, length to diameter equal to one, striking normal to the shelter at 375 m/sec. Three S-280 size and one HMMWV/CUCV size fully hardened shelter designs have been developed and tested for nuclear survivability. Lightweight composite S-280 and HMMWV/CUCV shelters are in the late stages of development.

7.4.2 Intermediate hardened shelter (7 psi). The 7 psi intermediate hardened shelter was designed to withstand an incident overpressure nuclear blast of 7 psi with a 54 cal/cm$^2$ total fluence. The foam and beam construction of the 7 psi shelter utilized aluminum skin sandwich panels with fiberglass stiffeners. Ballistic fragmentation protection was provided from a 60 grain fragment travelling at 275 m/sec using a ballistic/thermal applique on the shelter exterior. The S-280 size 7 psi shelter design has been developed and tested against NWE for nuclear survivability.

7.4.3 Intermediate hardened shelter (4 psi). One 4 psi intermediate hardened S-280 size shelter was designed to withstand an incident overpressure nuclear blast of 4 psi with a 25 cal/cm$^2$ total fluence. Ballistic fragementation protection was provided from the same 60 grain fragment travelling at 225 m/sec. This 4 psi nuclear survivable shelter was based upon the existing S-280C/G shelter design, with modifications to its door endwall and addition of a thermal/ballistic applique.

7.5 System hardening. These nuclear survivable shelters have been tested with an external, wall-mounted 18,000 Btuh horizontal ECU and a 100 cfm gas particulate filter unit (GPFU) using specially designed racks. This equipment was designed to prevent entry of the overpressure into the shelter during the air blast event. Since each system has different configuration requirements, alternate ECU's or additional penetrations into the shelter wall for power/signal entry, etc., could be required. Such modifications made to these shelters must not compromise the EMP shielding effectiveness or the structural integrity of the shelter system. Implicit with this is that modifications must not permit ballistic fragments to damage the EMP shield nor permit damage to the shelter by means of the thermal pulse. Changes to the shelter made by the integrator would require a survivability analysis for the system by USANCA (see 6.2). Extensively modified shelters could necessitate that further testing to be performed on the new system configuration to assure that requisite protection is achieved.

7.6 Vulnerabilities.

7.6.1 ECU mountings. The wall mounts offered in this handbook for the ECU's are all designed to withstand railroad hump loadings (see 3.2). A side benefit of this is the capability to survive an estimated nuclear peak free-field overpressure rated at 4 psi (see 20.1.2, and 20.2.3.2) with the following caveat: those members of the mounting frame which are directly exposed to the unattenuated thermal pulse may have a reduced strength at the time the shock front arrives. The ground mounts, too, have this built-in hardness but they must also be well anchored with guy lines at top and bottom to reduce shifting and to prevent the taller mounts for vertical ECU's from tipping.

7.6.2 ECU. The military ECU, itself, is a fairly sturdy piece of equipment.

7.6.2.1 Blast. The 18,000 Btu/hr PATRIOT split package ECU, a unit designed for added durability, has demonstrated in blast tube tests the ability to stand up to approximately 7.3 psi overpressure and continue to function. (Other units have not been so tested and their durability is questionable.) But the PATRIOT ECU did suffer some deformation to its enclosure which, if seams were opened or panels sprung, could cause problems if it is subsequently subjected to EMP. Further, the overpressure load which pushed in the side of the enclosure could have compromised the airtight seals necessary for CB protection, internally, between the compressor and the evaporator and, externally, in the ECU-shelter interface. What actually happened to such seals, if in fact they were in place for the test, is unknown since no data on this were collected. The blast tube test resulted in failure of the enclosure panels of the standard 18,000 Btuh vertical unit. Since then, the panels have been reinforced against this type of failure but the ECU has not been retested. Nevertheless, these units manufactured subsequent to 1981 incorporate the additional hardening.

7.6.2.2 Fragments. The enclosure which houses the ECU is for protection from the elements, not from an attack. High velocity fragments from either a nuclear blast or a conventional attack can be expected to penetrate it and to cause internal damage to the ECU. Also, for the remote ground mountings, the flexible ducting in all likelihood would be damaged or destroyed.

7.6.2.3 Thermal radiation. The exposed sections of the ECU's aluminum enclosure will probably suffer to some degree from any direct thermal radiation received. But the enclosure will provide adequate thermal shielding for the internal works. Any exposed gasketing or sealing would be subject to damage unless a high heat-resistant material is used. This applies also to any exposed flexible ducting.

7.7 Protective steps.

7.7.1 Wall-mounted ECU's. A blast hardened ECU would require a major redesign or an entirely new design. However, armor plate (steel, aluminum) or fiberglass and Kevlar appliques can be added to the top, bottom, and both sides of an ECU to provide a degree of protection comparable to of the shelter. The rear (condenser intake and discharge end) must remain largely exposed, except for the EMP shielding, to prevent inhibiting the air flow necessary for the ECU's proper functioning. The vulnerability of the rear can be reduced by the use of a baffle plate but great care should be taken to assure ample passage of air. The method of determining clearance described in Figure 4-1 should be useful in this respect. The armor will also provide adequate shielding against thermal radiation for those areas that it shields. In this regard, it should be noted that the 18,000 Btuh horizontal ECU's and 100 cfm GPFU's used in testing survived thermal exposure with only CARC paint protection. Structural mounting or racks used to fasten ECU's and MCPE's to the shelter can be designed for the shelter and the threat level specified.

7.7.2 Ground mounts. Remote ground mounts are particularly vulnerable because of the flexible ducting; for this reason, they usually are not considered for nuclear survivable shelters. In situations where they must be used, the risk can be reduced by flush mounting the ECU as illustrated in Figure 3-6; but even this would not be satisfactory for truck-mounted shelters. Protection of the ECU, itself, can be accomplished in the same manner as discussed in 7.7.1, above.

7.8 Protective siting and protective construction. Nuclear survivable shelters have been developed to satisfy the need for survivability on the tactical battlefield for essential communications, control and intelligence-gathering systems. Never-the-less, for the foreseeable future it is likely that a number of field Army and support area functions will continue to use unhardened shelters. For unhardened shelters, it might seem futile to harden ECU's and MCPE's. But hardening these ancillary items may give an edge to survival, albeit a slight one. However, the shelter, too, can be given improved protection which will at the same time enhance the survival prospects of the ECU. Siting and construction may shield against direct thermal radiation, intercept fragments, or deflect a shock wave just enough to permit survival which might otherwise not be possible.

7.8.1 Siting. To the extent that operational considerations permit, advantage can be taken of terrain by placing the shelter in defilade from likely directions of blast and thermal effects as well as from conventional attack.

7.8.2 Construction. Expedient construction might be used to substitute for protection afforded by the terrain, or in conjunction with the terrain to enhance protection for functions not having requirements for frequent, rapid relocation. Construction should be limited to shielding the shelter (bunkers, for example, would be too much, since they could replace the shelter). Protection might take the form of revetments and berms, using timber, earth, and sandbags, similar to aircraft parking revetments at forward airfields. Entrenching is another form of construction that offers possibilities when earthmoving equipment is available.

# APPENDIX A

## REFERENCES AND MAJOR SOURCES


1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE Handbook and Product Directory, 1988, Equipment, Atlanta, GA: ASHRAE, 1988. For copies of ASHRAE handbooks, inquire at 1791 Tullie Circle, N.E., Atlanta, GA 30329.

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3. Carrier Air Conditioning Company, Carrier System Design Manual, Part 2, Air Distribution, Seventh Printing, Syracuse, NY: Carrier Air Conditioning Company, 1966. For copies, write Carrier Air Conditioning Company, Carrier Parkway, P.O. Box 4808, Syracuse, NY 13221.

4. Engineering Laboratory, Computer Sciences Corporation, National Space and Technology Laboratories, NSTL Station, Mississippi, Chemical and Biological Protective Equipment Guidelines for Modular Collective Protection Equipment User Systems, Chemical Systems Laboratory Contractor Report, 1981. (Requests for document should be made to: Commander, U.S. Army Chemical Research Development and Engineering Center, ATTN: SMCCR-PPS, Aberdeen Proving Ground, Maryland 21010-5423.

5. Glasstone, Samuel and Phillip J. Dolan, ed, The Effects of Nuclear Weapons, U.S. Department of Defense and the Energy Research and Development Administration, Washington, D.C.: U.S. Government Printing Office, 1977.

6. Baumeister, Theodore, ed, Marks' Mechanical Engineers' Handbook, sixth edition, New York: McGraw-Hill Book Company, 1964. Copies of Marks' Handbook may be ordered through bookstores or from the publisher.

7. Mears, Merton D., Special Publication ARCSL-SP-79003, Handbook on Collective Protection, Aberdeen Proving Ground, MD: Chemical Systems Laboratory, U.S. Army Armament Research and Development Command, 1979. (Requests for document should be made to: Commander, U.S. Army Chemical Research Development and Engineering Center, ATTN: SMCCR-PPS, Aberdeen Proving Ground, Maryland 21010-5423.

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16. ________, MIL-HDBK 5, Metallic Materials and Elements for Aerospace Vehical Structures, Vol I.

17. ________, MIL-HDBK-23, Structural Sandwich Composites, U.S. Air Force.

18. ________, MIL-A-52767, Air Conditioners: Vertical and Horizontal, Compact.

19. ________, MIL-S-29409, Shelter Assembly, Knockdown.

20. ________, MIL-S-29410, Shelter Assembly, Rigid, General Purpose.

21. ________, MIL-S-29411, Shelter Assemblies, 10 Foot & 20 Foot, Electromagnetic Interference.

22. ________, MIL-S-44195, Shelter, Tactical, Expandable, Two Side.

23. ________, MIL-S-44196, Shelter, Tactical, Non-Expandable.

24. ________, MIL-S-44197, Shelter, Tactical, Expandable, One Side.

25. ________, MIL-S-55286, Shelter, Electrical Equipment S-280( )/G.

26. ________, MIL-S-55541, Shelter, Electrical Equipment, S-250( )/G.

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31. ________, MIL-STD-1407, Heaters, Vehicular Compartment; Heaters, Coolant, Engine; Heaters, Space; Heaters, Duct-Type.

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NOTE: Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099).

## APPENDIX B

## EXPLANATIONS AND ILLUSTRATIONS OF TERMS

Aspect ratio - In the cross-section of a duct, the ratio of the long side dimension to the short side dimension. The most efficient (least pressure loss) and least expensive duct (materials, fabrication, and installation) is round with a given aspect ratio of 1:1. The next most efficient and next least expensive is square, with an aspect ratio of 1:1. As the aspect ratio increases, the cost increases and the efficiency decreases. For the small systems dealt with here, these factors have relatively small impact as long as the aspect ratio stays below 5:1.

Btuh (British thermal units per hour) - The English system unit of heat transfer rate in which all heat loads and capacities discussed in this handbook are expressed. 1 Btu = amount of heat required to raise 1 lb of water 1 °F.

Cooling capacity - The measure of the ability of an ECU or air conditioner to remove heat from an enclosed space.

Cooling load - The rate at which heat must be removed from an enclosed space to maintain a given inside air temperature.

Environmental Control Unit (ECU) (See figure B-1) - Any device which processes air (cooling, heating, ventilating, dehumidifying, filtering, or a combination) to control environmental conditions within an enclosed space. Specifics on military ECU's may be found in appendix A, references 18 and 32.

- Horizontal ECU - An ECU designed so that its maximum dimension is horizontal.

- Vertical ECU - An ECU designed so that its maximum dimension is vertical.

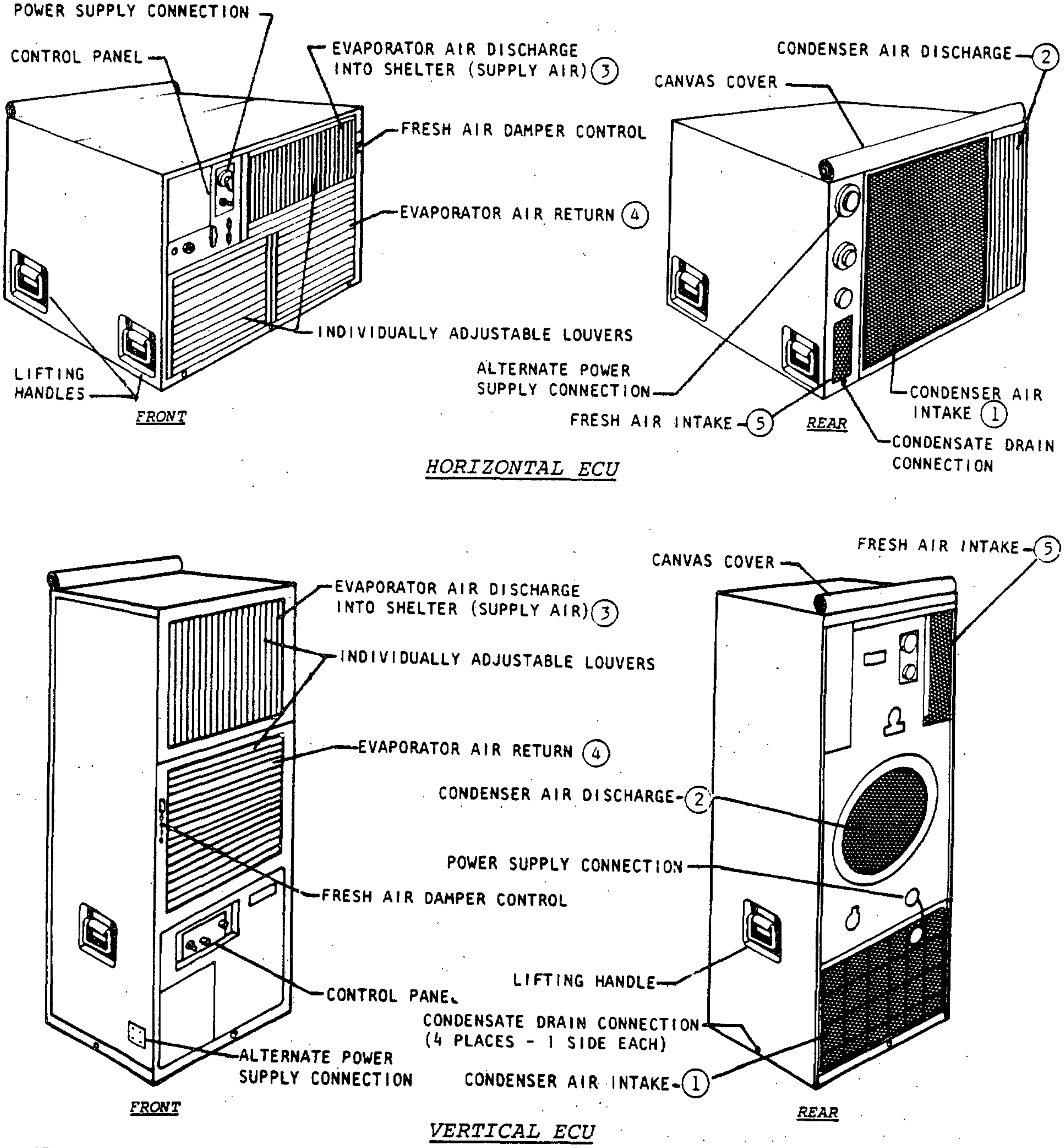
Equivalent diameter of a duct - One of the factors in determining pressure losses and resultant reductions in air flow is the circular equivalent of a rectangular duct. This is expressed in terms of the equivalent diameter of the rectangular section and can be computed using this formula:

$$\text{Equivalent diameter} = 1.3 \sqrt[8]{\frac{(ab)^5}{(a+b)^2}}$$

Where: a and b are the dimensions of two adjacent sides of the rectangle.

Gas Particulate Filter Unit (GPFU) - See figure B-2.

Heat gain - The rate at which heat enters into or is generated within an enclosed space.

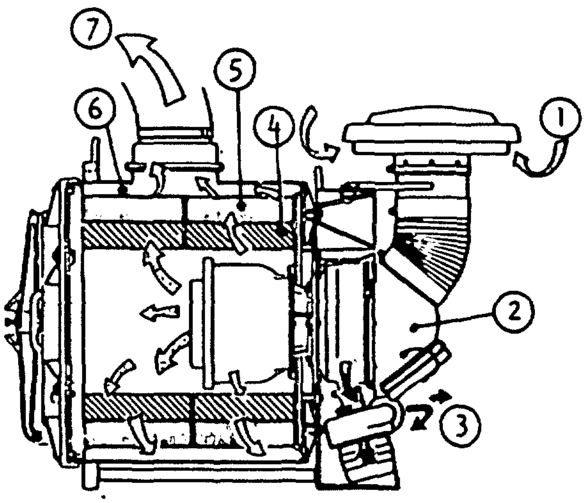



NOTE:

- Air entering the condenser air intake (1) cools the condenser and leaves through the condenser air discharge (2) . Since the condenser cooling air does not enter the shelter, filtering is not required in NBC operations.

- Air (supply air) enters the shelter through the evaporator air discharge (3) . There are two sources for supply air: air already in the shelter, which is taken into the ECU through the evaporator air return (4) for reconditioning, and outdoor air, entering through the fresh air (makeup air) intake (5) . In NBC situations, the fresh air intake must be closed to prevent intake of contaminated air as well as loss of shelter air pressure.

FIGURE B-1. Typical military environmental control units.




*GAS-PARTICULATE FILTER UNIT (GPFU) - A DEVICE WHICH PROVIDES CLEAN, FILTERED AIR AT SUFFICIENT RATE TO PERMIT THE BUILDUP AND MAINTENANCE OF A POSITIVE AIR PRESSURE IN A SHELTER. (ALSO SEE FIGURE 5-1.) THE AIR ENTERS THROUGH THE PROTECTIVE CAP (1) AND IS ROUTED TO THE DUST SEPARATOR (2), WHICH REMOVES AND EXHAUSTS (3) 90 PERCENT OF THE DUST. THE AIR PASSES THROUGH THE PARTICULATE FILTER (4), WHICH REMOVES PARTICULATE MATTER AND AEROSOLS, AND THEN THROUGH THE GAS FILTER (5) FOR REMOVAL OF GASEOUS TOXIC AGENTS. FROM THE FILTERS IT PASSES INTO A PLENUM (6) SURROUNDING THE FILTERS AND OUT THROUGH THE AIR OUTLET (7) TO THE ECU, SHELTER, AND PROTECTIVE ENTRANCE. THIS PROCESS RAISES THE AMBIENT AIR TEMPERATURE BY 10° TO 15°F. WHEN THE GPFU IS IN A DUST-FREE ENVIRONMENT OR WHEN MOUNTED 5 FEET OFF THE GROUND OR HIGHER IN A NORMAL ENVIRONMENT, IT MAY BE OPERATED WITHOUT THE DUST SEPARATOR.*

FIGURE B-2. Gas particulate filter unit.

Heat loss - The rate at which heat is transferred (lost) from an enclosed space.

Heat pump - To cite from reference 34: "The heat pump is a mechanism that can either remove heat from an indoor area and discharge this heat to the out-side, or it can be used to pick up heat from the outside and discharge it into the indoor area for heating." For details, see appendix A, reference 34.

- For heating, if the outdoor (evaporator) coil is operated at 0 °F, for example, the refrigerant in the coil can pick up heat from ambient air at temperatures as low as 10 or 15 °F. When compressed to 120 to 140 °F, the refrigerant will then release heat to cooler surrounding air being circulated to the shelter interior. Since the heat pump loses efficiency at lower temperatures, supplementary heaters are required to provide adequate heating capacity and are normal components of the unit.

- For cooling, the heating process is reversed by the use of a system of valves (e.g., the outside evaporator becomes the condenser) and the heat pump then functions basically as a normal air conditioner.

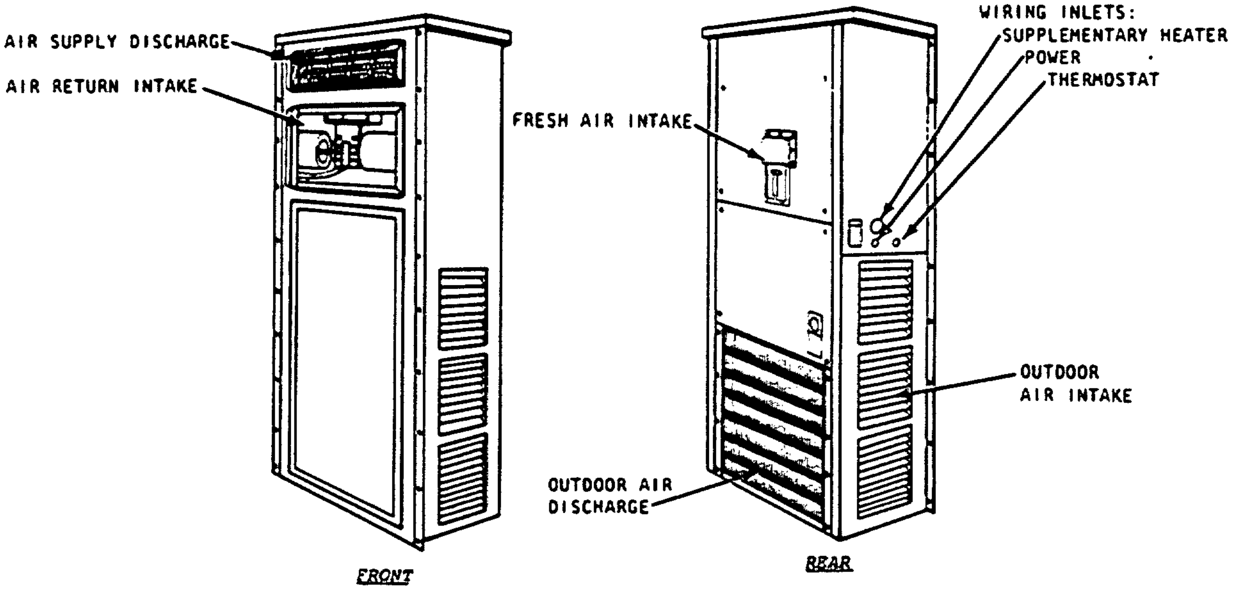
- The Navy heat pumps as now available are adaptations of Westinghouse commercial models and were not designed with tactical environments in mind. (See figure B-3.) They lack the ruggedness and durability under field conditions of the ECU's designed for military applications. When they are transported, it should be on smooth roads with the avoidance of shocks. The compressor of a wall-mounted unit failed in a road test which was less severe than railroad humping. Therefore, if subjected to cross-country road conditions or railroad humping, experience has shown that they can be expected to fail internally unless carefully packed and braced externally and internally. However, in peacetime, static situations they offer an additional range of options for environmental control.

Heating capacity - The measure of the ability of an ECU or heater to add heat to an enclosed space.

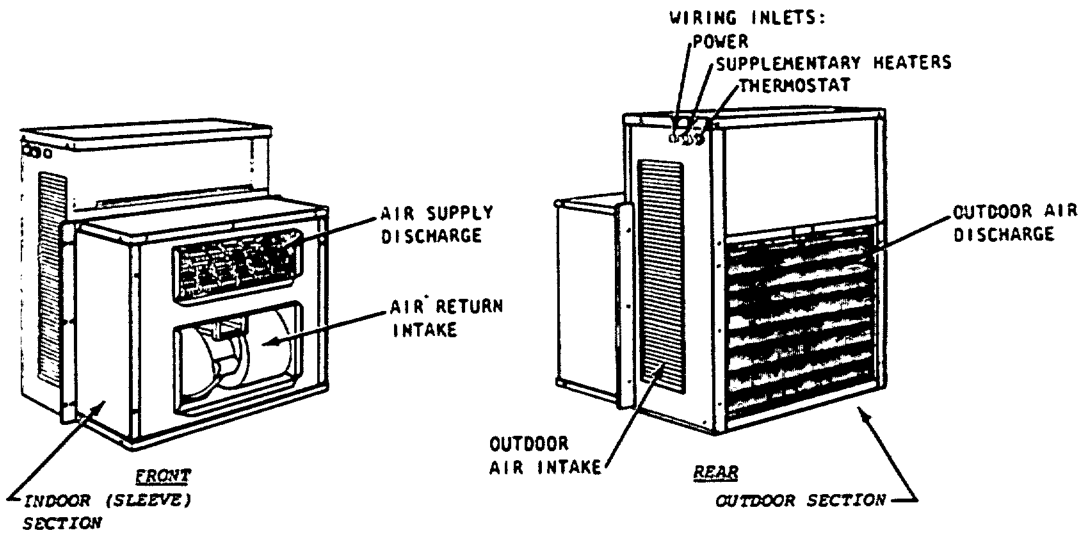
Heating load - The rate at which heat must be added to an enclosed space to maintain a given inside temperature.

Modular Collective Protection Equipment (MCPE) - A system of interacting modules necessary in a CBR environment to provide clean, filtered air to a shelter, to maintain a small positive air pressure in the shelter to prevent outside-to-inside leakage of contaminants, and to permit entry and exit of personnel without contaminating the shelter interior. The MCPE probably will operate in conjunction with an ECU. More description and an illustration may be found in 5.4.

Plenum - Basically, a large duct. One use is similar to an automotive engine manifold, that is, to collect air from more than one source before distributing it to one or more outlets. In another use, it is a wide duct with many small openings for air passage. It might cover an entire ceiling and distribute the air through the many outlets over the area. Plenums distribute air usually more gently and more quietly than more finite outlets but lack ability for precise regulation of flow and direction. A plenum may also be used for return air.




WALL-MOUNTED UNIT, HB036 AND HB022




SLEEVE-MOUNTED (THROUGH-WALL) UNIT, HE036R&S AND HE022R&S

NOTE:

- Units are to be used with ducting therefore have no attached grilles for the indoor supply and return.
- Units are controlled by thermostat mounted on shelter interior wall.

FIGURE B-3. Navy heat pumps.

Short circuit - A term used to describe the condition in which the supply air goes directly back into the return almost as soon as it is discharged. This is caused most often when an obstacle is too close in front of the supply and return outlets, retarding the proper flow of air. This might also occur when the obstacle blocks the return, leaving the return air no path other than across or through the supply flow. Remedies include relocating the obstacle, relocating the obstruction, or ducting the supply to where it is clear of the obstruction.

Throw - The horizontal distance that air will travel after it leaves the supply discharge before a specified reduced velocity, usually 50 feet per minute, is reached.

Ventilation - The process of introducing ambient air into an enclosed space by an ECU.

# APPENDIX C

## BLANK WORKSHEETS

10. Introduction. Included in this appendix are the following three blank worksheets:

a. Worksheet Part I - Cooling Requirement Estimate (Estimating steps 1 through 5).

b. Worksheet Part II - Heating Requirement Estimate (Estimating steps 6 through 12).

c. Worksheet Part III - Selection of ECU, (pages 1 and 2) (Estimating steps 13 through 17).

20. Use. These blank forms are to be reproduced and completed in accordance with the guidance provided in chapter 2.

## WORKSHEET PART I - COOLING REQUIREMENT ESTIMATE

Shelter Designation ______________________

Shelter Location ______________________

Shelter Occupants (Avg. No. of Persons) ______________

Required (Design) Inside Temperature ______________ °F

(If only heating is required, skip steps 1 through 5 and go to Worksheet II)

STEP

1. Solar/conduction heat gain: ______ (1a) Btuh x ______ (1b) x ______ (1c) = ______ (1) Btuh

2. Heat gain from electrical equipment/lights: ______ (2a) watts x 3.4 Btuh/watt = ______ (2) Btuh

3. Heat gain from personnel: ______ (3a) persons x 500 Btuh/person = ______ (3) Btuh

4. Heat gain from ventilation: ______ (4a) Btuh/cfm x ______ (4b) persons x 20 cfm/person = ______ (4) Btuh

5. Total cooling requirement: (1) + (2) + (3) + (4) = ______ (5) Btuh

Where to find (1a): Table IV, column C
(1b): Table IV, column E
(1c): Figure 2-5
(2a): Equipment and lights in shelter
(3a): Top of worksheet
(4a): Table IV, column G
(4b): Top of worksheet

## INSTRUCTIONS FOR COMPLETING WORKSHEET

### STEP 1 - SOLAR/CONDUCTION HEAT GAIN

- Find the shelter you want to cool in column A of table IV.
- For this type of shelter pick out the summer cooling load from column C and put it in worksheet space (1a).
- Find the location of the shelter on the map, figure 1-1, and note the pattern.
- Match the pattern with column E. Pick out the proper cooling factor and put it in worksheet space (1b).
- With your design inside temperature, turn to figure 2-5 and, using the solar conduction heat gain curve, find the correction factor and put it in space (1c).
- Perform multiplication and put the result in space (1).

### STEP 2 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of all electrical equipment and lights to be used in the shelter.
- Put the sum in space (2a) and multiply it by 3.4.
- Put the result in space (2).

### STEP 3 - HEAT GAIN FROM PERSONNEL

- Put the number of people to occupy the shelter in space (3a).
- Multiply by 500 and put the result in space (3).

### STEP 4 - HEAT GAIN FROM VENTILATION

- With the same climatic category pattern used in Step 1, find the summer heat gain factor from table IV, column G and put it in worksheet space (4a).
- Put the number of people in the shelter in space (4b).
- Perform the multiplication indicated on the worksheet and write the result in space (4).

### STEP 5 - TOTAL COOLING REQUIREMENT

- Perform the addition and put the sum in space (5). This is the cooling requirement for selecting the ECU.

## WORKSHEET PART II - HEATING REQUIREMENT ESTIMATE

Shelter Designation ______________________

Shelter Location ______________________

Shelter Occupants (Avg. No. of Persons) ______________________

STEP

6. Conduction heat loss: ________ (6a) Btuh x ________ (6b) = ________ (6) Btuh

7. Vent heat loss: ________ (7a) Btuh/cfm x ________ (7b) pers x 20 cfm/pers = ________ (7) Btuh

8. Heating requirement: (6) + (7) = (Read step 8 of instructions, below) ________ (8) Btuh

9. Heat gain from elec equip/lights: ________ (9a) watts x 3.4 Btuh/watt = ________ (9) Btuh

10. Heat gain from personnel: ________ (10a) pers x 500 Btuh/pers = ________ (10) Btuh

11. Total heat gain: (9) + (10) = ________ (11) Btuh

12. Net heating requirement: (8) - (11) = ________ (12) Btuh

Where to find (6a): Table IV, column D (7b): Top of worksheet
(6b): Table IV, column F (9a): Equipment and lights in shelter
(7a): Table IV, column H (10a): Top of worksheet

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 6 - CONDUCTION HEAT LOSS

- Find the shelter you want to cool in column A of table IV.
- For this type of shelter, pick out the winter heating load from column D and put it in worksheet space (6a).
- Find the location of the shelter on the map, figure 1-1, and note the pattern.
- Match the pattern with column F, table IV. Pick out the proper heating factor and put it in worksheet space (6b).
- Perform the multiplication and put the result in space (6).

STEP 7 - VENTILATION HEAT LOSS

- With the climatic category pattern used in step 6, find the winter heat loss factor in column H, table IV. and put it in space (7a).
- Put the number of people in the shelter in space (7b).
- Perform the multiplication and put the result in space (7).

STEP 8 - HEATING REQUIREMENT

- Add (6) and (7) and put the sum in worksheet space (8). This is your heating requirement if your operational equipment must be warmed before it can be safely started. In this case, use this figure in Worksheet Part III. If you do not require preheating for the equipment, your energy requirements can be reduced by recognizing the heat gained from electrical equipment and personnel in the shelter and following steps 9 through 12.

STEP 9 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of minimum electrical equipment and lights to be used during shelter operation.
- Put the sum in space (9a) and multiply it by 3.4.
- Put the results in space (9).

STEP 10 - HEAT GAIN FROM PERSONNEL

- Put the number of people in space (10a) and multiply by 500.
- Put the result in space (10).

STEP 11 - TOTAL HEAT GAIN

- Add (9) and (10) and put the sum in space (11).

STEP 12 - NET HEATING REQUIREMENT

- Subtract (11) from (8) and put the difference in space (12). This is the heating requirement for selecting the ECU.

## WORKSHEET PART III - SELECTION OF ECU (Page 1 of 2)

Shelter Designation: ______________________; Location: ______________________

Cooling Requirement: ______________ Btuh; Heating Requirement: ______________ Btuh

Design Inside Temperature: ______________ °F; Climatic Category: ______________________

Power Source Available: ________ volts, ________ phase, ________ Hertz, ________ wires

Reference table II and MIL-A-52767 for ECU data.

| STEP | HORIZONTAL COMPACT | VERTICAL COMPACT |
|---|---|---|
| SINGLE ECU | | |
| 13. Nominal capacity (Btuh): | ________ (13a) | ________ (13b) |
| 14. Actual rating (Btuh): | | |
| Cooling: | ________ (14a) X ________ (14b) = ________ (14c) | ________ (14d) X ________ (14e) = ________ (14f) |
| Heating: | ________ (14g) | ________ (14h) |

## INSTRUCTIONS FOR COMPLETING WORKSHEET

### SINGLE ECU

### STEP 13 - NOMINAL ECU CAPACITY

- From *table II*, select a horizontal and a vertical ECU each with a nominal capacity equal to the next size larger than the cooling requirement. Put these sizes in spaces (13a) and (13b).

### STEP 14 - ACTUAL RATING AND SELECTION

- From table II, find the cooling and heating "Rating Btuh" for these two ECU's. Put these into spaces (14a) and (14g) for the horizontal ECU and (14d) and (14h) for the vertical ECU.
- With your climatic category and desired interior temperature (design inside temperature), turn to figure 2-5. Using curve A or curve B, as determined by your climatic category, find the correction factor and put it into spaces (14b) and (14e). Multiply to determine the ECU actual rating.
- If cooling rating of either or both of these is equal to or slightly larger than the cooling requirement, you have completed the preliminary selection process and steps 15 and 16 may be skipped.
- If the heating rating is equal to or larger than the requirement, no supplementary heater will be required and 2-12 may be skipped. *If the heating rating is smaller than the requirement*, go to 2-12.
- You should complete steps 15 and 16 if the units in step 14 are smaller or much larger than the requirement.

WORKSHEET PART III - SELECTION OF ECU (Page 2 of 2)

DUAL ECU'S

15. Nominal capacities (Btuh):

_______ (15a) X 2 = _______ (15b)    _______ (15c) X 2 = _______ (15d)

16. Actual ratings (Btuh):

Cooling: _______ (16a) X _______ (16b) = _______ (16c)    _______ (16d) X _______ (16e) = _______ (16f)

Heating: _______ (16g)    _______ (16h)

17. Closest combination:

Cooling: 2 X (16a) or (16f) = _______ (17a) OR _______ (17b)

Heating: 2 X (16g) or (16h) = _______ (17c) OR _______ (17d)

## INSTRUCTIONS FOR COMPLETING WORKSHEET

### DUAL ECU'S

#### STEP 15 - NOMINAL CAPACITIES

- From table II, select the smallest pair of nominal capacities that satisfies the cooling requirement. Put these ratings in spaces (15a) and (15c). Multiply them by 2 and put the results in spaces (15b) and (15d). If the pair looks close, proceed with Step 16; if not, select another pair.

#### STEP 16 - ACTUAL RATINGS

- From table II, find the cooling and heating ratings for the vertical and horizontal ECU's picked in step 15; enter these in spaces (16a), (16d), (16g) and (16h). Enter in spaces (16b) and (16e) the correction factor used in (14b) and (14e). Multiply and put the results in spaces (16c) and (16f).

#### STEP 17 - CLOSEST COMBINATION OF ECU'S

- If a pair of ECU's satisfies and is closer to the cooling requirement than the single units of step 14, the pair, shelter space permitting, should be your preliminary selection. Heating consideration is the same as for step 14.

APPENDIX D

DESIGNS FOR ECU MOUNTING STRUCTURES

10. Introduction. This appendix offers several design concepts for mounting ECU's for field use with small shelters. For the intended ECU's and applications, the designs are more than conceptual, however, and may be used as shown with only minimal adaptation needed to accommodate to a specific shelter. (Shop drawings would be required for actual fabrication.) Since the ECU's addressed here are the ones which will be used in a majority of cases, the mounts will probably be adequate for most cases where retractable, wall, and remote mounts are desired.

20. General parameters.

20.1 ECU's and mounts.

20.1.1 Retractable mount for the 18,000 Btuh military compact vertical ECU. This mount is shown at figure D-1. The design was made with the S280 shelter in mind but is adaptable to other shelters as well as to other ECU's. If heavier ECU's are contemplated, heavier duty tracks will be required. (Check the weight of ECU against track manufacturer's claims for track carrying capacity.) Also, for a heavier unit, the provisions for anchoring the ECU for transit should be reevaluated.

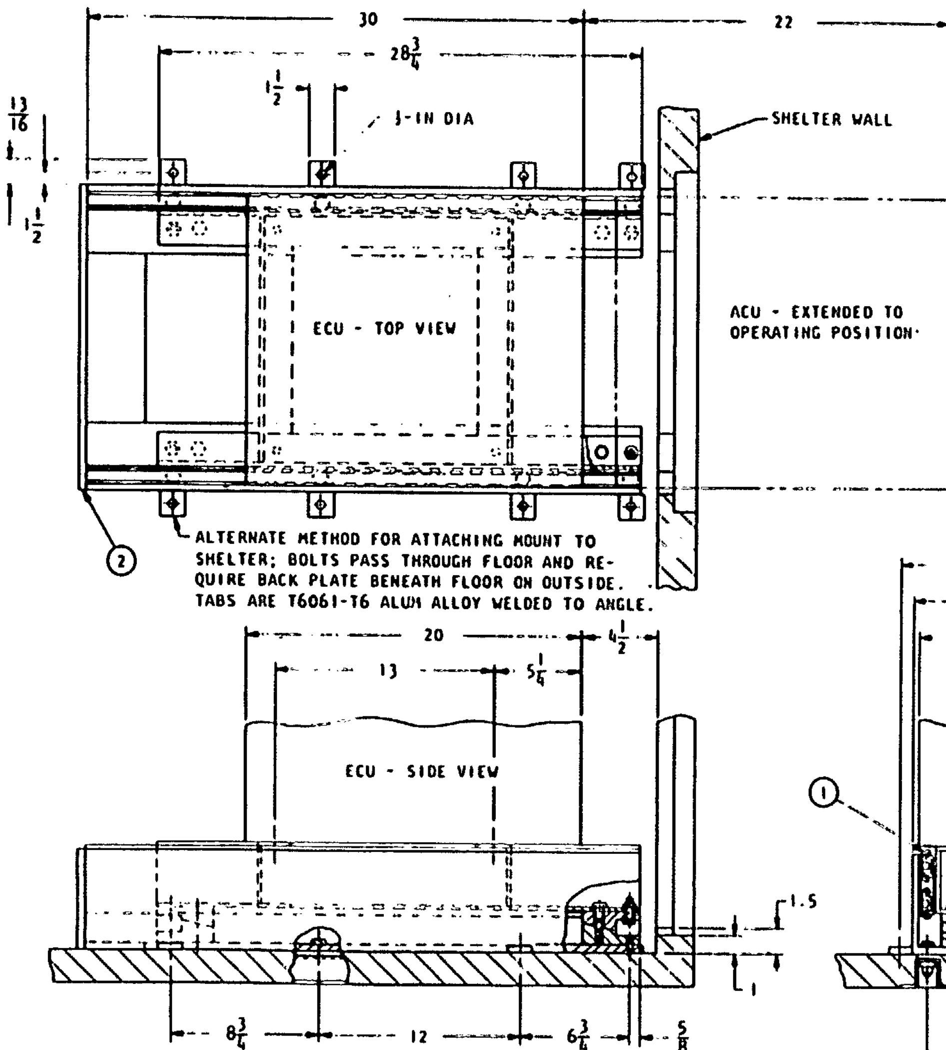
20.1.2 Wall mounting designs. These are mounting racks which allow the standard, compact, horizontal 9000, 18000, and 36000 Btuh ECU's to be attached, singly or in pairs, to small, transportable shelters. The racks are simple yet strong. They are designed to support the units during railroad transportation and the racks, themselves, are designed to withstand a nuclear peak free-field overpressure up to 7 psi. However, the rack designs are based on the structure of the unhardened S280 shelter. Because of concern as to whether the shelter structure will hold the rack beyond 4 psi, the whole mounting system (rack-connections-shelter structural frame) is usually rated at 4 psi. Hardened shelters with reinforced structural frames may permit the racks to realize their full potential of 7 psi. The designs are for horizontal ECU's; the horizontal configuration is more suited to fixed mounting on the front end of a truck-mounted shelter, such as the S280, and can fit above a truck cab. Wall mounting designs are shown on figures as follows:

a. Figure D-2: Mounting design for single 18,000 Btuh compact horizontal ECU (adaptable for 9,000 Btuh compact horizontal ECU).

b. Figure D-3: Mounting design for two 18,000 Btuh compact horizontal ECU's (adaptable for two 9,000 Btuh horizontal ECU's or one 18,000 Btuh horizontal ECU and one GPFU).

c. Figure D-4: Mounting for single 36,000 Btuh compact horizontal ECU.

20.1.3 Remote ground mount for the 18,000 Btuh military compact vertical ECU. The remote ground mount is at figures D-5 and D-6. It is a simple aluminum mounting designed to rest on the ground remote from the shelter. The mounting




| FIND NO. | QTY | DESCRIPTION |
|---|---|---|
| 1 | 2 | Angle, 6 x 4 x $\frac{7}{16}$, 4.91 lb/ft |
| 2 | 1 | Angle, 6 x 4 x $\frac{7}{16}$, 4.91 lb/ft |
| 3 | 2 | Channel, Army-Navy, 4 x 2, 2.205 lb/ft |
| 4 | | Channel, Army-Navy, 4 x 2, 2.205 lb/ft |
| 5 | 2 | Slim track, 2-section ball bearing slides. May be obtained from Barnes Engineering Company, Anaheim, CA, Model HD-282-30 or comparable item from other manufacturer. |

NOTES:

1. Find No. 1 thru 4 are 6061-T6 aluminum alloy.
2. All dimensions are in inches.
3. All bolts $\frac{1}{2}$-13UNC SAE with hex nuts unless otherwise indicated.
4. Space mounting holes on center-to-center spacing of outboard hat sections.

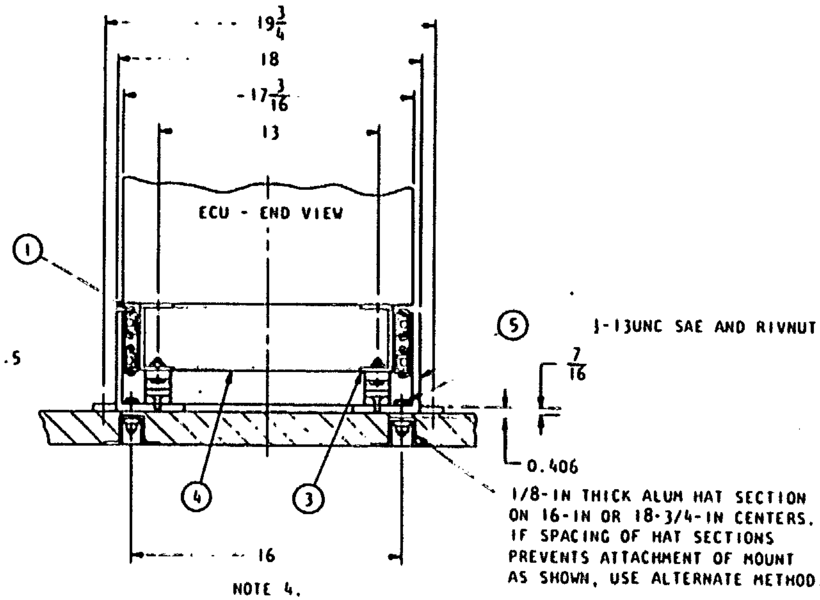
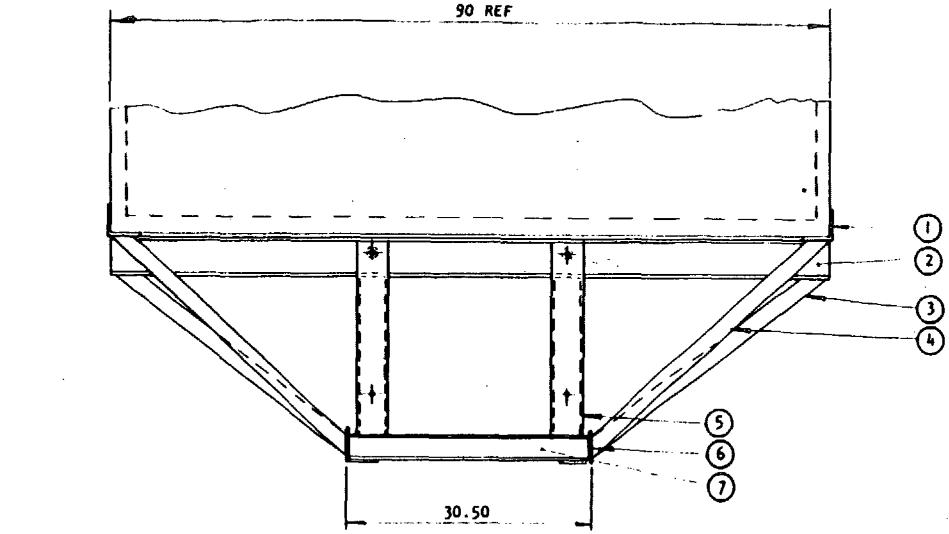



FIGURE D-1. Retractable floor mount for vertical 18,000 BTUH ECU.




NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

| FIND NO. | QTY | DESCRIPTION |
|---|---|---|
| 1 | 2 | Angle, 5 x 5 x 3/8 x 4.28 lb/ft |
| 2 | 1 | Wide Flange, Army-Navy, 5 x 5, 5.366 lb/ft |
| 3 | 2 | Tube, 2 OD x ¼ Wall |
| 4 | 2 | Tube, 2 OD x ¼ Wall |
| 5 | 2 | Channel, Alum. Assoc., 4 x 2, 1.738 lb/ft |
| 6 | 2 | Angle, 4 x 4 x ¼, 2.28 lb/ft |
| 7 | 1 | I-Beam, Alum. Assoc., 3 x 2.50, 1.637 lb/ft |

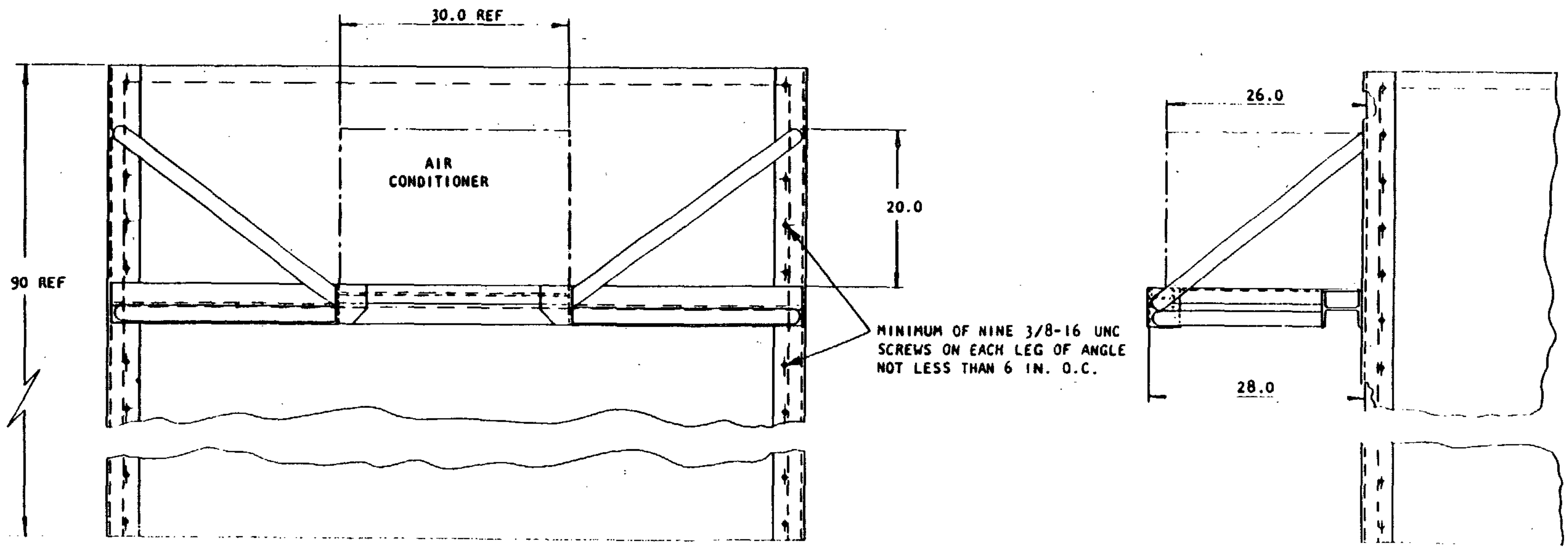
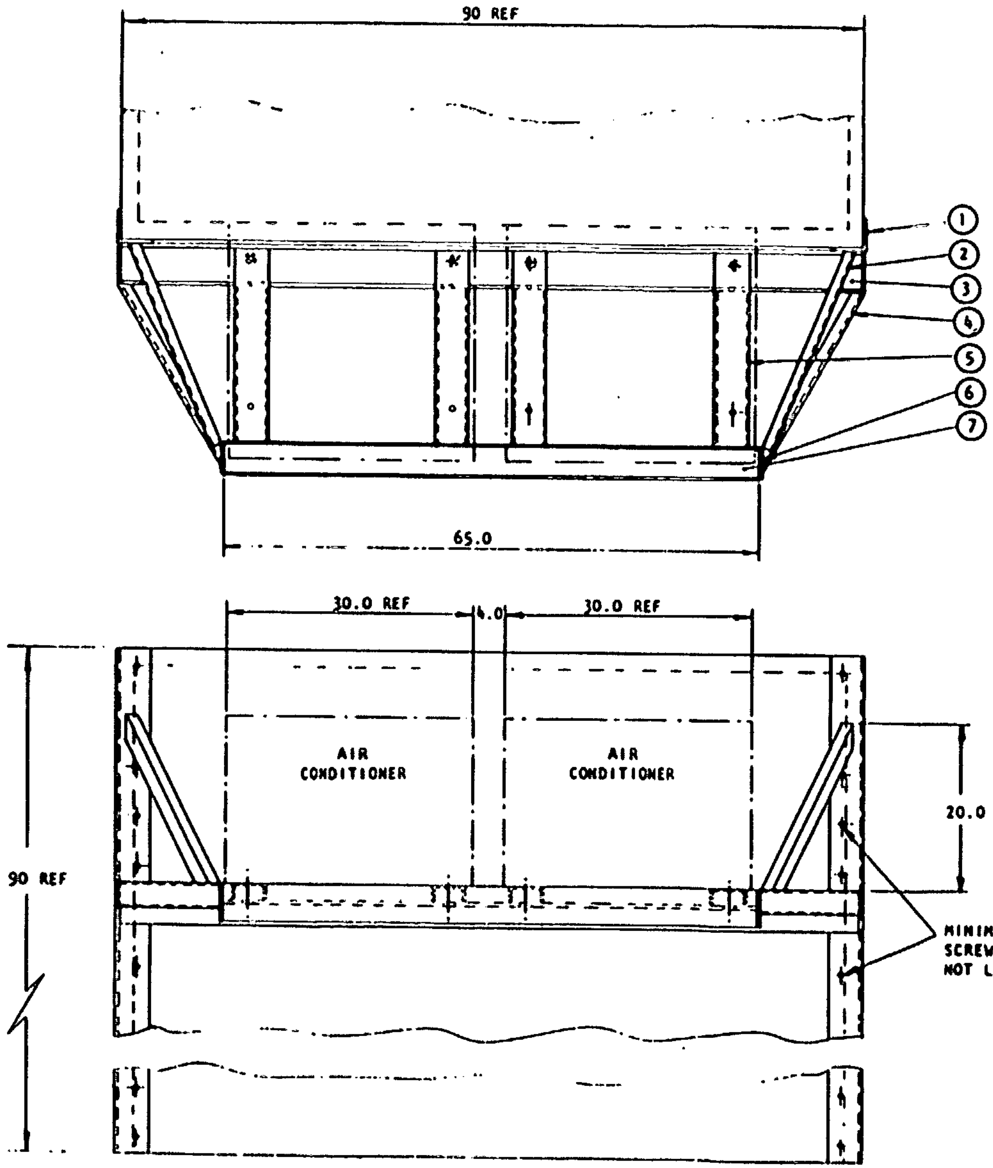



FIGURE D-2. Mounting for one 18,000 Btuh ECU on S280 tactical shelter.




NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

| FIND NO. | QTY | DESCRIPTION |
|---|---|---|
| 1 | 2 | Angle, 5 x 5 x 3/8 x 4.28 lb/ft |
| 2 | 2 | Channel, Army-Navy, 3 x 1.375, 0.993 lb/ft |
| 3 | 1 | Wide Flange, Army-Navy, 5 x 5, 5.366 lb/ft |
| 4 | 2 | Channel, 4 x 4 x ¼, 2.28 lb/ft |
| 5 | 4 | Channel, Alum. Assoc., 4 x 2, 1.738 lb/ft |
| 6 | 2 | Plate, 3/8 Thk, 6061-T651 |
| 7 | 1 | Wide Flange, Army-Navy, 4 x 4½, 2.867 lb/ft |

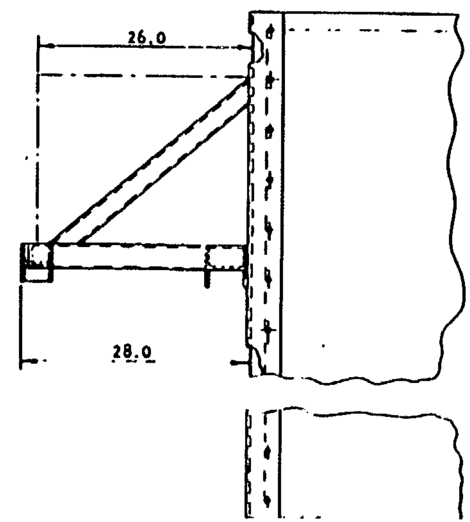
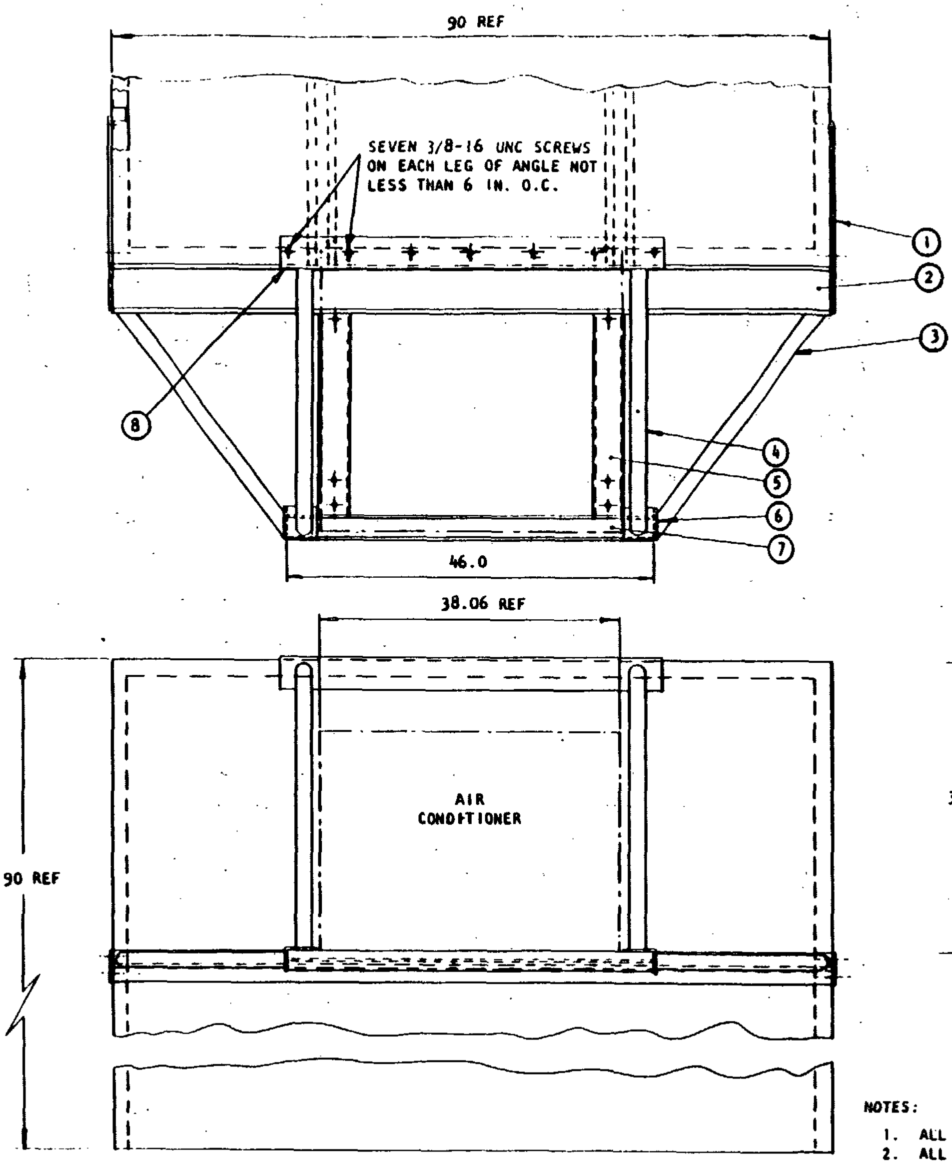


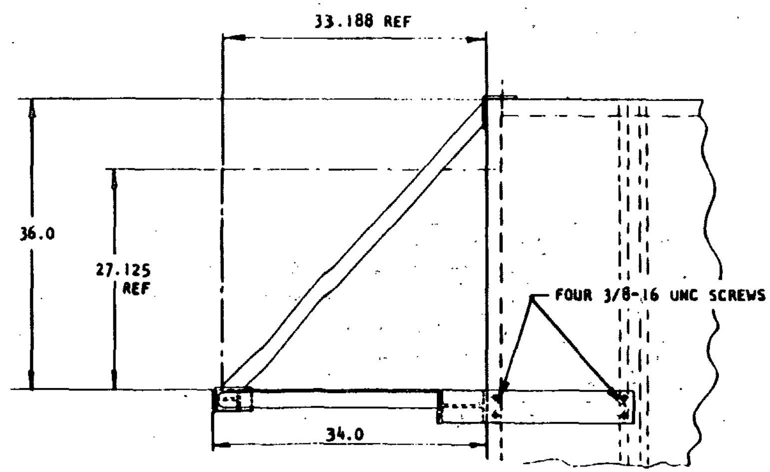

FIGURE D-3. Mounting for two 18,000 Btuh ECU's on S280 tactical shelter.




| FIND NO. | QTY | DESCRIPTION |
|---|---|---|
| 1 | 2 | Rect. Bar, 4 x 1/4 |
| 2 | 1 | I-Beam, Alum. Assoc., 6 x 4, 4.03 lb/ft |
| 3 | 2 | Tube, 2.00 x 1/4 Wall |
| 4 | 2 | Tube, 2.00 x 1/8 Wall |
| 5 | 2 | Channel, Alum. Assoc., 4 x 2.25, 2.331 lb/ft |
| 6 | 2 | Angle, 4 x 3 x 1/4 |
| 7 | 1 | I-Beam, Alum. Assoc., 3 x 2.5, 1.637 lb/ft |
| 8 | 1 | Angle, 6 x 6 x 1/2 x 6.75 lb/ft |

TO DEVELOP 4 PSI NUCLEAR OVERPRESSURE RESISTANCE WHEN MOUNTED ON HARDENED SHELTER, SUBSTITUTE:

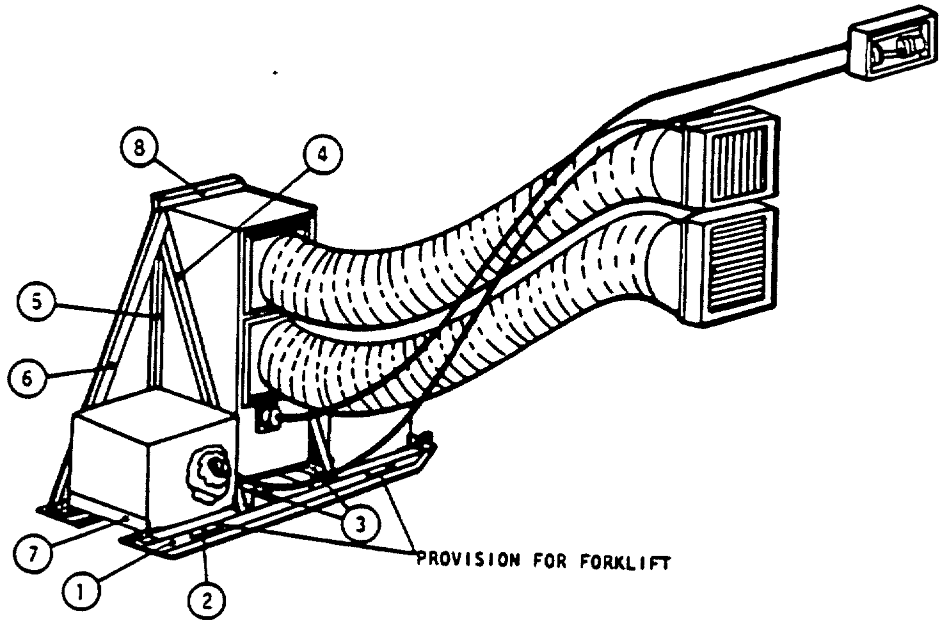
| FIND NO. | QTY | DESCRIPTION |
|---|---|---|
| 2 | 1 | I-Beam, A-N, 5 x 5 x 5.366 lb/ft |
| 5 | 2 | Channel, Alum. Assoc., 5 x 2.75 x 3.089 lb/ft |




NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

FIGURE D-4. Mounting for one 36,000 Btuh ECU on S280 tactical shelter.




| FIND NO. | QTY | DESCRIPTION | NOMINAL LENGTHS 6000 BTUH VERTICAL ECU | 9000 BTUH VERTICAL ECU | 18000 BTUH VERTICAL ECU |
|---|---|---|---|---|---|
| 1 | 2 | Wide Flange Beam Army-Navy Series 4" x 3" - 1.788 Lbs/Ft | 74-1/2" | 74-1/2" | 74-1/2" |
| 2 | 2 | Channel, Form From 1/8" Thick Sheet | 27-3/8" | 27-3/8" | 27-3/8" |
| 3 | 2 | Channel - Army-Navy 4" x 2" - 2.205 Lbs/Ft | 30" | 30" | 30" |
| 4 | 2 | Tubing, Square, 1-1/2" x 1/8" Thick | 40-3/4" | 43-5/8" | 55" |
| 5 | 2 | Tubing, Square, 1-1/2" x 1/8" Thick | 30-1/2" | 34-1/4" | 47-7/8" |
| 6 | 2 | Tubing, Square, 1-1/2" x 1/8" Thick | 37-15/16" | 41" | 53" |
| 7 | 4 | Angle, 3" x 2" x 1/4" | 30" | 30" | 30" |
| 8 | 1 | Angle, 3-1/2" x 2-1/2" x 1/4" | 21" | 21" | 21" |

Material: Find Numbers 1 , 2 , 3 , 7 , 8 Aluminum 6061-T6.
Find Numbers 9 , 5 , 6 Aluminum 6063-T52.

FIGURE D-5. Ground mount for vertical ECU.

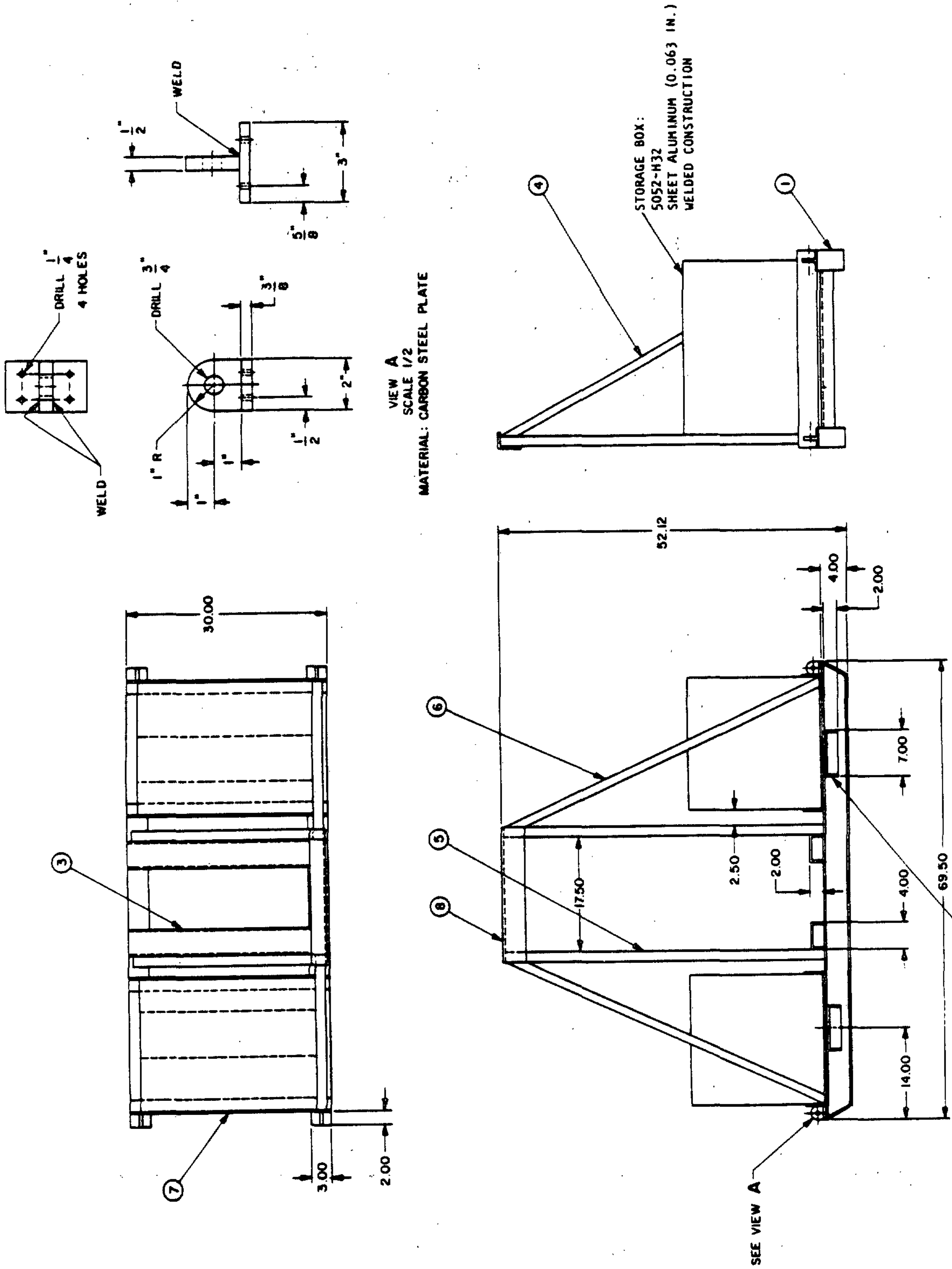



FIGURE D-6. Ground mount for 6,000 Btuh, 9,000 Btuh, or 18,000 Btuh ECU.

is designed to support the ECU during rail movement,[10] and withstand nuclear overpressure up to 7.3 psi. The mounting is adaptable to smaller ECU's by adjusting the lengths of structural members.

20.1.4 ECU durability. No test data are available to show whether the ECU, itself, can withstand the dynamic loads described above. This is a source of some concern. Design criteria specify that ECU's be able to withstand railroad humping and it is assumed that they are being manufactured in accordance with the specifications. However, the nuclear overpressure loading at 7.3 psi is worse than the humping loads and it is unlikely that the ECU's, without extensive protective measures, would survive it.

20.2 The shelter. The mounting designs in this appendix are based on the Army S280 C/G shelter, which is similar in end dimensions and construction features to most other unhardened and non-expandable shelters. These designs should be adaptable to other shelters of similar dimensions fairly easily.

20.2.1 Dimensions and weight. The S280 C/G shelter, the model used for mounting designs, has outside dimensions of 7-1/2 feet in height x 7-1/2 feet in width x 12 feet in length. It weighs about 1400 pounds and uses sandwich construction for the wall, roof, and floor panels.

20.2.2 Wall panel composition.

20.2.2.1 Foam core panel. The wall panels, to which the ECU racks must be attached, consist of a 2-inch thick urethane foam core (density 2 pcf) to which 0.040-inch thick sheets of 5052-H34 aluminum alloy have been cemented on both inside and outside surfaces. Although the panels are formed with aluminum extrusions on the edges and are stiffened with aluminum extrusions placed inside the panel, it is not feasible to transfer the dynamic loads from railroad humping directly to the composite wall. The lack of compressive and shear strength of the low-density urethane foam core is the limiting factor.

20.2.2.2 Paper honeycomb core. Paper honeycomb is a much stronger core material than 2 pcf urethane. For this reason, shelter panels with paper honeycomb cores[11] do not have internal stiffeners. The result is that the panel strength is comparable to urethane panels, and the ECU mounting frame attachment and load transfer are also comparable. The same mounting frame designs are adaptable to both urethane and paper honeycomb panels and no design was made specifically for either one.

20.2.3 Panel strength.

20.2.3.1 Strength in shear. Two leading shelter manufacturers[12] advised that the shelter end panel probably would not stand up to the design loadings (see 20.3), especially for the heavier ECU's, unless the panel were specifically constructed for the loads. They further said that it would be risky to fit a

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[10] Dynamic loadings caused by acceleration due to rail humping are 6g in the transverse and vertical directions and 10g in the longitudinal direction.
[11] Brunswick Shelters, for example.
[12] Craig Systems and Gichner Mobile Systems

standard mounting frame to an end panel without the aid of the structural drawings for the particular shelter being used, since the structural design of shelters is not uniform; the size, placement, and number of stiffeners is not assured even within a given shelter type and model. They therefore recommended transferring some of the loads to the side and roof panels which, in shear, can take them better than the end panel can be expected to take them in moment. The fact that the mount designs presented here do not rely specifically on the panel stiffeners for strength or bolted attachments makes it easier to adapt the mounts to a variety of end panel designs.

20.2.3.2 Hardened structure. Since the mounting racks are designed to survive limited nuclear overpressures, they must be attached to shelters hardened to a comparable degree. When attached to an unhardened shelter, a rack would survive only as long as the shelter does. Nevertheless, the mounting racks have been designed to be adaptable to either the unhardened or hardened shelter, the latter with the ability to withstand a peak free-field overpressure up to 7 psi.

20.3 Transportation shocks. In addition to the weight of the units, the rack must be capable of supporting the ECU's when subjected to the acceleration forces caused by railroad humping (see footnote to 20.1.3).

# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

*(See Instructions – Reverse Side)*

| 1. DOCUMENT NUMBER | 2. DOCUMENT TITLE |
|---|---|
| MIL-HDBK-116 | Environmental Control of Small Shelters |

**3a. NAME OF SUBMITTING ORGANIZATION**

**b. ADDRESS** *(Street, City, State, ZIP Code)*

**4. TYPE OF ORGANIZATION** *(Mark one)*

- ☐ VENDOR
- ☐ USER
- ☐ MANUFACTURER
- ☐ OTHER *(Specify)*: ______

**5. PROBLEM AREAS**

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

**6. REMARKS**

**7a. NAME OF SUBMITTER** *(Last, First, MI)* – Optional

**b. WORK TELEPHONE NUMBER** *(Include Area Code)* – Optional

**c. MAILING ADDRESS** *(Street, City, State, ZIP Code)* – Optional

**8. DATE OF SUBMISSION** *(YYMMDD)*



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