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Work Unit 1423A

SUMMARY
OF
RESEARCH REPORT

SHELTER PACKAGE VENTILATION KIT

OCD Work Unit 1423A

October 1965 GARD Report 1244

by

General American Transportation Corporation
General American Research Division
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Niles, Illinois

REVIEW NOTICE

This is a summary of a report which has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

INTRODUCTION

Certain fallout shelters in the United States require ventilation systems capable of supplying from 5 to about 30 cubic feet per minute of outside air per person sheltered in order to achieve a high confidence of maintaining tolerable conditions of temperature and humidity during hot weather.[1]

Many shelters with better protection factors, that have been identified in the National Fallout Shelter Survey, are in belowground areas and are not ventilated at all. Since the Office of Civil Defense does not own identified shelters, and since many shelters may be replaced by better shelters as the system is upgraded, the installation of conventional permanent ventilation systems is undesirable. Therefore, OCD required a study of the problem of shelter ventilation and the development of novel ventilation techniques tailored specifically to identified fallout shelters. The goals of this development program are portability, low cost, manual and electric drive, ease and universality of application.

The resulting Package Ventilation Kit (PVK) is a complete packaged mechanical ventilation system that is portable, can be assembled and deployed by untrained personnel, and can be driven either electrically or by human power. The PVK (see Figure 1) consists of two basis packages -- a Fan Assembly and Drive Module (see Figures 2 and 3).

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1. G. Engholm, "Physiological and Meteorological Aspects of Shelter Ventilation", paper presented at Scientific Working Party of NATO Civil Defense Committee, July 1965.

Figure 1 Package Ventilation Kit in Operation

This report discusses the design and the performance of the PVK. The unit has been thoroughly field tested[1,2] and no failures occurred after continuous operation of the unit for two weeks. Specification MIL-V-40645, "PACKAGE VENTILATION KIT, 20-INCH FAN, MODULAR DRIVE (CIVIL DEFENSE)", was published by OCD 16 August 1965, based on technical specification data developed by the General American Research Division under this contract.

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1. B. A. Libovicz and H. F. Behls, "Experimental Prototype Package Ventilation Kit, First Structural and Human Factors Test", prepared for the Office of Civil Defense under Stanford Research Institute Subcontract B-70925(4949A-28)-US, General American Transportation Corporation (GARD Report 1278-4.1), Niles, Illinois, May 1965.

2. B. A. Libovicz, R. B. Neveril, and H. F. Behls, "Preproduction Prototype Ventilation Kit, Second Structural and Human Factors Test", prepared for the Office of Civil Defense under Stanford Research Institute Subcontract B-70925 (4949A-28)-US, General American Transportation Corporation (GARD Report 1278-4.2), Niles, Illinois, August 1965.

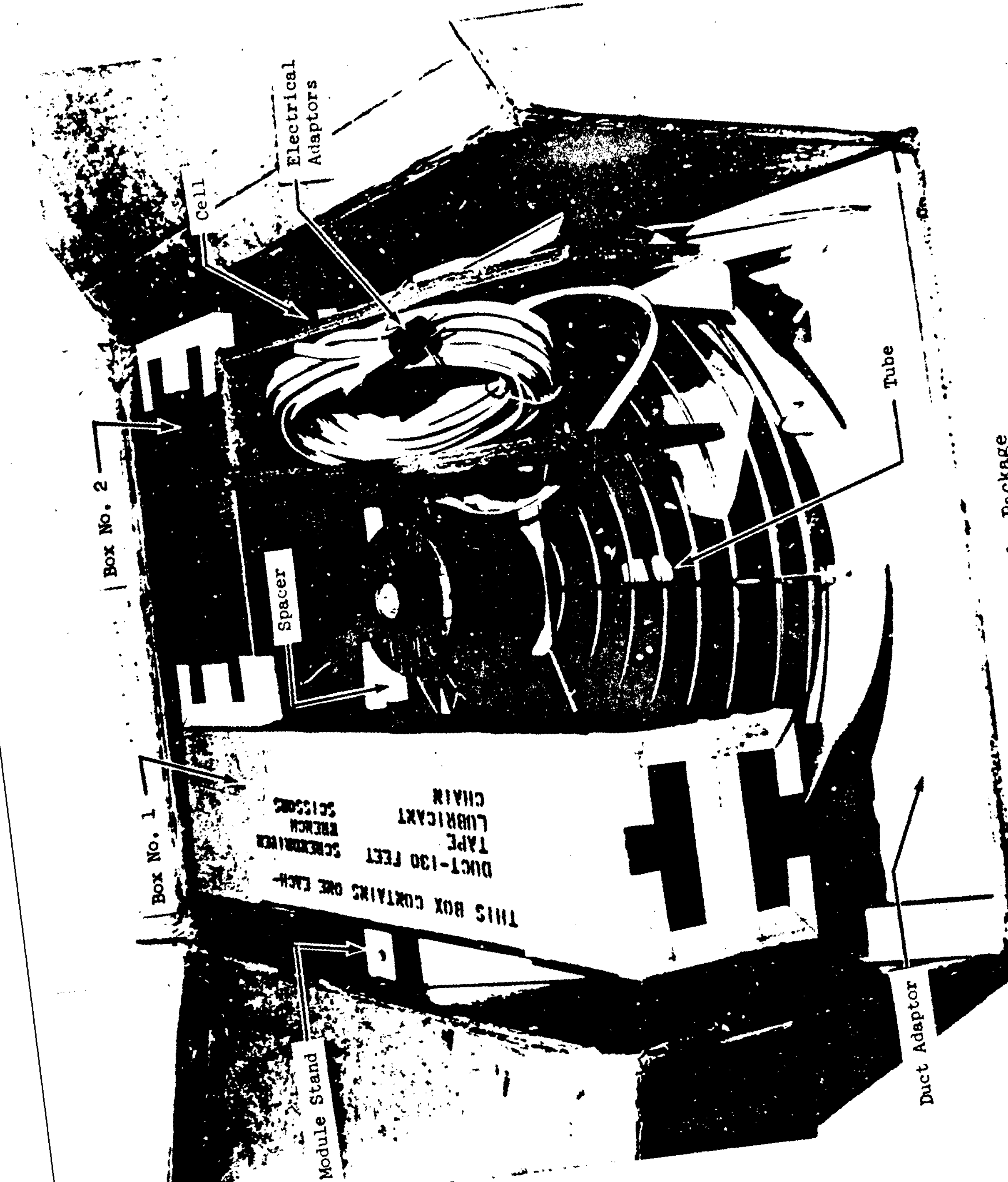

Figure 2 Fan Assembly Package

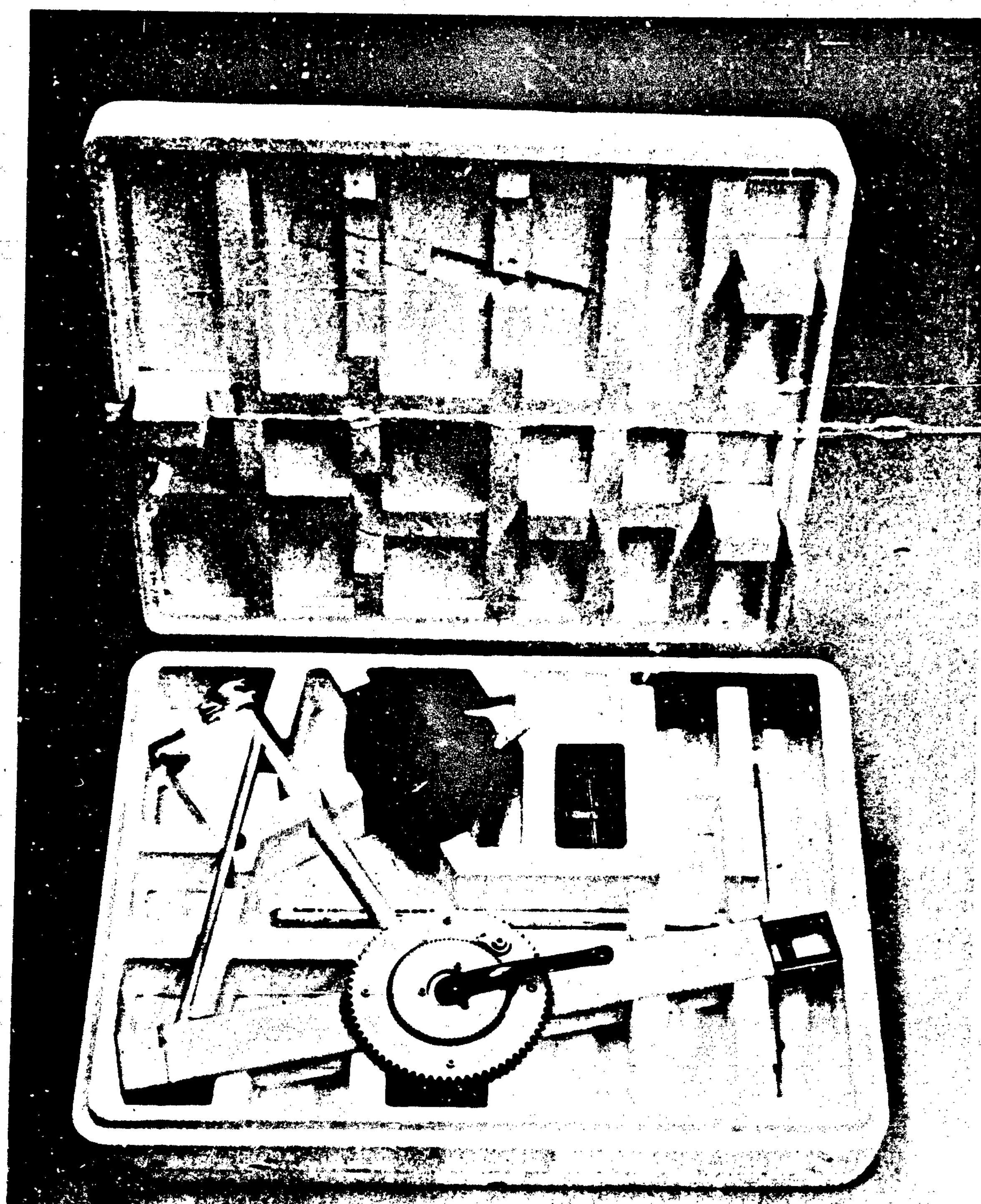

Figure 3 Drive Module Package

DESIGN

Drive Module

The bicycle-like drive is designed on a modular basis (see Figure 4). The basic dimensions are the same as those of a standard bicycle (see Figure 5). The main structural member of the Drive Module and Fan Assembly is the horizontal "spine". This beam member is fabricated from 2 inch by 3 inch rectangular steel tubing. This configuration was chosen because, in addition to its resistance to bending, it lends itself to a male-female interlocking joint which aligns the Drive Modules and Fan Assembly. Two types of connecting joints, and various methods for locating and locking the spines were designed, fabricated, and evaluated. The swaged-expanded joint is specified since its ease of assembly, alignment and rigidity are excellent, and its cost in production quantities is a minimum. Of the methods of locating and locking the spines relative to each other, the tapered pin is best. With this pin the holes in the spines are easily aligned with the tapered end, and the pin is easily inserted because of the long tapered section.

Fan Assembly

The Fan Assembly is arranged for use with ducting on the discharge side of the fan-shroud subassembly (see Figure 6). The PVK is thus used to exhaust stale, hot and humid air from the shelter.

<u>Shroud</u>: Of the three basic types of orifices -- sharp edge, cylindrical, and converging (cone or bell-mouth) -- the bell-mouth orifice develops higher static pressures in the operating range of the shelter ventilator and requires the least energy to drive the fan. Therefore, this orifice design was incorporated into the specifications.

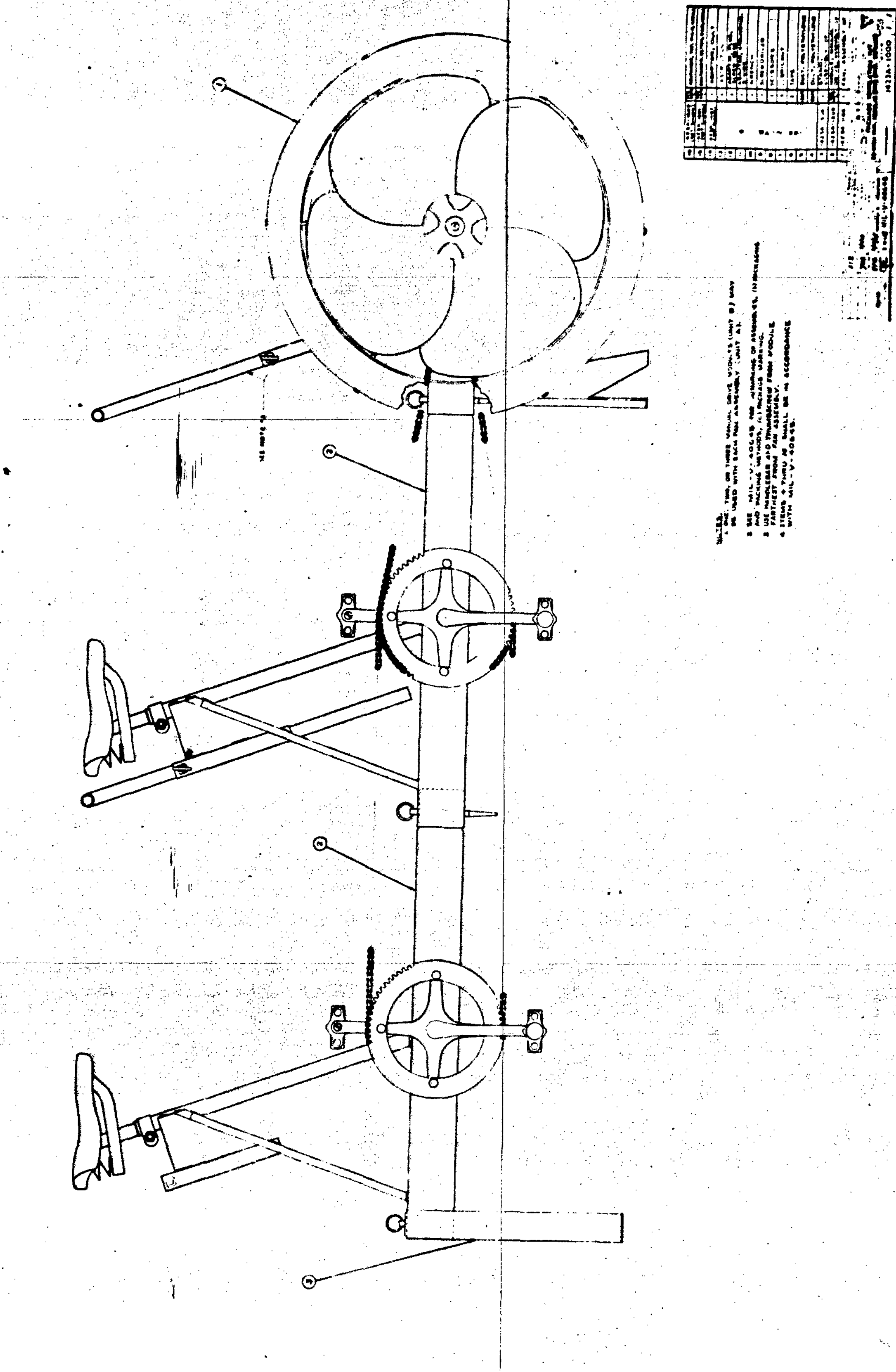

Figure 4 Package Ventilation Kit, 20-Inch Fan, Modular (Civil Defense)

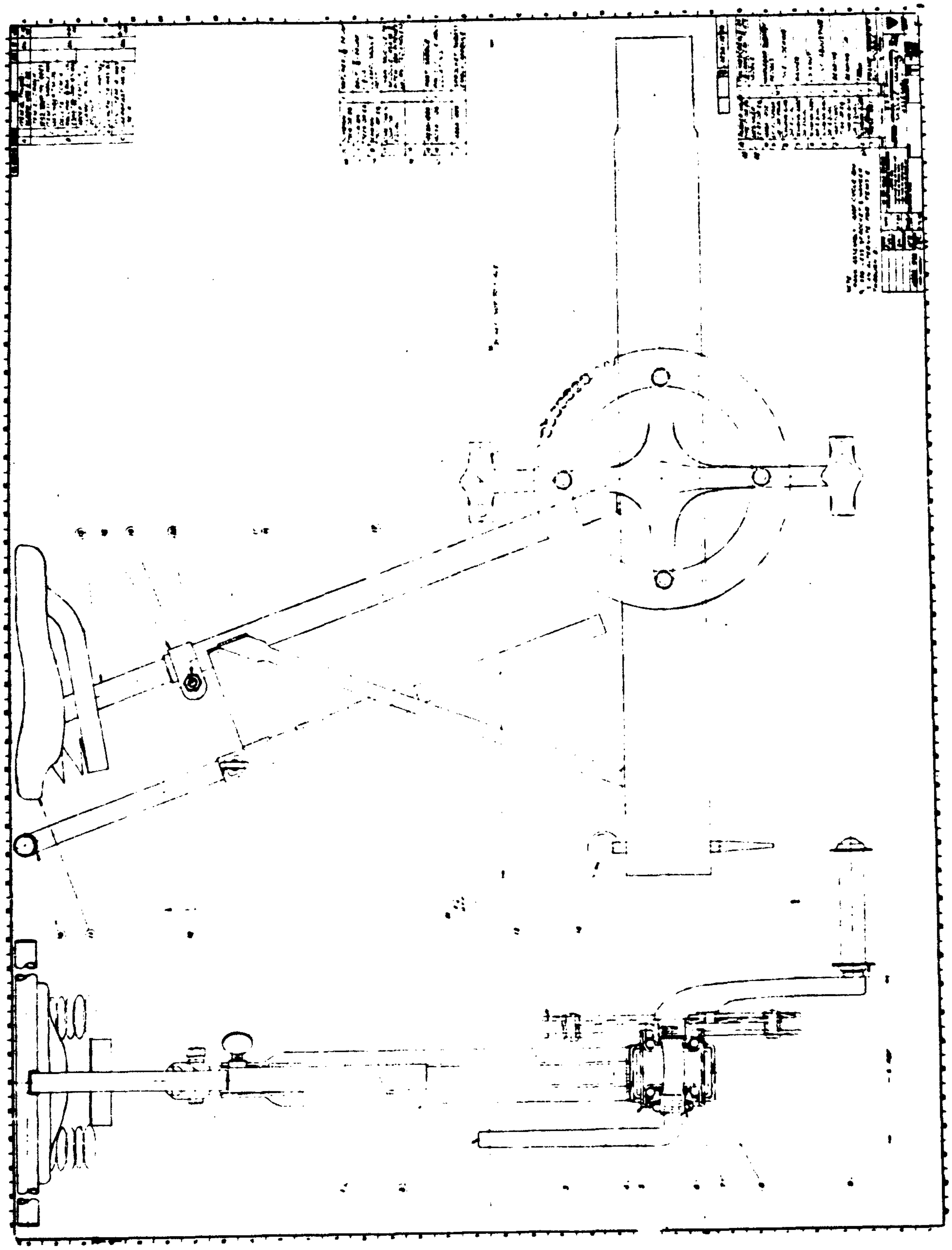

Figure 5 Module Assembly

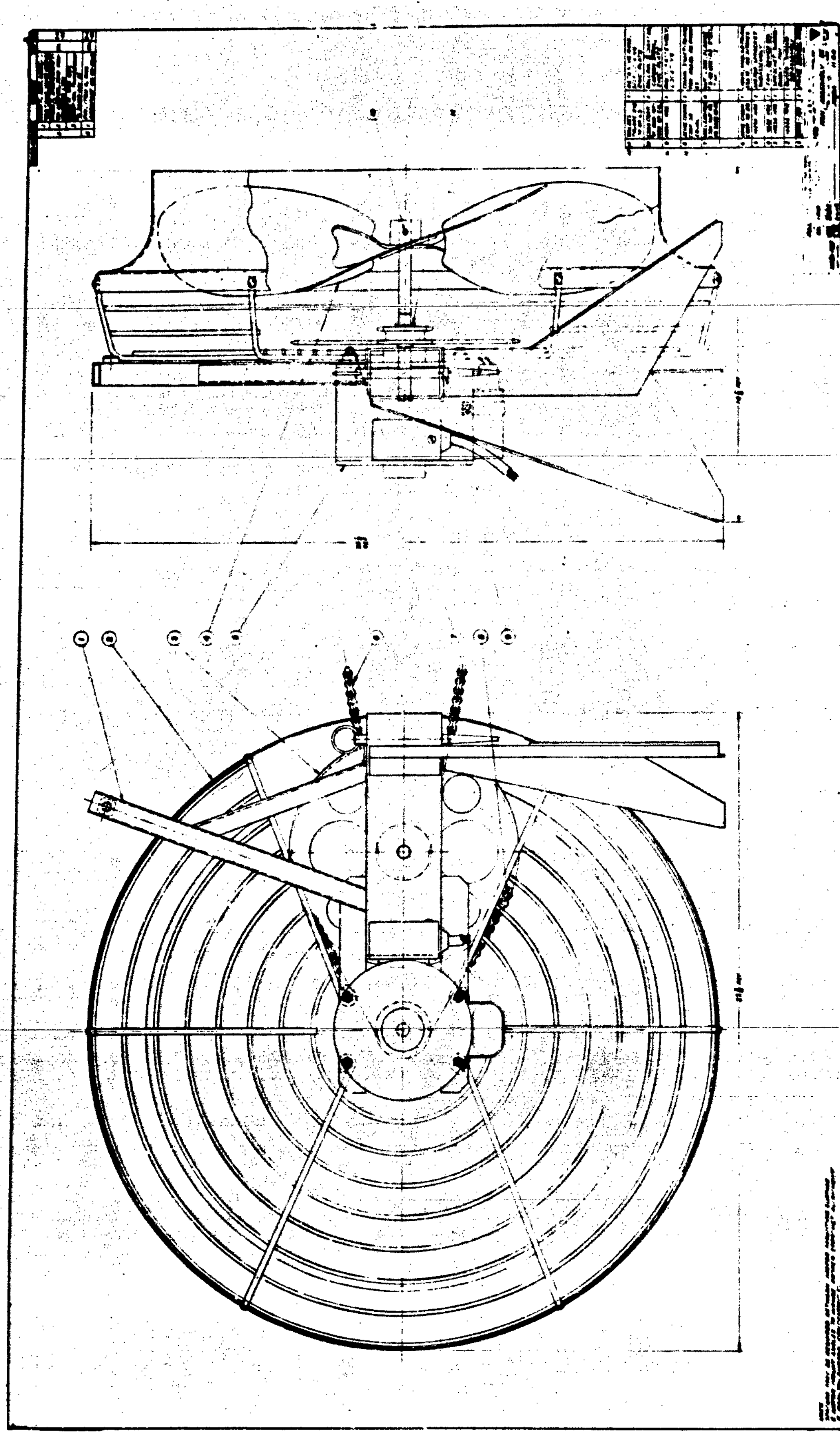

Figure 6 Fan Assembly

Motor: The motors considered for use in the PVK were the split phase, permanent-split capacitor, capacitor start-induction run, shaded pole, and the capacitor start-capacitor run.

The permanent-split capacitor and the shaded pole motors are the least expensive, and are generally used where a direct-drive is required, such as fan-coil units. The permanent-split capacitor (PSC) motor is specified because:

1. the air flow rate developed by the PSC motor is 5 percent greater than the shaded pole motor due to its higher operating speed,
2. the starting torque of the PSC motor is considerably higher, 125 percent of full load torque as compared to 25 percent of full load torque for the shaded pole motor,
3. the efficiency of the PSC motor is considerably greater, 61 percent as compared to 37 percent for the shaded pole motor,
4. the full load current at 1/3 horsepower for the PSC motor is 4.3 amperes, as compared to 6.8 amperes for the shaded pole motor,
5. the power losses to manually drive the unit are a minimum since this motor (also the shaded pole) does not have an integral cooling fan, and
6. the motor does not have any centrifugal switches, thus minimizing the transmission losses when the unit is manually driven, and increasing the reliability of the motor after long periods of storage.

Transmission

The fan is mounted on the motor shaft and thus can be driven when 115 volt single-phase A.C. power is available. The pedal drive is coupled to the fan shaft through an idler-shaft using roller chain and sprockets. An overall increase in speed from 55-62 rpm at the pedal crank to 1070-1206 rpm at the fan is obtained in two equal ratios. The first step-up (4.41 ratio) occurs between the 75 tooth module sprocket and the 17 tooth sprocket of the idler shaft sprocket subassembly. An identical speed step-up occurs between the 75 tooth sprocket of this subassembly (integral with the 17 tooth sprocket mentioned above) and the 17 tooth motor shaft sprocket. The overall speed ratio is 19.46 to 1. All module sprockets have 75 teeth, hence there is no speed change between modules. American Standards Association (ASA) No. 35 chain is used throughout the PVK.

Packaging

The packages developed for the Fan Assembly and the Drive Module are water-vaporproof meeting the requirements of Method IA-14, Specification MIL-P-116. These packages consist of an interior container, a heat sealed bag, and an exterior fibreboard carton.

Cost Analysis

The cost of a Package Ventilation Kit based on large production quantities is estimated to be $89 for the Fan Assembly, and $65 for the Drive Module A complete one-module PVK thus costs $154, and a complete two-module PVK $219.

Ventilation cost per shelteree have been determined based upon (1) the above costs, (2) an assumed minimum ventilation requirement of 15 cfm per shelteree, and (3) shelters with equivalent duct lengths of zero, 200 (see Figure 7), and 400 feet. These costs are presented as a function of shelter capacity for various stocking procedures including all one-module PVK's, all two-module PVK's, and for the combinations of one-module and two-module PVK's that result in the lowest ventilation cost. Similar cost curves could be generated for different minimum ventilation rates.

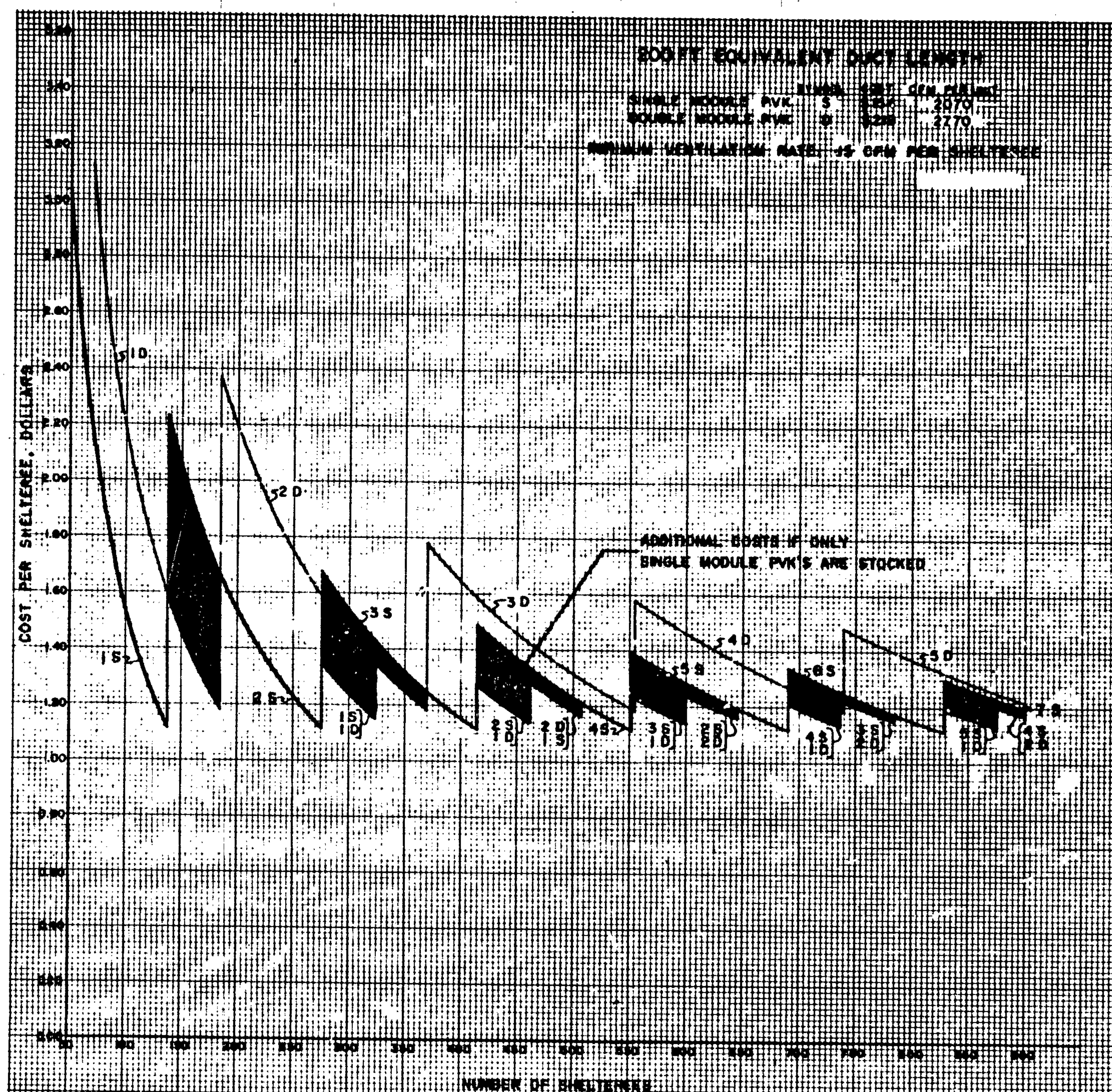

Figure 7 Ventilation Costs For Various PVK Stocking Methods

PERFORMANCE

Fan

The fan rating for standard air and air at an elevation of 5,000 feet are presented in Figures 8 and 9 respectively. These fan performance characteristics were determined by test per the National Electrical Manufacturers Association (NEMA) Code FM1-7.02. The friction losses for 20-inch diameter, 4-mil thick polyethylene tubing were also determined by test.[1] Ventilation rates developed by the PVK fan increases with increasing elevation because of the decreased air density and decreased duct resistance to flow as shown in Table I. However, the air density reduction due to altitude reduces the cooling ability of the air more rapidly. The net effect is that the PVK has less cooling ability at increased altitude; therefore, caution must be exercised when finalizing the PVK stocking procedures.

Transmission

The power losses in the transmission were determined by measuring the torque required to drive the assembly at various speeds with the fan removed. For up to three drive-modules the transmission power losses do not exceed 8 percent of the total input based on 0.1 hp input per drive-module (see Table II).

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1. R. B. Neveril and H. F. Behls, "Friction Loss In Flexible Plastic Air Duct", prepared for the Office of Civil Defense under Stanford Research Institute Subcontract B-70925(4949A-28)-US, General American Transportation Corporation (GARD Report 1278-2), Niles, Illinois, October 1965.

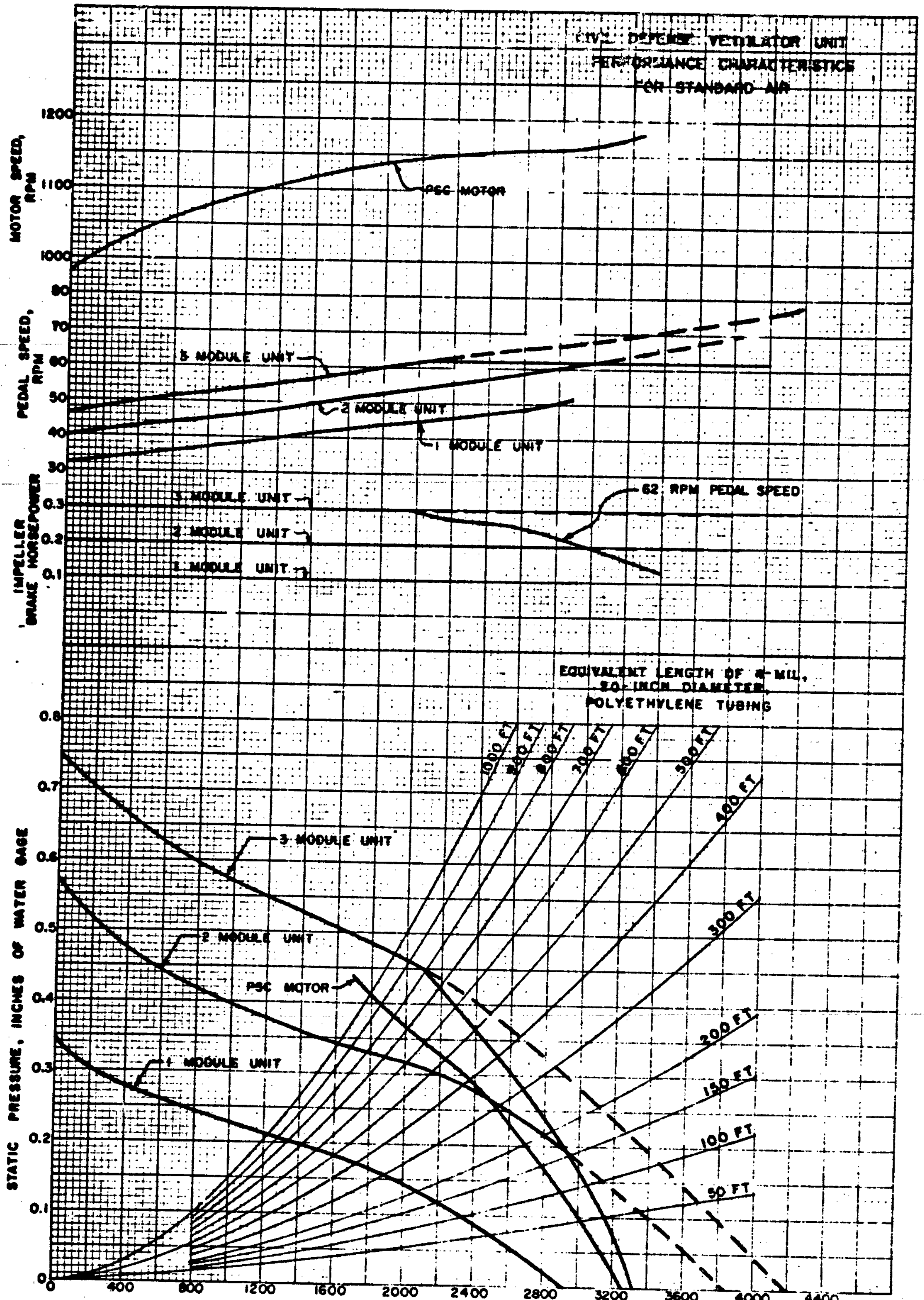

Figure 8 PVK Performance for Standard Air

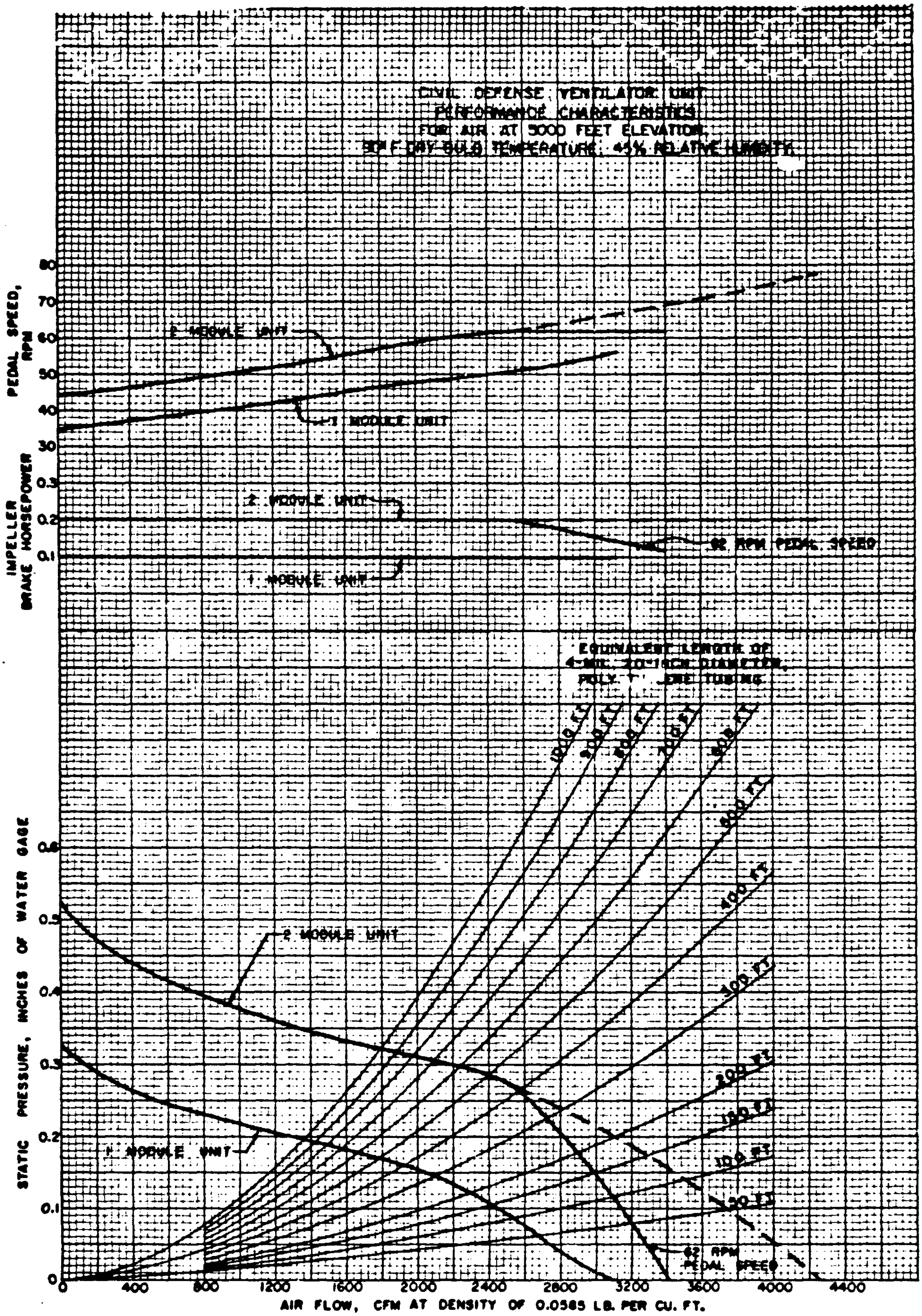

Figure 9 PVK Performance at 5,000 Feet Elevation

Table I

PVK Rating For Standard Air and 5,000 Feet Elevation

Equivalent Length of Duct System, Feet	One Drive-Module PVK			Two Drive-Module PVK			Motor-Fan Rating	
	Air Density, lb per cu ft		% Increase Air Flow Due to Decreased Density	Air Density, lb per cu ft		% Increase Air Flow Due to Decreased Density	Air Density, lb per cu ft 0.075 *	
	0.075 *	0.0585 #		0.075 *	0.0585 #			
	Air Flow, Q_s cfm	Air Flow Q_a cfm	$\frac{Q_a - Q_s}{Q_s} \times 100$	Air Flow, Q_s cfm	Air Flow Q_a cfm	$\frac{Q_a - Q_s}{Q_s} \times 100$	Air Flow, Q_m cfm	Speed, RPM
0	2920	3120	6.8	3310	3410	3.0	3250	1180
50	2500	2670	6.8	3160	3200	1.3	3020	1165
100	2340	2540	8.6	3050	3090	1.3	2900	1160
150	2190	2410	10.0	2950	2990	1.4	2790	1158
200	2080	2300	10.6	2800	2900	3.6	2690	1157
300	1890	2100	11.1	2540	2720	7.1	2520	1156
400	1730	1920	11.0	2330	2570	10.3	2370	1154
500	1600	1780	11.2	2150	2400	11.6	2230	1150
600	1510	1660	9.9	2010	2230	10.9	2110	1148
700	1420	1570	10.6	1880	2090	11.2	2010	1145
800	1340	1490	11.2	1780	1970	10.7	1930	1142
900	1280	1420	10.9	1690	1880	11.2	1850	1140
1000	1220	1380	13.1	1610	1790	11.2	1790	1138

* Air density of 0.075 lbs per cu ft (standard air) is at sea level (29.92 inches of Mercury Barometer), 70°F dry-bulb temperature, 0% relative humidity. Data from Figure 8.

\# Air density of 0.0585 lbs per cu ft is at 5,000 feet elevation (24.89 inches of Mercury Barometer), 90°F dry-bulb temperature, 45% relative humidity. Data from Figure 9.

Table II

Transmission Power Losses

Number of Drive Modules	Fan Shaft Speed, rpm	Power Losses, hp	Mechanical Efficiency, Percent
1	800	0.0073	92.7
2	1000	0.0122	93.9
3	1140	0.0167	94.4

Motor

The performance characteristics of the specially wound permanent split-capacitor (PSC) motor, as manufactured by the Emerson Electric Mfg. Co., is certified to meet all the quality assurance provisions of Section 4, Specification MIL-V-40645. This motor also meets the Underwriters Laboratories requirements for approval. The maximum measured temperature rise of the motor windings is 26.5°C when operating at 1/3 horsepower.[1] This same motor was installed in a PVK, and tested per NEMA Code FM1-7.02. The results of this test are shown in Figure 8.

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1. B. A. Libovicz, R. B. Neveril, and H. F. Behls, "Preproduction Prototype Ventilation Kit, Second Structural and Human Factors Test", prepared for the Office of Civil Defense under Stanford Research Institute Subcontract B-70925 (4949A-28)-US, General American Transportation Corporation (GARD Report 1278-4.2), Supplement II, "Package Ventilation Kit: Motor Test", Niles, Illinois, August 1965.