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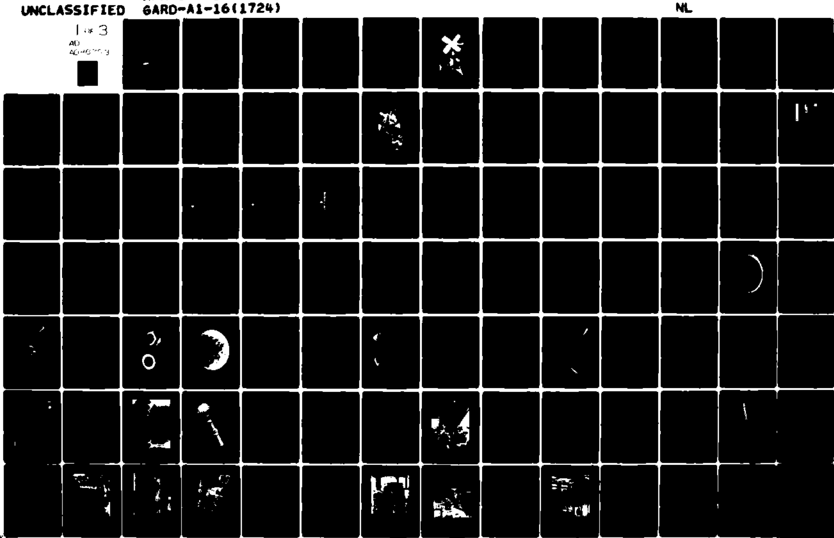

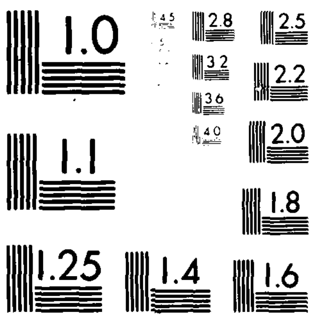

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The objective of this program was to conduct a study of alternate materials that could be utilized in the construction of a pedal ventilator kit (PVK). The goal of the study was to reduce unit cost in a large scale procurement. Cost savings and performance parameters were evaluated using the PVK developed in 1979 under Contract No. DCPA01-78-C-0184 as a basis for comparison.

A value analysis study was conducted on the PVK to determine viable

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) material/design revisions that offered potential manufacturing economies. Based on the conclusions of the study, one optimum design was chosen for fabrication. Prior to fabrication, five breadboard support frames were constructed and tested.

Fifteen fully assembled prototype pedal ventilator kits were constructed. Five of the PVK's were subsequently tested to assure compliance with performance and reliability requirements.

Preliminary specifications and operating instructions were generated for the PVK. In addition, production cost estimates based on a procurement of 100,000 units were formulated for FEMA budgetary purposes.

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DETACHABLE SUMMARY

GARD FINAL REPORT A1-16 (1724)
April, 1980

STUDY OF ALTERNATE MATERIAL FOR PEDAL VENTILATOR KITS

By

John M. Buday

For

Donald A. Bettge
FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D.C. 20472

under Contract No. DCPA01-79-C-0234
FEMA Work Unit 1423E

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INTRODUCTION

The objective of this program was to conduct a study of economical alternate materials that could be utilized in the construction of a pedal ventilator kit (PVK). The goal of the study was to reduce unit costs in a large scale procurement and validate the reliability of the selected design by performing a series of structural and environmental tests. Cost savings and performance characteristics were evaluated using the previous PVK developed in 1979 for DCPA under Contract No. DCPA01-78-C-0184 as a basis for comparison.

The program was initiated with a value analysis study of critical PVK components. Based on the resultant data from the study, several candidate designs employing new materials and/or cost saving processes were presented for evaluation. From these, one design reflecting the optimum material, configuration, performance and cost was chosen for construction and testing. This design is shown in Figure 1-1. Sufficient documentation was prepared to permit construction of the unit.

The support frame was determined to be most favorably influenced by cost saving material alternatives. Five breadboard support frames were constructed and tested to determine the structural integrity and storage resistance of the frame prior to further development. From the five frames, one frame was picked to be utilized for PVK fabrication. Using the approved frame, fifteen (15) prototype pedal ventilator kits were fabricated and assembled. Of these, five PVK's were tested to assure that the unit's performance and reliability were not compromised. The remaining 10 units were shipped to various FEMA depots for evaluation.

Preliminary specifications and operating instructions were formulated to establish a data baseline for the unit. In addition, production cost

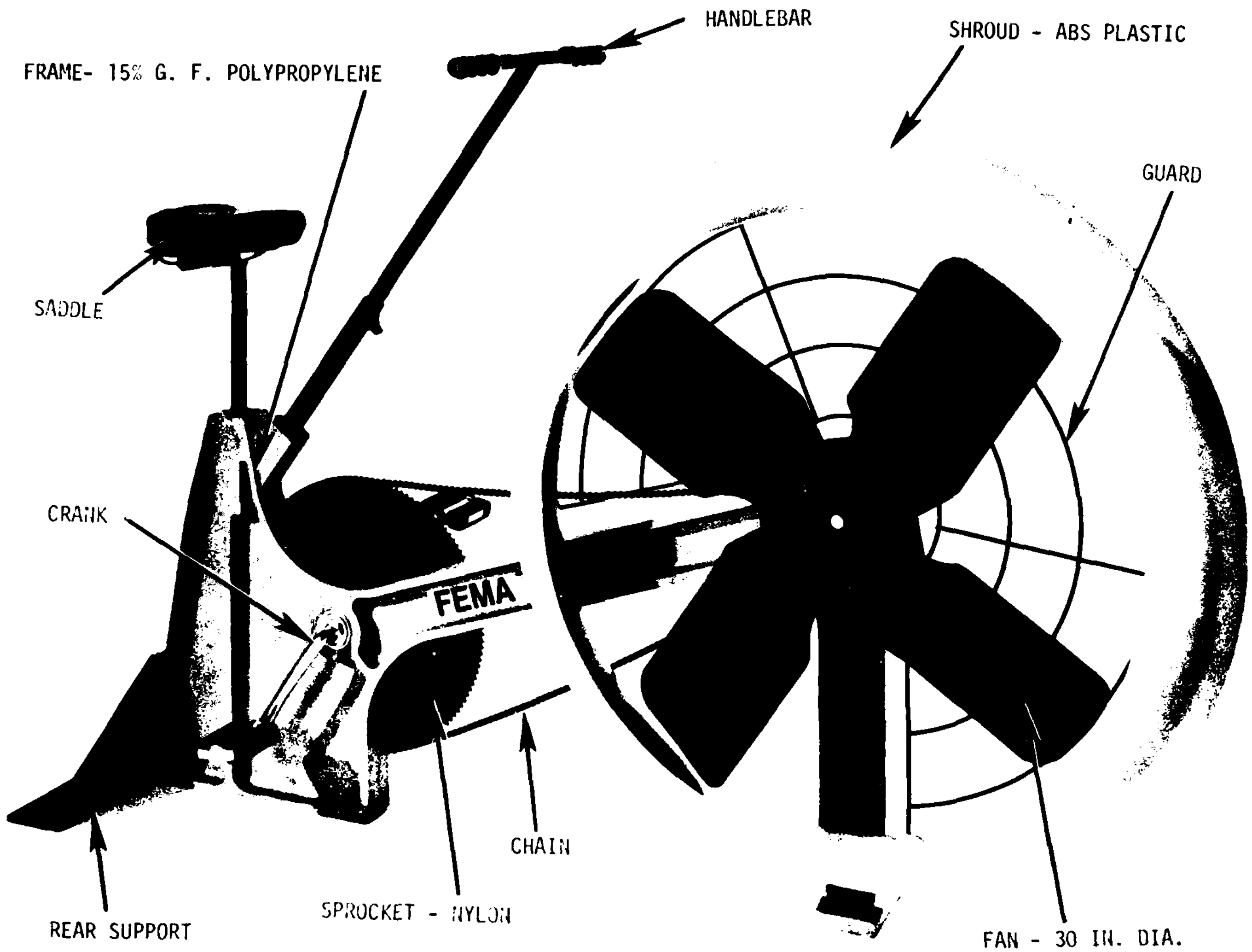

FIG. 1-1 PROTOTYPE PVK MODEL

estimates for a target production run of 100,000 units were generated for FEMA budgetary purposes.

VALUE ANALYSIS STUDY

The objective of the value analysis study was to conduct a review of the PVK at the component level to determine the optimum PVK alternate material(s) and configuration. The analysis was applied to material, fabrication methods, interchangeability features, storage life, deployment and reliability. Included in the effort was a study to determine the optimum fan diameter based on DCPA shelter CFM/occupant surveys.

The value analysis resulted in material revision and/or redesign of the following major PVK components.

- o Support Frame - glass-filled polypropylene
- o Shroud - ABS plastic
- o Drive Sprocket - reinforced nylon.

Preliminary investigations involving the above designs indicated substantial cost savings in a large scale procurement over previous PVK's.

BREADBOARD FRAME EVALUATION

The main support frame is the largest component offering the best possibility for maximum cost reduction. The frame provides the structural support for the operator and the interface for all key components of the unit. Five support frames of varying glass densities and/or materials were molded and tested prior to fabrication of any quantities of the assembled units. The frames were injection molded, utilizing the same one-cavity aluminum mold.

The following tests were performed on the frames to determine compliance to specifications.

- o Static Load Test (Creep)
- o Ultimate Load Test (to failure)
- o Environmental Resistance (high and low temperature)
- o Drop Test
- o Toppling Test (Impact)

The frame considered optimum as a result of the above test procedures was polypropylene - 15% glass-filled.

PROTOTYPE VENTILATOR VALIDATION

Using the approved frame configuration developed and tested in the previous task, GARD constructed and assembled fifteen prototype ventilation kits. The following specific tests were conducted to assure compliance of the fully assembled ventilator.

- o Hardware Failure Test
- o Environmental Test - High Temperature (+140°F)
- o Environmental Test - Low Temperature (-30°F)
- o Deployment Tests

ADDITIONAL RESEARCH INVESTIGATIONS

In addition to the above tasks, GARD conducted research activities on the following components/areas described below.

- o Handle Bar
- o Rear Support
- o Fan - 30" diameter

- Packaging Concepts (15 year storage)

PRODUCTION COST ESTIMATES

Estimates of production costs for the alternate material PVK were based on a target procurement quantity of 100,000 units each. The estimated costs were formulated using current (1979) inputs form fabricators' quotes, stan-hard hardware costs, production tooling quotes and cost escalation factors. In addition to costs for the basic PVK, estimates for packaging, accessories, burdens and profits are included for totalized unit cost purposes. The estimated costs of the PVK was reduced from $230.08 to $140.70.

Included in this report is a typical production assembly line concept for the PVK. The concept aided in computing manpower estimates for fabrication of the unit.

CONCLUSIONS

Any reservations regarding the viability of fiber reinforced plastics in the construction of the pedal ventilator were dismissed during the testing phases of the program. The chosen design was equal to, and in some cases, superior to, the former welded steel PVK. Environmental tests, in particular, performed at extreme high and low ambient temperatures had no detrimental effect on the unpackaged units. The test procedures were in conformance with MIL-STD-810C, which represents established environmental test methods (DOD) for determining the resistance of military equipment to the effects of natural and induced environments during storage without protective packaging Since the PVK will, in all probability, be contained in some enclosure during storage, GARD feels confident the units can safely endure the required 15-year minimum storage life. Excluding fire, it is predicted the PVK storage life would considerably exceed the requirement.

Perhaps the most dramatic result of the subject program is the reduction of the unit cost as compared to steel PVK's. The utilization of modern, high strength plastics on the major components of the PVK allows for savings in the associated labor required for previous models, which becomes significant in highly inflationary times. Cost comparisons noted in this report indicate a cost reduction of approximately 40% over the steel PVK.

Since the plastic manufacturers are coupled closely with the highly fluctuating petroleum industry, it is advised that the timing for any production run is extremely important. The large consumption of raw plastic compounds by the automotive industries has somewhat negated the recent cost spiraling realized by other raw products. In today's market, there is no assurance that this trend will continue.

FOREWORD

This final report was prepared by GARD, INC., Niles, Illinois for the Federal Emergency Management Agency under Contract No. DCPA01-79-C-0234. The effort performed under this program was monitored by Mr. Donald A. Bettge of Mitigation and Research, FEMA.

The report covers the work performed on the contract during the period of 27 March, 1979 to 30 April, 1980, and describes the value analysis study, fabrication and testing of an alternate material pedal ventilator kit (PVK) for use in Civil Defense Shelters.

The author wishes to thank Mr. R. J. Klima, Mr. R. E. Sadler, and Dr. L. B. Holmes for their many contributions to the performance of the above effort, and Mr. R. Patel for his work in generating the finite element analysis of the support frame. Thanks are also due to Mr. Bettge for his invaluable assistance during the course of the subject program.

Respectfully submitted,

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ABSTRACT

The objective of this program was to conduct a study of alternate materials that could be utilized in the construction of a pedal ventilator kit (PVK). The goal of the study was to reduce unit cost in a large scale procurement. Cost savings and performance parameters were evaluated using the PVK developed in 1979 under Contract No. DCPA01-78-C-0184 as a basis for comparison.

A value analysis study was conducted on the PVK to determine viable material/design revisions that offered potential manufacturing economies. Based on the conclusions of the study, one optimum design was chosen for fabrication. Prior to fabrication, five (5) breadboard support frames were constructed and tested.

Fifteen fully assembled prototype pedal ventilator kits were constructed. Five of the PVK's were subsequently tested to assure compliance with performance and reliability requirements.

Preliminary specifications and operating instructions were generated for the PVK. In addition, production cost estimates based on a procurement of 100,000 units were formulated for FEMA budgetary purposes.

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Section 1

BACKGROUND

The need for portable shelter ventilation equipment was specified by an Office of Civil Defense Task Group formed in 1963 to study the feasibility of various modes of ventilation and deployment.[(1)*] The design and development of the MIL-V-40645 modular package ventilation kit resulted from the recommendations of this task group.[(2)] The kit employed a 20-inch diameter propeller fan that could be electrically powered.

Subsequent shelter equipment evaluations conducted by GARD showed that this ventilator as designed could not readily be employed by untrained persons. Also, a cost optimization study, limited to fans with diameters of 36 inches or less, revealed that a shelter ventilation system of minimum cost would require three units with 36-inch diameter fans rather than 20-inch diameter fans.[(3)]

These units would be a one-operator pedal-driven unit, a four-operator pedal-driven unit, and a 5-HP electric motor-powered unit.[(4)] This program was conducted by GARD, INC. under subcontract to Stanford Research Institute.

The study was limited to fans with diameters of 36 inches or less, since it was assumed the minimum width of shelter doorways was 36 inches. A later study disclosed that the minimum width of doorways in commercial/institutional buildings is 31 inches. To avoid excessive pressure losses in ducts caused by restrictions at the doorways, it was decided, with OCD approval, to develop pre-assembled one and two-operator bicycle ventilator kits utilizing a fan and ducting system of 30 inches in diameter.

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* Superscripts refer to Section 7, References.

This requirement directly led to the development of the one-operator pedal ventilator kit under Contract No. DAHC20-68-C-0123 in January, 1971.[5] Renewed procurement interest by Defense Divil Preparedness Agency in 1978 prompted the initiation of a program to update the (1971) ventilator kit. The object of the program was to reduce fabrication and hardware costs wherever possible without detracting from the performance or reliability of the unit. GARD, under DCPA Contract No. DCPA01-78-C-0184 performed this program and realized cost savings of approximately 12% for the PVK.[6]

It became apparent during the performance of the above program that certain elements of the ventilator kit, particularly the support frame, could be substantially reduced in cost due to the new material advances that have occurred since the original kits were designed (1971). Concurrently, GARD became aware of the new DCPA civil defense posture which could result in an eventual high volume procurement. The high volume requirement permitted the consideration of reinforced plastics and composite materials for substantial reduction in cost. The application of new materials could result in reduced unit weight, more reliable storage life and reduced packaging needs.

FEMA decided that before any PVK design is finalized and subsequent large scale procurement occurs, a feasibility study of alternate materials was in order to realize possible cost savings. The feasibility study was initiated in April, 1979, under Contract No. DCPA01-79-C-0234. The objectives, methods, conclusions and recommendations are contained within this report.

Section 2

ALTERNATE MATERIAL PEDAL VENTILATOR KIT (PVK)

The previous ventilator kit re-evaluated under Contract No. DCPA01-78-C-0184, shown in Figure 2-1, utilizes a 4-bladed, 30-inch diameter fan powered by a sprocket/roller chain transmission ratio of 7.70:1. An average operator would apply a 0.1 HP input at a crank speed of approximately 55 to 60 RMP with a resultant fan velocity of 423 to 480 RPM. The unit incorporates a bellmouth shaped shroud for maximum efficiency resulting in an output air flow velocity of approximately 4200 CFM at the RPM stated above. A principal feature of this ventilator is that the unit is fully assembled when packaged.

The PVK described above was utilized as a basis for cost and performance comparison during the development of the alternate material PVK. This section will describe the evolution of the alternate material PVK from the value analysis study through the final design concept chosen.

2.1 Value Analysis Study

The program was initiated with a value analysis study which was implemented to determine the optimum PVK alternate material and configuration. The analysis was applied to materials, fabrication methods, interchangeability features, fan diameter and output. In addition, the parameters of storage life (15 years), deployment and reliability were primary considerations in the development of the unit. The goal of the study was to develop a ventilator kit that can be fabricated and assembled for the minimum cost possible, utilizing current technology.

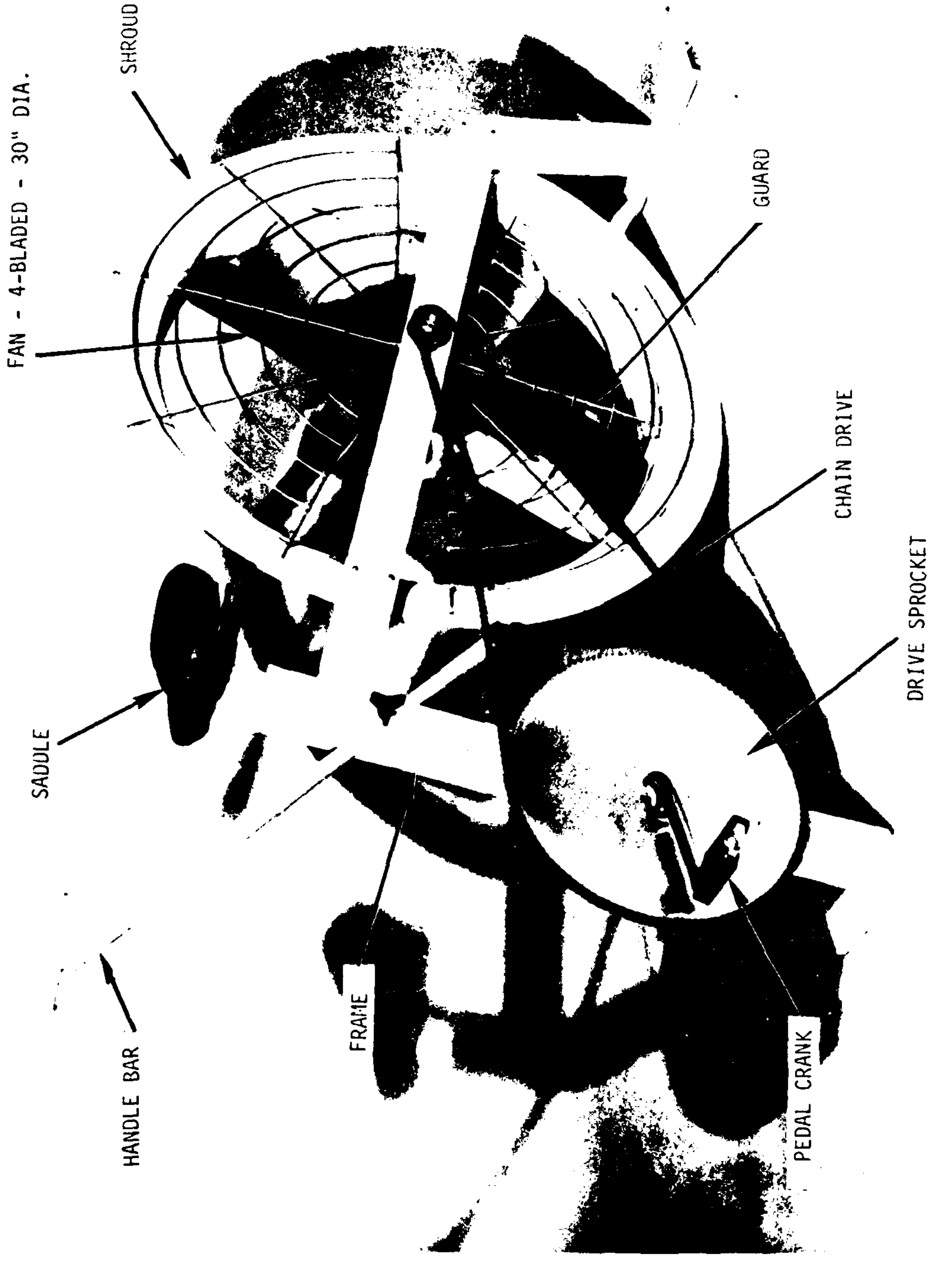


Figure 2-1 PEDAL VENTILATOR KIT

2.1.1 Material Selection

One of the primary considerations of the value analysis study was the determination of the optimum material to be used for the unit construction. Candidate PVK support frame materials, in particular, were carefully evaluated, since the frame was the PVK element offering the maximum potential cost reduction from previous steel frames. The parameters for the material analysis was a target production run of 100,000 units over a period of three years.

The following subsection describes the various methods and descriptions involving the selection of the optimum material.

2.1.1.1 Material Search

A program task was undertaken to examine alternate materials for the PVK. The evaluation criteria was established to include methods and ease of fabrication, optimum physical properties, and both raw material and fabrication costs.

The initial phases of the search involved the wide spectrum of all possible candidate materials including plastics, steel, aluminum, composites, wood, zinc and reinforced hardboard. The results of the survey indicated that injection molded, reinforced plastics (FRP) were superior to other candidate materials in meeting both economic and performance standards for PVK structural elements.

Fiberglass-reinforced plastics comprise a special group of reinforced plastics. These materials are a combination of flexible strands of fibrous glass and a plastic. The glass can be prepared in a variety of forms including mats, yarns, continuous strands, chopped strands, etc. The properties of the final product can be predetermined by the proper combination of thermosetting and thermoplastic resins and glass filler forms.

FRP are used in applications requiring both high mechanical strengths and lightweight requirements. This combination led to considerations of FRP as the principal alternate material candidate for the PVK. Combining fiberglass with plastics increases physical strength, stiffness, impact resistance and dimensional stability, while increasing use over wider temperature ranges. The specific gravity of FRP is roughly 20% that of steel and FRP products have strengths competitive with many structural materials. Depending on the amount of glass reinforcement used, and its particular geometry and arrangement in the resin mix, strengths can range from roughly half to several times those of structural steel. The plastics normally employed in FRP are the thermosetting materials, since highest strengths are obtained by combining the reinforcement properties of fiberglass with the cross-linked, three-dimensional gel structure of this type of plastic. However, due to the desirable properties of increased corrosion resistance demonstrated by the thermoplastic materials for PVK applications, structural part strength equivalencies can be obtained by optimizing fiberglass content in the basically straight chain polymeric thermoplastics. A further advantage to use thermoplastic resin bases is seen in fabrication by injection molding where thermoplastics do not undergo chemical curing as do the thermosets. Molding requirements for thermoplastics include heat applications only until the material softens and can be molded into the desired shape. After cooling, the substance hardens to the final product. Selection of thermoplastic resins thus improved the economics of molding press requirements which can become significant in the cost effective determination of the PVK alternate material.

A large variety of injection moldable thermoplastic materials were surveyed for applicability as alternate PVK materials. The categorical parameters examined included physical and mechanical properties, fabrication technology, performance in service requirements and interrelated cost factors.

The major parameter examined for structural plastics was tensile strength. As a group, reinforced plastics equal and can at times exceed the strength of structural steels. From the multitude of available plastic hydrids, the glass fiber-reinforced injection molded types with the highest strength levels have been listed in order of decreasing strength as shown in Table 2-2.[7] The table also contains information on other properties which will be discussed later in this report. As indicated in the chart, the strongest reinforced plastics are the polyamides (nylons) followed by the polycarbonates and the polypropylenes.

2.1.1.2 Fabrication Considerations

Having established the strongest FRP candidates, the advantages and limitations of the fabrication process must be considered. Fabrication parameters include filler selection (material, amount and configuration), fabrication process, fabrication hardware, and cost factors.

TABLE 2-2

PROPERTIES OF INJECTION MOLDED GLASS FIBER REINFORCED (GFR) PLASTICS

GFR PLASTIC BASE	% of Glass	Tensile Strength (ksi)	Specific Gravity	Elastic Modulus (10^5 psi)	Impact Strength	Water Absorption (% in 24 Hr.)
6/10 Nylon	40	35	1.52	18.0	6.0	2.0
6/10 Nylon	20	13	1.17	5.0	1.2	0.2
6 Nylon	Range	13-30.5	1.17-1.18	2.0-5.10	.8-1.8	1.5
6/12 Nylon	Range	25-29	1.34-1.45	12-18.5	1.39-3.36	.13-.2
6/6 Nylon	30	19.5-28	1.34-1.37	10.0-12.5	1.7-2.1	.65-.75
Polycarbonate	40 10	25 12	1.52 1.24	17.0 5.0	6.5 1.9	.20 .07
Polypropylene	40	14	1.22	8.0		
Polypropylene	30	13	1.12	8.5	1.5	.3
Polypropylene	20	7.0	.906	5.2	3.1	.01-.05
Polypropylene	10	6.5	.85	5.0	2.5	.01

Physical properties and moldability are important factors in determining the optimum filler concentration which can be employed. As a rule of thumb, the maximum filler content that can be employed before strength deteriorates is roughly 40% under normal molding conditions. (Normal molding conditions include molding press capacity ("tonnage") which is defined by tons of clamp pressure available for a given size mold. Part design must therefore consider the total area over which pressure must be applied to the mold. Clearance provided by the mold press to accommodate a given mold ("daylight") is also a design consideration.) Filler material selection is determined by chemical compatibility of the filler with the base resin. The directions in which the material will exhibit its greatest strength will be determined from the orientation of the fibers. That is, the directional characteristics of a material are derived from the amount of reinforcement arranged in a given direction. Randomly composed chopped strand mats, for example, are nondirectional. For reinforcements arranged in parallel, the material's greatest strength lies in the direction of the glass.

Glass is the most widely used reinforcement material. It is used in various forms, the least expensive being E glass. S and S-2 glasses are stronger, but more expensive, as is the case with most of the other commonly known reinforcements including graphite fibers. Source reliability, familiarity of manufacturing characteristics and price pointed to glass fibers as most likely candidates for reinforcement of the polypropylene. A relative newcomer is mica as filler coupled via low-cost chloroparaffin to the polypropylene matrix. According to Ford Motor Company, an enthusiastic user, this material hybrid offers large potential savings in direct substitution for glass-filled polypropylene because of the off-the-shelf availability of the components involved.

However, glass fibers are effective strengtheners, while mica is considered effective in reducing warpage and increasing rigidity.

Injection molding introduces the molding compound into the mold cavity in an elevated temperature, fluid state. Hence, molding temperature for fabrication is a critical parameter. This is especially true since the key step in IM process is the loading. The feed system must be designed properly and adjusted very carefully during start-up. If insufficient material is charged due to temperature, unfilled regions may develop in the mold cavities, producing a low density product with poor characteristics. Overfill can cause flashing and possible breakage during ejection.

These process parameters thus influenced material selection to obtain desired properties. The higher temperature requirements of nylons impose constraints on molding cycle times in addition to more critical design tolerances on the actual mold. These are especially important cost factors imposed by the process and material combination due to the part size being considered.

To minimize wear on the molding machine and to save time, doing as much work as possible in the previous, extruder-mixing operations is desirable. Using predispersed pellets puts nearly all of the workload on the extruder, and very little on the molding machine. A second advantage of using predispersed pellets is that molding cycle times are shorter, since only plasticizing, not dispersion as well, is done by the molding machine.

Predispersed pellets also provide higher and more consistent properties in the molded part than dry-blended or nondispersed materials, as shown in Figure 2-3, which depicts the normal distribution curves. The property tested, in this case, is tensile strength.

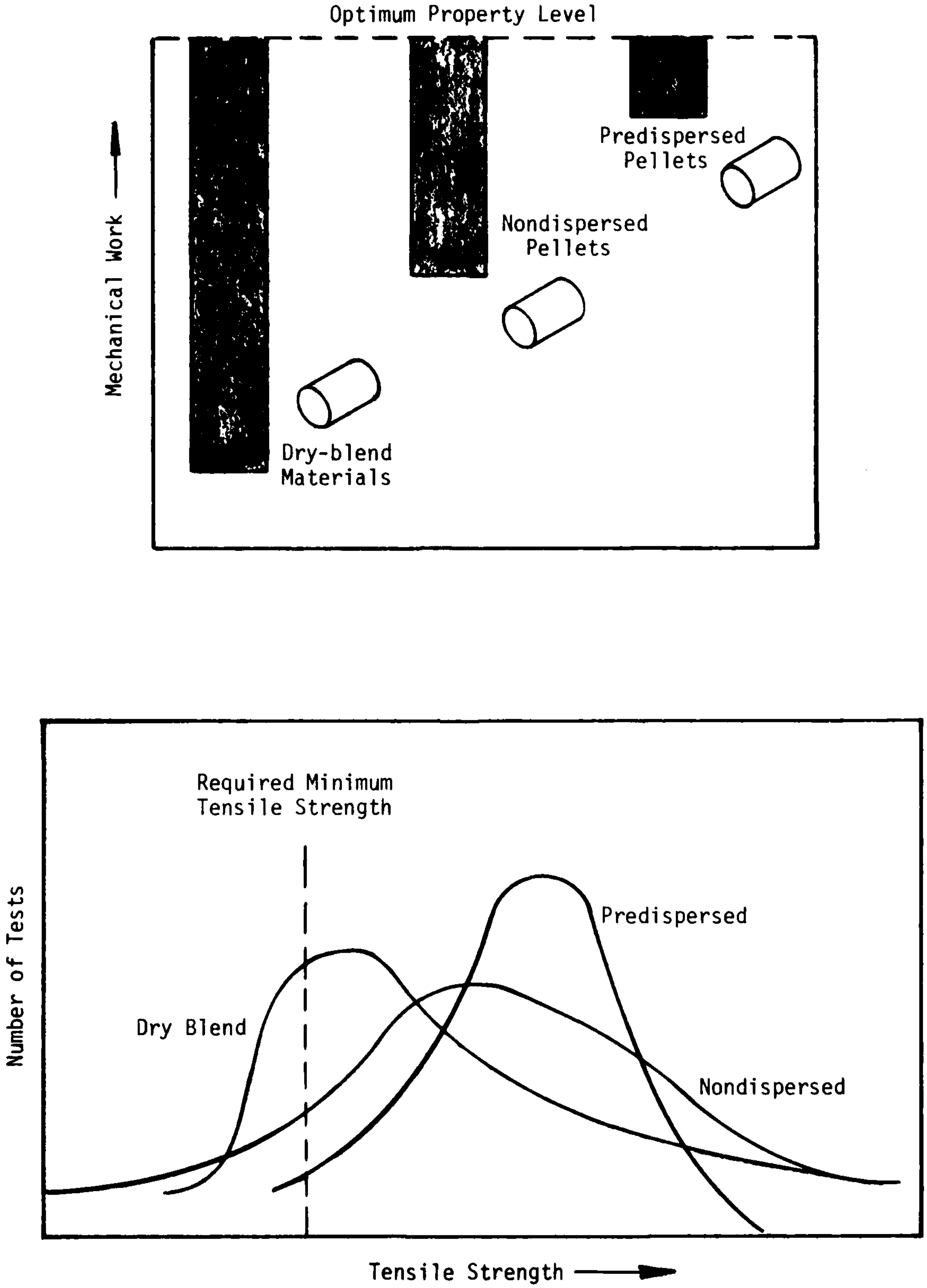


FIGURE 2-3 PREDISPERSED PELLET COMPARISON

2.1.1.3 Performance Considerations

A major consideration of FRP evaluation for the PVK is performance of the manufactured part under service conditions. Fiberglass is desirable as a filler material since it displays chemical and physical properties not unlike bulk glass. (Its mechanical properties are, however, quite different.) Glass fibers do not display creep at room temperature. Fatigue, however, as the term applies to glass, differs from the fatigue that takes place in metals. For metals, the loss in strength is a result of internal adjustments to the applied load (i.e., cold working). Fatigue in glass occurs by loss of strength caused by surface attack from the environment. Fatigue properties of FRP can therefore be seen to be modified by controlling the amount of glass fiber filler used. Specific to this application, a rule of thumb would be to specify filler content at the minimum which would provide the strength requirements of the part.

Probably one of the most important properties of FRP for PVK application is corrosion resistance or weatherability. Relative corrosion resistances for candidate materials are seen in Table 2-4. The advantages of polypropylenes over nylons are evident. In comparison of FRP with steel, it is significant to note that the steel industry alone devotes roughly 40% of its production towards the replacement of corroded materials, a fact which substantiates FRP materials for PVK use from both endurance and economic standpoints.

Material	Chemical Resistance To:				
	Weak Acids	Strong Acids	Weak Alkalis	Strong Alkalis	Organic Solvents
Nylon	G[a]	N[a]	E[a]	F[a]	G
Polycarbonate	E	G	G	F	N
Polyethylene	E	G	E	E	G
Polyproplyene	E	G	E	E	G
Polystyrene	E	G	G	G	N
Thermoplastic Polyester	F	N	N	N	E

[a] E = excellent; F = fair; G = good; N = not recommended.

FIGURE 2-4 CHEMICAL RESISTANCE PROPERTIES OF THE THERMOPLASTIC RESINS

2.1.1.4 Economic Considerations

FRP materials are attractive for numerous applications because of their design flexibility, high performance characteristics, and potential cost- and energy-saving advantages. The previous sections have enumerated those design and performance parameters which indicate that FRP will meet or exceed PVK requirements. This section deals with the cost- and energy-saving considerations of FRP for PVK design applications. Raw materials, cost fabrication and finishing expenses, transportation changes and product durability in storage/service environments are payback categories presented on a comparative basis with structural steel.

The cost per pound for a variety of competitive plastics and metals is given in Table 2-5. The raw material cost of polypropylene (30¢/lb) is low compared to other candidates, and is the same as cold rolled steel. The relative low cost of glass-filled polypropylene as compared to the other leading reinforced thermoplastic molding resins is indicated in Table 2-6.

Figure 2-7 graphically illustrates the energy requirements per unit volumes for metals and plastics. It is noted that the energy per unit volume for polypropylene costs approximately one-half as much as steel, while the nylons cost about 75% of the cost of the same unit of steel. This energy savings is reflected in the price per pound of plastics versus steel as shown in Table 2-5.

TABLE 2-5 RAW MATERIAL COST COMPARISON

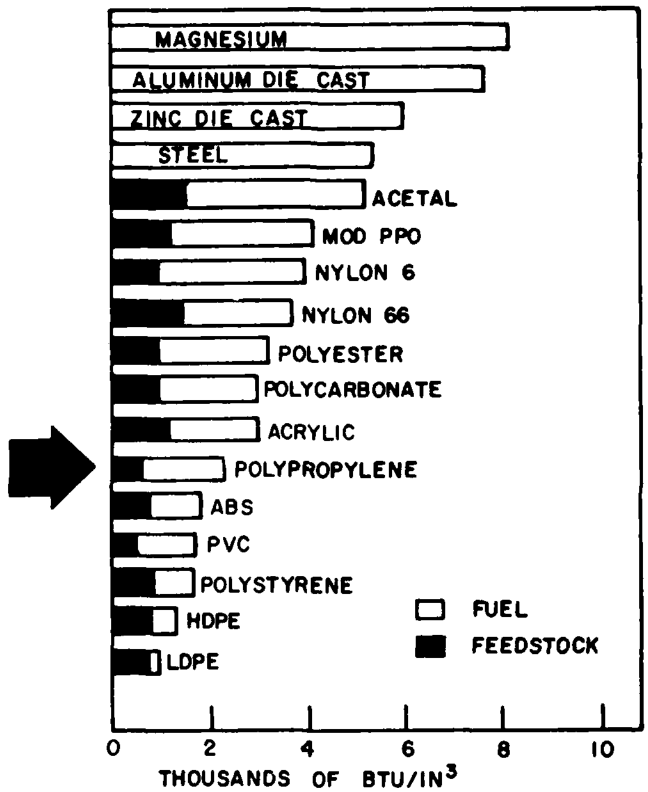
MATERIAL COST

Materials	Specific Gravity	¢/Lb.	¢/Cu. In.
DU PONT ENGINEERING PLASTICS			
Delrin* Acetal Resin	1.42	100	5.13
"Delrin" 500CL Acetal Resin	1.42	215	11.03
Zytel* 66 Nylon Resin	1.14	116	4.78
"Zytel" 612 Nylon Resin	1.07	206	7.97
"Zytel" Impact Modified	1.09	121	4.77
"Zytel" ST Super Tough	1.09	155	6.10
Lucite* T-1000 High Impact	1.15	79	3.28
OTHER DU PONT PLASTICS			
Alathon* Polyethylene Resin			
Low Density	0.914-0.940	31.5	1.04-1.07
High Density & Copolymers	0.941 & up	30.25	1.03-1.04
Du Pont EVA Copolymers	0.93-0.96	35-54.5	1.18-1.89
Surlyn* Ionomer Resin	0.94-0.96	68-76	2.31-2.64
"Lucite" Acrylic Resin	1.19	61	2.62
OTHER PLASTICS			
Polyester (thermoplastic)	1.31	98	4.64
Polystyrene—General Purpose	1.06	29-30	1.11-1.15
Polypropylene	0.905	30	0.98
Polyvinyl Chloride (Rigid)	1.20-1.37	27	1.17-1.34
Styrene Acrylonitrile Copolymer	1.07	45	1.74
ABS	1.04-1.06	48	1.80-1.84
Cellulose Acetate Butyrate	1.19	89	3.83
Modified Polyphenylene Oxide	1.09	113.5	4.47
Polycarbonate	1.20	113	4.90
Polysulfone	1.24	300	13.44
METALS			
Magnesium AZ—91B—ingot	1.81	101	6.60
Aluminum SAE-306			
(380-1% Zinc)—ingot	2.77	60-61.6	6.00-6.16
Aluminum SAE-309 (360)—ingot	2.64	60-60.5	5.72-5.77
Zinc SAE-903 ('Zamac' 3)—ingot	6.6	32.50	7.75
Brass-Yellow (#403)—ingot	8.5	62.25	19.11
Brass-85/5/5/5 (#115)—ingot	8.75	72.50	22.91
Steel-CR Alloy—strip	7.85	30.9-34.57	8.76-9.80
Steel—Hot Rolled Sheet	7.85	15.28	4.33
Steel-Stainless 304—bar	7.92	80.00	22.89
Iron-Pig, basic—pig	7.1	9.55	2.45

TABLE 2-6 COST COMPARISON OF REINFORCED THERMOPLASTIC MOLDING RESINS

Materials	% Reinforcing Agent*	Specific Gravity	¢/Lb.	¢/Cu. In.
DU PONT REINFORCED ENGINEERING PLASTICS				
DELRIN® 570	20	1.56	116	6.54
MINLON® 10B-40	40	1.50	87	4.71
"MINLON" 11C-40	40	1.48	87	4.65
RYNITE® 530	30	1.56	102	5.74
"RYNITE" 545	45	1.69	105	6.41
ZYTEL® 70 G-13L	13	1.22	124	5.47
"ZYTEL" 70 G-33L	33	1.38	124	6.18
"ZYTEL" 70 G-43L	43	1.51	124	6.77
"ZYTEL" 71 G-13L	13	1.18	127	5.41
"ZYTEL" 71 G-33L	33	1.35	127	6.19
"ZYTEL" 77 G-33L	33	1.32	207	9.87
"ZYTEL" 77 G-43L	43	1.46	207	10.91
OTHER REINFORCED PLASTICS				
Polystyrene	20	1.20	60	2.60
	30	1.28	63	2.91
Polypropylene	20	1.04	73	2.74
	30	1.13	76	3.10
Styrene Acrylonitrile	20	1.22	73	3.22
	30	1.31	75	3.55
ABS	20	1.22	77	3.29
	30	1.28	77	3.56
Polyphenylene Oxide (modified)	20	1.21	127.5	5.57
	30	1.27	132.5	6.08
Polycarbonate	20	1.35	172	8.39
	30	1.43	167	8.63
Polysulfone	20	1.38	326	16.25
	30	1.45	304	15.92
Polyester (Thermoplastic)	20	1.45	108	5.66
	30	1.52	105	5.77
Polyphenylene Sulfide	40	1.60	205	11.85
	50	1.70	220	13.51

*All Compositions Are Glass-Reinforced/Filled With The Exception Of "Minlon" (Mineral Filled) And 50% Polyphenylene Sulfide (Mineral Glass Filled)



COMPARISON OF THE ENERGY REQUIREMENTS PER UNIT VOLUME BETWEEN METALS AND PLASTICS

FIGURE 2-7

Fabrication and finishing costs for injection molded plastic parts are specifically more equipment intensive than the labor intensive costs of structural parts fabricated from steel. The major cost factor in FRP part fabrication is design and refinement of the mold itself. As a rule of thumb, the break-point for payback on mold fabrication cost is reached at 200,000 parts. In lesser quantity, however, the advantages of part-to-part uniformity, low post-fabrication finishing (dressing, painting, rust-proofing, etc.) and final product assembly labor and equipment costs remain economically attractive. FRP materials also offer versatility in control of fabrication costs. Comparison of the nylons against the polypropylenes exemplifies this control factor in terms of mold temperature. The higher molding temperature for nylon demands a longer cycle time resulting in increased mold time usage for a fixed number of parts to allow for uniform fill and proper cure.

2.1.1.5 Storage and Durability Considerations

Based on high strength-to-weight ratios, parts,such as the PVK frame, fabricated from FRP (as opposed to steel) offer savings in product handling, both as a raw material and final molded product. The impact resiliency and excellent resistance to corrosion and chemical attack indicated good storage capability.

GARD initiated intensive searches for commercial and/or industrial FRP products that have been subjected to tests for, or subjected to actual long term storage conditions. Because the 15 year storage life requirement for the PVK is unique to the product, no actual case histories were discovered. However, positive data was obtained from several sources.

Discussions with Underwriters Laboratory, who has extensive test data on a polypropylene electronic housing developed for Bell Telephone revealed the following conclusions:

- o Part retains its structural integrity for five years at a continuous 115°C (239°F).
- o Material has excellent resistance to water absorbtion.
- o Long term exposure to direct sunlight will deteriorate the structural integrity.
- o Low temperatures (-40°F) has no detrimental effect on the part.

The negative effect of sunlight (ultraviolet) was discounted since the PVK will be packaged and stored in a warehouse or shelter.

A boat seat support developed for Boston Whalers' 17 foot long fishing boat is another good example of the durability of polypropylene. The part, made of 10% glass reinforced polypropylene, replaced the previous cast aluminum supports. The part is exposed to the elements and is subjected to severe service and loading requirements. These parts have been implemented on Boston Whalers' "Montauk" model for the past seven years and have an excellent durability record. It should be noted that the seat support incorporates carbon black in the resin to negate ultraviolet effects.

Perhaps the most revealing data was obtained from the Polymers Technical Center of Hercules, Incorporated, located in Wilmington, Delaware. In discussions with Mr. C. D. McKinney of that facility, GARD learned of oven aging of Profax No. 6523 polypropylene material.[8] This is significant due to the close physical properties of that compound to Profax No. 6524 polypropylene, which GARD was considering for PVK fabrication. The environmental tests involved placing injection molded specimens (.050 x 0.5 x 5.0 inches) in an aluminum rack and exposing the specimen in a 150°C oven until the specimens fail. Failure is determined to be the initial onset of visible oxidation (discoloration). The failure time for No. 6523 is approximately 100 days at 150°C constant. An extrapolation of oven aging data for Profax No. 6523 to lower temperatures is shown graphically in Figure 2-8. The graph indicates that the structural integrity of the material would not fail until 10 years at 196°F, 40 years at 162°F, and 100 years at 149°F. Although the data presented is theoretical, one ·ould assume a significant error in the extrapolation and still exceed the 15 year storage requirement for the PVK.

2.1.1.6 Conclusions and Recommendations

Based on studies conducted and existing familiarity in industry with manufacturing of consistent plastic parts in large numbers, the choice for candidate materials for the PVK was narrowed down to glass-fiber reinforced polypropylenes. Although priority ratings based on the data in Table 2-2 points to nylon 6/12 as the prime candidate, its cost per pound compares very unfavorably with the polypropylene-based hybrids. Table 2-9 partially lists the data on four materials recommended here for further evaluation:

(1) Glass-fiber reinforced polypropylene (15%, 20%, and 30%), three variations to permit later interpolation to the most suitable combination.

(2) The 6/12 nylon hybrid to evaluate a higher strength level composite.

2.1.2 Determination of CFM Requirements

Before the alternative material PVK designs presented in Section 2.2 could be generated, it was necessary to verify the optimum fan diameter and output based on known shelter CFM requirements. The PVK design could then be sized to the chosen fan. Both a 24 and a 30 inch diameter fan were considered for the study.

EXTRAPOLATION OF DRY HEAT STABILITY DATA ON PRO-FAX 6-23

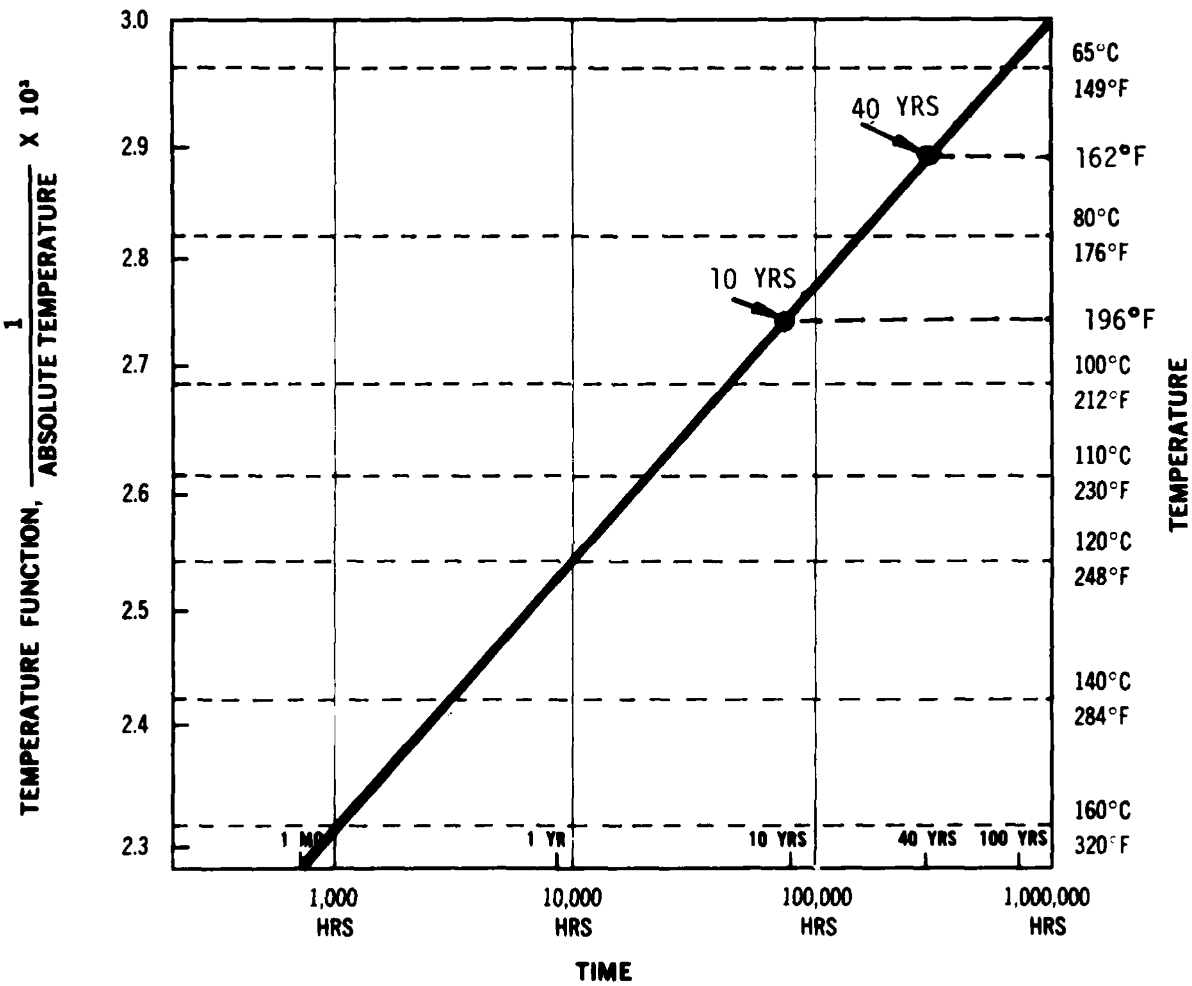


FIGURE 2-8

TABLE 2-9

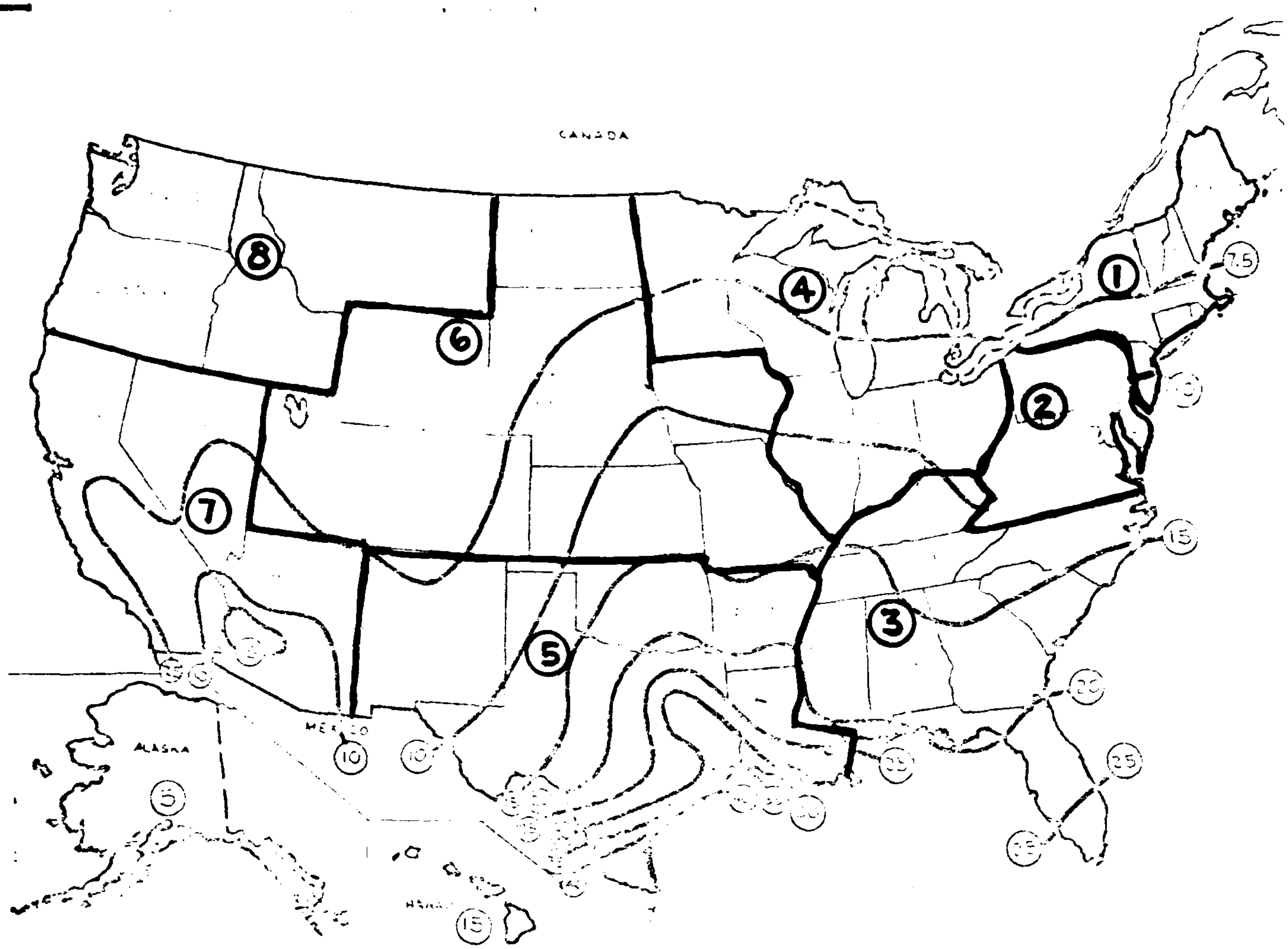
PROPERTIES OF CANDIDATE PVK MATERIALS

Properties	6/12 GFR Nylon	15% GFR polypropylene	20% GFR polypropylene	30% GFR polypropylene
Tensile Strength (ksi)	25-29	7.	11	20
Specific Gravity	1.34-1.45	0.96	1.033	1.115
Elastic Modulus (10^5 psi)	12-18.5	6.5	7.5	9.3
Impact Strength (ft-lb/in)	1.39-3.36	2.3	3.0	4.1
Water Absorption (% in 24 hrs)	0.13-0.2	0.01	0.03	0.04
Raw Material (cost: ¢/lb)	200	30	50	70

The data used in this CFM/Fan analysis was derived from the Regional Summary Table, which lists shelter sizes (number of occupants) for each of the eight national regions as a percent of the total number of shelters for that region. This table was converted to correlate shelter CFM requirements with the number of shelters for each region, and then to calculate the total number of shelters of all regions for each CFM requirement, which would then provide data to determine the CFM which would be adequate for most of the shelters as reported in the survey.

In order to convert the number of occupants to the shelter CFM requirements, the CFM per person requirement must be known. This factor is a geographical variable and for the purpose of the analysis, a constant value for each region was used based on a judgement of the ventilation requirements as shown. (See Figure 2-10.) The values used and the results of calculations are shown in the summary table (Figures 2-11 and 2-12). The CFM data was generated by a computer program written in APL and considered only the shelters with 900 occupants or less, which represents over 90% of all the shelters.

The ventilation requirements per person range from 7.5 to 40 CFM in increments of 2.5 CFM and the shelter sizes range to 900 occupants in increments of 100, thereby allowing a table to be generated showing CFM requirements in increments of 250 CFM for each region vs. the number of shelters. Totals are found by summing all of the region for each CFM increment and comparing this value to the total number of all shelters. The table indicates that 3000 CFM could be adequate for more than 60% of all the shelters. The largest number of shelters (68,880) required 2000 CFM



AMENDED MAP OF FORCED VENTILATION REQUIREMENTS (SCFM/OCCUPANT FOR 82°F ADJUSTED EFFECTIVE TEMPERATURE AND 90 ADEQUACY BASED UPON DAILY AVERAGE DATA (VENTILATION RATES PER STANDARD AIR, DENSITY = 0.075 lb/ft^3)

(PREVIOUS DCPA REGIONS ILLUSTRATED)

FIGURE 2-10 EIGHT CIVIL DEFENSE REGIONS WITH ESTIMATED CFM PER OCCUPANT

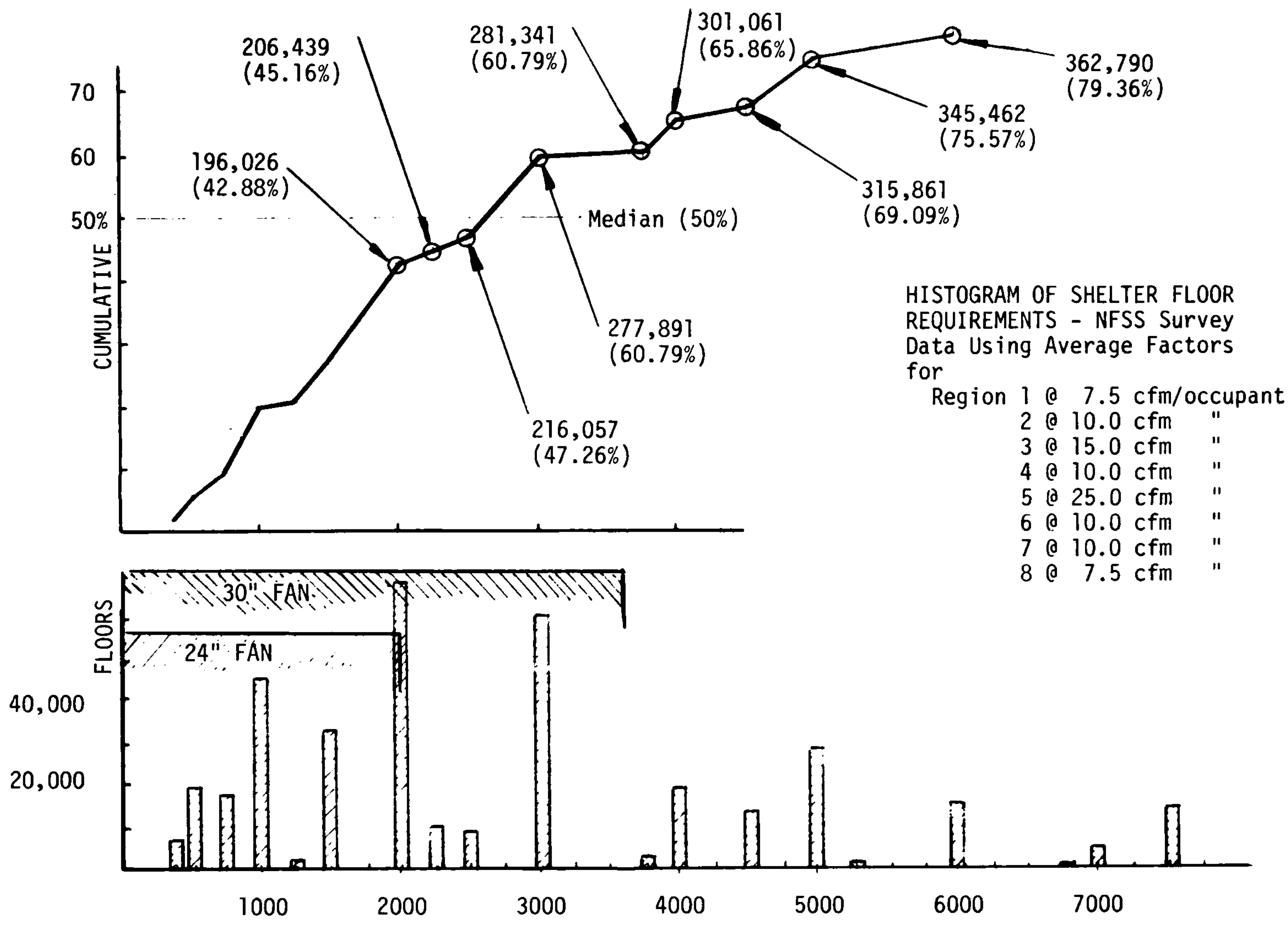
TABLE 1

CFM REQUIREMENTS BY FLOORS

CFM REQM'TS MAX	NO. OF FLOORS CUMULATIVE	% OF TOTAL INCLUSIVE
375	7369	1.62
500	26,563	5.81
750	45,057	9.86
1000	91,335	19.98
1250	94,083	20.58
1500	127,146	27.81
1750	127,146	27.81
2000	196,026	42.88
2250	206,439	45.16
2500	216,057	47.26
2750	216,057	47.26
3000	277,891	60.79
3250	277,891	60.79
3500	277,891	60.79
3750	281,341	61.54
4000	301,061	65.86
4250	301,061	65.86
4500	315,861	69.09
4750	315,861	69.09
5000	345,462	75.57
5250	347,118	75.93
5500	347,118	75.93
5750	347,118	75.93
6000	362,790	79.36
-12,000	415,171	90.81
TOTAL	457,156	100.00

- DATA BASED ON MAXIMUM CAPACITY ACCORDING TO REGIONAL SUMMARY DATA
- REGION 1 AND 8 ASSUMED AT 7.5 CFM PER PERSON
- REGION 2,4,6 AND 7 ASSUMED AT 10 CFM PER PERSON
- REGION 3 ASSUMED AT 15 CFM PER PERSON
- REGION 5 ASSUMED AT 25 CFM PER PERSON

FIGURE 2-11



SHELTER FLOOR CFM REQUIREMENTS

FIGURE 2-12

and would be represented by a shelter of 200 occupants or less requiring an average ventilation rate of 10 CFM per person.

The output for both a 24.0 and 30.0 inch diameter fan are superimposed on the graph shown in Figure 2-12 to illustrate the shelter floors that could be ventilated by these units. It is apparent that all subject shelter floors could be ventilated by usage of multiple and/or combination PVK's. The 30 inch fan alone will ventilate approximately 60% of the shelter spaces. The analysis reverified the 30 inch diameter fan being adequate for implementation on the PVK design concepts.

2.2 Alternate Material PVK Design

The objective of the PVK design effort was to reduce the unit PVK cost without sacrificing performance and reliability. The PVK support frame, in particular, was the recipient of close scrutiny, since it represents a substantial portion of total cost on previous models developed. As a result of the value analysis study presented in Section 2.1, 15% glass-filled polypropylene was a leading candidate for cost/strength considerations. All of the design concepts presented in this section were sized for that material's structural capacities. It was assumed that any matching test frame of reinforced nylon would be proportionately stronger for evaluation/comparison purposes.

The various frame designs are presented below, followed by the candidate materials and designs for other PVK components evaluated.

2.2.1 PVK Frame - "A" Frame Design

The first frame design generated by GARD closely followed the outline configuration of the welded steel frame utilized in the PVK updated under DCPA Contract No. DCPA01-78-C-0184. This concept is shown in Figures 2-13 and 2-14. The design features "I" beam construction with molded-in bosses for the crank, fan bearing and saddle support. Included were two FRP support feet which would be riveted to the frame before packaging.

The initial stress analysis revealed the cross-section shown in Section G-G was inadequate for a 200-lb operator. The inadequacy was verified by a frame mockup developed by Envirotech Plastic Division. The design configuration, while adequate in steel tubing, presented load distribution problems in FRP. The mockup also revealed the rear sloping support member would carry a load of approximately 166 lbs, resulting in an applied tension load of 135 lbs on the longitudinal brace located below. This spread or "creep" could increase the roller chain tension to a point where the operator input horsepower would be increased. In addition, long term load fluctuations (such as induced by operator pedaling) could result in cracks or failures at either junction of the longitudinal brace. The high level of the operator's seat (38" off the floor) was considered somewhat marginal for good vertical stability of the frame under operating loads. As such, the frame required redesigning and the "I" beam construction needed to be increased to 3.5" x 3.0" x .50".

The production cost estimates were $28 per frame and $12 per (2) support feet, resulting in a total cost of the "A" frame design of $40 per unit. The production tooling costs were estimated at $100,800.

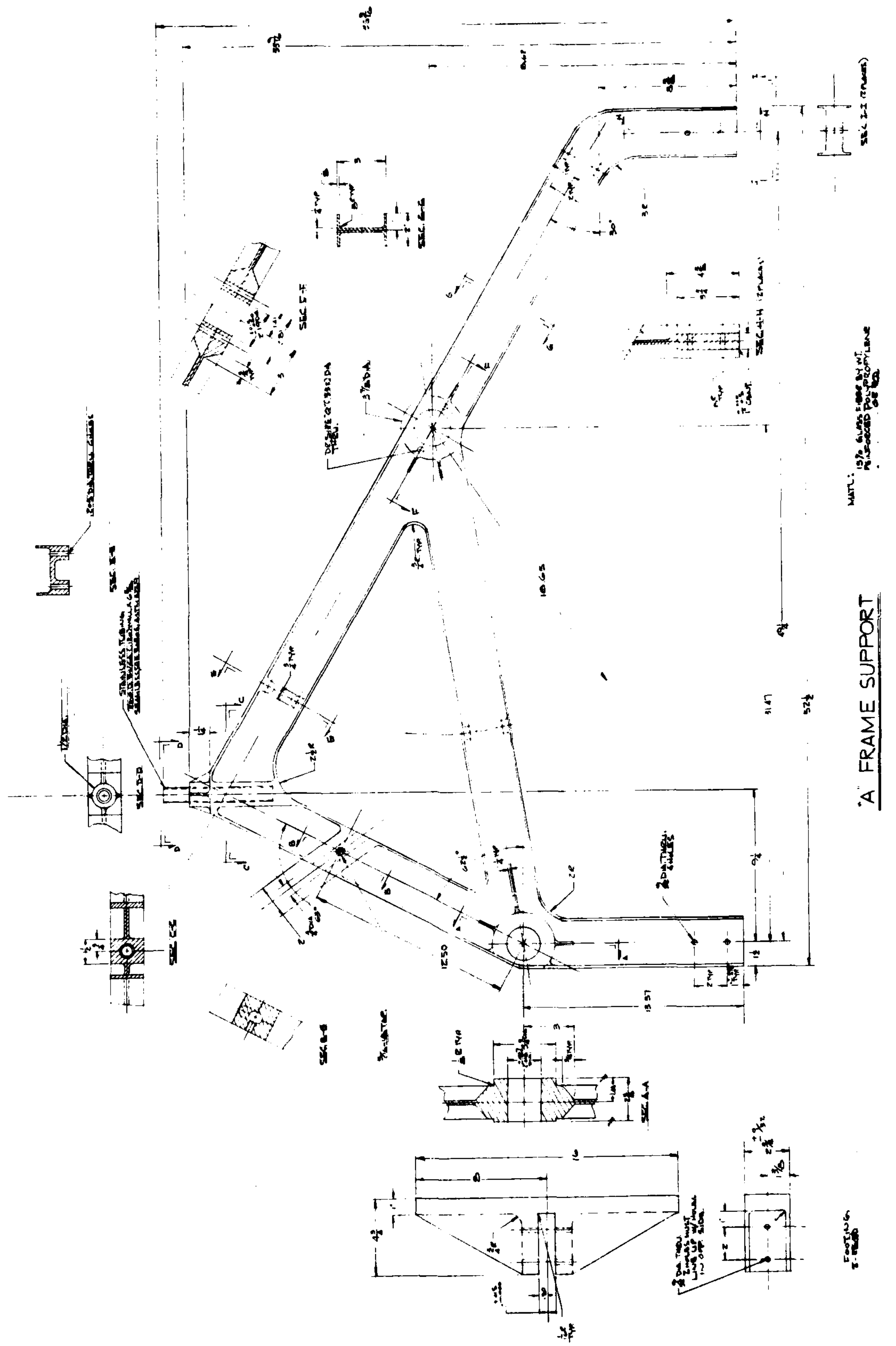
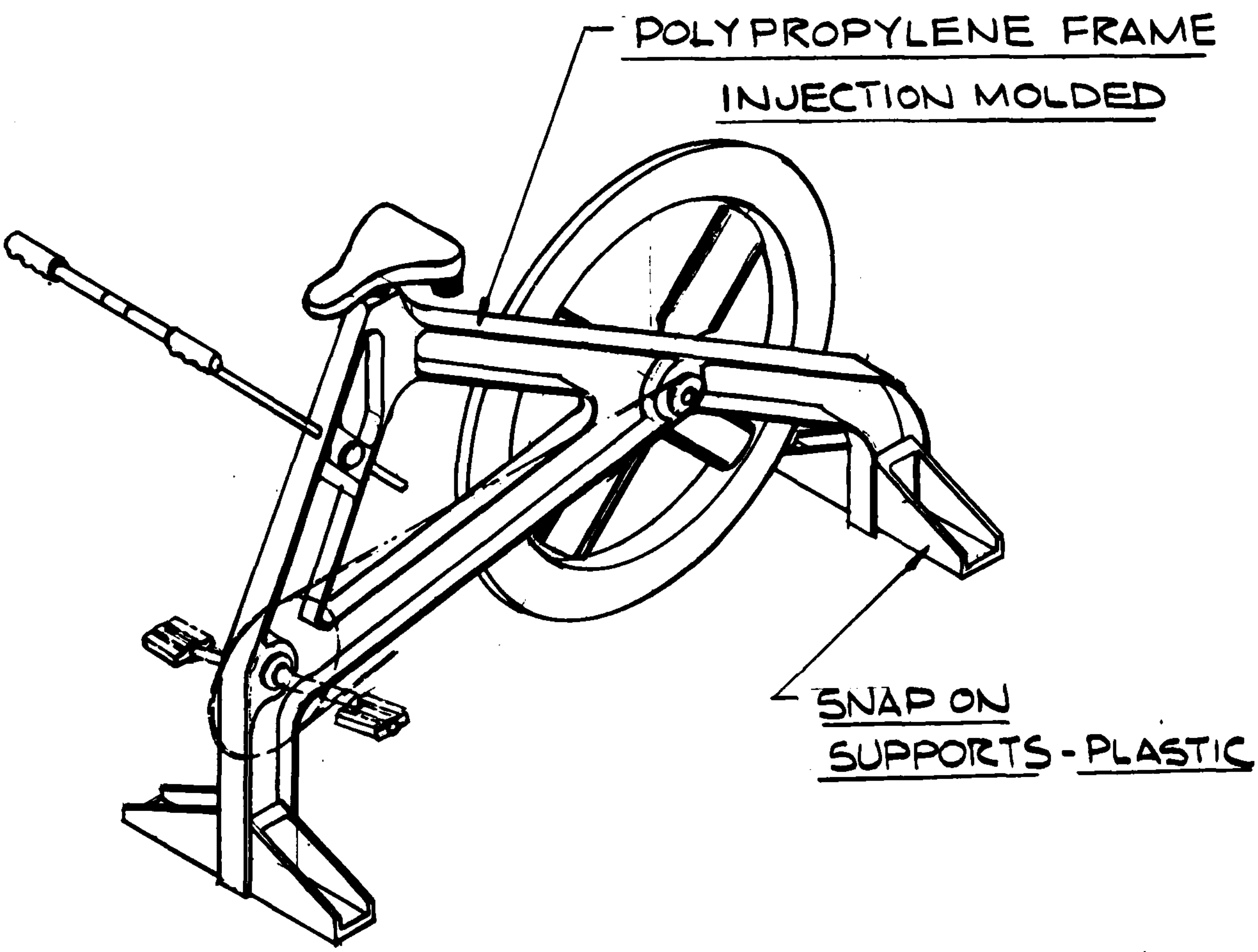


FIGURE 2-13



"A" FRAME CONCEPT

FIGURE 2-14

2.2.2 PVK Frame - Low Profile

Utilizing the data generated in the evaluation of the "A" frame concept, GARD endeavored to develop a concept that had a low center of gravity and utilized less material. One concept is shown in Figure 2-15. The unit featured a support frame of FRP. The frame provides the interface for the seat support, crank, fan bearings and support legs. The front and rear support tubular legs are permanently molded into the frame cavity. The legs can be pivoted up under the frame during storage and shipment of the unit. When the unit is deployed, the operator swings the legs down until they snap into the receptacle molded into each end of the frame.

The seat support and handle bar support are of tubular steel. Evident in Figure 2-15 is that some method of additional support would be required for the cantilevered shroud.

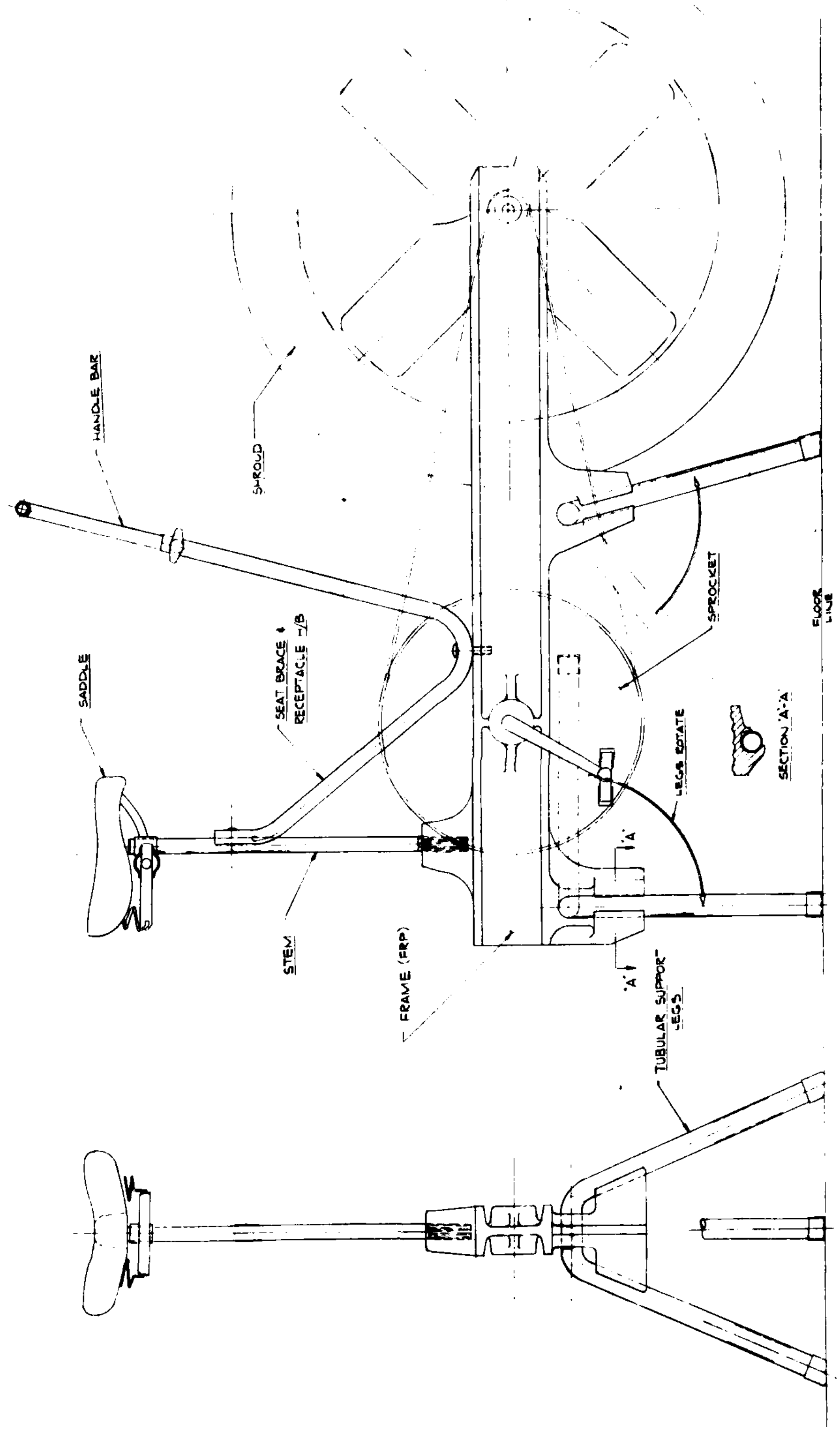
The reliability of the support leg attachment cavities was somewhat questionable in light of leg flexure problems coupled with possible fracturing of FRP material in load-bearing surfaces. In addition, the legs in the stored position still require the same width package as they would in the deployment position.

Some deflection of the horizontal beam was anticipated at the seat and crank junctures.

The production cost estimates for the low profile frame were $19 per frame and $80,000 for production tooling.

2.2.3 PVK Frame - Pedestal Design

The pedestal design is shown in Figure 2-16 and conceptually in Figure 2-17. This configuration offers certain advantages over the previous designs considered, and was presented as the primary candidate for future frame



FRAME, LOW PROFILE

FIGURE 2-15

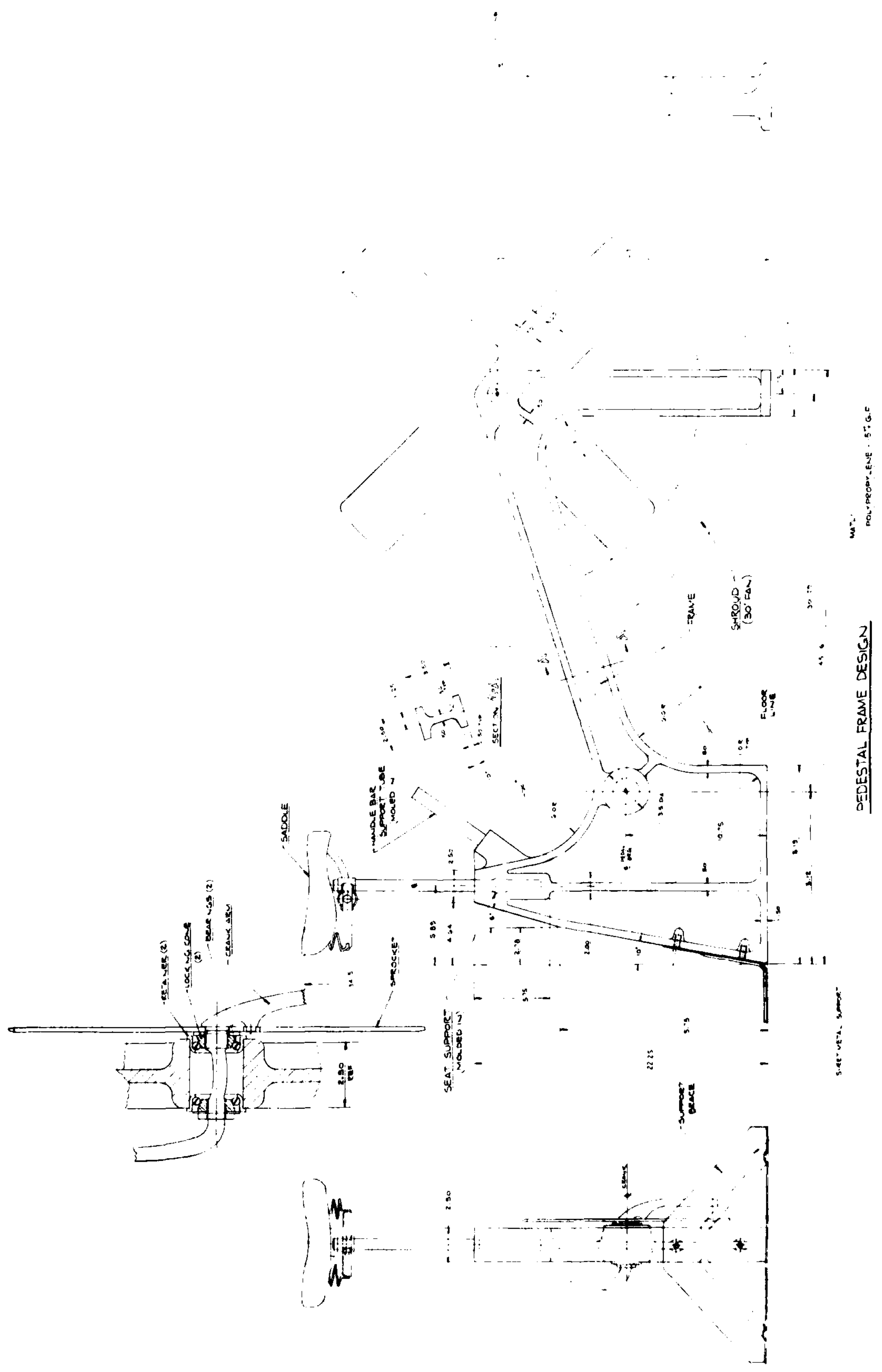
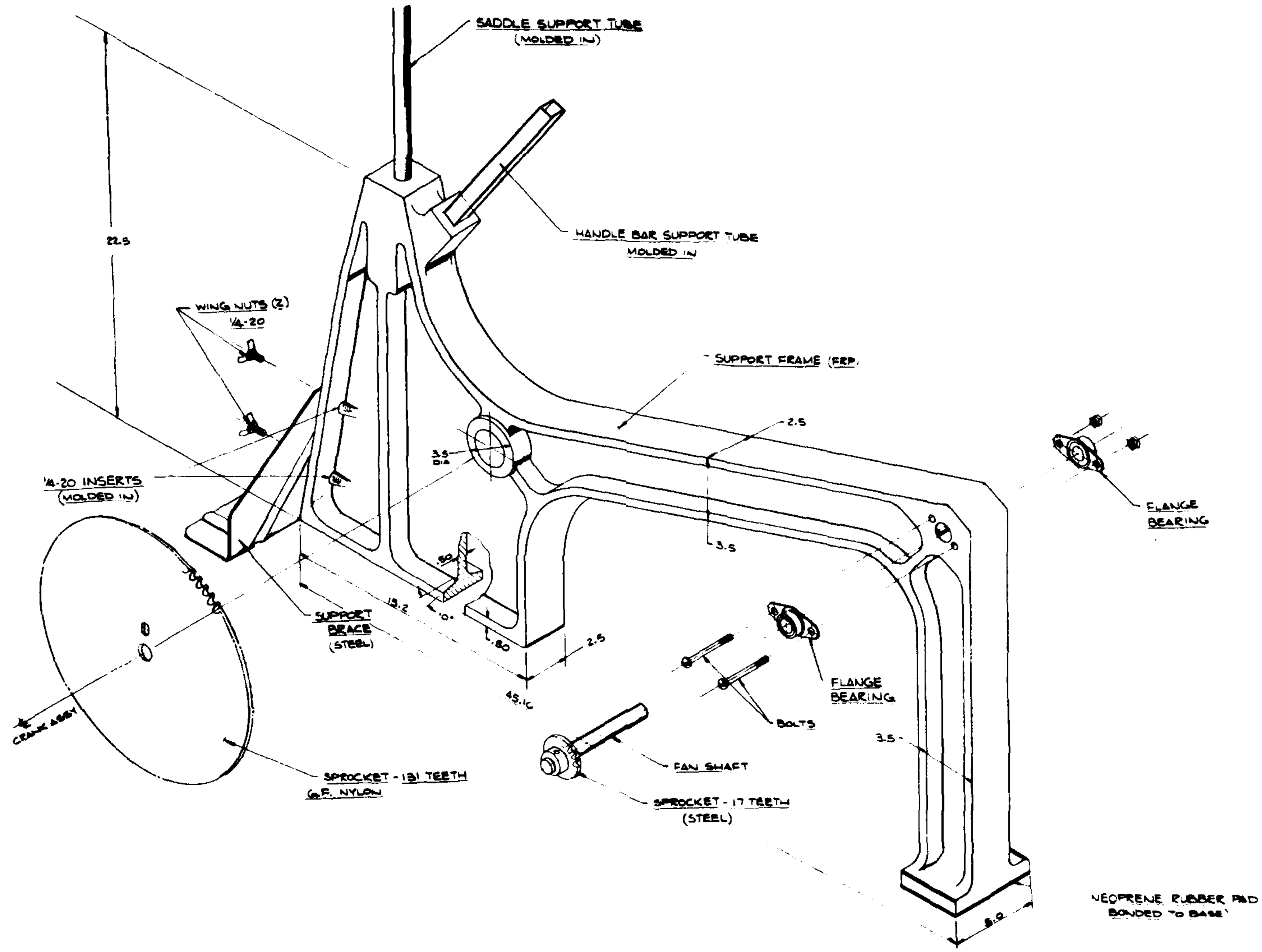

PEDESTAL FRAME DESIGN
SADDLE
SPROCKET
CRANK ARM
SEAT SUPPORT (MOLDED IN)
SHROUD (30" FAN)
FRAME
FLOOR LINE

FIGURE 2-16



PEDESTAL FRAME CONCEPT

FIGURE 2-17

validation and prototype fabrication. First, the design allows the frame to incorporate a 24, 26, or 30 inch diameter fan with the appropriate shroud and no changes to the mold. The universal frame would eliminate fabrication of various sizes and maintaining an inventory control. Structurally, the frame distrubutes all primary operator loads in compression rather than bending as in the case of the other concepts considered. The weight of the operator is transferred from the tubular seat support (molded permanently into the pedestal) vertically through the FRP pedestal into the floor. Crank loads generated during pedaling and mounting are again transferred to the floor through the pedestal. The wide flange (2.50") beam construction was found to be sufficient to restrict sideway deflection of the frame by chain-induced loads at the fan shaft.

The low center of gravity presents a stable unit laterally. Further stability is provided by a stamped steel flange support (16 ga) which would be attached by the operator with two threaded wing nuts at the time of deployment. The female threaded inserts for receiving the wing nuts are permanently molded into the frame during injection molding of the part. Steel was selected for the flange support on the basis of the strengths required.

The seat support tube and square handle support tube are also automatically encased in the pedestal frame during the mold of the part. The front leg of the unit is flared out to a five-inch width at the floor to provide increased bearing area. GARD anticipated using a 1/16 inch thick high friction rubber pad bonded to the base to prevent "walking" of the forward end during sustained operation.

If the handlebar and (2) pedals were provided as separate items to be installed by the operator, the package for the entire unit could be restricted to a width of 10.5 inches.

The support frame can be produced in minimum quantities of 160 frames per 8-hour shift or 50,000 per year. The cost of the frame is estimated at $23.00 each, with production tooling at approximately $98,000 (4-cavity mold).

GARD chose to fabricate an aluminum single-cavity-tool to injection mold the frame prototypes. The tooling cost was $9,500 and the tooling has an estimated life of 3,000 parts without refurbishing. The aluminum mold, if required, could have been readily modified (reworked) to add stiffeners and/or gussets wherever deemed necessary by subsequent testing. The delivery of the first sample was estimated to be 10 to 12 weeks after receipt of order. The frame color was optional from either dark brown, black, orange, red, or blue. White is available, but not recommended because the color density is not consistent throughout the part. Black offers the best resistance to ultraviolet light (sunlight). GARD chose blue.

The primary unfilled material considered for part fabrication was polypropylene, compound No. 6524 supplied by Hercules, Inc., Wilmington, Delaware. It was determined that the tooling and part fabrication would be performed by the Molded Products Division of Envirotech, Inc. located in Salt Lake City, Utah.

2.2.4 Shroud, Fan

Second to the support frame, one of the more costly components of the PVK is the fan shroud. The shroud and its bellmouth shape provides the interface for mounting the exhaust duct. The previous shroud was a spinning fabricated from 20 GA (.035) 1018 steel. The present unit cost of $28.50 each warranted the search for an alternate material.

GARD contacted a fabricator of fan shrouds for automotive and farm vehicles called Hadlock Plastics, located in Geneva, OH. Since the company manufactures custom production shrouds of reinforced fiberglass, GARD submitted prints of the shroud for a 30-inch diameter fan for quotation. The response indicated a unit cost of $9.79 each with a tooling requirement of approximately $27,500. The material was specified as 0.125 inch thick reinforced fiberglass. The fiberglass offered sufficient strength-to-weight ratio and good anti-corrosive properties. The approximate savings was $18.00 per unit over the steel shroud.

Further investigation revealed that the shroud, when produced in large quantities, could be sufficiently strong and substantially lower in cost than the fiberglass units described above if made by injection molding the part of high impact ABS plastic. The shroud cost for ABS plastic was quoted at $2.01 each. A single cavity mold capable of producing quantities in excess of 100,000 units cost approximately $31,000 with a delivery of 20 weeks ARO. The increased tooling costs amortized over a target production run of 100,000 shrouds was not considered significant.

The strength and impact resistance of the ABS material was considered excellent. In addition, the material was impervious to corrosion and chemical attack during long term storage. The ABS shroud material offered as much as its predecessors. The ABS material shroud was also lighter in weight than the steel and fiberglass models.

The ABS plastic shroud, shown in Figure 2-18, was picked as the most cost effective candidate for the alternate material PVK prototypes. These shrouds would be tested in the design validation phase of the program to assure compliance to FEMA requirements. Since the tooling costs for the shroud were prohibitive for the current program, it was decided to vacuum form the prototype shrouds to obtain representative models to those which would be injection molded during full-scale production.

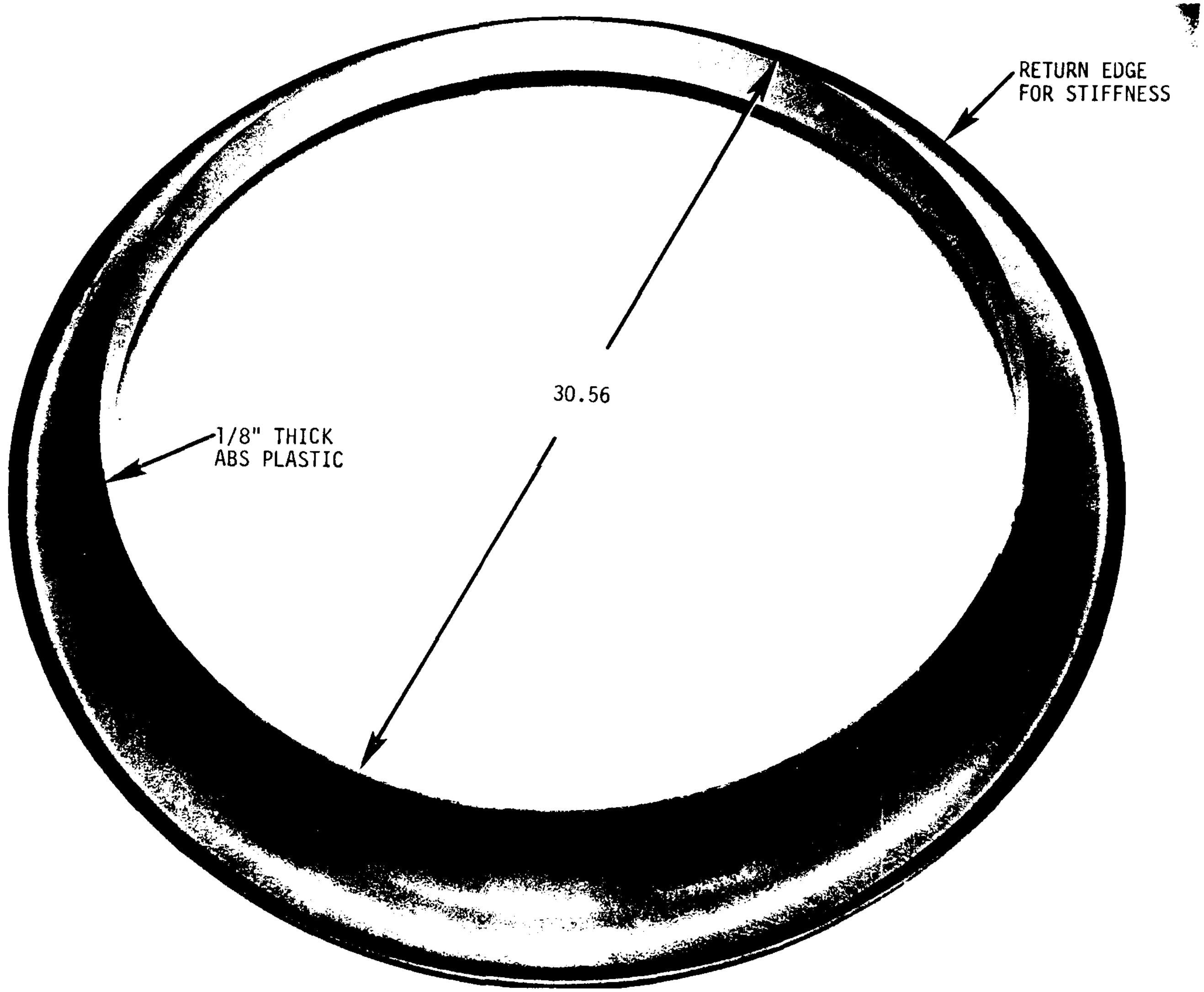


FIGURE 2-18 SHROUD, FAN (ABS PLASTIC)

2.2.5 Crank Assembly

The crank assembly includes crank arm, bearing cups, bearings, cone locking nuts and jam nuts. The previous crank assembly utilized on the previous PVK was quoted by the Schwinn Mfg. Company at $10.70 per unit in quantities of 10,000. GARD initiated a dual effort to reduce the cost of this assembly. Custom designs utilizing sleeve bearings and various crank configurations were investigated. Concurrently, an intensive search of existing manufacturers of similar equipment nationwide was initiated. The Thomas Register and independent information services were utilized. As a result of the search, the Wald Manufacturing Company of Maysville, KY was contacted. Wald manufactures and supplies bicycle accessories to distributors throughout the country. Their quote for the crank assembly was $5.75 in quantities of 100,000 units. The crank assembly is shown in Figure 2-19. The principal reasons for the low cost of this unit is as follows:

- Non-union shop.
- Matte finish rather than chrome.
- Lower class bearing.
- Cone races.

No design generated by GARD could compete with the Wald crank in cost or reliability. GARD concluded that the Wald crank is a viable alternative to the Schwinn model and implemented the unit on the alternate PVK prototype.

2.2.6 Implemented Bearing, Fan

The fan bearings were reviewed to determine the lowest cost alternates to the bearings selected for the previous PVK. Sleeve bearings could be utilized if a metal tube housing was molded into the frame as a receptacle

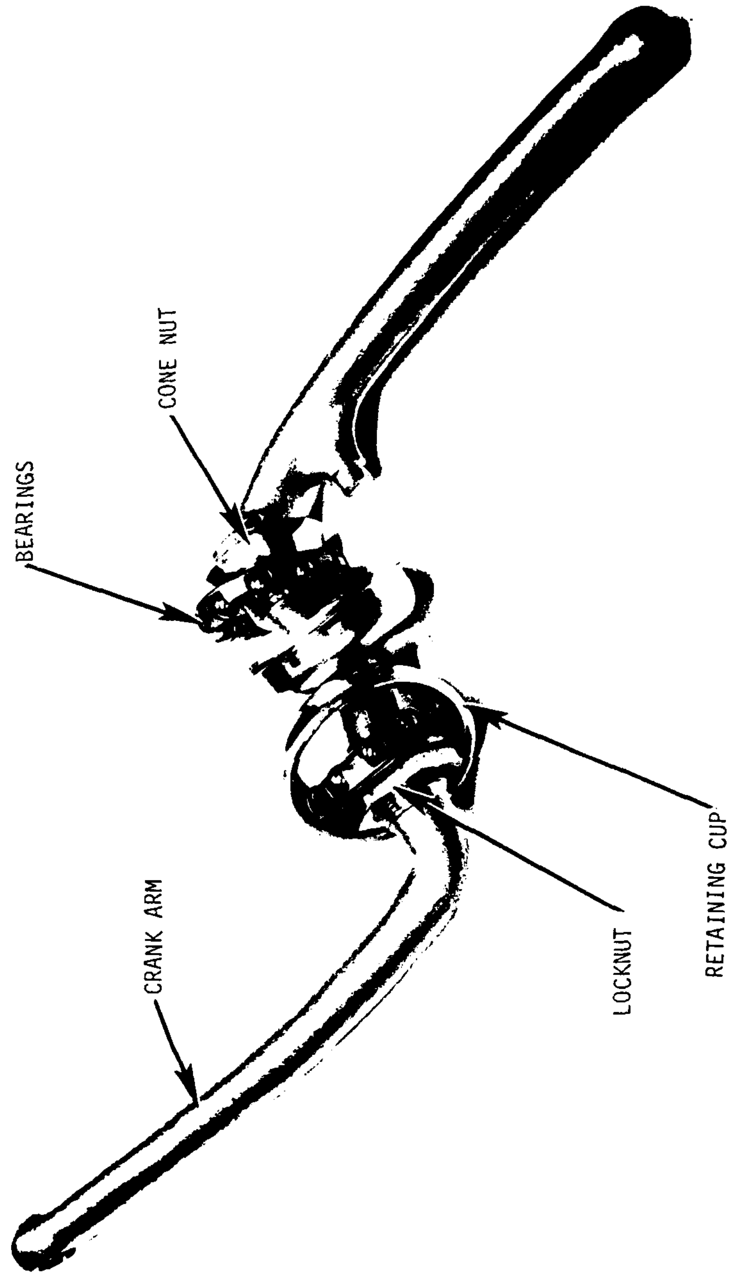


FIGURE 2-19 CRANK ASSEMBLY (LOW COST)

for the bearing. The metal housing would be necessary for more efficient dissipation of the heat generated by the rotating shaft loads. A sleeve bearing pressed directly into the plastic frame could deteriorate the outside bond of the housing/bearing through heat and possibly result in the entire bearing rotating with the shaft.

GARD uncovered a viable cost effective substitute for the sleeve bearing. The flange type bearing, manufactured by the Triangle Manufacturing Company in Oshkosh, Wisconsin, and shown in Figure 2-20, features a sheet metal stamped housing (galvanized) which provides the receptacle for a self-aligning sintered iron bearing. The sintered bearing is impregnated with 30 weight non-detergent oil suitable for the normal service life of the unit. The cost of the bearing in quantities of over 5000 each is a surprisingly low 17¢ each. A like model is also available with nylon bearings at the same price. GARD preferred the sintered iron bearing, but chose to incorporate both types on the PVK prototypes.

2.2.7 Drive Sprocket - 131 Teeth

The steel drive sprocket utilized on the previous PVK's represented a cost of $11.71 each in quantities of 10,000 units. A high strength nylon was considered a suitable alternate material as a result of the value analysis study for the drive sprocket. Specifically, a 40% glass-filled 6/10 nylon was determined to be most suitable, while the strength characteristics of the material only approach those of mild steel, quotes for the manufacture of the nylon sprocket indicated a unit cost of $7.00 each with a tooling cost of approximately $20,000. Due to the cost of tooling, GARD simulated the molded part by machining the sprockets of the proper material for testing and use on the 15 PVK prototypes. The nylon sprocket is shown in Figure 2-21.

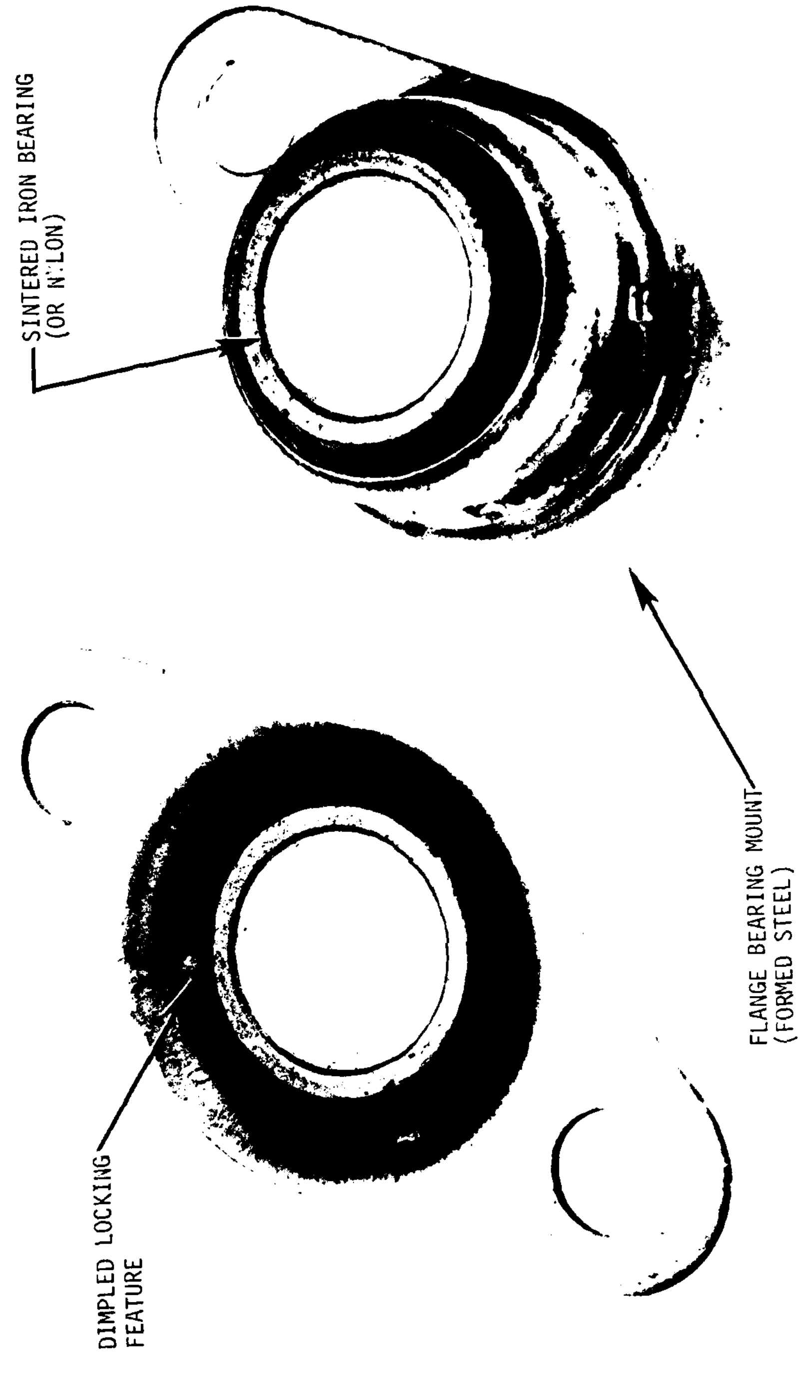


FIGURE 2-20 BEARING, FAN

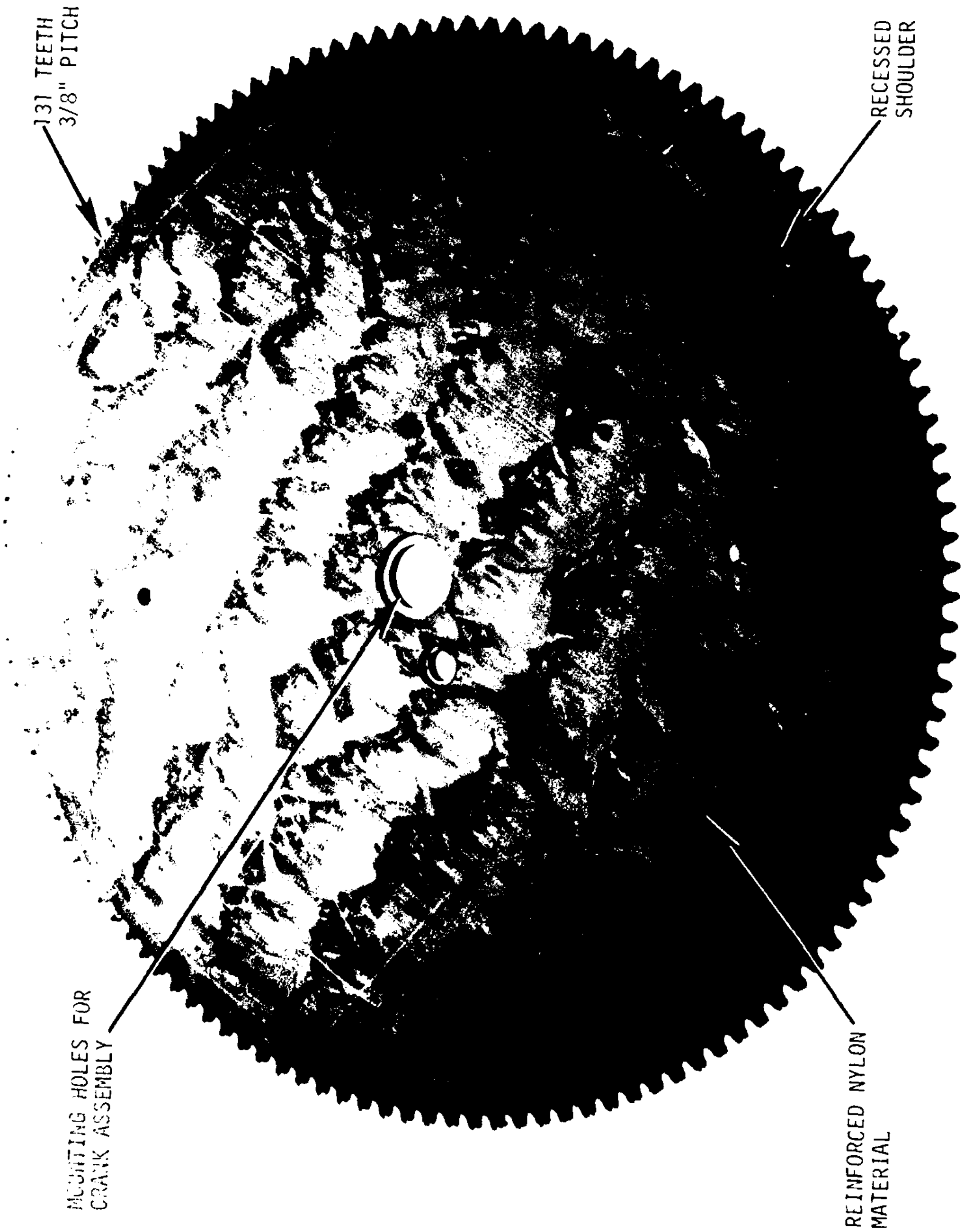


FIGURE 2-21 DRIVE SPROCKET, NYLON

A life test conducted for this part is described later in this report.

Subsequent to PVK validation, GARD received a quote on a revised design of the sprocket from Allied Products in Rockford, Illinois. The part was made of Nylatron G.S., and was quoted at $3.58 each with a tooling cost of $14,750. This design saves material costs by coring three holes 120° apart within the part body. Unfortunately, this design was received too late to be incorporated. Further analysis and testing of the new design would be required before it could be considered a viable replacement.

2.2.8 Sprocket, Fan

The fan sprocket used on previous PVK's was a steel 17-tooth #35 hub type. An identical sprocket is available from stock in glass-filled nylon. Due to the higher loading imparted by the drive chain on 3 to 4 teeth engagement, it is questionable as to whether the sprocket would survive the one-month service life. The revolutions of the fan sprocket are almost 8 times the cycle of the drive crank. If the PVK was operating for 70% of the one-month duration, the fan sprocket would see 14,150,000 revolutions. GARD chose to retain the steel sprocket pending a more viable alternate.

2.2.9 Fan, Plastic

In order to reduce the unit cost and weight of the steel 30" diameter fan used on previous PVK's, GARD reviewed the potential of injection molding the entire fan from plastic. The present fan is comprised of four contoured (20° pitch) steel blades, 30" tip diameter, riveted to a steel spider hub. The design of the fan meets the PVK requirements for an exceptionally efficient fan at low speeds (3200 CFM at 480 RPM) with moderate axial depth. This efficiency permits input horsepower as low as .10 HP which is consistent for the manually-powered device.

The manufacturer of the fan, Torin Corporation, expressed no interest in participating in a joint effort to change design or materials. A canvas of existing manufacturers of commercial portable air circulators indicates the plastic fan (entirely molded) technology stops at a maximum of 20 inch diameter. To design, fabricate tooling, and test a one-piece molded fan of 30 inch diameter represents a research program within itself.

Since the cost of the fan was a significant element of the total, GARD was motivated to pursue an alternate method of generating a plastic fan prototype. Investigations of plastic blades fastened to a steel or composite material hub were initiated. The intent of the study was to determine the feasibility of the construction by fabricating one prototype model for evaluation. The prototype fan is shown in Figure 2-22. The fan blades incorporate the identical blade design and configuration as the steel fan. The blades are mechanically fastened to an aluminum hub which also includes the shaft bore.

The preferred method of constructing the blades would involve tooling and injection molding. The cost associated with this process was prohibitive for this program. GARD determined a more economical method of generating the blade contours. The steel blades of the Torin fan were removed from the hub for use as temporary tooling. Sheets of .125 thick ABS plastic were cut to the exact outside configuration of the steel blades. These patterns were inserted into an oven preheated to 200°F for a duration of 20 minutes. The patterns (now pliable) were removed and instantly placed and aligned on the top side of a steel blade. A second steel blade was placed on the upper side of the plastic pattern, sandwiching the plastic between the two steel blades. Clamps were applied and the blade was allowed to set up for a period of one hour. When the clamps were removed, the process resulted in a plastic

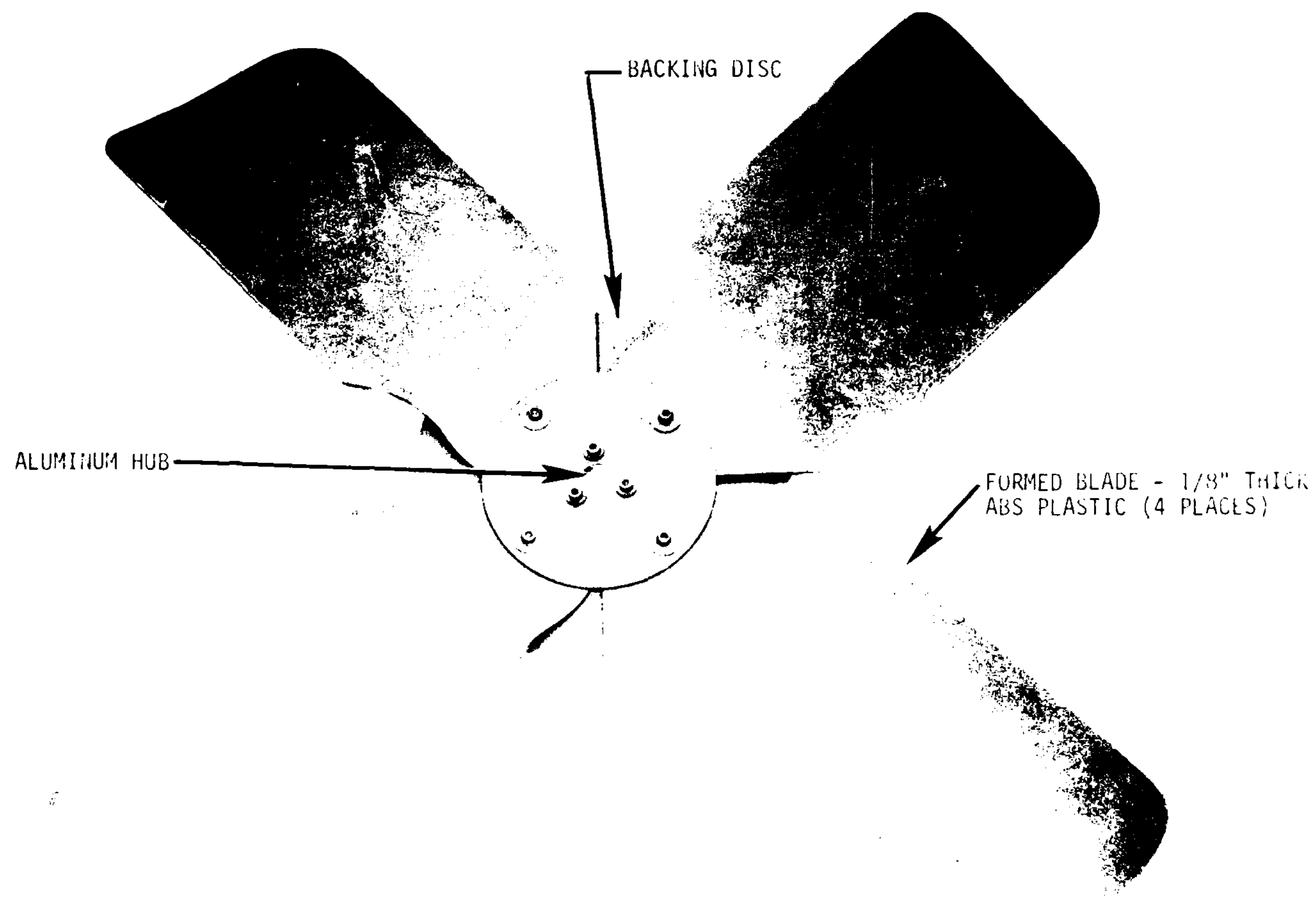


FIGURE 2-22 FAN, PROTOTYPE, ABS PLASTIC

blade which exactly represented the pitch and contour of the steel blade. Four blades were generated by the above method and attached to the aluminum hub.

The plastic fan assembly weighed 3.75 ibs versus the 10.3 lb weight of the steel fan. The unit was installed on a PVK and operated at the recommended RPM. While no measurements were made, it was observed that the starting inertia was low and the general PVK operation seemed easier with the plastic fan. Some fluttering of the fan was detectable at 500 RPM and higher.

The easier operation, which could imply a desirable lower horsepower input, would have occurred by any of the following:

1) The reduced weight of the fan would impart less frictional forces on the bearings.
2) The reduced input horsepower would generate less fluid power (air flow) for fans of the same efficiency (geometry).
3) The lower inertial effects of the plastic fan would permit readily changing speeds. The variable operator power input would be sensitive to these changes, thereby making the plastic fan seem easier to pedal.

It is GARD's conclusion that a plastic fan is feasible for potential use on the PVK; however, additional research and testing must be conducted to validate the unit.

2.2.10 Handle Bar, Plastic

The handle bar assembly utilized on previous PVK's consists of a .75 inch square steel tube welded perpendicular to a .75 inch diameter tube. Vinyl grips are incorporated at each end of round tube for the operator's hands. The total cost for the asembly, including grips, is estimated to be $3.92 each.

GARD determined whether a viable material substitute for the handle bar was available. Plastic material candidates such as reinforced polypropylene, nylon, ABS and polycarbonate were investigated. Of these, blown ABS (cycolac JP) was chosen as the most cost-effective material. The part in large quantities would be injection molded.

Since again molding costs prohibited fabricating a production part, a demonstration model, simulating the finished part, was hand-constructed. This model is shown in Figure 2-23. The model was determined not representative because it was constructed using general purpose ABS and structural adhesive. The production part would be one-piece with the grips molded in.

The quotations obtained for a production quantity of the handle bar indicate a unit cost of $1.45 each and tooling costs of $19,850. GARD believes the plastic handle bar is promising for incorporation into production PVK's, but retained the steel design for subsequent validation.

2.3 Design Review - PVK Concepts

A design review meeting was held at DCPA Research between GARD and DCPA Technical Representatives. The purpose of the meeting was to evaluate the PVK concepts discussed in Section 2.2 of this report and determine the optimum PVK configuration for fabrication and testing.

The pedestal PVK design presented in Section 2.2.3 was approved as the most cost-effective design. Upon approval, purchase orders for fabrication of the pedestal support frame tooling were released.

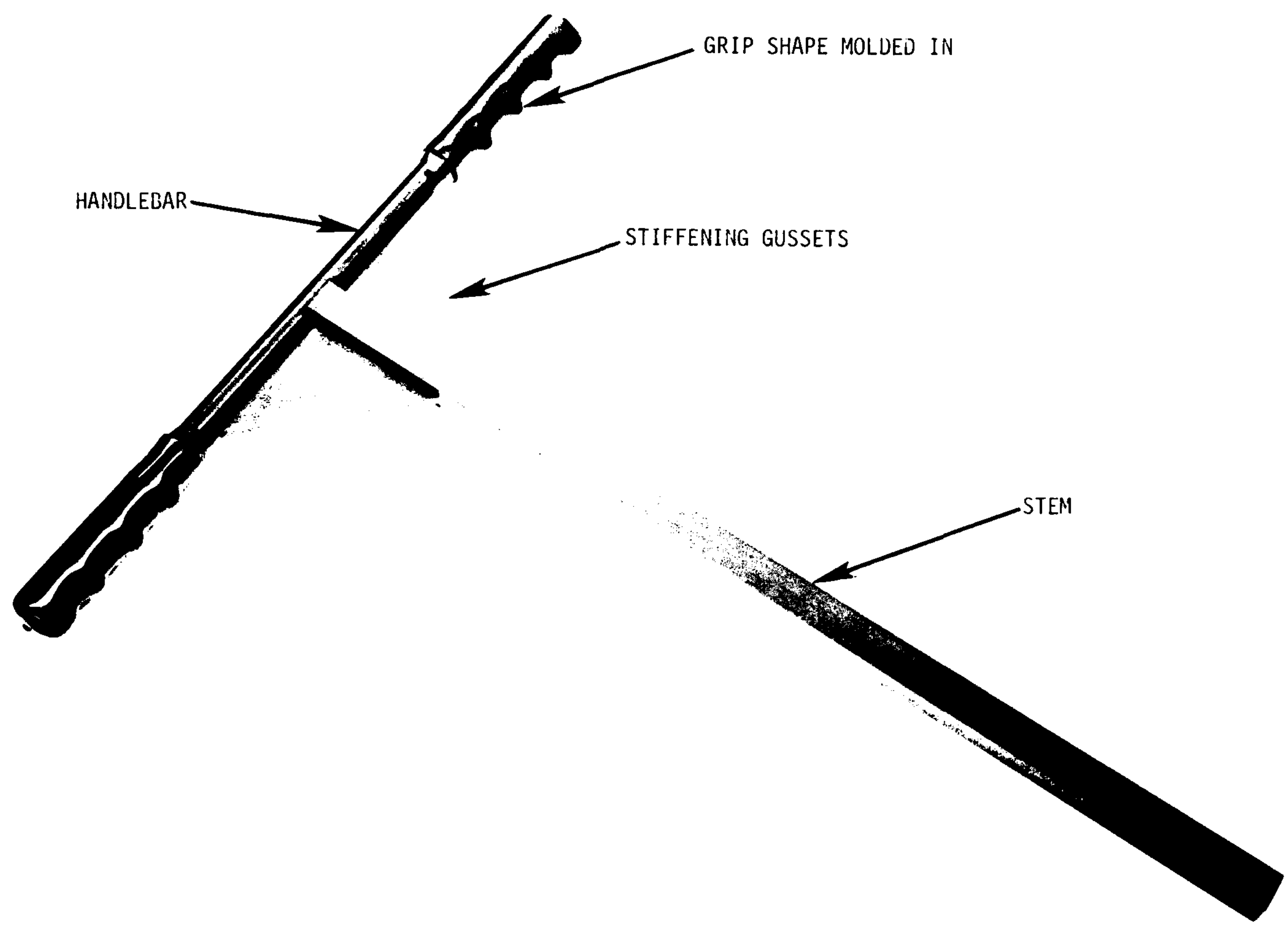


FIGURE 2-23 HANDLEBAR MODEL, PLASTIC

2.4 Design Documentation

Based on the PVK design concept approved at the design review, GARD initiated the formulation of documentation required for the unit. Included in the documentation package were design drawings, preliminary specifications, and draft operating instructions.

2.4.1 Design Drawings

GARD generated design drawings sufficient to permit construction of the alternate material PVK. The completed drawing package includes the following components.

- Design layout (Figure 2-24) - Drawn to a scale to establish PVK configuration.
- Final assembly (Figure 2-25) - Drawn to show assembled relationship of parts and purchased items.
- Frame - Detail drawing prepared sufficient to permit release for mold fabrication.
- Detail drawings prepared of the remaining PVK fabricated components.

2.4.2 Specifications

Preliminary draft procurement specifications were generated for the alternate material PVK. The specifications reflect the revised Military and Federal standards applicable to this program. The specification paragraphs relating to packaging and preservation procedures has been intentionally voided, since the parameters are yet to be determined. The specifications are included in Appendix A of this report.

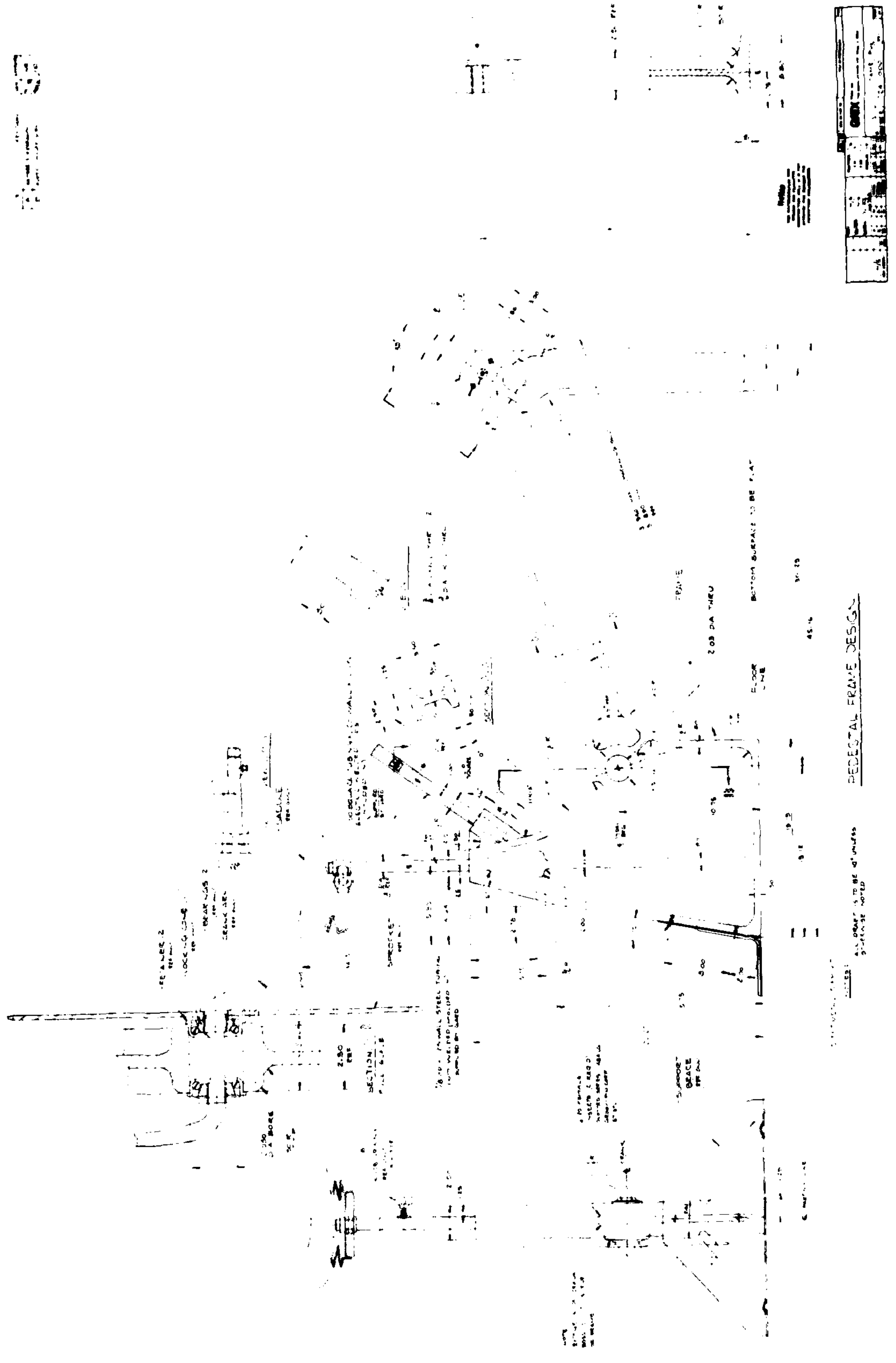


FIGURE 2-24 PVK DESIGN LAYOUT

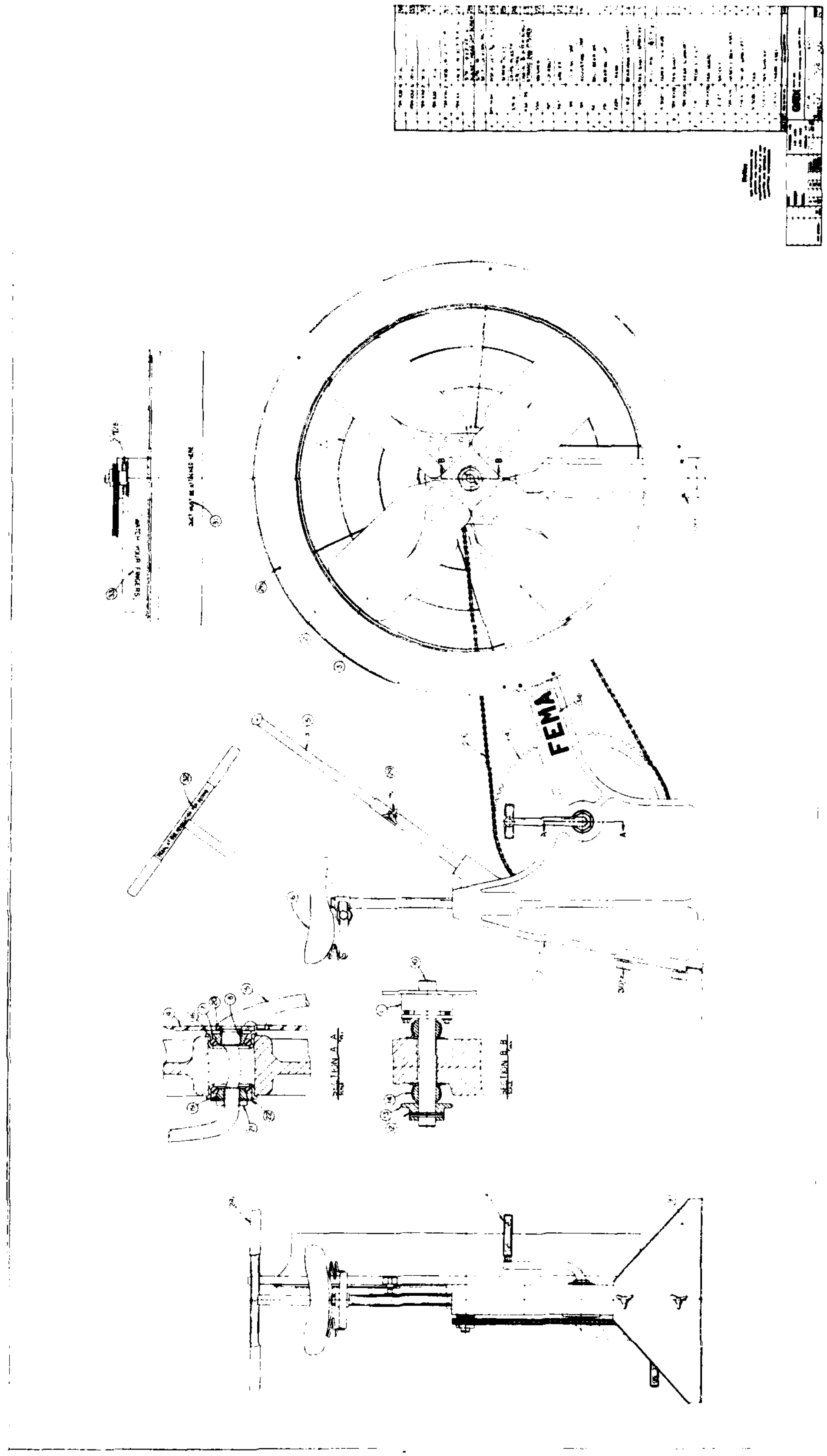


FIGURE 2-25 PVK - FINAL ASSEMBLY

2.4.3 Operating Instructions

Preliminary draft operating instructions were formulated for use with the PVK. The instructions include placement and deployment guidance. The operating instructions are shown in Appendix B of this report.

2.5 Pretest - Power Transmission Components

As part of the value analysis effort, GARD conducted a pretest of the major PVK drive components. For this purpose, several models of the drive sprocket, fan shaft, fan sprocket and 30 inch fan were fabricated or purchased. The goal of the test was to validate the drive components prior to constructing a fully assembled PVK.

The test fixture, which includes all the principal elements of the PVK transmission is shown in Figure 2-26. The test fixture is energized by a 1-horsepower motor which is geared down to 60 RPM, simulating the prescribed operational speed of the PVK. The test was designed to check the following components for reliability and wear factors.

- o Nylon sprocket (131 teeth)
- o Chain, Drive #35
- o Sprocket, Fan (17 teeth)
- o Bearings, Fan
- o Shaft, Fan

The 30 inch diameter fan was incorporated to duplicate the actual overhung load imposed in normal PVK operation. The total revolutions of the drive sprocket were recorded by an electronic digital counter.

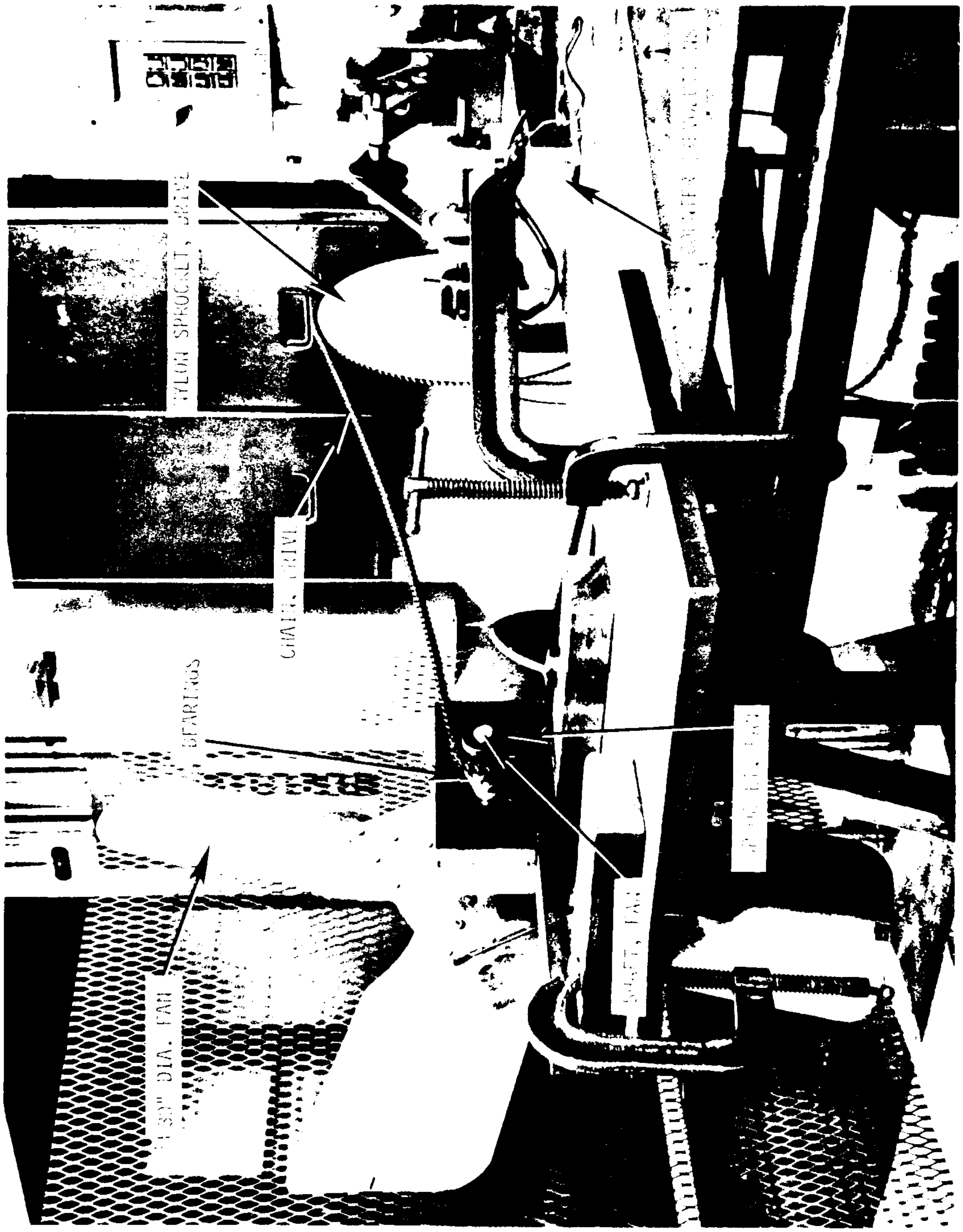


FIG. 2-26 TEST FIXTURE -
DRIVE COMPONENTS

It was GARD's intent to run the test until 1,800,000 revolutions were obtained. This would equate to approximately 21 days of operation, 24 hours per day. Because no appreciable component wear was in evidence upon reaching the above revolutions, the test was continued until at 2,689,398 revolutions, the test was concluded. This represents the equivalent of 31 days or a full month of continuous operation.

No significant wear factors were observed upon disassembling the test fixture and inspecting individual components.

The nylon sprocket, shown in Figure 2-27, indicated no appreciable deformation of the tooth profile. Slight flaking of the reinforcing fibers are in evidence at the crown of most teeth. This is due to frictional drag as each tooth exits the chain link upon disengaging. Since the chain wrap (approximately 180°) engages 65 teeth of the sprocket, the resultant loads incurred per tooth are extremely low. It was concluded that the nylon sprocket can meet and exceed PVK requirements.

The fan shaft assembly shown in Figure 2-28 realized 20,708,000 revolutions during the test, since the drive ratio was 7.7:1. The flange bearings when inspected indicated wear imposed by the chain tension loads. Each bearing had wear deformation on one side diametrically opposed to the other. The inboard bearing had a .002 T.I.R. runout and the outboard bearing indicated 0015 T.I.R. runout. This wear would be considered significant in a precise bearing application; however, the above wear factors are considered negligible for PVK operations.

Some brinelling of the fan shaft at the bearing areas was in evidence, but this is considered normal for an untreated shaft. Rather severe abrasion is shown on the shaft between the bearings, which is due to the shaft interfering with the test support member during a period of the test. The fan

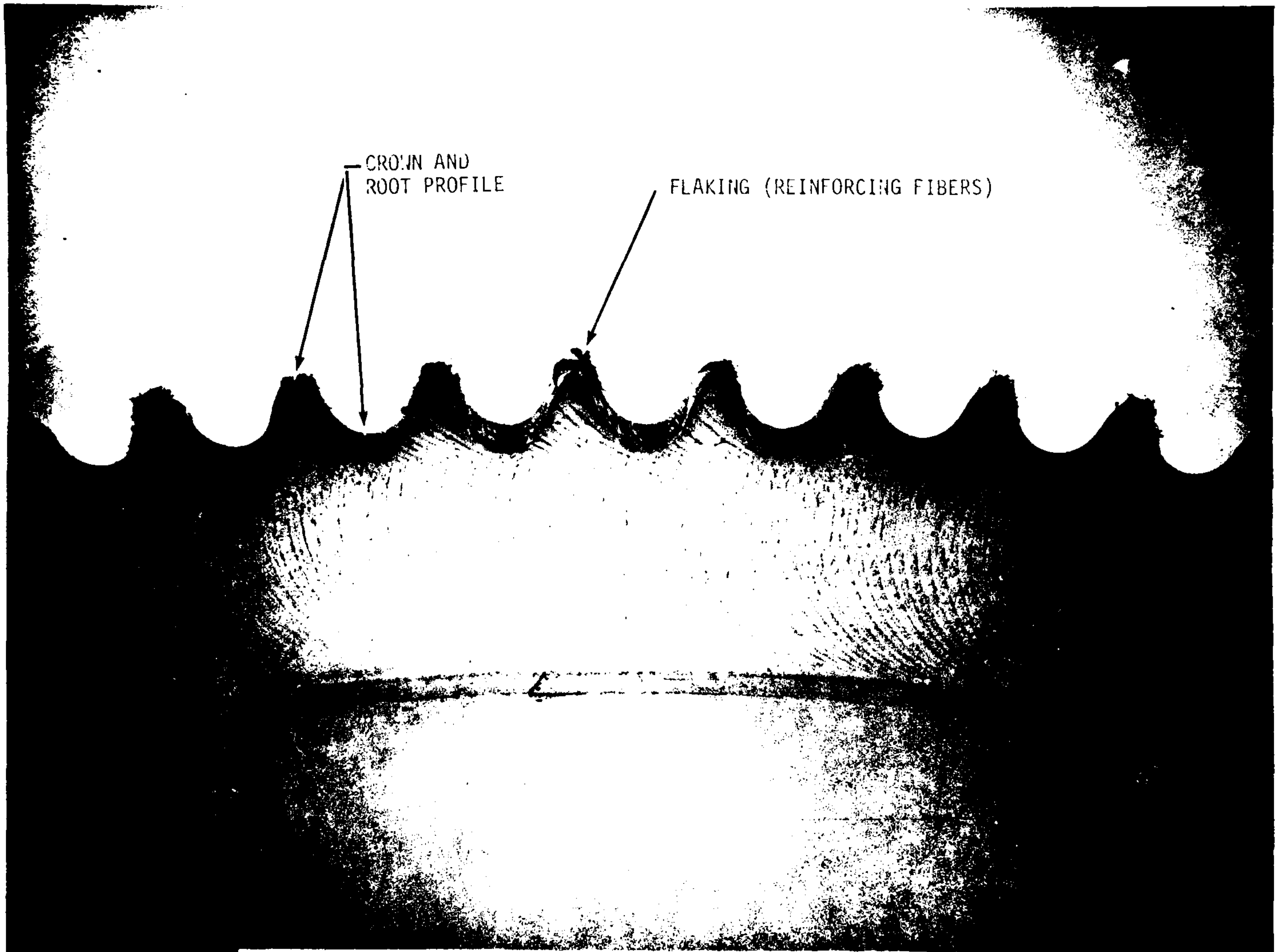


FIGURE 2-27 DRIVE SPROCKET, NYLON (2,689,398 REVOLUTIONS)

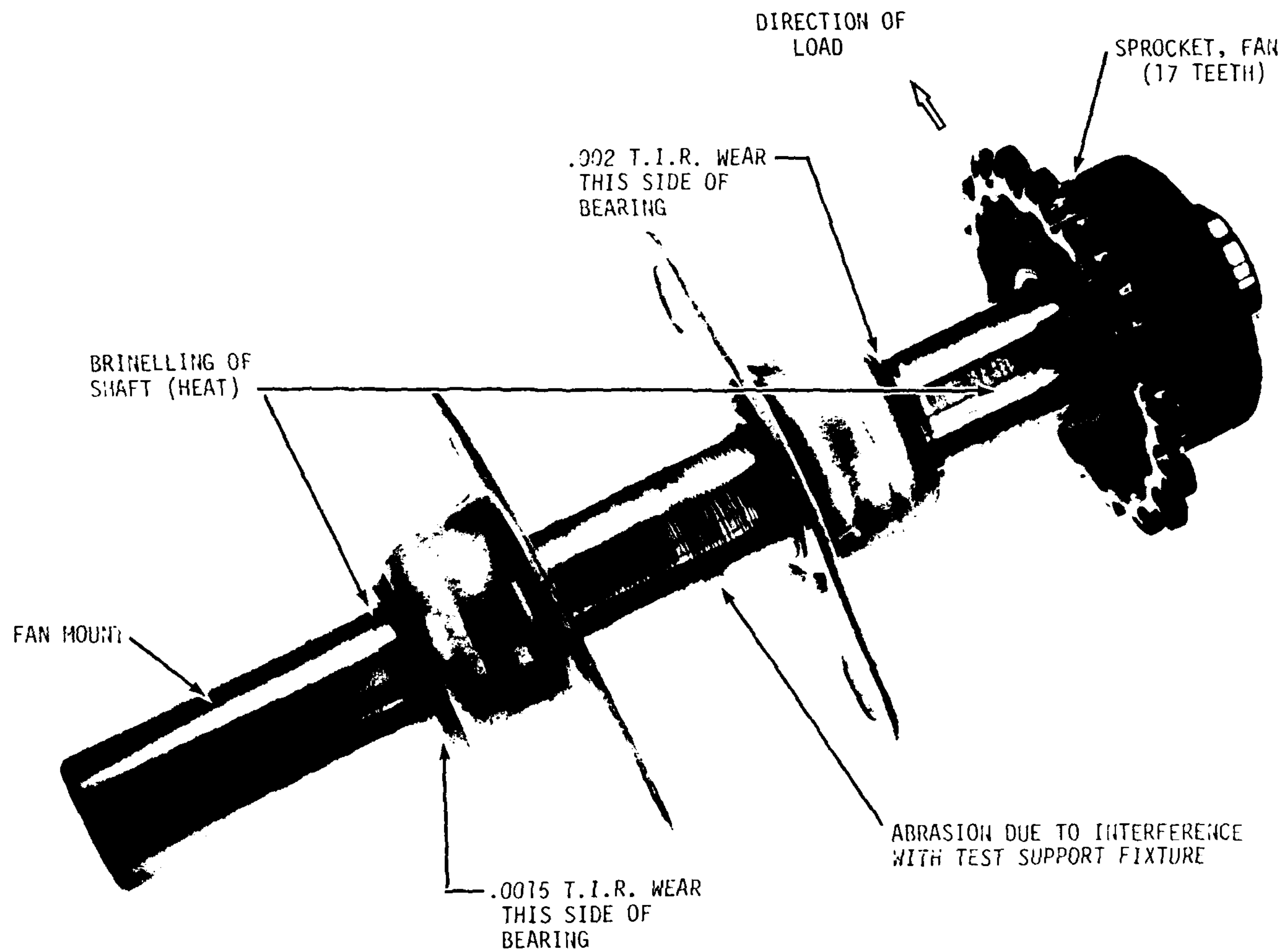


FIGURE 2-28 FAN SHAFT COMPONENTS (20,708,000 REVOLUTIONS)

sprocket (17 teeth) showed only slight wear on the side profile due to chain/sprocket misalignment.

In conclusion, the entire power transmission assembly was judged acceptable for incorporation for the PVK prototype.

Section 3

SUPPORT FRAME EVALUATION

In order to evaluate the structural integrity and storage resistance of the support frame prior to prototype fabrication, GARD constructed five (5) frames for testing purposes. The fabrication methods and test procedures are described in this section.

3.1 Fabrication of Frames

Using the support frame drawing as a basis, Envirotech Plastics Division, under subcontract to GARD, constructed a single cavity aluminum mold required to generate the frames required for testing.

GARD chose four frames of varying glass density polypropylene and one nylon frame for test evaluation. The five frame materials were specifically:

- o Polypropylene (unfilled) natural
- o Polypropylene - 15% glass-filled
- o Polypropylene - 20% glass-filled
- o Polypropylene - 30% glass-filled
- o 6/12 Nylon - 30% glass-filled.

In addition to the above, GARD constructed three additional frames for destructive testing and one for a display prototype model.

3.2 Testing of Frames

Upon delivery of the frames, GARD subjected the frames to a series of validation tests described below.

3.2.1 Static Load Test

Two prototype frames were subjected to a static load test to determine the ability of the frames to withstand the maximum static loads that normally would be applied in the operation of the unit. The test setup is shown in Figure 3-1. The two frames chosen for the test were constructed of: (1) unfilled polypropylene, and (2) 15% glass-filled polypropylene. Since these frames represent the lowest tensile strength of the five prototype frames and all frames were of sufficient strength, GARD concluded that successful resistance to the applied load on the two frames selected would preclude any similar tests to the remaining three frames.

The test involved the application of 275 pounds at the operator's saddle and 32 pounds at the maximum extension of the handlebars. Each frame was instrumented with four uniaxial strain gages bonded in the positions shown in Figure 3-2. The chosen gage positions represent the most potentially critical stressed areas of the frame. The intent of the strain gages was to determine the ambient temperature creep in micro-inches per inch when subjected to a sustained static load. Strain gage readings were taken at intervals of 15 minutes, 30 minutes, 1 hour, 8 hours, 24 hours, 48 hours, 72 hours, and 192 hours (8 days), after initial application of the load. The data points generated for the 15% glass-filled frame is shown in Figure 3-3 and in Figure 3-4 for the unfilled frame. It is noted that the creep curve on the graphs is seen to asymtotically approach a horizontal line at approximately the 5-day (120 hour) value on the times axis. At this point, it is assumed that the creep under load has stabilized and further compression and/or tension at the gaged locations ceased. Since the calculated unit stress in these areas is substantially within the elastic modulus properties of the frame material, it was concluded that the frame was acceptable for use under even extreme shelter operational conditions.

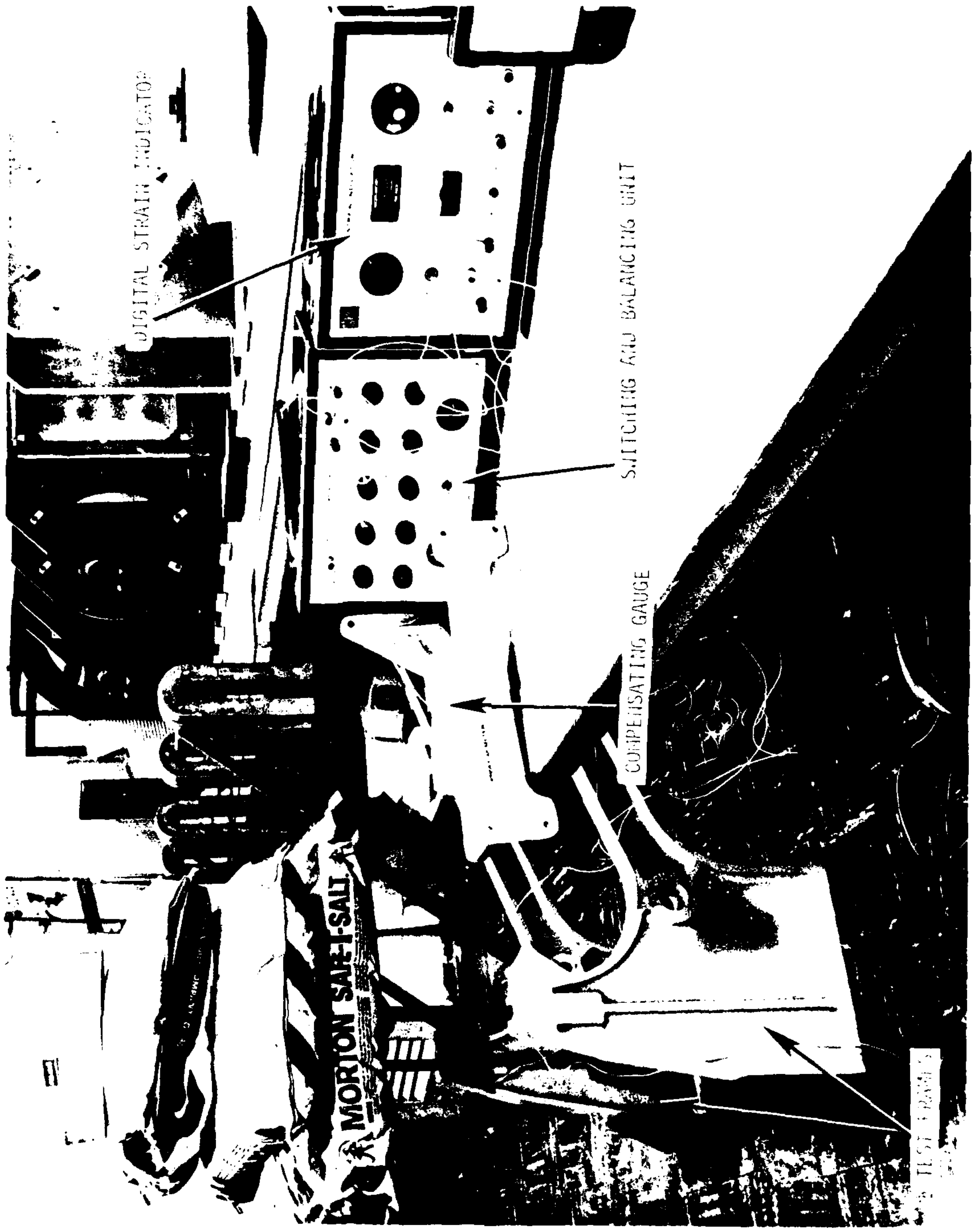


FIG. 3-1 TEST SETUP-STATIC LOAD

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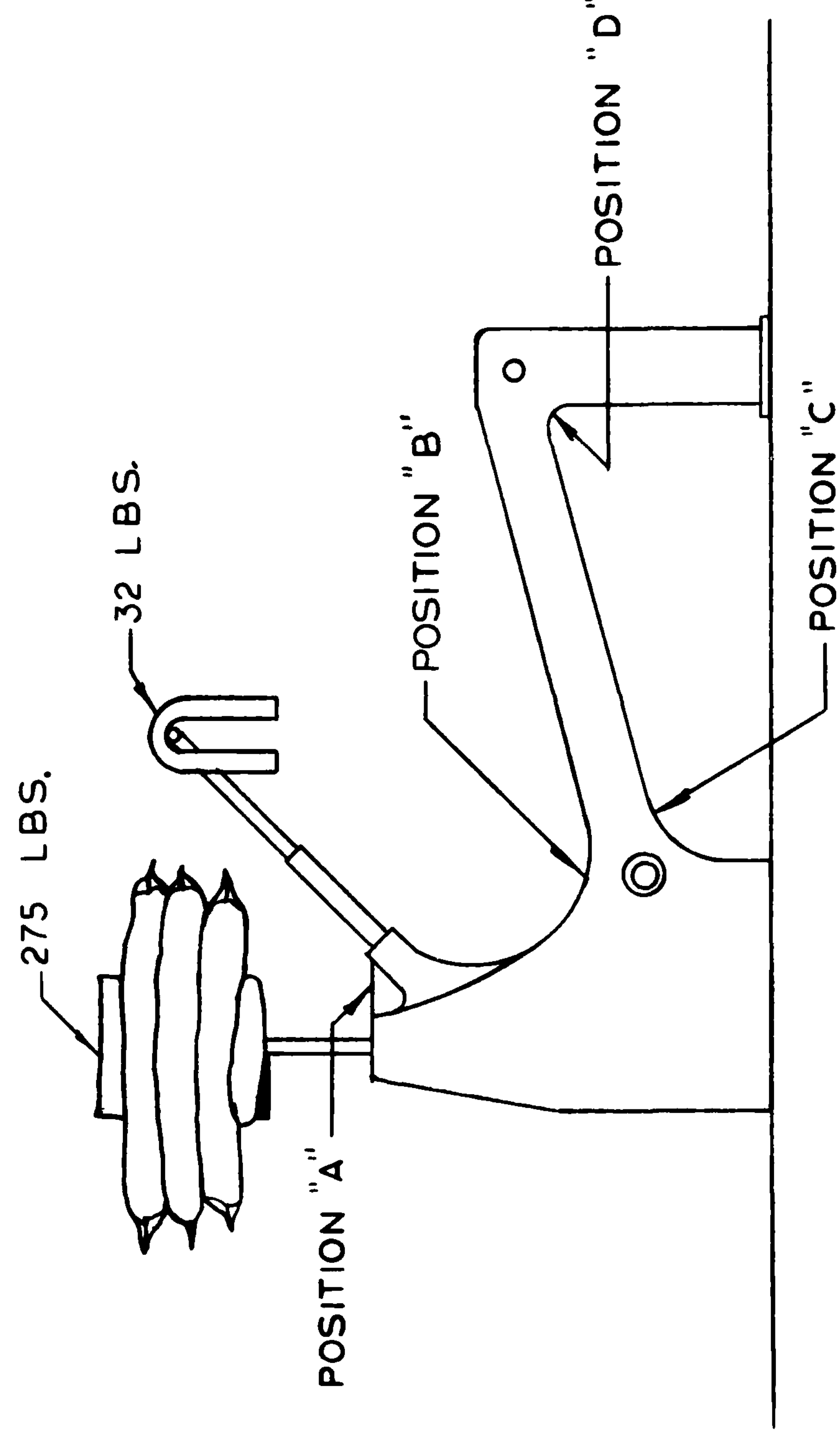
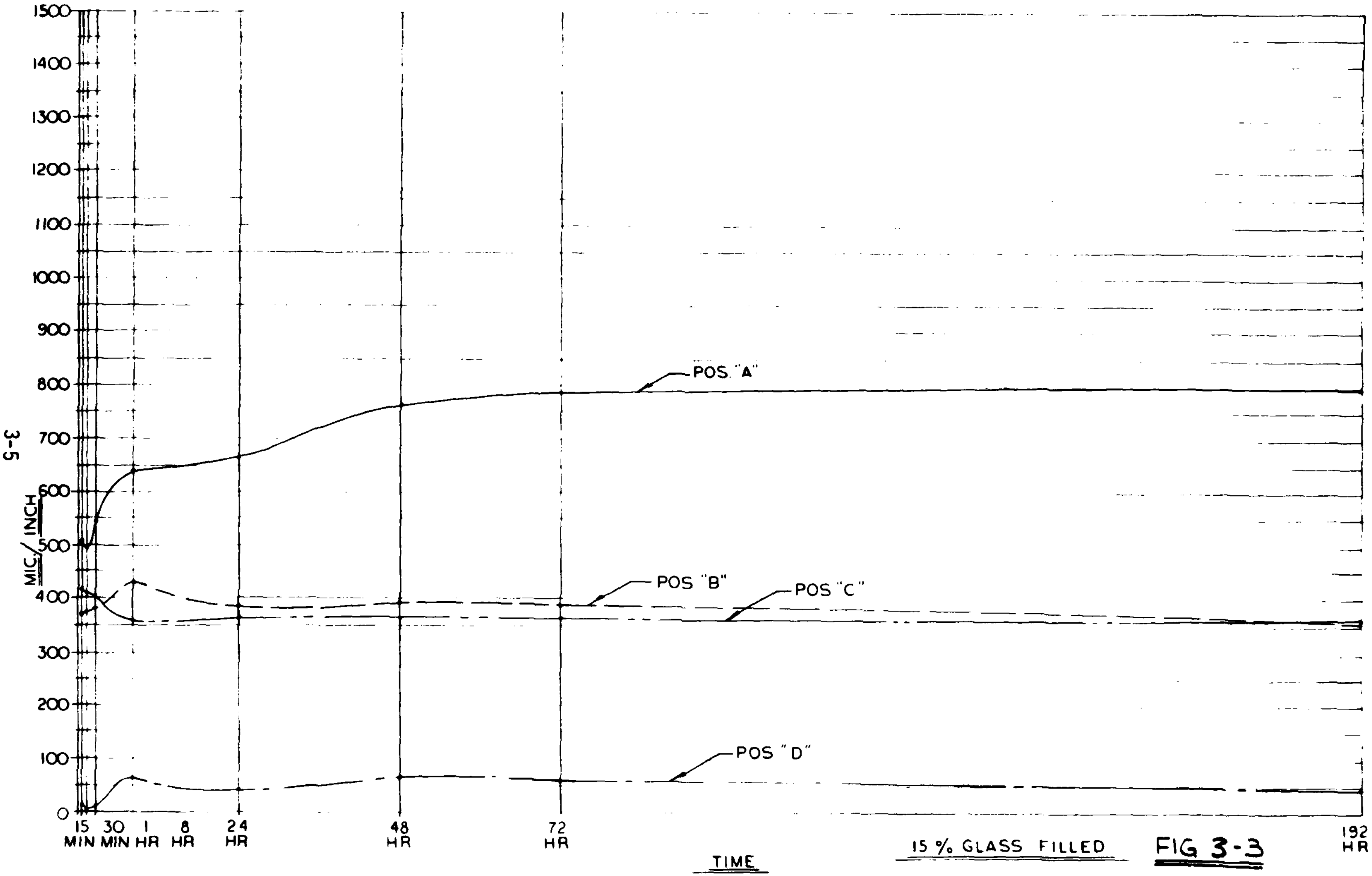
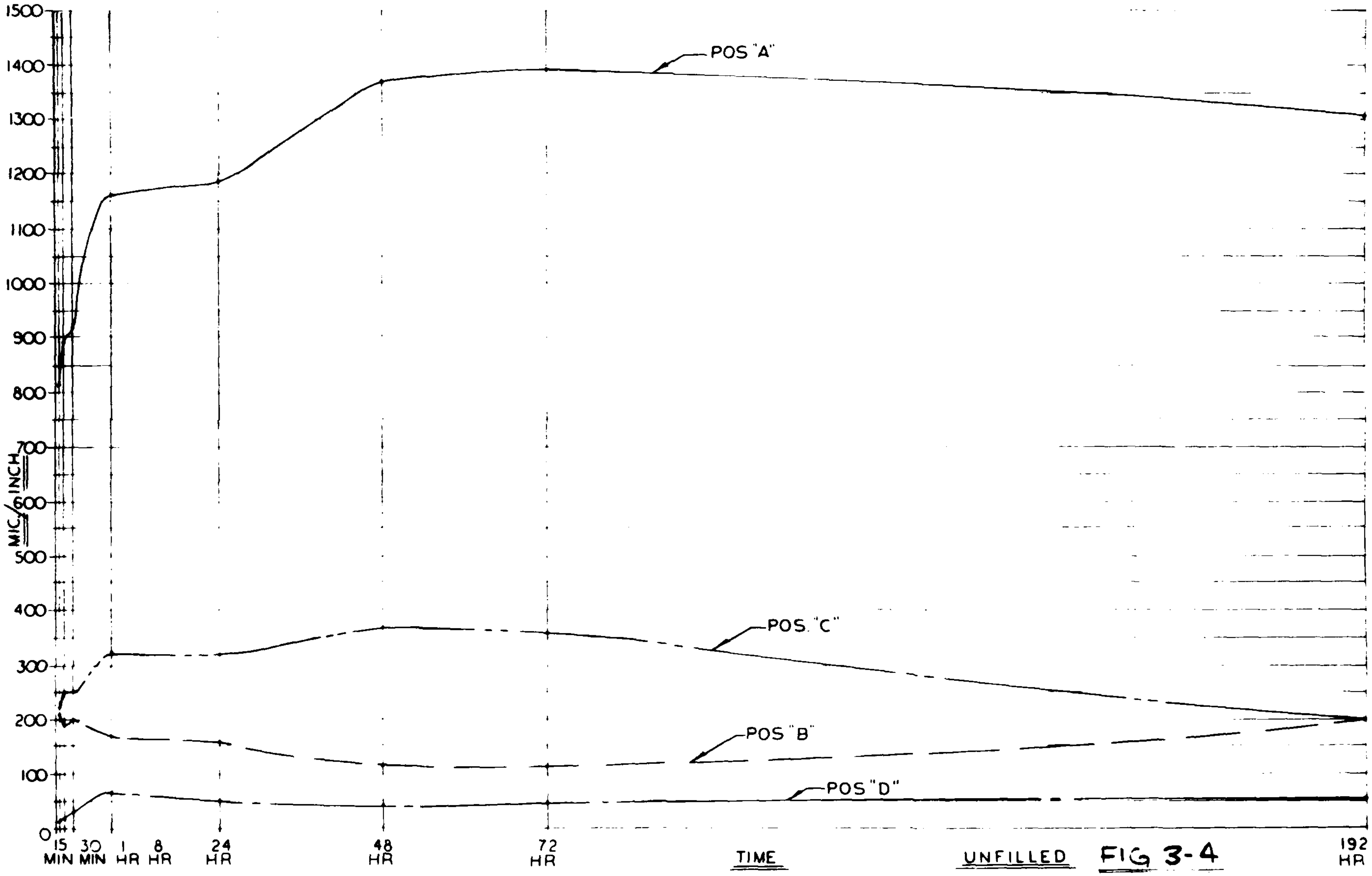


FIGURE 3-2



15 % GLASS FILLED

FIG 3-3



UNFILLED FIG 3-4

3.2.2 Compression Test (Ultimate)

GARD utilized a 15% glass-filled frame for a compression test between the top of the seat post and the pedestal base. The intent of the test was to load the unit in compression until failure occurred. A 20,000 lb capacity Tinius-Olsen machine was used in the reverse mode for the test. As the load was applied, the only failure that ultimately occurred was the bending of the seat support post (7/8 dia x 1/8 wall st. stl.) at 16,600 lbs. The tube deformation, which is approximately 10° from the normal vertical position, is shown in Figure 3-5. No cracks or indentation of the support frame was noted at the conclusion of the test.

GARD then applied a vertical downward compressive load at the extreme end of the molded-in handlebar support tube. At 1900 lbs, the tube went into bending, and at 2350 lbs, the forward wall of the tube support boss fractured. This condition is shown in Figure 3-6. A 16mm film was taken of both tests.

The results of both tests reflect higher strength values than predicted in GARD initial stress analysis generated in the material study phase.

3.2.3 Environmental Testing

Environmental tests were performed at Gaynes Testing Laboratories in Chicago, IL and supervised by GARD technical representatives. The five test frames evaluated are those described in Section 3.1. The primary purpose of the environmental tests was to determine the frames suseptibility to varying ambient temperature levels that may be encountered during both storage and operational modes.

GARD formulated two separate frame test procedures, high temperature and low temperature. The test procedures are, in general, extracted from the specifications listed in MIL-STD-810C titled "Environmental Test Methods".

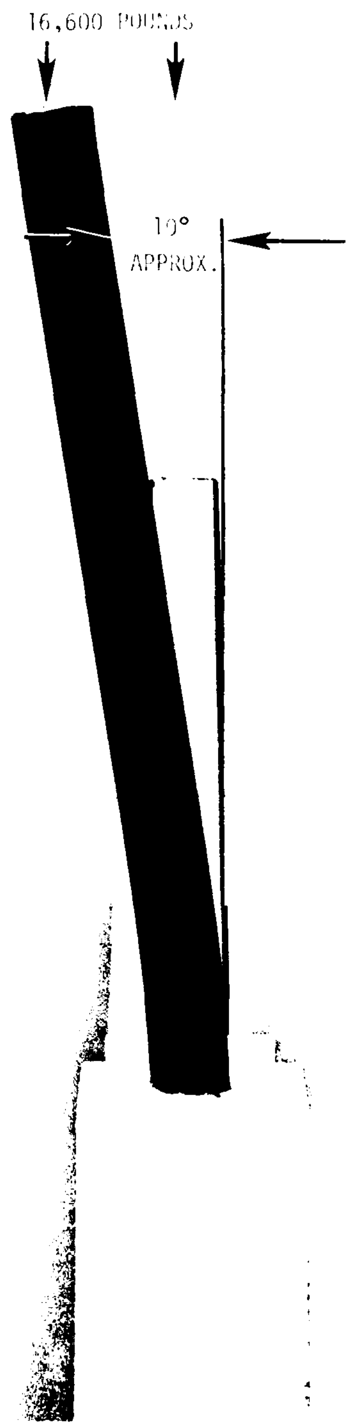


FIG. 3-5 SADDLE SUPPORT FAILURE

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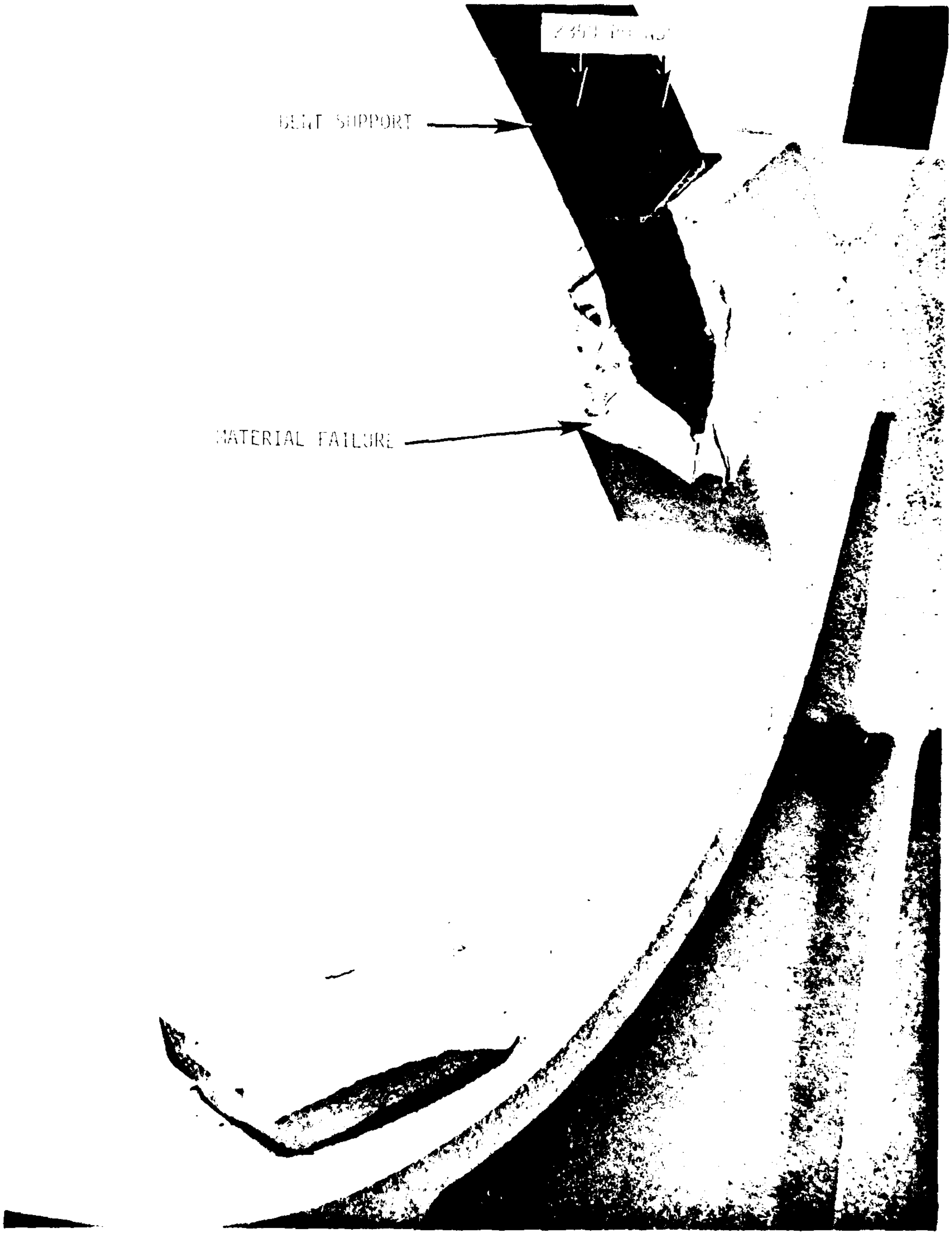


FIG. 3-6 HANDLEBAR SUPPORT FAILURE

GARD, INC.

This standard establishes uniform test methods for determining the resistance of military equipment to the effects of natural and induced environments peculiar to military operations. The specifics of the high and low temperature tests is to determine the effects of temperature extremes on the PVK frame without protective packaging.

The high and low temperature test procedures are included in Appendix C and D of this report.

Both tests were performed in a sealed Conrad 8 ft x 10 ft x 8 ft high walk-in chamber shown in Figure 3-7. The cycling of the chamber is controlled automatically by a timed cam-operated thermostat shown in Figure 3-8. Thermocouples combined with digital thermometers were attached to each frame to record the material surface temperature during the tests. The five test frames were positioned in the test chamber as indicated in Figure 3-9.

Before testing the frames, each individual support frame was placed on a machined tooling plate and its position marked so that after each subsequent test, the frame would be located in the same relative placement. Using a feeler gauge at one reference point (maintained throughout the evaluation), the gap between the tooling plate and frame was accurately recorded. The support frame was measured at the conclusion of each sequence so that any differential in measurement could be detected.

After the measurements were recorded, the rear support frame was attached to each frame and the entire assembly was placed inside the test chamber.

At the end of each test sequence, the PVK frames were inspected for possible warpage (tooling plate measurement), fractures or structural degradation. A technician simulating a weight of 229 pounds sat on the saddle for a period of five minutes to determine structural integrity.

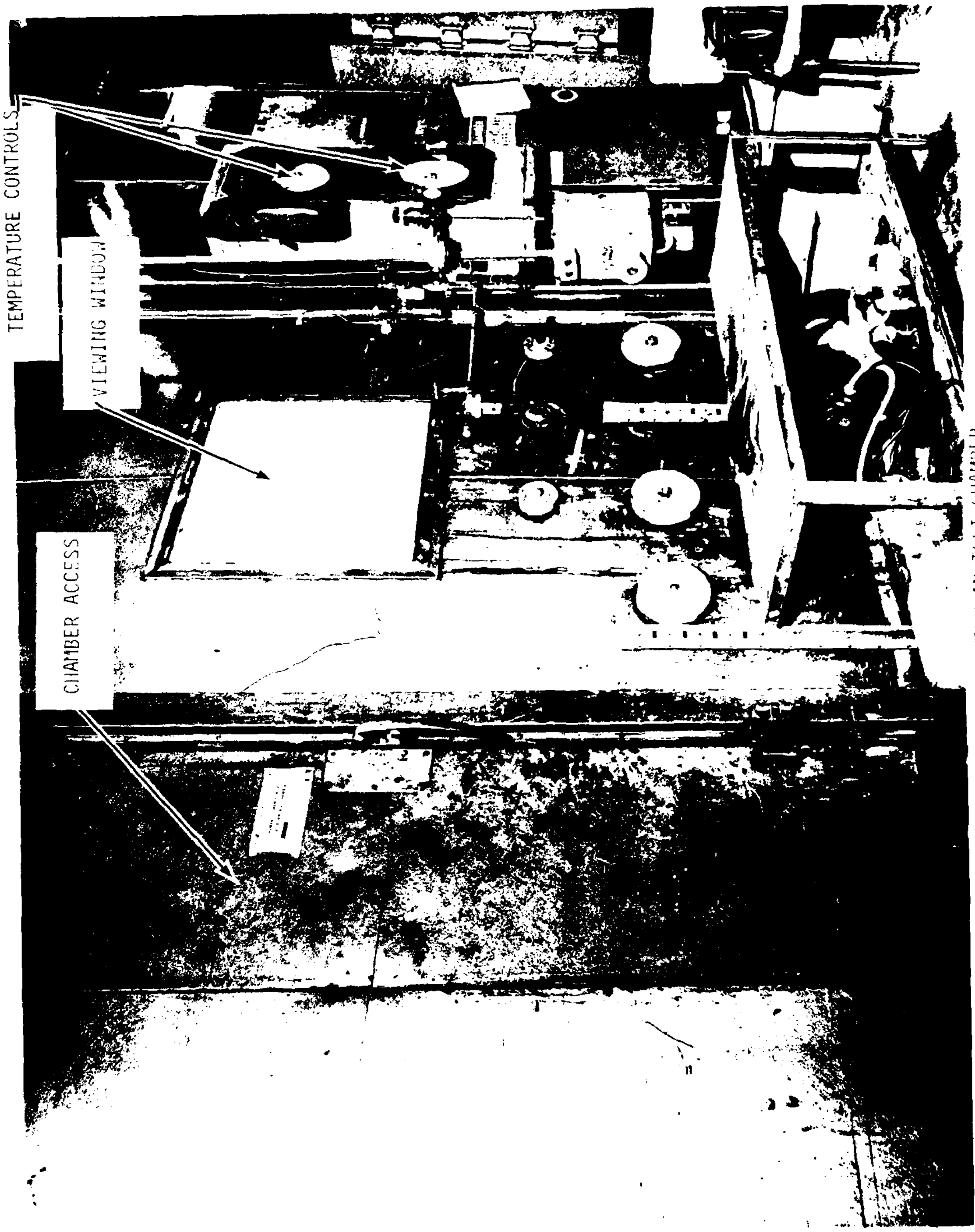
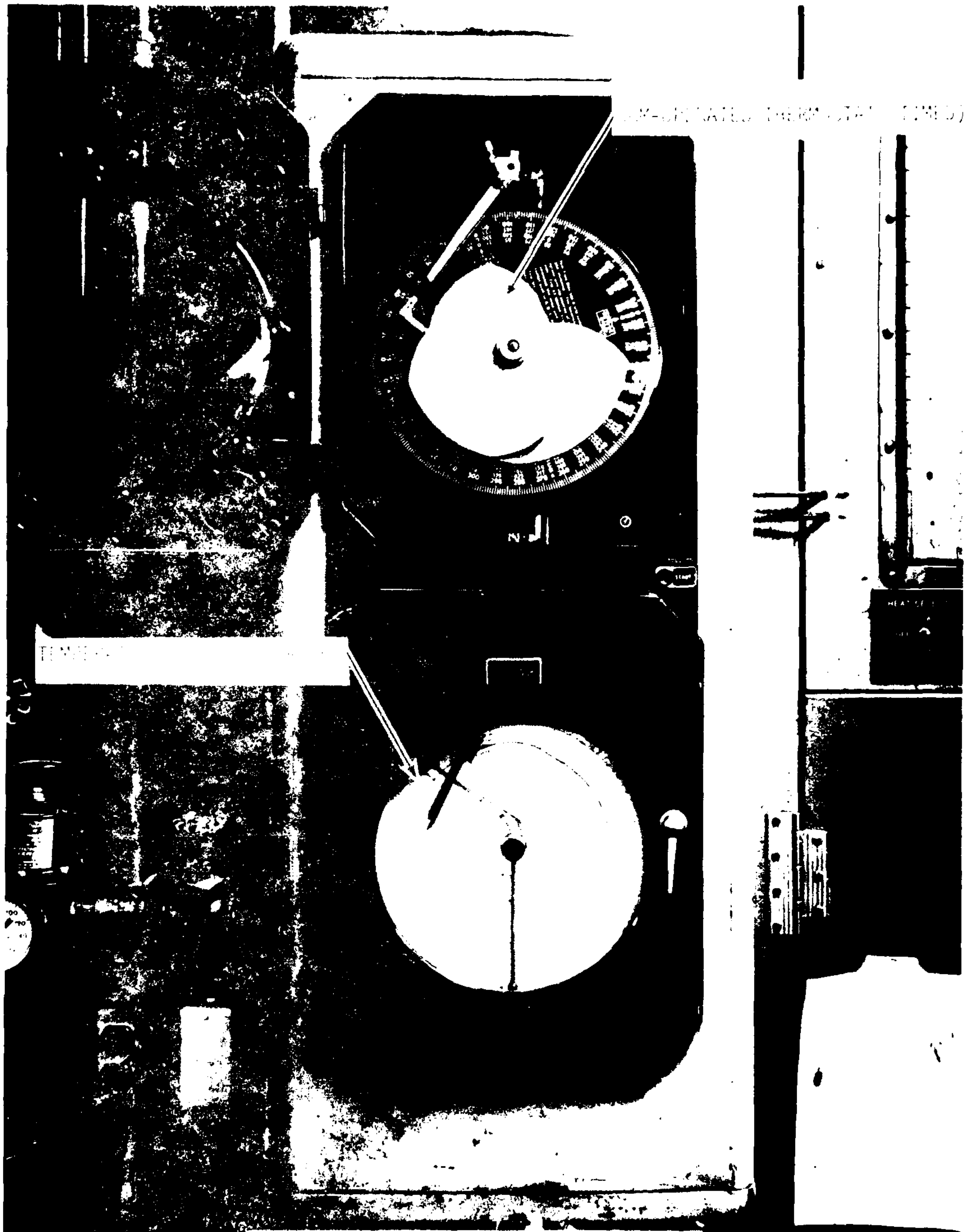


FIG. 3-7 SEALED WALK-IN TEST CHAMBER



TEMPERATURE CONTROL

FIG. 3-9 PVK FRAMES IN TEST CHAMBER

The specific test procedures were conducted as follows:

Procedure No. 1 - High Temperature

A. Temperature maintained at 60°C (140°F) - 48 hrs. - Low Relative Humidity.
B. Temperature reduced to 110°F to stabilization of frames
C. Inspection
D. Temperature reduced to room ambient
E. Inspection & Measurement

Procedure No. 2 - High Temperature Cycling

A. Temperature raised to 49°C (120°C) and held for 6 hours
B. Temperature raised within 1 hour to 60°C (140°C) and held for 4 hours.
C. Temperature lowered with 1 hour to 49°C (120°F)
D. Repeat steps A, B & C for a total of 3 complete cycles.
E. Temperature reduced to 110°F to stabilization of frames
F. Inspection
G. Temperature reduced to room ambient
H. Inspection & Measurement

Procedure No. 3 - Low Temperature

A. Temperature reduced to -34°C (-30°F) and held for 24 hours
B. Temperature raised to room ambient
C. Inspection & Measurement
D. Repeat steps A, B & C

At the conclusion of the environmental testing, it was determined that each support frame remained relatively unchanged after each test procedure sequence. There was no apparent fractures or structural degradation. The general appearance of each unit remained the same; there was no discoloration or flaking of the frame material. The operator saddle withstood the applied 229 lb. load without any change in structural integrity.

Based on the data presented by the environmental tests described above, GARD concluded that all five frames were capable of meeting the PVK storage parameters. The specific test report by Gaynes Laboratories is contained in Appendix G of this report.

3.2.4 Drop Test

GARD subjected the PVK frames to a series of drop tests to determine susceptibility to impact. The frames were allowed to free-fall from a distance of 12 inches and impact on a concrete floor. The 12 inch height simulates the free-fall incurred if the unit was being hand-carried for deployment position and was accidentally dropped. Each of the five frames was subjected to the drop test setup shown in Figure 3-10 for five cycles.

The frame was suspended at the predetermined height by an electrically triggered release mechanism. None of the frames indicated damage of any kind after the conclusion of the testing.

3.2.5 Toppling Test

In the toppling test, the frames are suddenly upset from a free standing position which caused them to fall over on their length and impact with a tiled floor. The test setup is shown in Figure 3-11. The frame is positioned perpendicular to the test bench. The saddle (seat) is impacted by a pneumatic cylinder energized by 40 psig. The impact results in the frame being rotated over on side and impacting the floor at a relatively high velocity (30 inches per second). All five frames were tested in this manner for 10 cycles each. No significant damage to the frames was observed. At certain points of impact (corners, protrusions, etc.), there was evidence of material abrasion.

GARD then subjected the same frames to an even more rigorous test. The test bench was elevated so as to allow the frames to be toppled from a height of 42 inches off the concrete floor. This test was to simulate the frame

FIG. 3-10 DROP TEST SETUP

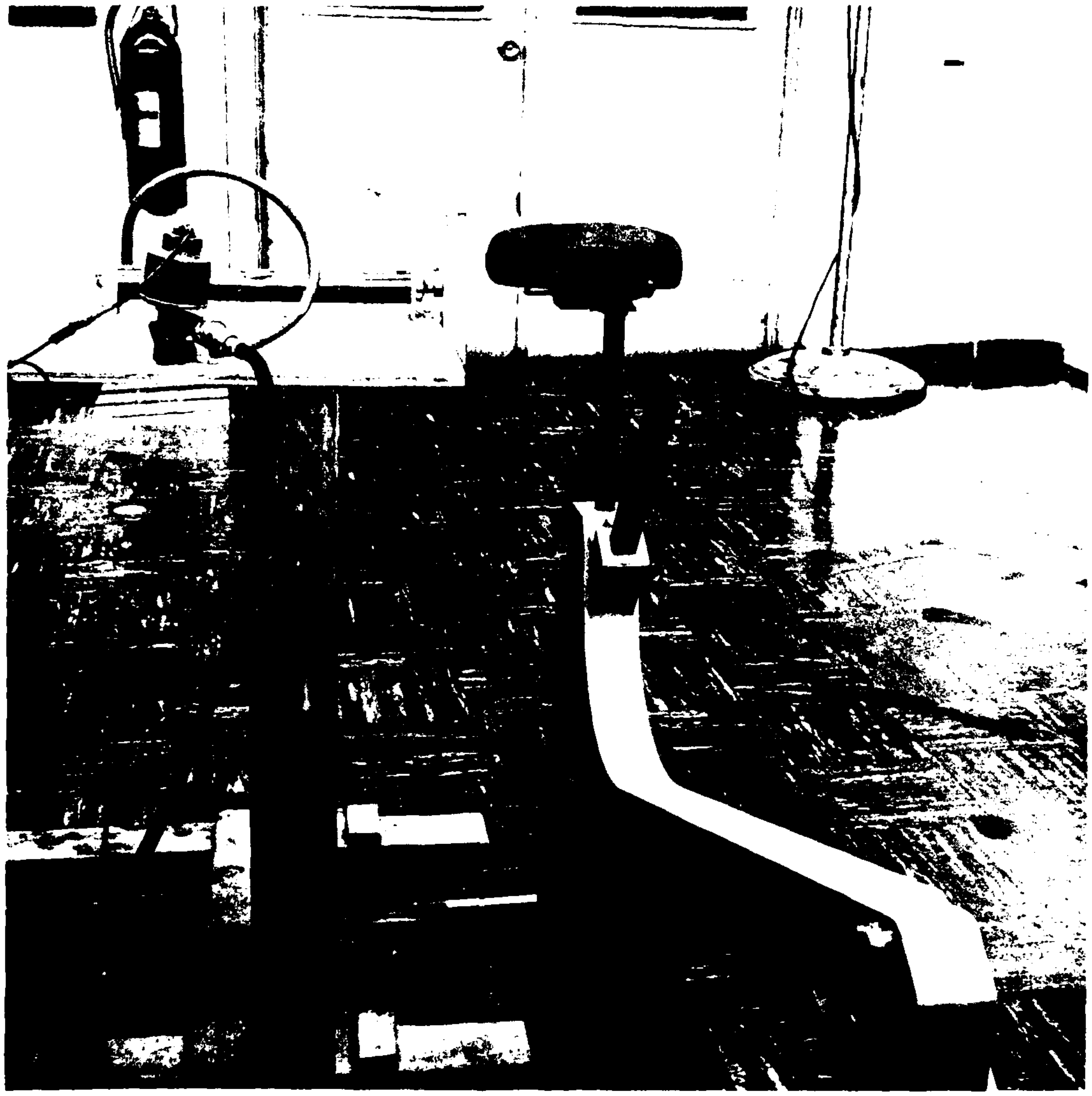


FIGURE 3-11 PVK - TOPPLING TEST, FLOOR HEIGHT

falling from a standard loading dock height onto a concrete floor. The test configuration is shown in Figure 3-12.

The frames again survived the impact with the floor with only minor abrasion, chipping and saddle damage in evidence.

3.2.6 Finite Element Model - PVK Frame

To assure the structural integrity of the PVK support frame and to provide a computerized base for future optimization, a finite element analysis was performed on the unit configuration.

The finite element method of stress analysis is a numerical technique in which the continuum of structure is discretized (divided) into small pieces or elements. These elements which may be of different shapes, are interconnected, and have varying loading conditions and physical properties. When utilizing the boundary constraints provided by the frame with the maximum loading conditions defined, the FEM process yields a system of algebraic equations, the solution of which contains the stress condition and deformation of each element.

The specific process is included and defined in Appendix J of this report. The conclusion of the analysis indicates the normal operating loads realized by the frame are well within stress limits and the design is conservative.

3.3 Conclusions - Support Frame

The five frames tested and analyzed as described in this section all have shown excellent resistance to environmental and structural tests. Any one of the five could quality as the production frame. The unfilled polypropylene frame represents the lowest material cost of the group. The unfilled polypropylene frame is $4.00 per unit less than the 15% glass-filled polypropylene frame.

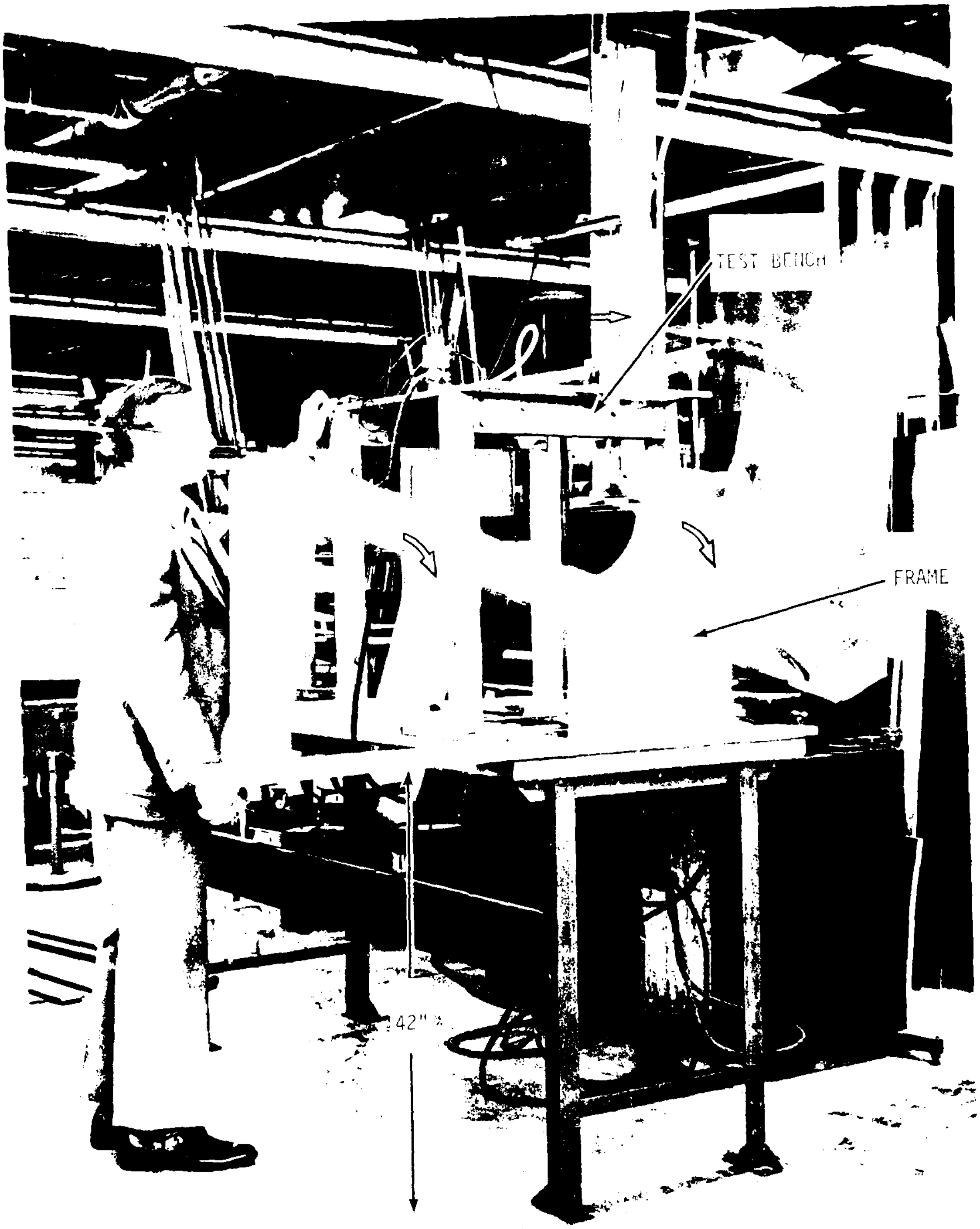


FIG. 3-12 TOPPLING TEST, 42 IN. HEIGHT

However, the 15% glass-filled polypropylene frame was selected for the following reasons:

(1) The mold shrinkage rate for 15% glass-filled polypropylene is 1/5th that of the unfilled type (.003 vs. .015 inch per inch). The lesser shrinkage would provide dimensionally more accurate frames and result in lower rejection rates in the injection molding process. This accuracy would be necessary for the various metal parts molded into the frame.

(2) The 15% glass-filled polypropylene has a 0.01% lesser water rate absorption than the unfilled type. Long storage lifes require a non-hygroscopic material that will retain its shape and maintain a dimensional stability.

(3) The unfilled polypropylene frame was significally less rigid than its glass-filled counterparts. GARD believes a certain amount of rigidity is necessary to maintain proper chain tension and for operator comfort and stability.

(4) It was both GARD's and FEMA's subjective opinion that the 15% glass-filled polypropylene was superior to the unfilled polypropylene for this application.

The 15% glass-filled polypropylene frame was chosen for implementation on the alternate material pedal ventilator kit.

Section 4

CONSTRUCTION AND VALIDATION - ALTERNATE MATERIAL PVK

In order to validate the fully constructed alternate material PVK, GARD fabricated, assembled and tested the PVK for conformance to environmental and operational requirements.

The efforts associated with fabrication and validation, including hardware failure, environmental and deployment test procedures are described in this section. In addition, packaging concepts developed for the PVK are presented and discussed.

4.1 Construction of Prototype PVK's

Using the approved frame developed and tested in Section 3, GARD constructed and assembled fifteen (15) prototype ventilator kits. The support frames were injection molded utilizing the single cavity aluminum mold developed for frame validation.

The following components, both fabricated and purchased, were incorporated into the PVK.

- Frame, Support - 15% glass-filled polypropylene
- Shroud, Fan - ABS nylon
- Sprocket, Drive - nylon
- Rear Support - steel
- Handle Bar Assembly - steel
- Guard, Fan - steel
- Fan, 30 inch diameter - steel*
- Saddle - vinyl*
- Grips (2) - vinyl*

- o Chain, 3/8 pitch, #35 - steel*
- o Pedals (2)*
- o Sprocket, Fan - steel*
- o Fan Shaft - steel
- o Crank Assembly - steel*
- o Knobs, Locking - ABS plastic*
- o Misc. Hardware*
- o Bearings, Fan - nylon/steel*

* Denotes purchased items.

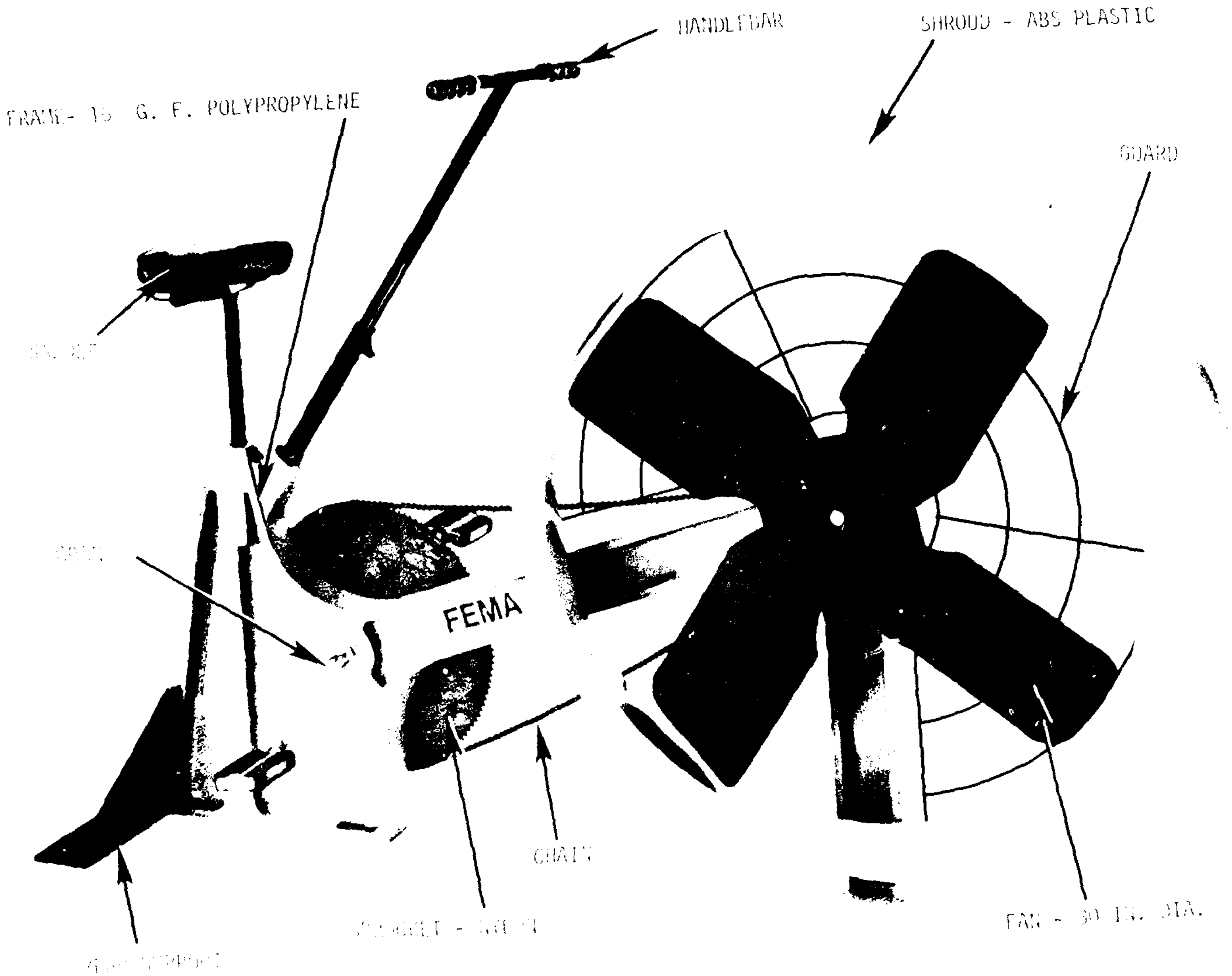
The fully assembled PVK is shown in Figure 4-1. Of the 15 prototypes fabricated, 9 PVK's were shipped to the Defense Logistics Agency, 1 to FEMA Mitigation and Research, and 5 retained at GARD for validation testing.

4.2 Validation of Ventilators

The alternate material PVK was subjected to a series of validation tests to assure the reliability of the unit in meeting the technical requirements. The testing was concentrated in three primary areas: hardware failure, environmental, and ease of deployment. The air flow of the fan was not tested, since the fan is the same as that tested in the performance of Contract No. DCPA01-78-C-0184. The following subsections describe test procedures and conclusions.

4.2.1 Mechanical Failure Test

A mechanical endurance test was performed with the PVK to determine the integrity of its components during long term operation. The test setup as shown in Figure 4-2 utilizes a motor driven pair of articulated arms which mechanically simulate the human input. The operator's saddle was


HANDLEBAR
SHROUD - ABS PLASTIC
FRAME- G. F. POLYPROPYLENE
GUARD
FEMA
CHAIN
FAN - IN. DIA.

4-1

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STUDY OF ALTERNATE MATERIAL FOR PEDAL VENTILATOR KITS.(U)

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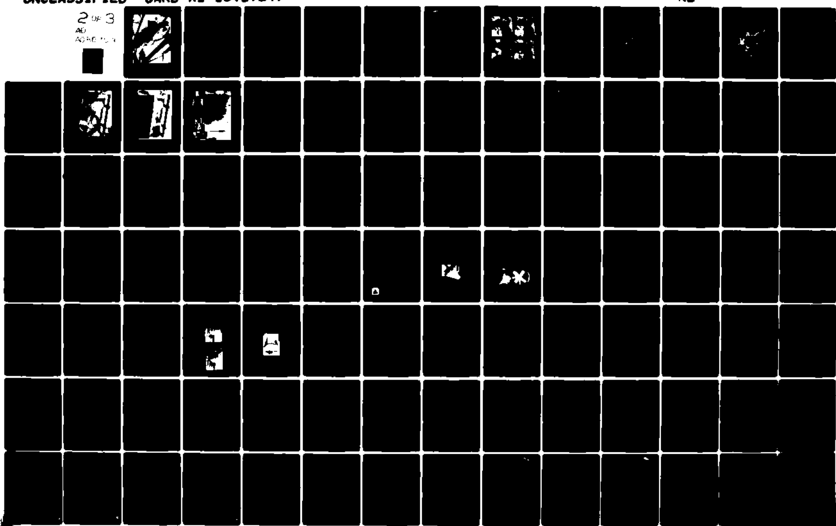
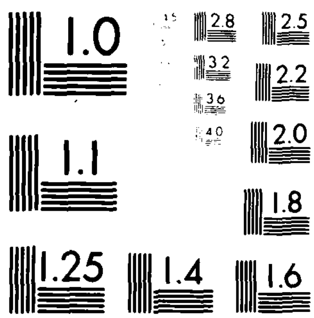




MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

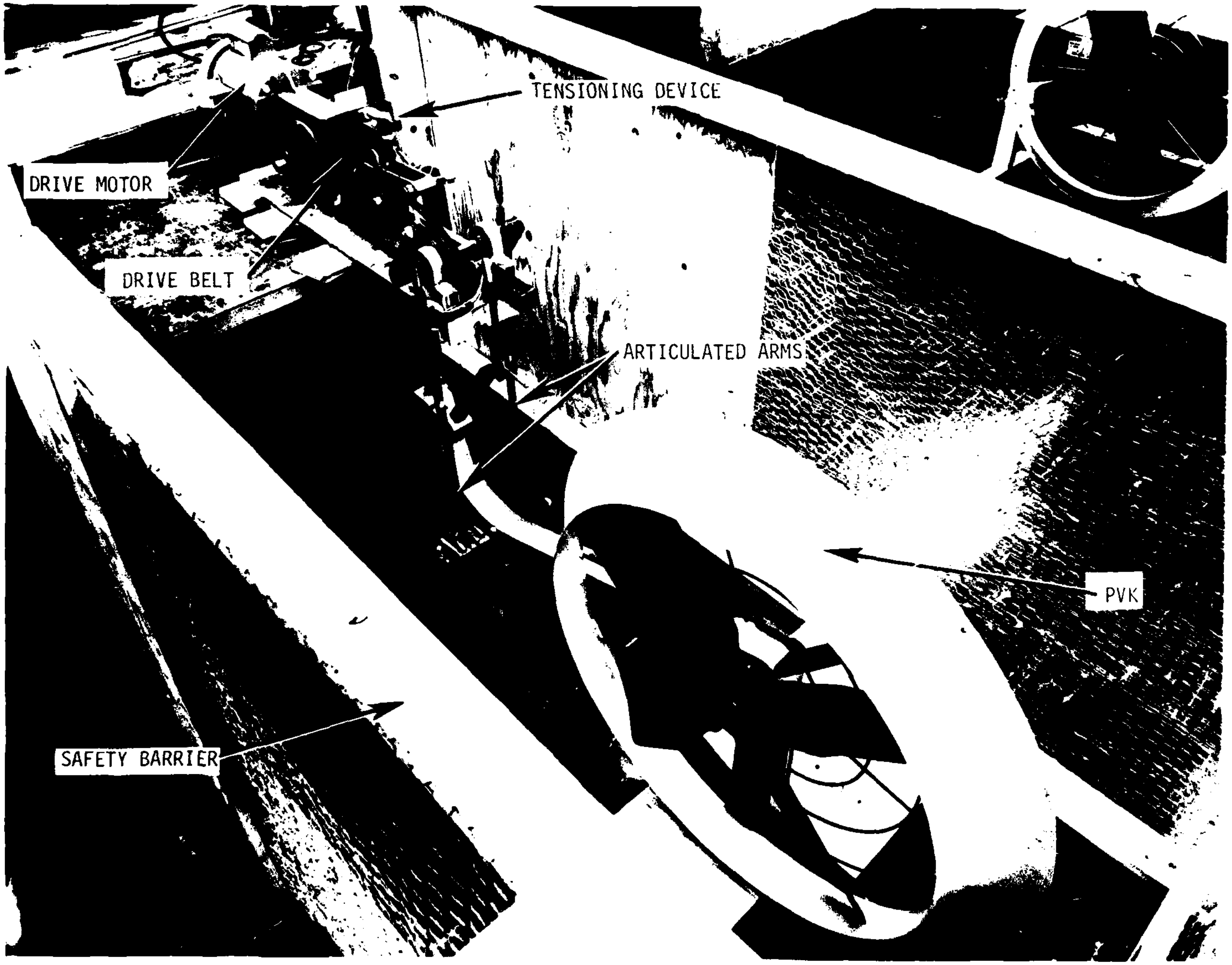


FIGURE 4-2 MECHANICAL FAILURE TEST SETUP

removed to accommodate the mounting of the drive unit. The PVK was driven continuously at 60 RPM by the mechanism, 8 hours daily for a total of 70 days.

The total revolutions recorded at the crank was close to 2,000,000. This translates to 3.3 weeks of operation, 24 hours per day. During the above testing, no component failure, wear factors or other visible defects occurred to the PVK. Also, no mechanical adjustments were necessary for the duration of the test.

4.2.2 Environmental Test - PVK

The objective of the environmental tests was to determine the effects of high and low temperature during storage (without protective packaging) and service use on a fully assembled PVK unit.

The testing methods utilized, which were in conformance with MIL-STD-810C titled "Environmental Test Methods" are identical to those performed on the PVK frame validation. The environmental tests were divided into two separate test specifications: high and low temperature. The tests, inspection criteria, and results are described in the following subsections.

4.2.2.1 High Temperature Test

The high temperature test was conducted in two distinct test procedures. Procedure 1 was intended to approximate the exposure of the PVK assembly to a high temperature storage condition for a period of time prior to operation of the units. Procedure 2 was intended to approximate the cyclic high temperature stresses that the PVK assembly could be exposed to during storage and operation. The chamber utilized is a Conrad 8 ft. x 10 ft. high walk-in enclosure with digital thermometer controls and temperature cycling cams.

The tests were conducted as follows:

Test Procedure No. 1 - High Temperature

- o Temperature maintained at 60°C (140°F) for a period of 48 hours - low relative humidity.
- o Temperature reduced to 110°F for stabilization of the PVK.
- o Inspection and five minutes of operation.
- o Temperature reduced to room ambient.
- o Inspection and five minutes of operation.

Test Procedure No. 2 - High Temperature Cycling

- o Temperature raised to 49°C (120°F) and held for 6 hour duration.
- o Temperature raised within one hour to 60°C (140°F) and held for 4 hours.
- o Temperature lowered within one hour to 49°C (120°F).
- o Repeat the above 3 steps for a total of 3 complete cycles.
- o Reduce temperature to 110°F to stabilization of the PVK.
- o Inspection and five minutes of operation.
- o Temperature reduced to room ambient.
- o Inspection and five minutes of operation.

The following inspection criteria was used upon the conclusion of each test:

- o Dimensional stability - Any distortion and/or warpage of PVK components as compared to the pretest condition.
- o Operational - Test personnel shall operate the PVK at the normal pedaling rate of 60 rpm for a period of not less than five (5) minutes to assure ease of operation. In addition, at the conclusion of the test, inspection of the following components shall take place:

- o Crank Assembly - binding
- o Fan Bearings - binding
- o Chain - too loose/tight
- o Shroud - clearance with fan
- o Sprockets - in line
- o Fasteners - loose.

4.2.2.2 Low Temperature Test

The low temperature test was conducted to determine the effects of low temperature on the PVK assembled unit during storage (without protective packaging) and service use. The specific test procedures were as follows:

- o Attach thermocouples to PVK to record surface temperature of material while test is in progress.
- o Lower internal chamber to a storage temperature of -34°C (-30°F) and maintain same for a period of 24 hours after stabilization.
- o Return the PVK to ambient temperatures and stabilize.
- o Inspect PVK - (same criteria as high temperature test).

4.2.2.3 Test Conclusions

The assembled PVK remained in the same relative condition at the end of each test procedure for both the high and low temperature tests. There was no apparent distortion, warpage or change in the components from a material standpoint or in relation to the overall assembly position. The PVK operated satisfactorily throughout each five minute period after each test series. No binding or looseness of the drive assembly was in evidence. The PVK structurally remained in the stable pretest condition.

Based on the above test results, GARD was confident in the units' operational and storage capabilities under extreme environmental conditions. Copies of the Gaynes Testing Lab reports on the subject test are included in Appendix H of this report.

4.2.3 Deployment Test

The final series of tests performed on the PVK involved the operation of the unit by a number of volunteers within GARD's business operations staff. The volunteers were solicited through an interoffice memo and represented male and female participants unfamiliar with the pedal ventilator kit.

A 40-foot long polyethylene duct of 30-inch diameter was attached to the fan shroud simulating actual shelter operational conditions. The 8-hour test was conducted in two morning sessions on 1 April and 2 April, 1980, as indicated in the test schedule shown in Figure 4-3.

A pedal crank speed of approximately 60 RPM was recommended to the operators for the 15 minute test run. All of the participants maintained this cycle rate during the testing. Photos taken during the performance of the operation test are shown in Figure 4-4. Typical of the comments the operators offered are the following:

- Seat should be higher, legs cramped (5 times)
- Seat uncomfortable (5 times)
- Lefthand pedal loose
- Seems to be hard to pedal
- Easy to operate.

The primary complaint seemed to relate to height of the saddle. GARD will re-evaluate the saddle-to-pedal ratio which is currently fixed for 14 year old-to-adult range. The only mechanical failure that occurred was the loosening of the lefthand pedal. Both pedal mounting threads should be

GATX GARD, INC.

TO Distribution

DATE 27 March 1980

FROM J. M. Buday JMB

SUBJECT PEDAL VENTILATOR TEST
(Two morning sessions on 1 April and 2 April, 1980)

9:00 - 9:15	(1)	M. Sternisha
9:15 - 9:30	(2)	H. Schiller
9:30 - 9:45	(3)	A. Horneck
9:45 - 10:00	(4)	K. Luhmann
10:00 - 10:15	(5)	T. Madanoglu
10:15 - 10:30	(6)	M. Zeszutko
10:30 - 10:45	(7)	R. Groenwald
10:45 - 11:00	(8)	S. Chrapkowski
11:00 - 11:15	(9)	A. Glueckert
11:15 - 11:30	(10)	M. Hagen
11:30 - 11:45	(11)	W. Grayczak
11:45 - 12:00	(12)	B. Roberts

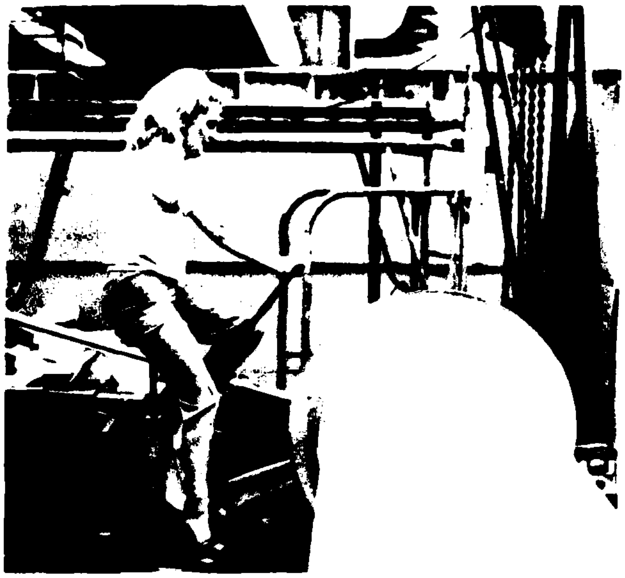
NOTE: Please contact me if the time allotments conflict with your schedule. Wear appropriate clothing for the test.

OPERATING INSTRUCTIONS:

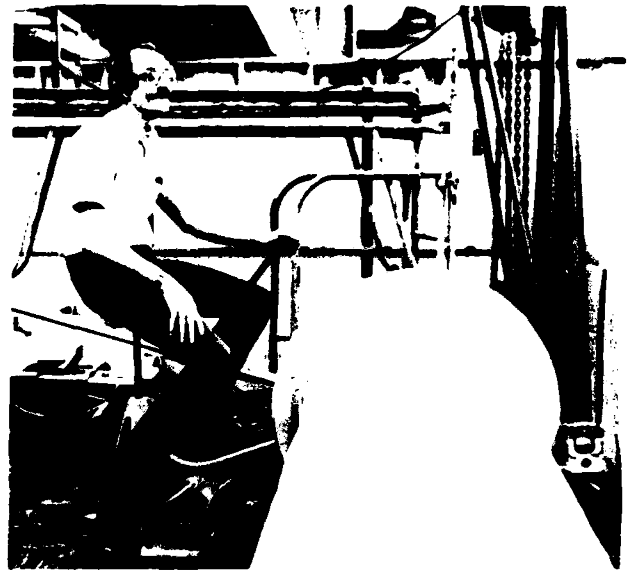
The recommended operational speed is one revolution of the pedal crank per second (60 RPM), but operators should pedal at any speed that is comfortable for the 15 minute duration.

JMB:hr

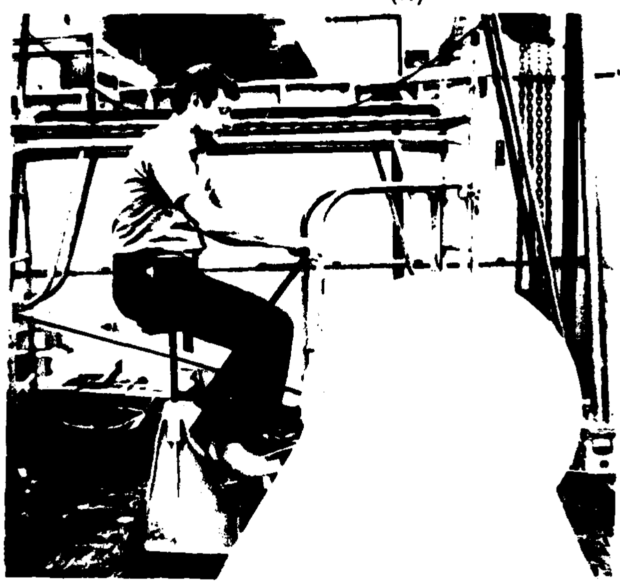
FIGURE 4-3 PVK TEST SCHEDULE



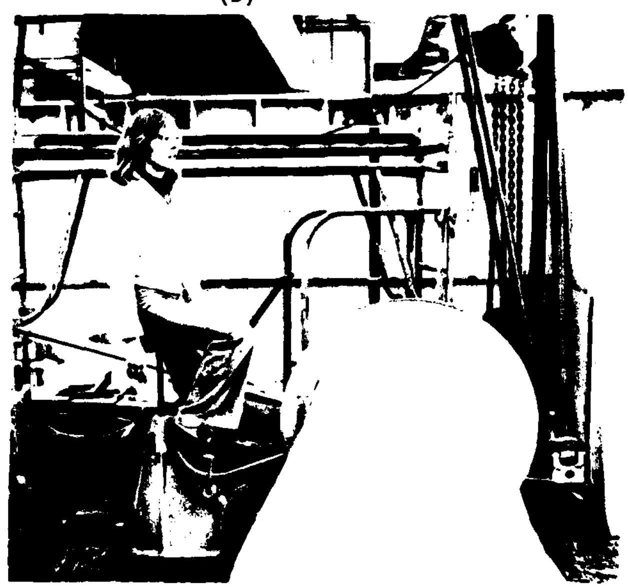
(A)



(B)



(C)



(D)

FIGURE 4-4 PVK OPERATOR DEPLOYMENT TEST PARTICIPANTS coated with Glyptol (locking agent) or equivalent in a production run of the PVK.

None of the 12 participants adjusted the handlebar height during the test. This was true in previous PVK deployment tests. Again, it was apparent that the redeeming feature of the PVK is its imilarity to the everyday bicycle or exercizer. All participants performed the proper operation of the unit without written or oral instructions. Most participants indicated they preferred the fan in front of them,for a more secure feeling as opposed to previous PVK's.

4.3 Packaging Concepts (PVK)

GARD developed several packaging concepts as possible candidates for the PVK. Included are styrofoam cartons, heat shrinkable wrap, and double wall cartons. The new materials incorporated on the PVK are, in general, non-corrosive, thereby allowing for less stringent packaging specifications than required for the steel PVK. Other requirements, such as stacking and warehousing or shipment handling, remain a major consideration. The intent of the packaging effort described here is to generate preliminary design concepts for consideration, recognizing that MIL-SPEC packaging may be too costly. However, the optimization of the package to minimize its cost will require further analysis, prototyping and testing.

4.3.1 Styrofoam Carton - PVK

The styrofoam carton shown in Figure 4-5 is similar to the type developed for the MIL-V-40645 PVK previously developed. The two-part (upper and lower) package has molded matching cavities to nestle the frame and required accessories. The overall dimensions of the package is 63 inches x 38 inches x 12 inches high. The material is 1.5 lb density wide cell styrofoam. The

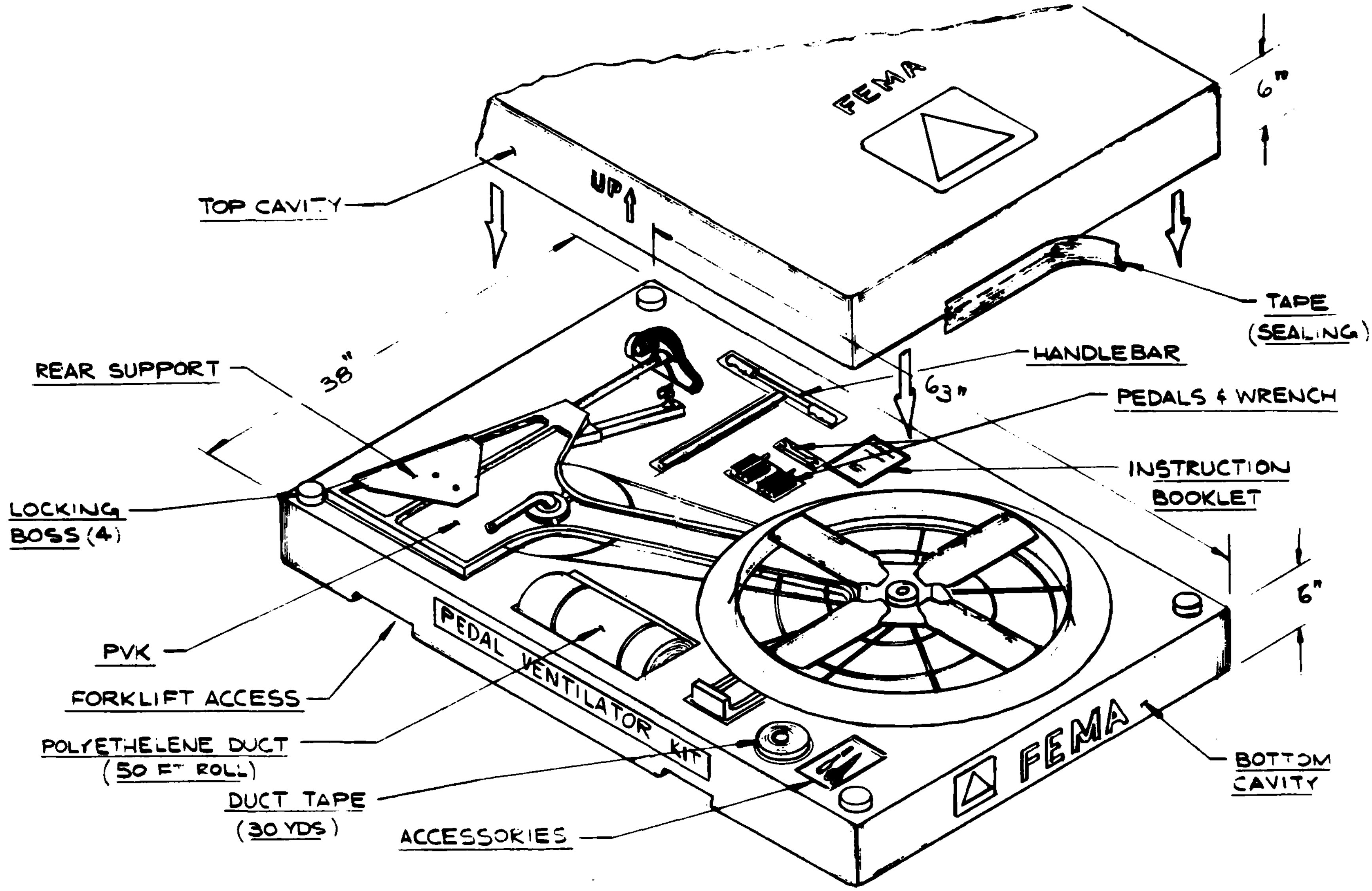


FIG. 4-5 STYROFOAM CARTON-PVK

lower cavity has two forklift access grooves molded in. All identification and logos are likewise cast in. The upper and lower cavities are nestled together and secured with weather-proof tape around the entire outside seam. Locking bosses are cast in the cavities at the four corners to resist shear loads applied to the package.

There are certain advantages in the styrofoam package over other concepts. The design and strength of material allows for stacking the PVK's in a flat mode for warehousing purposes. Stacks of PVK's up to 15 high result in compressive loads of approximately 1300 pounds on the bottom package of the stack. This translates to a loading of 100 pounds per square foot, which is within the structural limits of the packaging foam. In addition, the packaging design completely protects the PVK frame assembly from possibly taking a permanent set from unbalanced loading or stacking. There are also certain disadvantages in the styrofoam concept.

The packaging case as shown represents an estimated cost of $14.70 each in quantities of 100,000 units. The necessary tooling for the mold is approximately $14,500. This cost represents no significant advantage. Also, the PVK, when stored in the styrofoam carton, requires slightly more assembly by shelter occupants. The two pedals, rear support, and the handlebar must be assembled on the main frame subassembly prior to deployment. The degree of difficulty or time involved in this procedure is not considered significant.

4.3.2 Shrink Wrap - PVK

The shrink wrap packaging concept for the PVK is shown in Figure 4-6. This concept offers a lower cost than the styrofoam package discussed in the previous section. However, the protection to the PVK is also somewhat decreased.

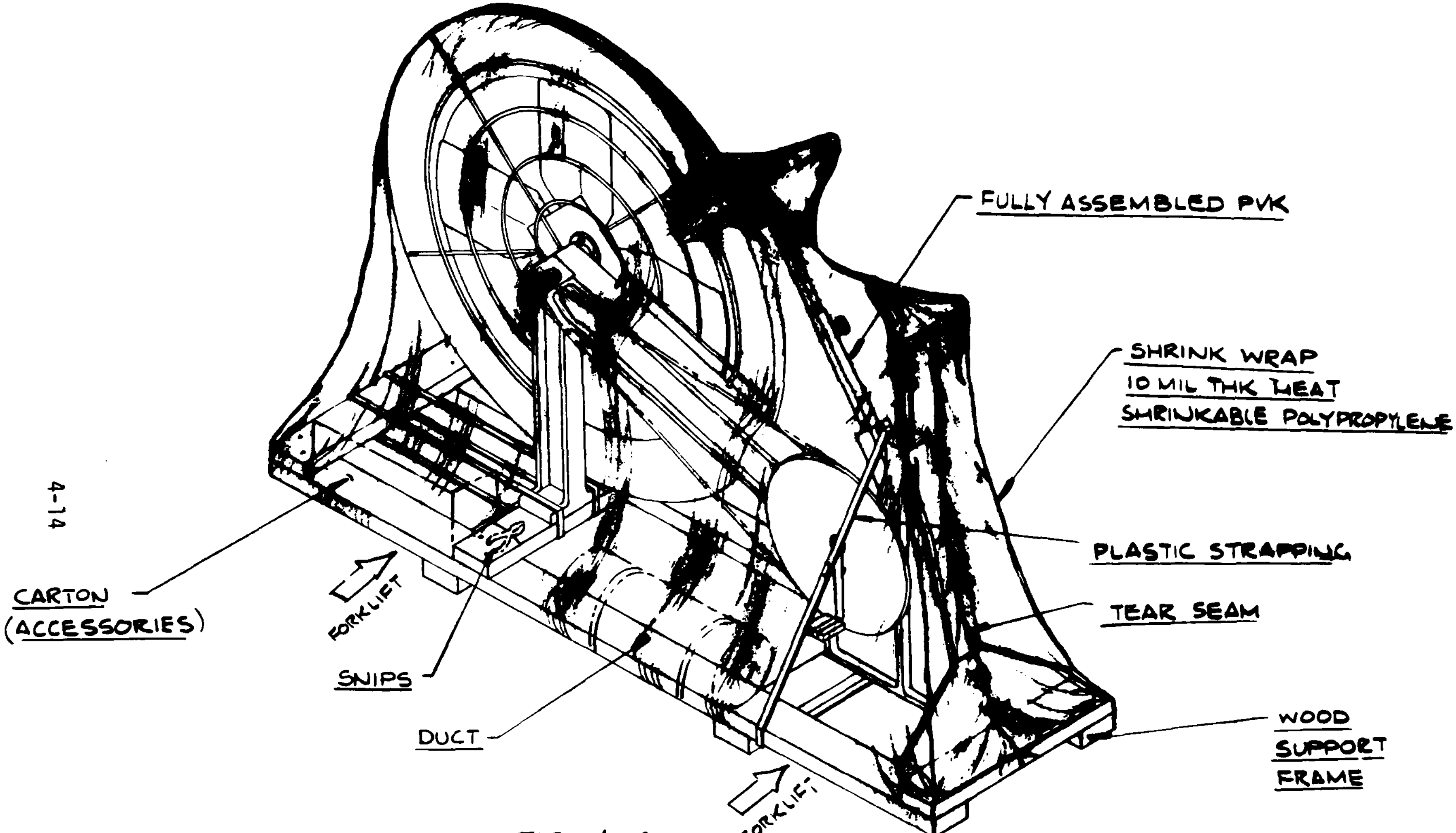


FIG. 4-6
SHRINK WRAP CONCEPT

This design involved a wooden support frame to which the PVK and accessories are secured with nylon retaining straps. The entire assembly (PVK secured to frame) is then automatically encapsulated with heat shrinkable polyethylene, 10 mils thick. The unit is then passed through a heat tunnel which shrinks the enclosing film until a snug fit on the assembly silhouette is obtained. It is suggested that black polyethylene be utilized, since it would aid in restricting ultraviolet attack on the frame should the unit be stored outside for a period of time. The black polyethylene would also restrict identification by the casual observer.

To remove the outside film covering, a tear strip tab is provided to split the enclosure along its length. Once the covering is removed,the snips are accessible for cutting the nylon retaining straps.

The advantages of the shrink wrap design are:

- Lower cost
- PVK is fully assembled (deployment)
- Wrap material can be utilized for blocking openings or apertures
- Damage to unit is detectable through packaging.

The disadvantages of the concept are listed below:

- Not adaptable to stacking (storage)
- Offers less protection to impact, piercing, or handling damage
- Less security (theft) for PVK and accessories.

The estimated cost for the materials involved is $7.50 per unit. Allowing for a $2.50 cost for strap application and construction of the frame, the total cost would be approximately $10.00 per unit. The estimated cost for the shrinkwrap machine and heat tunnel is $95,000.

Although the shrinkwrap concept represents a lower cost, the application is not considered viable unless storage and handling parameters are specified and enforced. The application of shrinkable polyethylene in higher temperature storage conditions would require additional analysis.

4.3.3 Carton Concept

The carton concept shown in Figure 4-7 represents a more conventional approach to containerizating the PVK. Sequence "A" illustrates the PVK assembly secured to a wooden shipment frame with nylon straps. Sequence "B" shows the protective carton being lowered over the PVK. Sequence "C" indicates final application of two nylon retaining straps.

The carton dimensions are 67 inches long x 19.75 inches wide x 43 inches high. It is a 3 sided carton with the bottom open. The carton material is 275 lb test double wall corrugated construction. A sealed bag containing snips to shear the strapping is permanently secured to the exterior of the carton.

The cost of the double wall container is $4.37 each in large quantities. The 2 x 4 frame is estimated at $3.80 with an associated assembly (labor) cost of $2.00. The completed container is estimated to cost $10.17 per unit in a 100,000 procurement purchase.

The double wall carton has sufficient rigidity to allow for stacking the PVK's three high. It also protects the unit from impact and piercing during shipment and storage. The concept as shown represents a viable candidate for conventional packaging of the PVK. However, GARD feels the wooded support frame requires further evaluation for more cost-effective materials.

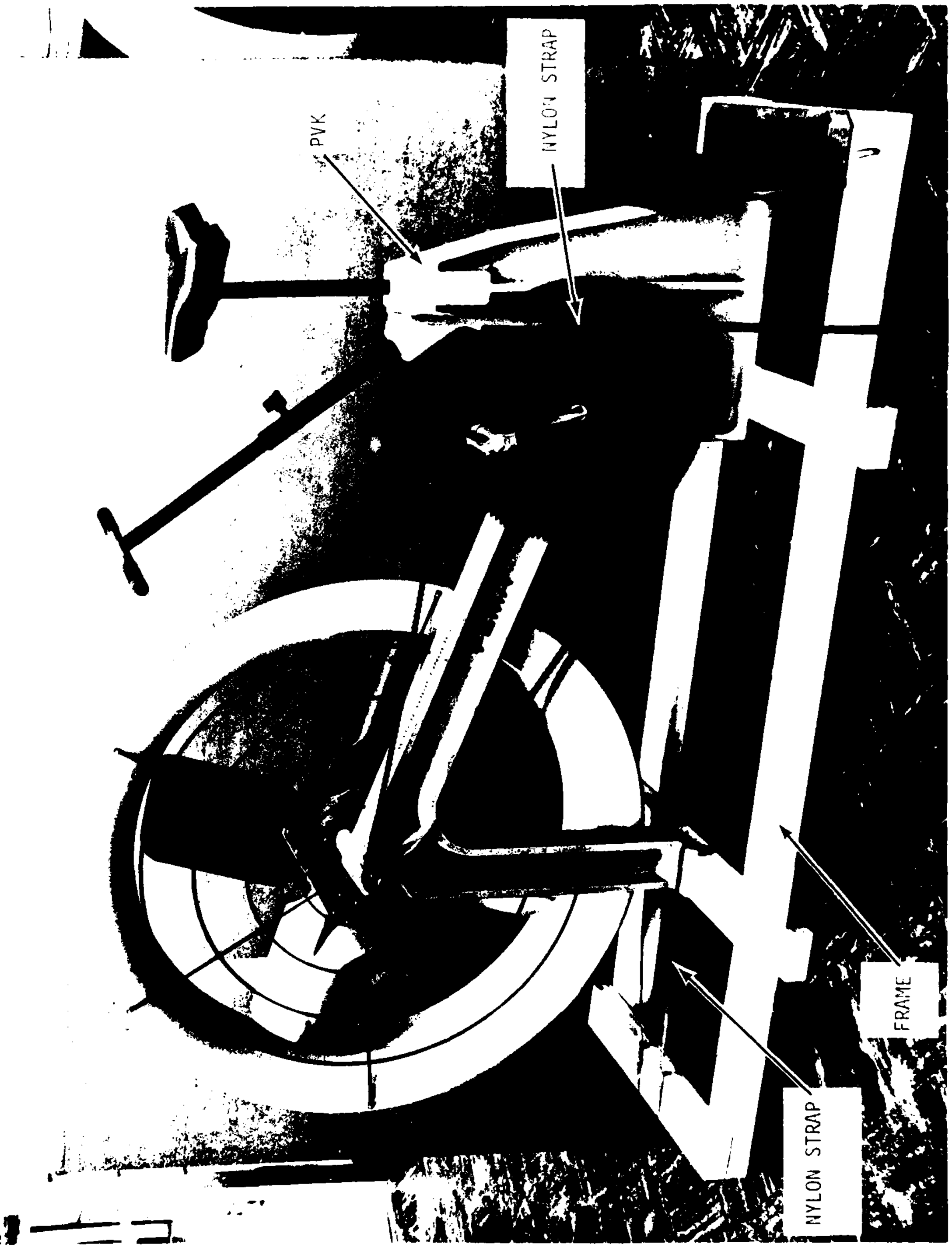


FIGURE 4-7a STEP A

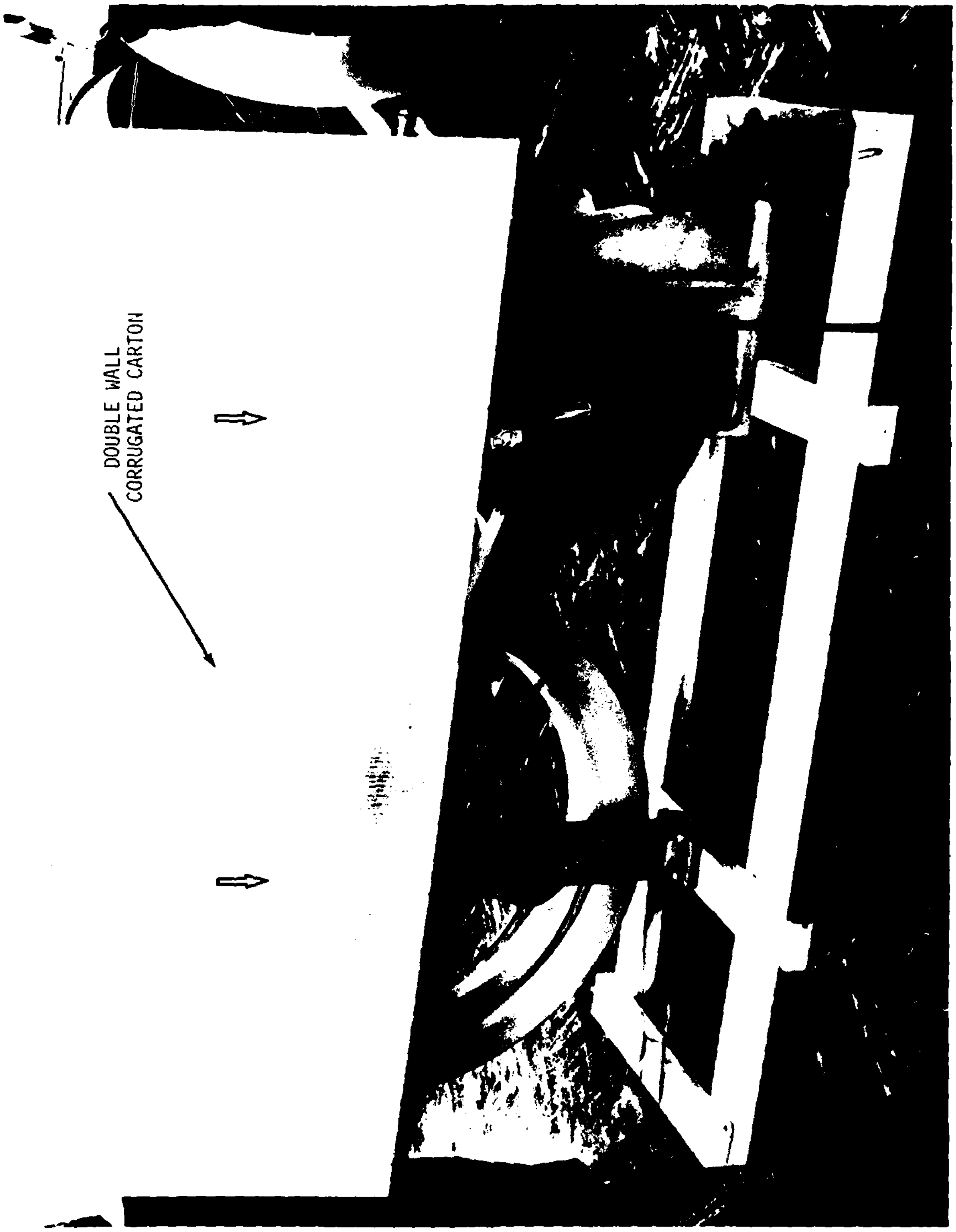


FIGURE 4-7b STEP B

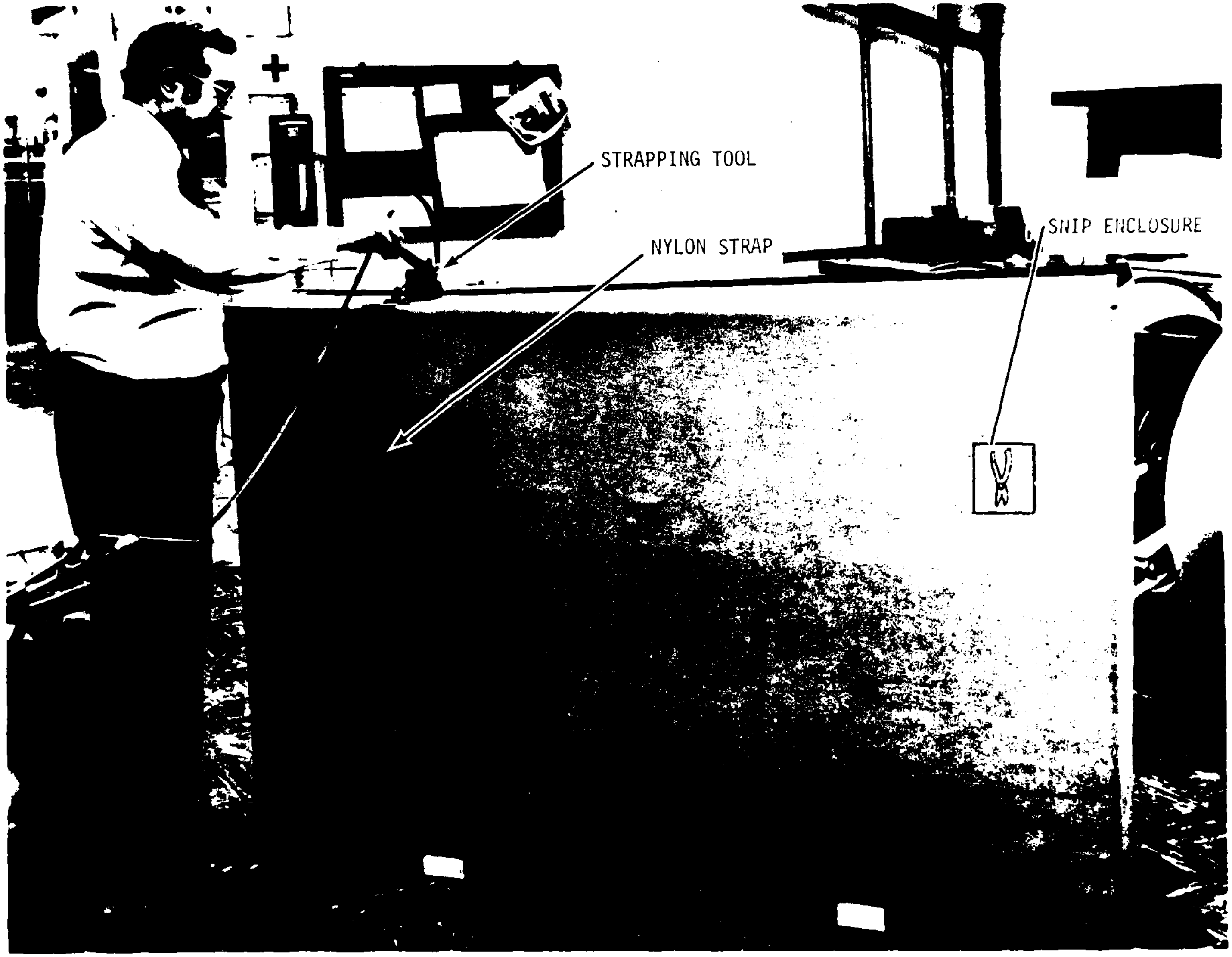


FIGURE 4-7c STEP C

Section 5

PRODUCTION COST ESTIMATES
ALTERNATE MATERIAL PVK

Estimates of production costs for the alternate material PVK were based on a target procurement quantity of 100,000 units each. In addition, the tooling estimates required for part fabrication and production assembly are included. The costs shown, for the majority of items, are derived from actual quotations received from vendors and suppliers based on the above-stated quantities.

The costing includes escalation factors due to inflation applied to certain materials and all labor rates. The cost summary for the alternate material PVK shown in Figure 5-1 includes materials, accessories, labor, burdens, profit and represents the total estimated procurement cost for the complete kit. The last sheet of Figure 5-1 shows the estimated cost savings of $89.38 or approximately 40% over the 1979 (steel) PVK. The steel PVK costs were updated to reflect the same labor rates and escalation factors as the 1980 alternate material PVK.

The concept of a typical PVK production line is shown in Figure 5-2. The estimated output for the line shown is 150 PVK's per 8 hour work day. One operator is required for the bearing hole reaming operation and six operators are positioned at the various work stations along the assembly conveyor. The assembly conveyor indexes every three minutes to a new assembly station. One additional operator (not shown) is required for packaging the PVK and periodically restocking the assembly stations as required. The assembly labor shown in GARD's cost estimates were formulated using the typical assembly line as a guide.

1980 PRODUCTION COST ESTIMATES
(100,000 UNIT PROCUREMENT)
ALTERNATE MATERIAL PVK

DWG/PART#	QTY REQD	DESCRIPTION	COST EA.	COST/ASSY	
FRAME ASSEMBLY - 1724E1001					
1724E1001	1	FRAME, SUPPORT	$ 22.65	$ 22.65	
1724B1003	1	STEM, SADDLE SUPPORT	.70	.70	
1724B1002	1	SUPPORT TUBE, HANDLE BAR	.95	.95	
WT2150	1	WELDNUT, 1/4-20	.05	.05	
25020	2	INSERTS, 1/4-20	.04	.08	
		SUBTOTAL MATERIALS - FRAME ASSEMBLY			$ 24.43
1724E1001	A/R	LABOR(5 MIN) REAMING BEARING HOLES		2.29	
		SUBTOTAL LABOR - FRAME ASSEMBLY			$ 2.29
PEDAL VENTILATOR ASSEMBLY - 1724J1000					
1724E1007	1	SHROUD, FAN	2.01	2.01	
1724C1005	1	DRIVE SPROCKET	3.58	3.58	
1724C1010	1	HANDLEBAR ASSEMBLY	3.80	3.80	
1724D1006	1	GUARD, FAN	5.28	5.28	
1724C1004	1	REAR SUPPORT	1.80	1.80	
1724B1009	1	SHAFT, FAN	1.30	1.30	
1724B1008	1	SPROCKET, FAN	2.35	2.35	
1724B1011-1	1	KNOB, LOCKING	.12	.12	
1724B1011-2	2	KNOB, LOCKING	.12	.24	
1724C1012-1	1	DECAL	.04	.04	
1724C1012-2	1	DECAL	.04	.04	
1724C1012-3	1	DECAL	.04	.04	
1724C1012-4	2	DECAL	.08	.16	
CZ-27	1	SADDLE	1.98	1.98	
FLW12	2	BEARINGS, FAN SHAFT	.17	.34	
2224	1	CRANK ARM	2.66	2.66	
290	2	BEARING CUP	.38	.76	
42	2	BALL BEARING	.60	1.20	
194A	1	ADJUSTING CONE	.45	.45	
194B	1	LOCKING CONE	.45	.45	
367	1	SPACER	.03	.03	
193	1	LOCK NUT	.18	.18	

FIGURE 5-1

354	1	WASHER	.02	.02
7140	2	PEDAL, FOOT	.63	1.26
R-3020-4	1	FAN, 30 IN.DIA	15.54	15.54
ASA #35	A/R	CHAIN, 3/8" PITCH-248P LG.	5.18	5.18
3/4 M	2	GRIPS, PLASTIC	.06	.12
COMMERCIAL	1	ROLLPIN, 3/16"x1 1/4"	.03	.03
COMMERCIAL	4	SCREW,#10,SHT MTL-1/2"LG	.03	.12
COMMERCIAL	5	POPRIVET, 5/32"x1/4" LG	.02	.10
COMMERCIAL	2	NUT,SELF LOCKING,5/16-18	.05	.10
COMMERCIAL	2	SOC.HD.CAP SCREEW 5/16x2 1/2	.15	.30
-	A/R	MISC.PLATING & PAINTING	.85	.85

SUBTOTAL MATERIALS - PEDAL VENTILATOR ASSEMBLY $ 52.43

1724J1000	A/R	LABOR (20 MIN), FINAL ASSEMBLY	9.17

SUBTOTAL LABOR - PEDAL VENTILATOR ASSEMBLY $ 9.17

DUCT

COMMERCIAL	1	POLYETHELYENE DUCT 31" x 0.004 x 50 FT	4.62	4.62
COMMERCIAL	1	PACKAGING, DUCT	.94	.94

SUBTOTAL DUCT $ 5.56

ACCESSORIES

COMMERCIAL	1	DUCT TAPE - 2" x 30 YDS	1.87	1.87
COMMERCIAL	1	SISSORS - 4"	.50	.50
COMMERCIAL	1	LUBRICATING OIL - 1 1/2 OZ.	.22	.22
COMMERCIAL	1	POLYETHELENE BAG	.55	.55

SUBTOTAL ACCESSORIES $ 3.14

FIGURE 5-1 (Continued)

INSTRUCTION BOOKLET

COMMERCIAL	1	INSTRUCTION BOOKLET	.50	.50	
	SUBTOTAL - INSTRUCTION BOOKLET			------ $	.50

PACKAGING

COMMERCIAL	1	INNER BOX	1.98	1.98	
COMMERCIAL	1	OUTER BOX	3.57	3.57	
COMMERCIAL	1	VAPOR BARRIER	1.38	1.38	
1477A6024	1	WOOD LATTICE	1.93	1.93	

	SUBTOTAL MATERIAL - PACKAGING			$	8.80
	A/R	LABOR (10 MIN) - PACKAGING		4.58	

	SUBTOTAL LABOR - PACKAGING			$	4.58

FIGURE 5-1 (Continued)

PEDAL VENTILATOR KIT TOTALS

ALTERNATE MATERIAL PVK

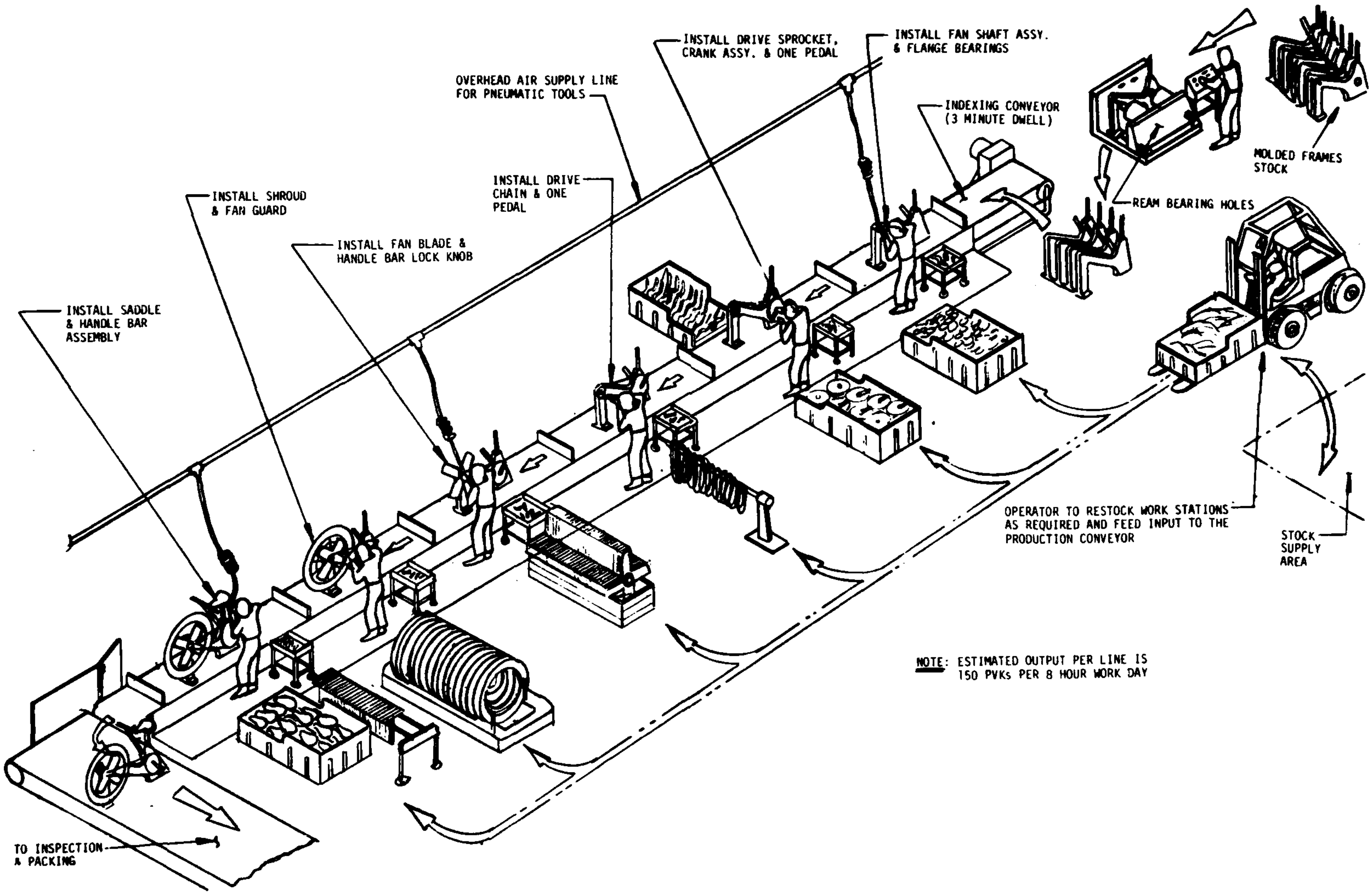
LABOR - 35 MIN @ 27.50/HR =	16.04		
MATERIALS	94.92		
MATL. BURDEN	9.97		
G&A	6.98		
	$ 111.87		
TOTAL COST		$ 127.91	
PROFIT		$ 12.79	
TOTAL PRICE ALT.MATL.PVK			$ 140.70

STEEL PVK (COST UPDATED FOR 1980)

LABOR - 1 HR 35 MIN. @ 27.50/HR =	43.54		
MATERIALS	140.53		
MATL BURDEN	14.76		
G&A	10.33		
	$ 165.67		
TOTAL COST		$ 209.16	
PROFIT		$ 20.92	
TOTAL PRICE STEEL PVK			$ 230.08

COST SAVINGS $ 89.38

FIGURE 5-1 (Continued)



NOTE: ESTIMATED OUTPUT PER LINE IS 150 PVKs PER 8 HOUR WORK DAY

FIGURE 5-2 CONCEPT OF TYPICAL PVK PRODUCTION LINE

The estimated tooling and production equipment costs for the alternate material PVK are shown in Figure 5-3. Included are the approximate lead time frames required for each item. The total tooling and production equipment costs are $217,250. The cost amortized over 100,000 PVK's is computed to be $2.17 per unit.

In addition to the reduction of the PVK manufacturing costs, significant savings can be realized in the shipment/transportation of the unit. The fully assembled alternate material PVK weighs 53 lbs as compared to the previous steel PVK gross weight of 72 lbs. This represents a weight reduction of some 19 lbs.

Based on an overland shipment (truck) charge of 22¢ per pound for a typical 800 mile destination radius, the savings per unit would be $4.18. This translates to an approximate savings of $400,000 in shipment charges for the 100,000 PVK quantities.

ESTIMATED TOOLING COSTS
FOR ALTERNATE MATERIAL PVK

ITEM	DELIVERY	COST
Frame Mold - 4 Cavity	34 weeks	$ 98,250
Shroud Mold - Single Cavity	18-20 weeks	31,000
Drive Sprocket Mold	16 weeks	14,750
Fan Guard Tooling	8 weeks	600
*Handle Bar Mold - 2 Cavity	12-14 weeks	19,850
	Total Tooling:	$164,450

* If plastic handlebar is chosen for production.

PRODUCTION EQUIPMENT REQUIRED
FOR PVK ASSEMBLY (As per Figure 5-2)

ITEM	DELIVERY	COST
Reaming Fixture	16 weeks	$ 12,000
Indexing Conveyor including Drive	20 weeks	21,000
Take-Away Conveyor	12 weeks	6,000
Pneumatic Tools & Supplies	8 weeks	3,800
Special Fixtures for Parts	12 weeks	10,000
	Total Production Equipment:	$ 52,800

Figure 5-3

Section 6

RECOMMENDATIONS

The following recommendations are made as a result of the work completed under this contract.

PRODUCTION DATA PACKAGE

Additional work is necessary to bring the present design to a state of procurement readiness. Specifically, a production data package, quality assurance and documentation control plans are required. GARD recommends the following tasks be conducted:

- o Generate Production Engineering Drawings
- o Generate Master Drawing List
- o Generate Procurement Specifications
- o *Finalize Deployment and Operating Instructions*
- o Generate Quality Assurance Plan
- o Generate Configuration Management Plan
- o Generate Drawing Change Procedure
- o Verify Data Package

PACKAGING

Significant changes have occurred in the packaging industry over the last five years. Specifically, package engineering has developed into a field of its own. Cost-effective methods toward packaging design have been established wherein new packaging techniques and materials have been found. Rather than rely upon a Federal specification to determine packaging requirements, GARD recommends a program to develop a production packaging design that would be economically consistent with the PVK.

REVISED BLAST WAVE EFFECTS TESTING

Major changes in the materials used to fabricate the PVK would require, of course, certain testing to assure the integrity of the unit had not been compromised. Blast wave effects testing performed on earlier designs should also be included to determine the vulnerability of the new design.

The blast vulnerability testing performed in 1971 on existing designs indicated the PVK became inoperative at peak free field flow velocities of 200-300 ft/sec and overpressures greater than 5 psi. The tests were performed in a shock tunnel employing the volume detonation technique with primacord. As the primacord was detonated in a compression chamber, the pressure increased very rapidly and allowed to expand into an adjoining test chamber, where the desired shock wave was generated. Various pressure measurements were taken as a function of time along with high speed motion pictures to obtain flow velocities.

Using the alternate material selected for the PVK and prototypes fabricated, the blast vulnerability test should be repeated on the new design. Materials with a high strength-to-weight ratio will be expected to survive as well as the previous design.

ALTERNATE PVK FAN

The present fan utilized is not cost-effective as compared to related PVK components. The fan's unit cost of $15.54 each in large scale production quantities represents a significant portion (15%) of the total cost of PVK components. In addition, the weight of the fan at 9-1/4 lbs each is 16% of the fully assembled PVK.

The present fan is manufactured by the Torin Corporation located in

Torrington, CT. The fan is comprised of 4 contoured steel blades (30" tip clearance) riveted to a steel spider-type hub. The design of the fan meets the PVK requirements for an exceptionally efficient fan at low speeds (3200 CFM at 480 RPM) with moderate axial depth. This efficiency permits input horsepower as low as .10 HP, which is consistent for the manually powered device.

The Torin Corporation has expressed no interest in revising its materials, design, or providing any options for any one specific customer to reduce the price of the fan. A search of other fan manufacturers revealed no stock fans exist that meet the efficient flow characteristics of the Torin model.

GARD, INC. recommends a program be conducted to develop a fan whose construction and unit cost would be a viable alternative to the Torin model.

PERIODIC REVIEW

Advancements in the state-of-the-art are continually being made in the manufacturing community. CAD/CAM, robotics, and lasers are among the few methods gaining recognition. In a few years, several other techniques and methods will be commonplace which may antiquate the current PVK design. GARD recommends a periodic review and subsequent value engineering analysis of the PVK design.

SUPPORT FRAME

The support frame developed under this contract was structurally tested and found to have a load safety factor of 8:1. The finite element analysis conducted independently by GARD later confirmed the test data. GARD believes this safety factor excessive and recommends the frame be modified. At least 2 lbs of the total material used in the frame can be removed without affecting its structural integrity. The modification would involve an appropriate rework to the aluminum single cavity mold. Nearly $100,000 would be saved in production buys of 100,000 units for every pound of material removed. The $1/unit savings may, in fact, increase, should the petroleum-based polypropylene costs increase as a result of the energy crisis.

Section 7

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6. J. M. Buday and R. J. Klima, "Development of Two Types of Ventilators", DCPA Work Unit 1423E, GARD Final Report 1703, GARD, INC, Niles, Illinois, April 1979.

7. Nicholas P. Cheremisinoff and P. N. Cheremisinoff, Fiberglass Reinforced Plastics Deskbook, 1978, Ann Arbor Science Publishers, Inc.

8. "Thermal Life of Profax 6-23 Polypropylene - Dry Heat Environment" Technical Bulletin PPD-35A; Hercules, Incorporated, Polymers Technical Center, Wilmington, Delaware.

Section 8

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APPENDIX A

PEDAL VENTILATOR KIT

PRELIMINARY SPECIFICATION

PRELIMINARY

LIMITED COORDINATION

MILITARY SPECIFICATION

VENTILATOR KIT, PEDAL OPERATED (FAN TYPE, PVK)

This limited coordination military specification has been prepared by the Federal Emergency Management Agency based upon currently available technical information, but it has not been approved for promulgation as a coordinated military specification. It is subject to modification. However, pending its promulgation as a coordinated military specification, it may be used in procurement (pending incorporation of packaging specifications).

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers the fabrication, assembly, performance, and packaging of a one-operator pedal-operated portable ventilation fan and removable plastic duct, for use in fallout shelters

1.2 Classification. Pedal-operated ventilator kits shall be of one type.

Type 1 - One-operator pedal ventilator kit. (See Figure 1.)

2. APPLICABLE SPECIFICATIONS, STANDARDS, DRAWINGS AND OTHER PUBLICATIONS

2.1 Specifications and Standards. The following specifications and standards of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

GGG-S-278	Shears And Scissors
L-P-378a	Plastic Film (Polyethylene Thin Gage)
QQ-Z-325C	Zinc Coating, Electrodeposited, Requirements For
TT-E-527C	Enamel, Alkyd, Lusterless

STANDARDS

Federal

FED.STD.NO.595	Colors

Military

MIL-STAD-105D	Sampling Procedures and Tables For Inspection by Attributes
MIL-STD-129F	Marking For Shipment And Storage
MIL-STD-171C	Finishing Of Metal And Wood Surfaces

(Single copies of this specification and other product specifications required by activities outside the Federal Government for bidding purposes are available without charge at the General Services Administration Regional Offices in Boston, New York, Atlanta, Chicago, Kansas City, Mo.; Dallas, Denver, San Francisco, Los Angeles, Seattle and Washington, D.C. Copies of the military specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Drawings. One-Operator Pedal Ventilator Kit

J1724-1000	Pedal Ventilator Assy
E1724-1001	Frame, Support
B1724-1002	Support Tube, Handle Bar
B1724-1003	Stem, Saddle Support
C1724-1004	Rear Support, Frame
C1724-1005	Sprocket, Drive
D1724-1006	Guard, Fan
E1724-1007	Shroud, Fan
B1724-1008	Sprocket, Fan Shaft
B1724-1009	Shaft, Fan
C1724-1010-1	Knob, Locking
B1724-1011-2	Knob, Locking
C1724-1012-1	Decal
C1724-1012-2	Decal
C1724-1012-3	Decal
C1724-1012-4	Decal

2.3 Other Publications. The following publications, of the issue in effect on date of invitation for bids, form a part of this specification:

Air Moving and Conditioning Association, Inc.

Publication: AMCA Standard 210
Test Code for Air Moving Devices

(Copies of AMCA publications may be obtained from the Air Moving and Conditioning Association, Inc., 30 West University Drive, Arlington Heights, Illinois 60004.)

3. REQUIREMENTS

3.1 Drawings. Unless otherwise specified herein, the materials and assembly thereof shall be as shown on the drawings (see 2.2); however, minor changes will be allowed. Any minor change or substitution of materials must not affect the rigidity of the unit and the performance requirements specified herein and must be approved by the contracting officer. Drawings are furnished for contractor quidance and informational purposes only to illustrate details of the required equipment. While every precaution has been taken to assure their accuracy, the contractor is responsible for dimensional adequacy and accurate fits for proper equipment assembly, alignment, and operation.

3.1.1 Contents of a Complete One-Operator Pedal Ventilator Kit shall be as follows:

(a) One-operator pedal ventilator, complete
(b) PVK instruction booklet, three copies
(c) Duct, polyethylene, one roll, 30-inch diameter by 50 feet long by 4 mil thick
(d) Tape, duct, pressure-sensitive, one roll, 2 inches wide by 30 yards long
(e) Lubricant, SAE20 oil, 1/1/2 ounces
(f) Scissors, one pair, 4-inch

3.1.2 <u>Frame Fabrication</u>

The frames, support as defined in Drawing No. E1724-1001 shall be fabricated to the specifications below.

3.1.1.1 Base Material - Polypropylene, heat stabilized homopolymer premixed resin, Hercules No. 6524 premix or equivalent.

3.1.1.2 Glass Reinforcement Material - 1/4 inch long chopped strand glass fiber, Owens-Corning No. K885 or equivalent, 1/4 inch chopped strand BB bundle size.

3.1.1.3 Pigment - The pigment shall be powered or pelletized concentrate Polychrome No. 75-8955 blue or equivalent.

3.1.1.4 Mix Ratio - The material mix ratio shall be 83% $\pm$ 2% baseresin, and 15% $\pm$ 2.5 % chopped glass fiber, and 1% to 2% pigment.

3.1.1.5 Process - Pressure bulk injection molded

3.1.1.6 Inserts - The stem, saddle support (B1724-1003), support tube, handlebar (B1724-1002) and (2) inserts No. 25020 shall be molded into the frames as per Drawing No. E1724-1001.

3.1.1.7 Finishing - After the frames are removed from the mold, all sprews or runners shall be removed and the part deflashed.

3.1.3 Metal Fabrication. Metal used in the fabrication of the equipment shall be free from kinks. The straightening of material shall be done by methods that will not cause injury to the metal. Shearing and chipping shall be done neatly and accurately. Corners shall be square and true.

3.1.4 Machine Work. Tolerance and gages for metal fits shall conform to the limitations specified herein and otherwise to the standards of best commercial practice. Finished contact and bearing surfaces shall be true and exact. Adequate gages shall be utilized to assure proper joint fit, interchangeability, alignment, chain tension, and fan concentricity with respect to the shroud.

3.1.5 Bolted Connections. Bolt holes shall be accurately punched or drilled and shall have the burrs removed. All bolts, screws and nuts shall be tight.

3.1.6 Welding. The surfaces of parts to be welded shall be free from rust, scale, paint, grease and other foreign matter. Welds shall develop adequate strength in the parts connected.

3.1.7 Heat Treatment. As specified on drawings.

3.1.8 Painting and Finishing. Major units and subassemblies shall be painted or finished as specified herein or on drawings.

3.2 Fan. The fan diameter shall be 30.00 $\pm$ 0.05 inches, the leading and trailing edges shall be in line within 0.11 inches and shall be statically balanced within 0.16 ounce-inches. The fan rotation shall be clockwise (facing air discharge), and the leading edge shall be from 1/8 tp 1/4 inch from the air discharge side of the shroud such that the fan does not project beyond the shroud. The fan shall be equal to and interchangeable with the Torin Manufacturing Co., fan number R-3020-4. Any substitution shall meet or exceed performance requirements stated in Figure 2.

3.3 Transmission. The ratio of fan shaft speed to pedal speed shall be approximately 7.7/1. The chain shall be American Standards Association No. 35. All chains shall be endless riveted.

3.4 Saddle. The seat shall have full three point spring suspension, and shall be a minimum of 9 inches long and 9-3/4 inches wide. The top shall be vinyl covered, rubber padded. The seat clamp shall be 7/8 inch dia. and the nut shall be hexagon, 9/16 across the flats. The saddle shall be finished by the standard methods of the manufacturer.

3.5 Accessories.

3.5.1 PVK Instruction Booklet. Each ventilation kit shall include three copies of the PVK instruction booklet. This publication will be furnished by the Federal Emergency Management Agency at the time of the contract award.

3.5.2 Duct, Polyethylene. One roll polyethulene duct, 30-inch diameter by 50 feet long by 4 mil thick with a flat dimension of 48 inches conforming to Type II, Grade C, Finish 1 of L-P378 shall be supplied with each ventilator unit.

3.5.3 Tape, Duct. One roll of pressure-sensitive duct tape, 2 inches wide by 30 yards long shall be furnished with each kit. The duct tape shall conform to PPP-T-60, Type III, Class 1, such as gray color Arno brand or equivalent.

3.5.4 Lubricant. One and one-half (1-1/2) ounces of SAE20 lube oil in a clear plastic container shall be furnished with each kit. The container shall be approximately 1 inch by 4-5/8 inches, and shall have a blind dispenser tip head.

3.5.5 Scissors. Contractor will furnish one 4-inch, blunt point scissors with each kit. Scissors shall be in accordance with GGG-S-278, Type II, Class 3, Style A and/or Style B, Size 4.

3.6 Lubrication at Assembly. The crank bearings shall be permanently lubricated with a lubricant formulated with a non-soap, organic-type thickener (di-amide-carbonyl) such as American Oil Company "RYKON" Grease No. 2. The grease shall be suitable for long shelf life stability without further lubrication during use.

3.7 Finish and Color. All parts shall be free from burrs, roughness, and rust. The subassemblies and assemblies, where a painted finish is required, shall be finished as follows unless other wise noted herein or on the drawings:

Cleaning - Finish 4.2 of MIL-STD-171.
Surface Treatment - Finish 5.3.1.3 or MIL-STD-171.
Prime - Finish 5.2 of MIL-STD-171.
Finish - One coat, enamel, Alkyd, Lusterless per fed. Spec. TT-E-527C, Black finish No. 37038.

The fan shaft sprocket, and fan shaft shall be finished as follows:

Zinc plate per QQ-Z-325, Class 2, Type II with clear chromate treatment.

3.8 Marking. Specific markings on the pedal ventilator shall be made by decal companies applied per instructions on the assembly drawing.

3.9 Workmanship. All materials used in the unit shall be of good commercial quality, entirely suitable for the purpose intended. The units, including all accessories, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of machining, fitting of parts, welding, riveting and marking of assemblies. Visual defects shall be cause for rejection.

3.10 Preproduction Sample. When specified in the contract or order (see 6.2) before production is commenced, a sample kit shall be submitted or made available to the contracting officer or his authorized representative for approval in accordance with 4.2. The approval of the preproduction sample authorizes the commencement of production, but does not relieve the supplier of responsibility for compliance with all applicable provisions of this specification. The preproduction sample shall be manufactured in the same facilities to be used for the manufacture of the production items.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection Responsibility. The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Preproduction Sample Inspection. When a preproduction sample is required, it shall be examined in accordance with applicable paragraphs of Section 3 and Section 4 (with laboratory tests at the contractor's expense). A two-week endurance test shall be required for the fan and transmission used in the preproduction model, if these components are different than the prototype components suggested for use in 3.2 or on drawing J1724-1000.

4.3 Production Inspection.

4.3.1 Performance. The inspector shall ascertain the units meet the performance requirements specified herein.

4.3.2 Workmanship. The units shall be inspected for rigidity, chain tension, alignment, interference of components, finish, color (see 3.7) and marking (see 3.8).

4.3.3 Packing and Marking.

4.4 Tests. If there is any change or substitution in the fan-shroud assembly, or transmission, other than the prototype components suggested for use in 3.2 or on Drawing J17241000, then performance tests for these items shall be required.

4.4.1 Fan Assembly Performance. The fan-shroud assembly shall be tested per AMCA Standard 210 at 480 RPM and shall have the performance characteristics shown in Figure 3.

4.4.2 Packaging.

4.5 Quality Conformance Inspection.

4.5.1 Lot. A lot shall consist of one day's production or all units offered for acceptance at one time.

4.5.2 Sampling for Examination. Sampling for examination shall be in accordance with MIL-STD-105. For major defects the AQL shall be 2.5 percent defective units, at inspection Level II. For minor defects, the AQL shall be 6.5 percent at inspection Level I (or S_2 for standard parts). Each minor characteristic shall be considered separately for acceptance of the lot.

4.5.2.2 Sampling for Tests. Sampling for tests shall be in accordance with MIL-STD-105 at inspection Level II. The AQL shall be 1.0 percent defective.

4.5.3 Examination. Each unit selected in accordance with 4.5.2.1 shall be examined for defects listed in Table I. Any sample having one or more defects shall be considered a defective unit.

TABLE I

CLASSIFICATION OF DEFECTS

Category	Defect
Major	
101	Packaging not acceptable
102	Package marking not as specified
103	Welds not acceptable
104	Chain too tight; will not fit sprockets
105	Components or hardware - including PVK instruction booklets - missing
106	Handle bar will not fit in front support leg.
107	Incorrect number of teeth in the sprockets
108	Material not as specified
109	Dimensions not as specified
110	Metal fabrication not suitable
111	Workmanship not acceptable
112	Finish not as specified or acceptable
113	Drive chain too loose
Minor	None

4.5.4 Function Tests. Samples selected in accordance with 4.5.2.2 shall be tested as specified herein. Any sample failing to pass any test shall be considered a defective unit.

4.5.4.1 Operate the ventilator at the normal pedaling rate of 60 RPM. Check for the following defects:

(a) Chain too loose
(b) Sprockets out of line
(c) Fan hitting the ground
(d) Fan hitting the fan guard
(e) Loose parts
(f) Bearings too loose
(g) Bearings too tight

4.6 Inspection of Preparation for Delivery. The contents, preservation, packaging, and marking shall be inspected to determine compliance with the requirements of Section 5 of this specification. (packaging to be determined)

5. PREPARATION FOR DELIVERY - (To be Determined)

6. NOTES

6.1 Intended Use. Pedal ventilator kits are intended for use in identified fallout shelters to provide the necessary ventilation air to maintain thermal and atmospheric control of the shelter's environment during a national emergency.

6.2 Ordering Data. Procurement documents should specify the following:

(a) Title, number and date of this specification
(b) Number of assemblies required
(c) Contract point for PVK instruction booklets (See 3.5.1)
(d) Whether preproduction sample is required. (See 3.10)

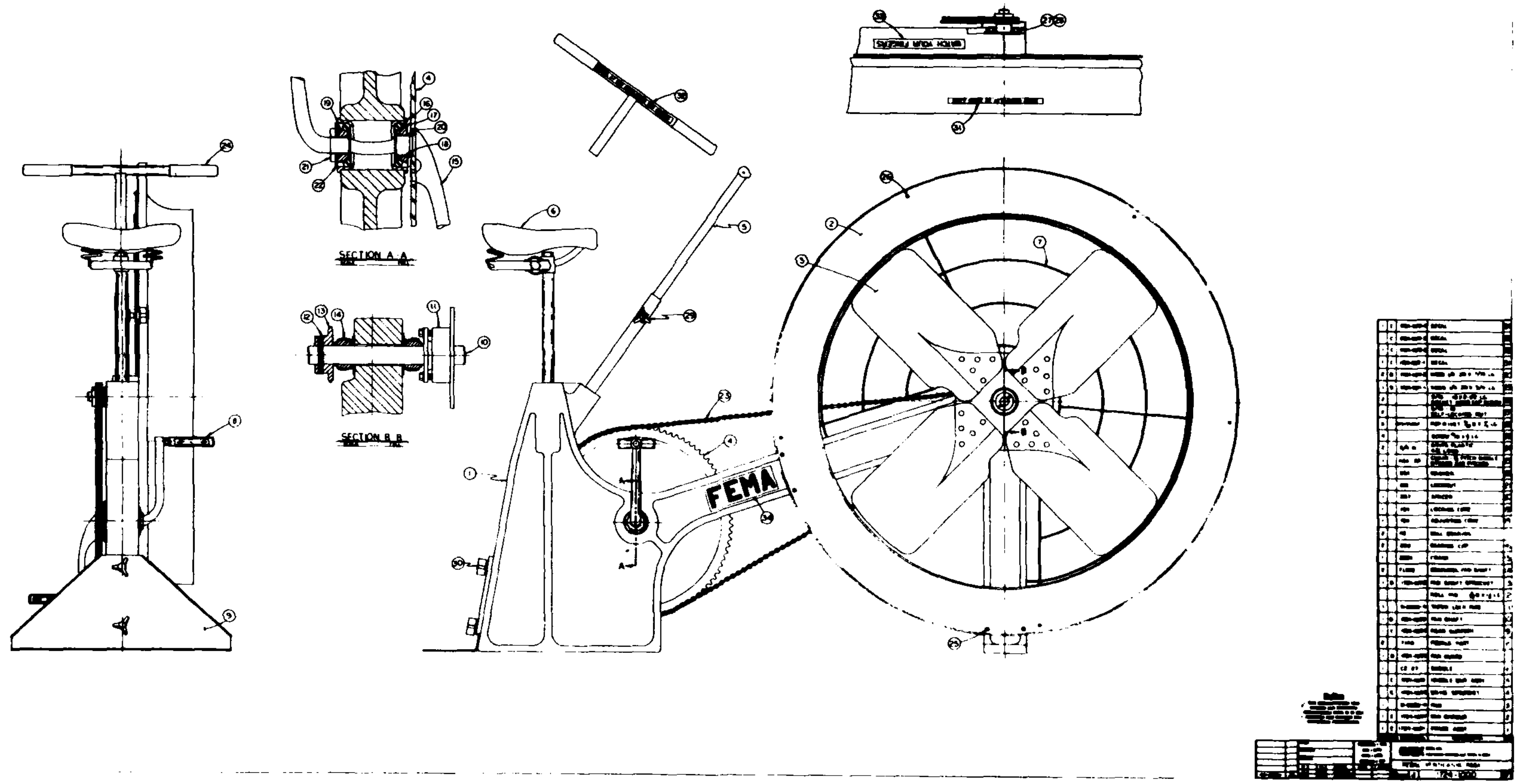


FIGURE 1 PEDAL VENTILATOR KIT (PVK)

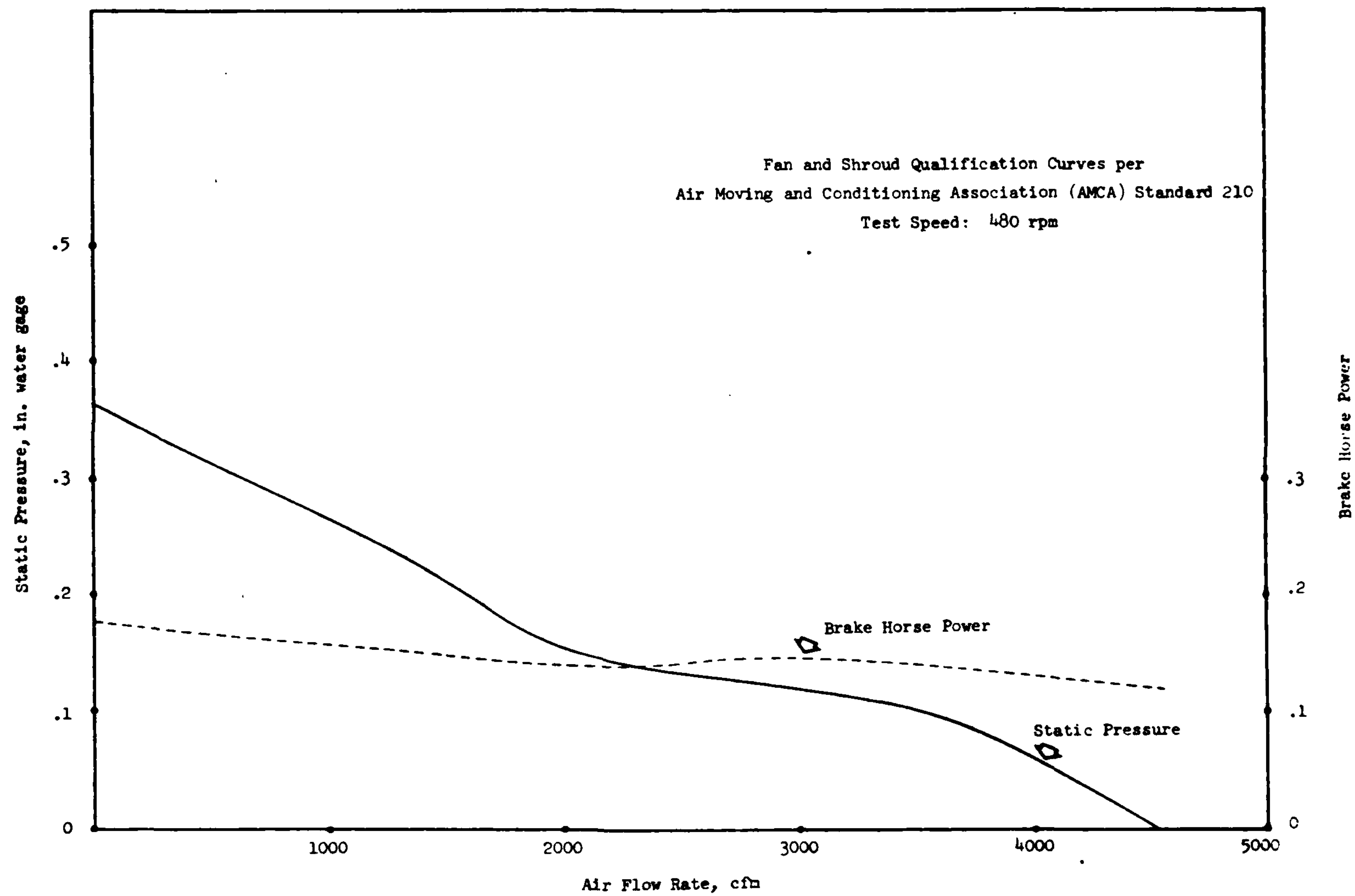


Figure 2 FAN AND SHROUD QUALIFICATION CURVES, ONE-OPERATOR PEDAL VENTILATOR

APPENDIX B

PEDAL VENTILATOR KIT
PRELIMINARY OPERATING INSTRUCTIONS

PEDAL VENTILATOR INSTRUCTIONS

LOCATION — ASSEMBLY — OPERATION

LIFE SAVING INFORMATION

DO NOT UNPACK VENTILATOR UNTIL INSTRUCTIONS SAY TO

YOU MUST DETERMINE THE LOCATION OF THE VENTILATORS NOW, OR THE GREAT NUMBER OF PEOPLE MAY CAUSE THE SHELTER TO BECOME TOO HOT TO OCCUPY WITHIN ONE HOUR.

READ INSTRUCTIONS PAGE BY PAGE AT ONCE !
FOLLOW THESE STEPS:

1. DETERMINE VENTILATOR LOCATION
2. MOVE BOX TO LOCATION
3. UNPACK BOX
4. ASSEMBLE VENTILATOR DUCT
5. OPERATE VENTILATOR CONTINUOUSLY

FEDERAL EMERGENCY MANAGEMENT AGENCY

The THREE people holding these Pedal Ventilator Instructions should work together as a team to set up ventilation.

Each team member must read the instructions now and follow all directions.

Decide any questions by talking it over and voting.

Should a Shelter Manager be present, follow his orders.

<u>IMPORTANT!</u> <u>BEFORE READING FURTHER</u>

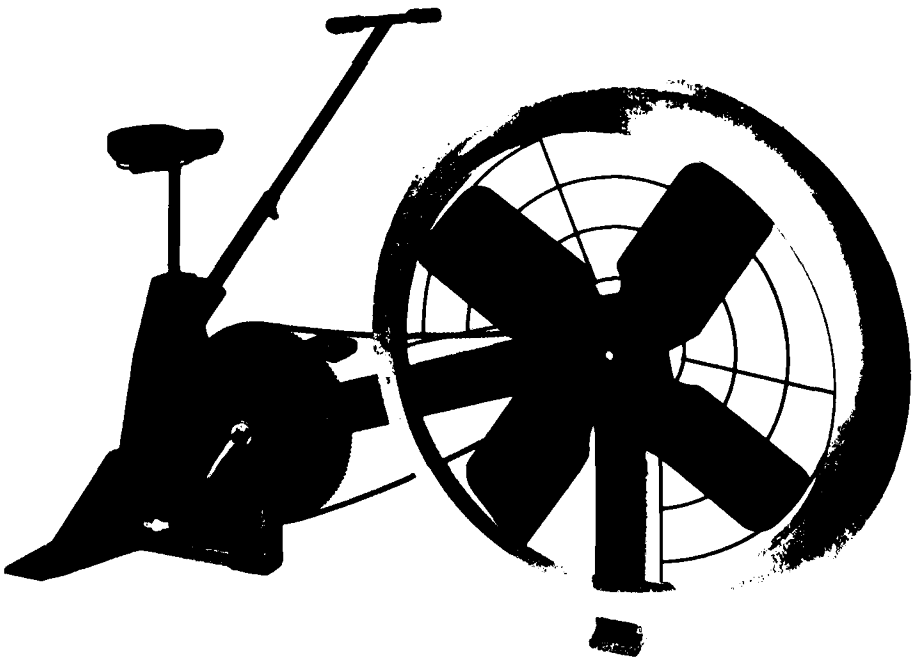
Assemble rear support plate to frame using two (2) threaded locking knobs as shown.

READ CAREFULLY!

- The fallout shelter you are in, may have one room or a number of rooms and areas together. You may have to stay in this shelter for several days or longer.

- Use the Pedal Ventilator (shown below) and the plastic exhaust duct (packed with it) to remove hot, stale air from shelter so fresh air can enter.

- Incoming, fresh air will be safe! After Ventilator is operating, if you are uncertain about radiation effects and shelter ventilation, use appendices at back of booklet. NOT NOW!



PEDAL VENTILATOR

DETERMINE BEST LOCATIONS FOR VENTILATORS

DO NOT UNPACK VENTILATOR YET

LOCATION PRINCIPLES

1. Pedal Ventilator has two parts:

   a. A fan to exhaust hot, stale air from shelter,

   b. A duct to carry this air out of shelter.

   Fresh air then enters shelter from doors, windows or other openings to replace hot, stale air.

2. There must be at least one outside opening so fresh air can create flow paths from outside opening(s) to fan of Pedal Ventilator.

3. You must set up your ventilation system to make fresh air paths go through as much of the shelter as possible. To learn how to do this, read every word of the following section. THIS IS VITAL!

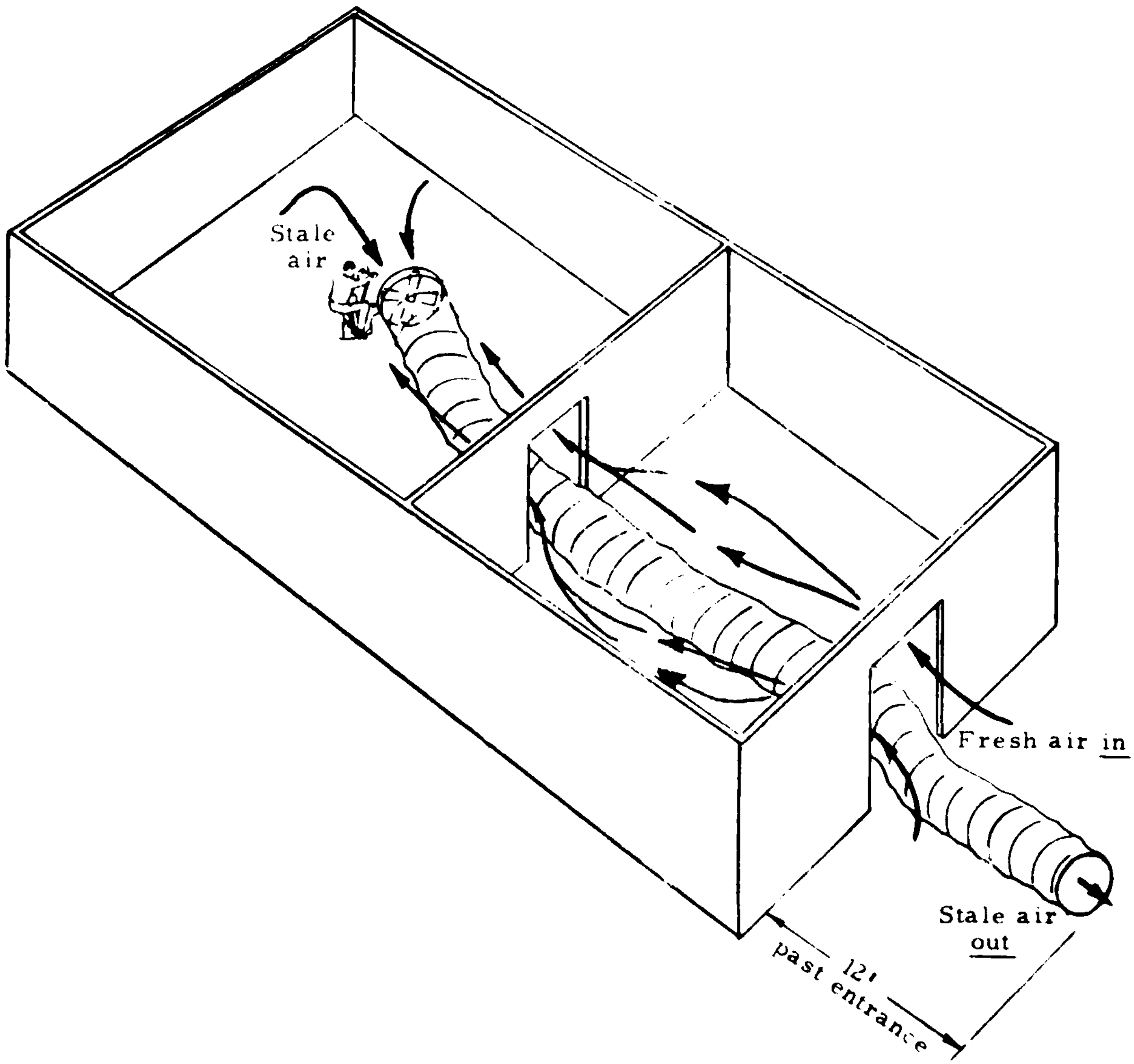
   The following models of shelters show how to locate the Ventilator in different types of shelters. Although the models may not be similar to the shelter you are in, each illustrates important location principles and should be studied carefully.

WHERE TO LOCATE

1. When Ventilator is placed inside a shelter or room with only one opening to outside air:

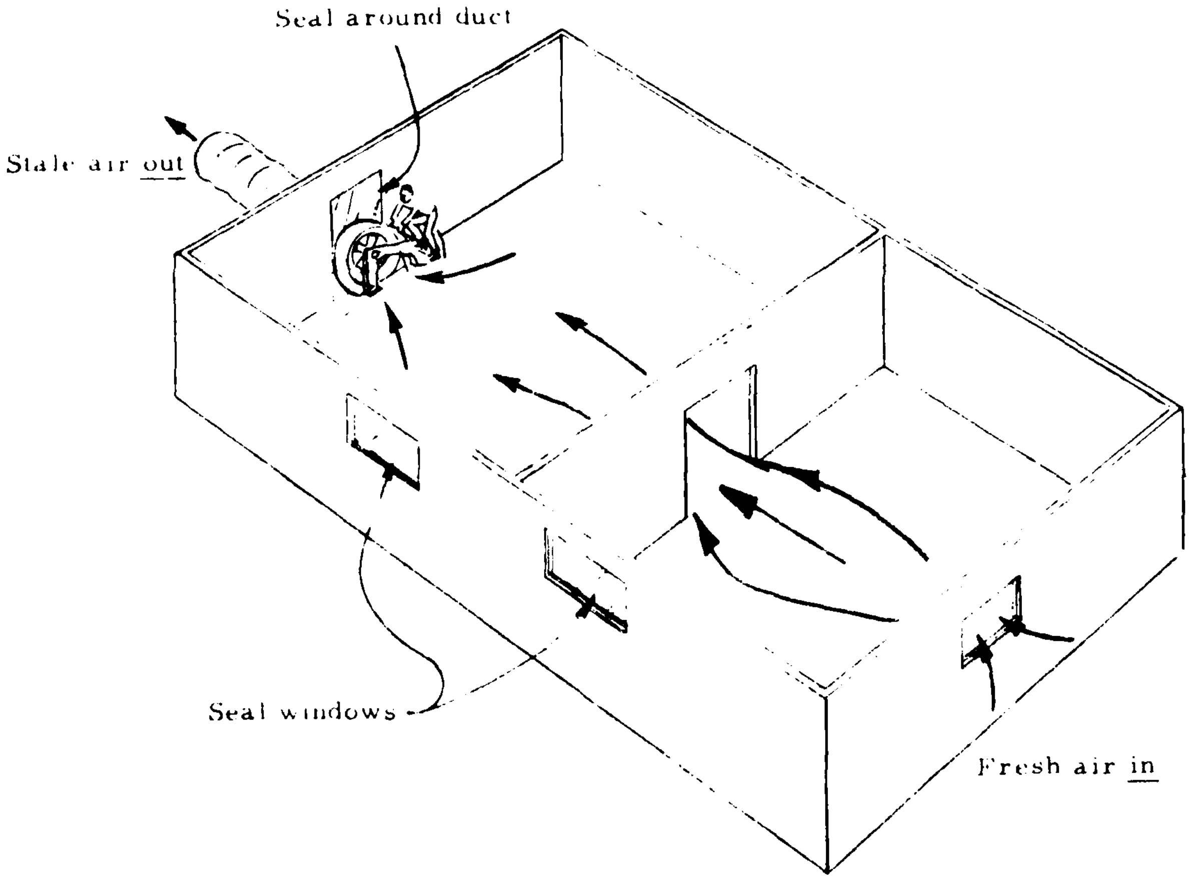
   - Place Ventilator as far from outside opening as possible, as long as 12 feet of duct can extend past shelter entrance.

   - DO NOT seal openings.



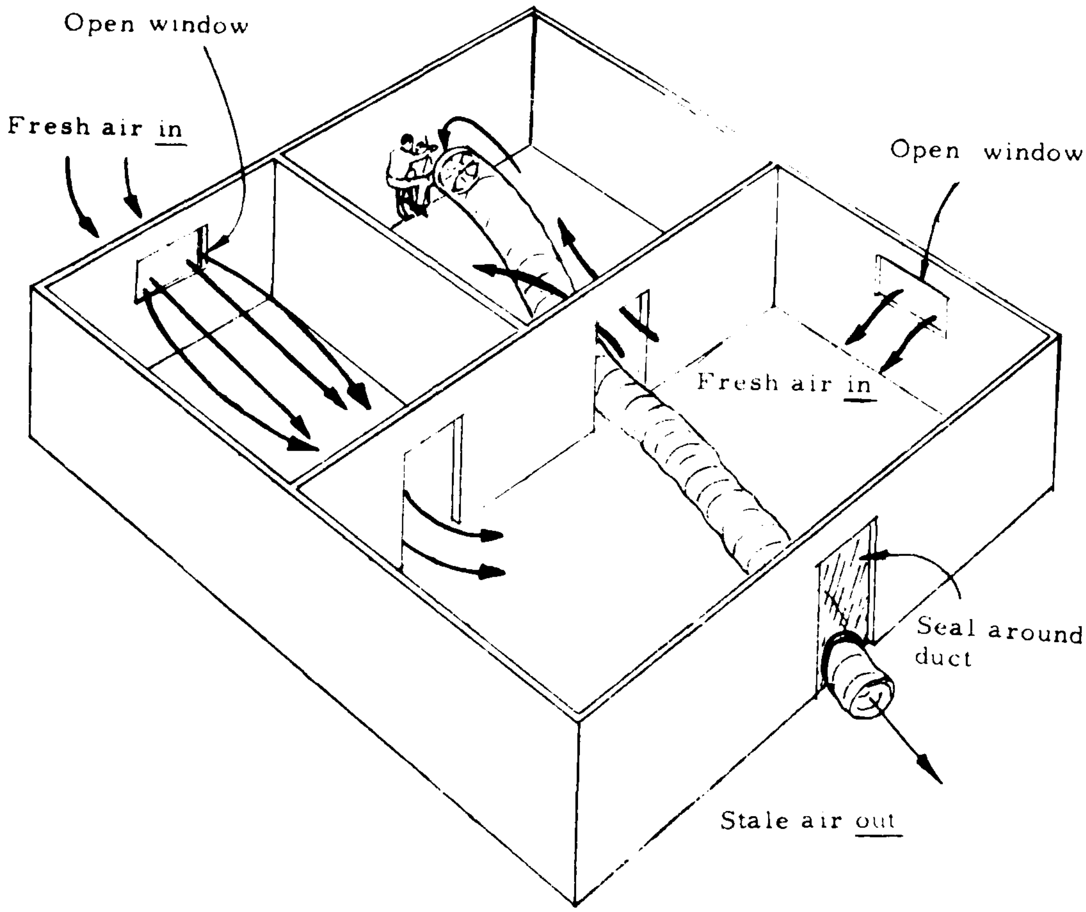
2. <u>When Ventilator is placed inside a shelter or room with more than one opening to outside air</u>:

- Seal all but the two openings which will form the longest air flow path between them,
- Place Ventilator right next to opening where duct will exit,
- After Ventilator and duct are in place, seal opening around duct.



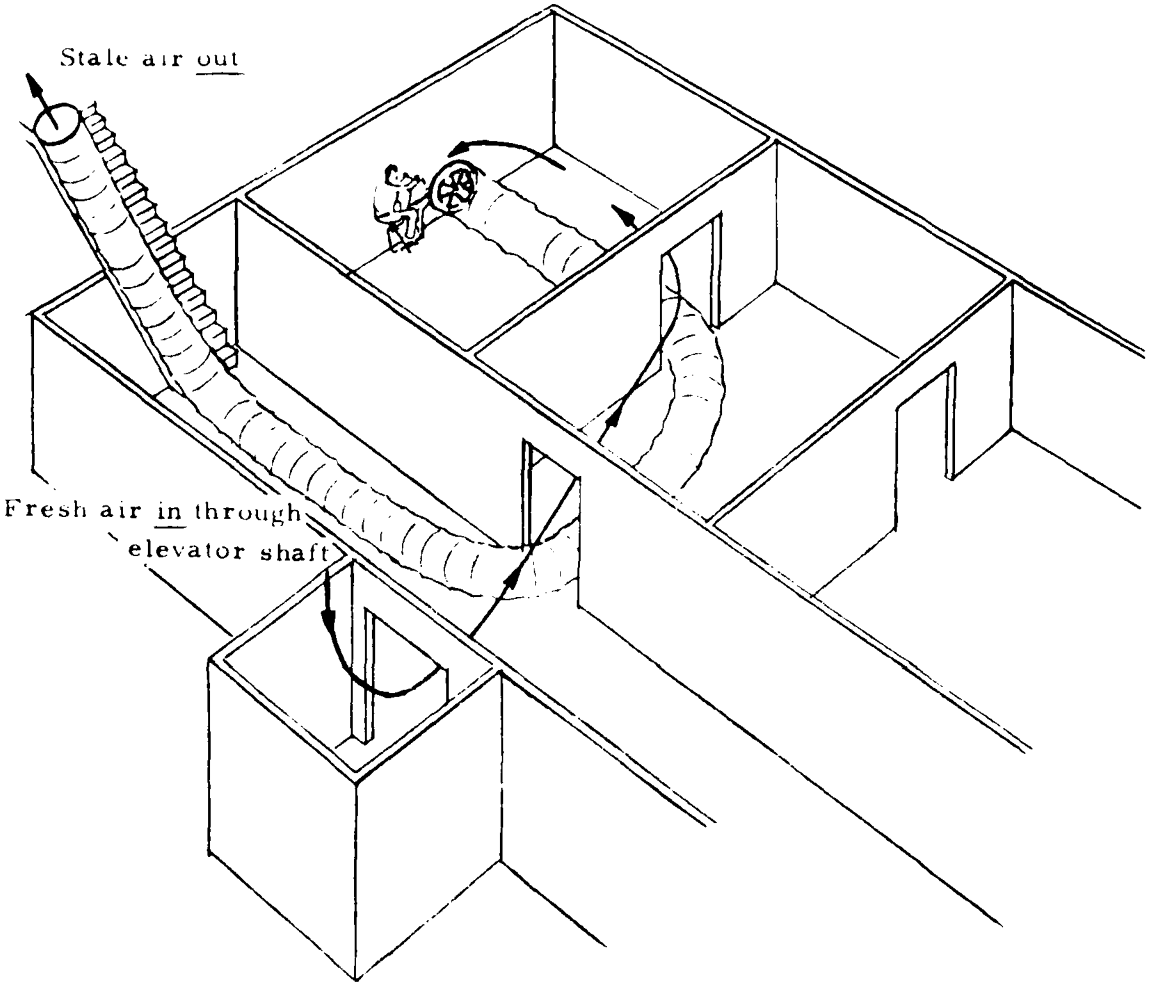
Models 3 and 4 show how to apply the principles of models 1 and 2 to shelters with several rooms.

3. Shelter with Three Rooms



- Stale air is pulled in by Ventilator and blown out through duct.
- Fresh air enters shelter through open windows.
- Note seal around duct, and Ventilator in corner, to create longest possible flow path.

4. Basement Shelter without Direct Opening to Outside



- Stale air is pulled in from basement by Ventilator and blown out through duct which is run up stairs.

- Fresh air enters through elevator shaft.

- Ventilator is placed as far from elevator shaft as possible.

NOW, FIND

—SHELTER BOUNDARIES

—ALL FRESH AIR OPENINGS

THEN:

1. DETERMINE VENTILATOR LOCATION
2. MOVE BOX TO LOCATION

ASSEMBLY INSTRUCTIONS

<u>AFTER</u> YOU HAVE PLACED
BOX IN PROPER LOCATION,

UNPACK AND ASSEMBLE,
USING THESE INSTRUCTIONS

READ ALL DIRECTIONS BEFORE WORKING ON EXHAUST DUCT

DO NOT UNROLL DUCT UNTIL INSTRUCTIONS SAY TO.

DO NOT WALK ON DUCT AT ANY TIME. IT WILL RIP!!

NEVER HANG DUCT, LEAVE IT ON FLOOR

Duct must run from Pedal Ventilator to outside of entire shelter area (through a window, doorway or other large opening). Avoid sharp bends in duct!

If an attack has already occurred and you think that there is radiation outside the shelter:

> Consult with radiation monitor or shelter manager before leaving shelter.
>
> If there is no advice available about radiation and you must leave the shelter, then leave it only for short periods and return as quickly as possible.

REMEMBER:

1. If fresh air comes in from same outside opening that duct passes through,

   Duct must extend 12 feet past outside opening.

   DO NOT SEAL opening.

2. If fresh air comes in from outside opening other than those which duct passes through, SEAL opening around duct, and other openings as necessary. It is not necessary to extend duct beyond a seal.

Connecting Duct

- Unroll a few feet of duct and stretch end of duct around fan ring.
- Secure duct end in place with several pieces of duct tape.

- Form complete duct-ring attachment by unrolling and securing duct tape around entire fan ring.

Laying Out Duct

- Without leaving shelter, unroll remaining duct and cut to size. Be sure to cut off enough duct for sealing purposes.

- Use duct tape to form a complete ring around free end to prevent tearing.

- Leave shelter to extend duct 12 feet past outside opening; adjust location of Ventilator if necessary. Tape down bottom of free end with several strips of duct tape, as shown below. Save excess tape and return to shelter as quickly as possible.

- Check duct and straighten out sharp bends.

- Use excess duct material and duct tape to make seals for windows, doors or around duct. Cut and tape material to form air-tight seal.

Operating Pedal Ventilator Manually

- If ventilator is pedalled, pedal at one revolution each second, as if you were riding an ordinary bicycle.

- Operate the ventilator continuously and keep children away.

Duct

- When ventilator is operating, duct must be inspected periodically for leaks which must be sealed with duct tape.

- Prevent duct damage by keeping people away from it.

APPENDIX C

TEST PROCEDURES - LOW TEMPERATURE
PVK FRAME

TEST PROCEDURES - LOW TEMPERATURE

PVK SUPPORT FRAME

1. METHOD - The testing method utilized is in conformance with method 502.1 of MIL-STD - 810C.

2. PURPOSE - The low temperature test is conducted to determine the effects of low temperature on the PVK support frame during storage (without protestive packaging) and service use.

3. TEST APPARATUS - Temperature chamber (sealed).

4. TEST ITEM - Five (5) separate PVK frames to be tested simultaneously with identical temperature and time duration. The five frames will be identified as follows:

   4.1 - Polypropylene (unfilled)
   4.2 - Polypropylene (15% glass filled)
   4.3 - Polypropylene (20% glass filled)
   4.4 - Polypropylene (30% glass filled)
   4.5 - Nylon/12 (30% glass filled)

5. TEST PROCEDURE

   5.1 Place the five (5) support frames specified in item 4 into the temperature chamber. The frames shall be in the operational position (vertical) supported by the rear stabilizing plates. Thermocouples shall be attached to each frame to record the surface temperature of the material while the test is in progress.

   5.2 Seal chamber and lower the internal chamber temperature to the storage temperature of -34°C (-30°F) and maintain same for a period of 24 hours after stabilization.

   5.3 Return the test items to standard ambient conditions and stabilize.

   5.4 After stabilization inspect the test items in accordance with paragraph 6.

   NOTE: The rate of temperature change (steps 5.2 & 5.3) may be the maximum attainable by the chamber, but shall not exceed 10°C (18°F) per minute.

6.0 INSPECTION CRITERIA

Upon completion of low temperature testing the five support frames will be inspected for the following defects.

6.1 Dimensional stability - as compared to pre-test data.

6.2 Warping - the part shall be laid on its side and gauged for warping (distortion) on a large tooling table.

6.3 Fractures and/or structural degradation - particularly in seat support and handlebar support junctures.

6.4 General appearance - discoloration or flaking or the frame material.

6.5 Structural - the operators saddle shall be attached to all five frames. Test personnel shall simulate the operation of each PVK for a period of not less than five (5) to visually check structural integrity of the unit.

7. Repeat above test sequence (item 5) for an additional 24 hour cycle.

APPENDIX D

TEST PROCEDURES - HIGH TEMPERATURE
PVK FRAME

TEST PROCEDURES - HIGH TEMPERATURE

PVK FRAME

1. METHOD - The testing method utilized is in conformance with method 501.1 of MIL-STD-810C.

2. PURPOSE - The high temperature test is conducted to determine the resistance of the support frames to elevated temperatures that may be encountered in storage (without protective packaging) or under service conditions.

3. PROCEDURES - The high temperature test is divided into two separate test procedures. Procedure I is intended to approximate the exposure of the frames to a high temperature storage condition for a period of time prior to operation of the units. Procedure II is intended to approximate the cyclic high temperature stresses that the frames are exposed to during storage and operation.

4. Test Apparatus - Temperature chamber (sealed).

5. TEST ITEM - Five (5) separate PVK frames to be tested simultaneously with identical temperature and time duration. The five frames will be identified as follows:

    5.1 - Polypropylene (unfilled)
    5.2 - Polypropylene (15% glass filled)
    5.3 - Polypropylene (20% glass filled)
    5.4 - Polypropylene (30% glass filled)
    5.5 - Nylon/12 (30% glass filled)

6. TEST PROCEDURE I - 6.1 Place the five (5) support frames specified in item 5 into the temperature chamber. The frames shall be in the operational position (vertical) supported by the rear stabilizing plates. Thermocouples shall be attached to each frame to record the surface temperature of the material while the test is in progress.

    6.2 Seal chamber and raise the internal chamber temperature to 60°C (140°F) and maintain the temperature for a period of 48 hours while insuring the relative humidity is not in excess of 15 percent.

6.3 At the conclusion of the 48 hours (140°F) testing adjust the internal chamber temperature of 110°F (the highest estimated operational temperature) and maintain until temperature stabilization of the frames is reached.

7. INSPECTION CRITERIA

Upon stabilization of the frames, remove and inspect the five frames for the following defects.

7.1 - Dimensional stability - as compared to pre-test data.

7.2 - Warping - the part shall be laid on its side and gauged for warping (distortion) on a large tooling table.

7.3 - Fractures and/or structural degradation - particularly in seat support and handlebar support junctures.

7.4 - General appearance - discoloration or flaking of the frame material.

7.5 - Structural - the operators saddle shall be attached to all five frames. Test personnel shall simulate the operation of each PVK for a period not less than five (5) minutes to visually check structural integrity of the unit.

8. Return the frames to standard ambient condition and stabilize.

9. Upon stabilization repeat the inspection procedures specified in item 7.0.

10. TEST PROCEDURE II

10.1 - Identical to item 6.1.

10.2 - Raise the internal chamber temperature to 49°C (120°F).

10.3 - Maintain internal chamber temperature for 6 hours at 49°C (120°).

10.4 - Raise the internal chamber temperature to 60°C (140°F) within a time period of one hour and then maintain at that temperature for 4 additional hours.

10.5 - Lower the internal chamber temperature to 49°C (120°F) within a time period of one hour.

10.6 - Repeat steps 3, 4, and 5 two additional times (making a total of three 12 hour cycles).

10.7 - Adjust the internal chamber temperature to 110°F (the highest estimated operational temperature) and maintain until temperature stabilization of the frames are reached.

11. Upon stabilization repeat the inspection procedures specified in item 7.0 of test procedure I.

12. Return the frames to standard ambient conditions and stabilize.

13. Re-inspect frames as per item 9.

APPENDIX E

TEST PROCEDURES - LOW TEMPERATURE
PVK ASSEMBLED UNIT

TEST PROCEDURES - LOW TEMPERATURE

PVK ASSEMBLED UNIT

1. METHOD - The testing method utilized is in conformance with Method 502.1 of MIL-STD-810C.

2. PURPOSE - The low temperature test is conducted to determine the effects of low temperature on the PVK assembled unit during storage (without protective packaging) and service use.

3. TEST APPARATUS - Temperature chamber (sealed).

4. TEST ITEM - One fully assembled PVK to include the following principal components:

   4.1 Frame - 15% glass re-inforced polypropylene

   4.2 Shroud - ABS plastic

   4.3 Drive Sprocket - nylon, Zytel #101/W/MDS

   4.4 Guard, Fan (steel)

   4.5 Fan, 30" dia. (steel)

   4.6 Rear Support (steel)

   4.7 Sprocket, Fan (steel)

   4.8 Drive Chain, #35 - 3/8" pitch (steel)

   4.9 Crank Assembly (steel)

   4.10 Flange Bearings, Fan (nylon)

   4.11 Handle Bar Assembly (steel)

   4.12 Saddle (vinyl/steel)

5. TEST PROCEDURE

   5.1 Place the assembled PVK specified in item 4 into the temperature chamber. The unit shall be in the operational position (vertical) supported by the rear stabilizing plate. Thermocouples shall be attached to the PVK to record the surface temperature of the material while the test is in progress.

5.2 Seal chamber and lower the internal chamber temperature to the storage temperature of -34°C (-30°F) and maintain same for a period of 24 hours after stabilization.

5.3 Return the test item to standard ambient conditions and stabilize.

5.4 After stabilization, inspect the test item in accordance with paragraph 6.

NOTE: The rate of temperature change (steps 5.2 and 5.3) may be the maximum attainable by the chamber, but shall not exceed 10°C (18°F) per minute.

6. INSPECTION CRITERIA

Upon stabilization of the assembled PVK, remove and inspect the unit for the following defects:

6.1 Dimensional stability - Any distortion and/or warpage of PVK components as compared to the pretest condition.

6.2 Operational - Test personnel shall operate the PVK at the normal pedaling rate of 60 rpm for a period not less than five (5) minutes to assure ease of operation. In addition, at the conclusion of the test, inspection of the following components shall take place:

6.2.1 Crank Assembly - binding

6.2.2 Fan Bearings - binding

6.2.3 Chain - too loose/tight

6.2.4 Shroud - clearance with fan

6.2.5 Sprockets - in line

6.2.6 Fasteners - loose

7. Repeat above test sequence (item 5) for an additional 24 hour cycle.

APPENDIX F

TEST PROCEDURES - HIGH TEMPERATURE
PVK ASSEMBLED UNIT

TEST PROCEDURES - HIGH TEMPERATURE

PVK ASSEMBLED UNIT

1. METHOD - The testing method utilized is in conformance with Method 501.1 of MIL-STD-810C.

2. PURPOSE - The high temperature test is conducted to determine the resistance of the PVK assembled unit to elevated temperatures that may be encountered in storage (without protective packaging) or under service conditions.

3. PROCEDURES - The high temperature test is divided into two separate test procedures. Procedure I is intended to approximate the exposure of the PVK assembly to a high temperature storage condition for a period of time prior to operation of the units. Procedure II is intended to approximate the cyclic high temperature stresses that the PVK assembly is exposed to during storage and operation.

4. TEST APPARATUS - Temperature chamber (sealed).

5. TEST ITEM - One fully assembled PVK to include the following principal components:

   5.1 Frame - 15% glass re-inforced polypropylene

   5.2 Shroud - ABS plastic

   5.3 Drive Sprocket - nylon, Zytel #101/W/MDS

   5.4 Guard, Fan (steel)

   5.5 Fan, 30" dia. (steel)

   5.6 Rear Support (steel)

   5.7 Sprocket, Fan (steel)

5.8 Drive Chain, #35 - 3/8" pitch (steel)

5.9 Crank Assembly (steel)

5.10 Flange Bearings, Fan (nylon)

5.11 Handle Bar Assembly (steel)

5.12 Saddle (vinyl/steel)

6. TEST PROCEDURE I -

6.1 Place the assembled PVK specified in item 5 into the temperature chamber. The unit shall be in the operational position (vertical) supported by the rear stabilizing plate. Thermocouples shall be attached to the PVK to record the surface temperature of the unit while the test is in progress.

6.2 Seal chamber and raise the internal chamber temperature to 60°C (140°F) and maintain the temperature for a period of 48 hours while insuring the relative humidity is not in excess of 15%.

6.3 At the conclusion of the 48 hours (140°F) testing, adjust the internal chamber temperature to 110°F (the highest estimated operational temperature) and maintain until temperature stabilization of the PVK is reached.

7. INSPECTION CRITERIA -

Upon stabilization of the assembled PVK, remove and inspect the unit for the following defects:

7.1 Dimensional stability - Any distortion and/or warpage of PVK components as compared to the pretest condition.

7.2 Operational - Test personnel shall operate the PVK at the normal pedaling rate of 60 rpm for a period not less than five (5) minutes to assure ease of operation. In addition, at the conclusion of the test, inspection of the following components shall take place:

7.2.1 Crank Assembly - binding

7.2.2 Fan Bearings - binding

7.2.3 Chain - too loose/tight

7.2.4 Shroud - clearance with fan

7.2.5 Sprockets - in line

7.2.6 Fasteners - loose

8. Return the PVK to standard ambient condition and stabilize.

9. Upon stabilization, repeat the inspection procedures specified in item 7.0.

10. <u>TEST PROCEDURE II</u> -

10.1 - Identical to item 6.1.

10.2 - Raise the internal chamber temperature to 49°C (120°F).

10.3 - Maintain internal chamber temperature for 6 hours at 49°C (120°F).

10.4 - Raise the internal chamber temperature to 60°C (140°F) within a time period of one hour and then maintain at that temperature for four additional hours.

10.5 - Lower the internal chamber temperature to 49°C (120°F) within a time period of one hour.

10.6 - Repeat steps 3, 4, and 5 two additional times (making a total of three 12-hour cycles).

10.7 - Adjust the internal chamber temperature to 110°F (the highest estimated operational temperature) and maintain until temperature stabilization of the PVK is reached.

11. Upon stabilization, repeat the inspection procedures specified in item 7.0 of Test Procedure I.

12. Return the PVK to standard ambient conditions and stabilize.

13. Re-inspect PVK as per item 9.

APPENDIX G

ENVIRONMENTAL TESTS
PVK SUPPORT FRAME

TEST REPORT

GATX
GARD, INC.
NILES, ILL.

ENVIRONMENTAL TESTS
ON
PVK SUPPORT FRAMES

JOB No. 79693

ORDER No. H22929

DATE Jan. 21, 1980

GAYNES

TESTING LABORATORIES, INC.

1642–52 West Fulton Street • Chicago, Illinois 60612 • Area Code 312/421-5257

Member American Council of Independent Laboratories

TEST OBJECTIVE:

The purpose of the tests was to subject five (5) separate PVK Support Frames to a series of High Temperature and Low Temperature Tests designed to simulate possible storage and service conditions. At the conclusion of these tests, the individual frames were to receive a Flat Drop from a 12" height to simulate a possible Shock Load during the course of handling and assembly.

TEST PRODUCTS:

Polypropylene (unfilled)
Polypropylene (15% glass filled)
Polypropylene (20% glass filled)
Polypropylene (30% glass filled)
Nylon 12 (30% glass filled)

TEST PROCEDURE - GENERAL:

The individual support frame was placed on the surface plate (large planer table) and its position was marked so that for subsequent tests it would be in the same relative placement. Using a feeler gage at one reference point (maintained throughout the evaluation) the raised area was recorded accurately.
The support frame was measured at the conclusion of each sequence so that comparisons could be made.

After the measurement was recorded, a rear stabilizing plate was attached to the frame and the entire assembly, including the saddle, was placed inside the walk-in chamber. Individual thermocouples were attached to each frame to recorded the body temperature during the test sequence.

And the end of each sequence, the units were inspected for possible warpage, fractures or structural degradation.
A technician, holding sufficient weight to induce a total load of 229 lbs, sat on the saddle to determine structural integrity:

Procedure No. 1 - High Temperature
A. Temperature maintained at 60°C (140°F) - 48 hrs. - Low Relative Humidity.
B. Temperature reduced to 110°F to stabilization of frames
C. Inspection
D. Temperature reduced to room ambient
E. Inspection & Measurement

Procedure No. 2 - High Temperature Cycling

A. Temperature raised to 49°C (120°C) and held for 6 hours
B. Temperature raised within 1 hour to 60°C (140°C) and held for 4 hours.
C. Temperature lowered with 1 hour to 49°C (120°F)
D. Repeat steps A, B & C for a total of 3 complete cycles.
E. Temperature reduced to 110°F to stabilization of frames
F. Inspection
G. Temperature reduced to room ambient
H. Inspection & Measurement

Procedure No. 3 - Low Temperature

A. Temperature reduced to -34°C (-30°F) and held for 24 hours
B. Temperature raised to room ambient
C. Inspection & Measurement
D. Repeat steps A, B & C

Test Results - Temperature

Each support frame remained relatively unchanged at the end of each test procedure sequence and at the conclusion of the test. Warpage was minimal (See Data Sheet). There were no apparent fractures or structural degradation.
The general appearance of each unit remained the same; there was no discoloration or flaking of the frame material. The operator saddle withstood the applied 229 lb. load without any change in structural integrity.

Drop Test Procedure:

Using a rope sling each support frame was raised to a height of 12" (See Photo) and then automatically released so that the front and rear base surfaces struck the concrete floor.Inspection was made, thereafter, of each frame for possible damage.

Test Results - Drop

Each support frame remained in satisfactory condition at the conclusion of the drop test.

Test Equipment & Instrumentation Used

1. Conrad 8' x 10' x 8' High Walk-in Chamber
   (-90°F to +280°F and Low & High Relative Humidity capacity)
2. Fluke #2190A digital thermometer & appropriate theromocouple wire
3. Straight edge table.
4. Starrett #172A - Feeler gage
5. Budgit 1 ton Electric Hoist
6. Gaynes Style No. 10-ER Electric Release Mechanism

GENERAL DATA SHEET

GAYNES TESTING LABORATORIES, INC.

1642 West Fulton Street, Chicago Illinois 60612

COMPANY: GATX - GARD INC	ADDRESS: NILES, ILL		ORDER NO. N22929
TEST: ENVIRONMENTAL	SPECIFICATION:	PARAGRAPH:	PROJECT NO. 79693
CONDITIONING:	MODEL NO:		DATE:
MATERIAL:	SERIAL NO:		TESTED BY:
REMARKS:	TEMP: °	RH: %	LAB SUP CHECK:
	BAR. PRESS: IN HG		WITNESSED BY:

NO.	IDENTIFICATION	INITIAL	DISTORTION (WARPAGE) AT MAX. POSITION (INCHES) AFTER 1ST HIGH TEMP.	AFTER 2ND HIGH TEMP	AFTER 1ST COLD TEMP	AFTER 2ND COLD TEMP
1	BLUE-POLYPROPYLENE (20% GLASS FILLED)	.012	.014	.014	.013	.014
2	BLUE-POLYPROPYLENE (UNFILLED)	.000	.003	.012	.015	.016
3	BLUE-POLYPROPYLENE (30% GLASS FILLED)	.031	.027	.024	.022	.022
4	BLACK-NYLON 30% GLASS FILLED	.000	.008	.014	.022	.025
5	BLUE-POLYPROPYLENE 15% GLASS FILLED	.027	.027	.014	.018	.022

PAGE

GENERAL DATA SHEET

GAYNES TESTING LABORATORIES, INC.

1642 West Fulton Street, Chicago, Illinois 60612

COMPANY: GATX-6180, INC.	ADDRESS: NILES, ILL	ORDER NO. N22929
TEST:	SPECIFICATION: PARAGRAPH:	PROJECT NO. 79693
CONDITIONING:	MODEL NO:	DATE: JAN. 3, 1980
MATERIAL:	SERIAL NO:	TESTED BY
REMARKS:	TEMP: ° RH: %	LAB. SUP. CHECK:
	BAR. PRESS: IN. HG	WITNESSED BY

	TIME	CHAMBER	1	2	3	4	5
1/3	8:00	140.2	130.9	130.4	135.2	140.2	133.6
	9:37	141.4	127.8	135.6	137.7	135.1	136.2
	3:52	138.8	131.8	135.6	136.6	135.5	136.1
	4:07	142.4	133.8	138.4	139.9	138.4	139.2
1/4	8:04	141.8	136.6	140.1	140.8	140.1	140.5
	8:46	139.5	135.1	137.8	137.9	137.2	137.4
	9:36	140.4	135.4	138.3	138.7	138.0	138.4
	3:36	140.8	135.2	138.0	138.6	137.8	138.2
1/5	7:35	110.00	110.0	114.1	111.1	112.2	112.4
	8:30	109.6	111.3	109.8	109.4	110.0	109.7
	11:00	109.3	109.1	109.1	109.7	109.8	109.6
		OPENED CHAMBER - CHECKED EACH UNIT WITH STRAIGHT EDGE					
		NO APPARENT CHANGE					

GENERAL DATA SHEET

GAYNES TESTING LABORATORIES, INC.

1642 West Fulton Street, Chicago Illinois 60612

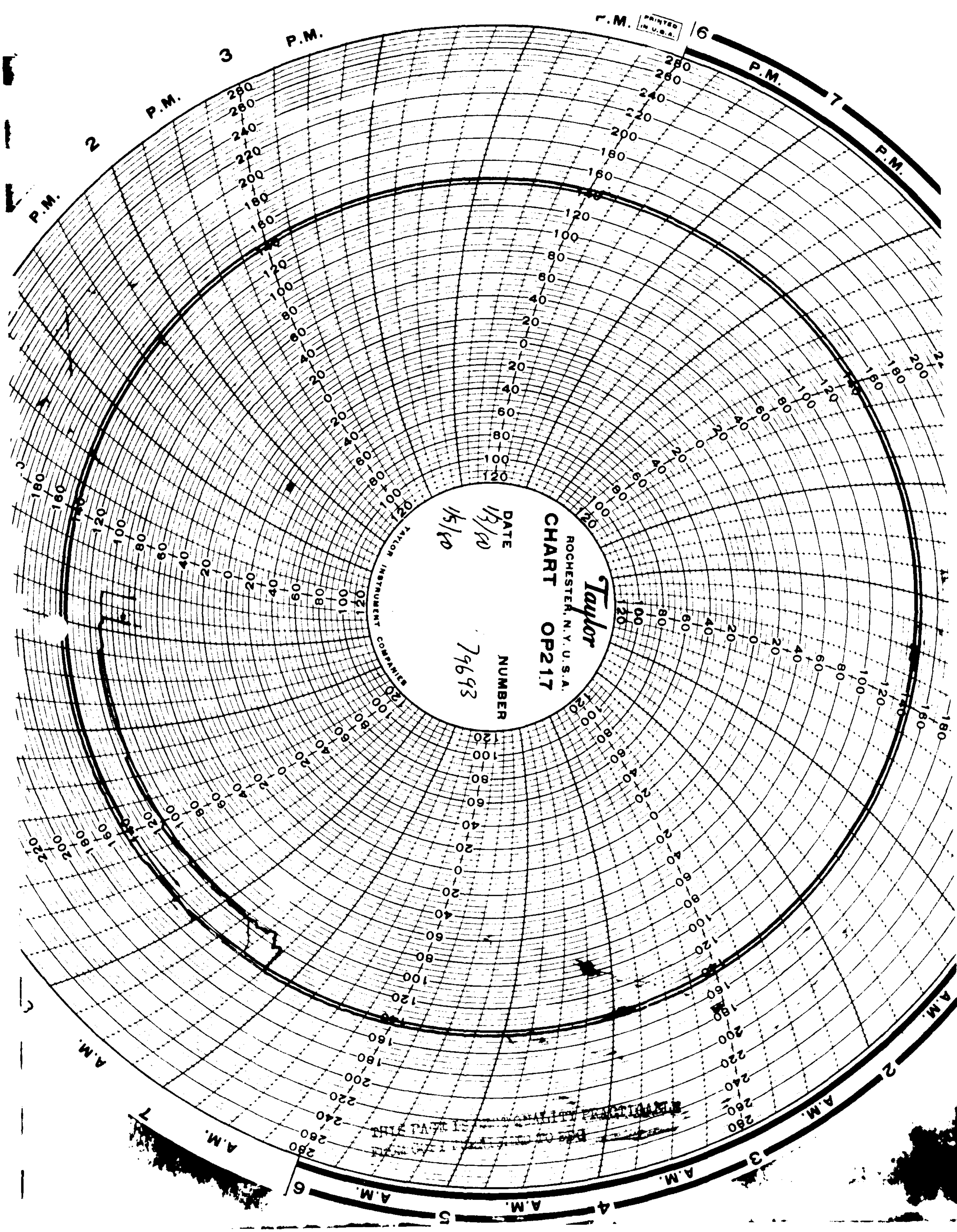
COMPANY: GATX - GARD INC.	ADDRESS: NILES, ILL.		ORDER NO: N 22929
TEST:	SPECIFICATION:	PARAGRAPH:	PROJECT NO: 79693
CONDITIONING:		MODEL NO:	DATE:
MATERIAL:		SERIAL NO:	TESTED BY:
REMARKS:		TEMP: ° RH: %	LAB. SUP. CHECK:
		BAR. PRESS: IN. HG	WITNESSED BY:

		CHAMBER	1	2	3	4	5
1/2	8:22	109.3					
	9:22	120.2	111.5	111.7	112.7	112.0	112.2
	10:27	119.7	115.6	115.2	115.7	115.5	115.4
	1:38	119.8	116.7	116.4	116.8	116.7	116.8
	4:21	136.4	131.6	132.0	131.9	131.1	131.8
	7:20	141.5	139.5	138.9	137.7	138	139.4
	9:00	119.3	119.3	116.7	116.6	115.8	117
1/9	7:57	115.1	113.4	113.6	113.1	113.3	113.6
	8.00	ENTERED ROOM - MAN WEIGHING 204 LBS, WITH 25 LB WEIGHT ADDED (229#)					
		- SAT ON EACH UNIT - NO APPARENT CHANGE					
		CHECKED FOR STRAIGHTNESS - NO APPARENT CHANGE					
	12:44	-29.0	-21.3	-20.1	-22.8	-21.3	-19.3
	2:30	-27.6	-27.5	-26.7	-25.9	-24	-22.1
	4:00	-28.9	-29.1	-27.8	-26.8	-24.9	-23.7
	4:16	-29.2	-29.6	-28.1	-27.3	-25.1	-24.6
1/10	7:06 AM	-31.1	-30.8	-28.8	-28.6	-28.5	-28.3
	8:00	-29.6	-29.7	-28.1	-28.0	-28.1	-28.2
	12:16	-28.9	-28.6	-27.0	-26.5	-26.3	-26.7
	12:51	59.5	33.0	29.7	34.1	30.8	26.4
	4:25	-30.6	-30.9	-27.9	-26.0	-24.8	-25.1
	7:07	-34.	-33.3	-32.6	-32.5	-32.2	-32.0
	2:22	-34.4	-34.2	-33.0	-32.4	-31.4	-31.2
	3:00	-35.0	-35.3	-33.5	-33.2	-32.1	-31.7

PAGE

GARD, INC.
JOB NO. 7[illegible]

GAYNES TESTING LABORAT[illegible]



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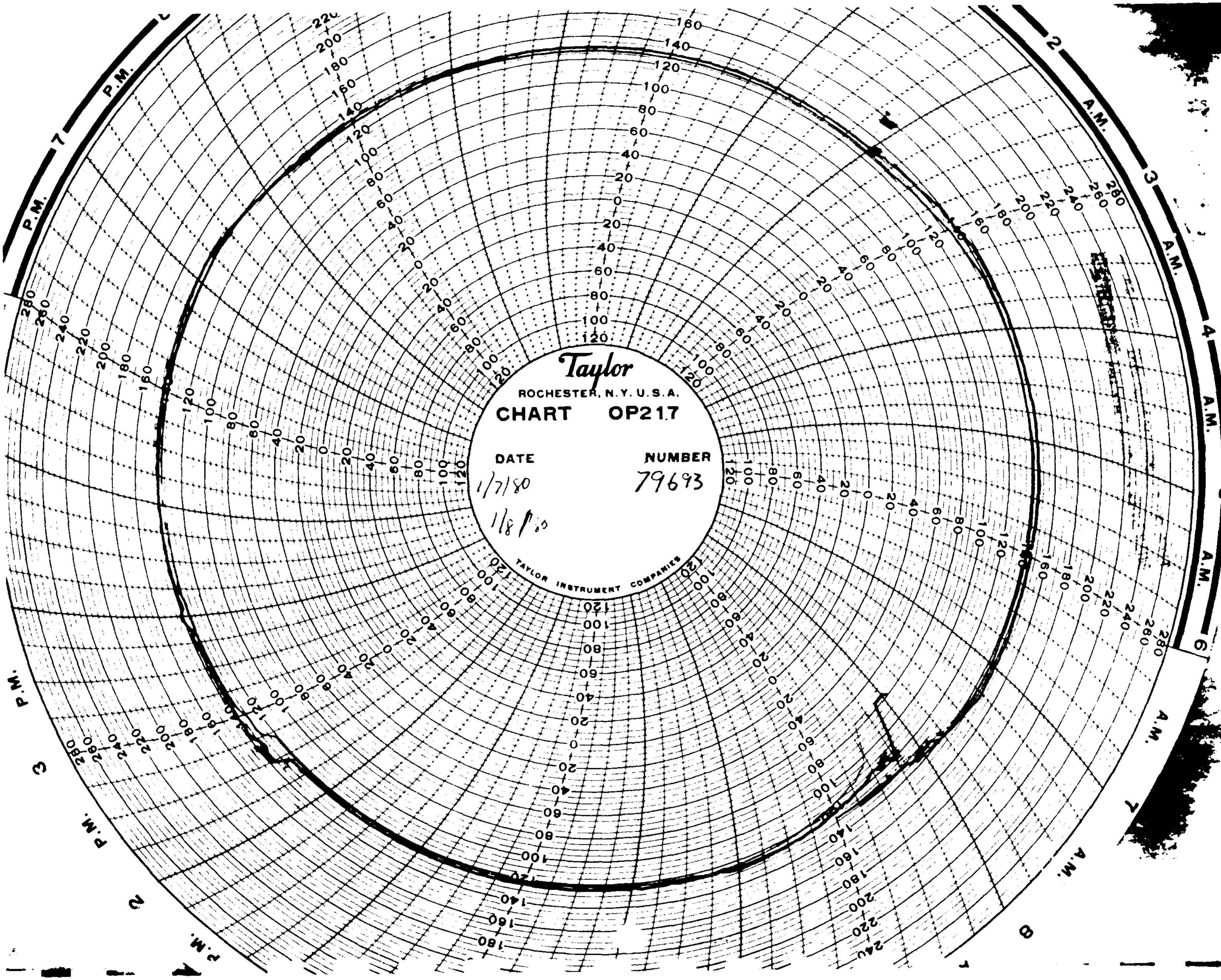

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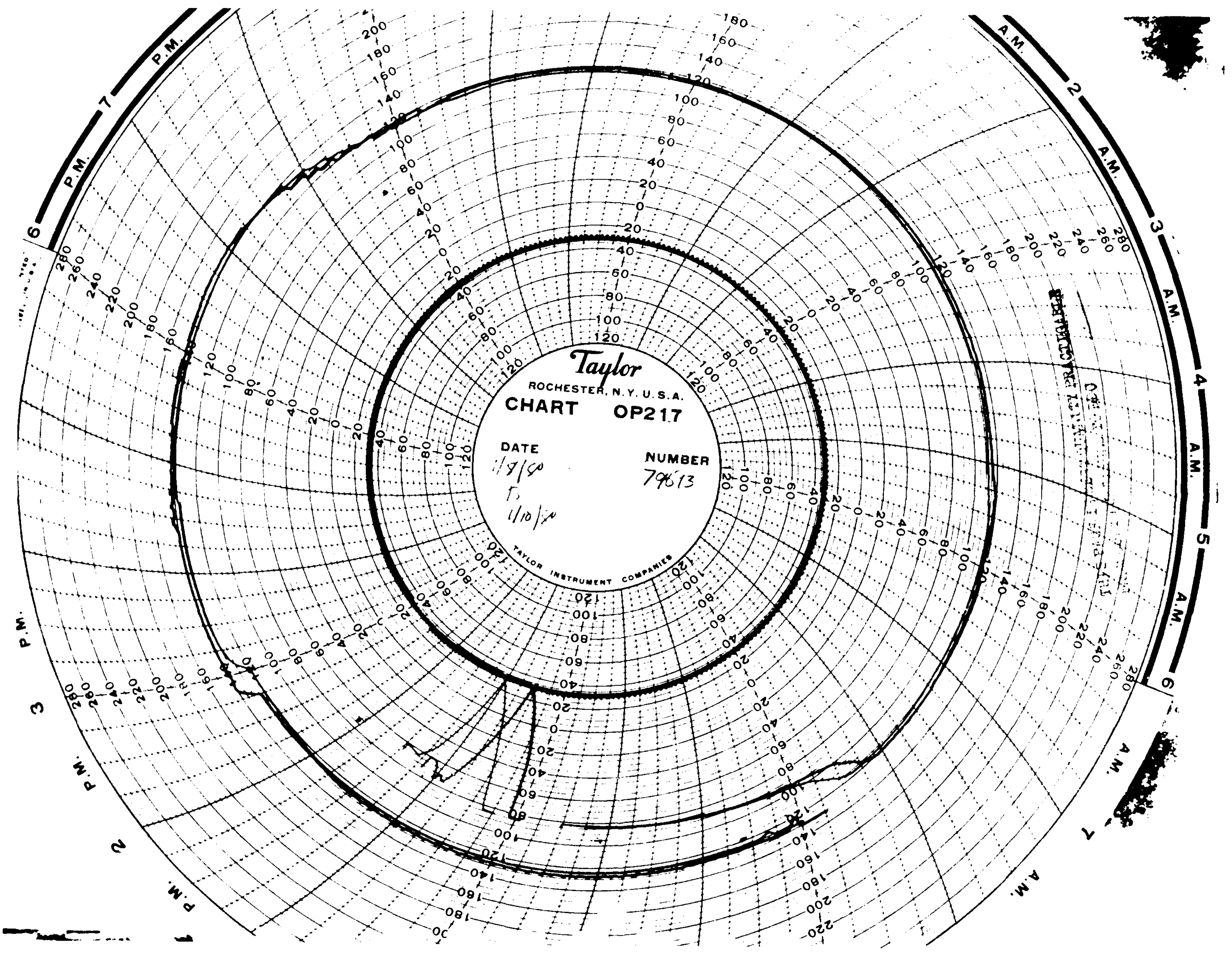
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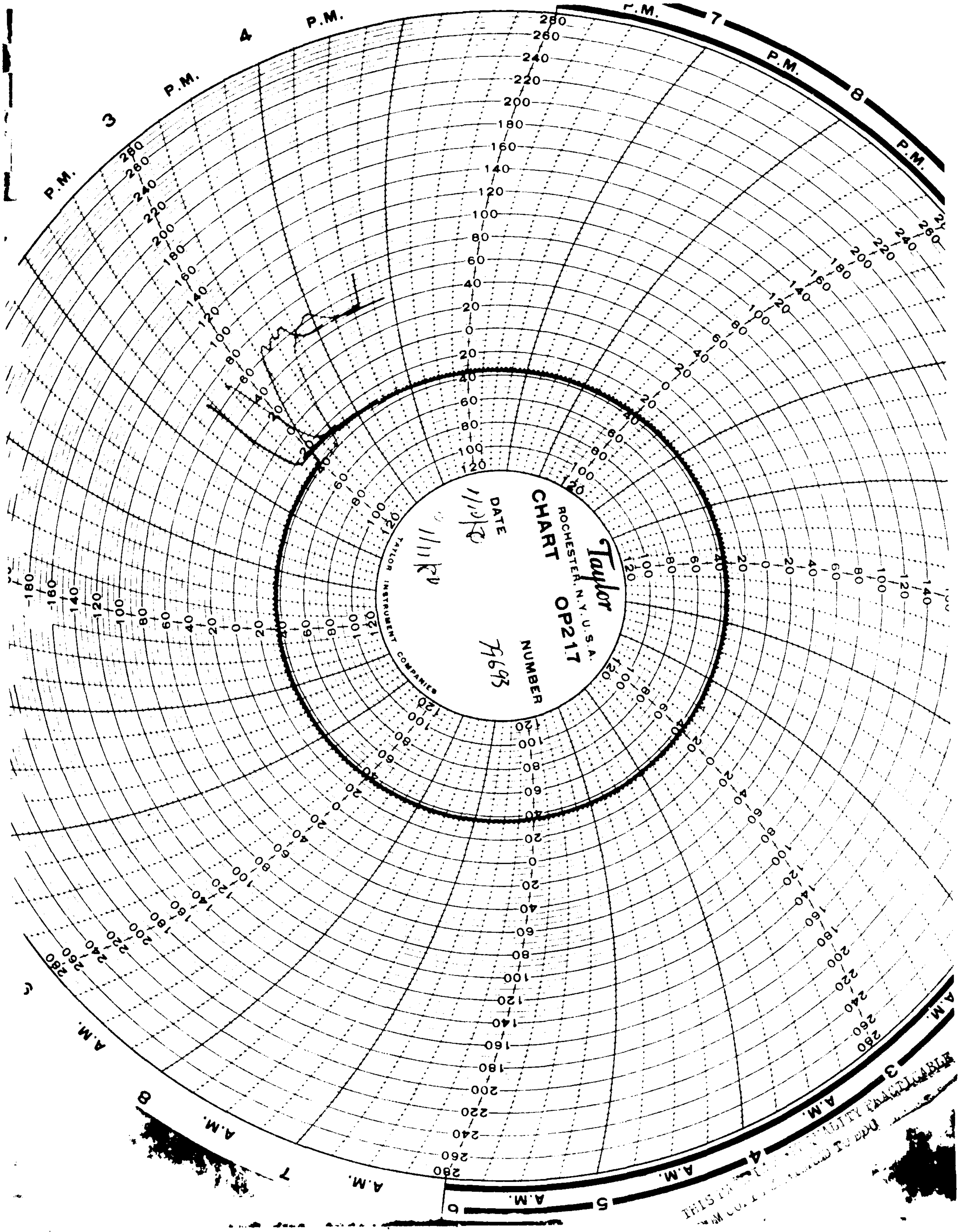
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APPENDIX H

ENVIRONMENTAL TESTS

FULLY ASSEMBLED PVK

TEST REPORT

GARD, INC.
DIVISION OF GATX
NILES, ILL.

TESTS ON

ASSEMBLED PVK

JOB No. 80236

ORDER No. H23272

DATE March 31, 1980

GAYNES

TESTING LABORATORIES, INC.

1642–52 West Fulton Street • Chicago, Illinois 60612 • Area Code 312/421-

Member American Council of Independent Laboratories

TEST OBJECTIVE:

The purpose of the tests was to subject a fully assembled PVK unit to a series of High Temperature and Low Temperature Tests designed to simulate possible storage and service conditions.

TEST ITEM - One fully assembled PVK was provided to include the following principal components: (As stated by GARD)

4.1 Frame - 15% glass re-inforced polypropylene

4.2 Shroud - ABS plastic

4.3 Drive Sprocket - nylon, Zytel #101/W/MUS

4.4 Guard, Fan (Steel)

4.5 Fan, 30" dia. (Steel)

4.6 Rear Support (Steel)

4.7 Sprocket, Fan (Steel)

4.8 Drive Chain, #35 - 3/8" pitch (Steel)

4.9 Crank Assembly (Steel)

4.10 Flange Bearing, Fan (Nylon)

4.11 Handle Bar Assembly (Steel)

4.12 Saddle (Vinyl/Steel)

TEST PROCEDURE No. 1 - High Temperature

A. Temperature maintained at 60°C (140°F) - 48 hrs. - Low Relative Humidity.
B. Temperature reduced to 110°F to stabilization of unit.
C. Inspection and five minutes of operation.
D. Temperature reduced to room ambient.
E. Inspection and five minutes of operation.

TEST PROCEDURE No. 2 - High Temperature Cycling

A. Temperature raised to 49°C (120°F) and held for 6 hours.
B. Temperature raised within 1 hour to 60°C (140°C) and held for 4 hours.
C. Temperature lowered with 1 hour to 49°C (120°F).
D. Repeat steps A, B & C for a total of 3 complete cycles.
E. Temperature reduced to 110°F to stabilization of unit.
F. Inspection and five minutes of operation.
G. Temperature reduced to room ambient.
H. Inspection and five minutes of operation.

TEST PROCEDURE No. 3 - Low Temperature

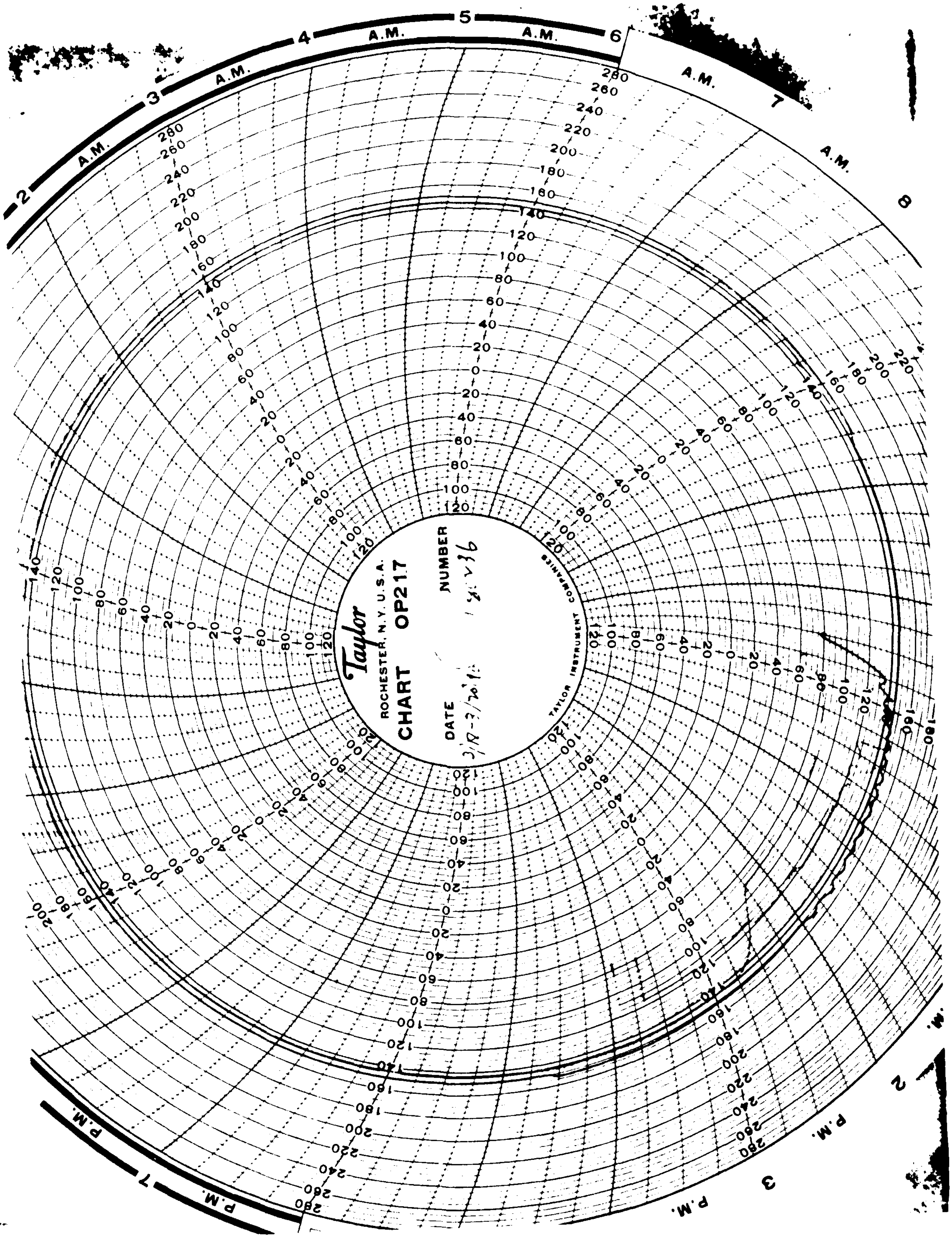
A. Temperature reduced to -34°C (-30°F) and held for 24 hours.
B. Temperature raised to room ambient.
C. Inspection and five minutes of operation.
D. Repeat steps A, B & C.

RESULTS

The PVK Unit remained in the same relative condition at the end of eac test procedure sequence and at the conclusion of the test. There was no apparent distortion, warpage or change in the components from a material standpoint or in relation to the overall assembly position. The unit operated satisfactorily throughout each test series.

TEST EQUIPMENT & INSTRUMENTATION USED

1. Conrad 8' x 10' x 8' High Walk-in Chamber (-90°F to +280°F and Low & High Relative Humidity capacity)
2. Fluke #2190A digital thermometer & appropriate theromocouple wire.
3. Gaynes 4' x 6' x 6' High small Walk-in Chamber (-35°F to + 50°F capacity).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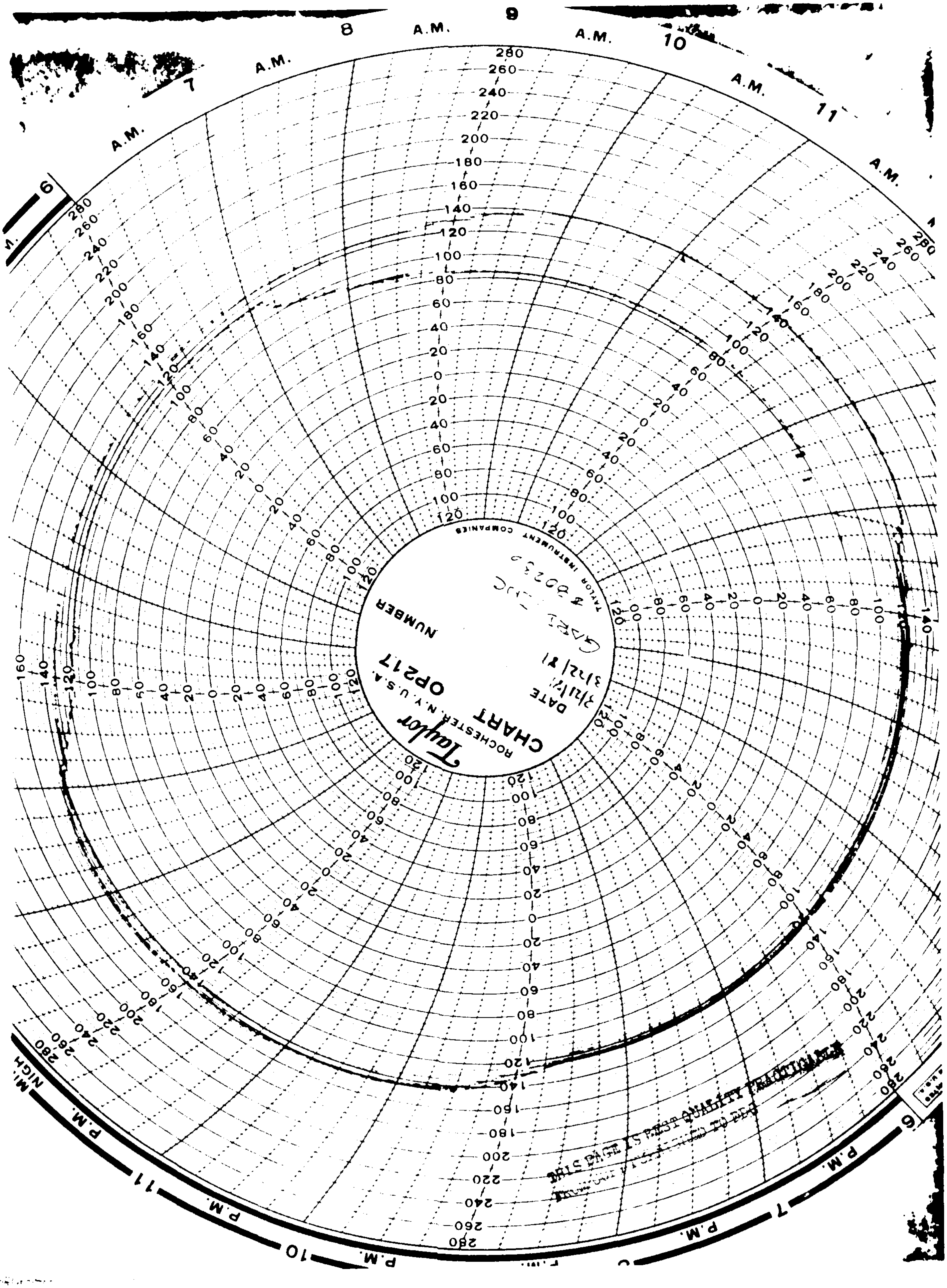

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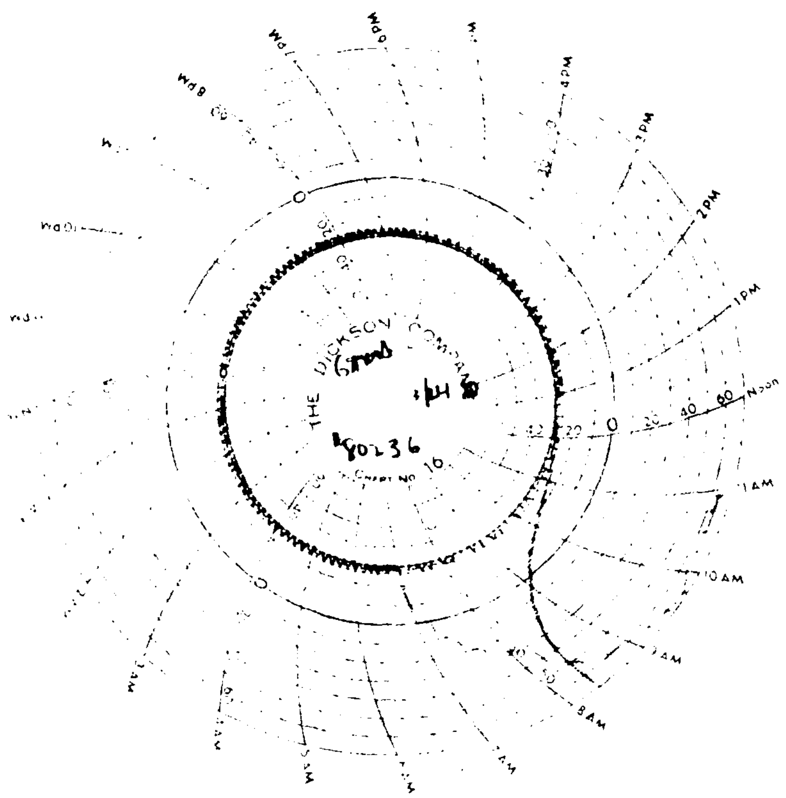
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1AM
10AM
8AM
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20
40
60

APPENDIX J

FINITE ELEMENT MODEL
PVK FRAME

DEMONSTRATIVE STUDY OF FEM STRESS ANALYSIS FOR PEDAL VENTILATOR FRAME

Prepared by

R. N. Patel

GARD, INC.
7449 North Natchez Avenue
Niles, IL

March 1980

1.0 Introduction

The objective of this technical effort is to demonstrate the capability of using Finite Element Technique for the stress analysis of the pedal ventilator frame.* The finite element method of stress analysis is a numerical technique in which the continuum of structure is discretized (divided) into small pieces or elements. These elements may be of different shapes, are interconnected and they may have different loading conditions and physical properties. In conjunction with the boundary constraints provided by supports and with the loading condition defined, the foregoing process yields the system of algebraic equations, the solution of which contains the stress condition and deformation of each element.

The NASTRAN FEM package is used for the analysis, attempted here. The forthcoming presentation discusses the technical efforts and the final result. The technical efforts include the comprehensive discussion on the preparation of the input data. Also, the report demonstrates the use of the graphic package called FASTDRAW. There are two different load cases considered. The result accomplished shows that the FEM technique has potential to optimize the design of the structure. The result is mainly focused on load case-1 which represents the operating loading condition. The result also includes the plot of the deformed shape.

* This technical effort was funded by GARD and conducted as a training exercise.

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STUDY OF ALTERNATE MATERIAL FOR PEDAL VENTILATOR KITS.(U)
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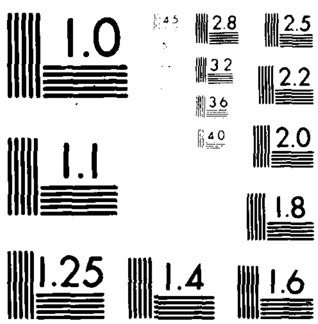


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

2.0 Technical Efforts

2.1 Model Construction

The mathematical model used for finite element analysis is a 2-dimensional model. It is composed of plate elements. The graphic package, FASTDRAW, was used to prepare the model. The FASTDRAW is a software which is composed of a series of graphic functions and subroutines. When these functions and subroutines are called upon in a predetermined sequence, it will construct the desired finite element model. The graphic terminal would be used to construct the model. Figure 2 attached with this report is the picture of the frame model. Also, a pre-stage model structure is shown in Figure 1. The model is composed of 449 elements and 501 grids.

2.2 Loading Definition and Boundary Constraints

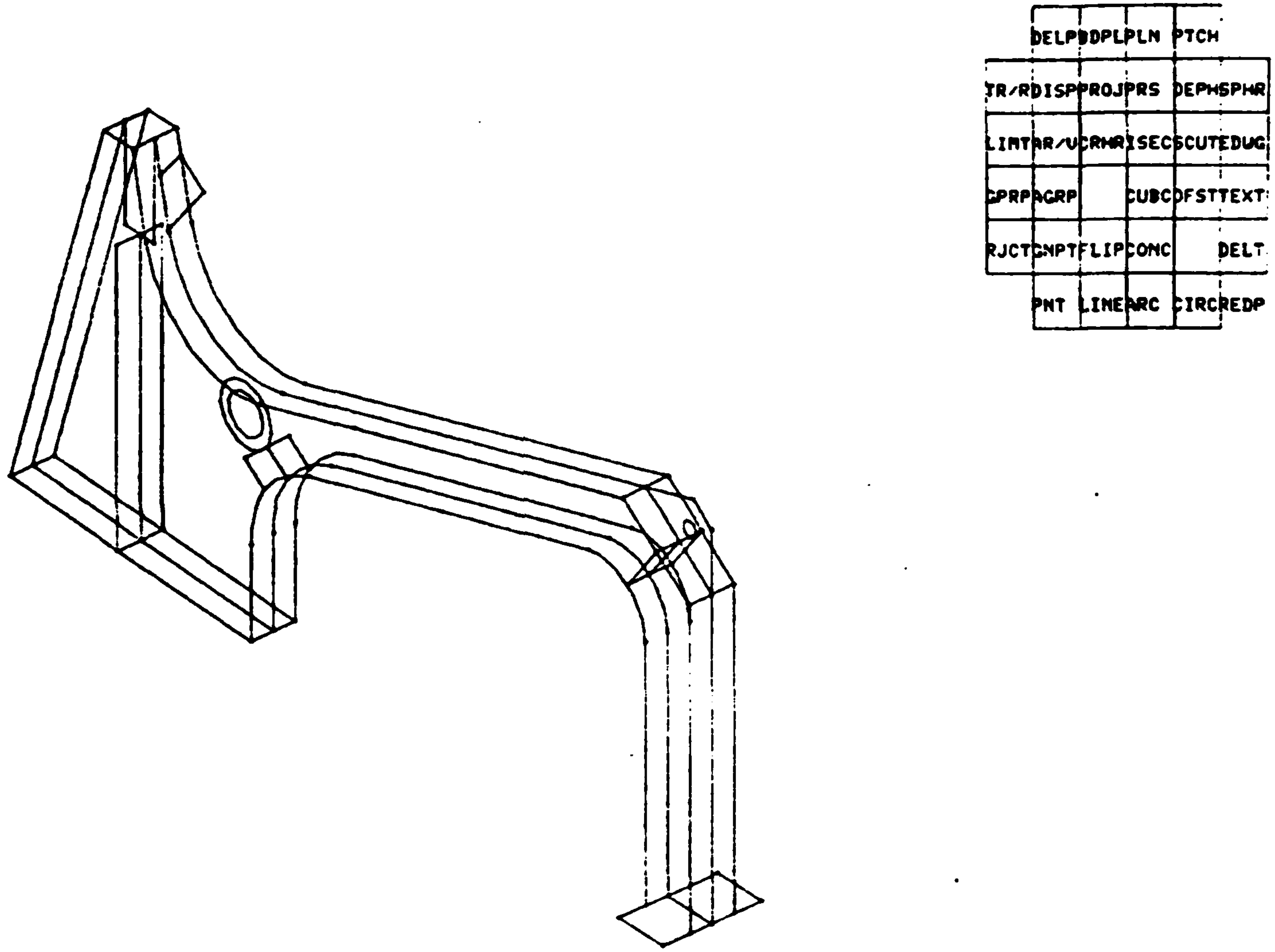
There are two different load cases considered in the analysis. The load case-1 represents the actual operating condition. The load data was obtained from the analytical stress analysis report. The loading, being considered here, is the result of the operator, acting on the saddle bar, the handle, and the pedal. Also the chain tension is considered in load case-1. The boundary constraint for load case-1 is due to the frame sitting on an uneven ground. The loading and the support for case-1 is shown in Figure 3. In load case-2, only the dead load is considered acting on the handle bar. Figure 4 shows the loading and the boundary constraint for case-2.

2.3 Material

The saddle bar and the handle bar are of steel, for which

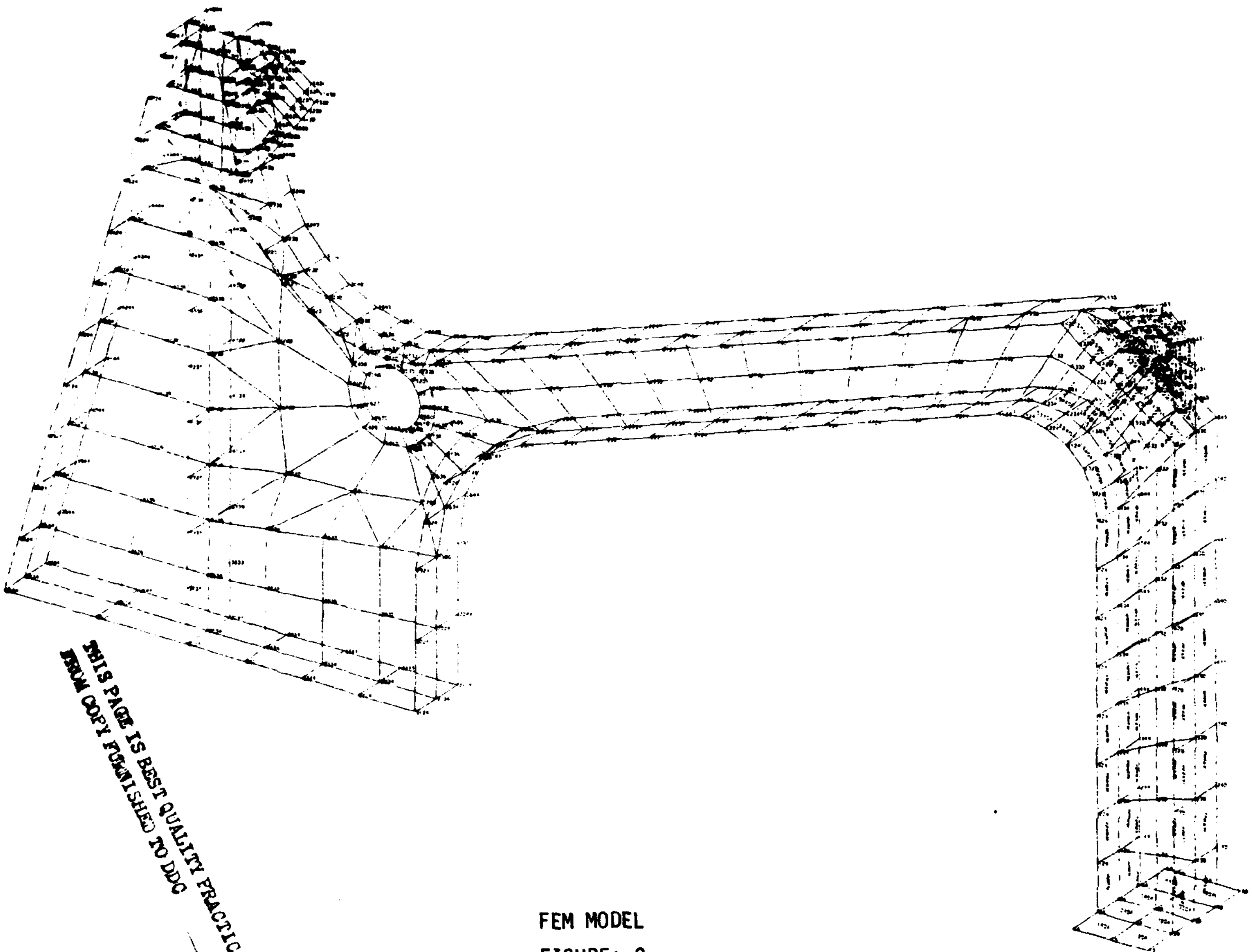
(1) the Poisson's ratio = 0.3 and

(2) modulus of elasticity = 30,000,000 psi.



PRE-STAGE FEM MODEL

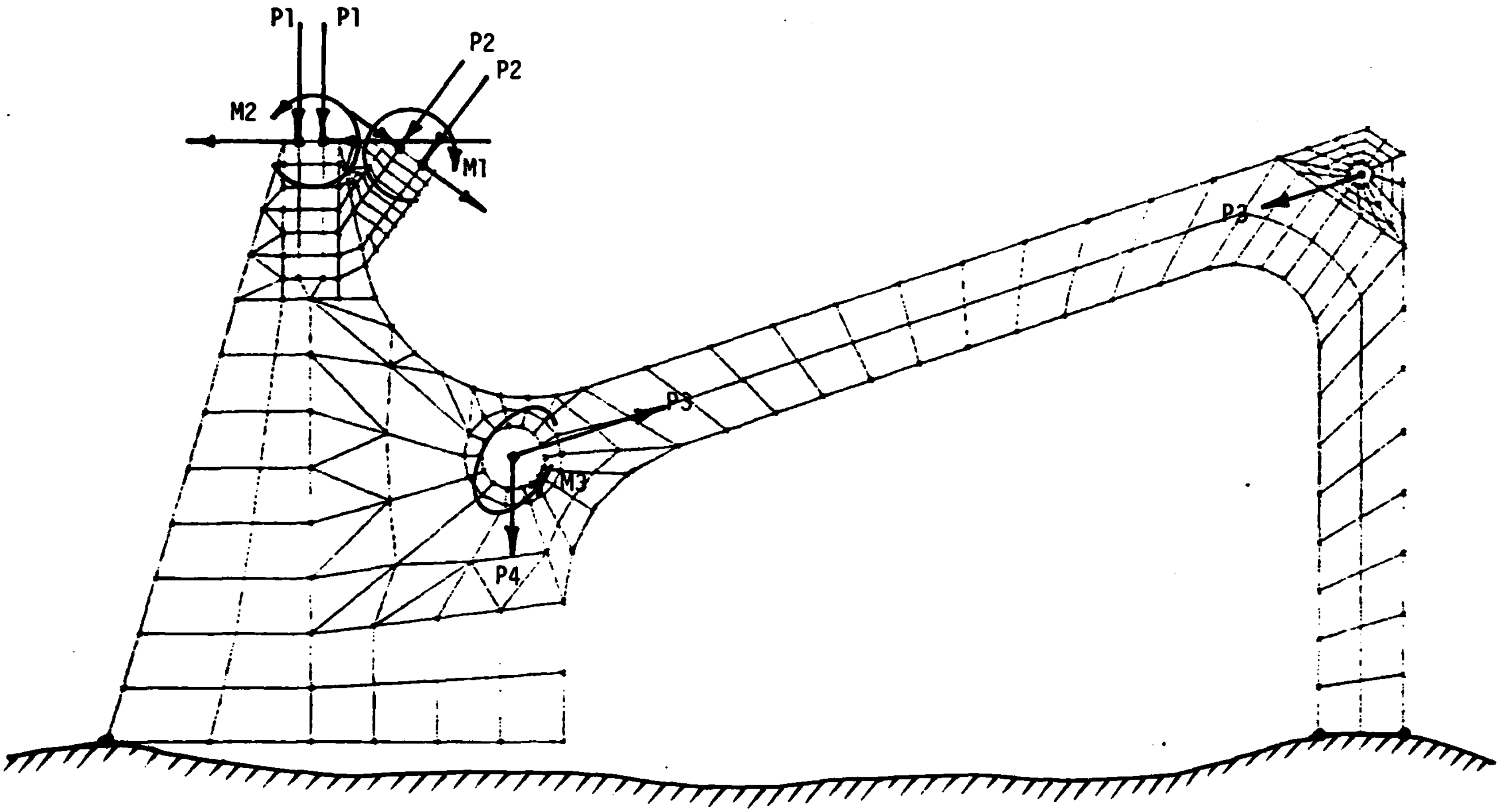
FIGURE: 1



FEM MODEL

FIGURE: 2

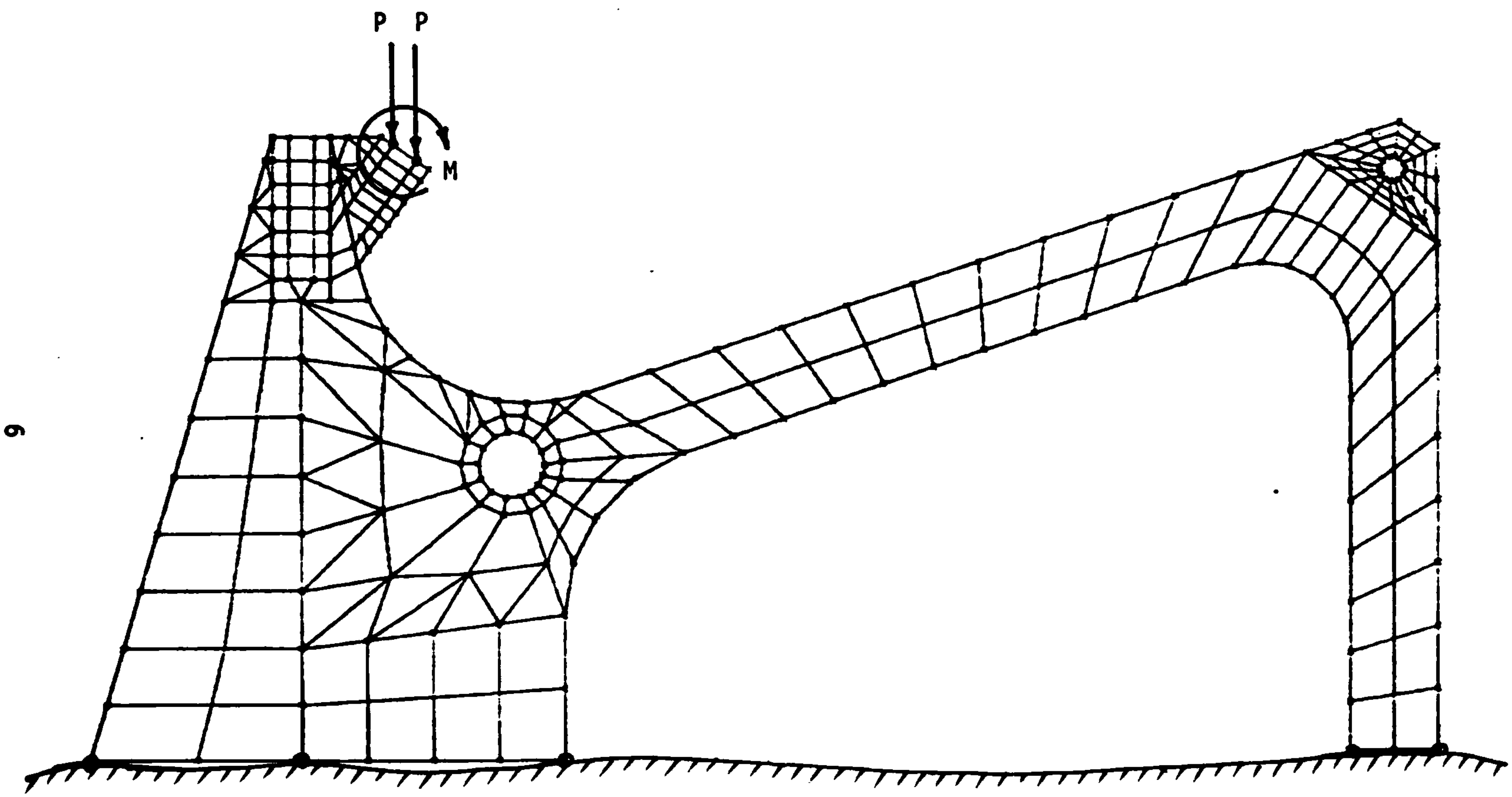
P1 = 150 lbs.
P2 = 21.6 lbs.
P3 = 167 lbs.
P4 = 200 lbs.
M1 = 757 inch-lbs.
M2 = 1340 inch-lbs.
M3 = 1110 inch-lbs.



LOAD CASE-1 AND BOUNDARY CONSTRAINTS

FIGURE: 3

P = 1175 lbs.
M = 6561.2 lbs.



LOAD CASE-2 AND BOUNDARY CONSTRAINTS

FIGURE: 4

The pedestal frame material is polypropylene plastic*for which:

(1) the Poisson's ratio = 0.43 and

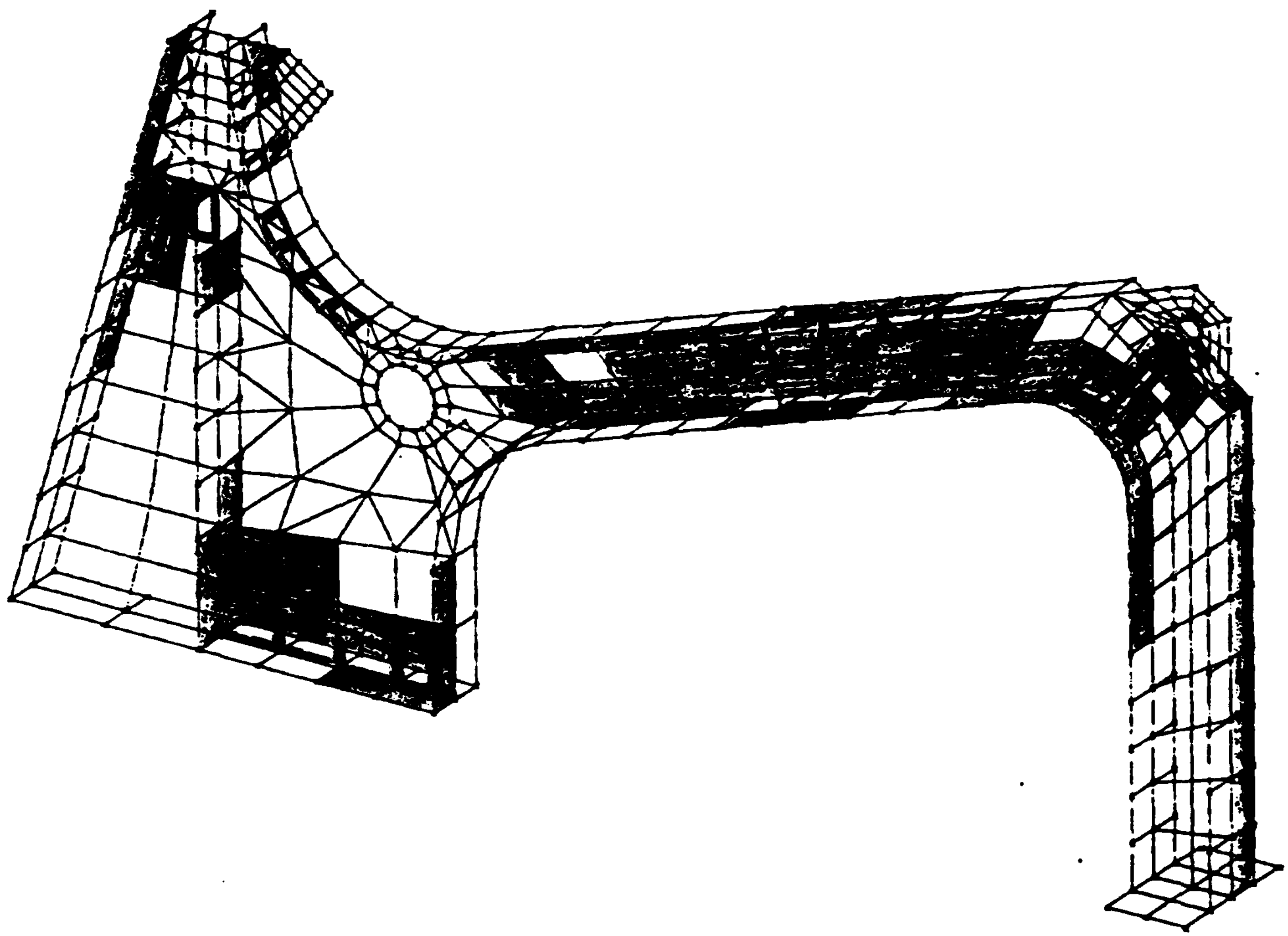
(2) modules of elasticity = 520,000 psi.

3.0 Result and Comments

The stress output for load case-1 is shown in Figures 5 through 8. In each figure, different stress ranges are considered and elements having stress which falls into the related stress range are shown shaded. Figures 9 and 10 show the deformed shape of the structure for case-1 and case-2, respectively. It is evident from the result that the stresses generated due to operating loading are well within limit and the design is safe. However, no effort is expended to optimize the design which could be achieved using this technique because stresses are defined continuously within the structure.

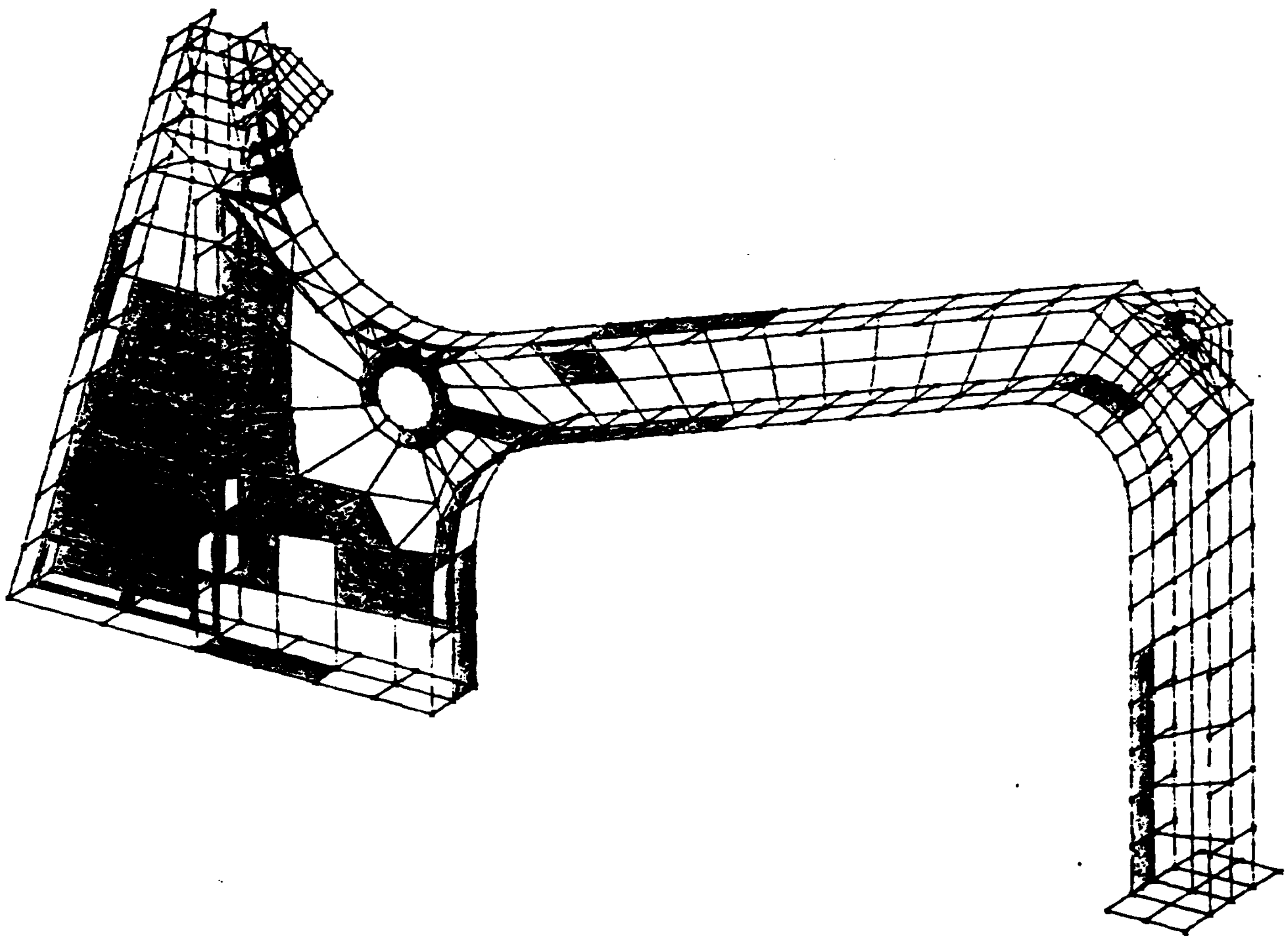
It was found that the model is over-simplified in the area where the saddle bar and handle bar join with the frame. It is, therefore, recommended that a more realistic stress condition could be obtained if the frame section under consideration were simulated as 3-D brick elements rather than 2-D plate elements along with the general 2-dimensional model.

* 15% glass-filled.



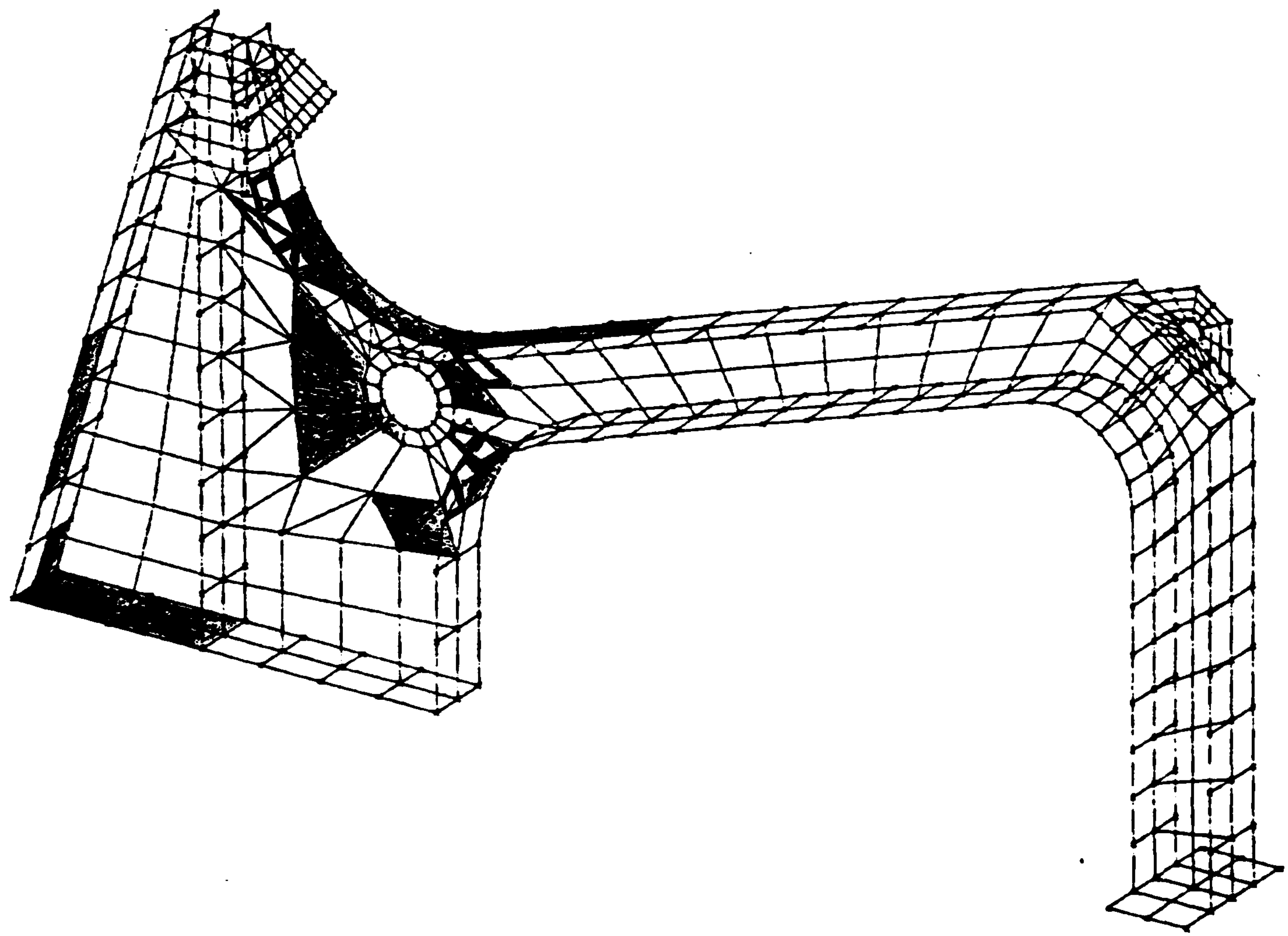
STRESS LEVEL σ = 100 PSI TO σ = 199 PSI

FIGURE: 5



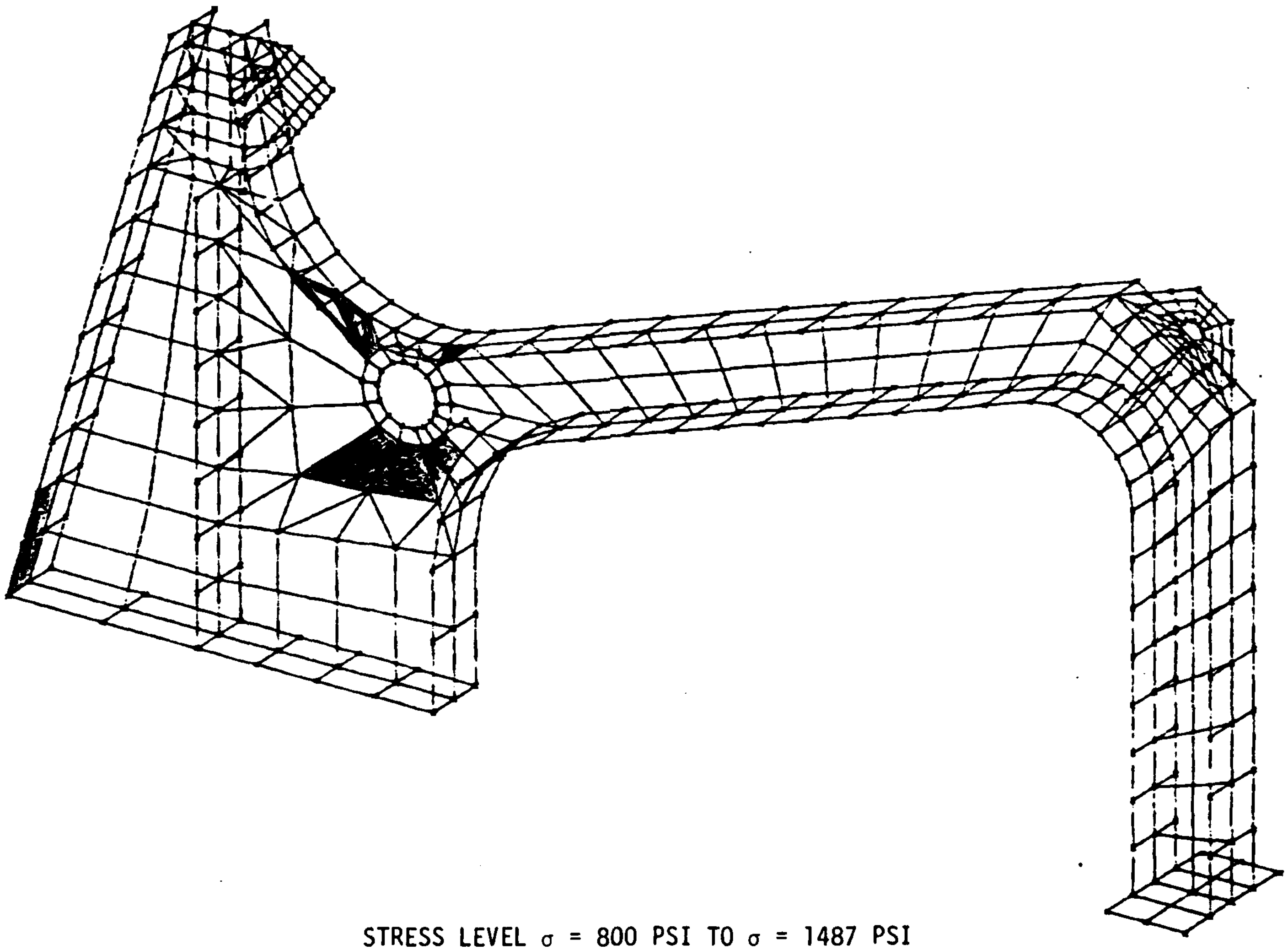
STRESS LEVEL σ = 200 PSI TO σ = 399 PSI

FIGURE: 6



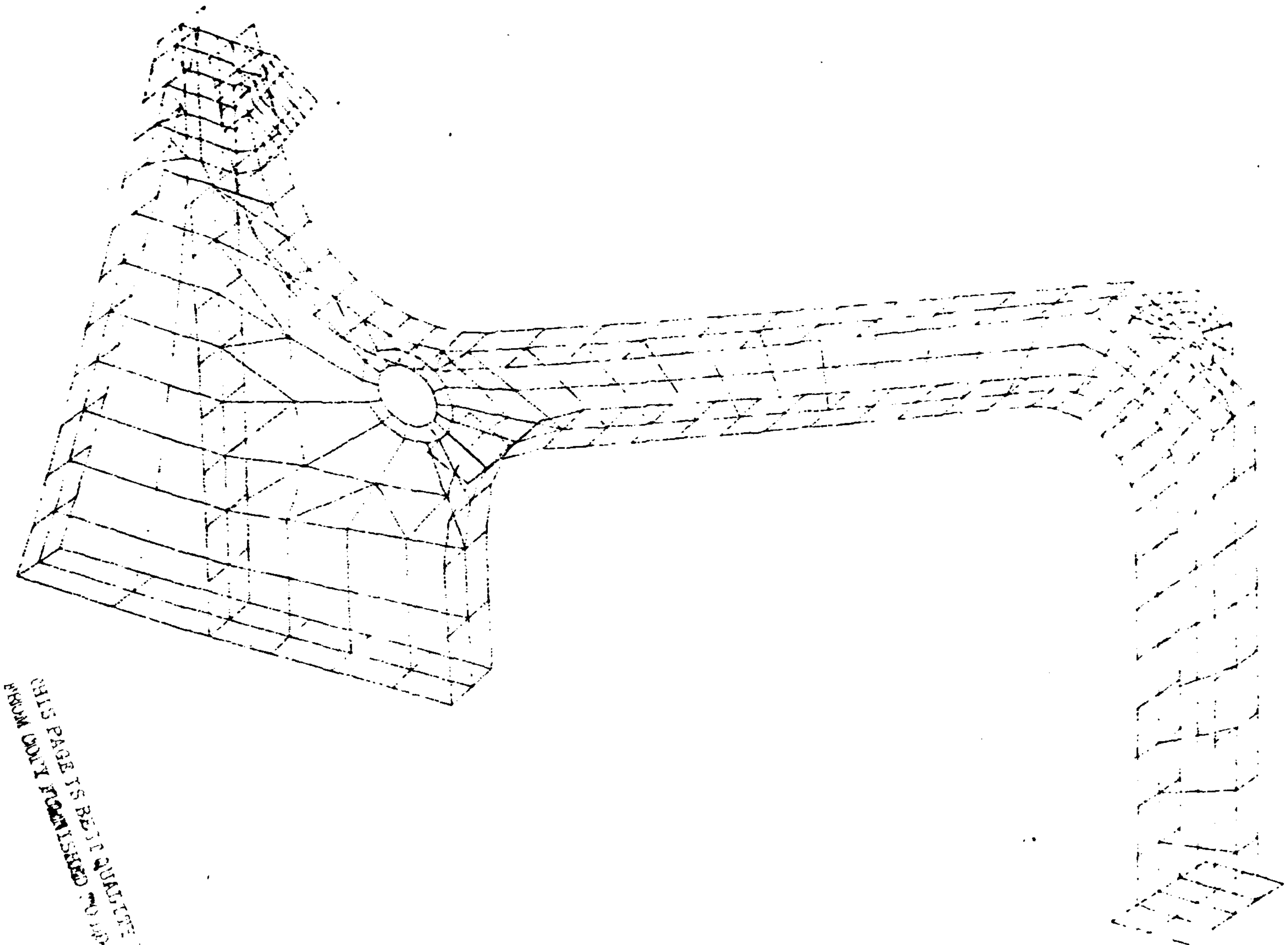
STRESS LEVEL σ = 400 PSI TO σ = 799 PSI

FIGURE: 7



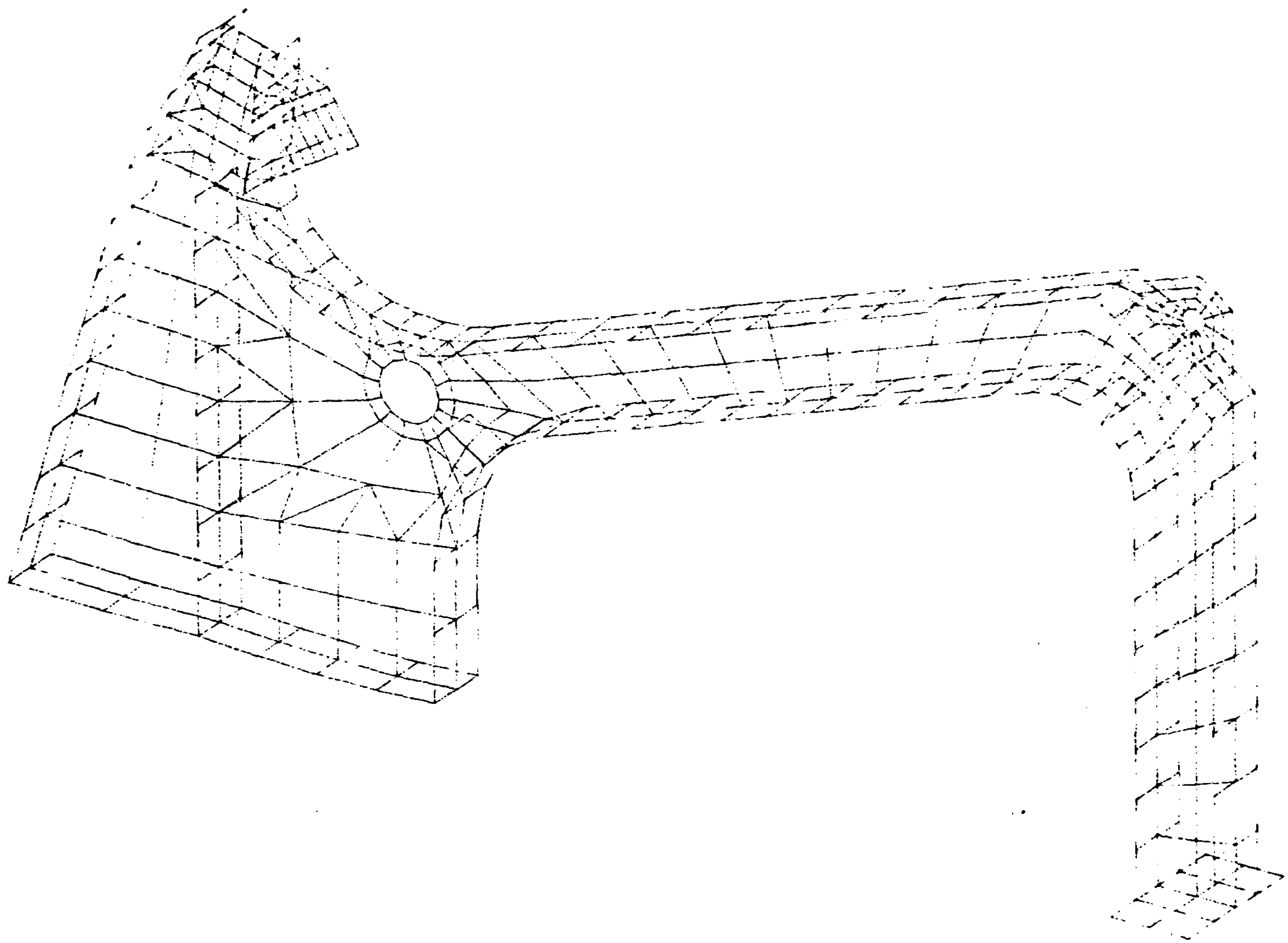
STRESS LEVEL σ = 800 PSI TO σ = 1487 PSI

FIGURE: 8



DEFORMED FRAME FOR LOAD CASE-1

FIGURE: 9



DEFORMED FRAME FOR LOAD CASE-2

FIGURE: 10

GARD, INC., NILES, ILLINOIS

Study of Alternate Material Pedal Ventilator Kits
GARD Final Report A1-16 (1724)
FEMA Contract No. DCPA01-79-C-0234, FEMA Work Unit 1423E
By Buday, J. M.
June 1980 (UNCLASSIFIED) pp

The objective of the subject program was to conduct a study of Alternate Materials that could be utilized in the construction of a Pedal Ventilator Kit (PVK). The goal of the study was to reduce the unit cost in a large scale procurement. Cost savings and performance parameters were evaluated using the PVK developed in 1979 under Contract No. DCPA01-78-C-0184 as a basis for cost comparison. A value analysis study was conducted on the PVK to determine viable material/design revisions that offered potential manufacturing economies. Based on the conclusion of the study, one optimum design was chosen for fabrication. Prior to fabrication, five breadboard support frames were constructed and tested. Fifteen fully assembled PVKs were constructed, of which five were tested to assure compliance with performance and reliability requirements. Preliminary operating instructions and specifications were generated for the PVK. In addition, production cost estimates based on a procurement of 100,000 units were formulated for FEMA budgetary purposes.

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