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ENVIRONMENTAL CONTROL PACKAGES USING BELOW AMBIENT TEMPERATURE
THERMAL STORAGE

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During the Period September 30, 1986 - March 10, 1989

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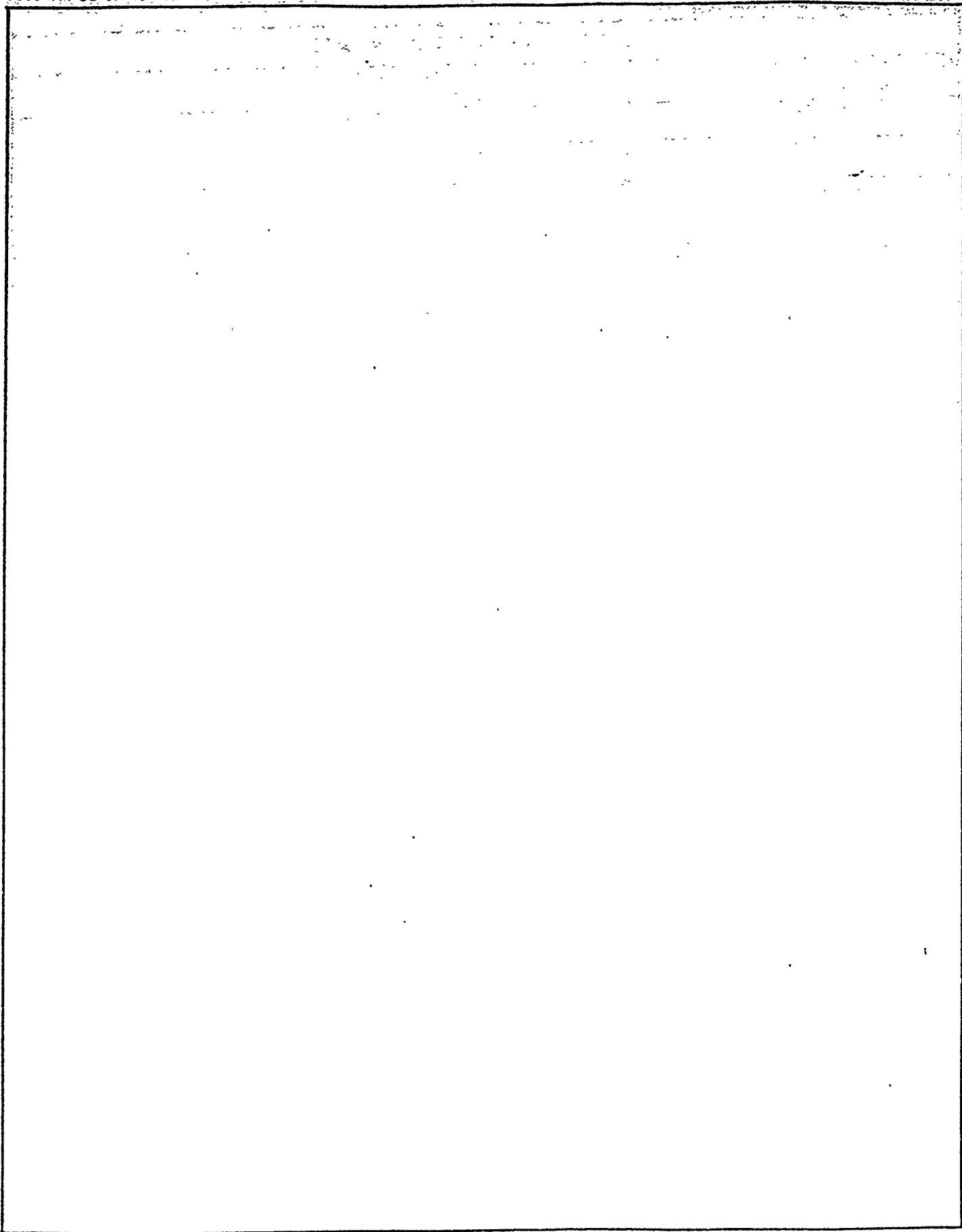
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SUMMARY

The living space environment of military vehicles can become oppressive when the vehicles are operating in hot-dry or hot-humid climates.

The objective of this program was to develop microclimate cooling systems (MCS) for providing cool air to crew members on board military vehicles, particularly those vehicles equipped with nuclear, biological and chemical (NBC) air filtering systems.

The design concept for the MCS was to employ a phase change material to store heat as latent heat of fusion.

Heat removed from the crew members would be stored in the MCS until environmental conditions favored the rejection of that heat, that is, nighttime as opposed to daytime. Heat rejection done at night is more efficient than during the day. Net energy consumption for the MCS can be minimized.

A secondary objective was to extend the thermal energy storage technology developed in this program towards applications in the commercial and private sector.

Technical efforts in Phase II were directed at evaluating candidate phase change materials; designing a full scale MCS capable of achieving the necessary thermal performance but not necessarily meeting all structural requirements to make it field test worthy (i.e., a bench test MCS as opposed to a prototype MCS); and testing the MCS for thermal performance evaluation.

These efforts were successfully completed and the following conclusions made:

- Water is the most effective phase change material (PCM because of its high volumetric energy storage capacity.
- A modular approach for thermal storage is most desirable since separate PCM modules afford both on and off-vehicle personnel cooling capability.
- MCS which employ PCM for energy storage show potential for net energy savings of up to 16% over standard refrigeration units. This savings diminishes considerably when considering the energy cost of transportation in military vehicles due to the added weight of the MCS. Landbased installations, such as tactical shelters would have more energy savings potential.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1
1.1 EXECUTIVE SUMMARY	1
1.2 BACKGROUND	1
1.3 PHASE II - TECHNICAL OBJECTIVE	4
1.4 SUMMARY OF WORK EFFORT	4
1.4.1 Task 1: Development of Specific Requirements . .	5
1.4.2 Task 2: Evaluate Thermal Energy Storage Mediums .	5
1.4.3 Task 3: Preliminary Design and Evaluation	5
1.4.4 Task 4: Detailed Design and Fabrication	6
1.4.5 Task 5: Testing and Task 6: Evaluation of Test Data	6
1.4.6 Task 7: Survey to Determine Commercial Applications	7
1.4.7 Task 8: Drawings	7
2.0 TECHNICAL APPROACH	8
2.1 TASK 1: DEVELOPMENT OF SPECIFIC REQUIREMENTS	8
2.2 TASK 2: EVALUATE THERMAL ENERGY STORAGE MEDIA	8
2.3 TASK 3: PRELIMINARY DESIGN AND EVALUATION	13
2.3.1 Design Concepts	13
2.3.2 Preliminary Design: Thermal Energy Storage (TES) Unit Design	21
2.3.3 Preliminary Design: Micro-Climate Cooling System (MCS)	21
2.4 TASK 4: DETAILED DESIGN AND FABRICATION	21
2.5 TASK 5 - TESTING	21

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TABLE OF CONTENTS
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<u>Section</u>	<u>Page</u>
2.6 TASK 6 - EVALUATION OF TEST DATA	63
2.7 TASK 7 - SURVEY TO DETERMINE COMMERCIAL APPLICATIONS .	66
3.0 CONCLUSIONS AND RECOMMENDATIONS	72
3.1 PHASE CHANGE MATERIAL	72
3.2 THERMAL STORAGE	72
3.3 ENERGY SAVINGS	72
3.4 COMMERCIAL APPLICATIONS	72
APPENDICES -	
A - SAMPLE CALCULATIONS FOR THERMAL LOAD PROFILES	75
B - MATERIAL SAFETY DATA SHEETS FOR MATERIALS USED IN THIS PROGRAM	79
C - MCS OPERATING INSTRUCTIONS	118

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Cutaway view of a heat pipe	3
2	Flow chart illustrating preliminary design and evaluation process	14
3	Solar thermal load profiles	15
4	Preliminary microclimate cooling system design concept . .	22
5	PCM module	26
6	Thermal resistance between warm air and PCM during melting as a function of module radius and fin pitch on module heat pipes	27
7	Heat transfer rate during melting as a function of module radius and fin pitch on module heat pipes	28
8	Heat transfer rate during freezing as a function of module radius and fin pitch on module heat pipes	30
9	Refrigeration unit evaporator temperature as a function of module outside radius and module heat pipe fin pitch . . .	31
10	Coefficient of performance vs. refrigeration unit evaporator temperatures	33
11	Preliminary design for TES unit employed in a 4 man C.S. unit	35
12	Layout of preliminary MCS design	37
13	Instrumented PCM module	38
14	Heat Pipe materials compatibility test	40
15	Refrigerant unit evaporator designs	43
16	MCS melt cycle performance verification test	45
17	Melt cycle test apparatus	46
18	Experimental results for melt cycle performance verification tests	48
19	Condensing coil assembly	51
20	Evaporator assembly	52

LIST OF FIGURES
(continued)

<u>Figure</u>		<u>Page</u>
21	Partially complete thermal energy storage unit	53
22	Installation of evaporator assembly	54
23	Air inlet side of bench test MCS	55
24	Air exit side of bench test MCS	56
25	MCS frame assembly	57
26	MCS unit test setup schematic	60
27	Thermocouple map	61
28	Rate and quantity of heat removed from MCS airstream . . .	64
29	MCS unit airstream temperatures	65

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 MCS Design Requirements	9
2 Desireable Characteristics for Practical PCM's	11
3 Properties Data for Alternative PCM	12
4 Daily Temperatures and Humidities for Various Locations	16
5 Comparison of Alternative Preliminary Designs	18
6 Comparison of Preliminary MCS Design Concepts	20
7 Relative Comparison of PCM Module Design Concept Variations	24
8 Major MCS Component Specifications	49
9 Values for Refrigeration Unit Operating Parameters	62
10 Comparison of Test Results with Design Values	67
11 Results of Cost Advantage Analysis for the Application of Thermal Energy Storage to Residential Cooling: Summer 1987	70
12 Various Utility Rates on a Monthly Basis: Summer 1987 . .	71

1.0 INTRODUCTION

1.1 EXECUTIVE SUMMARY

Military vehicles are required to operate in oppressive, high temperature and high humidity climates. Cooling must be provided for crew members on board these vehicles in order for the crew to function properly.

The objectives for the Phase II SBIR work conducted during the period September 1986 to March 1989 were:

- To evaluate and select a suitable phase change material.
- To design, build, and test a micro-climate cooling system capable of providing sufficient cooling to a four member crew operating in an oppressive environment aboard a military vehicle. (i.e., 55°F db air at 18 cfm/man for 10.5 hours or more).

Phase change materials for storing thermal energy were evaluated. A transient computer model was developed to aid in predicting and evaluating energy storage performance. A full scale MCS unit was designed, built, and tested. This unit was designed to meet thermal performance requirements and was not intended as a field test worthy unit. Stated simply, this unit is a laboratory bench test unit and not a prototype.

Water was the selected PCM because of its high volumetric heat storage capacity. Ethanol was added to the water in a concentration of 5% to prevent damage to MCS hardware which would occur as the water went from liquid to solid. A modular approach to storing and utilizing the PCM was selected because this offered two distinct features: 1) MCS of similar design but various capacities could be manufactured using the same basic building blocks (i.e., the PCM modules); and 2) PCM modules could potentially provide both on and off-vehicle personnel cooling.

A four-man bench test MCS was built and tested. It contained 144 PCM modules. It was to cool 135°F dry air to 55°F for 10.5 hours at a rate of 72 cfm. It operated at approximately 93% of design capacity, cooling 129°F dry air to 62.3°F for 10.25 hours at a flowrate of 70.2 cfm.

A summary of the Phase II conclusions are presented in Section 3.0.

1.2 BACKGROUND

Public Law 95-79 requires collective protection for personnel on armored vehicles. As a result, nuclear, biological, and chemical (NBC) protective clothing is used by these personnel. Personnel heat stress problems surfaced, particularly in connection with NBC protective clothing.

One solution to the heat stress problem is to cool the crew members on armored vehicles with refrigerated air. Air can be cooled with a conventional refrigerant air conditioner. However, air conditioners consume a lot of power, particularly when operated at high heat rejection temperatures.

It would be desirable to store at least a portion of the heat removed from the air during unfavorable heat rejection conditions and then to reject it to the surroundings during favorable conditions (lowest heat sink temperature).

The capacity of the air conditioners used to cool crew members aboard military vehicles could be substantially reduced if a portion of the day's heat load could be stored and then later rejected into the environment at night, when it is cooler.

Phase-change materials (PCM's) can be used to store thermal energy as latent heat of fusion. PCM's as heat storage mediums have been used for many years in the solar energy field. One of the challenges that faces the designer of a TES unit which employs a PCM is getting heat into and out of the PCM.

The heat pipe is well suited for transferring appreciable heat loads over small temperature gradients as is the case with TES units.

A cut-away view of a typical heat pipe is seen in Figure 1. Heat pipes are sealed evacuated devices that transfer heat by the evaporation and condensation of a working fluid. They are low-mass devices and have a high specific power. Heat pipes are passive, and do not require external power for their operation other than the heat which is to be transferred. Addition of heat evaporates a portion of the working fluid and increases the local vapor pressure. This increase in pressure moves

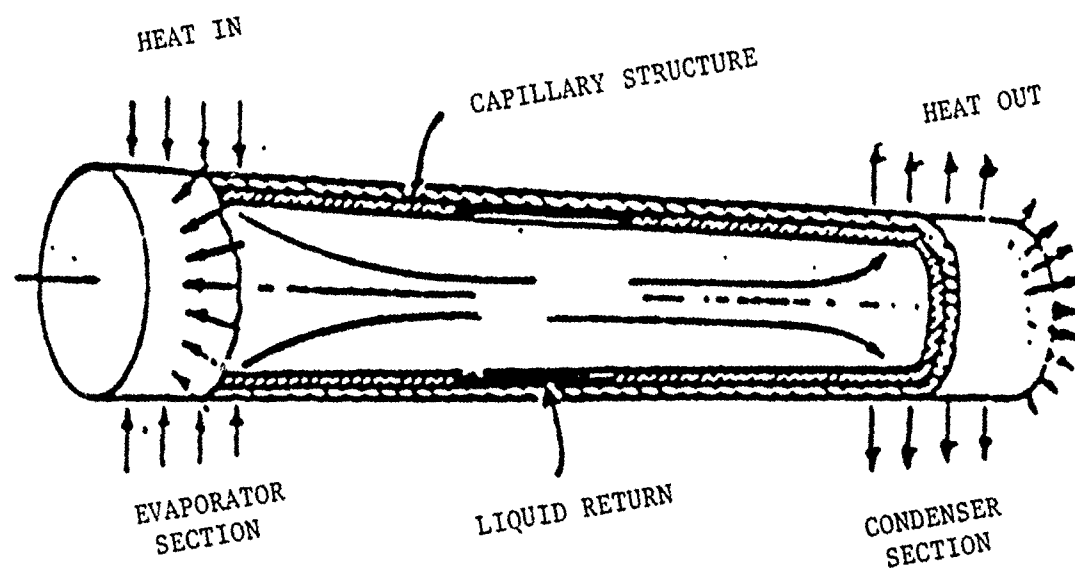


Figure 1. Cutaway view of a heat pipe

the vapor down the pipe to an area of lower pressure and temperature. The vapor condenses and gives up its absorbed heat. The condensed working fluid is returned to the heat input zone (evaporator) by gravitational body force or by capillary action in a suitable wick structure.

Heat pipes can be made to operate against gravity by using a capillary wick structure. Heat pipes which require gravity for returning the liquid from the condenser to the evaporator act as thermal diodes and can be useful tools.

1.3 PHASE II - TECHNICAL OBJECTIVE

This report details work done by Thermacore for Phase II, 1986 SBIR Contract Number DAAK70-860-C-0122. The primary objective of this Phase II research and development program was to design, build, and test a full scale micro-climate cooling system for providing cool air to crew members aboard military vehicles.

A secondary objective was to extend the thermal energy storage technology developed in this program towards applications in the commercial and private sector.

1.4 SUMMARY OF WORK EFFORT

The Phase II work effort for this program was comprised of eight (8) tasks and reporting. These tasks are listed below, and the results for each are briefly summarized in the following paragraphs.

- Development of Specific Requirements
- Evaluate Thermal Energy Storage Mediums
- Preliminary Design and Evaluation
- Detailed Design and Fabrication
- Testing
- Evaluation of test data
- Survey to Determine Commercial Applications
- Drawings

1.4.1 Task 1: Development of Specific Requirements

The design requirements for micro-climate cooling systems which provide cool air to crew members aboard military vehicles were detailed at a meeting between Thermacore and Army personnel held at the inception of the Phase II program in November, 1986. The requirements for developing MCS units include heat removal rate, air volumetric flowrate, outlet air temperature, total heat load, operating temperatures and humidities and time. The requirements are documented in Section 2.1 and form the basis for the rest of the development effort.

1.4.2 Task 2: Evaluate Thermal Energy Storage Mediums

The MCS developed in this program make use of thermal energy storage to provide cooling and use the latent heat of fusion of a phase change material (PCM) to store thermal energy.

Literature surveys and telephone calls were made in an effort to identify and evaluate candidate PCM. Several candidate materials were identified. A comparison of important PCM properties for these candidates was conducted. From thermal performance considerations, the two most important parameters for selecting a PCM for use in an MCS are the melting temperature and the volumetric heat storage capacity. Based on these criteria and others, water was the selected PCM. This effort is documented fully in Section 2.2

1.4.3 Task 3: Preliminary Design and Evaluation

This task was intended to generate concepts for MCS using PCM and evaluate their respective merits and shortcomings with respect to the design requirements. The selected concept operates in the following manner: frozen water acting as a PCM stores all of the heat load while cooling the crew members during peak hours and then rejects that heat to a vapor compression refrigeration unit during off-peak heat load hours. The refrigeration unit operates only during off-peak heat loads, so net daily electrical energy consumption is minimized. This concept offers a maximum net energy savings of 16% over a standard refrigeration unit not employing thermal energy storage. The amount of water required for a four

man MCS in 8.02 ft³ or 457 pounds.

A modular approach for storing PCM was selected over bulk storage because this approach offered the advantage of greater design flexibility in terms of configuring hardware, and offered off-vehicle personnel working capability. The heat pipe makes it possible to have on-vehicle and off-vehicle thermal storage cooling of personnel. The heat pipe and its low thermal resistance makes it possible to "plug-in" to a heat exchanger easily and with high effectiveness. The heat exchangers might be a circulating fluid type or two-phase refrigerant evaporators and might be carried by vehicle or on a crew member's person.

A more complete description of the selected preliminary design including components, system configurations, materials of construction and modes of operation are included in Section 2.3. The work effort to arrive at a preliminary design is also described in Section 2.3.

1.4.4 Task 4: Detailed Design and Fabrication

This task focused on turning the selected preliminary design into working hardware. Included in this effort was the specifying of all parts and materials; production of detailed fabrication drawings; procurement of parts and materials; and fabrication of a bench-test MCS. The MCS was built as a four-man unit; having 36 PCM modules per man; weighing approximately 750 pounds; and having a total volume of approximately 26 cubic feet.

Section 2.4 contains more information on the MCS design and the fabrication of the bench-test unit.

1.4.5 Task 5: Testing and Task 6: Evaluation of Test Data

The MCS was instrumented to measure temperatures and air flow rates. It was operated under hot-dry environmental conditions (i.e., dry bulb temperatures in excess of 120°F and relative humidities less than 10%). Initial performance tests were unsuccessful. Several PCM modules burst as the PCM (water) froze and expanded. This problem was rectified by using a 5% ethanol-95% water mixture as the PCM.

Performance tests were successfully completed. The unit provided 61,540 Btu of cooling which was 95% of the required capacity of 65,000 Btu. The unit cooled 129°F dry bulb air for 10.25 hours at a time average temperature and flowrate of 62°F and 70.2 cfm. These compare with the design values of 55°F at 71 cfm for 10.5 hours. A more complete discussion on test hardware and procedure is presented in Section 2.5 and on evaluation of test results in Section 2.6.

1.4.6 Task 7: Survey to Determine Commercial Applications

A survey was conducted to identify potential commercial markets for latent heat thermal energy storage (LHTES) technology. LHTES appears most useful for solar heat applications, waste heat recovery and storage for heat pumps, and cooling applications where savings in utility costs can be had. The technology developed in this program does show potential for improving upon the efficiency of equipment used in these applications and would reduce electrical energy consumption. However, the costs associated with these improvements does not appear justified based on current estimates for energy costs.

Section 2.7 details the efforts and results of this task.

1.4.7 Task 8: Drawings

Drawings of the preliminary design were submitted to Army BRDEC at the midterm of this program. Final drawings were submitted to Army BRDEC in conjunction with this Final Report.

2.0 TECHNICAL APPROACH

This section of the report covers the results of work done for each of the eight tasks on this program.

2.1 TASK 1: DEVELOPMENT OF SPECIFIC REQUIREMENTS

A well performing microclimate cooling system (MSC) would provide sufficient cooling to crew members aboard their military vehicle. It would also integrate with other onboard systems; at the same time allowing the crew members to perform their duties efficiently without being encumbered by the cooling system. The MCS designed in this program was to provide the needed cooling using refrigerated air and should, therefore, be capable of interfacing with onboard air filtering and air distribution equipment.

In an effort to establish specific design requirements for MCS, a meeting was held between Army and Thermacore personnel. Design requirements and operating conditions established at that meeting are presented as Table 1.

2.2 TASK 2: EVALUATE THERMAL ENERGY STORAGE MEDIA

In Phase I of this program alternative thermal energy storage media were evaluated. These storage media were of two types: thermochemical processes and phase change materials. A general description of these storage media types follows:

There are two basic categories of thermochemical processes:

1. Heat of Reaction - reversible chemical reactions with relatively high heats of reaction. Example: reacting a metal or metal alloy with hydrogen gas to form a metal hydride. This reaction absorbs heat and can later be reversed to give up this heat.
2. Heat of Solution - mixing of chemicals that have a negative heat of solution. Example: Mixing ammonium nitrate with water to absorb heat. This type of process is difficult to reverse.

It should be noted that in the previous two examples both hydrogen and ammonium nitrate are explosive and high factors of safety must be used in the design of their respective containers.

TABLE 1. MCS Design Requirements

OPERATION TIME	12 HOURS
CHARGING TIME	12 HOURS
OPERATING POSITION	60% GRADE IN ALL DIRECTIONS
OUTSIDE AIR	120°F 3% RH
	95°F 74% RH
INSIDE AIR TEMPERATURE - OUTSIDE TEMP.	+15°F
COOL AIR SUPPLIED TO PLUG IN COOLING VESTS AT:	
18 CFM/MAN	
<u>4 MAN OCCUPANCY</u>	
72 CFM OF COOL AIR	
OUTLET AIR TEMPERATURE	55°F DRY BULB
COOLING CAPACITY	1200Btu/HR/MAN*
PRESSURE DROP THROUGH MCS	20" H ₂ O + (DROP THROUGH TES UNIT)
WEIGHT	MINIMIZED
VOLUME (INCLUDING SHAPE & SIZE)	MINIMIZED
ALLOWABLE PERFORMANCE DEGRADATION WITH TIME	1000 HOUR MEAN TIME BETWEEN FAILURES
ON BOARD AIR CONDITIONING CAPACITY, EVAPORATOR, AND CONDENSER ARRANGEMENTS, DUCTING LOCATIONS, ETC.	SIZED AND CONFIGURED TO MEET THERMAL REQUIREMENTS WHILE MINIMIZING WEIGHT AND VOLUME

Conforms to Human Factors Engineering Design and Criteria as described in MIL-STD-1472.

Conforms to DARCOM-R-702-24 (Material Deterioration Prevention and Control).

*1200 Btu/Hr removed from crew member and absorbed by conditioned air.

Other, safer, materials for storing heat by thermochemical processes are being researched and developed at facilities across the country. Some of these firms have reported encouraging results but recognize that work is still needed before these materials are usable for practical design of thermal energy storage units.

Based on the foregoing discussion, Thermacore chose phase change materials (PCM's) for use in the MCS developed in Phase II. The requirements for selecting a suitable PCM are outlined in Table 2.

Alternative PCM's were identified to serve as thermal energy storage mediums. A partial list of these PCM's is included in Table 3. Only the PCM's exhibiting a satisfactory melting temperature are listed.

From a thermal standpoint, the two most important parameters for selecting a PCM to use in a MCS are the melting temperature and the volumetric heat storage capacity. Polyethylene glycol E400 has a favorable melting temperature but a volumetric heat storage capacity less than half that of water.

The calcium bromide, chloride PCM is no longer produced for domestic markets due to a lack of commercial interest. The equipment required to make the calcium bromide, chloride PCM is very expensive and Dow Chemical considers the PCM proprietary.

The sodium sulfate dehydrate-salt mixture is not recommended for use as a PCM based on real time experiments conducted at the University of Delaware. The PCM was found to degrade after only a few cycles when subjected to the type of charging/discharging cycles expected in practical applications. Earlier studies done on the PCM concluded that it had satisfactory properties for freeze/thaw cycling, but those studies were based on accelerated cycling experiments.^{1,2}

TABLE 2. Desirable Characteristics for Practical PCM's

Thermal Properties

- Suitable phase transition temperature
- High latent heat of transition
- Good heat transfer

Physical Properties

- Favorable phase equilibria
- Low vapor pressure
- Small volume change
- High density

Kinetic Properties

- No supercooling
- Sufficient crystallization rate

Chemical Properties

- Long-term chemical stability
- Compatible with materials of construction
- Nontoxic
- No fire hazard
- No nuisance factor

Economics

- Abundant
 - Available
 - Cost effective
-

TABLE 3. Properties Data for Alternative PCM

PCM	CaBr ₂ ·6H ₂ O/ CaCl ₂ ·6H ₂ O	Na ₂ SO ₄ ·10H ₂ O/ KCl/NH ₄ Cl	Polyethylene Glycol E40	H ₂ O
Melting Temperature (°C)	15	8	7	0°C
Heat of Fusion (kJ/kg)	140	121	125	332
Volumetric Heat Storage (MJ/m ³) Capacity	249	180	138	332
Density (kg/m ³) Liquid	1780	1490	1100	1000
Solid	1940	---	1200	920
Thermal Conductivity (W/m°C) Liquid	---	0.55	---	0.56
Solid	---	0.70	---	2.21
Specific Heat (kJ/kg°C) Liquid	---	3.1	---	4.22
Solid	---	3.1	---	---
Crystallization Rate	Satisfactory*	Satisfactory*	Satisfactory	---
Degree of Supercooling (°C)	Satisfactory*	Satisfactory*	Satisfactory	---
Relative Rank	3	4	2	1

* - No quantitative data found in literature although listed as having a satisfactory degree of supercooling and crystallization rate.

Water exhibits all of the desirable characteristics for a PCM listed in Table 2 with the exception of one physical property - a small volume change during change of phase. Water expands considerably as it freezes. An MCS using water as a PCM for energy storage should be designed to account for this fact.

2.3 TASK 3: PRELIMINARY DESIGN AND EVALUATION

The purpose of this task was to generate a design concept and detail that concept to arrive at a preliminary MCS design capable of meeting the established requirements. A flow chart which outlines the preliminary design process is illustrated in Figure 2. Each rectangular box represents a stage in the process. The work and results for each stage are discussed separately below.

2.3.1 Design Concepts

Before generating and evaluating alternative concepts, it was helpful to define representative operating conditions. This began with the definition of typical design day thermal load profiles. Two such profiles are shown in Figure 3. Figure 3A is a profile adapted from the MCS design requirements documented in Table 4 for the "hot-dry" conditions. For a period of twelve hours 72 scfm of 120°F air is filtered and raised in temperature to 135°F. This air must then be cooled to 55°F dry bulb. This requires an MCS capacity of 1836 W (6266 Btu/hr). For the next twelve hour period no cooling is required. For calculation purposes a night-time ambient temperature of 80°F is assumed.

A more typical profile would show a gradual rise in temperature during the morning hours, leveling off during mid-day, then gradually dropping off during the evening hours. The temperature leveling off again at night. One such profile is shown in Figure 3B.

In this case, the day-time ambient temperature ramps from 80°F DB at 6:00 a.m. to 120°F DB at 1:00 a.m., remains at 120°F DB until 5:30 p.m., and then ramps down to 80°F DB at 9:00 p.m. Calculations based on thermal

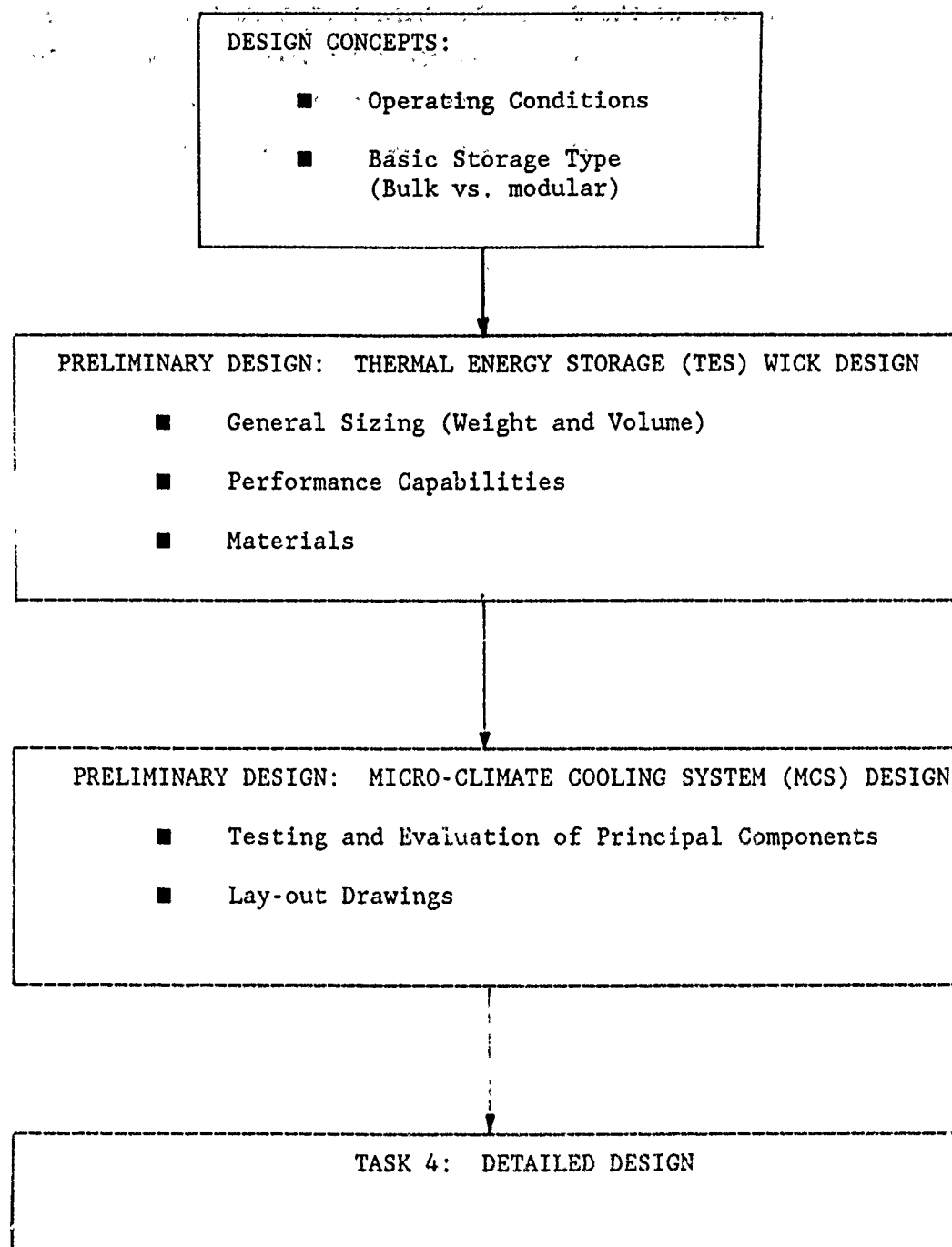
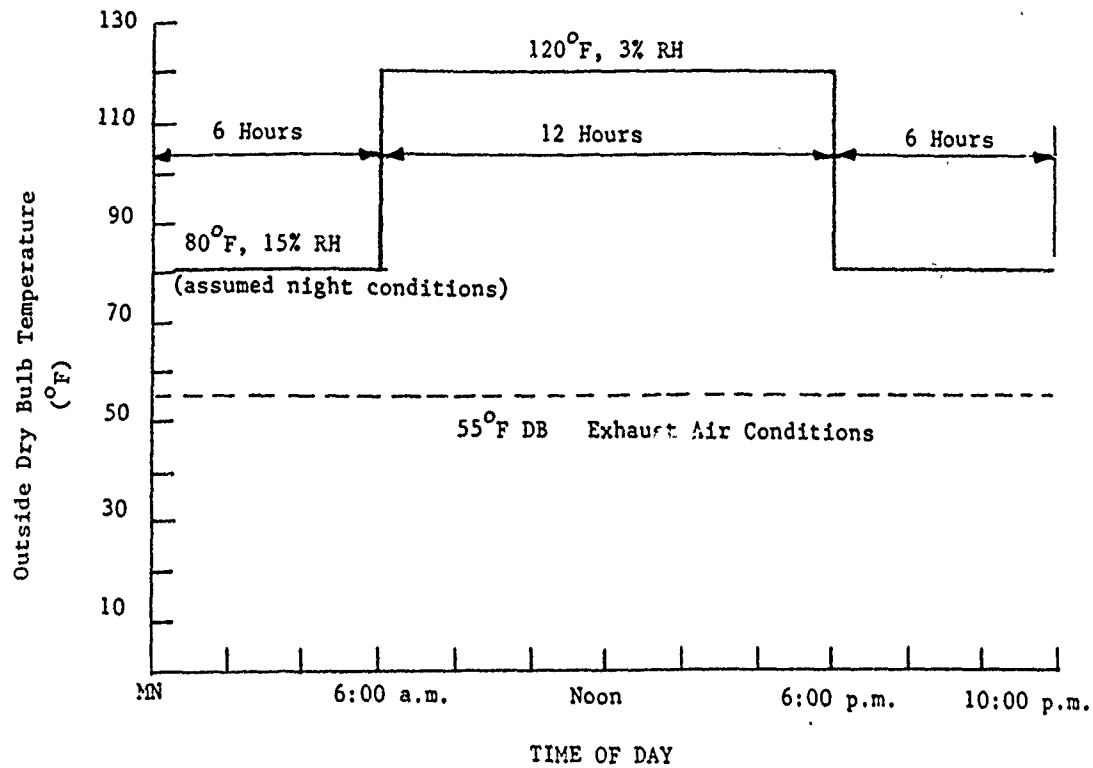
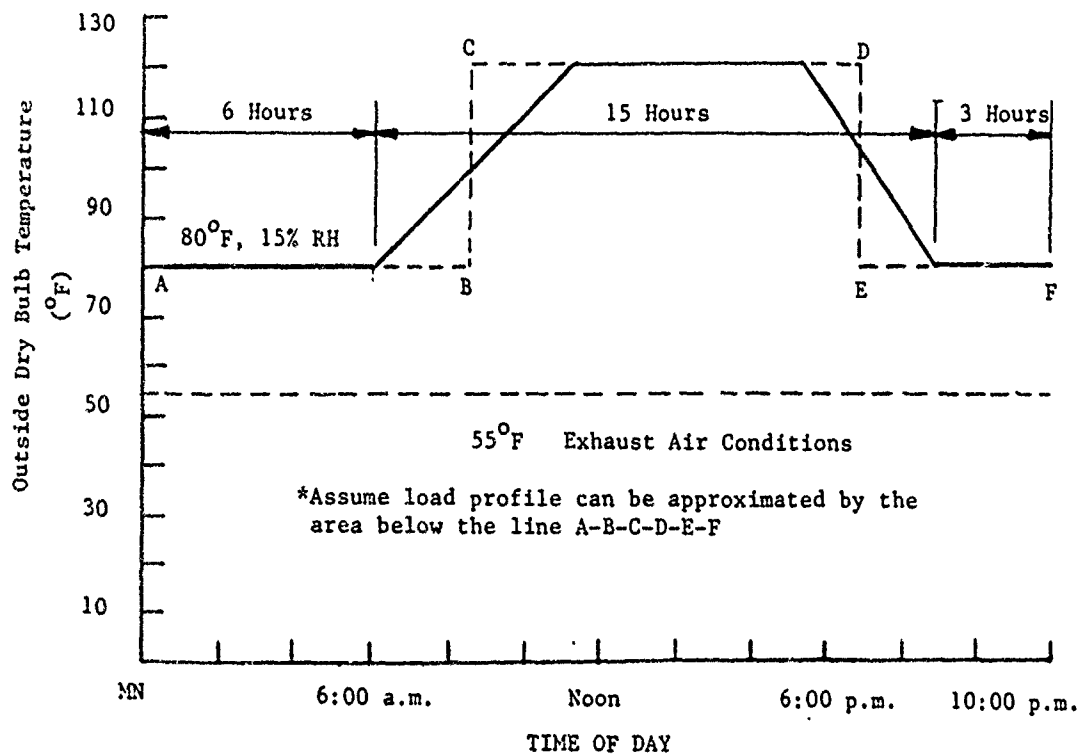


Figure 2. Flow chart illustrating preliminary design and evaluation process



A. Original temperature profile used in Phase I work



B. Typical "hot-dry" temperature profile

Figure 3. Solar thermal load profiles

TABLE 4. Daily Temperatures and Humidities for Various Locations

LOCATION	SUMMER			LOW TEMPERATURE ° F***
	HIGH TEMPERATURE ° F*	RELATIVE HUMIDITY %**		
Dhahran, Saudi Arabia	111	31		79
Merida, Mexico	97	49		76
New Delhi, India	110	34		84
Alice Springs, Australia	104	27		77
El Centro, California	112	15		78
Monroe, Louisiana	99	38		79
Design Day (Dry Conditions)	120	3		80

*1% design value: In a normal summer there would be approximately 30 hours at or above a 1% design value.

**Based on a 1% design value wet bulb and dry bulb temperatures.

***Based on Mean daily temperature range. (e.g., Dharan, Saudi Arabia with 1% design dry bulb of 111°F and Mean daily range of 32°F: Low temperature = 111°F - 32°F = 79°F).

load profile B allow for cooling of the crew members night-time air as well as the day. The MCS must have a peak capacity of 1836 W (6266 Btu/hr) and an off-peak capacity of 932 W (3181 Btu/hr).

Justification for assuming a night-time ambient temperature of 80°F can be made from Table 4 which shows daily highs and lows for summer conditions in several "hot-dry" climates⁴. Both thermal profiles A and B were used during design stages and again during test performance evaluation.

The procedure used for determining nominal refrigeration capacities and energy consumptions for alternative MCS concepts was as follows:

- Define a thermal load profile (described in Section 2.3.1).
- Define operating scenario (e.g., an MCS employs an amount of water as a PCM sufficient to minimize compressor capacity. The compressor runs continuously day and night. Stored heat is rejected at night only).
- Determine day and night refrigeration in capacity for alternative refrigerants (i.e., R12 and R22).
- Determine net energy consumption and compare alternatives.

Calculations for several operating scenarios were conducted. The results of which are shown in Table 5 for thermal load profile B, the typical "hot dry" design day.

In Table 5 the estimated weights, energy consumption rates, and total energy consumption per day for the following MCS operating scenarios are shown.

- A MCS that employs no thermal energy storage (vapor compression refrigeration cycle), which is considered the baseline for comparison.
- A MCS that employs an amount of water as the PCM sufficient to minimize the size of the compressor.
- A MCS that uses thermal storage exclusively during peak heat load hours and employs water as the PCM.

TABLE 5. Comparison of Alternative Preliminary Designs

Operating Scenario	A Vapor Compression Refrigeration Unit provides all of the required cooling.	A Refrigeration Unit works in parallel with a TES Unit to provide day's cooling. The compressor capacity minimized.	A TES Unit provides all of day's cooling. Refrig. Unit provides night-time cooling and freezes PCM.	A TES Unit provides all of day's cooling. Refrig. Unit provides night-time cooling and freezes PCM.
Thermal Load Profile (refer to Figure 1)	B	B	B	B
Phase Change Material (PCM)	None	H ₂ O	H ₂ O	PGE-E400
Weight/Volume of PCM	N/A	127 lbs (2.04 ft ³)	457 lbs/8.02 ft ³	1225 lbs/16.35ft ³
Estimated Condensing Unit Weight	40 lbs	27 lbs	53 lbs	53 lbs
Day Time Average Power Consumption	1860 Btu/hr	1340 Btu/hr	0	0
Night Time Average Power Consumption	500 Btu/hr	1050 Btu/hr	1631 Btu/hr	1417 Btu/hr
Net Energy Consumption Per Day	26,200 Btu	28,240 Btu	22,020 Btu	19,130 Btu
Percent Reduction in Energy Consumption Over Baseline	Baseline	-7.8%	+16.0%	+27.0%

- A MCS that uses thermal storage exclusively during peak heat load hours and employs polyethylene glycol E400, as the PCM.

Sample calculations used to arrive at the results in Table 5 are included as Appendix A.

From Table 5, it is evident that thermal energy storage can be used to reduce energy consumption of MCS onboard military vehicles. The energy consumption per day can be reduced by up to 27% using PEG-E400 as the PCM, and up to 15% using water as the PCM over the baseline design concept. It is also apparent from Table 5 that the concept employing water as the PCM is considerably lighter and more compact than the concept employing PEG-E400 as the PCM. The operating scenario which minimizes net daily energy consumption is to store all of the day-time heat load in a PCM and then reject that heat at night.

After defining the MCS design concept to have the following:

- Water as the PCM to provide all day-time cooling.
- Refrigeration unit to operate only at night freezing PCM and providing cooling if needed.

The next step was to determine how best to configure and access the PCM.

In general, all thermal energy storage units are either bulk storage units or modular storage units. The primary difference is that a modular unit consists of a number of similar PCM containers which can be added or subtracted from a storage unit in a building block fashion, whereas, a bulk storage unit consists of only one or a few large PCM containers. Most thermal energy storage units used for building cooling applications are bulk storage units. A relative comparison of the advantages and drawbacks for both types of storage is shown in Table 6.

Modular storage was selected for application to micro-climate cooling systems because of its potential for greater design flexibility, and off-vehicle personnel cooling capability.

TABLE 6. Comparison of Preliminary MCS Design Concepts

	<u>Bulk</u>	<u>Modular</u>
Volume	Similar	Similar
Mass	Similar	Similar
Design flexibility	Some	Considerable
System can be operated passively (fan power required only)	Yes	Yes
Off-vehicle capability	No	Yes
Modular design (easily scaled to accommodate differing crew sizes)	No	Yes
Closed system (low contamination risk)	Yes	Yes
Controls simple (individual temperature regulation)	Yes	Yes

A design concept for the PCM modules is depicted in Figure 4. Modules of this type can be used for personnel cooling in two ways: 1) As one of many modules in a MCS located onboard the vehicle to which the personnel are attached via umbilical hoses; and 2) as a separate or pair of modules carried by an individual in backpack fashion, as he or she performs tasks on and off the vehicle. The modules would be operated in the following manners:

- In an MCS the modules would cool air as it passes over their outside surfaces, thus, melting the ice from the outside inward. To refreeze the modules, the heat pipes, which protrude from the modules, remove heat from the water and transfer it to the evaporator of the vapor compression refrigeration unit.
- In a backpack, the modules would cool air either directly as the air passes over them, or indirectly as the air passes over the exposed portion of the heat pipe. Refreezing of the modules would be accomplished by installing them in the MCS and operating the refrigeration unit, as described above.

2.3.2 Preliminary Design: Thermal Energy Storage (TES) Unit Design

This effort was directed towards designing the thermal energy storage (TES) portion of the MCS. The focus was on optimizing heat transfer from and to the PCM while minimizing volume and weight of the system. Since the PCM module is the basic building block of the TES unit, a suitable module design was detailed. Included in this effort was a determination of suitable construction materials.

Referring again to Figure 4 showing a PCM module design concept, we see that this concept is comprised of a PCM, a PCM container, and one or more heat pipes. Variations of this concept were reviewed and a preliminary module design was selected. The concept variations were based on available forms of construction materials for the PCM container and included: rigid rectangular tubing, rigid cylindrical tubing and a flexible bag. Materials considered for construction of these modules included aluminum, various grades of plastic, metal foils, and metallized

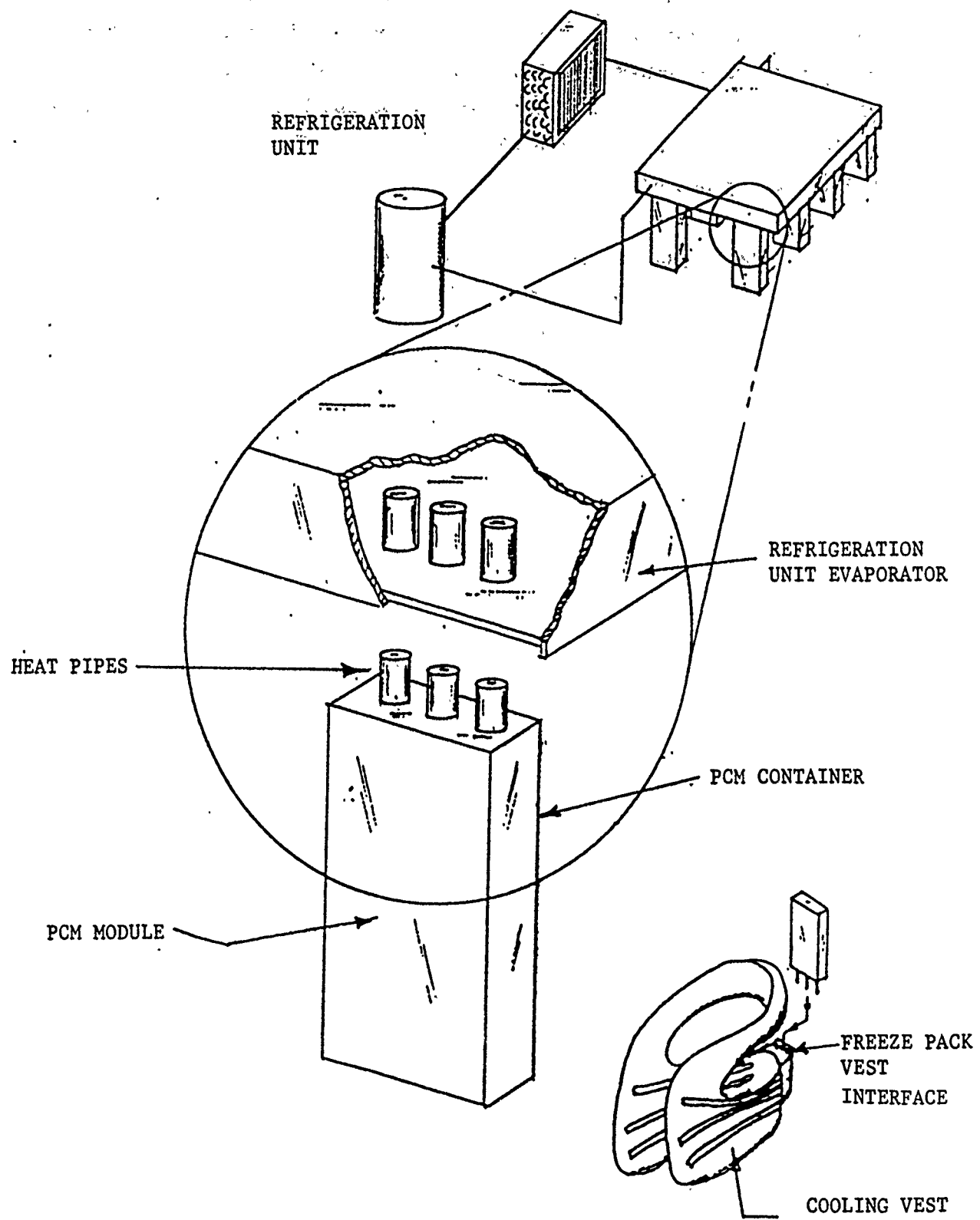


Figure 4. Preliminary microclimate cooling system design concept

plastics. PCM modules made with any of these materials would be utilized in the manner described in the previous section for onboard and offboard applications. A comparison of the relative advantages and disadvantages for these concept variations was made and is included as Table 7.

In terms of thermal performance, the plastics are nearly as good as aluminum as a container material. Low heat transfer rates through the container wall means thermal conductivity is not a driving factor. Since plastics are less dense, more flexible, lower in cost, and chemically inert, they are the materials of choice for the PCM module containers. Because the right cylindrical module concept can be fabricated from stock plastic tubing and requires relatively simple closures, it is less expensive than the other concepts and inherently easier to fabricate. This tends to give it a higher reliability. The rectangular concept would require a special extrusion or multiple welds, making it more expensive and/or less reliable.

The flexible bag concept would require some form of framework to support it in order to give it strength and consistent heat transfer characteristics. The added design complexity makes it more expensive to manufacture. In consideration of the above observations, the right cylindrical module concept was selected for more detailed design.

Cellulose acetate butyrate (CAB) was the PCM container material chosen because it is available in a wide range of stock tubing and sheet sizes, is inexpensive, exhibits good ductility, and is solvent weldable.

Water was selected as the PCM because of its high volumetric heat storage capability. Aluminum or titanium in combination with either acetone, ammonia, or a fluorocarbon refrigerant were chosen as the heat pipe materials because of their high reliability, and good heat transfer, strength, and weight characteristics.

Design analyses were conducted to determine PCM module size and consequently number required per MCS assembly. This was necessary in order to establish an overall configuration for the thermal energy storage unit. The PCM modules were optimized for thermal performance during both the freezing and melting cycles. Parametric analysis were used to establish design optimums.

TABLE 7. Relative Comparison of PCM Module Design Concept Variations

<u>Concept</u>	<u>Rectangular</u>	<u>Right Cylindrical</u>	<u>Flexible Bag</u>
Heat Transfer during Melting	Adequate	Adequate	Adequate
Heat Transfer During Freezing	Adequate	Adequate	Adequate
Potential Materials of Fabrication	Plastics, Aluminum	Plastics, Aluminum	Plastics, Metal Foils, Metallized Plastics
Strength	High	High	Low
Design Complexity	Moderate	Low	Moderate
Cost of Fabrication	Moderate	Low	Moderate
Reliability	Depends on fabrication method	High	Uncertain
Quality Assurance	Depends on fabrication method	High	Moderate
Freeze/Thaw Resistance	Moderate	Moderate	High

Figure 5 shows a typical PCM module. Certain assumptions were made prior to conducting the parametric analysis. These assumptions are listed below:

1. One aluminum heat pipe is employed per module and is located along the central axis.
2. The heat transfer film coefficient along the outside surface of the module is constant and equal to $18.5 \text{ W/m}^2\text{C}$.
3. During the melt cycle, the surrounding air temperature is 95°F .
4. Heat transfer through the PCM is by conduction only and is one dimensional (radial).
5. The cellulose acetate Butyrate module container is 0.063 inch thick.

The value for the film coefficient in assumption (2) above was derived using a Nusselt equation for air flowing over closely spaced cylinders; in this case, 18 cfm air flowing over a single column of four or more cylinders spaced 0.125 inch apart.

Results from the parametric analyses are shown in Figures 6 through 9 where the independent variables are module radius and fins per inch along the heat pipe. The dependant variable in Figure 5 is the thermal resistance between warm air and the PCM during the melt cycle. The thermal resistance is defined at the point where the solid/liquid PCM interface is furthest from the air, that is, where thermal resistance is maximum. Two curves are shown. One curve represents a PCM module with no fins along the heat pipe. The second curve is for a module with 8 fins/inch along its heat pipe. This figure illustrates two things: (1) that thermal resistance during melting is greatly reduced by using fins along the heat pipe (e.g., a nominal reduction by four times using 8 fins/inch versus no fins), and (2) that for a module not employing fins, an optimum module radius exists that minimizes thermal resistance. The values for thermal resistance in Figure 6 were used to determine heat transfer rates based on 95°F air and a $18.5 \text{ W/m}^2\text{C}$ film coefficient. The results are presented in Figure 7 where again module radius is the independent variable, and curves are shown for 8 fins/inch and no fins/inch along the heat pipe. Curves are also shown for the heat

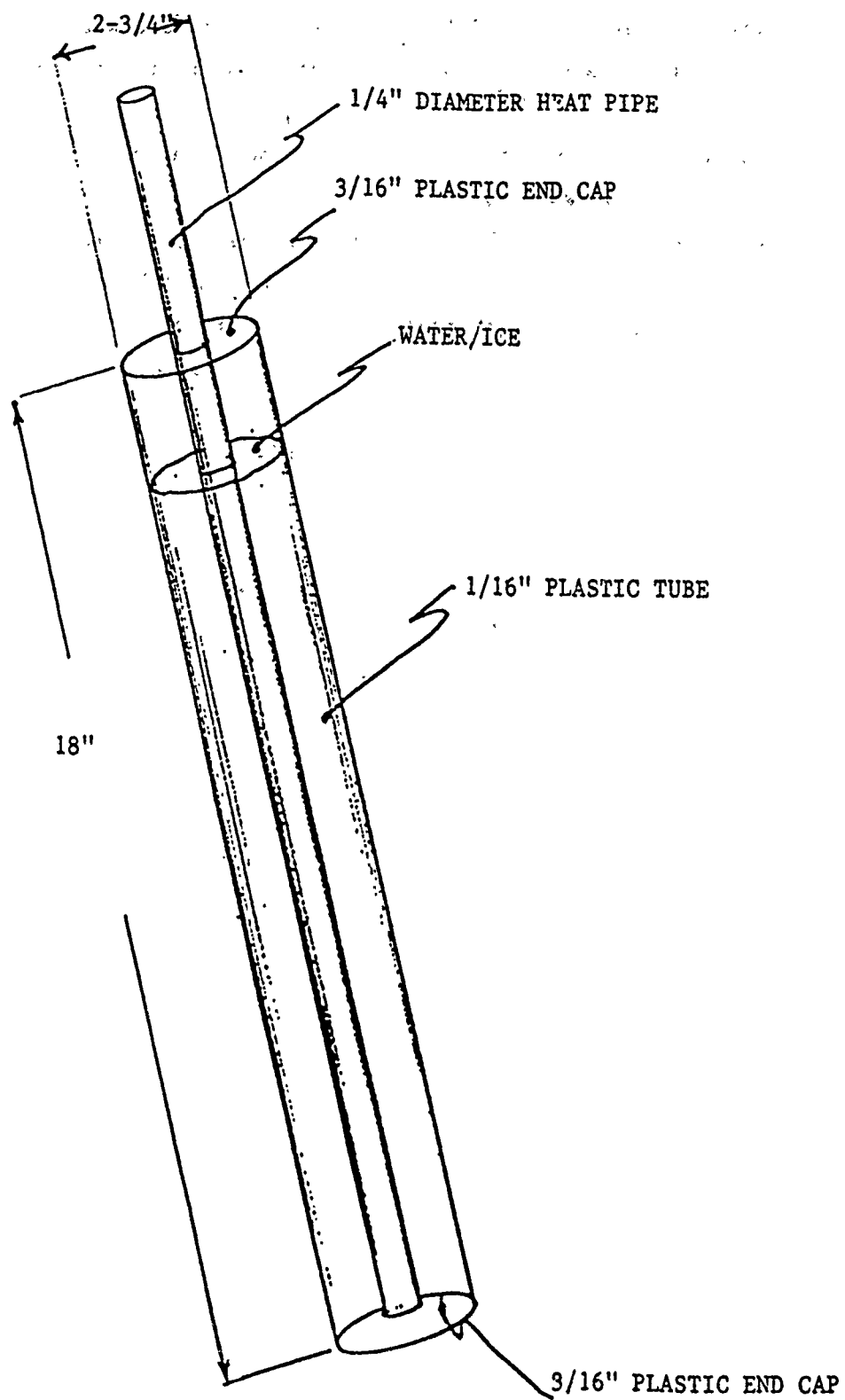


Figure 5. PCM module

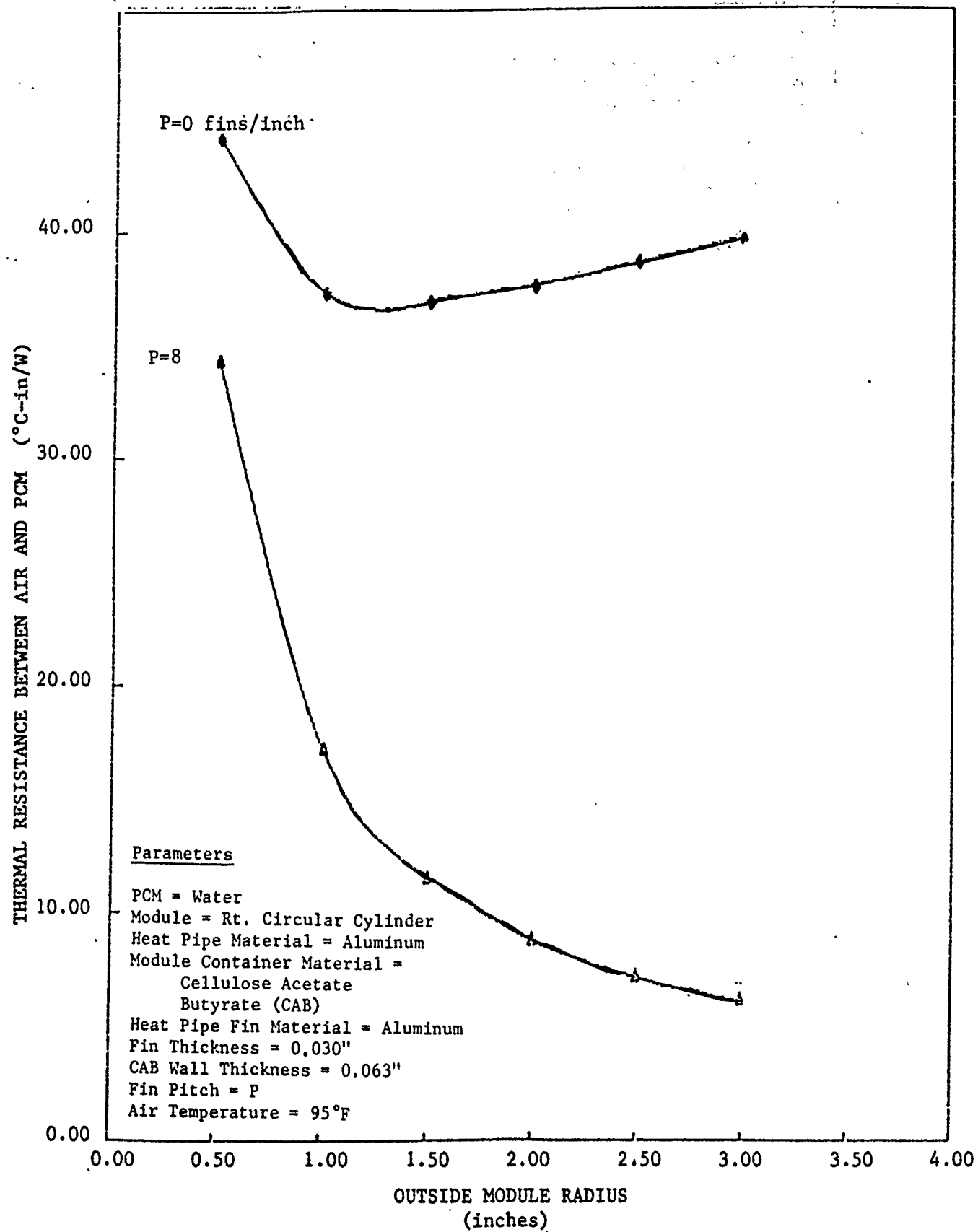


Figure 6. Thermal resistance between warm air and PCM during melting as a function of module radius and fin pitch on module heat pipes.

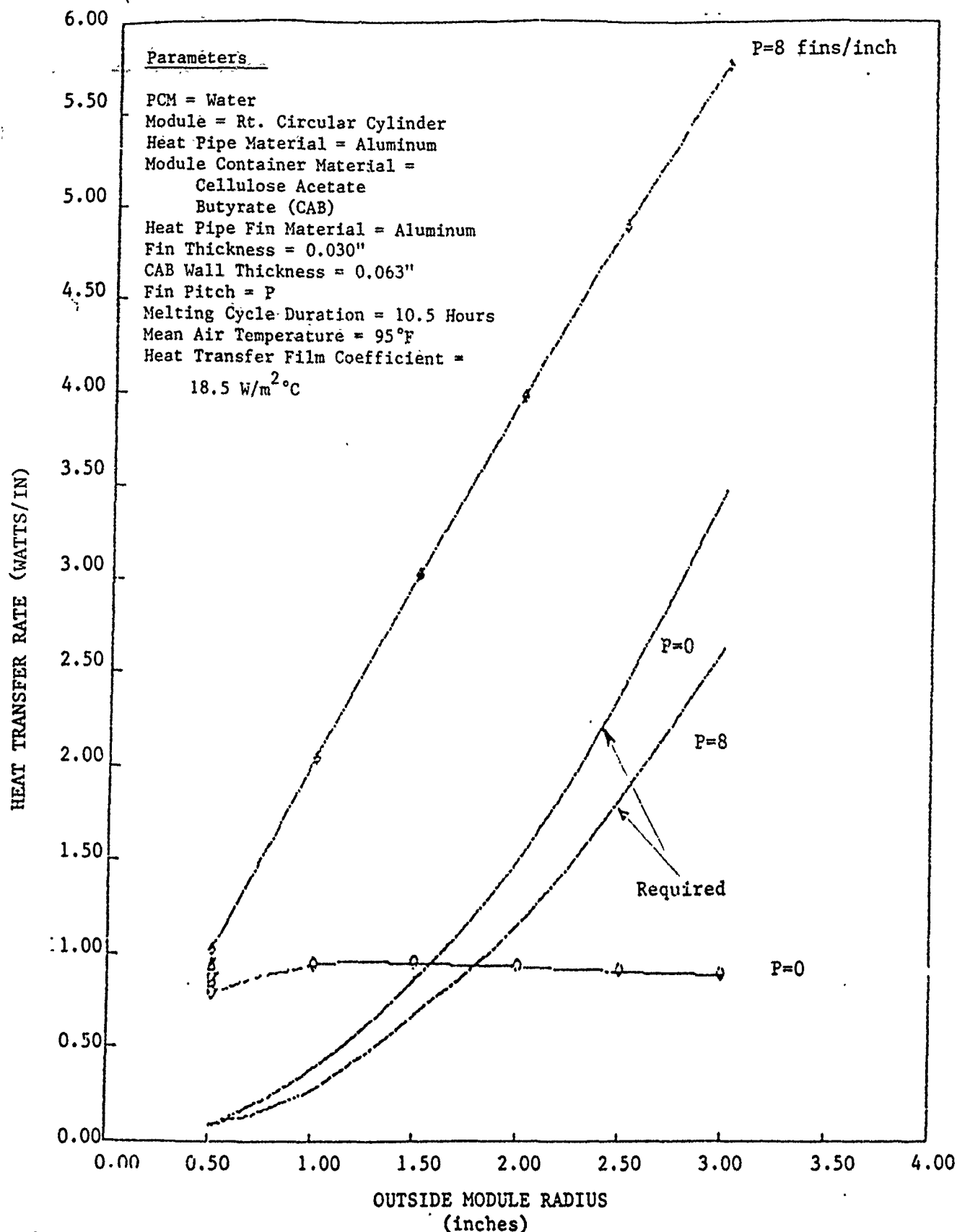


Figure 7. Heat transfer rate during melting as a function of module radius and fin pitch on module heat pipes.

$$\text{Heat Transfer Rate} = \frac{(\text{Mean Air Temp.} - \text{PCM Freezing Temp.})}{(\text{Thermal Resistance to Melting})}$$

transfer rate which is required to occur given a cooling cycle duration of 10.5 hours. This cooling cycle duration comes from Thermal Profile B discussed earlier in Section 2.3.1. The following comments can be made concerning the information in Figure 7.

- The PCM module containing a heat pipe with 8 fins/inch removes heat much more effectively from warm air than the module with no fins/inch, particularly for larger outside radii.
- For a given module radius, the required heat transfer rate diminishes with increasing fin pitch. This is because the fins displace equal volume of PCM and reduce the net energy storage capacity for a PCM module on a per unit length basis.
- In the 8 fins/inch case, the heat transfer rate is in excess of the required value for all module radii. However, for the no fins/inch case, modules having radii greater than about 1.6 inch are unacceptable. Modules of radius less than 1.6 inch should perform satisfactorily.

Heat transfer results during the freeze cycle are presented in Figure 8. Results are presented in the same format as the previous figure, Figure 7. In this case, the freeze cycle is 13.5 hours, and the heat sink is assumed to be at -11°C . It is again apparent that fins greatly enhance heat transfer rates. It is also apparent that for the no finning case, the heat transfer rate is in excess of what is required for module radii up to about 2.2 inch. In this figure it is assumed that in addition to being isothermal, the heat pipe's transport capacity is non-limiting. In reality, all heat pipes have an upper limit on heat transport capacity. Those considered for this application can, for the sake of argument, be considered to have a limit of 20 to 50 watts. The actual value depends on numerous factors including: working fluids, temperature, pipe diameter and length, etc.

The influence of module radius on refrigeration unit evaporator temperature is presented in Figure 9. This figure illustrates two things: (1) as module radius increases, heat must conduct greater distances and evaporator temperature falls, and (2) fins markedly reduce this effect. For a module of 1.50 inch or less the difference in evaporator temperature

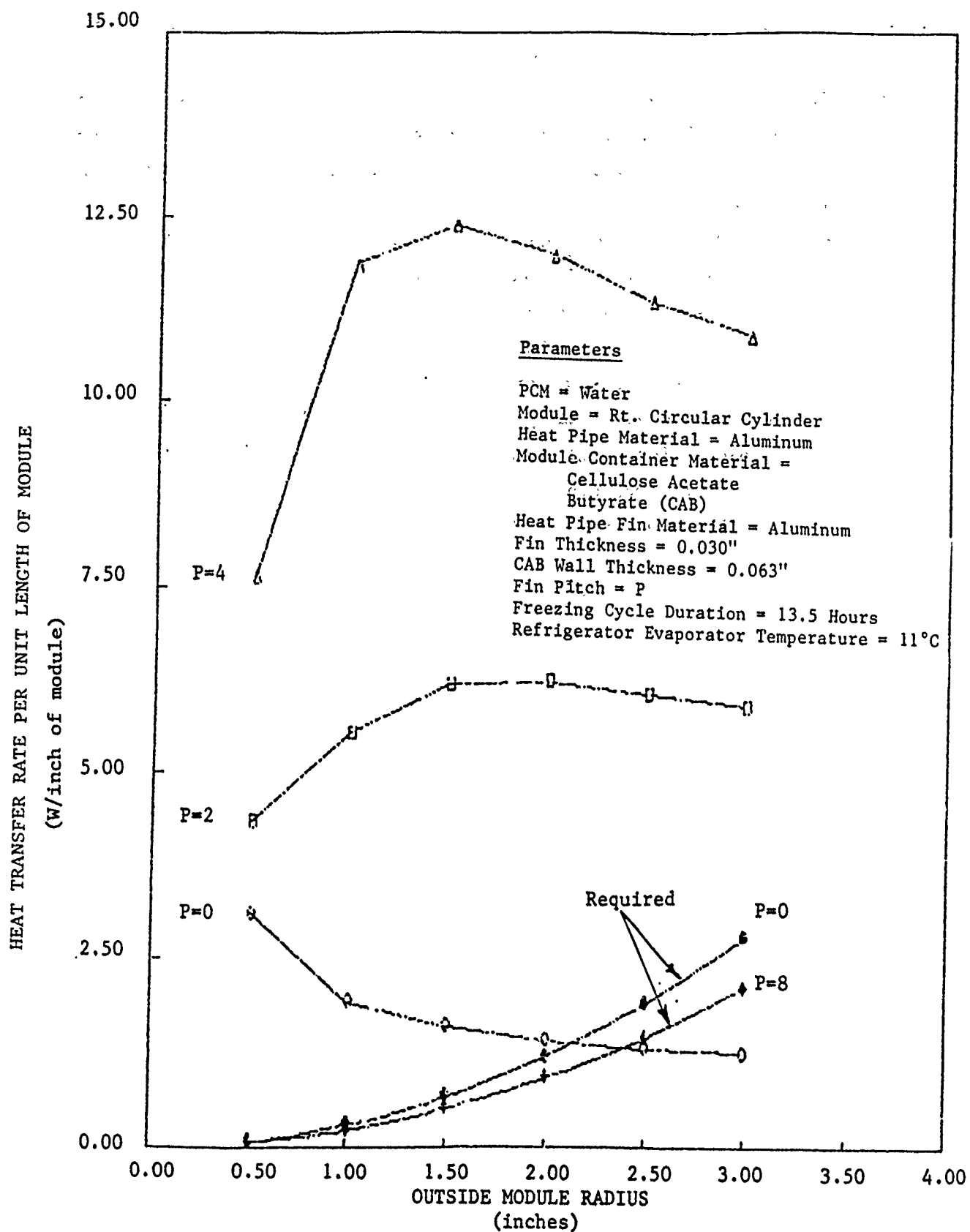


Figure 8. Heat transfer rate during freezing as a function of module radius and fin pitch on module heat pipes.

$$\text{Heat Transfer Rate} = \frac{\text{Refrigeration Evaporator Temp.} - \text{PCM Freezing Temp.}}{\text{Thermal Resistance to Freezing}}$$

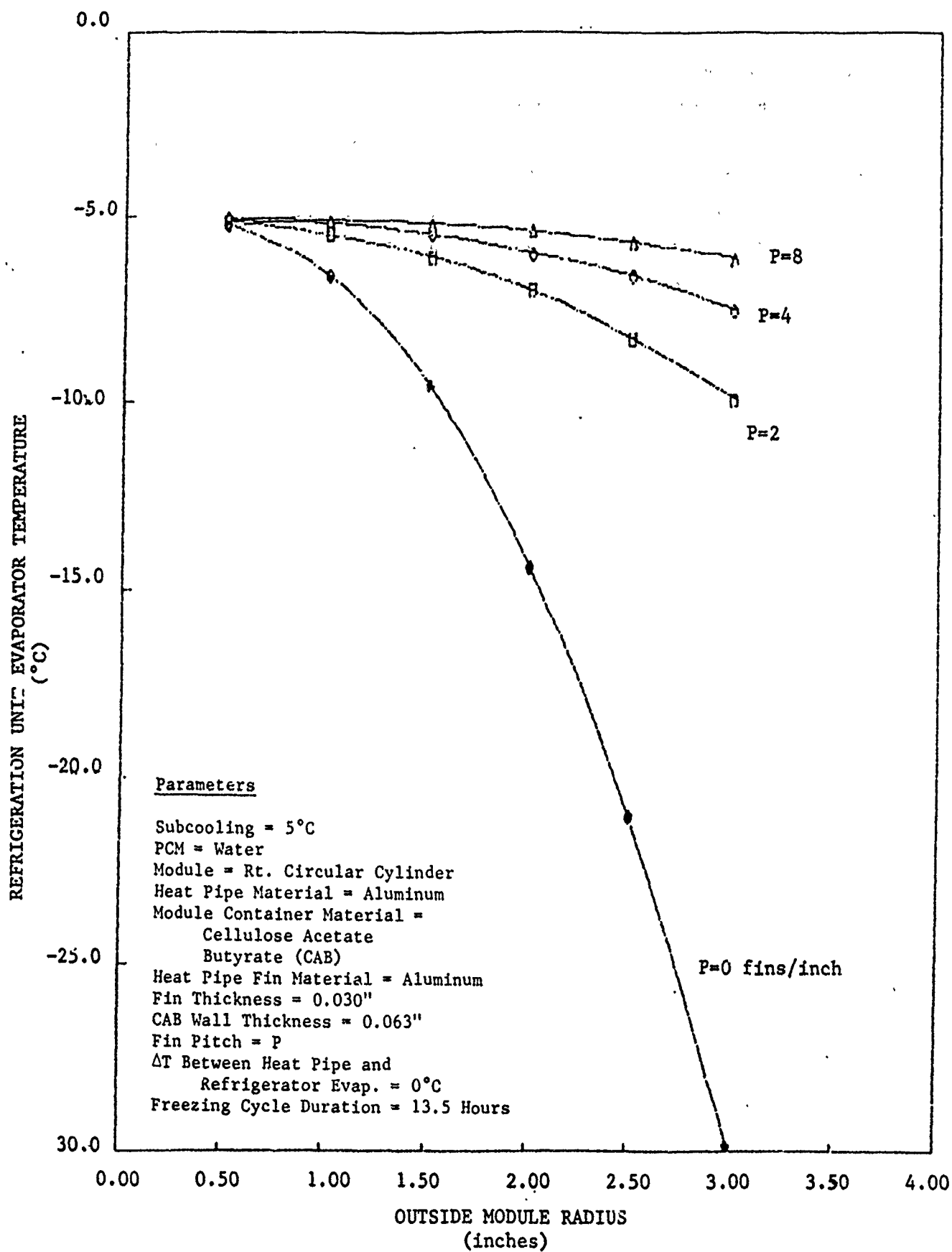


Figure 9. Refrigeration unit evaporator temperature as a function of module outside radius and module heat pipe fin pitch.

(for finned versus the unfinned case is at best 4°C. Figure 9 assumes 5°C of subcooling and no temperature difference between heat pipe and refrigeration unit. Subcooling or supercooling is the temperature drop below the freezing point a fluid undergoes before it begins to crystalize. In practice, the amount of subcooling will be less than 5°C and there will exist a temperature gradient between heat pipe and refrigerator. The sum of the two is expected to be about 5°C.

Higher evaporator temperatures do result in better refrigeration unit coefficients of performance (COP). This is quantified in Figure 10 where COP is plotted against evaporation temperature for an ideal vapor compression cycle using R12 and having condensing temperatures of 100°F and 140°F.

For the evaporator temperatures of Figure 9 corresponding to modules of radius 1.50 inch and having 8 fins/inch and no fins/inch respectively, the difference in COP between the two is seen to be 0.6 at 100°F condensing and 0.25 at 140°F condensing. The COP improvement due to the fins is on the order of 10 to 13 percent. Although fins do improve system performance, other factors need to be considered before selecting a finned design over an unfinned design. These factors are listed and discussed below:

- Structural - The cyclic expansion and contraction of the water within the modules would almost certainly damage transverse fins. Therefore, fins would have to be either longitudinal plate fins or needle fins.
- Thermal Resistance - To realize the thermal performance benefits attributable to finning of the heat pipe, the contact resistance between heat pipe and fins must be negligible. Mechanical or epoxy joining would most likely be unsatisfactory. Many brazes are unsatisfactory because of poor thermal conductivity, thermal expansion mismatches, or complicated brazing operations. An integral fin-heat pipe envelope is the only practical solution and that means a specially made fin tube, either by extrusion or other forming process.

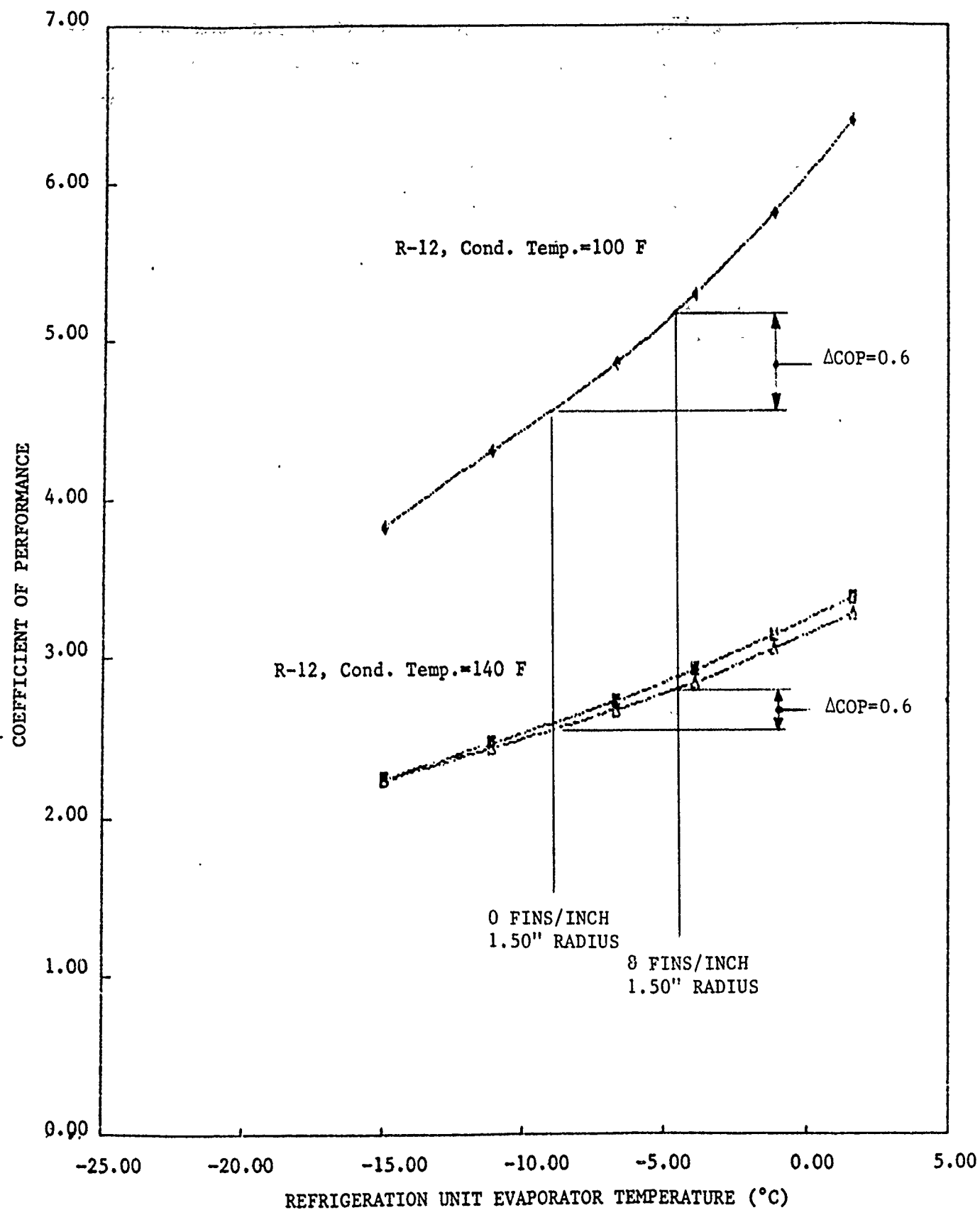


Figure 10. Coefficient of performance vs. refrigeration unit evaporator temperatures

- Cost and Complexity - The cost of finned heat pipes are considerably greater than unfinned heat pipes. The costs are attributable to both the price of the finned tube and the added complexity of the processing operations.
- Measured Versus Ideal COP - The actual MCS COP will be lower than that of an ideal vapor compression cycle because of fan power requirements and refrigerant pressure drops. Because of this the role finning plays in improving system COP may be substantially mitigated.

In light of these factors, a PCM module employing an unfinned heat pipe was selected for use in the bench test MCS. An evaluation of the thermal performance for the MCS would determine whether later generation PCM modules should employ finned heat pipes. The selected PCM module design is similar to that shown in Figure 4.

The four man MCS thermal energy storage (TES) unit will require 144 of the modules. Each module weighs approximately 3.5 lbs; has a PCM volume of 97 in³ in a cylinder 2.75 inches in diameter by 18 inches long and has a thermal storage capacity of 457 Btu.

A sketch of the preliminary design for the TES unit is shown in Figure 11. This unit showed potential to meet all of the design requirements. The incoming air is divided into four discreet air streams, which are separated by baffles. Air flows over the outside surfaces of the modules. The air flow paths are laid out such that thermal gradients across the baffles are minimized. That is, the temperatures for adjacent air streams are approximately equal. Additionally, the overall size and weight of the TES unit is minimized. Outlet air temperature is regulated by an air bypass system. The inlet air is divided into a primary stream which flows over the modules, and a bypass stream which does not contact the modules. Prior to being delivered to the personnel, the two air streams are recombined. The outlet air temperature can be controlled by the user, who is able to change the percentage of the total air that is bypassed.

The TES unit couples with a refrigeration unit at the evaporator shown as the top in Figure 11. Discussions for the preliminary design of

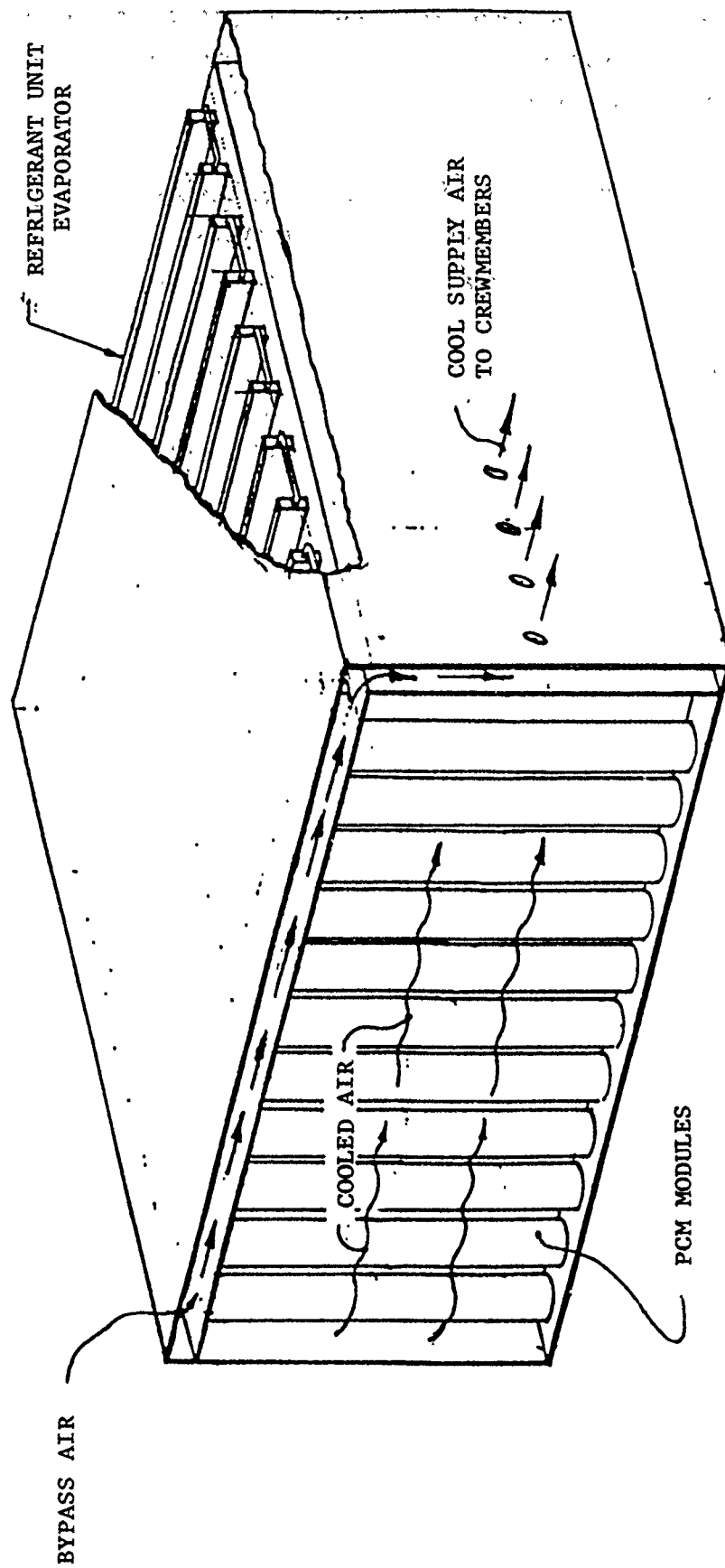


Figure 11. Preliminary design for TES unit employed
in 4 man M.C.S. unit

the evaporator and air bypass temperature control system are presented in the next section. The next section also describes preliminary design of other necessary MCS components.

2.3.3 Preliminary Design: Micro-Climate Cooling System (MCS)

This step in the preliminary design process was directed at establishing a preliminary overall design for the MCS and its principal components and subsystems. As part of this effort, lay-out drawings were made; the PCM module design was further detailed; and tests were conducted to evaluate the module's thermal performance. It is convenient at this point to describe the lay-out of the preliminary MCS design and illustrate its principal components and subsystems. Figure 12 shows the lay-out for the preliminary MCS design.

The TES unit comprises the bulk of the MCS volume. The top view shows PCM module orientation and the baffles which separate them into four discreet air streams. One stream is used per crew member. The Air Handling System is comprised of the blower, air bypass valve, duct work, and air mixing chamber. The air mixing chamber is shown near the rear of MCS as it is shown in Figure 12. The refrigerant evaporator connects directly to the PCM modules via the module heat pipes. It is located directly above the TES unit. The condensing unit consisting of compressor, receiver, condensing coil, and associated refrigerant lines is shown as the front right portion of the MCS as it is shown in Figure 12.

The main components of the TES unit are, of course, the PCM modules; a preliminary design for which was presented in the previous section. The design for the modules was further detailed.

Thermal performance and design qualification tests were conducted and successfully completed for the PCM modules, including module heat pipes.

Six PCM modules were constructed and subjected to successive freeze/thaw cycling to evaluate structural integrity and later subjected to air flow cooling tests to verify the cooling capability of the modules and MCS design. The air flow cooling tests are discussed later in this section.

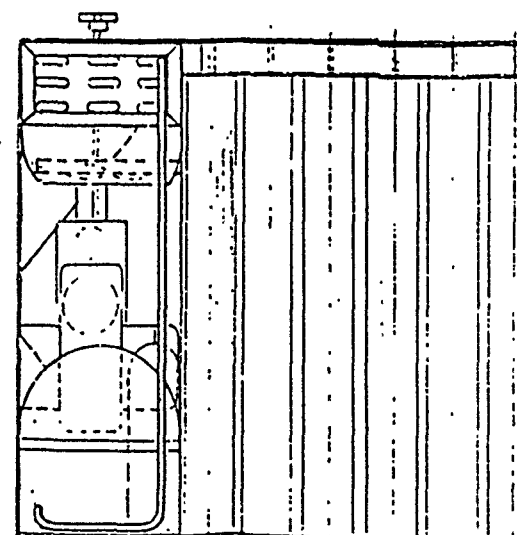
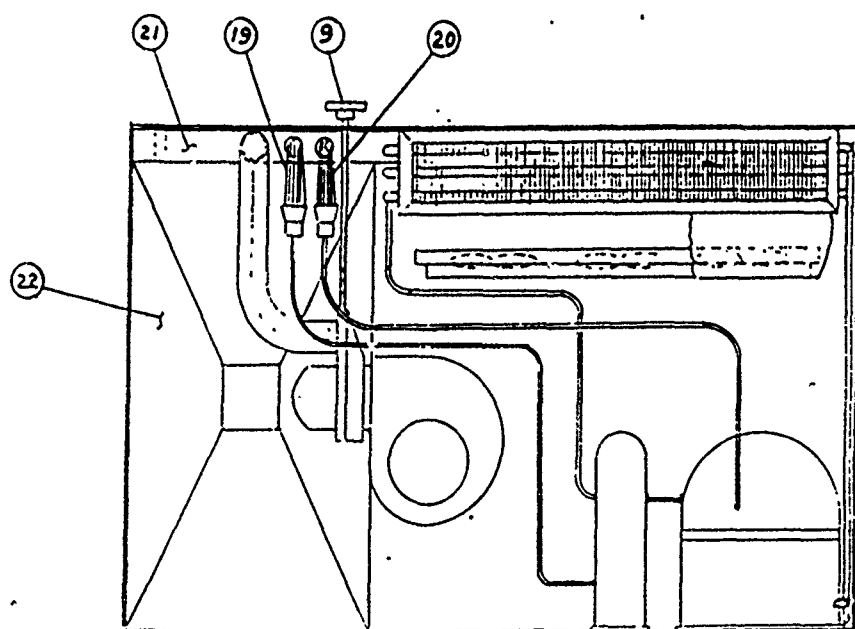
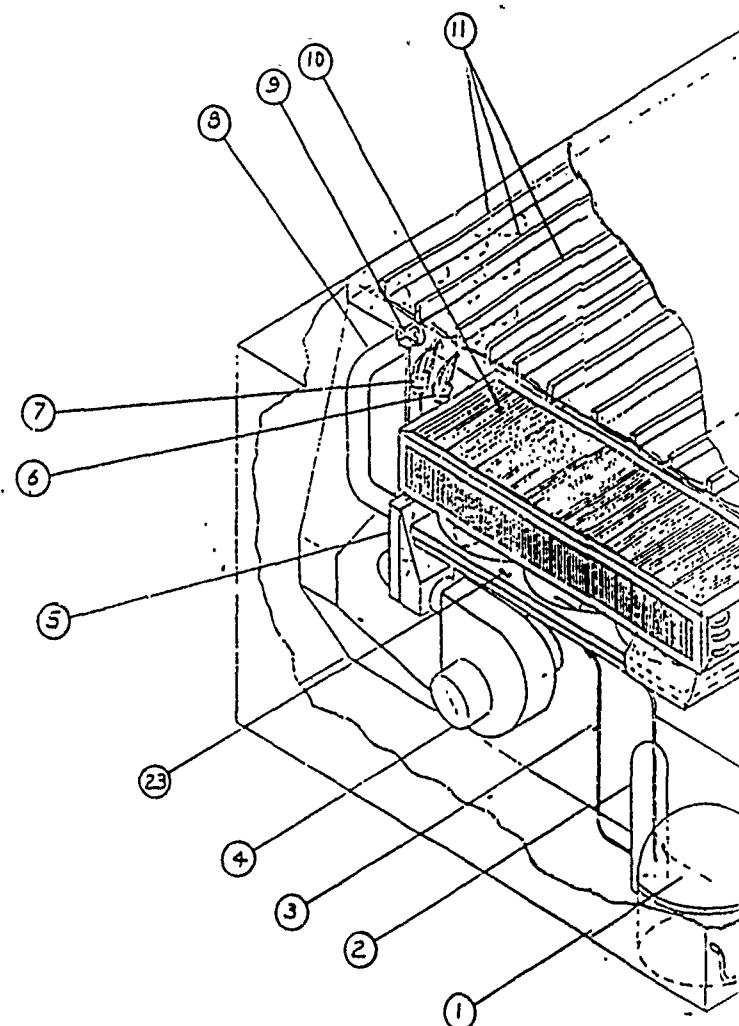
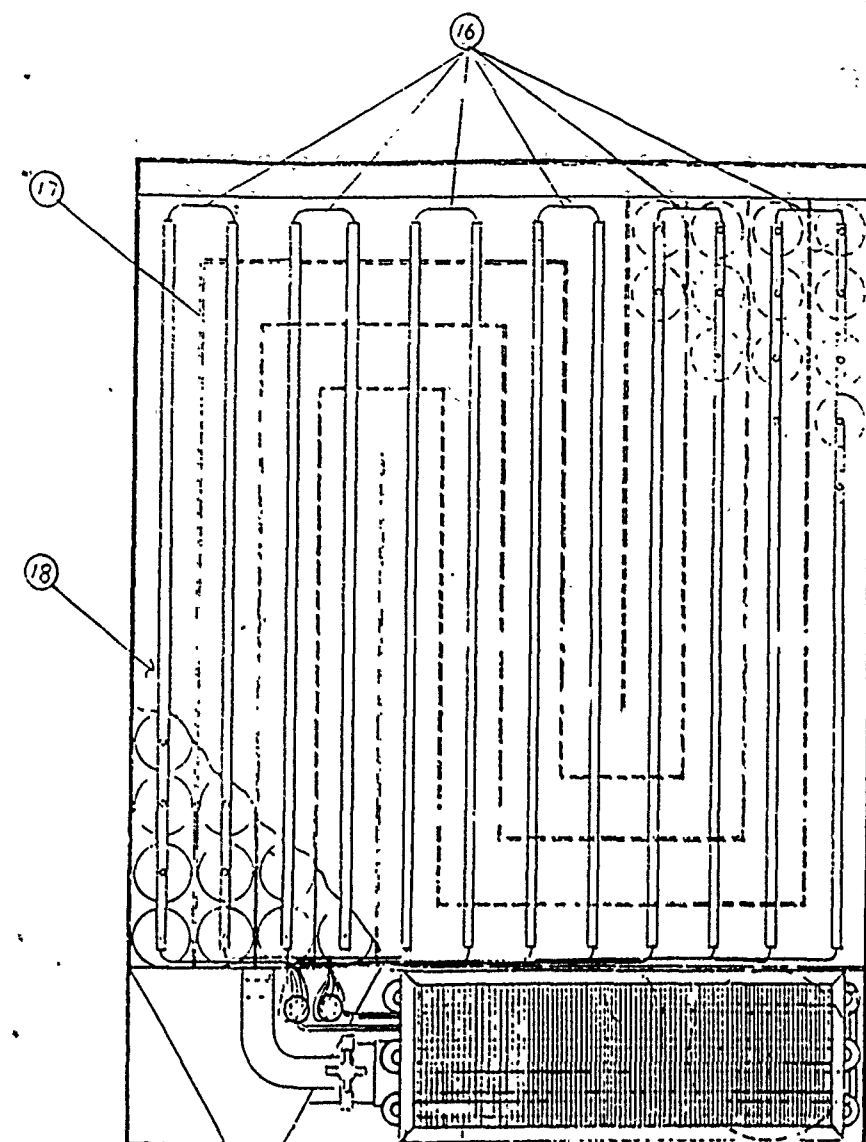
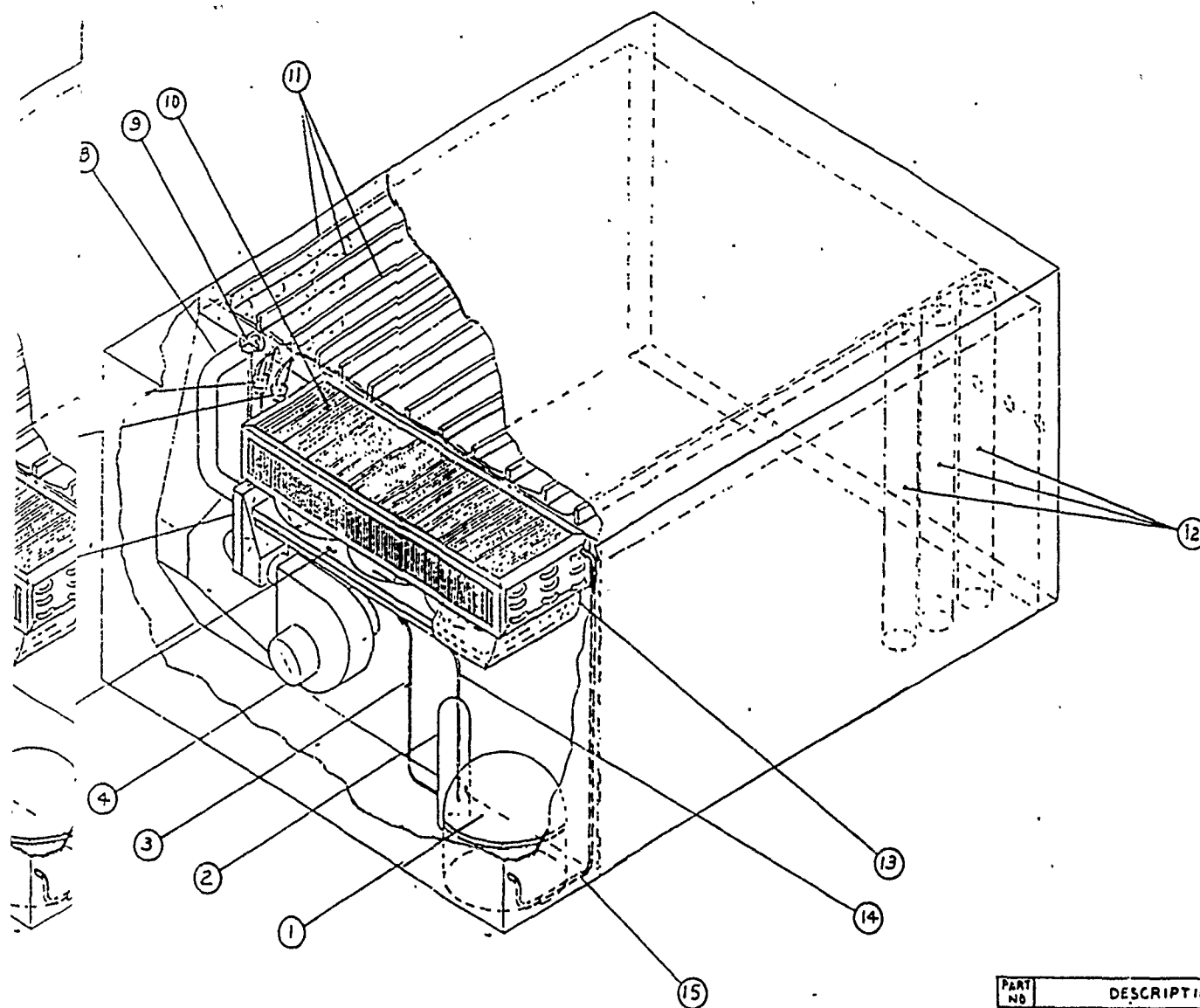


Figure 12. Layout of preliminary MCS design



PART NO	DESCRIPTION
1	HERMETIC COMPRESSOR
2	LIQUID REFRIGERANT RECEIVER
3	REFRIGERANT LINE
4	BLOWER
5	AIR BYPASS VALVE
6	REFRIGERANT COLLECTION MANIFOLD
7	REFRIGERANT DISTRIBUTOR MANIFOLD
8	AIR BYPASS HOSE
9	AIR BYPASS VALVE ADJUSTMENT KNOB
10	CONDENSING COIL ASSEMBLY
11	EVAPORATOR BLOCKS
12	PCM MODULES
13	FAN SHROUD
14	COMPRESSOR SUCTION LINE
15	COMPRESSOR DISCHARGE TUBE
16	EVAPORATOR TUBES
17	BAFFLES
18	T.E.S. UNIT TOP COVER PLATE
19	REFRIGERANT DISTRIBUTOR LINES
20	REFRIGERANT COLLECTION LINES
21	AIR BYPASS DUCT COVER PLATE
22	T.E.S. UNIT AIR INLET DUCT
23	CONDENSER FAN ASSEMBLY

ary MCS design

The PCM modules were constructed of cellulose acetate butyrate (CAB). Along the longitudinal axis of each module was located a 1/4 inch diameter heat pipe. The modules were nominally 18 inches long by 2-3/4 inches in diameter. A photograph showing one of these modules instrumented with thermocouples for melt cycle tests is included as Figure 13.

Following each freeze/thaw cycle, the modules were inspected visually. They suffered no apparent damage. All modules underwent a minimum of six cycles, and one module as many as ten cycles.

Several alternative heat pipe material combinations were identified. Candidate enclosure materials include aluminum, copper, titanium, and stainless steel. Aluminum with its low density, high strength, high thermal conductivity and relatively low cost is the most desirable candidate, provided it can be shown to be compatible with the heat pipe working fluid and the PCM. Recall the selected PCM is water and will likely contain algicides.

Candidate working fluids include refrigerants R_{11} , R_{12} , R_{22} , R_{114} and ammonia. The compatibility data for the aforementioned heat pipe material combinations is limited. To acquire the necessary data, Thermacore adopted the approach described below.

Aluminum/ammonia and stainless steel/ammonia are known to be compatible material combinations. They received consideration for use in the bench-test MCS built and tested in this program. The other materials for which long term heat pipe compatibility is uncertain were not considered for use in the bench-test article. Should, after tests, any of those combinations prove compatible, then they will be considered for use in MCS prototypes.

A matrix of compatibility tests for candidate material combinations was constructed. Figure 14 illustrates the compatibility test matrix. The heat pipes denoted by a asterisk were constructed under this program.

It was cost prohibitive to fabricate heat pipes for every candidate materials combination. Thermacore elected to fabricate heat pipes with working fluids R_{11} , and R_{114} . Test data for pipes containing these fluids can be used to determine their suitability as working fluids and along with test data for previously built pipes containing R_{11} and R_{113} can be

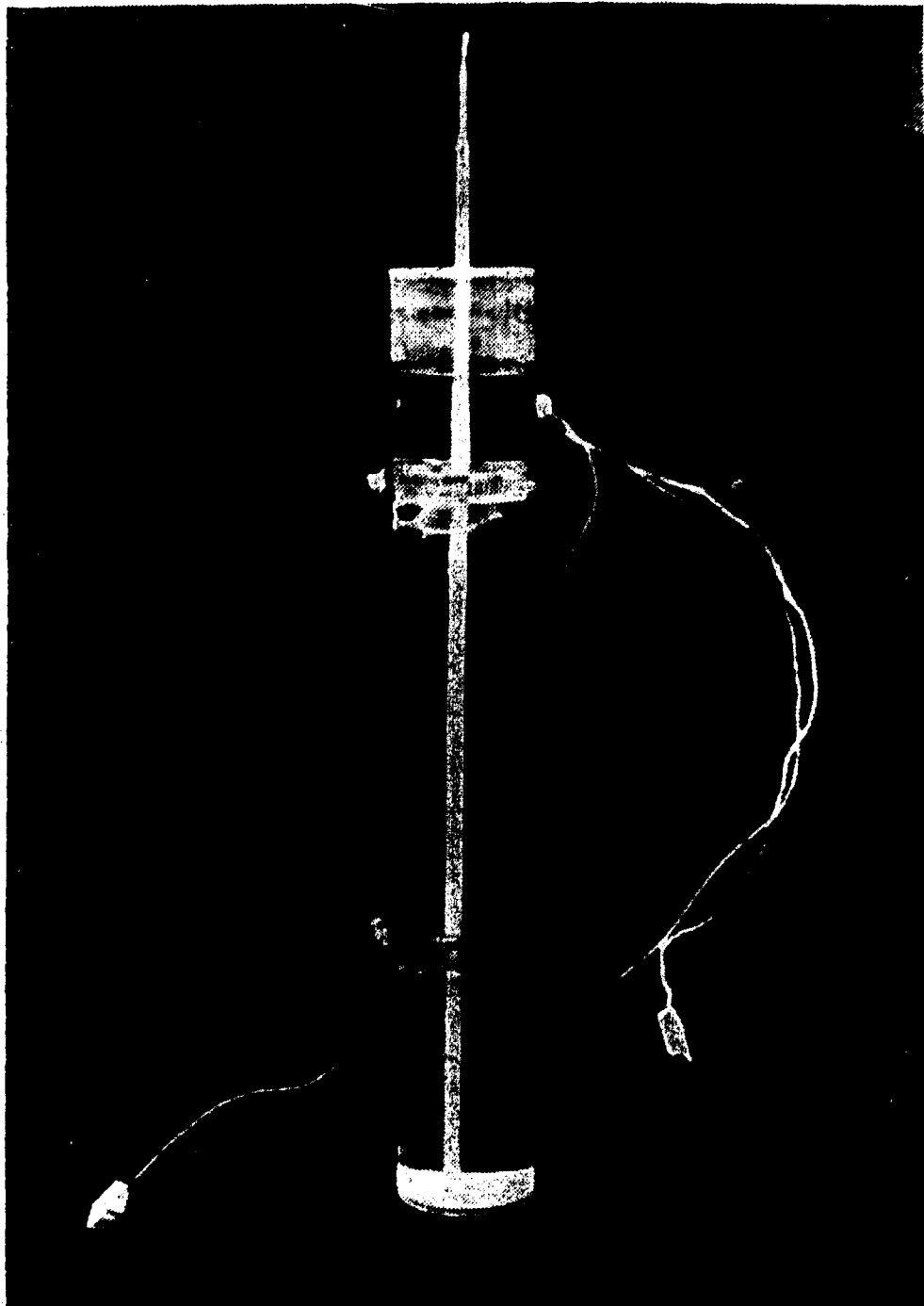


Figure 13. Instrumented PCM module

Enclosure Material	Grade	Working Fluid	ΔT Initial (°C)	ΔT Final (°C)	Hours of Operation
■	1100	Ammonia	3	1	60,380
■	6061	Ammonia	0	0	20,520
■	5052	Ammonia	0	2	20,520
■	1100	R ₁₁₃	1	11	20,520
■	5086	R ₁₁₃	2	1	20,520
■	6061	R ₁₁₃	5	10	20,520
Aluminum	5052	R ₁₁	5	8	20,520
■	1100	R ₁₁	2	7	20,520
■	5086	R ₁₁	2	8	20,520
■	6061	R ₁₁	2	67	11,640
■	5052	R ₁₁	5	16	20,520
■	3003*	R ₁₁	9	12	10,490
■	6061	R ₁₁₄	5	6	16,600
■	5052*	R ₁₁₄	14	13	10,640
■	CDA-122*	R ₁₁	11	12	10,440
Copper	CDA-101*	R ₁₁	14	20	9,140
■	CDA-122*	R ₁₁₄	14	16	10,460
■	CDA-101*	R ₁₁₄	15	14	10,460
■	304	Ammonia	2	5	18,455
Stainless Steel	304*	R ₁₁	6	9	10,460
■	304*	R ₁₁₄	3	7	10,460
■	Unalloyed	Ammonia	1	1	42,900
Titanium	Unalloyed	R ₁₁₃	2	25	42,900
■					

Figure 14. Heat pipe materials compatibility test

used indirectly to determine the suitability of R_{12} and R_{22} as heat pipe working fluids. The DuPont product information bulletin compares the pyrolysis of "Freons" 11, 12, 22, 113, and 114 in a quartz tube along with the effects that various metals have on their decomposition rates with respect to temperature.

This bulletin shows that R_{12} and R_{114} decompose in quartz and steel at similar rates and temperatures while R_{22} behaves similarly to R_{113} .

The decomposition or chemical reaction of a working fluid within a heat pipe manifests itself as an increase in temperature differential between heat pipe evaporation and heat pipe condenser. By monitoring this temperature differential over time, ΔT in Figure 14 heat pipe materials compatibility can be assessed.

From the data in Figure 14 the following observations may be made.

- R_{114} appears compatible with all aluminum and copper grades listed.
- Ammonia is compatible with aluminum, stainless steel and titanium grades listed.
- R_{11} appears compatible with Copper CDA-122.
- R_{113} appears incompatible with aluminum and titanium.

The heat pipe materials combinations with potential for use in the MCS are listed below:

- Ammonia-aluminum (1000, 3000, 5000, 6000 series)
- Ammonia-titanium
- Ammonia-stainless steel (300 series)
- R_{11} - Copper CDA-122
- R_{114} - aluminum (1000, 3000, 5000, 6000 series)
- R_{114} - Copper CDA-101 and CDA-122

As stated earlier, aluminum/ammonia and stainless steel/ammonia were the materials combinations considered for use in the bench-test MCS. Aluminum with its higher strength to weight ratio was the first choice of the two. Six 1/4 inch diameter aluminum heat pipes were constructed and inserted in the PCM modules prior to the freeze/thaw cycling tests. Although the aluminum was a marine grade, alloy 5052, it showed signs of surface degradation after being submerged in water for several weeks. It

was apparent that the aluminum would require some form of surface treatment to inhibit corrosion. Any flaws in the surface protection (e.g. scratches) would become potential failure points.

Thermacore elected to use stainless steel as the heat pipe enclosure material. It is compatible with both the working fluid and the PCM; is stronger than aluminum and therefore affords an extra measure of protection against burst; and is easy to work with.

A 1/4 inch diameter, twenty inch long stainless steel/ammonia heat pipe was fabricated and subjected to thermal performance verification tests. The pipe contained no wick structure. It was operated vertically in a reflux mode (i.e., condenser above evaporator). Five thermocouples were attached along the outside wall of the pipe: three in the evaporator region and two in the condenser region. The evaporator section was immersed in a water bath. The condenser was attached to a cooling block which was cooled by means of a vapor compression refrigeration unit. During the test the heat pipe was allowed to remove heat from the water, forming ice, and reject the heat to the cooler block. This is the manner it would be required to operate in the MCS design. Upon evaluation of the test results, it was found that the power throughout of ten watts at an evaporator temperature of -3°C agreed with predicted values. However, the corresponding condenser temperature of -16°C was considerably colder than the predicted value of -6 to -8°C . A depressed heat pipe condenser temperature would cause the MCS refrigeration unit evaporator to run colder; thus, resulting in a lower overall coefficient of performance. The depressed heat pipe condenser temperature is believed to be due to inadequate redistribution of the working fluid from the condenser to the evaporator.

A single wrap of 100 mesh stainless steel screen was inserted into the pipe to serve as a wick structure which would aid in distributing the working fluid. The pipe was again processed, charged with fluid, instrumented and tested as before. The temperature profile for the pipe with screen did not differ substantially from the pipe without screen. A 1/2 inch diameter by 20 inch long stainless steel/ammonia heat pipe with no wick structure (thermosyphon) was fabricated and tested in the manner

described for the 1/4 inch pipe. The temperature difference between evaporator and condenser for this pipe was measured at 5° and predicted to be 2 to 3°C.

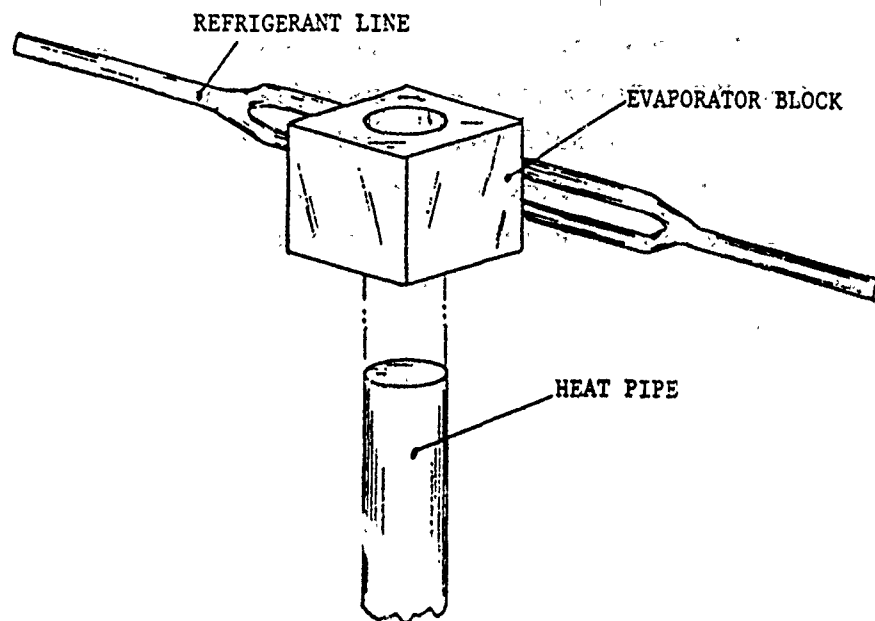
A half-inch diameter heat pipe design was selected for use in the bench-test MCS. Thermacore believes a 1/4 inch diameter heat pipe can be designed to have a sufficiently uniform temperature profile but would likely require a complex wick structure, making it considerably more expensive to manufacture. A "complex" wick structure provides low impedance liquid flow paths isolated from the vapor passage(s).

For the thermal energy storage based MCS, the heat sink for each of the module heat pipes will be the evaporator of the vapor compression refrigeration unit. Two designs for refrigeration unit evaporators were used and evaluated during the heat pipe performance tests. The two designs differed in how they attached to the PCM modules. Figure 15 shows sketches for both designs: A) close fit and, B) mechanically clamped. Both designs were found to have satisfactory temperature drops at the heat pipe-to-evaporator interfaces and were readily fabricable. Integration of the modules with the mechanically clamped evaporator was superior, presenting minimal alignment problems and making it simple to insert and remove individual modules from the evaporator assembly. The mechanically clamped evaporator was therefore the design selected for use in the MCS.

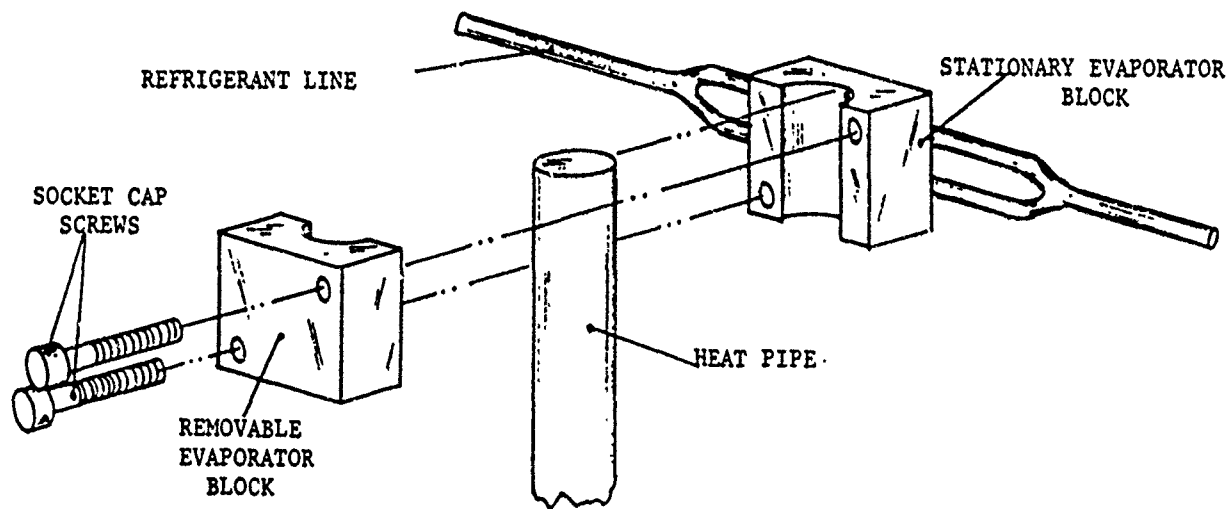
Thermal performance tests of the PCM modules during the melt cycle were also conducted in order to experimentally determine the heat transfer film coefficient and verify the MCS design cooling capability.

Figure 16 is an illustration of the test set-up showing ducting arrangement and equipment and instrumentation layouts. Figure 17 is a photograph of the actual test set-up. Six PCM modules 2.75 inches in diameter and 18 inches in length were used in the test. These were the same modules used in the freeze/thaw cycling tests.

The air flowrate over the modules averaged 17.2 scfm at an average inlet temperature of 28.3°C (82.9°F). The rate at which the modules removed heat from the air averaged 76.5 Btu/hr/module for a period of eight hours. No air bypass was used for this test. During actual operation of the MCS, a portion of the inlet air stream will be bypassed



A. SLIP FIT



B. MECHANICALLY CLAMPED

Figure 15. Refrigerant unit evaporator designs

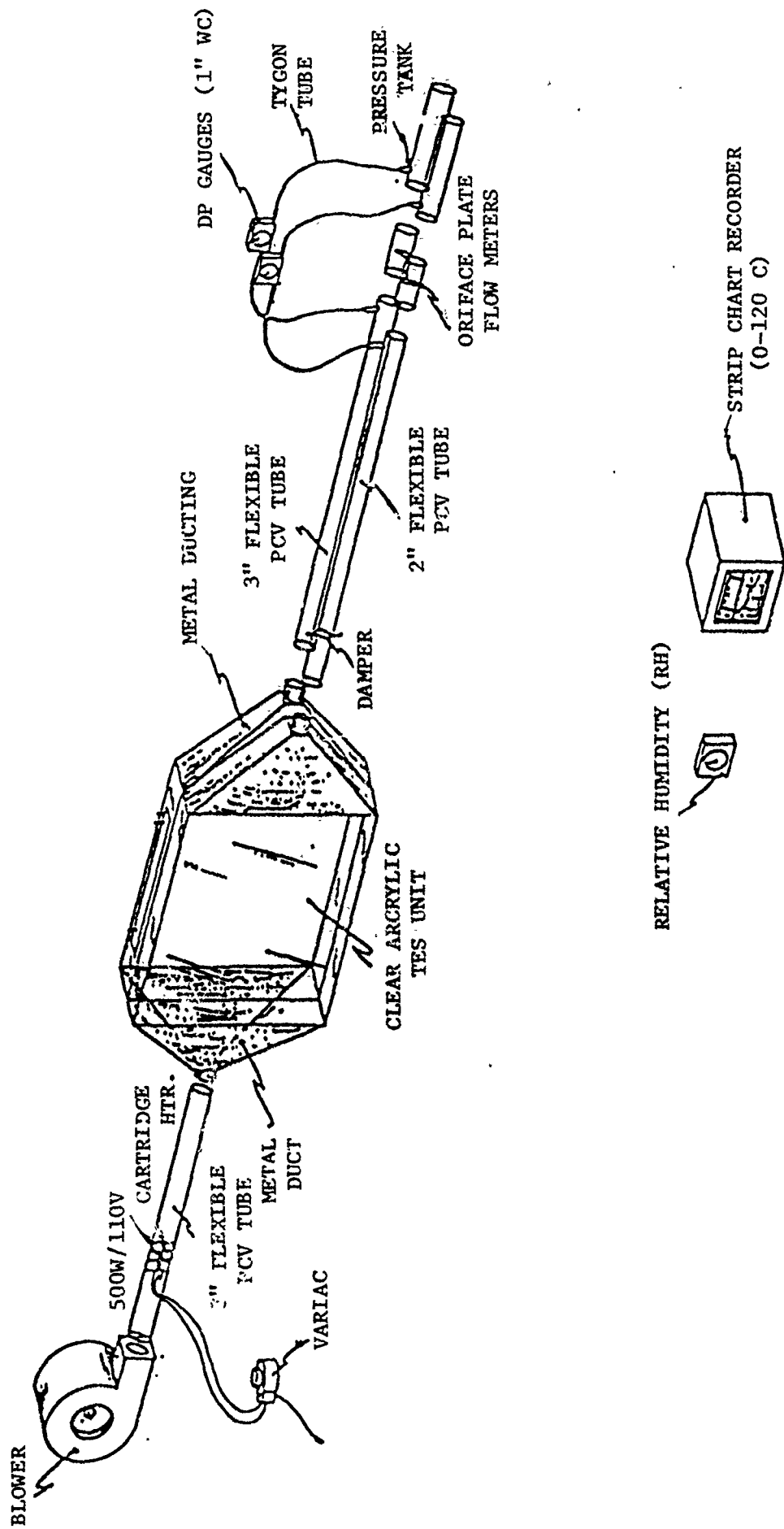


Figure 16. MCS melt cycle performance verification test



Figure 17. Melt cycle test apparatus

from the modules and then mixed with the air which was passed over the modules. The percentage of air which is bypassed will vary over the cooling (melt) cycle of the MCS. More air will be bypassed near the beginning of the cycle and less towards the end. In this manner the outlet temperature will be regulated.

Figure 18 includes the experimental results for the melt cycle tests. The plot shows the measured rate of heat removal over time. Also shown in this figure is the required heat removal rate with air bypass. The average heat capacity per module was measured at 610 Btu. A latent heat capacity of 460 Btu per module is required. The additional measured capacity of 33 percent is attributable to sensible heat storage. The heat transfer film coefficient was determined to be $16.8 \text{ W/cm}^2\text{C}$ which is 6.7 percent below the predicted value of $18.5 \text{ W/m}^2\text{C}$. The agreement was excellent, particularly in light of the fact that the air flowrate of 17.2 scfm was 4.4 percent below the value of 18 scfm used for prediction calculations.

Results of the preliminary design efforts were reviewed with Army BRDEC personnel, and the bench-test MCS entered the detailed design phase.

2.4 TASK 4: DETAILED DESIGN AND FABRICATION

This effort included specifying all parts and materials; producing detailed fabrication drawings; procuring parts and materials; and fabricating bench-test MCS.

Specifications for major components are presented in Table 8. Principal assemblies that make up the MCS include the following:

- Frame Assembly
- Air Ducting and Baffles
- Evaporator Assembly
- Condensing Unit
- PCM Modules

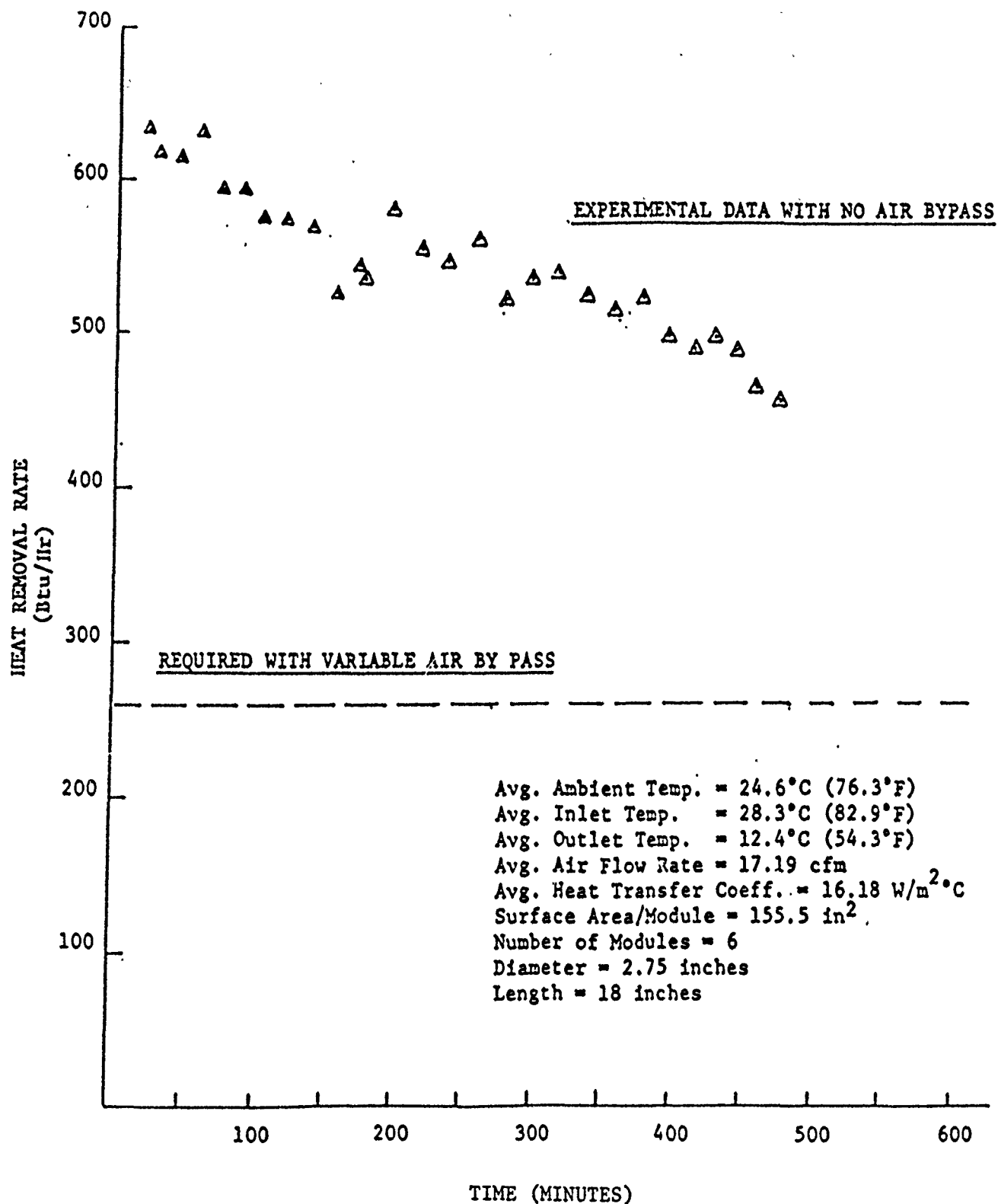


Figure 18. Experimental results for melt cycle performance verification tests

TABLE 8 Major MCS Component Specifications

Evaporator Unit

- 3/16" Copper Refrigeration Tubing
- Aluminum 2-piece Chiller Blocks
- 40 lbs Total Weight (approximately)
- Evaporator Temperature: 5°F

Thermal Energy Storage Unit

- PCM - Water
- Algicide-bactericide - Tower Trine N-25 Biocide
- 144 Modules
- Capacity: 65,000 Btu
- 0.8" WC Pressure Drop @ 72 CFM
- 500 lbs. (approximately)
- 39" x 39" x 20"

Refrigeration Unit Condenser

- Refrigerant - R₁₂
- Inlet Air Temperature - 80°F
- Outlet Air Temperature - 91°F
- Condensing Temperature - 104°F
- 22" x 6 1/8" x 7 1/8" Incl. Fans
- 4 rows, 6 tubes per row - staggered
- 6 fins/inch, 0.015" thick aluminum
- 3/8" Diameter Copper Tubing
- 3 Fans, 170 CFM/Fan @ 0.27" WC, 230 volt - single phase

Compressor

- TECUMSEH, Model AH7480A
- Hermetic Reciprocating Type
- R₁₂
- 14.5" x 8" Diameter (approximately)
- 230 volt - single phase
- 8,000 Btu/Hr @ 20°F Evaporating and 130°F Condensing Temperatures

Pressure Blower

- ITT JABSCO, PAR BRAND Model 34739-0031
 - 7 3/4" x 8" x 6 5/8" Overall Dimensions
 - 78 Watts, 0.80 amps free air, 115
 - 1.68 inches water cut-off
 - 150 cfm, free air
 - 100 cfm @ 1.2 inch water
-

Photographs of the principal MCS assemblies are included in this report. A brief description of each assembly and its corresponding figure follows:

- Figure 25, MCS Frame Assembly, shows structural members and air inlet diffuser duct. The nominal dimensions are 50 inches by 40 inches by 20 inches.
- Figure 19, Condensing Coil Assembly, shows plumbing and fan arrangements. The nominal dimensions are 22 inches by 6 inches by 7 inches. This unit is designed to handle 8100 Btu/hr at a condensing temperature of 104°F and air inlet temperature of 80°F. Each fan delivers 170 cfm @ 0.27" wc.
- Figure 20, Evaporator Assembly, shows representative section of refrigeration unit evaporator. Copper refrigeration tubes are soldered directly to aluminum clamp blocks. Each block clamps to and removes heat from a heat pipe and delivers that heat to the refrigerant flowing through the copper tubes.
- Figure 13, Instrumented PCM Modules, shows the heat pipe and plastic container which make up a typical PCM module. The thermocouples were glued to the exterior of these modules in order to gain freeze/thaw data for the MCS during performance testing.
- Figure 21, Partially Complete Thermal Energy Storage Unit. The PCM modules, each with a heat pipe along its central axis, are shown installed in the thermal energy storage unit. Also shown are the baffles for directing air flow; the control switch box (middle right) and voltage transformer (lower right).
- Figure 22, Installation of Evaporator Assembly, shows the evaporator assembly fitted over the thermal energy storage unit. The left foreground shows the air exit region.

Photographs showing the air inlet side and air exit side of the MCS are included as Figures 23 and 24. A brief description of each follows:

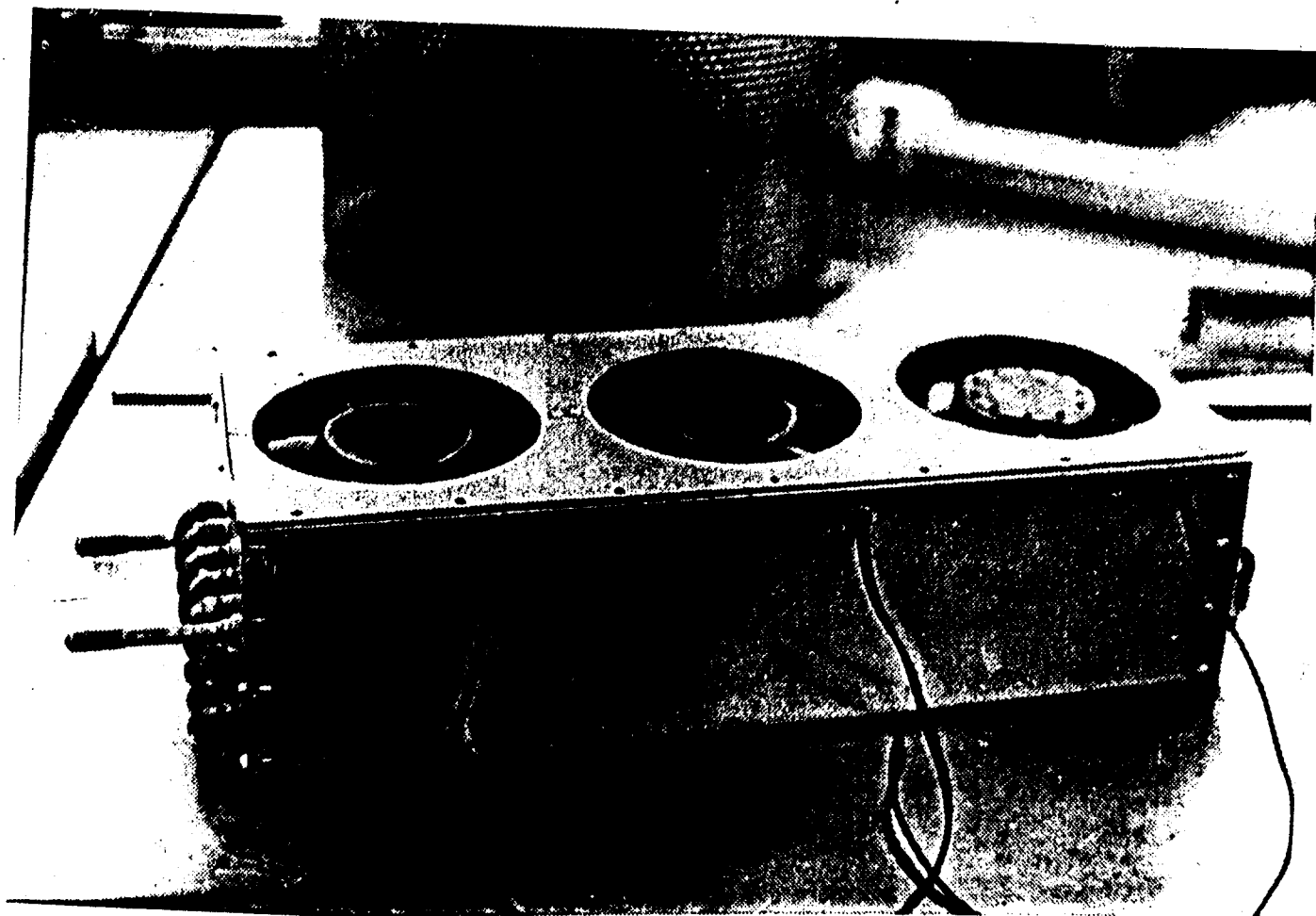


Figure 19. Condensing coil assembly

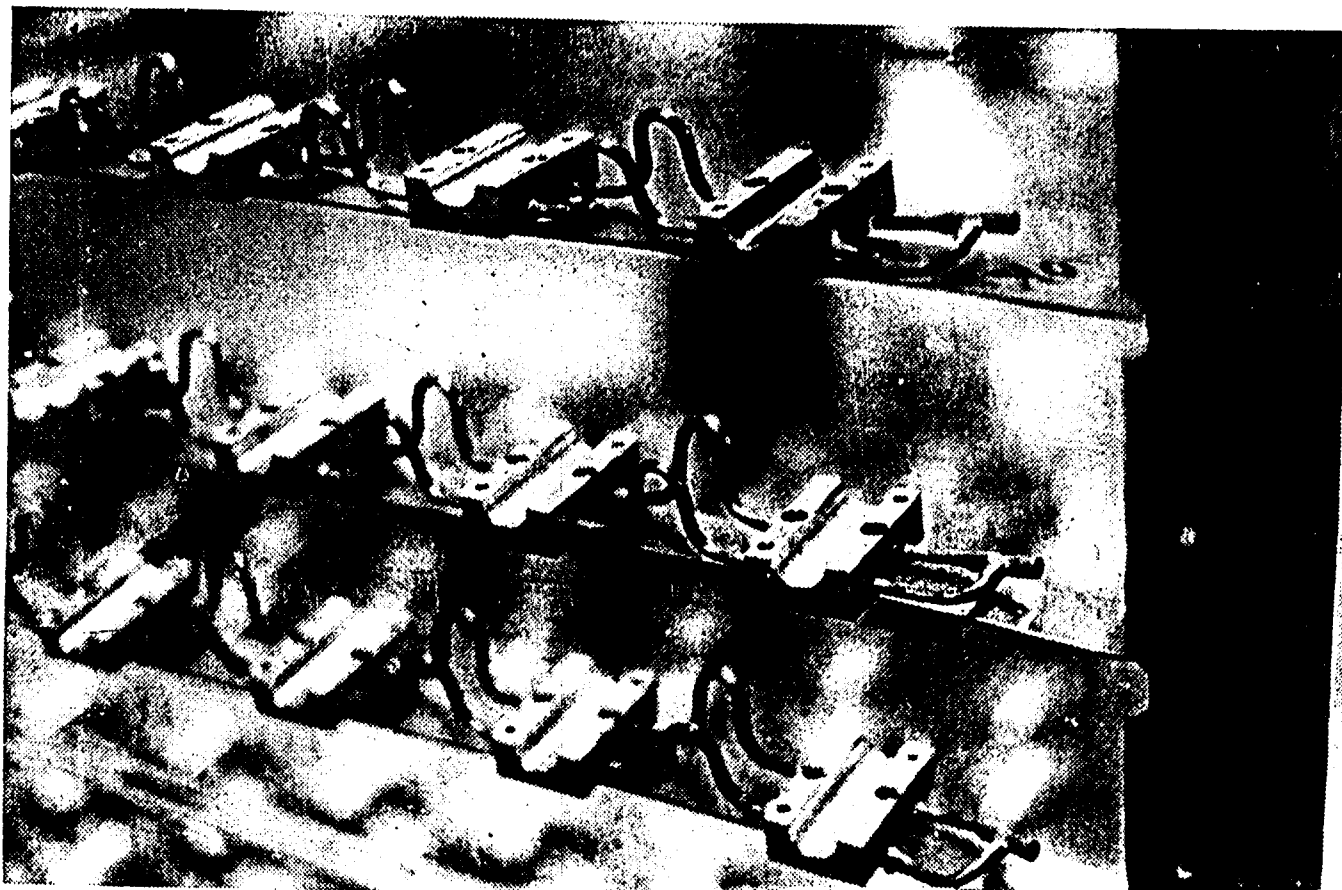


Figure 20. Evaporator assembly

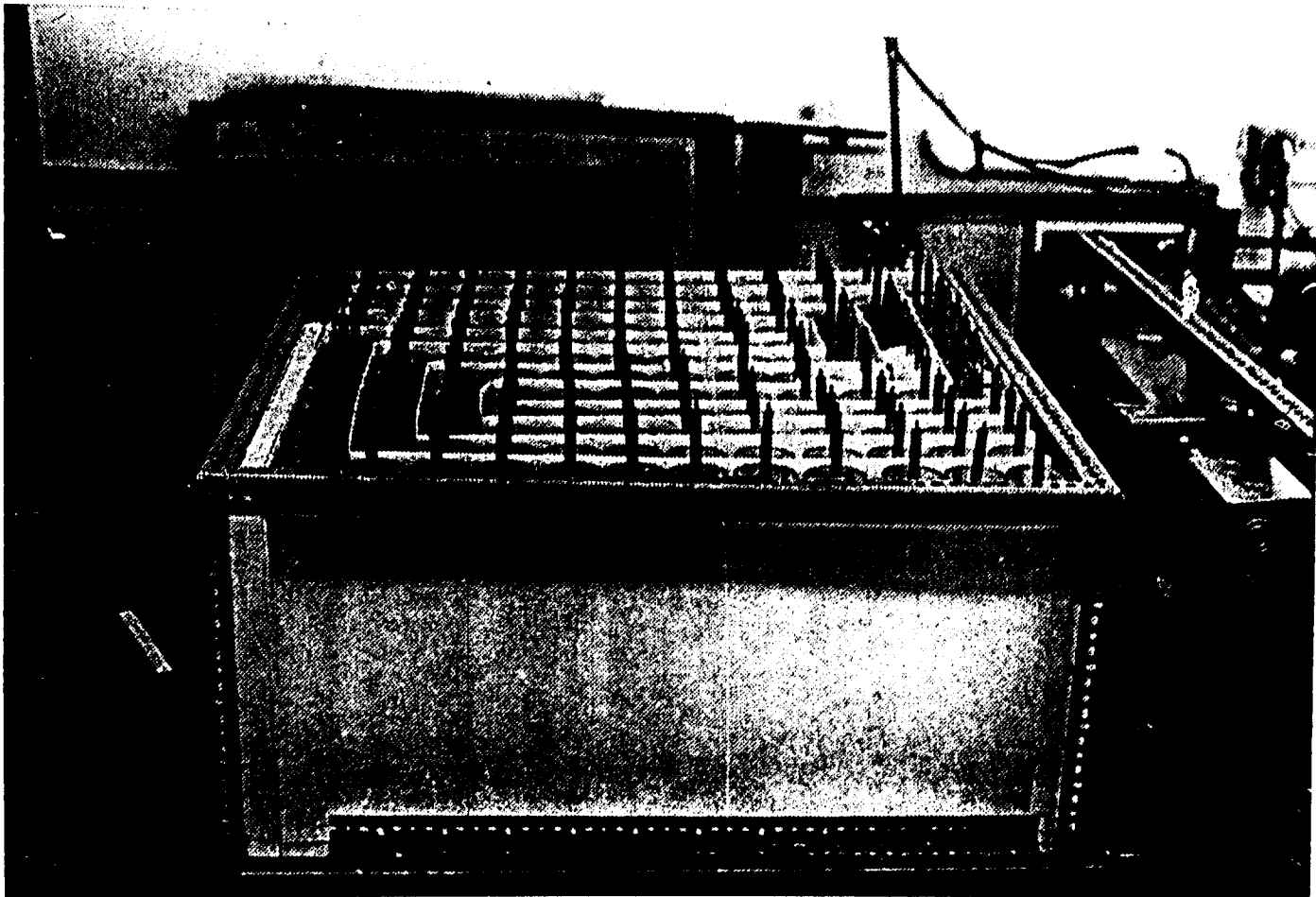


Figure 21. Partially complete thermal energy storage unit

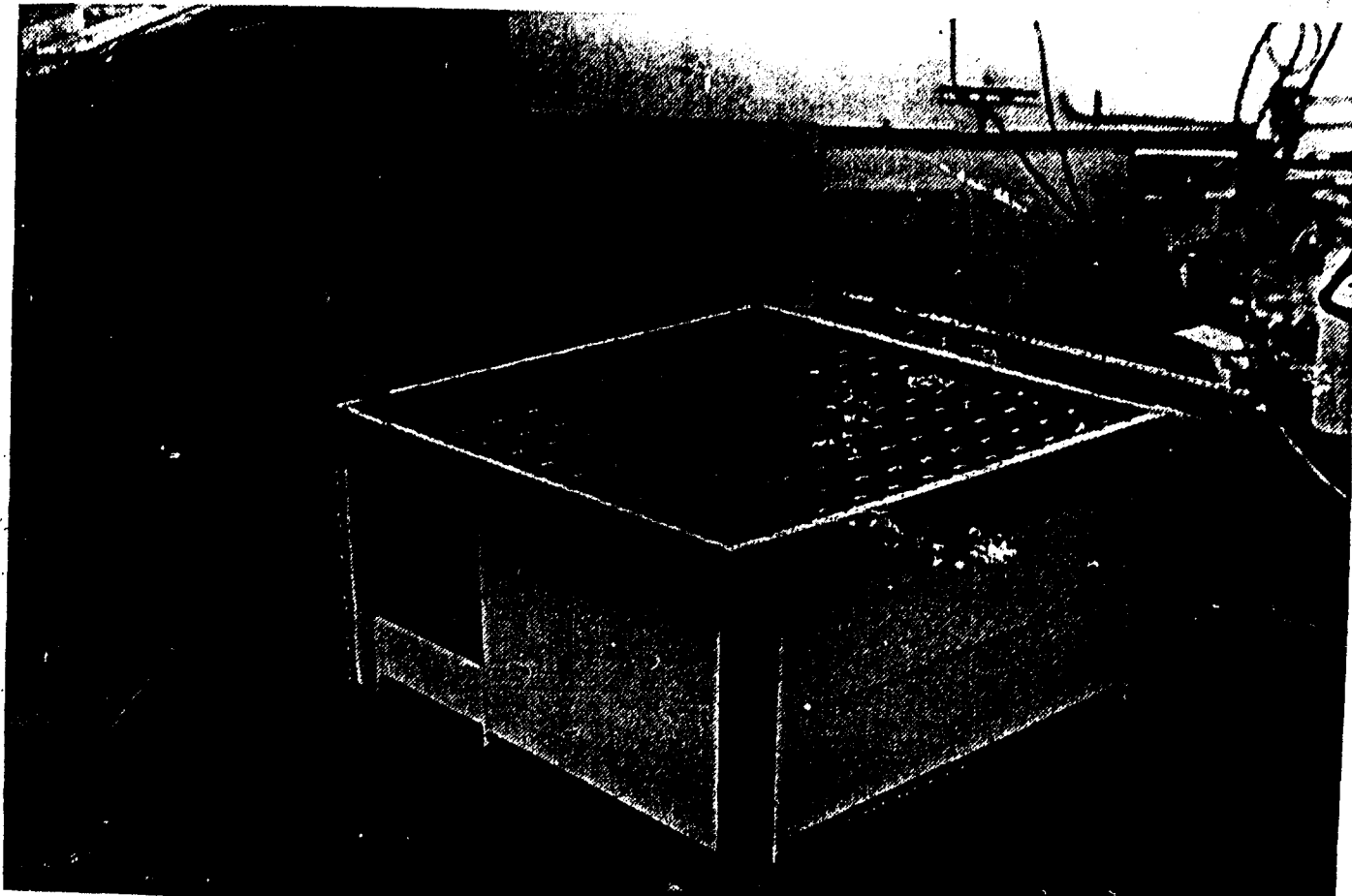


Figure 22. Installation of evaporator assembly

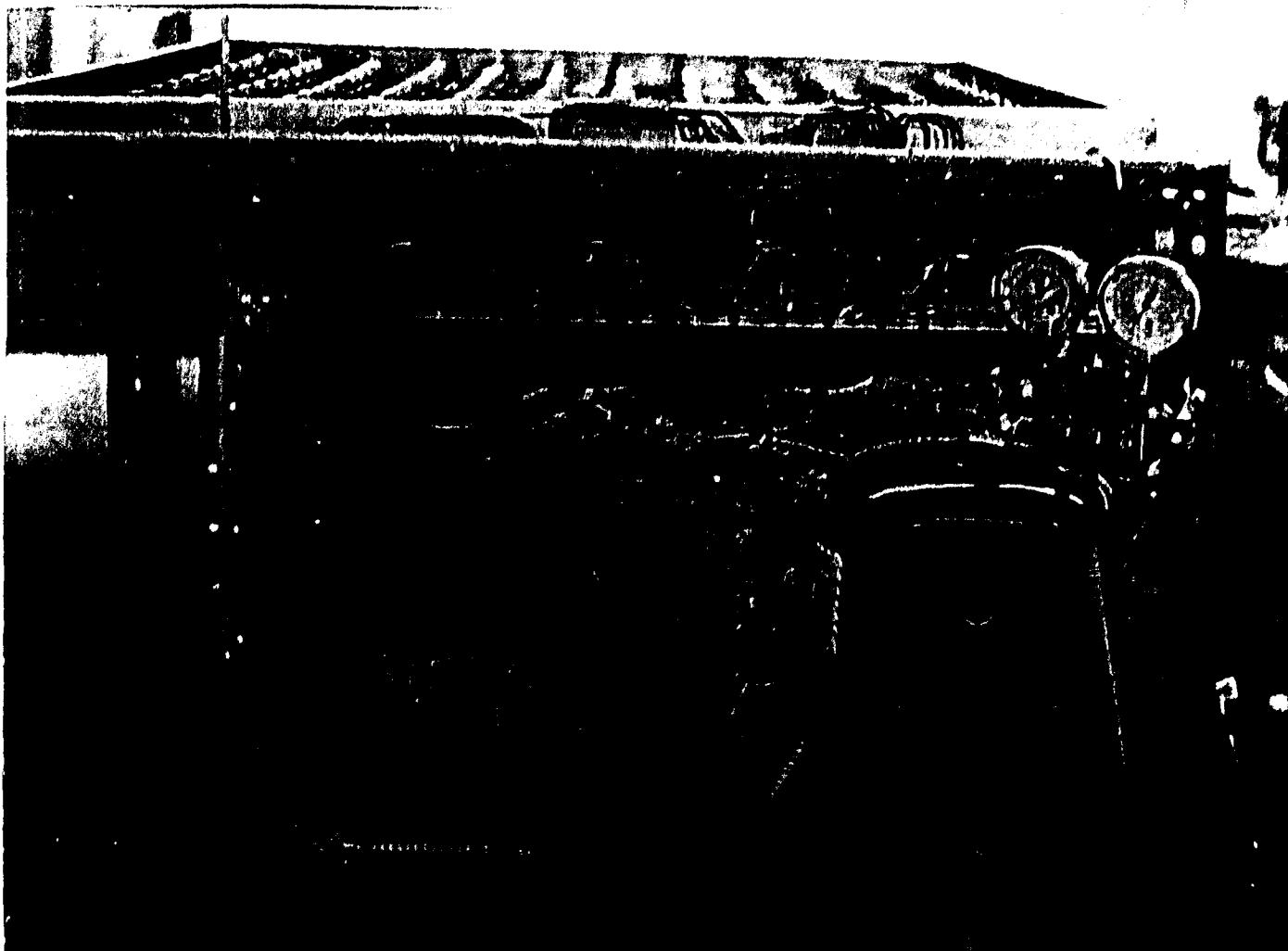


Figure 23. Air inlet side of bench test MCS

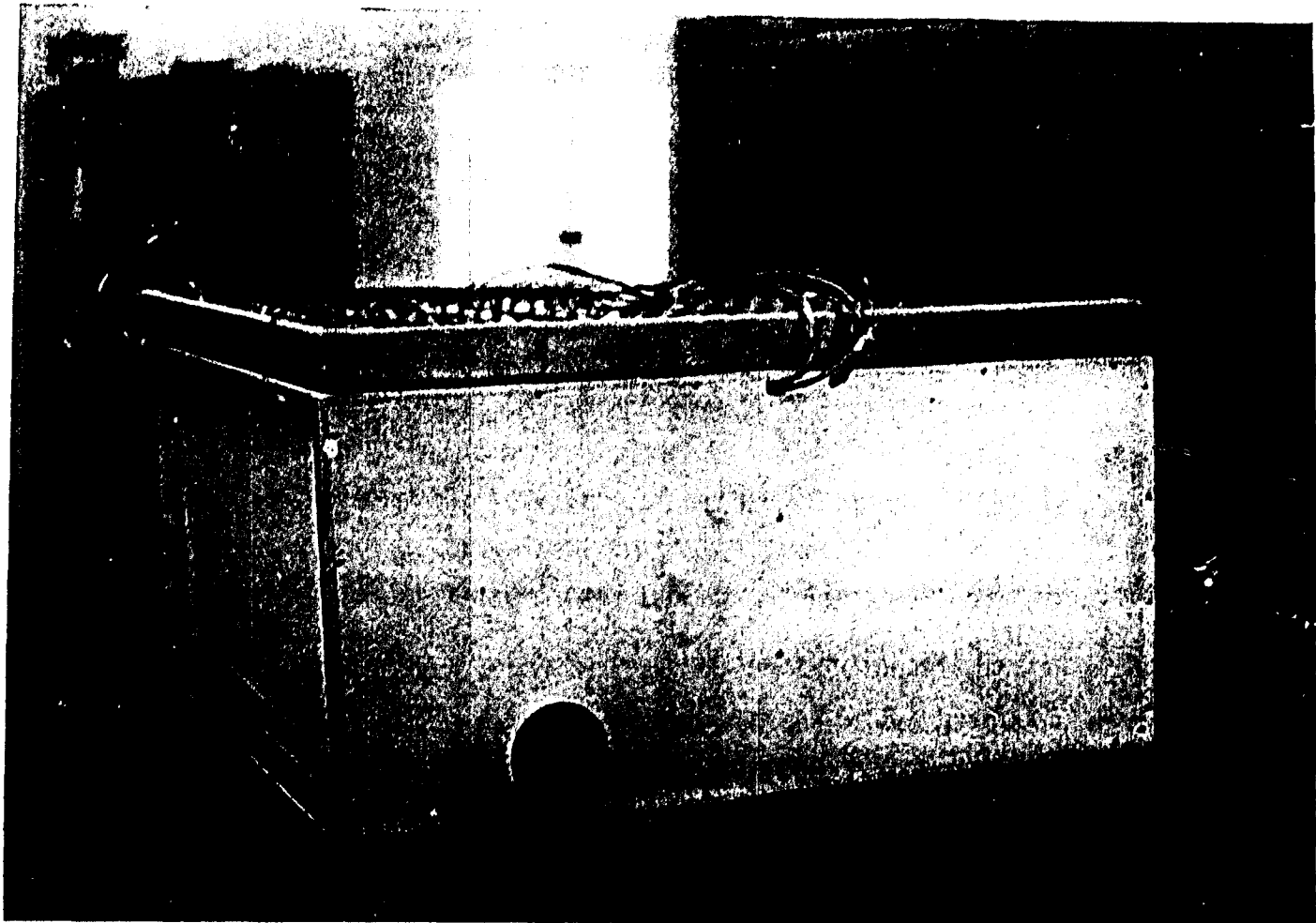


Figure 24. Air exit side of bench test MCS

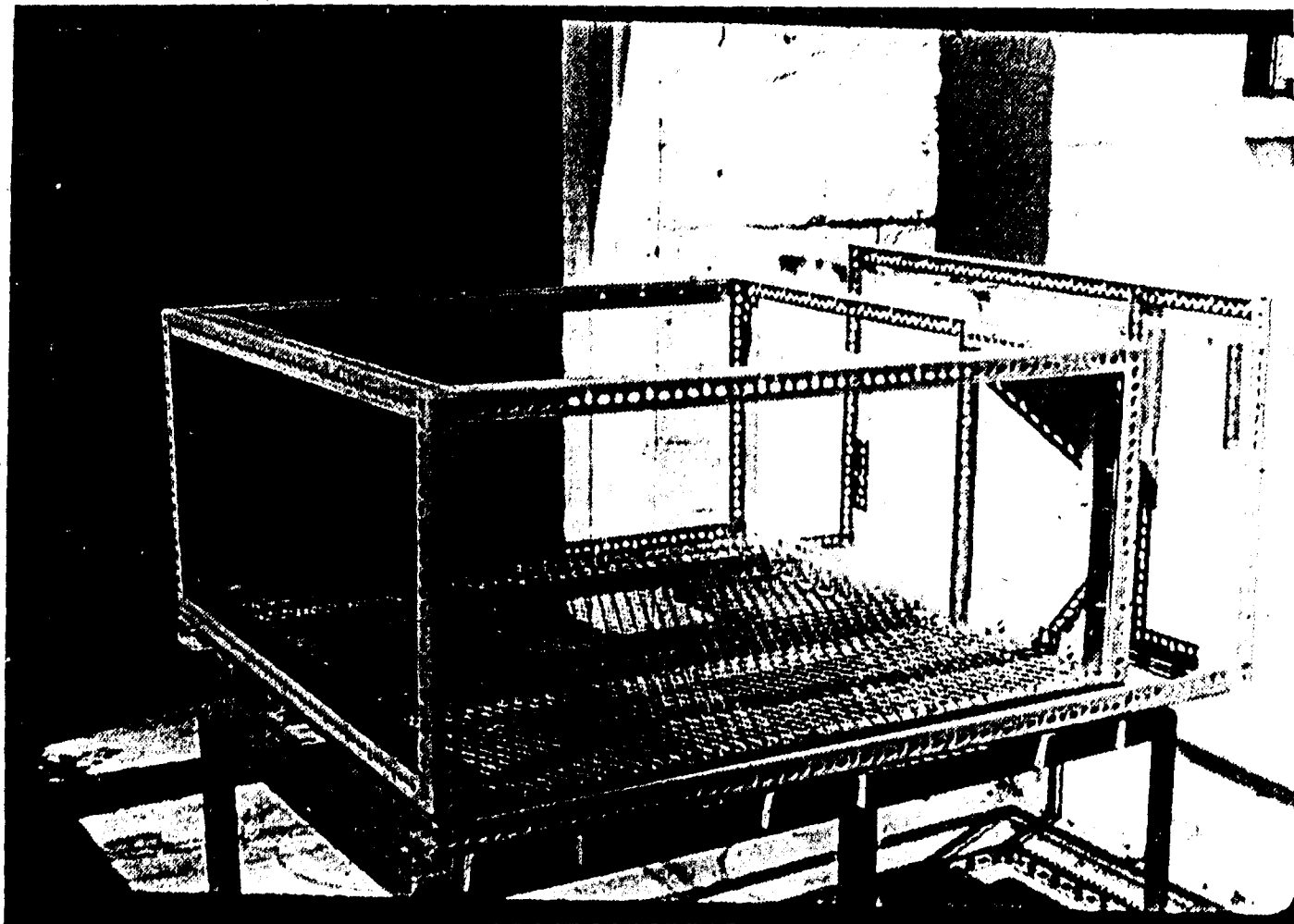


Figure 25. MCS frame assembly

■ Figure 23 - Air inlet side of bench test MCS.

This photograph was taken before installing the condensing coil, the last component installed in the system, and shows refrigeration components such as compressor (lower right), accumulator (lower middle), expansion valve (center), and distributor lines and manifolds (top center). Also shown in the photograph are the voltage transformer and starter relay (lower left), blower and bypass-air gate valve (middle left), and inlet air diffuser duct (behind gate valve).

■ Figure 24 - Air exit side of bench test MCS.

This photograph shows the air exit duct (lower left), evaporator assembly (top) and several thermocouple wires.

Instructions for proper operation of the MCS are included in Appendix C.

2.5 TASK 5 - TESTING

Two series of tests were conducted. The first series, qualification tests, were conducted to verify the following:

- Satisfactory flow rates for primary and bypass air streams.
- Satisfactory refrigeration unit operation.
- Sufficient heat transfer between PCM modules and refrigeration unit.

Initial tests showed excessive air flow restriction at the gate valve for the bypass air stream. This was resolved by increasing the gate valve orifice diameter for the bypass air. After this alteration, both primary and bypass air streams demonstrated satisfactory flow rates. The combined flow of both streams at the exit duct was measured at 71 cfm which is close to the required value of 72 cfm.

The refrigeration unit was charged with R-12 and operated. The operation of each evaporator circuit was verified by allowing frost to build up on the evaporator and observing the rate of frost accumulation.

Thermocouples were used to measure temperatures on the exterior surface of a typical PCM module. The change in sensible heat for the module was determined and provided an estimate of heat removal rate for the unit during the charge cycle. Refrigerant pressures were measured at the suction and discharge lines to determine evaporating and condensing temperatures. The relative humidity, flowrate, and dry bulb temperatures

for the air stream across the condensing coils were also measured, and, with electrical power input, were used to determine net refrigeration capacity and effectiveness of thermal coupling between the storage medium and refrigeration system.

The results of these measurements are listed in Table 9. Refrigeration capacities based on compressor ratings are included in Table 9 for comparison.

Actual measurements of heat removal during the freezing cycle are difficult; rate of ice formation must be known. An estimate of heat removal from the PCM during freezing is provided in Table 8. This estimate is based on the assumption that the ratio of actual capacity to compressor capacity during freezing is identical to that during pull down and that the net heat removal rate attributable to thermal inertia and outside losses is constant and equal to the rate during pull down.

Upon completion of the qualification tests, the bench test MCS was prepared for thermal performance tests. A schematic representation of the test setup is shown in Figure 26. Test hardware, and instrumentation locations are shown. The dehumidifier-preheater was designed to take ambient air at 70°F to 85°F dry bulb and 50% to 70% relative humidity and deliver it to the MCS unit at 120°F $\pm$ 5°F dry bulb and less than 10% relative humidity. Operated without the dehumidifier, the preheater could deliver warm, moist air with a dry bulb temperature in the range of 85°F to 95°F and relative humidity corresponding to the moisture content at ambient conditions.

Temperatures were recorded by means of thermocouples and a strip chart recorder. A thermocouple map is shown in Figure 27. Dry bulb and wet bulb temperatures were measured using mercury thermometers and used to determine relative humidities. The tests were arranged to allow the MCS to freeze PCM overnight and thaw during the day. A timer was used to shut the refrigeration unit off automatically at the end of the prescribed charge cycle.

The MCS was operated with nominal inlet conditions of 115°F and 10% relative humidity.

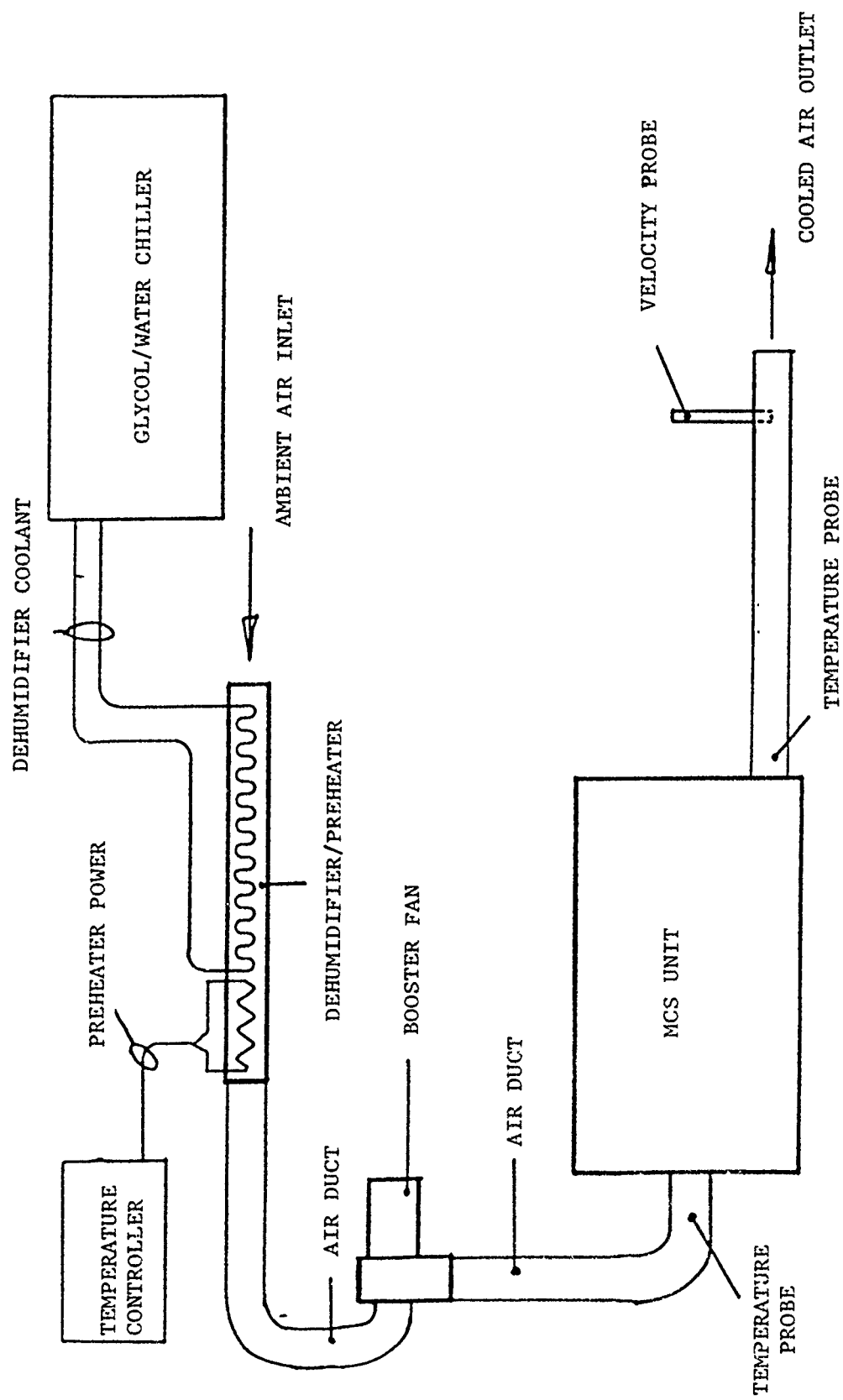


Figure 26. MCS unit test setup schematic

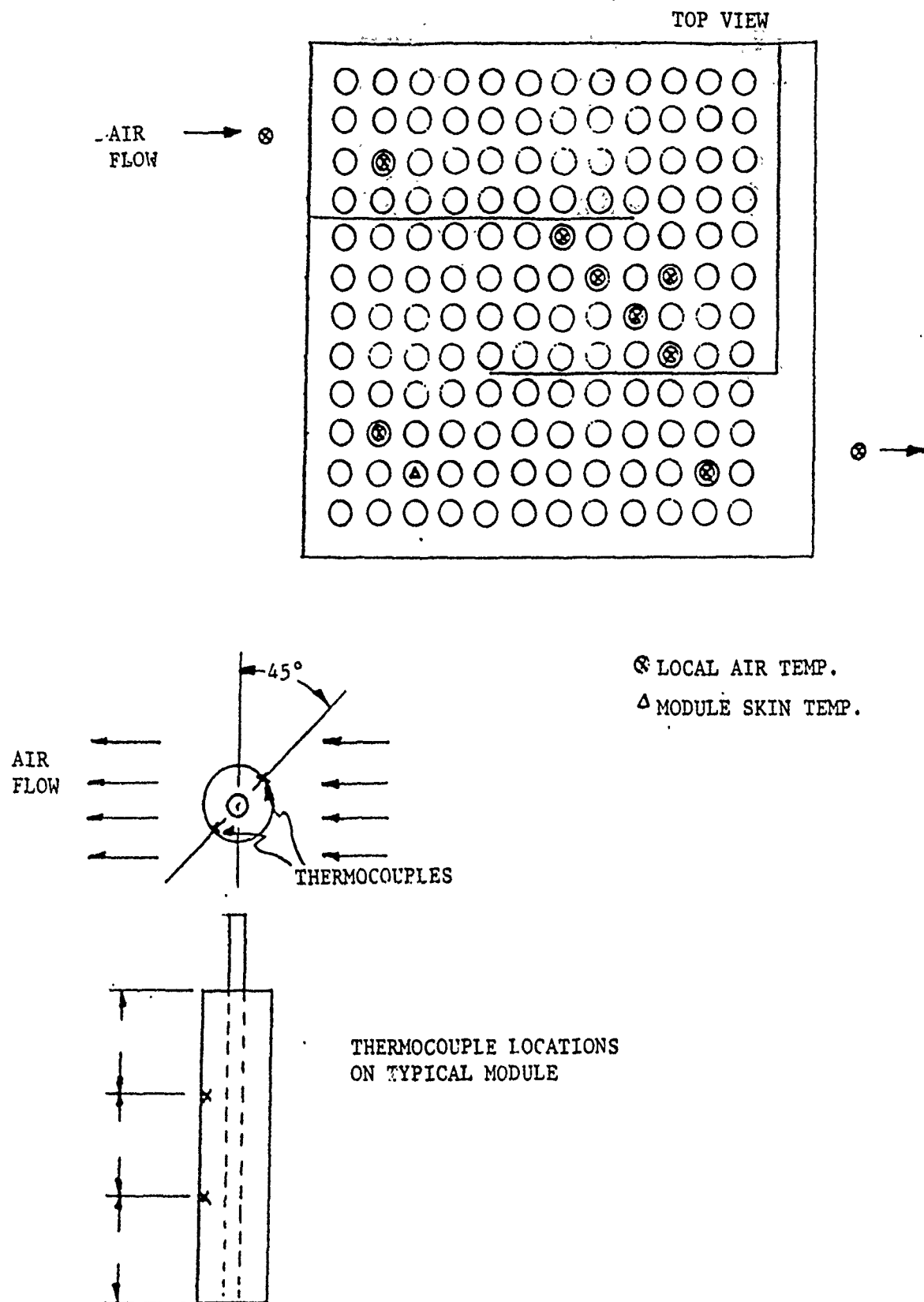


Figure 27. Thermocouple map

TABLE 9. Values for Refrigeration Unit Operating Parameters

	Module Temperature	Mean Suction Pressure	Mean Discharge Pressure	Mean Evaporating Temperature	Mean Condensing Temperature	Compressor* Refrigeration Capacity	Actual Capacity	Heat Removal From PCM
Pull Down Cycle	72°F Initial	17 psig	158 psig	14°F	120°F	7040 Btu/Hr	6370 Btu/Hr (Measured)	5460 Btu/Hr (Measured)
	32°F Final							
Freeze Cycle	32°F	11 psig	140 psig	4°F	112°F	5780 Btu/Hr	5200 Btu/Hr (Estimated)	4290 Btu/Hr (Estimated)

* Compressor Refrigeration Capacity = Capacity at given evaporating and condensing temperatures as specified by the manufacturer x Ratio of actual suction pressure to suction pressure at rating point

For the Tecumseh Model AH 7480A compressor used in the bench test MCS, the manufacturer capacity rating is 8,000 Btu/Hr at 20°F evaporating and 130°F condensing.

2.6 TASK 6 - EVALUATION OF TEST DATA

Preliminary results for the thaw cycle tests under the 115°F inlet conditions are shown in Figures 28 and 29.

Figure 28 shows the rate and quantity of heat removed from the air stream. The net heat removal was 46,070 Btu which is 70% of the total latent heat storage capacity. The cooling effectiveness of the MCS in terms of outlet air temperature is illustrated in Figure 29. The MCS delivered 71 cfm of air at 55°F to 60°F for a period of 6.5 hours. The remaining 4 hours saw a steady increase in exhaust air approaching 70°F at the conclusion of the cycle. The design value exhaust temperature was 55°F for the full duration of the thaw cycle.

The net heat storage for the MCS reduced with subsequent freeze/thaw cycles. The MCS was disassembled; whereupon, it was discovered that the PCM modules were rupturing. It appears that the rate of ice formation within the modules varied over their lengths. Ice forming near the top of the module would completely span the module diameter well before the ice forming near the bottom. The ice near the top would trap water below which, while freezing, would expand and rupture the PCM container.

Earlier freeze/thaw cycling of modules during the preliminary design effort showed no signs of rupture. Despite efforts to simulate the same thermal environment as would occur during MCS tests.

Thermacore undertook to rectify the module design problems and complete a successful MCS performance test.

Many module design concepts were generated. Those showing merit were built, installed in the MCS, and subjected to successive freeze thaw cycles. Two concepts survived the thermal cycling with no apparent damage. They are described below:

- Additive Module Concept - consisting of 5 volume percent ethanol. The crystal structure of the ice is less ordered. Volume expansion upon freezing is reduced, and the module does not rupture.
- Distributor Tube Module Concept - consisting of a nominal half-inch diameter tube slightly shorter than the length of the module and open at both ends which is immersed in the water and extends above the liquid level. Water trapped below the ice level is able to rise up the tube and spill onto the upper surface of the ice where it, in turn, freezes.

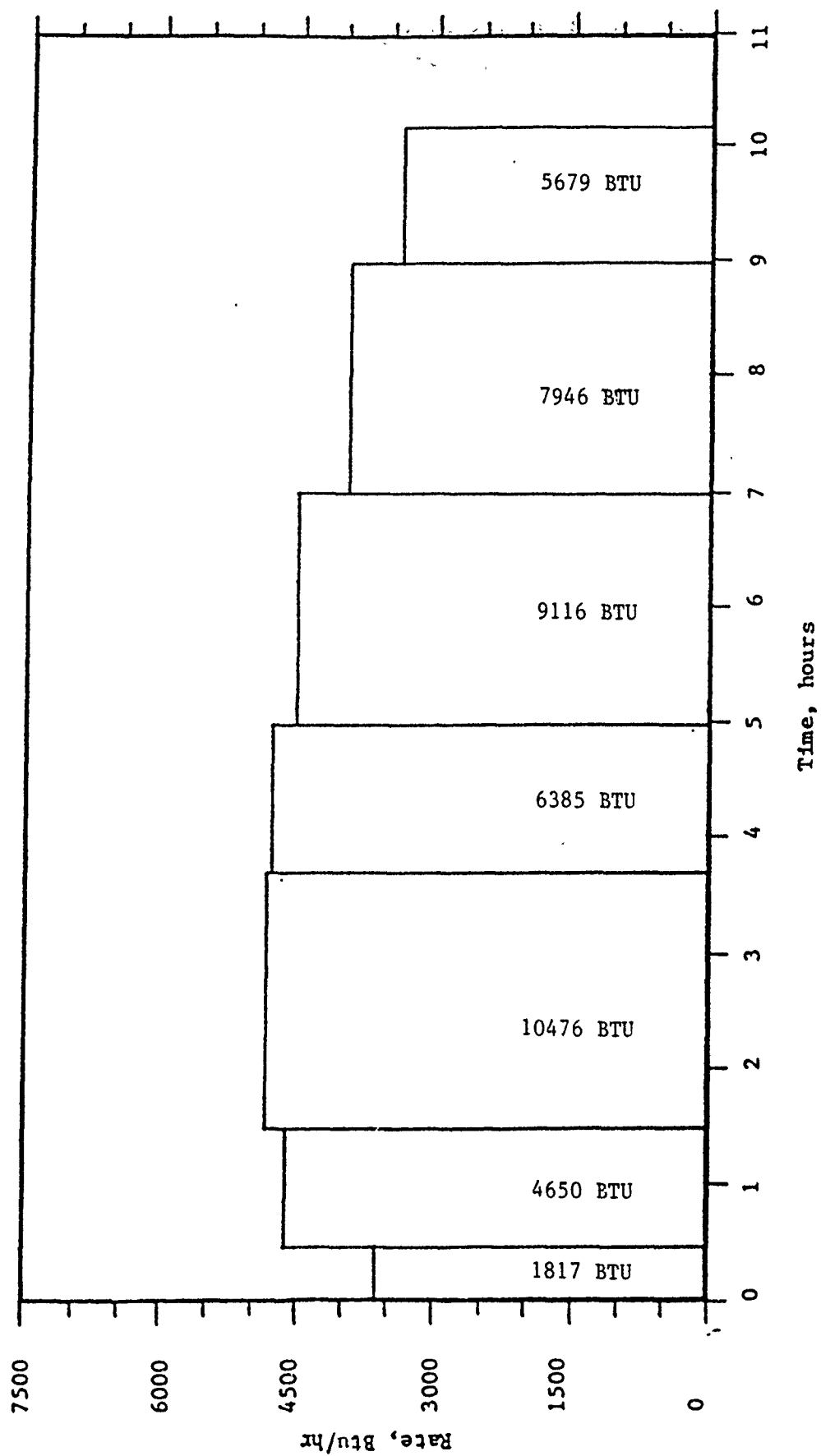


Figure 28. Rate and quantity of heat removed from MCS airstream

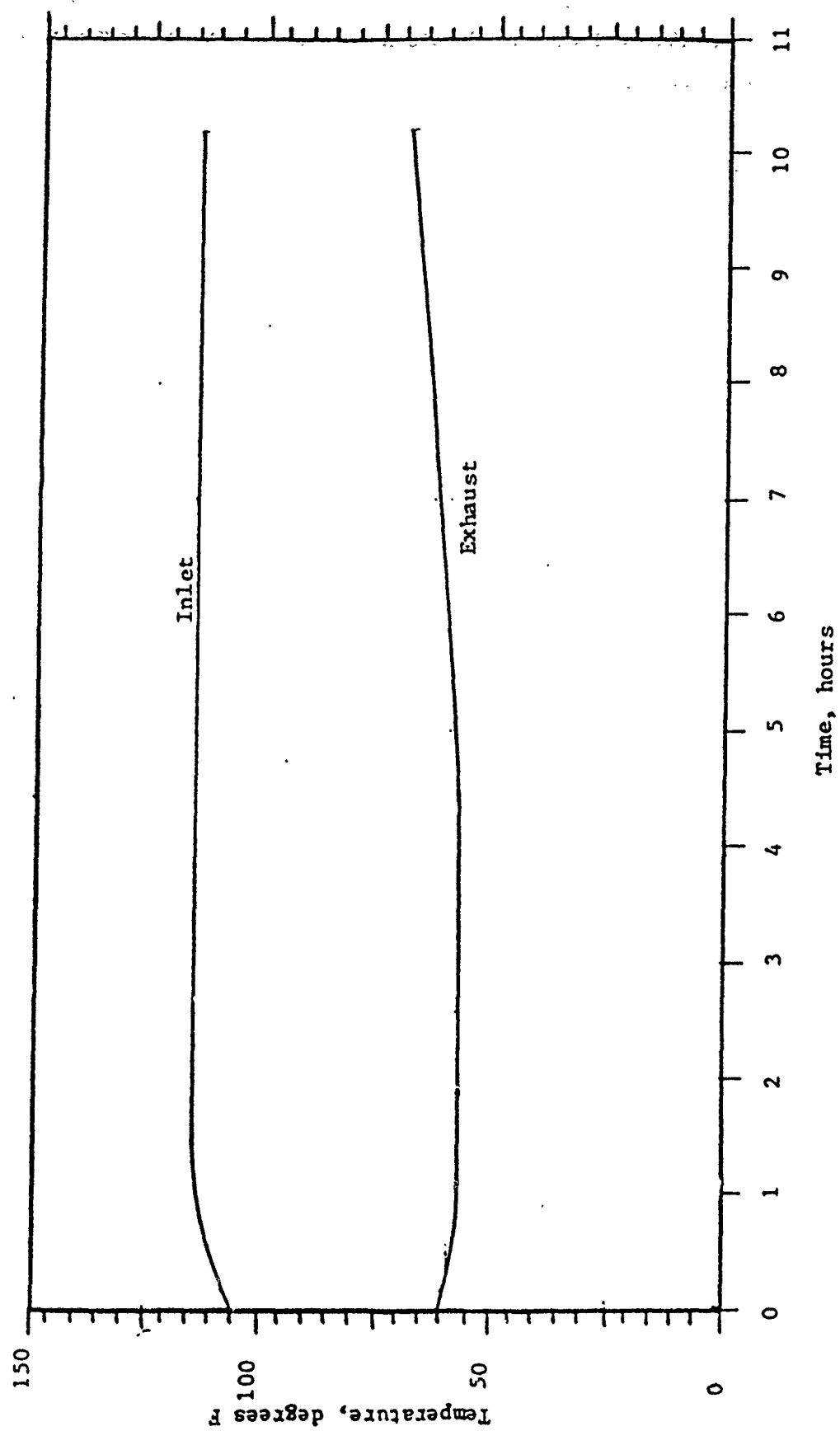


Figure 29. MCS unit airstream temperatures

Ten modules each of the above described modules were fabricated, installed in the MCS, and subjected to six successive freeze-thaw cycles. The MCS was disassembled. The modules were inspected for signs of damage. Two of the distributor tube type modules ruptured. All of the additive type modules survived intact. The ethanol additive concept was selected for use in the MCS. A complete set of new modules were fabricated and installed in the bench-test MCS. These modules contained 5 volume percent ethanol. The ethanol was expected to eliminate bursting of the modules upon freezing, although, at a cost of 5 to 10% of heat storage capacity.

The MCS was again instrumented and thermal performance tested. Results of those tests are shown in Table 10 and compared against required design values. The reduction in net heat storage capacity for the unit is a result of the 5% ethanol addition to the PCM. The protracted charge time is a result of two factors. They are discussed below.

- Reduced evaporator temperature - this was caused in part by the freezing point depression of the PCM due to the addition of ethanol and impact by higher than predicted temperature gradients between modules and refrigeration unit evaporator.
- Heat gain from surroundings - which effectively diminishes the useful refrigeration capacity. Heat gain was larger than designed for because of the depressed evaporator temperatures and limited insulation effectiveness.

2.7 TASK 7 - SURVEY TO DETERMINE COMMERCIAL APPLICATIONS

A literature survey and phone calls were made to identify potential commercial markets for thermal energy storage technology.

Three broad categories were identified for latent heat energy storage (LHTES) products. They are: 1) LHTES modules for storing solar heat in residential and office buildings; 2) LHTES modules for waste heat recovery and active heat storage for use as a heat source for heat pumps; and 3) LHTES systems for providing cooling needs and reducing utility costs in office buildings.

TABLE 10. Comparison of Test Results with Design Values

	<u>Test Values</u>		<u>Design Values</u>
<u>Cooling Cycle (Thaw):</u>	Run #1	Run #2	Hot-Dry
Duration (hours)	10.5	10.25	10.5
Net Cooling (Btu)	55,343	60,739	65,000
Mean Outlet Temperature (dry bulb)	59°F	62.3°F	55°F
Mean Air Flow Rate (cfm)	62.1	70.2	72
Inlet Temperature (dry bulb)	125°F	129	135°F
Inlet Relative Humidity	<5%	<5%	3%
<u>Charging Cycle (Freeze):</u>			
Duration	23.0	23.0	13.5
Charge Rate	3,620	3,620	6,170
Evaporator Temperature	-2°F	-2°F	5°F
Condenser Temperature	107	107	104°F

Many companies have developed and marketed products for the first of these categories, storage of solar heat, but only a few have survived. Those that have survived do a limited business, primarily with solar enthusiasts. The two (LHTES) markets that might enjoy some success fit into the second and third categories; that is, LHTES systems developed as heat sources for heat pump applications and LHTES systems developed for building cooling applications.

The reason heat pumps and building cooling systems that use LHTES technology are becoming so attractive is because they reduce utility costs as a result of:

- Higher equipment operating efficiencies
 - A part or all of the heat load is rejected to the lowest heat sink temperature which maximizes the equipment efficiency and minimizes total power consumption.
- Reduced Utility Rates
 - Many utility companies have structured rates where energy costs during off-peak hours are less than during peak demand hours.

The geographical areas where utility rates are structured are the areas which benefit the most from LHTES technology.

An example of a building that takes advantage of reduced utility costs by employing a LHTES is the Merchandise Mart in Chicago, Illinois. This building employs an ice thermal storage unit that produces 2,200,000 pounds of ice per day during off-peak periods.⁷ By shifting their daytime cooling electricity demand to night-time, they will save an estimated \$250,000 annually in energy savings alone. The owner's of Merchandise Mart are realizing savings in first costs as well by choosing a LHTES system over other, more conventional refrigerated air systems. Based on the success of the LHTES used in the Merchandise Mart, it seemed plausible that similar technology could be used to develop LHTES cooling systems for private homes.

A study was conducted to determine the economic benefits of applying Thermacore's technology to residential thermal energy storage cooling applications. The objective of the study was to determine the cost to the consumer for cooling his or her home by the following strategies:

- Conventional vapor compression cycle air conditioning.
- Full thermal energy storage using an ice bank and conventional refrigeration technology. Here the term full thermal energy storage means that the ice provides 100 percent of the cooling and the refrigeration unit operates only during off-peak electricity demand hours to recharge the system.
- Full thermal energy storage using an ice bank and conventional thermal energy storage technology in combination with heat pipes. The heat pipes have the effect of raising the system's thermal efficiency.

A list of the parameters used in the study, along with the results of the study, are included in Table 11.

The utility rates for three different companies were used to arrive at the results in Table 11. These rates are shown in Table 12. Several observations can be made from Table 11.

Note that appreciable cost savings can only be realized in regions with highly-structured rates. For example: Philadelphia, where savings of \$9.34 per month per ton of refrigeration can be realized using conventional thermal energy storage technology and an additional \$0.97 per month per ton of refrigeration can be realized with the incorporation of heat pipe technology. The results in Table 11 also show that the cost savings due to higher operating efficiency (attributable to the heat pipes) is small in comparison with the savings associated with using off-peak electricity. In fact, unless utility rates rise drastically, the cost to manufacture and install heat pipes for this type of application would not be offset by the cost of electrical power consumption for a period of several decades.

The remaining hardware for TES units in residential cooling application, is well developed and field tested. Consequently the development and production of residential TES units does not appear to be a profitable venture for Thermacore

Thermacore continues to research markets for LHTES technology, but at this time has no specific commercial plans.

TABLE 11. Results of Cost Advantage Analysis for the Application of Thermal Energy Storage to Residential Cooling: Summer 1987

Average Summer High Temperature	86°F dry bulb
Average Summer Low Temperature	64°F dry bulb
Required Cooling Time	10 hours
Ice Refreezing Time	12 hours

Operating Cost per Ton of Refrigeration: (monthly basis)

<u>Utility Company</u>	<u>Air Conditioner</u>	<u>TES (using ice)</u>	<u>TES (using Ice and heat pipes)</u>
Pennsylvania Power & Light	\$14.33 - \$17.12	\$15.75	\$15.22
Metropolitan Edison	\$16.78	\$15.90	\$15.07
Philadelphia Electric	\$21.66	\$12.32	\$11.35

TABLE 12. Various Utility Rates on a Monthly Basis: Summer 1987

PENNSYLVANIA POWER & LIGHT:

Peak

\$5.07 serv. chrg.

+ \$0.087231 Per kWh
below 200 kWh

or + \$0.067062 per kWh

Off-Peak

\$11.60 up to 2kW
instantaneous demand

+ \$ 6.12 additional chrg.
per kW above 2 kW

\$.02988 per kWh

METROPOLITAN EDISON:

Peak

\$6.34/mo. serv. chrg.

+ \$0.07559 per kWh

Off-Peak

\$ 9.39/mo. serv. chrg.

+ \$ 0.0469 per kWh up to
3,000kWh

PHILADELPHIA ELECTRIC:

Peak

\$ 4.67/mo. serv. chrg.

+ \$ 0.0551 per kWh
up to 500 kWh/mo.

or + \$ 0.1368 per kWh above
500 kWh/mo.

Off-Peak

\$ 4.67/mo. serv. chrg.

+ \$ 0.123 per kWh
up to 500 kWh

or + \$ 0.1368 per kWh above
500 kWh/mo.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The objectives of this Phase II SBIR program were met in every respect. A microclimate cooling system was fabricated using water as a phase change material (PCM). It was operated at 93% of design capacity cooling 129°F dry air to 62.3°F for 10.3 hours at a flowrate of 70.2 cfm. Additional conclusions are summarized, below:

3.1 PHASE CHANGE MATERIAL

Water is the most effective phase change material evaluated during this effort. It had the best volumetric energy storage capacity.

3.2 THERMAL STORAGE

A modular approach for thermal storage is considered to be more desirable than bulk storage. Separate PCM modules afford both on and off vehicle personnel cooling capacity.

3.3 ENERGY SAVINGS

Microclimate cooling systems which employ PCM for energy storage show potential for net energy savings of up to 16% over standard refrigeration units. This savings diminishes considerably when considering the energy cost of transportation in military vehicles due to the added weight of the MCS. Landbased installations, such as tactical shelters would have more energy savings potential.

3.4 COMMERCIAL APPLICATIONS

A survey was conducted to identify any commercial applications for thermal energy storage technology. Results show some applications in areas served by utilities with lower rates during off-peak hours. These applications can be met with conventional, nonheat pipe technology.

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LIST OF ACRONYMS

MCS: Microclimate Cooling System
NBC: Nuclear, Biological and Chemical
PCM: Phase Change Material
TES: Thermal Energy Storage

APPENDIX A

SAMPLE CALCULATIONS FOR THERMAL LOAD PROFILES

Title: _____

Page _____ of _____

Required Capacity and Energy Consumption
for refrigeration unit MCS.

Calculated by: _____

Date _____

Approved by: _____

Date _____

Purpose: To determine the capacity and energy required to run a conventional refrigeration unit for use as a micro-climate cooling system (mcs) aboard military vehicles.

Thermal Load Profile: (Figure A.)

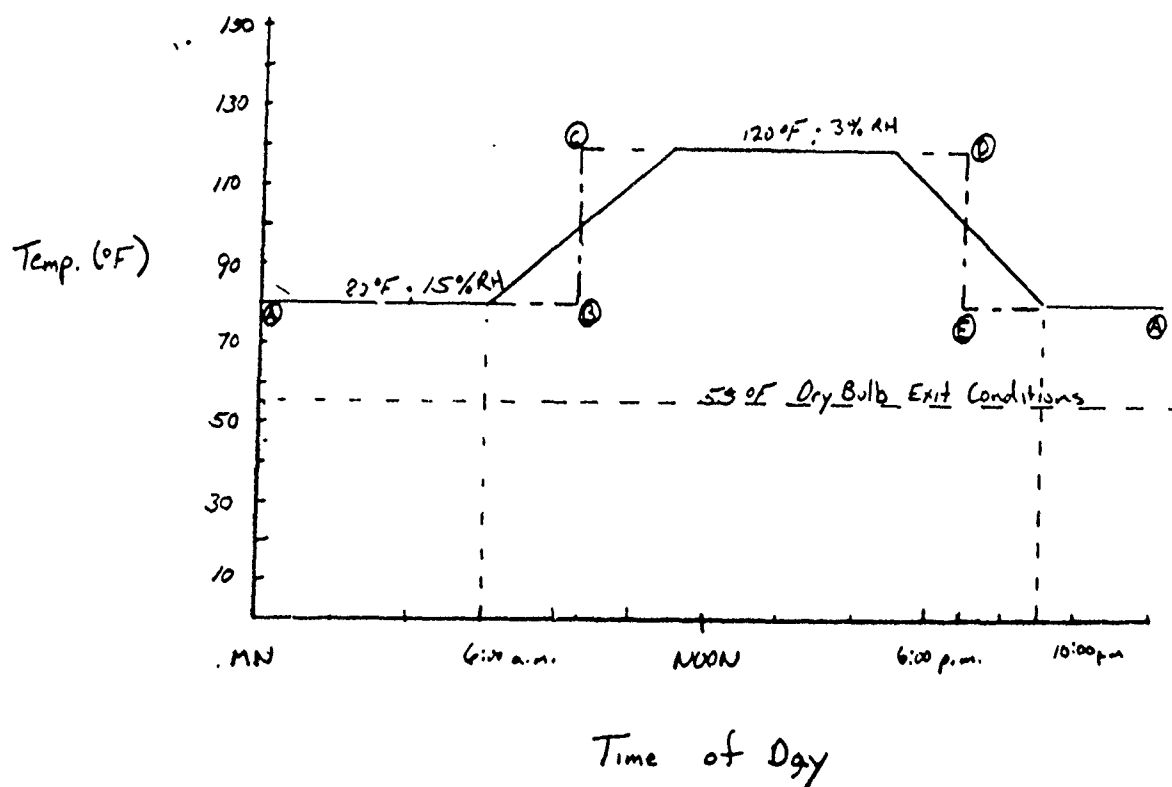


FIG. A

Operating Scenario:

a refrigeration unit is required to accomplish all of the day's cooling during both peak and off-peak hours. No thermal storage is provided. The air to be cooled has the initial conditions shown in Figure A. This air is filtered and raised in temperature by 15°F at a rate of 72 scfm prior to be cooled to 55°F Dry bulb.

Title: _____ Page _____ of _____
 _____ Calculated by: _____ Date _____
 _____ Approved by: _____ Date _____

Determination of Required Capacities During Peak and Off-Peak Hours :

Assume : the line A-B-C-D-E-A represents the load for one day and the barometric pressure is that of sea level such that a standard psychrometric chart can be used to calculate enthalpy changes in the air.

Initial Conditions : $T_i = 135^\circ\text{F}$, $RH_i = 3\%$; $H_i = 37.00 - (0.59) \frac{\text{BTU}}{\text{lb}} = 36.41 \frac{\text{BTU}}{\text{lb}}$

Final Conditions : $T_f = 55^\circ\text{F}$, $RH_f = 31\%$; $H_f = 16.90 - (0.01) = 16.89 \frac{\text{BTU}}{\text{lb}}$

$$\Delta H = H_i - H_f = 19.52 \frac{\text{BTU}}{\text{lb}}$$

density of air @ $70^\circ\text{F} = 0.0743 \frac{\text{lb}}{\text{ft}^3}$

$$\dot{m}_{\text{air}} = (0.0743 \frac{\text{lb}}{\text{ft}^3}) (72 \text{ ft}^3/\text{min}) = 5.350 \frac{\text{lb}}{\text{min}}$$

$$\dot{Q} = 19.52 \frac{\text{BTU}}{\text{lb}} (5.350 \frac{\text{lb}}{\text{min}}) (60 \frac{\text{min}}{\text{hr}}) = 6266 \frac{\text{BTU}}{\text{hr}}$$

Refrigeration Capacity (Peak hours) : $6266 \frac{\text{BTU}}{\text{hr}}$

Initial Conditions : $T_i = 95^\circ\text{F}$, $RH_i = 10\%$; $H_i = 27.00 - (0.20) = 26.80 \frac{\text{BTU}}{\text{lb}}$

Final Conditions : $T_f = 55^\circ\text{F}$, $RH_f = 31\%$; $H_f = 16.90 - (0.01) = 16.89 \frac{\text{BTU}}{\text{lb}}$

$$\Delta H = H_i - H_f = 9.91 \frac{\text{BTU}}{\text{lb}}$$

$$\dot{Q} = 9.91 \frac{\text{BTU}}{\text{lb}} (5.350 \frac{\text{lb}}{\text{min}}) (60 \frac{\text{min}}{\text{hr}}) = 3181 \frac{\text{BTU}}{\text{hr}}$$

Refrigeration Capacity (Off-Peak HRS.) : $3181 \frac{\text{BTU}}{\text{hr}}$

Duration Peak Load = 10.5 HRS.

Duration off-Peak Load = 13.5 HRS

Title: _____

Page _____ of _____

Calculated by: _____

Date _____

Approved by: _____

Date _____

Determination of Refrigeration Unit Performance :

Refrigerant - R12

Assume : 20°F differences between heat sink and condenser coils and heat source and evaporator coils, and the cycle is an ideal refrigeration cycle.

	h_e $\frac{\text{BTU}}{\text{lb}}$	h_r $\frac{\text{BTU}}{\text{lb}}$	h_g $\frac{\text{BTU}}{\text{lb}}$ or P_{sat} (psia)	
Evap. Temp., $T_e = 35^\circ\text{F}$	16.163	80.930	0.14616	47.263
Cond. Temp. (Peak), $T_c = 140^\circ\text{F}$	41.162	89.967	0.19703	221.32
Cond. Temp. (Off-P.), $T_c = 100^\circ\text{F}$	31.100	87.029	0.16315	131.86

With the aid of saturation and superheat data, the following are obtained.

[Peak HRS.] [Off-Peak HRS.]

Superheat ($\frac{\text{BTU}}{\text{lb}}$)	2.930	1.695
Work of compression ($\frac{\text{BTU}}{\text{lb}}$)	11.767	7.794
Net Refrig. Effect, NRE ($\frac{\text{BTU}}{\text{lb}}$)	39.768	49.830
Coefficient of Performance, COP	3.38	6.39
Compression Ratio, CR	4.7:1	2.81:1

Refrigerant Circulated, $\dot{m}$:

$$\text{Peak HRS. } \dot{m} = \frac{6266 \frac{\text{BTU}}{\text{HR}}}{39.768 \frac{\text{BTU}}{\text{lb}}} = 157.56 \frac{\text{lb}}{\text{HR}}$$

$$\text{Off-Peak } \dot{m} = \frac{3181 \frac{\text{BTU}}{\text{HR}}}{49.830 \frac{\text{BTU}}{\text{lb}}} = 63.837 \frac{\text{lb}}{\text{HR}}$$

Rate of work, $\dot{Q}$:

$$\text{Peak HRS. } \dot{Q} = (11.767 \frac{\text{BTU}}{\text{lb}})(157.56 \frac{\text{lb}}{\text{HR}}) = 1859 \frac{\text{BTU}}{\text{HR}}$$

$$\text{Off-Peak } \dot{Q} = (7.794)(63.837) = 498 \frac{\text{BTU}}{\text{HR}}$$

Energy Consumption, Q_{TOT} : 19,470 BTU , Peak hours
6720 BTU , Off-Peak hours

APPENDIX B

MATERIAL SAFETY DATA SHEETS FOR
MATERIALS USED IN THIS PROGRAM

MARMON / KEYSTONE CORPORATION

THE PIPE AND TUBING PEOPLE

P.O. Box 992, Butler, PA 16001
EMERGENCY PHONE NUMBER (412) 283-3000

ISSUE DATE:
JANUARY 1, 1989

MATERIAL SAFETY DATA SHEET

TRADE NAME (Common Name or Synonym)

Aluminum Alloy

CHEMICAL NAME

Alloy Series 1000, 2000, 3000, 5000, 6000 and 7000

I. INGREDIENTS

Material or Component	CAS Number	% Weight	EXPOSURE LIMITS	
			OSHA PEL (mg/m ³)	ACGIH TLV (mg/m ³)
Base Metal				
Aluminum (Al)	7429-90-5	90-99.7	Not Established	10.0 Metal Dust & Oxide 5.0 Welded Fume
Alloying Elements				
Chromium (Cr)	7440-47-3	<0.01-0.4	1.0 Chrome Metal	0.5 Chrome Metal
Copper (Cu)	7440-50-8	<0.05-6.0	0.1 Fume/1.0 Dust	0.2 Fume/1.0 Dust
Iron (Fe)	7439-89-6	<0.35-1.0	10 Oxide Fume	5 Oxide Fume
Magnesium (Mg)	1309-48-4	<0.03-4.9	15 Oxide Fume	10 Oxide Fume
Manganese (Mn)	7439-96-5	<0.02-1.5	5c Dust/5c Fume	5c Dust/1 Fume
Silicon (Si)	7440-21-3	<0.25-1.2	Not Established	10 Total Dust
Titanium (Ti)	7440-32-6	<0.02-0.2	15 Ti Dioxide	10 Ti Dioxide
Zinc (Zn)	1314-13-2	<0.05-6.1	5 Oxide Fume	10 Dust/5 Fume
Bismuth (Bi)	7440-69-9	<0.40-0.7	Not Established	Not Established
Boron (B)	7440-42-8	0.06 max	15 Oxide Fume	10 Oxide Fume
Lead (Pb)	7439-92-1	<0.40-0.7	.05 Dust & Fume	0.15 Dust & Fume
Vanadium (V)	7440-62-2	0.05 max	0.5c Dust/0.1c Fume	0.05 Dust/0.05 Fume
Note: Aluminum alloys will be comprised of various combinations of the elements shown above. In addition, other alloying elements may be present in minute quantities. No permissible exposure limits (PEL) or threshold limit values (TLV) exist for aluminum alloys. Values shown are applicable to component elements.				

II. PHYSICAL DATA

MATERIAL IS (At Normal Conditions) ☐ LIQUID ☒ SOLID ☐ GAS ☐ OTHER		APPEARANCE AND ODOR Silvery-Grey, Odorless	% VOLATILE BY VOLUME N/A	VAPOR DENSITY N/A
ACIDITY/ALKALINITY pH = N/A	Melting Point Boiling Point	900-1200 °F N/A °F	Specific Gravity (H ₂ O = 1) Approx. 2.5-2.9 Solubility in water (% by weight) Negligible	VAPOR PRESSURE (mm Hg at 20°C) N/A

III. PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY PROTECTION: Appropriate dust/mist/fume respirator should be used to avoid excessive inhalation of particulates. If exposure limits are reached or exceeded, use NIOSH approved equipment.	HANDS, ARMS AND BODY: Protective gloves should be worn as required for welding, burning or handling operations.
EYES AND FACE: Safety glasses should be worn when grinding or cutting. Face shields should be worn when welding or cutting.	OTHER CLOTHING AND EQUIPMENT: As required depending on operations and safety codes.

IV. EMERGENCY MEDICAL PROCEDURES

INHALATION	Remove to fresh air, if condition continues, consult a physician.
EYE CONTACT	Flush thoroughly with running water to remove particulate, obtain medical attention.
SKIN CONTACT	Remove particles by washing thoroughly with soap and water. Seek medical attention if condition persists.
INGESTION	If significant amounts of metal are ingested, consult physician.

V. HEALTH/SAFETY INFORMATION

Health	For standard operations (e.g. melting, cutting, grinding), aluminum alloys present a low health risk by inhalation and are usually considered a nuisance dust. Toxicity by ingestion—none expected. Skin and eyes—not an irritant. Welding and plasma cutting of alloys high in copper (2000 and 7000 series) may present the potential for overexposure to copper fumes which can result in upper respiratory tract irritation, nausea, and metal fume fever. Nickel and chromium are other alloying elements considered hazardous as fume; however, they do not present a carcinogenic or other health concern due to their low concentrations of the chemical form in which they are present. Overexposure to lead fumes over an extended period of time can result in such toxic effects as central nervous system disturbances, renal changes, peripheral neuropathy, gastrointestinal disturbances, anemia, and chromosomal changes. The welding of aluminum alloys may generate carbon monoxide, carbon dioxide, ozone nitrogen oxides, infrared radiation and ultraviolet radiation. MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Individuals with chronic respiratory disorders (i.e.: asthma, chronic bronchitis, emphysema, etc.) may be adversely affected by any fume or airborne particulate matter exposure. OCCUPATIONAL EXPOSURE LIMITS: See Products Ingredients Section I.				
Fire and Explosion	FLASH POINT	AUTO IGNITION TEMPERATURE	FLAMMABLE LIMITS IN AIR		EXTINGUISHING MEDIA
	N/A °F	N/A	Lower Upper	N/A %	For molten aluminum use dry powder or sand.
Reactivity	FIRE AND EXPLOSION HAZARDS Aluminum tubular products do not present fire or explosion hazards under normal conditions.			EXTINGUISHING MEDIA NOT TO BE USED Do not use water or halogen agents on molten aluminum	
	STABILITY ☒ Stable ☐ Unstable		INCOMPATIBILITY (MATERIALS TO AVOID) Reacts with strong acids to form hydrogen gas.		
	CONDITIONS TO AVOID: Aluminum products under normal conditions are stable during use, storage and transportation. Halogen acids and sodium hydroxide in contact with aluminum may generate explosive mixtures of hydrogen. Finely divided aluminum, such as small chips and fines, will form explosive mixtures in air. It also will form explosive mixtures in air in the presence of bromates, iodates, or ammonium nitrate. Strong oxidizers cause violent reactions with considerable heat generation				

VI. ENVIRONMENTAL

SPILL OR LEAK PROCEDURES Fine turnings and small chips should be swept or vacuumed. Scrap metal can be reclaimed for reuse.
WASTE DISPOSAL METHOD* Used or unused product should be disposed of in accordance with Federal, State or Local Laws and Regulations. *Disposer must comply with Federal, State and Local disposal or discharge laws.

VII. ADDITIONAL INFORMATION

Do not touch cast aluminum metal or heated aluminum product without knowing metal temperature. Aluminum experiences no color change during heating. Burns could result. Series 2000 and 7000 alloys should be stress relieved prior to sawing or cutting to avoid cracking. Aluminum powder must be packaged and shipped as a flammable solid. Minimize and control operations producing dust and fume.
DISCLAIMER The information in this MSDS was obtained from sources which we believe are reliable; however, the information is provided without any representation or warranty, express or implied, regarding the accuracy or correctness. The conditions or methods of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.



E.P.A. Reg. No. 8959-22

E.P.A. Est. No. 8959-WI-1

BIOCIDE

FOR USE IN COMMERCIAL & INDUSTRIAL RECIRCULATION WATER TOWERS

ACTIVE INGREDIENT

Polyoxyethylene (dimethyliminomethylene) dimethyliminomethylene dichloride

25%

INERT INGREDIENTS

Weight Per Gallon

75%

Weight of Active Ingredient Per Gallon

8.82 lbs (4.0 kg)

2.11 lbs (0.96 kg)

APPLICATIONS: TOWERTRINE™ N-25 is used to control algae, bacteria and fungi in commercial and industrial cooling towers. Prior to its use, systems must be cleaned to remove algal growth, microbiological slime and other deposits. An initial slug addition of 2.4 to 6.0 fluid ounces of TOWERTRINE™ N-25 per 1,000 gallons of water, to provide a concentration of 8 to 20 parts per million based on the total weight of water in the system, is recommended. Subsequent slug additions of 0.6 to 6.0 fluid ounces of TOWERTRINE™ N-25 per 1,000 gallons of water (2 to 20 parts per million) should be employed every 2 to 5 days or as needed. The frequency of addition depends upon the relative amount of bleedoff and the severity of the microbiological problem. Slug additions should be made in the sump water of the cooling tower.

CAUTION

KEEP OUT OF REACH OF CHILDREN

Harmful if swallowed. May cause skin damage. Avoid contact with skin and eyes. In case of contact, flush with plenty of water for at least 15 minutes. If eye irritation persists, get medical attention. Avoid contamination of food.

DO NOT REUSE CONTAINER

DESTROY WHEN EMPTY

This product is toxic to fish. Do not add treated effluent to lakes, streams, or ponds. Do not contaminate water by cleaning of equipment or disposal of waste. Use only as directed on label.

NET CONTENTS GALLONS (liters)

Weight Per Gallon 8.82 lbs (4.0 kg)

Manufactured by

ab applied biochemists inc

030-04-1-0-1

TOWERTRINE™ N-25
TECHNICAL SERVICE REPORT NO. 201-384

E.P.A. Reg. No. 8959-22

E.P.A. Est. No. 8952-WI-1

TOWERTRINE™ N-25
BIOCIDE
FOR USE IN COMMERCIAL & INDUSTRIAL RECIRCULATION WATER TOWERS

Towertrine™ N-25 is a highly effective polymeric quaternary ammonium algaecide and bactericide concentrate which may be diluted with water to prepare ready-to-use biocides of any desired concentration. It is also suitable for use in large industrial operations, without dilution. It is especially effective in controlling algae, most forms of bacteria, fungi and other slime-forming microorganisms that contribute to the biological fouling of cooling towers and heat exchangers. **Towertrine™ N-25** can be used in both acid and alkaline systems, and, unlike other biocides, it does not cause foaming.

APPLICATION RATES

Towertrine™ N-25 is most effective if, prior to its use, the system is cleaned to remove algae growth, microbiological slime, mud and silt. An initial slug of 2.4-6.0 fluid ounces of **Towertrine™ N-25** per 1,000 gallons of water will provide 8-20 parts per million based on the total weight of water in the system. Subsequent additions of 0.6-6.0 fluid ounces of **Towertrine™ N-25** per 1,000 gallons of water (2 to 20 parts per million) should be employed every 2-5 days or as needed.

AVAILABLE PACKAGING

Towertrine™ N-25 is available in 1 gallon, 5 gallon, 30 gallon and 55 gallon plastic containers. The concentrated product can be handled and stored in most materials of plastic construction and in stainless steel.

CAUTION

Towertrine™ N-25 may be harmful if swallowed. In case of accidental ingestion, call a physician. May cause skin damage. Avoid contact with skin and eyes. In case of contact, flush area with plenty of water for at least 15 minutes. If eye irritation persists, seek medical attention. Avoid contamination of food. Do not reuse empty container. When empty, rinse and destroy.

This product is toxic to fish. Do not discharge treated effluent into lakes, streams or ponds. Do not contaminate waters by cleaning of equipment and disposal of waste water.

NOTICE

Neither Applied Biochemists, Inc., nor the seller makes any warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use of this product which is contrary to the label.

MARMON / KEYSTONE CORPORATION

THE PIPE AND TUBING PEOPLE

P.O. Box 992, Butler, PA 16001
EMERGENCY PHONE NUMBER (412) 283-4500

ISSUE DATE
January 1, 1988

MATERIAL SAFETY DATA SHEET

TRADE NAME (Common Name or Synonym)

Brass - half hard, soft, Mr naval, muntz free cutting leaded

CHEMICAL NAME

Brass/Various

I. INGREDIENTS

NOTE: PRODUCTS UNDER NORMAL CONDITIONS DO NOT REPRESENT AN INHALATION, INGESTION OR CONTACT HEALTH HAZARD

BASE METAL ALLOYING ELEMENTS AND METALLIC COATINGS	CAS NUMBER	% COMPOSITION BY WEIGHT (1)	ACGIH TLV (mg/m ³) (2)
Base Metal Copper (Cu)	7440-50-8	60-70	1 (Dust & Mist)
Alloying Elements Zinc (Zn)	1314-13-2	30-40	5 (As Fume)
Tin (Sn)	7440-31-5	<1	2
Free Cutting Leaded Lead (Pb)	7439-92-1	<4	05 (OSHA Lead Std)

(1) % OF ALLOYING MATERIAL VARIES WITH GRADE OF MATERIAL (2) 1985-1986 ACGIH THRESHOLD LIMIT VALUE

II. PHYSICAL DATA

MATERIAL IS (At Normal Conditions) ☐ LIQUID ☒ SOLID ☐ GAS ☐ OTHER		APPEARANCE AND ODOR Gold/Yellow, Odorless	
ACIDITY/ALKALINITY pH = N/A	Melting Point 1600 °F Boiling Point N/A °F	Specific Gravity (H ₂ O = 1) > 8 Solubility in water (% by weight) N/A	VAPOR PRESSURE (mm Hg at 20°C) N/A

III. PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY PROTECTION NIOSH/MSHA approved dust and fume respirator should be used to avoid excessive inhalation of particulates when exposure exceeds TLVs	HANDS ARMS AND BODY Protective gloves should be worn as required for welding, burning or handling operations
EYES AND FACE Safety glasses or goggles should be utilized as required by exposure	OTHER CLOTHING AND EQUIPMENT As required depending on operations and safety codes

IV. EMERGENCY MEDICAL PROCEDURES

INHALATION EYE CONTACT SKIN CONTACT INGESTION	Remove to fresh air; if condition continues, consult a physician. Flush with water for at least 15 minutes; obtain medical attention. Remove particles by washing thoroughly with soap and water. Seek medical attention if condition persists. If significant amounts of metal are ingested, consult physician.
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V. HEALTH/SAFETY INFORMATION

Health	Short term exposure to fumes, dust may provide irritation of eyes and respiratory system. Inhalation of high concentrations of freshly formed oxide fumes of copper, zinc and lead may cause metal fume fever characterized by a metallic taste in the mouth, dryness and irritation of the throat and influenza-like symptoms.			
	Inhalation or ingestion of lead particles may result in lead-induced systemic toxicity. Symptoms of lead poisoning include abdominal cramps, anemia, muscle weakness and headache. Prolonged exposure can cause behavioral changes, kidney damage, CNS damage and reproductive effects.			
Fire and Explosion	FLASH POINT N/A °F	AUTO IGNITION TEMPERATURE N/A °F	FLAMMABLE LIMITS IN AIR Lower N/A % Upper A %	EXTINGUISHING MEDIA N/A
	FIRE AND EXPLOSION HAZARDS Steel products in the solid state present no fire or explosion hazard.		EXTINGUISHING MEDIA NOT TO BE USED N/A	
Reactivity	STABILITY ☒ Stable ☐ Unstable	INCOMPATIBILITY (MATERIALS TO AVOID) Mercury, Ammonia, Acetylene, Acids		
	CONDITIONS TO AVOID Exposure during storage to strong acids, bases or oxidizing agents			
	HAZARDOUS DECOMPOSITION PRODUCTS Toxic gases, aerosols and vapors may be released in a fire involving copper alloys if fumes of other compounds or other contacting materials are involved.			

VI. ENVIRONMENTAL

SPILL OR LEAK PROCEDURES Fine turnings and small chips should be swept or vacuumed. Scrap metal can be reclaimed for reuse.
WASTE DISPOSAL METHOD: Used or unused product should be disposed of in accordance with Federal, State or Local Laws and Regulations.
*Disposer must comply with Federal, State and Local disposal or discharge laws.

VII. ADDITIONAL INFORMATION

In welding, precautions should be taken for airborne contaminants which may originate from components of the welding rod. Arc or spark generated when welding or burning could be a source of ignition for combustible and flammable materials.
DISCLAIMER The information in this MSDS was obtained from sources which we believe are reliable, however, the information is provided without any representation or warranty, express or implied, regarding the accuracy or correctness. The conditions or methods of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.



ECP 2079 11 (8-79)

MATERIAL SAFETY DATA SHEET

SECTION I

PRODUCT NAME **TENITE® Butyrate Formulas 203, 289, 516** SIZE **1/8-in Pellets**

CHEMICAL NAME **Mixture**

FORMULA: **Mixture**

MANUFACTURER **Marketed by Eastman Chemical Products, Inc.**

ADDRESS: **Kingsport, Tennessee 37662**

FOR INFORMATION ON HEALTH HAZARDS CALL **Monday thru Friday, 8 a.m.-5 p.m. (Eastern), (615) 247-0411, Ext. 3613, all other times (615) 247-0411, Ext. 4666**

FOR OTHER INFORMATION CALL **Same number as above Extension 4469** INFORMATION EFFECTIVE AS OF **January 1982**

SECTION II: HAZARDOUS INGREDIENTS OF MIXTURES

PRINCIPAL HAZARDOUS COMPONENT (S)	%	TLV (Units)
None known to Eastman.		

SECTION III PHYSICAL DATA

BOILING POINT (°F)	Not applicable.	SPECIFIC GRAVITY (H ₂ O = 1)	1.18-1.22 (Varies with flow)
VAPOR PRESSURE (mm Hg)	Not applicable.	PERCENT VOLATILE BY VOLUME (%)	Not applicable.
VAPOR DENSITY (AIR = 1)	Not applicable.	EVAPORATION RATE (1)	Not applicable
SOLUBILITY IN WATER	Negligible.		
APPEARANCE AND ODOR	Pellets with characteristic odor.		

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	LeI	Uel
Not applicable (nonvolatile) (Combustible)	Not applicable		

EXTINGUISHING MEDIA **Water spray, Dry chemical, CO₂**

SPECIAL FIRE FIGHTING PROCEDURES **Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes**

UNUSUAL FIRE AND EXPLOSION HAZARDS **Refer to NFPA Pamphlet No. 63, "Prevention of Dust Explosions in Industrial Plants" if this material is to be reduced to or collected as a powder**

SECTION V HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

Not established; however, see Section IX.

EFFECTS OF OVEREXPOSURE

None expected.

EMERGENCY AND FIRST AID PROCEDURES

If burned by contact with molten material, cool as quickly as possible with water and see a physician for removal of adhering material and treatment of burn.

SECTION VI REACTIVITY DATA

STABILITY

UNSTABLE

STABLE

X

CONDITIONS TO AVOID

Not applicable.

INCOMPATIBILITY
(Materials to avoid)

Oxidizing materials can cause a reaction.

HAZARDOUS DECOMPOSITION PRODUCTS

As with any other organic material, combustion will produce carbon dioxide and probably carbon monoxide.

HAZARDOUS POLYMERIZATION

May Occur

Will Not Occur

X

CONDITIONS TO AVOID

Not applicable.

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN
IN CASE MATERIAL IS
RELEASED OR SPILLED

Collect and contain for salvage or disposal.

WASTE DISPOSAL METHOD

Incineration or landfill.

Observe all Federal, state, and local laws concerning health and environment

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION
(Specify type)

None should be needed.

VENTILATION

LOCAL EXHAUST

If needed to control fumes.

SPECIAL

None known to Eastman

MECHANICAL (general)

Recommended.

OTHER

None known to Eastman.

PROTECTIVE GLOVES

Should be worn to protect against thermal burns.

EYE PROTECTION

Safety glasses should be worn in any type of industrial setting.

OTHER PROTECTIVE EQUIPMENT

Safety shower.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN
IN HANDLING AND STORING

No special precautions are known to Eastman.

OTHER PRECAUTIONS

Good industrial hygiene practices should be followed which include minimizing inhalation of dusts, vapors, and degradation products. A threshold limit value (TLV) has not been established however, ventilation adequate to maintain dust concentrations below the TLV for nuisance particulates (30 mppcf or 10 mg/m³) should be provided

The information contained herein is furnished without warranty of any kind. Employers should use this information only as a supplement to other information gathered by them and must make independent determinations of suitability and completeness of information from all sources to assure proper use of these materials and the safety and health of employees.

MARMON / KEYSTONE CORPORATION

THE PIPE AND TUBING PEOPLE

P.O. Box 992, Butler, PA 15001
EMERGENCY PHONE NUMBER (412) 263-0000

Revised
March 1989
JLS
ISSUE DATE:
JANUARY 1, 1989

MATERIAL SAFETY DATA SHEET

TRADE NAME (Common Name or Synonym)

Carbon and Alloy Steels

CHEMICAL NAME

AISI/SAE Grades 10xx thru 93xx

I. INGREDIENTS

Material or Component	CAS Number	% Weight	EXPOSURE LIMITS	
			OSHA PEL (mg/m ³)	ACGIH TLV (mg/m ³)
Base Metal				
Iron (Fe)	7439-89-6	86.5-99.5	10 Oxide Fume	5 Oxide Fume
Alloying Elements				
Aluminum (Al)	7429-90-5	<0.1-0.5	Not Established	10 Dust/5 Fume
Bismuth (Bi)	7440-69-9	<0.2-0.5	Not Established	Not Established
Boron (B)	7440-42-8	<.01-1.0	15 Oxide Fume	10 Oxide Fume
Carbon (C)	7440-44-0	<.10-1.5	Not Established	Not Established
Chromium (Cr)	7440-47-3	<.40-10	1.0 Chrome Metal	0.5 Chrome Metal
Columbium (Cb)	7440-03-1	<.15-.35	Not Established	Not Established
Copper (Cu)	7440-50-8	<.30-1.90	0.1 Fume/1.0 Dust	0.2 Fume/1.0 Dust
Lead (Pb)	7439-92-1	<.01-.15	.05 Dust & Fume	.15 Dust & Fume
Manganese (Mn)	7439-96-5	<.04-0.7	5c Dust/5c Fume	5c Dust/1 Fume
Molybdenum (Mo)	7439-98-7	<.15-1.10	15 Insoluble Compounds	10 Insoluble Compounds
Nickel (Ni)	7440-02-0	<.01-10	1 Nickel Metal	1 Nickel Metal
Phosphorous (P)	7723-14-0	<.040-.12	0.1 Phosphorous	0.1 Phosphorous
Silicon (Si)	7440-21-3	<.15-2.00	Not Established	10 Total Dust
Sulfur (S)	7704-34-9	<.050-.35	13 Sulfur Dioxide	5 Sulfur Dioxide
Vanadium (V)	7440-62-2	<.01-0.15	0.5c Dust/0.1c Fume	0.05 Dust/0.05 Fume
Zinc Coating	1314-13-2	2 oz/lit	5 Oxide Fume	10 Dust/5 Fume
Aluminum Coating	7429-90-5	0.5 oz/lit	Not Established	10 Dust/5 Fume
Note: The above listing is a summary of elements used in alloying steel. Various grades of steel will contain different combinations of these elements. Trace elements may also be present in minute amounts. No permissible exposure limits (PEL) or thresholds limit values (TLV) exist for steel. Values shown are applicable to component elements.				

II. PHYSICAL DATA

MATERIAL IS (At Normal Conditions) ☐ LIQUID ☒ SOLID ☐ GAS ☐ OTHER		APPEARANCE AND ODOR Grey-Black, Odorless	% VOLATILE BY VOLUME N/A	VAPOR DENSITY N/A
ACIDITY/ALKALINITY pH = N/A	Melting Point Boiling Point	Approx. 2800 °F N/A °F	Specific Gravity (H ₂ O = 1) Approx. 7 Solubility in water (% by weight) N/A	VAPOR PRESSURE (mm Hg at 20°C) N/A

III. PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY PROTECTION: Appropriate dust/mist/fume respirator should be used to avoid excessive inhalation of particulates. If exposure limits are reached or exceeded, use NIOSH approved equipment.	HANDS, ARMS AND BODY: Protective gloves should be worn as required for welding, burning or handling operations.
EYES AND FACE: Safety glasses should be worn when grinding or cutting. Face shields should be worn when welding or cutting.	OTHER CLOTHING AND EQUIPMENT: As required depending on operations and safety codes.

IV. EMERGENCY MEDICAL PROCEDURES

INHALATION	Remove to fresh air, if condition continues, consult a physician.
EYE CONTACT	Flush thoroughly with running water to remove particulate, obtain medical attention.
SKIN CONTACT	Remove particles by washing thoroughly with soap and water. Seek medical attention if condition persists.
INGESTION	If significant amounts of metal are ingested, consult physician.

V. HEALTH/SAFETY INFORMATION

Health	Steel products in their solid state present no inhalation, ingestion, or contact health hazard. Operations such as burning, welding, sawing, brazing, grinding, and machining, which result in elevating the temperature of the product to, or above its melting point, or result in the generation of airborne particulates may present hazards. The major exposure hazard is inhalation. Effects of overexposure to fume and dust are as follows: ACUTE: Excessive inhalation of metallic fumes and dust may result in irritation of eyes, nose and throat. High concentrations of fumes and dusts of iron-oxide, manganese, copper, zinc and lead may result in metal fume fever. Typical symptoms last from 12 to 48 hours and consist of a metallic taste in the mouth, dryness and irritation of the throat, chills and fever. CHRONIC: Chronic and prolonged inhalation of high concentrations of fumes or dust of the following elements may lead to the conditions listed opposite the element: Aluminum: May initiate fibrotic changes to lung tissue Bismuth: No chronic debilitating symptoms indicated Boron: No chronic debilitating symptoms indicated Chromium: Lesions of the skin and mucous membranes, possibly cancer of the nose or lungs-bronchogenic carcinoma Copper: No chronic debilitating symptoms indicated Iron: Siderosis, pulmonary effects. No chronic debilitating symptoms indicated Lead: Anemia, urinary dysfunction, weakness, constipation, nausea, nervous disorder Manganese: Bronchitis, pneumonitis, lack of coordination Molybdenum: Respiratory tract irritation, possible liver and kidney damage, bone deformity Nickel: Lesions of the skin and mucous membranes, possibly cancer of the nose or lungs-bronchogenic carcinoma Phosphorous: Necrosis of the mandible Sulfur: (As sulfur dioxide) Edema of the lungs Vanadium: (As vanadium pentoxide) Emphysema, pneumonia Zinc: Gastrointestinal inflammation reported in animal studies MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Individuals with chronic respiratory disorders (i.e., asthma, chronic bronchitis, emphysema, etc.) may be adversely affected by any fume or airborne particulate matter exposure. OCCUPATIONAL EXPOSURE LIMITS: See Products Ingredients Section I. Chromium and Nickel have been identified by the International Agency for Research on Cancer (IARC) and/or the National Toxicology Program (NTP) as potential cancer causing agents.					
	FLASH POINT N/A °F		AUTO IGNITION TEMPERATURE N/A		FLAMMABLE LIMITS IN AIR Lower N/A % Upper N/A %	EXTINGUISHING MEDIA For molten metal use dry powder or sand.
Fire and Explosion	FIRE AND EXPLOSION HAZARDS Steel tubular products do not present fire or explosion hazards under normal conditions. Fine metal particles such as produced in grinding or sawing can burn. High concentrations of metallic fines in the air may present an explosion hazard.				EXTINGUISHING MEDIA NOT TO BE USED Do not use water on molten metal.	
Reactivity	STABILITY ■ Stable □ Unstable		INCOMPATIBILITY (MATERIALS TO AVOID) Reacts with strong acids to form hydrogen gas.			
	CONDITIONS TO AVOID: Steel at temperatures above the melting point may liberate fumes containing oxides of iron and alloying elements. Avoid generation of airborne fume and dust.					
	HAZARDOUS DECOMPOSITION PRODUCTS: Metallic dust or fumes may be released during welding, burning, grinding and possibly machining. Refer to ANSI Z49.1					

VI. ENVIRONMENTAL

SPILL OR LEAK PROCEDURES

Fine turnings and small chips should be swept or vacuumed. Scrap metal can be reclaimed for reuse.

WASTE DISPOSAL METHOD*

Used or unused product should be disposed of in accordance with Federal, State or Local Laws and Regulations.

*Disposer must comply with Federal, State and Local disposal or discharge laws.

VII. ADDITIONAL INFORMATION

In welding, precautions should be taken for airborne contaminants which may originate from components of the welding rod.

Arc or spark generated when welding or burning could be a source of ignition for combustion and flammable materials.

DISCLAIMER

The information in this MSDS was obtained from sources which we believe are reliable, however, the information is provided without any representation or warranty, express or implied, regarding the accuracy or correctness.

The conditions or methods of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.

MATERIAL SAFETY DATA SHEET

DATE: 11/25/85

FOR
COPPER

REVISION: _____

COMPLIES WITH THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200)

SECTION I

MANUFACTURER'S NAME AND ADDRESS

Small Tube Products
P.O. Box 1674
Altoona, PA 16603

EMERGENCY TELEPHONE NO.

814-695-4491

CHEMICAL NAME AND SYNONYMS

CDA 102

TRADE NAME AND SYNONYMS

Oxygen Free

CHEMICAL FAMILY Metal/Metal Alloy

FORMULA Cu

SECTION II HAZARDOUS INGREDIENTS

(COMPONENTS (CAS NO.))	PCT (%)	OSHA*		ACGIH*		IDLH*	OTHER
		PEL	CEILING	TLV	STEL		
Copper (7440-50-8) Fume Dusts and Mists (as Cu)	100%	0.1 1.0	- -	0.2 1.0	- -	unk unk	
REMARKS: Basis for TLV: Cu - irritant properties							

*Units: mg/m³

SECTION III PHYSICAL AND CHEMICAL DATA

BOILING POINT (°C)	2595	SPECIFIC GRAVITY (H ₂ O = 1)	8.96
MELTING POINT (°C)	1083	PERCENT VOLATILE, BY VOLUME (%)	N/A
VAPOR PRESSURE (mm Hg.) @ 1628°C	1.0	EVAPORATION RATE (_____ = 1)	N/A
VAPOR DENSITY (AIR = 1)	N/A	OTHER:	N/A
SOLUBILITY Insoluble in water. Soluble in acids			
APPEARANCE AND ODOR: Reddish, lustrous metal, no odor			
REMARKS:			

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD): N/A	FLAMMABLE LIMITS (LEL/UEL): N/A
EXTINGUISHING MEDIA: Unk	AUTOIGNITION TEMPERATURE (°C): N/A
SPECIAL FIREFIGHTING PROCEDURES: N/A	
UNUSUAL FIRE AND EXPLOSION HAZARDS: Finely divided dust is flammable.	
REMARKS: Vapor explosion may result from contact of water with molten metal.	

SECTION V REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID: N/A
	STABLE	X	
INCOMPATIBILITY (MATERIALS TO AVOID) Solid Copper acetylides which are shock sensitive may be formed by copper dusts and mists in the presence of acetylene. Contact with acids may liberate flammable and explosive hydrogen gas.			
HAZARDOUS DECOMPOSITION PRODUCTS: Cu ₂ O			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID: N/A
	WILL NOT OCCUR	X	
REMARKS:			

SECTION VI SPILL/LEAK OR DISPOSAL PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Evacuate unprotected personnel from the spill/release area. Ventilate the area of release. Absorb liquid (with contaminant) by use of vermiculite, dry sand, earth, or similar material.
WASTE DISPOSAL METHOD: Reclaim, if possible. Seal waste in container. Check with local/state authorities regarding landfill disposal.
REMARKS:

SECTION VII EMERGENCY AND FIRST AID PROCEDURES

EYE: Flush with large amounts of water. SKIN: Wash with mild soap and water, if irritation persists, get follow-up medical attention. INHALATION: Move person to fresh air. Perform CPR, if necessary. INGESTION: Give large amounts of water and induce vomiting, if conscious.
REMARKS: Refer accident victim for medical attention following any accidental eye exposure, inhalation, or ingestion.

SECTION VIII HEALTH HAZARD DATA

ROUTES OF EXPOSURE: Inhalation of dusts, fumes, or mists is the primary route of exposure for most health effects. Ingestion results from pulmonary clearance following inhalation and from poor personal hygiene.

TARGET ORGAN/MODE OF ACTION:

Cu : Eyes, nose, throat, skin - irritation; "Flu-like" symptoms; liver (rare)

SIGNS AND SYMPTOMS:

NOTE: Signs and symptoms of overexposure may include any of the following. Many of these effects, if they should be removed, are also related to other causal factors, occupational or otherwise. It should also be noted that, with the exception of hypersensitive or hypersusceptible persons, these effects are only associated with acute or chronic overexposure.

Cu: Irritation of the eyes, nasal mucosa, skin, upper respiratory tract; metallic taste, skin or hair discoloration (green); allergic dermatitis (rare); "Metal Fume Fever" (characteristic influenza-like symptoms include: fever, chills, aches, fatigue, dry throat, nausea, and usually elevated white blood cell count; all of which are rapidly and completely reversible upon removal. Ingestion may result in nausea, vomiting, diarrhea, gastritis; "Wilson's Disease" (extremely rare genetic predisposition to abnormal uptake and storage of Cu by the body) may intensify the toxic effects in chronic exposure situations. Fragments of copper metal or alloys lodged in eye may result in discoloration and abscess.

PREPLACEMENT MEDICAL CONSIDERATIONS: Chronic respiratory disease, skin disease, and Wilson's disease.

MEDICAL SURVEILLANCE: Employees developing any of the above conditions should be referred for further medical evaluation. Diagnostic tests include increased urinary levels of copper, or leucocytosis for metal fume fever.

CARCINOGEN/MUTAGEN/TERATOGEN:

unk

REMARKS: Adverse health effects from over exposure are primarily associated with processes involving welding, cutting, grinding, or smelting of this product.

SECTION IX SPECIAL PROTECTION INFORMATION

VENTILATION	LOCAL EXHAUST: Design for process, concentration, toxicity; as needed MECHANICAL (GENERAL): May be used depending on process, concentration and/or toxicity. Consult Ind Hyg.	SPECIAL: Ventilate hot work in confined spaces OTHER: Refer to 29 CFR 1910.94 and .252 (grinding, buffing, polishing, welding, cutting, brazing, etc.)
PROTECTIVE GLOVES: See Other Protective Equip.		EYE PROTECTION: See Other Protective Equip.
CONTAINMENT/ISOLATION PRACTICES: Design for process, if feasible.		
RESPIRATORY PROTECTION:		
CONCENTRATION	TYPE OF RESPIRATORY PROTECTION	
10 X PEL or Less	Fume or High Efficiency Particulate (HEPA) Filter Respirator w/ Half Facepiece	
50 X PEL or Less	HEPA Filter Respirator w/ Full Facepiece	
100 X PEL or Less	Helmet Type Powered Air Purifying Respirator (PAPR) w/ HEPA Filter	
1000 X PEL or Less	Hood or Tight-fitting Full Facepiece Powered Air Purifying Respiratory w/ HEPA Filter	
2000 X PEL or Less	Type C Supplied Air Respiratory (airline) Full Facepiece, Hood, or Helmet operated in Positive Pressure Mode (Pressure-Demand, Continuous Flow) at Manufacturer's maximum recommended flow rate for Hood/Helmet or 6 cfm for Full Facepiece	
Greater than 2000 X PEL or Unknown Concentrations	Self-Contained Breathing Apparatus (SCBA), Open Circuit Type operated in Positive Pressure Mode -OR- Type C Airline operated in Positive Pressure Mode in combination with Escape Provision (Short Duration, Positive Pressure, Open Circuit SCBA)	
OTHER PROTECTIVE EQUIPMENT: Gloves and Eye Protection selection must be based on the process hazards or the physical/thermal hazards such as leather welding gloves, welding helmet, or face-shield for grinding.		

SECTION X SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Do not wear contact lenses while wearing a respirator or when dusts, mists, or fumes may get into eyes.

OTHER PRECAUTIONS: Good personal hygiene and housekeeping practices will serve to minimize exposure and reduce the spread of surface contamination.

SECTION XI OTHER INFORMATION

- REFERENCES:**
1. Title 29 Code of Federal Regulations, Part 1910; "Occupational Safety and Health Standards"
 2. NIOSH/OSHA, Occupational Health Guidelines for Chemical Hazards, DHHS NIOSH Publication No. 81-123, USGPO, Washington, D.C., 1981
 3. ACGIH, Threshold Limit Values for Chemical Substances and Physical Agents

NOTE: Other references available on request

CODES: N/A - not applicable
 unk - No data found

140-SCR Series
MATERIAL SAFETY DATA SHEET
 FOR COATINGS, RESINS AND RELATED MATERIALS
 (Approved by U.S. Department of Labor "Essentially Similar" to form OSHA-20)

MANUFACTURER'S NAME
 THE SHERWIN-WILLIAMS COMPANY
 101 Prospect Avenue N.W.
 Cleveland, Ohio 44115
 DATE OF PREPARATION
 5-May-86

EMERGENCY TELEPHONE NO.
 (216) 566-2917

INFORMATION TELEPHONE NO.
 (216) 566-2902

Section I -- PRODUCT IDENTIFICATION

PRODUCT NAME
 SUPERACRYLIC® Controls Rust Spray Enamel

PRODUCT NUMBERS AND COLORS

140-0506	Hard Gloss Black.	140-0563	Cocoa Brown.
140-0514	Wt. Iron Flat Black.	140-0571	Sun Yellow.
140-0522	Apliance White.	140-0589	Metal Primer Red.]
140-0530	Chrome Aluminum]	140-0597	Wt. Iron Flat White
140-0548	Hi-visibility Red.	140-0613	Metal Primer Gray.]
140-0555	Federal Blue.	140-0621	Machinery Gray.

PRODUCT CLASS
 Aerosol Acrylic Enamel

Section II -- HAZARDOUS INGREDIENTS

CAS No.	Concentration	by Weight %	by Volume %	OSHA-PEL	OSHA-TL	OSHA-TL
74-98-6	Propane (Propellant)	10	1000	1000	PPH	760.0
75-28-5	2-Methylpropane (Propellant)	15	1000		PPH	760.0
75-09-2	Dichloromethane	10-25	100	500	PPH	420.0
108-88-3	Toluene	0-15	100	200	PPH	22.0
1330-70-7	Xylene	10-70	100	100	PPH	5.9
71-36-3	1-Butanol	0-5	50	100	PPH	5.5
67-64-1	Acetone	0-10	750	1000	PPH	180.0
78-93-3	Methyl Ethyl Ketone	0-15	200	200	PPH	70.0
763-69-9	Ethyl 3-ethoxypropionate.	0-5	Not Estab.			0.9

** For specific percent hazardous ingredients for products in (), see Section X

Section III -- PHYSICAL DATA

EVAPORATION RATE -- Faster than Ether	VAPOUR DENSITY -- Heavier than Air
BOILING RANGE (°F) <0 - 125	% VOLATILE VOLUME >75
	WT/GAL N.A.

Section IV -- FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY CLASSIFICATION
 RED LABEL -- Extremely Flammable Flash below 21°F

EXTINGUISHING MEDIA
 Carbon Dioxide, Dry Chemical, Foam

UNUSUAL FIRE AND EXPLOSION HAZARDS
 Keep containers tightly closed. Isolate from heat, electrical equipment, sparks, and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent. Obtain medical attention.

Continued on page 2

SPECIAL FIRE FIGHTING PROCEDURES

Full protective equipment including self-contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

Section V -- HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE -- See Section II
 EFFECTS OF OVEREXPOSURE

ACUTE: In a confined area vapors in high concentration are anesthetic. Overexposure may result in lightheadedness and staggering gait. Irritant to skin and upper respiratory system.

CHRONIC: Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage.

EMERGENCY AND FIRST AID PROCEDURES

If INHALED: If affected, remove from exposure. Restore breathing. Keep warm and quiet. If on SKIN: Wash affected area thoroughly with soap and water. Remove contaminated clothing and launder before re-use.

If in EYES: Flush eyes with large amounts of water for 15 minutes. Get medical attention.

If SWALLOWED: Never give anything by mouth to an unconscious person. DO NOT INDUCE VOMITING. Give several glasses of water. Seek medical attention.

Section VI -- REACTIVITY DATA

STABILITY -- Stable

HAZARDOUS DECOMPOSITION PRODUCTS

By fire: Carbon Dioxide, Carbon Monoxide, Hydrogen Chloride

HAZARDOUS POLYMERIZATION -- Will Not Occur

Section VII -- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition. Ventilate and remove with inert absorbent.

WASTE DISPOSAL METHOD

Vaste from this product may be hazardous as defined under the Resource Conservation and Recovery Act (RCRA) 40 CFR 261. Waste must be tested for ignitability to determine the applicable EPA hazardous waste numbers.

Do not incinerate. Depressurize container. Dispose of in accordance with Federal, State, and Local regulations regarding pollution.

Section VIII -- PROTECTION INFORMATION

PRECAUTIONS TO BE TAKEN IN USE

Use only with adequate ventilation. Avoid breathing vapor and spray mist. Avoid contact with skin and eyes. Wash hands after using.

VENTILATION

Local exhaust preferable. General exhaust acceptable if the exposure to materials in Section II is maintained below applicable exposure limits. Refer to OSHA Standards 1910.104, 1910.108

RESPIRATORY PROTECTION

If personal exposure cannot be controlled below applicable limits by ventilation, wear respiratory device approved by NIOSH/MSHA for protection against materials in Section II.

Continued on page 3

PROTECTIVE GLOVES

Wear gloves which are recommended by glove supplier for protection against materials in Section II.

EYE PROTECTION

Wear safety spectacles with unperforated sideshields.

Section IX -- PRECAUTIONS

DOL STORAGE CATEGORY -- 1A

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Contents are EXTREMELY FLAMMABLE. Keep away from heat, sparks, and open flame. Vapors will accumulate readily and may ignite explosively.

During use and until all vapors are gone: Keep area ventilated - Do not smoke - Extinguish all flames, pilot lights, and heaters - Turn off stoves, electric tools and appliances, and any other sources of ignition.

Consult NFPA Code. Use approved Bonding and Grounding procedures.

Contents under pressure. Do not puncture, incinerate, or expose to temperature above 120°F. Heat from sunlight, radiators, stoves, hot water, and other heat sources could cause container to burst. Do not take internally. Keep out of the reach of children.

OTHER PRECAUTIONS

Intentional misuse by deliberately concentrating and inhaling the contents can be fatal or fatal.

Section X -- PERCENT HAZARDOUS INGREDIENTS

	-0530	-0589	-0613
Propane (Propellant)	10	15	15
2-Methylpropane (Propellant)	15	—	—
Dichloromethane	20	—	—
Toluene	40	—	—
Xylene	—	20	15
1-Butanol	—	<5	<5
Acetone	—	25	35
Methyl Ethyl Ketone.	—	15	10

This Material Safety Data Sheet conforms to the Hazard Communication standard, 29 CFR 1910.1200(g)(4), for similar complex mixtures.

The above information pertains to this product as currently formulated, and is based on the information available at this time. Addition of reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44 01367

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing,
Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME 24 Richmond Hill Ave.		EMERGENCY TELEPHONE NO.
Pharmco Products, Inc. Stamford, CT 06904-2324		(203) 356-0019
ADDRESS (Number, Street, City, State, and Zip Code) Plant: 395 Hook Road, Bayonne, NJ 07002		
CHEMICAL NAME AND SYNONYMS ETHANOL, PURE ETHYL ALCOHOL		TRADE NAME AND SYNONYMS ETHYL ALCOHOL U.S.P.
CHEMICAL FAMILY ALCOHOL	FORMULA CH ₃ CH ₂ OH	

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Unit)	ALLOYS AND METALLIC COATINGS	%	TLV (Unit)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES				%	TLV (Unit)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	173°	SPECIFIC GRAVITY (H ₂ O=1)	0.8160
VAPOR PRESSURE (mm Hg.) @ 68°F	44	PERCENT VOLATILE BY VOLUME (%)	100
VAPOR DENSITY (AIR=1)	1.59	EVAPORATION RATE (_____ =1)	
SOLUBILITY IN WATER			
APPEARANCE AND ODOR			

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	CLOSED CUP 48°F	FLAMMABLE LIMITS	LM	UM
EXTINGUISHING MEDIA	CO ₂ or Dry Chemical Extinguisher; Large Spill, use Water Spray or alcohol Foam.			
SPECIAL FIRE FIGHTING PROCEDURES	Water in straight hose stream will scatter & spread fire and should not be used.			
UNUSUAL FIRE AND EXPLOSION HAZARDS	Water away from heat, spark, and open flame. Keep container closed and in			

SECTION V - HEALTH HAZARD DATA	
THRESHOLD LIMIT VALUE	1000 PPM daily 8-hour exposure
EFFECTS OF OVEREXPOSURE	Irritation of eyes, nose and throat. Headache & drowsiness may occur. Liquid causes intoxication. Lethal dose 1-pint.
EMERGENCY AND FIRST AID PROCEDURES	Avoid contacting liquid with eyes, skin, clothing. Flush with water in case of contact. Avoid inhalation of vapor. If breathing affected by vapor inhalation, remove to fresh air. Call physician. Administer Oxygen. SPEED IS OF PRIMARY IMPORTANCE.

SECTION VI - REACTIVITY DATA			
STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATIBILITY (Materials to avoid) OXIDIZING MATERIALS			
HAZARDOUS DECOMPOSITION PRODUCTS CARBON MONOXIDE			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII - SPILL OR LEAK PROCEDURES	
STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Large spills on ground resulting from container rupture or accident, if not contained by diking, should be generously diluted with water spray. Avoid flushing directly into stream or sewer. Contained spills should be recovered to the extent possible for proper waste disposal.	
WASTE DISPOSAL METHOD If custom disposal service not available, large quantities may be burned in a combustion chamber by a competent Engineer. Small quantities may be poured upon sand or dirt contained by a shallow pan and cautiously burned, local codes permitting.	

SECTION VIII - SPECIAL PROTECTION INFORMATION		
RESPIRATORY PROTECTION (Specify type) Where high concentration of vapor exists, all-purpose canister recommended		
VENTILATION	LOCAL EXHAUST From floor and low spaces	SPECIAL Prefer explosion windows
	MECHANICAL (General) Floor mounted fan or blower	OTHER Explosion-proof equipment
PROTECTIVE GLOVES Rubber or other approved material		EYE PROTECTION CHEMICAL SAFETY GOGGLES
OTHER PROTECTIVE EQUIPMENT		

SECTION IX - SPECIAL PRECAUTIONS	
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING Follow State and Municipal Codes as well as requirements of Insurance Carrier. Consult CHEMICAL SAFETY GUIDES, published by M.C.A.	
OTHER PRECAUTIONS Employee must be well trained in proper handling techniques.	
Consult pertinent bulletins published by M.C.A. on MATERIALS HANDLING	

DU PONT

MATERIAL SAFETY DATA SHEET

IDENTIFICATION

Name:
Freon® 12

Chemical Family:
Halogenated Hydrocarbon

Synonyms:
R-12, Refrigerant 12,
Dichlorodifluoromethane

Formula:
 CCl_2F_2

CAS Name:
Methane, Dichlorodifluoro

CAS Registry No.:
75-71-8

Manufacturer/Distributor:
E. I. du Pont de Nemours & Co. (Inc.)

Medical Emergency Phone:
(800) 441-3637

Address:
Freon® Products Division
Wilmington, DE 19898

Transportation Emergency Phone:
CHEMTREC (800) 424-9300

PHYSICAL DATA

Boiling Point (°F): -21.6

Percent Volatile by Volume: 100

Density: 1.311 g/cc @ 77°F

Vapor Pressure: 80 psig @ 77°F

Vapor Density (Air = 1): 4.2

Solubility in H₂O: 0.028% by wt @ 77°F

Form: Liquefied Gas

Appearance: Clear

Color: Colorless

Odor: Slight ethereal odor

HAZARDOUS COMPONENTS

Material:
Dichlorodifluoromethane

Approximate %:
100

HAZARDOUS REACTIVITY

Stability:
Material is stable. However, avoid open flames and high temperatures.

Incompatibility:
Alkali or alkaline earth metals - powdered Al, Zn, Be, etc.

Decomposition: Freon® 12 can be decomposed by high temperatures (open flames, glowing surfaces, etc.) forming hydrochloric and hydrofluoric acids - possible carbonyl halides.

Polymerization: Will not occur.

FIRE AND EXPLOSION DATA

Flash Point:
None

Method:
TOC

Autoignition Temperature:
Not Determined

Flammable Limits in Air, % by Vol.
Lower: Nonflammable
Upper: Nonflammable

Autodecomposition Temperature:
>1400°F

Fire and Explosion:
Cylinders may rupture under fire conditions. Decomposition may occur.

Extinguishing Media:
Nonflammable

Special Fire Fighting Instructions:
Self-contained breathing apparatus (SCBA) may be required if cylinders rupture and contents are released under fire conditions.

HEALTH HAZARD INFORMATION

Principal Health Hazards:

Inhalation: Vapor is heavier than air and can cause suffocation by reducing oxygen available for breathing. Breathing high concentrations of vapor may cause light-headedness, giddiness, shortness of breath, and may lead to narcosis, cardiac irregularities, unconsciousness or death. LC50 Rat 800,000 ppm/30 min.

Note: In screening tests with experimental animals, exposure at approximately 50,000 ppm (v/v) and above, followed by a large intravenous epinephrine challenge, has induced serious cardiac irregularities.

Skin: Liquid contact can cause frostbite.

Eye: Liquid contact can cause frostbite. Tests in rabbit eyes with a 50% solution in mineral oil and with vapors resulted in no observable damage.

Oral: Rats were fed Freon®-12 dissolved in peanut oil. No deaths occurred at highest feasible dose - 1000 mg/kg.

Exposure Limits:

PEL (OSHA) 1000 ppm
TLV® TWA (ACGIH) 1000 ppm

Safety Precautions: Avoid breathing vapors and liquid contact with skin or eyes.
Use only in well ventilated area.

First Aid:

Inhalation: Remove to fresh air, call a physician. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Do not give epinephrine or similar drugs.

Note to Physicians: Because of a possible increased risk of eliciting cardiac dysrhythmias, catecholamine drugs, such as epinephrine, should be considered only as a last resort in life threatening emergencies.

Eye: In case of liquid contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

Skin: Flush with water. Treat for frostbite if necessary.

Medical Conditions Possibly Aggravated by Exposure:

Cardiovascular Disease - See Principal Health Hazards: Inhalation Section.

Other Health Hazards:

Freon® 12 is not classified as carcinogenic by IARC, NTP, or OSHA. Based on animal studies and human experiences this fluorocarbon poses no hazard to man relative to systemic toxicity, carcinogenicity, mutagenicity, or teratogenicity when occupational exposures are below its TLV®.

PROTECTION INFORMATION

Generally Applicable Control Measures:

Normal ventilation for standard manufacturing procedures is generally adequate. Local exhaust should be used when large amounts are released. Mechanical ventilation should be used in low places.

Personal Protective Equipment:

Lined butyl gloves should be used when handling liquid. Chemical splash goggles should be worn when handling liquid. Under normal manufacturing conditions, no respiratory protection is required when using this product. Self-contained breathing apparatus (SCBA) is required if a large release occurs.

DISPOSAL INFORMATION

Spill, Leak or Release: Ventilate area--especially low places where heavy vapors might collect. Remove open flames.

Waste Disposal: EPA Hazardous Waste No. UO 75
Comply with federal, state, and local regulations. Reclaim by distillation or remove to a permitted waste disposal facility.

SHIPPING INFORMATION

Domestic--Other than Air (DOT)

Proper Shipping Name	Dichlorodifluoromethane
Hazard Class	Nonflammable Gas
UN No.	1028
DOT Label(s)	Nonflammable Gas
DOT Placard	Nonflammable Gas

International Water or Air (IMO/ICAO)

Proper Shipping Name	Dichlorodifluoromethane
Hazard Class	Nonflammable Gas
UN No.	1028
IMO/ICAO Label	Nonflammable Gas

Other Information

Shipping Containers	Cylinders, ton tanks, tank cars
Storage Conditions	Clean, dry area. Do not heat above 125°F

Date Revised: 10/85

Person responsible: T. D. Armstrong, C&P Dept., Freon® Products Lab.,
Chestnut Run, Bldg. 711, Wilmington, DE 19898
(302) 999-3847 or (302) 999-4338.

E-77811-1

REF 2/1.15





Loctite
Corporation

705 North Mountain Road
Newington, Connecticut 06111
Telephone: (203) 278-1280
Telex 99348

MATERIAL SAFETY DATA SHEET

I. PRODUCT IDENTIFICATION

Product Name GASKET ELIMINATOR® 504 SEALANT Part No. 504
Product Type Anaerobic Formula No. _____

II. COMPOSITION

<u>Ingredients</u>	<u>% by Wt.</u>	<u>Hazard</u>
Polyglycol Dimethacrylates	75-80	See Section IV. ↓
Cellulose Acetate Butyrate	5-10	
Proprietary Thixotrope	4-5	
Saccharin**	4-5	
Cumene Hydroperoxide*	~2	
Silicon Dioxide***	~3	
Ethylene glycol	1-3	
N,N-Dialkyltoluidines	<1	

*In a single test, pure cumene hydroperoxide caused tumors in one of thirty experimental animals when injected under the skin. **Saccharin has been shown to cause tumors in experimental animals when fed in large amounts for prolonged periods. ***Inhalation of pure silicon dioxide dust has been shown to cause pulmonary effects. In light of the low concentration of these components in the product, it is our best technical judgment that normal use of this product poses no such hazards. These warnings are present only to comply with OSHA regulations.

III. CHEMICAL AND PHYSICAL PROPERTIES

Vapor Pressure	<u>< 5 mm at 80°F</u>	Specific Gravity	<u>~1.09 at 80°F</u>
Vapor Density	<u>Unknown</u>	Boiling Point	<u>> 300°F</u>
Solubility in Water	<u>Slight</u>	pH	<u>dna</u>
Appearance	<u>Orange Gel</u>	Odor	<u>Mild</u>

IV. TOXICITY AND HEALTH HAZARD DATA

Toxicity Eye Irritant.
Oral LD50 >5000 mg/kg TLV Does not apply
Dermal LD50 >2000 mg/kg
Symptoms of Overexposure May cause dermatitis on prolonged contact in sensitive individuals.

Emergency Treatment Procedures

Ingestion: Do not induce vomiting. Keep individual calm. Obtain medical attention.
Inhalation: Does not apply.
Skin Contact: Flush with water.
Eye Contact: Flush at least 15 minutes with water. Obtain medical attention.

Personal Protection

Eyes: Safety glasses or goggles mandatory.
Skin: Rubber or plastic gloves recommended.
Ventilation: Not normally necessary.

GASKET ELIMINATOR® 504 SEALANT

V. FLAMMABILITY AND EXPLOSIVE PROPERTIES

Flash point > 200°F Method TCC
Explosive Limits (% by volume in air) Lower dn % Upper dn %
Recommended Extinguishing Agents CO₂, Foam, Dry Chemical
Hazardous Products Formed by Fire or Thermal Decomposition: Irritating organic vapors.
Unusual Fire or Explosion Hazards: None
Compressed Gases Name None
Pressure at Room Temperature _____

VI. REACTIVITY DATA

Stability ☒ Stable ☐ Unstable
Hazardous Polymerization ☐ May Occur ☒ Will Not Occur
Hazardous Decomposition Products (non-thermal)
None
Incompatibility None

VII. SPILL OR LEAK AND DISPOSAL PROCEDURES

Steps to be taken in case of spill or leak: Soak up as much as possible. Residues may be cleaned with solvent. Store in partly filled, closed container until disposal.
Recommended methods of disposal: Landfill or incinerate in accordance with EPA and local regulations.

VIII. STORAGE AND HANDLING PROCEDURES

Storage: Store below 110°F to preserve shelf-life.
Handling: Avoid prolonged skin contact. Keep away from eyes.

IX. SHIPPING REGULATIONS

Type or Class DOT Not restricted
IATA Not restricted

Prepared By: Martin Hauser
Title: Vice President - Environmental Health and Safety
Date: November 1, 1985

MATERIAL SAFETY DATA SHEET
FOR COATINGS, RESINS AND RELATED MATERIALS

(Approved by U.S. Department of Labor "Essentially Similar" to Form OSHA-20)

RAW "TUBED" NAME EMERGENCY TELEPHONE NO.
SHERWIN-WILLIAMS COMPANY (216) 566-2917
P.O. Box 1000
Cleveland, Ohio 44115
DATE OF PREPARATION INFO/PHONE TELEPHONE NO.
5-May-85 (216) 566-2902

Section I -- PRODUCT IDENTIFICATION

PRODUCT NAME - Trade Mark
Lacquer
PRODUCT NUMBERS AND COLORS 140-0936 Clear Acrylic.
140-0951 Glistening White. 140-0977 Dead Flat Black
PRODUCT CLASS
Aerosol Acrylic Lacquer

Section II -- HAZARDOUS INGREDIENTS

CAS No.	Ingredient	% by Weight	ACGIH-TL	OSHA-PPE	OSHA-IDL	OSHA-TL	OSHA-VL
75-58-6	Propane (Propellant)	15	1000	1000	PPH	760.0	
75-28-5	2-Methylpropane (Propellant)	0-15	1000		PPH	760.0	
64742-89-8	1,4-Aliphatic Hydrocarbon Solvent	0-5	100	500	PPH	53.0	
64742-89-5	V. M. & P. Naphtha	0-5	300		PPH	12.0	
75-09-2	Dichloromethane	15-25	100	500	PPH	420.0	
106-88-1	Toluene	0-30	100	200	PPH	22.0	
1330-70-7	Xylene	0-5	100	100	PPH	5.9	
67-56-1	Methanol	0-5	200	200	PPH	92.0	
64-17-5	Ethanol	0-5	1000	1000	PPH	44.0	
67-63-0	2-Propanol	0-5	400	400	PPH	33.0	
78-92-2	2-Butanol	0-5	100	150	PPH	12.0	
111-76-2	2-Butoxyethanol	0-5	25	50	PPH	0.6	
67-64-1	Acetone	10-25	750	1000	PPH	180.0	
78-93-1	Methyl Ethyl Ketone	0-15	200	200	PPH	70.0	
110-19-0	Isobutyl Acetate	0-5	150	150	PPH	12.5	
741-69-9	Ethyl Methacrylate	<5	Not Estab.			0.9	

* % specific percent hazardous ingredients in each product, see Section I

Section III -- PHYSICAL DATA

EVAPORATION RATE - Faster than Ether VAPOR DENSITY - Heavier than Air
BOILING RANGE (F): 1 VOLATILE VOLUME MT/GAL
<0 - 325 >75 N.A.

Section IV -- FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY CLASSIFICATION FLASH POINT <0 F TCC LEL 0.7
RED LABEL - Extremely Flammable, Flash below 21 F
EXTINGUISHING MEDIA
Carbon Dioxide, Dry Chemical, Foam

UNUSUAL FIRE AND EXPLOSION HAZARDS

Keep containers tightly closed. Isolate from heat, electrical equipment, sparks, and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent. Obtain medical attention.

SPECIAL FIRE FIGHTING PROCEDURES

Full protective equipment including self contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

Section V -- HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE -- See Section II

EFFECTS OF OVEREXPOSURE

ACUTE: In a confined area vapors in high concentration are anesthetic. Overexposure may result in lightheadedness and staggering gait. Irritant to skin and upper respiratory system.

CHRONIC: Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage.

EMERGENCY AND FIRST AID PROCEDURES

IF INHALED: If affected, remove from exposure. Restore breathing. Keep warm and quiet.
IF ON SKIN: Wash affected area thoroughly with soap and water.
IF IN EYES: Flush eyes with large amounts of water for 15 minutes.
IF SWALLOWED: Never give anything by mouth to an unconscious person. DO NOT INDUCE VOMITING. Give several glasses of water. Seek medical attention.

Section VI -- REACTIVITY DATA

STABILITY -- Stable

HAZARDOUS DECOMPOSITION PRODUCTS

By fire: Carbon Dioxide, Carbon Monoxide, Hydrogen Chloride

HAZARDOUS POLYMERIZATION -- Will Not Occur

Section VII -- SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition. Ventilate and remove with inert absorbent.

WASTE DISPOSAL METHOD

Waste from this product may be hazardous as defined under the Resource Conservation and Recovery Act (RCRA) 40 CFR 261. Waste must be tested for ignitability to determine the applicable EPA hazardous waste numbers.

Do not incinerate. Depressurize container. Dispose of in accordance with Federal, State, and Local regulations regarding pollution.

Section VIII -- PROTECTION INFORMATION

PRECAUTIONS TO BE TAKEN IN USE

Use only with adequate ventilation. Avoid breathing vapor and spray mist. Avoid contact with skin and eyes. Wash hands after using.

VENTILATION

Local exhaust preferable. General exhaust acceptable if the exposure to materials in Section II is maintained below applicable exposure limits. Refer to OSHA Standards 1910.94, 1910.107, 1910.108.

Continued on page 3

Continued on page 3

RESPIRATORY PROTECTION

If personal exposure cannot be controlled below applicable limits by ventilation, wear respiratory device approved by NIOSH/MSHA for protection against materials in Section II.

PROTECTIVE GLOVES

Wear gloves which are recommended by glove supplier for protection against materials in Section II.

EYE PROTECTION

Wear safety spectacles with unperforated side shields.

Section IX -- PRECAUTIONS

DCL STORAGE CATEGORY -- 1A

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Contents are EXTREMELY FLAMMABLE. Keep away from heat, sparks, and open flame. Vapors will accumulate readily and may ignite explosively.

During use and until all vapors are gone, keep area ventilated. Do not smoke. Extinguish all flames, pilot lights, and heaters. Turn off stoves, electric tools and appliances, and any other sources of ignition.

Consult NFPA Code. Use approved Bonding and Grounding procedures.

Contents under pressure. Do not puncture, incinerate, or expose to temperature above 120°F. Keep from sunlight, radiators, stoves, hot water, and other heat sources. Do not cause container to burst. Do not take internally. Keep out of the reach of children.

OTHER PRECAUTIONS

Intentional abuse by deliberately concentrating and inhaling the contents can be harmful or fatal.

Section X -- PERCENT HAZARDOUS INGREDIENTS

	-0936	-0951	0969	0977
Propane (Propellant)	15	15	15	15
2-Methylpropane (Propellant)	—	—	15	—
1,4-Aliphatic Hydrocarbon Solvent	<5	<5	—	—
V. M. & P. Naphtha	<5	<5	—	—
Dichloromethane	15	20	25	20
Toluene	<5	<5	10	—
Xylene	<5	<5	—	—
Methanol	<5	—	—	—
Ethanol	—	<5	—	—
2-Propanol	<5	—	—	—
2-Butanol	<5	<5	—	<5
2-Butoxyethanol	—	<5	—	—
Acetone	25	20	10	20
Methyl Ethyl Ketone	15	15	—	10
Isobutyl Acetate	<5	<5	—	<5
Ethyl Methacrylate	<5	<5	<5	<5

This Material Safety Data Sheet conforms to the Hazard Communication standard,

29 CFR 1910.1200(g)(4) for similar complex mixtures.

The above information pertains to this product as currently formulated, and is based on the information available at this time. Addition of reducers or other additives to this product may substantially alter the composition and hazards of the product. Since conditions of use are outside our control, we make no warranties, express or implied, and assume no liability in connection with any use of this information.

Rec'd
8-8-88

MATERIAL SAFETY DATA SHEET

REVISED: 01/15/88

SECTION I	PRODUCT IDENTIFICATION
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MANUFACTURER'S NAME :	ALUCOBOND TECHNOLOGIES, INC.
ADDRESS :	P.O. BOX 507
CITY/STATE :	BENTON, KENTUCKY 42025
EMERGENCY CONTACT :	JAMES BURR
PHONE NUMBER :	(502) 527-1370
TRADE NAME :	SINTRA 12.700
SYNONYM :	EXPANDED PVC SHEET, POLYVINYL CHLORIDE SHEET

SECTION II	HAZARDOUS INGREDIENTS
------------	-----------------------

INGREDIENTS	PERCENT BY WT.	OCCUPATIONAL EXPOSURE LIMITS TLV-TWA
POLYVINYL CHLORIDE	98%	CONTAINS < 5PPM VINYL CHLORIDE MONOMER WHOSE LIMITS ARE 10MG/CUBIC METER.
ANTIMONY TRIOXIDE	< 2%	0.5MG/CUBIC METER (ACGIH)
LEAD	< .2%	0.15MG/CUBIC METER (ACGIH)

SECTION III	PHYSICAL DATA
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APPEARANCE. ODORLESS, PLASTIC SHEET

SPECIFIC GRAVITY (H₂O = 1) : 0.7G/CC

SOLUBILITY IN WATER: INSOLUBLE

SECTION IV

FIRE AND EXPLOSION DATA

FLASH POINT: > 700 DEGREES FAHRENHEIT (ASTM D 1929)

MINIMUM AUTOIGNITION TEMPERATURE: N/A

EXTINGUISHING METHOD: CO₂, DRY CHEMICAL, WATER SPRAY AS A COOLING METHOD

UNUSUAL FIRE AND EXPLOSION HAZARDS: PVC WILL BURN IN THE PRESENCE OF OTHER MATERIALS WHICH SUPPORT COMBUSTION AND WILL EMIT HYDROGEN CHLORIDE GAS, CARBON MONOXIDE AND CARBON DIOXIDE.

SPECIAL FIRE FIGHTING PROCEDURES: SELF-CONTAINED BREATHING APPARATUS SHOULD BE WORN.

SECTION V

HEALTH HAZARD INFORMATION

EFFECTS OF OVEREXPOSURE:

ACUTE: PHYSICAL IRRITATION OF THE EYES MAY RESULT FROM EXPOSURE TO HIGH CONCENTRATIONS OF PVC DUST DURING CERTAIN FABRICATION OPERATIONS. REPEATED OVEREXPOSURE TO ANTIMONY TRIOXIDE MAY CAUSE COUGHING, DIZZINESS, HEADACHES, DIARRHEA AND CRAMPS

CHRONIC: REPEATED LONG-TERM INHALATION AND INGESTION OF ANTIMONY TRIOXIDE MAY CAUSE CARDIAC PROBLEMS.

SPECIAL PRECAUTIONS: AVOID PROLONGED INHALATION OF HIGH DUST CONCENTRATIONS AND INGESTION OF THE MATERIAL. WASH HANDS BEFORE EATING, DRINKING OR SMOKING. WEAR PROPER EYE AND RESPIRATORY PROTECTION WHEN WORKING IN AREAS OF HIGH DUST CONCENTRATIONS. CARE SHOULD BE TAKEN DURING THERMOFORMING OPERATIONS WHEN TEMPERATURES EXCEED 350 DEGREES FAHRENHEIT. DECOMPOSITION OF THE MATERIAL MAY OCCUR. HYDROGEN CHLORIDE GASES MAY BE EMITTED DURING DECOMPOSITION AND FROM DIRECT EXPOSURE TO FLAME. DIRECT EXPOSURE TO FLAME MAY ALSO EMIT LEAD OR ANTIMONY.

EMERGENCY AND FIRST AID PROCEDURES: IF CONTACT WITH SKIN OR EYES, WASH IMMEDIATELY UNDER WATER FOR AT LEAST 15 MINUTES. FOR INHALATION EXPOSURE, REMOVE TO FRESH AIR. CONTACT PHYSICIAN.

SECTION VI

REACTIVITY DATA

STABILITY: STABLE

HAZARDOUS DECOMPOSITION PRODUCTS: HYDROGEN CHLORIDE GAS MAY BE EMITTED FROM DIRECT EXPOSURE TO FLAME AND DURING DECOMPOSITION.

INCOMPATIBILITY: AVOID STORING WITH COMBUSTIBLE MATERIALS.

SECTION VII

SPILL OR LEAK DATA

WASTE DISPOSAL: DISPOSE OF IN COMPLIANCE WITH LOCAL REGULATIONS

HANDLING AND STORAGE PRECAUTIONS: SEE ABOVE STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED. MONITORING SHOULD BE PERFORMED IF MATERIAL IS HEATED, FOR PROTECTION AGAINST HYDROGEN CHLORIDE GAS AND OTHER COMPONENTS.

SECTION VIII

SPECIAL PROTECTION INFORMATION

PERSONAL PROTECTIVE EQUIPMENT:

RESPIRATORY: AN OSHA APPROVED RESPIRATOR MUST BE USED WHEN ENGINEERING CONTROLS CANNOT BE IMPLEMENTED. WHERE ENGINEERING CONTROLS CANNOT BE IMPLEMENTED, THE MINIMUM PROTECTION FOR LOW DUST LEVELS IS 1/2 MASK RESPIRATOR. FOR THERMOFORMING OPERATIONS USE AN AIR-PURIFYING CANISTER

EYE: EYE PROTECTION MUST BE WORN WHEN WORKING IN DUST CONCENTRATIONS AND DURING SAWING OR OTHER OPERATIONS WHICH MIGHT CAUSE FLYING CHIPS.

VENTILATION: LOCAL EXHAUST

PROTECTIVE GLOVES: STANDARD PROTECTIVE GLOVES SHOULD BE WORN TO AVOID SKIN IRRITATION.

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing,
Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME HANDY & HARTMAN		EMERGENCY TELEPHONE NO. (212) 752-3400
ADDRESS (Number, Street, City, State, and ZIP Code) 850 Third Avenue, New York, NY 10022		
CHEMICAL NAME AND SYNONYMS Silver-Copper-Phosphorus Alloy		TRADE NAME AND SYNONYMS Sil Fos (AWS B CuP-5)
CHEMICAL FAMILY Brazing Filler Metal	FORMULA 15% Silver, 80% Copper, 5% Phosphorus	

SECTION II - HAZARDOUS INGREDIENTS

Filler Metal & Flux Components	CAS#	%	ACGIH** TLV-TWA	Decomposition Products	CAS#	% Max	ACGIH* TLV-TWA
Silver (Ag)	7740-22-4	15	N.A.	Silver Metal Fume (Ag)	7740-22-4	15	0.1 mg/
Copper (Cu)	7740-50-8	80	N.A.	Copper Fume (Cu)	7740-50-8	80	0.2 "
Phosphorus (P)	7723-14-0	5	N.A.	Phos Pentoxide (P ₂ O ₅)	1314-56-3	5.	N.A.

- * Thought should also be given to the filler metal and base metals being joined and to possible base metal coating which could emit fumes on heating, depending on their particular chemistry.
- ** Approximate milligrams of substance per cubic meter of air or parts per million-Time weighted average per workday. (See ANSI/AWS F1.1 for sampling and testing methods)
- *** C Denotes "Ceiling Limit" = not to be exceeded at any time.

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	N.A.	SPECIFIC GRAVITY (H ₂ O=1)	8.44
VAPOR PRESSURE (mm Hg.)	N.A.	PERCENT VOLATILE BY VOLUME (%)	N.A.
VAPOR DENSITY (AIR=1)	N.A.	EVAPORATION RATE (_____ =1)	N.A.
SOLUBILITY IN WATER	N.A.		
APPEARANCE AND ODOR	Metallic - rod, wire, strip, powder		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	N.A.	FLAMMABLE LIMITS	Lel	Uel
		N.A.		
EXTINGUISHING MEDIA	N.A.			
SPECIAL FIRE FIGHTING PROCEDURES	N.A.			
UNUSUAL FIRE AND EXPLOSION HAZARDS	N.A.			

SECTION V - HEALTH HAZARD DATA			
THRESHOLD LIMIT VALUES:		0.2 mg/m ³ Cu fume ; 0.1 mg/m ³ Ag metal	
MAJOR EXPOSURE HAZARD - INHALATION			
CUMULATIVE LIMITS: Welding (Brazing) Fumes - Total Particulate ($C_1 + C_2 + \dots + C_N$) ≤ 5 mg/m ³ ; (C=Concentration: T=TLV) $C_1/T_1 + C_2/T_2 + \dots + C_N/T_N \leq 1$; See Section IX			
EFFECTS OF OVEREXPOSURE: Remove victim from contaminated area. Administer oxygen. Call doctor. Give artificial respiratory if breathing has stopped (See Footnote)			
EMERGENCY & FIRST AID PROCEDURE: Remove victim from contaminated area. Administer oxygen. Call doctor. Give artificial respiration if breathing has stopped. See Footnote.			
SECTION VI - REACTIVITY DATA			
STABILITY:	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	Stable at room temperature
INCOMPATIBILITY:			
N.A.			
HAZARDOUS DECOMPOSITION PRODUCTS: Copper & phosphate fumes may be evolved during brazing. Copper-phosphate slag is formed but this is not a hazard.			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	N.A.
SECTION VII - SPILL OR LEAK PROCEDURES			
STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED, OR SPILLED:			
N.A.			
WASTE DISPOSAL METHOD:			
N.A.			
SECTION VIII - SPECIAL PROTECTION INFORMATION			
RESPIRATORY PROTECTION: None for brazing in properly ventilated area. In confined space use an airline respirator or hose mask, NIOSH, U.S. Bureau of Mines approved hose Type C or self-contained air respirator.			
VENTILATION: (For fumes & gases.)	LOCAL EXHAUST: Air flow to produce velocity of 100 lineal Ft./Min. in brazing zone.		
	MECHANICAL: 2,000 cu. ft./min/brazer (see footnote).		
	NATURAL (MIN): 10,000 cu. ft./brazer - 16 ft. ceiling - No obstructions.		
PROTECTIVE GLOVES: Leather welding gloves.		EYE PROTECTION: Plastic frame safety spectacle with side shields - filter lenses shade #3 or 4	
OTHER PROTECTIVE EQUIPMENT: Normal clothing for torch brazing. (Avoid flammable fabrics.)			
SECTION IX - SPECIAL PRECAUTIONS			
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Avoid heating above recommended brazing temperature range (1300-1500°F) as excessive fumes may result.			
OTHER PRECAUTIONS: This filler metal may be used with a separately applied fluoride flux which when heated gives off fumes that can irritate eyes, nose and throat. Avoid fumes. (TLV = 2.5 mg/m ³) Use only in well ventilated spaces. Avoid contact of flux with eyes or skin. Do not take flux internally. (See Footnote)			
FOOTNOTE: Refer to "Dangerous Properties of Industrial Materials" by N. Irving Sax, and AWS Standard Z49.1 - Safety in Welding and Cutting", published by the American Welding Society, P.O. Box 351040, Miami Fl 33135			

10/2/84

10/01/85

ALL-STATE WELDING PRODUCTS DIVISION

MATERIAL SAFETY DATA SHEET
FILLER METALS AND WELDING RODS

(Approved by U.S. Department of Labor "Essentially Similar" to Form OSHA 20)

SECTION I	
Manufacturer's Name: ALL-STATE WELDING PRODUCTS DIVISION	Emergency Telephone No. 800-638-1647 717-637-8911
Address: (Number, Street, City, State and Zip Code) P. O. Box 600, 5112 Allendale Lane, Taneytown, MD 21787	
Trade Name: ALL-STATE #509 Solder	

SECTION II - HAZARDOUS INGREDIENTS					
Covering or Flux	WT %	TLV (Units) Mg/M3	Other CAS NO.	WT %	TLV (Units) Mg/M3
			Zinc 1314-13-2	17.5	5.0
			Cadmium 1306-19-0	82.5	C 0.05

SECTION III - PHYSICAL DATA
NOT APPLICABLE

SECTION IV - FIRE AND EXPLOSION HAZARD DATA
NOT APPLICABLE

SECTION V - HEALTH HAZARD DATA

Effects of Overexposure: Faintness, possible nausea, short term. Long term may affect pulmonary function and/or may cause metal fume fever.

Emergency & First Aid Procedures: Remove to fresh air, call physician

Carcinogenicity: NTP -Yes; IARC -Yes; OSHA -No.

SECTION VI - REACTIVITY DATA

Stability	Unstable		Conditions to Avoid
	Stable	X	

Incompatibility (Materials to Avoid): NONE

Hazardous Decomposition Products: Overheating will produce zinc and cadmium fumes.

See AWS handbook Section I page 9.24-9.30

Hazardous Polymerization: NOT APPLICABLE

SECTION VII - SPILL OR LEAK PROCEDURES

NOT APPLICABLE

SECTION VIII - SPECIAL PROTECTION INFORMATION (See Note)

Respiratory Protection (specify type) Weld Fume Respirator or Airline Respirator for confined space or where exposures are above TLV.

Ventilation:

Local Exhaust: Yes, in confined spaces

Mechanical (general): Yes, where exposures exceed TLV

Eye Protection: Colored Adsorptive Lens No. 4 to 6

Protective Gloves: Welder's Protective Gloves

Other Protective Equipment: Protective Clothing - Leather Apron

SECTION IX - SPECIAL PRECAUTIONS (See Note)

Other Precautions: Arc & Sparks could be source of ignition of combustible products.

NOTE: Reference is directed, without endorsement or recommendation, to the ANSI Standard Safety in Welding & Cutting Z49.1-1973 (American Welding Society Publication Z49.1-1973).

MARMON / KEYSTONE CORPORATION

THE PIPE AND TUBING PEOPLE

P.O. Box 992, Butler, PA 16001
EMERGENCY PHONE NUMBER (412) 283-3000

ISSUE DATE
JANUARY 1, 1989

MATERIAL SAFETY DATA SHEET

TRADE NAME (Common Name or Synonym)

Stainless Steels

CHEMICAL NAME

AISI/SAE Grades 300 Series, 400 Series, Special Alloys

I. INGREDIENTS

Material or Component	CAS Number	% Weight	EXPOSURE LIMITS	
			OSHA PEL (mg/m ³)	ACGIH TLV (mg/m ³)
Base Metal				
Iron (Fe)	7439-89-6	38.0-86.5	10 Oxide Fume	5 Oxide Fume
Alloying Elements				
Aluminum (Al)	7429-90-5	< 0.1-0.5	Not Established	10 Dust/5 Fume
Carbon (C)	7440-44-0	< 0.3-2.0	Not Established	Not Established
Chromium (Cr)	7440-47-3	< 10-27	1.0 Chrome Metal	0.5 Chrome Metal
Cobalt (Co)	7440-48-4	< 0.1-75	0.1 Cobalt Metal	0.05 Cobalt Fume
Copper (Cu)	7440-50-8	< 1.8-4.5	0.1 Fume/1.0 Dust	0.2 Fume/1.0 Dust
Manganese (Mn)	7439-96-5	< 2-10	5c Dust/5c Fume	5c Dust/1 Fume
Molybdenum (Mo)	7439-98-7	< 0.4-5	15 Insoluble Compounds	10 Insoluble Compour.
Nickel (Ni)	7440-02-0	< 12-34	1 Nickel Metal	1 Nickel Metal
Phosphorous (P)	7723-14-0	< 0.1-0.6	0.1 Phosphorous	0.1 Phosphorous
Selenium (Se)	7782-49-2	< 0.1-0.3	0.2 Se Metal	0.2 Se Metal
Silicon (Si)	7440-21-3	< 15-2.0	Not Established	10 Total Dust
Sulfur (S)	7704-34-9	< 0.1-0.6	13 Sulfur Dioxide	5 Sulfur Dioxide
Titanium (Ti)	7440-32-6	< 0.1-0.70	15 Ti Dioxide	15 Ti Dioxide
Columbium } (Cb + Ta)	7440-03-1	< 0.1-1.10	Not Established	Not Established
Tantalum }	7440-25-7		5.0 Ta Metal	5.0 Ta Metal
Note: The above listing is a summary of elements used in alloying stainless steels. Various grades of stainless steel will contain different combinations of these elements. Trace elements may also be present in minute amounts. No permissible exposure limits (PEL) or thresholds limit values (TLV) exist for stainless steel. Values shown are applicable to component elements.				

II. PHYSICAL DATA

MATERIAL IS (At Normal Conditions) ☐ LIQUID ☒ SOLID ☐ GAS ☐ OTHER		APPEARANCE AND ODOR Silvery-Grey, Odorless	% VOLATILE BY VOLUME N/A	VAPOR DENSITY N/A
ACIDITY/ALKALINITY pH = N/A	Melting Point Approx. 2400-2800 °F Boiling Point N/A °F	Specific Gravity (H ₂ O = 1) Approx. 8 Solubility in water (% by weight) N/A	VAPOR PRESSURE (mm Hg at 20°C) N/A	

III. PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY PROTECTION: Appropriate dust/mist/fume respirator should be used to avoid excessive inhalation of particulates. If exposure limits are reached or exceeded, use NIOSH approved equipment.	HANDS, ARMS AND BODY: Protective gloves should be worn as required for welding, burning or handling operations.
EYES AND FACE: Safety glasses should be worn when grinding or cutting. Face shields should be worn when welding or cutting.	OTHER CLOTHING AND EQUIPMENT: As required depending on operations and safety codes.

IV. EMERGENCY MEDICAL PROCEDURES

INHALATION	Remove to fresh air. If condition continues, consult a physician.
EYE CONTACT	Flush thoroughly with running water to remove particulate, obtain medical attention.
SKIN CONTACT	Remove particles by washing thoroughly with soap and water. Seek medical attention if condition persists.
INGESTION	If significant amounts of metal are ingested, consult physician.

V. HEALTH/SAFETY INFORMATION

Health	Stainless steel products in their solid state present no inhalation, ingestion, or contact health hazard. Operations such as burning, welding, sawing, brazing, grinding, and machining, which result in elevating the temperature of the product to, or above its melting point, or result in the generation of airborne particulates may present hazards. The major exposure hazard is inhalation. Effects of overexposure to fume and dust are as follows. ACUTE: Excessive inhalation of metallic fumes and dust may result in irritation of eyes, nose and throat. High concentrations of fumes and dusts of iron-oxide, manganese, copper, zinc and lead may result in metal fume fever. Typical symptoms last from 12 to 48 hours and consist of a metallic taste in the mouth, dryness and irritation of the throat, chills and fever. CHRONIC: Chronic and prolonged inhalation of high concentrations of fumes or dust of the following elements may lead to the conditions listed opposite the element: Aluminum: Irritation of the eyes, nose and throat. Chromium: Lesions of the skin and mucous membranes, possibly cancer of the nose or lungs-bronchogenic carcinoma Cobalt: Respiratory tract irritation, skin rash Copper: Irritation of the eyes, nose and throat, metal fume fever Iron: Pulmonary effects, siderosis Manganese: Bronchitis, pneumonitis, lack of coordination Molybdenum: Respiratory tract irritation, possible liver and kidney damage, bone deformity Nickel: Lesions of the skin and mucous membranes, possibly cancer of the nose or lungs-bronchogenic carcinoma Phosphorous: Necrosis of the mandible Selenium: Nasal and bronchial irritation, gastrointestinal disturbances, garlic breath odor Sulfur: (As sulfur dioxide) Edema of the lungs Titanium: No chronic debilitating symptoms indicated Cloumbian/Tantalum: No chronic debilitating symptoms indicated MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Individuals with chronic respiratory disorders (i.e., asthma, chronic bronchitis, emphysema, etc) may be adversely affected by any fume or airborne particulate matter exposure. OCCUPATIONAL EXPOSURE LIMITS: See Products Ingredients Section I. Chromium and Nickel have been identified by the International Agency for Research on Cancer (IARC) and/or the National Toxicology Program (NTP) as potential cancer causing agents.					
Fire and Explosion	FLASH POINT N/A °F		AUTO IGNITION TEMPERATURE N/A		FLAMMABLE LIMITS IN AIR Lower N/A % Upper N/A %	EXTINGUISHING MEDIA Does not present fire or explosion hazards under normal conditions. Use dry powder or sand on molten metal.
	FIRE AND EXPLOSION HAZARDS Stainless tubular products do not present fire or explosion hazards under normal conditions. Fine metal particles such as produced in grinding or sawing can burn. High concentrations of metallic fines in the air may present an explosion hazard.					EXTINGUISHING MEDIA NOT TO BE USED Do not use water on molten metal or fires caused by fine metal particles.
Reactivity	STABILITY ■ Stable □ Unstable		INCOMPATIBILITY (MATERIALS TO AVOID) Reacts with strong acids to form hydrogen gas.			
	CONDITIONS TO AVOID: Stainless steel at temperatures above the melting point may liberate fumes containing oxides of iron and alloying elements.					
	HAZARDOUS DECOMPOSITION PRODUCTS: Metallic dust or fumes may be produced during welding, burning, grinding and possibly machining. Refer to ANSI Z49.1					

VI. ENVIRONMENTAL

SPILL OR LEAK PROCEDURES

Fine turnings and small chips should be swept or vacuumed. Scrap metal can be reclaimed for reuse.

WASTE DISPOSAL METHOD*

Used or unused product should be disposed of in accordance with Federal, State or Local Laws and Regulations.

*Disposer must comply with Federal, State and Local disposal or discharge laws.

VII. ADDITIONAL INFORMATION

In welding, precautions should be taken for airborne contaminants which may originate from components of the welding rod.

Arc or spark generated when welding or burning could be a source of ignition for combustion and flammable materials.

DISCLAIMER

The information in this MSDS was obtained from sources which we believe are reliable; however, the information is provided without any representation or warranty, express or implied, regarding the accuracy or correctness.

The conditions or methods of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage, or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.



MATERIAL SAFETY DATA SHEET

EASTMAN CHEMICAL PRODUCTS, INC.
Kingsport, Tennessee 37662

For Health Hazard Information, call: (615) 229-6094, 8am-5pm (Eastern), Mon.-Fri.
(615) 229-4374 at all other times

For other information, call: (615) 229-4373 Date of Preparation: 01-16-85

Approved by U. S. Department of Labor: Essentially Similar to OSHA-20

SECTION I. IDENTIFICATION

- Product Name: Uvex® Plastic Sheet
- Formula: Mixture

SECTION II. PRODUCT AND COMPONENT HAZARD DATA

A. COMPONENTS:	Approx Percent	TLV	CAS Reg. No.
Cellulose acetate butyrate	80-95	-	9004-36-8
Plasticizer	1-16*	-	--
Processing aids/stabilizers	<5	-	--

*Varies depending upon flow requirements.

B. PRECAUTIONARY LABEL STATEMENTS:

If burned by contact with molten material, cool as quickly as possible with water and see a physician for treatment of burn.

Note to Physicians. Burns should be treated as thermal burns. Product is a polymer of low toxicity; therefore, there is no urgent need to remove it from the skin because of concern about toxicity.

SECTION III. PHYSICAL DATA

- Appearance and Odor: Sh...ting from 0.040-0.250 in thick; faint characteristic odor.
- Boiling Point: Not applicable.
- Specific Gravity (H₂O = 1): 1.20
- Vapor Pressure: Not applicable (nonvolatile).
- Percent Volatile by Volume: Not applicable.
- Vapor Density (Air = 1): Not applicable.
- Evaporation Rate (= 1): Not applicable.
- Solubility in Water: Negligible.

MSDS-10,657A-1 (01-85)
Replaces MSDS-4500

ION IV. FIRE AND EXPLOSION HAZARD DATA

- Flash Point: Not applicable (nonvolatile). Combustible
- Autoignition Temperature: 455°C (150°F); method used: ASTM D 2155
 - Flammable Limits: Not applicable.
 - Extinguishing Agent: Water Spray, Dry Chemical, CO₂, or Foam.
 - Special Fire-Fighting Procedures: Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes.
 - Unusual Fire and Explosion Hazards: None known to Eastman.

SECTION V. REACTIVITY DATA

- Stability: Stable.
- Incompatibility: Oxidizing materials can cause a reaction.
- Hazardous Decomposition Products: As with any other organic material, combustion will produce carbon dioxide and probably carbon monoxide.
- Hazardous Polymerization: Will not occur.

SECTION VI. TOXICITY AND HEALTH

A. EXPOSURE LIMITS

- OSHA Permissible Exposure Limit (PEL): Not established.
- Threshold Limit Value (TLV): Not established.

B. EXPOSURE EFFECTS

Inhalation: No specific hazard known to Eastman.

Eyes: No specific hazard known to Eastman.

Skin: Molten material will produce thermal burns.

C. FIRST AID

Skin: If burned by contact with molten material, cool as quickly as possible with water and see a physician for treatment of burn.

Note to Physicians. Burns should be treated as thermal burns. Product is a polymer of low toxicity; therefore, there is no urgent need to remove it from the skin because of concern about toxicity.

D. ANIMAL TOXICITY DATA

Toxicity data for the major product components are provided.

Cellulose Acetate Butyrate

<u>Test</u>	<u>Species</u>	<u>Result (1)</u>	<u>Toxicity Classification (2)</u>
Acute oral LD ₅₀	Rat	>6400 mg/kg	Practically nontoxic*
Dermal LD ₅₀	Guinea pig	>1000 mg/kg	
Skin irritation	Guinea pig	Slight	
Skin sensitization	Guinea pig	None	

MSDS-10,657A-2 (01-85)
Replaces MSDS-4500

*For maximum level tested.

Feeding Study No. 1: Rats fed diets containing 20% of the compound for 7 days consumed approx 16 g/kg/day with a maximum daily intake of 18.5 g/kg/day. The animals showed no ill effect from this massive dosage. (1)

Feeding Study No. 2: Rats were fed diets containing 1.0% and 5.0% of the compound for 99 days. No biologically significant effects were noted in feed intake, weight gain, clinical signs, hematology, gross pathology, or histopathology. (1)

Feeding Study No. 3: Dogs were fed 50 to 150 g/day of the compound for 4 mo without toxic effect.

In rats, intratracheal injection of cellulose acetate butyrate dust suspended in 0.25 mL of water gave no evidence of specific pulmonary reaction as judged by the histological appearance of the lungs at 10 days and 14 days after injection. (1)

Plasticizer

<u>Test</u>	<u>Species</u>	<u>Result (1)</u>
Acute oral LD ₅₀	Mouse	>12.8 g/kg
Dermal LD ₅₀	Guinea pig	>10 mL/kg
Skin irritation	Guinea pig	Slight
Skin sensitization	Guinea pig	None
Eye irritation	Rabbit	None

*For maximum level tested.

SECTION VII. PERSONAL PROTECTION AND CONTROLS

A. RESPIRATORY PROTECTION

None should be needed.

B. VENTILATION

General: Recommend at least 10 air changes per hour for good general room ventilation.

Local Exhaust: If needed to control vapor/fume from heated material.

C. SKIN AND EYE PROTECTION

Safety glasses should be worn in any type of industrial operation. Gloves should be worn to protect against thermal burns.

D. OTHER CONTROL MEASURES

A safety shower should be available. Good industrial hygiene practice should be followed which includes minimizing skin contact, and minimizing inhalation of fume and degradation products.

SECTION VIII. SPECIAL STORAGE AND HANDLING PRECAUTIONS

No special precautions are known to Eastman.

SECTION IX. SPILL, LEAK, AND DISPOSAL PRACTICES

Steps to be Taken in Case Material is Released or Spilled: Not applicable.

Waste Disposal Method: Incineration. Observe all federal, state, and local laws concerning health and environment.

SECTION X. ENVIRONMENTAL EFFECTS DATA

This product has not been tested for environmental effects.

SECTION XI. TRANSPORTATION

DOT Hazard Classification: Not regulated by DOT.

SECTION XII. REFERENCES

1. Unpublished data, Health and Environment Laboratories, Eastman Kodak Co., Rochester, New York.
 2. H. C. Hodge and J. H. Sterner. Tabulation of toxicity classes. Am. Ind. Hyg. Assoc. Q. 1949; 10:93-96.
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The information contained herein is furnished without warranty of any kind. Users should consider these data only as a supplement to other information gathered by them and must make independent determinations of suitability and completeness of information from all sources to assure proper use and disposal of these materials and the safety and health of employees and customers.

MSDS-10,657A-4 (01-85)
Replaces MSDS-4500

APPENDIX C
MCS OPERATING INSTRUCTIONS

Operation/Specification Summary for Microclimate Cooling System

Source:

Unit was built by Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601, under Contract Number DAAK70-86-C-0122 with Belvoir RD&E Center; Belvoir Procurement Division, FT. Belvoir, VA 22060-5606.

Power Requirements:

Electrical input of 240V, 60HZ, single phase. Peak draw is 7 amps (1KW). Connect supply to black and white wires; green wire is ground.

Operating Instructions:

■ Background

This Microclimate Cooling System is a first-of-a-kind bench test unit. Modifications and improvements are expected to be implemented as a result of increased operating experience. Consequently, parts and supporting structure are designed to be bolted in place to allow easier modification and/or replacement.

■ Charge Cycle:

Set bypass air stream valve to its lowest position. Turn on condenser fans and compressor. In a 75-80°F ambient, unit will pull down in 3 hours and be fully charged in 23 hours. Turn off condenser fans and compressor when done.

Overcharging is not expected to cause system damage. However, sufficient operating experience has not been accumulated under the full range of ambient conditions. If damage occurs, it will most likely be manifested in the form of ruptured PCM canisters.

At the present time, there are no instruments installed that can be used to monitor the degree of canister charging. A pressure gage could be installed at the evaporator inlet for this purpose. Alternatively, several charge and discharge cycles could be run with increasing charge intervals. The unit would be considered fully charged when an increase in the charge interval did not result in an increase in the discharge interval.

Safety circuits have not been installed in the Freon system to prevent operation with a high or low pressure. Pressure switches could be installed at the compressor suction and discharge for this purpose.

Discharge Cycle:

Turn on utility air stream fan. Regulate outlet temperatures by raising or lowering the position of the bypass air stream valve. With a 135°F inlet temperature, unit will deliver 60° air for 10½ hours.