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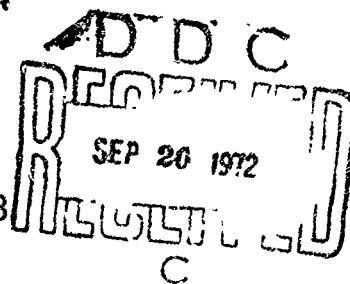
Melting Characteristics and Bulk
Thermophysical Properties of Solid Hydrogen

William Contreras
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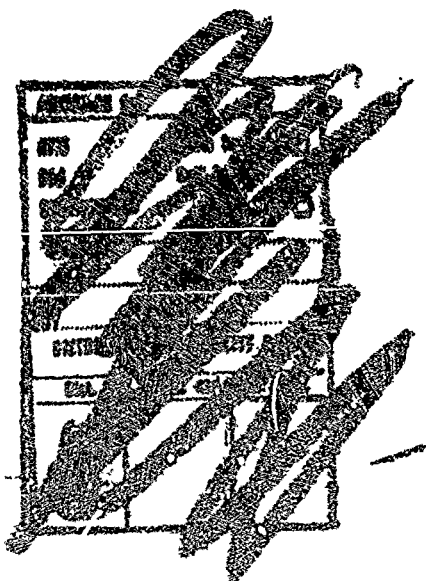
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Technical Report AFRPL-TR-72-48

July 1972

Air Force Rocket Propulsion Laboratories
Directorate of Laboratories
Air Force Systems Command
United States Air Force
Edwards, California

ERRATA

to

Report AFRPL-TR-72-48

"Melting Characteristics and Bulk Thermophysical
Properties of Solid Hydrogen"

Make the following changes:

On page 7, line 4, change, "in Appendix (D).", to, "in Appendix (E)."

On page B-4, add Table B-1 (attached) by removing the gummed backing
and pasting Table B-1 onto page B-4.

On page C-3, third paragraph, first sentence, change, "... are given in
Appendix (A)." to, "... are given in Appendix (B), Figure B-1, and
Appendix (C), Figures C-3 and C-4."

On page E-1, third paragraph, second sentence, change, "... must resort
to a discriticized ..." to, "... must resort to a discretized . .".

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13. ABSTRACT

The experimental determination of the melting characteristics of solid hydrogen has been accomplished. This required the measurements of appropriate thermodynamic parameters, themophysical properties and fluid flow rates required to characterize the melting of solid hydrogen in terms of an overall heat transfer coefficient, operating conditions and initial solid geometry. Correlations for both melting characteristics and thermophysical properties (K, α) are given. It was found that favorable thermophysical properties of solid hydrogen contributed to a relatively fast melting rate. A comparison of the thermal conductivity obtained from the experimental solid with reported measurements for crystals reveals a significant reduction attributed to mechanical imperfections.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Melting Characterisitcs						
Thermophysical Properties						
Thermal Conductivity						
Thermal Diffusivity						
Solid Hydrogen Cryostat						
Gas Superheat						
Liquid Subcool						
Thermal Excursions						
Bulk Solid Hydrogen						

18

AFRPL-TR-72-48

Melting Characteristics and Bulk Thermophysical Properties of Solid Hydrogen

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Grumman Aerospace Corporation

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FOREWORD

This report was prepared at Grumman Aerospace Corporation, Advanced Development Section by William Contreras and Mansuk Lee, under U. S. A. F. Contract No. F04611-71-C-0063. Others who contributed to the study and the preparation of this report were C. R. Hedberg, Noel P. Bannerton, C. Y. Huie, Dr. R. H. Thaler, and Dr. R. S. Thorsen. The contract was initiated under Project No. 3058. The work was administered under the direction of the Air Force Rocket Propulsion Lab., Edwards Air Force Base, with Mr. Peter A. Van Splinter (LKPD) as initial Project Officer, followed by Mr. John E. Branigan (LKCC) as Project Engineer.

This report covers work from July 1971 to May 1972 and was submitted by the authors in May 1972. This is the final report under Contract No. F04611-71-C-0063.

This technical report has been reviewed and is approved.

/S/ John E. Branigan
Project Engineer
AF Rocket Propulsion Laboratory
Edwards Air Force Base

ABSTRACT

The thermal conductivity (K) and the melting characteristics of solid hydrogen (SH_2) were experimentally determined. The thermal diffusivity (α) was derived from the thermal conductivity values. Determination of the solid melting characteristics required the measurement of appropriate thermodynamic parameters and fluid flow rates needed to describe the melting of SH_2 in terms of an overall heat transfer coefficient, operating conditions and initial solid geometry. Correlations were found for melting characteristics and also for thermophysical properties (K, α). Correlation formulas for the melting characteristics were corrected to permit scaling the melting experimental data to rocket tankage situations.

CONTENTS

ILLUSTRATIONS

v

TABLES

SYMBOLS

English

A_o	Initial solid surface exposed to gas.
a_i	Tri-diagonal matrix coefficient.
$b = r_2 - r_1$	Annular thickness of the solid.
b_i	Tri-diagonal matrix coefficient.
C	Specific heat at constant pressure.
$c = \dot{v}/f$	Proportionality constant.
c_i	Tri-diagonal matric coefficient.
c_o	Correction factor.
D	Diameter of the solid hydrogen.
d_i	Factored matrix element.
E_1, E_2, E_3, E_4	Functions
$e = emf$	Voltage output
e_i	Factored matrix element.
F	Function
f	Frequency or function
f_i	Inhomogeneous vector.
G	Function
g_i	Intermediate solution vector.
h	Enthalpy
$\bar{h}$	Time-averaged enthalpy
I	Result of integration
K_i	Thermal conductivity vector.
$L = V/A_o$	Conduction length
L_s	Inital height of the solid proportional to convection length

ℓ	Exponent
M	Total mass integrated with respect to time
m	Exponent
$\dot{m}$	Mass flow rate
N	Total number of intervals or total number of cycles
n	Exponent
P	System pressure
Q	Volumetric flow rate
$\bar{Q}$	Total heat leak
$\dot{Q}$	Heat transfer rate
R	Gas constant or radius
r	Radius
$r = (r - r_1)/b$	Dimensionless radius
T	Temperature
$\bar{T}$	Temperature corresponding to the time-averaged enthalpy
t	Time measured from the reference point
$t*$	Melting period
U	Specific internal energy or overall heat transfer Coefficient
V	Initial solid volume
v	Specific volume
$\dot{v}$	Volumetric flow rate
$Y = \left(\dfrac{M_1}{M_s(0)}\right)$	Ratio of total incoming gas mass to total initial solid mass

Greek Symbol

α	Thermal diffusivity of the solid hydrogen
Δ	Difference
$\delta = r_1/b$	Dimensionless inner radius
δh	Superheat or subcool
θ	Experimentally measured temperature
λ	Latent heat of fusion
λ'	Enthalpy difference combining the latent heat of vaporization and liquid sensible heat
ρ	Density
$\tau = t/b^2$	Scaled time

Subscripts

c	Cooling process
cv	Control volume
corr	Corrected value
g	Gas
h	Heat process
i	Spatial index in the numerical integration, index or inside
j	Time index in the numerical integration, index
LV	Liquid-vapor interface
ℓ	Liquid
o	initial, outside and reference
s	Solid
SL	Solid-Liquid interface
T	Total or tank
1	Incoming fluid or inside radius
2	Outgoing fluid or outside radius

SECTION I

INTRODUCTION

The objective of this program was to determine the thermal and heat transfer characteristics of solid hydrogen (SH_2) in order to obtain melt rates. This required the measurement of the thermophysical properties and melting characteristics of bulk SH_2.

Data describing the melt rates of SH_2 are needed for the engineering design of feed systems for SH_2 rocket propulsion systems. Slow melt rates could critically limit the rapid flow of liquid hydrogen required for boosters and some primary propulsion systems; very high melt rates could make the liquid hydrogen flow uncontrollable.

Theoretical considerations indicate that SH_2 has the large values of thermal diffusivity (α) and thermal conductivity (K) needed to achieve high solid melting rates. The data gathered in this program tend to confirm these indications.

SECTION II

SUMMARY

The results of an analytic and experimental study of the thermophysical properties and melt rates of SH_2 are presented.

The analysis included the following:

- Thermophysical properties: A procedure to determine conductivity and diffusivity was developed

- Melting characteristics: Overall heat and mass balances and thermodynamic parameters were used to investigate melting.

The experimental program consisted of the measurement of appropriate parameters. It included:

- Thermophysical properties: Temperature profiles were measured at different locations inside the solid during cooling and heating

- Melting characteristics: The flow rate of liquid hydrogen (LH_2) resulting from the melting of SH_2 and the condensation of gaseous hydrogen (resulting from its use as a source of heat) was measured, as were other thermodynamic parameters such as pressure and temperature of fluids in and out of the solid hydrogen cryostat.

The values of thermal conductivity and thermal diffusivity were derived from the temperature profiles measured during the thermophysical experiments.

The melting data were organized in accordance with theoretical considerations made evident by the preceding analysis to establish correlations among the initial length of the SH_2, the hot gas to solid mass requirement for adequate flow of LH_2, the pressure level of the system, the superheat of the entering gas and subcooling of the exiting liquid, and an overall heat transfer coefficient.

SECTION III

DISCUSSION - THERMOPHYSICAL PROPERTIES

1. GENERAL

The advantages of storing cryogenic propellants, particularly hydrogen, as a solid have been demonstrated at GAC and elsewhere (1, 2). However, because liquid must be fed to the engine, the advantages of solid storage can be exploited only if the technological difficulties of melting the solid and transferring the resultant liquid upon demand can be overcome.

On the other hand, melting of solid hydrogen, especially when the solid temperature is below its melting point, is heavily dependent upon the solid thermophysical properties, namely thermal diffusivity for the transient heating period and liquid thermal conductivity during the steady melting of the solid. Existing thermal conductivity data both near triple point temperature and below is very scarce. This data has been obtained for very carefully formed solid crystals, free of imperfections. For solid hydrogen formed under nonlaboratory controlled conditions one may expect imperfections such as occlusions and cracks, especially as the solid is cooled down below a certain temperature; resulting hairline cracks act as thermal resistances to the flow of heat throughout the solid. For this kind of bulk solid hydrogen no thermophysical property data exists at present.

Thermal conductivity, a dimensional parameter appearing in the equation of transient heat conduction, is important in heat transfer problems in which conduction dominates; the same is true of the product ρc which also appears in said equation. Furthermore, the ratio of the former to the latter quantities when properties are constant, known as the thermal diffusivity (α) of the material, determines the time scale associated with the material response to temperature distu. ances. Various measurement methods have been developed to determine these properties, each with experimental techniques best suited to particular material characteristics. Common to each method, however, is a computational procedure based on the use of the heat conduction equation, supported by appropriate temperature and heat flux measurements.

Although different procedures are required for determining thermal diffusivity of different materials, there is a general approach to these measurements. For a steady state condition, if thermal conductivity is determined experimentally and specific heat and density are known, diffusivity can be computed. Alternatively, transient methods using the unsteady form of the heat equ. ;ion with constant thermophysical properties can be used to determine diffusivity directly from computations based on measured temperature histories without the need for heat flux measurement. In selecting a suitable method, severe low-temperature solid hydrogen storage restrictions preclude the use of any experimental techniques that require the placement of the SH_2 outside the dewar. Techniques incompatible with the solid hydrogen storage facility (laser point source methods (3, 4), and line source methods (5) are also precluded. All indirect methods based on the determination of

conductivity in steady state experiments require heat flux information. These methods are unacceptable because of the difficulties associated with heat flux measurement, identification, and control. Consequently, only transient methods can be considered compatible with the experimental configuration and the overall restrictions imposed by the low-temperature, low-pressure, storage environment.

Transient measurement schemes may be classified according to the periodic or monotonic nature of the experimental temperature variations and according to whether the material has a constant or temperature-dependent diffusivity. Regardless of the temperature dependence of thermal diffusivity, computations based on a temperature-independent thermal diffusivity may be of value in establishing average diffusivity. Alternatively, if measurements are made over sufficiently small temperature ranges, thermal diffusivity may actually be a weak function of temperature over the range of experimental conditions and therefore may be regarded as a constant. Unfortunately, this is not the case for solid hydrogen.

The non-linearities appearing in the heat equation as a result of the temperature-dependent properties preclude the construction of exact solutions by classical methods. Therefore either numerical or approximate analytical methods must be used. Analytical forms are more convenient to handle; however, numerical schemes are more flexible in treating non-linear properties and general time-dependent boundary conditions. Consequently, an accurate, stable numerical scheme capable of treating both the non-linear property variations and the measured transient boundary conditions was implemented [6].

Analytical solutions corresponding to experimental conditions for the case of constant α may be obtained by a number of methods [7]. For the more complicated case in which α is temperature dependent, this procedure is not applicable because of the difficulties in treating non-linear heat conduction, which must incorporate a diffusivity function of unknown form.

The problem of determining $\alpha(T)$ may be resolved by constructing the complete diffusivity function. This is done by assuming that the diffusivity is constant within small temperature ranges, and performing experimental tests over a series of these small temperature ranges. The validity of this approach [8] shows that α may be assumed constant to the first order within the total inital temperature differences in these tests, if the initial steady condition is one of uniform temperature. Consequently, the complete diffusivity function can be constructed over a wide temperature range using the simple constant techniques which becomes applicable in each step of the construction process. On the other hand, acceptable first order accuracy in regions in which α is a rapidly varying function may require very small temperature differences. In this case, the linearized construction process necessarily consists of an appropriate average of one diffusivity curve based on stepwise heating and a second curve based on stepwise cooling.

To confirm the quasi-linear construction process, the thermophysical property functions may be incorporated in the following variable property heat equation applied across the complete temperature range:

$$\rho(T)c(T) \frac{\partial T}{\partial t} = \nabla \cdot \left[k(T) \nabla T \right]$$

Computed interior solid hydrogen temperatures obtained from the solution to the non-linear equation, together with the constructed diffusivity curve from which we can obtain $K(T)$ may be compared with experimentally monitored hydrogen temperatures. Agreement of the computed and measured temperatures implies the validity of the property data used for the computations over the full temperature range.

Confidence in the accuracy of the numerical scheme was established by computing the transient temperature for conductivities of the form $k = $ constant $*T^n$. Since steady solutions are easily obtained analytically, those were compared with long time transient computer solutions. Three-significant-figure accuracy is obtained with ten interior mesh points.

Part 1 of this method consists of an indirect measurement of α at the discrete points between 10° and $25^\circ R$. This is accomplished by a comparison of an experimentally determined temperature history of solid hydrogen and computed temperatures with boundary and initial conditions corresponding to experimental conditions. The thermophysical property K, necessary to the computational scheme is constructed in a sequence of five (5) preliminary experiments. These preliminary experiments, based on an assymptotic analysis for small temperature perturbations are designed so that the thermal transport process may be described using constant thermophysical properties (evaluated at the initially uniform temperature of the solid in each experiment). In each of these five experiments, the uniform temperature is established by control of the helium flow rate. The solid boundary temperature is then given a small change ($0.2^\circ R$ max.) using the helium flow rate and the dewar jacket pressure control and is continuously recorded until a steady temperature is reached. Three interior test section temperatures are likewise recorded. A comparison of the recorded and computed temperatures immediately leads to a determination of α and K corresponding to the uniform initial temperature. In this manner five values of α and K are obtained between 10 and $25^\circ R$.

Using these constructed values of K as an initial approximation, part 2 of the procedure consists of correcting the initial approximation to $K(T)$, again using a comparison of measured temperatures and computed temperatures. However, the solid is now subjected to a full temperature difference of $15^\circ R$ and in this case a non-linear computational scheme must be used. The functional form of $K(T)$ required to obtain agreement between computed and measured temperatures is then determined to be the actual conductivity. The thermal diffusivity is finally obtained using published ρc data.

The $0.2^\circ R$ temperature change was selected from an estimate of tolerable temperature measurement error assuming a 15% error in α at $10^\circ R$ as shown in appendix (D). From the T.C. calibration curves, $0.2^\circ R$ change corresponds to approximately 2.5 microvolts. The best multi-channel strip chart recorder available for this program records 2 micro-volt/division. Furthermore, because of high amplification factor, the noise level of the recorder is about ± 1 micro-volt which negates its use for this application.

Because of instrumentation difficulties as well as the inability to maintain an inital homogeneous temperature distribution within the solid as prescribed analytically, the above "construction method" was not sucessful. Instead, a revised technique designated as an "inverse" finite difference procedure had to be devised which obviated the need for very small temperature

excursions within the solid as required by the previous technique. The net effect of this new approach is to permit rather large temperature excursions, i.e., $1^\circ R$, which relaxes the high resolution requirements of the instrumentation to be used. This new approach designated as an "inverse" finite difference procedure is an alternate method for the direct determination of the thermal conductivity $K(T)$ of solid hydrogen (SH_2). In this alternate method the measured SH_2 temperature may be considered to be the "output" variable corresponding to a "control" variable $K(T)$. In this case one requires that $K(T)$ be determined so that the difference between the measured temperature and the temperature computed using the heat equation

$$\rho(T) \; C \; (T) \; \frac{\partial T}{\partial t} = \nabla \cdot \left[K(T) \nabla T \right]$$

with boundary conditions

$$T(R_i, \; t) = T_i(t), \; T(R_o, \; t) = T_o(t)$$

and initial condition

$$T(r, 0) = T_0(r)$$

applied to the region occupied by the SH_2 be as small as possible. This criterion may be expressed as the integral condition.

$$I(t) = \int_0^t \left[\Theta(r,t) - T(r,t; K(T)) \right]^2 dt \Rightarrow \text{minimum}$$

where Θ is the measured temperature at the point r and T is the computed temperature at the point r, which depends on $K(T)$.

This integral must be minimized consistent with the heat equation constraint, which requires that admissible functions $T(r,t: K(T))$, must be solutions to the heat equation together with the associated initial and boundary conditions.

Applying procedures from the theory of optimal control, one can justify formally the intuitive result,

$$T(r,t; K(T)) = \Theta(r,t)$$

that is, applying the correct thermal conductivity function $K(T)$ in the computation of $T(r,t; K(T))$ will insure the equality of the measured temperature Θ and the computed temperature T. Consequently, what may be considered an inverse finite difference procedure is obtained if the heat equation is approximated over an interior net (grid) corresponding to actual thermocouple positions. The resulting N simultaneous equations may be used to solve for N functions

$$K(\Theta_i(t)) \quad i = 1,2, \dots N$$

where $\Theta_i(t)$ represents the measured values of the temperature at position i. The parameter t may then be eliminated between $K(\Theta_i(t))$ and $\Theta_i(t)$ to obtain $K(\Theta_i)$. In principle, all the $K(\Theta_i)$ are equivalent; however, due to truncation errors inherent in the finite difference approximation and errors

in measuring and recording θ_i (t), this may not be the case. The final K (T), will therefore be presented as some appropriate mean of all the K (θ_i). The numerical scheme developed for the direct determination of K (T) is shown in Appendix (D).

2. TEST PROCEDURE

a. General

Experiments were performed to investigate the thermophysical properties of solid hydrogen. If the solid is subcooled below its triple point, specific knowledge of the thermal diffusivity and consequently of the thermal conductivity is required to properly predict the solid melting rate; if the solid is at triple point temperature, knowledge of its thermophysical properties is inconsequential.

Solid hydrogen was made using the Grumman owned and designed solid hydrogen cryostat. The procedures followed during assembly and checkout of the overall facility are enumerated step by step in (9). Description of tests are narrated, beginning after the final preparation of the facility has been completed.

Liquid hydrogen is introduced into the cryostat after the system comprising the cryostat and all the gas and liquid transfer lines has been vacuum-pumped down to a pressure level less than 5 microns; chill-down of the system is continued for some time until eventually a desired liquid level inside the H_2 dewar is obtained.

The cryostat is composed of three regions; an inner region where the hydrogen is solidified, a middle region (annular space) which shields the inner region, and an outer region consisting of two annular spaces. The middle region is evacuated and the first annular space of the outer region filled with liquid nitrogen to minimize ambient heat leak to the inner region while the remaining annular space is evacuated in order to minimize environmental heat leak to the liquid nitrogen bath. In addition, LN_2 cooled radiation shields located at the top of the cryostat are used to cut down conductive and radiative heat leak from above into the experiment.

After the desired liquid height has been achieved and the system is in thermal equilibrium, liquid helium is allowed to flow into the LHe heat exchanger, which is submerged in the liquid hydrogen bath. Removal of sensible and latent heat from the liquid hydrogen by means of the liquid helium refrigerant, eventually permits solid to begin forming on the heat exchanger surface. The solidification propagates radially outwards, towards the glass wall of the cryostat, resulting in an annular cylindrical column of solid.

During the freezing process, a constant pressure slightly above atmospheric is maintained in the liquid hydrogen by the continuous addition of gaseous hydrogen. A dip tube provided at the bottom of the cryostat for the draining of melted liquid hydrogen is pressurized with gaseous helium to prevent liquid hydrogen from reaching inside the tube. This liquid, if allowed to fill the dip tube from the bottom up, eventually freezes and plugs the liquid withdrawal flow passage.

Slow cool-down of the liquid until freezing is completed results in all cases in a very transparent and crack-free solid hydrogen; rapid cool-down produces a cryopumping effect which results in a very porous, non-transparent solid.

b. Measurement of Temperature Profiles

The temperature of the solid was varied by adjusting the helium flow rate in the LHe heat exchanger from its freezing point temperature of 24.6 degrees Rankine down to somewhere in the neighborhood of 7.6 degrees Rankine during the cooling excursion. The temperatures were reversed during the heating part of the excursion cycle. The upper temperature limit was dictated by the melting point, the lower limit by the cooling capacity of the heat exchanger which utilizes liquid helium as the heat sink temperature.

The solid was cooled down radially outwards by the LHe heat exchanger; it was heated radially inwards by heating the glass wall of the middle region of the cryostat surrounding the solid. The heat leak was easily controlled by adjusting the residual gas pressure in the annular space between the cryostat inner glass wall and the liquid nitrogen bath wall.

Temperature profiles as a function of time for several specified radial and axial positions were continuously monitored during cooling and heating temperature excursions. To achieve this, three arrays of temperature sensors, each consisting of as many as eight thermocouples, were installed at three different locations. These locations were chosen at three different heights and two angular positions inside the cylindrical shell region of the solid hydrogen. In this way, the uniformity of the temperature profile in the axial direction was checked along with its radial symmetry. In addition, a few precalibrated germanium thermistors were installed near the thermocouples to check the behavior of the thermocouples against those of the thermistors.

Temperature excursions were carried out at slow, moderate and rapid rates. The effect of the cooling or heating rate is noticeable in the crystal structure of the solid; rapid cooling rates tend to crack the solid almost immediately while slow cooling postpone the appearance of these cracks until the temperature of the solid has been lowered substantially below its triple point.

Heating of the solid from liquid helium temperatures to its melting point helps anneal the crack-filled solid and consequently eliminates these cracks and occlusions; fast heating of the solid, causes extremely rapid temperature variations throughout the solid and makes the temperature measurements more difficult and more susceptible to thermocouple time-lag errors.

3. EXPERIMENTAL RESULTS

An inverse finite difference procedure as described in the thermophysical property determination analysis section was used to obviate the need for very small temperature excursions within the solid as required by the previously described "construction" method. Several runs were made in conjunction with this latter technique, but the results were not considered satisfactory because of the magnitude of the instrumentation error in measuring thermal excursions of approximately 0.2°R. This is required for tolerable α error as shown in Appendix (D). The construction technique also required maintaining an initial homogenous temperature distribution within the solid at the start of each termal excursion. This necessitated very fine

experimental techniques not possible with the present cryostat. For these reasons the construction method was abandoned after several experimental attempts.

The inverse finite difference solution of the heat conduction equation was successfully used to determine the thermal conductivity of solid and its functional dependence on temperature. The technique was developed by first using a test case in which an arbitrarily simple temperature profile for the solid was prescribed. The actual temperature profile as measured experimentally, was finally programmed into the solution and results obtained as shown in Tables I, II, and III.

A total of six (6) experimental runs were made, (Tables IV thru IX) of which runs 8, 9 and 13B were selected on the basis of correlating trends. All other runs were discarded. From these runs cooling and heating curves were obtained by approximate straight line fit as shown in Figures 1 and 2.

The experimental bulk solid hydrogen curves obtained in this program have been compared to reported experimental curves [4, 12, 13] for very small, annealed crystals, presumable free of occlusions. We found that two different curves could be obtained from the experimental data, one for cooling and the other for heating. In all cases the values obtained in this program were lower than the existing ones, especially those obtained during the cooling excursion. The presence of hairline cracks observed in the bulk solid hydrogen during cooling helps explain the difference between this and other reported values. From these curves a relationship for the thermal conductivity of solid hydrogen was obtained, one for the cooling of solid hydrogen below its triple point, the other for heating of a solid from a sub-cooled condition to its triple point temperature. The values of thermal diffusivity α were derived from the obtained value of K and from existing ρC vs. T information. The plotted values are shown in Figures 3 and 4.

for cooling
$$K_c = 46.4 \, e^{-0.247T} \tag{1}$$

$$\rho C = 4.544 \times 10^{-5} \, T^{3.516} \qquad 15.0 < T < 24.6°R$$

$$\alpha \equiv \frac{K_c}{\rho C} = 10.21 \times 10^{+5} \, T^{-3.516} \, e^{-0.247T} \tag{2}$$

for heating
$$k_h = 396.0 \, e^{-0.359T} \tag{3}$$

$$\rho C = 4.544 \times 10^{-5} \, T^{3.516} \qquad 10.0 < T < 19.5°k$$

$$\alpha \equiv \frac{K_h}{\rho C} = 87.2 \times 10^{+5} \, T^{-3.516} \, e^{-0.359T} \tag{4}$$

Instrumentation error estimates of about $+8\%$ on the average temperature of the solid represent an approximate $\pm 40\%$ error in the calculated values of the thermal conductivity.
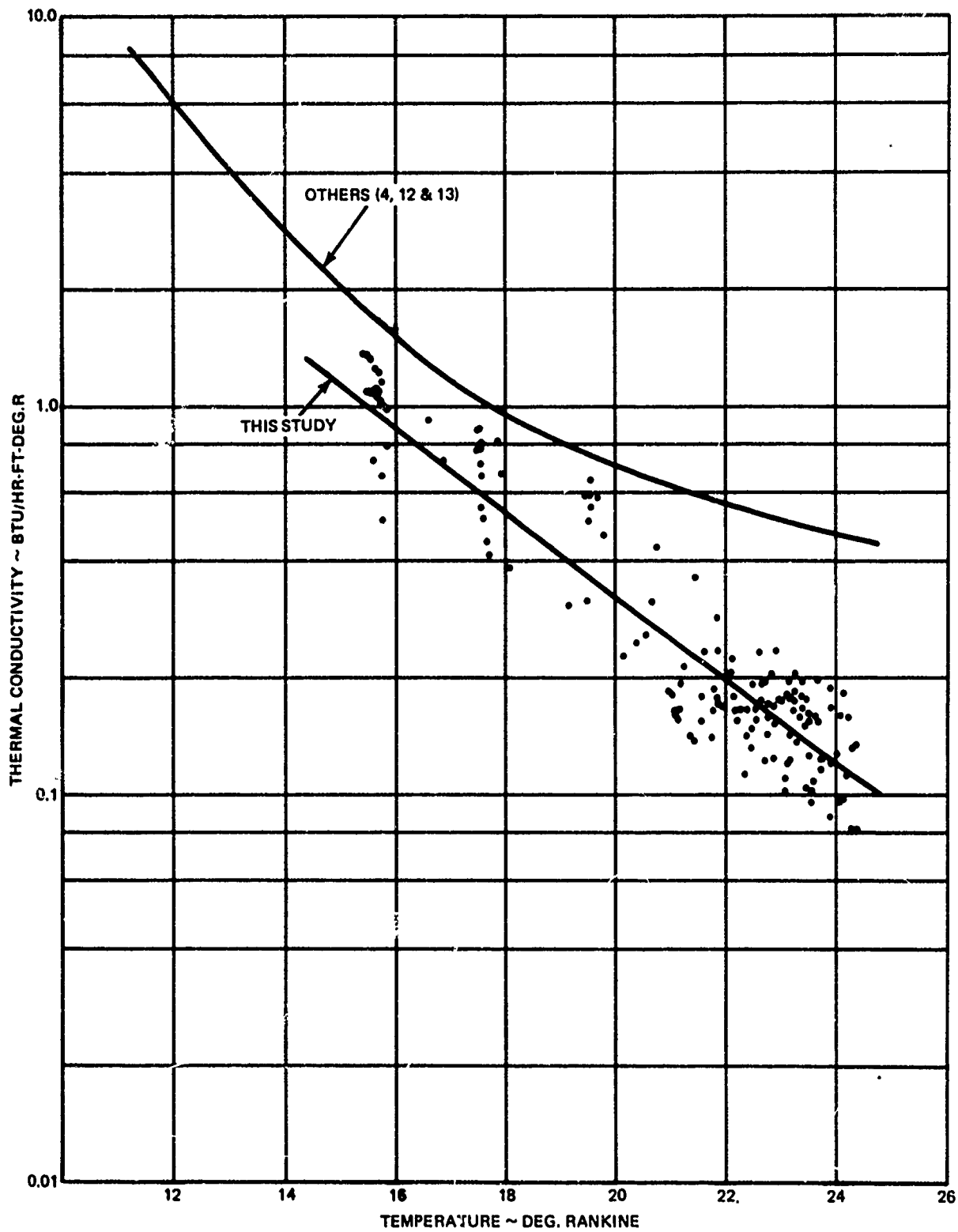
FIG. 1 THERMAL CONDUCTIVITY OF SOLID HYDROGEN (COOLING)
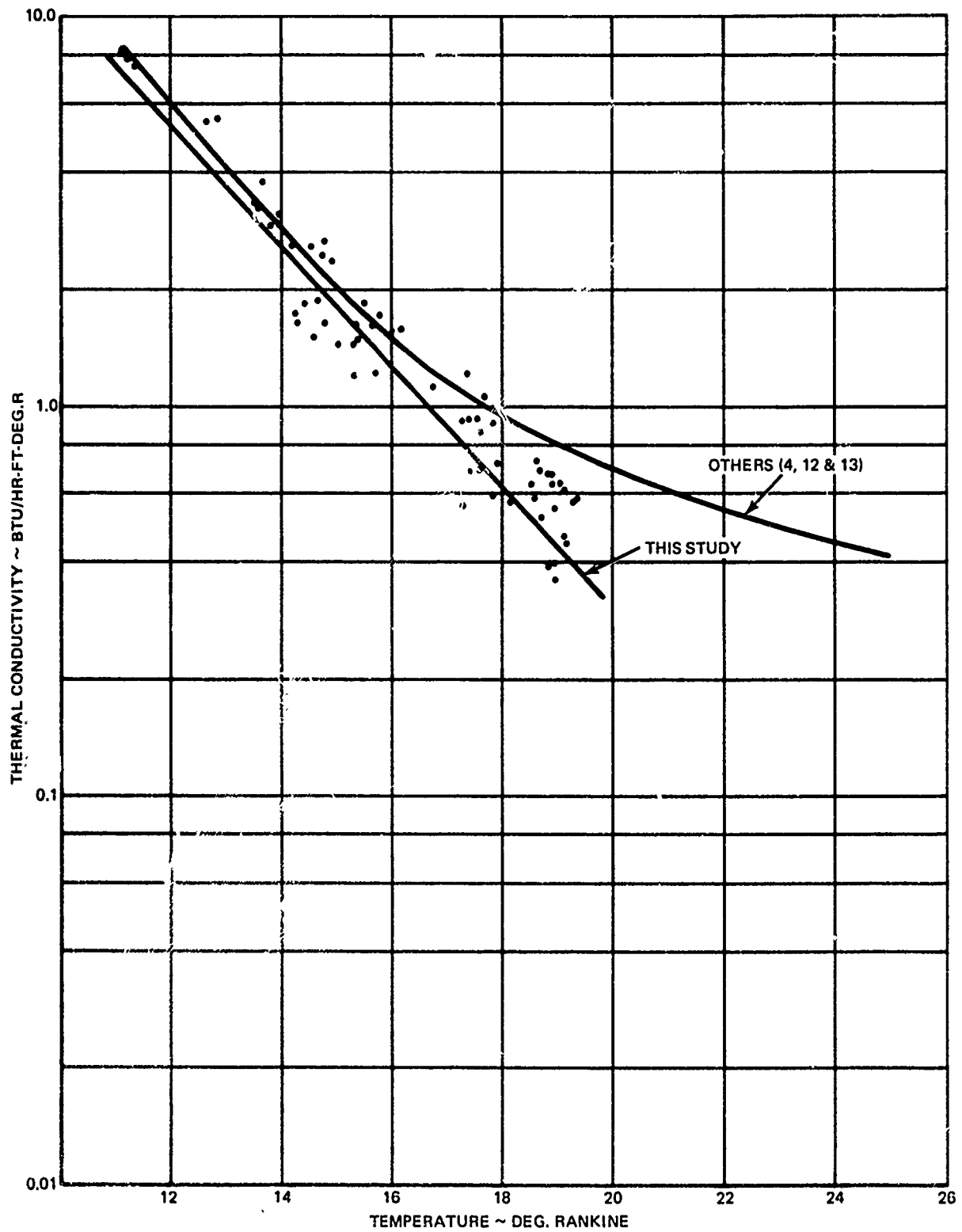
FIG. 2 THERMAL CONDUCTIVITY OF SOLID HYDROGEN (HEATING)

11
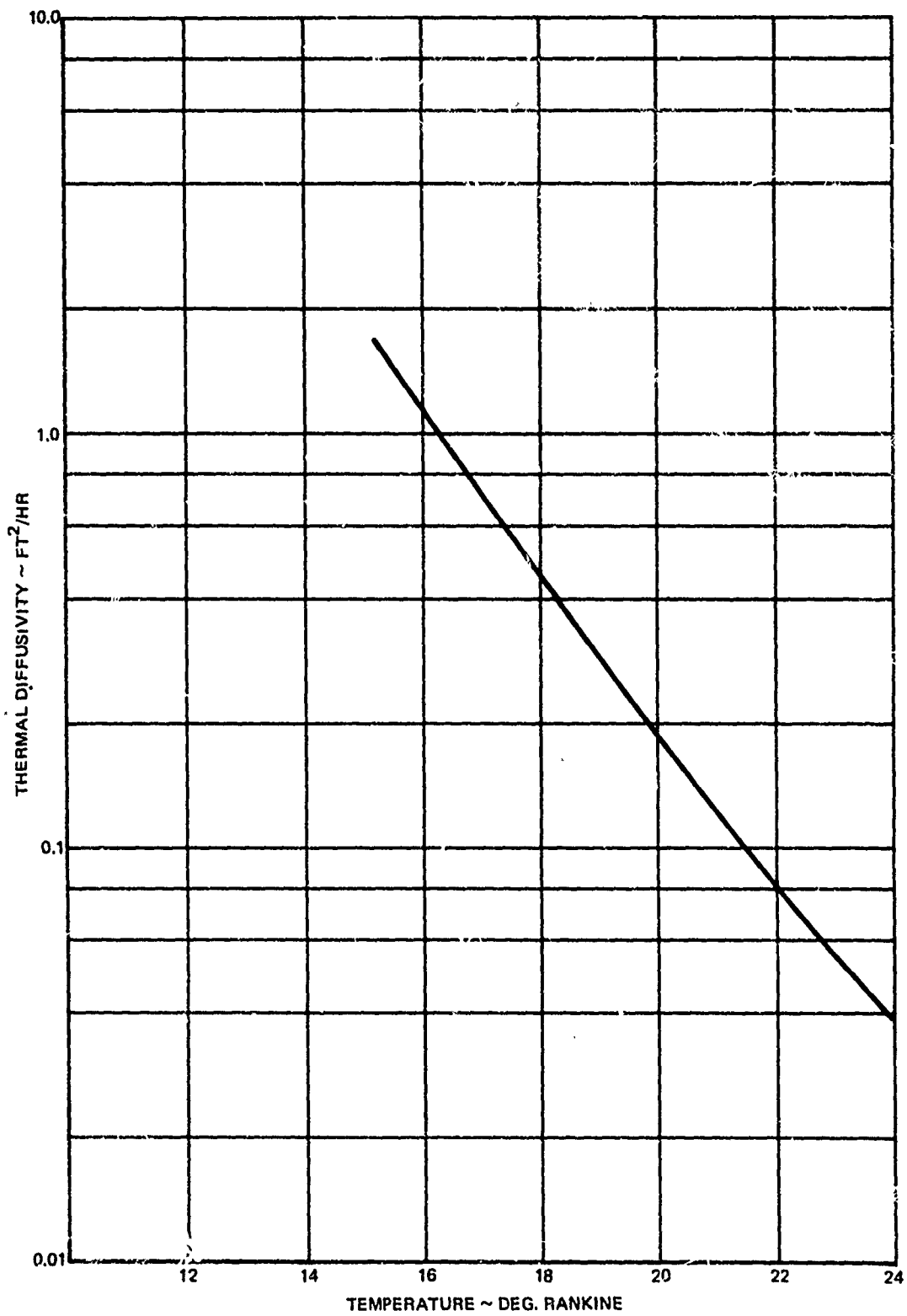
FIG. 3 THERMAL DIFFUSIVITY OF SOLID H_2 (COOLING)
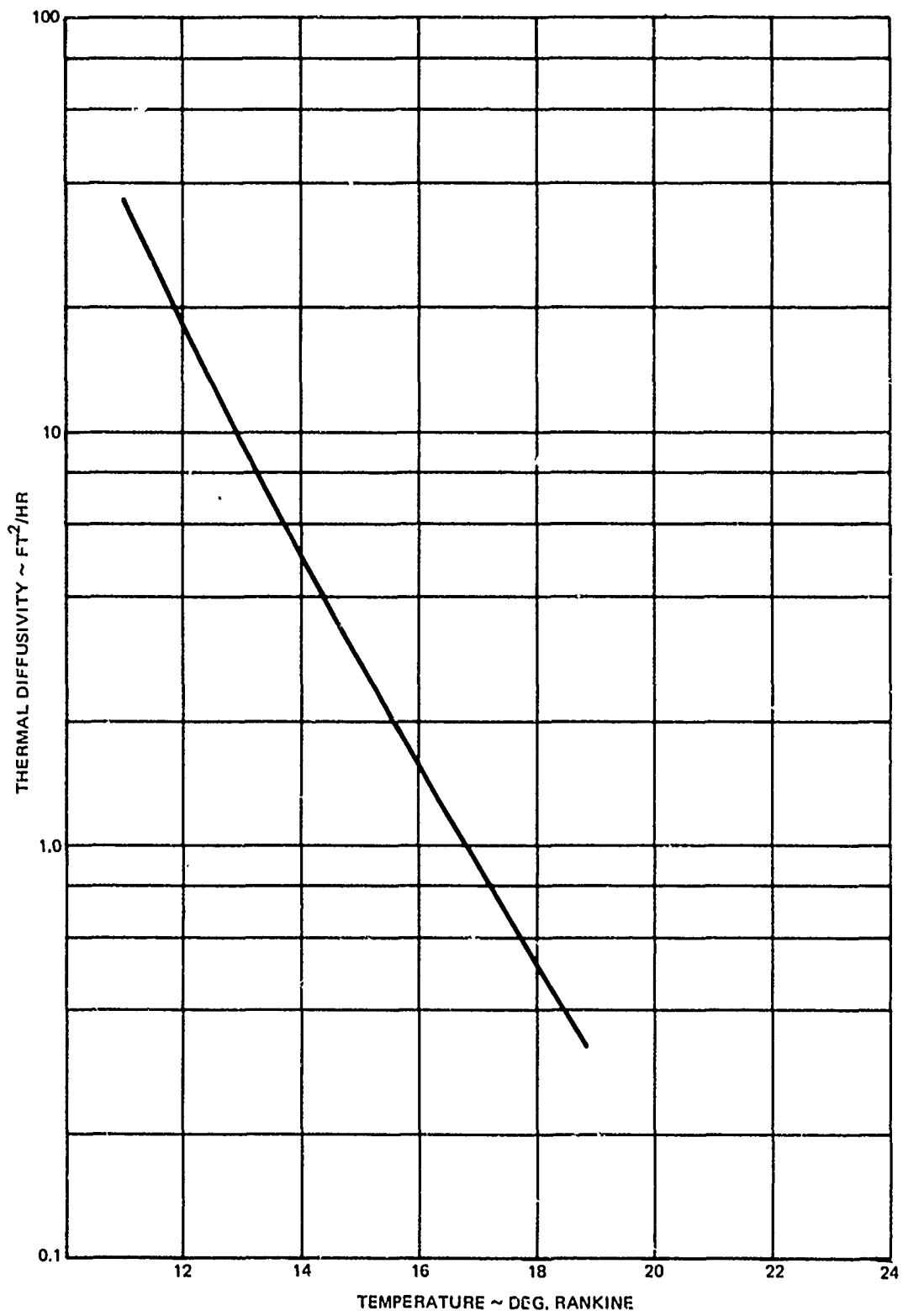
FIG. 4 THERMAL DIFFUSIVITY OF SOLID H_2 (HEATING)

13

TABLE I THERMAL CONDUCTIVITY OF SOLID H$_2$

CALCULATED FROM HEATING/COOLING TEMPERATURE PROFILE

(RUN NO. = 8)

THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)	THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)
Heating		Cooling	
1.217	15.664	0.435	20.775
1.455	15.317	0.361	21.458
1.222	15.076	0.465	19.807
2.379	14.918	0.588	19.661
2.676	14.809	0.319	19.488
2.478	14.717	0.594	19.572
1.883	14.622	0.552	19.389
1.069	17.636	0.645	19.571
1.130	16.771	0.503	19.524
0.582	19.367	0.588	19.454
0.638	18.527		
0.715	17.943		
0.940	17.575		
1.205	17.355		
0.574	19.284		
0.640	19.030		
0.676	18.849		
0.663	18.908		
0.725	18.631		
0.391	18.991		
0.511	18.807		
0.596	18.581		
0.635	19.061		
0.518	18.731		
0.609	19.113		
0.637	18.941		
0.525	18.799		
0.688	18.701		
0.544	18.967		
0.390	18.833		
0.446	19.175		
0.466	19.078		
0.352	18.993		

TABLE II THERMAL CONDUCTIVITY OF SOLID H_2

CALCULATED FROM COOLING TEMPERATURE PROFILE

(RUN NO. = 9)

THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)	THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)
0.726	15.621	.153	21.569
0.725	16.874	.156	22.553
0.805	17.384	.137	23.310
0.081	24.286	.126	23.826
0.081	24.410	.095	24.077
0.307	19.152	0.178	21.562
0.314	20.658	0.192	22.512
0.284	21.943	0.184	23.240
0.133	24.365	0.195	23.727
0.259	20.591	0.189	23.953
0.236	21.855	0.130	22.477
0.236	22.881	0.122	23.196
0.198	23.649	0.125	23.677
0.181	24.136	0.120	23.899
0.133	24.311	0.137	21.452
0.164	21.794	0.141	22.397
0.170	22.812	0.120	23.121
0.154	23.578	0.109	23.601
0.160	24.068	0.113	22.359
0.157	24.253	0.101	23.078
0.140	21.749	0.095	23.559
0.143	22.764	0.101	23.528
0.125	23.527	0.117	23.747
0.127	24.016	0.152	21.365
0.112	24.200	0.165	22.293
0.122	22.680	0.155	23.002
0.102	23.448	0.162	23.473
0.088	23.948	0.154	23.674
0.247	20.394	0.154	21.340
0.231	21.616	0.165	22.257
0.235	22.616	0.157	22.956
0.097	23.380	0.164	23.418
0.169	23.889	0.155	23.616
0.097	24.117		

TABLE II THERMAL CONDUCTIVITY OF SOLID H_2

CALCULATED FROM COOLING TEMPERATURE PROFILE (Cont.)

(RUN NO. = 9)

THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)	THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)
0.143	21.318	0.176	23.200
0.155	22.223	0.163	21.096
0.151	22.911	0.170	21.924
0.158	23.364	0.156	22.547
0.153	23.559	0.159	22.959
0.167	21.295	0.141	23.146
0.179	22.187	0.181	21.051
0.169	22.863	0.179	21.870
0.172	23.309	0.148	22.491
0.161	23.501	0.123	22.906
0.229	20.176	0.182	21.003
0.216	21.257	0.188	21.813
0.224	22.136	0.166	22.431
0.205	22.803	0.154	22.852
0.203	23.245	0.110	23.073
0.177	23.440		
0.195	21.213		
0.207	22.081		
0.191	22.740		
0.196	23.177		
0.177	23.376		
0.165	21.184		
0.179	22.038		
0.175	22.686		
0.180	23.117		
0.173	23.315		
0.163	21.160		
0.175	22.002		
0.170	22.639		
0.175	23.062		
0.166	23.257		
0.159	21.131		
0.169	21.965		
0.164	22.594		
0.177	23.010		

TABLE III THERMAL CONDUCTIVITY OF SOLID H_2

CALCULATED FROM HEATING TEMPERATURE PROFILE

(RUN NO. = 13B)

THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)	THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)
7.537	11.334	0.910	17.821
7.821	11.250	0.927	17.443
8.210	11.128	0.781	17.372
4.029	13.004	0.558	17.302
5.482	12.808	0.883	17.621
5.476	12.663	0.697	17.576
2.567	14.506		
2.618	14.202		
3.130	13.978		
2.926	13.804		
3.830	13.679		
3.287	13.586		
3.354	13.508		
1.494	15.376		
1.464	15.039		
1.635	14.781		
1.523	14.578		
1.840	14.428		
1.637	14.315		
1.709	14.227		
1.587	16.172		
1.516	15.940		
1.718	15.758		
1.639	15.615		
1.842	15.505		
1.795	15.425		
1.632	15.363		
1.203	15.314		
0.571	18.169		
0.598	17.838		
0.722	17.598		
0.683	17.417		
0.910	17.292		
0.789	17.203		
0.854	17.138		

TABLE III THERMAL CONDUCTIVITY OF SOLID H_2

CALCULATED FROM COOLING TEMPERATURE PROFILE (Cont.)

(RUN NO. = 13B)

THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)	THERMAL CONDUCTIVITY (BTU/HR.-FT.-DEG. R)	TEMPERATURE (DEG. R)
0.386	18.054		
0.677	17.980		
0.779	17.578		
0.447	17.629		
0.417	17.669		
0.778	17.484		
0.549	17.549		
0.514	17.604		
0.872	17.472		
0.872	17.522		
0.804	17.557		
0.713	17.572		
0.660	17.564		
0.583	17.530		
0.916	16.628		
1.086	15.470		
1.093	15.565		
1.107	15.643		
1.095	15.707		
1.156	15.758		
1.004	15.799		
0.984	15.834		
0.793	15.862		
1.377	15.405		
1.337	15.487		
1.306	15.558		
1.265	15.619		
1.225	15.669		
1.059	15.712		
1.017	15.747		
0.660	15.776		
0.503	15.799		

TABLE IV THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 8)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	R2	R14	R4	R5	R6
0.750	1.313	1.594	1.876	2.439	3.125

THE BASE EMF(EMB) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

EMB1 (MIC.V)	EMB2 (MIC.V)	EMB14 (MIC.V)	EMB4 (MIC.V)	EMB5 (MIC.V)	EMB6 (MIC.V)
-1114.	-1098.	-1090.	-1094.	-1066.	-1067.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MIC.V)	T1 (DEG.R)	EMF2 (MIC.V)	T2 (DEG.R)	EMF14 (MIC.V)	T14 (DEG.R)	EMF4 (MIC.V)	T4 (DEG.R)	EMF5 (MIC.V)	T5 (DEG.R)	EMF6 (MIC.V)	T6 (DEG.R)
0.	-1196.	16.101	-1191.	14.920	-1186.	14.598	-1196.	14.491	-1167.	14.276	-1192.	13.632
10.	-1193.	16.429	-1189.	15.135	-1185.	14.706	-1195.	14.598	-1166.	14.384	-1191.	13.740
20.	-1191.	16.639	-1189.	15.242	-1183.	14.920	-1194.	14.706	-1165.	14.491	-1190.	13.847
30.	-1188.	16.960	-1187.	15.350	-1181.	15.135	-1193.	14.813	-1164.	14.598	-1189.	13.954
40.	-1184.	17.389	-1184.	15.672	-1179.	15.350	-1190.	15.135	-1162.	14.813	-1186.	14.276
50.	-1130.	22.219	-1174.	16.745	-1173.	15.994	-1183.	15.886	-1157.	15.350	-1160.	14.920
60.	-1140.	22.112	-1168.	17.389	-1166.	16.745	-1178.	16.423	-1150.	16.101	-1174.	15.564
70.	-1143.	21.790	-1162.	18.033	-1162.	17.174	-1174.	16.852	-1146.	16.530	-1170.	15.994
80.	-1147.	21.897	-1159.	18.355	-1158.	17.604	-1170.	17.282	-1145.	16.638	-1167.	16.316
90.	-1141.	22.004	-1156.	18.677	-1155.	17.926	-1168.	17.496	-1141.	17.067	-1164.	16.638
100.	-1140.	22.112	-1153.	18.999	-1153.	18.140	-1165.	17.818	-1139.	17.282	-1161.	16.960
110.	-1137.	22.219	-1151.	19.214	-1151.	18.355	-1164.	17.926	-1137.	17.496	-1159.	17.174
120.	-1137.	22.434	-1150.	19.321	-1149.	18.570	-1162.	18.140	-1135.	17.711	-1157.	17.389
130.	-1135.	22.648	-1148.	19.536	-1147.	18.784	-1161.	18.248	-1133.	17.926	-1155.	17.604
140.	-1133.	22.863	-1147.	19.643	-1146.	18.892	-1160.	18.355	-1132.	18.033	-1153.	17.818
150.	-1134.	22.756	-1145.	19.858	-1144.	19.106	-1150.	18.570	-1131.	18.140	-1152.	17.926
160.	-1133.	22.863	-1144.	19.965	-1143.	19.214	-1157.	18.677	-1130.	18.248	-1150.	18.140
170.	-1131.	23.078	-1143.	20.072	-1142.	19.321	-1155.	18.892	-1129.	18.355	-1149.	18.248
180.	-1131.	23.078	-1141.	20.287	-1141.	19.428	-1154.	18.999	-1128.	18.462	-1148.	18.355
190.	-1131.	23.078	-1141.	20.287	-1140.	19.536	-1153.	19.106	-1125.	18.784	-1146.	18.355
200.	-1140.	22.112	-1140.	20.394	-1139.	19.643	-1152.	19.214	-1125.	18.784	-1147.	18.462
210.	-1155.	20.716	-1142.	20.180	-1138.	19.750	-1150.	19.428	-1124.	18.892	-1146.	18.570
220.	-1159.	20.072	-1145.	19.858	-1138.	19.750	-1150.	19.428	-1123.	18.999	-1145.	18.677
230.	-1162.	19.750	-1146.	19.750	-1139.	19.643	-1150.	19.428	-1123.	18.999	-1144.	18.784
240.	-1163.	19.643	-1146.	19.750	-1140.	19.536	-1151.	19.321	-1122.	19.106	-1144.	18.784
250.	-1164.	19.536	-1147.	19.643	-1140.	19.536	-1150.	19.428	-1121.	19.214	-1143.	18.892
260.	-1165.	19.428	-1148.	19.536	-1141.	19.428	-1150.	19.428	-1121.	19.214	-1142.	18.999
270.	-1166.	19.321	-1149.	19.428	-1141.	19.428	-1150.	19.428	-1120.	19.321	-1141.	19.106
280.	-1166.	19.321	-1149.	19.428	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1141.	19.106
290.	-1167.	19.214	-1150.	19.321	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1140.	19.214
300.	-1167.	19.214	-1150.	19.321	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1140.	19.214
310.	-1167.	19.214	-1150.	19.321	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1139.	19.321
320.	-1167.	19.214	-1150.	19.321	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1139.	19.321
330.	-1166.	19.321	-1150.	19.321	-1142.	19.321	-1151.	19.321	-1120.	19.321	-1139.	19.321

TABLE V   THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 9)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	T2	R14	R4	P5	R6
0.750	1.313	1.594	1.876	2.439	3.125

THE BASE EMF(OC'H) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

EMF1 (MICoV) -1105.	EMF2 (MICoV) -1129.	EMF14 (MICoV) -1076.	EMF4 (MICoV) -1111.	EMF5 (MICoV) -1068.	EMF6 (MICoV) -1091.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MICoV)	T1 (DEG.R)	EMF2 (MICoV)	T2 (DEG.R)	EMF14 (MICoV)	T14 (DEG.R)	EMF4 (MICoV)	T4 (DEG.R)	EMF5 (MICoV)	T5 (DEG.R)	EMF6 (MICoV)	T6 (DEG.R)
0.	-1240.	10.412	-1213.	15.242	-1156.	16.316	-1168.	18.794	-1118.	19.536	-1140.	19.603
10.	-1240.	10.412	-1213.	15.242	-1157.	16.208	-1168.	18.764	-1118.	19.536	-1141.	19.530
20.	-1240.	10.412	-1214.	15.139	-1157.	16.209	-1169.	18.677	-1118.	19.536	-1142.	19.420
30.	-1237.	10.734	-1212.	15.390	-1153.	16.638	-1161.	19.536	-1078.	23.829	-1097.	24.250
40.	-1234.	11.056	-1208.	15.779	-1147.	17.287	-1156.	20.072	-1078.	23.829	-1096.	24.366
50.	-1232.	11.271	-1202.	16.423	-1147.	17.818	-1152.	20.502	-1078.	23.829	-1096.	24.366
60.	-1231.	11.378	-1198.	16.852	-1130.	18.248	-1149.	20.824	-1079.	23.722	-1096.	24.366
70.	-1231.	11.378	-1197.	16.960	-1136.	19.462	-1147.	21.038	-1079.	23.722	-1097.	24.236
80.	-1231.	11.378	-1196.	17.067	-1136.	18.462	-1146.	21.145	-1079.	23.722	-1097.	24.258
90.	-1231.	11.378	-1196.	17.067	-1135.	18.570	-1146.	21.146	-1079.	23.722	-1097.	24.258
100.	-1231.	11.378	-1196.	17.067	-1135.	18.570	-1146.	21.146	-1079.	23.722	-1097.	24.258
110.	-1231.	11.378	-1196.	17.067	-1135.	18.570	-1146.	21.146	-1079.	23.722	-1097.	24.258
120.	-1231.	11.378	-1196.	17.067	-1135.	18.570	-1146.	21.146	-1079.	23.722	-1096.	24.251
130.	-1230.	11.486	-1196.	17.067	-1136.	18.462	-1147.	21.038	-1081.	23.507	-1098.	24.151
140.	-1230.	11.486	-1197.	16.960	-1136.	18.462	-1148.	20.931	-1082.	23.400	-1099.	24.044
150.	-1229.	11.593	-1197.	16.960	-1137.	18.355	-1148.	20.931	-1083.	23.292	-1099.	24.044
160.	-1228.	11.700	-1196.	17.067	-1137.	18.355	-1149.	20.824	-1084.	23.185	-1099.	24.044
170.	-1227.	11.808	-1196.	17.067	-1137.	18.355	-1149.	20.824	-1084.	23.185	-1100.	23.936
180.	-1226.	11.915	-1195.	17.174	-1136.	18.462	-1149.	20.824	-1084.	23.185	-1100.	23.936
190.	-1225.	12.022	-1195.	17.174	-1136.	18.462	-1149.	20.824	-1085.	23.078	-1101.	23.829
200.	-1225.	12.022	-1195.	17.174	-1136.	18.462	-1150.	20.716	-1085.	23.078	-1101.	23.829
210.	-1224.	12.130	-1195.	17.174	-1137.	18.355	-1150.	20.716	-1085.	23.078	-1102.	23.722
220.	-1224.	12.130	-1195.	17.174	-1137.	18.355	-1150.	20.716	-1086.	22.970	-1102.	23.722
230.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1151.	20.609	-1086.	22.970	-1103.	23.614
240.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1151.	20.609	-1086.	22.970	-1103.	23.614
250.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1151.	20.609	-1087.	22.863	-1104.	23.507
260.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1151.	20.609	-1088.	22.756	-1105.	23.400
270.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1152.	20.502	-1089.	22.648	-1106.	23.292
280.	-1223.	12.237	-1195.	17.174	-1137.	18.355	-1152.	20.502	-1090.	22.541	-1107.	23.185
290.	-1223.	12.237	-1195.	17.174	-1138.	18.248	-1152.	20.502	-1091.	22.434	-1108.	23.078
300.	-1223.	12.237	-1195.	17.174	-1138.	18.248	-1153.	20.394	-1092.	22.326	-1108.	23.078
310.	-1223.	12.237	-1195.	17.174	-1138.	18.248	-1153.	20.394	-1093.	22.219	-1109.	22.970

TABLE VI THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 10)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	R2	R14	R4	R5	R6
0.797	1.319	1.594	1.876	2.439	3.125

THE BASE EMF(OF/R) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

EMR1 (MIC.V)	EMR2 (MIC.V)	EMR14 (MIC.V)	EMR4 (MIC.V)	EMR5 (MIC.V)	EMR6 (MIC.V)
0.	-1095.	-1093.	-1099.	-1085.	-1092.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MIC.V)	T1 (DEG.R)	EMF2 (MIC.V)	T2 (DEG.R)	EMF14 (MIC.V)	T14 (DEG.R)	EMF4 (MIC.V)	T4 (DEG.R)	EMF5 (MIC.V)	T5 (DEG.R)	EMF6 (MIC.V)	T6 (DEG.R)
0.	0.	0.000	-1169.	17.389	-1156.	18.140	-1148.	19.536	-1110.	22.219	-1100.	24.044
20.	0.	0.000	-1169.	17.389	-1156.	18.140	-1149.	19.428	-1110.	22.219	-1100.	24.044
40.	0.	0.000	-1180.	15.779	-1167.	16.960	-1160.	18.248	-1111.	22.112	-1100.	24.044
60.	0.	0.000	-1194.	14.276	-1182.	15.390	-1174.	16.745	-1118.	21.360	-1101.	23.930
80.	0.	0.000	-1200.	13.632	-1189.	14.598	-1182.	15.886	-1129.	20.180	-1101.	23.930
100.	0.	0.000	-1202.	13.418	-1192.	14.276	-1186.	15.457	-1136.	19.428	-1101.	23.930
120.	0.	0.000	-1203.	13.310	-1194.	14.062	-1189.	15.135	-1140.	18.999	-1101.	23.930
140.	0.	0.000	-1204.	13.203	-1195.	13.954	-1192.	14.813	-1144.	18.570	-1101.	23.930
160.	0.	0.000	-1206.	12.988	-1197.	13.740	-1196.	14.384	-1151.	17.818	-1101.	23.930
140.	0.	0.000	-1208.	12.774	-1200.	13.418	-1200.	13.954	-1160.	16.852	-1101.	23.930
200.	0.	0.000	-1210.	12.559	-1203.	13.096	-1205.	13.418	-1171.	15.672	-1107.	23.272
220.	0.	0.000	-1212.	12.344	-1206.	12.774	-1210.	12.881	-1182.	14.491	-1115.	22.502
240.	0.	0.000	-1214.	12.130	-1209.	12.452	-1213.	12.559	-1190.	13.632	-1173.	16.208
260.	0.	0.000	-1216.	11.915	-1212.	12.130	-1217.	12.130	-1197.	12.881	-1193.	14.062
280.	0.	0.000	-1218.	11.700	-1214.	11.915	-1220.	11.808	-1204.	12.130	-1205.	12.774
300.	0.	0.000	-1220.	11.486	-1217.	11.593	-1222.	11.593	-1207.	11.808	-1222.	11.022
320.	0.	0.000	-1221.	11.378	-1219.	11.486	-1224.	11.378	-1210.	11.486	-1217.	11.486
340.	0.	0.000	-1221.	11.378	-1219.	11.378	-1224.	11.378	-1211.	11.378	-1218.	11.378

TABLE VII THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 13A)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	R2	R14	R4	R5	R6
0.750	1.313	1.594	1.876	2.439	3.125

THE BASE EMF(*EVR) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

EMR1 (MIC.V)	EMR2 (MIC.V)	EMR14 (MIC.V)	EMR4 (MIC.V)	EMR5 (MIC.V)	EMR6 (MIC.V)
0.	-1099.	-1083.	-1094.	-1086.	-1093.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MIC.V)	T1 (DEG.R)	EMF2 (MIC.V)	T2 (DEG.R)	EMF14 (MIC.V)	T14 (DEG.R)	EMF4 (MIC.V)	T4 (DEG.R)	EMF5 (MIC.V)	T5 (DEG.R)	EMF6 (MIC.V)	T6 (DEG.R)
0.	0.	0.000	-1206.	13.418	-1185.	13.954	-1179.	15.779	-1131.	20.072	-1097.	24.473
10.	0.	0.000	-1207.	13.310	-1186.	13.847	-1180.	15.672	-1133.	19.858	-1097.	24.473
20.	0.	0.000	-1208.	13.203	-1187.	13.740	-1181.	15.564	-1135.	19.643	-1097.	24.473
30.	0.	0.000	-1209.	13.096	-1188.	13.632	-1182.	15.457	-1137.	19.428	-1097.	24.473
40.	0.	0.000	-1209.	13.096	-1189.	13.525	-1183.	15.350	-1139.	19.214	-1097.	24.473
50.	0.	0.000	-1210.	12.988	-1189.	13.525	-1184.	15.242	-1141.	18.999	-1097.	24.473
60.	0.	0.000	-1211.	12.881	-1190.	13.418	-1185.	15.135	-1142.	18.692	-1097.	24.473
70.	0.	0.000	-1211.	14.881	-1191.	13.310	-1187.	14.920	-1145.	16.570	-1098.	24.366
80.	0.	0.000	-1212.	12.774	-1191.	13.310	-1188.	14.813	-1147.	18.355	-1098.	24.366
90.	0.	0.000	-1213.	12.666	-1191.	13.310	-1189.	14.706	-1149.	18.140	-1099.	24.258
100.	0.	0.000	-1213.	12.666	-1192.	13.203	-1191.	14.491	-1151.	17.926	-1101.	24.044
110.	0.	0.000	-1214.	12.559	-1193.	13.096	-1193.	14.276	-1154.	17.604	-1104.	23.722
120.	0.	0.000	-1215.	12.452	-1194.	12.988	-1195.	14.062	-1158.	17.174	-1108.	23.292
130.	0.	0.000	-1217.	12.237	-1196.	12.774	-1198.	13.740	-1163.	16.638	-1113.	22.756
140.	0.	0.000	-1218.	12.130	-1198.	12.559	-1202.	13.310	-1170.	15.886	-1121.	21.897
150.	0.	0.000	-1221.	11.808	-1202.	12.130	-1207.	12.774	-1180.	14.813	-1135.	20.394
160.	0.	0.000	-1223.	11.593	-1204.	11.915	-1213.	12.130	-1195.	13.203	-1200.	13.418
170.	0.	0.000	-1228.	11.056	-1212.	11.056	-1225.	10.842	-1215.	11.056	-1222.	11.056
180.	0.	0.000	-1235.	10.305	-1219.	10.305	-1231.	10.198	-1221.	10.412	-1227.	10.520
190.	0.	0.000	-1237.	10.090	-1221.	10.090	-1233.	9.983	-1223.	10.198	-1229.	10.305
200.	0.	0.000	-1239.	9.876	-1223.	9.876	-1235.	9.768	-1225.	9.983	-1232.	9.983
210.	0.	0.000	-1240.	9.768	-1225.	9.661	-1237.	9.554	-1227.	9.768	-1234.	9.768
220.	0.	0.000	-1243.	9.446	-1227.	9.446	-1239.	9.339	-1229.	9.554	-1236.	9.554
230.	0.	0.000	-1245.	9.292	-1229.	9.232	-1239.	9.339	-1230.	9.446	-1237.	9.446
240.	0.	0.000	-1245.	9.232	-1229.	9.232	-1239.	9.339	-1230.	9.446	-1237.	9.446
250.	0.	0.000	-1245.	9.232	-1229.	9.232	-1239.	9.339	-1230.	9.446	-1237.	9.446

TABLE VIII THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 13B)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	R2	R14	R4	R5	R6
0.759	1.313	1.594	1.876	2.439	3.125

THE BASE EMF(BEMR) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

BEMR1 (MIC.V)	EMR2 (MIC.V)	EMR14 (MIC.V)	EMR4 (MIC.V)	EMR5 (MIC.V)	EMR6 (MIC.V)
0.	-1099.	-1088.	-1101.	-1086.	-1093.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MIC.V)	T1 (DEG.R)	EMF2 (MIC.V)	T2 (DEG.R)	EMF14 (MIC.V)	T14 (DEG.R)	EMF4 (MIC.V)	T4 (DEG.R)	EMF5 (MIC.V)	T5 (DEG.R)	EMF6 (MIC.V)	T6 (DEG.R)
-30.	0.	0.000	0.	0.000	-1244.	8.158	0.	0.000	-1238.	8.988	-1247.	8.973
-20.	0.	0.000	0.	0.000	-1244.	8.158	0.	0.000	-1238.	8.988	-1247.	8.973
-10.	0.	0.000	0.	0.000	-1244.	8.158	0.	0.000	-1237.	8.895	-1246.	8.980
0.	0.	0.000	-1254.	8.266	-1243.	8.266	-1251.	8.852	-1236.	8.802	-1245.	8.980
10.	0.	0.000	-1210.	12.988	-1205.	12.344	-1220.	12.130	-1208.	11.808	-1240.	11.271
20.	0.	0.000	-1187.	15.457	-1143.	14.706	-1195.	14.491	-1198.	13.954	-1170.	13.052
30.	0.	0.000	-1175.	16.745	-1172.	15.886	-1144.	15.564	-1179.	14.920	-1160.	14.706
40.	0.	0.000	-1169.	17.389	-1165.	16.638	-1161.	16.316	-1172.	15.672	-1161.	15.427
50.	0.	0.000	-1164.	17.926	-1161.	17.067	-1176.	16.852	-1167.	16.208	-1176.	15.974
60.	0.	0.000	-1160.	18.355	-1157.	17.496	-1173.	17.174	-1163.	16.636	-1173.	16.316
70.	0.	0.000	-1158.	18.570	-1154.	17.818	-1170.	17.496	-1159.	17.067	-1169.	16.745
80.	0.	0.000	-1157.	18.677	-1153.	17.926	-1167.	17.618	-1157.	17.282	-1166.	17.067
90.	0.	0.000	-1158.	18.570	-1151.	18.140	-1166.	17.925	-1155.	17.496	-1155.	17.174
100.	0.	0.000	-1159.	18.462	-1151.	18.140	-1166.	17.926	-1154.	17.604	-1163.	17.389
110.	0.	0.000	-1161.	18.248	-1152.	18.033	-1166.	17.926	-1153.	17.711	-1162.	17.496
120.	0.	0.000	-1165.	17.819	-1154.	17.818	-1167.	17.818	-1153.	17.711	-1161.	17.604
130.	0.	0.000	-1169.	17.389	-1157.	17.496	-1169.	17.604	-1153.	17.711	-1161.	17.604
140.	0.	0.000	-1171.	17.174	-1159.	17.282	-1171.	17.389	-1154.	17.604	-1162.	17.496
150.	0.	0.000	-1174.	16.852	-1161.	17.067	-1172.	17.282	-1156.	17.387	-1163.	17.389
160.	0.	0.000	-1176.	16.638	-1163.	16.852	-1174.	17.067	-1158.	17.174	-1164.	17.282
170.	0.	0.000	-1178.	16.423	-1164.	16.745	-1175.	16.960	-1159.	17.067	-1165.	17.174
180.	0.	0.000	-1179.	16.316	-1165.	16.638	-1177.	16.745	-1160.	16.960	-1166.	17.067
190.	0.	0.000	-1180.	16.208	-1167.	16.423	-1179.	16.530	-1162.	16.745	-1167.	16.960
200.	0.	0.000	-1182.	15.994	-1169.	16.208	-1180.	16.423	-1164.	16.530	-1169.	16.745
210.	0.	0.000	-1183.	15.885	-1170.	16.101	-1181.	16.316	-1166.	16.316	-1170.	16.636
220.	0.	0.000	-1185.	15.672	-1171.	15.994	-1183.	16.101	-1167.	16.208	-1172.	16.423
230.	0.	0.000	-1186.	15.564	-1173.	15.779	-1184.	15.994	-1169.	15.994	-1173.	16.316
240.	0.	0.000	-1187.	15.457	-1175.	15.564	-1185.	15.886	-1170.	15.886	-1175.	16.101
250.	0.	0.000	-1188.	15.350	-1176.	15.457	-1187.	15.672	-1171.	15.779	-1177.	15.886
260.	0.	0.000	-1189.	15.242	-1177.	15.350	-1189.	15.457	-1173.	15.564	-1179.	15.672

23

TABLE IX   THERMOPHYSICAL PROPERTY TEST DATA (RUN NO. 15)

THE RADIAL POSITIONS OF THERMOCOUPLES ARE GIVEN BELOW IN INCHES

R1	R2	R14	R4	R5	R6
0.750	1.313	1.594	1.876	2.439	3.125

THE BASE EMF(BEMR) AT THE H2 MELTING POINT OF 24.6 DEG. R FOR EACH THERMOCOUPLE IS GIVEN BELOW

EMR1 (MIC.V)	EMR2 (MIC.V)	EMR14 (MIC.V)	EMR4 (MIC.V)	EMR5 (MIC.V)	EMR6 (MIC.V)
0.	-1089.	-1099.	-1095.	-1075.	-1091.

TRANSIENT BEHAVIORS OF SIX(6) THERMOCOUPLES ARE GIVEN BELOW IN TERMS OF EMF AND TEMPERATURE

TIME (SEC)	EMF1 (MIC.V)	T1 (DEG.R)	EMF2 (MIC.V)	T2 (DEG.R)	EMF14 (MIC.V)	T14 (DEG.R)	EMF4 (MIC.V)	T4 (DEG.R)	EMF5 (MIC.V)	T5 (DEG.R)	EMF6 (MIC.V)	T6 (DEG.R)
0.	0.	0.000	-1237.	9.373	-1243.	8.373	-1249.	8.480	-1229.	8.373	-1245.	8.373
10.	0.	0.000	-1237.	9.373	-1243.	8.373	-1249.	8.480	-1229.	8.373	-1245.	8.373
20.	0.	0.000	-1237.	9.373	-1243.	8.373	-1248.	8.480	-1229.	8.373	-1245.	8.373
30.	0.	0.000	-1237.	9.373	-1243.	8.373	-1248.	8.480	-1229.	8.373	-1245.	8.373
40.	0.	0.000	-1183.	14.169	-1195.	13.525	-1214.	12.130	-1193.	12.237	-1206.	11.555
50.	0.	0.000	-1171.	15.457	-1185.	14.598	-1202.	13.418	-1183.	13.510	-1195.	13.140
60.	0.	0.000	-1165.	16.131	-1178.	15.350	-1195.	14.169	-1175.	14.169	-1183.	14.472
70.	0.	0.000	-1161.	16.530	-1173.	15.886	-1190.	14.706	-1171.	14.598	-1183.	13.626
80.	0.	0.000	-1158.	16.952	-1169.	16.316	-1185.	15.242	-1167.	15.026	-1179.	13.627
90.	0.	0.000	-1155.	17.174	-1167.	16.530	-1142.	15.564	-1163.	15.457	-1176.	13.717
100.	0.	0.000	-1159.	17.389	-1164.	16.852	-1179.	15.686	-1160.	15.779	-1172.	16.200
110.	0.	0.000	-1150.	17.711	-1162.	17.067	-1177.	16.101	-1157.	16.101	-1170.	16.423
120.	0.	0.000	-1148.	17.926	-1159.	17.389	-1174.	16.423	-1154.	16.423	-1167.	16.743
130.	0.	0.000	-1147.	18.033	-1157.	17.604	-1171.	16.745	-1153.	16.530	-1165.	16.960
140.	0.	0.000	-1146.	18.140	-1156.	17.711	-1170.	16.852	-1152.	16.530	-1164.	17.067
150.	0.	0.000	-1147.	18.033	-1155.	17.818	-1169.	16.960	-1151.	16.852	-1163.	17.067
160.	0.	0.000	-1147.	18.033	-1155.	17.818	-1167.	17.174	-1150.	16.852	-1163.	17.067
170.	0.	0.000	-1149.	17.818	-1155.	17.818	-1166.	17.282	-1155.	16.852	-1163.	17.067
180.	0.	0.000	-1150.	17.711	-1156.	17.711	-1166.	17.282	-1149.	16.960	-1163.	17.067
190.	0.	0.000	-1152.	17.496	-1157.	17.604	-1165.	17.389	-1149.	16.960	-1164.	17.067
200.	0.	0.000	-1154.	17.282	-1159.	17.389	-1165.	17.389	-1149.	16.960	-1165.	16.960
210.	0.	0.000	-1157.	16.960	-1161.	17.174	-1166.	17.282	-1153.	16.852	-1167.	16.745
220.	0.	0.000	-1160.	16.638	-1163.	16.960	-1168.	17.067	-1151.	16.745	-1169.	16.530
230.	0.	0.000	-1161.	16.530	-1165.	16.745	-1169.	16.960	-1153.	16.530	-1171.	16.316
240.	0.	0.000	-1163.	16.316	-1167.	16.530	-1171.	16.745	-1154.	16.423	-1173.	16.101
250.	0.	0.000	-1165.	16.101	-1169.	16.316	-1173.	16.530	-1156.	16.208	-1175.	15.888

24

SECTION IV

DISCUSSION - MELTING CHARACTERISTICS

1. GENERAL

A melting technique requiring no active heating elements, and relying solely on gaseous hydrogen as the energy source, has been investigated with the goal of achieving an experimental correlation relating melting rates to such parameters as the gas pressure, amount of gas superheat, liquid subcool and solid geometry configuration (tank geometry). The strong dependence of the thermophysical properties of SH_2 on temperature precludes the possibility of simple analytical prediction techniques for its melting rate; the problem is aggravated by the severe mathematical complexities introduced due to transient phase change and the existence of a three-phase heat transfer problem, from superheated gas to a liquid layer (formed from both simultaneous condensation of the gas and melting of the solid) to the subcooled solid; the problem is somewhat simplified if we assume the solid temperature to be that of melting. This simplification has been used throughout the analysis of the melting problem. Experiments have been planned in conjunction with a control volume analysis which obviates the need for detailed information internal to the control volume.

From a' priori knowledge of the thermophysical properties of SH_2, it is expected that melting of the solid will take place rather rapidly, even with the solid in a subcooled condition; the melting rate will obviously increase considerably if the solid is at its melting temperature throughout; all melting experiments were carried out under this condition.

2. PARAMETRIC ANALYSIS

a. Overall Mass and Heat Balance Considerations

When conservation of mass is applied to a control volume interior to the SH_2 Cryostat and occupied by the solid hydrogen and its vapor, one can write, neglecting the mass of vapor:

$$\frac{d}{dt}[M_T(t)] + \dot{m}_2 - \dot{m}_1 = 0 \tag{5}$$

where $\dot{m}_1$ is the mass flow rate of the entering gas and $\dot{m}_2$, the mass flow rate of the outgoing liquid for the melting process over a period of time t*. Equation (1) may be integrated to give us

$$M_T(0) = M_S(0) = M_2 - M_1 \tag{6}$$

25

where
$$M_T(t*) \ll M_T(0) \approx M_S(0)$$

$M_S(0)$ is the initial solid mass, M_1 the total mass of the entering hot gas and M_2, the total mass of the outgoing liquid; by definition

$$M_j = \int_0^{t*} \dot{m}_j \, dt \qquad j = 1, 2 \qquad (7)$$

where M_j is the total mass.

Applying the energy equation to the same control volume we obtain

$$\dot{Q}_{cv} = \frac{d}{dt} [M_T(t) \, U_T(t)] + \dot{m}_2 \, h_2 - \dot{m}_1 \, h_1 \qquad (8)$$

Integrating (4) for the entire process results in

$$\bar{Q}_{cv} = \int_0^{t*} (\dot{m}_2 \, h_2 - \dot{m}_1 \, h_1) \, dt + M_T(t*) \, U_T(t*) - M_T(0) \, U_T(0)$$

$$= - M_S(0) \, U_S(0) + M_2 \, \bar{h}_2 - M_1 \, \bar{h}_1 \qquad (9)$$

where

$$M_T(t*) \ll M_T(0) \approx M_S(0)$$

$$\bar{h}_j = \frac{1}{M_j} \int_0^{t*} m_j \, h_j \, dt \qquad j = 1, 2 \qquad (10)$$

$$\bar{Q}_{cv} = \int_0^{t*} \dot{Q} \, dt \qquad (11)$$

$$M_j = \int_0^{t*} m_j \, dt \qquad j = 1, 2 \qquad (12)$$

equation (5) is rewritten as

$$M_S(0) \, (h_\ell^{SL} - h_S(0)) = \bar{Q}_{cv} - M_2 \, (\bar{h}_2 - h_\ell^{SL}) + M_1 \, (\bar{h}_1 - h_g^{LV}) \qquad (13)$$

$$- M_2 \, h_\ell^{SL} + M_1 \, h_g^{LV} - M_S(0) \, P \, v_S + M_S(0) \, h_\ell^{SL}$$

or

$$M_S(0) \left(h_\ell^{SL} - h_S(0)\right) = \bar{Q}_{cv} + M_1 \left[\delta h_g - \delta h_\ell + \left(h_\ell^{LV} - h_\ell^{SL}\right) + \right.$$

$$\left.\left(h_g^{LV} - h_\ell^{LV}\right)\right] - M_S(0) \left(\delta h_\ell + P v_s\right)$$

where

$$\delta h_g = \bar{h}_1 - h_g^{LV} \ , \quad \delta h_\ell = \bar{h}_2 - h_\ell^{SL} \quad \text{and} \quad M_2 = M_1 + M_S(0)$$

(see Figure 5)

To simplify equation (13), the term $\bar{Q}_{cv}$ may be assumed negligible. This assumption implies that no environmental heat leak into the cryostat is permissible. The design of the cryostat as described previously minimizes external heat leak by the use of refrigerated radiation shields at the top of the cryostat and side refrigeration baths. The assumption of negligible heat leak was used in this analysis.

Finally,

$$1 = Y \ \frac{\delta h_g - \delta h_\ell + \lambda'_{fg}}{\lambda_{SL}} \ - \frac{1}{\lambda_{SL}} \left(\delta h_\ell + P v_s\right) \tag{14}$$

where

$$Y = \frac{M_1}{M_S(0)}$$

$$\lambda_{SL} = h_\ell^{SL} - h_S(0)$$

$$\lambda'_{fg} = h_g^{LV} - h_\ell^{SL}$$

b. General Relationship Between Analysis and Experiments

The thermodynamic parameters which determine the performance of solid melting during liquid acquisition have been formulated and cast in non-dimensional form previously. A convenient relationship among these parameters has been developed for the purpose of organizing experimental results for the melting process.

Liquid drainage height controls the heat transfer area exposed to the hot gas when the solid hydrogen is heated from above. If there is no drainage height at all, the entering gas may escape the control volume through the dip tube without being condensed after losing some sensible heat. Drainage height was kept at a minimum, just sufficient to prevent bypassing of the hot gas; therefore liquid drainage height effects on the melting characteristics of the solid will be ignored. The two important unknown melting variables t* (total
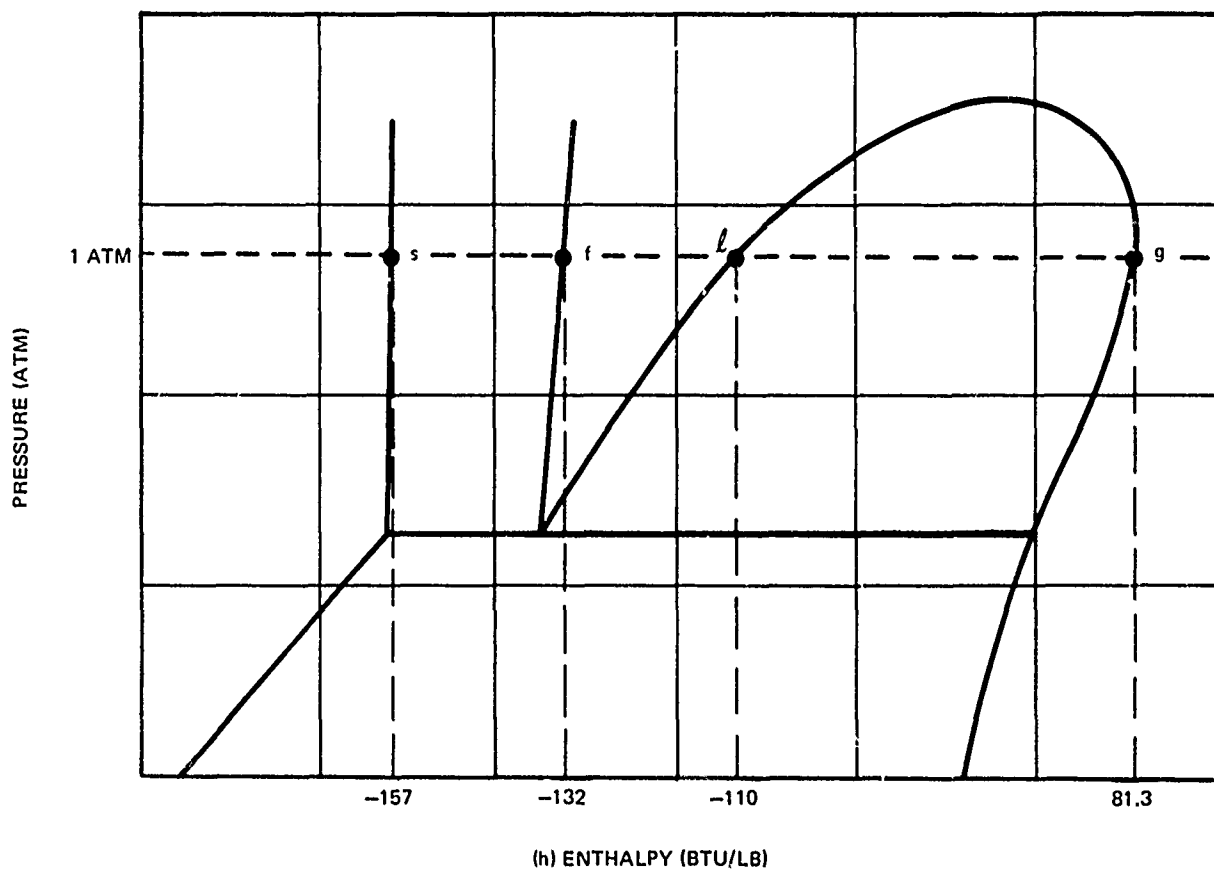
FIG. 5 THERMODYNAMIC DIAGRAM

28

time to melt) and Y (ratio of total gas mass to initial solid mass) are given by the following functional relationships:

$$0 = F \left(t^*, Y, \delta h_g, \delta h_\ell, L_s, L, M_s, P, \Delta T, \bar{T}_1, H_2 \text{ properties} \right) \quad (15)$$

where F dependence on t* must be determined experimentally and

$$0 = G \left(Y, \delta h_g, \delta h_\ell, M_s(0), P, H_2 \text{ properties} \right) \quad (16)$$

where the functional relationship G is obtained by applying the overall conservation equation of energy and mass to the experimental dewar over the total melting period as given by equation (14). Futhermore, an overall heat transfer coefficient for the process may be introduced as

$$U_o = \frac{M_s(0) \lambda_{SL}}{A_o(L) \ t^* \ \Delta T}, \text{ which implies}$$

$$U_o = f \left(\Delta T, t^*, \lambda_{SL}, L_s, L, M_s \right)$$

or equations (15) and (16) reduce to

$$U_o = E_1 \left(Y, \frac{\delta h_g}{\delta h_\ell}, L_s, P, \bar{T}_1 \right) \quad (17)$$

Further reduction by modifying the overall heat transfer coefficient leads to

$$U_o \left(\frac{\bar{T}_1}{T_o} \right)^\ell \left(\frac{P_o}{P} \right)^m \left(\frac{L_s}{D_o} \right)^n = E_2 \left(Y, \frac{\delta h_g}{\delta h_\ell} \right) \quad (18)$$

where T_o and P_o are the reference temperature and pressure at atmospheric conditions, D_o the solid initial outside diameter and ℓ, m and n experimentally obtained exponents.

The explicit dependence of equation (18) on pressure, temperature and geometry ratios was arbitrarily chosen to non-dimensionalize pressure, temperature and heating length.

3. TEST PROCEDURE

Solid hydrogen is prepared as described in Section III, 2. When solidification is completed, flow conditioning of the hot hydrogen to be used as melting agent is started. Liquid helium flow into the heat exchanger located at the center of the cryostat is stopped while ambient hydrogen gas is brought into the gas conditioning piping system where it is heated to a desired temperature. The hot gas bypasses the cryostat and is vented to atmosphere via the vent system until the solid cryostat and flow box are ready for the melting experiment at which time the conditioned gas is admitted through the top of the cryostat and allowed to contact the solid.

Simultaneously, the vacuum-jacketed transfer line for the withdrawal of melted liquid hydrogen is chilled down with externally supplied liquid hydrogen. In this manner, heat leak into the liquid flowing inside the transfer line is minimized; this prevents the drained liquid from boiling and the possible flow transfer instability due to flow oscillations such as is the case during two-phase flow transfer.

Chill-down of the transfer line is followed by pulling a vacuum on the dip tube which will guarantee flow once the solid surrounding the inlet to this tube is melted. The loss of vacuum is used as a signal for the initiation of flow of the pre-conditioned gas to be used as melting agent. In the meantime, the helium heat exchanger is vacuum pumped down to evacuate whatever helium remains in its interior. This prevents the helium exchanger from acting as a heat sink and allows the heat extracted from the melting gas to go in its entirety into the solid.

By means of breaking the vacuum in the middle region (annular space of cryostat), heat is allowed to leak into the outer periphery of the solid hydrogen until the solid around the dip tube entrance is melted and the flow passage for the liquid becomes unobstructed. At the same time, due to the solid melting, a small liquid layer (gap) develops between the solid hydrogen periphery and the cryostat inner glass wall as the solid recedes away from the hot glass wall. This gap allows the liquid hydrogen produced by the melting solid and the condensing gaseous hydrogen, to travel downwards to the bottom of the cryostat where it is being continuously drained by the dip tube.

As the dip tube is unblocked by the melting SH_2 surrounding it, the vacuum in the transfer line is broken, as shown by a vacuum-pressure gauge reading. This loss of vacuum triggers the feed of conditioned gaseous hydrogen into the solid hydrogen cryostat. Temperature and pressure measurements of incoming and outgoing fluids are continuously recorded.

Initial visual inspection at the transparent glass section installed immediately downstream of the liquid flow meter revealed two-phase flow transfer. Because the transfer line was designed for liquid flow, it was concluded that severe heat leak outside the cryostat, due possibly to instrumentation boss penetrations, do not permit the use of a liquid flow meter. Cavitation would introduce very serious errors in the readings and damage the instrument. Instead, the two-phase flow was rerouted to an alternate flow loop where a gas flow meter is used with a heat exchanger. This heat exchanger vaporizes all the liquid inside the transfer line and raises its temperature to nearly ambient conditions before feeding the gas to the downstream gas flow meter.

As hydrogen starts flowing through this gas flow meter, the middle region (annular space) which had been previously pressurized with gaseous hydrogen to permit heating of the solid periphery is vacuum pumped down to minimize any residual gas-controlled heat leak across the glass wall into the solid hydrogen. Concurrently, conditioned hydrogen gas is introduced into the cryostat and dumped over the top of the solid. The conditioned gas in contact with the cold solid causes the solid to melt into a round-nosed bullet-shaped surface; the liquid hydrogen produced during the melting-condensation process forms a thin liquid layer on the solid surface which runs down along the solid surface towards the bottom of the cryostat due to its own gravity and external pressure gradients.

During the melting period, mass and energy cross a fixed control volume. This control volume encompasses a region initially occupied by the solid hydrogen and its vapor. Mass and energy were monitored continuously at the boundary of this control volume. Mass flow rates were determined by monitoring the gas volume flow rate and its density simultaneously. Energy flow was determined by monitoring flow enthapies in and out of the control volume, in addition to the mass flow rates. Enthalpy measurements were made by recording fluid temperatures with thermocouples. In the event of two-phase flow transfer, temperature information alone is not sufficient to determine the flow of enthalpy. In such cases, the enthalpy of the flow is arrived at by the use of overall heat and mass balance equations. Assumptions of adiabatic control volume and no gas bypass of the liquid at the bottom of the cryostat were made for such cases.

The flow meters selected were of turbine transducer type with frequency output levels proportional to the volumetric flow rate. For purposes of recording, frequency was converted to D.C. voltage readings, using frequency-voltage converters, and the amplified voltage fed into a multi-channel strip chart recorder as shown in Appendix (A), 3d. Type E thermocouples were used at flow meter locations to correct flow measurements at temperatures other than those used for calibration and to measure flow enthalpy in and out of the cryostat. Amplified thermocouple outputs were fed into multi-channel strip chart recorders as shown in Appendix (A), 3b.

Calibrations of the Type E thermocouples and flow meters were performed by the manufacturers, but the data reduction later revealed that the air calibration curve of flow meter FM-3 was not good. This flow meter was recalibrated later by allowing a known amount of hydrogen flow through the flow meter. From the frequency reading it was possible to determine the calibration constant.

In each run of the melting experiments, the hot gas inlet temperature, the solid height, and the gas pressure over the solid were independently chosen to investigate their roles in the melting process.

4. EXPERIMENTAL RESULTS

The thermodynamic parameters which determine the performance of solid melting during liquid acquisition are formulated and cast in non-dimensional form. A convenient relationship among these parameters was developed for the purpose of organizing experimental results. The steps leading to such a relationship are presented in the analysis section.

A total of seventeen (17) melting runs were made; of these only fourteen (14) runs were selected (Tables X thru XXV and Figures 6 thru 8). Selection of runs was made on the basis of completeness of information. Because of instrumentation failures during particular runs, extrapolation of measurements were made with the help of mass and energy balance equations. From the tests, the effects of system gas pressure, temperature of entering hot hydrogen gas and the effect of height-to-diameter aspect ratio of the solid on its melting characteristics were determined.

The Dewar pressure level was varied from 2 to 6 PSIG, and the gas temperature was changed approximately from 865 to 336 degrees Rankine. Variation in the aspect ratio was achieved by changing the solid height in the SH_2 dewar while maintaining the diameter.

31

TABLE X SOLID H2 MELTING TEST DATA (RUN NO. = 1 --- INLET TO CONTROL VOLUME)

P= 34.7 PSIA,   FLOW TOTALIZER= 34121. CYCLES,   FOD= 5.0 HZ/DIV,   FGV= 120.0 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	Z VDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZAH (BTU/MN)	EMF25 (MIL.V)	TEM25 (DEG.R)
0	25.9	1.24	530.1	129.	1.07	0.9998	0.01232	0.0132					-3.87	364.9
5	27.4	1.23	529.8	137.	1.14	0.9998	0.01233	0.0140					-3.77	369.2
10	28.1	1.23	529.8	140.	1.17	0.9998	0.01233	0.0144					-3.64	374.4
15	28.6	1.23	529.8	143.	1.19	0.9998	0.01233	0.0146					-3.50	379.6
20	28.9	1.22	529.5	144.	1.20	0.9998	0.01233	0.0148					-3.41	382.7
25	28.6	1.21	529.2	143.	1.19	0.9998	0.01234	0.0147					-3.32	385.7
30	29.1	1.20	528.9	145.	1.21	0.9998	0.01235	0.0149					-3.24	388.3
35	30.1	1.19	528.6	150.	1.25	0.9998	0.01235	0.0154					-3.15	391.2
40	30.9	1.19	528.6	154.	1.28	0.9998	0.01235	0.0159					-3.07	393.7
45	29.8	1.19	528.6	149.	1.24	0.9998	0.01235	0.0153					-3.00	396.0
50	29.1	1.19	528.6	145.	1.21	0.9998	0.01235	0.0149					-2.90	399.1
55	28.9	1.19	528.6	144.	1.20	0.9998	0.01235	0.0148					-2.80	402.3
60	28.5	1.19	528.6	142.	1.18	0.9998	0.01235	0.0146					-2.73	404.5
65	28.1	1.19	528.6	140.	1.17	0.9998	0.01235	0.0144					-2.65	407.1
70	28.5	1.19	528.6	142.	1.18	0.9998	0.01235	0.0146					-2.60	408.8
75	31.3	1.19	528.6	156.	1.30	0.9998	0.01235	0.0161					-2.55	410.4
80	42.6	1.19	528.6	213.	1.77	0.9998	0.01235	0.0219					-2.45	413.0
85	42.6	1.19	528.6	213.	1.77	0.9998	0.01235	0.0219					-2.35	417.1
90	42.3	1.19	528.6	211.	1.76	0.9998	0.01235	0.0217					-2.32	418.1
95	42.3	1.12	526.5	211.	1.76	0.9997	0.01240	0.0218					-2.30	418.0
100	42.4	1.11	526.2	212.	1.76	0.9997	0.01241	0.0219					-2.15	424.0
105	42.4	1.10	525.9	212.	1.76	0.9997	0.01242	0.0219					-1.95	430.6
110	39.9	1.08	525.3	199.	1.66	0.9997	0.01243	0.0206					-1.92	431.0
115	44.1	1.07	525.0	220.	1.83	0.9997	0.01244	0.0228					-1.86	433.
120	60.6	1.06	524.7	303.	2.52	0.9997	0.01244	0.0314					-1.81	435.3
125	58.6	1.06	524.7	293.	2.44	0.9997	0.01244	0.0303					-1.73	437.9
130	56.8	1.03	523.8	284.	2.36	0.9997	0.01247	0.0295					-1.62	441.3
135	53.9	1.00	523.0	269.	2.24	0.9996	0.01249	0.0280					-1.50	445.4
140	58.8	0.98	522.3	294.	2.44	0.9996	0.01250	0.0306					-1.40	448.5
145	59.1	0.97	522.0	295.	2.46	0.9996	0.01251	0.0308					-1.30	451.7
150	56.0	0.96	521.7	280.	2.33	0.9996	0.01252	0.0292					-1.13	456.9
155	48.8	0.96	521.7	244.	2.03	0.9996	0.01252	0.0254					-0.95	462.3
160	32.1	0.94	521.1	160.	1.33	0.9996	0.01253	0.167					-0.84	465.7
165	23.8	0.92	521.5	119.	0.99	0.9996	0.01254	0.0124					-0.72	469.3
170	19.8	0.92	521.5	99.	0.82	0.9996	0.01254	0.0103					-0.50	474.3
175	14.6	0.91	520.2	73.	0.60	0.9995	0.01255	0.0076					-0.50	476.3
180	10.0	0.91	520.2	50.	0.41	0.9996	0.01255	0.0052					-0.31	480.4
185	0.0	0.92	520.5	0.	0.00	0.9996	0.01254	0.0000					-0.25	484.1

TOTAL NO. OF CYCLES (INTEGRATED) = 33508.671 CYCLES,   TOTAL MASS (INTEGRATED) = 0.056 LBS
TOTAL NO. OF CYCLES (MEASURED) = 34121.007 CYCLES,   TOTAL ENTHALPY(INTEGRATED) = BTU
AVERAGE ENTHALPY OF FLO   =   BTU/LB

TABLE X   SOLID H2 MELTING TEST DATA (RUN NO. = 1 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 196069. CYCLES,   FQD= 20.0 HZ/DIV,   FCV= 7.95 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMP (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZVDT (LB/MN)	EMFH (MIL.V)	TE ~ (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	5.0	2.17	556.7	100.	12.56	1.0003	0.00497	0.0624	0.44	505.5	1682.8	105.11
5	3.0	2.15	556.2	60.	7.53	1.0002	0.00497	0.0375	-0.12	490.2	1613.4	60.53
10	5.4	2.13	555.6	108.	13.56	1.0002	0.00498	0.0675	-0.73	470.1	1545.7	104.40
15	10.0	2.10	554.8	200.	25.12	1.0002	0.00498	0.1253	-1.04	459.7	1510.0	189.31
20	22.0	2.04	553.1	440.	55.27	1.0002	0.00500	0.2766	-1.38	449.2	1476.5	408.48
25	32.5	1.98	551.4	650.	81.65	1.0002	0.00501	0.4099	-1.44	447.3	1470.7	602.60
30	34.0	1.96	550.9	680.	85.42	1.0002	0.00502	0.4292	-1.50	445.4	1464.8	628.84
35	34.0	1.92	549.7	680.	85.42	1.0001	0.00503	0.4301	-1.57	443.1	1456.3	627.16
40	33.8	1.88	548.5	676.	84.92	1.0001	0.00504	0.4284	-1.64	440.9	1451.3	621.77
45	34.0	1.83	547.1	680.	85.42	1.0001	0.00505	0.4321	-1.57	433.3	1427.4	616.84
50	36.8	1.77	545.4	736.	92.46	1.0001	0.00507	0.4691	-2.10	425.6	1401.7	657.66
55	39.0	1.70	543.4	780.	97.98	1.0000	0.00509	0.4990	-2.26	420.2	1382.2	689.81
60	40.0	1.64	541.7	816.	102.51	1.0000	0.00510	0.5237	-2.42	414.3	1361.4	712.99
65	41.0	1.58	540.0	820.	103.01	1.0000	0.00512	0.5279	-2.70	405.5	1321.8	697.66
70	39.2	1.50	537.7	784.	98.49	0.9999	0.00514	0.5069	-2.98	396.0	1279.7	648.69
75	38.1	1.42	535.4	762.	95.72	0.9999	0.00516	0.4947	-3.28	387.0	1232.5	609.87
80	38.5	1.34	533.0	770.	96.73	0.9998	0.00519	0.5021	-3.58	376.7	1184.4	594.25
85	39.8	1.25	530.6	796.	100.00	0.9998	0.00521	0.5216	-3.62	375.2	1176.0	613.90
90	45.4	1.17	528.0	908.	114.07	0.9997	0.00524	0.5977	-3.65	374.0	1171.8	700.45
95	49.4	1.08	525.3	988.	124.12	0.9997	0.00526	0.6536	-3.90	363.6	1133.4	740.86
100	49.2	0.97	522.0	984.	123.61	0.9996	0.00530	0.6550	-4.15	351.7	1106.4	724.79
105	47.2	0.85	518.4	944.	119.59	0.9996	0.00533	0.6328	-4.17	350.7	1104.9	699.24
110	45.5	0.76	515.7	910.	114.32	0.9995	0.00536	0.6132	-4.20	349.2	1105.0	676.40
115	44.0	0.67	512.9	880.	110.55	0.9995	0.00539	0.5961	-4.17	350.7	1104.9	656.77
120	42.8	0.58	510.1	856.	107.53	0.9994	0.00542	0.5830	-4.15	351.7	1106.4	645.10
125	41.8	0.49	507.3	836.	105.02	0.9994	0.00545	0.5725	-4.16	351.2	1105.6	633.05
130	40.9	0.39	504.2	816.	102.51	0.9993	0.00548	0.5622	-4.18	350.2	1104.2	620.91
135	41.0	0.28	500.9	820.	103.01	0.9993	0.00552	0.5668	-4.19	347.7	1103.6	627.04
140	46.0	0.20	498.2	920.	115.57	0.9992	0.00555	0.6414	-4.21	348.7	1102.3	707.13
145	50.0	0.12	495.7	1000.	125.62	0.9992	0.00558	0.7007	-4.20	349.2	1103.0	772.92
150	42.0	0.02	492.6	840.	105.52	0.9991	0.00561	0.5923	-4.19	349.7	1103.6	653.74
155	40.8	-0.08	489.4	816.	102.51	0.9990	0.00565	0.5790	-4.19	349.7	1103.6	639.11
160	40.4	-0.20	485.7	808.	101.51	0.9990	0.00569	0.5778	-4.20	349.2	1103.0	637.34
165	40.2	-0.31	482.2	804.	101.00	0.9989	0.00573	0.5790	-4.20	349.2	1103.0	638.67
170	40.8	-0.45	477.9	816.	102.51	0.9988	0.00579	0.5929	-4.21	348.7	1102.3	653.70
175	40.0	-0.59	473.8	800.	100.50	0.9988	0.00584	0.5862	-4.16	351.2	1105.6	648.20
180	40.0	-0.74	468.9	800.	100.50	0.9987	0.00590	0.5923	-4.16	354.1	1110.5	657.63
185	39.0	-0.90	464.0	780.	97.99	0.9986	0.00596	0.5835	-4.15	351.7	1106.4	645.70
190	39.0	-1.05	459.4	780.	97.99	0.9985	0.00602	0.5893	-4.20	349.2	1103.0	650.10
195	39.8	-1.20	454.8	796.	100.00	0.9984	0.00610	0.6075	-4.20	349.2	1103.0	670.13
200	40.5	-1.35	450.1	810.	101.75	0.9983	0.00614	0.6246	-4.20	349.2	1103.0	688.94
205	40.0	-1.50	445.4	800.	100.50	0.9983	0.00621	0.6234	-4.20	349.2	1103.0	687.62
210	39.5	-1.67	439.9	790.	99.24	0.9982	0.00629	0.6232	-4.20	347.2	1103.0	687.44
215	38.1	-1.85	434.0	762.	95.72	0.9981	0.00637	0.6092	-4.20	349.2	1103.0	672.02
220	39.0	-2.03	427.9	790.	97.99	0.9979	0.00646	0.6323	-4.20	349.2	1103.	697.51
225	38.6	-2.20	422.2	776.	97.48	0.9978	0.00655	0.6376	-4.21	348.7	1102.3	702.96
230	39.6	-2.33	417.8	792.	99.49	0.9978	0.00662	0.6575	-4.21	348.2	1102.3	724.90
235	38.8	-2.55	410.4	776.	97.48	0.9976	0.00674	0.6557	-4.22	348.2	1101.8	722.52
240	21.0	-2.75	403.9	420.	52.76	0.9975	0.00685	0.3606	-4.23	347.7	1101.2	397.13
245	22.5	-2.94	397.3	450.	56.53	0.9974	0.00695	0.3922	-4.22	348.2	1101.8	432.15
250	26.5	-2.97	396.9	530.	66.58	0.9974	0.00697	0.4630	-4.22	348.2	1101.8	510.10
255	27.4	-3.00	396.0	548.	68.84	0.9974	0.00698	0.4798	-4.22	348.2	1101.8	528.70
260	27.0	-3.06	394.1	540.	67.83	0.9973	0.00702	0.4751	-4.21	349.7	1102.3	523.79
265	26.8	-3.12	392.2	536.	67.33	0.9973	0.00705	0.4738	-4.21	348.7	1102.3	522.71
270	23.8	-3.21	389.3	476.	59.79	0.9972	0.00710	0.4439	-4.20	347.2	1102.	489.31
275	18.6	-3.30	386.4	372.	46.73	0.9972	0.00716	0.3337	-4.15	354.1	1110.5	370.60
280	10.4	-3.37	384.1	208.	26.13	0.9971	0.00720	0.1877	-3.99	359.4	1121.8	210.62
285	0.0	-3.45	381.3	0.	0.00	0.9971	0.00725	0.0000	-3.95	361.3	1126.7	0.00

TOTAL NO. OF CYCLES (INTEGRATED) = 199779.417 CYCLES,   TOTAL MASS (INTEGRATED) = 2.352 LBS

TOTAL NO. OF CYCLES (MEASURED) = 196069.31 CYCLES,   TOTAL ENTHALPY (INTEGRATED) = 2744.327 BTU

AVERAGE ENTHALPY OF FLOW = 1166.325 BTU/LB

TABLE XI   SOLID H2 MELTING TEST DATA (RUN NO. = 2 --- INLET TO CONTROL VOLUME)

P= 34.7 PSIA,   FLOW TOTALIZER= 90940. CYCLES,   FOO= 5.0 HZ/DIV,   FOV= 120.0 HZ/CFM

TIME (SEC)	OF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FO (HZ)	VOT (CFM)	C (---)	RHO (LB/FT3)	ZMOT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)	EMF2S (MIL.V)	TEM2S (DEG.R)
0	11.3	1.11	526.2	56.	0.47	0.9997	0.01241	0.0058					-5.50	302.0
5	22.6	1.11	526.2	113.	0.94	0.9997	0.01241	0.0116					-5.40	306.6
10	33.8	1.12	526.5	169.	1.40	0.9997	0.01240	0.0174					-5.30	310.4
15	33.2	1.12	526.5	166.	1.38	0.9997	0.01240	0.0171					-5.20	314.5
20	32.7	1.13	526.8	163.	1.36	0.9997	0.01239	0.0168					-5.10	318.3
25	32.2	1.14	527.1	161.	1.34	0.9997	0.01239	0.0166					-5.00	322.0
30	31.6	1.15	527.4	158.	1.31	0.9997	0.01238	0.0163					-4.90	326.5
35	31.0	1.15	527.4	155.	1.29	0.9997	0.01238	0.0159					-4.80	326.9
40	30.5	1.15	527.4	152.	1.27	0.9997	0.01238	0.0157					-4.70	332.5
45	32.3	1.15	527.4	161.	1.34	0.9997	0.01238	0.0166					-4.60	336.4
50	34.1	1.16	527.7	170.	1.42	0.9997	0.01237	0.0175					-4.50	341.0
55	36.0	1.16	527.7	180.	1.50	0.9997	0.01237	0.0185					-4.40	346.1
60	46.4	1.15	527.4	232.	1.93	0.9997	0.01238	0.0239					-4.30	351.6
65	56.8	1.15	527.4	284.	2.36	0.9997	0.01238	0.0293					-4.20	357.2
70	67.1	1.14	527.1	335.	2.79	0.9997	0.01239	0.0346					-4.10	360.0
75	67.4	1.13	526.8	337.	2.80	0.9997	0.01239	0.0348					-4.00	359.0
80	67.7	1.10	525.9	338.	2.82	0.9997	0.01242	0.0350					-3.90	363.6
85	68.1	1.07	525.0	340.	2.83	0.9997	0.01244	0.0352					-3.80	367.9
90	67.8	1.04	524.1	339.	2.82	0.9997	0.01246	0.0351					-3.70	372.1
95	67.4	1.01	523.2	337.	2.80	0.9997	0.01248	0.0350					-3.60	375.9
100	67.0	0.99	522.6	335.	2.79	0.9996	0.01249	0.0348					-3.50	379.6
105	65.8	0.97	522.0	329.	2.74	0.9996	0.01251	0.0342					-3.40	383.1
110	64.5	0.95	521.4	322.	2.68	0.9996	0.01252	0.0336					-3.40	383.5
115	63.2	0.94	521.1	316.	2.63	0.9996	0.01253	0.0329					-3.30	386.4
120	61.9	0.93	520.8	309.	2.57	0.9996	0.01254	0.0323					-3.20	389.6
125	60.7	0.92	520.5	303.	2.52	0.9996	0.01254	0.0317					-3.20	389.6
130	59.5	0.91	520.2	297.	2.47	0.9996	0.01255	0.0311					-3.10	392.8
135	58.4	0.90	519.9	292.	2.43	0.9996	0.01256	0.0305					-3.00	396.0
140	57.3	0.90	519.9	286.	2.38	0.9996	0.01256	0.0299					-3.00	396.0
145	56.2	0.89	519.6	281.	2.34	0.9996	0.01257	0.0294					-2.90	399.1
150	55.8	0.88	519.3	279.	2.32	0.9996	0.01257	0.0292					-2.80	402.3
155	55.4	0.88	519.3	277.	2.30	0.9996	0.01257	0.0290					-2.70	405.5
160	55.0	0.88	519.3	275.	2.29	0.9996	0.01257	0.0288					-2.70	405.5
165	54.9	0.89	519.6	274.	2.28	0.9996	0.01257	0.0287					-2.60	408.6
170	54.7	0.89	519.6	273.	2.27	0.9996	0.01257	0.0286					-2.50	412.1
175	54.5	0.90	519.9	272.	2.27	0.9996	0.01256	0.0285					-2.40	415.4
180	55.2	0.91	520.2	276.	2.29	0.9996	0.01255	0.0288					-2.30	416.8
185	55.9	0.93	520.5	279.	2.32	0.9996	0.01254	0.0292					-2.30	418.8
190	56.7	0.95	521.4	283.	2.36	0.9996	0.01252	0.0295					-2.20	422.2
195	58.1	0.97	522.0	290.	2.42	0.9996	0.01251	0.0302					-2.10	425.6
200	59.5	0.98	522.3	297.	2.47	0.9996	0.01250	0.0309					-2.10	425.6
205	60.8	1.00	523.0	304.	2.53	0.9996	0.01249	0.0316					-2.00	429.0
210	69.7	1.02	523.5	348.	2.90	0.9997	0.01247	0.0362					-1.90	432.3
215	78.6	1.04	524.1	393.	3.27	0.9997	0.01246	0.0408					-1.80	435.6
220	87.6	1.04	524.1	438.	3.64	0.9997	0.01246	0.0454					-1.80	435.6
225	86.8	1.05	524.4	434.	3.61	0.9997	0.01245	0.0450					-1.70	438.9
230	86.2	1.05	524.4	431.	3.59	0.9997	0.01245	0.0447					-1.70	438.9
235	85.6	1.06	524.7	428.	3.56	0.9997	0.01244	0.0443					-1.60	442.2
240	85.3	1.06	524.7	426.	3.55	0.9997	0.01244	0.0442					-1.60	442.2
245	85.1	1.05	524.4	425.	3.54	0.9997	0.01245	0.0441					-1.50	445.4
250	84.8	1.05	524.4	424.	3.53	0.9997	0.01245	0.0439					-1.50	445.4
255	84.7	1.04	524.1	423.	3.52	0.9997	0.01246	0.0439					-1.40	448.5
260	84.6	1.04	524.1	423.	3.52	0.9997	0.01246	0.0439					-1.40	448.5
265	84.4	1.04	524.1	422.	3.51	0.9997	0.01246	0.0438					-1.30	451.7
270	84.0	1.04	524.1	420.	3.50	0.9997	0.01246	0.0436					-1.30	451.7
275	83.7	1.04	524.1	418.	3.48	0.9997	0.01246	0.0434					-1.20	454.8
280	83.4	1.06	524.7	417.	3.47	0.9997	0.01244	0.0432					-1.10	457.9
285	83.0	1.08	525.3	415.	3.45	0.9997	0.01243	0.0429					-1.00	461.0
290	82.5	1.08	525.3	412.	3.43	0.9997	0.01243	0.0427					-0.99	461.3
295	82.0	1.10	525.9	410.	3.41	0.9997	0.01242	0.0424					-0.97	461.9
300	54.0	1.08	525.3	270.	2.25	0.9997	0.01243	0.0279					-0.93	463.1
305	27.0	1.06	524.7	135.	1.12	0.9997	0.01244	0.0140					-0.90	464.0
310	0.0	1.04	524.1	0.	0.00	0.9997	0.01246	0.0000					-0.86	465.2

TOTAL NO. OF CYCLES (INTEGRATED) = 93458.468 CYCLES,   TOTAL MASS (INTEGRATED) = 0.157 LBS

TOTAL NO. OF CYCLES (MEASURED) = 90940.015 CYCLES,   TOTAL ENTHALPY(INTEGRATED) = _____ BTU

AVERAGE ENTHALPY OF FLOW = _____ BTU/LB

TABLE XI SOLID H2 MELTING TEST DATA (RUN NO. = 2 --- OUTLET FROM
CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 156742. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	1.50	537.7	0.	0.0	1.0000	0.00515	0.0	1.25	530.4	1774.2	0.0
5	5.8	1.47	536.9	116.	14.57	0.9999	0.00516	0.0751	0.76	516.3	1723.1	129.45
10	11.7	1.45	536.3	234.	29.40	0.9999	0.00516	0.1517	0.31	501.7	1666.9	252.87
15	17.5	1.43	535.7	350.	43.97	0.9999	0.00517	0.2271	-0.15	487.3	1609.8	365.66
20	26.3	1.40	534.8	526.	66.08	0.9999	0.00517	0.3419	-0.62	472.7	1554.5	531.52
25	35.1	1.38	534.2	702.	88.19	0.9999	0.00518	0.4568	-0.87	465.0	1527.5	697.80
30	44.0	1.35	533.4	880.	110.55	0.9999	0.00519	0.5736	-1.12	457.3	1502.0	861.55
35	44.3	1.32	532.5	886.	111.31	0.9999	0.00520	0.5784	-1.17	455.8	1497.1	865.98
40	44.6	1.30	531.9	892.	112.06	0.9999	0.00520	0.5830	-1.23	453.9	1491.2	869.35
45	45.0	1.25	530.4	900.	113.07	0.9998	0.00522	0.5898	-1.41	448.3	1473.6	869.19
50	44.9	1.20	529.0	898.	112.81	0.9998	0.00523	0.5902	-1.60	442.2	1455.0	858.68
55	44.7	1.15	527.5	894.	112.31	0.9998	0.00525	0.5892	-1.77	436.7	1437.9	847.12
60	44.5	1.10	526.0	890.	111.81	0.9998	0.00526	0.5882	-1.95	430.7	1418.7	834.45
65	45.3	1.03	523.9	904.	113.82	0.9997	0.00528	0.6011	-2.35	417.2	1370.7	823.94
70	46.1	0.97	522.1	922.	115.83	0.9997	0.00530	0.6138	-2.75	403.9	1314.5	806.86
75	47.0	0.91	520.3	940.	118.09	0.9997	0.00532	0.6280	-2.90	399.2	1291.9	811.27
80	47.3	0.85	518.5	946.	118.84	0.9996	0.00534	0.6342	-3.05	394.4	1268.8	804.65
85	47.6	0.76	515.7	952.	119.60	0.9996	0.00537	0.6415	-3.15	391.3	1253.2	803.98
90	48.0	0.69	513.6	960.	120.60	0.9995	0.00539	0.6496	-3.29	388.1	1237.4	803.81
95	45.7	0.62	511.4	914.	114.82	0.9995	0.00541	0.6211	-3.45	381.4	1204.9	748.31
100	43.6	0.55	509.2	872.	109.55	0.9995	0.00543	0.5950	-3.65	374.1	1171.8	697.29
105	41.5	0.48	507.1	830.	104.27	0.9994	0.00546	0.5688	-3.67	373.3	1168.6	664.67
110	41.7	0.40	504.6	834.	104.77	0.9994	0.00549	0.5743	-3.70	372.1	1163.7	668.37
115	41.9	0.32	502.1	838.	105.28	0.9993	0.00551	0.5799	-3.89	364.1	1134.8	658.11
120	42.0	0.25	499.9	840.	105.53	0.9993	0.00554	0.5839	-4.08	355.1	1112.3	649.42
125	43.1	0.15	496.7	862.	108.29	0.9992	0.00557	0.6029	-4.04	357.1	1116.3	673.02
130	44.2	0.05	493.6	884.	111.06	0.9992	0.00561	0.6222	-4.00	357.0	1120.7	697.32
135	45.5	-0.02	491.4	910.	114.32	0.9991	0.00563	0.6434	-4.00	359.0	1120.7	721.03
140	45.8	-0.10	488.8	916.	115.08	0.9991	0.00566	0.6509	-4.00	359.0	1120.7	729.48
145	46.1	-0.20	485.7	922.	115.83	0.9990	0.00570	0.6594	-3.97	360.4	1124.3	741.31
150	46.5	-0.30	482.6	930.	116.83	0.9990	0.00573	0.6694	-3.95	361.3	1126.8	754.22
155	45.7	-0.40	479.5	914.	114.82	0.9989	0.00577	0.6621	-3.92	362.7	1130.7	748.61
160	45.1	-0.50	476.4	902.	113.32	0.9989	0.00581	0.6576	-3.90	363.6	1133.4	745.32
165	44.5	-0.65	471.7	890.	111.81	0.9988	0.00587	0.6562	-3.90	363.6	1133.4	742.56
170	44.7	-0.80	467.1	894.	112.31	0.9987	0.00592	0.6645	-3.90	363.6	1133.4	753.19
175	44.1	-0.95	462.5	882.	110.80	0.9986	0.00598	0.6621	-3.85	365.8	1140.5	755.09
180	43.5	-1.10	457.9	870.	109.30	0.9985	0.00604	0.6595	-3.80	368.0	1147.9	757.17
185	30.6	-1.25	453.3	612.	76.88	0.9984	0.00611	0.4687	-3.77	369.2	1152.5	540.20
190	17.8	-1.40	448.6	356.	44.72	0.9984	0.00617	0.2755	-3.75	370.1	1155.7	318.37
195	5.0	-1.55	443.8	100.	12.56	0.9983	0.00624	0.0782	-3.75	370.1	1155.7	90.38
200	4.0	-1.70	439.0	80.	10.05	0.9982	0.00630	0.0633	-3.75	370.1	1155.7	73.10
205	3.0	-1.87	433.3	60.	7.54	0.9981	0.00639	0.0480	-3.73	370.9	1158.8	55.68
210	2.0	-2.05	427.3	40.	5.03	0.9980	0.00648	0.0325	-3.72	371.3	1160.5	37.69
215	4.2	-2.22	421.6	84.	10.55	0.9979	0.00657	0.0691	-3.71	371.7	1162.2	80.34
220	6.3	-2.40	415.5	126.	15.83	0.9978	0.00666	0.1052	-3.70	372.1	1163.7	122.43
225	8.5	-2.56	410.1	170.	21.36	0.9977	0.00675	0.1438	-3.70	372.1	1163.7	167.32
230	10.0	-2.73	404.6	200.	25.13	0.9975	0.00684	0.1715	-3.70	372.1	1163.7	199.52
235	11.5	-2.86	400.4	230.	28.89	0.9975	0.00691	0.1992	-3.70	372.1	1163.7	231.82
240	13.0	-3.00	396.0	260.	32.66	0.9974	0.00699	0.2277	-3.70	372.1	1163.7	264.97
245	11.5	-3.14	391.6	230.	28.89	0.9973	0.00707	0.2037	-3.72	371.3	1160.5	236.36
250	10.0	-3.28	387.1	200.	25.13	0.9973	0.00715	0.1791	-3.75	370.1	1155.7	207.04
255	8.5	-3.39	383.4	170.	21.36	0.9972	0.00722	0.1537	-3.82	367.1	1144.9	175.99
260	5.6	-3.50	379.6	112.	14.07	0.9971	0.00729	0.1023	-3.90	363.6	1133.4	115.92
265	2.8	-3.50	379.6	56.	7.04	0.9971	0.00729	0.0511	-3.88	364.5	1136.2	58.10
270	0.0	-3.50	379.6	0.	0.0	0.9971	0.00729	0.0	-3.85	365.8	1140.5	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 163919.500 CYCLES,   TOTAL MASS   (INTEGRATED) =   1.834 LBS
TOTAL NO. OF CYCLES (MEASURED) = 156742.000 CYCLES,   TOTAL ENTHALPY(INTEGRATED) =2288.359 BTU
AVERAGE ENTHALPY OF FLOW   =   1247.634 BTU/LB

TABLE XII SOLID H$_2$ MELTING TEST DATA

(RUN. NO. = 3, INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0				-8.30	200				-7.20
5					205				
10				-8.25	210				-6.90
15					215				
20				-8.10	220				-6.40
25				.	225				
30				-8.05	230				-6.20
35					235				
40				-8.00	240				-6.20
45					245				
50				-7.95	250				-6.10
55					255				
60				-7.95	260				-6.10
65					265				
70				-7.93	270				-6.00
75					275				
80				-7.91	280				-6.00
85					285				
90				-7.90	290				-6.00
95					295				
100				-7.90	300				-5.95
105					305				
110				-7.94	310				-5.93
115					315				
120				-7.94	320				-5.45
125					325				
130				-7.80	330				-5.78
135					335				
140				-7.30	340				-5.75
145					345				
150				-7.30	350				-5.40
155					355				
160				-7.23	360				-5.20
165					365				
170				-7.20	370				-5.10
175					375				
180				-7.20	380				-5.25
185					385				
190				-7.20	390				-5.20
195					395				

36

TABLE XII (Cont.)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
400				-5.00	600				-3.30
405					605				
410				-4.75	610				-2.70
415					615				
420				-4.55	620				-2.90
425				.	625				
430				-4.45	630				-3.24
435					635				
440				-4.35	640				-3.10
445					645				
450				-4.45	650				-3.10
455					655				
460				-4.25	660				-3.15
465					665				-3.15
470				-4.25	670				
475									
480				-4.20					
485									
490				-3.90					
495									
500				-3.70					
505									
510				-3.65					
515									
520				-3.65					
525									
530				-3.60					
535									
540				-3.60					
545									
550				-3.55					
555									
560				-3.55					
565									
570				-3.53					
575									
580				-3.45					
585									
590				-3.40					
595									

TABLE XII   SOLID H2 MELTING TEST DATA (RUN NO. = 3 --- OUTLET FROM CONTROL VOLUME)
(Cont.)

P= 14.7 PSIA,   FLOW TOTALIZER= 200429. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	1.10	526.0	0.	0.0	0.9998	0.00526	0.0	0.65	512.3	1708.0	0.0
5	5.0	1.07	525.1	100.	12.56	0.9997	0.00527	0.0662	-0.08	489.5	1618.4	107.13
10	7.9	1.05	524.5	158.	19.85	0.9997	0.00528	0.1047	-0.80	467.1	1534.9	160.72
15	5.8	1.03	523.9	116.	14.57	0.9997	0.00528	0.0770	-0.85	465.6	1529.6	117.72
20	7.0	1.02	523.6	140.	17.59	0.9997	0.00529	0.0929	-0.90	464.1	1524.4	141.67
25	10.8	1.01	523.3	216.	27.14	0.9997	0.00529	0.1435	-0.95	462.5	1519.2	217.96
30	14.0	1.00	523.0	280.	35.18	0.9997	0.00529	0.1861	-1.00	461.0	1514.1	281.76
35	17.4	0.98	522.4	348.	43.72	0.9997	0.00530	0.2315	-1.10	457.9	1504.0	348.25
40	20.0	0.95	521.5	400.	50.25	0.9997	0.00531	0.2666	-1.20	454.8	1494.1	398.34
45	21.4	0.95	521.5	428.	53.77	0.9997	0.00531	0.2853	-1.32	451.1	1482.4	422.87
50	20.0	0.95	521.5	400.	50.25	0.9997	0.00531	0.2666	-1.45	447.0	1469.7	391.83
55	18.2	0.95	521.5	364.	45.73	0.9997	0.00531	0.2426	-1.55	443.8	1459.9	354.19
60	15.7	0.95	521.5	314.	39.45	0.9997	0.00531	0.2093	-1.65	440.6	1450.0	303.46
65	12.5	0.95	521.5	250.	31.41	0.9997	0.00531	0.1666	-1.75	437.3	1439.9	239.93
70	9.2	0.95	521.5	184.	23.12	0.9997	0.00531	0.1226	-1.85	434.0	1429.5	175.31
75	4.9	0.95	521.5	98.	12.31	0.9997	0.00531	0.0653	-1.91	432.0	1423.1	92.95
80	3.0	0.95	521.5	60.	7.54	0.9997	0.00531	0.0400	-1.96	430.3	1417.6	56.69
85	2.2	0.95	521.5	44.	5.53	0.9997	0.00531	0.0293	-2.07	426.6	1405.2	41.21
90	2.2	0.95	521.5	44.	5.53	0.9997	0.00531	0.0293	-2.17	423.3	1393.4	40.86
95	2.1	0.95	521.5	42.	5.28	0.9997	0.00531	0.0280	-2.26	420.2	1382.3	38.69
100	2.0	0.95	521.5	40.	5.03	0.9997	0.00531	0.0267	-2.35	417.2	1370.7	36.54
105	1.8	0.93	520.9	36.	4.52	0.9997	0.00531	0.0240	-2.49	412.5	1351.9	32.47
110	2.4	0.90	520.0	48.	6.03	0.9996	0.00532	0.0321	-2.62	408.2	1333.5	42.78
115	2.3	0.90	520.0	46.	5.78	0.9996	0.00532	0.0307	-2.68	406.2	1324.8	40.73
120	2.5	0.90	520.0	50.	6.28	0.9996	0.00532	0.0334	-2.75	403.9	1314.5	43.93
125	12.0	0.90	520.0	240.	30.15	0.9996	0.00532	0.1604	-2.68	406.2	1324.8	212.53
130	24.0	0.90	520.0	480.	60.30	0.9996	0.00532	0.3208	-2.62	408.2	1333.5	427.85
135	27.5	0.90	520.0	550.	69.10	0.9996	0.00532	0.3676	-2.66	406.9	1327.7	488.11
140	34.6	0.90	520.0	692.	86.93	0.9996	0.00532	0.4625	-2.70	405.6	1321.9	611.42
145	32.0	0.90	520.0	640.	80.40	0.9996	0.00532	0.4278	-2.80	402.3	1307.1	559.15
150	23.2	0.80	516.9	464.	58.29	0.9996	0.00535	0.3120	-2.90	399.2	1291.9	403.02
155	22.5	0.80	516.9	450.	56.53	0.9996	0.00535	0.3025	-2.85	400.7	1299.5	393.16
160	22.5	0.80	516.9	450.	56.53	0.9996	0.00535	0.3025	-2.80	402.3	1307.1	395.44
165	20.7	0.80	516.9	414.	52.01	0.9996	0.00535	0.2783	-2.80	402.3	1307.1	363.80
170	18.7	0.80	516.9	374.	46.98	0.9996	0.00535	0.2514	-2.80	402.3	1307.1	328.65
175	17.5	0.80	516.9	350.	43.97	0.9996	0.00535	0.2353	-2.87	400.1	1296.5	305.08
180	17.0	0.80	516.9	340.	42.71	0.9996	0.00535	0.2286	-2.95	397.6	1284.3	293.57
185	15.8	0.78	516.3	316.	39.70	0.9996	0.00536	0.2127	-3.03	395.0	1271.9	270.54
190	14.1	0.75	515.4	282.	35.43	0.9996	0.00537	0.1901	-3.10	392.8	1261.1	239.79
195	14.7	0.75	515.4	294.	36.93	0.9996	0.00537	0.1982	-3.16	390.9	1251.6	248.12
200	15.3	0.75	515.4	306.	38.44	0.9996	0.00537	0.2063	-3.23	388.7	1240.5	255.96
205	17.7	0.72	514.5	354.	44.47	0.9995	0.00538	0.2391	-3.16	390.9	1251.6	299.29
210	20.2	0.70	513.9	404.	50.75	0.9995	0.00539	0.2732	-3.10	392.8	1261.1	344.54
215	21.3	0.67	513.0	426.	53.52	0.9995	0.00540	0.2886	-3.00	396.0	1276.6	368.45
220	22.0	0.65	512.3	440.	55.28	0.9995	0.00540	0.2985	-2.90	399.2	1291.9	385.58

38

225	22.0	0.63	511.7	440.	55.28	0.9995	0.00541	0.2988	-2.90	399.2	1291.9	386.04
230	21.9	0.60	510.8	438.	55.03	0.9995	0.00542	0.2980	-2.90	399.2	1291.9	384.97
235	21.7	0.58	510.2	434.	54.52	0.9995	0.00542	0.2956	-2.90	399.2	1291.9	381.92
240	21.2	0.55	509.2	424.	53.27	0.9995	0.00543	0.2893	-2.90	399.2	1291.9	373.79
245	22.0	0.53	508.6	440.	55.28	0.9994	0.00544	0.3006	-2.93	398.2	1287.4	386.99
250	22.0	0.50	507.7	440.	55.28	0.9994	0.00545	0.3012	-2.95	397.6	1284.3	386.77
255	22.3	0.48	507.1	446.	56.03	0.9994	0.00546	0.3056	-2.98	396.6	1279.7	391.12
260	22.8	0.45	506.1	456.	57.29	0.9994	0.00547	0.3131	-3.00	396.0	1276.6	399.66
265	22.3	0.43	505.5	446.	56.03	0.9994	0.00547	0.3066	-3.00	396.0	1276.6	391.38
270	21.4	0.40	504.6	428.	53.77	0.9994	0.00549	0.2947	-3.00	396.0	1276.6	376.27
275	21.1	0.35	503.0	422.	53.02	0.9993	0.00550	0.2915	-3.05	394.4	1268.8	369.87
280	20.5	0.30	501.4	410.	51.51	0.9993	0.00552	0.2841	-3.10	392.8	1261.1	358.26
285	20.0	0.28	500.8	400.	50.25	0.9993	0.00553	0.2775	-3.20	289.7	1245.3	345.58
290	19.4	0.25	499.9	388.	48.74	0.9993	0.00554	0.2697	-3.30	386.4	1229.3	331.52
295	18.9	0.23	499.2	378.	47.49	0.9993	0.00554	0.2631	-3.33	385.5	1224.5	322.12
300	19.5	0.20	498.3	390.	48.99	0.9993	0.00555	0.2719	-3.35	384.8	1221.2	332.08
305	19.5	0.17	497.3	390.	48.99	0.9992	0.00556	0.2724	-3.47	380.7	1201.6	327.34
310	19.4	0.14	496.4	388.	48.74	0.9992	0.00558	0.2715	-3.60	376.0	1180.1	320.45
315	20.5	0.09	494.8	410.	51.51	0.9992	0.00559	0.2879	-3.60	376.0	1180.1	339.68
320	24.0	0.04	493.3	480.	60.30	0.9992	0.00561	0.3381	-3.60	376.0	1180.1	398.94
325	23.2	-0.03	491.0	464.	58.29	0.9991	0.00564	0.3282	-3.55	377.8	1188.3	390.07
330	22.5	-0.10	488.8	450.	56.53	0.9991	0.00566	0.3198	-3.50	379.6	1196.6	382.64
335	20.8	-0.11	488.5	416.	52.26	0.9991	0.00567	0.2958	-3.60	376.0	1180.1	349.06
340	21.0	-0.12	488.2	420.	52.76	0.9991	0.00567	0.2988	-3.70	372.1	1163.7	347.76
345	21.5	-0.19	486.0	430.	54.02	0.9990	0.00569	0.3073	-3.70	372.1	1163.7	357.63
350	22.0	-0.26	483.8	440.	55.28	0.9990	0.00572	0.3159	-3.70	372.1	1163.7	367.59
355	22.0	-0.31	482.3	440.	55.28	0.9990	0.00574	0.3169	-3.70	372.1	1163.7	368.77
360	21.0	-0.35	481.0	420.	52.76	0.9989	0.00575	0.3033	-3.70	372.1	1163.7	352.91
365	22.8	-0.40	479.5	456.	57.29	0.9989	0.00577	0.3303	-3.70	372.1	1163.7	384.39
370	21.8	-0.45	477.9	436.	54.77	0.9989	0.00579	0.3168	-3.70	372.1	1163.7	368.72
375	21.4	-0.53	475.4	428.	53.77	0.9988	0.00582	0.3126	-3.70	372.1	1163.7	363.82
380	22.3	-0.60	473.3	446.	56.03	0.9988	0.00585	0.3273	-3.70	372.1	1163.7	380.84
385	23.3	-0.65	471.7	466.	58.54	0.9988	0.00587	0.3430	-3.70	372.1	1163.7	399.21
390	21.8	-0.70	470.2	436.	54.77	0.9987	0.00589	0.3220	-3.70	372.1	1163.7	374.72
395	13.6	-0.70	470.2	272.	34.17	0.9987	0.00589	0.2009	-3.70	372.1	1163.7	233.77
400	11.0	-0.70	470.2	220.	27.64	0.9987	0.00589	0.1625	-3.70	372.1	1163.7	189.08
405	8.8	-0.72	469.6	176.	22.11	0.9987	0.00589	0.1301	-3.70	372.1	1163.7	151.46
410	10.0	-0.75	468.7	200.	25.13	0.9987	0.00591	0.1482	-3.70	372.1	1163.7	172.45
415	12.8	-0.77	468.0	256.	32.16	0.9987	0.00591	0.1899	-3.70	372.1	1163.7	221.02
420	14.0	-0.80	467.1	280.	35.18	0.9987	0.00592	0.2081	-3.70	372.1	1163.7	242.21
425	13.8	-0.82	466.5	276.	34.67	0.9987	0.00593	0.2054	-3.70	372.1	1163.7	239.06
430	13.5	-0.85	465.6	270.	33.92	0.9987	0.00594	0.2014	-3.70	372.1	1163.7	234.32
435	13.4	-0.88	464.7	268.	33.67	0.9986	0.00596	0.2003	-3.70	372.1	1163.7	233.05
440	12.6	-0.92	463.4	252.	31.66	0.9986	0.00597	0.1888	-3.70	372.1	1163.7	219.71
445	13.7	-0.96	462.2	274.	34.42	0.9986	0.00599	0.2058	-3.70	372.1	1163.7	239.52
450	16.0	-1.00	461.0	320.	40.20	0.9986	0.00600	0.2410	-3.70	372.1	1163.7	280.46
455	16.0	-1.03	460.1	320.	40.20	0.9986	0.00602	0.2415	-3.70	372.1	1163.7	281.02
460	16.3	-1.07	458.8	326.	40.95	0.9985	0.00603	0.2467	-3.70	372.1	1163.7	287.05
465	15.6	-1.13	457.0	312.	39.20	0.9985	0.00606	0.2370	-3.70	372.1	1163.7	275.83
470	16.2	-1.18	455.4	324.	40.70	0.9985	0.00608	0.2470	-3.70	372.1	1163.7	287.40
475	16.9	-1.22	454.2	338.	42.46	0.9985	0.00609	0.2583	-3.70	372.1	1163.7	300.63

TABLE XII   (CONT)

480	17.0	-1.26	453.0	340.	42.71	0.9984	0.00611	0.2606	-3.70	372.1	1163.7	303.23
485	16.4	-1.30	451.7	326.	41.21	0.9984	0.00613	0.2521	-3.70	372.1	1163.7	293.33
490	14.6	-1.34	450.5	292.	36.68	0.9984	0.00614	0.2250	-3.70	372.1	1163.7	261.85
495	13.2	-1.34	450.5	264.	33.17	0.9984	0.00614	0.2034	-3.70	372.1	1163.7	236.74
500	12.0	-1.35	450.2	240.	30.15	0.9984	0.00615	0.1851	-3.70	372.1	1163.7	215.37
505	11.7	-1.37	449.5	234.	29.40	0.9984	0.00616	0.1807	-3.70	372.1	1163.7	210.28
510	11.8	-1.40	448.6	236.	29.65	0.9984	0.00617	0.1826	-3.70	372.1	1163.7	212.52
515	12.3	-1.43	447.6	246.	30.90	0.9983	0.00618	0.1908	-3.70	372.1	1163.7	221.99
520	12.6	-1.45	447.0	252.	31.66	0.9983	0.00619	0.1957	-3.70	372.1	1163.7	227.72
525	12.9	-1.47	446.4	258.	32.41	0.9983	0.00620	0.2006	-3.70	372.1	1163.7	233.47
530	12.9	-1.50	445.4	258.	32.41	0.9983	0.00621	0.2011	-3.70	372.1	1163.7	233.97
535	12.8	-1.55	443.8	256.	32.16	0.9983	0.00624	0.2002	-3.70	372.1	1163.7	232.99
540	13.0	-1.60	442.2	260.	32.66	0.9982	0.00626	0.2041	-3.70	372.1	1163.7	237.48
545	13.2	-1.60	442.2	264.	33.17	0.9982	0.00626	0.2072	-3.70	372.1	1163.7	241.13
550	10.7	-1.60	442.2	214.	26.88	0.9982	0.00626	0.1680	-3.70	372.1	1163.7	195.47
555	10.0	-1.63	441.2	200.	25.13	0.9982	0.00627	0.1573	-3.70	372.1	1163.7	183.08
560	12.0	-1.65	440.6	240.	30.15	0.9982	0.00628	0.1891	-3.70	372.1	1163.7	220.01
565	13.5	-1.68	439.6	270.	33.92	0.9982	0.00630	0.2132	-3.70	372.1	1163.7	248.06
570	13.5	-1.72	438.3	270.	33.92	0.9982	0.00631	0.2138	-3.70	372.1	1163.7	248.79
575	13.3	-1.72	438.3	266.	33.42	0.9982	0.00631	0.2106	-3.70	372.1	1163.7	245.11
580	13.5	-1.72	438.3	270.	33.92	0.9982	0.00631	0.2138	-3.70	372.1	1163.7	248.79
585	14.0	-1.76	437.0	280.	35.18	0.9982	0.00633	0.2224	-3.70	372.1	1163.7	258.78
590	14.5	-1.80	435.7	290.	36.43	0.9981	0.00635	0.2310	-3.70	372.1	1163.7	268.82
595	14.7	-1.81	435.3	294.	36.93	0.9981	0.00636	0.2344	-3.70	372.1	1163.7	272.74
600	14.5	-1.82	435.0	290.	36.43	0.9981	0.00636	0.2314	-3.70	372.1	1163.7	269.23
605	13.0	-1.86	433.7	260.	32.66	0.9981	0.00638	0.2080	-3.70	372.1	1163.7	242.11
610	8.0	-1.90	432.3	160.	20.10	0.9981	0.00640	0.1284	-3.70	372.1	1163.7	149.45
615	3.8	-1.91	432.0	76.	9.55	0.9981	0.00641	0.0610	-3.70	372.1	1163.7	71.04
620	7.0	-1.92	431.7	140.	17.59	0.9981	0.00641	0.1125	-3.70	372.1	1163.7	130.97
625	9.2	-1.93	431.3	184.	23.12	0.9980	0.00642	0.1480	-3.70	372.1	1163.7	172.26
630	10.5	-1.94	431.0	210.	26.38	0.9980	0.00642	0.1691	-3.70	372.1	1163.7	196.75
635	9.2	-1.95	430.7	184.	23.12	0.9980	0.00643	0.1483	-3.70	372.1	1163.7	172.53
640	9.8	-1.96	430.3	196.	24.62	0.9980	0.00643	0.1580	-3.70	372.1	1163.7	183.92
645	10.2	-1.98	429.7	204.	25.63	0.9980	0.00644	0.1647	-3.70	372.1	1163.7	191.72
650	9.8	-2.00	429.0	196.	24.62	0.9980	0.00645	0.1585	-3.70	372.1	1163.7	184.49
655	9.8	-2.01	428.7	196.	24.62	0.9980	0.00646	0.1587	-3.70	372.1	1163.7	184.64
660	8.2	-2.02	428.3	164.	20.60	0.9980	0.00646	0.1329	-3.70	372.1	1163.7	154.61
665	0.0	-2.00	429.0	0.	0.0	0.9980	0.00645	0.0	-3.70	372.1	1163.7	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 202668.688 CYCLES,   TOTAL MASS   (INTEGRATED) =   2.395 LBS
TOTAL NO. OF CYCLES (MEASURED) = 200429.000 CYCLES,   TOTAL ENTHALPY(INTEGRATED) =2963.409 BTU
AVERAGE ENTHALPY OF FLOW   =   1237.342 BTU/LB

P= 34.7 PSIA,   FLOW TOTALIZER=   0. CYCLES,   FOJ= 10.0 HZ/DIV,   FOV= 120.0 HZ/CFM

TIME (SEC)	OF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FO (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFM (MIL.V)	TEMM (DEG.R)	H (BTU/LB)	ZMH (BTU/MNT)	EMF23 (MIL.V)	TEMF23 (DEG.R)
0	14.2	0.66	512.6	142.	1.18	0.9995	0.01274	0.0150					-7.70	200.4
5	14.2	0.66	512.6	142.	1.18	0.9995	0.01274	0.0150					-7.50	211.0
10	14.2	0.66	512.6	142.	1.18	0.9995	0.01274	0.0150					-7.60	205.8
15	14.2	0.66	512.6	142.	1.18	0.9995	0.01274	0.0150					-7.70	200.4
20	14.2	0.65	512.3	142.	1.18	0.9995	0.01275	0.0150					-7.60	194.6
25	14.2	0.65	512.3	142.	1.18	0.9995	0.01275	0.0150					-7.80	194.6
30	14.2	0.65	512.3	142.	1.18	0.9995	0.01275	0.0150					-7.90	188.5
35	14.2	0.65	512.3	142.	1.18	0.9995	0.01275	0.0150					-8.00	182.0
40	14.2	0.65	512.3	142.	1.18	0.9995	0.01275	0.0150					-7.80	194.6
45	14.1	0.64	512.0	141.	1.17	0.9995	0.01275	0.0149					-7.70	200.4
50	14.1	0.64	512.0	141.	1.17	0.9995	0.01275	0.0149					-7.60	205.8
55	14.1	0.63	511.7	141.	1.17	0.9994	0.01276	0.0149					-7.50	211.0
60	14.1	0.63	511.7	141.	1.17	0.9994	0.01276	0.0149					-7.40	216.0
65	14.1	0.62	511.4	141.	1.17	0.9994	0.01277	0.0150					-7.30	221.0
70	14.1	0.61	511.1	141.	1.17	0.9994	0.01278	0.0150					-7.20	226.0
75	14.1	0.61	511.1	141.	1.17	0.9994	0.01278	0.0150					-7.10	231.0
80	14.1	0.61	511.1	141.	1.17	0.9994	0.01278	0.0150					-7.00	236.0
85	14.1	0.60	510.7	141.	1.17	0.9994	0.01278	0.0150					-6.90	240.9
90	14.1	0.59	510.4	141.	1.17	0.9994	0.01279	0.0150					-6.80	245.9
95	14.0	0.59	510.4	140.	1.16	0.9994	0.01279	0.0149					-6.60	255.4
100	13.8	0.58	510.1	138.	1.14	0.9994	0.01280	0.0147					-6.40	264.4
105	13.7	0.58	510.1	137.	1.14	0.9994	0.01280	0.0146					-6.10	276.9
110	13.6	0.57	509.8	136.	1.13	0.9994	0.01281	0.0145					-6.00	281.0
115	13.5	0.56	509.5	135.	1.12	0.9994	0.01282	0.0144					-5.90	285.0
120	13.4	0.54	508.9	134.	1.11	0.9994	0.01283	0.0143					-5.80	289.2
125	13.2	0.52	508.3	132.	1.09	0.9994	0.01285	0.0141					-5.80	289.2
130	13.1	0.50	507.6	131.	1.09	0.9994	0.01286	0.0140					-5.70	293.4
135	13.0	0.48	507.0	130.	1.08	0.9994	0.01288	0.0139					-5.70	293.5
140	12.0	0.47	506.7	120.	1.00	0.9994	0.01289	0.0128					-5.60	297.7
145	11.0	0.47	506.7	110.	0.91	0.9994	0.01289	0.0118					-5.50	302.0
150	10.5	0.46	506.4	105.	0.87	0.9994	0.01289	0.0112					-5.40	306.2
155	11.5	0.45	506.1	115.	0.95	0.9993	0.01290	0.0123					-5.30	310.4
160	16.6	0.43	505.5	166.	1.38	0.9993	0.01292	0.0178					-5.20	314.5
165	17.0	0.41	504.8	170.	1.41	0.9993	0.01293	0.0183					-5.20	314.5
170	16.5	0.39	504.2	165.	1.37	0.9993	0.01295	0.0178					-5.20	314.5
175	16.0	0.38	503.9	160.	1.33	0.9993	0.01296	0.0172					-5.00	322.0
180	15.5	0.37	503.6	155.	1.29	0.9993	0.01297	0.0167					-4.90	325.4
185	15.0	0.35	503.0	150.	1.25	0.9993	0.01298	0.0162					-4.90	325.4
190	14.1	0.33	502.3	141.	1.17	0.9993	0.01300	0.0152					-4.70	332.5
195	13.2	0.31	501.7	132.	1.09	0.9993	0.01302	0.0143					-4.50	341.0
200	12.7	0.30	501.4	127.	1.05	0.9993	0.01302	0.0137					-4.40	346.1
205	12.2	0.29	501.1	122.	1.01	0.9993	0.01303	0.0132					-4.30	351.0
210	12.0	0.27	500.4	120.	1.00	0.9992	0.01305	0.0130					-4.20	357.2
215	11.8	0.25	499.8	118.	0.98	0.9992	0.01306	0.0128					-4.10	360.0
220	11.8	0.25	499.8	118.	0.98	0.9992	0.01306	0.0128					-4.00	359.0
225	11.8	0.24	499.5	118.	0.98	0.9992	0.01307	0.0128					-3.90	363.0
230	11.6	0.23	499.2	116.	0.96	0.9992	0.01308	0.0126					-3.80	367.9
235	11.2	0.23	499.2	112.	0.93	0.9992	0.01308	0.0122					-3.75	372.1
240	11.4	0.21	498.6	114.	0.94	0.9992	0.01310	0.0124					-3.70	372.1
245	11.6	0.20	498.2	116.	0.96	0.9992	0.01311	0.0126					-3.60	375.9
250	11.8	0.18	497.6	118.	0.98	0.9992	0.01312	0.0128					-3.50	379.6
255	12.0	0.17	497.3	120.	1.00	0.9992	0.01313	0.0131					-3.40	383.1
260	12.1	0.17	497.3	121.	1.01	.9992	0.01313	0.0132					-3.40	383.1
265	12.2	0.17	497.3	122.	1.01	.992	0.01313	0.0133					-3.30	386.4
270	12.1	0.17	497.3	121.	1.00	0.9992	0.01313	0.0132					-3.20	387.0
275	12.0	0.17	497.3	120.	1.00	0.9992	0.01313	0.0131					-3.20	389.6
280	12.3	0.18	497.6	123.	1.02	0.9992	0.01312	0.0134					-3.10	392.0
285	12.7	0.19	497.9	127.	1.05	0.9992	0.01311	0.0138					-3.10	392.5
290	12.8	0.20	498.2	128.	1.06	0.9992	0.01311	0.0139					-3.00	396.0
295	12.9	0.21	498.6	129.	1.07	0.9992	0.01311	0.0140					-2.90	399.1
300	12.9	0.22	498.9	129.	1.07	0.9992	0.01309	0.0140					-2.80	402.3
305	13.0	0.23	499.0	130.	1.08	0.9992	0.01308	0.0141					-2.80	402.3
310	12.9	0.24	499.5	129.	1.07	0.9992	0.01307	0.0140					-2.70	402.2
315	12.8	0.24	499.5	128.	1.06	.9992	0.01307	0.0139					-2.70	405.5
320	12.5	0.25	499.4	125.	1.04	0.9992	0.01306	0.0136					-2.60	408.6

TOTAL NO. OF CYCLES (INTEGRATED) = 42537.336 CYCLES,   TOTAL MASS (INTEGRATED) = 0.076 LBS
TOTAL NO. OF CYCLES (MEASURED) =   CYCLES,   TOTAL ENTHALPY (INTEGRATED) =   BTU
AVERAGE ENTHALPY OF FLOW =   BTU/LB

TABLE XIII SOLID H$_2$ MELTING TEST DATA (RUN NO. = 4---OUTLET FROM CONTROL VOLUME (Cont.)

P= 14.7 PSIA.   FLOW TOTALIZER= 151235. CYCLES.   FQD= 20.0 HZ/DIV.   FQV= 7.96 HZ/CFM

TIME (SEC)	OF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VCT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.50	507.7	0.	0.0	0.9994	0.00545	0.0	0.05	493.0	1634.5	0.0
5	2.2	0.50	507.7	44.	5.53	0.9994	0.00545	0.0301	-0.18	486.3	1606.1	48.37
10	5.2	0.50	507.7	104.	13.07	0.9994	0.00545	0.0712	-0.50	476.4	1568.1	111.62
15	9.3	0.50	507.7	166.	23.37	0.9994	0.00545	0.1273	-0.56	474.5	1561.3	198.76
20	14.0	0.50	507.7	280.	35.18	0.9994	0.00545	0.1916	-0.73	469.3	1542.4	295.60
25	11.9	0.50	507.7	238.	29.90	0.9994	0.00545	0.1629	-0.78	467.7	1537.0	250.38
30	11.3	0.50	507.7	226.	28.39	0.9994	0.00545	0.1547	-0.83	466.2	1531.7	236.93
35	18.0	0.50	507.7	360.	45.23	0.9994	0.00545	0.2464	-0.89	464.4	1525.4	375.87
40	27.8	0.50	507.7	556.	69.85	0.9994	0.00545	0.3806	-0.95	462.5	1519.2	578.14
45	31.7	0.50	507.7	634.	79.65	0.9994	0.00545	0.4339	-1.12	457.3	1502.0	651.79
50	31.9	0.50	507.7	638.	80.15	0.9994	0.00545	0.4367	-1.30	451.7	1484.3	648.18
55	35.4	0.50	507.7	708.	88.94	0.9994	0.00545	0.4846	-1.50	445.4	1464.8	709.85
60	36.9	0.50	507.7	738.	92.71	0.9994	0.00545	0.5051	-1.80	435.7	1434.8	724.73
65	38.1	0.50	507.7	762.	95.73	0.9994	0.00545	0.5216	-2.10	425.6	1401.7	731.06
70	36.6	0.50	507.7	732.	91.96	0.9994	0.00545	0.5010	-2.50	412.1	1350.5	676.61
75	35.5	0.50	507.7	710.	89.20	0.9994	0.00545	0.4860	-2.60	408.8	1336.4	649.42
80	40.2	0.50	507.7	804.	101.01	0.9994	0.00545	0.5503	-2.70	405.6	1321.9	727.41
85	30.0	0.50	507.7	600.	75.38	0.9994	0.00545	0.4107	-2.80	402.3	1307.1	536.77
90	5.0	0.50	507.7	100.	12.56	0.9994	0.00545	0.0684	-2.90	399.2	1291.9	88.43
95	0.0	0.50	507.7	0.	0.03	0.9994	0.00545	0.0001	-3.10	392.8	1261.1	0.17
100	0.0	0.50	507.7	0.	0.03	0.9994	0.00545	0.0001	-3.30	386.4	1229.3	0.17
105	0.0	0.50	507.7	0.	0.03	0.9994	0.00545	0.0001	-3.30	386.4	1229.3	0.17
110	0.0	0.50	507.7	0.	0.03	0.9994	0.00545	0.0001	-3.20	389.7	1245.3	0.17
115	7.0	0.50	507.7	140.	17.57	0.9994	0.00545	0.0958	-3.00	396.0	1276.6	122.33
120	9.2	0.50	507.7	184.	23.12	0.9994	0.00545	0.1259	-2.90	399.2	1291.9	162.70
125	12.0	0.50	507.7	240.	30.15	0.9994	0.00545	0.1643	-3.40	383.1	1213.1	199.27
130	13.4	0.50	507.7	268.	33.67	0.9994	0.00545	0.1834	-3.80	368.0	1147.9	210.57
135	16.0	0.50	507.7	320.	40.20	0.9994	0.00545	0.2190	-3.80	368.0	1147.9	251.42
140	20.5	0.50	507.7	410.	51.51	0.9994	0.00545	0.2806	-3.80	368.0	1147.9	322.14
145	23.2	0.50	507.7	464.	58.29	0.9994	0.00545	0.3176	-3.80	368.0	1147.9	364.57
150	23.7	0.50	507.7	474.	59.55	0.9994	0.00545	0.3244	-3.80	368.0	1147.9	372.42
155	23.0	0.47	506.8	460.	57.79	0.9994	0.00546	0.3154	-3.70	372.1	1163.7	367.07
160	23.6	0.45	506.1	472.	59.30	0.9994	0.00547	0.3240	-3.70	372.1	1163.7	377.10
165	25.5	0.45	506.1	510.	64.07	0.9994	0.00547	0.3501	-3.60	376.0	1180.1	413.19
170	27.8	0.45	505.1	556.	69.85	0.9994	0.00547	0.3817	-3.60	376.0	1180.1	450.45
175	30.5	0.42	505.2	610.	76.63	0.9994	0.00548	0.4196	-3.60	376.0	1180.1	495.11
180	28.1	0.40	504.6	562.	70.60	0.9994	0.00549	0.3870	-3.60	376.0	1180.1	456.71
185	27.2	0.39	504.3	544.	68.34	0.9994	0.00549	0.3749	-3.60	376.0	1180.1	442.35
190	30.5	0.38	503.9	610.	76.63	0.9994	0.00549	0.4206	-3.60	376.0	1180.1	496.33
195	30.5	0.36	503.3	610.	76.63	0.9993	0.00550	0.4211	-3.60	376.0	1180.1	496.94
200	30.2	0.35	503.0	604.	75.88	0.9993	0.00550	0.4172	-3.60	376.0	1180.1	492.35
205	30.6	0.31	501.7	612.	76.88	0.9993	0.00552	0.4238	-3.60	376.0	1180.1	500.11
210	29.4	0.29	502.8	588.	73.87	0.9993	0.00553	0.4079	-3.60	376.0	1180.1	481.40
215	29.3	0.24	499.5	546.	73.62	0.9993	0.00554	0.4076	-3.60	376.0	1180.1	480.95
220	31.8	0.20	498.3	636.	79.70	0.9993	0.00555	0.4434	-3.60	376.0	1180.1	523.30
225	31.8	0.15	497.0	636.	79.90	0.9992	0.00557	0.4446	-3.60	376.0	1180.1	524.61
230	29.5	0.12	495.8	590.	74.12	0.9992	0.00558	0.4134	-3.60	376.0	1180.1	487.89
235	27.6	0.10	495.1	552.	69.35	0.9992	0.00559	0.3873	-3.60	376.0	1180.1	457.04
240	30.5	0.08	494.5	610.	76.63	0.9992	0.00560	0.4285	-3.60	376.0	1180.1	505.70
245	31.0	0.07	494.2	620.	77.89	0.9992	0.00560	0.4358	-3.60	376.0	1180.1	514.32
250	28.4	-0.05	490.4	568.	71.36	0.9991	0.00564	0.4023	-3.60	376.0	1180.1	474.78
255	25.1	-0.08	489.5	502.	63.07	0.9991	0.00565	0.3563	-3.70	372.1	1163.7	414.59
260	26.7	-0.12	488.2	534.	67.09	0.9991	0.00567	0.3799	-3.70	372.1	1163.7	442.15
265	26.7	-0.16	487.0	534.	67.09	0.9991	0.00568	0.3809	-3.70	372.1	1163.7	443.27
270	25.6	-0.20	485.7	512.	64.32	0.9990	0.00570	0.3662	-3.50	379.6	1196.6	438.15
275	27.2	-0.19	486.0	544.	68.34	0.9990	0.00569	0.3888	-3.40	383.1	1213.1	471.64
280	35.8	-0.18	486.3	716.	89.95	0.9990	0.00569	0.5114	-3.30	386.4	1229.3	628.65
285	36.6	-0.31	482.3	732.	91.96	0.9990	0.00574	0.5272	-3.30	386.4	1229.3	648.07
290	32.7	-0.45	477.7	654.	82.16	0.9989	0.00579	0.4753	-3.30	386.4	1229.3	584.24
295	28.2	-0.53	475.4	564.	70.85	0.9988	0.00582	0.4120	-3.30	386.4	1229.3	506.44
300	29.8	-0.60	473.3	596.	74.87	0.9988	0.00585	0.4373	-3.30	386.4	1229.3	537.60
305	28.1	-0.65	471.7	562.	70.60	0.9988	0.00587	0.4137	-3.20	389.7	1245.3	515.19
310	26.0	-0.70	470.2	520.	65.33	0.9987	0.00589	0.3840	-3.20	389.7	1245.3	478.24
315	23.5	-0.75	468.7	470.	59.05	0.9987	0.00591	0.3482	-3.10	392.8	1261.1	439.14
320	18.0	-0.80	467.1	360.	45.23	0.9987	0.00592	0.2676	-3.10	392.8	1261.1	337.46
325	5.7	-0.85	465.6	114.	14.32	0.9987	0.00594	0.0850	-3.00	396.0	1276.6	108.53

TOTAL NO. OF CYCLES (INTEGRATED) = 151568.313 CYCLES.   TOTAL MASS   (INTEGRATED) =   1.760 LBS
TOTAL NO. OF CYCLES (MEASURED) = 151235.000 CYCLES.   TOTAL ENTHALPY(INTEGRATED) =2213.684 BTU
AVERAGE ENTHALPY OF FLOW   =   1257.433 BTU/LB

TABLE XIV SOLID H$_2$ MELTING TEST DATA

(RUN. NO. = 5, INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0	100			-5.7	200	100			-2.86
5					205				-2.78
10				-5.7	210				-2.70
15					215				-2.70
20				-5.7	220	Estimated			-2.70
25				-5.6	225				-3.4?
30				-5.5	230				-4.20
35				-5.3	235				-3.75
40				-5.1	240				-3.30
45				-5.0	245				-3.30
50				-4.9	250				-3.30
55				-4.8	255	100			-3.30
60				-4.8					
65				-4.8					
70				-4.8					
75				-4.5					
80				-4.2					
85				-4.2					
90				-4.2					
95				-4.1					
100	Estimated			-3.9					
105				-3.8					
110				-3.7					
115				-3.6					
120				-3.6					
125				-3.5					
130				-3.5					
135				-3.4					
140				-3.3					
145									
150				-3.20					
155				-3.15					
160				-3.10					
165				-3.07					
170				-3.05					
175				-3.02					
180				-3.00					
185				-2.95					
190				-2.90					
195	100			-2.88					

TABLE XIV SOLID H2 MELTING TEST DATA (RUN NO. = 5 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA.   FLOW TOTALIZER= 86059. CYCLES.   FQO= 20.0 HZ/DIV.   FQV= 7.96 HZ/CFM

TIME (SEC)	QF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.70	513.9	0.	0.0	0.9995	0.00539	0.0	0.70	513.9	1713.9	0.0
5	4.1	0.70	513.9	82.	10.30	0.9995	0.00539	0.0555	0.20	498.3	1653.2	91.68
10	4.7	0.69	513.6	94.	11.81	0.9995	0.00539	0.0636	-0.30	482.6	1591.6	101.24
15	5.2	0.68	513.3	104.	13.07	0.9995	0.00539	0.0704	-0.40	479.5	1579.7	111.24
20	6.9	0.67	513.0	138.	17.34	0.9995	0.00540	0.0935	-0.60	473.3	1556.7	145.55
25	9.8	0.66	512.6	196.	24.62	0.9995	0.00540	0.1329	-0.60	473.3	1556.7	206.84
30	15.0	0.65	512.3	300.	37.69	0.9995	0.00540	0.2035	-0.70	470.2	1545.7	314.53
35	21.5	0.64	512.0	430.	54.02	0.9995	0.00541	0.2918	-0.80	467.1	1534.9	447.95
40	27.5	0.63	511.7	546.	68.59	0.9995	0.00541	0.3708	-1.00	461.0	1514.1	561.43
45	35.2	0.62	511.4	704.	88.44	0.9995	0.00541	0.4784	-1.20	454.8	1494.1	714.76
50	32.8	0.61	511.1	656.	82.41	0.9995	0.00541	0.4460	-1.30	451.7	1484.3	662.06
55	32.0	0.60	510.8	640.	80.40	0.9995	0.00542	0.4354	-1.40	448.6	1474.6	642.05
60	32.0	0.60	510.8	640.	80.40	0.9995	0.00542	0.4354	-1.60	442.2	1455.0	633.53
65	33.5	0.58	510.2	670.	84.17	0.9995	0.00542	0.4564	-1.90	432.3	1424.2	649.95
70	33.2	0.55	509.2	664.	83.42	0.9995	0.00543	0.4531	-2.20	422.2	1389.7	629.69
75	31.4	0.55	509.2	628.	78.89	0.9995	0.00543	0.4285	-2.70	405.6	1321.9	566.46
80	13.0	0.55	509.2	260.	32.66	0.9995	0.00543	0.1774	-3.30	386.4	1229.3	218.10
85	5.0	0.55	509.2	100.	12.56	0.9995	0.00543	0.0682	-3.40	383.1	1213.1	82.78
90	3.0	0.55	509.2	60.	7.54	0.9995	0.00543	0.0409	-3.60	376.0	1180.1	48.32
95	2.5	0.55	509.2	50.	6.29	0.9995	0.00543	0.0341	-3.60	376.0	1180.1	40.26
100	1.2	0.55	509.2	24.	3.02	0.9995	0.00543	0.0164	-3.60	376.0	1180.1	19.33
105	2.2	0.55	509.2	44.	5.53	0.9995	0.00543	0.0300	-3.60	376.0	1180.1	35.43
110	7.8	0.55	509.2	156.	19.60	0.9995	0.00543	0.1065	-3.60	376.0	1180.1	125.62
115	12.2	0.55	509.2	244.	30.65	0.9995	0.00543	0.1665	-3.60	376.0	1180.1	196.49
120	16.5	0.55	509.2	330.	41.46	0.9995	0.00543	0.2252	-3.60	376.0	1180.1	265.74
125	22.6	0.55	509.2	452.	56.78	0.9995	0.00543	0.3084	-3.60	376.0	1180.1	363.98
130	24.7	0.55	509.2	494.	62.06	0.9995	0.00543	0.3371	-3.60	376.0	1180.1	397.80
135	24.3	0.50	507.7	486.	61.06	0.9994	0.00545	0.3326	-3.60	376.0	1180.1	392.54
140	24.4	0.47	506.8	488.	61.11	0.9994	0.00546	0.3346	-3.60	376.0	1180.1	394.88
145	26.2	0.45	506.1	524.	65.83	0.9994	0.00547	0.3597	-3.60	376.0	1180.1	424.53
150	23.2	0.45	506.1	464.	58.29	0.9994	0.00547	0.3186	-3.60	376.0	1180.1	375.92
155	23.5	0.45	506.1	470.	59.05	0.9994	0.00547	0.3227	-3.60	376.0	1180.1	380.78
160	23.5	0.44	505.8	470.	59.05	0.9994	0.00547	0.3229	-3.60	376.0	1180.1	381.01
165	24.8	0.43	505.5	496.	62.31	0.9994	0.00547	0.3409	-3.60	376.0	1180.1	402.33
170	23.8	0.42	505.2	476.	59.80	0.9994	0.00548	0.3274	-3.60	376.0	1180.1	386.35
175	22.4	0.41	504.9	448.	56.28	0.9994	0.00548	0.3083	-3.60	376.0	1180.1	363.84
180	24.2	0.40	504.6	484.	60.80	0.9994	0.00549	0.3333	-3.60	376.0	1180.1	393.32
185	24.7	0.40	504.6	494.	62.06	0.9994	0.00549	0.3402	-3.60	376.0	1180.1	401.45
190	22.8	0.40	504.6	456.	57.29	0.9994	0.00549	0.3140	-3.60	376.0	1180.1	370.57
195	19.5	0.40	504.6	390.	48.93	0.9994	0.00549	0.2686	-3.60	376.0	1180.1	316.93
200	19.0	0.40	504.6	380.	47.74	0.9994	0.00549	0.2617	-3.60	376.0	1180.1	308.81
205	18.6	0.35	503.9	372.	46.73	0.9993	0.00550	0.2570	-3.60	376.0	1180.1	303.24
210	17.0	0.34	502.7	340.	42.71	0.9993	0.00551	0.2350	-3.60	376.0	1180.1	277.32
215	14.0	0.32	502.1	280.	35.13	0.9993	0.00551	0.1938	-3.60	376.0	1180.1	228.67
220	10.2	0.10	501.4	204.	25.61	0.9993	0.00552	0.1414	-3.60	376.0	1180.1	166.81
225	9.8	0.30	501.4	196.	24.62	0.9993	0.00552	0.1358	-3.60	376.0	1180.1	160.27
230	8.4	0.30	501.4	168.	21.11	0.9993	0.00552	0.1164	-3.60	376.0	1180.1	137.37
235	5.6	0.30	501.4	112.	14.07	0.9993	0.00552	0.0776	-3.60	376.0	1180.1	91.58
240	5.2	0.30	501.4	104.	13.07	0.9993	0.00552	0.0721	-3.60	376.0	1180.1	85.04
245	5.4	0.30	501.4	108.	13.57	0.9993	0.00552	0.0749	-3.60	376.0	1180.1	88.31
250	7.8	0.10	501.4	156.	19.60	0.9993	0.00552	0.1081	-3.50	379.6	1196.6	129.35
255	0.0	0.10	501.4	0.	0.0	0.9993	0.00552	0.0	-3.50	379.6	1196.6	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 86359.438 CYCLES.   TOTAL MASS   (INTEGRATED) = 0.982 LB.
TOTAL NO. OF CYCLES (MEASURED) = 86059.000 CYCLES.   TOTAL ENTHALPY(INTEGRATED) =1265.076 BTU
AVERAGE ENTHALPY OF FLOW   = 1288.450 BTU/LB

TABLE XV SOLID H_2 MELTING TEST DATA

(RUN. NO. = 6, INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0	180			-7.7	200	130			-2.0
5				-7.7	205	125			-1.8
10				-7.6	210	120			-1.6
15				-7.6	215	117			-1.4
20				-7.6	220	115			-1.3
25				-7.6	225	113			-1.2
30				-7.6	230	110			-1.1
35				-7.6	235	107			-1.0
40				-7.6	240	103			-0.9
45				-7.6	245	100			-0.8
50				-7.6					
55				-7.5					
60				-7.4					
65				-7.3					
70				-7.1					
75				-6.7					
80	180			-6.3					
85	178			-5.9					
90	176			-5.5					
95	175			-5.2					
100	174			-4.9					
105	172			-4.5					
110	170			-4.2					
115	168			-4.0					
120	167			-3.7					
125	166			-3.6					
130	165			-3.4					
135	163			-3.2					
140	162			-3.1					
145	161			-3.0					
150	160			-2.9					
155	155			-2.7					
160	150			-2.5					
165	148			-2.4					
170	143			-2.3					
175	140			-2.2					
180	138			-2.1					
185	136			-2.0					
190	134			-1.9					
195	132			-1.9					

45

TABLE XV SOLID H2 MELTING TEST DATA (RUN NO. = 6 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 90660. CYCLES,   FQO= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.50	507.7	0.	0.0	0.9994	0.00545	0.0	0.50	507.7	1690.1	0.0
5	8.2	0.45	506.1	164.	20.60	0.9994	0.00547	0.1126	0.10	495.1	1640.8	184.74
10	12.5	0.40	504.6	250.	31.41	0.9994	0.00549	0.1722	-0.30	482.6	1591.6	274.01
15	17.7	0.35	503.0	354.	44.47	0.9993	0.00550	0.2445	-0.40	479.5	1579.7	386.29
20	18.5	0.30	501.4	370.	46.48	0.9993	0.00552	0.2564	-0.60	473.3	1556.7	399.11
25	18.4	0.30	501.4	368.	46.23	0.9993	0.00552	0.2550	-0.70	470.2	1545.7	394.14
30	18.4	0.30	501.4	368.	46.23	0.9993	0.00552	0.2550	-0.80	467.1	1534.9	391.38
35	19.7	0.25	499.9	394.	49.50	0.9993	0.00554	0.2739	-0.80	467.1	1534.9	420.34
40	21.1	0.20	498.3	422.	53.02	0.9993	0.00555	0.2942	-0.90	464.1	1524.4	448.53
45	21.5	0.20	498.3	430.	54.02	0.9993	0.00555	0.2998	-1.00	461.0	1514.1	453.95
50	21.9	0.20	498.3	-438.	55.03	0.9993	0.00555	0.3054	-1.10	457.9	1504.0	459.32
55	28.0	0.15	496.7	560.	70.35	0.9992	0.00557	0.3917	-1.10	457.9	1504.0	589.10
60	31.7	0.10	495.1	634.	79.65	0.9992	0.00559	0.4448	-1.20	454.8	1494.1	664.64
65	32.0	0.10	495.1	640.	80.40	0.9992	0.00559	0.4490	-1.30	451.7	1484.3	666.54
70	34.1	0.10	495.1	682.	85.68	0.9992	0.00559	0.4785	-1.40	448.6	1474.6	705.61
75	37.5	0.11	495.5	750.	94.22	0.9992	0.00559	0.5259	-1.40	448.6	1474.6	775.48
80	18.3	0.02	492.6	366.	45.98	0.9992	0.00562	0.2581	-1.50	445.4	1464.8	378.07
85	10.0	-0.01	491.7	200.	25.13	0.9991	0.00563	0.1413	-1.60	442.2	1455.0	205.60
90	5.7	-0.04	490.7	114.	14.32	0.9991	0.00564	0.0807	-1.70	439.0	1445.0	116.61
95	5.0	-0.04	490.7	100.	12.56	0.9991	0.00564	0.0708	-2.00	429.0	1413.2	100.04
100	4.9	-0.04	490.7	98.	12.31	0.9991	0.00564	0.0694	-2.30	418.8	1377.2	95.56
105	4.7	-0.04	490.7	94.	11.81	0.9991	0.00564	0.0665	-2.80	402.3	1307.1	86.97
110	4.5	-0.04	490.7	90.	11.31	0.9991	0.00564	0.0637	-3.40	383.1	1213.1	77.29
115	4.5	-0.04	490.7	90.	11.31	0.9991	0.00564	0.0637	-3.50	379.6	1196.6	76.24
120	4.6	-0.04	490.7	92.	11.56	0.9991	0.00564	0.0651	-3.70	372.1	1163.7	75.79
125	3.0	-0.04	490.7	60.	7.54	0.9991	0.00564	0.0425	-3.70	372.1	1163.7	49.43
130	10.0	-0.04	490.7	200.	25.13	0.9991	0.00564	0.1416	-3.70	372.1	1163.7	164.76
135	20.4	-0.04	490.7	408.	51.26	0.9991	0.00564	0.2888	-3.70	372.1	1163.7	336.10
140	21.8	-0.04	490.7	436.	54.77	0.9991	0.00564	0.3086	-3.70	372.1	1163.7	359.17
145	23.0	-0.04	490.7	460.	57.79	0.9991	0.00564	0.3256	-3.70	372.1	1163.7	378.94
150	27.0	-0.04	490.7	540.	67.84	0.9991	0.00564	0.3823	-3.70	372.1	1163.7	444.84
155	20.0	-0.04	490.7	400.	50.25	0.9991	0.00564	0.2832	-3.70	372.1	1163.7	329.51
160	14.5	-0.04	490.7	290.	36.43	0.9991	0.00564	0.2053	-3.70	372.1	1163.7	238.90
165	17.8	-0.04	490.7	356.	44.72	0.9991	0.00564	0.2520	-3.70	372.1	1163.7	293.27
170	20.0	-0.10	488.8	400.	50.25	0.9991	0.00566	0.2842	-3.70	372.1	1163.7	330.77
175	19.5	-0.10	488.8	390.	48.99	0.9991	0.00566	0.2771	-3.70	372.1	1163.7	322.50
180	18.0	-0.10	488.8	360.	45.23	0.9991	0.00566	0.2558	-3.70	372.1	1163.7	297.70
185	24.0	-0.10	488.8	480.	60.30	0.9991	0.00566	0.3411	-3.70	372.1	1163.7	396.93
190	30.4	-0.10	488.8	608.	76.38	0.9991	0.00566	0.4320	-3.70	372.1	1163.7	502.78
195	30.2	-0.15	487.3	604.	75.88	0.9991	0.00568	0.4306	-3.70	372.1	1163.7	501.06
200	28.8	-0.17	486.6	576.	72.36	0.9990	0.00569	0.4111	-3.70	372.1	1163.7	478.45
205	27.2	-0.19	486.0	544.	68.34	0.9990	0.00569	0.3888	-3.70	372.1	1163.7	452.44
210	26.8	-0.20	485.7	536.	67.34	0.9990	0.00570	0.3833	-3.70	372.1	1163.7	446.08
215	26.0	-0.23	484.8	520.	65.33	0.9990	0.00571	0.3726	-3.70	372.1	1163.7	433.59
220	25.0	-0.25	484.1	500.	62.81	0.9990	0.00572	0.3587	-3.70	372.1	1163.7	417.45
225	23.8	-0.27	483.5	476.	59.80	0.9990	0.00572	0.3419	-3.70	372.1	1163.7	397.92
230	27.4	-0.29	482.9	448.	56.28	0.9990	0.00573	0.3222	-3.70	372.1	1163.7	374.99
235	19.4	-0.32	482.0	388.	48.74	0.9990	0.00574	0.2796	-3.70	372.1	1163.7	325.40
240	10.0	-0.35	481.0	200.	25.13	0.9989	0.00575	0.1444	-3.70	372.1	1163.7	168.05
245	0.0	-0.37	480.4	0.	0.0	0.9989	0.00576	0.0	-3.50	379.6	1196.0	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 91239.625 CYCLES,   TOTAL MASS   (INTEGRATED) =   1.067 LBS
TOTAL NO. OF CYCLES (MEASURED) = 90650.000 CYCLES,   TOTAL ENTHALPY(INTEGRATED) =1396.592 BTU
AVERAGE ENTHALPY OF FLOW   =   1308.310 BTU/LB

TABLE XVI SOLID H2 MELTING TEST DATA (RUN NO. = 9 --- INLET TO CONTROL VOLUME)

P= 39.7 PSIA,   FLOW TOTALIZER=   9. CYCLES,   FOD= 5.0 HZ/DIV,   FGV= 120.0 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FG (HZ)	VDT (CF?)	C (---)	RHO (LB/FT3)	ZVDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)	EMF23 (MIL.V)	TEM23 (DEG.R)
0	15.9	1.40	534.8	79.	0.66	0.9999	0.01397	0.0092					-7.59	206.3
5	14.4	1.38	534.2	72.	0.59	0.9999	0.01399	0.0083					-7.65	203.1
10	13.8	1.36	533.6	69.	0.57	0.9998	0.01400	0.0080					-7.17	227.5
15	13.1	1.34	533.0	65.	0.54	0.9998	0.01402	0.0076					-6.70	230.7
20	12.5	1.33	532.7	62.	0.52	0.9998	0.01402	0.0073					-6.90	240.9
25	12.0	1.32	532.4	60.	0.50	0.9998	0.01403	0.0070					-7.10	231.0
30	11.9	1.31	532.1	59.	0.49	0.9998	0.01404	0.0069					-6.95	236.4
35	11.5	1.30	531.8	57.	0.47	0.9998	0.01405	0.0067					-6.80	245.7
40	11.2	1.29	531.6	56.	0.46	0.9998	0.01406	0.0065					-6.72	249.1
45	11.3	1.29	531.6	56.	0.47	0.9998	0.01406	0.0066					-6.65	253.1
50	11.0	1.29	531.6	55.	0.45	0.9998	0.01406	0.0064					-6.47	261.3
55	10.3	1.29	531.6	51.	0.42	0.9998	0.01406	0.0060					-6.40	264.4
60	10.0	1.30	531.8	50.	0.41	0.9998	0.01405	0.0058					-6.30	266.6
65	10.7	1.31	532.1	53.	0.44	0.9998	0.01404	0.0062					-6.20	272.8
70	10.0	1.32	532.4	50.	0.41	0.9998	0.01403	0.0058					-6.10	276.9
75	9.0	1.32	532.4	45.	0.37	0.9998	0.01403	0.0052					-6.00	281.0
80	9.0	1.33	532.7	45.	0.37	0.9998	0.01402	0.0052					-5.90	285.0
85	9.0	1.34	533.0	49.	0.41	0.9998	0.01402	0.0057					-5.80	289.2
90	9.0	1.35	533.3	45.	0.37	0.9998	0.01401	0.0052					-5.70	293.4
95	9.0	1.37	533.9	45.	0.37	0.9998	0.01399	0.0052					-5.60	297.1
100	9.0	1.39	534.5	45.	0.37	0.9999	0.01398	0.0052					-5.55	299.0
105	9.3	1.40	534.8	46.	0.38	0.9999	0.01397	0.0054					-5.50	302.0
110	8.0	1.41	535.1	40.	0.33	0.9999	0.01396	0.0046					-5.25	312.5
115	5.0	1.41	535.1	40.	0.33	0.9999	0.01396	0.0046					-5.00	322.6
120	8.0	1.43	535.6	40.	0.13	0.9999	0.01395	0.0046					-4.85	334.4
125	8.0	1.45	536.2	40.	0.33	0.9999	0.01393	0.0046					-4.30	351.0
130	8.0	1.49	537.4	40.	0.33	0.9999	0.01390	0.0046					-4.20	357.2
135	8.0	1.52	538.3	40.	0.33	0.9999	0.01388	0.0046					-4.10	360.6
140	8.0	1.55	539.1	40.	0.33	0.9999	0.01386	0.0046					-4.00	357.5
145	8.0	1.58	540.0	40.	0.33	1.0000	0.01384	0.0046					-3.90	363.0
150	8.0	1.61	540.8	40.	0.33	1.0000	0.01382	0.0046					-3.80	367.9
155	8.0	1.64	541.7	40.	0.33	1.0000	0.01379	0.0045					-3.70	372.1
160	8.0	1.68	542.9	40.	0.33	1.0000	0.01376	0.0045					-3.65	374.0
165	8.0	1.70	543.4	40.	0.33	1.0000	0.01375	0.0045					-3.60	375.9
170	8.0	1.72	544.0	40.	0.33	1.0000	0.01373	0.0045					-3.55	377.8
175	8.0	1.75	544.9	40.	0.33	1.0000	0.01371	0.0045					-3.50	379.8
180	8.0	1.78	545.7	40.	0.33	1.0001	0.01369	0.0045					-3.45	381.3
185	8.0	1.80	546.3	40.	0.33	1.0001	0.01368	0.0045					-3.40	383.1
190	8.0	1.83	547.1	40.	0.33	1.0001	0.01365	0.0045					-3.35	384.7
195	8.0	1.84	547.4	40.	0.33	1.0001	0.01365	0.0045					-3.30	386.4
200	8.0	1.85	547.7	40.	0.33	1.0001	0.01364	0.0045					-3.25	386.0
205	8.0	1.86	548.0	40.	0.33	1.0001	0.01363	0.0045					-3.20	387.6
210	8.0	1.88	548.5	40.	0.33	1.0001	0.01362	0.0045					-3.10	392.8
215	8.0	1.89	548.8	40.	0.33	1.0001	0.01361	0.0045					-3.00	378.0
220	8.0	1.91	549.4	40.	0.33	1.0001	0.01360	0.0045					-2.90	399.1
225	8.0	1.92	549.7	40.	0.33	1.0001	0.01359	0.0045					-2.80	402.3
230	8.0	1.93	550.0	40.	0.33	1.0001	0.01358	0.0045					-2.70	405.3
235	8.0	1.93	550.0	40.	0.33	1.0001	0.01358	0.0045					-2.60	408.0
240	8.0	1.94	550.3	40.	0.33	1.0001	0.01358	0.0045					-2.55	410.4
245	8.0	1.96	550.8	40.	0.33	1.0002	0.01356	0.0045					-2.50	412.1
250	8.0	1.97	551.1	40.	0.33	1.0002	0.01356	0.0045					-2.50	412.1

TOTAL NO. OF CYCLES (INTEGRATED) = 11595.244 CYCLES,   TOTAL MASS (INTEGRATED) = 0.022 LBS
TOTAL NO. OF CYCLES (MEASURED) =   CYCLES,   TOTAL ENTHALPY (INTEGRATED) =   BTU
AVERAGE ENTHALPY OF FLOW   =   BTU/LB

TABLE XVI   SOLID H2 MELTING TEST DATA (RUN NO. = 9 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 142895. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	-0.05	490.4	0.	0.0	0.9991	0.00564	0.0	0.20	498.3	1653.2	0.0
5	11.4	-0.05	490.4	228.	28.64	0.9991	0.00564	0.1615	-0.20	485.7	1603.7	258.99
10	16.1	-0.05	490.4	322.	40.45	0.9991	0.00564	0.2281	-0.40	479.5	1579.7	360.30
15	19.5	-0.05	490.4	390.	48.99	0.9991	0.00564	0.2763	-0.70	470.2	1545.7	427.00
20	23.4	-0.05	490.4	468.	58.79	0.9991	0.00564	0.3315	-1.00	461.0	1514.1	501.93
25	32.0	-0.05	490.4	640.	80.40	0.9991	0.00564	0.4533	-1.15	456.4	1499.1	679.57
30	37.5	-0.05	490.4	750.	94.22	0.9991	0.00564	0.5313	-1.30	451.7	1484.3	788.56
35	38.6	-0.05	490.4	772.	96.98	0.9991	0.00564	0.5468	-1.40	448.6	1474.6	806.35
40	38.5	-0.05	490.4	770.	96.73	0.9991	0.00564	0.5454	-1.50	445.4	1464.8	798.95
45	41.6	-0.05	490.4	832.	104.52	0.9991	0.00564	0.5893	-1.60	442.2	1455.0	857.49
50	41.4	-0.05	490.4	828.	104.02	0.9991	0.00564	0.5865	-1.70	439.0	1445.0	847.49
55	41.0	-0.05	490.4	820.	103.02	0.9991	0.00564	0.5808	-1.85	434.0	1429.5	830.31
60	42.5	-0.05	490.4	850.	106.78	0.9991	0.00564	0.6021	-2.00	429.0	1413.2	850.86
65	41.6	-0.05	490.4	832.	104.52	0.9991	0.00564	0.5893	-2.05	427.3	1407.5	829.49
70	41.7	-0.05	490.4	834.	104.77	0.9991	0.00564	0.5908	-2.10	425.6	1401.7	828.06
75	42.0	-0.05	490.4	840.	105.53	0.9991	0.00564	0.5950	-2.20	422.2	1389.7	826.89
80	44.0	-0.05	490.4	880.	110.55	0.9991	0.00564	0.6233	-2.30	418.8	1377.2	858.45
85	43.2	-0.07	489.8	864.	108.54	0.9991	0.00565	0.6128	-2.40	415.5	1364.1	835.39
90	44.2	-0.10	488.8	884.	111.06	0.9991	0.00566	0.6282	-2.50	412.1	1350.5	848.32
95	43.8	-0.15	487.3	876.	110.05	0.9991	0.00568	0.6245	-2.55	410.5	1343.5	838.96
100	30.0	-0.20	485.7	600.	75.38	0.9990	0.00570	0.4291	-2.60	408.8	1336.4	573.41
105	23.0	-0.23	484.8	460.	57.79	0.9990	0.00571	0.3296	-2.60	408.8	1336.4	440.46
110	23.0	-0.25	484.1	460.	57.79	0.9990	0.00572	0.3300	-2.60	408.8	1336.4	441.03
115	26.5	-0.27	483.5	530.	66.58	0.9990	0.00572	0.3807	-3.00	396.0	1276.6	486.04
120	28.8	-0.30	482.6	576.	72.36	0.9990	0.00573	0.4146	-3.40	383.1	1213.1	502.91
125	29.2	-0.32	482.0	584.	73.37	0.9990	0.00574	0.4209	-3.50	379.6	1196.6	503.62
130	28.5	-0.35	481.0	570.	71.61	0.9989	0.00575	0.4116	-3.60	376.0	1180.1	485.68
135	28.1	-0.37	480.4	562.	70.60	0.9989	0.00576	0.4063	-3.62	375.2	1176.7	478.12
140	28.0	-0.40	479.5	560.	70.35	0.9989	0.00577	0.4056	-3.65	374.1	1171.8	475.35
145	28.0	-0.45	477.9	560.	70.35	0.9989	0.00579	0.4070	-3.67	373.3	1168.6	475.56
150	27.5	-0.50	476.4	550.	69.10	0.9989	0.00581	0.4010	-3.70	372.1	1163.7	466.63
155	27.2	-0.55	474.8	544.	68.34	0.9988	0.00583	0.3979	-3.75	370.1	1155.7	459.84
160	27.0	-0.60	473.3	540.	67.84	0.9988	0.00585	0.3962	-3.80	368.0	1147.9	454.85
165	26.6	-0.65	471.7	532.	66.83	0.9988	0.00587	0.3916	-4.25	346.7	1100.2	430.86
170	26.2	-0.70	470.2	524.	65.83	0.9987	0.00589	0.3870	-4.70	327.2	1081.7	418.59
175	26.0	-0.75	468.7	520.	65.33	0.9987	0.00591	0.3853	-4.70	327.2	1081.7	416.74
180	26.2	-0.80	467.1	524.	65.83	0.9987	0.00592	0.3895	-4.70	327.2	1081.7	421.32
185	25.6	-0.85	465.6	512.	64.32	0.9987	0.00594	0.3818	-4.70	327.2	1081.7	413.01
190	25.0	-0.90	464.1	500.	62.81	0.9986	0.00595	0.3741	-4.70	327.2	1081.7	404.65
195	25.0	-0.95	462.5	500.	62.81	0.9986	0.00598	0.3753	-4.70	327.2	1081.7	405.98
200	23.5	-1.00	461.0	470.	59.05	0.9986	0.00600	0.3540	-4.70	327.2	1081.7	382.88
205	22.4	-1.05	459.5	448.	56.28	0.9986	0.00602	0.3385	-4.70	327.2	1081.7	366.17
210	23.8	-1.10	457.9	476.	59.80	0.9985	0.00604	0.3609	-4.70	327.2	1081.7	390.36
215	23.1	-1.15	456.4	462.	58.04	0.9985	0.00606	0.3514	-4.70	327.2	1081.7	380.15
220	23.2	-1.20	454.8	464.	58.29	0.9985	0.00608	0.3542	-4.70	327.2	1081.7	383.08
225	22.5	-1.25	453.3	450.	56.53	0.9984	0.00611	0.3446	-4.70	327.2	1081.7	372.78
230	22.0	-1.30	451.7	440.	55.28	0.9984	0.00613	0.3381	-4.70	327.2	1081.7	365.74
235	20.5	-1.35	450.2	410.	51.51	0.9984	0.00615	0.3162	-4.70	327.2	1081.7	341.98
240	17.5	-1.40	448.6	350.	43.97	0.9984	0.00617	0.2708	-4.70	327.2	1081.7	292.95
245	15.0	-1.45	447.0	300.	37.69	0.9983	0.00619	0.2330	-4.70	327.2	1081.7	251.98
250	3.5	-1.50	445.4	70.	8.79	0.9983	0.00621	0.0545	-4.70	327.2	1081.7	59.00
255	0.0	-1.55	443.8	0.	0.0	0.9983	0.00624	0.0	-4.70	327.2	1081.7	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 143639.563 CYCLES,   TOTAL MASS   (INTEGRATED) =   1.727 LBS
TOTAL NO. OF CYCLES (MEASURED) = 142895.000 CYCLES,   TOTAL ENTHALPY(INTEGRATED) =2206.462 BTU
AVERAGE ENTHALPY OF FLOW   =   1277.876 BTU/LB

TABLE XVII SOLID H$_2$ MELTING TEST DATA

(RUN. NO. = 10 INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0	280	5.85		-7.60	200	301	3.11		-4.10
5		5.88		-7.59	205	303	3.07		-4.05
10		5.92		-7.58	210	312	3.03		-4.00
15		5.96		-7.54	215	318	3.02		-4.00
20		6.00		-7.50	220	318	3.01		-4.00
25		5.98		-7.44	225	318	2.98		-3.93
30		5.96		-7.38	230	319	2.96		-3.85
35		5.91		-7.29	235	329	2.93		-3.70
40		5.87		-7.20	240	323	2.91		-3.55
45		5.82		-7.17	245	318	2.90		-3.32
50	Estimated	5.78		-7.15	250	330	2.89		-3.20
55		5.76		-7.08	255	330	2.88		-3.15
60		5.74		-7.00	260	323	2.88		-3.10
65		5.68		-6.85	265	320	2.87		-2.97
70		5.62		-6.70	270	324	2.85		-2.85
75		5.41		-6.50					
80		5.20		-6.30					
85		5.01		-6.15					
90		4.82		-6.00					
95		4.74		-5.87					
100		4.71		-5.75					
105		4.62		-5.67					
110		4.54		-5.60					
115		4.43		-5.59					
120		4.32		-5.58					
125		4.28		-5.49					
130		4.24		-5.40					
135		4.12		-5.20					
140	263	4.00		-5.00					
145	263	3.81		-4.95					
150	268	3.72		-4.90					
155	254	3.62		-4.80					
160	254	3.51		-4.70					
165	257	3.6		-4.60					
170	262	3.52		-4.50					
175	265	3.28		-4.47					
180	270	3.24		-4.45					
185	280	3.21		-4.40					
190	283	3.17		-4.35					
195	302	3.15		-4.22					

49

TABLE XVII SOLID H2 MELTING TEST DATA (RUN NO. = 10 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 186633. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZVDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZHH (BTU/MN)
0	0.0	-0.26	483.8	0.	0.00	0.9989	0.00572	0.0000	0.40	504.5	1677.9	0.00
5	5.6	-0.26	483.9	112.	14.07	0.9989	0.00572	0.0804	-0.30	482.5	1591.6	121.97
10	7.0	-0.26	483.8	140.	17.58	0.9989	0.00572	0.1005	-0.75	468.6	1540.2	154.80
15	10.6	-0.26	483.8	212.	26.63	0.9989	0.00572	0.1521	-0.63	466.2	1531.7	233.11
20	17.6	-0.26	483.8	352.	44.22	0.9989	0.00572	0.2526	-0.90	464.0	1524.3	385.20
25	24.0	-0.26	483.8	480.	60.30	0.9989	0.00572	0.3445	-0.93	463.1	1521.2	524.21
30	33.5	-0.26	483.8	670.	84.17	0.9989	0.00572	0.4809	-0.95	462.5	1519.2	730.72
35	35.6	-0.27	483.5	712.	89.44	0.9989	0.00572	0.5114	-1.17	455.7	1477.1	765.71
40	36.5	-0.28	483.2	730.	91.70	0.9989	0.00572	0.5247	-1.40	448.5	1474.6	773.77
45	36.8	-0.30	482.5	736.	92.46	0.9989	0.00573	0.5297	-1.65	440.5	1450.0	768.12
50	36.9	-0.31	482.2	738.	92.71	0.9989	0.00573	0.5314	-1.90	432.3	1424.2	756.96
55	35.8	-0.32	481.9	716.	89.94	0.9989	0.00574	0.5159	-1.92	431.6	1422.0	733.75
60	34.0	-0.33	481.6	680.	85.42	0.9989	0.00574	0.4903	-1.95	431.6	1418.1	695.70
65	26.2	-0.34	481.3	524.	65.82	0.9989	0.00574	0.3781	-1.93	431.3	1427.9	531.26
70	27.0	-0.35	481.0	540.	67.83	0.9989	0.00575	0.3899	-1.90	432.3	1424.2	555.29
75	44.4	-0.36	480.7	888.	111.55	0.9989	0.00575	0.6415	-1.97	430.0	1416.5	908.85
80	45.6	-0.37	480.4	912.	114.57	0.9989	0.00576	0.6593	-2.05	427.3	1407.5	926.05
85	45.4	-0.38	480.0	908.	114.07	0.9989	0.00576	0.6568	-2.07	426.6	1405.2	923.06
90	40.3	-0.40	479.4	806.	101.25	0.9989	0.00577	0.5838	-2.10	425.6	1401.7	818.30
95	31.8	-0.43	478.5	636.	79.89	0.9988	0.00578	0.4615	-2.10	425.6	1401.7	647.02
100	23.8	-0.45	477.9	476.	59.79	0.9988	0.00579	0.3459	-2.10	425.6	1401.7	484.87
105	38.3	-0.47	477.2	766.	96.23	0.9988	0.00579	0.5573	-2.10	425.6	1401.7	781.20
110	47.1	-0.50	476.3	942.	118.34	0.9988	0.00580	0.6867	-2.10	425.6	1401.7	962.65
115	47.9	-0.57	474.2	958.	120.35	0.9988	0.00583	0.7015	-2.17	423.2	1393.4	977.53
120	46.7	-0.65	471.7	934.	117.33	0.9987	0.00586	0.6875	-2.25	420.5	1383.5	951.20
125	43.3	-0.68	470.8	866.	108.79	0.9987	0.00587	0.6387	-2.27	419.8	1381.0	882.11
130	31.8	-0.71	469.8	636.	79.89	0.9987	0.00588	0.4700	-2.30	418.8	1377.2	647.29
135	35.0	-0.75	468.6	700.	87.93	0.9987	0.00590	0.5186	-2.35	417.1	1370.7	710.91
140	43.0	-0.85	465.5	860.	108.04	0.9986	0.00594	0.6413	-2.40	415.4	1364.1	874.66
145	44.2	-0.95	462.5	884.	111.05	0.9986	0.00598	0.6635	-2.50	412.1	1350.4	896.10
150	43.2	-1.05	459.4	864.	108.54	0.9985	0.00602	0.6528	-2.60	408.8	1336.4	872.49
155	53.0	-1.12	457.3	1060.	133.16	0.9985	0.00605	0.8047	-2.61	408.5	1335.9	1074.26
160	49.0	-1.20	454.8	980.	123.11	0.9984	0.00608	0.7479	-2.62	408.1	1333.5	997.47
165	39.5	-1.35	450.1	790.	99.24	0.9983	0.00614	0.6091	-2.66	406.5	1327.7	808.04
170	39.2	-1.50	445.4	784.	98.49	0.9983	0.00621	0.6109	-2.68	406.2	1324.8	809.39
175	40.0	-1.70	438.9	800.	100.50	0.9981	0.00630	0.6325	-2.72	404.9	1318.9	834.25
180	40.0	-1.90	432.3	800.	100.50	0.9980	0.00640	0.6421	-2.76	403.6	1313.0	843.10
185	39.3	-2.00	429.0	786.	98.74	0.9980	0.00645	0.6357	-2.81	402.0	1305.5	830.01
190	41.8	-2.10	425.6	836.	105.02	0.9979	0.00650	0.6815	-2.86	400.4	1298.0	884.03
195	41.6	-2.23	421.2	832.	104.52	0.9978	0.00657	0.6852	-2.83	401.3	1302.5	892.65
200	39.4	-2.45	413.8	786.	98.99	0.9977	0.00668	0.6605	-2.86	402.3	1301.0	863.42
205	39.0	-2.57	409.9	780.	97.98	0.9976	0.00675	0.6601	-2.87	400.1	1296.5	855.95
210	39.5	-2.70	405.5	790.	99.24	0.9975	0.00682	0.6756	-2.95	397.5	1284.3	867.72
215	34.9	-2.90	402.3	698.	87.68	0.9975	0.00687	0.6016	-2.96	396.6	1279.1	769.97
220	35.0	-2.90	399.1	780.	97.98	0.9974	0.00691	0.6777	-3.00	396.0	1276.0	865.15
225	37.8	-3.00	396.0	756.	94.97	0.9974	0.00698	0.6620	-2.95	397.5	1284.3	850.20
230	39.5	-3.10	392.8	790.	99.24	0.9973	0.00704	0.6973	-2.85	400.7	1277.5	905.22
235	30.2	-3.25	384.0	604.	75.87	0.9972	0.00713	0.5396	-2.75	403.9	1314.5	709.64
240	26.0	-3.40	383.1	520.	65.32	0.9971	0.00722	0.4705	-2.75	403.9	1314.5	615.00
245	25.9	-3.55	377.8	518.	65.07	0.9970	0.00732	0.4752	-2.75	403.9	1314.5	0. 70
250	26.4	-3.70	372.1	532.	66.83	0.9969	0.00743	0.4955	-2.60	408.8	1336.4	662.00
255	24.5	-3.78	368.9	490.	61.55	0.9969	0.00749	0.4604	-2.65	408.8	1336.4	615.10
260	18.0	-3.85	365.8	360.	45.22	0.9968	0.00754	0.3413	-2.60	408.8	1336.4	456.00
265	7.8	-3.87	364.9	156.	19.59	0.9968	0.00758	0.1461	-2.60	408.8	1336.4	171.70
270	0.0	-3.90	363.6	0.	0.00	0.9968	0.00761	0.0000	-2.60	408.8	1336.4	0.00

TOTAL NO. OF CYCLES (INTEGRATED) = 183039.500 CYCLES,   TOTAL MASS (INTEGRATED) = 2.413 LBS
TOTAL NO. OF CYCLES (MEASURED) = 186633.031 CYCLES,   TOTAL ENTHALPY(INTEGRATED) = 3300.817 BTU
AVERAGE ENTHALPY OF FLOW = 1364.653 BTU/LB

50.

TABLE XVIII SOLID H_2 MELTING TEST DATA

(RUN. NO. = 12 INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0		1.26	5.10	-7.10	200		1.91	3.60	-4.00
5		1.26	5.10	-6.68	205		1.93	3.57	-4.98
10		1.25	5.10	-6.28	210		1.96	3.55	-3.96
15		1.25	5.10	-6.43	215		1.98	3.53	-3.92
20		1.24	5.10	-6.58	220		2.00	3.50	-3.88
25		1.22	4.95	-6.40	225		2.03	3.47	-3.84
30		1.20	4.80	-6.28	230		2.05	3.45	-3.80
35		1.20	4.70	-6.10	235		2.07	3.42	-3.78
40		1.19	4.65	-5.78	240		2.10	3.40	-3.76
45		1.19	4.60	-5.80	245			3.38	-3.72
		1.23							
50		1.26	4.54	-5.88	250		2.10	3.36	-3.69
55		1.29	4.50	-5.80	255		2.11	3.34	-3.66
60		1.33	4.45	-5.77	260		2.11	3.32	-3.63
65		1.38	4.41	-5.58	265		2.10	3.30	-3.60
70		1.44	4.38	-5.60	270		2.10	3.28	-3.57
		1.49							
75		1.55	4.34	-5.55	275		2.10	3.25	-3.55
80		1.60	4.30	-5.50	280		2.09	3.23	-3.52
85		1.65	4.27	-5.48	285		2.09	3.20	-3.50
90		1.70	4.25	-5.46	290		2.09	3.18	-3.47
95		1.72	4.21	-5.37	295		2.10	3.15	-3.45
100		1.75	4.17	-5.28	300		2.10	3.12	-3.43
105		1.77	4.13	-5.17	305		2.12	3.11	-3.40
110		1.77	4.10	-5.07	310		2.14	3.10	-3.38
115		1.76	4.12	-5.01	315		2.16	3.08	-3.36
120		1.76	4.14	-4.96	320		2.18	3.06	-3.34
125		1.76	4.07	-4.88	325		2.20	3.04	-3.32
130		1.76	4.00	-4.80	330		2.23	3.02	-3.31
135		1.76	3.96	-4.75	335		2.26	3.00	-3.30
140		1.76	3.92	-4.70	340		2.29	2.98	-3.27
145		1.76	3.89	-4.60	345		2.31	2.96	-3.25
150		1.76	3.86	-4.52	350		2.33	2.94	-3.23
155		1.77	3.83	-4.47	355		2.35	2.92	-3.20
160		1.79	3.80	-4.42	360		2.38	2.91	-3.18
165		1.80	3.77	-4.36	365		2.41	2.90	-3.16
170		1.81	3.75	-4.30	370		2.44	2.88	-3.14
175		1.83	3.72	-4.26	375		2.46	2.86	-3.12
180		1.85	3.70	-4.21	380		2.48	2.84	-3.10
185		1.86	3.68	-4.17	385		2.50	2.82	-3.10
190		1.87	3.66	-4.13	390		2.52	2.80	-3.10
195		1.89	3.63	-4.07	395		2.55	2.78	-3.10

51

TABLE XVIII (Cont.)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
400		2.58	2.76	-3.10					
405		2.61	2.75	-3.10					
410		2.65	2.74	-3.10					
415		2.69	2.72	-3.11					
420		2.74	2.70	-3.12					
425		2.79	2.68	-3.14					

TABLE XVIII SOLID H2 MELTING TEST DATA (RUN NO. = 12 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA, FLOW TOTALIZER= 173397. CYCLES, FQD= 20.0 HZ/DIV, FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.25	499.8	0.	0.00	0.9992	0.00553	0.0000	0.35	503.0	1671.8	0.00
5	7.0	0.24	499.5	140.	17.58	0.9992	0.00554	0.0973	0.00	492.0	1628.3	158.55
10	9.4	0.23	499.2	198.	23.61	0.9992	0.00554	0.1308	-0.65	471.7	1551.2	202.95
15	11.4	0.22	498.9	228.	28.64	0.9992	0.00554	0.1587	-0.79	467.7	1537.0	244.04
20	21.2	0.21	498.6	424.	53.26	0.9992	0.00555	0.2954	-0.90	464.0	1524.3	450.37
25	23.2	0.20	498.2	464.	58.29	0.9992	0.00555	0.3235	-0.99	461.0	1515.1	490.17
30	28.8	0.19	497.9	576.	72.36	0.9992	0.00555	0.4018	-1.04	459.7	1510.0	606.85
35	32.0	0.17	497.3	640.	80.40	0.9992	0.00556	0.4470	-1.14	456.6	1500.0	670.65
40	32.3	0.15	496.7	646.	81.15	0.9992	0.00557	0.4518	-1.25	453.2	1489.2	672.60
45	33.0	0.14	496.4	660.	82.91	0.9992	0.00557	0.4619	-1.42	447.5	1472.6	680.24
50	32.7	0.13	496.0	654.	82.16	0.9992	0.00557	0.4579	-1.60	442.2	1455.0	666.40
55	34.1	0.11	495.4	682.	85.67	0.9992	0.00558	0.4782	-1.75	437.3	1439.9	608.59
60	18.3	0.10	495.1	366.	45.97	0.9991	0.00558	0.2567	-1.90	432.3	1424.2	365.72
65	4.7	0.09	494.8	94.	11.80	0.9991	0.00559	0.0659	-2.50	412.1	1350.0	89.12
70	11.5	0.08	494.5	230.	28.89	0.9991	0.00559	0.1615	-2.75	403.9	1314.5	212.39
75	15.9	0.07	494.2	316.	39.69	0.9991	0.00560	0.2221	-2.85	400.7	1279.5	263.67
80	19.5	0.06	493.8	390.	48.99	0.9991	0.00560	0.2743	-2.95	397.5	1284.3	352.52
85	22.2	0.05	493.5	444.	55.77	0.9991	0.00560	0.3125	-2.98	396.0	1279.7	377.96
90	23.6	0.04	493.2	472.	59.29	0.9991	0.00561	0.3324	-3.00	396.0	1276.0	424.30
95	24.5	0.04	493.2	490.	61.55	0.9991	0.00561	0.3451	-3.03	395.0	1271.9	438.76
100	26.0	0.03	492.9	520.	65.32	0.9991	0.00561	0.3664	-3.05	394.4	1266.0	465.00
105	25.5	0.03	492.9	510.	64.17	0.9991	0.00561	0.3594	-3.15	391.2	1253.2	450.43
110	25.1	0.02	492.6	502.	63.06	0.9991	0.00561	0.3540	-3.25	388.0	1237.3	435.03
115	25.8	0.02	492.6	516.	64.82	0.9991	0.00561	0.3638	-3.32	385.7	1226.1	446.15
120	25.3	0.01	492.3	506.	63.56	0.9991	0.00562	0.3570	-3.40	383.1	1213.1	433.13
125	25.7	0.00	492.0	514.	64.57	0.9991	0.00562	0.3629	-3.44	381.7	1206.5	437.86
130	24.8	-0.01	491.6	496.	62.31	0.9991	0.00562	0.3504	-3.48	380.3	1199.5	420.51
135	25.0	-0.02	491.3	500.	62.81	0.9991	0.00563	0.3534	-3.49	379.9	1198.3	423.53
140	25.0	-0.03	491.0	500.	62.81	0.9991	0.00563	0.3537	-3.50	379.6	1196.6	423.27
145	25.4	-0.04	490.7	508.	63.81	0.9991	0.00563	0.3596	-3.50	379.6	1196.6	433.32
150	23.8	-0.05	490.4	476.	59.79	0.9991	0.00564	0.3371	-3.50	379.6	1196.6	403.47
155	24.0	-0.07	489.7	480.	60.30	0.9991	0.00565	0.3404	-3.51	377.2	1195.0	406.61
160	23.9	-0.10	488.8	478.	60.05	0.9990	0.00566	0.3396	-3.52	378.9	1193.3	405.52
165	24.3	-0.12	488.2	486.	61.05	0.9990	0.00566	0.3457	-3.54	375.2	1175.0	411.47
170	22.9	-0.14	487.5	458.	57.53	0.9990	0.00567	0.3262	-3.56	377.4	1106.7	367.19
175	24.0	-0.15	487.2	480.	60.30	0.9990	0.00567	0.3421	-3.60	375.9	1180.1	403.79
180	24.9	-0.17	486.6	496.	62.31	0.9990	0.00568	0.3540	-3.55	377.4	1106.7	420.13
185	36.1	-0.20	485.7	722.	90.70	0.9990	0.00569	0.5163	-3.53	376.5	1171.6	615.30
190	24.2	-0.23	484.7	484.	60.80	0.9990	0.00570	0.3467	-3.50	379.6	1196.6	414.99
195	20.6	-0.27	483.5	412.	51.75	0.9989	0.00572	0.2959	-3.50	379.6	1196.6	354.16
200	22.8	-0.30	482.5	456.	57.29	0.9989	0.00573	0.3281	-4.00	355.1	1112.3	365.00
205	22.2	-0.33	481.6	444.	55.77	0.9989	0.00574	0.3201	-4.60	330.6	1006.8	347.99
210	22.0	-0.37	480.4	440.	55.27	0.9989	0.00576	0.3141	-3.99	359.9	1123.0	357.25
215	22.0	-0.40	479.4	440.	55.27	0.9989	0.00577	0.3187	-3.97	360.4	1124.2	356.33
220	21.8	-0.44	478.2	436.	54.77	0.9989	0.00578	0.3166	-3.95	361.3	1126.7	356.70
225	21.5	-0.47	477.2	430.	54.02	0.9988	0.00579	0.3124	-3.90	365.6	1133.4	354.62

TABLE XVIII (Cont)

230	21.4	-0.50	476.7	428.	53.76	0.9749	0.0154	.5120	-4.53	344.2	1097.7	342.33
235	21.7	-0.63	478.5	434.	54.52	0.9935	0.00573	0.3149	-4.28	349.2	1103.0	347.42
240	21.5	-0.45	477.4	436.	54.77	0.9940	0.00575	0.3170	-4.55	332.6	1.590	345.27
245	21.9	-0.60	473.7	439.	55.02	0.9990	0.0 584	0.3213	-4.55	332.6	1097.0	350.02
250	21.5	-0.65	471.7	436.	54.77	0.9947	0.00565	.329 9	-4.55	332.6	1097.0	347.55
255	21.5	-0.70	470.1	436.	54.77	0.9947	0.0564	.3219	-4.55	332.5	1097.0	350.00
260	21.4	-0.73	469.2	428.	53.76	.9947	0.00585	0.3167	-4.55	332.6	1097.0	344.92
265	21.2	-0.77	468.0	424.	53.26	0.9947	0.00591	0.3145	-4.55	332.0	1097.0	342.50
270	21.4	-0.80	467.1	428.	53.76	0.9946	0.00592	0.3181	-4.55	332.6	1097.0	345.47
275	21.0	-0.84	465.9	420.	52.76	0.9946	0.00594	0.3130	-4.55	332.6	1097.0	340.00
280	20.8	-0.87	464.9	415.	52.26	0.9946	.0595	.315 5	-4.55	332.6	1097.0	330.31
285	20.7	-0.90	464.0	414.	52.01	0.9946	0.00596	0.3097	-4.55	332.6	1097.0	337.55
290	20.5	-0.95	462.5	410.	51.50	0.9946	0.00598	.3977	-4.55	332.5	1099.0	335.17
295	20.4	-1.00	461.0	408.	51.25	0.9985	0.00600	0.3072	-4.55	332.0	1097.0	334.55
300	20.6	-1.05	459.4	412.	51.75	0.9945	0.00602	0.3113	-4.55	332.6	1097.0	337.00
305	19.4	-1.10	457.9	398.	48.76	0.9915	0.0604	0.2941	-4.55	332.6	1000.0	320.00
310	20.9	-1.15	456.3	418.	52.51	0.9985	0.00606	0.3179	-4.57	331.6	1086.2	346.05
315	19.8	-1.20	454.8	396.	49.74	0.9984	0.00608	0.3022	-4.58	331.4	1097.6	326.79
320	18.9	-1.25	453.2	376.	47.23	0.9984	0.00610	0.2879	-4.57	331.0	1087.0	313.11
325	18.5	-1.30	451.7	370.	46.49	0.9984	0.00612	.2845	-4.57	331.4	1097.0	307.11
330	18.4	-1.35	450.1	366.	46.23	0.9984	0.0614	.2834	-4.57	331.0	1097.0	300.55
335	18.3	-1.40	448.5	366.	45.97	0.9984	0.00615	0.2432	-4.57	331.	.3171.0	307.94
340	18.8	-1.45	447.0	376.	47.23	0.9984	0.00619	0.2919	-4.57	331..	1097.0	313.047
345	22.2	-1.50	445.4	444.	55.77	0.9983	0.00621	0.3459	-4.57	331.	1097.0	376.21
350	20.3	-1.55	443.8	406.	51.0	0.9982	0.0623	.3175	-4.57	331.0	1097.0	343.04
355	17.4	-1.60	442.2	346.	43.71	0.9982	0.00625	0.2731	-4.57	331.0	1097.0	276.79
360	17.0	-1.65	440.5	340.	42.71	0.9982	0.00628	.2676	-4.55	331.	1097.0	271.22
365	18.9	-1.70	438.9	378.	47.43	0.9981	0.00630	0.2900	-4.55	331.0	1097.0	324.90
370	22.4	-1.75	437.3	448.	56.23	0.9981	0.00632	0.3555	-4.59	331.0	1097.0	350.57
375	22.4	-1.80	435.6	448.	56.23	0.9981	0.00635	0.3565	-4.57	331.0	1097.0	2.5402
380	15.9	-1.85	434.0	318.	39.74	0.9980	0.0637	.2524	-4.57	331.0	1097.0	276.41
385	14.9	-1.90	432.3	298.	37.43	0.9980	0.00640	0.2391	-4.57	331.0	1097.0	260.07
390	13.5	-1.93	431.3	270.	33.91	0.9980	0.00641	0.2172	-4.57	331.0	1097.0	233.10
395	10.8	-1.96	430.3	216.	27.13	0.9980	0.00643	0.1741	-4.57	331.0	1097.0	187.30
400	9.0	-2.00	429.1	180.	22.61	.9980	0.00645	0.1455	-4.57	331.0	1097.0	155.30
405	6.4	-2.01	428.6	128.	16.08	0.9980	0.00645	0.1036	-4.55	331.0	1097.0	112.00
410	4.2	-2.02	428.3	84.	10.55	0.9979	0.00646	0.0680	-4.55	331.0	1097.3	73.99
415	2.8	-2.03	427.9	56.	7.03	0.9979	0.00646	0.0454	-4.59	331.0	1097.0	47.30
420	2.0	-2.04	427.6	40.	5.02	0.9979	0.00647	0.0324	-4.60	337.3	1074.3	53.51
425	0.0	-2.05	427.3	0.	0.0	.9979	0.00647	.00.0	-4.53	344.2	1097.9	0.30

TABLE XIX SOLID H$_2$ MELTING TEST DATA

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0			6.85	-5.60	200			4.00	-3.40
5			6.00	-5.15	205			3.97	
10			5.30	-5.15	210			3.94	
15			5.40	-5.40	215			3.90	
20			5.45	-5.48	220			3.87	-3.30
25			5.45	-5.49	225			3.83	
30			5.38	-5.51	230			3.80	
35			5.30	-5.53	235			3.77	
40			5.26	-5.56	240			3.74	-3.20
45			5.22	-5.56	245			3.72	
50				-5.56	250			3.70	
55				-5.56	255			3.66	
60			5.08	-5.56	260			3.62	-3.06
65			5.04	-5.56	265			3.58	
70			5.00	-5.55	270			3.54	
75			4.95	-5.45	275			3.52	
80			4.90	-5.18	280			3.50	-2.92
85			4.87	-5.15	285			3.46	
90			4.85	-5.08	290			3.42	
95			4.82	-5.00	295			3.40	
100			4.74	-4.92	300			3.38	-2.80
105			4.71	-4.72	305			3.34	-2.77
110			4.68	-4.40	310			3.30	-2.75
115			4.64	-4.24	315			3.27	-2.72
120			4.60	-4.09	320			3.	-2.70
125			4.55	-4.00	325			3.23	-2.67
130			4.50	-3.92	330			3.20	-2.65
135			4.46	-3.90	335			3.17	-2.63
140			4.42	-3.82	340			3.	-2.60
145			4.38		345			3.12	-2.58
150			4.34	-3.75	350			3.10	-2.55
155			4.32		355			3.09	-2.52
160			4.28	-3.72	360			3.08	-2.50
165			4.24		365			3.06	-2.48
170			4.20		370			3.04	-2.46
175			4.16		375			3.02	-2.44
180			4.12	-3.55	380			3.00	-2.42
185			4.10		385			2.97	
190			4.08		390			2.95	
195			4.04		395			2.93	

TABLE XIX (Cont.)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
400			2.90						
405			2.87						
410			2.85						
415			2.82	-2.30					
420			2.80						
425			2.78						
430			2.76						
435			2.74						
440			2.72						
445			2.70	-2.20					
450			2.68	-2.18					
455			2.66						
460			2.64						
465			2.62						
470			2.61	-2.10					
475			2.60						
480			2.58						
485			2.56						
490			2.54						
495			2.52						
500			2.50						
505			2.48						
510			2.46	-2.00					
515			2.44						
520			2.42						
525			2.41						
530			2.40	-1.92					

TABLE XIX SOLID H2 MELTING TEST DATA (RUN NO. = 13 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA.   FLOW TOTALIZER= 144553. CYCLES.   FOD= 20.0 HZ/DIV.   FOV= 7.96 HZ/CFM

TIME (SEC)	OF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FO (HZ)	VOT (CFM)	C (---)	RHO (LB/FT3)	ZMOT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.0	492.0	0.	0.0	0.9991	0.00563	0.0	0.02	492.6	1630.8	0.0
5	7.5	0.0	492.0	150.	18.84	0.9991	0.00563	0.1059	-0.12	488.2	1613.4	170.88
10	13.7	0.0	492.0	274.	34.42	0.9991	0.00563	0.1935	-0.45	477.9	1573.9	304.49
15	13.1	0.0	492.0	262.	32.91	0.9991	0.00563	0.1850	-0.72	469.6	1542.5	285.53
20	13.5	0.0	492.0	270.	33.92	0.9991	0.00563	0.1906	-0.94	462.8	1520.2	289.82
25	12.1	0.0	492.0	242.	30.40	0.999·	0.00563	0.1709	-1.08	458.5	1506.0	257.33
30	12.2	0.0	492.0	244.	30.65	0.9991	0.00563	0.1723	-1.20	454.8	1494.1	257.41
35	20.3	0.0	492.0	406.	51.00	0.9991	0.00563	0.2867	-1.32	451.1	1482.4	424.95
40	23.6	0.0	492.0	472.	59.30	0.9991	0.00563	0.3333	-1.38	449.2	1476.5	492.08
45	25.7	-0.01	491.7	514.	64.57	0.9991	0.00563	0.3632	-1.44	447.3	1470.7	534.10
50	26.6	-0.02	491.4	532.	66.83	0.9991	0.00563	0.3761	-1.55	443.9	1459.9	549.11
55	26.9	-0.03	491.0	538.	67.59	0.9991	0.00564	0.3806	-1.62	441.6	1453.0	553.02
60	27.1	-0.04	490.7	542.	68.09	0.9991	0.00564	0.3837	-1.70	439.0	1445.0	554.40
65	26.1	-0.05	490.4	522.	65.58	0.9991	0.00564	0.3697	-1.75	437.3	1439.9	532.41
70	24.6	-0.06	490.1	492.	61.81	0.9991	0.00565	0.3487	-1.80	435.7	1434.8	500.33
75	23.8	-0.07	489.8	476.	59.80	0.9991	0.00565	0.3376	-1.85	434.0	1429.5	482.60
80	22.5	-0.08	489.5	450.	56.53	0.9991	0.00565	0.3194	-1.95	430.7	1418.7	453.09
85	22.0	-0.09	489.2	440.	55.23	0.9991	0.00566	0.3125	-1.98	429.7	1415.4	442.26
90	19.3	-0.10	488.8	386.	48.49	0.9991	0.00566	0.2743	-2.00	429.0	1413.2	387.62
95	18.3	-0.10	488.8	366.	45.98	0.9991	0.00566	0.2601	-2.00	429.0	1413.2	367.54
100	17.4	-0.10	488.8	348.	43.72	0.9991	0.00566	0.2473	-2.00	429.0	1413.2	349.46
105	16.2	-0.10	488.8	324.	40.70	0.9991	0.00566	0.2302	-2.00	429.0	1413.2	325.36
110	15.5	-0.10	488.5	310.	38.94	0.9991	0.00566	0.2203	-2.00	429.0	1413.2	311.30
115	16.3	-0.10	488.8	326.	40.95	0.9991	0.00566	0.2317	-2.00	429.0	1413.2	327.37
120	16.1	-0.10	488.8	322.	40.45	0.9991	0.00566	0.2288	-2.00	429.0	1413.2	323.35
125	16.9	-0.12	488.2	338.	42.46	0.9991	0.00567	0.2405	-2.02	428.3	1410.9	339.31
130	15.5	-0.14	487.6	310.	38.94	0.9991	0.00568	0.2208	-2.04	427.6	1408.7	311.09
135	16.0	-0.15	487.3	320.	40.20	0.9991	0.00568	0.2281	-2.06	427.0	1406.4	320.81
140	15.7	-0.16	487.0	314.	39.45	0.9991	0.00568	0.2240	-2.08	426.3	1404.0	314.48
145	15.8	-0.18	486.3	316.	39.70	0.9990	0.00569	0.2257	-2.10	425.6	1401.7	316.36
150	16.0	-0.20	485.7	320.	40.20	0.9990	0.00570	0.2288	-2.12	424.9	1399.4	320.24
155	16.0	-0.20	485.7	320.	40.20	0.9990	0.00570	0.2288	-2.14	424.3	1397.0	319.70
160	15.2	-0.20	485.7	304.	38.19	0.9990	0.00570	0.2174	-2.16	423.6	1394.6	303.19
165	15.0	-0.20	485.7	300.	37.69	0.9990	0.00570	0.2145	-2.18	422.9	1392.2	298.68
170	15.0	-0.20	485.7	300.	37.69	0.9990	0.00570	0.2145	-2.20	422.2	1389.7	298.16
175	14.4	-0.20	485.7	288.	36.18	0.9990	0.00570	0.2060	-2.22	421.6	1387.3	285.72
180	14.5	-0.20	485.7	290.	36.43	0.9990	0.00570	0.2074	-2.24	420.9	1384.8	287.19
185	14.4	-0.20	485.7	288.	36.18	0.9990	0.00570	0.2060	-2.25	420.5	1383.5	284.95
190	14.1	-0.20	485.7	282.	35.43	0.9990	0.00570	0.2017	-2.27	419.9	1381.0	278.51
195	14.2	-0.22	485.1	284.	35.68	0.9990	0.00571	0.2034	-2.29	419.2	1378.5	280.33
200	14.4	-0.24	484.5	288.	36.19	0.9990	0.00571	0.2065	-2.30	418.8	1377.2	284.37
205	14.2	-0.26	483.9	284.	35.68	0.9990	0.00572	0.2039	-2.32	418.2	1374.6	290.26
210	14.3	-0.28	483.2	286.	35.93	0.9990	0.00573	0.2056	-2.33	417.8	1373.3	282.33
215	14.2	-0.30	482.6	284.	35.51	0.9990	0.00573	0.2044	-2.35	417.2	1370.7	280.18
220	14.2	-0.30	482.6	284.	35.68	0.9990	0.00573	0.2044	-2.37	416.5	1368.1	279.64

TABLE XIX (Cont)

225	13.8	-0.30	482.6	276.	34.67	0.9990	0.00573	0.1986	-2.39	415.8	1365.4	271.24
230	13.8	-0.30	482.6	276.	34.67	0.9990	0.00573	0.1986	-2.40	415.5	1364.1	270.97
235	13.8	-0.30	482.6	276.	34.67	0.9990	0.00573	0.1986	-2.41	415.1	1362.8	270.71
240	13.5	-0.30	482.6	270.	33.92	0.9990	0.00573	0.1943	-2.42	414.8	1361.4	264.56
245	13.1	-0.35	481.0	262.	32.91	0.9989	0.00575	0.1892	-2.44	414.1	1358.7	257.03
250	12.5	-0.40	479.5	250.	31.41	0.9989	0.00577	0.1811	-2.45	413.8	1357.3	245.80
255	13.1	-0.40	479.5	262.	32.91	0.9989	0.00577	0.1898	-2.46	413.5	1356.0	257.34
260	13.2	-0.40	479.5	264.	33.17	0.9989	0.00577	0.1912	-2.48	412.8	1353.2	258.78
265	13.1	-0.40	479.5	262.	32.91	0.9989	0.00577	0.1898	-2.49	412.5	1351.9	256.56
270	12.9	-0.40	479.5	258.	32.41	0.9989	0.00577	0.1869	-2.50	412.1	1350.5	252.39
275	12.9	-0.43	478.5	258.	32.41	0.9989	0.00578	0.1872	-2.53	411.1	1346.3	252.09
280	13.2	-0.46	477.6	264.	33.17	0.9989	0.00579	0.1920	-2.55	410.5	1343.5	257.91
285	12.6	-0.46	477.6	252.	31.66	0.9989	0.00579	0.1832	-2.58	409.5	1339.2	245.41
290	12.3	-0.46	477.6	246.	30.90	0.9989	0.00579	0.1789	-2.60	408.8	1336.4	239.05
295	12.1	-0.46	477.6	242.	30.40	0.9989	0.00579	0.1760	-2.61	408.5	1334.9	234.92
300	12.0	-0.46	477.6	240.	30.15	0.9989	0.00579	0.1745	-2.62	408.2	1333.5	232.72
305	12.2	-0.48	477.0	244.	30.65	0.9989	0.00580	0.1777	-2.66	406.9	1327.7	235.88
310	13.5	-0.50	476.4	270.	33.92	0.9989	0.00581	0.1968	-2.70	405.6	1321.9	260.20
315	13.5	-0.52	475.7	270.	33.92	0.9988	0.00582	0.1971	-2.72	404.9	1318.9	259.96
320	13.4	-0.55	474.8	268.	33.67	0.9988	0.00583	0.1960	-2.74	404.3	1316.0	257.95
325	12.5	-0.56	474.5	250.	31.41	0.9988	0.00583	0.1830	-2.76	403.6	1313.0	240.24
330	14.2	-0.57	474.2	284.	35.68	0.9988	0.00584	0.2080	-2.78	403.0	1310.0	272.47
335	14.3	-0.58	473.9	286.	35.93	0.9988	0.00584	0.2096	-2.80	402.3	1307.1	273.94
340	14.3	-0.60	473.3	286.	35.93	0.9988	0.00585	0.2099	-2.90	399.2	1291.9	271.12
345	13.7	-0.63	472.3	274.	34.42	0.9988	0.00586	0.2014	-2.93	398.2	1287.4	259.33
350	14.2	-0.65	471.7	284.	35.68	0.9988	0.00587	0.2091	-2.96	397.3	1282.8	268.18
355	14.4	-0.68	470.8	288.	36.18	0.9988	0.00588	0.2124	-3.00	396.0	1276.6	271.18
360	14.8	-0.70	470.2	296.	37.19	0.9987	0.00589	0.2186	-3.02	395.4	1273.5	278.39
365	15.0	-0.72	469.6	300.	37.69	0.9987	0.00589	0.2218	-3.04	394.7	1270.4	281.83
370	13.8	-0.75	468.7	276.	34.67	0.9987	0.00591	0.2045	-3.06	394.1	1267.3	259.16
375	13.4	-0.77	468.0	268.	33.67	0.9987	0.00591	0.1988	-3.08	393.5	1264.2	251.35
380	14.0	-0.80	467.1	280.	35.18	0.9987	0.00592	0.2081	-3.20	389.7	1245.3	259.19
385	14.1	-0.82	466.5	282.	35.43	0.9987	0.00593	0.2099	-3.23	388.7	1240.5	260.38
390	14.5	-0.84	465.9	290.	36.43	0.9987	0.00594	0.2161	-3.26	387.7	1235.7	267.08
395	13.2	-0.86	465.3	264.	33.17	0.9987	0.00595	0.1970	-3.30	386.4	1229.3	242.19
400	13.4	-0.88	464.7	268.	33.67	0.9986	0.00596	0.2003	-3.34	385.1	1222.8	244.88
405	12.9	-0.90	464.1	258.	32.41	0.9986	0.00601	0.1930	-3.37	384.1	1218.1	235.13
410	13.3	-0.93	463.1	266.	33.42	0.9986	0.00598	0.1994	-3.40	383.1	1213.1	241.91
415	13.5	-0.95	462.5	270.	33.92	0.9986	0.00598	0.2027	-3.40	383.1	1213.1	245.87
420	14.8	-0.97	461.9	296.	37.19	0.9986	0.00599	0.2225	-3.40	383.1	1213.1	269.90
425	15.8	-1.00	461.0	316.	39.70	0.9986	0.00600	0.2380	-3.40	383.1	1213.1	288.71
430	17.2	-1.02	460.4	?.	?.22	0.9986	0.00601	0.2594	-3.40	383.1	1213.1	314.71
435	18.2	-1.05	459.5	?.	?5.73	0.9986	0.00602	0.2751	-3.40	383.1	1213.1	333.67
440	17.7	-1.08	458.5	?.	44.47	0.9985	0.00604	0.2680	-3.40	383.1	1213.1	325.15
445	18.0	-1.10	457.9	?.	45.23	0.9985	0.00604	0.2729	-3.41	382.8	1211.5	330.65
450	13.8	-1.13	457.0	276.	34.67	0.9985	0.00606	0.2097	-3.42	382.4	1209.8	253.66
455	7.4	-1.15	456.4	148.	18.59	0.9985	0.00606	0.1126	-3.43	382.1	1208.2	136.02
460	0.0	-1.?	455.8	0.	0.0	0.9985	0.00607	0.0	-3.44	381.7	1206.5	0.0
465	0.	-?.?0	454.8	0.	0.0	0.9985	0.00608	0.0	-3.45	381.4	1204.9	0.0
470	5.?	-.22	454.2	110.	13.82	0.9985	0.00609	0.0841	-3.46	381.1	1203.3	101.16
475	?.?	-.24	453.6	.94.	11.81	0.9985	0.00610	0.0719	-3.47	380.7	1201.6	86.44
480	3.8	-1.26	453.0	76.	9.55	0.9984	0.00611	0.0582	-3.48	380.3	1199.9	69.89
485	2.4	-1.28	452.3	48.	6.03	0.9984	0.00612	0.0368	-3.49	380.0	1198.3	44.14
490	2.4	-1.30	451.7	48.	6.03	0.9984	0.00613	0.0369	-3.50	379.6	1196.6	44.14
495	3.2	-1.34	450.5	64.	8.04	0.9984	0.00614	0.0493	-3.50	379.6	1196.6	59.01
500	4.6	-1.37	449.5	92.	11.56	0.9984	0.00616	0.0710	-3.49	380.0	1198.3	85.13
505	4.9	-1.40	448.6	98.	12.31	0.9984	0.00617	0.0758	-3.48	380.3	1199.9	91.00
510	5.2	-1.43	447.6	104.	13.07	0.9983	0.00618	0.0806	-3.47	380.7	1201.6	96.90
515	5.1	-1.46	446.7	102.	12.81	0.9983	0.00620	0.0793	-3.46	381.1	1203.3	95.37
520	4.0	-1.50	445.4	80.	10.05	0.9983	0.00621	0.0623	-3.45	381.4	1204.9	75.11
525	3.3	-1.55	443.8	66.	8.29	0.9983	0.00624	0.0516	-3.45	381.4	1204.9	62.19
530	0.0	-1.60	442.2	0.	0.0	0.9982	0.00626	0.0	-3.55	377.8	1188.3	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 145638.625 CYCLES.   TOTAL MASS (INTEGRATED) = 1.746 LBS
TOTAL NO. OF CYCLES (MEASURED) = 144553.000 CYCLES.   TOTAL ENTHALPY (INTEGRATED) = 2366.343 BTU
AVERAGE ENTHALPY OF FLOW = 1355.135 BTU/LB

58

TABLE XX SOLID H_2 MELTING TEST DATA

(RUN. NO. = 14 INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0			6.9	-6.4	200			3.45	-2.70
5			6.2	-6.0	205				
10			5.5	-5.7	210				
15			5.1		215				
20			4.8	-5.6	220			3.35	-2.40
25			4.7	.	225				
30			4.6	-5.6	230				
35					235				
40			4.45	-5.3	240			3.25	-2.20
45					245				
50			4.35	-5.3	250				
55					255				
60			4.25	-5.0	260			3.20	-1.95
65					265				
70				-4.7	270				
75					275				
80			4.10	-4.6	280			3.10	-1.75
85					285				
90				-4.45	290				
95					295				
100			3.95	-4.40	300			3.05	-1.70
105					305				
110					310			3.00	-1.70
115					315				
120			3.85	-4.10	320				
125									
130									
135									
140			3.70	-3.75					
145									
150									
155									
160			3.60	-3.40					
165									
170									
175									
180			3.50	-3.00					
185									
190									
195									

TABLE XX SOLID H2 MELTING TEST DATA (RUN NO. = 14 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 173822. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VOT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	-0.05	490.4	0.	0.00	0.9991	0.00564	0.0000	0.03	492.9	1652.0	0.00
5	4.5	-0.05	490.4	90.	11.30	0.9991	0.00564	0.0637	0.02	492.0	1630.8	103.96
10	6.7	-0.05	490.4	134.	16.83	0.9991	0.00564	0.0949	-0.15	487.2	1609.6	152.79
15	13.5	-0.05	490.4	270.	33.91	0.9991	0.00564	0.1912	-0.53	475.4	1564.6	299.24
20	20.0	-0.05	490.4	400.	50.25	0.9991	0.00564	0.2833	-0.92	463.4	1522.3	431.32
25	23.4	-0.05	490.4	468.	58.79	0.9991	0.00564	0.3314	-1.03	460.0	1511.0	500.91
30	25.0	-0.05	490.4	500.	62.81	0.9991	0.00564	0.3541	-1.14	456.6	1500.0	531.26
35	23.5	-0.05	490.4	470.	59.04	0.9991	0.00564	0.3329	-1.17	455.7	1497.1	498.40
40	30.1	-0.05	490.4	602.	75.62	0.9991	0.00564	0.4264	-1.20	454.8	1494.1	637.12
45	31.9	-0.05	490.4	638.	80.15	0.9991	0.00564	0.4519	-1.32	451.0	1482.4	669.91
50	34.0	-0.05	490.4	680.	85.42	0.9991	0.00564	0.4816	-1.45	447.0	1469.7	707.92
55	31.1	-0.05	490.4	622.	78.14	0.9991	0.00564	0.4405	-1.52	444.7	1462.9	644.52
60	30.5	-0.05	490.4	610.	76.63	0.9991	0.00564	0.4320	-1.60	442.2	1455.0	628.08
65	30.2	-0.06	490.1	614.	75.87	0.9991	0.00564	0.4281	-1.65	440.5	1450.0	620.77
70	30.2	-0.08	489.4	604.	75.87	0.9990	0.00565	0.4206	-1.70	438.9	1445.0	619.40
75	26.0	-0.10	488.8	520.	65.32	0.9990	0.00566	0.3695	-1.75	437.3	1439.9	532.06
80	31.2	-0.11	488.5	624.	78.39	0.9990	0.00566	0.4436	-1.80	435.6	1434.7	636.59
85	32.8	-0.12	488.2	656.	82.41	0.9990	0.00566	0.4667	-1.85	434.0	1429.5	667.21
90	32.6	-0.13	487.9	652.	81.90	0.9990	0.00567	0.4641	-1.90	432.3	1424.2	661.09
95	32.7	-0.14	487.5	654.	82.16	0.9990	0.00567	0.4659	-1.93	431.3	1420.9	662.03
100	34.1	-0.15	487.2	682.	85.67	0.9990	0.00567	0.4861	-1.95	430.6	1418.7	689.75
105	33.2	-0.16	486.9	664.	83.41	0.9990	0.00568	0.4736	-2.00	429.0	1413.2	669.35
110	33.0	-0.17	486.6	660.	82.91	0.9990	0.00568	0.4710	-2.05	427.3	1407.5	663.06
115	31.8	-0.18	486.3	636.	79.89	0.9990	0.00569	0.4542	-2.07	426.6	1405.2	638.32
120	32.0	-0.19	486.0	640.	80.40	0.9990	0.00569	0.4573	-2.08	426.3	1404.0	642.21
125	33.3	-0.20	485.7	666.	83.66	0.9990	0.00569	0.4762	-2.09	425.9	1402.9	668.17
130	36.2	-0.22	485.0	724.	90.95	0.9990	0.00570	0.5184	-2.10	425.6	1401.7	726.69
135	35.8	-0.25	484.1	716.	89.94	0.9990	0.00571	0.5136	-2.15	423.9	1395.8	716.99
140	34.6	-0.27	483.5	692.	86.93	0.9989	0.00572	0.4970	-2.20	422.6	1389.7	690.83
145	39.6	-0.30	482.5	792.	99.49	0.9989	0.00573	0.5700	-2.23	421.2	1386.0	790.06
150	36.3	-0.33	481.6	726.	91.20	0.9989	0.00574	0.5235	-2.25	420.5	1383.5	724.33
155	35.7	-0.37	480.4	714.	89.69	0.9988	0.00576	0.5161	-2.28	419.5	1379.7	712.23
160	35.7	-0.40	479.4	714.	89.69	0.9988	0.00577	0.5171	-2.30	418.8	1377.2	712.20
165	36.0	-0.43	478.5	720.	90.45	0.9988	0.00578	0.5225	-2.30	418.8	1377.2	719.66
170	35.3	-0.46	477.6	706.	88.69	0.9988	0.00579	0.5133	-2.30	418.8	1377.2	707.03
175	35.2	-0.52	475.7	704.	88.44	0.9988	0.00581	0.5139	-2.35	417.1	1370.7	704.42
180	37.5	-0.57	474.2	750.	94.22	0.9988	0.00583	0.5492	-2.40	415.4	1364.1	749.64
185	35.5	-0.63	472.3	710.	89.19	0.9987	0.00585	0.5219	-2.41	415.1	1362.7	711.54
190	33.4	-0.69	470.5	668.	83.91	0.9987	0.00588	0.4930	-2.42	414.8	1361.1	671.20
195	32.2	-0.75	468.6	644.	80.90	0.9987	0.00590	0.4771	-2.46	413.4	1356.0	647.02
200	33.2	-0.80	467.1	664.	83.41	0.9986	0.00592	0.4935	-2.50	412.1	1350.0	666.50
205	37.0	-0.85	465.5	740.	92.96	0.9986	0.00594	0.5518	-2.51	411.8	1349.1	744.51
210	35.6	-0.90	464.0	712.	89.44	0.9986	0.00596	0.5327	-2.52	411.4	1347.7	717.95
215	35.2	-0.98	461.6	704.	88.44	0.9985	0.00599	0.5295	-2.56	410.1	1342.0	710.65
220	35.0	-1.05	459.4	700.	87.93	0.9985	0.00602	0.5289	-2.60	408.8	1336.4	706.00
225	35.2	-1.13	456.9	704.	88.44	0.9985	0.00605	0.5348	-2.60	408.8	1336.4	714.72
230	34.0	-1.20	454.8	680.	85.42	0.9984	0.00608	0.5190	-2.60	408.8	1336.4	693.61
235	34.1	-1.30	451.7	682.	85.67	0.9984	0.00612	0.5240	-2.62	408.1	1333.5	698.89
240	35.9	-1.40	448.5	718.	90.20	0.9983	0.00616	0.5555	-2.64	407.5	1330.6	739.29
245	34.5	-1.50	445.4	690.	86.68	0.9983	0.00621	0.5376	-2.69	405.8	1323.3	711.56
250	33.0	-1.60	442.2	660.	82.91	0.9982	0.00625	0.5180	-2.75	403.9	1314.5	680.94
255	31.1	-1.68	439.6	622.	78.14	0.9981	0.00629	0.4910	-2.73	404.5	1317.4	646.95
260	25.0	-1.76	436.9	500.	62.81	0.9981	0.00633	0.3970	-2.70	405.5	1321.6	524.90
265	18.2	-1.88	433.0	364.	45.72	0.9981	0.00639	0.2917	-2.75	404.5	1314.5	383.45
270	16.8	-2.00	429.0	336.	42.21	0.9980	0.00645	0.2717	-2.80	402.3	1307.0	355.22
275	17.5	-2.05	427.3	350.	43.97	0.9979	0.00647	0.2842	-2.84	401.0	1301.0	369.76
280	18.0	-2.10	425.6	360.	45.22	0.9979	0.00649	0.2934	-2.88	399.7	1294.4	382.05
285	18.3	-2.13	424.6	366.	45.97	0.9979	0.00651	0.2990	-2.94	397.8	1285.8	384.52
290	18.5	-2.16	423.5	370.	46.48	0.9978	0.00653	0.3030	-3.10	392.8	1261.0	382.10
295	17.4	-2.20	422.2	348.	43.71	0.9978	0.00655	0.2859	-3.20	389.6	1245.3	356.10
300	15.8	-2.24	420.2	316.	39.69	0.9977	0.00657	0.2604	-3.30	386.4	1229.3	320.22
305	8.9	-2.32	419.1	178.	22.36	0.9978	0.00661	0.1476	-3.40	383.1	1213.1	179.13
310	0.0	-2.40	415.4	0.	0.00	0.9977	0.00666	0.0000	-3.50	379.6	1196.6	0.00

TOTAL NO. OF CYCLES (INTEGRATED) = 177449.406 CYCLES,   TOTAL MASS   (INTEGRATED) = 2.130 LBS
TOTAL NO. OF CYCLES (MEASURED) = 173822.031 CYCLES,   TOTAL ENTHALPY(INTEGRATED) =2957.257 BTU
AVERAGE ENTHALPY OF FLOW   =   1384.388 BTU/LB

60

TABLE XXI SOLID H_2 MELTING TEST DATA

(RUN. NO. = 15 INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0		1.020			200			8.95	-4.3'
5					205				
10					210		1.908		
15		1.032			215				
20					220				
25					225		1.96;		
30		1.140			240				
35					235				
40					240		2.04;		
45		1.290			245				
50					250			8.22	-3.80
55					255		2.118		
60		1.440			260				
65					265				
70					270		2.120		
75		1.530			275				
80					280				
85					285		2.310		
90		1.620			290				
95					295				
100					300		2.388	7.53	-3.20
105		1.692			305				
110					310				
115					315		2.436		
120		1.752			320				
125					325				
130					330		2.478		
135		1.746			335				
140					340				
145					345		2.514		
150		1.740			350			6.92	-2.80
155					355				
160					360		2.526		
165		1.740			365				
170					370				
175					375		2.532		
180		1.788			380				
185					385				
190					390		2.520		
195		1.836			395				

61

TABLE XXI (Cont.)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
400			6.35	-2.40					
405		2.532							
410									
415									
420									
425				.	.				
430									
435		2.508							
440									
445									
450		2.490	5.83	-2.20					
455									
460									
465		2.424							
470									
475									
480		2.292							
485									
490									
495		2.184							
500			5.40	-1.80					
505									
510		2.118							.
515		2.082							

62

TABLE XXI SOLID H2 MELTING TEST DATA (RUN NO. = 15 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA,   FLOW TOTALIZER= 156045. CYCLES,   FQD= 20.0 HZ/DIV,   FQV= 7.96 HZ/CF"

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CF")	C (---)	RHO (LB/FT3)	ZMDT (LB/"N)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.00	492.0	0.	0.00	0.9991	0.00562	0.0000	0.05	493.5	1634.5	0.00
5	8.4	0.00	492.0	168.	21.10	0.9991	0.00562	0.1186	-0.45	477.9	1573.9	186.69
10	8.8	0.00	492.0	176.	22.11	0.9991	0.00562	0.1242	-0.95	462.5	1519.2	188.79
15	10.2	0.00	492.0	204.	25.62	0.9991	0.00562	0.1440	-1.04	459.7	1510.0	217.50
20	13.0	0.00	492.0	260.	32.66	0.9991	0.00562	0.1835	-1.14	456.6	1500.0	275.36
25	15.4	0.00	492.0	308.	38.69	0.9991	0.00562	0.2174	-1.21	454.5	1493.1	324.72
30	20.0	0.00	492.0	400.	50.25	0.9991	0.00562	0.2824	-1.28	452.3	1486.3	419.77
35	21.0	0.00	492.0	420.	52.76	0.9991	0.00562	0.2965	-1.34	450.4	1480.4	439.03
40	18.2	-0.05	490.4	364.	45.72	0.9991	0.00564	0.2578	-1.40	448.6	1474.6	380.20
45	16.5	-0.05	490.4	330.	41.45	0.9991	0.00564	0.2337	-1.47	446.3	1467.8	343.09
50	15.5	-0.05	490.4	310.	38.94	0.9991	0.00564	0.2195	-1.54	444.1	1460.9	320.79
55	16.4	-0.05	490.4	328.	41.20	0.9991	0.00564	0.2323	-1.61	441.8	1454.0	337.81
60	16.6	-0.05	490.4	332.	41.70	0.9991	0.00564	0.2351	-1.68	439.6	1447.0	340.29
65	18.0	-0.05	490.4	360.	45.22	0.9991	0.00564	0.2549	-1.73	438.9	1445.0	360.47
70	18.2	-0.05	490.4	364.	45.72	0.9991	0.00564	0.2578	-1.72	438.3	1443.0	372.05
75	18.1	-0.05	490.4	362.	45.47	0.9991	0.00564	0.2564	-1.76	436.9	1438.9	368.95
80	17.4	-0.05	490.4	348.	43.71	0.9991	0.00564	0.2464	-1.80	435.6	1434.7	353.66
85	16.1	-0.05	490.4	322.	40.45	0.9991	0.00564	0.2280	-1.83	434.6	1431.6	326.53
90	16.8	-0.05	490.4	336.	42.21	0.9991	0.00564	0.2379	-1.85	434.0	1429.5	340.22
95	17.5	-0.05	490.4	350.	43.96	0.9991	0.00564	0.2479	-1.87	433.3	1427.4	353.67
100	18.0	-0.10	488.9	360.	45.22	0.9990	0.00566	0.2558	-1.90	432.3	1424.2	364.32
105	17.5	-0.10	488.9	350.	43.96	0.9990	0.00566	0.2487	-1.91	432.0	1423.1	353.93
110	17.8	-0.15	487.2	356.	44.72	0.9990	0.00567	0.2537	-1.92	431.6	1422.0	360.67
115	16.5	-0.15	487.2	330.	41.45	0.9990	0.00567	0.2352	-1.93	431.3	1420.9	334.26
120	15.9	-0.15	487.2	318.	39.94	0.9990	0.00567	0.2266	-1.95	430.6	1418.7	321.61
125	17.5	-0.15	487.2	350.	43.96	0.9990	0.00567	0.2494	-1.98	429.6	1415.4	353.15
130	17.1	-0.15	487.2	342.	42.96	0.9990	0.00567	0.2437	-2.02	428.3	1410.9	343.98
135	16.7	-0.15	487.2	334.	41.95	0.9990	0.00567	0.2380	-2.03	427.9	1409.8	335.66
140	17.2	-0.15	487.2	344.	43.21	0.9990	0.00567	0.2452	-2.04	427.6	1408.6	345.43
145	17.5	-0.15	487.2	350.	43.96	0.9990	0.00567	0.2494	-2.05	427.3	1407.5	351.17
150	17.8	-0.15	487.2	356.	44.72	0.9990	0.00567	0.2537	-2.06	426.9	1406.3	356.90
155	17.2	-0.15	487.2	344.	43.21	0.9990	0.00567	0.2452	-2.12	424.9	1399.3	343.16
160	16.0	-0.15	487.2	320.	40.20	0.9990	0.00567	0.2281	-2.17	423.2	1393.4	317.65
165	16.7	-0.15	487.2	334.	41.95	0.9990	0.00567	0.2380	-2.18	422.9	1392.1	331.47
170	17.1	-0.17	486.5	342.	42.96	0.9990	0.00568	0.2441	-2.19	422.5	1390.9	339.54
175	17.8	-0.18	486.3	356.	44.72	0.9990	0.00569	0.2542	-2.19	422.5	1390.9	353.67
180	18.0	-0.18	486.3	360.	45.22	0.9990	0.00569	0.2571	-2.20	422.2	1389.7	357.53
185	18.9	-0.20	485.7	378.	47.48	0.9990	0.00569	0.2703	-2.23	421.2	1386.0	374.67
190	19.3	-0.20	485.7	386.	48.49	0.9990	0.00569	0.2760	-2.26	420.2	1382.2	381.57
195	18.0	-0.20	485.7	360.	45.22	0.9990	0.00569	0.2574	-2.28	419.5	1379.7	355.21
200	17.5	-0.20	485.7	350.	43.96	0.9990	0.00569	0.2502	-2.30	418.6	1377.2	344.71
205	17.0	-0.20	485.7	340.	42.71	0.9990	0.00569	0.2431	-2.33	417.6	1373.3	333.92
210	17.0	-0.20	485.7	340.	42.71	0.9990	0.00569	0.2431	-2.35	417.1	1370.7	333.28
215	17.0	-0.25	484.1	340.	42.71	0.9990	0.00571	0.2439	-2.37	416.4	1368.0	333.71
220	17.4	-0.30	482.5	348.	43.71	0.9989	0.00573	0.2504	-2.38	416.1	1366.7	342.33
225	17.2	-0.30	482.5	344.	43.21	0.9989	0.00573	0.2475	-2.39	415.0	1365.4	338.06

63

TABLE XXI (Cont)

230	16.4	-0.30	452.5	336.	-2.45		. 273	..452	-. .		
235	18.9	-0.30	452.5	378.	-7.44	0.497	. 573	..272J	-..43	614.4	1300.0	370.01
240	19.0	-0.35	481.4	382.	47.73	0.099-0	. 575	.2743	-2.45	413.4	1350.0	372.05
245	18.5	-0.40	479.4	376.	47.23	0.9999	0.00 577	..2723	-2.40	412.5	1335.2	363.57
250	17.6	-0.40	479.4	352.	46.22	0.9969	0.00577	0.2949	-2.50	412.1	1350.4	344.34
255	18.5	-0.45	479.4	370.	46.44	0.9939	0.00577	0.2650	-2.53	411.1	1346.3	360.00
260	19.2	-0.40	479.4	384.	48.24	0.9989	0.00577	0.2781	-2.55	410.4	1343.5	373.70
265	19.0	-0.40	479.4	380.	47.73	0.9989	0.00577	0.2752	-2.59	409.1	1337.8	368.24
270	19.1	-0.43	478.5	382.	47.98	0.9988	0.00578	0.2772	-2.63	407.8	1332.0	369.31
275	19.7	-0.46	477.6	394.	49.49	0.9948	0.00579	0.2865	-2.63	437.0	1332.0	351.04
280	18.6	-0.48	476.9	?	46.73	0.9954	.00580	0.2708	-2.64	437.5	1330.6	360.40
285	18.0	-0.50	476.3		45.22	0.9990	0.00590	0.2624	-2.67	406.5	1326.2	346.00
290	17.7	-0.53	475.4		44.47	0.9998	0.00582	0.2505	-2.70	405.5	1321.0	341.01
295	17.3	-0.55	474.9	346.	43.46	0.9988	0.00582	0.2530	-2.72	404.9	1316.9	335.77
300	17.0	-0.57	474.2	340.	42.71	0.9988	0.00583	.2459	-2.75	403.9	1314.5	327.91
305	17.3	-0.60	473.2	346.	43.46	0.9988	0.00584	.2529	-2.77	403.3	1311.5	332.97
310	16.9	-0.62	472.6	338.	42.46	0.9987	0.00585	0.2483	-2.80	402.3	1307.0	324.53
315	16.7	-0.64	472.0	334.	41.95	0.9987	0.00586	0.2457	-2.82	401.7	1304.0	322.42
320	16.9	-0.66	471.4	338.	42.46	0.9987	0.00587	0.2489	-2.85	400.7	1299.5	323.55
325	17.6	-0.68	470.8	352.	44.22	0.9987	0.00587	0.2596	-2.88	377.7	1294.9	335.21
330	17.3	-0.70	470.1	346.	43.46	0.9987	0.00588	0.2555	-2.92	395.5	1286.9	327.35
335	16.9	-0.73	469.2	338.	42.46	0.9987	0.00589	0.2501	-2.98	396.6	1279.1	320.00
340	17.2	-0.75	468.6	344.	43.21	0.9987	0.00590	0.2548	-3.04	394.7	1270.4	323.80
345	16.9	-0.78	467.7	338.	42.46	0.9997	0.00591	0.2509	-3.14	391.5	1254.8	314.05
350	18.1	-0.80	467.1	362.	45.47	0.9986	0.00592	0.2690	-3.25	385.3	1237.3	332.96
355	20.8	-0.83	466.2	416.	52.26	0.9986	0.00593	0.3098	-3.31	360.1	1227.1	360.39
360	20.9	-0.87	464.9	418.	52.51	0.9986	0.00595	0.3121	-3.38	383.7	1216.3	379.67
365	20.5	-0.90	464.0	410.	51.50	0.9986	0.00596	0.3067	-3.39	383.4	1214.7	372.64
370	19	-0.93	463.1	372.	46.73	0.9986	0.00597	0.2788	-3.40	385.1	1213.1	335.31
375	17.8	-0.97	461.9	356.	44.72	0.9986	0.00599	0.2675	-3.42	383.1	1213.1	324.01
380	17.9	-1.00	461.0	356.	44.72	0.9985	0.00600	0.2661	-3.46	383.1	1213.1	323.25
385	18.1	-1.03	460.0	362.	45.47	0.9985	0.00601	0.2731	-3.45	381.3	1204.9	329.15
390	18.0	-1.07	458.8	360.	45.22	0.9985	0.00603	0.2723	-3.50	379.6	1196.0	325.70
395	17.7	-1.10	457.9	354.	44.47	0.9985	0.00604	0.2683	-3.52	378.9	1193.3	320.27
400	17.4	-1.15	456.3	348.	43.71	0.9985	0.00606	0.2647	-3.54	378.2	1190.0	315.02
405	17.3	-1.17	455.7	346.	43.46	0.9984	0.00607	0.2635	-3.55	375.7	1183.4	311.89
410	17.2	-1.20	454.8	344.	43.21	0.9984	0.00608	0.2625	-3.62	375.2	1176.8	306.96
415	17.0	-1.23	453.9	340.	42.71	0.9984	0.00609	0.2600	-3.63	374.8	1175.1	305.30
420	17.4	-1.27	452.6	348.	43.71	0.9984	0.00611	0.2669	-3.64	374.4	1173.5	313.10
425	19.4	-1.30	451.7	388.	48.74	0.9984	0.00612	0.2981	-3.65	374.0	1171.8	349.41
430	14.3	-1.33	450.7	286.	35.92	0.9983	0.00613	0.2202	-3.66	373.6	1170.2	257.13
435	6.6	-1.37	449.5	132.	14.58	0.9983	0.00615	0.1019	-3.67	373.3	1160.6	117.11
440	3.5	-1.40	448.5	76.	9.54	0.9983	0.00616	0.0586	-3.68	372.9	1160.9	65.62
445	3.5	-1.40	448.5	72.	9.04	0.9983	0.00616	0.0557	-3.79	368.4	1149.5	64.04
450	4.0	-1.40	448.5	80.	10.05	0.9983	.00616	0.0619	-3.90	363.0	1133.4	70.15
455	8.4	-1.40	448.5	169.	21.10	0.9983	0.00616	0.1299	-3.85	365.3	1140.3	148.49
460	10.5	-1.43	447.6	210.	26.39	0.9983	0.00618	0.1628	-3.80	367.9	1147.9	180.73
465	10.0	-1.45	447.0	200.	25.12	0.9983	0.00619	0.1553	-3.85	365.0	1140.5	177.12
470	9.0	-1.48	446.0	180.	22.61	0.9983	0.00620	0.1400	-3.90	363.6	1133.4	156.75
475	8.3	-1.50	445.4	166.	20.85	0.9983	0.00621	0.1293	-3.97	360.4	1124.2	145.45
480	6.2	-1.53	444.4	124.	15.57	0.9982	0.00622	0.0968	-4.05	356.6	1115.2	107.99
485	5.6	-1.55	443.9	112.	14.07	0.9982	0.00623	0.0875	-4.02	356.0	1118.4	97.96
490	5.6	-1.59	442.8	112.	14.07	0.9982	0.00624	0.0877	-4.00	357.0	1122.1	75.57
495	5.3	-1.60	442.2	106.	13.31	0.9982	0.00625	0.0831	-4.30	344.2	1097.9	91.34
500	5.1	-1.60	442.2	102.	12.81	0.9982	.00625	0.0800	-4.60	330.0	1006.0	27.01
505	4.5	-1.61	441.8	96.	12.06	0.9982	0.00625	0.0754	-4.50	330.0	1030.0	0.475
510	3.8	-1.62	441.5	76.	9.54	0.9982	0.00626	0.0597	-4.00	330.0	1000.0	94.72
515	0.0	-1.63	441.2	0.	0.01	0.9982	0.00627	. .	-4.00	330.5	1000.0	0.000

TOTAL NO. OF CYCLES (INTEGRATED) = 150159.000 CYCLES. TOTAL MASS (INTEGRATED) = 1.096 605
TOTAL NO. OF CYCLES (MEASURED) = 156045.331 CYCLES. TOTAL ENTHALPY(INTEGRATED) = 4624.337 B°U
AVERAGE ENTHALPY OF FLOW = 1330.730 BTU/LB

64

TABLE XXII   SOLID H2 MELTING TEST DATA (RUN NO. = 16 --- INLET TO CONTROL VOLUME)

P= 29.7 PSIA.   FLOW TOTALIZER= 13560. CYCLES.   FJD= 5.0 HZ/DIV.   FDV= 12060. HZ/CFM

TIME (SEC)	DT (DIV)	FREQ (HILO)	TC F (DEG.R)	FD (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	Z DT (LB/S)	E HH (MILEV)	TE H (DEG.R)	H (BTU/LB)	ZDH (BTU/SEC)	E HH29 (MILEV)	TCH29 (DEG.R)
0	2.0	5.63	653.3	19.	0.08	1.0021	5.0955	0.0037	5.95	661.6	224.09	1.50	-0.25	2707
5	5.0	5.53	449.8	25.	0.28	1.0010	0.00860	0.0317	5.53	650.3	223.03	4.00	-0.10	2709
10	5.1	5.36	446.0	25.	0.21	1.0019	0.02865	0.0318	5.76	655.3	221.00	4.07	-0.50	2060
15	10.2	5.22	442.2	51.	0.42	1.0013	0.00870	0.0037	5.65	653.7	221.65	6.21	-5.50	2702
20	12.1	5.01	436.5	60.	0.50	1.0017	0.00878	0.0044	5.60	652.3	224.00	9.01	-5.60	2707
25	12.1	4.41	430.7	60.	0.52	1.0016	0.01086	0.0044	5.50	649.5	220.00	9.06	-5.50	3104
30	14.0	4.64	426.0	70.	0.58	1.0015	0.00893	0.0052	5.47	648.5	220.00	11.40	-5.15	3104
35	22.2	4.47	421.7	111.	0.92	1.0016	0.00900	0.0183	5.43	646.9	217.66	16.37	-4.70	3254
40	23.5	4.35	417.5	117.	0.97	1.0014	0.00905	0.0300	5.35	645.6	215.67	17.42	-4.65	3304
45	25.0	4.23	414.5	125.	1.04	1.0013	0.00901	0.0094	5.30	644.2	215.09	20.12	-4.40	3401
50	25.0	4.14	411.0	125.	1.04	1.0013	0.00913	0.0095	5.25	642.0	217.01	20.70	-4.20	3570
55	24.0	4.05	409.4	120.	1.00	1.0012	0.00917	0.0091	5.23	641.5	217.02	19.01	-3.95	3613
60	24.2	3.99	507.7	121.	1.00	1.0012	0.00052	0.0042	5.15	643.1	217.06	20.15	-3.65	3507
65	26.3	3.93	505.0	131.	1.09	1.0011	0.00022	0.0141	5.10	639.7	217.00	21.00	-3.65	3740
70	23.0	3.97	404.5	119.	0.99	1.0011	0.00024	0.0091	5.00	639.2	217.03	17.00	-3.50	3750
75	25.2	3.92	402.9	126.	1.04	1.0011	0.00927	0.0097	5.05	637.3	217.02	21.04	-3.45	3610
80	24.5	3.79	401.9	122.	1.02	1.0011	0.00929	0.0094	5.00	636.0	215.45	20.45	-3.35	3046
85	25.0	3.74	400.0	125.	1.04	1.0011	0.00033	0.0097	4.95	634.6	214.01	20.05	-3.35	3004
90	26.4	3.70	599.5	132.	1.09	1.0010	0.00932	0.012.	4.93	634.0	217.05	22.04	-3.10	3720
95	25.0	3.66	599.4	125.	1.04	1.0010	0.00934	0.0057	4.92	633.2	217.09	20.00	-3.00	3900
100	24.0	3.60	596.4	120.	1.00	1.0010	0.00936	0.0093	4.66	632.1	217.00	20.00	-2.65	4001
105	24.2	3.54	595.2	121.	1.01	1.0010	0.00939	0.094	4.63	631.2	217.07	20.02	-2.70	4002
110	24.4	3.53	595.0	124.	1.03	1.0009	0.00935	0.057	4.60	630.4	217.02	20.73	-2.60	4060
115	24.4	3.42	594.7	122.	1.02	1.0009	0.00954	0.75	4.10	627.2	214.03	20.05	-2.50	4304
120	25.2	3.43	594.0	126.	1.04	1.0005	0.00939	0.058	4.73	525.4	214.02	20.00	-2.25	4305
125	26.0	3.54	595.0	130.	1.08	1.0009	0.00935	0.051	4.70	527.6	214.03	21.03	-2.10	4250
130	26.0	3.44	593.4	130.	1.08	1.0009	0.00962	0.02	4.65	626.2	214.07	21.03	-2.00	4270

TOTAL NO. OF CYCLES (INTEGRATED) = 13594.00 CYCLES.   TOTAL MASS (INTEGRATED) = 0.017 LBS.
. TOTAL NO. OF CYCLES (MEASURED) = 13560.01 CYCLES.   TOTAL ENTHALPY (INTEGRATED) = 37.567 BTU.
   AVERAGE ENTHALPY OF FLO   =   2155.99 BTU/LB.

65

TABLE XXII   SOLID H2 MELTING TEST DATA (RUN NO. = 16 --- OUTLET FROM CONTROL VOLUME) (CONT)

P= 14.7 PSIA.   FLOW TOTALIZER = 96093. CYCLES.   FQD= 20.0 HZ/DIV.   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VCT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZHH (BTU/MN)
0	0.0	0.0	492.0	0.	0.0	0.9991	0.00563	0.0	-0.10	488.8	1615.9	0.0
5	7.0	0.0	492.0	140.	17.59	0.9991	0.00563	0.0989	-0.30	482.6	1591.6	157.33
10	11.0	0.0	492.0	220.	27.64	0.9991	0.00563	0.1553	-0.50	476.4	1568.1	243.56
15	17.4	0.0	492.0	348.	43.72	0.9991	0.00563	0.2457	-1.00	461.0	1514.1	372.04
20	22.3	0.0	492.0	446.	56.03	0.9991	0.00563	0.3149	-1.45	447.0	1469.7	462.83
25	32.6	-0.01	491.7	652.	81.91	0.9991	0.00563	0.4607	-1.48	446.0	1466.8	675.70
30	37.7	-0.02	491.4	754.	94.72	0.9991	0.00563	0.5331	-1.50	445.4	1464.8	780.86
35	40.0	-0.03	491.0	800.	100.50	0.9991	0.00564	0.5659	-1.60	442.2	1455.0	823.46
40	37.0	-0.04	490.7	740.	92.96	0.9991	0.00564	0.5238	-1.85	434.0	1429.5	748.82
45	18.0	-0.04	490.7	360.	45.23	0.9991	0.00564	0.2548	-2.00	429.0	1413.2	360.13
50	18.0	-0.04	490.7	360.	45.23	0.9991	0.00564	0.2548	-2.50	412.1	1350.5	344.15
55	17.5	-0.04	490.7	350.	43.97	0.9991	0.00564	0.2478	-3.00	396.0	1276.6	316.29
60	35.5	-0.04	490.7	710.	89.20	0.9991	0.00564	0.5026	-3.25	388.1	1237.4	621.89
65	41.2	-0.04	490.7	824.	103.52	0.9991	0.00564	0.5833	-3.50	379.6	1196.6	697.98
70	42.5	-0.04	490.7	850.	106.78	0.9991	0.00564	0.6017	-3.45	381.4	1204.9	724.96
75	41.0	-0.04	490.7	820.	103.02	0.9991	0.00564	0.5805	-3.40	383.1	1213.1	704.16
80	53.0	-0.10	488.8	1060.	133.17	0.9991	0.00566	0.7532	-3.35	384.8	1221.2	919.86
85	51.2	-0.12	488.2	1024.	128.64	0.9991	0.00567	0.7286	-3.30	386.4	1229.3	895.63
90	42.5	-0.14	487.6	850.	106.78	0.9991	0.00568	0.6055	-3.28	387.1	1232.5	746.36
95	49.3	-0.16	487.0	986.	123.37	0.9991	0.00568	0.7033	-3.26	387.7	1235.7	869.12
100	50.0	-0.18	486.3	1000.	125.63	0.9990	0.00569	0.7142	-3.23	388.7	1240.5	886.03
105	26.7	-0.20	485.7	534.	67.09	0.9990	0.00570	0.3819	-3.20	389.7	1245.3	475.56
110	30.4	-0.22	485.1	608.	76.38	0.9990	0.00571	0.4354	-3.20	389.7	1245.3	542.16
115	35.3	-0.24	484.5	706.	98.69	0.9990	0.00571	0.5062	-3.20	389.7	1245.3	630.35
120	36.1	-0.25	484.1	722.	90.70	0.9990	0.00572	0.5180	-3.33	385.5	1224.5	634.28
125	34.8	-0.26	483.8	696.	87.44	0.9990	0.00572	0.4997	-3.45	381.4	1204.9	602.01
130	40.3	-0.28	483.2	806.	101.26	0.9990	0.00573	0.5794	-3.47	380.7	1201.6	695.13
135	37.5	-0.30	482.6	750.	94.22	0.9990	0.00573	0.5398	-3.50	379.6	1196.6	645.94
140	24.5	-0.33	481.5	470.	61.56	0.9990	0.00575	0.3533	-3.60	376.0	1180.1	416.98
145	16.0	-0.37	480.4	320.	40.20	0.9989	0.00575	0.2314	-3.70	372.1	1163.7	269.23
150	7.5	-0.40	479.5	150.	18.84	0.9989	0.00577	0.1087	-3.70	372.1	1163.7	126.45
155	2.0	-0.42	478.8	40.	5.03	0.9989	0.00578	0.0290	-4.70	327.2	1081.7	31.38
160	0.0	-0.44	478.2	0.	0.0	0.9989	0.00579	0.0	-4.70	327.2	1081.7	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 95579.750 CYCLES.   TOTAL MASS   (INTEGRATED) =   1.140 LBS
TOTAL NO. OF CYCLES (MEASURED) = 96093.000 CYCLES.   TOTAL ENTHALPY (INTEGRATED) =1459.594 BTU
AVERAGE ENTHALPY OF FLOW   = 1279.939 BTU/LB

TABLE XXIII SOLID H_2 MELTING TEST DATA

(RUN. NO. = 17 INLET TO CONTROL VOLUME)

TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)	TIME (SEC)	FREQUENCY (HZ)	EMFF (MIL.V)	EMFH (MIL.V)	EMF23 (MIL.V)
0	221.0		8.10	-5.80	200	168.0		6.20	-0.60
5	210.0		8.36	-5.33	205	170.0		6.17	-0.40
10	150.5		8.60	-4.75	210	165.0		6.14	-0.20
15	142.0		8.34	-4.67	215	165.0		6.11	-0.09
20	150.5		8.10	-4.60	220	153.0		6.08	+0.03
25	153.0		7.92	-4.55	225	155.0		6.03	+0.03
30	164.0		7.75	-4.50	230	155.0		5.99	+0.03
35	154.0		7.67	-4.25	235	152.0		5.95	0.01
40	159.0		7.60	-4.00	240	157.0		5.90	0.0
45	155.0		7.55	-3.90	245	177.5		5.93	0.0
50	160.5		7.50	-3.80	250	201.0		5.95	0.0
55	165.0		7.43	-3.70	255	198.5		5.98	0.0
60	165.0		7.36	-3.60	260	203.0		5.80	0.0
65	183.0		7.32	-3.42	265	185.5		5.75	0.05
70	164.0		7.28	-3.25	270	171.0		5.70	0.10
75	151.0		7.22	-3.62	275	169.0		5.65	0.15
80	156.5		7.16	-4.00	280	169.0		5.60	0.20
85	160.5		7.13	-4.08	285	180.0		5.55	0.28
90	161.0		7.11	-4.15					
95	170.0		6.99	-4.00					
100	189.5		6.96	-3.85					
105	194.0		6.92	-3.55					
110	175.0		6.88	-3.25					
115	181.0		6.84	-2.70					
120	160.5		6.80	-2.15					
125	155.0		6.77	-2.37					
130	166.5		6.70	-2.60					
135	165.0		6.65	-2.60					
140	169.5		6.60	-2.60					
145	179.5		6.56	-2.42					
150	194.5		6.52	-2.25					
155	192.5		6.48	-2.07					
160	197.0		6.44	-1.90					
165	175.0		6.41	-1.47					
170	161.0		6.37	1.05					
175	161.0		6.33	-1.42					
180	165.0		6.30	-1.80					
185	169.0		6.27	-1.67					
190	155.0		6.25	-1.55					
195	156.0		6.23	-1.07					

67

TABLE XXIII SOLID H2 MELTING TEST DATA (RUN NO. = 17 --- OUTLET FROM -- CONTROL VOLUME) (CONT)

P= 14.7 PSIA.   FLOW TOTALIZER= 175288. CYCLES.   FQO= 20.0 HZ/DIV,   FQV= 7.96 HZ/CFM

TIME (SEC)	DF (DIV)	EMFF (MIL.V)	TEMF (DEG.R)	FQ (HZ)	VDT (CFM)	C (---)	RHO (LB/FT3)	ZMDT (LB/MN)	EMFH (MIL.V)	TEMH (DEG.R)	H (BTU/LB)	ZMH (BTU/MN)
0	0.0	0.20	498.3	0.	0.0	0.9993	0.00555	0.0	1.20	529.0	1769.0	0.0
5	7.5	0.23	499.2	150.	18.84	0.9993	0.00554	0.1044	0.65	512.3	1708.0	178.30
10	10.5	0.25	499.9	210.	26.38	0.9993	0.00554	0.1460	0.10	495.1	1640.8	239.49
15	14.1	0.20	496.3	282.	35.43	0.9993	0.00555	0.1966	0.16	497.0	1648.2	324.08
20	18.1	0.15	496.7	362.	45.48	0.9992	0.00557	0.2532	0.25	499.9	1659.4	420.16
25	25.8	0.07	494.2	516.	64.82	0.9992	0.00560	0.3627	0.16	497.0	1648.2	597.86
30	32.1	0.0	492.0	642.	80.65	0.9991	0.00563	0.4533	0.06	493.9	1635.8	741.49
35	33.5	-0.05	490.4	670.	84.17	0.9991	0.00564	0.4746	-0.05	490.4	1622.1	769.82
40	36.5	-0.10	488.8	730.	91.71	0.9991	0.00566	0.5187	-0.15	487.3	1609.8	835.03
45	32.7	-0.13	487.9	654.	82.16	0.9991	0.00567	0.4656	-0.25	484.1	1597.6	743.87
50	30.0	-0.16	487.0	600.	75.38	0.9991	0.00568	0.4280	-0.35	481.0	1585.6	678.62
55	32.4	-0.18	486.3	648.	81.41	0.9990	0.00569	0.4628	-0.40	479.5	1579.7	731.12
60	38.1	-0.20	485.7	762.	95.73	0.9990	0.00570	0.5449	-0.45	477.9	1573.9	857.66
65	40.9	-0.23	484.8	818.	102.76	0.9990	0.00571	0.5861	-0.63	472.3	1553.4	910.46
70	45.0	-0.26	483.8	900.	113.07	0.9990	0.00572	0.6461	-0.80	467.1	1534.9	991.70
75	48.2	-0.30	482.6	964.	121.11	0.9990	0.00573	0.6938	-0.96	462.2	1518.2	1053.36
80	49.5	-0.36	480.7	990.	124.37	0.9989	0.00576	0.7159	-1.12	457.3	1502.0	1074.38
85	42.0	-0.43	478.5	840.	105.53	0.9989	0.00578	0.6098	-1.23	453.9	1491.2	909.10
90	38.5	-0.50	476.4	770.	96.73	0.9989	0.00581	0.5614	-1.34	450.5	1480.5	831.07
95	44.4	-0.55	474.8	888.	111.56	0.9988	0.00583	0.6495	-1.39	448.9	1475.6	958.36
100	41.8	-0.60	473.3	836.	105.03	0.9988	0.00585	0.6134	-1.43	447.6	1471.7	902.76
105	40.5	-0.65	471.7	810.	101.76	0.9988	0.00587	0.5963	-1.51	445.1	1463.9	872.87
110	40.5	-0.70	470.2	810.	101.76	0.9987	0.00589	0.5982	-1.60	442.2	1455.0	870.40
115	42.5	-0.78	467.7	850.	106.78	0.9987	0.00592	0.6310	-1.60	442.2	1455.0	918.13
120	41.1	-0.86	465.3	822.	103.27	0.9987	0.00595	0.6134	-1.60	442.2	1455.0	892.53
125	41.4	-0.97	461.9	828.	104.02	0.9986	0.00599	0.6224	-1.60	442.2	1455.0	905.55
130	40.3	-1.08	458.5	806.	101.26	0.9985	0.00604	0.6103	-1.60	442.2	1455.0	887.94
135	40.1	-1.14	456.7	802.	100.75	0.9985	0.00606	0.6097	-1.60	442.2	1455.0	887.08
140	39.7	-1.25	453.3	794.	99.75	0.9984	0.00611	0.6.81	-1.66	440.3	1449.0	881.14
145	39.6	-1.37	449.5	792.	99.50	0.9984	0.00616	0.6116	-1.69	439.3	1446.0	884.36
150	39.3	-1.50	445.4	786.	98.74	0.9983	0.00621	0.6125	-1.72	438.3	1443.0	883.83
155	38.3	-1.58	442.9	766.	96.23	0.9983	0.00625	0.6003	-1.74	437.6	1440.9	865.06
160	37.5	-1.65	440.6	750.	94.22	0.9982	0.00628	0.5908	-1.76	437.0	1438.9	850.11
165	38.0	-1.77	436.7	760.	95.48	0.9981	0.00634	0.6040	-1.78	436.3	1436.8	967.88
170	37.8	-1.90	432.3	756.	94.97	0.9981	0.00640	0.6068	-1.80	435.7	1434.8	870.59
175	37.3	-2.00	429.0	746.	93.72	0.9980	0.00645	0.6034	-1.83	434.7	1431.6	863.83
180	35.8	-2.10	425.6	716.	89.95	0.9979	0.00650	0.5837	-1.86	433.7	1428.5	833.79
185	34.0	-2.20	422.2	680.	85.43	0.9979	0.00655	0.5588	-1.87	433.3	1427.4	797.57
190	33.5	-2.30	418.8	670.	84.17	0.9978	0.00661	0.5550	-1.88	433.0	1426.3	791.55
195	29.5	-2.40	415.5	590.	74.12	0.9978	0.00666	0.4926	-1.89	432.7	1425.3	702.12
200	24.1	-2.50	412.1	482.	60.55	0.9977	0.00672	0.4057	-1.90	432.3	1424.2	577.78
205	24.0	-2.58	409.5	480.	60.30	0.9977	0.00676	0.4066	-1.93	431.3	1420.9	577.76
210	25.9	-2.65	407.2	518.	65.08	0.9976	0.00680	0.4412	-1.96	430.3	1417.6	625.53
215	29.0	-2.77	403.3	580.	72.96	0.9975	0.00686	0.4988	-1.98	429.7	1415.4	706.01
220	30.3	-2.90	399.2	606.	76.13	0.9975	0.00693	0.5265	-2.00	429.0	1413.2	744.09
225	32.2	-3.00	396.0	644.	80.90	0.9974	0.00699	0.5640	-2.01	428.7	1412.1	796.36
230	30.1	-3.10	392.8	602.	75.63	0.9974	0.00705	0.5314	-2.02	428.3	1410.9	749.76
235	24.4	-3.20	389.7	488.	61.31	0.9973	0.00710	0.4343	-2.06	427.0	1406.4	610.71
240	21.5	-3.30	386.4	430.	54.02	0.9972	0.00716	0.3858	-2.10	425.6	1401.7	540.81
245	20.4	-3.33	385.5	408.	51.26	0.9972	0.00718	0.3670	-2.13	424.6	1398.2	513.13
250	19.4	-3.36	384.4	388.	48.74	0.9972	0.00720	0.3499	-2.16	423.6	1394.6	488.00
255	17.7	-3.42	382.4	354.	44.47	0.9972	0.00724	0.3209	-2.17	423.3	1393.4	447.19
260	16.2	-3.48	380.3	324.	40.70	0.9971	0.00727	0.2953	-2.18	422.9	1392.2	411.15
265	14.7	-3.49	380.0	294.	36.93	0.9971	0.00728	0.2682	-2.19	422.6	1390.9	373.10
270	10.2	-3.50	379.6	364.	45.73	0.9971	0.00729	0.3324	-2.20	422.2	1389.7	461.96
275	21.5	-3.55	377.8	430.	54.02	0.9971	0.00732	0.3945	-2.21	421.9	1388.5	547.82
280	18.0	-3.60	376.0	360.	45.23	0.9971	0.00736	0.3319	-2.22	421.6	1387.3	460.48
285	0.0	-3.65	374.1	0.	0.0	0.9970	0.00740	0.0	-2.23	421.2	1386.0	0.0

TOTAL NO. OF CYCLES (INTEGRATED) = 177589.375 CYCLES.   TOTAL MASS   (INTEGRATED) =   2.274 LBS
TOTAL NO. OF CYCLES (MEASURED) = 175288.000 CYCLES.   TOTAL ENTHALPY(INTEGRATED) =3348.254 BTU
AVERAGE ENTHALPY OF FLOW   =   1472.245 BTU/LB

TABLE XXIV - MELTING EXPERIMENTS DATA

RUN NO.	MASS INITIAL $M_S(0)$ (LB.)	MASS OUT M_2 (LB.)	MASS IN M_1 (LB.)	ENTHALPY IN h_1 (BTU/LB.)	TEMP. IN T_1 (°R)	ENTHALPY OUT h_2 (BTU/LB.)	PHASE OUT ($-$)	MELTING TIME t^* (SEC.)	SYST. PRESS. P (PSIG)
1	2.257	2.352	0.095	2026	603	− 68.8	GL	290	4
2	2.251	2.408	0.157	2110	628	− 9.19	GL	270	6
3	2.194	2.394	0.200	1350	419	− 31.1	GL	665	2
4	1.592	1.760	0.168	1792	539	+ 29.04	GL	325	4
5	0.917	0.981	0.064	2296	678	+ 3.63	GL	255	3.5
6	0.917	1.067	0.150	2422	716	+205.6	GAS	245	5
9	1.577	1.726	0.149	2145	638	+ 41.7	GL	255	6
10	2.253	2.419	0.166	1520	466	− 42.0	GL	270	5
12	1.895	2.109	0.214	1981	591	+ 59.0	GL	425	4
13	1.920	1.988	0.068	1981	591	− 82.0	GL	530	2
14	1.895	2.136	0.241	1990	595	+ 84.0	GAS	310	4
15	1.895	1.966	0.071	2398	708	− 63.0	GL	515	2
16	0.987	1.139	0.152	2159	640	+147.0	GAS	160	6
17	2.175	2.274	0.099	2287	674	− 52.0	GL	285	55

69

TABLE XXV - MELTING EXPERIMENTS DATA

RUN NO.	SUPERHEAT RATIO $\delta h_g / \delta h_m$ (—)	TEMP. DIFF. $(\overline{T}_1 - \overline{T}_S)$ ($^{\circ}R$)	INVERSE OF AREA $1/A_o$ ($FT.^{-2}$)	HEIGHT OF SOLID L_S (FT.)	OVERALL HEAT TRANS. COEFFICIENT U ($BTU/FT.^2 - hr\ ^{\circ}R$)	MASS RATIO Y (—)
1	30.6	578	0.283	2.041	0.343	0.0421
2	16.5	603	0.283	2.036	0.352	0.0697
3	12.58	394	0.290	1.984	0.219	0.0912
4	10.6	514	0.391	1.440	0.335	0.1055
5	16.4	653	0.642	0.830	0.318	0.0698
6	6.93	691	0.642	0.830	0.312	0.1636
9	11.9	613	0.395	1.427	0.359	0.0945
10	16.0	441	0.283	2.038	0.481	0.0737
12	9.95	566	0.333	1.714	0.236	0.1129
13	38.0	566	0.329	1.737	0.190	0.0354
14	8.84	570	0.333	1.714	0.321	0.1272
15	33.5	683	0.333	1.714	0.162	0.0374
16	7.44	615	0.602	0.893	0.544	0.1540
17	27.58	649	0.293	1.967	0.310	0.0455
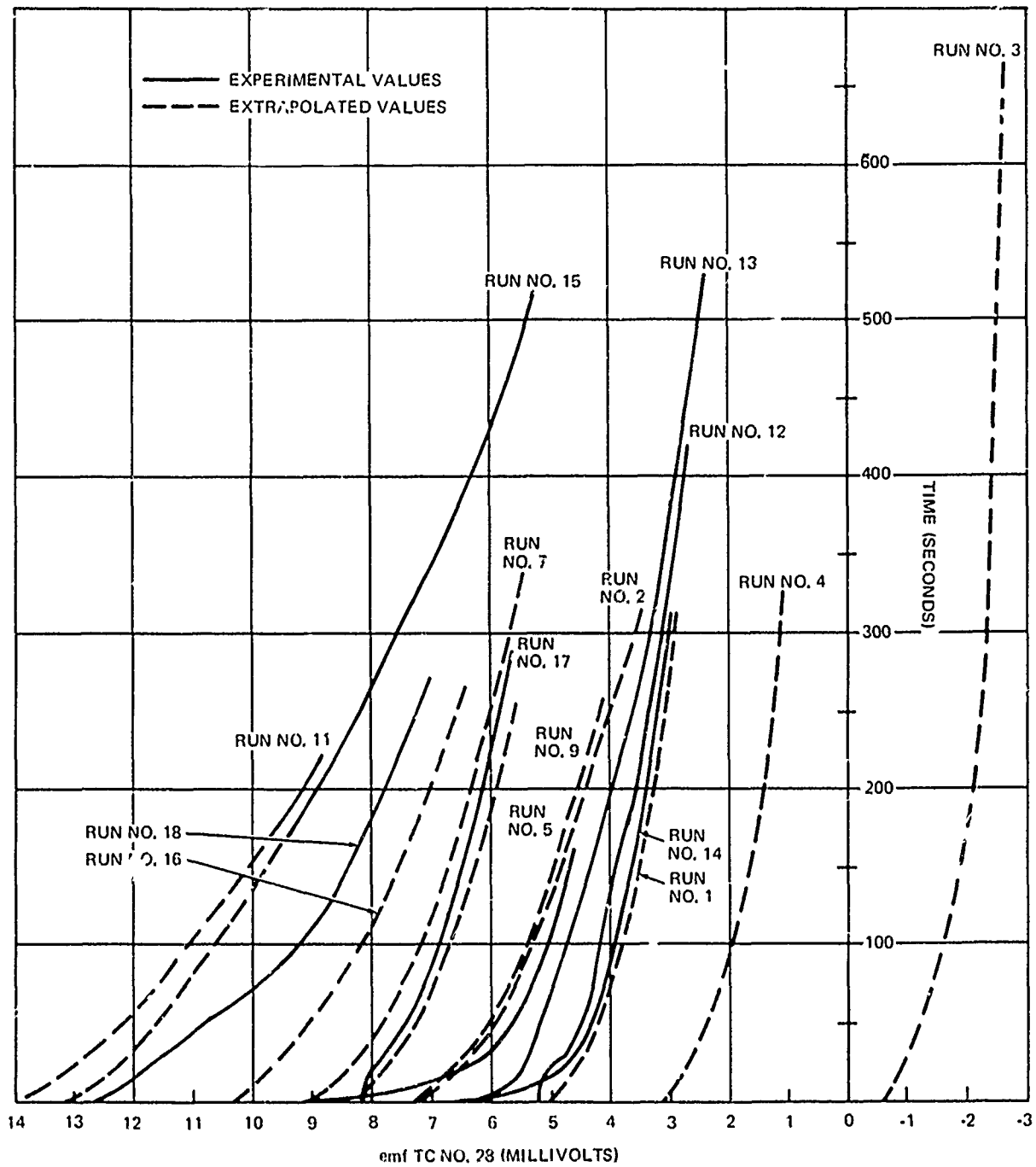
FIG. 6 EXPERIMENTAL AND EXTRAPOLATED VALUES OF THERMOCOUPLE
NO. 28 EMF vs TIME
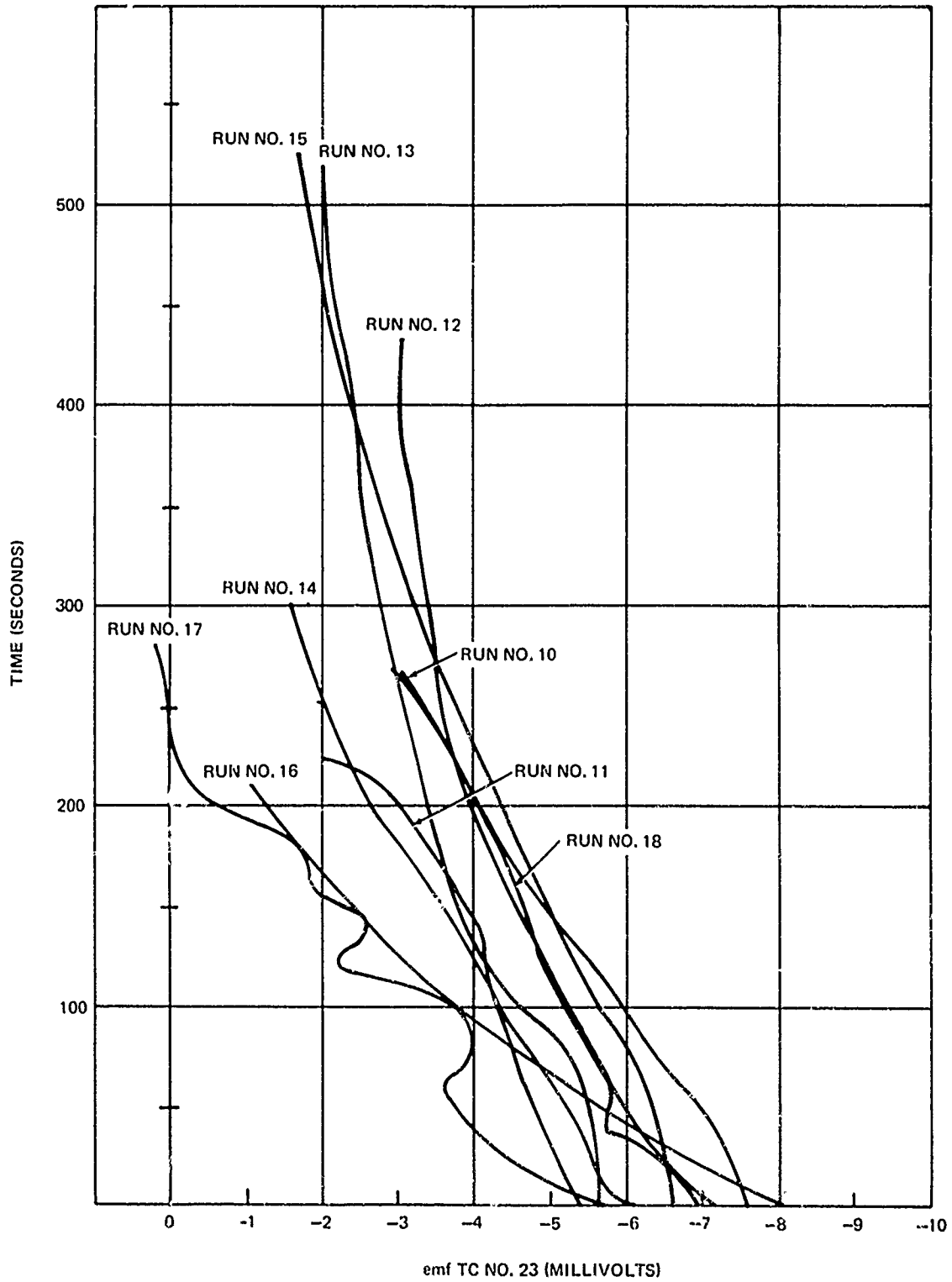
FIG. 7 EXPERIMENTAL VALUES OF THERMOCOUPLE NO. 23 EMF vs TIME

72
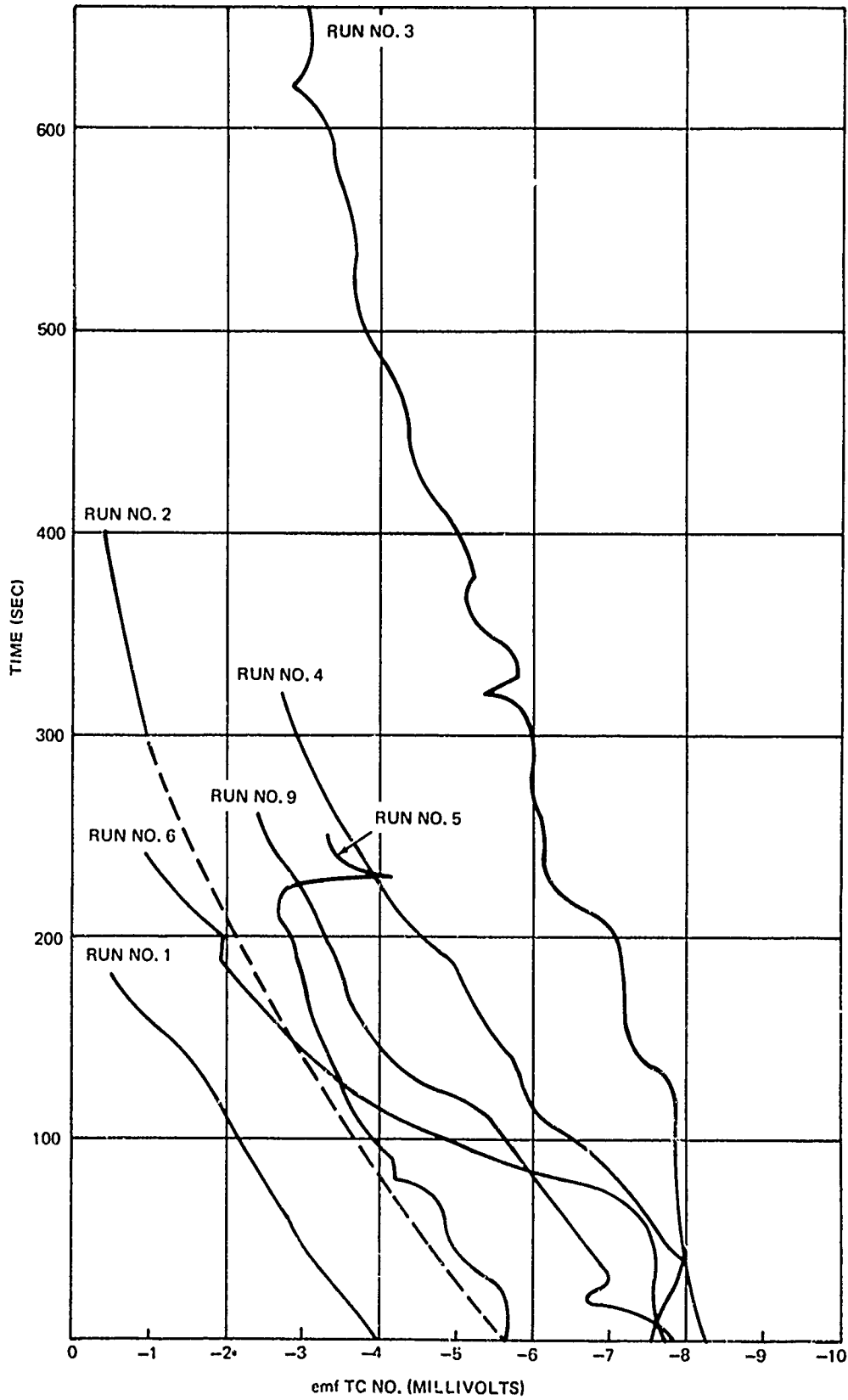
FIG. 8 EXPERIMENTAL VALUES OF THERMOCOUPLE NO. 23 EMF vs TIME

73

From analytical considerations, a functional relationship between an overall heat transfer coefficient, the degree of subcool of the liquid and superheat of the gas flowing in and out of the SH_2 cryostat, and the ratio of mass of heating vapor to mass of initial solid is predicted. A theoretical functional relationship, however, cannot be found explicitly because of the nature of the "control volume" analysis; instead, test results were plotted which will permit finding such a relationship experimentally. As it turned out, plotting U_0 vs Y, with the gas superheat/liquid subcool ratio as a parameter is not very useful, since all constant gas superheat/liquid subcool ratio lines are vertical lines intersecting the Y coordinate axis. This kind of plot will not permit a unique determination of the overall heat transfer coefficient, given a specified mass and superheat/subcool ratio. In other words, these last two ratios are not independent of each other as was assumed in the theoretical derivation. Because of this functional dependence, a relationship between the superheat/subcool ratio and the mass ratio was developed through the use of overall conservation of energy and mass applied to a control volume including the initial mass of solid hydrogen. This explicit relationship is given in the analysis section.

In Figure 9 we have plotted the experimental values and obtained an experimental relationship. Gas superheat/liquid subcool ratio vs. mass ratio are presented in Figure 10. Given a specified gas superheat/liquid subcool ratio, one determines Y from Figure 10. With Y, U_{corr} is determined from Figure 9, from which U_0 can be obtained. The exponents used for the dimensionless terms were chosen from actual data in an effort to reduce the spread of experimental points. A least square fit was finally used to be able to arrive at a simple relationship between U_{corr} and Y. The correlation finally obtained is given as

$$U_{corr} = 0.09582 - 0.40769Y = U_0 \left(\frac{\overline{T}_1}{T_0}\right)^{\ell} \left(\frac{P_0}{P}\right)^m \left(\frac{L_s}{D_0}\right)^n \tag{19}$$

$$\ell = 1.0; \quad m = 9.7367; \quad n = 0.5211;$$

where

$$U_0 = \frac{M_s(0)\,\lambda_{SL}}{A_0 t^* (\overline{T}_1 - T_s)} \qquad \left(\frac{BTU}{hr\text{-}ft^2\text{-}^{\circ}R}\right) \tag{20}$$

$$Y = \frac{\text{total mass of entering gas}}{\text{mass of initial solid}}$$

5. EVALUATION OF MELTING EXPERIMENTAL DATA CORRELATION

As described in the parametric analysis section,

$$U_0 \left(\frac{\overline{T}_1}{T_0}\right)^{\ell} \left(\frac{P_0}{P}\right)^m \left(\frac{L_s}{D_0}\right)^n = E_2 \left(Y, \frac{\delta h_g}{\delta h_{\ell}}\right) \tag{18}$$
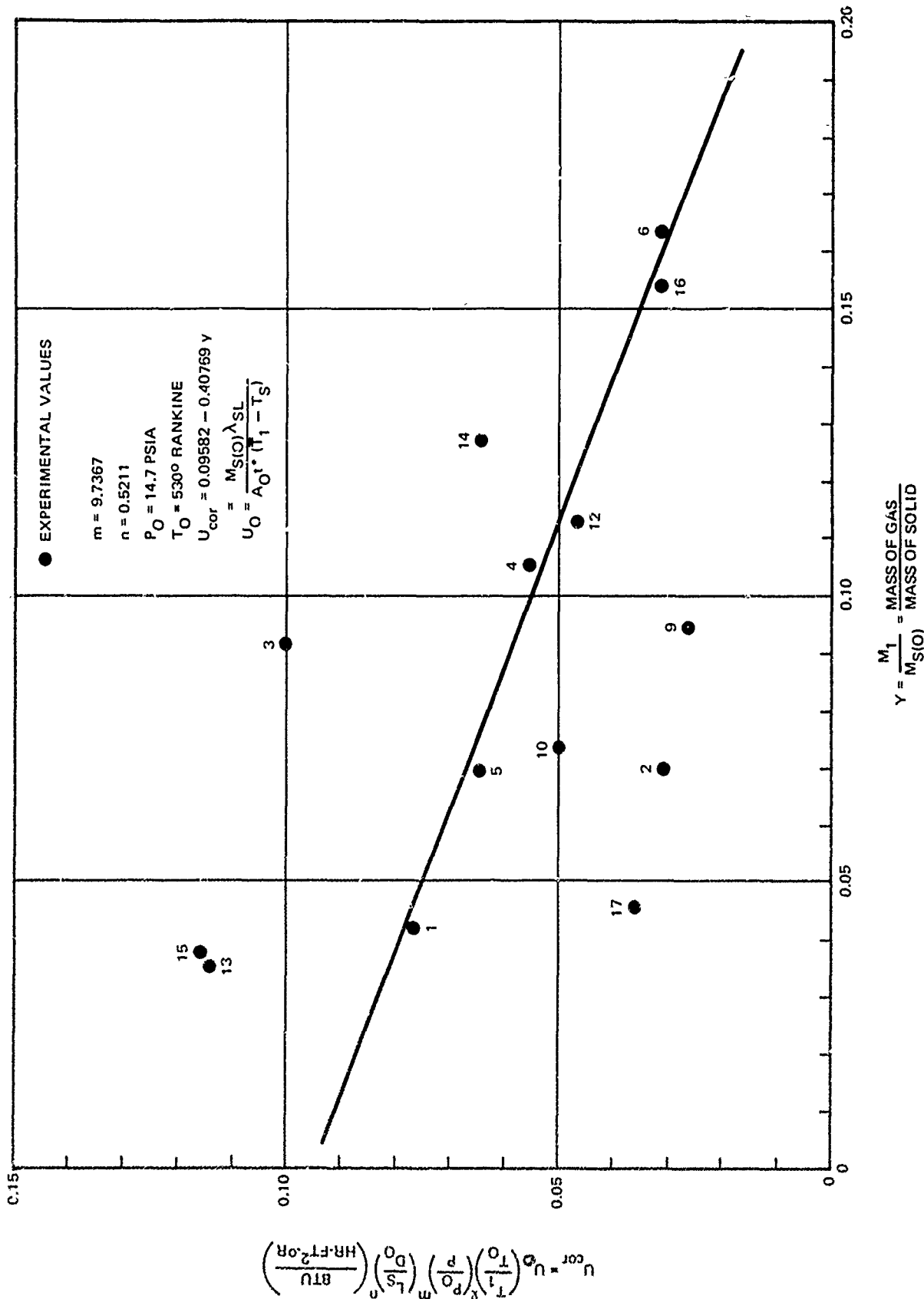
FIG. 9 SH$_2$ MELTING, CORRECTED OVERALL HEAT TRANSFER COEFFICIENT vs MASS RATIO

EXPERIMENTAL VALUES

$m = 9.7367$
$n = 0.5211$
$P_O = 14.7$ PSIA
$T_O = 530°$ RANKINE
$U_{cor} = 0.09582 - 0.40769\ Y$

$$= \frac{M_{S(O)}\lambda_{SL}}{A_{OI}\cdot(T_1 - T_S)}$$

$$U_O = \frac{M_{S(O)}\lambda_{SL}}{A_{OI}\cdot(T_1 - T_S)}$$

$Y = \frac{M_1}{M_{S(O)}} = \frac{\text{MASS OF GAS}}{\text{MASS OF SOLID}}$

$$U_{cor} = U_O\left(\frac{T_1}{T_O}\right)^{\ell}\left(\frac{P}{P_O}\right)^m\left(\frac{L_S}{D_O}\right)^n\left(\frac{D_O}{\text{HR-FT}^2\text{-}°R}\right)$$

75
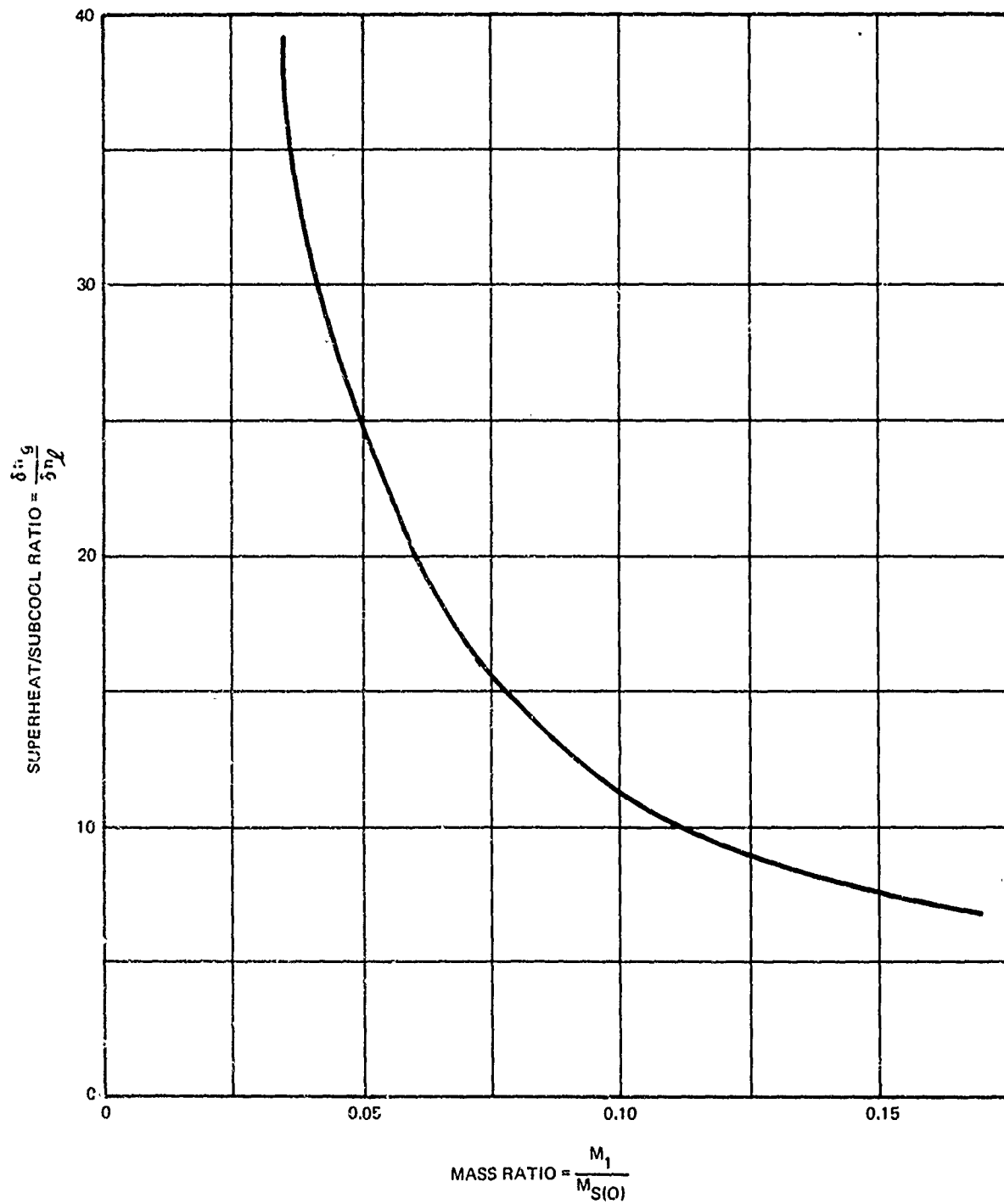
FIG. 10 SH$_2$ MELTING, SUPERHEAT/SUBCOOL RATIO VS MASS RATIO

76

furthermore from Equation (14) we obtain

$$\frac{\delta h_g}{\delta h_\ell} = \frac{\text{inlet gas superheat}}{\text{outlet liquid subcooling}} = E_3 \; (Y) \qquad (21)$$

Finally one arrives at

$$U_o \; (\frac{\bar{T}_1}{T_o})^\ell \; (\frac{P_o}{P})^m \; (\frac{L_s}{D_o})^n = E_4 \; (Y) \qquad (22)$$

Where the exponents ℓ , m, n are to be obtained from the experiments. This type of relationship is presented as Eq. (19).

The exponents ℓ, m and n were determined by systematically reducing the data to a best fit curve; maximum deviations from the best fit curve usually correspond to runs for which some experimental information was missing and had to be obtained by extrapolation, thus making the accuracy of these calculated values somewhat questionable. On the basis of a detailed analysis of each run a maximum deviation of $\pm$ 40% is considered possible; about 50% of all runs were correlated by Eq. (19) within $\pm$ 7%.

The error estimate for the above correlations can be traced to measurement errors as described in the calibration section and to errors due to analytical assumptions, such as the negligible heat leak into the cryostat; from instrumentation considerations one may expect errors of about 15%; to properly determine the error associated with heat leak into the cryostat a comparison between the theoretical vs. experimental superheat/subcool ratios obtained as a function of mass ratio will be required.

Under normal circumstances, i.e., single phase flow in and out of the cryostat or with the help of a vapor quality meter for the case of two phase flow, the above error could have been easily estimated. Unfortunately, because of the design of the cryostat and transfer line, the drained liquid was exposed inside the H_2 Dewar to the incoming hot gas; this additional heat leak into the 1/4" liquid withdrawal line running approximately 48" from the bottom to the top of the inner Dewar contributed to the vaporizing of the liquid being drained.

In the absence of a vapor quality meter we made use of the analytically derived adiabatic energy equation and the experimentally measured mass fluxes to arrive at the relation between the superheat/subcool and the mass ratios respectively. Obviously the heat quantity that went into the liquid was extracted from the gas which ultimately resulted in a longer melting time for the solid.

The net result of the above effects is an overestimate on the total mass of heating gas which in turn represents an overestimate of the total mass of liquid and the melting time. It was felt that the time rate of draining mass

of liquid was not affected considerably, because of the balanced nature of the two effects.

6. SCALING-UP OF EXPERIMENTAL MELTING DATA

The correlation presented in IV, 4 was obtained from analytical considerations involving overall mass and energy equations and experimentally determined melting data. As such it represents a general formulation applicable to a specific melting scheme, namely melting of solid hydrogen at the melt temperature with superheated gaseous hydrogen in contact with the solid both at the top and the sides.

The experimentally obtained exponents affecting the given relationship may be characteristic of the melting apparatus used; this apparatus as described in Appendix (A) simulates to a certain degree the geometrical and thermal characteristics of a typical cryogenic tank; thus one may expect these exponent values to change, as one proceeds to scale-up the melting data to flight type tankage situations; the degree of change on the values obtained from the melting data of this program is not considered to be substantial because of the actually simulated tank characteristics; for actual tank configurations other than the simulated ones in this program, specific values of these exponents will have to be experimentally determined.

Use of Eq. (19) for scaling-up involving tank configurations resembling the cryostat used in this program is considered to be appropriate and on the conservative side. To be able to use Eq. (19) one may specify the degree of superheat/subcool ratio, and with the help of Figure 10 find Y; with the specified value of Y, from Eq. (19) one obtains U_{corr}, from which we can solve for U_0 once the thermodynamic and geometric dimensionless ratios are specified. From (16) we solve for t* (melting time) after initial mass of solid and total heat transfer surface have been fixed. The temperature difference in (20) is fixed once the degree of gas superheat has been specified; the total gas mass flow is obtained readily since Y is known, from which M_1, the entering mass of heating gas is obtained, a simple overall mass balance then permits obtaining the total mass of liquid to be drained; liquid drainage rates are obtained by averaging the total mass of drained liquid over the drainage time. In selecting the superheat/subcool ratio, the liquid subcooling is always fixed by the liquid inlet condition to the engine. Selecting a gas heating temperature automatically fixes the gas superheat and the temperature difference used in the overall heat transfer coefficient U_0.

The above formulation also permits finding the required total mass of gas needed to melt a specified initial mass of solid, within a prescribed time once a total mass of liquid feed to an engine has been fixed. This determination involves a trial and error type solution.

For the purpose of illustration, the scaling-up of the melting data to an 8' diameter x 16' length cylindrical tank, containing 4410 lbs of solid hydrogen, subject to a total of 147 lb of heating gas at 340°F inlet gas condition was analyzed using the relationships found experimentally in this program. The results indicate that about 50 minutes is required to melt such a mass of solid. The equivalent liquid withdrawal rate is about 150 GPM. These results were obtained without the help of heat transfer surface other than that exposed to the gas. By allowing the gas both to impinge the solid

directly and flow inside a heat exchanger in contact with the solid, pre-
liminary calculations show that an improvement on the liquid drain rate
over the above calculated values of one order of magnitude is possible.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Measured thermal conductivity and thermal diffusivity of bulk (non-annealed) SH_2 was found to differ from reported values of carefully annealed crystals, a factor attributed to visible imperfections in the solid. Considerable disagreement is noticeable especially during the cooled down phase, when rapid subcooling of the solid cause hairline cracks throughout the solid.

The determination of the melting characteristics of solid hydrogen required the experimental measurements of thermodynamic parameters, thermophysical properties and fluid flow rates needed to characterize the melting of solid hydrogen in terms of an overall heat transfer coefficient, operating conditions and tank geometry considerations respectively. From these measurements, it was possible to arrive at an experimental correlation which permits the scaling up of the melting data to flight type tankage situations. Improvements on the obtained correlation can be accomplished by a more thorough analysis involving the differential field equations for conservation of mass, momentum and energy for the three fluid phases involved.

As expected, reasonably high melting rates were obtained, a result attributed to the exceptional thermophysical properties of the material and its thermal behavior. These high melting rates are lower than those required for booster applications, but the potential exists for improvement to the desired levels.

Because high melting rates are possible, it is expected that SH_2 can be successfully used as a fuel in a rocket propulsion system in place of liquid hydrogen.

No attempt was made to improve the melting characteristics of the solid, but it became evident the higher melting rates are possible permitting impingement of the gas on the solid and by increasing the heat transfer surface through the use of heat exchangers. It is recommended that means to improve the solid melting rates be investigated in conjunction with a more refined thermodynamic analysis.

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APPENDIX (A)

SOLID HYDROGEN FACILITY

Existing

The Grumman H_2 facility is located at the Calverton site. This area is suited for hazardous testing and is situated so that it yields no hazard to other activities. Originally erected as a rocket test bay, it presently houses the Air Force-sponsored study of the melting characteristics of SH_2.

Building Services

The 16 x 20 foot test bay is heated and has adequate water, electrical power, and high pressure air supply to meet the experimental needs of present SH_2 programs. It is equipped with an overhead crane (1-ton capacity) with a hook height of 16 feet.

Safety Systems

The structure is enclosed with a frangible roof and a frangible front wall, Figure (A-1.) The test cell contains the following permanent safety systems.

- Roof exhaust fans - sized for one air change per minute.

- Hydrogen detectors - "Davis" type approved for H_2 gas environment.

- Aluminum grate floor over rock fill for continuous electrical ground system and fast evaporation of spills.

- Large (6 inch) vent line for emergency dump of liquid charge and two 1 inch vent lines for normal vent. These vent systems are equipped with check valves to prevent back flow of air into the H_2 system.

Cryogenic Systems

Adjacent to the test bay are concrete pads for storage of LH_2 and LN_2 dewars. Transfer of liquid hydrogen is accomplished through vacuum jacketed lines from this pad to the test dewar, across a reinforced concrete wall. Also located outside the test bay are the electrical supply panel, auxiliary vacuum equipment and high pressure gas supply for nitrogen, helium and hydrogen.

Modifications

Determination of the melting characteristics of solid hydrogen required modification of the existing facility which is also used for the thermophysical determination.
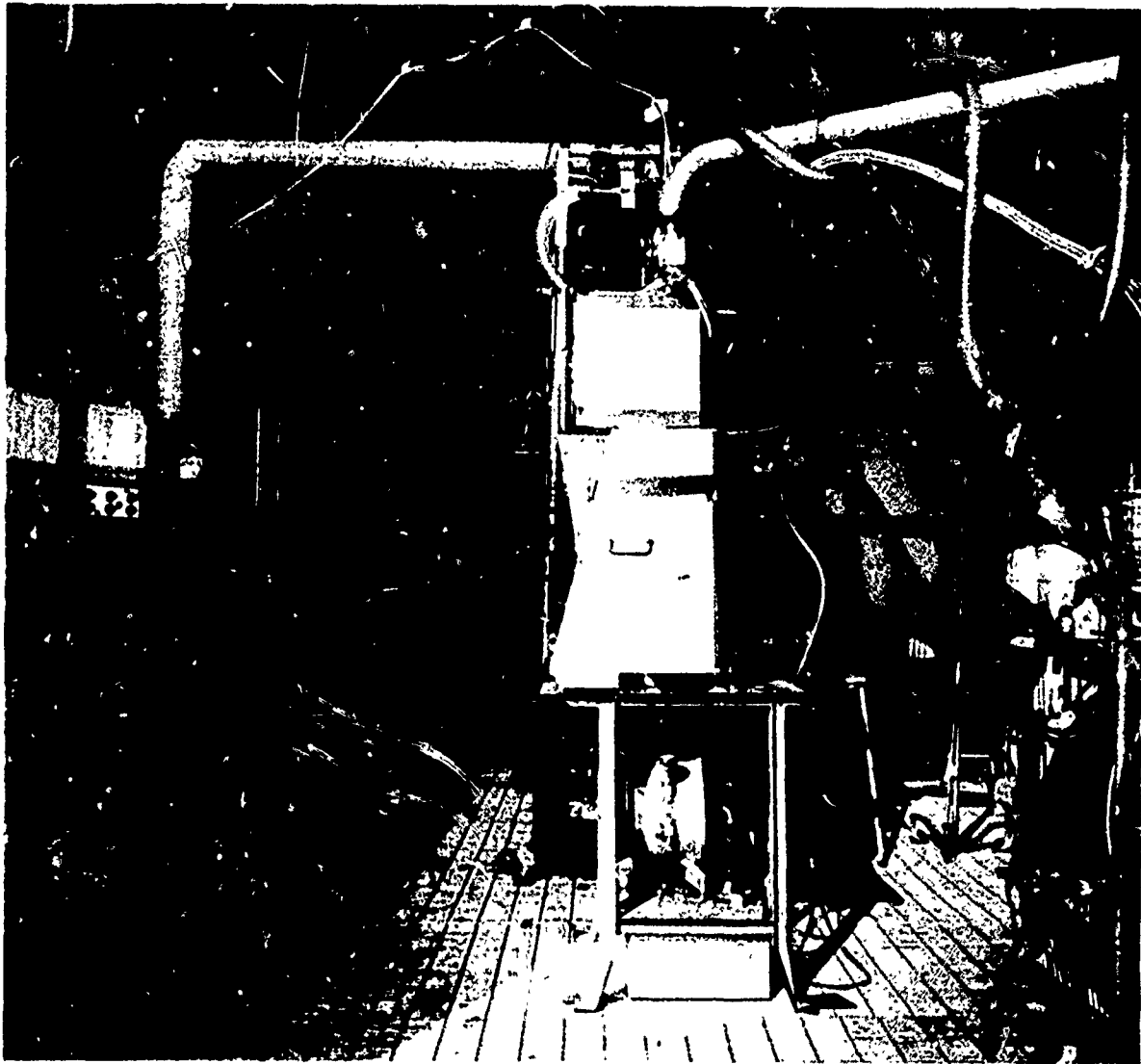
FIG. A-1 GRUMMAN SH$_2$ FACILITY

Selection of line sizes, valve and regulator sizes, flow meter ranges, vaporizing and differential heating heat exchanger and instrumentation requirements necessitated determination of liqud drainage flow rates. A simplified analytical model for the simultaneous melting and vapor process was developed, postulating vertical laminar liquid film flow adjacent to the solid suface, (10). On the basis of this model and from available pressure drop for flow, line sizes and hardware components were selected; modified items both for the SH_2 cryostat and the flow box are described below.

Description of Apparatus (See Figure A-2)

Located inside the test bay is the cryogenic test bench consisting of: (1) SH_2 cryostat, (2) flow box, (3) operating panel and data acquisition system. In addition, portable 150 liter LN_2 and 500 liter LHe supply dewars are available inside the facility.

(1) SH_2 Cryostat

The hydrogen cryostat contained in an aluminum safety box is an assembly consisting of (a) one cylindrical vacuum jacketed glass hydrogen dewar, (b) one cylindrical vacuum jacketed glass nitrogen dewar, (c) a liquid helium heat exchanger, (d) a modified liquid hydrogen withdrawal line, (e) a high vacuum system, and (f) instrumentation.

The vacuum jacketed glass hydrogen dewar is a 17 liter capacity container when unassembled; however, when the liquid helium heat exchanger, LH_2 withdrawal line, and instrumentation are assembled together into the H_2 glass dewar its net volume is reduced to 16.1 liters.

The hydrogen dewar is a modified "Lab Glass Inc." flask model LG-7642, 6.25" I.D. x 8.25" O.D. x 42.5" overall height, silverized on both surfaces facing the vacuum annuli, except for a 5" wide front view port and a 1" wide rear view port running from top to bottom respectively. The top of the vessel is fitted with a standard 6" pipe flange to permit supporting the entire H_2 dewar assembly from a 11" stainless plate.

The dewar has been volume calibrated for different liquid levels from top to bottom. These liquid levels have been engraved as circumferential lines on the outside surface of the H_2 dewar.

The glass H_2 assembly in turn is nested inside another dewar flask, referred as the nitrogen dewar: this container is 10.625" I.D. x 12.0" O.D. x 40" overall height, opened at the top and non silverized to permit visual access into the inner H_2 dewar; the annuli formed between the two concentric dewars is filled up with LN_2 which acts as a refrigerated shield to the inner dewar, helping to minimize the environmental heat leak flux into the experiment. Liquid level control of the LN_2 bath is accomplished automatically by means of a liquid level controller.

FIG. A-2 GAC SH₂ FACILITY FLOW SCHEMATIC

A4.3

A-4.2

A-4.1

IG 63 TCG 77 PG 61 PG 62 PG 115

LH₂ SUPPLY

MV 56   PG 54   TO VENT   MV 11   TC 28

TO VENT

RV 57

TO VENT   RV 6

HE 2

MV 8

CT 2

TC 101

HE 6

CV 1

RV 2   TO VENT

MV 10   MV 12

CV 2

WM 104

TO VENT

RV 58

GH₂ PURGE

MV 15   MV 6

MV 26   MV 25

MV 17   HE-3   FM 3 (GAS)

FLOW BOX   FM 2 (LIQUID)

MV-18

MV-19

CV-3   TO VENT

PG 4   TC 27

MV 35   MV 36

HE-5

TC 26   MV 5

FM 1

MV 7

PG

MV 9

TC

GERATED

LH₂ SUPPLY   TC 23

HX 87 LH₂

SH₂ CRYOSTAT

LH₂ WITH DRAWAL LINE

LHe HEAT XCHNGR 86

SH₂ DEWAR VACUUM ANNULI

TO VENT

MV 125

MV 46   MV 47   RV-48

LN₂ SUPPLY

LN₂ SHIELD DEWAR

AV 73

LN₂ DEWAR VACUUM ANNULI

LN₂

MV 42   TC 43   IG 41   MV-38

MV 45   TC 44   IG-78   MV 40

MV 39   MV 37

TC 50

VV   VV 5

MV 14   VV 1

TC 22

DIFFUSION PUMP DP 67

VV 3

CV 3   MP 64

CV 4   MP 65

TC 34   VV

VV 6

MV 12   VV 4

TC 21

DIFFUSION PUMP DP 66

VV 2

IG 79

MV 1   MV 2

FIG. A-2 GAC-SH$_2$ FACILITY FLOW SCHEMATIC

A-4

Nestled inside the inner glass dewar is the liquid helium heat exchanger (c), 1" diameter x 1.5" diameter x 36.5" long double pipe stainless steel freezing exchanger supported from the top support plate. Its purpose is to freeze the adjacent LH_2 bath into which it is submerged, using LHe as refrigerant. LHe is admitted through the top of the inner pipe following downwards to the bottom of the exchanger where it reverses direction and flow upwards in the annuli formed by the two concentric pipes. The exiting vapor at the top is finally vented out

Surrounding the vent line of the heat exchanger there is a metal shroud with provisions for flow of LN_2 refrigerant to minimize conductive heat leaks down the wall of the heat exchanger after freezing of the LH_2 is completed and the flow of LHe is stopped. An additional two, concentric, polished copper shields, parallel to the top support plate are brazed to the LN_2 refrigerated metal shroud surrounding the heat exchanger vent line. These refrigerated radiation shields help protect the solid hydrogen from thermal radiation emanating from the ambient connected top support plate.

Also located inside the inner glass dewar is the modified LH_2 withdrawal line (d). This line made of 0.25" o.D. stainless steel tubing runs from the bottom of the H_2 dewar to the top support plate where it exits after becoming a 1" O.D. vacuum jacketed transfer line. Outside of the safety box this transfer line becomes a 2.0" vacuum jacketed line with a 0.5" O.D. LH_2 inner line. The LH_2 withdrawal draining line permits the liquid accumulated on the bottom of the H_2 dewar which results from condensation of the heating gas and melting of the solid; the drained liquid is transferred through the 2" vacuum jacketed line to a flow box where the liquid volumetric flow rates are measured.

In the assembly of the LH_2 withdrawal line care is taken to allow the line to rest against the glass wall and to reach down until it almost touches the bottom of the H_2 dewar. During the freezing period GHe is introduced into this line and the gas bubbled through the liquid until freezing of the liquid adjacent to the tip of the tube takes place. In this way one guarantees, unplugging of the line by not permitting liquid into it which may block its entrance and maximum drainage respectively. If blockage is present prior to drainage, application of heat across the glass wall and into the tube is required.

The high vacuum system (e) consists of two 4" water cooled diffusion pumps with their corresponding 5CFM forepumps, manifolding and controls. These systems are assembled and manifolded together to permit high vacuum pumping of the vacuum jackets of the glass dewars, the SH_2 dewar and all lines connected to the apparatus. Vacuums better than 10^{-6} torr have been obtained for this experimental apparatus.

The SH_2 experiment instrumentation is located inside and outside the H_2 dewar. Its main purpose is to permit temperature and pressure measurements at different locations. These measurements involve recording of the solid hydrogen temperature distribution, incoming hot gas and outgoing liquid product. Temperature measurements of the solid hydrogen are used for the thermophysical property evaluation of the solid. Temperature measurements of the flowing fluids, in conjunction with flow rate measurements are used to evaluate the melting characteristics of the solid hydrogen.

Interior temperature instrumentation is arranged at different locations throughout the H_2 dewar; to facilitate its mechanical support, two thermocouple spacers were designed and attached firmly near the top and bottom of the LHe heat exchanger; these spacers consisting each of one invar ring with four (4) equally distanced, symmetrical radial spokes jig bored at three fixed radiis, riding on a nylon bushing properly clamped to the outer periphery of the LHe heat exchanger permit the support and controlled spacing of three nylon strings per radial spoke used to support the various thermocouples cold measuring junctions.

A total of 12 nylon strings arranged in a cross like manner were used. In addition, a nylon "spider" assembly properly supported at the base of the heat exchanger continuously maintained all the nylon strings in tension to avoid slacking and possible change in the radial dimensions of the T.C.'s locations. These locations are very critical during the thermophysical experiments and small variations in the radial temperature gradients due to radial distance variations may introduce serious errors in the thermophysical properties being investigated.

Because of the range of temperatures existing throughout the experiments the use of different T.C.'s material was required. For incoming hot gas the use of chromel-constantan T.C. wire (Type E) was indicated. This wire material was also used for outgoing liquid product because of the availability of sheathed wire which allowed for a more rugged operation.

For low temperature measurements of the SH_2 two kinds of temperature sensors were used, namely thermocouples and resistance thermometers. Gold, (0.07%) iron-chromel wire 0.005" thick was used for the thermocouple sensors. Germanium thermistors were used to help calibrate the thermocouples. These thermistors had been calibrated previously against known standards, see reference (11). Actual locations of temperature instrumentation arrays can be seen on Figures A-3 and A-4.

Array numbers 1, 2, and 3 were assigned to gold, iron-chromel cold junctions, in such a way that array no. 1 faced the front window of the cryostat while arrays nos. 2 and 3 were located at 90° angles both to the left and right of the front window.

FIG. A-3 SOLID HYDROGEN CHAMBER AND THERMOCOUPLE PLACEMENT
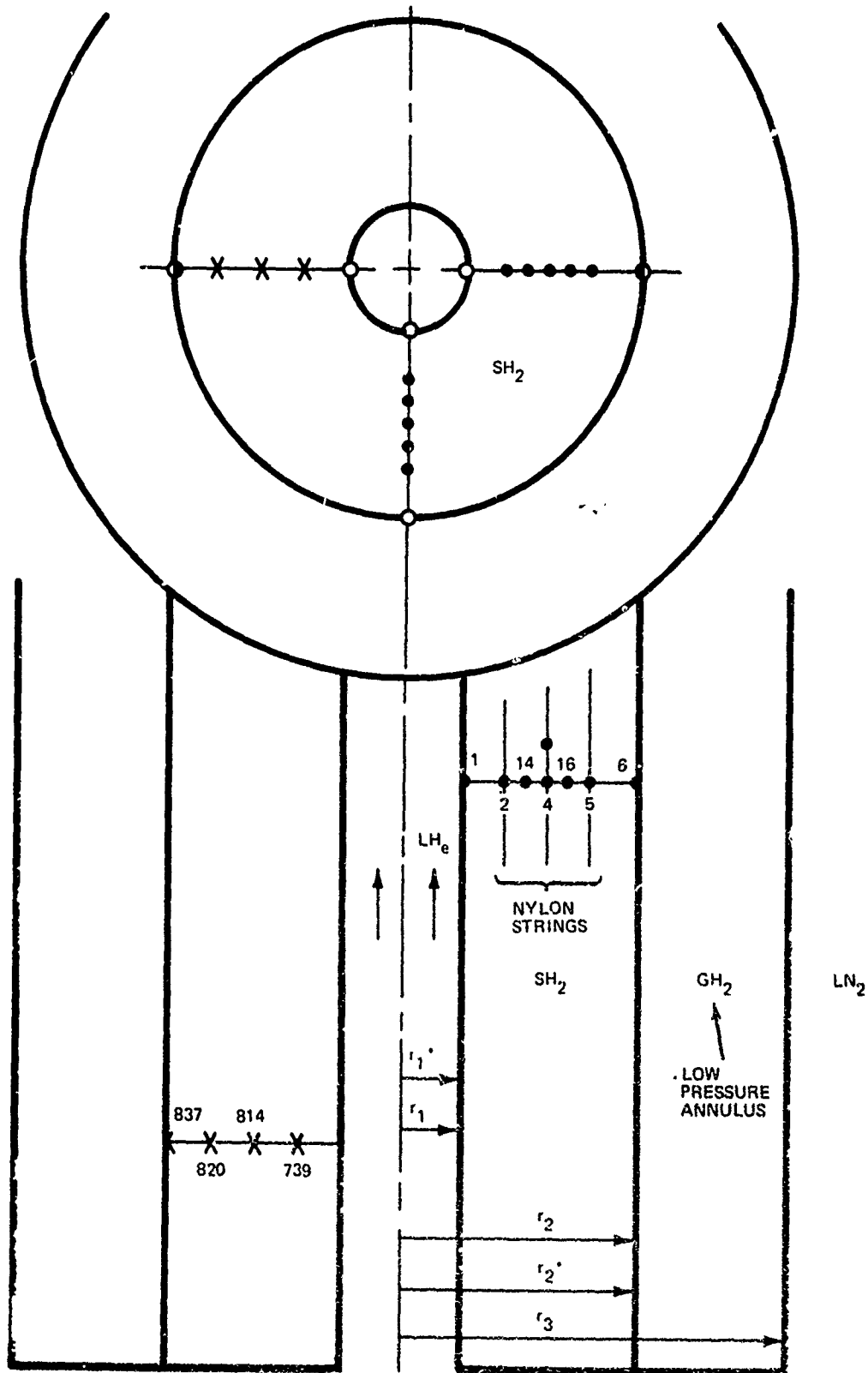
- ● GOLD, IRON-CHROMAL THERMOCOUPLES
- ✗ GERMANIUM RESISTORS

r_1 = 3/4 INCH
r_2 = 3.125 INCH
r_3 = 4 INCH
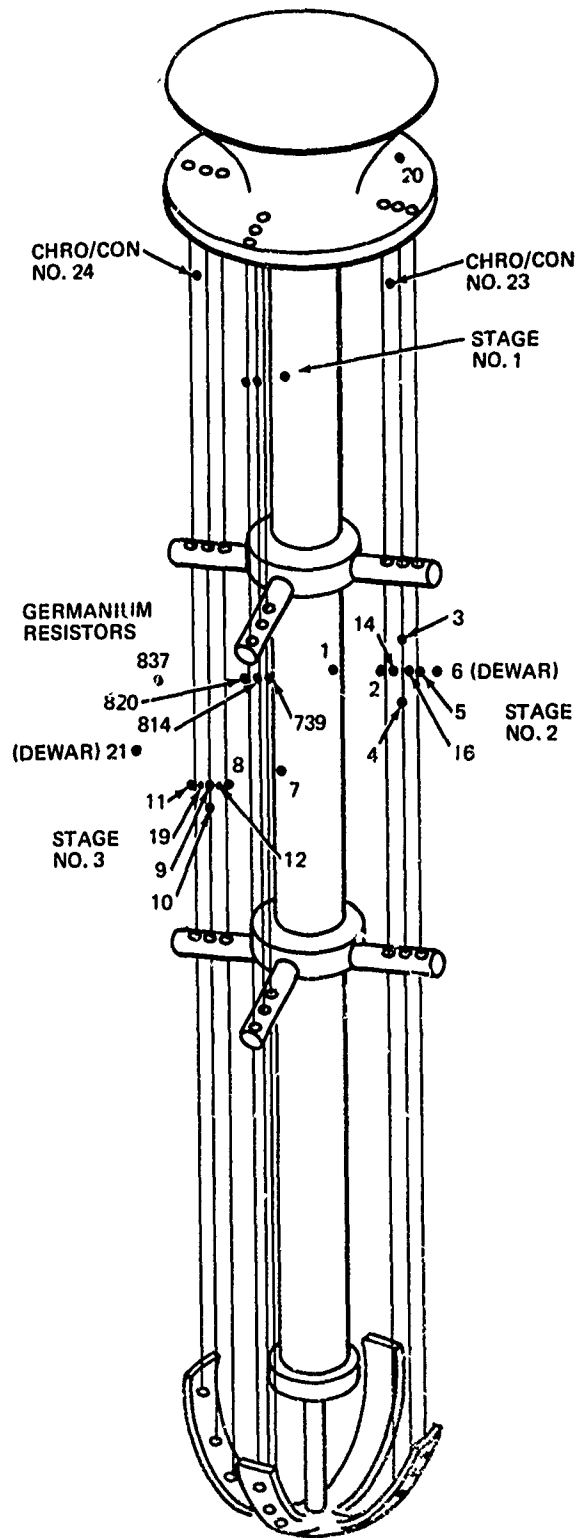
FIG. A-4 SH$_2$ CRYOSTAT — TC LOCATION MAP

In total, 20 thermocouples were positioned throughout the solid. In addition, an array of 4 germanium resistors were located 180° from array no. 2. Type "E" thermocouples nos. 23 and 24 were located at the top of the solid, slight below the bottom copper radiation shield; these two thermocouples measured the vapor temperatures above the solid. Temperature recordings were also made on the inlet and outlet piping to and from the cryostat, using Type "E" thermocouples. Their location can be seen from Figure A-2.

Pressure measurements for the solid hydrogen cryostat are obtained through the use of overlapping pressure measuring instruments ranging from ionization - vacuum gage tubes, to thermocouple gages. to absolute pressure Wallace-Tiernan bellow pressure gages (0.1 mm to 100 mm Hg range) to compound (30" -0-15 PSI), helicoid pressure gages.

In addition to the above instrumentation, the SH_2 cryostat was modified by the addition of gas and liquid heaters and controllers. These heaters and controllers allowed heating of the incoming gas to a prescribed temperature and its control thereafter. Heat exchanger HE 1 is made out of several lengths of 3.5" O.D. stainless steel tubing connected in series, externally wrapped with stainless steel strap heaters with a total heating capacity of 6.3 KW. An "Alnor" pyrometic solid state controller (0-400°F range) was used for controlling these heaters. Heat exchanger HE 2 is made out of several lengths of 2.5" O.D. stainless steel tubing connected in series, externally wrapped with stainless steal strap heaters with 2.5KW total heating capacity. A "Love" controller with variable voltage regulation was used in conjunction with these heaters.

Flow measurements of incoming gas to the SH_2 cyrostat were made with a COX model CRL-8 (1/2") hydrogen gas meter with a flow range of 2 to 10 ACFM. This meter is a cryogenic turbine flow transducer type with 1.0 PSI pressure drop at maximum flow rate, calibrated with air at ambient temperature. Continuous temperature recordings of flow past this flow meter were made to permit correcting flow measurements due to temperature variations. In addition, a wet test meter FM-8 was used to measure the total volume of possible vented gas due to overpressurization of the cryostat. This meter is an American Meter Co. model AL-19, 5 to 80 CFM capacity with temperature correction capability.

(2) Flow Box

This is an assembly of two flow meters and corresponding piping contained in an aluminum box, purged continously with gaseous nitrogen. Three front windows permit observation of the flow regimes past the flow meters exiting through a clear glass tubing section. The discharge end of the LH_2 withdrawal line, carrying the liquid drained from the SH_2 cyrostat, is a 1/2" x 1/2" diameter superinsulated vacuum jacketed transfer line terminating in a piping manifold inside the flow box. This manifold feeds three separate flow loops, namely a liquid, a vapor, and chill down and by-passing, piping

systems respectively. Proper valving permits distributing the flow for the required flow configuration.

Flow meters to measure melting and condensing experimental flow rates are located downstream of the flow distributing manifold, one for the liquid branch and one for the vapor branch. In the liquid branch, liquid product from the experiment is measured directly without a change in phase. The liquid flow meter used for this measurement is a FM-2 COX model CRL-6 (1/2") LH_2 meter with a flow range of 1.5 to 15 GPM, with 6.5 PSI pressure drop at maximum flow rate. The discharged flow from this meter, is vaporized and the gas vented to atmosphere via a common vent header. In the vapor branch, liquid and vapor product (two phase transfer) from the experiment is converted to single phase gas prior to flow measurements. AN FM-3 Cox Model CRL-20 (1 1/4") hydrogen gas meter with a flow range of 8.5 to 85 ACFM, with 1 PSI pressure drop at maximum flow was used for this measurement determination; the exhaust from this meter was vented to atmosphere via a 1" vent line.

Above flow meters are of the cryogenic turbine flow transducer type, calibrated by the manufacturer with water, and 20 PSIA ambient temperature air respectively.

(3) **Data Acquisition System**

The data system is capable of recording 22 Gold, Iron-Chromel thermocouples, 4 Germanium thermistors and 2 flow meter outputs. The system block diagram and equipment layout are shown on Figures A-5 and A-6. It consists of:

(a) **Gold, Iron-Chromel Thermocouples** (See Figure A-7)

Emf's generated by the thermocouples are picked up at their reference junctions which are maintained at LN_2 temperature, by two conduction shielded wires and fed to an output junction patch panel. A total of eight thermocouples can be patched into high gain differential D.C. amplifiers (Preston model 8300) per test. The conditioned output signals are then made to drive potentriometric type strip chart recorders (Bristol).

(b) **Chromel-Constantan**

Same as above.

(c) **Germanium Thermistors** (See Figures A-8 and A-9)

Variations in resistance due to temperature changes are converted into emf signals by a constant current in a series circuit. These signals are fed into high gain, D.C. differential amplifiers and then made to drive strip chart recorders (Bristol) as described previously.
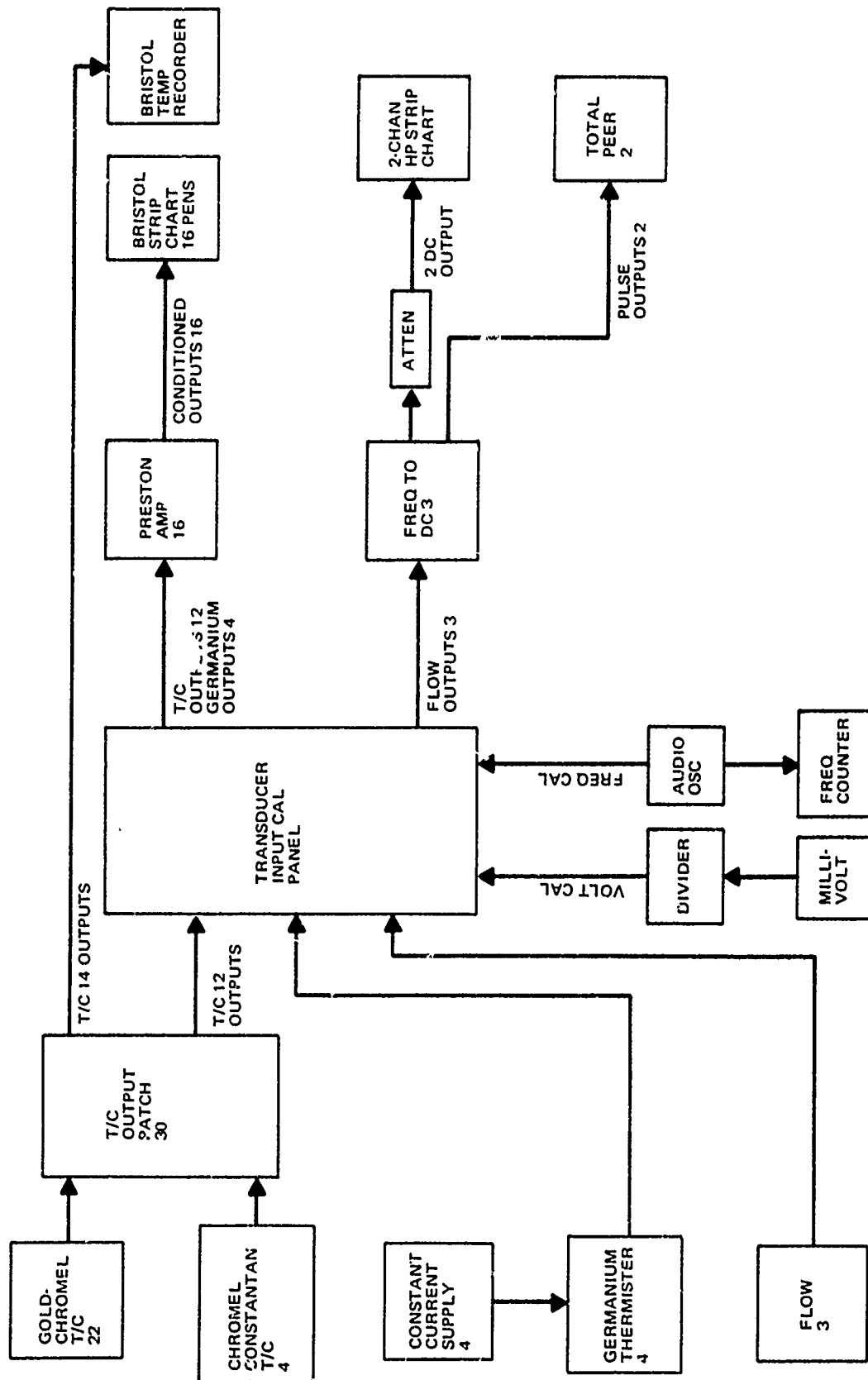
FIG. A-5 INSTRUMENTATION BLOCK DIAGRAM

RACK 1

| MILLIVOLT SOURCE |
| INPUT/CAL PATCH |
| DIVIDER |
| FLOW   ATTENUATOR |
| PRESTON AMP 1-8 |
| PRESTON AMP 9-16 |
| FREQ TO DC 1-3 |

RACK 1

RACK 2

| BRISTOL STRIP CHART CHAN 1-4 |
| BRISTOL STRIP CHART CHAN 5-8 |
| HP STRIP CHART CHAN 1-2 |

RACK 2

RACK 3

| EPUT FLOW TOTALIZER NO. 1 |
| CONSTANT CURRENT SUPPLY 1-4 |
| BRISTOL STRIP CHART CHAN 9-12 |
| BRISTOL STRIP CHART CHAN 13-16 |
| EPU FLOW TOTALIZER NO. 2 |

RACK 3
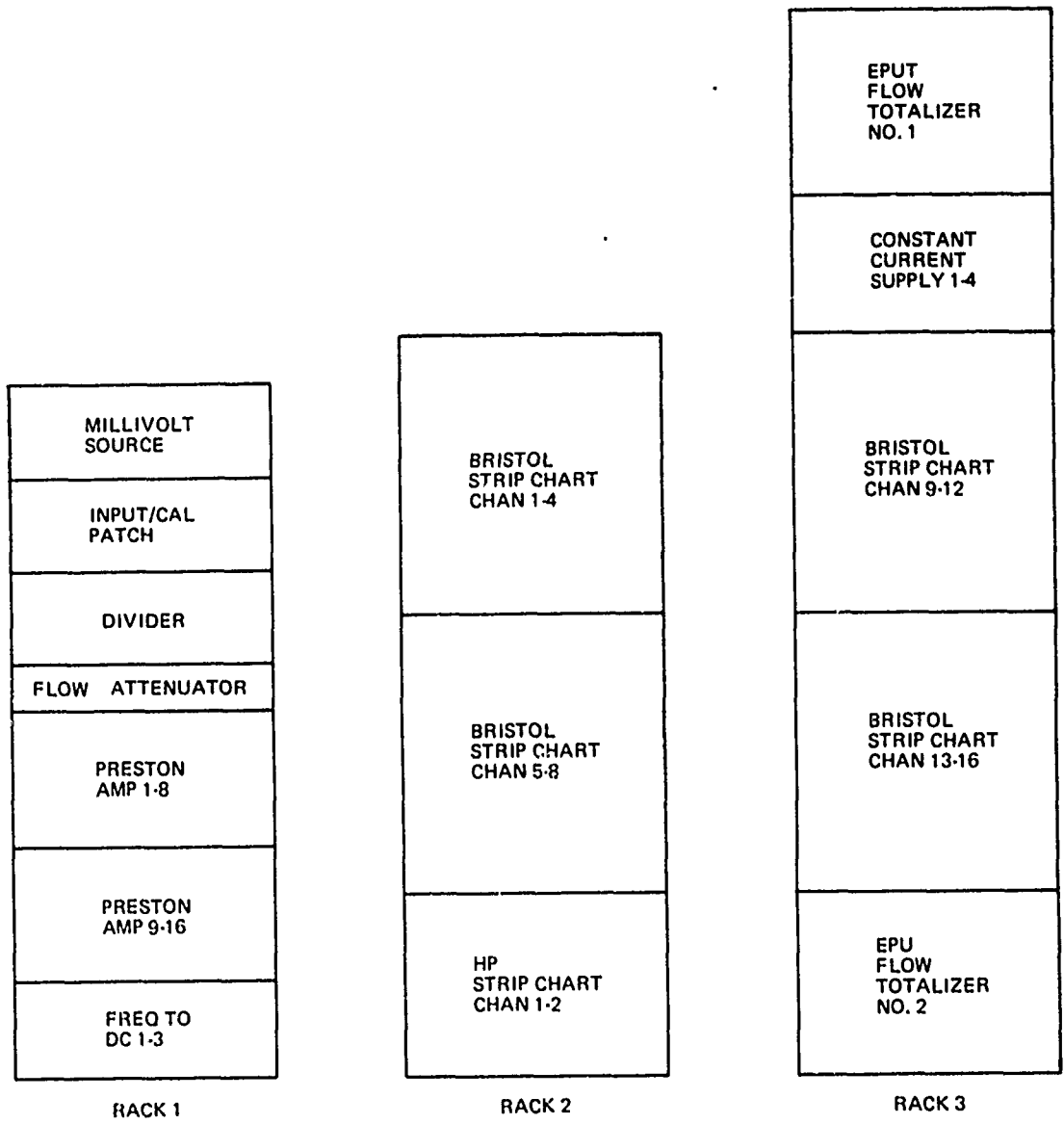
FIG. A-6 INSTRUMENTATION RACK LAYOUT (NOT TO SCALE)

FIG. A-7 GOLD, IRON-CHROMEL/CHROMEL-CONST TC INSTRUMENTATION SCHEMATIC
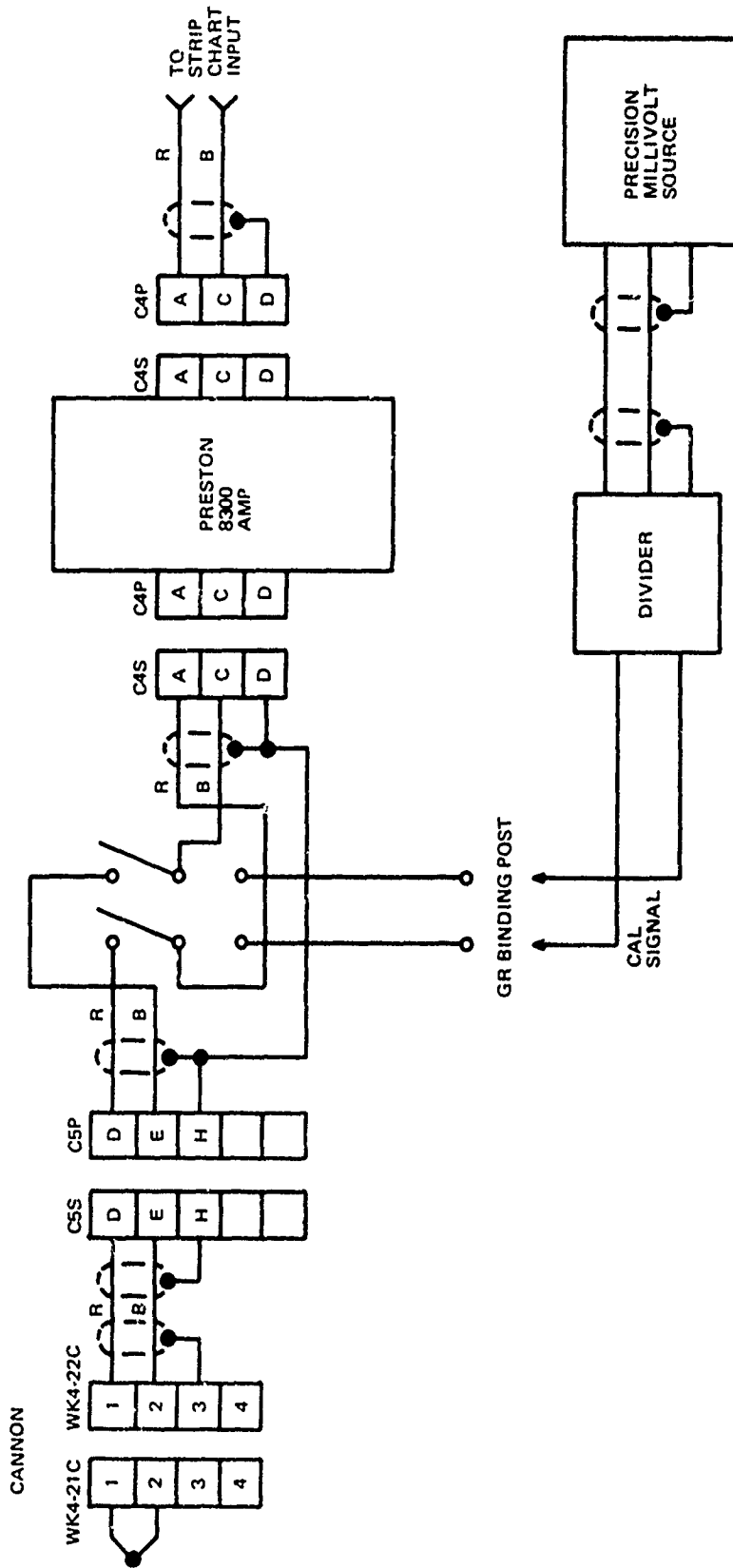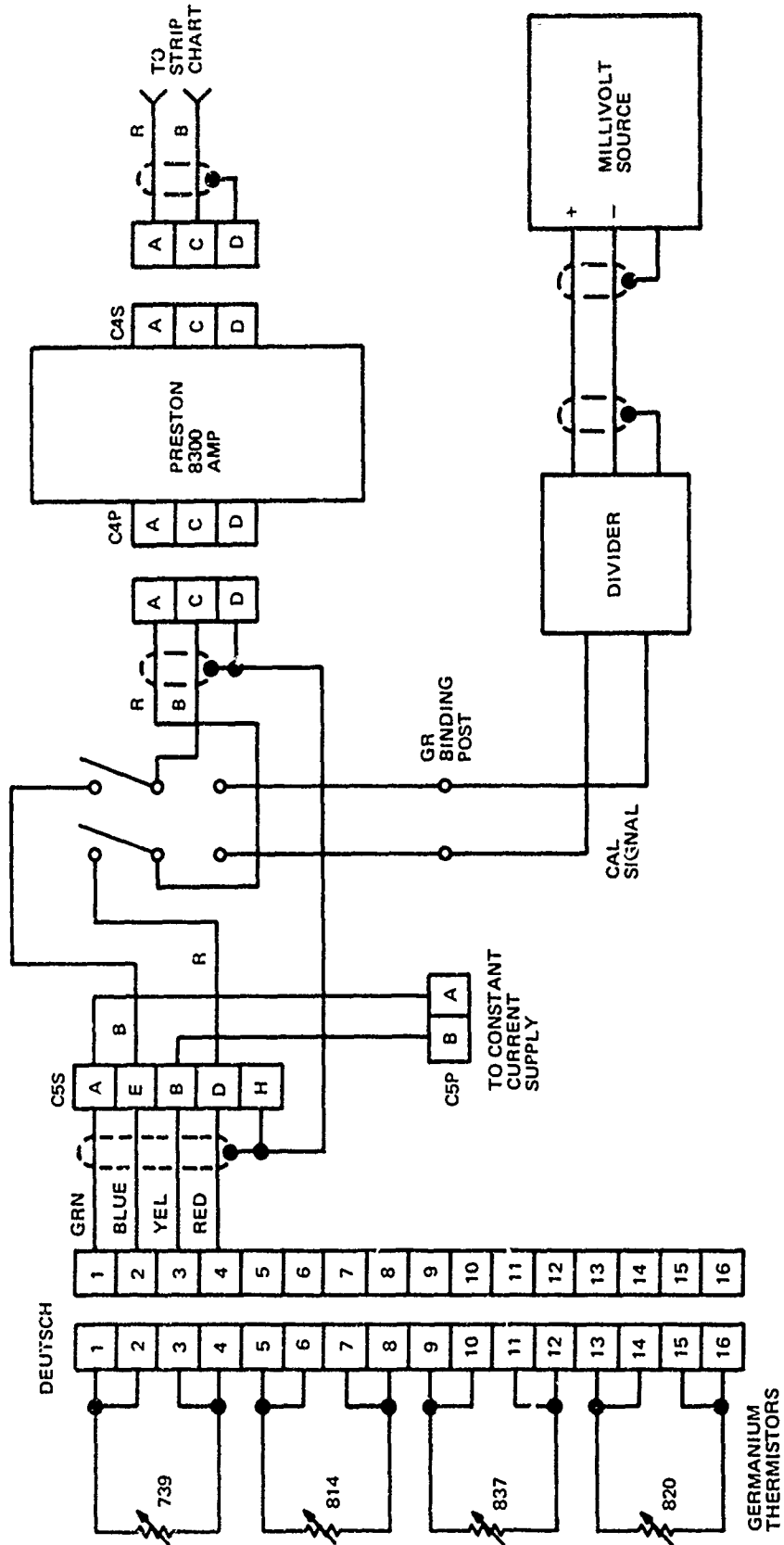
TYPICAL 1 OF 13

FIG. A-8 GERMANIUM THERMISTOR INSTRUMENTATION SCHEMATIC

TYPICAL 1 OF 4
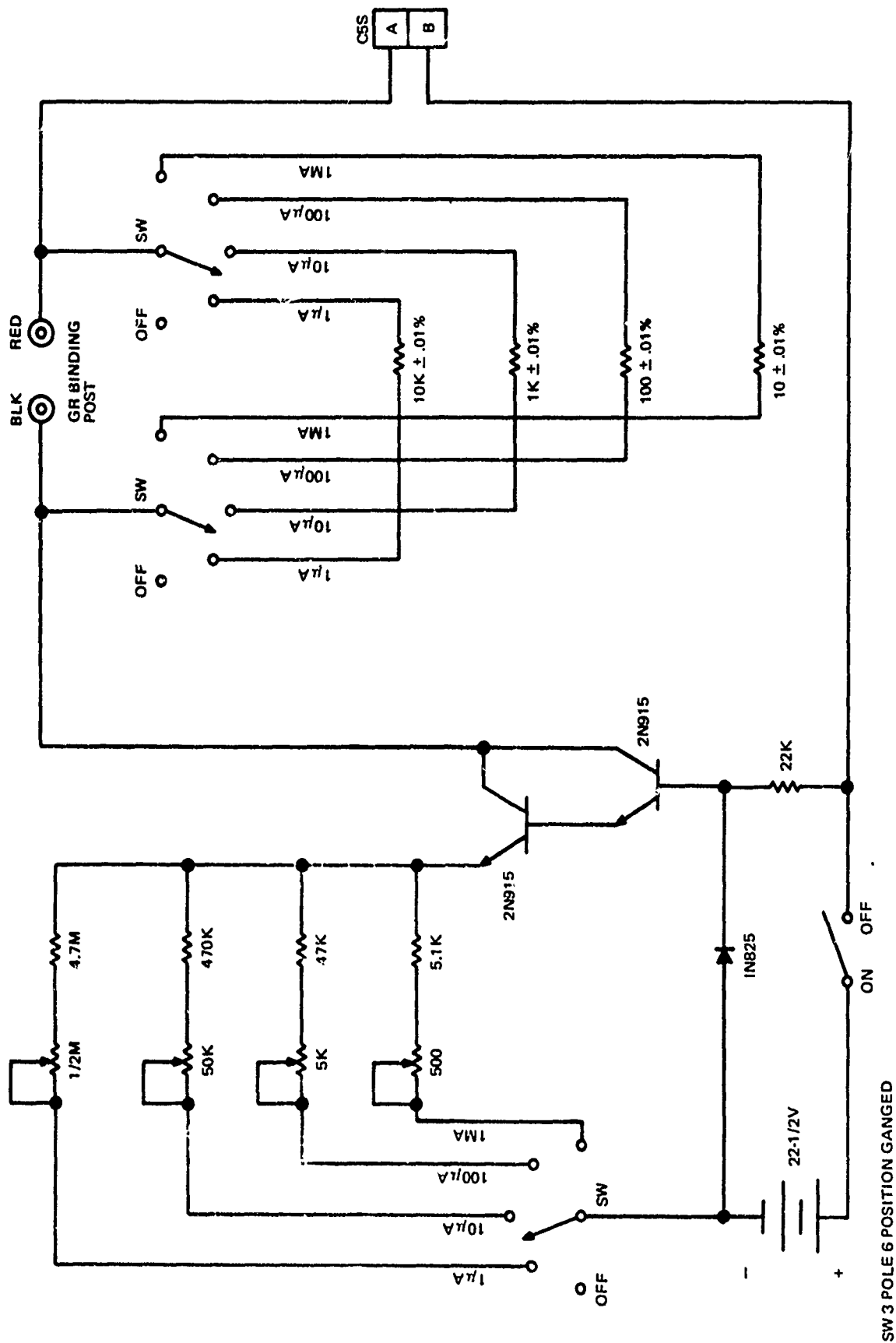
FIG. A-9 CONSTANT CURRENT SUPPLY INSTRUMENTATION SCHEMATIC (TYPICAL)
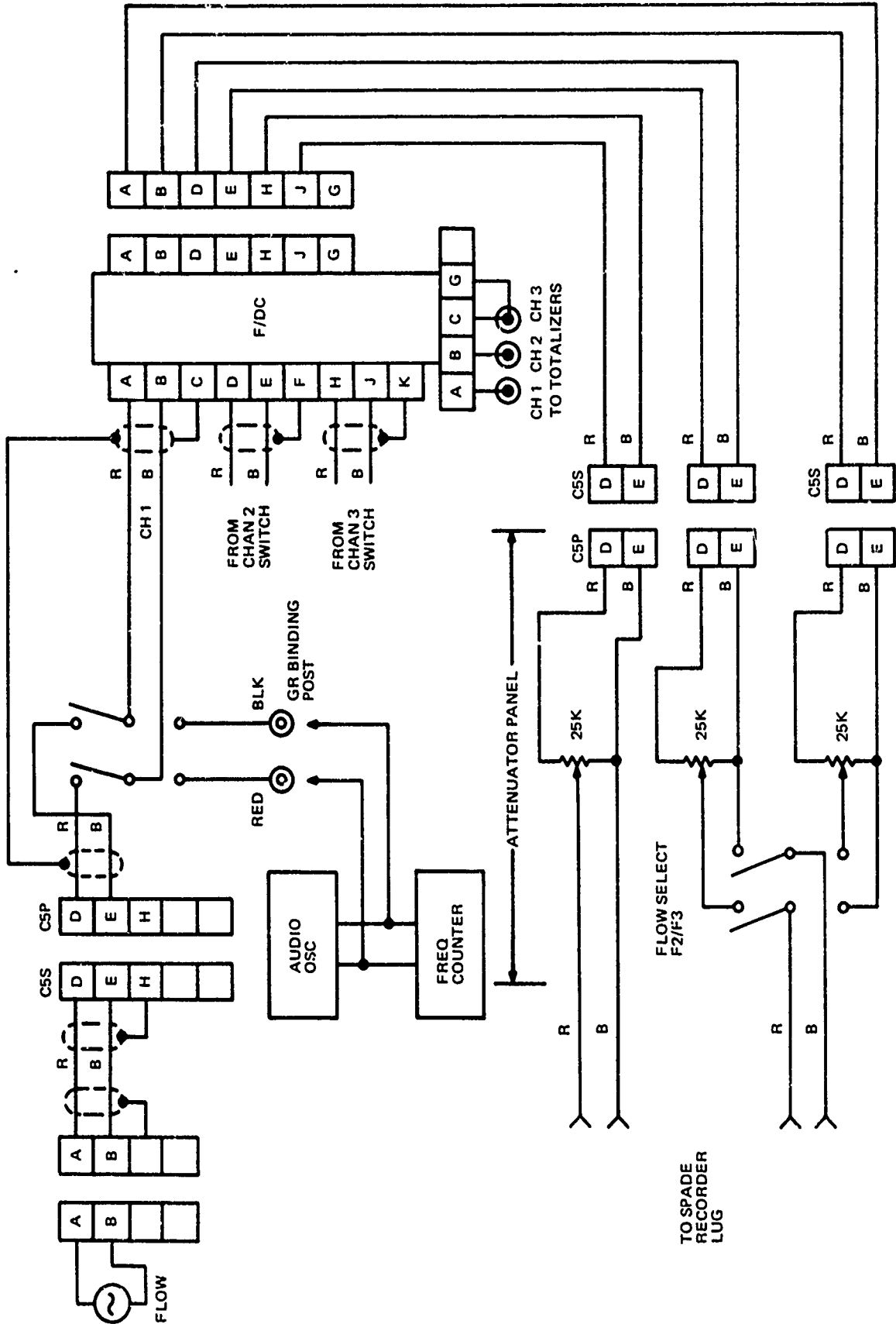
FIG. A-10 FLOW METER INSTRUMENTATION SCHEMATIC

(d) <u>Flow</u> (See Figure A-10)

Sinusoidal signals of varying amplitude and frequency as functions of flow rate are generated by turbine type flow meters. These signals are fed to D.C. converters (Andadex PI400) where they are translated into analog and pulse outputs. The analog D.C. signals are fed into strip charts (Hewlett Packard) where pen displacement is made proportional to flow rate. The pulse outputs signals are fed to EPUT meters where totalized flow can be recorded. (Beckman)

APPENDIX (B)

EXPERIMENTAL DATA REDUCTION

Acquisition of data has been described previously. Data can be classified according with the type of measurements involved, namely flow and temperature measurements for the melting experiments and temperature and time measurements for the thermophysical experiments.

Melting Experiments

The melting experiments as described under test procedures, involved measurements of incoming and outgoing fluids to and from the cryostat and the flow box. Mass flow rates and enthalpies of the flowing fluids were specifically measured. Calculation of either the incoming or outgoing mass flow rate was achieved by obtaining the product of volumetric flow rate, $\dot{\upsilon}$, and density, ρ ; furthermore, frequency, f, generated by the flow meter is proportional to the volume flow rate, thus

$$\dot{\upsilon} = cf \tag{23}$$

where c is the proportionality constant which is unique for the given flow meter. When the calibration reference temperature is different from that of the actual condition, a correction factor c_0 should be applied, (see Figure B-1)

$$\dot{\upsilon}_c = c_0 c f \tag{24}$$

Since the hydrogen density, ρ , for the temperature and the pressure ranges experienced by the flow meters can be expressed in the ideal gas form, one can have

$$\rho = \frac{P}{RT} \tag{25}$$

where R is the gas constant of the hydrogen. If we express the temperature, T, in terms of the emf output, e, of the thermocouple, the temperature can be written as a function of e

$$T = G(e) \tag{26}$$

then the instantaneous mass flow rate, $\dot{m}$, can be put into the following, from equations (21) through (24):

$$\dot{m} = \rho\dot{\upsilon} = \frac{c_0 c P f}{R G(e)} \tag{27}$$
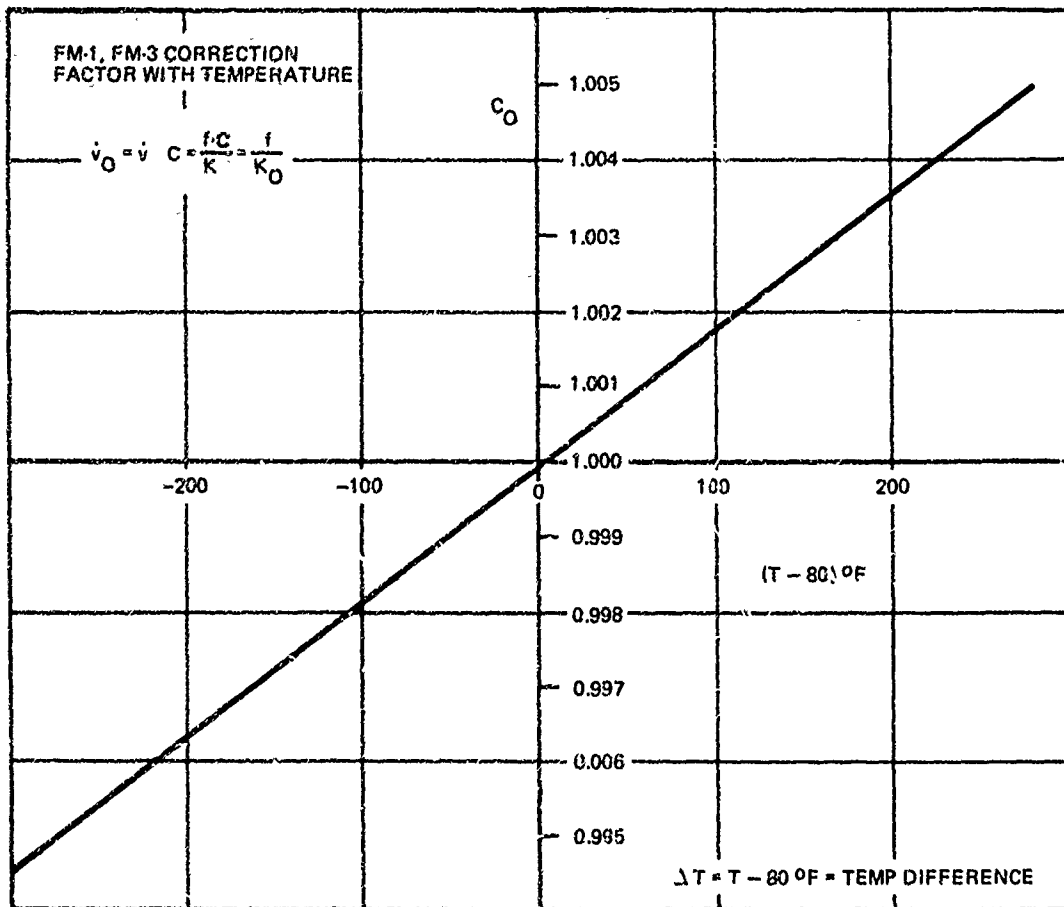
FIG. B-1 FLOW METER TEMPERATURE CORRECTION FACTOR

TABLE B-1 - THERMODYNAMIC PROPERTIES OF HYDROGEN USED IN THE CALCULATION

Internal Energy of Solid,	U_S = -157	Btu/Lb. @ 1 atm and 24.9°R
Latent Heat of Fusion,	λ_{SL} = 25	Btu/Lb. @ 1 atm
Latent Heat of Vaporization,	λ_{LV} = 191.3	Btu/Lb. @ 1 atm
Gas Enthalpy at Boiling Point,	h_g^{LV} = 81.3	Btu/Lb. @ 1 atm
Liquid Enthalpy at Freezing Point,	h_ℓ^{SL} = -132	Btu/Lb. @ 1 atm
Boiling Point @ 1 atm,	T = 36.5	Degrees Rankine
Freezing Point @ 1 atm,	T = 24.9	Degrees Rankine

* Computed from the values tabulated in the N.B.S. monograph
  94 para-hydrogen data.

B. 2 - B

The total mass, M_j, recorded during the melting period was computed by means of integrating the mass flow rate over the period, t^*, utilizing the trapezoidal integration rule.

$$M_j = \int_0^{t^*} \dot{m}_j \, dt = \Delta t \left[\frac{1}{2}(\dot{m}_0 + \dot{m}_n) + \sum_{\cdot 1}^{i=n-1} \dot{m}_i \right] \qquad j = 1,2 \qquad (28)$$

where Δt is the integration interval of t^*/N.

In the experiment, two flow totalizers, one for each flow meter were used in addition to strip chart recorders. The totalizers total the number of cycles from the frequency output of the flow transducers over the melting period. The total count N_M, registered in each flow totalizer was compared with the integrated value of frequency over the same period in order to ensure the accuracy of integration. The total number of cycles was obtained from

$$N_I = \int_0^{t^*} f \, dt = \Delta t \left[\frac{1}{2}(f_0 + f_n) + \sum_{I}^{i=n-1} f_i \right] \qquad (29)$$

If it turned out that the integrated value N_I differed from the measured one N_M by a small amount, the integrated value of M_j was corrected proportionately.

Because the incoming hot gas flow meter malfunctioned occasionally, its reading was usually compared with the value obtained from the overall mass balance equation, if the recorded reading was lower than the calculated one it was ignored and the calculated one used for computation purposes. Extrapolating criteria was developed from recording behavior of previous and subsequent runs.

The average enthalpy over the melting period was calculated from the expression

$$\bar{h} = \frac{1}{M} \int_0^{t^*} \dot{m}h \, dt = \frac{\Delta t}{M} \left[\frac{1}{2}(\dot{m}_0 h_0 + \dot{m}_n h_n) + \sum_{1}^{i=n-1} \dot{m}_i h_i \right] \qquad (30)$$

To calculate the above expression, it is assumed that enthalpy is a function of temperature only. Knowing temperature variations with time will permit a complete determination of h; temperature variations with time can be obtained from thermocouple information in the form of emf vs. time; from calibration charts one obtains temperature versus time plots as shown in the tabulated data section; values of ($\bar{h}_1$) were calculated for all incoming hot gas cases. Because the exiting fluid from the cryostat was mostly two-phase, the average enthalpy was calculated by employing the overall energy and mass equations as given by (6) and (9).

$$\bar{h}_2 = \frac{1}{M_2} \left[M_1 \bar{h}_1 + M_s(0) U_s(0) \right] \qquad (31)$$

The average flow temperature has been calculated from knowledge of the average flow enthalpy and the use of enthalpy vs. temperature curves.

Specific values of thermodynamic properties used in this calculation are tabulated in Table B-I.

Thermophysical Property Determination

Experimental data was reduced using temperature calibration curves obtained from calibration runs as described in the calibration procedures section. Initial data was obtained every ten seconds for the duration of each run. Because of the uneveness, in the temperature profile and the thermocouple array spacing, specifically between the heat exchanger and first nylon strong and last nylon string and glass wall respectively, use was made of a least square fit technique which smoothed-out the experimental values in the radial direction and permitted choosing an equal radial grid spacing for purposes of computer programming. A Lagrangian interpolation technique for both space and time coordinates was then used to permit arbitrary selection of time and space grid sizes compatible with finite difference, numerical solution stability criteria. For the four runs chosen it was found that five second time intervals and 0.216" space intervals guaranteed computational stability and reasonable accuracy.

APPENDIX (C)

CALIBRATION PROCEDURES

Two types of measurements were used throughout the experiments, namely temperature and flow; temperature instrumentation made use of thermocouple wire.

Type E, T.C. wire was used for measurements involving flow temperatures; gold, iron-chromel wire was prescribed for the determination of temperature profile at selected interior and boundary points of the solid. Because of the nature of temperature excursions on the solid and the time transients associated with such measurements, a very thin wire (0.005") was selected and a calibration procedure developed so as to be able to calibrate each thermocuple individually. Type E thermocouples were manufactured and calibrated by the Omega Engineering Company and their curves used in the reduction of the experimental data, (see Figure C-1).

For the gold, iron-chromel thermocouples the calibration consisted in locating all the wires inside the cryostat which permitted in place calibration of the individual thermocouples; in this way we prevented the introduction of spurious emf's due to handling of the wires after calibration was completed, which is the usual case if one decided to use the wire manufacturers calibration curves or the average calibration curves available for this particular type of thermocouple from the National Bureau of Standards.

As a secondary standard temperature reference use was made of four germanium resistors, which have been calibrated previously, [11] all traceable to NBS primary standard reference temperatures. Three germanium resistors were used, one for each nylon string on which the cold measuring functions were located and one other in the liquid nitrogen reference bath. The first series of calibrations were made with a gold, 0.02% iron-chromel wire but had to be rejected because of the lack of repeatability due to temperature drift with time. This necessitated the complete re-wiring of the cryostat with a more stable wire containing a higher iron content; this wire is designated as gold, 0.07% iron and is manufactured by Sigmund Kohn Inc.

The second series of thermocouple calibrations was successfully accomplished and repeatability assured. The technique consisted in chilling the cryostate to liquid hydrogen temperatures first, after which the system was allowed to stabilize for about 24 hours until all germanium sensor readings indicated no temperature stratification throughout the medium; to accomplish this effect liquid hydrogen was allowed to bubble very slowly from the bottom up; once agreement of temperature and pressure was obtained with NBS's known standard thermodynamic charts for LH_2, liquid helium was introduced into the LHe heat exchanger and cool-down of the LH_2 bath was initiated; at NPT conditions the emf output of each T.C. was recorded and the corresponding temperature assigned to it. Cool down of the bath continued until triple point was obtained as confirmed by the temperature measurements of the resistors and the absolute pressure measurements of the Wallace-Tiernam pressure gages.
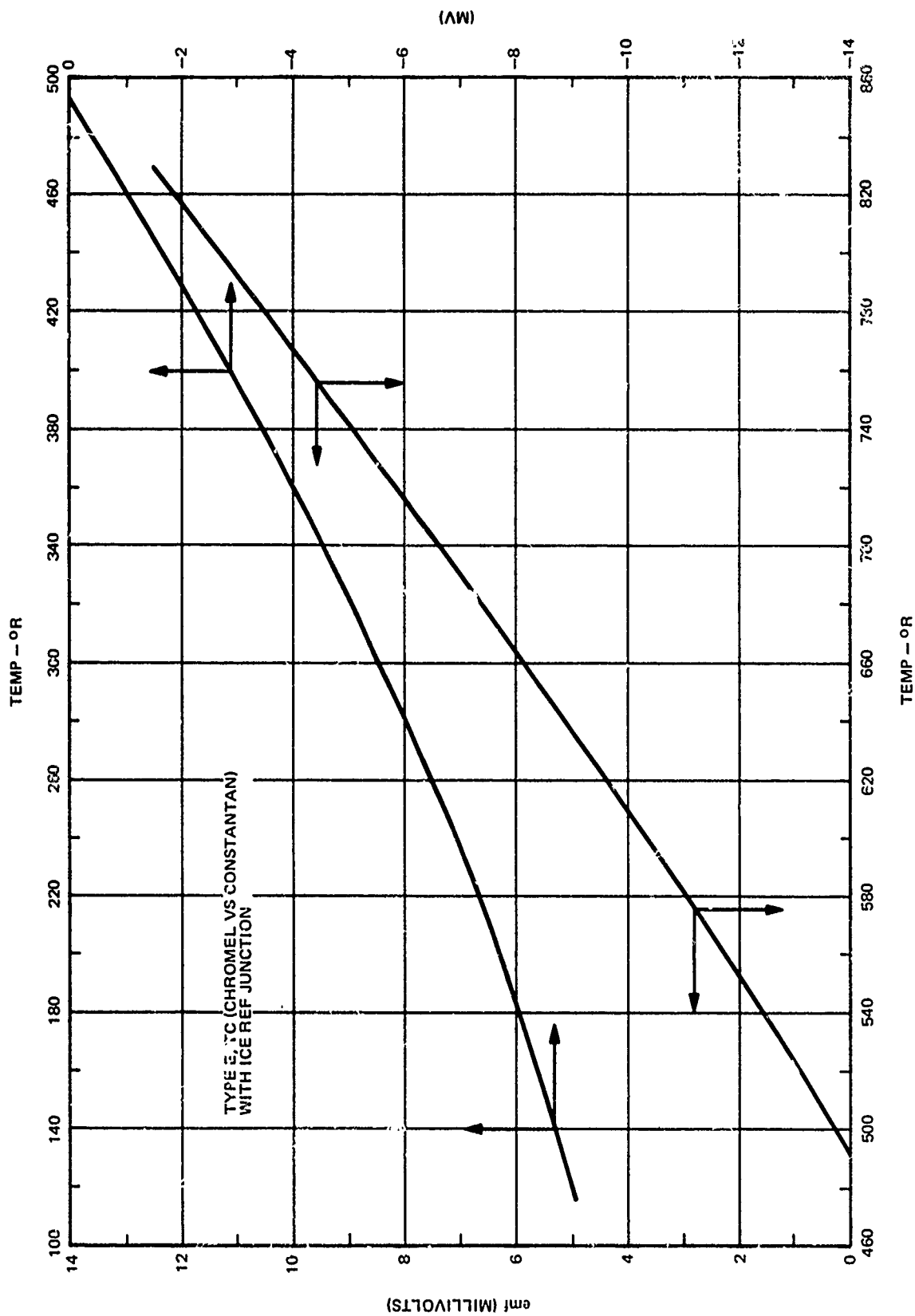
FIG. C-1 TYPE E THERMOCOUPLE CALIBRATION CURVE

C-2

Visual inspection also permitted confirmation of this temperature since the growth of the ice layer could be followed until it reached both the particular T.C. and germanium resistor, located symmetrically 180° apart from each other; to the corresponding measured emf of each T. C. the triple point temperature was assigned. The process was continued in a similar fashion as the solid was subcooled down to almost liquid helium temperatures. To help smoothing-out of the calibration curves, use was made of the NBS standard calibration curves as shown in Figure C-2. From this graph it can be seen that all T.C. curves differed from the NBS curves, and that only two of them had identical calibration curves. These curves were used in the actual data reduction of the thermophysical property experiments.

Flow measurements required calibration of flow meters, both for gaseous and liquid flow. Meters FM-1 and FM-3 are used for gas and FM-2 used for liquid. These meters manufactured by the Cox Instrument Company are of the turbine transducer type. The meters were originally calibrated by the vendor using air for the gas meters and water for the liquid meters. (See Figure (C-3 and C-4).

The calibration and temperature correction curves are given in Appendix (A). On the basis of these calibrations the experimental data was reduced and corrected for all runs. It was found from these measurements that the total mass of withdrawn liquid was in all cases smaller than the initial mass of solid by as much as 65% which led us to doubt the manufacturers calibration curves. As a consequence GAC recalibrated these meters using hydrogen fluid and a new curve was determined for FM-3 as shown in Figure C-4. The ensuing data reduction using the new calibration values showed the mass of liquid in all runs to be larger than the initial mass of solid, by the amount of heating gas condensed as should be expected.

To obtain the new calibration values, LH_2 was allowed into the inner dewar of the hydrogen cryostat; this dewar had been volume calibrated previously, permitting filling the dewar to a known volume. The final volume determination was made visually across the front and rear cryostat windows. Having fixed a known volume of LH_2 to be removed out of the cryostat, the LH_2 was pressurized slightly and transferred out via the flow meter to be calibrated. As the volume decreased differentially in the cryostat, time, cryostat volume change, and frequency output of the turbine meter were continuously recorded; from this information the new curve was obtained.

Calibration error is mostly attributed to the instrument error inherent in the pick-up and conditioning of the input signal generated by the measuring sensor.

For the temperature sensors, conditioning and recording instrumentation used as described in the data acquisition system section, a ± 8% error has been estimated; flow measurements on the other hand account for about ± 7% estimated error.

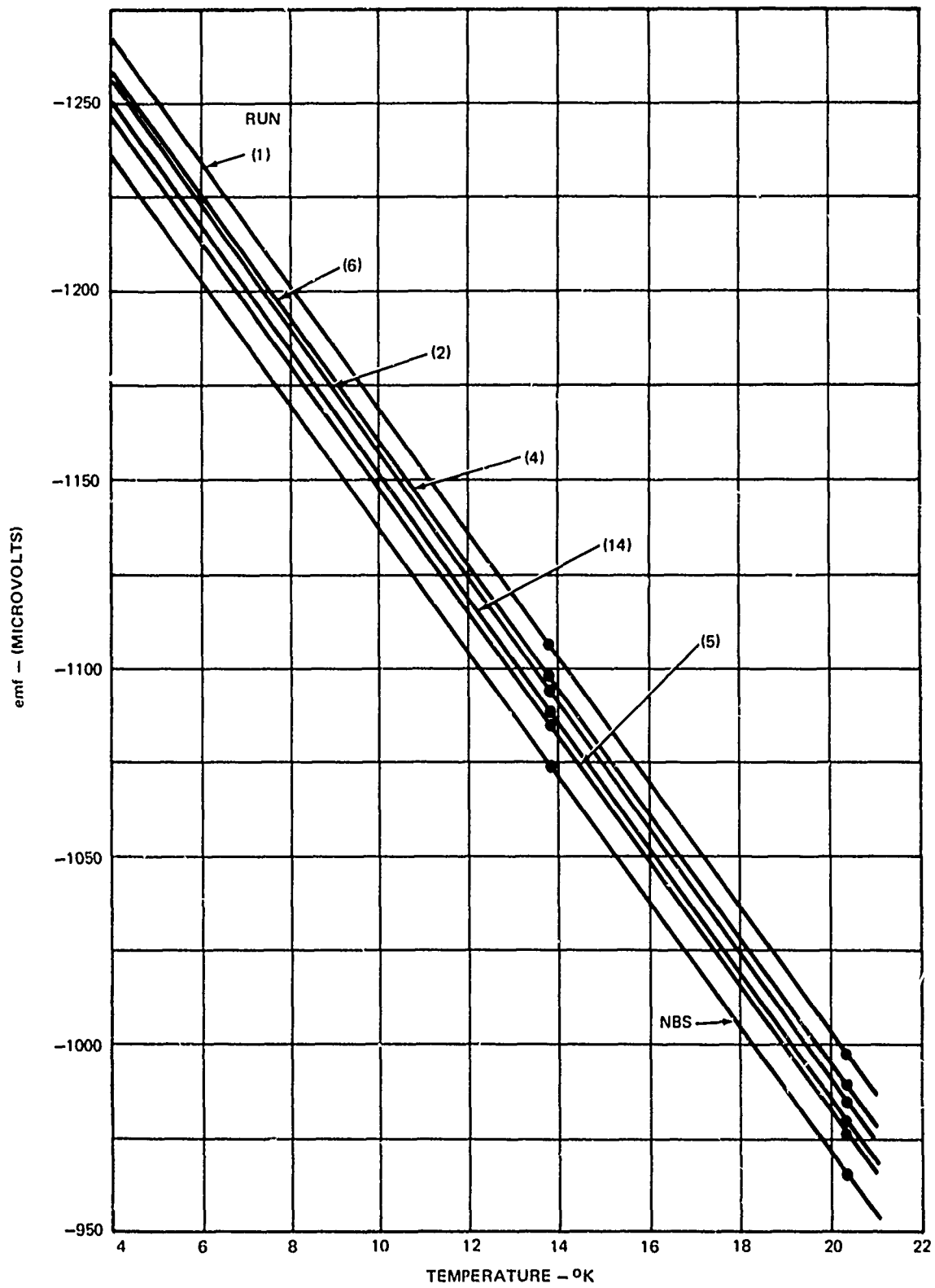FIG. C-2 GOLD, 0.07% IRON-CHROMEL CALIBRATION CURVE

COX INSTRUMENTS DIVISION
CALIBRATION CURVE
MODEL CRL-3 S/N 16763

NOTE: CALIBRATION MEDIUM
WAS AIR AT AMBIENT TEMP
AND A NOMINAL PRESSURE
OF 20 PSIA RANGE 2—10 ACFM

FM-1 (GAS)
$\left(\dfrac{f}{120} = Q_A \text{ACFM}\right)$

FM-2 (LIQUID)
$\left(\dfrac{f}{97} = Q_A \text{ACFM}\right)$

Q ACTUAL CUBIC FEET PER MIN. (ACFM)

F FREQUENCY (CYCLES PER SECOND)
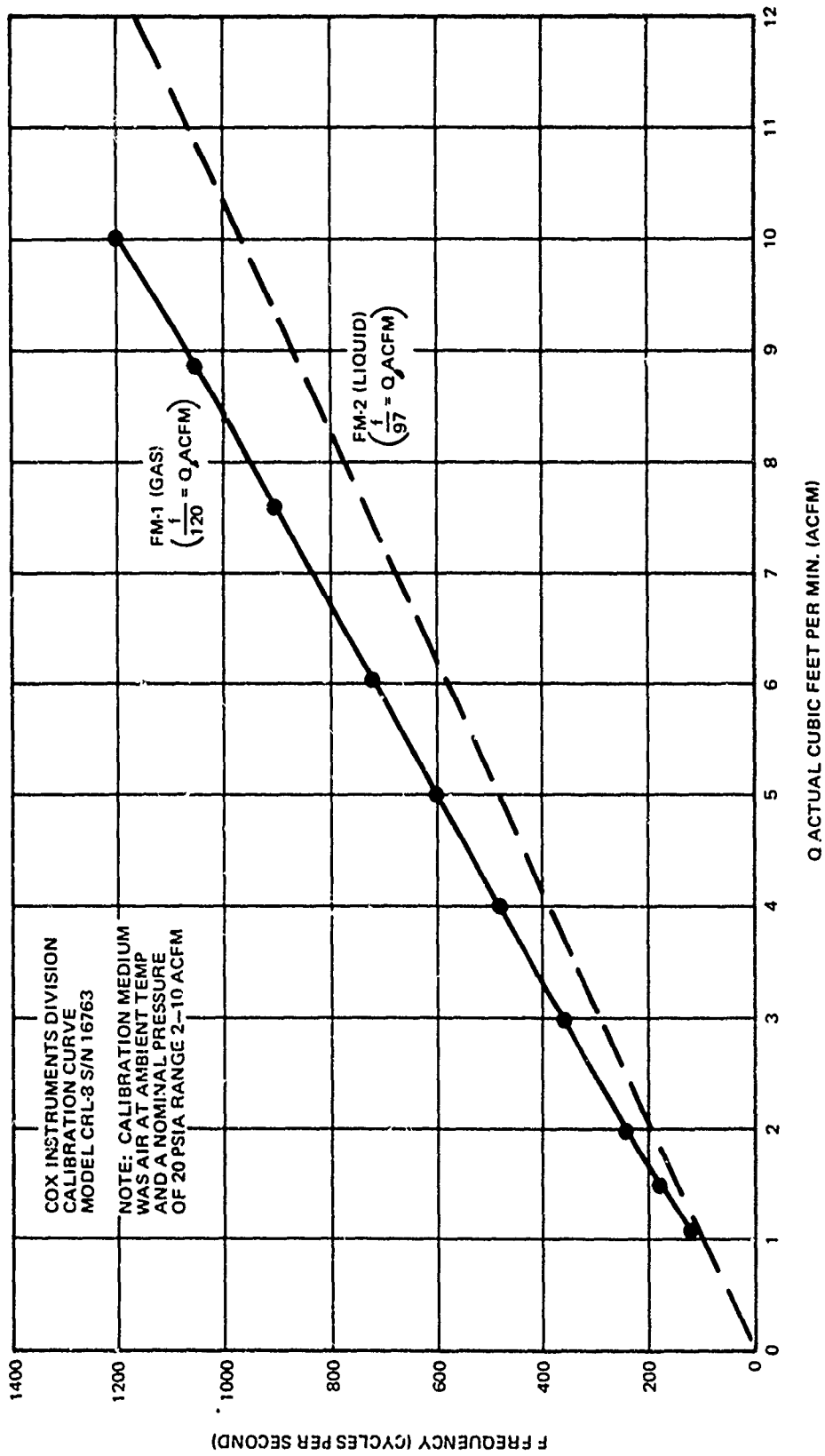
FIG. C-3 FM-1, FM-2 FLOWMETER CALIBRATION CURVE

C-5
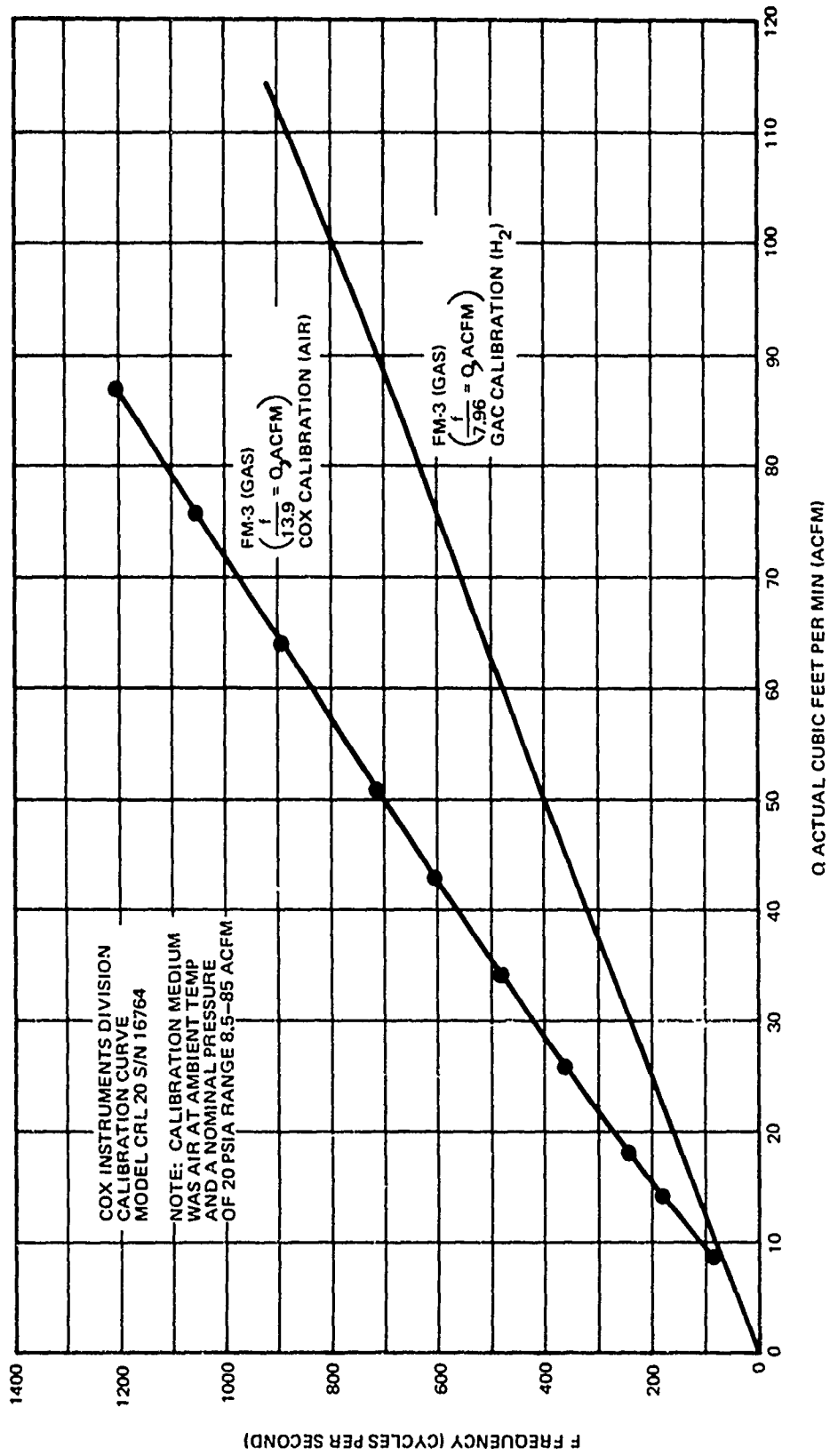
FIG. C-4 FM-3, FLOWMETER CALIBRATION CURVE

The figure contains the following labels:

COX INSTRUMENTS DIVISION
CALIBRATION CURVE
MODEL CRL 20 S/N 16764

NOTE: CALIBRATION MEDIUM
WAS AIR AT AMBIENT TEMP
AND A NOMINAL PRESSURE
OF 20 PSIA RANGE 8.5–85 ACFM

FM-3 (GAS)
$\left(\dfrac{f}{13.9} = Q_{ACFM}\right)$
COX CALIBRATION (AIR)

FM-3 (GAS)
$\left(\dfrac{f}{7.96} = Q_{ACFM}\right)$
GAC CALIBRATION (H_2)

Q ACTUAL CUBIC FEET PER MIN (ACFM)

F FREQUENCY (CYCLES PER SECOND)

APPENDIX (D)

ESTIMATE OF TOLERABLE TEMPERATURE MEASUREMENT ERROR

The strong temperature dependence of solid H_2 (SH_2) thermal diffusivity necessitates accurate knowledge of the temperature level at which it is being evaluated. Prior to initiating the thermophysical properties experiments it was essential that a relationship between temperature measurement errors and the resultant error in the deduced value of α be established. An accurate statement of this relationship requires accurate <u>a priori</u> knowledge of α as a function of temperature. However, existing data for thermophysical properties k, ρ and C_p permit determination of an estimate of this relationship.

Simple analytical expressions fitting the available data for k and the product ρC_p were established for $8°R < T < 24.8°R$. The resultant expression for α ($\alpha = k/\rho/C_p$) is

$$\alpha \approx 1.18 \times 10^{10} \, T^{-8.13} \, ft.^2/hr.$$

with T in degrees Rankine. Logarithmic differentiation then results in

$$\frac{d\alpha}{\alpha} = -8.13 \frac{dT}{T}$$

Thus a 1% change or uncertainty in temperature results in an 8% change or uncertainty in α. Rearranging the last equation one obtains,

$$\Delta T = -\frac{1}{8.13} \left(\frac{\Delta \alpha}{\alpha}\right) T$$

For a given percentage error in α, i.e., ($\Delta \alpha / \alpha$) x 100, a relationship between the allowable error in temperature measurement, ΔT, as a function of nominal temperature level, T can be established. Based on the above calculations, the graph, Figure D-1, shows that an error of 10% in α requires temperature measurement accuracy to within $\pm 0.1°R$ at $8°R$. At higher temperatures the requirement is not as stringent.
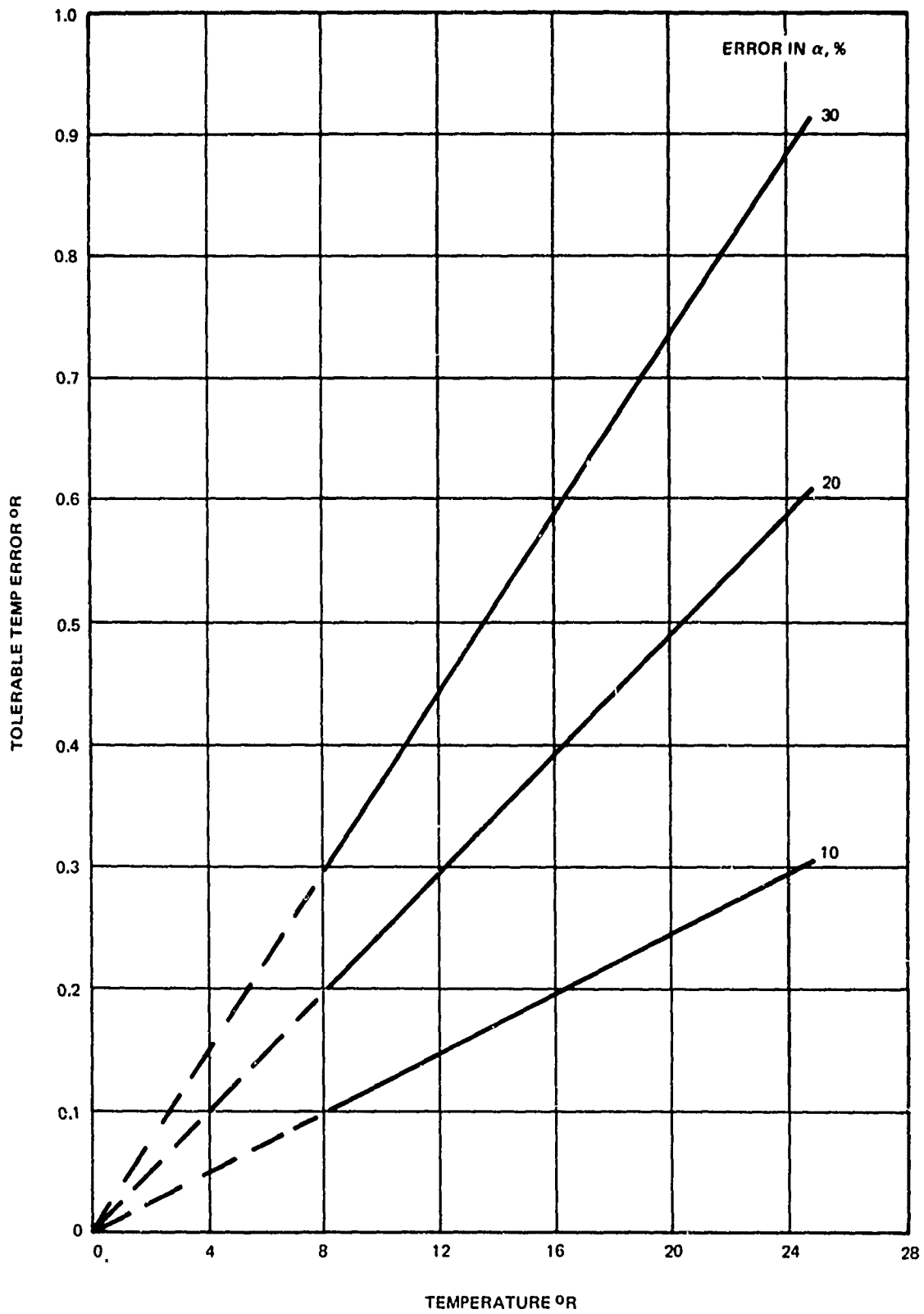
FIG. D-1 α SH$_2$ ERROR vs TOLERABLE TEMPERATURE ERROR

APPENDIX (E)

A NUMERICAL SCHEME FOR THE DIRECT DETERMINATION OF K(T)

The thermal conductivity of solid hydrogen, $K(T)$, appears as an unknown function in the heat equation which describes the transport of energy through the hollow cylindrical region in Figure A-3.

$$\rho(T) \, c \, (T) \, \frac{\partial T}{\partial t} = \nabla \cdot [K(T) \, \nabla T] \qquad (32)$$

Once the temperature $T(r,t)$ is determined for the solid region, equation (32) may be regarded as a single equation for $K(T)$. However, the temperature is actually measured only at a few positions and one therefore must resort to a discriticized form of (32) over an interior net corresponding to actual thermocouple positions. In this manner one obtains N equations for N values of $K(T_i)$ as a function of the T_i, i=1, 2, ..., N and the known functions $\rho(T_i) \, c^1(T_i)$.

The apparently severe restriction due to the instrumentation at relatively few interior position may be alleviated through the use of an approximating function, which would permit interpolation and extrapolation at arbitrary interior points. In this form the resulting equation system is actually an inverse finite difference approximation for the "coefficient" $K(T)$.

Formal justification of the method may be given by requiring that the difference between the experimentally measured temperatures $\Theta(r,t)$ and the temperatures appearing in the heat equation (32) be as small as possible, i.e.,

$$I(K) = \int_{0}^{t} \int_{R_1}^{R_2} [\Theta(r,t) - T(r,t; K(T))] \, dr \, dt \Rightarrow \quad (33)$$
$$\text{minimum}$$

Condition (33) is satisfied if the measured temperatures $\Theta(r,t)$ are inserted into a discriticized form of (32) to obtain an equation system for $K(T_i)$ over each discriticized time increment.

From the heat equation in cylindical coordinates we have

$$\rho c \, \frac{\partial T}{\partial t} (r,t) = \frac{1}{r} \, \frac{\partial}{\partial r} \left[r \, k(T) \, \frac{\partial T}{\partial r} \right] \qquad (34)$$

or by substituting

$$r = (\tilde{r} + \delta) \, b \, ; \quad \tau = \frac{t}{b^2}$$
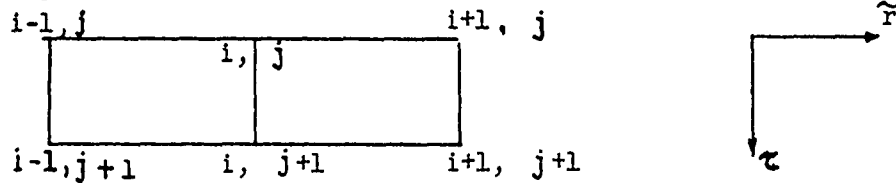
where

$$b = r_2 - r_1 : \quad \delta = \frac{r_1}{b} \, ; \quad \tilde{r} = \frac{r - r_1}{b}$$

we obtain

$$\rho(T)\,c\,(T)\,\frac{\partial T}{\partial \tau}(\tilde{r},\tau) = \frac{1}{(\tilde{r}+\delta)}\frac{\partial}{\partial \tilde{r}}\left[\,(\tilde{r}+\delta)\,K(T)\,\frac{\partial T}{\partial \tilde{r}}\right] \quad (35)$$

or over the grid shown below

thus $T = T(i,\gamma)$

$$\rho(T_i^{j+\frac{1}{2}})\quad C(T_i^{j+\frac{1}{2}})\quad\left(\frac{T_i^{j+1}-T_i^{j}}{\Delta\tau}\right)=$$

$$\frac{1}{(\tilde{r}_i+\delta)\,\Delta\tilde{r}}\left\{(\tilde{r}_{i+\frac{1}{2}}+\delta)\,K_{i+\frac{1}{2}}^{j+\frac{1}{2}}\,\frac{1}{2\Delta\tilde{r}}\left[(T_{i+1}-T_i)^{j+1}+(T_{i+1}-T_i)^{j}\right]\right.$$

$$\left.-(\tilde{r}_{i-\frac{1}{2}}+\delta)\,K_{i-\frac{1}{2}}^{j+\frac{1}{2}}\,\frac{1}{2\Delta\tilde{r}}\left[(T_i-T_{i-1})^{j+1}+(T_i-T_{i-1})^{j}\right]\right\} \quad (36)$$

rearranging the above

$$\rho(T_i^{j+\frac{1}{2}})\,C(T_i^{j+\frac{1}{2}})\,\frac{(T_i^{j+1}-T_i^{j})}{\left(\frac{\Delta\tau}{2\Delta\tilde{r}^2}\right)}=K_{i+\frac{1}{2}}^{j+\frac{1}{2}}\,A-K_{i-\frac{1}{2}}^{j+\frac{1}{2}}\,B \quad (37)$$

where

$$A=\frac{(\tilde{r}_{i+\frac{1}{2}}+\delta)}{(\tilde{r}_i+\delta)}\left[(T_{i+1}-T_i)^{j+1}+(T_{i+1}-T_i)^{j}\right]$$

$$=\frac{(\tilde{r}_i+\delta+\frac{\Delta\tilde{r}}{2})}{(\tilde{r}_i+\delta)}\left[(T_{i+1}-T_i)^{j+1}+(T_{i+1}-T_i)^{j}\right]$$

$$B=\frac{(\tilde{r}_i+\delta-\frac{\Delta\tilde{r}}{2})}{(\tilde{r}_i+\delta)}\left[(T_i-T_{i-1})^{j+1}+(T_i-T_{i-1})^{j}\right]$$

for

$$i = 3, \ldots N-1$$

$$j = 1, 2, \ldots$$

$$\Delta\tilde{r}=\frac{1}{N}$$

Second order interpolation is given by

$$K_{i+\frac{1}{2}}^{j+\frac{1}{2}} = \frac{1}{2} \left(K_{i+1}^{j+\frac{1}{2}} + K_i^{j+\frac{1}{2}} \right) \tag{38}$$

$$K_{i-\frac{1}{2}}^{j+\frac{1}{2}} = \frac{1}{2} \left(K_i^{j+\frac{1}{2}} + K_{i-1}^{j+\frac{1}{2}} \right) \tag{39}$$

then

$$4 \, (\Delta \tilde{r})^2 \, \rho \, (T_i^{j+\frac{1}{2}}) \, c \, (T_i^{j+\frac{1}{2}}) \, \frac{(T_i^{j+1} + T_i^{j})}{\Delta \tau}$$

$$= K_{i+1}^{j+\frac{1}{2}} \, A + K_i^{j+\frac{1}{2}} \, (A - B) - K_{i-1}^{j+\frac{1}{2}} \, B \qquad i = 3, \ldots N-1 \tag{40}$$

$$J = 1, 2,$$

Second order extrapolation for the points at $i = 2$, $i = N$ is given by

$$K_{2-\frac{1}{2}}^{j+\frac{1}{2}} = \frac{3}{2} \, K_2^{j+\frac{1}{2}} - \frac{1}{2} K_3^{j+\frac{1}{2}} \tag{41}$$

$$K_{2+\frac{1}{2}}^{j+\frac{1}{2}} = \frac{1}{2} \left(K_3^{j+\frac{1}{2}} + K_2^{j+\frac{1}{2}} \right)$$

and

$$K_{N+\frac{1}{2}}^{j+\frac{1}{2}} = \frac{3}{2} \, K_N^{j+\frac{1}{2}} - \frac{1}{2} K_{N-1}^{j+\frac{1}{2}} \tag{42}$$

$$K_{N-\frac{1}{2}}^{j+\frac{1}{2}} = \frac{1}{2} \left(K_N^{j+\frac{1}{2}} + K_{N-1}^{j+\frac{1}{2}} \right)$$

Finally one obtains an $(N-1) \times (N-1)$ system of equations for the N unknown conductivities $K_i^{j+\frac{1}{2}}$

$$\rho(T_2^{j+\frac{1}{2}}) \, c \, (T_2^{j+\frac{1}{2}}) \, \frac{(T_2^{j+\frac{1}{2}} - T_2^{j})}{\frac{(\Delta \tau)}{(2 \Delta \tilde{r}^2)}} = K_2^{j+\frac{1}{2}} \left(\frac{A}{2} - \frac{3}{2} B \right) + K_3^{j+\frac{1}{2}} \left(\frac{A}{2} + \frac{B}{2} \right) \qquad i=2 \tag{43}$$

$$\rho(T_i^{j+\frac{1}{2}}) \, C(T_i^{j+\frac{1}{2}}) \, \frac{(T_i^{j+\frac{1}{2}} - T_i^{j})}{\left(\dfrac{\Delta\tau}{2\,\Delta\tilde{r}^2}\right)} = K_{i+1}^{j+\frac{1}{2}}\left(\frac{A}{2}\right) + K_i^{j+\frac{1}{2}}\left(\frac{A}{2} - \frac{B}{2}\right) \tag{44}$$
$$- K_{i-1}^{j+\frac{1}{2}}\left(\frac{B}{2}\right)$$
$$2 < i < N$$

$$\rho(T_N^{j+\frac{1}{2}}) \, C(T_N^{j+\frac{1}{2}}) \, \frac{(T_N^{j+\frac{1}{2}} - T_N^{j})}{\left(\dfrac{\Delta\tau}{2\,\Delta\tilde{r}^2}\right)} = K_N^{j+\frac{1}{2}}\left(\frac{3A}{2} - \frac{B}{2}\right) - K_{N-1}^{j+\frac{1}{2}}\left(\frac{A}{2} + \frac{B}{2}\right) \tag{45}$$
$$i = N$$

The system of equations is tri-diagonal and appears in the form

$$
\begin{bmatrix}
a_1 & c_1 & & & & \\
b_2 & a_2 & c_2 & & & \\
& & b_i & a_i & c_i & \\
& & & b_{m-1} & a_{m-1} & c_{m-1} \\
& & & & b_m & a_m
\end{bmatrix}
\begin{bmatrix}
k_1 \\ k_2 \\ k_i \\ k_{m-1} \\ k_m
\end{bmatrix}
=
\begin{bmatrix}
f_1 \\ f_2 \\ f_i \\ f_{m-1} \\ f_m
\end{bmatrix}
\tag{46}
$$

The solution may be obtained directly after a factorization of the co-efficient matrix given by,

$$
\begin{bmatrix}
a_1 & c_1 & & & \\
b_2 & a_2 & c_2 & & \\
& & b_i & a_i & c_i \\
& & & & b_m & a_m
\end{bmatrix}
\begin{bmatrix}
K_1 \\ K_2 \\ K_i \\ K_m
\end{bmatrix}
=
\begin{bmatrix}
e_1 & & & \\
b_2 & e_2 & & \\
& & b_i & e_i & \\
& & & & b_m & e_m
\end{bmatrix}
\begin{bmatrix}
1 & d_1 & & \\
& 1 & d_2 & \\
& & 1 & d_i \\
& & & & 1
\end{bmatrix}
\begin{bmatrix}
K_1 \\ K_2 \\ K_i \\ K_m
\end{bmatrix}
=
\begin{bmatrix}
e_1 & & & \\
b_2 & e_2 & & \\
& & b_i & e_i & \\
& & & & b_m & e_m
\end{bmatrix}
\begin{bmatrix}
g_1 \\ g_2 \\ g_i \\ g_m
\end{bmatrix}
\tag{47}
$$

The solution is the obtained using the formulas,

$$e_1 = a_1 \quad , \quad d_1 = c_1/e_1 \quad , \quad g_1 = f_1/e_1$$
$$\left.
\begin{aligned}
e_i &= a_i - b_i d_{i-1} \\
d_i &= c_i/e_i \\
g_i &= (f_i - b_i g_{i-1})/e_i
\end{aligned}
\right\} \quad i = 2, 3, \ldots m \tag{48}$$
$$k_m = g_m$$
$$K_i = g_i - d_i K_{i+1} \quad \cdots \quad i = m-1, \ldots 2, 1$$