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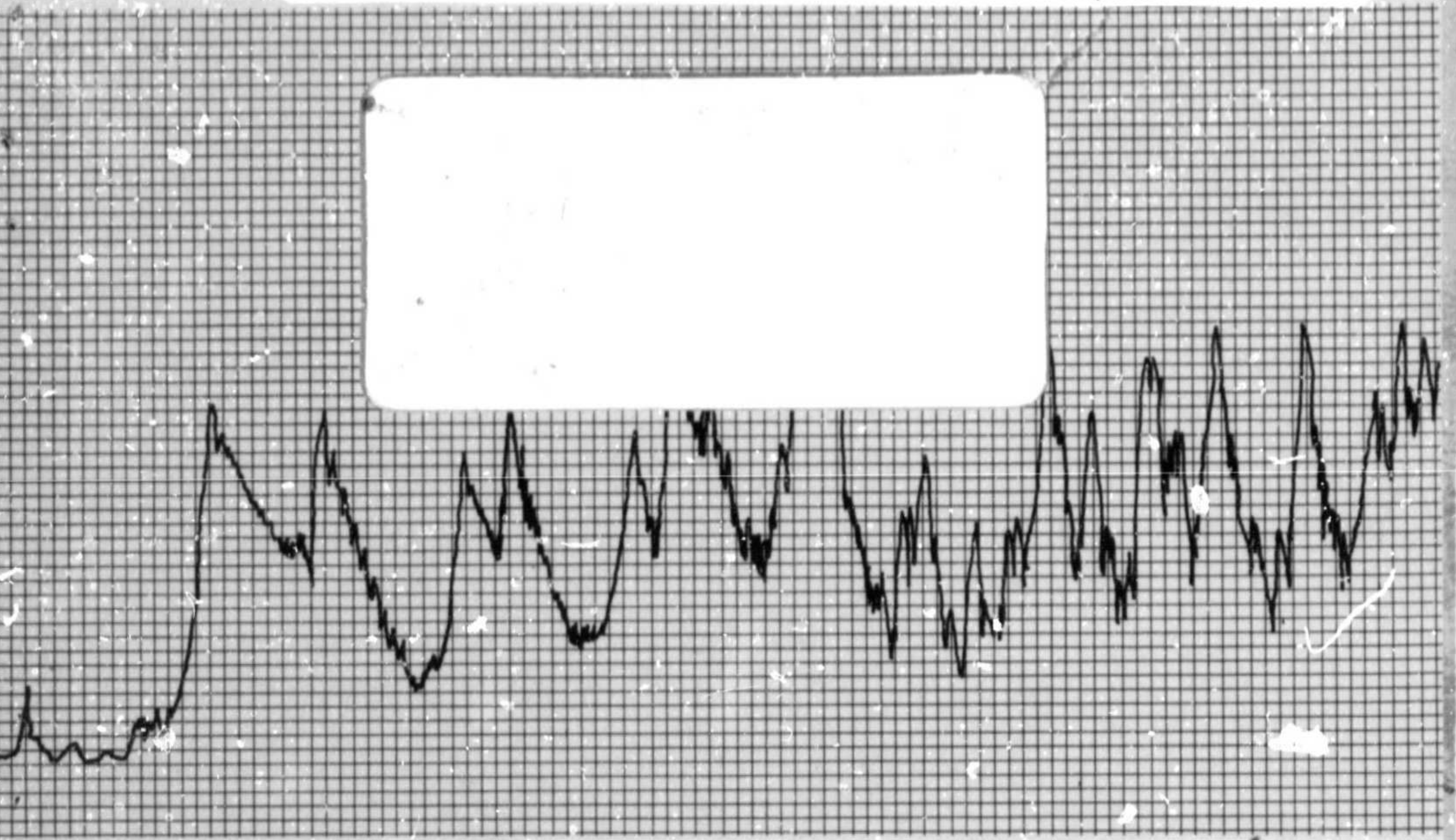

engineering REPORT

CONCEPT DEVELOPMENT EVALUATION FOR JOHN DEERE/UA STS MIDDECK EXPERIMENT LOCATION

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FOREWORD

The material presented in this report was compiled by Wyle Laboratories for the Program Development Office of the NASA Marshall Space Flight Center under Contract Number NAS8-35615. The NASA/MSFC contracting officer's technical representative for this effort was Mr. James Fountain, NASA/PD.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES

LIST OF TABLES

CONCEPT DEVELOPMENT EVALUATION FOR JOHN DEERE/UA STS MIDDECK EXPERIMENT LOCATION

1.0 SUMMARY

The purpose of this effort was to consider and evaluate some specific concepts for performing a number of extremely low gravity (i.e., microgravity) experiments involving the directional solidification of samples of high carbon, cast iron alloys. The specific experiments considered herein are those proposed by the John Deere Company and the University of Alabama (John Deere/UA) and were conceived to permit scientific investigation of the resultant microstructures and mechanical properties of the test samples after the microgravity environment processing.

This study was limited to consideration of the NASA/MSFC furnace payloads, referred to herein as the Automated Directional Solidification Furnace (ADSF) systems, for performance of the John Deere/UA experiments. Three ADSF systems were reviewed and are as follows:

1. Low-temperature ADSF (ADSF-I)
2. High-temperature ADSF (ADSF-II)
3. Advanced ADSF (AADSF)

Table 1 provides a quick-look summary of some of the features and operating characteristics of these furnaces.

Experiment location concepts were further limited to the NASA Space Transportation System (STS) orbiter middeck and cargo bay locations. Further, emphasis has been placed on consideration of the orbiter middeck for the John Deere/UA experiments for reasons outlined by Ponce and Thoeny (March 1984) in a recent Rockwell International study. According to Ponce and Thoeny, the STS orbiter middeck offers unique attributes, as listed on page 3.

TABLE 1. QUICK-LOOK FURNACE (ADSF) COMPARISONS

	ADSF-I (F. Reeves, May 1984)	ADSF-II (General Electric Co., June 1984)	AADSF (NASA/MSFC, December 1983)
STS Configured Location	Orbiter Middeck	Orbiter Cargo Bay	Orbiter Cargo Bay
Current Status (Oct. 1984)	In Flight Qual. at NASA/MSFC	Under Development at NASA/MSFC	Prototype Only
Maximum Temperature & Temperature Gradient	≤500°C, ~250°C/cm (F. Reeves, October 1984)	1600°C, ~470°C/cm (F. Reeves, May 1984)	1400°C, ~900°C/cm
Specimens Per Flight	1-4	1-4	1-2
Furnace Bore Diam. (ID)	~1.0 cm (F. Reeves, October 1984)	~0.8 cm (Grumman Aerospace Corp., June 1984)	Not Stated
Allowable Crucible Diam. (OD)	~0.6 cm	~0.6 cm	2.0 cm +
Maximum Sample Diam. (OD)	~0.4 cm	~0.4 cm	0.8 cm +
Overall Crucible Length	~35 cm	~35 cm	~20-25 cm
Furnace Translation Rate	7.5 to 120mm/h	0.1 to 500mm/h	0.4 to 50mm/h
Peak System Power (@ 28V D.C.)	~110 watts	~394 watts	< 500 watts
External Cooling Loop: - Flow Rate (Freon) - Inlet Temperature	 N/A N/A	 380 to 420 lbm/h 34°F to 67°F	 TBD TBD
Operating Atmosphere	GN_2 backfill with about 200 ppm H_2O	GN_2 backfill with about 200 ppm H_2O	Vacuum, Inert Gas

- "A benign man-rated environment for experiments and experimentation
- A man/experiment interface that allows interaction between man and certain types of experiments to increase the potential for successful experiment operation and desired results.
- Frequent flight and reflight opportunities for experimenters
- Late experiment entry/interface shortly before launch
- Early egress after landing."

The study documented herein may be summarized by the following overall conclusions:

1. The proposed John Deere/UA experiment is quite demanding in terms of the number of samples desired, sample size ($\geq$ 0.5 cm), and temperature (1500 - 1550°C).
2. None of the NASA/MSFC ADSF systems are fully adequate to perform the proposed John Deere/UA experiments.
3. The high-temperature ADSF (ADSF-II) would be marginally acceptable for processing the small diameter microstructure samples, but limited to 4 samples per flight.
4. Modification of the existing NASA/MSFC ADSF payloads (i.e., the ADSF-I and ADSF-II) would be extensive to permit sample exchange, furnace restart, and data storage. Further, the low-temperature ADSF (ADSF-I) is limited to $\leq$ 500°C.
5. Modification of the prototype Advanced ADSF (AADSF) to permit sample exchange and middeck location would also be extensive and the sophistication of the AADSF in terms of its extremely high temperature gradient is unwarranted for the John Deere/UA experiments.
6. Development of a new ADSF (referred to as ADSF-III herein) for the John Deere/UA experiments may be the most efficient means for performing all of the desired microstructural and mechanical property evaluations. The features of such a furnace are outlined herein.

The remainder of this report documents Wyle Laboratories' effort through October 1984 under several task headings. Section 2.0 describes the results of Task 1 which was to gather, assess, and document the scientific objectives and experiment requirements for the John Deere/UA proposed experiment. Section 3.0 includes the results of Task 1A which was to gather and summarize information on candidate ADSF payloads. Section 4.0 documents the results of Task 2 which was to compare the John Deere/UA experiment requirements versus candidate ADSF payloads including candidate STS orbiter experiment locations. Section 5.0 provides a discussion of the results of Task 3 which included consideration of modifications to existing ADSF systems and the proposed construction of a new ADSF (ADSF-III) specifically for the John Deere/UA experiments. Finally, Section 6.0 lists all references cited throughout the effort.

2.0 TASK 1. GATHER, ASSESS, AND DOCUMENT REQUIREMENTS FOR JOHN DEERE EXPERIMENT

The purpose of this task was to assimilate and evaluate requirements relevant to a proposed John Deere Company study for low gravity processing of iron-carbon alloys of the cast iron type. Throughout this report, the John Deere experiment's scientific requirements have been summarized from information provided by Dr. P.A. Curreri (NASA/MSFC Space Sciences Laboratory). Dr. Curreri is the NASA science advisor for the John Deere experiment.

2.1 SCIENTIFIC OBJECTIVES

The overall scientific objectives of the John Deere experiment are to investigate the microstructure and mechanical properties of high carbon iron (cast iron) alloys that result when solidified in a low-gravity environment. The elimination of convection and flotation during processing of the alloys in a low-gravity environment should produce new and interesting materials having structures and properties difficult to produce in ground-based experiments. Background information on the scientific aspects of low-gravity processing of cast iron, especially the directional solidification of high carbon iron alloys, may be found in a number of references (e.g., P.A. Curreri et al., April 1983).

A list of prioritized scientific objectives was documented in a preliminary proposal to NASA entitled "Low Gravity Processing of Iron-Carbon Alloys of the Cast Iron Type" (D.M. Stefanescu, April 1984). From this proposal prepared by Dr. Stefanescu (Note 1), Dr. Curreri selected several experiments and divided them into two separate phases, with experiments of varying priorities proposed for each phase. These proposed experiments are summarized in Tables 2 and 3.

NOTE 1 - Dr. Stefanescu is a consultant for the John Deere Company and is associated with the University of Alabama.

TABLE 2. PHASE I – EXPERIMENTS TO INVESTIGATE MICROSTRUCTURE OF HIGH CARBON IRON ALLOYS PROCESSED IN LOW-G ENVIRONMENT

PRIORITY	EXPERIMENT	NUMBER OF SAMPLES DESIRED
First	High Carbon – "Directional Property" Iron	2–4
Second	High Carbon – Spheroidal	2–4
Third	Eutectic Cell Size Study	2–4

NOTES: The Phase I experiments are proposed based on the use of "existing" high temperature directional solidification furnace technology (i.e., ADSF at 1500–1550°C).

TABLE 3. PHASE II - EXPERIMENTS TO INVESTIGATE THE MECHANICAL PROPERTIES OF HIGH CARBON IRON ALLOYS PROCESSED IN LOW-G ENVIRONMENT

PRIORITY	EXPERIMENT	NUMBER OF SAMPLES DESIRED
	Mechanical Property Investigation of the Following Irons:	
First	- High Carbon - "Directional Property" Iron	15-45
Second	- High Carbon - Spheroidal Iron	15-45
Third	- Dendritic Cast Iron	15-45

NOTES: The Phase II experiments would also use a high temperature (1500 - 1550°C) directional solidification furnace, but would require the capability for sample exchange due to the large number of samples desired.

2.0 EXPERIMENT REQUIREMENTS

Attainment of the John Deere/UA experiment scientific objectives described herein can be met only through the processing of a sufficient number of samples through an experimental apparatus capable of providing adequate test conditions and data output. The performance and instrumentation requirements are currently being established. A preliminary summary of these requirements as outlined by Dr. Curreri (P.A. Curreri, June - September, 1984) are presented in Tables 4 and 5. Figures 1, 2 and 3, respectively, show the nominally desired temperature versus time, temperature gradient, and sample configuration for the John Deere/UA experiments.

TABLE 4. PERFORMANCE REQUIREMENTS – FURNACE TO PROCESS JOHN DEERE EXPERIMENTS (P.A. CURRERI, JUNE – SEPTEMBER 1984)

	PHASE I & II EXPERIMENTS (NOTE 1)
Performance Requirement:	
Samples processed per flight	Multiple (Note 1)
Gravitational level	<<0.01g
Furnace temperature	1500 – 1500°C (Fig. 1)
Quench block temperature	~15 – 50°C (Fig. 1)
Temperature gradient	200 – 400°C/cm (Fig. 2)
Time vs. temperature	Figure 1
Total run time per sample	~11 – 15 hours (max.)
Translation rate	0.1 mm/min → 1 cm/min (Note 4)
Crucible atmosphere	Argon (pressurized) (Note 5)
Sample diameter (Note 3)	0.5 – 1.0 cm (larger sizes for Phase II)
Sample length (Note 3)	$\geq$ 4 cm (Note 2)
Sample material (Note 3)	Fe/C alloy (P, Mn, Si, etc.)
Crucible material (Note 3)	$Al_2 0_3$ (Alumina)
Crucible diameter (OD)	1.0 – 1.2 cm
Furnace bore diameter (ID)	1.3 – 1.5 cm

NOTE 1 – Experiments outlined in Tables 2 and 3.

NOTE 2 – The sample length is that portion which is directionally solidified. The Phase II samples are desired to be ≥ 6 cm.

NOTE 3 – A preferred sample configuration is shown in Figure 3.

NOTE 4 – Approximately 10 percent of the samples are desired to be processed at a translation rate of 0.1 mm/min. The majority of samples (90 percent) would be processed at a translation rate of 1-2 mm/min.

TABLE 5. INSTRUMENTATION REQUIREMENTS – FURNACE TO PROCESS JOHN DEERE EXPERIMENTS (P.A. CURRERI, JUNE – SEPTEMBER, 1984)

	PHASE I EXPERIMENTS (NOTE 1)	PHASE II EXPERIMENTS (NOTE 1)
Instrumentation Requirement:		
Accelerometers	3 axis	3 axis
Sample thermocouples (Note 2)	2–4	2–4
Furnace thermocouples (Note 2)	2	2
Quench block thermocouples (Note 2)	2	2
Furnace position indicator (Note 2)	TBD	TBD
Data sample rate	10 times/s	10 times/s

NOTE 1 – Experiments outlined in Tables 2 and 3.

NOTE 2 – Number of sensors and indicators for each furnace.

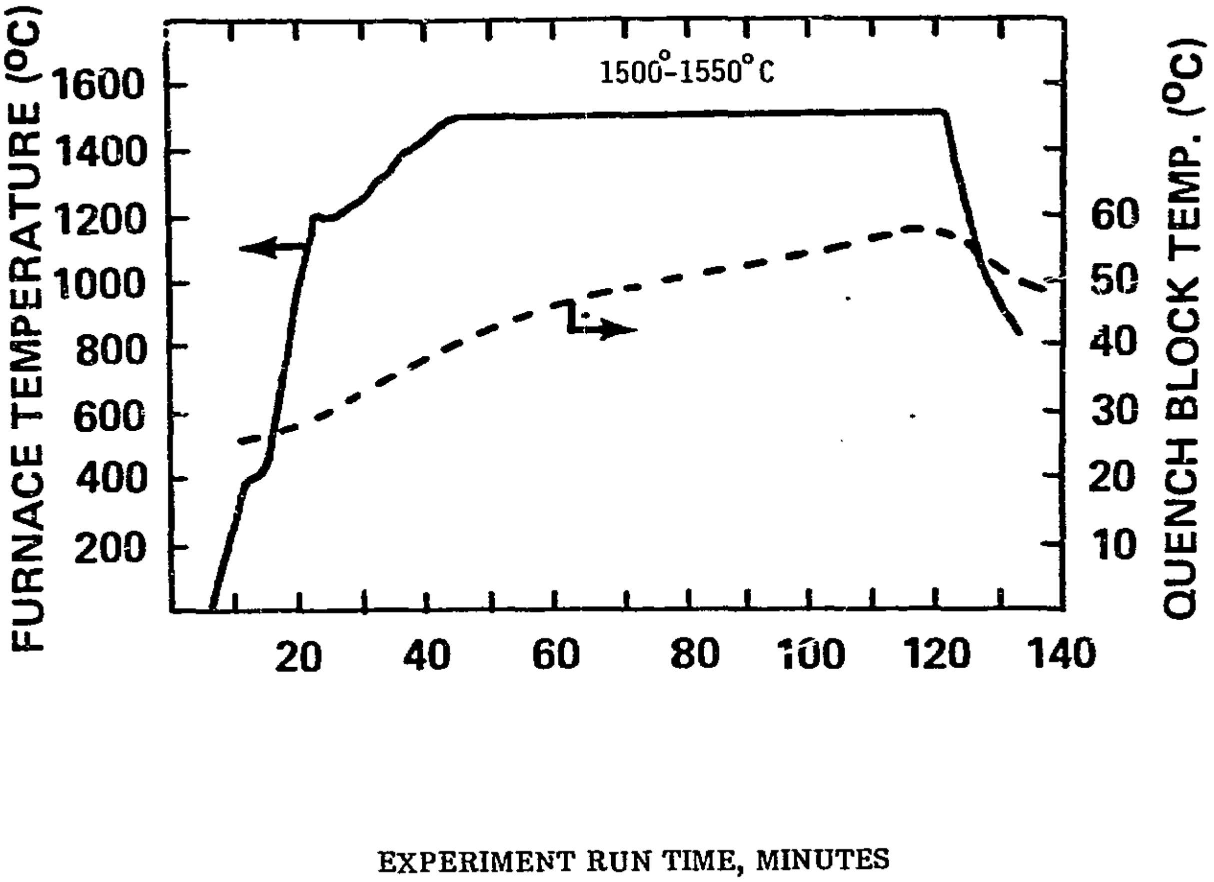


FIGURE 1. TIME VS. TEMPERATURE REQUIREMENT (P.A. CURRERI ET AL., APRIL 1983)

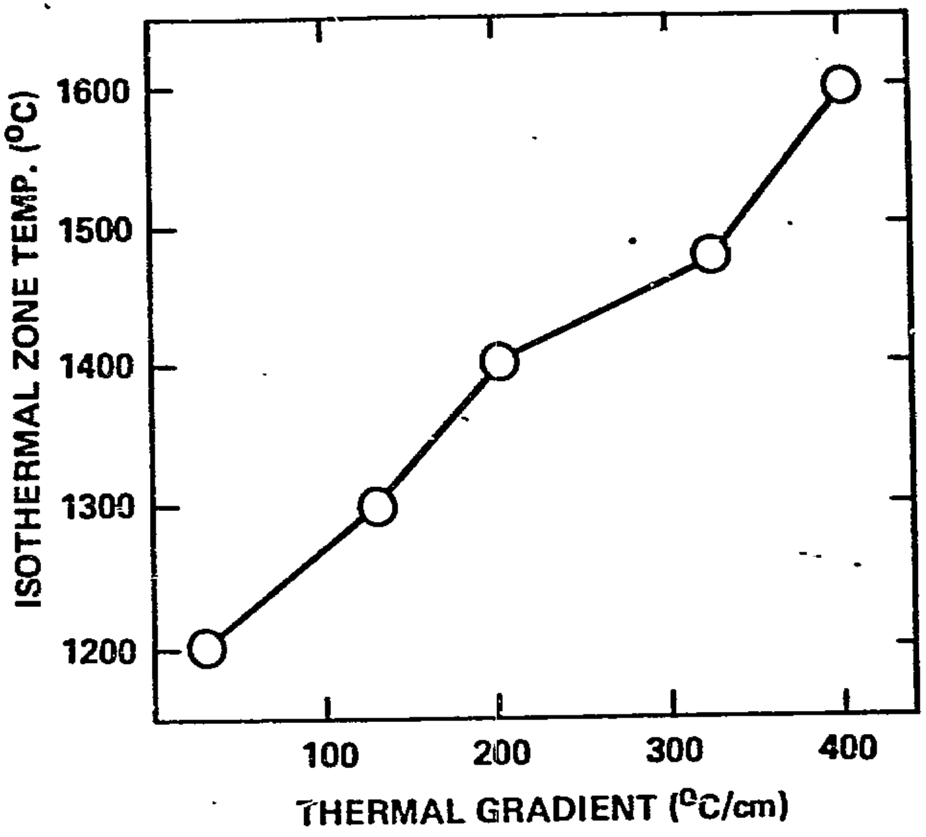
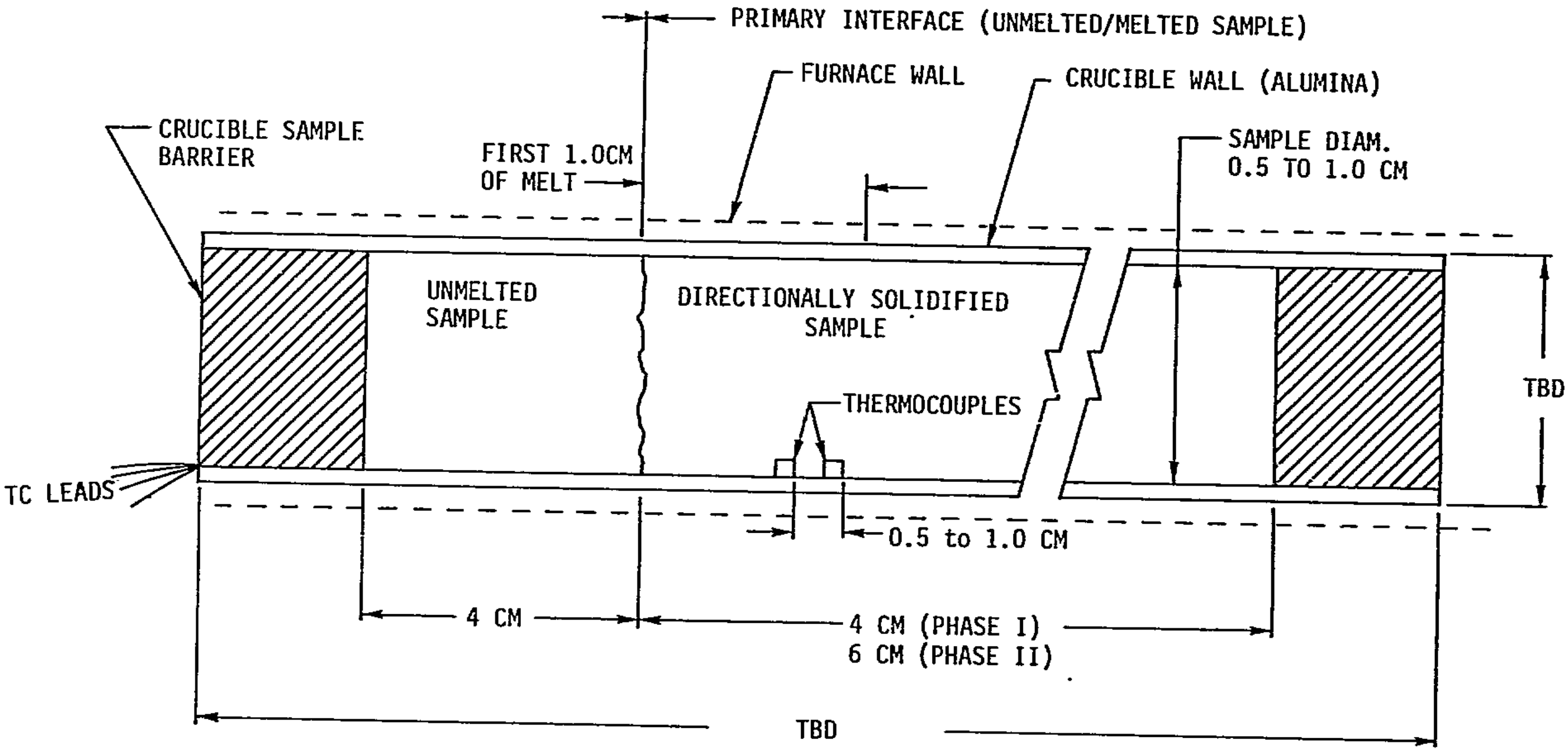


FIGURE 2. THERMAL GRADIENT VERSUS FURNACE TEMPERATURE
(P.A. CURRERI ET AL, APRIL 1983)
(FOR CONDITION OF TEMPERATURE BETWEEN 1120° AND 1180°C IN AN EMPTY CRUCIBLE)



NOT TO SCALE

NOTE: AN INERT GAS (E.G., ARGON) IS DESIRED FOR SURROUNDING THE CRUCIBLE

FROM: P. CURRERI
7/3/84

FIG. 3. PREFERRED SAMPLE CONFIGURATION - JOHN DEERE EXPERIMENTS

3.0 TASK 1A. GATHER AND SUMMARIZE INFORMATION ON APPLICABLE FURNACE PAYLOADS

The purpose of this task was to assimilate and briefly summarize the available information on payloads (furnaces) applicable to the John Deere/UA experiment described in Task 1 (Section 2.0) and outlined in Table 4. The type of furnace needed to meet the performance requirements is commonly referred to as a "directional solidification furnace". A number of such furnaces have been constructed (or proposed) and the NASA/MSFC version of these furnaces will be briefly described here. Included are the following:

- Low temperature ADSF (ADSF-I, Automated Directional Solidification Furnace)
- High Temperature ADSF (ADSF-II)
- Advanced ADSF (i.e., AADSF)

A summary of some relevant information and the status of these furnaces is provided by Table 1, page 2, and Table 6 on the following page.

3.1 LOW TEMPERATURE ADSF (ADSF-I)

Documentation has been reviewed relative to the General Electric Company low temperature automated directional solidification furnace (ADSF-I). This documentation includes a General Electric Operation and Maintenance Manual for the ADSF-I (General Electric Company, April 1984) and a NASA/MSFC technical overview for use of the ADSF-I in the space transportation system (STS) middeck processing of aligned magnetic composites (Bi/MnBi) experiment (F. Reeves, May 1984). A summary overview of the ADSF-I is presented in Table 7.

The General Electric Company prepared a detailed O & M Manual (General Electric Company, April 1984) for the Automated Directional Solidification Furnace, designated ADSF-I for STS Orbiter middeck applications. Although the maximum furnace temperature for the ADSF-I was not clearly stated in this O & M Manual, the coolant loop (50 - 50 water - glycol) is self-contained within the Furnace EAC (Figure 4). Further, it was stated that the equipment was designed such that "...one furnace

TABLE 6. CURRENT STATUS OF VIABLE NASA/MSFC ADSF SYSTEMS

FURNACE/DEVELOPER/NASA CONTACT	FURNACE FEATURES	EXPERIMENT/STS FLIGHT SCHEDULE	STATUS
ADSF-I/GE (Note 1)/Fred Reeves (MSFC)	● Lo-Temp. ($\leq 500^{\circ}C$) ● Cooling is self-contained ● 4 test specimens/flight ● Sample diameter, 4 mm. ● Configured for STS Middeck	First GAC (Note 2) Bi/Mn Bi experiment (Note 3) was approved for STS-16, August 24, 1984. Second GAC Bi/Mn Bi experiment approved for STS-23, March 18, 1985.	Furnace system is complete. Is in STS flight qualification at MSFC.
ADSF-II/GE (Note 1)/Fred Reeves (MSFC)	● Hi-Temp. ($\leq 1600^{\circ}C$) ● Cooling loop to external heat exchanger ● Configured for STS orbiter cargo bay ● 4 test specimens/flight ● Crucible diameter, 6mm ● Sample diameter, 4mm	One of three GAC Samarium/Cobalt (Co-Sm) experiments (Note 3) approved for flight. Earliest STS flight condition is 1 August 1985.	Furnace currently being assembled at MSFC
AADSF/NASA, MSFC/Iva Yates (MSFC)	● Hi-Temp. ($\leq 1400^{\circ}C$) ● Hi-Temp. gradient (to $900^{\circ}C/cm$) ● Will be designed to operate in STS orbiter cargo bay ● 2 test specimens/flight ● Crucible diameter, 2.0 cm	Several experiments identified. First may be MSFC experiment to grow single crystal Hg Cd Te.	Currently exists only as a prototype. Furnace is in development phase.

NOTE 1 - General Electric, Advanced Energy Programs Department, King of Prussia, PA

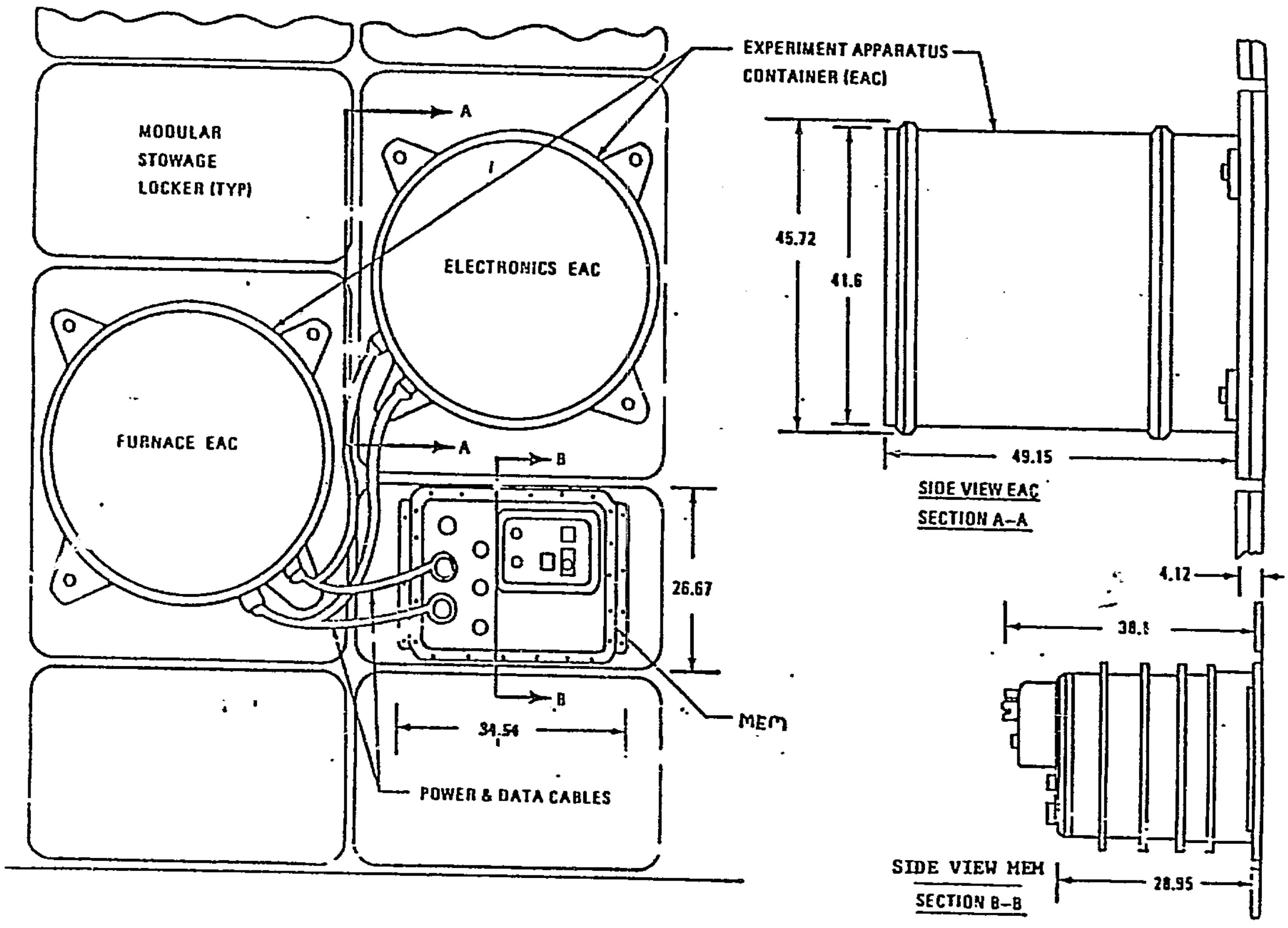
NOTE 2 - Grumman Aerospace Corporation, Materials and Structural Mechanics/Research Department, Bethpage, New York - Dr. D. J. Larson, Jr., Principal Investigator

NOTE 3 - The GAC Bi/Mn Bi and Co-Sm experiments are entitled "Orbital Processing of Aligned Magnetic Composites."

TABLE 7. ADSF-I APPARATUS OVERVIEW (NOTE 1)

APPARATUS/DEVELOPER:	AUTOMATED DIRECTIONAL SOLIFICATION FURNACE General Electric Company, King of Prussia, Pennsylvania
APPARATUS ACROYNYM:	ADSF-I
APPARATUS USE HISTORY:	Original Design Flown On Three Low-G Sounding Rocket (SPAR) Flights
PAYLOAD LOCATION:	Configured for STS Orbiter Middeck (See Figure 4 for example)

NOTE 1 Information from F. Reeves, May 1984, unless otherwise noted.



NOTE: DIMENSIONS IN CENTIMETERS

FIGURE 4. SCHEMATIC OF ADSF-I IN MID DECK LOOKING FORWARD AT STOWAGE LOCKERS (F. REEVES, MAY 1984)

operates at a time to limit the container touch temperature to 113°F." More recent information indicates that the ADSF-I can attain temperatures up to 600°C without exceeding the 113°F touch temperature (F. Reeves, July 1984).

Although the General Electric O & M Manual is quite detailed (i.e., 86 pages), the following paragraphs summarize the salient features of the ADSF-I described therein.

3.1.1 System Description The ADSF-I system consists of three major components in this configuration. The basic function of each of these three components is as follows (refer to Figure 4):

Middeck Equipment Module (MEM) - The MEM "...is the location of the power on/off switch for the system and the location of the system status flags as well as the experiment data recorder."

Electronics EAC - The ADSF-I control electronics are contained in the Electronics EAC and controls the ADSF-I furnace operation through interface with the MEM.

Furnace EAC - The ADSF-I furnace is contained within the Furnace EAC and is described in more detail below.

3.1.2 Furnace Description The Furnace EAC contains four individual furnaces shown in the block diagram of Figure 5. Each furnace consists of a nichrome wire-wound heating element surrounding a hollow center core mounted in super thermal insulation (Figure 5). The following description of the ADSF furnace continues from the General Electric Company (April 1984):

> "The bottom section of the metal shell contains a toroidal copper shaped quench block that is actively water cooled. This furnace quench block assembly is mounted on a moving carriage that is slowly moved by a motor, belt and pulley arrangement to a lead screw shaft drive. The upper and lower apparatus support plates contain the chucks to mount the stationary ampoule (crucible) in the center of the furnace. The ampoule is not in contact with the furnace and heat transfer is by radiation to the heating element and quench block."

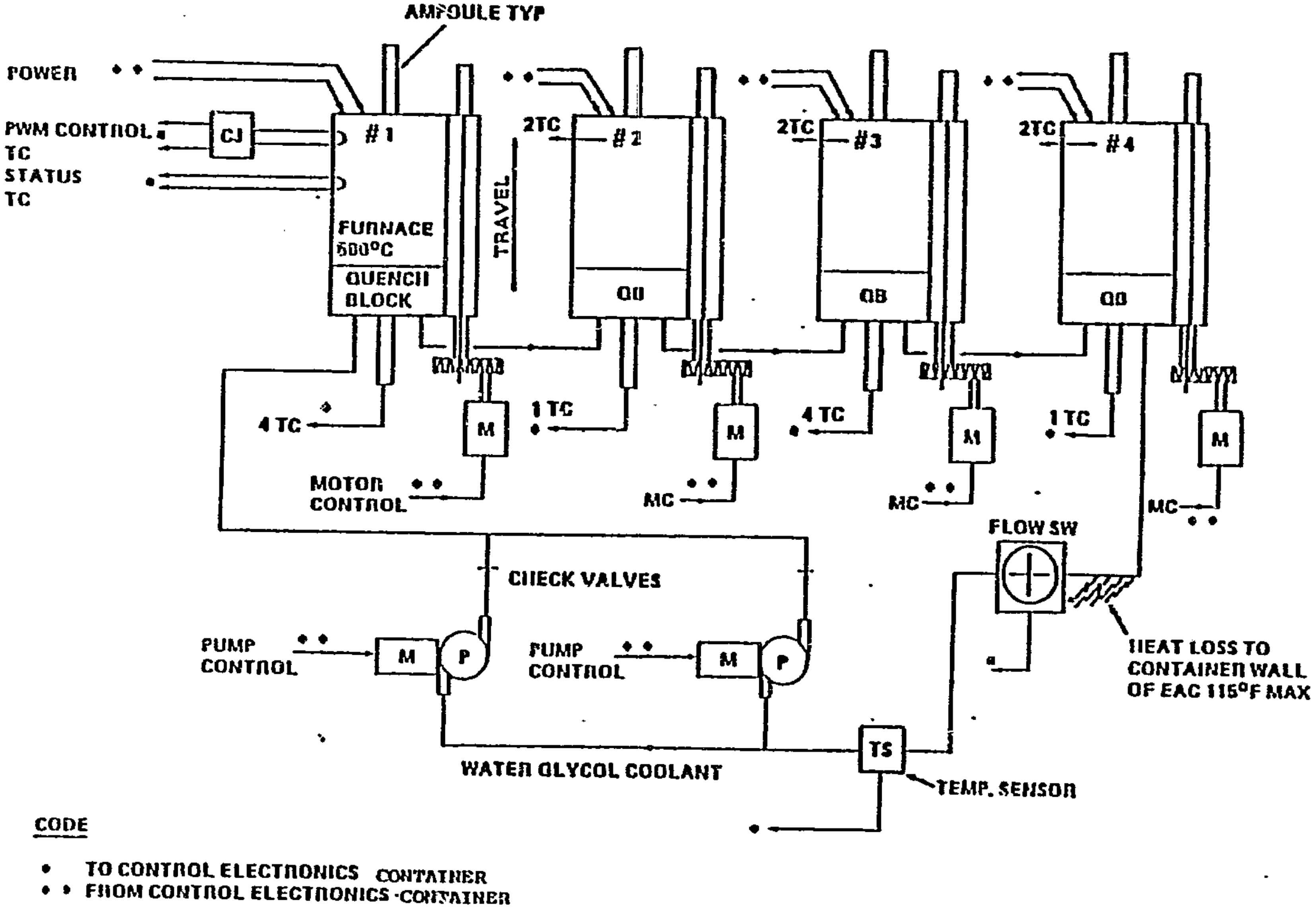


FIGURE 5. ADSF-I FURNACE EAC FUNCTIONAL BLOCK DIAGRAM (GENERAL ELECTRIC COMPANY, APRIL 1984).

"Two furnaces move in the +Z apparatus direction and the other two move in the -Z direction along the symmetrical long axis. Only one furnace operates at a time to limit the container touch temperature to 113°F.

The 50-50 water-glycol coolant volume is approximately 15 cubic inches. Two pumps (one operating at a time) via check valves circulate the coolant in a series closed loop through each furnace and to a toroidal tank around the center of the apparatus. The toroidal tank has a fin to radiate the heat input to the inner wall of the container.

Switching of the operating pump is controlled by the electronics in the Control Electronics Container (CEC) and is controlled by a flow switch in the coolant loop. A loss of coolant flow due to possible cavitation will alternate pumps. An accumulator reservoir is a part of the coolant loop to supply coolant due to losses by water vapor through the flex silicone tubing.

Each furnace assembly is instrumented to give four (4) sample temperatures in the ampoule and linear position of the furnace assembly. Two thermocouples in each furnace are connected to the CEC for temperature control (compensated) and status (non-compensated)."

3.1.3 Control Electronics Description Since the GE operational maintenance manual (General Electric Company, April 1984) provides a detailed description of the function of the various components within the Electronics EAC (Figure 4), only the salient features will be summarized here.

Operation of the Control Electronics (CE) is started when 28V (±4V) DC is applied by means of the MEM on/off switch. The ADSF system is then under control of a sequence which contains a crystal controlled clock to generate pulses for seconds, minutes, and hours. The sequence controls the timing operations of the ADSF system and is programmable prior to launch. Further features of the automated control of the ADSF system is as follows:

- The sequence is prevented from recycling back to a previously run furnace if a power disturbance is encountered.

- Any of the four furnaces within the ADSF system can be selected to operate initially and then progress through the other furnaces in turn.

- A temperature enable line prevents another furnace from starting until the temperature in the furnace that was just previously turned off has decayed to a preset limit.

- Upon receipt of an "at temperature" signal from a furnace status module, the following sequence is initiated:

  - The "at temperature" signal starts a programmable interval timer to establish furnace soak time (~30 min).

  - When satisfied, the interval timer starts the furnace currently in operation at a programmable linear speed for a programmable interval time from minutes to 99 hours. The linear speed is programmable to be normal, twice normal, and four times normal.

3.2 HIGH TEMPERATURE ADSF (ADSF-II)

The high temperature ADSF-II was constructed to the subsystems level by General Electric, Advanced Energy Programs Department, King of Prussia, Pennsylvania. Some features of the ADSF-II have been summarized in Tables 1 and 6. The ADSF-II is being assembled and checked out at NASA/MSFC (F. Reeves, October 1984). The furnace was developed to perform high temperature ($\leq 1600^{o}C$) directional solidification experiments such as the Grumman Aerospace Corporation Sumarium - Cobalt Experiment (Grumman, June 1984) entitled, "Orbital Processing of Aligned Magnetic Composites."

The basic design and many of the components of the ADSF-II are identical to the ADSF-I described previously. The salient features of the two furnaces were previously compared in Table 1. The Critical Design Review of the ADSF-II as prepared by the General Electric Company (General Electric, June 1984) details the status of the furnace system as of June 27-28, 1984. Also, some of the design changes from the low temperature unit (ADSF-I) were outlined. Some of these changes are as follows:

- Major Additions/Modifications to Low Temperature ADSF (ADSF-I)
  - Platinum Wire Furnace Cores
  - Staged Furnace Control for Wide Resistance Variation
  - New Heat Exchanger Design for Use with Freon Cooling System

- Major Additions/Modifications for Use in MSL-2
  - EMI Filtering
  - Fusing
  - Interconnect Harness
  - Signal Converter for Command and Display

- Improvements Added from Experience on Low Temperature Development System
  - Analog Detection Circuit Hysteresis
  - Relay Contact Debounce Provisions.

3.3 ADVANCED AUTOMATED DIRECTIONAL SOLIDIFICATION FURNACE (AADSF)

As summarized in Table 6, the AADSF is being developed by the NASA/MSFC Space Sciences Laboratory. The effort is under the direction of Mr. Iva Yates (MSFC/JA) and the AADSF prototype is being constructed and tested by Mr. Billy Aldrich (MSFC/ES). This furnace is not a viable unit for near-term John Deere experiments since its flight qualification is quite likely to extend into at least calendar year 1986 (NASA/MSFC, December 1983). Also, the NASA Science Advisor for the John Deere experiments, Dr. P.A. Curreri (MSFC/ES), stated that the sophistication of the AADSF (e.g., extremely high thermal gradient) was not required (P.A. Curreri, June - September, 1984). Also, the current AADSF specifications consider a maximum temperature of 1400°C (the John Deere experiment requires 1500-1550°C, see Table 4).

For completeness, the AADSF Specifications (NASA/MSFC, December 1983) are summarized in Table 8. Also, these specifications state that the design is limited to two test specimens per flight.

TABLE 8. AADSF SPECIFICATIONS (NASA/MSFC, DECEMBER 1983)

Weight	~ 68Kg
Overall Dimensions	17.8cm dia x 56cm long
Power Required (total)	<500 watts
Experiment Ampoule Dimensions	2.0cm x 20cm long
Hot End Temperature Range	amb. to 1100°C
Cold End Temperature Range	amb. to 600°C
Booster Heater Temperature Range	amb. to 1400°C
Booster Heater Width	.228cm
Heat Transfer Medium (soft mold)	Graphite, BN
Heat Transfer Medium Thickness	.167cm
Temperature Uniformity w/Heat Leveler	±1°C
Temperature Constancy (control)	±.25°C
Heat Sink H_2O Flow	400 ml/min
Housing Cooling Flow	260 ml/min
Thermal Gradient (dependent upon exp. material)	0 to >900°C/cm
Operating Atmosphere	Vacuum, Inert gas, Reducing

NOTE: THE ABOVE SPECIFICATIONS ARE PRELIMINARY AND DO NOT NECESSARILY REFLECT FLIGHT CONFIGURATION VALUES.

4.0 TASK 2. COMPARE JOHN DEERE/UA EXPERIMENT REQUIREMENTS VERSUS CANDIDATE PAYLOAD CAPABILITIES

The purpose of this task was to compare the scientific requirements of the John Deere/UA experiment (see Task 1, Section 2.0) with the capabilities and limitations of any of the automated directional solidification furnace (ADSF) systems under consideration (see Task 1A, Section 3.0). A summary of the scientific requirements of the John Deere/UA experiment has been delineated in Tables 2-5 and a schematic of a preferred sample and crucible configuration for the experiment was shown in Figure 3. Table 1 provided a comparison of the capabilities of the low-temperature ADSF (ADSF-I) and the high-temperature ADSF (ADSF-II) payloads. Finally, Table 8 provides a preliminary list of specifications and capabilities for the advanced automated directional solidification furnace (AADSF) system.

The following paragraphs provide comparisons of the experiment requirements with the furnace (payload) capabilities. These comparisons have been separated into two primary STS experiment locations, i.e., 1) the STS orbiter middeck, and 2) the STS orbiter cargo bay. Consideration of a Spacelab payload location is not included herein due to the comparatively long preparation time for flight.

4.1 STS ORBITER MIDDECK EXPERIMENT LOCATION

A number of accommodation studies have been performed relevant to the STS Orbiter middeck as a candidate location for experiments. One of the most recent and thorough of these studies is that prepared by Rockwell International (Ponce and Thoeny, March 1984). The Rockwell study was divided into two parts. Part I considered some twelve locations in the middeck (Figure 6) as viable candidates for the "near-term" accommodation of experiments. "Near-term" accommodation was defined as requiring little or no orbiter modification for experiment accommodation. Part II of the Rockwell study considered a "far-term" conceptual design of an experiment accommodation. This "far-term" accommodation would require some major modifications to the orbiter and would result in a Middeck Experiment Station (MIDES, see Figure 7).

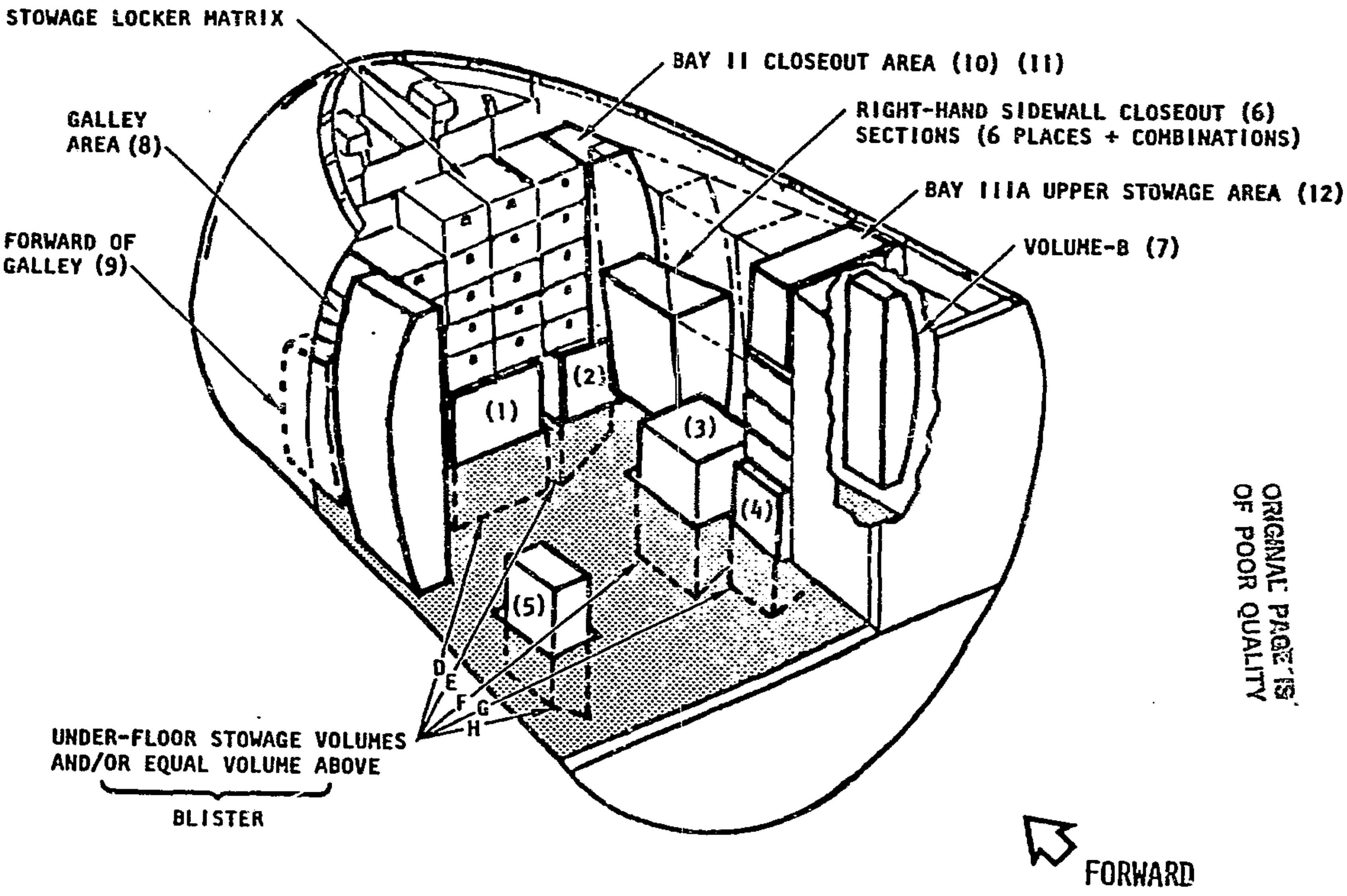


FIGURE 6. MIDDECK EXPERIMENT ACCOMMODATION - CANDIDATE LOCATION SURVEY RESULTS (PONCE AND THOENY, MARCH 1984)

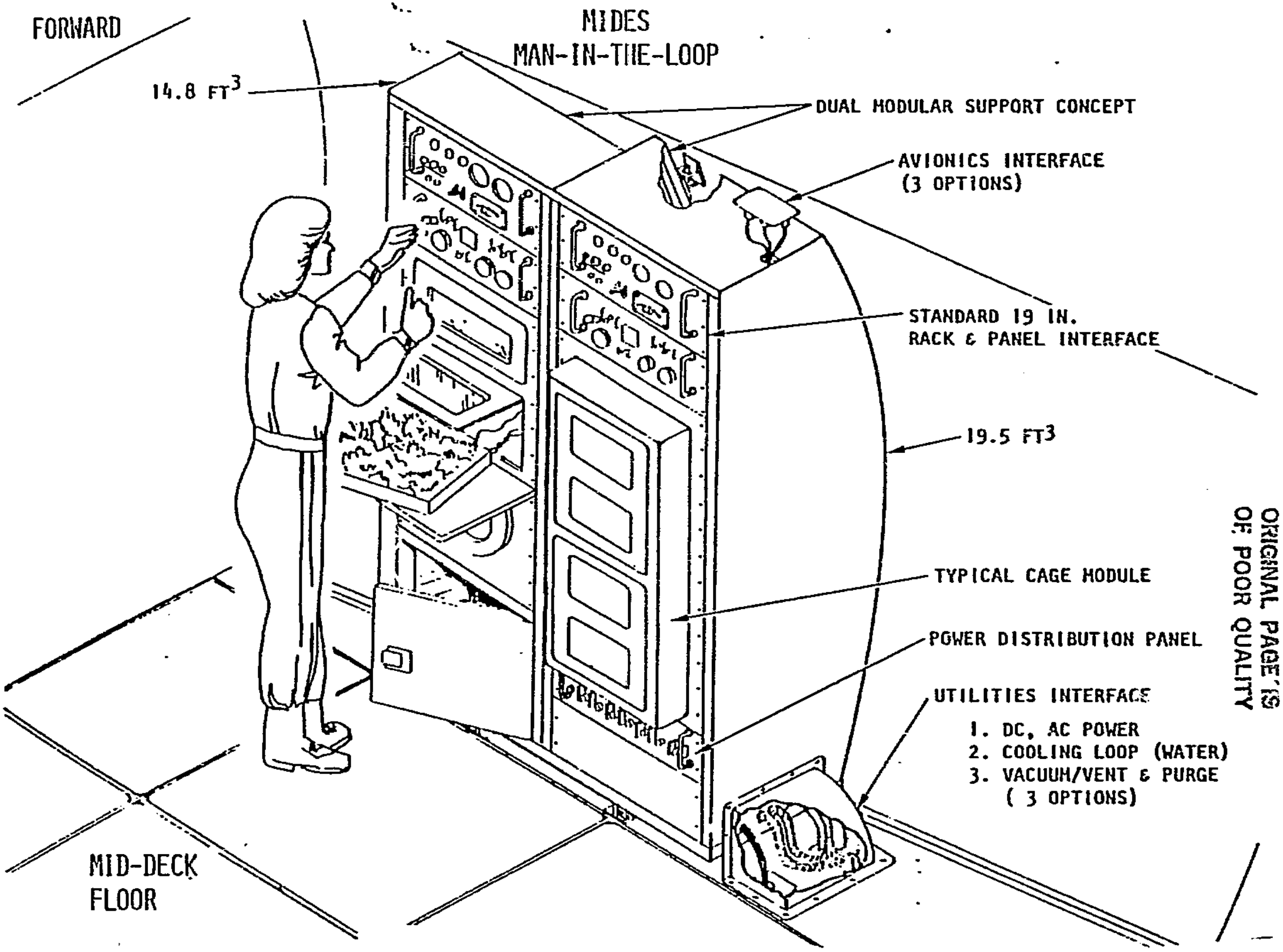


FIGURE 7. MIDDECK EXPERIMENT ACCOMMODATION – FAR-TERM MIDDECK EXPERIMENT STATION (MIDES) (PONCE AND THOENY, MARCH 1984)

Based on the Rockwell study, there are a number of middeck locations that could be made to accommodate an experiment of the John Deere/UA type. Power, coolant loops, vent lines, etc. could be provided if a viable experiment payload were available. However, the following paragraphs indicate that none of the NASA/MSFC ADSF systems truly meet the full requirements of the proposed John Deere/UA experiment.

4.1.1 Low-Temperature ADSF (ADSF-I). The low-temperature ADSF-I is currently configured for use in the STS orbiter middeck location (see Figure 4). Although this furnace system has been delivered to NASA/MSFC and is nearing completion of flight qualification, there are several serious limitations which reduce the ADSF-I payloads viability for the John Deere/UA experiment. Some of these limitations are listed in Table 9.

The major limitation of the ADSF-I system is that it was designed for a maximum furnace hot zone operating temperature of up to 500°C. Upgrading this furnace to the 1500-1550°C temperature requirement of the John Deere/UA experiment would require major modifications.

Therefore, it is recommended that the ADSF-I not be considered further. Additional comments on the use of the ADSF-I system are included in Task 3 (Section 5.0).

4.1.2 High-Temperature ADSF (ADSF-II). As summarized in Task 1A (Section 3.0), the high-temperature ADSF (ADSF-II) is being configured for an STS Orbiter MSL-2 (cargo bay) location. Although the ADSF-II furnace temperature ($\leq 1600^{\circ}C$) satisfies the John Deere/UA experiment requirements (1500 -1550°C), there are a number of other considerations to be made. Some of these considerations are summarized in Table 10.

Table 10 indicates that the ADSF-II payload system is either acceptable, or marginally acceptable, for all of the John Deere/UA Experiment requirements. The exceptions for the ADSF-II in the STS Orbiter middeck location are listed on page 29.

TABLE 9. USE OF THE ADSF-I SYSTEM PAYLOAD FOR THE JOHN DEERE EXPERIMENTS - STS MIDDECK LOCATION

CONSIDERATION	SCIENTIFIC AND/OR STS REQUIREMENT	ADSF-I SYSTEM CAPABILITY	COMMENT
Furnace Temperature (Max.)	1500 - 1550°C	≤ 500°C	ADSF-I system would require major modifications
Payload Thermal Control	45°C (113°C) (Note 1)	~113°C (Note 2)	Touch temperature (113°F) satisfied in STS orbiter middeck by self-contained coolant loop for up to 600°C furnace temperature
Samples Processed/Flight			
• Phase I (Table 1)	2–4	1–4	Consideration satisfied
• Phase II (Table 2)	15–45 (Note 3)	1–4	Not acceptable
Sample Diameter	0.5 cm (1.0 cm desired)	~ 0.4 cm	Marginal acceptance
All Other Considerations	See Tables 4 & 5	See Table 1	Generally acceptable

Note 1 - A maximum allowable payload "touch temperature" has been taken as 45°C (113°F) for the STS Orbiter middeck.

Note 2 - Noted in General Electric, April 1984, page 2.

Note 3 - A specific number of samples to be processed per flight has not been established for the Phase II Experiments.

TABLE 10. USE OF THE ADSF-II SYSTEM PAYLOAD FOR THE JOHN DEERE EXPERIMENTS – STS MIDDECK LOCATION

CONSIDERATION	SCIENTIFIC AND/OR STS REQUIREMENT	ADSF-II SYSTEM CAPABILITY	COMMENT
Furnace Temperature (Max.)	1500 – 1550°C	$\leq$ 1600°C	Acceptable
Payload Thermal Control	45°C (113°C) (Note 1)	See Note 2	ADSF-II configured for external coolant loop (freon)
Samples Processed/Flight			
• Phase I (Table 1)	2–4	1–4	Acceptable
• Phase II (Table 2)	15–45 (Note 3)	1–4	Not acceptable
Sample Diameter	0.5 cm (1.0 cm desired)	~0.4 cm	Marginal acceptance
Crucible Atmosphere	Inert gas (e.g., Argon)	Nitrogen Purge	See text
All Other Considerations	See Tables 4 & 5	See Table 1	Generally acceptable

Note 1 – A maximum allowable payload "touch temperature" has been taken as 45°C (113°F) for the STS Orbiter middeck.

Note 2 – Payload "touch temperatures" have been bounded at ~54 – 66°C (130 – 150°F) for an STS Orbiter middeck structure temperature of ~27°C (80°F) in the absence of any external coolant loop.

Note 3 – A specific number of samples to be processed per flight has not been established for the Phase II Experiments.

1. Touch temperature requirement
2. Crucible atmosphere
3. Sample diameter
4. Sample exchange.

Each of these exceptions will be discussed briefly in the following paragraphs.

Touch Temperature Requirement:

The allowable "touch" temperature for an experimental apparatus mounted in the Orbiter middeck has been baselined at 45°C (113°F). Computations for the touch temperature of the high-temperature ADSF (ADSF-II) have indicated a range of 148°F-160°F in the absence of any external coolant loop and for assigned normal middeck structure temperatures of 61°F-80°F (Appendix 1 of General Electric, September 1982).

Several trade studies were made subsequent to these computations but no touch temperature approaching 113°F was obtained. An exception was that of Appendix 2 of the General Electric reference (September 1982), where a reflective, wide-mesh screen was assumed to be placed around the furnace EAC. The result of the screen was that the ADSF-II furnace EAC would become "...a little hotter (5-10°F at most...)" but the protective screen would be at an acceptable touch temperature.

It has not been determined whether there would be any adverse effect internal to the ADSF-II system EAC if no external coolant loop is used. The quench block temperature would stabilize at a higher steady-state temperature and all of the components inside the furnace EAC would operate at a higher temperature.

Based on the information currently available, it is recommended that an external coolant loop be used with the ADSF-II if configured for the middeck location. If this is impossible within the desired mission timelines, it is recommended that the following considerations be evaluated in more detail:

a. Assume the use of a protective wide-mesh screen to be placed over the ADSF-II furnace EAC.

b. Compute steady-state temperatures of the ADSF-II furnace EAC assuming that the protective screen (a. above) is in place and that an appropriately high EAC effective emittance can be obtained by coating the EAC cover.

c. Compute the steady-state quench block temperature of the ADSF-II furnace under the conditions of a. and b. Assess the impact of these temperatures on the John Deere/UA experiment.

Crucible Atmosphere:

The desired atmosphere surrounding the furnace crucibles in the John Deere/UA experiment has been stated (P.A. Curreri, June-September 1984) to be an inert gas (e.g., Argon). In its present status, the high-temperature ADSF-II is configured to include a nitrogen purge and steady-state nitrogen atmosphere in the STS orbiter cargo bay (General Electric, June 1984). Assuming that an inert atmosphere must be included to surround the John Deere/UA experiment crucibles, then an EAC purge line must be provided in the middeck location and a location must be established for the purge gas storage bottle.

If no pressurized gas line is permissible in the orbiter middeck, then the high-temperature ADSF-II cannot be located in the middeck. Conversely, if the pressurized gas line is permissible, than an interesting possibility is presented. Assuming that the furnace EAC is appropriately purged and charged during pre-launch preparation, then no purging during flight should be required in the middeck if no sample exchange is performed. This possibility could eliminate the need for a vent line in the middeck.

Sample Diameter:

The desired sample diameter for the John Deere experiment has been stated as 0.5 cm (1.0 cm preferred) (P.A. Curreri, June-September 1984). Since the allowable crucible outside diameter is ~0.6 cm for use in the high-temperature ADSF-II, it is clear that the maximum sample diameter is more likely to be 0.3-0.4 cm. This diameter may be marginally acceptable for the Phase I microstructure samples, but is probably unacceptable for the Phase II mechanical property samples (see Table 4). Thus, the following considerations are necessary for use of the high-temperature ADSF-II in any location:

a. Consider the acceptability of a sample diameter of 0.3 - 0.4 cm.

b. Investigate the modifications required to increase the bore of the ADSF-II furnaces.

Sample Exchange:

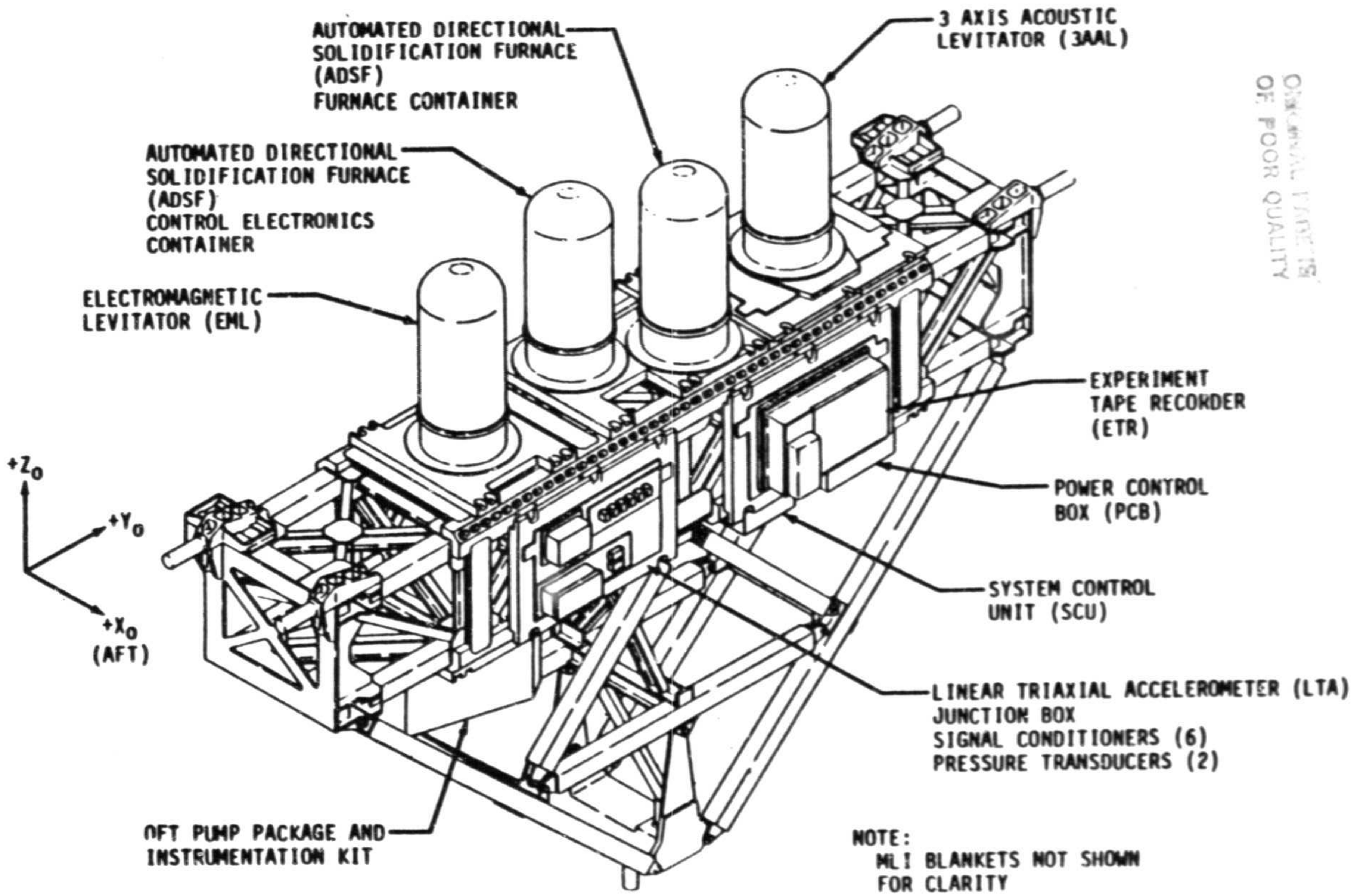
As currently configured - or under consideration - none of the NASA/MSFC ADSF systems permit any inflight sample exchange. See Task 3 (Section 5.0) for a further discussion of this consideration.

4.1.3 Advanced ADSF (AADSF). The NASA/MSFC advanced ADSF (AADSF) has been proposed to be configured for the STS orbiter cargo bay location (NASA/MSFC, December 1983). Thus, all of the limitations described above for locating the high-temperature ADSF (ADSF-II) in the STS orbiter middeck also apply to the AADSF. An exception is that of the sample diameter which is satisfactory in the proposed AADSF.

4.2 STS ORBITER CARGO BAY EXPERIMENT LOCATION

The John Deere/UA experiment proposal has requested a large number of samples (Tables 2 and 3) to be processed to fulfill the Phase I and Phase II requirements (see Task 1A, Section 3.0). However, the STS orbiter cargo bay location would permit the processing of only a limited number of samples if only one of the current ADSF payload systems were operating per flight. Thus, of the existing or proposed ADSF systems, only the Phase I experiment requirements (6 - 12 samples) could be considered. Further, due to the ADSF-I system limitations outlined previously, only the ADSF-II and the AADSF systems need be considered.

4.2.1 High-Temperature ADSF (ADSF-II). The high-temperature ADSF (ADSF-II) system is being configured for the STS orbiter cargo bay for mounting on the MSL-2 (see Figure 8). Capabilities of the ADSF-II system have been outlined briefly in Table 1.



NOTE:
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FOR CLARITY

FIGURE 8. ADSF-II MOUNTED ON MSL-2

In its current configuration and proposed orbiter location (i.e., cargo bay), the ADSF-II limitations are as follows:

1. Small sample diameter (~0.3 - 0.4 cm)
2. Limited number of samples processed per flight (4 max.)
3. No sample exchange capability.

Each of these limitations will be considered briefly in the following paragraphs.

Sample Diameter:

Considerations relevant to the sample diameter were discussed in a preceding paragraph where the ADSF-II system was considered for an STS orbiter middeck location. The same considerations apply if the ADSF-II system is considered for an orbiter cargo bay location, i.e.

a. Consider the acceptability of a sample diameter of 0.3 - 0.4 cm.
b. Investigate the modifications required to increase the bore of the ADSF-II furnaces.

Number of Samples and Sample Exchange:

Since the current configuration of the ADSF-II system can process a maximum of 4 samples per flight, only the Phase I experiment sample requirement (6 - 12 samples total, Table 2) can be approached efficiently. Consideration of sample exchange during flight is out of the question with the ADSF-II.

4.2.2 Advanced Automated Directional Solidification Furnace (AADSF). The proposed capabilities of the AADSF (NASA/MSFC, December 1983) were discussed briefly in Task 1A (Section 3.0) and summarized in Table 8. As currently envisioned, the AADSF cannot be considered for the John Deere/UA experiments due to its limitation of only two samples processed per flight. However, if the AADSF design were to include sample exchange in an STS orbiter middeck location configuration it could possibly meet or exceed all of the John Deere/UA requirements.

5.0 TASK 3. PROPOSED MODIFICATIONS TO EXISTING ADSF SYSTEMS OR CONSTRUCTION OF NEW ADSF

5.1 VIABILITY OF MODIFYING EXISTING ADSF SYSTEMS

The purpose of this task was to consider those modifications deemed necessary to be made to the existing ADSF systems to allow successful completion of the John Deere/UA experiments on the NASA STS orbiter. The studies performed under Task 2 (Section 4.0) concluded that only the high-temperature ADSF system (ADSF-II) in its current configuration should be considered further. The low-temperature ADSF (ADSF-I), although configured for the orbiter middeck, would require major modifications to be used for the higher temperature (1500 - 1550°C) John Deere/UA experiment. Also, the ADSF-I has already been assigned to other experiments. Although some consideration has been given to the use of the advanced automated directional solidification furnace system (AADSF), this system is still in the development phase and is also being considered for other experiments. Finally, it should be noted that none of the above furnaces (i.e., ADSF-I, ADSF-II, and AADSF) are being developed to include sample exchange during orbit, a serious limitation for the John Deere/UA experiment.

With the above constraints under consideration, some interest has been expressed in constructing a new furnace that would more fully meet the needs of the John Deere/UA experiment. Again, considering the proposed John Deere/UA experiments (Tables 2 and 3), it is seen that the proposed number of samples processed would be as follows:

PROPOSED QUANTITY OF SAMPLES PROCESSED - JOHN DEERE/UA

	Minimum Samples	Desired Samples
Phase I - Microstructures	6	12
Phase II - Mechanical Properties	45	135

Thus, processing only the Phase I samples would require a minimum of two flights to accomplish the minimum requirements if the ADSF could only process 4 samples per flight (as in the case of the ADSF-II). The Phase II experiment minimum requirement of 45 samples (135 samples desired) is completely beyond the consideration of the existing ADSF systems in the absence of sample exchange capability during flight.

Thus, the remainder of this Task 3 effort is devoted to a discussion of the following considerations:

a. Development of a new ADSF System (ADSF-III), see Section 5.2
b. Modification of the existing high-temperature ADSF (ADSF-II) for sample exchange, see Appendix A.

5.2 DEVELOPMENT OF A NEW ADSF SYSTEM (ADSF-III)

The development of a new automated directional solidification furnace (ADSF) system that could satisfy all of the sample processing requirements of the John Deere/UA experiments (Tables 2 and 3) indicates that such a system should have the following features:

- Sample exchange (insertion and removal) must be performed several times per flight
- Sample exchange must be readily accomplished by a payload specialist or astronaut
- Multiple samples must be carried aboard the STS orbiter
- The required amount of processing data is likely to require recording by onboard tape cassettes
- Existing ADSF technology should be used where appropriate.

Conceptual design and cost estimation of a new ADSF system (referred to herein as ADSF-III) requires individual consideration of the following topics:

a. Furnace Payload Performance and Instrumentation Requirements
b. Mission Requirements and Payload Specialist Involvement
c. Furnace Electro-Mechanical Design
d. Control Electronics Design
e. GSE Requirements.

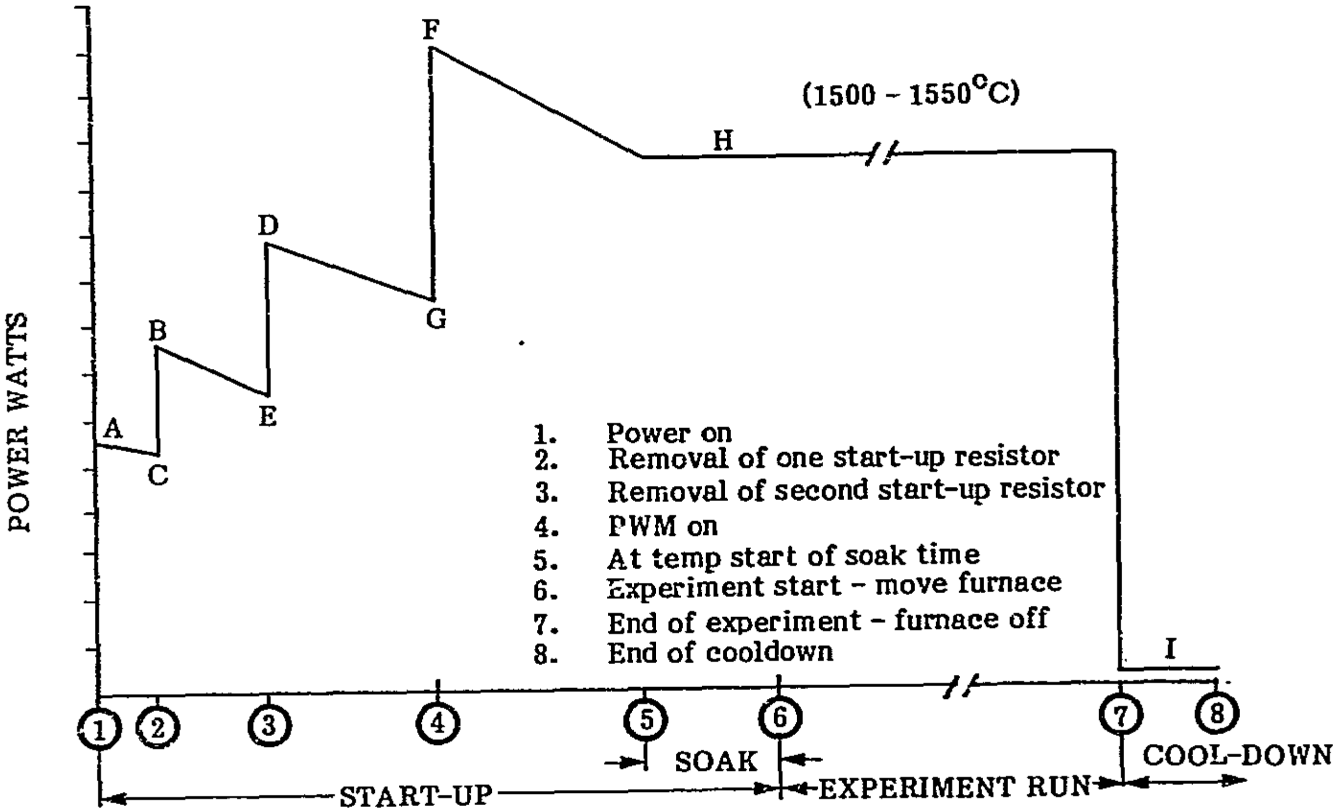
5.2.1 **Furnace Payload Performance and Instrumentation Requirements.** Tables 4 and 5 provided a listing of the basic requirements for furnace performance, instrumentation, and data sampling. Some of the requirements listed must be considered approximate at this time since they are highly design dependent. For example, the quench block temperature will depend on the cooling system selected (i.e., external loop or radiative cooling) and the sizes of the sample, crucible and furnace bore. Likewise, the total run time per sample (start-up to end of cool-down) is a function of furnace design, soak time required, and desired sample translation rate.

Note that the information contained in Tables 4 and 5 is based on a per furnace basis. If it is determined that only one furnace can operate at a time, then there is no advantage to having more than one furnace in a cannister (furnace EAC) with a sample exchange capability.

5.2.2 **Mission Requirements and Payload Specialist Involvement.** The elapsed time between insertion of a new sample until processing is completed and the furnace has cooled down determines the minimum mission time required to process a sample. Figure 9, based on the high-temperature ADSF-II system (General Electric, June 1984), indicates that the total sample processing time (insertion through cool-down and removal) is approximately as follows:

	Total Processing Time/Samples	
Samples	Translation Rate = 0.1mm/min	1mm/min
Phase I Specimens (~4 cm solidification length)	10-11 hours	3-4 hours
Phase II Specimens (~6 cm solidification length)	13-14 hours	4-5 hours

These sample processing times are based on a furnace start-up to end-of-soak time of ~2 hours (Figure 9) and an assumed cool-down time of ~1-2 hours. The major variable (i.e., the experiment run time) is strongly dependent on the selected furnace translation rate. Thus, at the lowest desired translation rate of 0.1 mm/min the experiment run time (Timeline ⑥ through ⑦ in Figure 9) would be ~7 hours for directionally solidifying a 4 cm sample and ~10 hours for a 6 cm sample. Conversely, at a translation rate of 1 mm/min, the experiment run times would be approximately



FC (WATTS) AT 28V

A	B	C	D	E	F	G	H	I
110	151	105	195	132	317	170	243	13

TIMELINE (MINUTES) AT 28V (NOTE 1)

1	2	3	4	5	6	7	8
0	12	28	47	103	133	533	653

NOTE 1 - Experiment run times given for 4 cm sample solidification @ 0.1 mm/min translation rate. (Add ~ 200 min to timelines ⑦ and ⑧ for 6cm sample solidification).

Figure 9. FURNACE CONTROL POWER - TIME PROFILE (1500°C) - FOR 28V D.C. NOMINAL (GENERAL ELECTRIC, JUNE 1984)

0.7 and 1.0 hours for the 4 cm and 6 cm samples, respectively. Note that the furnace start-up, soak, and cool-down times must be added to the experiment run time to obtain the total processing times per sample tabulated above.

Also, note that the lowest furnace translation rate (0.1 mm/min) would probably be applied to only some 10 percent of the samples, while the majority (~90 percent) would be processed at a much higher translation rate (say 1 mm/min) (P.A. Curreri, June - September 1984).

With a single furnace operating at the lowest translation rate (0.1 mm/min), the maximum number of samples processed per day of mission time is approximately two. Thus, a mission of seven days in orbit could potentially process all of the desired Phase I specimens (e.g., 12 specimens) as shown in Figure 10.

In terms of power requirements, Figure 9 shows the furnace wattage required for a nominal 28 V D.C. power supply. These values, which were based on a crucible OD of ~0.6 cm for the ADSF-II, are probably too low for this new (ADSF-III) furnace It is likely that the maximum furnace power required will approach 400 - 450 watts at 28 V D.C. Figure 11 shows the electronics control power requirements for the ADSF-II. This electronics power profile requirement is probably reasonable for the ADSF-III design.

Since this new furnace design (ADSF-III) assumes manual insertion and removal (exchange) of the experiment specimens, a payload specialist (or astronaut) would be responsible for performing this function.

5.2.3 **Furnace Electro-Mechanical Design.** The electro-mechanical design of the proposed new ADSF system (ADSF-III) may be based largely on the available technology of the NASA/MSFC ADSF systems (ADSF-I and ADSF-II) already constructed.

The overall dimensions, weights, and suggested locations are summarized below:

Suggested Mounting Location: STS Orbiter Middeck Storage Locker

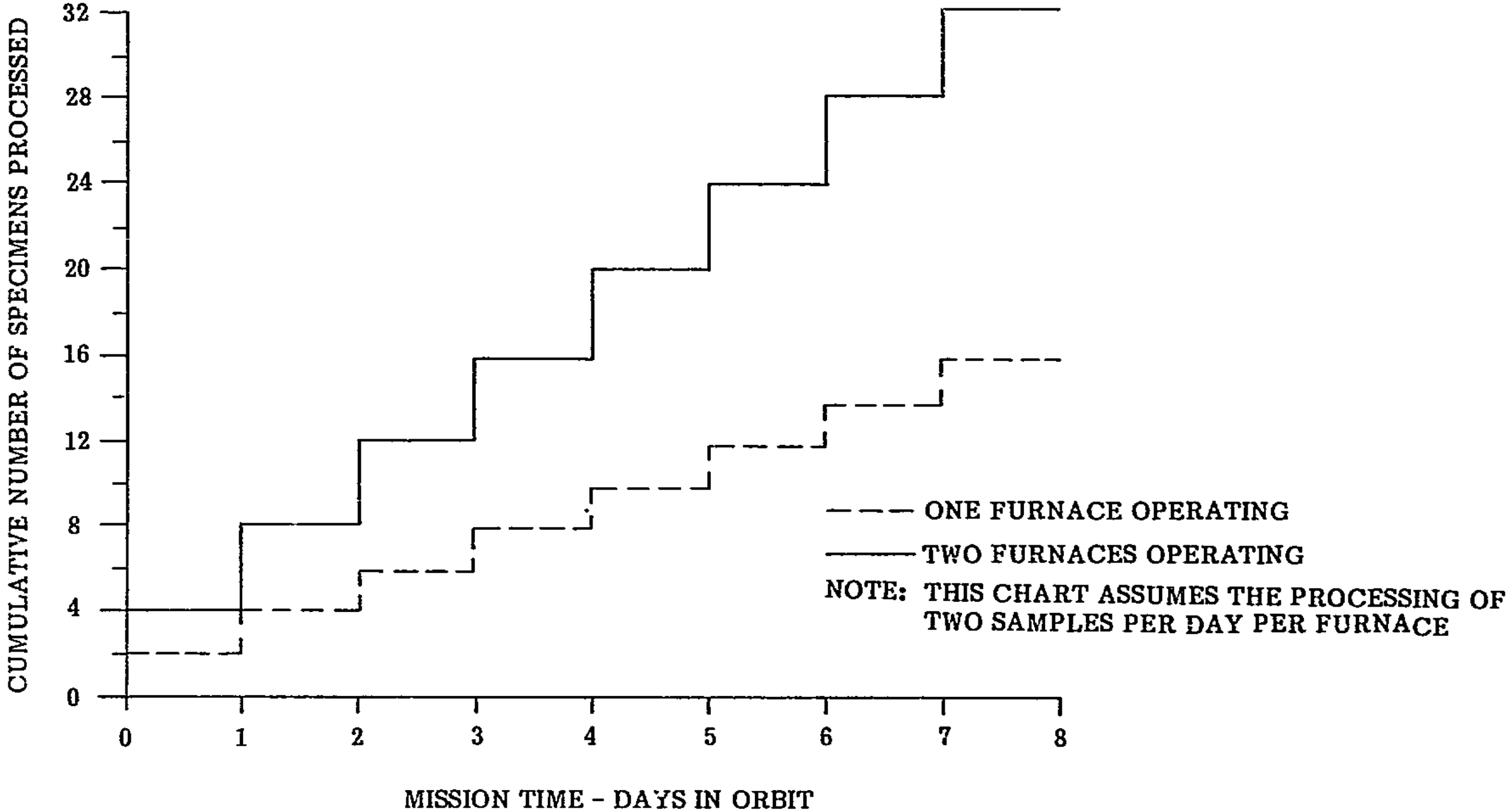
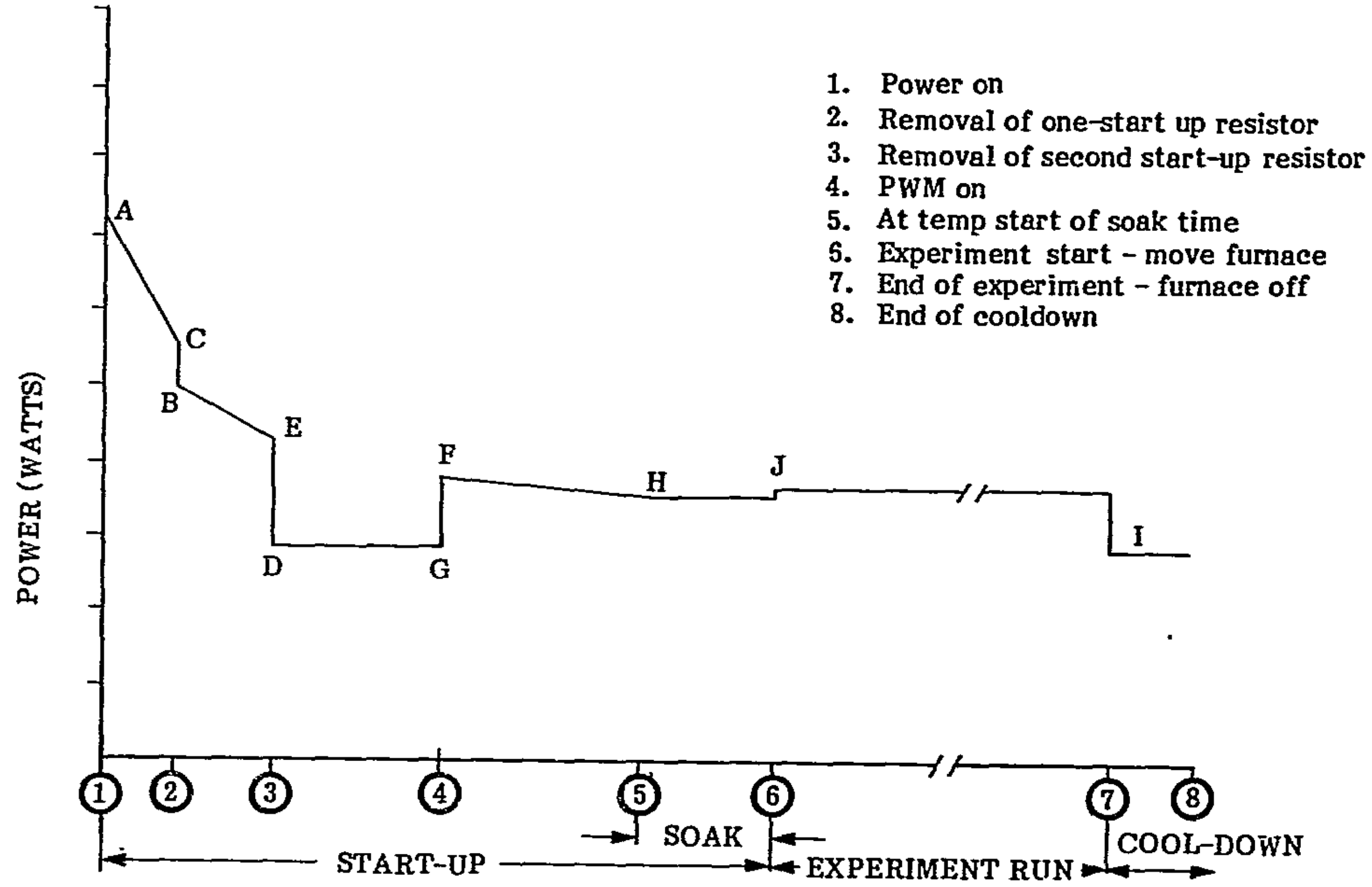


Figure 10. JOHN DEERE/UA SPECIMENS PROCESSED AS A FUNCTION OF MISSION TIME



CEC (WATTS) AT 28V

A	B	C	D	E	F	G	H	I	J
144	98	112	57	85	77	57	70	57	74

TIMELINE (MINUTES) AT 28V (NOTE 1)

1	2	3	4	5	6	7	8
0	12	28	47	103	133	533	653

NOTE 1 - Experiment run times given for 4 cm sample solidification 0.1 mm/min translation rate. (Add ~ 200 min to timelines ⑦ and ⑧ for 6 cm sample solidification)

Figure 11. ELECTRONICS CONTROL POWER - TIME PROFILE FOR 1500°C FURNACE - NOMINAL 28V D.C. (GENERAL ELECTRIC, JUNE 1984)

Furnace Envelope Dimensions: EAC* Outside Diameter = 41.6 cm (16.4 in)
EAC Height = 49.2 cm (19.4 in)
Total Furnace EAC Weight: 27.2 kg (60 lbs) (est.)

The final design of the ADSF-III is likely to not require full use of the ADSF-I or ADSF-II EAC envelopes. Note that the ADSF-I as configured for the STS orbiter middeck (Figure 12) consumes 5 modular storage locker spaces. Consideration should be given to designing the ADSF-III system to require a maximum of 4 modular storage lockers.

Regarding the electro-mechanical design complexity of the ADSF-III system, the following equipment items would be located in the furnace EAC:

1. High-temperature furnace module and quench block assembly
2. Furnace translation mechanism, including
    - motor
    - drive mechanism (screw drive rod, belt and pulley or gear train)
    - linear bearing rod
3. Coolant loop, pump, and reservoir
4. Coolant loop heat exchanger
5. Furnace position indicator (linear potentiometer)
6. Sensors and sensor connector blocks
7. Power leads and power connector blocks
8. Crucible retainer/positioner blocks
9. Inert atmosphere inlet and purge ports
10. Upper and lower structural plates.

These equipment items are shown schematically in Figure 13. The selection and/or design of these components may be based on refined versions of the ADSF-I and ADSF-II technology.

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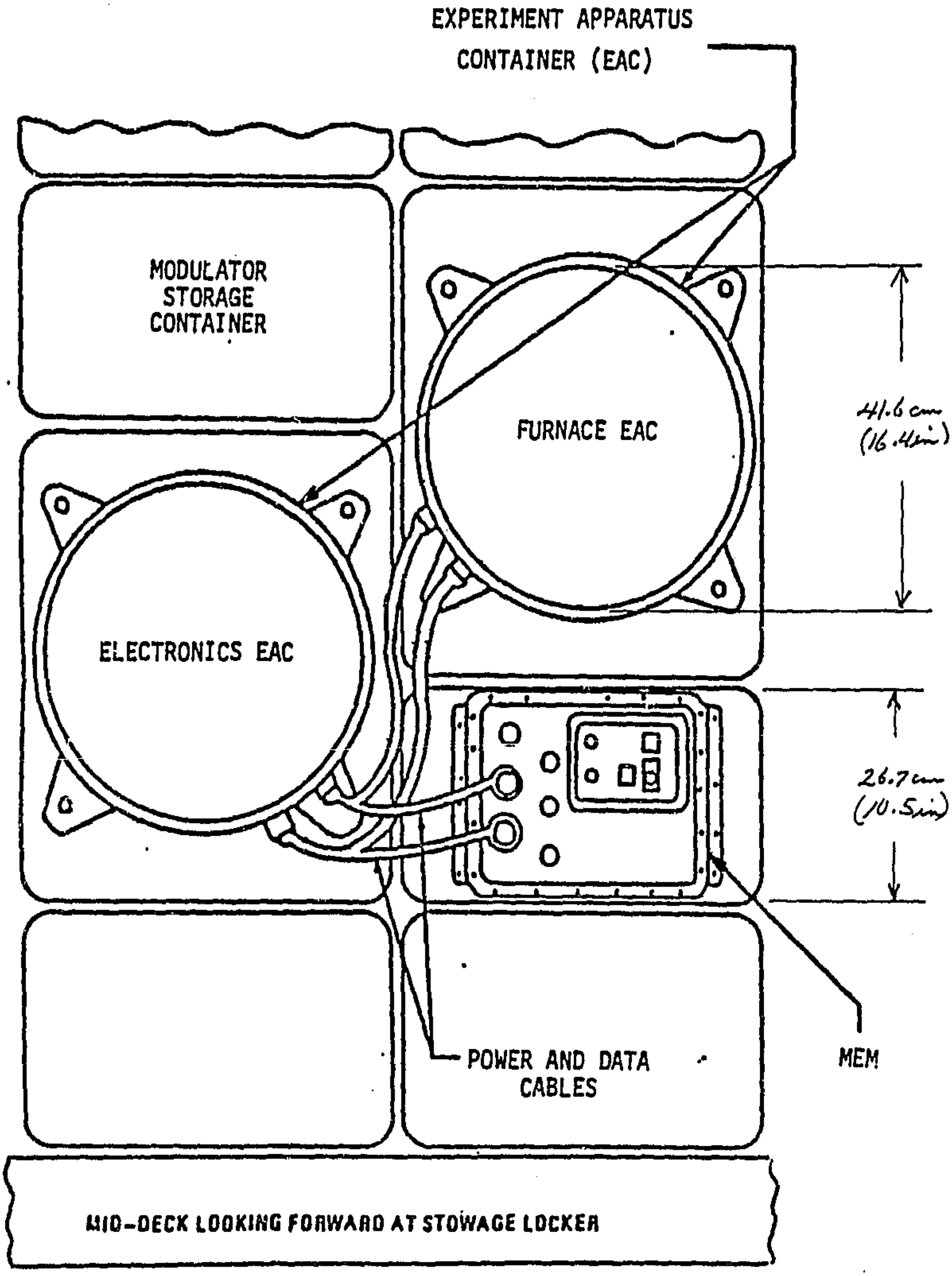
*EAC - Experiment Apparatus Container



MIDDECK LOOKING FORWARD AT STORAGE LOCKER

Figure 12. ADSF MIDDECK SUB SYSTEM LAYOUT

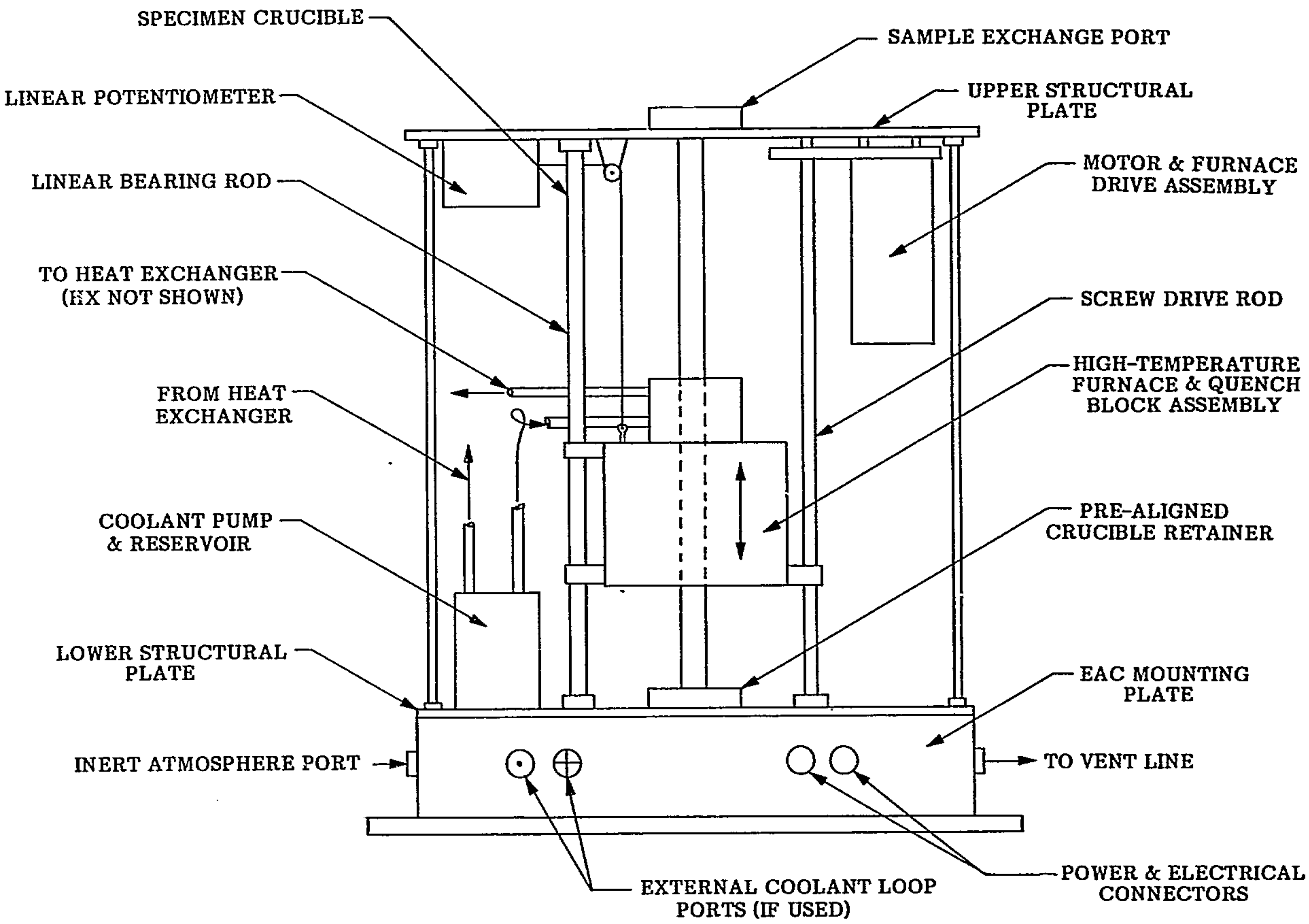


Figure 13. ADSF-III MODULAR ASSEMBLY – EQUIPMENT IN FURNACE EAC

5.2.4 Electronics Control Subsystem Design. The electronics control subsystem design for the newly proposed ADSF-III system should consider that of the high-temperature ADSF-II as a reference (General Electric, June 1984). However, the ADSF-III electronics control subsystem must incorporate the following major changes:

1. The furnace operating sequence will be re-initiated several times per flight.
2. Control of only one furnace will be required.
3. Furnace status indicators must be included to alert payload specialist of experiment completion.
4. Multiple data cassettes may be required to record the large amount of data taken.

The overal dimensions, weights, and suggested locations are summarized below:

Suggested Mounting Location: STS Orbiter Middeck Storage Locker
Electronics Envelope Dimensions: TBD (≤ Furnace EAC dimensions)
Total Electronics Control Subsystem Weight: <18kg (<40 lbs)

It is suggested that the newly proposed ADSF-III electronics control subsystem can be significantly simplified over that for the earlier ADSF-I and ADSF-II systems. The complexity of the earlier electronics subsystem is illustrated by Figures 14 and 15.

Also shown in Figure 12 is a middeck electronics module (MEM). The MEM serves as the ADSF system operation and status monitor and includes any required recording devices. For multiple sample processing, the MEM for the new ADSF-III will most likely include a cassette recorder.

5.2.5 GSE Requirements. The GSE requirements for a new ADSF (ADSF-III) would be similar to those for either the current ADSF-I or ADSF-II. The GSE hardware identified in the General Electric operating and maintenance manual (General Electric, April 1984) includes the following:

a. Control and Test Panel
b. Coolant Fill and Pressure Test Bench.

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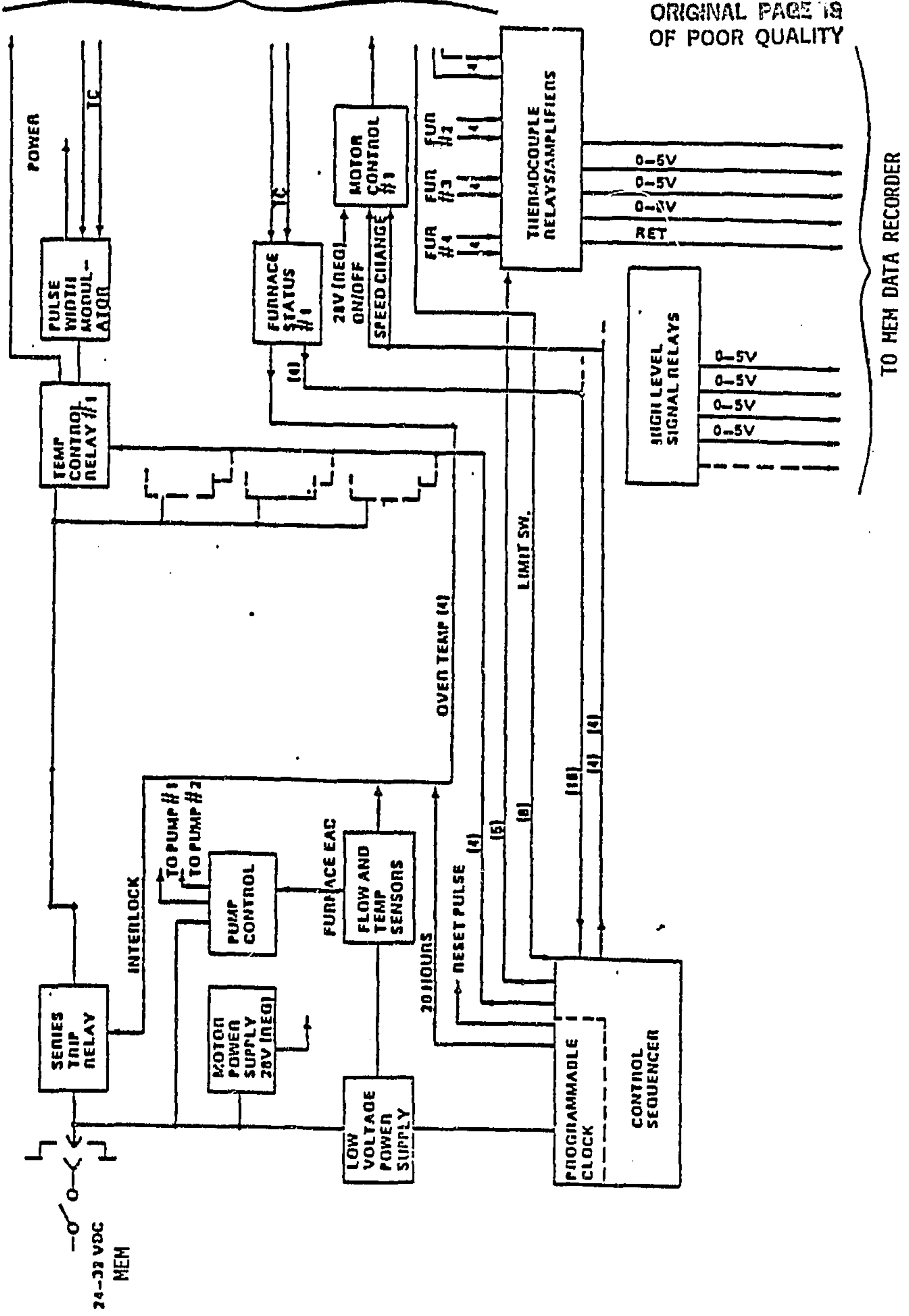

Figure 14. CONTROL ELECTRONICS EAC FUNCTIONAL BLOCK DIAGRAM

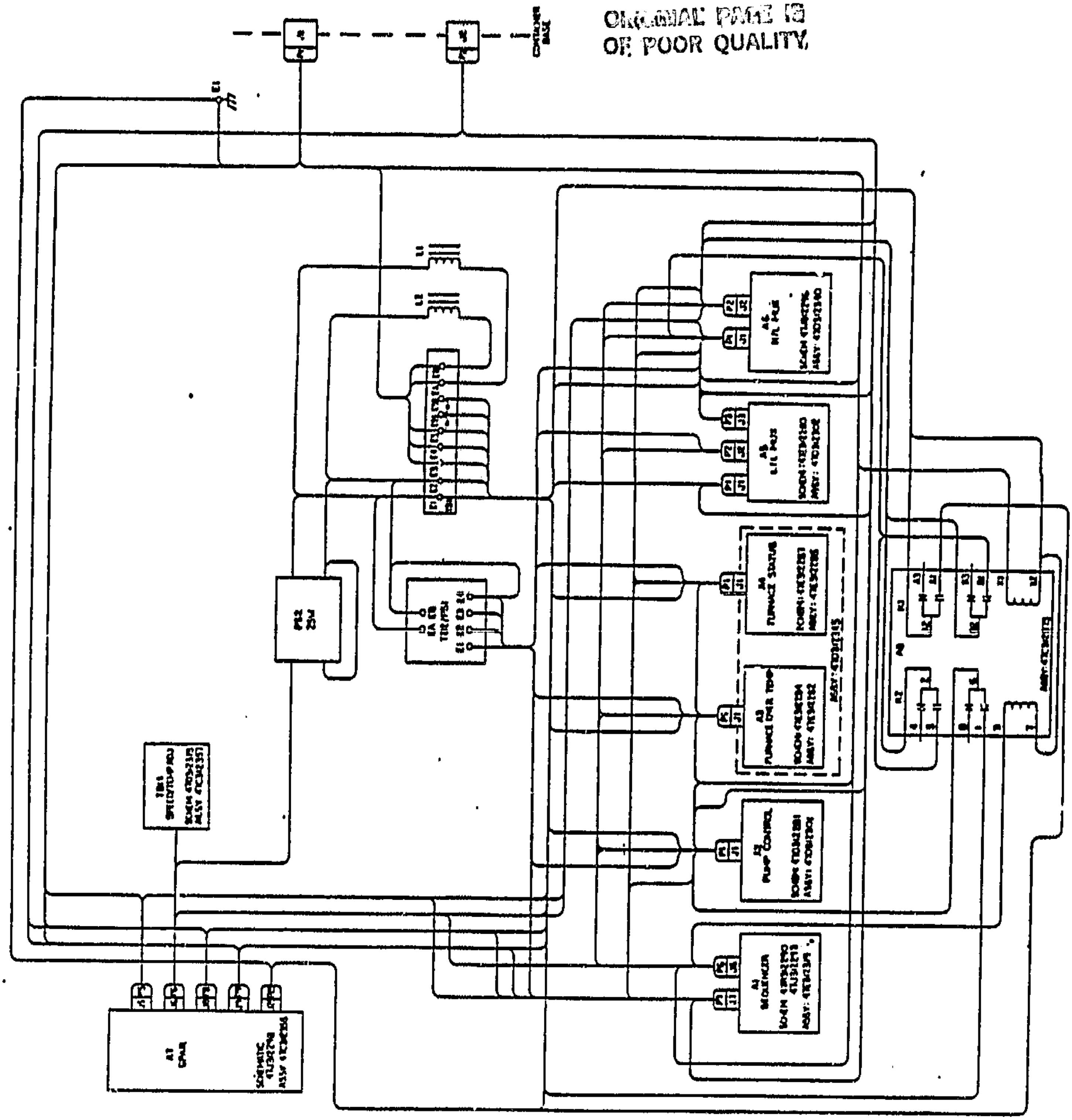

Figure 15. CONTROL ELECTRONICS EAC SCHEMATIC BLOCK DIAGRAM

The control and test panel is used (in the case of both the ADSF-I and ADSF-II systems) for 1) bench testing, 2) qualification testing, 3) launch site ground support, and 4) sample alignment. Each of these functions is described in detail in the General Electric document (April 1984).

The coolant fill and pressure test bench (also described in General Electric, April 1984) is used for all testing and launch site preparation.

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APPENDIX A

NOTES ON ADSF SAMPLE EXCHANGE

APPENDIX A

ADSF SAMPLE EXCHANGE

A-1. Assumptions Regarding Sample Exchange

If it is desired to have the capability of sample exchange for ADSF systems flown as payloads on the STS in the Orbiter Middeck or Spacelab, the following assumptions are made:

a. Sample exchange will be performed manually rather than automatically. This is to minimize complexity.

b. A mission payload specialist or astronaut will be able to perform sample exchanges routinely on a flexible schedule.

c. No sample alignment with respect to the furnace bore will be required after ground preparation of the ADSF system.

d. Sample exchanges will require only the removal of access plates (or a single plate) on the ADSF system cover (EAC) and the removal of a special access nut on the ADSF top plate.

e. The position of the ADSF individual furnace (or furnaces) during sample exchange will not affect the procedure for inserting or removing a sample.

A-2. Crucible Requirements

Crucibles currently used, or envisioned for use, with either the high-temperature ADSF (ADSF-II) or the Advanced ADSF (AADSF) shall continue to be acceptable if the following requirements are met:

a. The crucibles must be manufactured to a uniform diameter, longitudinal straightness, and length.

b. The samples placed within the crucibles must be restrained in position by snug fitting end caps that will serve to keep the samples from moving during handling.

c. The samples will be encased in a special, thin-walled sheath extending the full length of the crucible (Figure A.1). This sheath will be withdrawn after insertion of the crucible into the furnace.

d. The samples will be carried aboard the STS Orbiter in a special carrying case prepared by the principal investigator (PI) as shown in Figure A.2.

A-3. Furnace System Modification Requirements

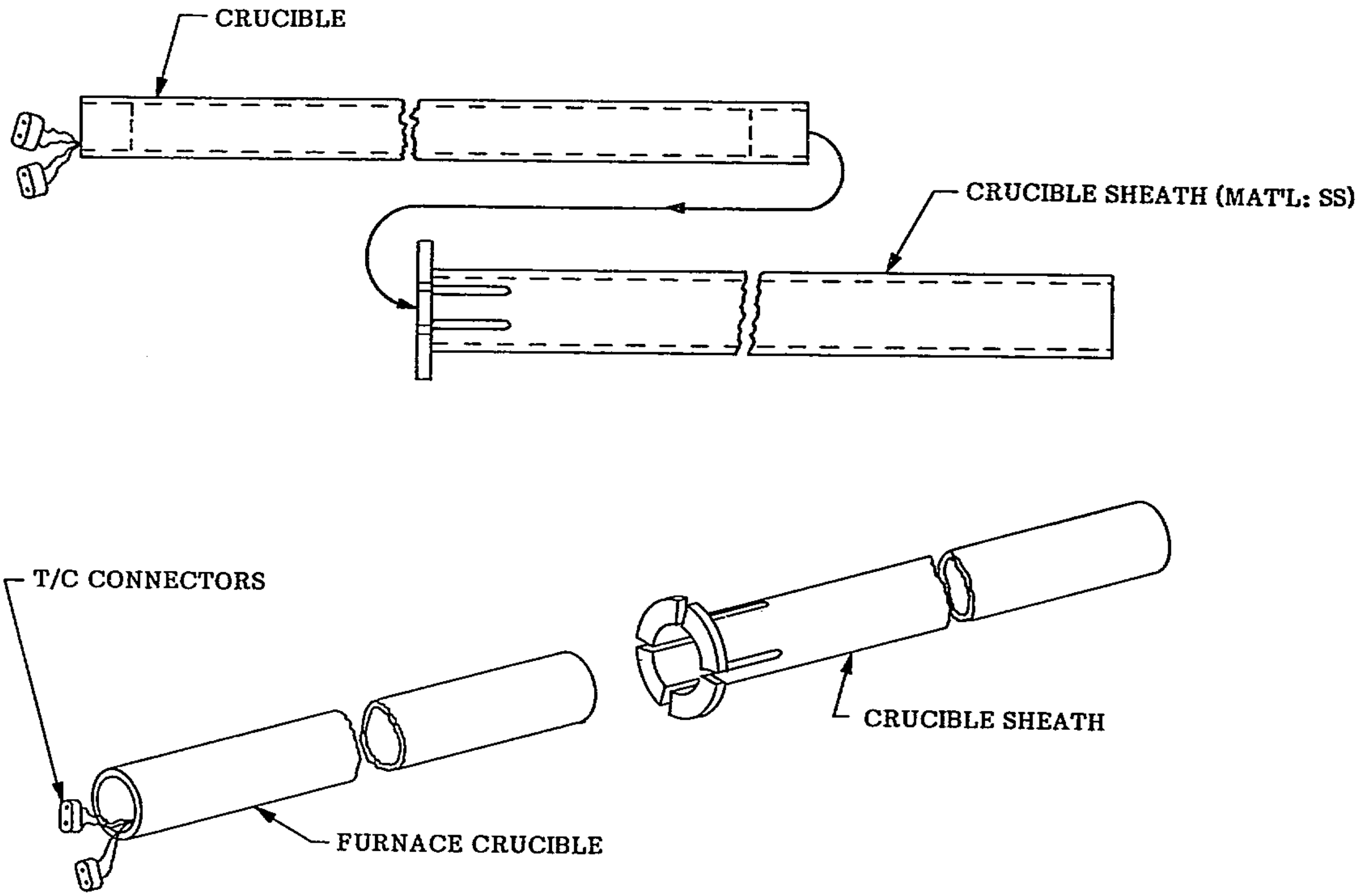
None of the NASA/MSFC ADSF systems currently permit sample exchanges during flight. It is concluded that modifications to any of the ADSF's to permit sample exchanges may be possible, but not insignificant. Modifications would include revisions to the ADSF system upper and lower base plates, modification to the EAC cover, and revision to electronics package, including the data recording equipment.

a. Existing ADSF systems would require major changes to both the upper and lower base plates to incorporate crucible positioning devices (such as those shown in Figure A.3).

b. New ADSF system designs, such as the NASA/MSFC AADSF, should consider the incorporation of manual sample exchange capability.

c. Reprogramming of the ADSF system electronics would be required to permit restarting of the furnace operating sequences.

d. Data recording capabilities would require additional storage for the requested furnace operations.



NOTE: THE PURPOSE OF THE CRUCIBLE SHEATH IS TO PROTECT CRUCIBLE DURING HANDLING & SAMPLE EXCHANGE.

FIGURE A.1 <u>CRUCIBLE AND CRUCIBLE SHEATH FOR MANUAL EXCHANGE</u>

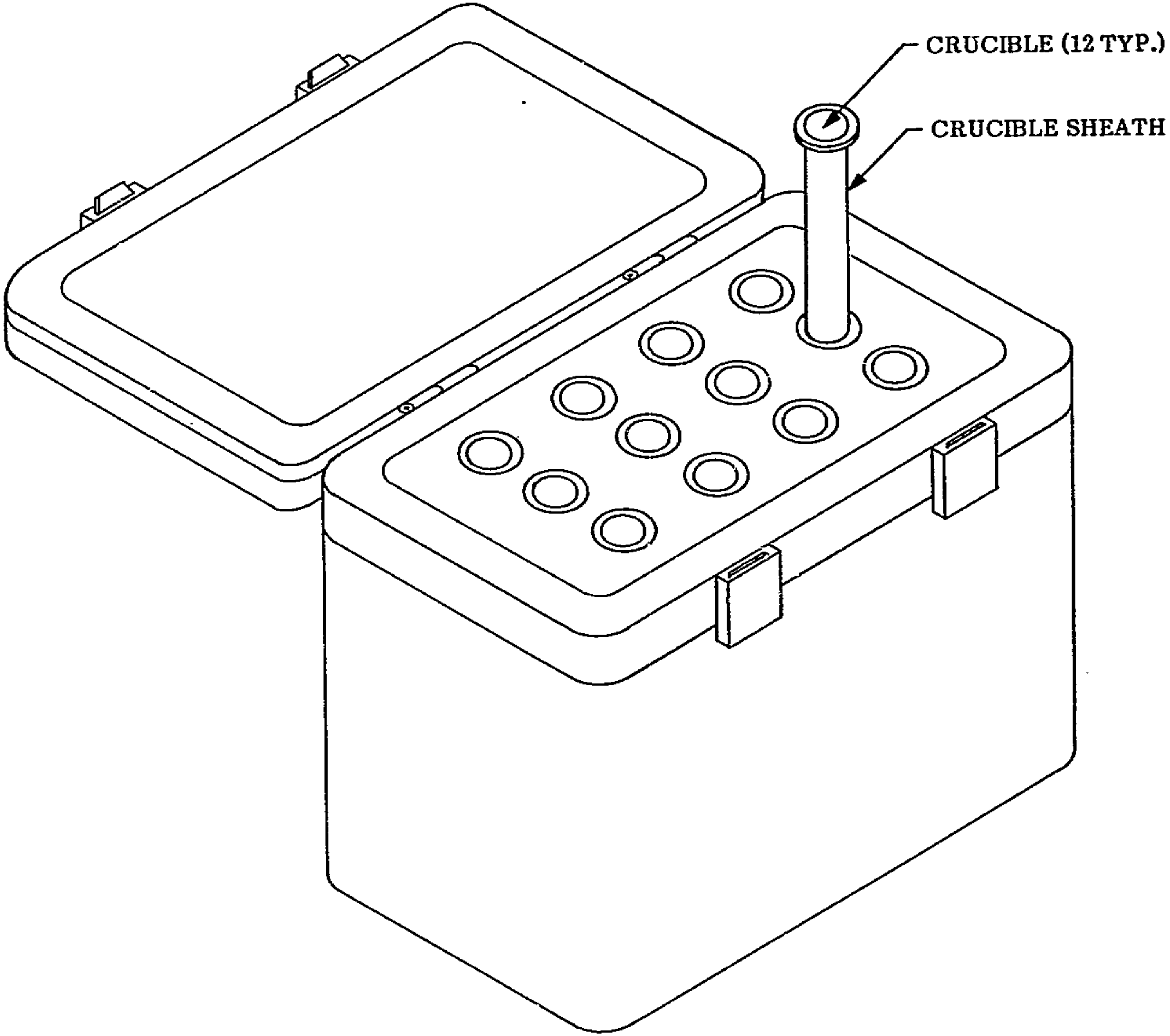


FIGURE A.2. CRUCIBLE CARRYING CASE

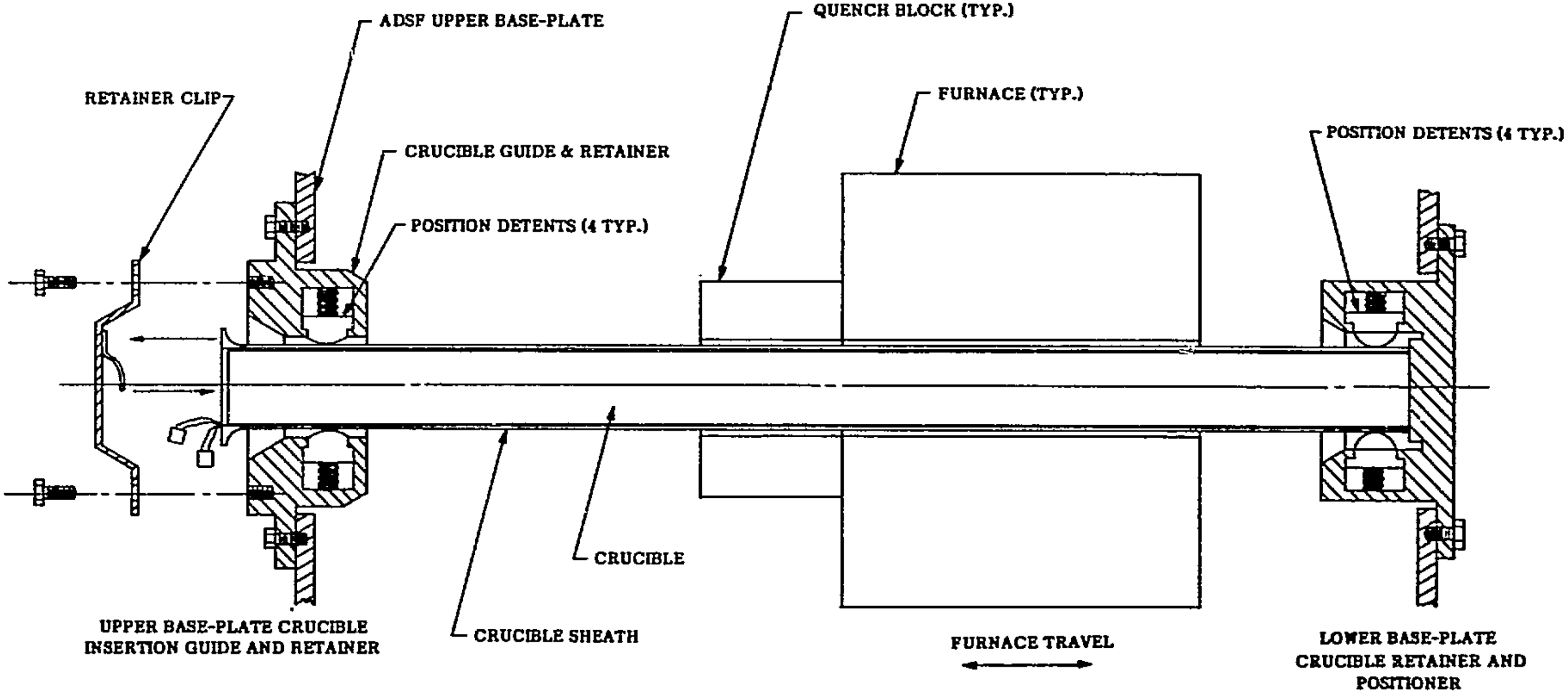


FIGURE A.3 CONCEPT FOR MANUAL CRUCIBLE EXCHANGE DURING FLIGHT