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Design/Use of the Remotely Operated Bakeout Box Shutter (ROBBS)

Brian P. Ottens, NASA Goddard Space Flight Center

ABSTRACT

A thermal vacuum box bakeout and certification allows orbital payloads to be cleaned and certified when the background TQCM measurements (a measure of how much molecular contamination is on a payload or chamber) are unacceptable or unmanageable in the standard thermal vacuum chamber.

The box bakeout procedure is usually performed in 4 steps: bakeout the box, certify the box, bake out the payload, and finally certify the payload. In the procedure's current setup, the contaminant conduction hole ("lid") is initially open and a vacuum chamber break must occur between the bakeout and certification phases to close the box from the vacuum chamber. This exposure is necessary to allow the outgassed contaminants to escape the box's volume rapidly during bakeout phase, but payload certification isn't usually performed while the lid is still open, because it exposes the payload, TQCM, and box volume to chamber contaminants.

The Remotely Operated Bakeout Box Shutter (ROBBS) is a new facility design and will allow the remote closure of the contamination hole while the chamber is still under vacuum, and with little or no time to do so.

KEYWORDS

Space Simulation, Box Bakeout, Thermal Vacuum, Test Engineering, Contamination Engineering, Robotics, NASA Goddard Space Flight Center, Facilities Engineering, Mechanical Engineering Design

INTRODUCTION

With the increasing schedule, financial, and craftsmanship pressures of current spacecraft design and manufacturing, the final stages, most notably integration and testing (I&T), often receive an equal or greater amount of responsibility for meeting these targets. As a result, an increased demand for efficient, economical testing has arisen; and when results focus on customer satisfaction, I&T facilities are looking for multiple ways to reduce operating costs and process time. The Remotely Operated Bakeout Box Shutter (ROBBS) is a new facility design that will help Goddard Space Flight Center reduce the time and resources required to execute a box bakeout.

BACKGROUND

Because optical instruments aboard earth and space science observatories are rapidly increasing in sensitivity and complexity, the need for effective, controlled, timely, and economical molecular bakeouts becomes an increasingly significant factor for mission success. The ability to eliminate unnecessary pumpdowns, chamber breaks, and obstacles in thermal vacuum may accumulate for an enormous reduction in time, labor, and economic resources; and it is the continuous goal of the testing facility to insure that bakeouts are as quick, cost-effective, and efficient as possible.

However, the ability to keep cost and time schedules should not jeopardize the cleanliness, safety, or integrity of a bakeout; and one must carefully plan these factors before adding new facility equipment. Factors such as reactivity, predictiblity, and reliability must all be considered before approving a design for implementation.

AEROSPACE CONTAMINATION

A contaminant is defined as any foreign material that causes a degradation in a system intolerant of its presence, and optical systems are especially sensitive to molecular contamination because it decreases reflectivity, increases absorptivity, and reduces transmission (Thomson, 1997). All three of these properties are very important and must be carefully controlled when designing optical and solar array systems, especially in the ultra-violet (UV) spectrum. In addition, optical surfaces are often the highest contaminated areas in an instrument because the surface's low temperature increases the likelihood of condensation, and UV exposure affixes these residues to a surface through a process known as photopolymerization (Arnold and Hall, 1996).

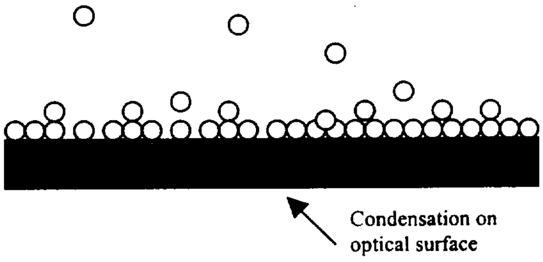

Figure 1 – Contamination of an optical surface

In the aerospace industry, most molecular contamination occurs from one of two sources:

- Volatile organics within the bulk of polymers diffusing out under vacuum conditions, or
- Surface residues deposited during handling or integration (Thomson, 1997).

These films are often composed of hydrocarbons, esters, and silicones (Keski-Kuha, 1997), and the thermal vacuum bakeout is one of the most common methods of controlling contamination in the aerospace industry (Muscari, 1996) primarily because of its likelihood of inducing material outgassing before launch (Barengoltz, 1997).

THE GSFC BOX BAKEOUT PROCEDURE

Approximately 6 years ago, the Space Simulation Section and the Contamination Engineering Section at Goddard Space Flight Center (GSFC) jointly launched a procedure published by Kays and Mahone (1986) to measure the partial pressure of a condensable product outgassing from a test item inside a space simulation chamber. This method would be crucial in measuring and achieving the 1Hz/hr outgassing criteria for many Hubble Space Telescope (HST) instruments.

The method published by Kays and Mahone in 1986 involved placing an isothermal box inside the vacuum chamber, placing the test article inside the box, pumping down to the specified pressure, and taking the necessary TQCM measurements. The box would have a small gas conduction hole for contaminants to escape, and the TQCM would directly obstruct the conduction hole so that condensable molecules would easily contact and condense on the TQCM face. Because the Kays and Mahone method included a box along with the standard test equipment, in many GSFC documents the procedure became known as a "*box bakeout.*"

Currently, the Space Simulation Section at GSFC usually performs a box bakeout in 4 steps: bakeout the box, certify the box, bake out the payload, and certify the payload. The bakeout phases are executed to allow molecular contaminants to quickly evaporate and be removed through the vacuum pump, and the certification phases are executed to provide an accurate TQCM measurement of how contaminated a payload actually is.

Bakeout of the box is usually accomplished while the box is between 80-100°C, the box lid is open, and the TQCM and chamber environment are cold.

Certification of the box is usually performed while the TQCM and chamber environment are cold, the box is at a pre-defined temperature, and the box lid is closed.

During bakeout phase, the combination of these conditions allow molecular contaminants to escape the warm box through the lid and conduction hole where they easily condense in the chamber environment or get pumped from the system.

However, during certification phase, the conditions allow contaminants to escape the box's volume only through the small conduction hole and easily condense on the TQCM, thereby accurately measuring the amount of contaminants released from inside the box.

TQCM measurements ("TQCM counts") are constantly recorded and monitored for attainment of the designated background level, and are often referenced in future steps as "the background." Knowing exactly what TQCM measurement was taken before inserting the payload allows a contamination engineer to subtract those TQCM counts from the TQCM measurements taken while the payload was present and obtain a close approximation of how much contamination can be attributed to the payload.

The third phase, payload bakeout, begins when the bakeout article is placed inside the certified box, and a similar procedure to box bakeout is performed. The bakeout phase is responsible for cleaning and inducing as much outgassing as possible on the orbital payload. The chamber environment and TQCM are still cold to condense the floating molecules, and the box is open and warm to allow contaminants to escape quickly and easily. As in the previous step, TQCM measurements are monitored and recorded for attainment of the pre-determined level, oftentimes referencing a measurement slightly above the last recorded level from box certification phase.

The fourth and final step of a box bakeout is payload certification. Payload certification provides a measurement of how clean the payload and box environment are, and TQCM counts taken during the box certification phase are subtracted from TQCM counts taken during this phase to approximate the maximum number of counts contributed to the reading by the payload. During payload certification phase, the chamber and TQCM are cold to condense floating molecules, and the box is warm and closed to obtain an accurate measure of how quickly the payload is outgassing.

Prior to the implementation of ROBBS, a chamber break was necessary between the bakeout and certification phases, simply to close the box from chamber contamination exposure. This chamber break would add approximately 4-6 hours to the entire procedure, but with the implementation of ROBBS, chamber exposure is remotely controlled via a motor and door and can be operated while the system is at any temperature, any pressure, and any contamination criteria.

ROBBS also allows contamination engineers to quickly and repeatedly change the box status from open to closed, and vice versa. This addition is especially useful in instances when the payload outgassing rate is too high to meet payload certification requirements within a reasonable length of time, and additional baking-out is necessary. It is also convenient when a contamination engineer estimates that a box or hardware will not need a bakeout to meet certification criteria, and he/she can jump directly to certification phase, thereby reducing the costs and time necessary to bakeout the payload.

Another adaptation of ROBBS may allow it to be used on the "capton tent" arrangement currently used in some instances. This option must be further investigated before commenting on its effectiveness, but the author's initial thoughts indicate something may be accommodated.

LINEAR AND STEPPER MOTORS

Like rotary motors, linear motors use the same principles of magnetic induction to induce forces or moments on the target of their magnetic field. But unlike rotary motors, no mechanical linkages such as ballscrews are necessary because linear motors create pure translational motion, not rotational torque. One way of visualizing how the linear motor utilized for ROBBS is configured is to imagine unrolling the inductance coils from a rotational motor, as in figure 2.

The other unique characteristic of the ROBBS motor is that it is a stepper motor. A stepper motor (like a linear motor) operates on the same type of electromagnetic principles as a regular motor, but it contains special wiring or gears to control the exact position, speed, and acceleration of the system.

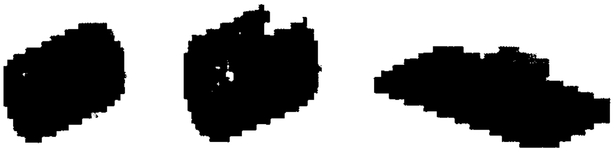

Figure 2 – Imaginary "unrolling" process to create a motor similar to the one used for ROBBS (courtesy www.normag.com)

Stepper motors are usually recognizable by their multiple leads (usually 5-6), and each one or two of these leads provides power to a separate coil inside the motor housing. Power to these leads are sequenced and pulsed such that one full sequence of pulses will provide exactly *1 step* (1.8°-90° in rotary motors) of movement.

THE ROBBS ELECTRO-MECHANICAL SYSTEM

The ROBBS electro-mechanical system consists of 3 basic elements: the *Normag* 0602 linear motor, the *Advanced Micro Systems (AMS)* DCB241 stepper motor controller, and the insulation/sheath hardware.

The Normag 0602 motor was selected for its ability to provide smooth, consistent, linear motion for the lowest cost and greatest compatibility to vacuum conditions.

The DCB-241 two-phase, bipolar motor controller was selected for its logic inputs, low cost, and ability to handle high power. The DCB-241 can handle 24-40VDC, with a max current of 1.2A, all of which fall within the specified requirements for the 0602.

Hardware was designed for maximum thermal stability, reliability, and economy; and temperature induced material strains were accounted for before fabrication.

A detailed drawing of the hardware, motor specifications, and DCB-241 features can be found in appendix 2.

TEST SETUP

For validation and confirmation of the ROBBS system, the following method was employed:

- Select GSFC space simulation chamber 238 to perform the procedure (chamber specifications listed in appendix 3)
- Select bakeout box #01 to mount the ROBBS system
- Run the box bakeout and collect TQCM and cold finger data.

Though ROBBS will be operated in both certification (figure 3) and bakeout modes (figure 4), only 1 mode of operation will be tested for validation. This mode will be a transition from closed shutter to open shutter under a constant temperature, pressure, and contaminant loading criteria. These conditions were as follows:

- Chamber environment: +80°C,
- Box Temperature: +80°C,
- TQCM Temperature: -20°C.

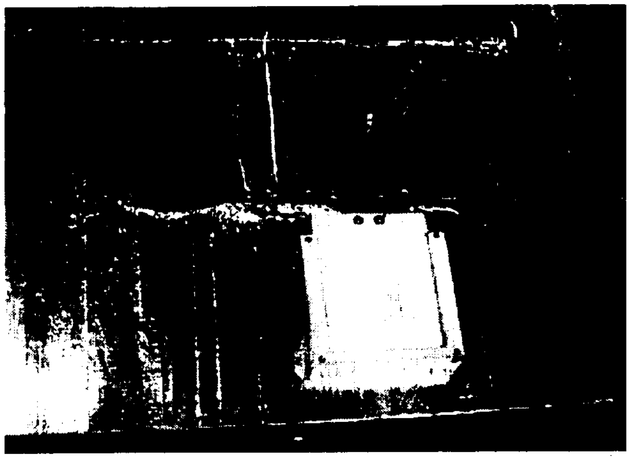

Figure 3 – ROBBS in certification mode during testing.

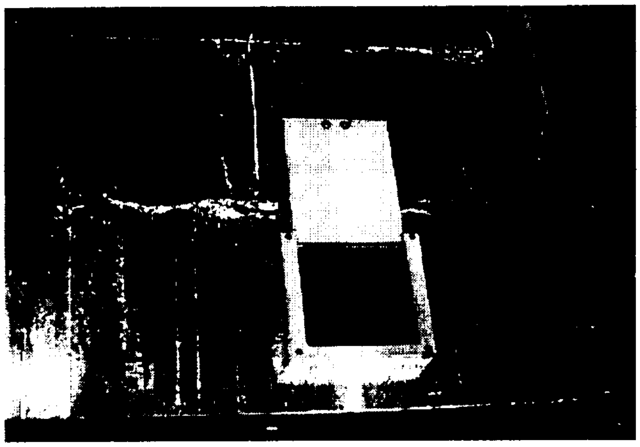

Figure 4 – ROBBS in bakeout mode during testing.

RESULTS

After the procedure in the previous section was performed, the box shutter opened according to plan. Limited amounts of TQCM data was collected because the payload was outgassing at such a high rate, but the box TQCM was able to sustain an acceptable temperature (-20°C) for small intervals of time shown in appendix 4.

When viewing the data in appendix 4, one can see that the TQCM deltas were very erratic during the closed phases, but somewhat more stable during the open phases. When viewing the delta TQCM frequencies during the open phase, one can see the gradual reduction of contaminants from the box evidenced by the reduction of TQCM deltas. Unfortunately, it is unclear from the comparison to data from the closed phase what magnitude this reduction was aided.

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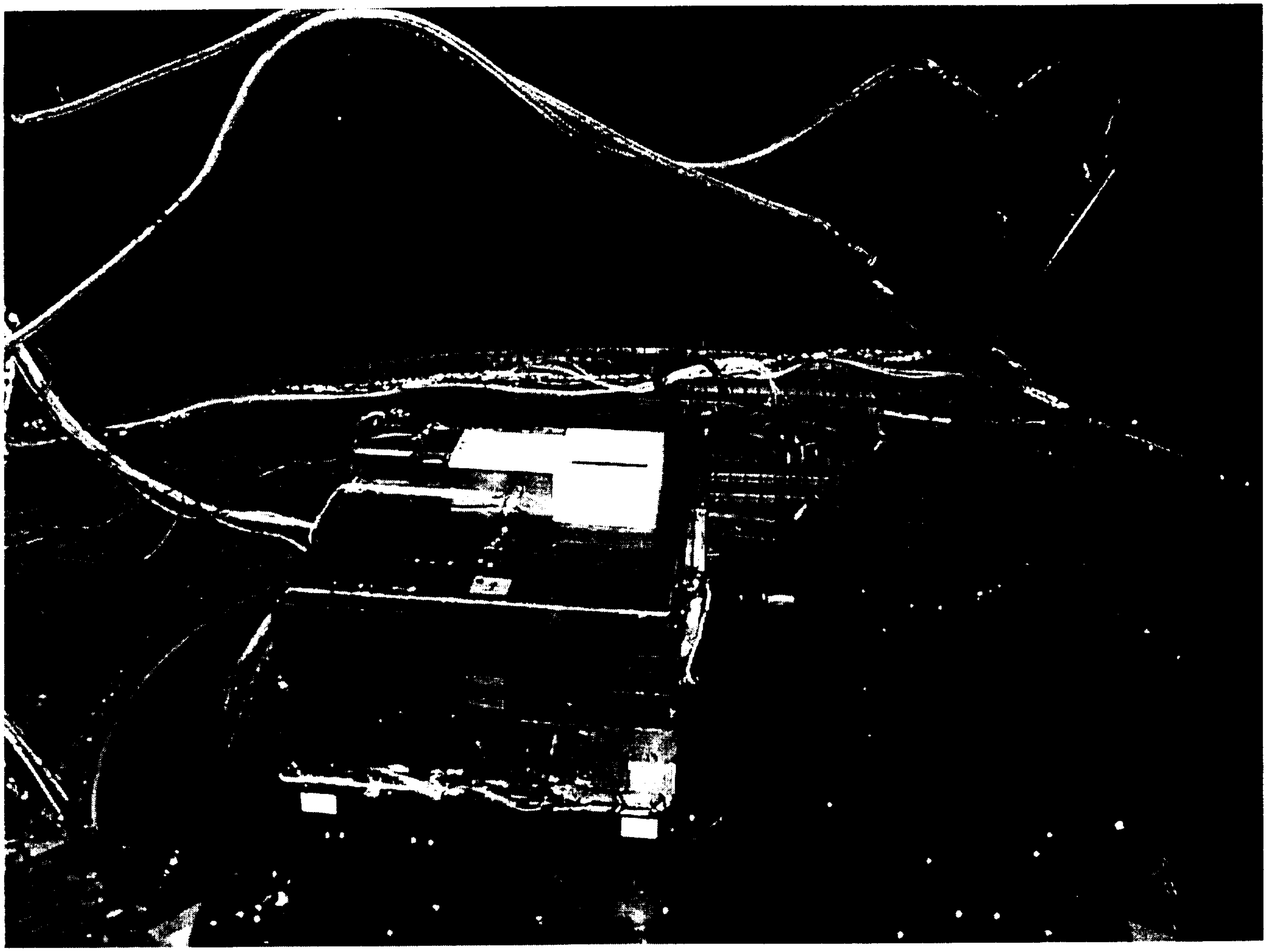
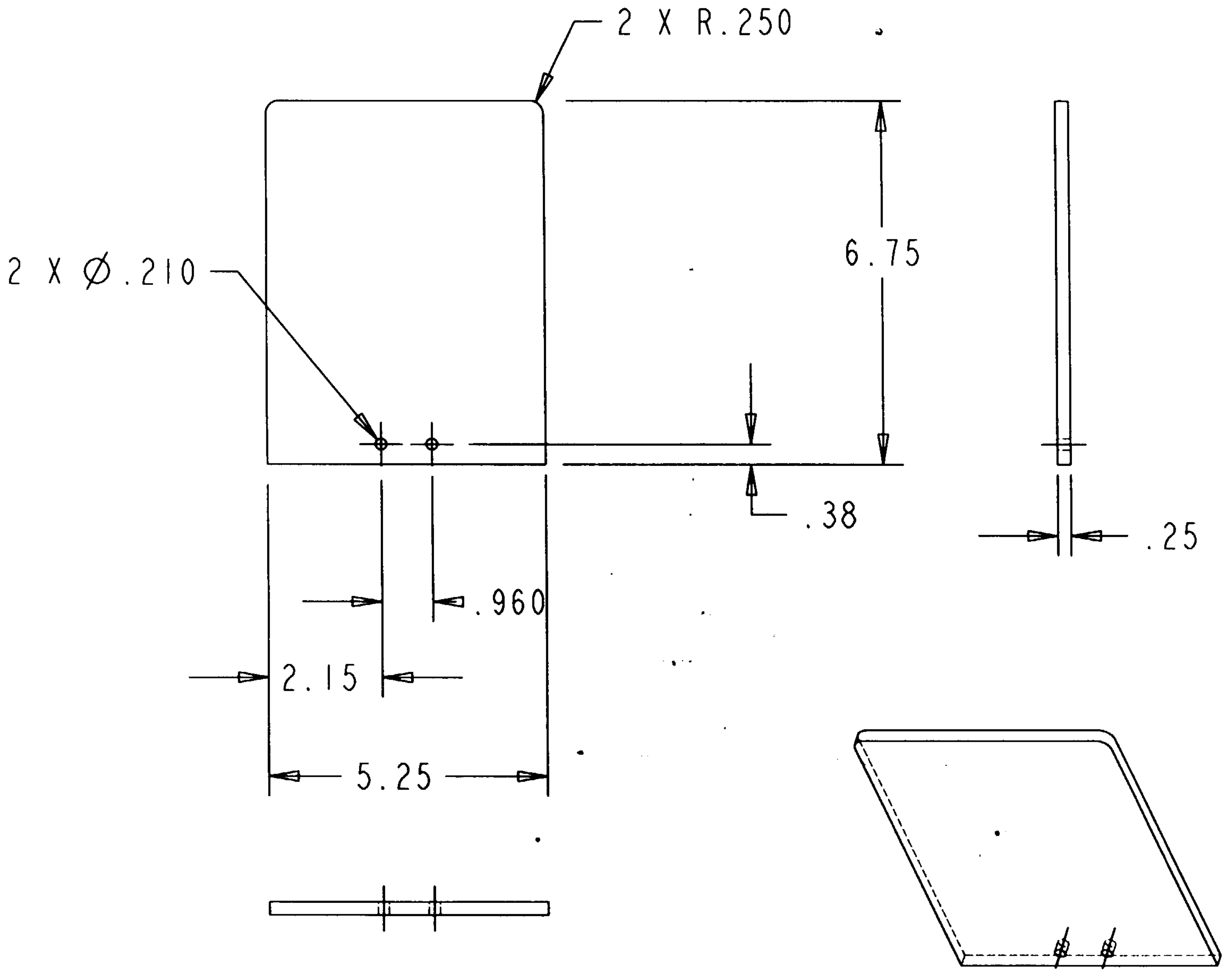
Appendix 1



Appendix 2



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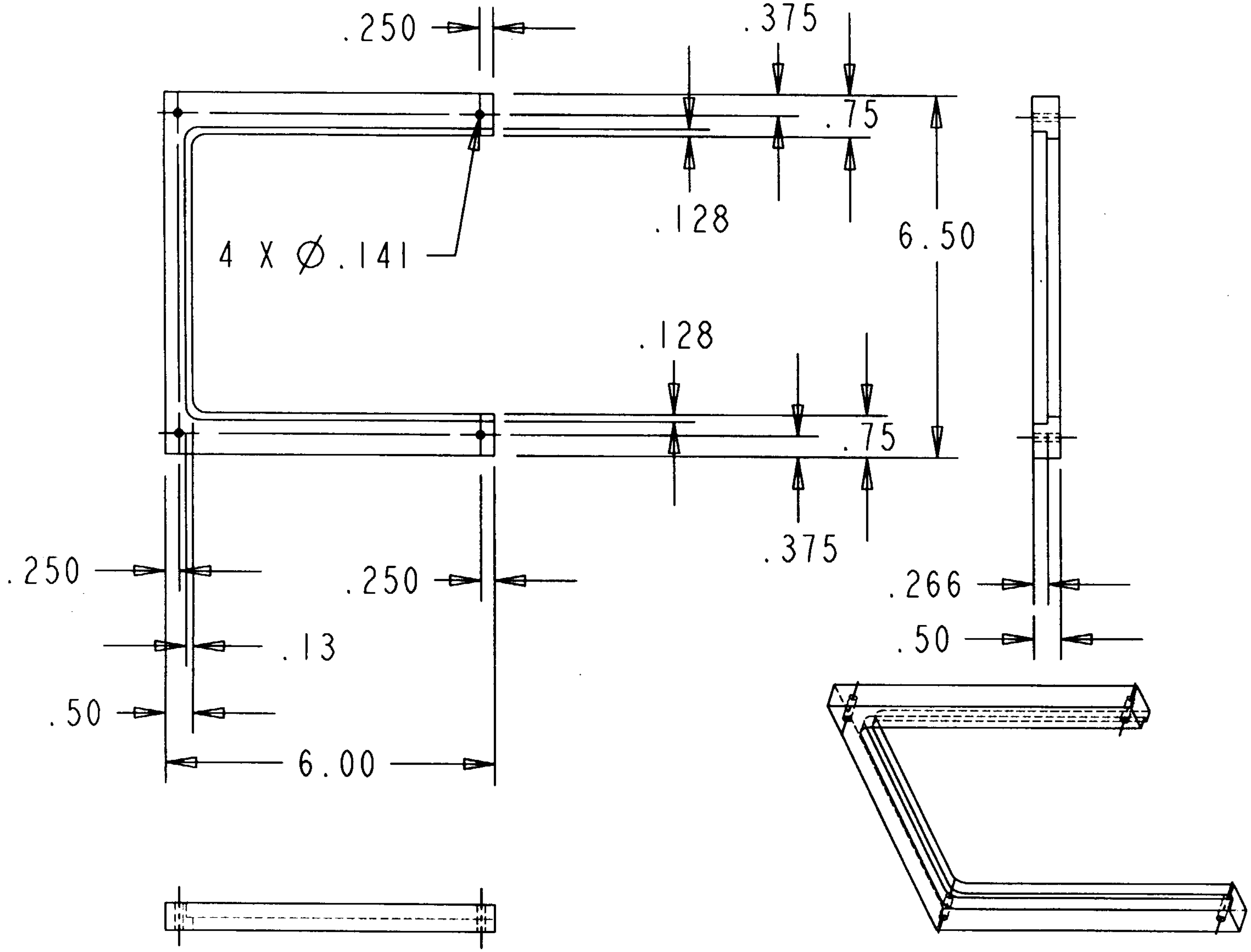

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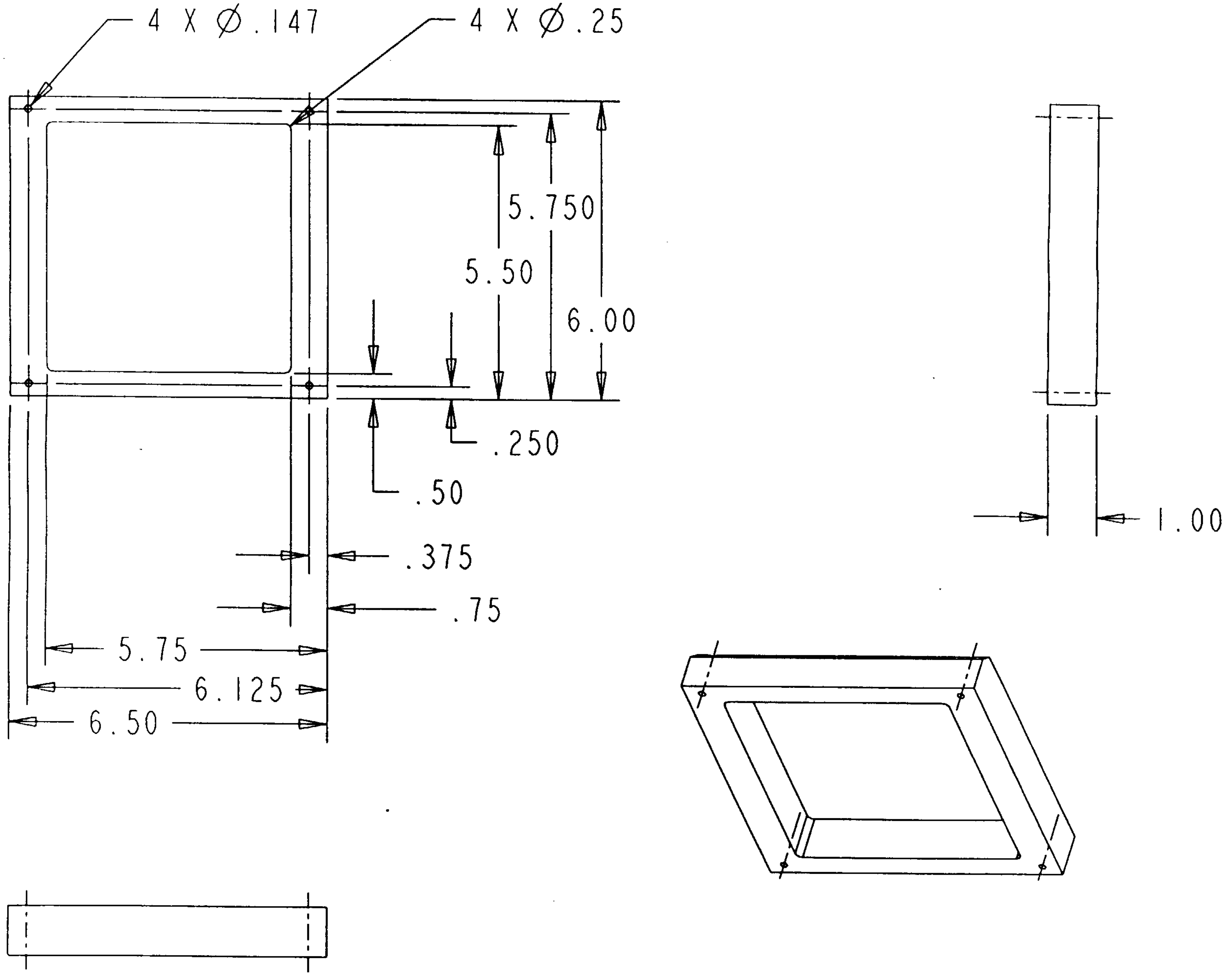

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Motion Control Division®
ADVANCED MICRO SYSTEMS, INC.
2 Townsend West, Nashua, NH 03063-1277 603-882-1447 FAX 603-881-7600

DCB-241

COMMANDS

ASCII	Description
ESC	Abort/Terminate
@	Soft Stop
^C	Reset
+	Index in Plus Direction
-	Index in Minus Direction
[	Read NV Memory
]	Read Limits, Hardware
\	Write to NV Memory
^	Read Moving Status
A	Port Read/Write (optional)
B	Jog Speed, Slow/Fast (optional)
C	Restore/Initialize
D	Divide Step Rates
E	Enable Auto Power Down
F	Find Home (SPS)
G	GO from Address
I	Initial Velocity (SPS)
J	Jump to Address
K	Ramp Slope
L	Loop on Port (optional)
M	Move at a Constant Speed
O	Set Origin
P	Program Mode
Q	Query Program
R	Index to Target Position
S	Store Parameters
T	Set Trip Point
V	Slew Velocity (SPS)
W	Wait "N" Milliseconds
X	Examine Parameters
Z	Display Position

PROGRAMS

Using a host computer or dumb terminal, programs can be stored in non-volatile memory (2k bytes) and initiated via the serial communication port, the "GO" input or auto-power-up.

INPUT SIGNALS

Input signals include: Home, Limit A & B, Go, Soft Stop, and Ground. All signals have a 5 volt range.

OPTIONAL I.O.

Three optional input ports are available that can test and branch to multiple motion subroutines. Two programmable outputs are also available to drive solid state relays and other devices. A separate "TRIP" function provides automatic program branching when a specified position is passed.

SPECIFICATIONS

Electrical

Output Current (Peak)	1.2 Amps
Chopping Frequency	20kHz
Input Voltage	+24 to 40Vdc
Motor Step Resolution	Half Step
Non-Volatile Memory	2k Bytes
Position Counter	±8,388,607
Baud Rate	9600 BPS

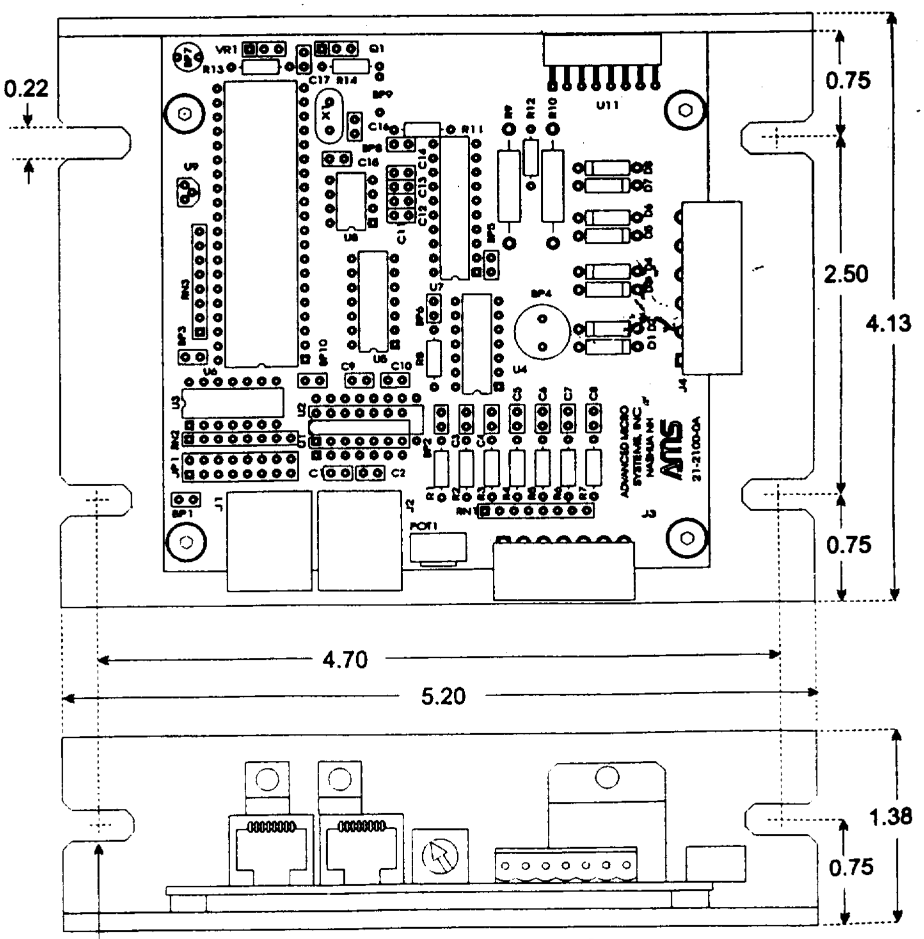
Thermal

Operating Temperature	0 to +50° C
Storage Temperature	-40 to +125° C
Plate Temperature (max)	+70° C

Mechanical

Size	4.13 x 5.20 x 1.38 In.
Weight	8 Oz.

MOUNTING DIMENSIONS



SLOTS ACCOMODATE 10-32 MOUNTING HARDWARE

NORMAG

NORTHERN MAGNETICS INC.
25026 Anza Drive • Santa Clarita, CA 91355 • USA
(805) 257-0216 • FAX (805) 257-2037

SINGLE AXIS HIGH PERFORMANCE LINEAR STEPPER MOTORS

GENERAL DESCRIPTION:

NORMAG high performance linear stepper motors are capable of high position accuracies without a position feedback loop.

The moving electromagnetic primary or "forcer" travels over a grooved .040 inch pitch stationary secondary or "platen".

The airgap between these parts is maintained by integral airbearings (=> no mechanical contact) except for the smallest model which rides on ball bearings.

Lateral guidance is achieved by either ball bearings, guide rails or air-bearings.

Motion is achieved by powering the forcer with a two [redacted] micro stepping driver. Each pulse causes the forcer to move 1 microstep and the frequency at which these microsteps are generated determines the velocity of the forcer. The fullstep is .010 inch for two phase, .005 inch for four phase forcers.

The focers can be modified to meet the customers mounting requirements.

The platens are available in different lengths to meet the customers stroke requirements. They can be mounted on steel or aluminum, tubes and bars as well as steel I-Beams.

ADVANTAGES:

- High reliability, long life.
- No mechanical linkages => no backlash.
- High acceleration.
- Rapid response.
- Smooth and reversible travel.
- Travel lengths from 1" on up (unlimited).
- Higher accuracies with position feedback.
- Velocities up to 100 in/sec.

OPTIONS:

- Two or four phase operation.
- Lateral guide bearing selection.
- X-Y gantry systems.
- Custom platens.
- Any customer required modifications.

APPLICATIONS:

- High speed positioning and velocity control.
- Pick and Place equipment.
- PCB assembly and inspection.
- Automated inspection system.
- Laser and water jet cutters.
- Positioning tables.
- Robotics.
- Automated sewing systems.
- Parts transfer systems.
- Many others.

MOTOR SPECIFICATIONS:

TABLE 1:

MODEL		0602-2	0604-2	1302-2	1304-4	1304-2	2002-2
Number of Phases		2	2	2	2	4	2
Static Force	lbs	2.0	4.0	5.0	10.0	10.0	8.0
Force @ 40 ips	lbs	1.0	2.0	3.5	7.0	7.0	6.0
Resistance/Coil	ohms	1.5	0.9	2.2	1.1	2.2	3.0
Inductance/Coil	mh	0.8	0.5	1.3	0.65	1.3	6.6
Amps/Phase	amps	1.5	3.0	2.0	4.0	2.0	2.0
Airgap	inch	0.0015	0.0015	0.0015	0.0008	0.0008	0.0008
Air Pressure	psi	—	—	—	60	60	60
Airflow	scfh	—	—	—	30	30	30
Max. Forcer Temp	C	110	110	110	110	110	110
Weight	lbs	0.4	—	0.8	1.1	1.1	1.0
Repeatability*	inch	±0.0004	±0.0004	±0.0004	±0.0004	±0.0004	±0.0004
Resolution*	inch	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cyclic error	inch	±0.0002	±0.0002	±0.0002	±0.0015	±0.0015	±0.0015
Bearing Type		BALL	BALL	BALL	AIR	AIR	AIR
SCFM		N/A	N/A	N/A	2.5	2.5	3.5

TABLE 2:

MODEL		2004-2	2004-4	2504-2	2504-4	2508-2	2508-4
Number of Phases		2	4	2	4	2	4
Static Force	lbs	20.0	20.0	25.0	25.0	50.0	50.0
Force @ 40 ips	lbs	14.0	14.0	17.5	17.5	35.0	35.0
Resistance/Phase	ohms	1.5	3.0	1.8	3.6	0.9	1.8
Inductance/Phase	mh	1.03	6.6	4.0	8.0	2.0	4.0
Amps/Phase	amps	4.0	2.0	4.0	2.0	8.0	4.0
Airgap	inch	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Air Pressure	psi	80	80	80	80	80	80
Airflow	scfh	40	40	60	60	60	60
Max. Forcer Temp	C	110	110	110	110	110	110
Weight	lbs	1.3	1.3	1.5	1.5	2.8	2.8
Repeatability*	inch	±0.0004	±0.0004	±0.0004	±0.0004	±0.0004	±0.0004
Resolution*	inch	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cyclic error	inch	±0.0015	±0.0015	±0.0015	±0.0015	±0.0015	±0.0015
Bearing Type		AIR	AIR	AIR	AIR	AIR	AIR
SCFM		3.5	3.5	3.5	3.5	3.5	3.5

*dependent on drive electronics and system implementation.

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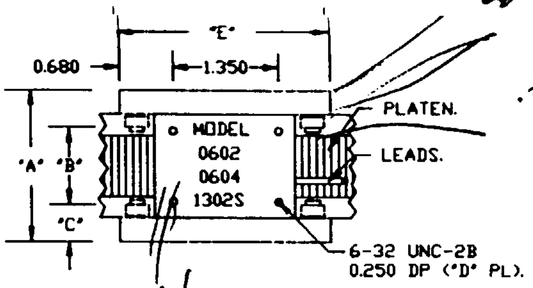

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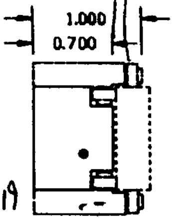

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FORCER			
	MODEL		
	0602	0604	1302S
'A'	1.920	1.920	2.660
'B'	0000	0000	1.420
'C'	0.950	0.950	0.620
'D'	2.000	2.000	4.000
'E'	2.710	4.620	2.850

L .27
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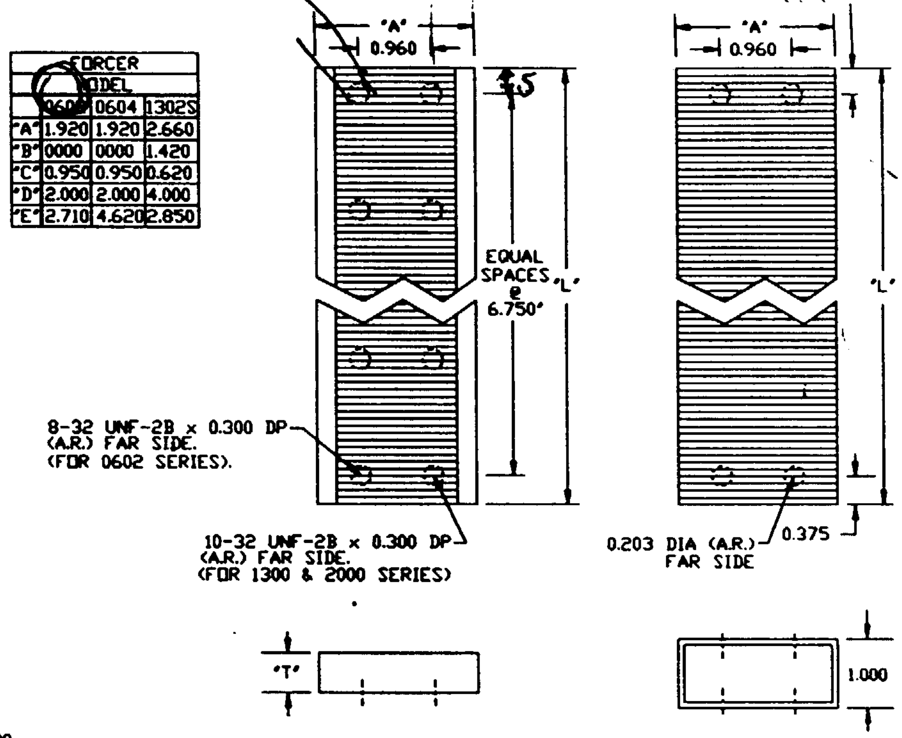
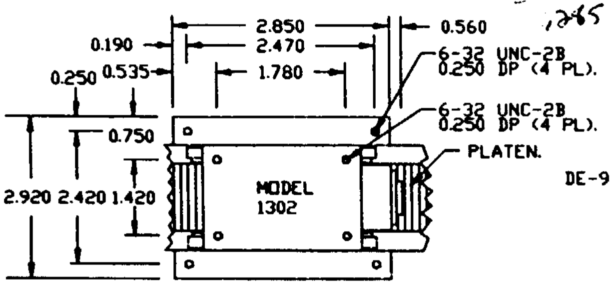
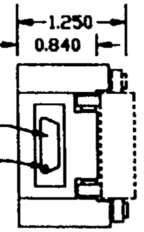
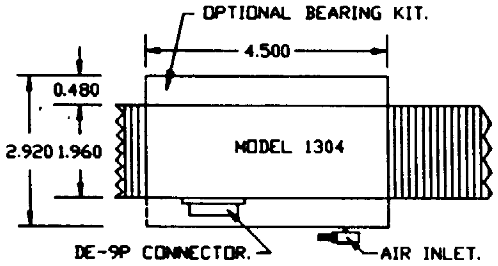
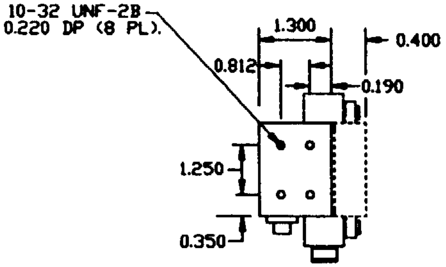
.107







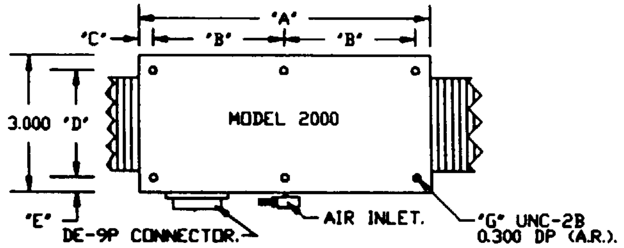


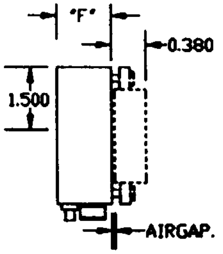


SOLID PLATEN				
FOR 0602 SERIES				
MODEL	'L'	'A'	'T'	WT #
225-669-11	58.0	1.21	0.350	6.1
225-669-02	29.0	1.21	0.350	3.1
225-669-02	14.5	1.21	0.350	1.5
FOR 1300 SERIES				
225-684-01	58.0	1.96	0.468	14.5
225-684-02	29.0	1.96	0.468	7.3
225-684-08	14.5	1.96	0.468	3.7

FOR 2000 SERIES				
225-947-01	96.0	1.96	0.468	24.0
225-947-02	72.0	1.96	0.468	18.0
225-947-03	60.0	1.96	0.468	15.0
225-947-04	36.0	1.96	0.468	9.0
225-947-05	18.0	1.96	0.468	5.5

FOR 2000 SERIES			
225-948-01	60.0	1.96	10.0
225-948-02	36.0	1.96	5.3
225-948-03	18.0	1.96	2.9





FORCER		
	MODEL	
	2002	2004
'A'	2.850	4.630
'B'	1.780	2.160
'C'	0.540	0.150
'D'	1.420	2.700
'E'	0.780	0.150
'F'	0.950	1.120
'G'	6-32	8-32

NORMAG "Manufacturer of linear motors, actuators and steppers."

NORTHERN MAGNETICS INC.

25026 Anza Drive • Santa Clarita, CA 91355 • USA
(805) 257-0216 • FAX (805) 257-2037

DIMENSIONS ARE FOR REFERENCE ONLY

Appendix 3

3.6.3.4 3.7M X 4.6M (12' X 15') CRYOPUMPED VACUUM CHAMBER (FACILITY 238)

DESCRIPTION: This vertical facility is a large, cylindrical thermal vacuum chamber which is used for thermal vacuum and thermal balance testing, and baking out spacecraft hardware. Test articles are normally loaded through the top of the chamber using the building crane; however, small payloads can be transported through the personnel entrance. Ports for electrical feedthroughs, liquid/gas feedthroughs, and viewing are located around the perimeter of the chamber. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

MODE OF OPERATION: With the chamber dome rolled back, the overhead crane is used to lower the payload onto the support fixture. In most cases, special fixturing must be designed due to the uniqueness of the test article support system. Once installed, the payload is instrumented and connected to the ground support equipment via feedthroughs. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Initial chamber evacuation is provided by two rotary piston mechanical pumps, with four closed cycle cryopumps for high vacuum pumping. Each cryopump is isolated from the chamber by a sliding gate main valve to allow off-line cool down and regeneration.

PARAMETERS:

Test pressure:	<67 µpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-90°C to 90°C (-130°F to 194°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	1.8 x 10^4 lit (4,800 gal)/sec N_2 @ 133 µpa (10^{-6} torr)
Evacuation time:	Atm to 133 µpa (10^{-6} torr) in 2 hours

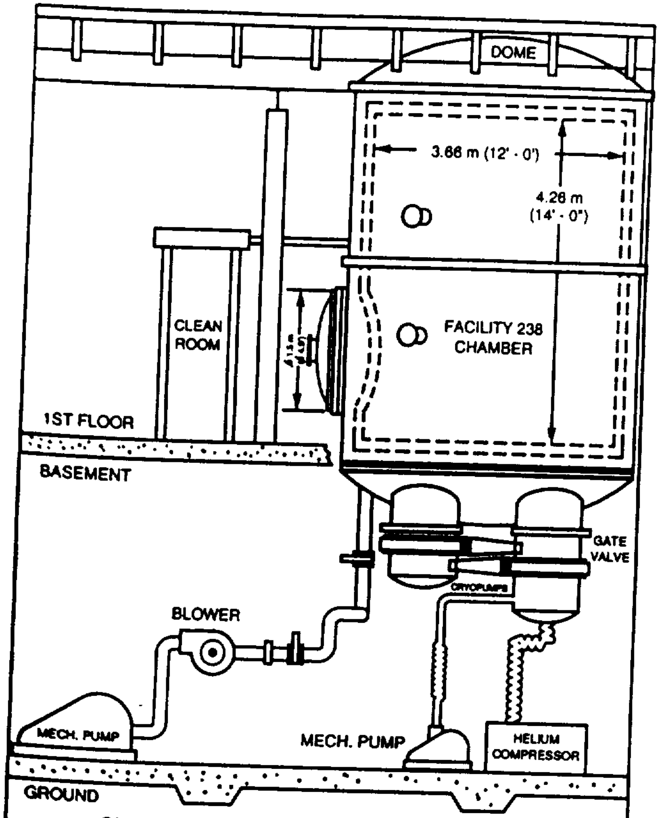
PHYSICAL CHARACTERISTICS:

Test volume:	3.4m D x 4.3m H (11'2" x 14'2")
Payload support:	Floor level - 1.2m (4') square platform Side wall - hard points at 1.8m and 3.7m (6' and 12') levels
Personnel door:	1.5m (5') diameter
Crane capacity:	4,536 Kg (5 ton)
Viewport dimensions:	23cm (9") diameter
Standard elec. feedthroughs:	36 - 37 pin connectors (RF feedthroughs available on request)

INTEGRAL INSTRUMENTATION:

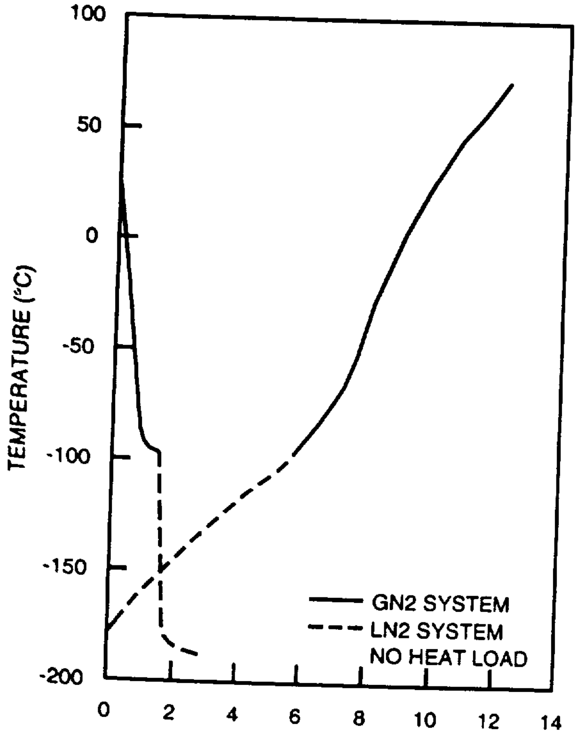
Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr) Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	300 thermocouple or thermistor channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



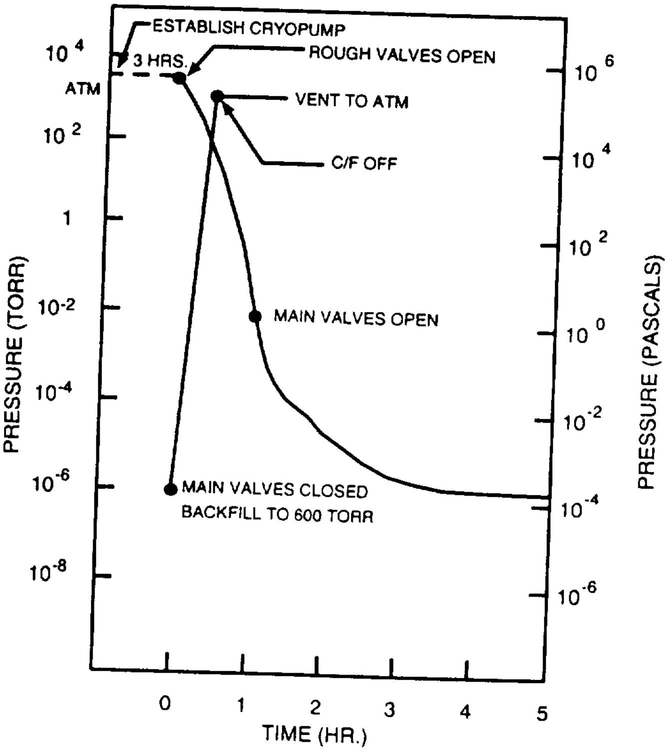
CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 238

CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE

A918.005



PRESSURE PARAMETERS

Appendix 4

Time (min)	TQCM Frequency	Delta TQCM Frequency	ROBBS Status	middle 12 minute averages for the delta frequency
0	17121.7	NA	Closed	
2	18054.9	933.2	Closed	
4	17985.6	-69.3	Closed	
6	18751.7	766.1	Closed	
8	18943	191.3	Closed	
10	19280.7	337.7	Closed	153.5167
12	18983.2	-297.5	Closed	
14	18685.5	-297.7	Closed	
16	18906.7	221.2	Closed	
18	19077.7	171	Closed	
20	19034.6	-43.1	Closed	
488	12516	NA	Open	
490	13106.1	590.1	Open	
492	13669.8	563.7	Open	487.2833
494	14179	509.2	Open	
496	14640.3	461.3	Open	
498	15064.3	424	Open	
500	15439.7	375.4	Open	
1378	5700.9	NA	Open	
1380	5941.3	240.4	Open	
1382	6189.5	248.2	Open	
1384	6442.3	252.8	Open	
1386	6689.8	247.5	Open	
1388	6934.4	244.6	Open	
1390	7181.1	246.7	Open	
1392	7428.2	247.1	Open	
1394	7672.1	243.9	Open	
1396	7914.3	242.2	Open	
1398	8157.3	243	Open	
1400	8399	241.7	Open	
1402	8637.4	238.4	Open	
1404	8874.9	237.5	Open	
1406	9112.3	237.4	Open	
1408	9347	234.7	Open	
1410	9578.3	231.3	Open	
1412	9809.9	231.6	Open	
1414	10039.9	230	Open	
1416	10265.4	225.5	Open	
1418	10489.6	224.2	Open	223.3667
1420	10713.7	224.1	Open	
1422	10932.9	219.2	Open	
1424	11150.1	217.2	Open	
1426	11366.7	216.6	Open	
1428	11576.8	210.1	Open	
1430	11787.9	211.1	Open	
1432	11995.4	207.5	Open	
1434	12198.6	203.2	Open	
1436	12399.3	200.7	Open	
1438	12599.5	200.2	Open	
1440	12793.1	193.6	Open	
1442	12983.4	190.3	Open	
1444	13172.8	189.4	Open	
1446	13356.7	183.9	Open	
1448	13535.6	178.9	Open	
1450	13714.8	179.2	Open	
1452	13888	173.2	Open	
1454	14054.9	166.9	Open	
1456	14219.2	164.3	Open	
1458	14381.9	162.7	Open	

TO: James Frost From Brian Ottens

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