ARA Projects 4810 and 5057

TWA Flight 800
1/4-Scale Fuel Tank Explosions Phase II
Fall 1998 and Spring 1999 Test Series

Final Report

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TABLE OF CONTENTS

Section **Page**

LIST OF APPENDICES

APPENDIX

LIST OF FIGURES

LIST OF TABLES

SECTION 1.0

INTRODUCTION

1.1 PROJECT MANAGEMENT AND PERSONNEL

The TWA Flight 800 1/4-scale fuel tank testing was a joint project performed by Applied Research Associates, Inc. (ARA) and the California Institute of Technology (Caltech). This report consolidates two test series. The first test series was completed in the Fall of 1998 (Tests 31-70), and the second series (Tests 71-79) during the Spring of 1999. Differences in the test series are noted throughout this document. This report documents ARA's effort.

Under ARA's and Caltech's management structure, the principal investigators have full responsibility for the overall project. These duties included technical performance, adherence to test scheduling, development and monitoring of budgets, administration, and program level interfacing with NTSB personnel. Mr. Larry Brown was the ARA principal investigator, while Dr. Joe Shepherd was the principal investigator for Caltech.

In a project of this scope and schedule, direct and timely communication between ARA/Caltech, the subcontractors, and the NTSB technical staff was essential. Dr. Merritt Birky and Dr. Vern Ellingstad were available for consultation for all of the test series and visited the test facility during this project to provide guidance and direction. Dr. Joseph Kolly was present and assisted during most of the heated jet fuel tests. Their input was important for the timely execution and successful conduction of the test series. Major issues that significantly affected the test schedule, budget, and technical quality were brought to the attention of the project managers and the appropriate NTSB personnel for resolution.

Other personnel who performed key roles in the success of this project were Mr. Tim Samaras, Mr. Mike Rictor, Mr. Bob Lynch, Mr. Peter Dzwilewski and Ms. Sheila Becker, all from ARA, and Dr. Chris Krok, Dr. Julian Lee and Mr. Pavel Svitek, all from Caltech. The above named personnel were instrumental in the design, fabrication, field preparations, testing, instrumentation, and data analysis. In addition, they supported the administration duties required of this contract.

The administration of this contract was important to the success of the overall project. Standard corporate labor and cost accounting procedures and tools were used. In addition, in order to track costs and procurements more closely, the ARA Rocky Mountain Division tracked costs locally and employed their purchase order system to ensure that timely deliveries and schedules were met.

The technical progress of this effort was monitored in several ways. In addition to the NTSB visits, project meetings with the team members in Colorado, informal discussions with ARA/Caltech, and internal ARA project meetings, the progress was also monitored by internal program reviews. Additionally, project efforts were documented in project logbooks. Technical quality was maintained both through the internal ARA/Caltech review process, as well as the comments and interaction of NTSB personnel. The final report and the internal documentation were reviewed and approved by the ARA Division Manager before the document was released. Mr. Peter Dzwilewski, Vice President of ARA and the Rocky Mountain Division Manager performed the Corporate review of the final report.

1.2 PROJECT PLAN

The elements of the project plan, along with the as-tested schedule, are given in Figure 1. This shows how the various activities fit together and how they were phased in time. The elements of the project plan were in a logical sequence of tasks that led to the successful accomplishment of the objectives of the "**1/4-Scale Fuel Tank Explosions**" program.

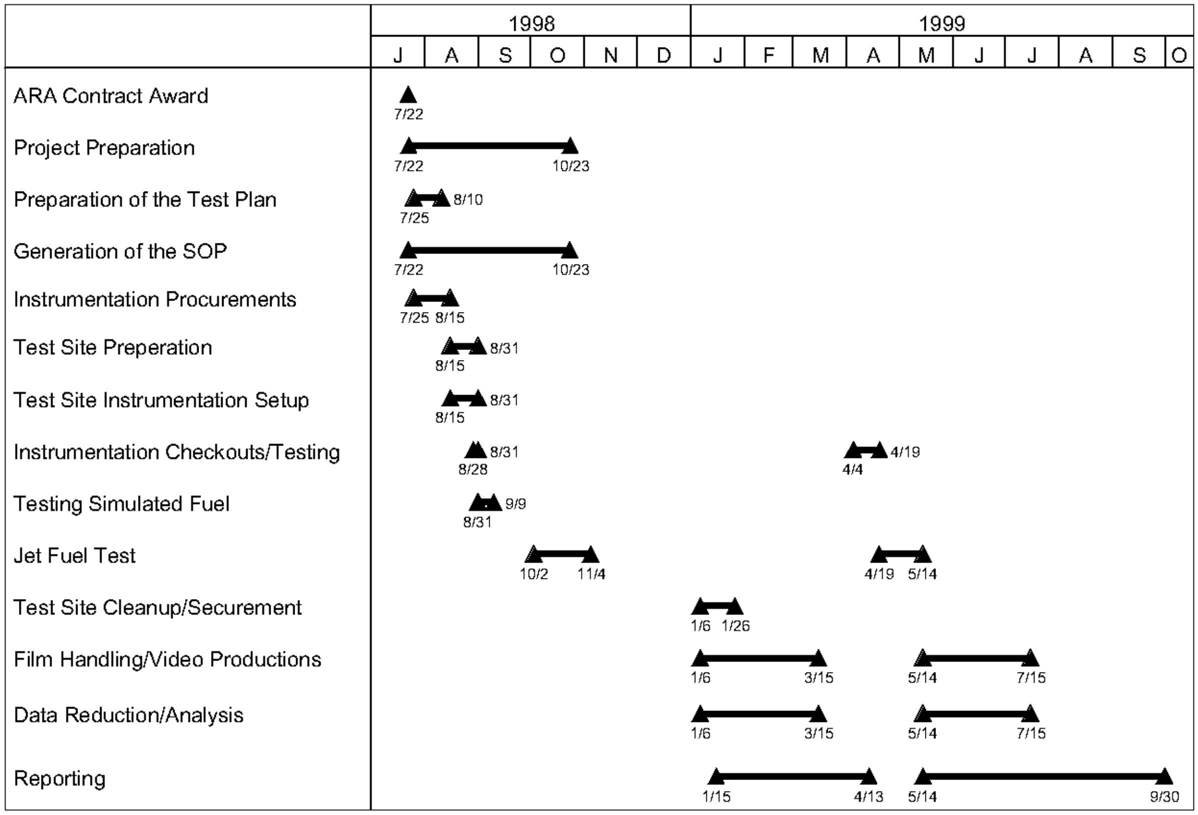


Figure 1. Project Plan for the Fuel/Air Explosive Testing

1.3 PROJECT PLAN ELEMENTS DISCUSSION

Project Preparation: Fielding preparations began immediately after award of the contract and included ordering the long lead time procurements for the tank fixture, optical, and instrumentation systems. The logistics required for this project were also planned during this time period.

Preparation of the Test Plans: Caltech provided the Test Plans at the beginning of each of the two test series.

Generation of the S.O.P. (Standard Operating Procedures): The S.O.P. was generated to address the operational and safety requirements for this test series. The S.O.P. format was comprehensive in detailing the general site operation and specific in addressing the gas vapor/fuel handling and timing-and-firing procedures and other test site issues. All site personnel were required to read and understand the S.O.P. prior to conducting this test program. Each test was conducted in strict accordance with these procedures to assure personnel/site safety and to maintain control of the test procedures.

Instrumentation Procurements: Procurement procedures were implemented for photographic supplies, storage medium, cabling/connectors, site power, and other hardware/software items required to implement the test program.

Test Site Preparations: The test fixture was prepared after being in storage for less than a year. Instrumentation was reinstalled, and the 1/4-scale tank plumbing hardware was reassembled.

Laboratory Photographic "Breadboard": Checkouts of photographic systems were performed during this phase of the project. Camera exposure checkouts and full-scale film runs were conducted in the ARA laboratories prior to field deployment.

Instrumentation Setup: The laboratory-checked instrumentation and photo-instrumentation systems were packed and transported to the ARA test facility for installation into the previously positioned bunkers and vans. Interconnecting cable terminations were completed for the control, firing, and instrumentation lines.

Checkouts/Testing: This task included the checkouts and functioning of all the control, firing, and instrumentation systems. Transducers and other sensors were field tested to assure adequate signal-to-noise ratios were achieved and functioned to ascertain calibration validity. Photographic systems were checked with "full-up" film runs to determine the accuracy of timing and verification of exposure values for the upcoming test series.

Testing: The testing program was conducted in two parts. The first part was the simulated fuel test series, which included some repeated tests from 1997. The second part was the heated jet fuel test series, which included the fabrication of the building, insulation, installation of the heaters and controllers, and checkouts. The testing was carried out at two different times. Tests 31 to 70 were completed in the Fall of 1998, and Tests 71 to 79 were completed in the Spring of 1999. The test matrices for the two series are shown in Tables 1 and 2.

Table 1. Fall 1998 Test Matrix

Test	Date	Partitions	Ignition Location	Temperature (°C)	Press (kPa)	Vented	Fuel	Comments
Replica Tests								
31	8/31/98	All Strong	5	Ambient		Y	V	Baseline replica of Test 4 Mixture incorrect due to MKS gauge failure DO NOT USE
31a	9/3/98	All Strong	5	27.5	82.0	Y	V	Repeat of Test 31 with Heise gauge
31b	9/9/98	All Strong	5	28.0	82.2	Y	V	Replica of Test 31a
32	9/2/98	All Strong	5	35.5	82.3	Y	V	Baseline replica of Test 4 Fuel manifold closed
33	9/4/98	All Strong	1	25.0	82.3	Y	V	Replica for Test 7 Fuel manifold closed Film broke
34	9/4/98	All Strong	1	39.0	82.2	Y	V	Replica of Test 7 Fuel manifold closed Replaced port window due to leak
34a	9/8/98	All Strong	1	38.7	82.1	Y	V	Replica of Test 6 Fuel manifold closed
35	9/3/98	All Strong	2	40.0	82.2	Y	V	Replica of Test 6 Fuel manifold closed Filament broke
35a	9/8/98	All Strong	2	40.0	81.9	Y	V	Replica of Test 35 Filament broke
35b	9/9/98	All Strong	2	40.1	82.2	Y	V	Replica of Test 35
36	9/3/98	All Strong	2	46.4	82.0	Y	V	Replica of Test 6 Fuel manifold closed
39	9/4/98	All Strong	2L	43.0	82.3	Y	V	Comparison for Tests 35 & 36
Jet A – Demo								
40	10/6/98	All Strong	2L	50.3	58.5	Y	Jet A	Vapor sampling in all Bays 1-6
42	10/2/98	All Strong	2L	40.1	58.6	Y	Jet A	Vapor sampling in Bays 1-5
Jet A – 40°C								
44	10/13/98	All Strong	5	40.5	58.5	Y	Jet A	Vapor sampling in Bay 1
46	10/8/98	All Strong	2	40.3	58.5	Y	Jet A	Vapor sampling in Bays 2,5
48	10/5/98	All Strong	2L	39.9	58.6	Y	Jet A	Vapor sampling in all bays

Table 1. Fall 1998 Test Matrix (continued)

Test	Date	Partitions	Ignition Location	Temperature (°C)	Press (kPa)	Vented	Fuel	Comments
Jet A – 50°C								
51	10/12/98	All Strong	5	50.5	58.5	Y	Jet A	Vapor sampling in one bay
53	10/9/98	All Strong	2	50.7	58.5	Y	Jet A	Vapor sampling in Bays 1,2,5
55	10/7/98	All Strong	2L	50.0	58.5	Y	Jet A	Vapor sampling in Bays 1,2,6
Jet A – 45°C								
58	10/14/98	All Strong	2L	45.0	58.5	N	Jet A	Vapor sampling in Bay 1
Quenching Tests								
61	10/21/98	Single Bay	Mid	49.5	58.5	N	Jet A	Heat transfer, combustion completeness Pre- and post-sampling in 1 bay
62	10/22/98	Single Bay	Mid	50.0	58.5	N	Jet A	Replica of Test 61
63	10/23/98	Two Bays	Mid	50.1	58.5	N	Jet A	2-in. hole Pre- and post-sampling in 2 bays
64	10/27/98	Two Bays	Mid	49.9	58.5	N	Jet A	0.25-in. x 2-in. slot Pre- and post-sampling in 2 bays
65	10/26/98	Two Bays	Mid	50.2	58.5	N	Jet A	Replica of Test 63
66	10/28/98	Two Bays	Mid	49.8	58.5	N	Jet A	Replica of Test 64
Alternate Fuel								
67	10/29/98	All Strong	2L	50.2	58.5	Y	Jet A	Sampling in Bays 1 and 6
68	10/30/98	All Strong	2L	50.2	58.5	Y	Jet A	Replica of Test 67
Part Strong								
69	11/3/98	Part Strong	2L	39.9	58.5	Y	Jet A	Sampling in 2 bays
70	11/4/98	Part Strong	2L	40.5	58.5	Y	Jet A	Replica of Test 69

Notes:

1. Simulant mixture is 1.4% C_3H_8, 7% H_2, 91.6% air
2. All partitions include SWBI, MS, SWB2 and both partial ribs
3. Ignition location that simulates compensator; 2L, butt line, 2 in. from bottom (compensator)
4. Part Strong has strong SWB1, MS, SWB2 and partial ribs. SWB3 and FS are weak
5. Standard fuel was supplied by ARCO. Alternate fuel source was purchased at a local airport east of Denver
6. Post samples to be analyzed for CO, CO_2, O_2, N_2,

Table 2. Spring 1999 Test Matrix

Test	Date	Partitions	Ignition Location	Temperature (°C)	Press (kPa)	Vented	Fuel	Comments
Jet A Flame Speed								
71	5/5/99	Single Bay	Center	40.5	58.5	N	Jet A (Denver)	Shakedown test
72	5/6/99	Single Bay	Center	40.0	58.5	N	Jet A (ARCO)	Single bay to check flame speed
73	5/7/99	Single Bay	Center	40.5	58.6	N	Jet A (ARCO)	Replica of Test 72
Jet A Quenching								
74	5/10/99	Two Bays/ Slot	Mid	40.0	58.5	N	Jet A (ARCO)	Quenching test with 0.25-in. x 2-in. slot STRINGERS LEFT OPEN UNINTENTIONALLY
75	5/11/99	Two Bays/ Slot	Mid	50.0	58.5	N	Jet A (ARCO)	Quenching test with 0.25-in. x 2-in. slot
76	5/11/99	Two Bays/ Slot	Mid	40.0	58.5	N	Jet A (ARCO)	Quenching test with 0.25-in. x 2-in. slot
77	5/12/99	Two Bays/ Hole	Mid	40.0	58.5	N	Jet A (ARCO)	Quenching test with 2-in. diam. hole
78	5/13/99	Two Bays/ Hole	Mid	50.0	58.5	N	Jet A (ARCO)	Quenching test with 1-in. diam. hole
79	5/13/99	Two Bays/ Hole	Mid	50.0	58.5	N	Jet A (ARCO)	Quenching test with 1.5-in. diam. hole

Notes:

1. Center igniter is in geometric center of single bay configuration
2. Mid igniter is in geometric center of Bays 5,6,4,3 combined
3. Quenching tests use special midspar with only a single orifice in the geometric center of the partition
4. ARCO fuel has a 115°F flash point
5. Denver fuel has a 130°F flash point

Test Site Cleanup/Securement: The spent project materials were disposed of and the instrumentation and photoinstrumentation equipment was removed from the test site for safekeeping and maintenance during this task. Site security, power, and building structures were maintained for possible future testing activity.

Film Handling/Video Conversions, Copying: This phase of the project involved the coalescing of the film and video records. Film splicing was performed and a high-resolution video master was produced and copies were made to provide working material for final report documentation and composite video production procedures. Video records were likewise edited into working copies and a master videotape was produced for the final report. The film from the 35-mm cameras was developed and selected prints were generated. The daily 35-mm documentary film and prints were assembled into photographic albums for documentation and future review.

Data Reduction and Analysis: All recorded data from the instrumentation systems was backed up during the test series. The backup information was archived on ZIP disks for data reduction and analysis activities. The data reduction and analysis included the pressure, temperature, and the motion switches. In addition, test site daily weather, and event time weather were tabulated for inclusion into the report.

Reporting: The coalesced data from the test operations and transducer data were assembled into this final report. This report also includes the test site descriptions, operational issues, and plots of each data channel. Photographic documentation was used in this final report to clarify and provide visualization of the test site conditions and test results. Film and video records were transmitted to Caltech for their final report.

SECTION 2.0

TEST SITE FACILITY DESCRIPTION

2.1 HEATER REQUIREMENTS FOR 1/4-SCALE FLIGHT 800 TESTING

The second test series of this program required the jet fuel to be heated to 50°C to generate the fuel vapors present during the accident. It was also a requirement to keep the temperature of the tank within ±1°C to prevent vapor condensation from forming on the tank walls. To maintain this temperature control, special attention was given to radiation losses/cooling of the tank. The power requirements for the heaters were calculated to bring the tank up to temperature in a reasonable time.

To minimize the wind/rain effects on the heating process, a housing (14'x14'x12' high) was constructed around the test fixture (Figure 2). Two additional considerations for placing a building around the fixture were the ejection of panels and post-event burning. The housing has sliding doors with the ejection side of the fixture placed close to that side of the housing. The sliding doors to the west were used to gain access to the building. In order to vent flames outside the housing (until the nitrogen purging puts them out), the cargo bay used during last year's testing was installed and fitted to exit the east side of the building.

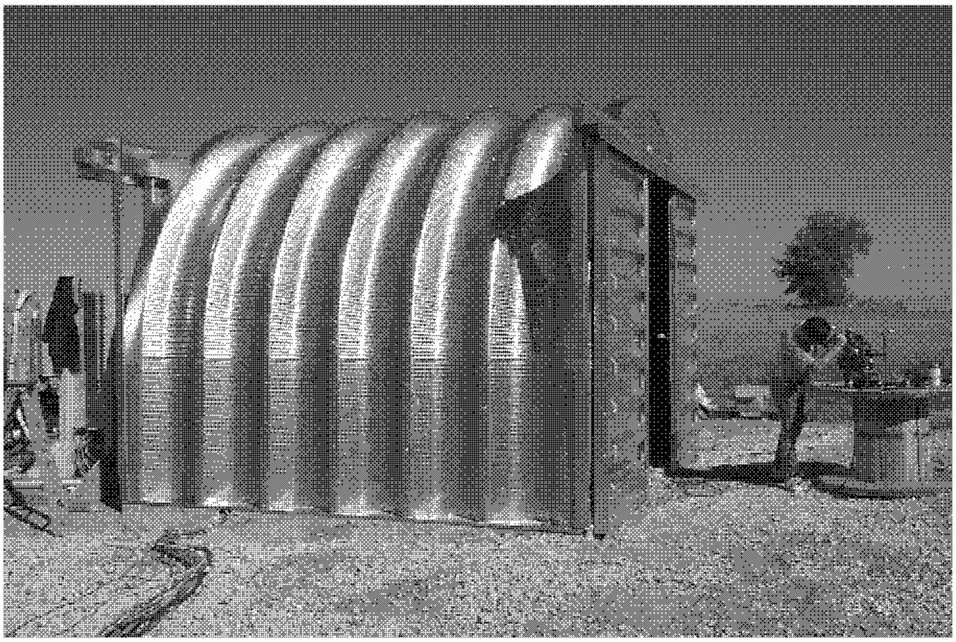


Figure 2. Heater Enclosure for the 1/4-Scale Fixture

Because just heating the air inside the housing would take most of the day to bring the fixture temperature up to 50°C, 66 heating elements were also placed on the fixture itself. Heating element strips (2" by 20" strips, 400 W each) were also placed on the top and bottom of the fixture (thin strips are required because of the placement of all transducers/access-points into the top tank structure). Two strip heaters were placed on each of the eight horizontal I-beams (four beams welded to the top plate and four beams welded to the bottom plate). The heater block diagram is shown in Figure 3. Finally, the rear wall of the fixture has six strip heaters (4” by 15”, 600 W each) mounted (Figure 4). This provided a total of 26 kW of power of heating. Calculations indicated that it would take approximately four hours to raise the average temperature of the 7000 lb. fixture to 50°C (from normal ambient temperature), leaving the remainder of the soak time for equalizing the temperature.

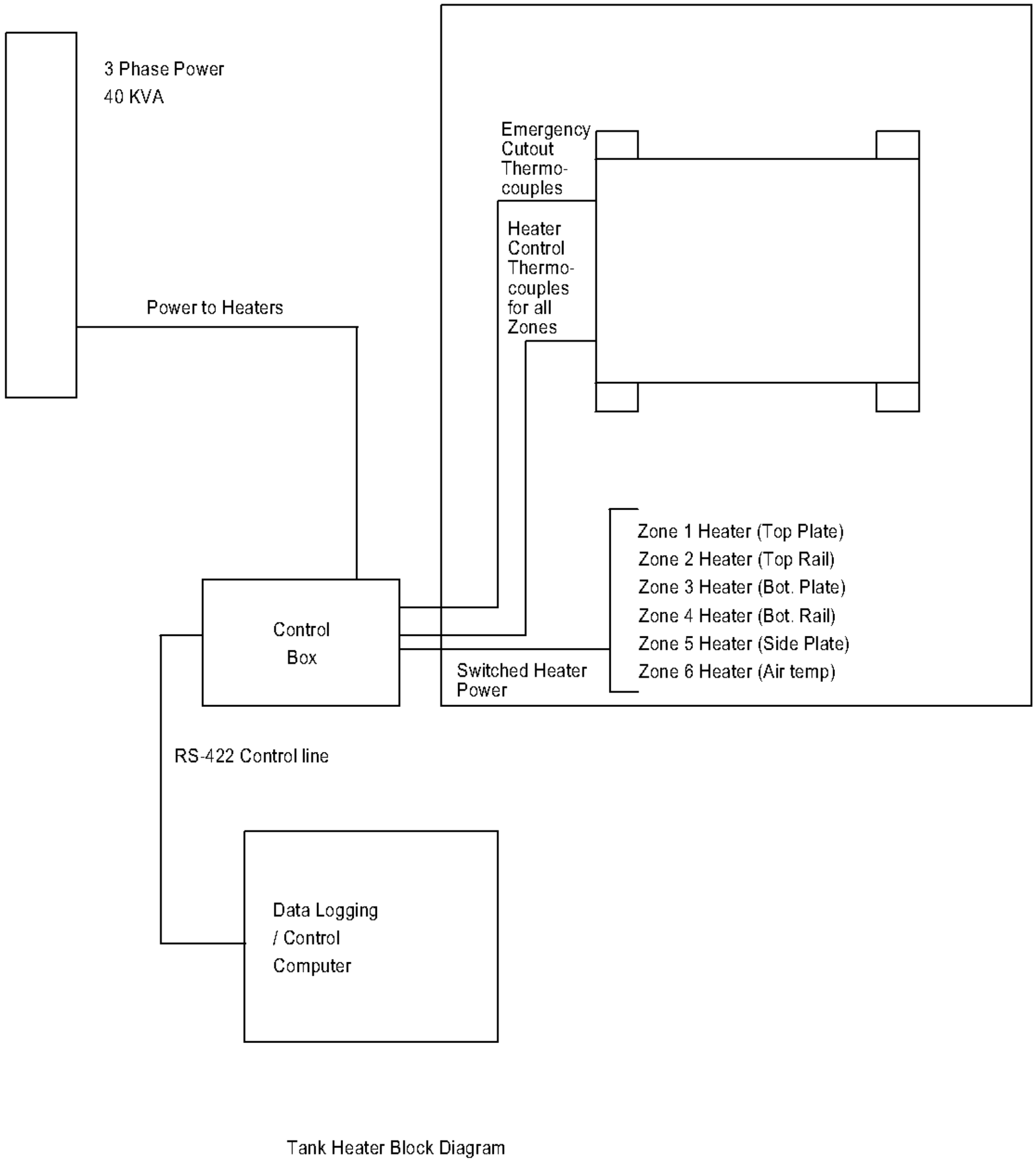


Figure 3. Heater Block Diagram

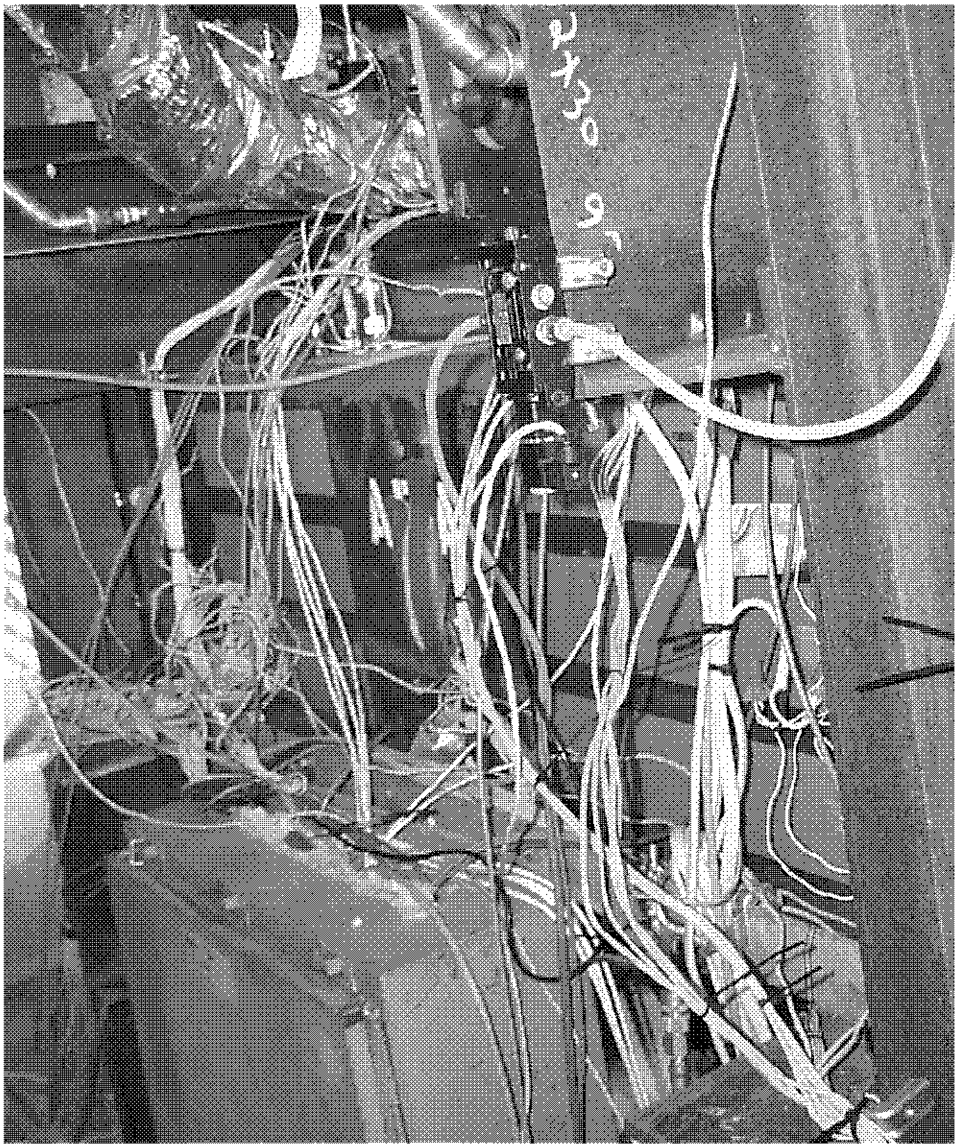


Figure 4. View of Heaters on Side of the Tank

The heating elements were separated into five zones (top plate, bottom plate, rear wall, upper four I-beams, and the lower four I-beams). Each zone was controlled by a proportional integral and derivative (PID) controller with solid state relays capable of controlling 100 amps each. A controller temperature sensor was placed in the center of its respective controlling zone, near the heating elements. This offered the best compromise for heater control.

Calculations had shown that without any insulation (or housing), the fixture would lose approximately 20 kW when it was at maximum temperature. Therefore, insulation was required. Three methods for insulation were explored: (1) Sections of insulating panels placed in intimate contact with the external metal surfaces of the fixture, (2) Large insulation panels placed as close as possible around the fixture, (3) Heated air all around the fixture. The first option had the problem that there are a lot of transducer/access-points that need to be accessed, so large holes would have to be cut into the insulation to allow access. These holes would then provide a cool spot for that part of the tank, or additional insulating boots would have to be placed over the transducer after it was installed. This method seemed to be very labor intensive both in initial preparations and in the day-to-day operation. The second option would be quicker for initial preparations, but would still slow down day-to-day operations. Also, it would not insulate as effectively because cool air entering the holes in the insulation around the windows would be able to circulate all around the fixture. The third option was chosen because it was not difficult to heat the air inside the housing, and once the test was completed, the air (and any smoke/fumes) could be vented outside and work could commence immediately. Also, this method of insulation was ideal since all external fixture surfaces would be in contact with air that is at the same temperature as the fixture.

Calculations had shown that approximately 5 kW would be lost through the walls and floor when the housing was at full temperature. Six 1500 W heaters, connected to a single PID controller, were used to keep the air at the desired temperature. A large blower was used for circulating the air with the temperature sensor placed near the exit of the blower. This blower could also be used to ventilate the housing once the test has been completed.

A heater control box was designed and installed on the outside of the building for the control of the five heater zones and the one air heater (Figure 5). It contained six PID temperature controllers, the emergency cutout relays, and ten SCR power controllers. The emergency cut-out relays have a separate thermocouple and these were used as an independent safety measure in case of an SCR failure and would prevent the heat strips from being locked on with no control, resulting in thermal runaway.

A Lexan window was placed in the housing wall. The Lexan window was aligned with the fixture windows so special requirements were not necessary for removing insulation/doors immediately prior to testing. A foam plug was fabricated to prevent heat loss of the last aluminum panel.

One additional consideration was the heating of the liquid Jet A fuel. Because of safety concerns, it was decided that the fuel would remain in cold storage while the fixture was being prepared for a test and while the test fixture was being heated overnight. Then in the morning, the cold fuel was added to an external tank. With all personnel cleared away from the test area, the fuel was poured into the external tank, and after the firing line was armed, it would then be gravity or vacuum fed into the fixture by a solenoid release valve operated remotely in the instrumentation van. Once the fuel had entered the tank, the bottom plate temperature would drop a few degrees. It took about 20 minutes for the tank to come back to the required test temperature.

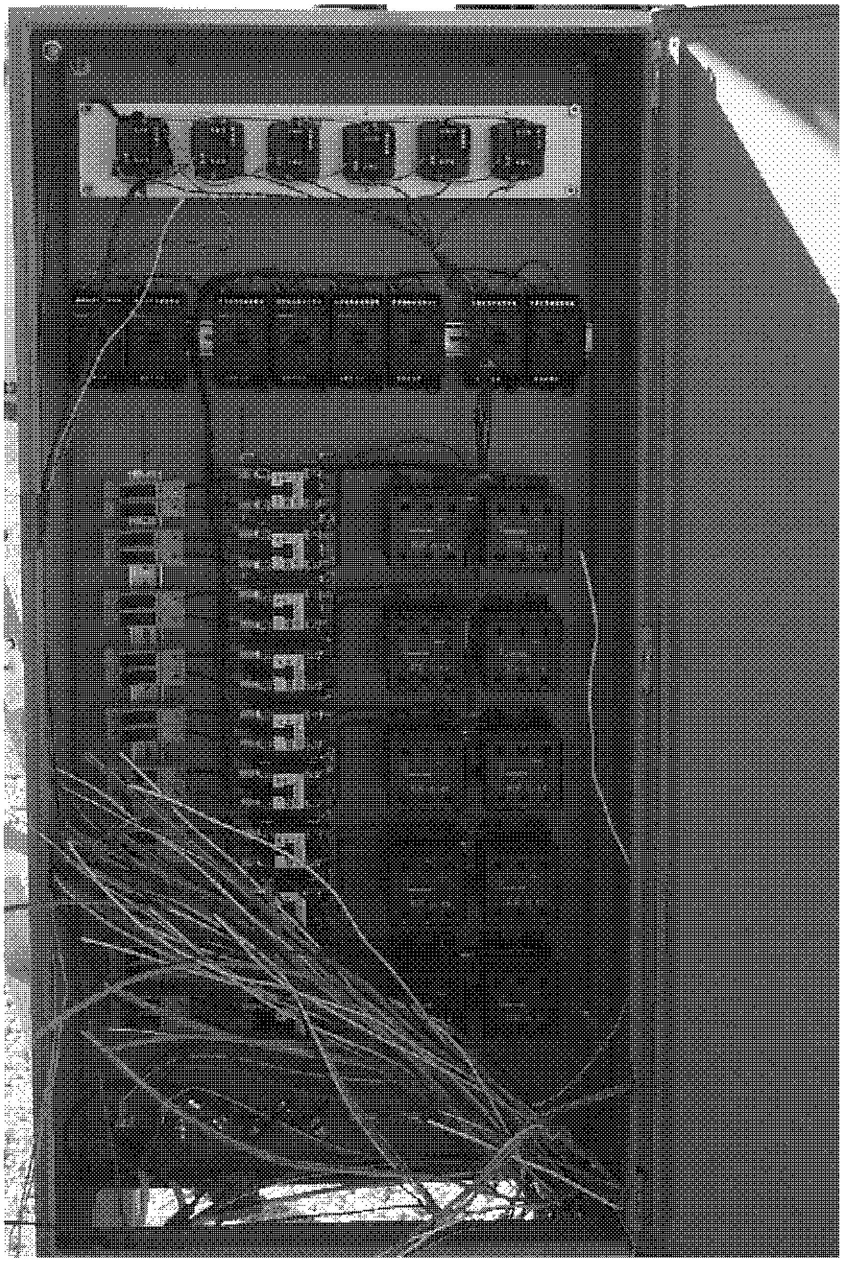


Figure 5. Heater Control Box

Thermocouples were placed at strategic locations on the fixture, in the air, inside the housing, and in the fuel vessel, so that the temperature could be monitored to verify that equilibrium temperature was achieved before proceeding with the test event. The readings were monitored by a remote link at the instrumentation van using an RS-422 serial link between the controllers and a PC. The software at the PC allowed the controllers to be programmed and controlled from the instrumentation van.

2.2 HEATER TESTS

Several tests were conducted on the 1/4-scale tank fixture to verify that constant temperature could be achieved over the entire tank structure. The largest variances in temperature were found to exist in two places: one, near the opening of the SWB expulsion port, and two, near the ground where the legs of the tank were joined at the concrete base. These locations were well removed from the fuel bays and did not affect test results. All of the other tank temperatures were within 1°C.

The 50°C preliminary tests showed that the tank was not reaching the desired temperature due to heat losses in the building. More insulation was added to decrease these losses. Also, a fan was installed near the top of the tank for additional air circulation. This improved the temperature equilibration on the top of the fixture. Another test was conducted and it successfully reached the 50°C setpoint without experiencing any problems.

2.2.1 Heater Operation

After the tank was reassembled from storage, a thorough test was performed on the instrumentation systems and on the ignition filament. Once everything was proven to be operational, the heaters were turned on and checked to make sure all heater elements were energized. The system was then monitored for the balance of the afternoon to ensure that the proper regulation of the heater system was achieved. Once the performance of the temperature regulators has been verified, the building was closed up and secured. The system was run overnight with the controller bringing the system up to temperature.

On the morning of each test, the 1/4-scale tank fixture was checked for temperature uniformity and accuracy. Adjustments were made to the controllers to correct any errors due to uneven heating distribution before a specific test was conducted.

2.3 INSTRUMENTATION/PHOTOINSTRUMENTATION SYSTEMS

The electronic measurement channels used on the 1/4-scale testing program to characterize the combustion process consisted of 14 channels of temperature, 7 channels of quasi-static pressure, and 8 channels of panel motion detectors. This resulted in a total of 29 channels of electronic measurements. The photo-instrumentation used to document the combustion phenomena consisted of two high-speed cameras, one high-speed video camera, four video cameras, two timed 35-mm cameras, one 35-mm documentary camera, and one digital documentary camera. This resulted in 11 channels of photoinstrumentation. In addition, pertinent test day weather information was taken which consisted of six channels of information relating to wind speed, wind direction, instrument van temperature, outdoor temperature, barometric pressure, and humidity. Therefore, a total of 46 channels of active measurements were used to characterize test performance. A brief review of the function of each type of measurement channel(s) is presented below. An instrumentation block diagram is shown in Figure 6.

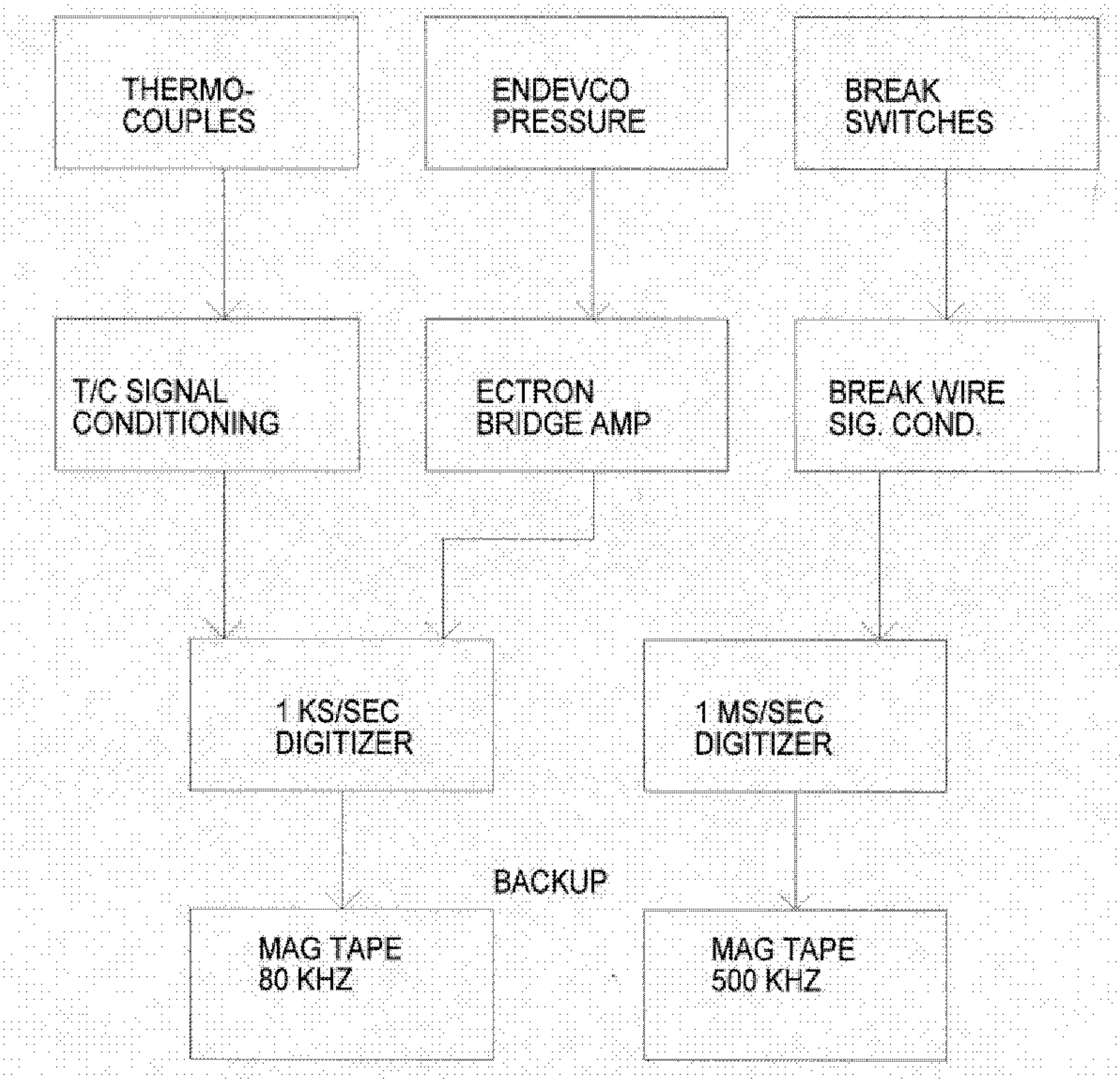


Figure 6. Instrumentation Block Diagram

Temperature (14 Channels): Used to measure the temperature in two places inside each bay of the 1/4-scale test fixture.

Quasi-Static Pressure (7 Channels): These pressure transducers were used to measure the quasi-static pressure of Bays 0-6. The transducers were fitted with thermal protection and debris shields to ensure high quality test to test data was obtained. Figure 7 depicts the transducers that were used.

Figure 7. Quasi-Static Pressure Transducers

Panel Motion Detectors (8 Channels): These break-switch sensors were positioned at each partition in the test fixture to measure the time of movement relative to event time zero. They were used on the part strong tests (Tests 69 and 70).

High-Speed Photography for Combustion, Test Overview, and Test Documentation (2 Channels): High-speed cameras were used to provide the spatial resolution necessary to document the dynamic events associated with these tests. One camera was used to document combustion effects, and the other camera was used to document panel ejection and fireball characteristics.

Pseudo-Schlieren Light Source for Tests 71-79: A "folded" version of the high-intensity light source that was used for the previous test series was constructed for use inside the building. Figure 8 shows the framework and the lights mounted near the bottom pointing up at an 18" by 5' mirror.

Video Cameras for Combustion, Test Overview, Documentary Information (4 Cameras): One SVHS video camera was used to provide real-time combustion monitoring, and the other two SVHS video cameras provided dynamic documentation of test performance and a "quick-look" of the panel expulsion along with a safety overview. Figure 9 shows the cameras located at the main camera station.

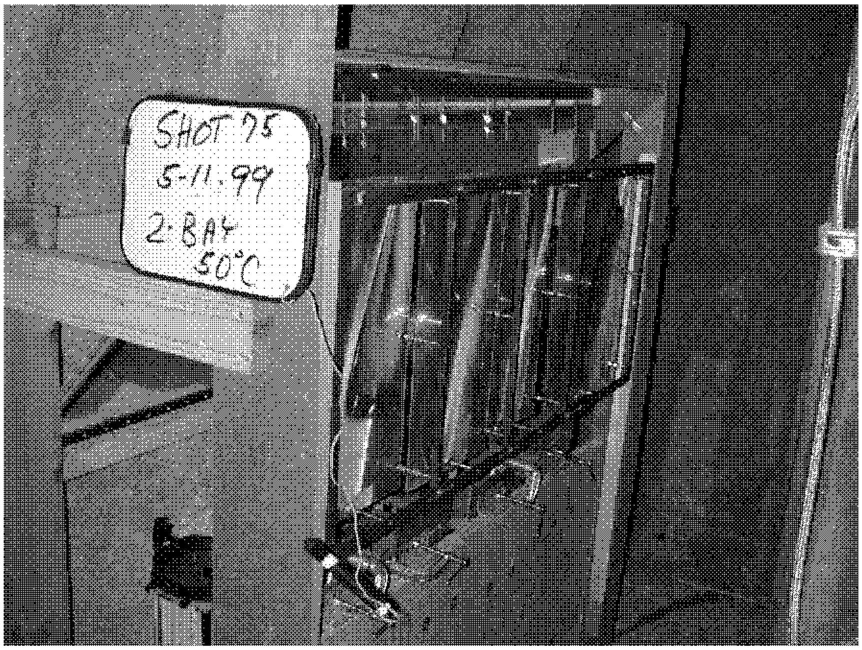


Figure 8. Light Source Framework

Figure 9. View of Main Camera Station

Timed 35 mm Cameras for Combustion Documentation (2 Cameras): Two 35 mm cameras were timed for the first exposure to occur at event time zero, with successive frames at 4 and 8 frames-per-second. This provided very high resolution of the fireball effects and good general test site overview photography. These two cameras were used for Tests 69 and 70.

Documentary 35 mm Camera for General Pre- and Post-Test and General Test Site Documentation (1 Camera): A 35 mm camera was dedicated to the test program to provide full documentation of all pre-test activity/setup and to provide post-event information.

High-Speed Video System (HSVS) (1 Camera): A Kodak high-speed video system was used in the second half of the test series for the quenching Tests 71-79. Data was saved in TIF format and stored on CDRs. This camera was run through a beam splitter and both the DBM and the HSVS were aligned on the same optical axis. Figure 10 depicts the setup.

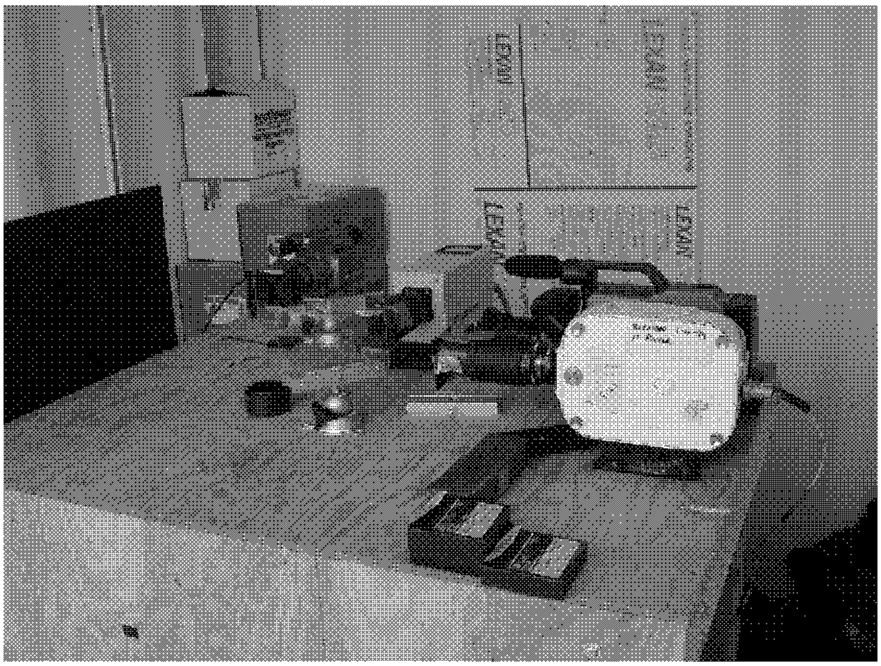


Figure 10. High-Speed Video, DBM and Beam Splitter

Digital Documentation: Test Site Overviews (1 Camera): A digital camera was used early in the program to generate pictures that could be sent to the various researchers via e-mail for assessing the site condition and progress.

2.4 TEST TIMING/SEQUENCING/FIRING

Firing System: ARA designed and built an automated electronic firing system capable of delivering 15.8 Joules of energy to the firing line. The unit has a 1400 microfarad capacitor that was charged to approximately 150 volts. A rapid discharge was obtained by a SCR firing circuit that was able to deliver the energy in less than 10 microseconds.

The discharge characteristics were dependent on the looped inductance of the firing line and the resistance of the electric match or filament ignition source (Figure 11).

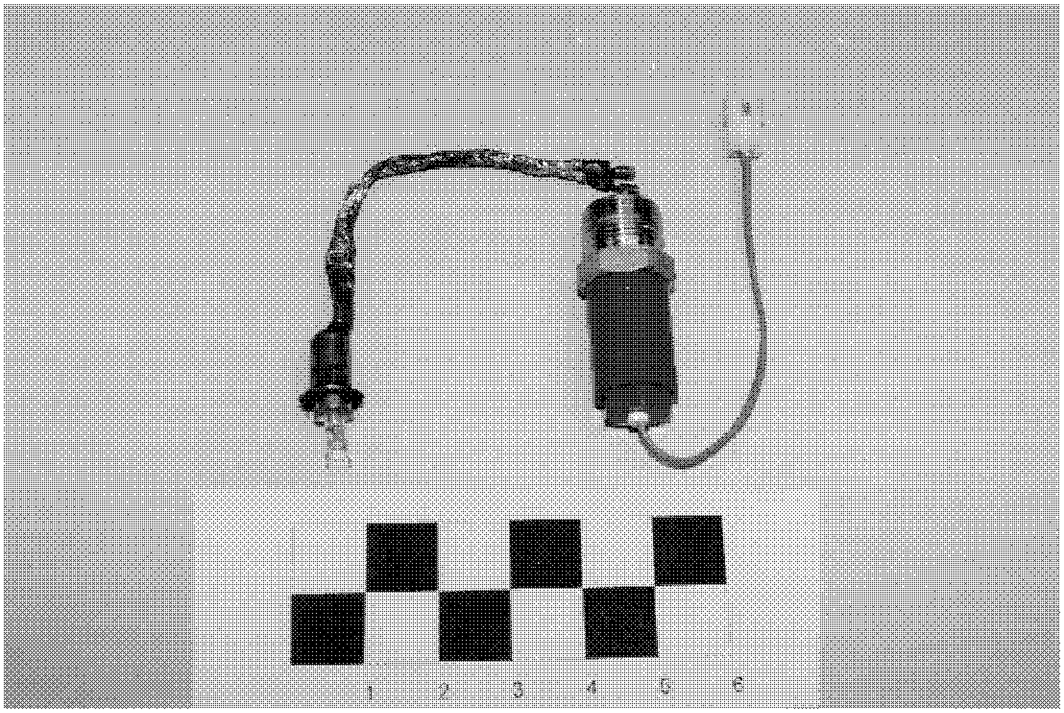


Figure 11. Ignitor Filament Assembly

The firing system incorporated an arming key that effectively locked out the firing system during the arming process. This prevented unauthorized operation of the system while the experiments were being armed. The firing line also was shorted both at the instrumentation trailer and at the test fixture. The firing system was controlled by the firing sequencer/timer (Figure 12). The sequencer enabled the charging of the firing system at T-30 seconds, and at T-0 seconds a firing pulse was sent to discharge the unit into the ignition source. The system was manually armed with the safety key to meet on-site safety requirements.

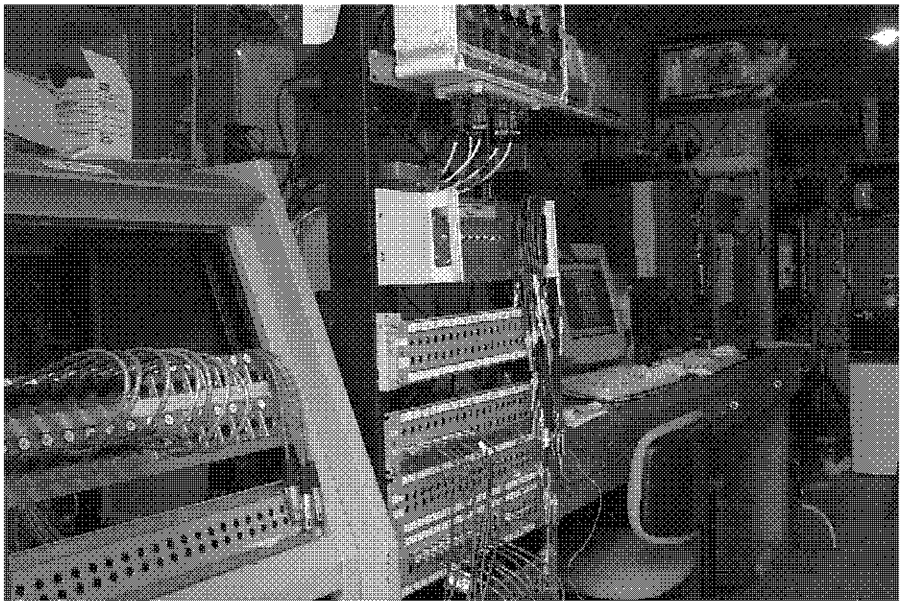


Figure 12. View of Sequencer and Patch Panels

Due to the safety considerations of the gaseous mix or the possibility of a primary bulb failure, an additional bulb filament was installed in another bay to provide a secondary ignition source for the gaseous mix in the event of a misfire. Two separate firing lines were used to provide independent control of the two firing filaments. During the test campaign, there was never a failure of the first firing line. The second ignitor was used in some tests to initiate the flammable mixtures after the tests where some of the chambers did not ignite. This was done for safety reasons for personnel working on the fixture during post-shot teardown.

SECTION 3.0

TEST OPERATIONS

The test plan was developed to optimize the testing schedule which would provide the required data in a timely and consistent manner. The first phase of the test program was to use the tank with the simulated vapor fuel to repeat some of tests that were performed in the 1997 test series. After the first phase was completed, the testing was suspended until the building was constructed to house the 1/4-scale test fixture for the heated jet fuel tests. After the final installations were performed, the checkouts and preliminary ignition tests and validation checks were conducted. After all systems were ready, the testing matrices, as shown in Tables 1 and 2, were conducted.

3.1 TEST TEAM

The success of this experimental testing program was the result of the dedicated performance of all the team members. Mr. Larry Brown was the ARA Project Manager (assisted by Mr. Tim Samaras, Mr. Mike Rictor, Mr. Bob Lynch and Mr. Peter Dzwilewski). Dr. Joseph Shepherd (assisted by Dr. Chris Krok, Dr. Julian Lee, and Mr. Pavel Svitek) of Caltech was the technical monitor responsible for the overall direction of this project. Together, they were responsible for the following testing activities:

- Technical quality
- Adherence to test schedules
- Fuel vapor/Jet A flammability laboratory testing
- Test fixture/test facility design and implementation
- Instrumentation design, calibration, installation, operation, and maintenance
- Optical designs
- Design/implementation of photoinstrumentation systems
- Design/implementation of the tank heating system
- Test implementation
- Documentation of test conditions
- Quick-look data evaluations
- Data processing/coordination
- Data analysis
- Reporting

Other team members with significant contributions to test planning and test matrix development included Dr. Merritt Birky, Dr. Vern Ellingstat, Dr. Dennis Crider and Dr. Dan Bower of the NTSB, and Dr. Mel Baer and Dr. Robert Gross of SNL, Dr. Kees Van Wingerden of CMR, and Dr. Paul Thibault of CDL. Dr. Joseph Kolly (NTSB) was present during most of the heated jet fuel testing. Their contributions on the data required for modeling activities and the generation of the test matrix were instrumental to the success of this program.

3.2 TEST SITE SECURITY AND SAFETY

3.2.1 Physical Security

Critical physical security items included the safeguarding of the energetic materials (electric matches and explosive gas mixtures), instrumentation, photo-instrumentation, and the test fixture. The ARA Test Facility is remote from the Denver area and is, therefore, subject to possible intrusion. The 55-acre test facility is located approximately two miles off the main access road and is protected by two security gates. A security fence, topped with concertina wire to discourage breaching activities surrounds the site itself. The test facility was further secured by padlocked and security-alarmed buildings. Routine personnel visits to the test site during non-test times further enhanced the physical security of the site.

3.2.2 Safety

The primary safety concerns regarding the 1/4-scale testing resided with the handling of the explosive products and with the explosive gas mixtures, particularly when the test fixture was loaded prior to testing. ARA employees with Colorado Explosive Permits were used to handle all arming and firing procedures. All testing, for all phases of this project effort, was conducted in strict accordance with established and approved Standard Operating Procedures (SOPs). In addition, all site personnel were required to understand and abide by the ARA General Safety Procedures established for the test site. First aid supplies, protective clothing and equipment, fire extinguishers, and warning lights were located at this facility. On active test days, a daily meeting was conducted by site personnel prior to the 1/4-scale testing to inform all personnel of the schedule, safety, or other conflicts pertinent to the success of the program.

One safety concern was in the handling of the jet fuel during the heated jet fuel tests. The small supply fuel canister was relocated to the outside of the building so the fuel could be loaded at ambient temperature to reduce safety concerns.

3.3 TEST PROCEDURES

3.3.1 Pre-Test Preparations

Pre-test preparations consisted of facility activation, construction/installation of test hardware, calibration of equipment, instrument checkouts (includes electronic and photographic systems), and predictions of peak pressure, temperature, fireball, and fragmentation issues and effects. The checkout procedures included dry runs of the firing sequence (with ignitors installed), triggering/functioning of the camera systems and the signal conditioning/recording systems, and stimulating the sensors to determine operability. Depending on the test condition for each test, the fuel vapor/Jet A volumes were selected and prepared, the particular partitions were installed, windows were installed and a leak check was performed.

Specific pre-test preparations for the different test conditions included setting the sensitivity level of the recording system for expected transducer outputs and the camera fields-of-view (FOV) and exposure levels were adjusted to meet test objectives. The sensing systems were individually stimulated to produce an electrical output which was observed and verified by the recording systems. Likewise, the photographic systems were viewed and the video recorders were functioned and monitored. In addition to standard checkouts at various times during the test program, calibration procedures were performed for the entire system in-place. Selected transducers were pressurized to a known value (NIST traceable) and measured. A thermocouple calibrator unit was used to verify the accuracy of the temperature measurements. Only when all systems were checked for their operational readiness would the test countdown be initiated. This included an S.O.P. checklist of the ignitor installations, gas handling/loading operations, site assessment, and range clearance. Typically, this pre-cursor to the firing countdown would take 15-20 minutes for the gas mixtures to stabilize and equilibrate. One hour was allocated for heating the Jet A for those tests.

3.3.2 Countdown Procedure

In addition to the S.O.P. used for each test scenario, a detailed instrumentation, mechanical, and gas handling checklist was used for all tests. This sequence of operations began with site clearance and energetic material loading preparations. The instrumentation components were systematically checked prior to gas loading and just prior to the 60-second countdown.

With all in readiness, the test site was again checked for unauthorized/unnecessary personnel and the gas mixture (Jet A with liquid for selected tests) was loaded into the test fixture. During all pre-test activities dealing with the gas loading and pre-firing test procedures, the firing systems and the ignitor lines were shorted as a safety measure. The instrumentation van had direct and positive control of test site safety and could abort the timing and firing systems in the event of safety or performance-related problems.

A digital sequence timer was used to provide automatic control signals to the data recorders, camera systems, and the firing circuit as described in Section 2.4. These systems were thoroughly tested in the dry runs preceding the arrival and loading of the energetic materials into the test fixture.

When all pre-fire checklists and responsibilities were completed, the energetic material handler authorized the instrumentation personnel to proceed with the test. At this point, all personnel were required to be in their designated locations in accordance with the S.O.P. and the checklist procedures. The test sequence was then initiated. Post-event, the gas and energetic material handlers assessed the “quick-look” data to provide assurance that combustion was achieved in all test fixture bays. This assessment also included evaluation of the video recording which was used for site surveillance and event documentation. The energetic material handler inspected the test bed area for any unreacted energetic material and any other potential unsafe conditions, such as fires/afterburning, and shorted the firing lines. Once test site conditions were determined to be safe, the facility was prepared for re-entry and radio communications to that effect were relayed to other on-site personnel so they could resume their normal program operations.

3.3.3 Post-Test Procedures

Quick-Look Data Review: Immediately after each test, the instrumentation personnel performed data storage backup to prevent accidental loss of data and then automatically plotted the pressure and temperature test data for "quick-look" evaluation. If required, the data from the tape recorders was digitized and displayed/plotted for evaluation of the analog sensor signatures. This process provided a basis for analyzing the preliminary results of the test, provided insight on whether all bays experienced combustion phenomenon, provided assurance that it was safe to re-enter the site area, and produced information on the relative performance of the sensor suites. This assessment also provided the basis for replacing transducers, changing transducer ranges, timing changes, and other instrumentation adjustments to enhance and optimize test results.

Photographic and Video Review: Immediately after each test, the 16 mm high-speed camera film was prepared for overnight shipment to a film processing laboratory in Yuma, Arizona. Normal film turnaround time was three days. As soon as the film was received from processing, ARA/Caltech personnel performed a film review of test information to evaluate the combustion results and made exposure adjustments as necessary to compensate for test conditions.

Video records were reviewed post-event in the instrumentation van to assess their quality and adjustments were made as required. Video tape backups were made to "archive" the video information throughout the test series.

The 35 mm film records were processed in laboratories in the Denver area and were routinely reviewed for quality and completeness of documentation.

SECTION 4.0

TEST SYSTEM PERFORMANCE

4.1 OVERVIEW

Overall, the performance of the test fixture, instrumentation, photoinstrumentation, and the quality of data were very good. The test fixture performed as designed and was flexible enough to accommodate test matrix changes in partition configurations, fuel mixture, and was able to retain its structural integrity throughout the test series. The instrumentation systems were likewise compatible to test matrix changes, met calibration and quick-look data requirements, and had a minimum of down time due to hardware, software, or other problems. The photoinstrumentation systems performed very well; however, there was a failure of one high-speed camera during the part-strong configuration (Tests 69 and 70). Compensation was provided using the high-speed camera that had covered the panel ejections. This camera was pulled and used to provide coverage in the main camera station. The replacement cameras performed well.

The performance of the major components of the test system will be briefly described in this section of the report.

4.2 TEST SITE PERFORMANCE

The ARA ordnance test site facility located 30 miles southeast of the Denver area was well suited to performing these fuel/air explosions. Heavy equipment was available to service the major test site issues of site development and to install the “cargo bay” on the fixture for the heated jet fuel tests.

The additional commercial on-site power that was added for the heaters performed very well with no power outages encountered. The established security and safety procedures were found to be sound and allowed the test schedules to be accomplished in a safe and timely manner. No major snow storms were encountered during the months in which the tests were conducted.

The communications systems, which included several land-line telephones, cell phones, and a fax machine served the test site well and allowed continuous communication opportunities for all test site personnel. The fax line also served as an uploading point to provide timely data to the 1/4-scale testing world wide web homepage for the daily dissemination of data.

Safety, security, SOPs and the on-site checklists performed their missions well. All testing was conducted in a safe, secure, and timely fashion.

4.3 TRANSDUCERS

The transducer suite selected to document the 1/4-scale test fixture performance worked very well. The Endevco transducers used to measure the quasi-static pressure, which were fitted with thermal protection (black grease backfilled) and with a debris shield worked extremely well for protecting the gauges from the thermal events. This protection was demonstrated in the in-series pressure calibration checks and in the post-test series transducer calibrations performed in the ARA laboratories. Less than 2% calibration shift was experienced throughout the test series.

4.4 SIGNAL CONDITIONING AND DATA ACQUISITION PERFORMANCE

The signal conditioning systems performed as designed. The thermocouple signal conditioning installed in the gas handling Conex, which was located approximately 10 feet from the test fixture, required the use of line drivers to meet the desired signal-to-noise ratios and served well for the test series. All pressure signal conditioning worked well. Motion sensor signal conditioning performed well with little maintenance required.

The digital and analog acquisition (recording) systems performed well throughout the test series. The multiple PC's worked very well and produced timely hard copy and data archival procedures for each test, post-event. The three digital recording systems performed reliably and did not cause any test holds, missed-trigger conditions, or other problems that could have affected the test schedule. The ARA modified LabView software produced reliable configuration, calibration, quick-look, and hard copy information.

4.5 TIMING AND FIRING PERFORMANCE

The timing system performed well during the course of the test program. This system provided accurate and reliable timing and sequencing operations of the satellite instrumentation and photoinstrumentation systems that documented the test events. This system provided sequenced operation of the diagnostic systems from T-60 seconds, through event time zero, and through T+10 seconds.

4.6 PHOTOGRAPHIC AND OPTICAL PERFORMANCE

The photographic systems worked very well in all aspects. The optical design for the combustion photography worked as well in the field as the laboratory tests suggested it would. Furthermore, the design was robust enough to withstand the rigors of the field environment and withstood the resulting overpressures from the weak partition tests. The combustion photography demonstrated a high degree of optical density resolution to produce good video composite production and reproduction.

The SVHS video and 35 mm cameras used for test site documentation worked well with no problems encountered. The video documentation was used for composite video productions and the 35 mm prints were arranged in photographic albums along with the timed 35 mm test film records.

APPENDIX A

FIELD NOTES

1/4-Scale Model Tests

Test No.	Date	Shot Time	Ambient Pressure (Torr)	Temp. in Tank (°C)	Leak Rate (Torr/ min.)	Target Pressure (Torr)	Actual Pressure (Torr)	Final Pressure (Torr)	Mixing Time (Minutes)
31	8/31/98	2:04 pm	N/A	29.8	0.1	N/A	N/A	N/A	15
31a	9/3/98	10:53 am	616.8	27.5	0.15	565.0	564.8	615.0	15
31b	9/9/98	10:00 am	615.7	28	0.225	563.9	564.1	614.8	15
32	9/2/98	2:54 pm	616.1	35.5	0.3	564.4	564.0	617.3	15
33	9/4/98	10:14 am	618.2	25	0.3	566.3	565.9	617.5	15
34	9/4/98	12:59 pm	616.9	39	0.3	565.1	565.1	616.5	15
34a	9/8/98	1:32 pm	615.3	38.7	0.075	563.6	563.6	615.4	15
35	9/3/98	1:32 pm	616.8	40	0.075	564.8	565.1	616.6	15
35a	9/8/98	2:52 pm	614.9	40	0.15	563.3	563.1	614.2	15
35b	9/9/98	12:58 pm	615.4	40.1	0.375	563.7	563.8	614.0	15
36	9/3/98	2:46 pm	615.7	45	0.075	563.9	563.4	615.2	15
39	9/4/98	3:05 pm	617.3	43	0.075	565.4	565.1	616.9	15

1/4-Scale Model Tests Comments

Test No.	Comments
31A	Cap line to liquid fill same as Test 31. Ignition location: 10.5" from rear partial rib, 19.5" from inside port window, 5.5" from SWB1, 8.5" from bottom. **Used Heise gauge supplied by Caltech on Tests 31-39.**
31B	Element intact post-test. Fuel liquid valves open between chambers. Ignition location: 10.5" from rear partial rib window, 19.5" from inside port window, 5.5" from SWB1, 8.5" from bottom. 37 psi remaining with gas bottle. Bulb #1156 long life. 9 psi line pressure (type).
32	P/S vents open. Ignition location: 10.5" from rear partial rib window, 19.5" from inside port window, 5.5" from SWB1, 8.5" from bottom.
33	Bay 1. Ignition location: 6-1/4" from SWB2, 27-9/16" from starboard window (inside), 8-3/4" from bottom. Condition of ignitor good.
34	Replaced unused port window for this shot due to leak. Ignition location: 6-1/4" from SWB2, 27-9/16" from starboard window (inside), 8-3/4" from bottom. Condition of ignitor good.
34A	Ignition location: 6-1/4" from SWB2. 27-9/16" from starboard window (inside), 8-3/4" from bottom. Condition of ignitor good.
35A	Fuel valve closed (type). Ignition location: 27-1/2" from inside of starboard window, 4-3/8" from MS, 8-5/8" from bottom. New ignitor (primary). Igniter filament broke during ignition.
35B	Ignition location: 27-1/2" from starboard window, 4-3/8" from MS, 8-5/8" from bottom. 370 psi remaining in gas bottle. 9 psi line pressure. 9-10 psi is standard pressure on this test for simulant gas.
36	Minus one video recorder for this test. Ignition location: 4-3/8" from MS, 8-5/8" from bottom. New ignitor (primary). Igniter filament broke during ignition.
39	Ignitor location: 26" from starboard window, facing starboard, 2" up. Ignitor Element has Fore/Aft orientation.

1/4-Scale Model Tests

Test No.	Date	Time	Ambient Pressure (Torr)	Target Temp. in Tank (°C)	Actual Temp. in Tank (°C)	Actual Temp. in Tank at Sample Fill (°C)	Initial Target Pressure (Torr)	Initial Actual Pressure at Shot (Torr)	Initial Actual Pressure at Sample Fill (Torr)	Leak Rate (Torr/min)	Mixing Time (Minutes)
40	10/6/98	2:22 pm	656.5	50°	50.3	50.3	438.9	438.9	438.9	good	
42	10/2/98	2:35 pm	616	40°	40.5	40.1	438.9	439.9	438.8	0	55
44	10/13/98	10:45 am	624.2	40	40.5	40.5	438.9	438.8	438.9	good	77
46	10/8/98	10:45 am	623.1	40	40.25	40.25	438.9	438.9	439.5	good	60
48	10/5/98	10:40 am	619.4	40	39.9		438.9	439.2	438.8	0	47
51	10/12/98	12:08 pm	626.2	50	50.1	50.1	438.9	438.7	438.9	good	78
53	10/9/98	12:04 pm	629.7	50	50.7	50.7	438.9	438.9	438.9	good	90
55	10/7/98	11:05 am	627.6	50	50.0	50.0	438.9	438.9	438.9	good	60
58	10/14/98	10:34 am	619.1	45	45.0	45.5	438.9	438.7	438.9	good	75
61	10/21/98	11:22 am	631.8	50	49.5	49..5	438.9	438.5	438.9	good	75
62	10/22/98	10:54 am	628.7	50	50.0	50.0	438.9	438.6	438.9	good	75

1/4-Scale Model Tests Comments

Test No.	Comments
40	Number 5-1/2 rubber corks. Partial ribs notched to clear liquid Jet-A fill holes. Bay 1 did not combust. Sampling in all bays.
42	1st air bleed (open vents) @ 2:13 pm up to 426.9 Torr. 2nd air bleed (fuel fill) @ 2:14 pm up to 438 Torr. (Decreased slightly). Fill sample canisters @ 2:29 pm. Pressure down to 430 Torr. Forgot to open canister valve in Bay 6.
44	Sample Bay 1. Mixing pump flow ≈ 3.5 cfm. Filament orientation forward/aft. Corks did not pop. Only Bays 5 and 6 combusted.
46	Measured cfm of mixing pump ≈ 3.3 cfm. New #6 corks on vents. Sampling Bays 2 + 5. Filament intact.
48	Mixing pump temperature @ 10:02 am = 17.4°C. Ignitor sequence from video: 1 = ignitor bay (2), 2 = Bay 1, 3 = All bays, 4 = Bays 4, 5, 6, and Bay 1 flames persist longer. Ignitor filament whole after shot.
51	Sample bays = 5, 1. Filament orientation forward/aft. Mix pump flow ≈ 3.5 cfm. Only Bays 5/6 combusted!!? Corks did not pop.
53	Pump flow ≈ 3.5 cfm. Sample bottles 1, 2, 5. Filament intact. Bays 5/6 didn't burn.
55	Same vent corks as Test 40. Tank re-leveled. Sampling in Bays 1, 2, 6. Little 4" diameter puddles in Bays 3 + 1 (fuel back flow from vent table?) Pump cleaned & tested (flow check valves only). Bays 1 + 3 did not go. Rear partial rib broke.
58	Sample Bay 1. Mixing pump flowing great ≈ 3.5 cfm. Did not evacuate sample line. Bay 1 did not burn. Rear Partial Rib broke.
61	Single bay – tank has no partitions. Filament centered 9" from top & bottom, 21-3/4" from front & back, 29-7/8" from windows. Post- and pre-sample bottles attached. MKS acting strange: jumping of about ± 0.3 Torr minutes before shot. Liquid Jet A drained from tank is clear. Bay 3 pre-sample bottle #379093, Bay 4 post-sample bottle #379132. Mixing pump flow rate ≈ 3.5 cfm.
62	No partitions. Filament centered horizontally & vertically same as Test 61. We forgot to change shot number on building number is still 61. Didn't do post-fill until 5 min. after shot. MKS pressure dropped from 438.9 to 438.6 when mixing pump turned off just before shot. Sampling from Bay 4 post-sample bottle #379177. Bay 3 pre-sample bottle #379168. Mixing pump flow rate still good @ 3.5 cfm.

1/4-Scale Model Tests

Test No.	Date	Time	Ambient Pressure (Torr)	Target Temp. in Tank (°C)	Actual Temp. in Tank (°C)	Actual Temp in Tank Sample Fill (°C)	Initial Target Pressure (Torr)	Initial Actual Pressure (Torr)	Initial Actual Pressure at Sample Fill Torr)	Leak Rate (Torr/min.)	Mixing Time (Minutes)
63	10/23/98	10:54 am	626.7	50	50.1	50.1	438.9	438.6	438.9	< 0.04	75
64	10/27/98	10:20 am	624.8	50	49.9	50.1	438.9	438.9	438.9	good	75
65	10/26/98	11:50 am	622.9	50	50.15	50.2	438.9	438.9	438.9	good	75
66	10/28/98	11:01 am	609.5	50	49.8	43.6	438.9	438.0	438.8	good	75
67	10/29/98	10:17 am	621.1	50	50.2	50.4C	438.9	438.8	438.9	0.03	80
68	10/30/98	10:42 am	622.4	50	50.15	50.4	438.9	438.8	438.8	0.05	75
69	11/3/98	1:46 pm	621.1	50	39.9	40.0	438.9	438.9	439.8	0.03	70
70	11/4/98	11:43 pm	622.5	40	40.2	40.5	438.9	438.9	439.0	good ≈ 0.02	75
71	5/5/99	5:12 pm	616.9	40	40.5	N/A	438.9	438.8	N/A	good	75
72	5/6/99	3:36 pm	620.6	40	40.0	N/A	438.9	439.0	N/A	good	73
73	5/7/99	4:15 pm	620.3	40	40.0	N/A	438.9	439.5	N/A	good	120
74	5/10/99	1:15 pm	616.1	40	40.0	N/A	438.9	438.7	N/A	good	87
75	5/11/99	10:33 am	621.0	50	50.0	50.0	438.9	438.9	438.9	good	73
76	5/11/99	4:57 pm	620.1	40	40.0	40.05	438.9	438.9	438.9	0.06	75
77	5/12/99	11:26 am	622.1	40	40.0	40.5	438.9	430.8	439.0	0.03	85
78	5/13/99	10:19 am	617.0	50	50.0	50.0	438.9	438.7	438.8	0.03	75
79	5/13/99	3:35 pm	618.0	50	51.0	51.0	438.9	438.7	438.9	0.08	77

1/4-Scale Model Tests Comments

Test No.	Comments
63	2 bay shot w/2" hole partition. Sampling from Bays 1, 3 pre-sample; Bays 2, 4 post-sample. Mixing pump flow rate ≈ 3.5 cfm. Capped off vent lines P & S Bay 1.
64	1/4" × 2" slit in plate. Slit is horizontal. Mixing pump flow rate same. Vent lines capped off same as Test 63. Ignition is the same as Test 63. Bays 1, 3 pre-sample, Bay 2, 4 post-sample.
65	Same as Test 63. 2" hole 2 bay shot. Bay 1 bottle #379175. Bay 3 bottle #379143. Pre-sampling only "Bays 1 & 3". Mixing pump flow rate ≈ 3.5 cfm. Vent lines on Bay 1 capped to prevent communication between bays. We changed T/C #8. Skipped Test 64 to save time – will do Test 64 after Test 65.
66	Same test conditions as Test 64. Set up for a possible post-sample. No post-sample. Pre-sampling in Bays 1, 3 again. Bay 1 bottle #379153. Bay 3 bottle #379109.
67	Return to 6-bay configuration. Pre-sampling from Bays 1 and 6. Rubber stoppers in vents-open vent valves 1 min before shot. Vent stringers returned to Bay 1 port & starboard using Jet A from Reno. Ignition location: 26" from starboard window, 2" from bottom plate facing down with east/west filament orientation. Bay 1 bottle #3739116. Bay 6 bottle #379113.
68	Ignition location: 26" from starboard window, 2" up, facing south with east/west orientation. All conditions same as Test 67 except bulb base orientation. Bay 1 bottle #379111. Bay 6 bottle #379176.
69	1st shot with partial strong. Had a leak due to new panel design. Replace SWB3 flat panel with panel left over from last year's tests. Mixing pump still going strong ≈ 3.5 cfm. Vent plugs in same as before. Sample from Bays 1, 6 pre-sample only – Bay 1 bottle #379165. Bay 6 bottle #379133. ARCO fuel. Worst leak rate this series 0.3 Torr per minute. Less time mixing because of leak rate.
70	Same as Test 69 using SWB3 panel left over from last year's tests. Some extra RTV was used between SWB3 and steel frame to keep leak rate low. Mixing pump still working fine @ 3.5 cfm. Sample Bays 1, 6 pre-sample only ARCO fuel. Pre-sample Bay 1 bottle #379138. Bay 6 bottle #379163.
72	No sampling of tank mix. Sample taken of ARCO fuel before fuel loading. Fuel heated prior to loading (temp ?) with space heater. Pressure after the burn 460.0 Torr. Thermocouple #4 – bad reading.
73	Open sample valve produced pressure rise-bottle not a vacuum? Radiant heating of hut during mix increased temperatures in tank. 2 hour mixing time totals with door cracked for 1 hour to allow temp to stabilize at 40°C ≈45 min mix at 40°C before shot.
74	Final pressure 450.6 Torr. Mixing line between bays was not disconnected.
75	2-bay shot with slot. Mixing pump check 2 min. 21 sec. filling 39-gallon bay. Vent line capped off to prevent communication between bays. Found tank pressurized on arrival to 680 Torr. Ignition location centered in what would be Bays 3-6. Sampling: pressure only dropped by 0.2 Torr.
76	Same as Test 75 except for temperature. Ignition appears further aft than in previous shot with ¼" slot.
77	2" hole on center partition same as Test 76. Both bays ignited.
78	Video high-speed 1000–fps framerate. 1" hole between bays. T.C. #10 replaced. Receptor bay did not ignite.
79	1.5" hole on midspar. 1000-fps framerate on video. Both bays ignited - only sampling receptor bay.

APPENDIX B

WEATHER DATA

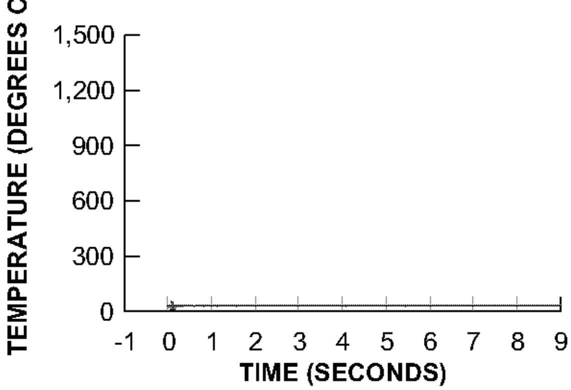
Weather Data

Shot No.	Barometric Pressure (inches)	Wind Speed (miles per hour)	Wind Direction	Temperature (°F)	Relative Humidity (%)	Shot Time
31	30.30	6	NW	78	41	2:04 pm
32	30.17	7	N	84	24	2:54 pm
31a	30.19	8	WNW	82	24	10:53 am
35	30.26	7	SW	89	17	1:32 pm
36	30.20	6	SSW	93	10	2:46 pm
33	30.25	13	S	82	27	10:14 am
34	30.24	17	SSE	91	16	12:59 pm
39	30.23	14	SSE	94	16	3:05 pm
34a	30.16	7	E	88	26	1:32 pm
35a	30.14	7	S	90	24	2:52 pm
31b	30.15	5	S	79	27	10:47 pm
35b	30.15	7	W	88	21	12:58 pm
42	29.91	4	SW	60	53	2:35 pm
48	30.03	5	WNW	43	59	10:40 am
40	30.23	2	NW	60	27	2:22 pm
55	30.30	4	WNW	57	57	11:05 am
46	30.22	8	SSW	69	24	10:45 am
53	30.20	5	NNE	68	21	12:04 pm
51	30.31	4	WNW	53	36	12:08 pm
44	30.24	14	SE	69	21	10:45 am
58	30.00	6	SSW	66	32	10:34 am
61	30.47	7	NNE	58	40	11:22 am
62	30.36	8	NW	52	55	10:54 am
63	30.28	4	NNE	59	44	10:54 am
65	30.14	6	WNW	57	50	11:50 am
64	30.18	8	NW	52	78	10:20 am
66	29.85	28	W	47	76	11:01 am
67	30.06	2	NW	56	34	10:17 am
68	30.13	2	SW	40	71	10:42 am
69	30.06	Calm		36	87	1:46 pm
70	30.17	5	SSW	39	79	11:43 pm
71	29.89	20	E	44	49	5:12 pm
72	29.99	9	W	55	27	3:36 pm
73	29.93	8	SE	73	21	4:15 pm
74	29.86	10	E	43	72	1:15 pm
75	30.05	11	WE	43	33	10:33 am
76	30.07	8	SW	42	68	4:57 pm
77	30.08	11	WSW	53	33	11:26 am
78	29.81	17	S	70	30	10:19 am
79	29.72	19	S	79	24	3:35 pm

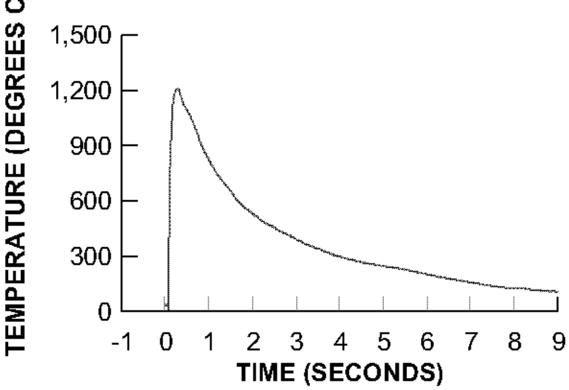
APPENDIX C

TEMPERATURE DATA IN BAYS

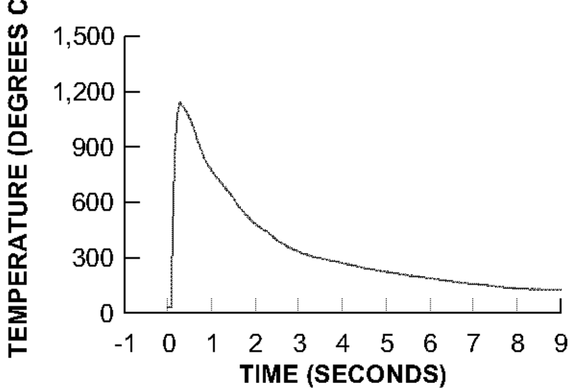
TEST 31
THERMOCOUPLE 1
BAY 5



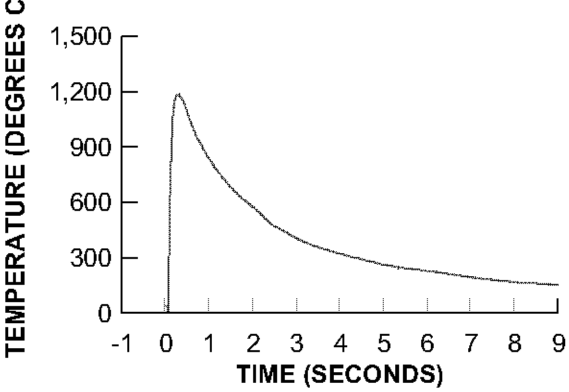
TEST 31
THERMOCOUPLE 2
BAY 6



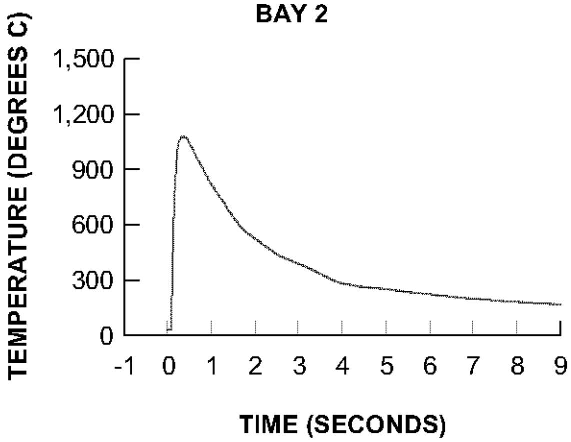
TEST 31
THERMOCOUPLE 3
BAY 3



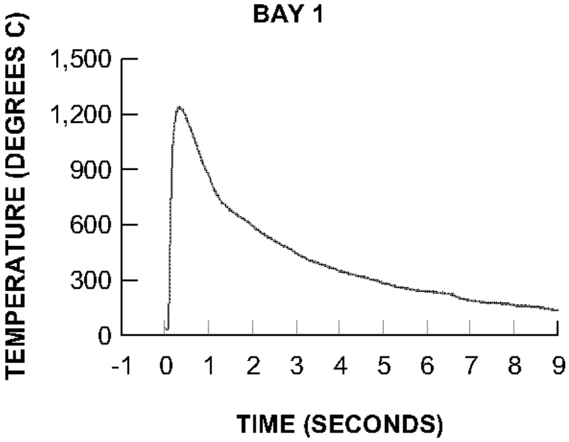
TEST 31
THERMOCOUPLE 4
BAY 4



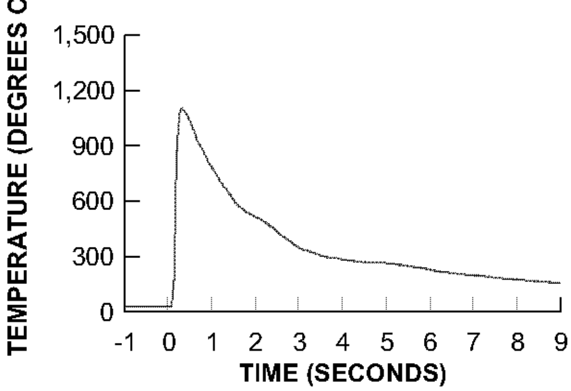
TEST 31
THERMOCOUPLE 5
BAY 2



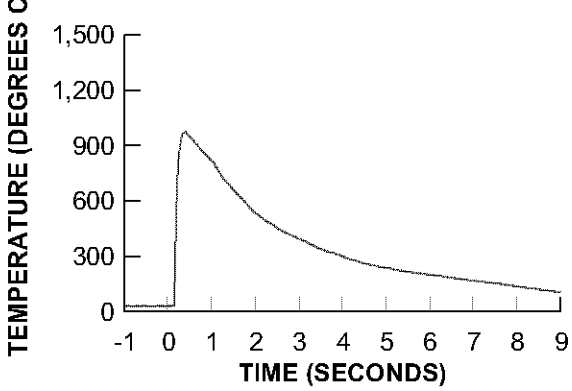
TEST 31
THERMOCOUPLE 6
BAY 1



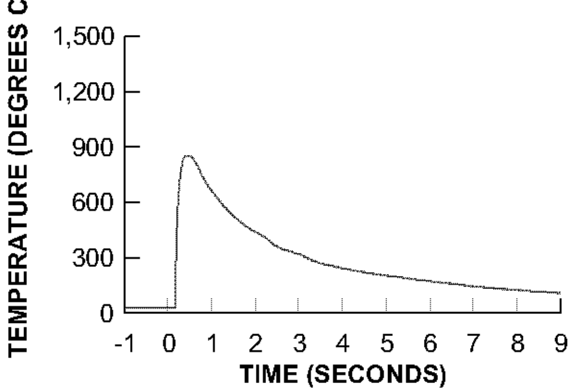
TEST 31A
THERMOCOUPLE 1
BAY 5



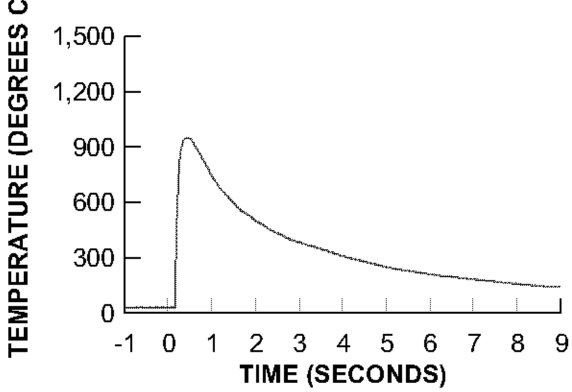
TEST 31A
THERMOCOUPLE 2
BAY 6



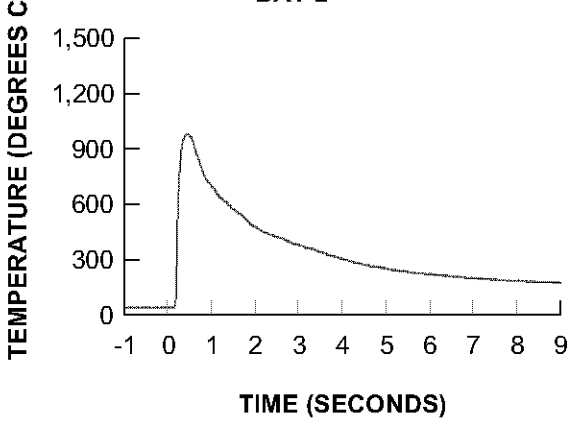
TEST 31A
THERMOCOUPLE 3
BAY 3



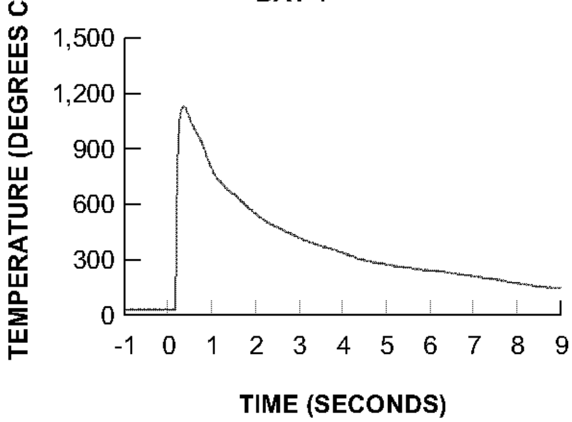
TEST 31A
THERMOCOUPLE 4
BAY 4



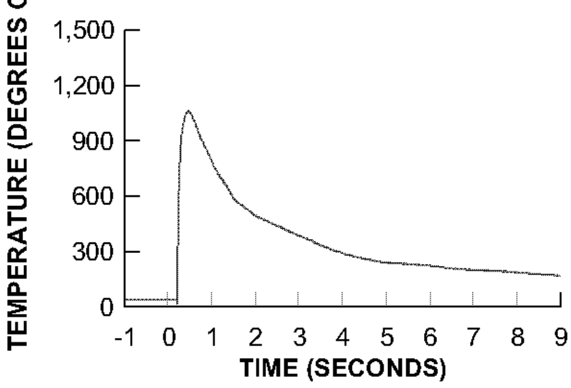
TEST 31A
THERMOCOUPLE 5
BAY 2



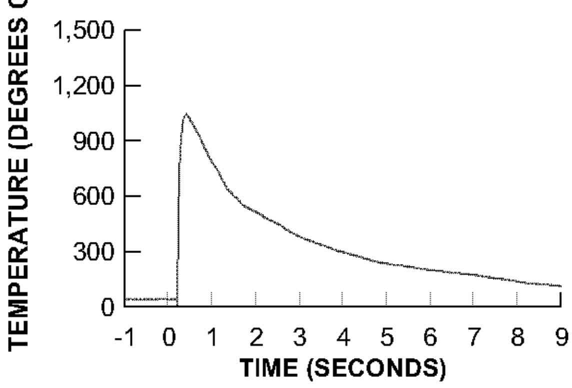
TEST 31A
THERMOCOUPLE 6
BAY 1



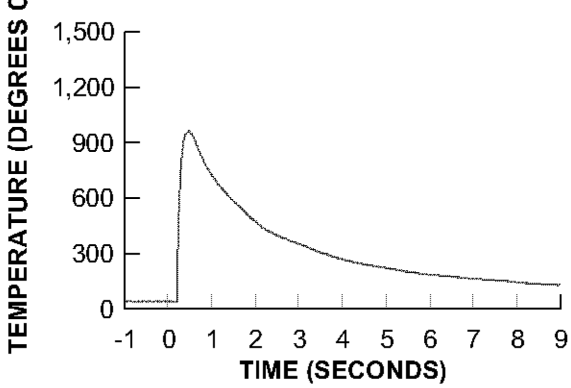
TEST 31B
THERMOCOUPLE 1
BAY 5



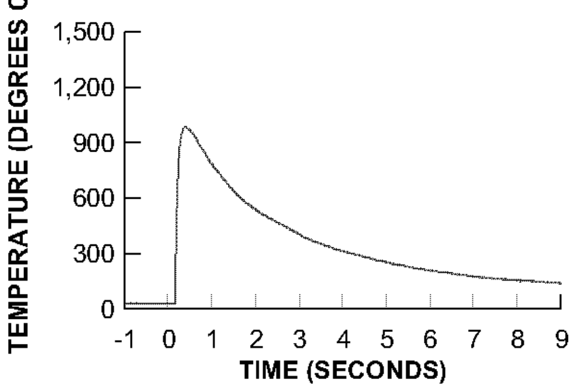
TEST 31B
THERMOCOUPLE 2
BAY 6



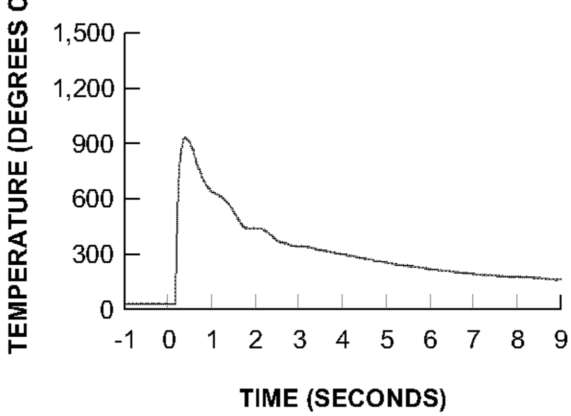
TEST 31B
THERMOCOUPLE 3
BAY 3



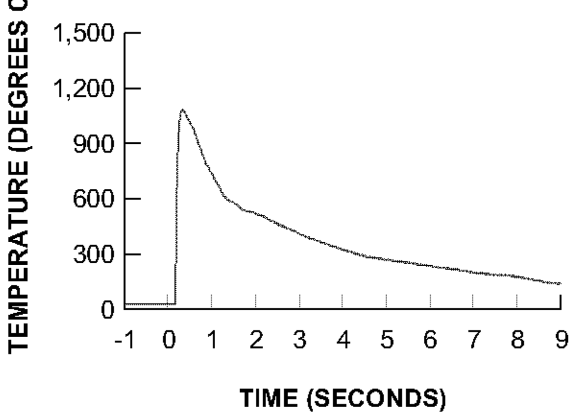
TEST 31B
THERMOCOUPLE 4
BAY 4



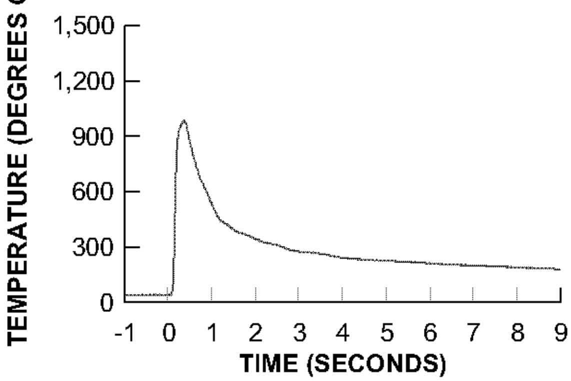
TEST 31B
THERMOCOUPLE 5
BAY 2



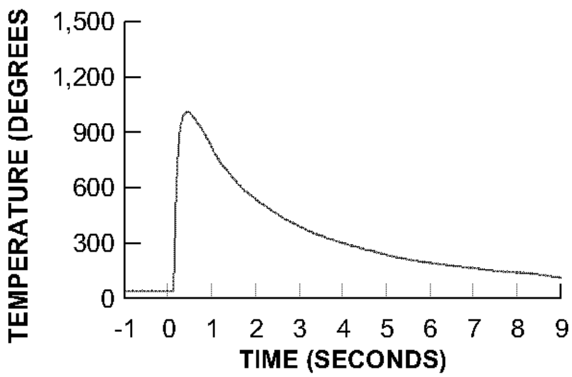
TEST 31B
THERMOCOUPLE 6
BAY 1



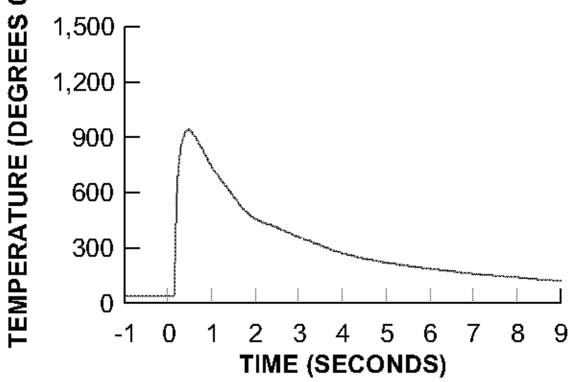
TEST 32
THERMOCOUPLE 1
BAY 5



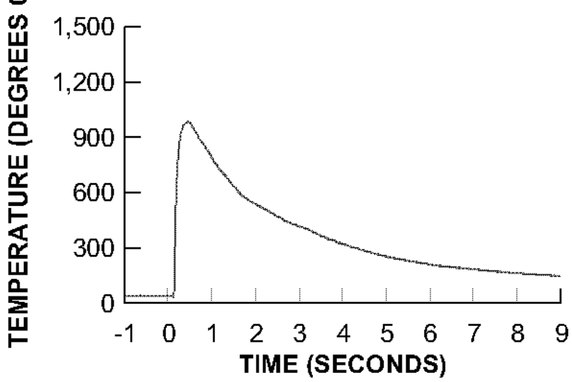
TEST 32
THERMOCOUPLE 2
BAY 6



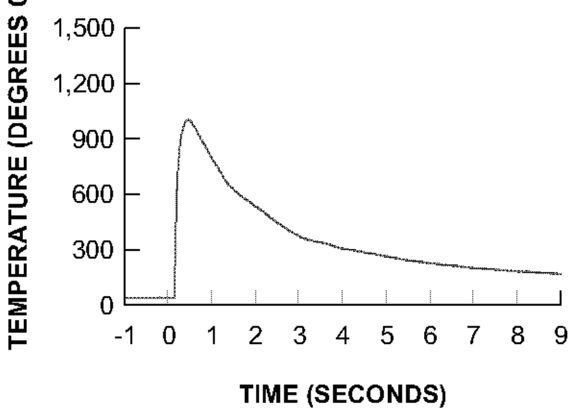
TEST 32
THERMOCOUPLE 3
BAY 3



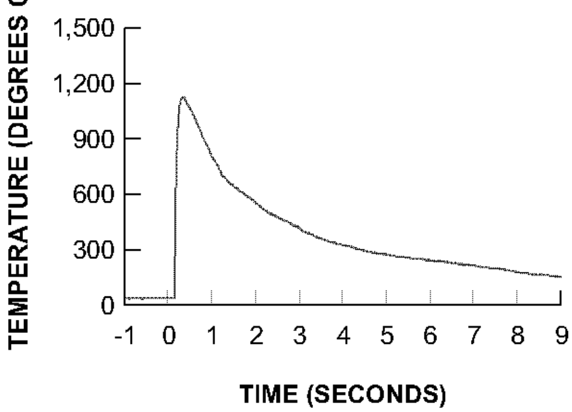
TEST 32
THERMOCOUPLE 4
BAY 4



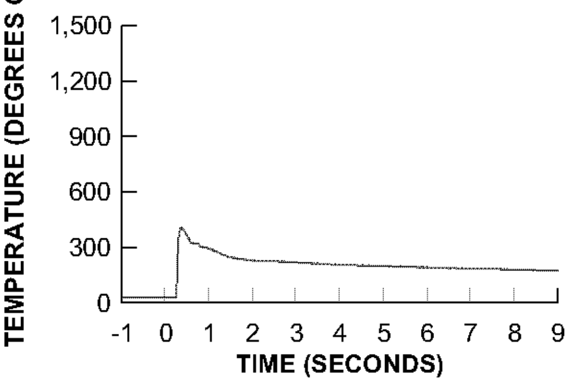
TEST 32
THERMOCOUPLE 5
BAY 2



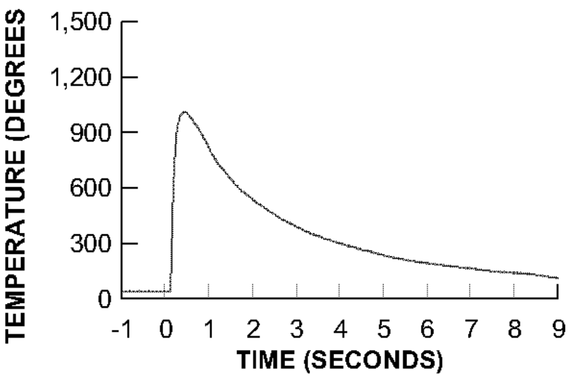
TEST 32
THERMOCOUPLE 6
BAY 1



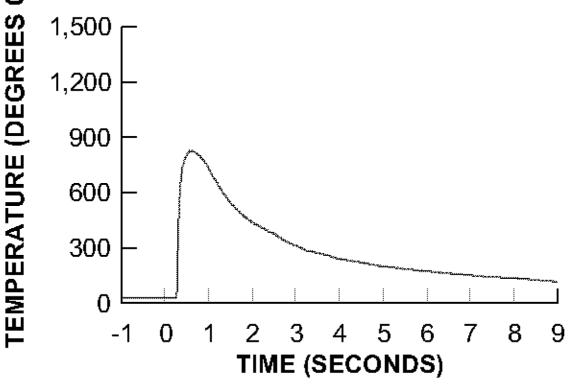
TEST 33
THERMOCOUPLE 1
BAY 5



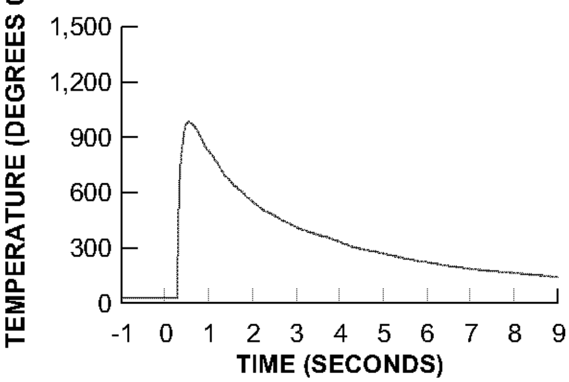
TEST 33
THERMOCOUPLE 2
BAY 6



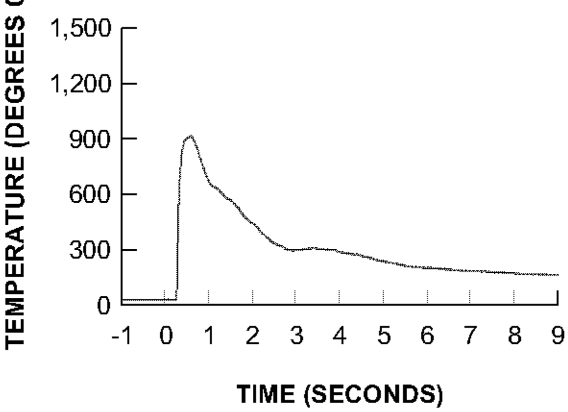
TEST 33
THERMOCOUPLE 3
BAY 3



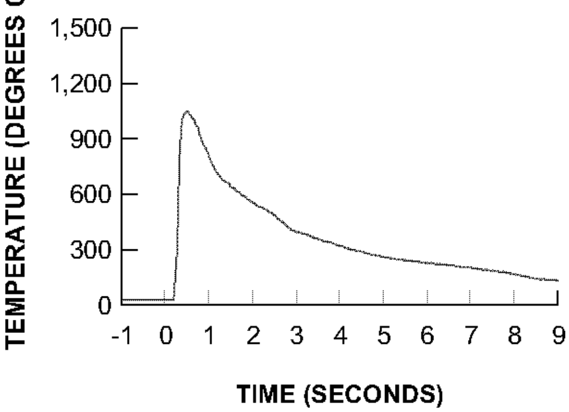
TEST 33
THERMOCOUPLE 4
BAY 4



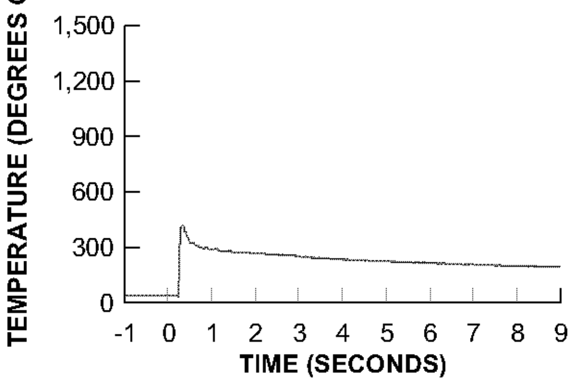
TEST 33
THERMOCOUPLE 5
BAY 2



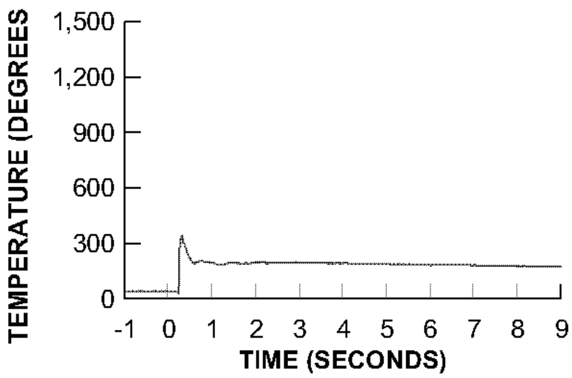
TEST 33
THERMOCOUPLE 6
BAY 1



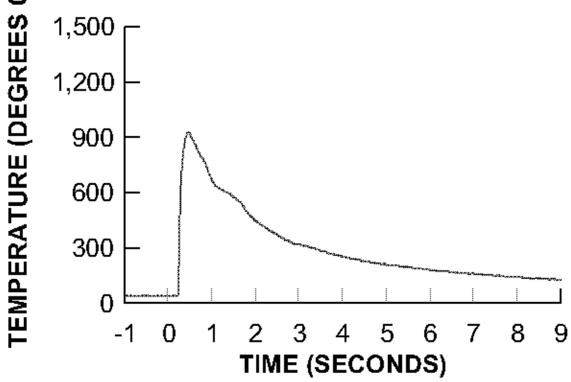
TEST 34
THERMOCOUPLE 1
BAY 5



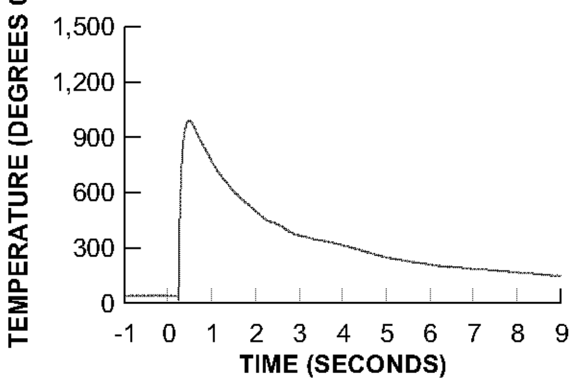
TEST 34
THERMOCOUPLE 2
BAY 6



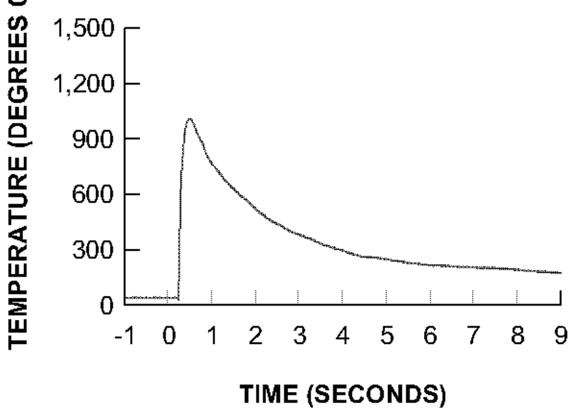
TEST 34
THERMOCOUPLE 3
BAY 3



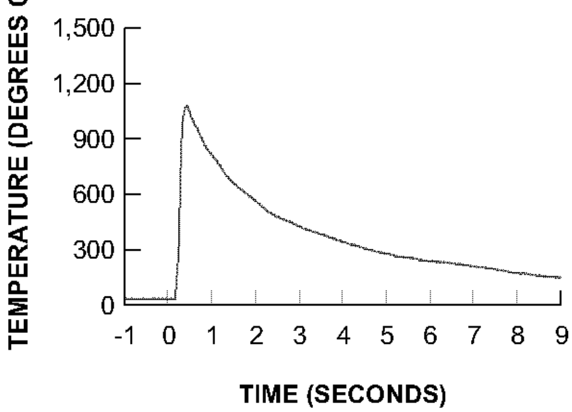
TEST 34
THERMOCOUPLE 4
BAY 4



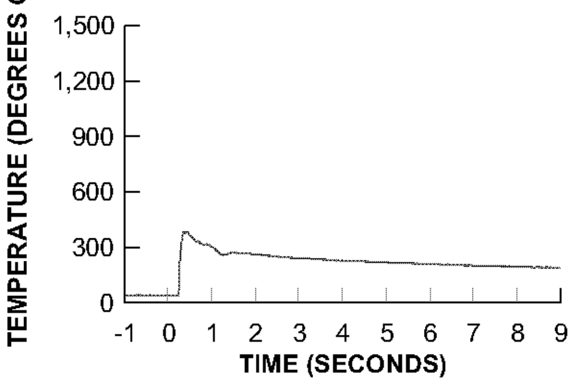
TEST 34
THERMOCOUPLE 5
BAY 2



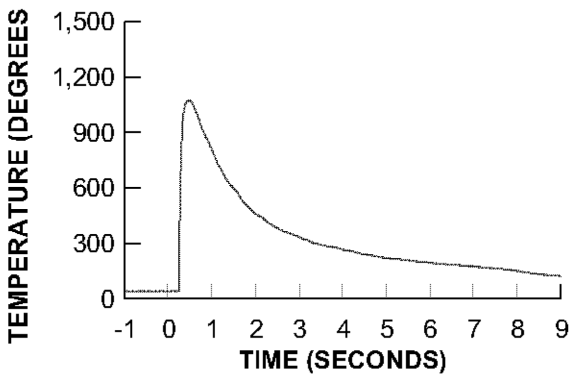
TEST 34
THERMOCOUPLE 6
BAY 1



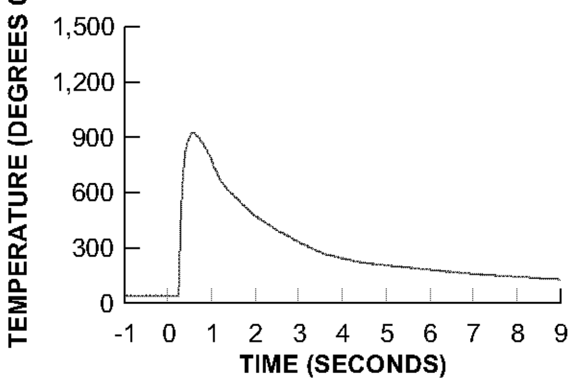
TEST 34A
THERMOCOUPLE 1
BAY 5



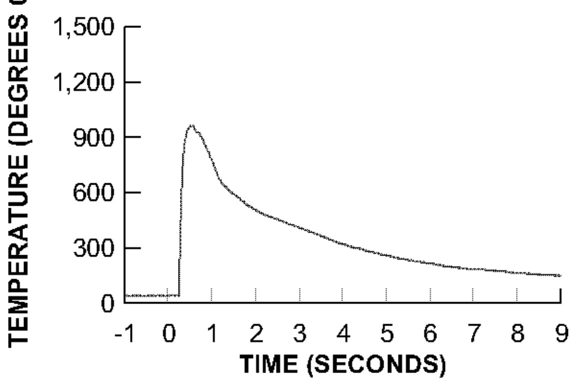
TEST 34A
THERMOCOUPLE 2
BAY 6



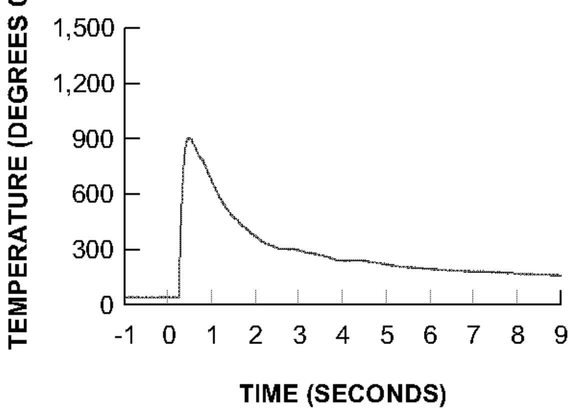
TEST 34A
THERMOCOUPLE 3
BAY 3



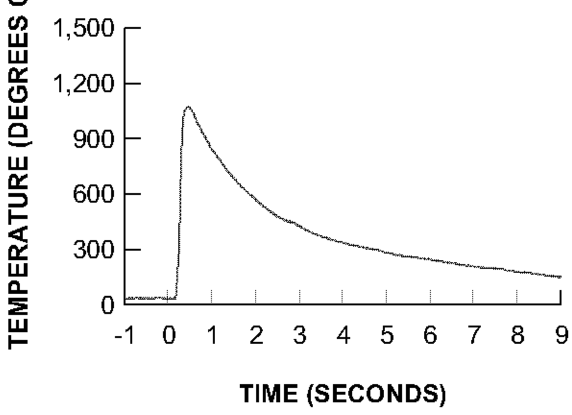
TEST 34A
THERMOCOUPLE 4
BAY 4



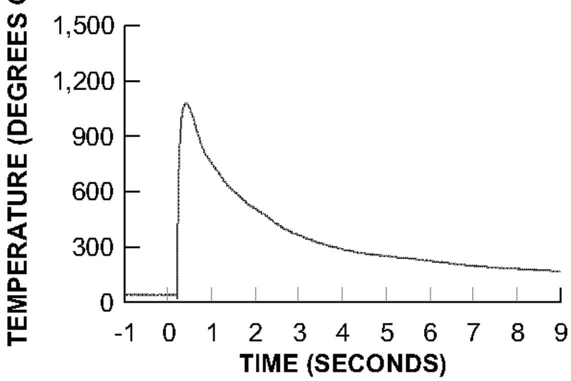
TEST 34A
THERMOCOUPLE 5
BAY 2



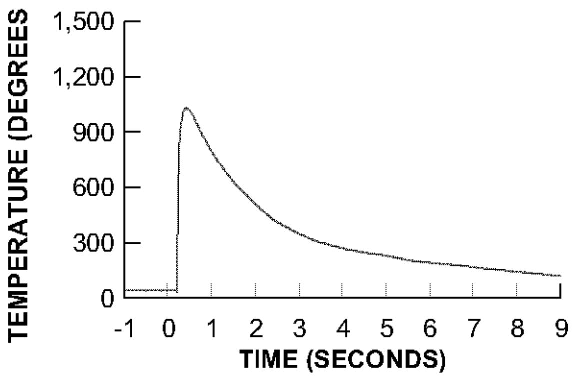
TEST 34A
THERMOCOUPLE 6
BAY 1



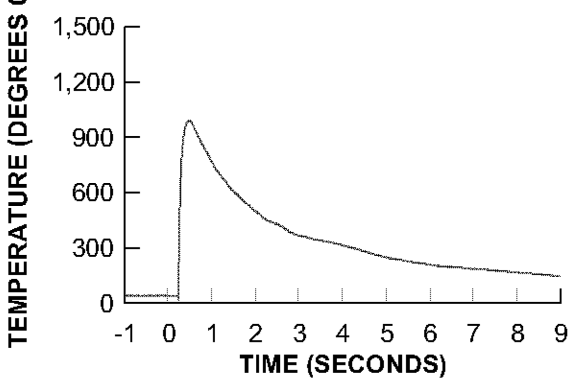
TEST 35
THERMOCOUPLE 1
BAY 5



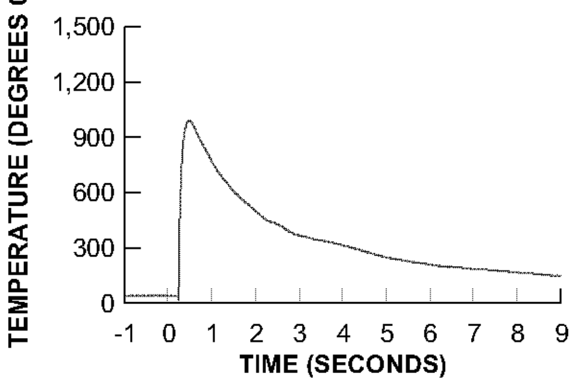
TEST 35
THERMOCOUPLE 2
BAY 6



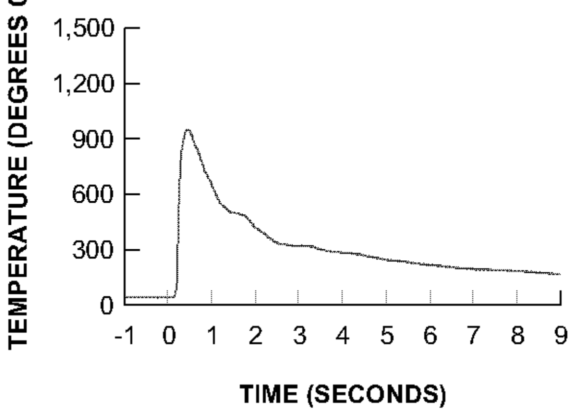
TEST 35
THERMOCOUPLE 3
BAY 3



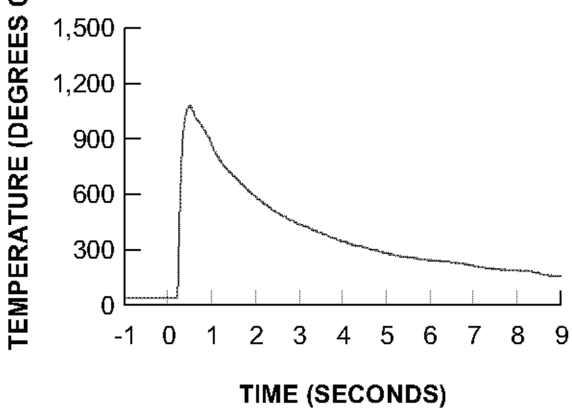
TEST 35
THERMOCOUPLE 4
BAY 4



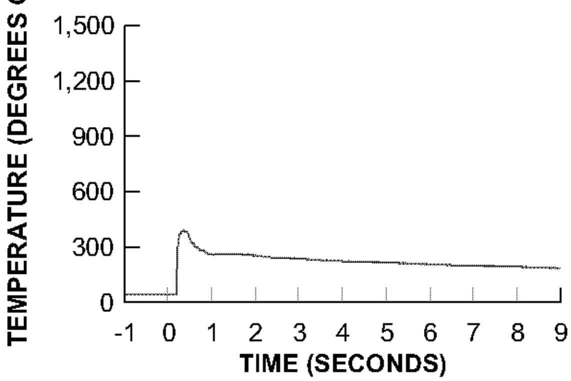
TEST 35
THERMOCOUPLE 5
BAY 2



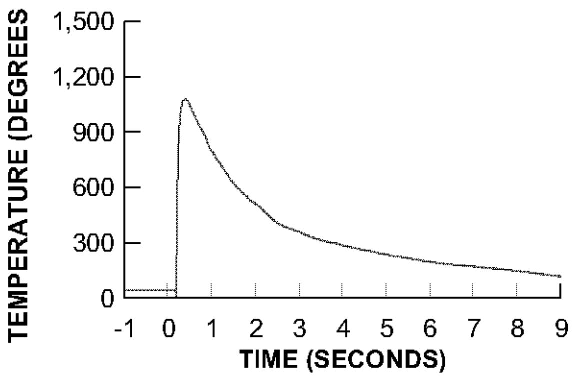
TEST 35
THERMOCOUPLE 6
BAY 1



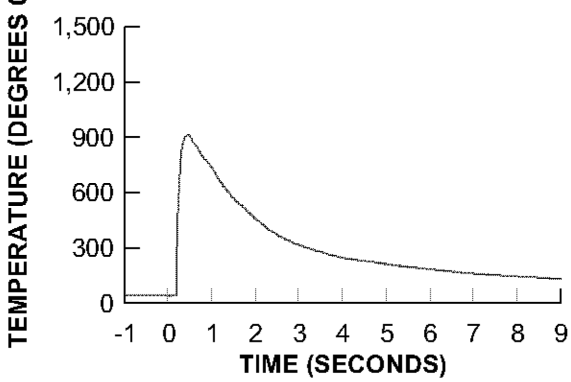
TEST 35A
THERMOCOUPLE 1
BAY 5



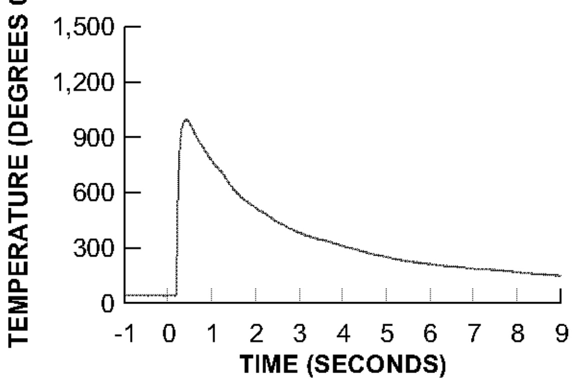
TEST 35A
THERMOCOUPLE 2
BAY 6



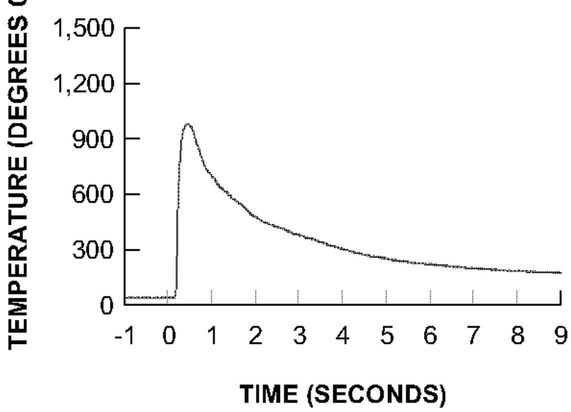
TEST 35A
THERMOCOUPLE 3
BAY 3



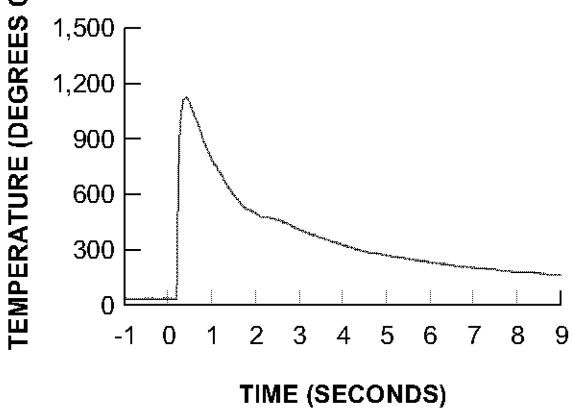
TEST 35A
THERMOCOUPLE 4
BAY 4



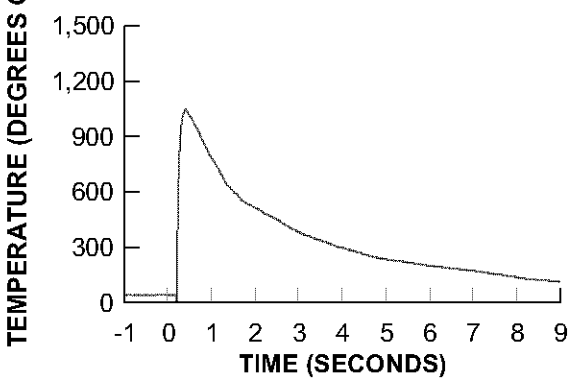
TEST 35A
THERMOCOUPLE 5
BAY 2



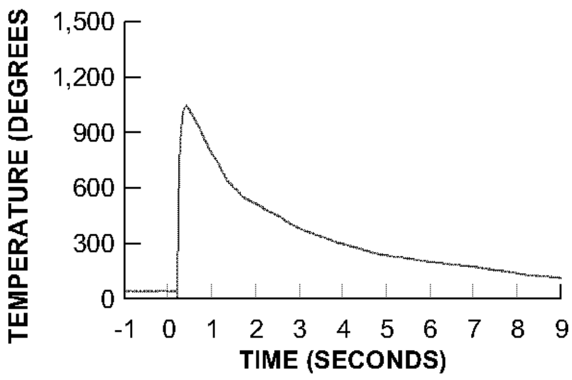
TEST 35A
THERMOCOUPLE 6
BAY 1



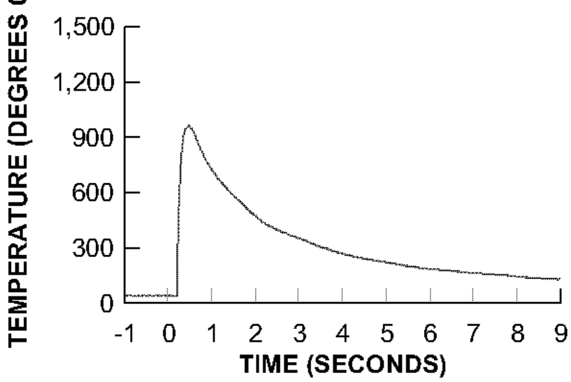
TEST 35B
THERMOCOUPLE 2
BAY 6



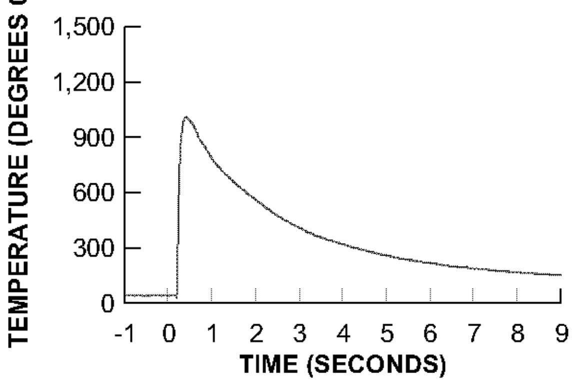
TEST 35B
THERMOCOUPLE 2
BAY 6



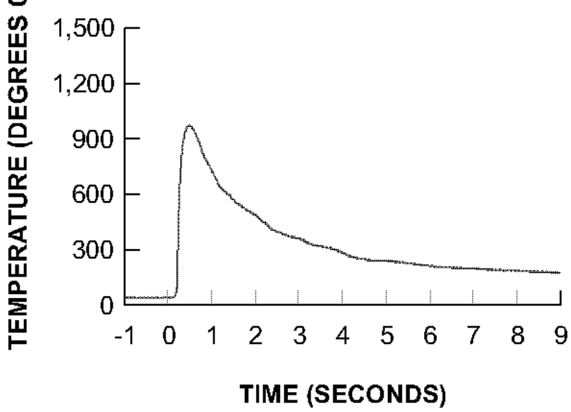
TEST 35B
THERMOCOUPLE 3
BAY 3



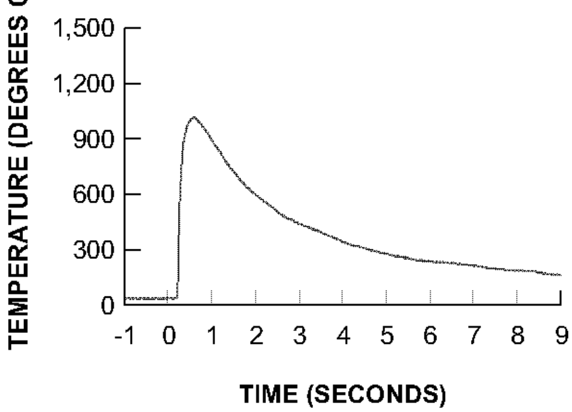
TEST 35B
THERMOCOUPLE 4
BAY 4



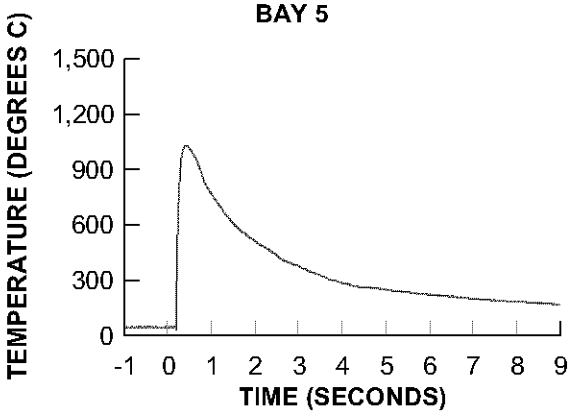
TEST 35B
THERMOCOUPLE 5
BAY 2



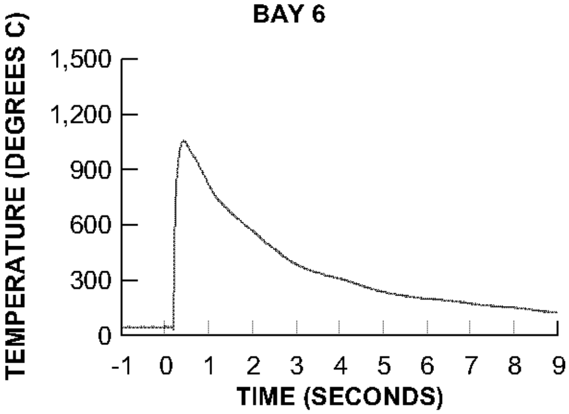
TEST 35B
THERMOCOUPLE 6
BAY 1



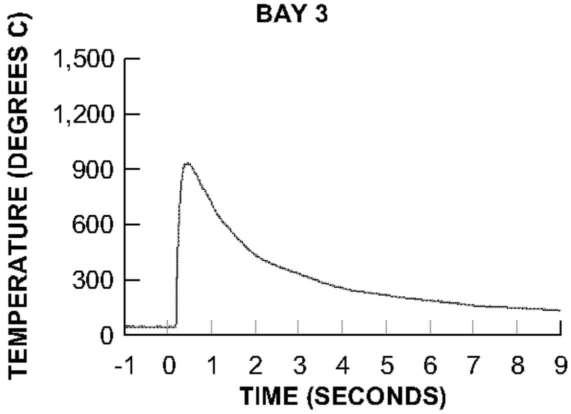
TEST 36
THERMOCOUPLE 1
BAY 5



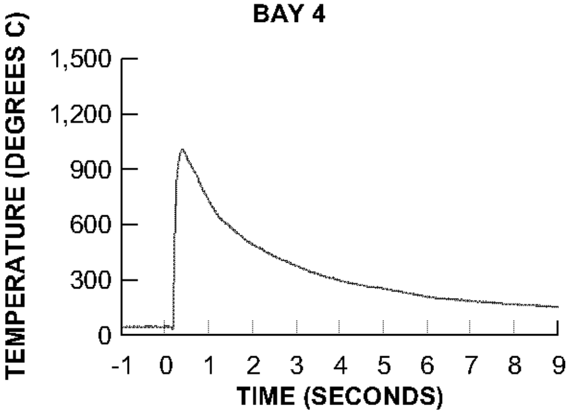
TEST 36
THERMOCOUPLE 2
BAY 6



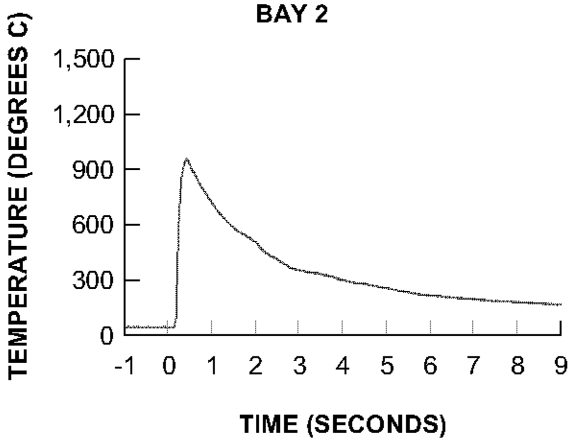
TEST 36
THERMOCOUPLE 3
BAY 3



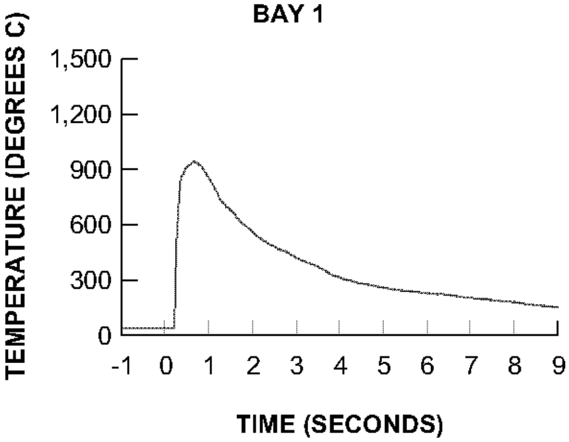
TEST 36
THERMOCOUPLE 4
BAY 4



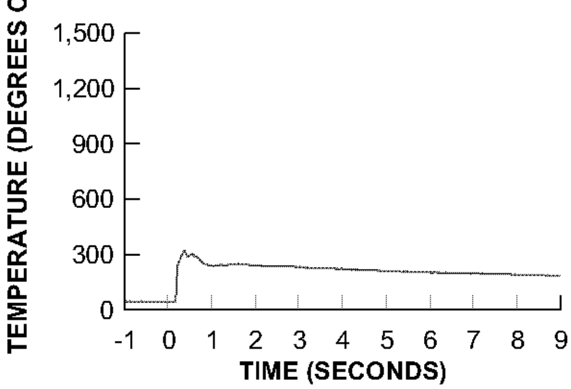
TEST 36
THERMOCOUPLE 5
BAY 2



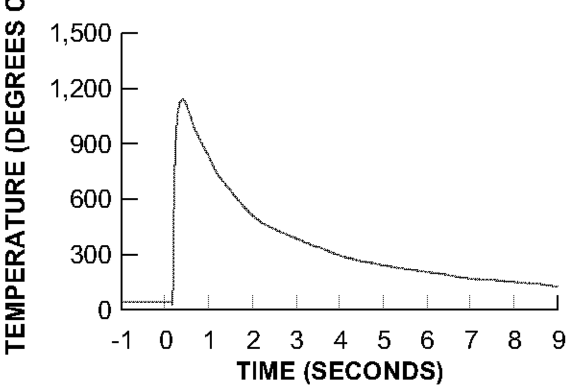
TEST 36
THERMOCOUPLE 6
BAY 1



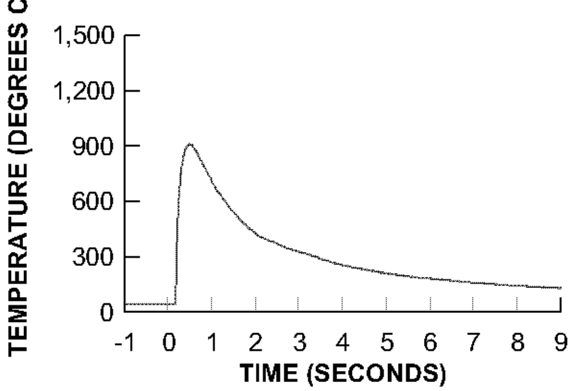
TEST 39
THERMOCOUPLE 1
BAY 5



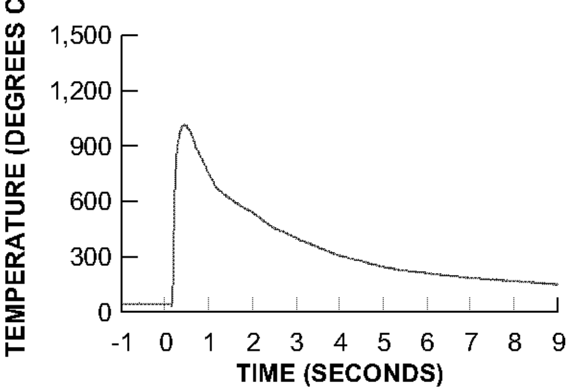
TEST 39
THERMOCOUPLE 2
BAY 6



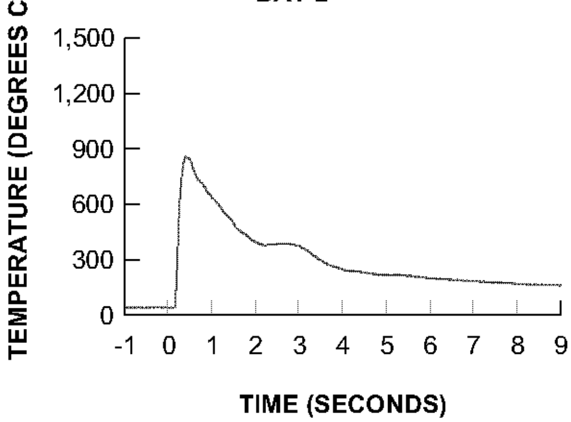
TEST 39
THERMOCOUPLE 3
BAY 3



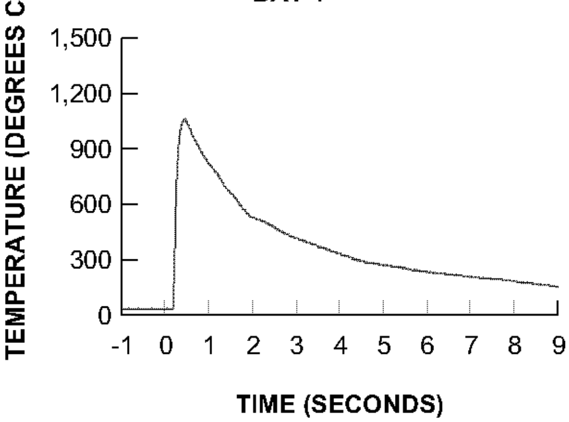
TEST 39
THERMOCOUPLE 4
BAY 4



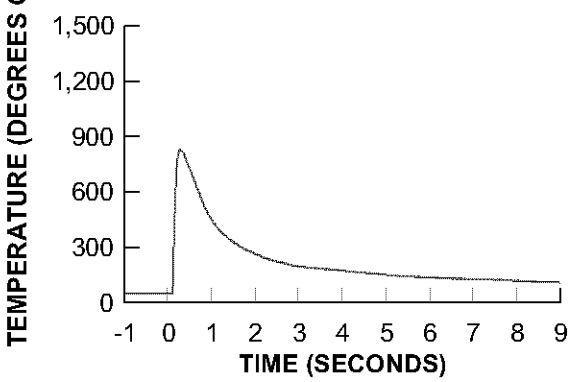
TEST 39
THERMOCOUPLE 5
BAY 2



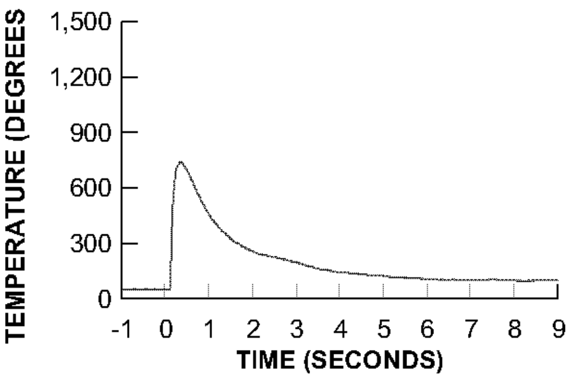
TEST 39
THERMOCOUPLE 6
BAY 1



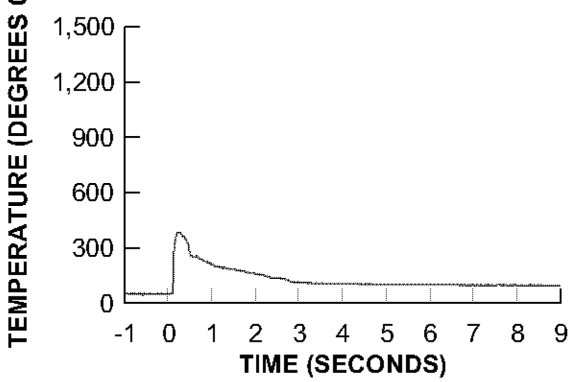
TEST 40
THERMOCOUPLE 1
BAY 5



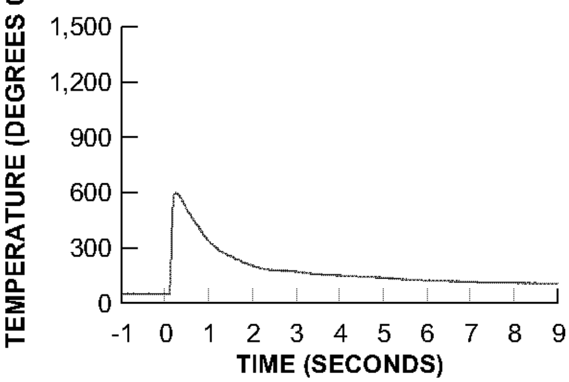
TEST 40
THERMOCOUPLE 2
BAY 6



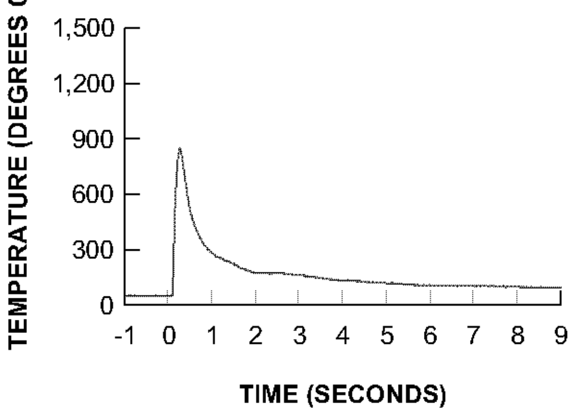
TEST 40
THERMOCOUPLE 3
BAY 3



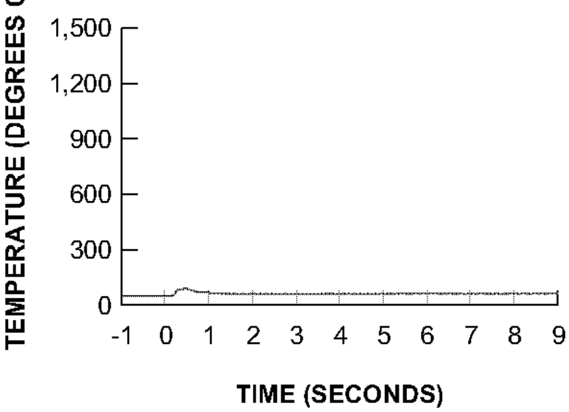
TEST 40
THERMOCOUPLE 4
BAY 4



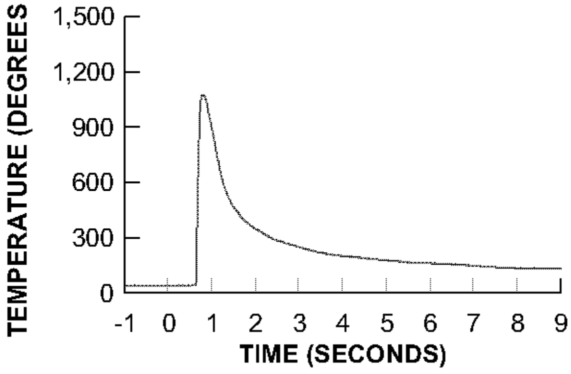
TEST 40
THERMOCOUPLE 5
BAY 2



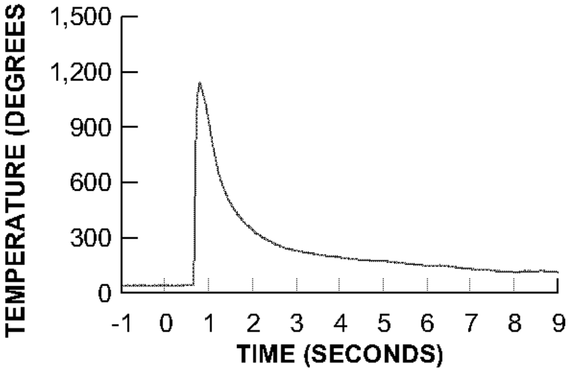
TEST 40
THERMOCOUPLE 6
BAY 1



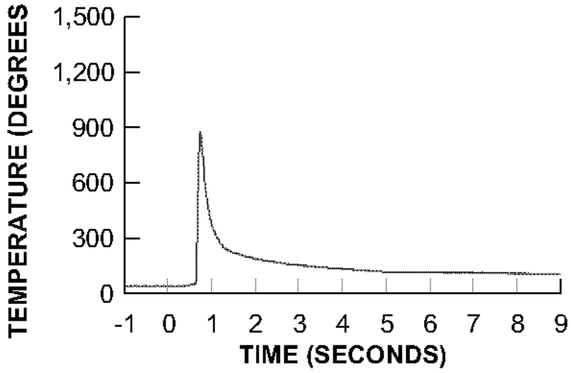
TEST 42
THERMOCOUPLE 1
BAY 5



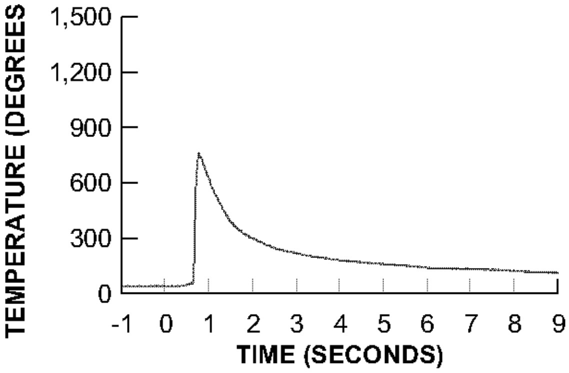
TEST 42
THERMOCOUPLE 2
BAY 6



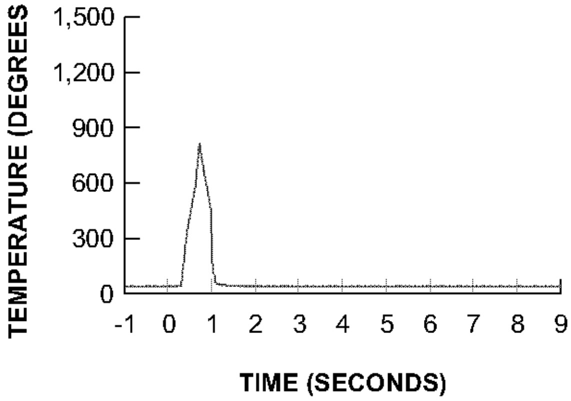
TEST 42
THERMOCOUPLE 3
BAY 3



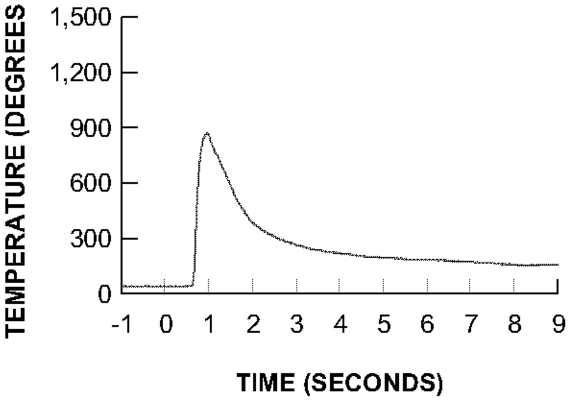
TEST 42
THERMOCOUPLE 4
BAY 4



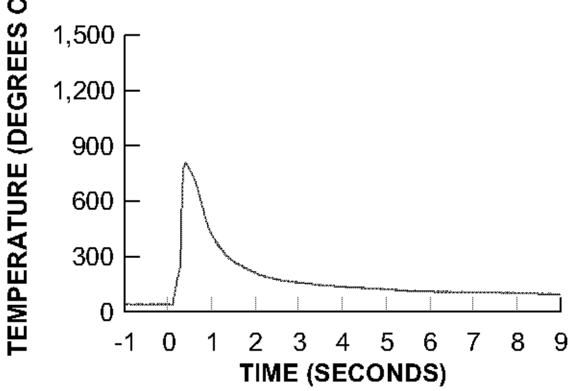
TEST 42
THERMOCOUPLE 5
BAY 2



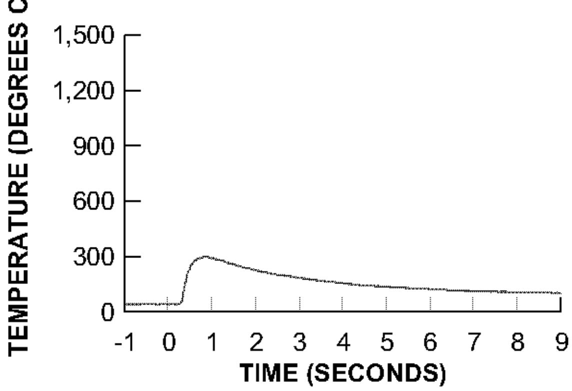
TEST 42
THERMOCOUPLE 6
BAY 1



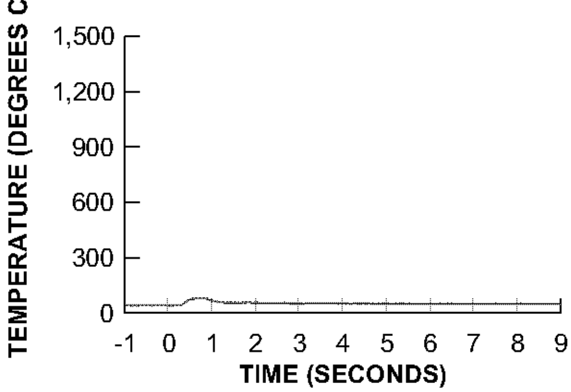
TEST 44
THERMOCOUPLE 1
BAY 5



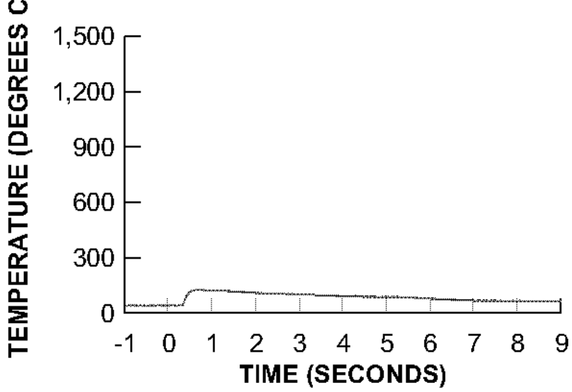
TEST 44
THERMOCOUPLE 2
BAY 6



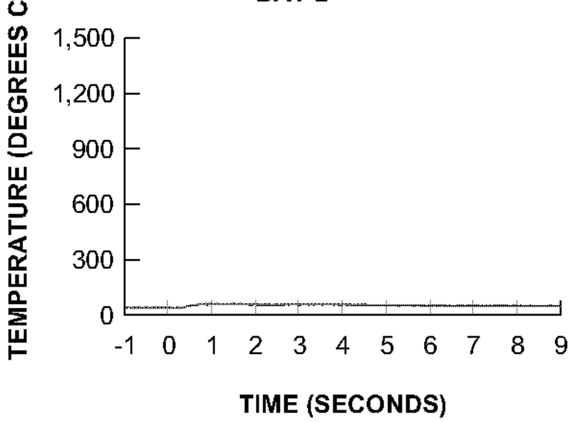
TEST 44
THERMOCOUPLE 3
BAY 3



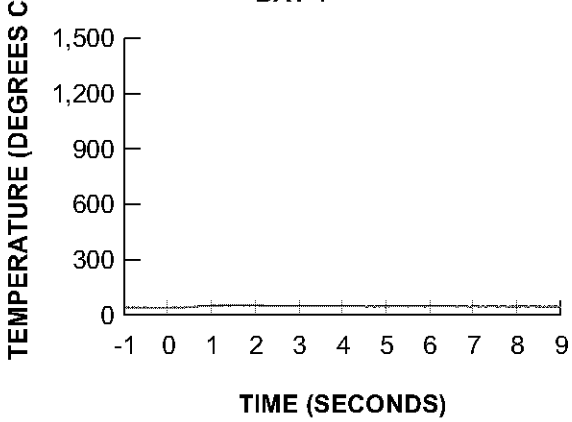
TEST 44
THERMOCOUPLE 4
BAY 4



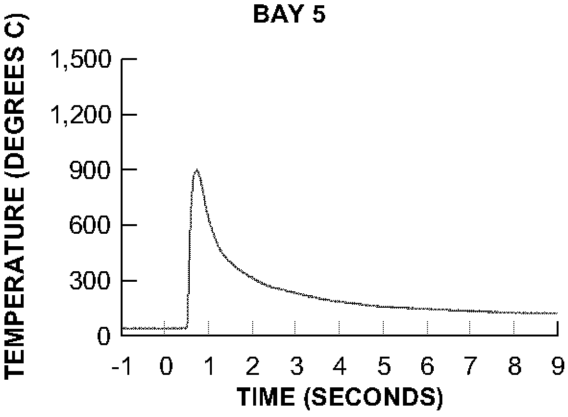
TEST 44
THERMOCOUPLE 5
BAY 2



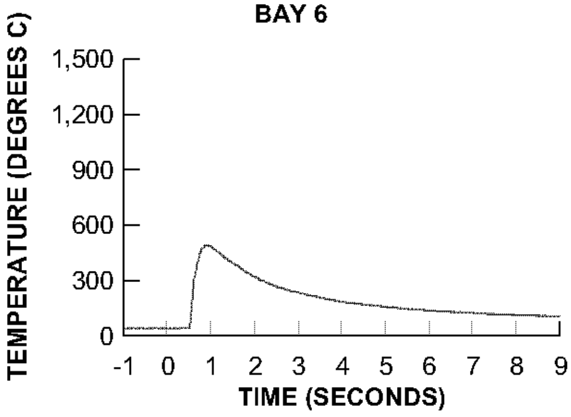
TEST 44
THERMOCOUPLE 6
BAY 1



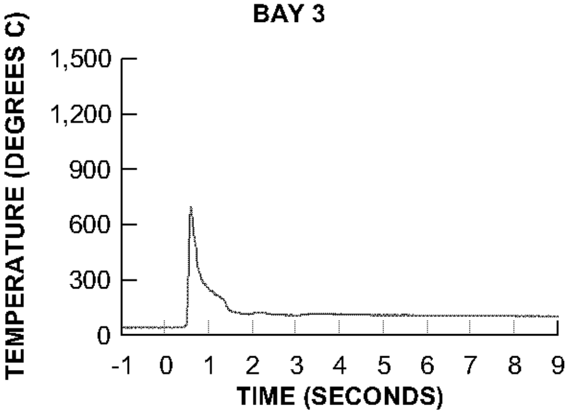
TEST 46
THERMOCOUPLE 1
BAY 5



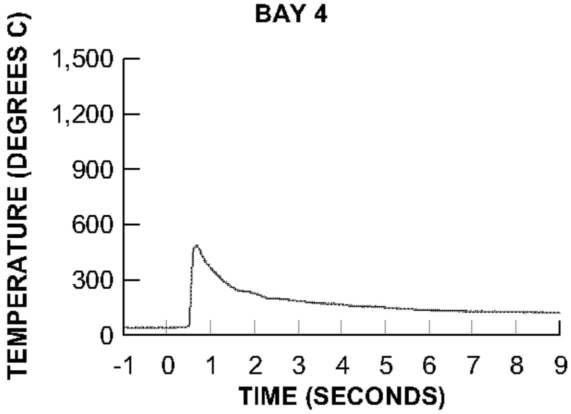
TEST 46
THERMOCOUPLE 2
BAY 6



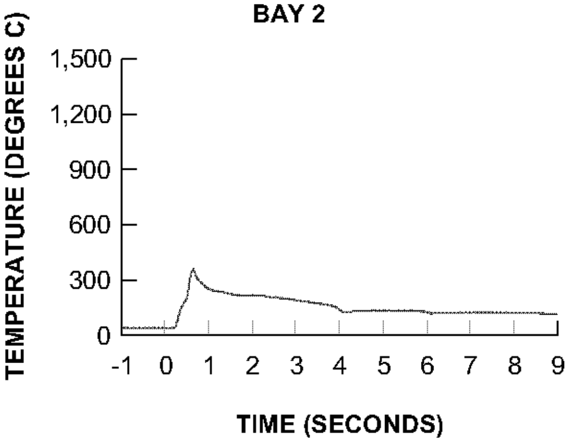
TEST 46
THERMOCOUPLE 3
BAY 3



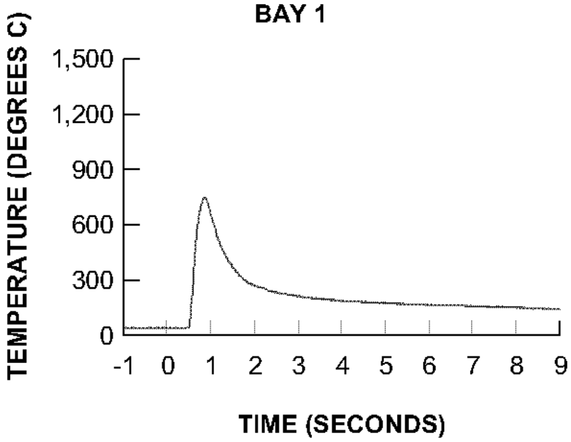
TEST 46
THERMOCOUPLE 4
BAY 4



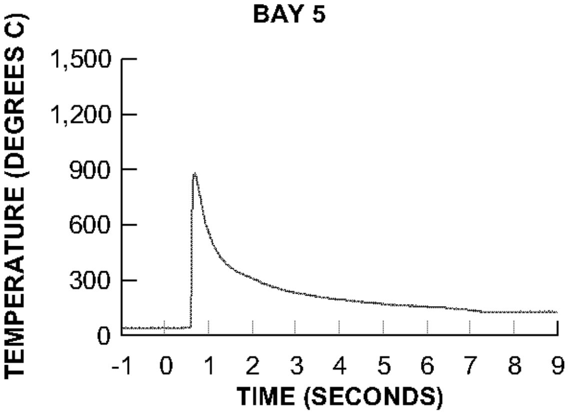
TEST 46
THERMOCOUPLE 5
BAY 2



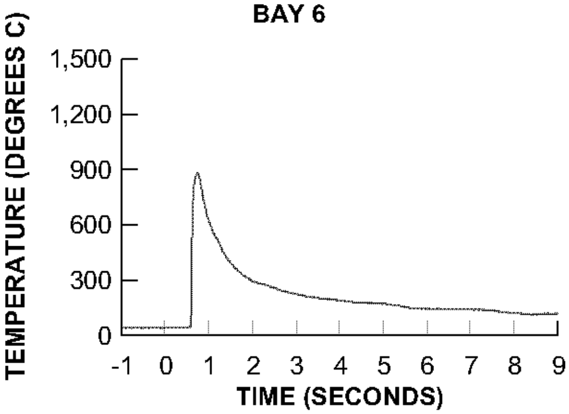
TEST 46
THERMOCOUPLE 6
BAY 1



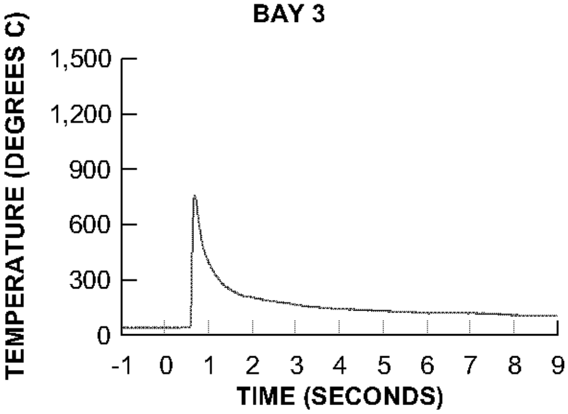
TEST 48
THERMOCOUPLE 1
BAY 5



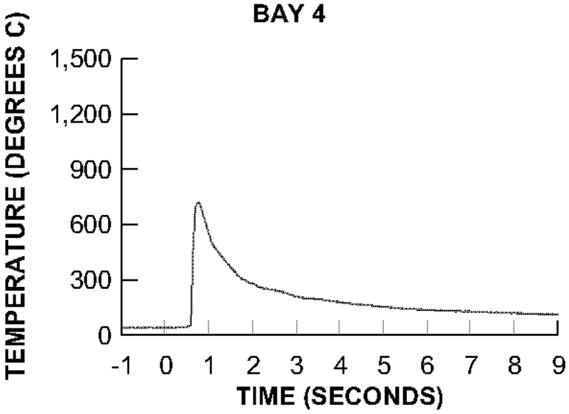
TEST 48
THERMOCOUPLE 2
BAY 6



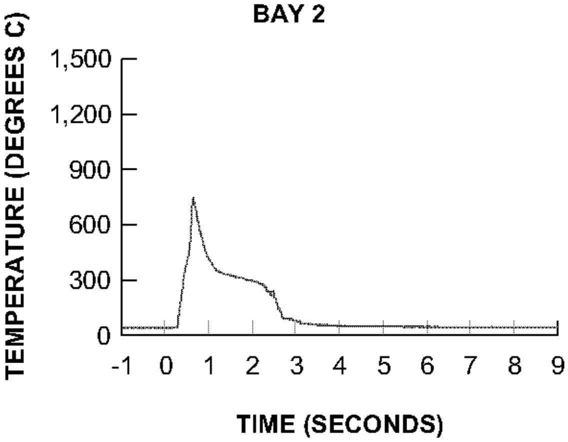
TEST 48
THERMOCOUPLE 3
BAY 3



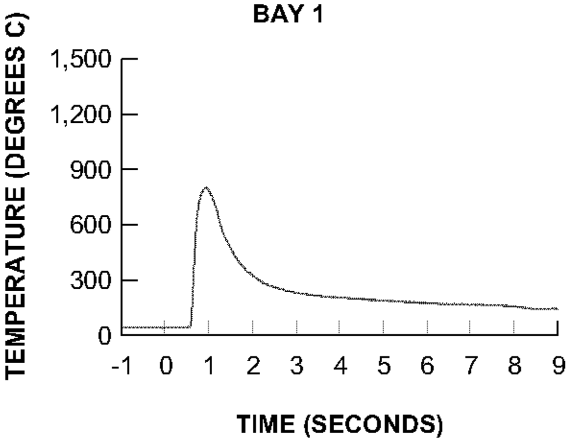
TEST 48
THERMOCOUPLE 4
BAY 4



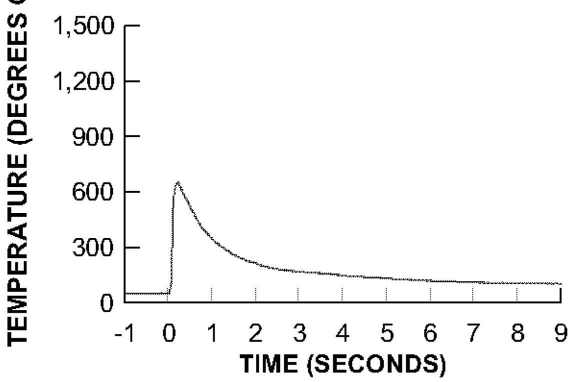
TEST 48
THERMOCOUPLE 5
BAY 2



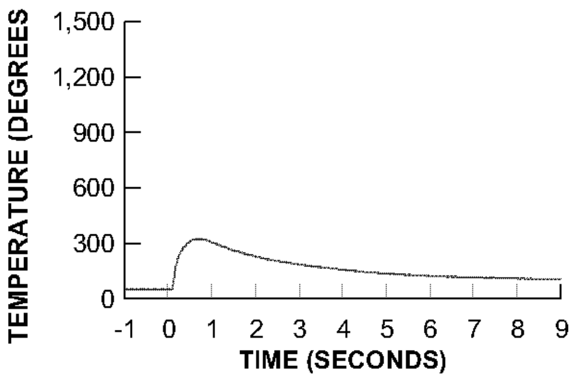
TEST 48
THERMOCOUPLE 6
BAY 1



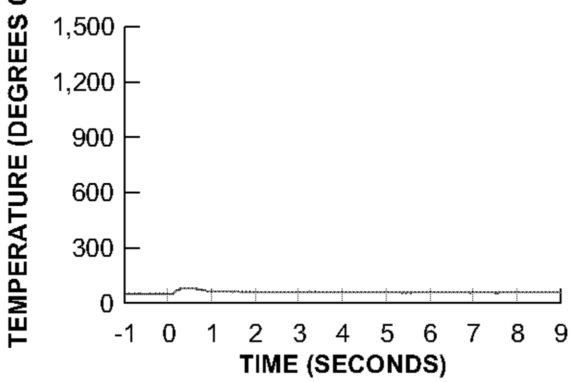
TEST 51
THERMOCOUPLE 1
BAY 5



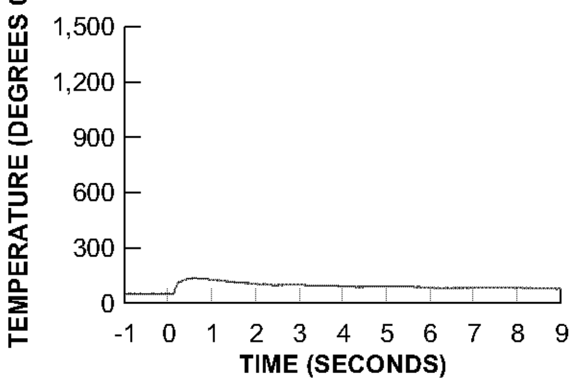
TEST 51
THERMOCOUPLE 2
BAY 6



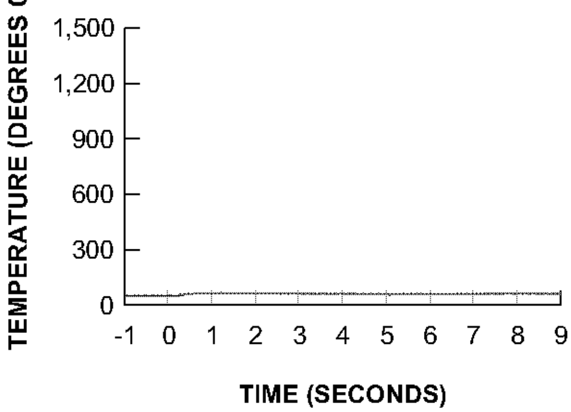
TEST 51
THERMOCOUPLE 3
BAY 3



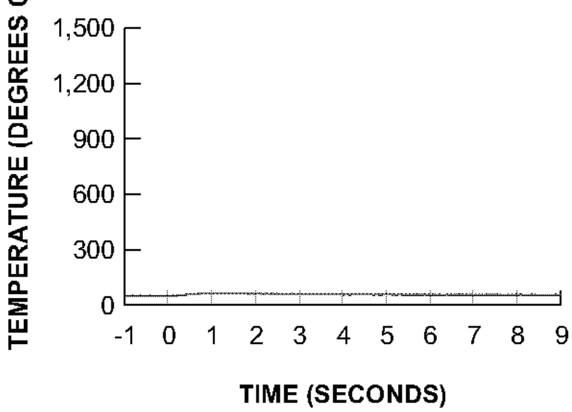
TEST 51
THERMOCOUPLE 4
BAY 4



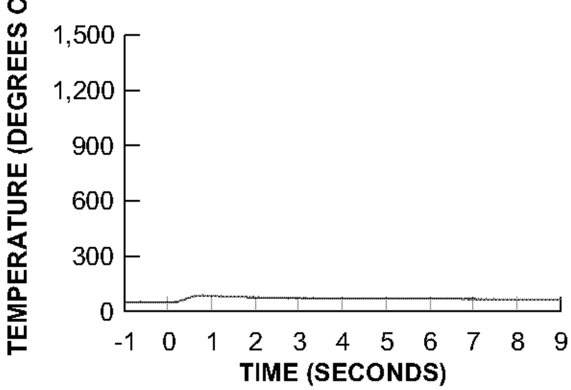
TEST 51
THERMOCOUPLE 5
BAY 2



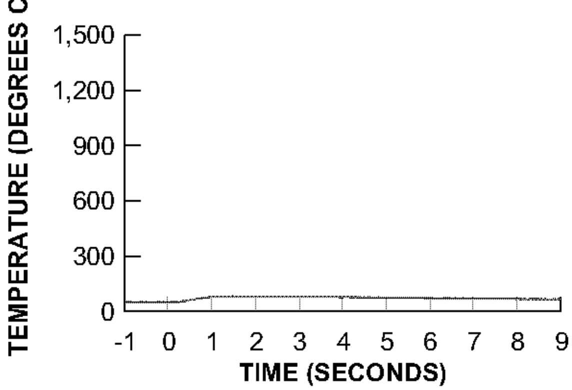
TEST 51
THERMOCOUPLE 6
BAY 1



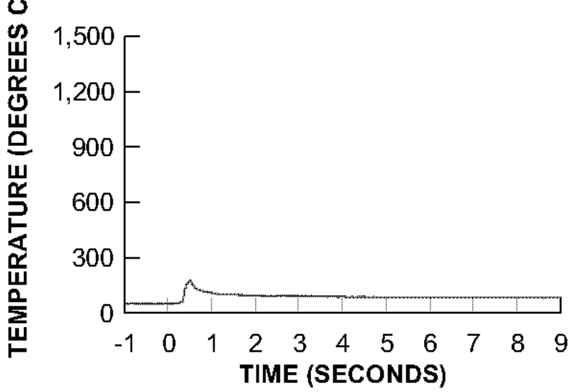
TEST 53
THERMOCOUPLE 1
BAY 5



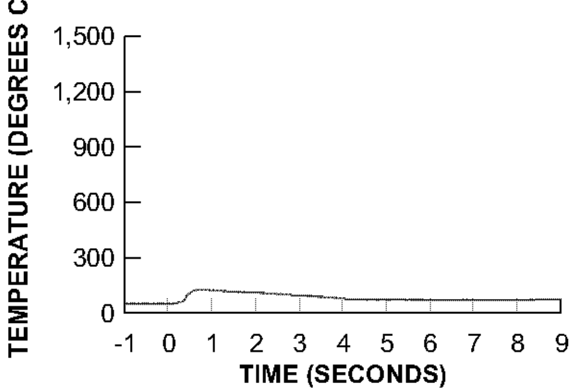
TEST 53
THERMOCOUPLE 2
BAY 6



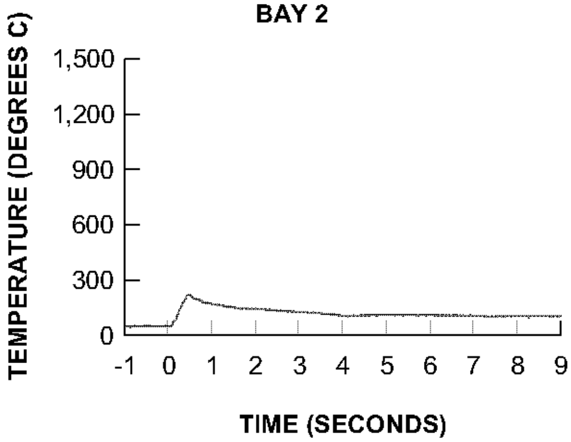
TEST 53
THERMOCOUPLE 3
BAY 3



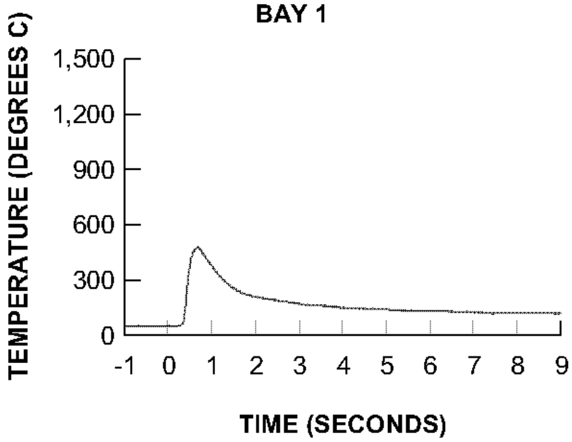
TEST 53
THERMOCOUPLE 4
BAY 4



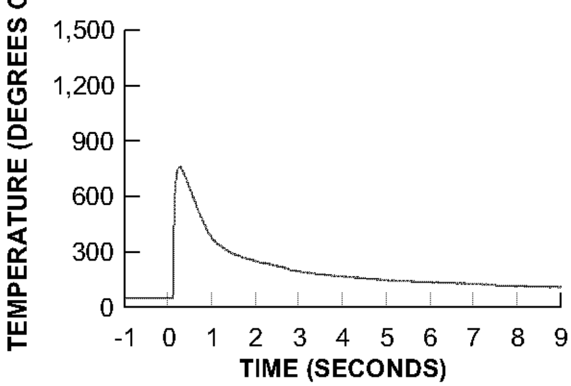
TEST 53
THERMOCOUPLE 5
BAY 2



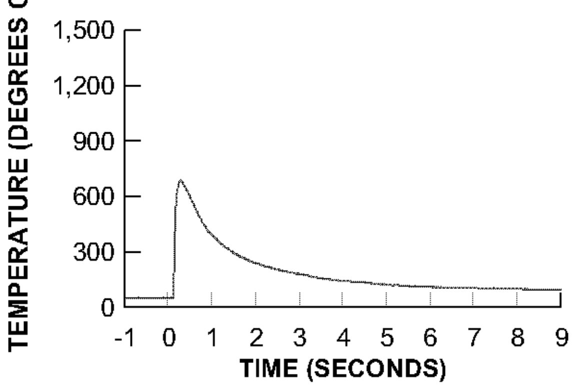
TEST 53
THERMOCOUPLE 6
BAY 1



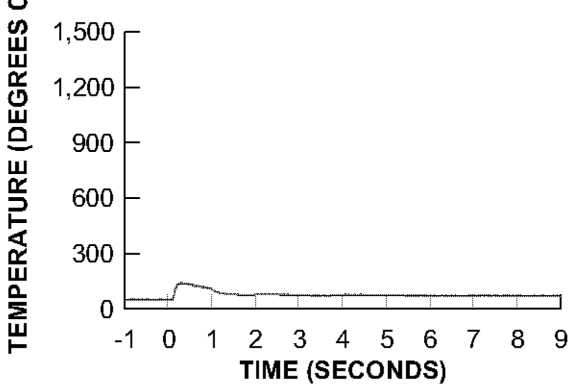
TEST 55
THERMOCOUPLE 1
BAY 5



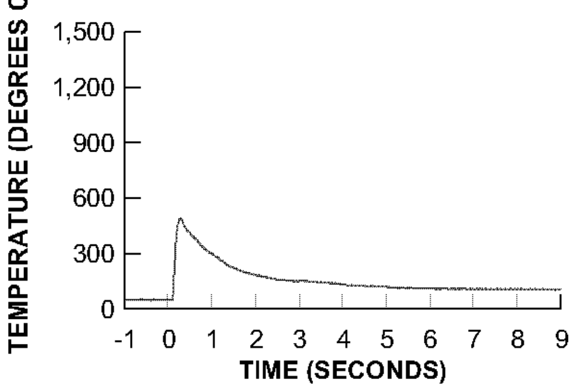
TEST 55
THERMOCOUPLE 2
BAY 6



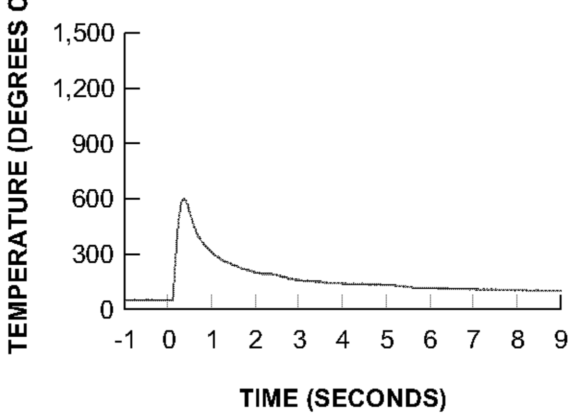
TEST 55
THERMOCOUPLE 3
BAY 3



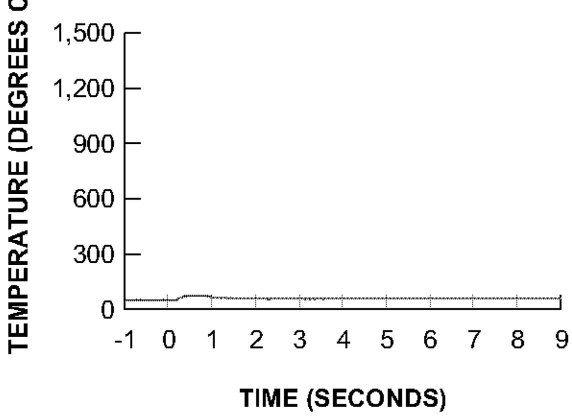
TEST 55
THERMOCOUPLE 4
BAY 4

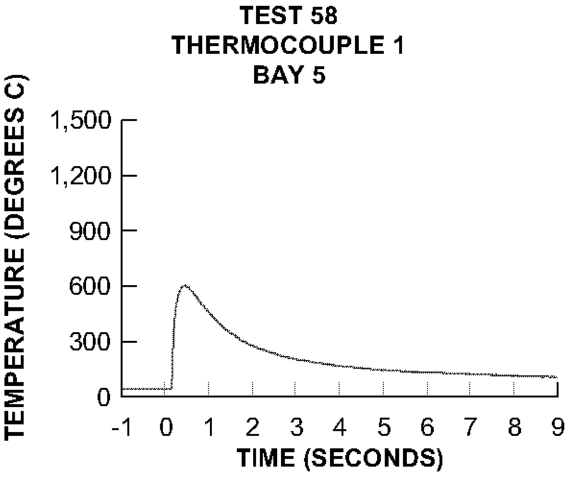


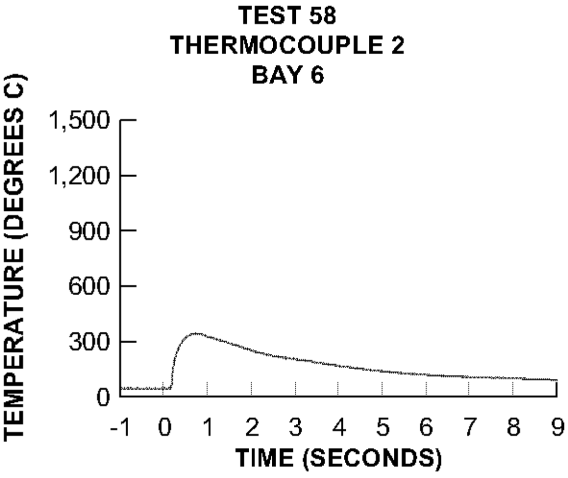
TEST 55
THERMOCOUPLE 5
BAY 2

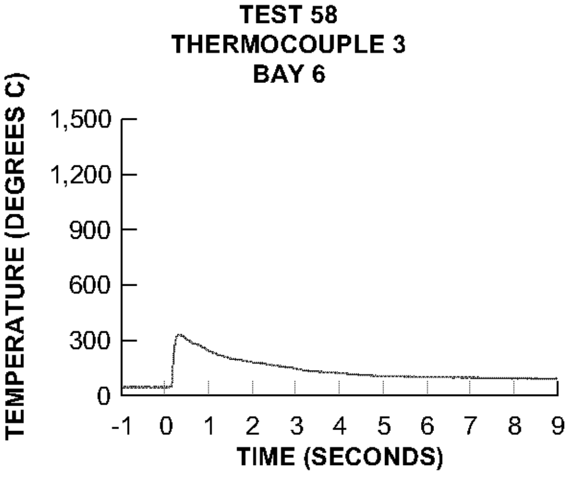


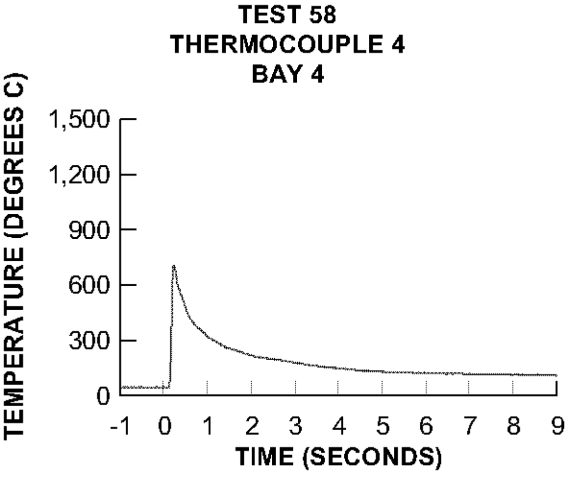
TEST 55
THERMOCOUPLE 6
BAY 1

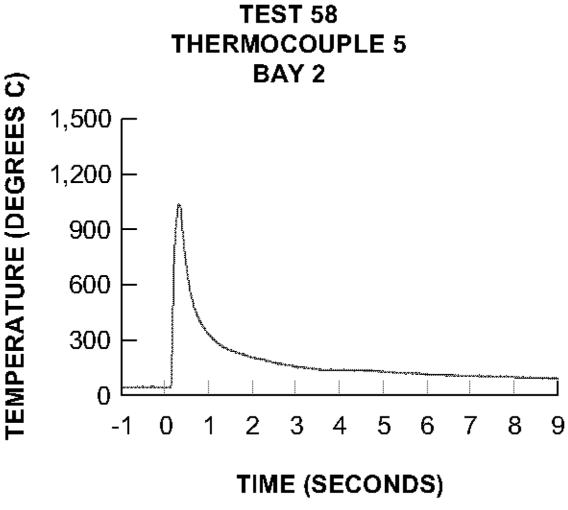


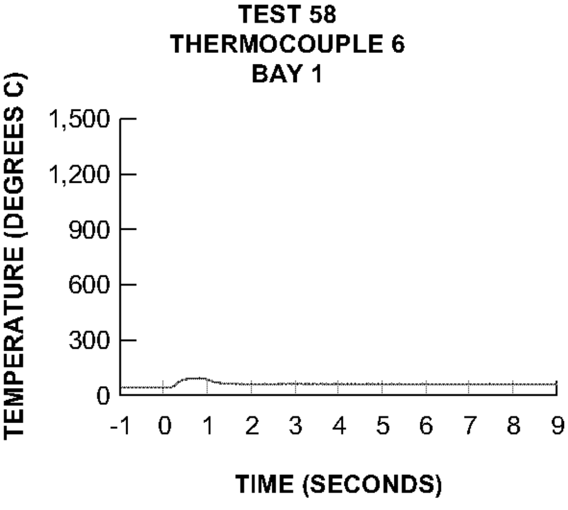

TEST 58
THERMOCOUPLE 1
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 58
THERMOCOUPLE 2
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

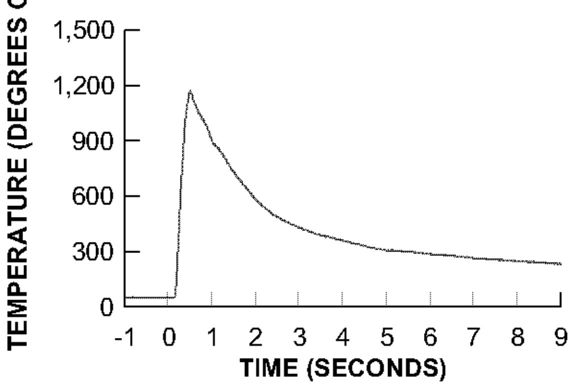

TEST 58
THERMOCOUPLE 3
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 58
THERMOCOUPLE 4
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

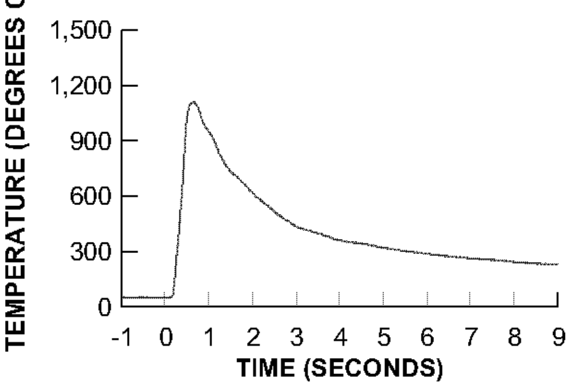

TEST 58
THERMOCOUPLE 5
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 58
THERMOCOUPLE 6
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

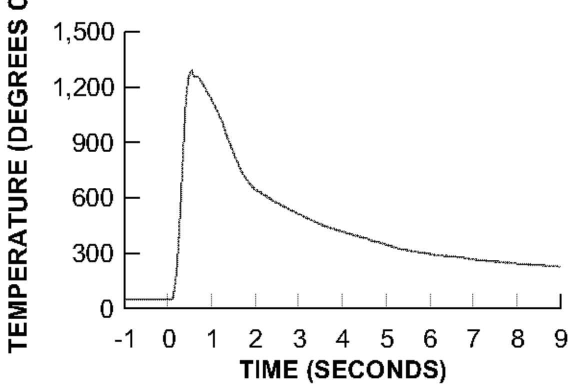
TEST 61
THERMOCOUPLE 1
BAY 5



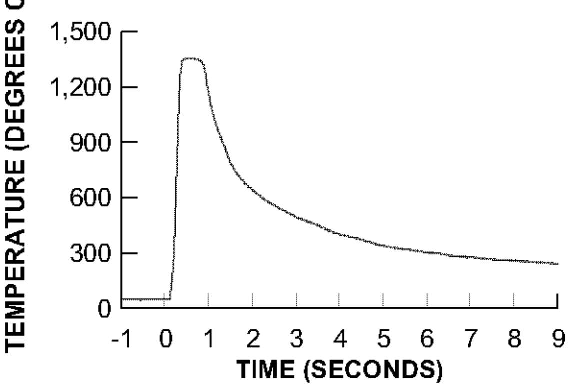
TEST 61
THERMOCOUPLE 2
BAY 6



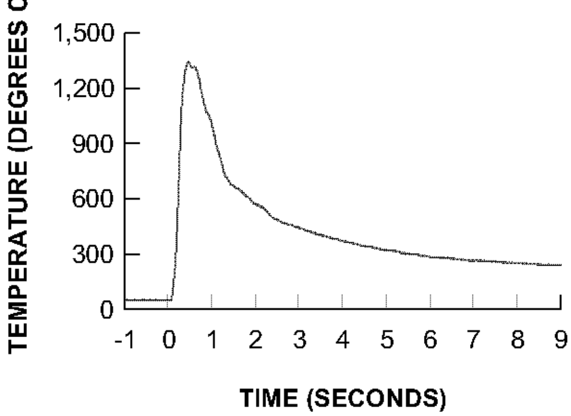
TEST 61
THERMOCOUPLE 3
BAY 3



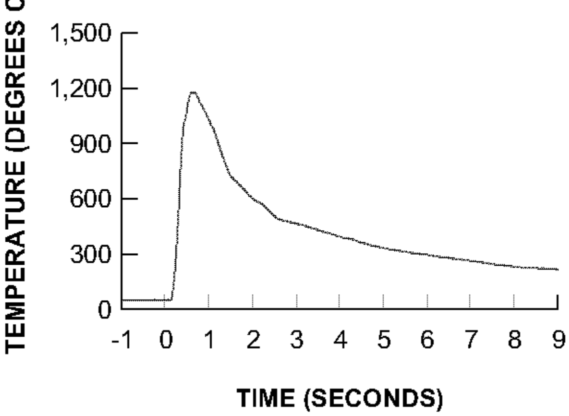
TEST 61
THERMOCOUPLE 4
BAY 4



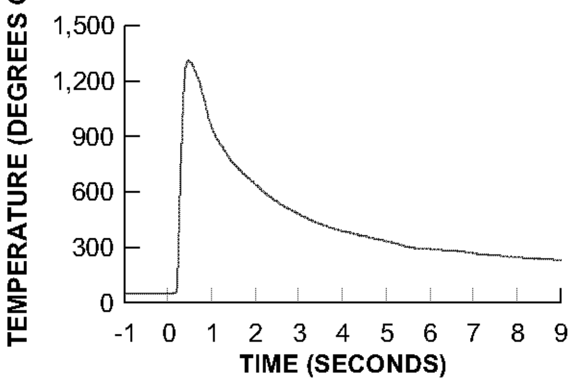
TEST 61
THERMOCOUPLE 5
BAY 2



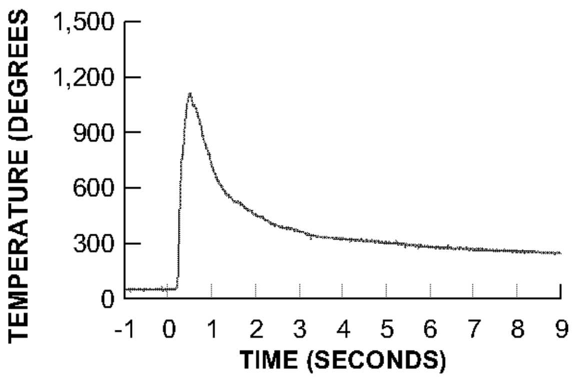
TEST 61
THERMOCOUPLE 6
BAY 1



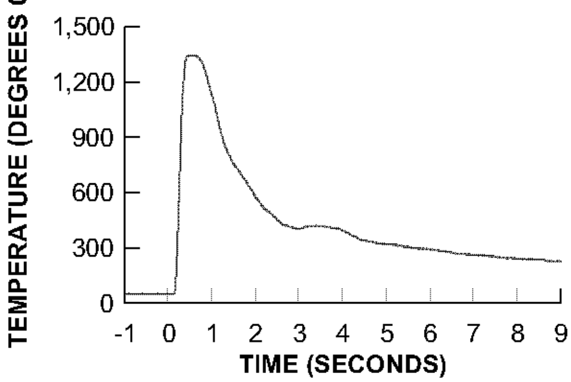
TEST 61
THERMOCOUPLE 7
BAY 5



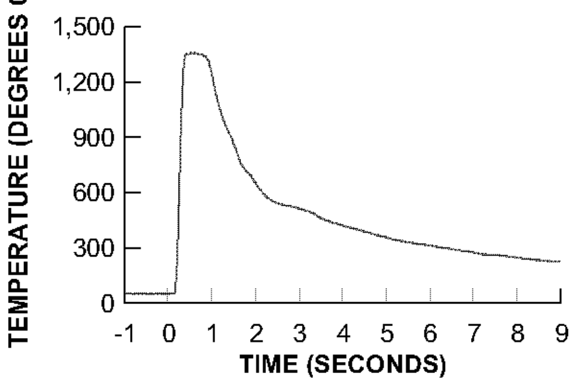
TEST 61
THERMOCOUPLE 8
BAY 6



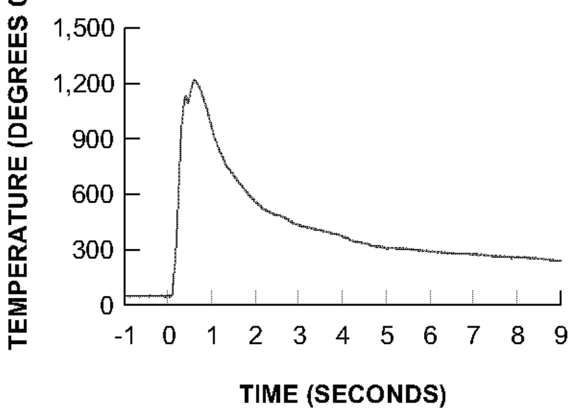
TEST 61
THERMOCOUPLE 9
BAY 3



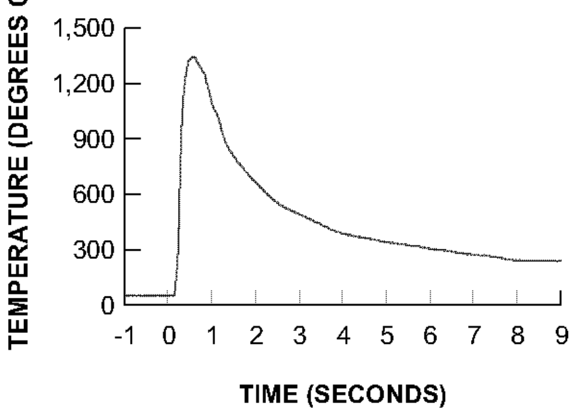
TEST 61
THERMOCOUPLE 10
BAY 4



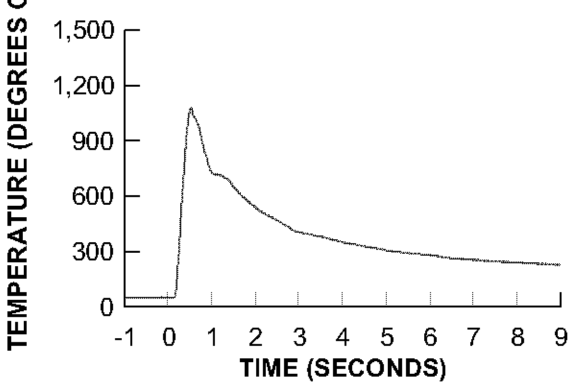
TEST 61
THERMOCOUPLE 11
BAY 2



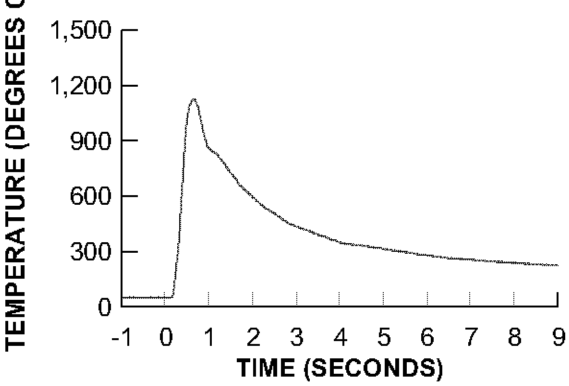
TEST 61
THERMOCOUPLE 12
BAY 1



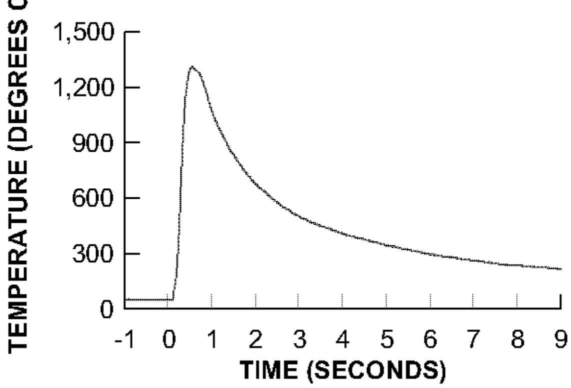
TEST 62
THERMOCOUPLE 1
BAY 5



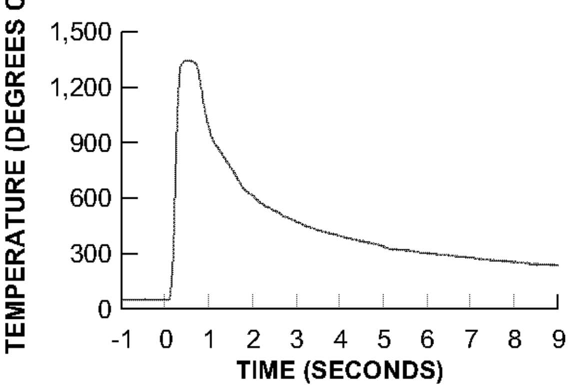
TEST 62
THERMOCOUPLE 2
BAY 6



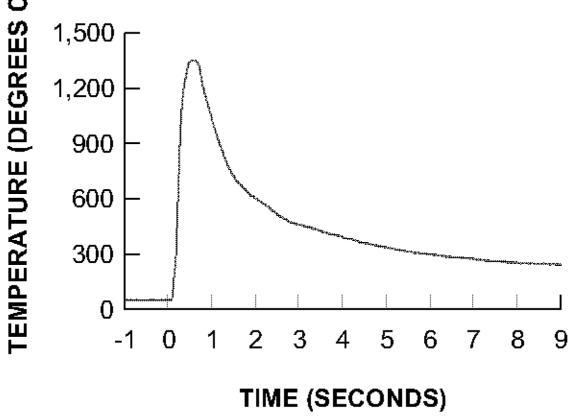
TEST 62
THERMOCOUPLE 3
BAY 3



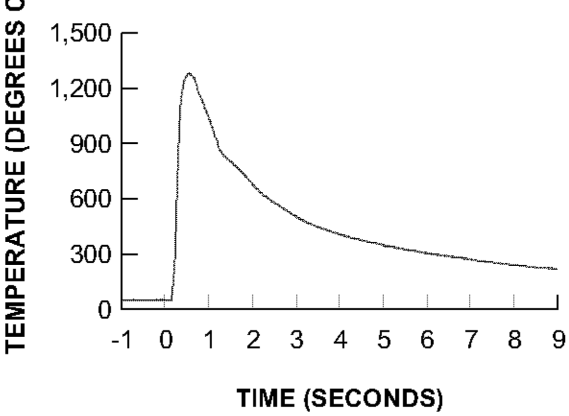
TEST 62
THERMOCOUPLE 4
BAY 4



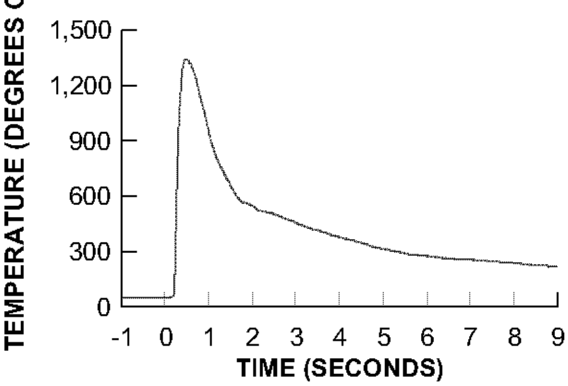
TEST 62
THERMOCOUPLE 5
BAY 2



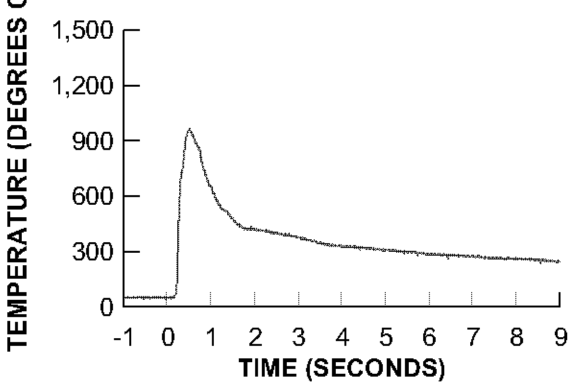
TEST 62
THERMOCOUPLE 6
BAY 1



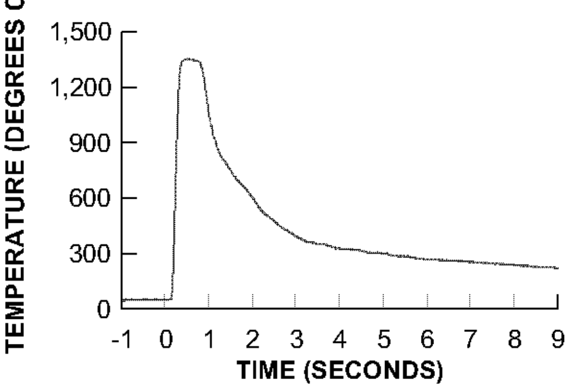
TEST 62
THERMOCOUPLE 7
BAY 5



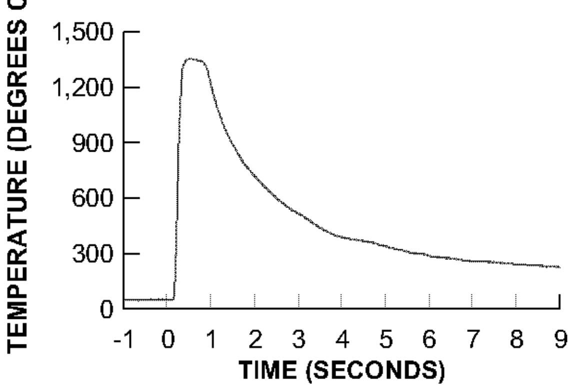
TEST 62
THERMOCOUPLE 8
BAY 6



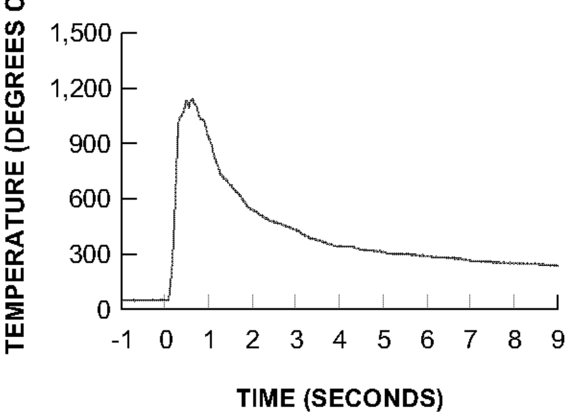
TEST 62
THERMOCOUPLE 9
BAY 3



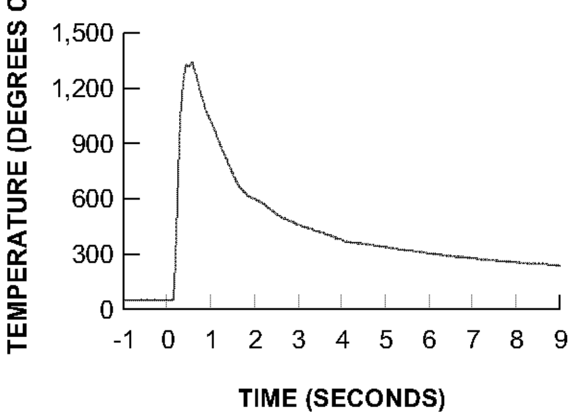
TEST 62
THERMOCOUPLE 10
BAY 4



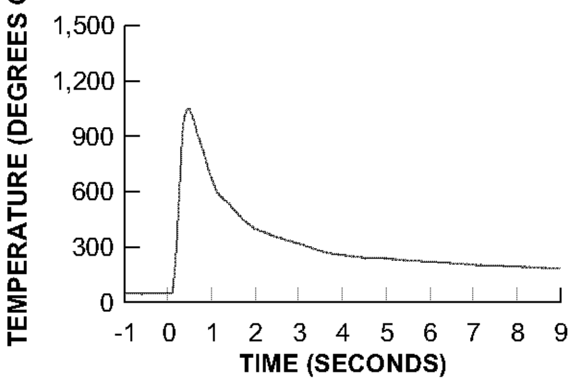
TEST 62
THERMOCOUPLE 11
BAY 2



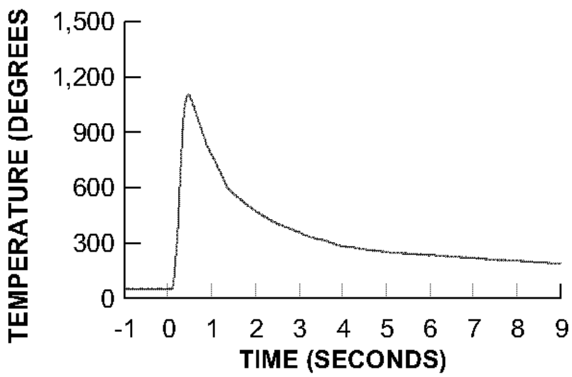
TEST 62
THERMOCOUPLE 12
BAY 1



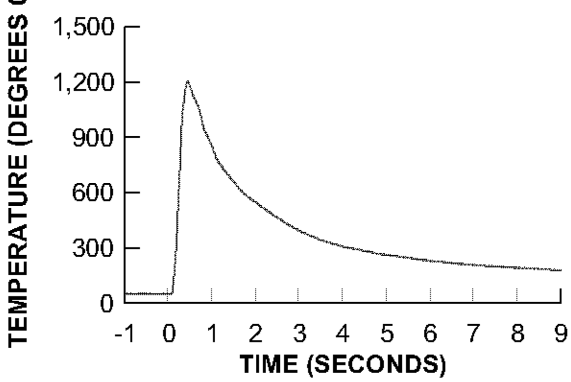
TEST 63
THERMOCOUPLE 1
BAY 5



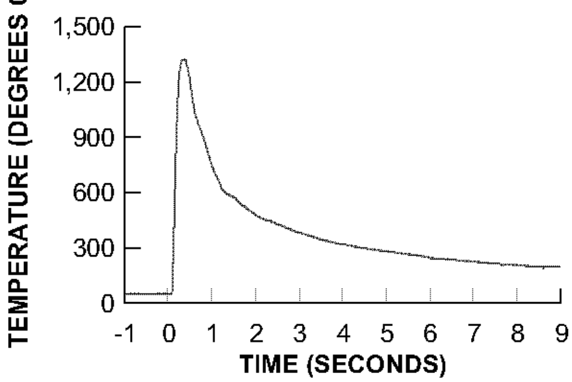
TEST 63
THERMOCOUPLE 2
BAY 6



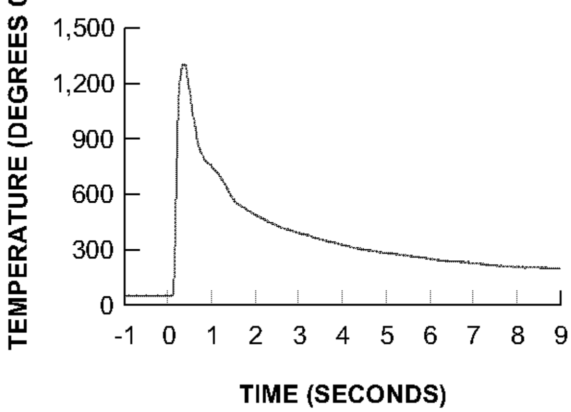
TEST 63
THERMOCOUPLE 3
BAY 3



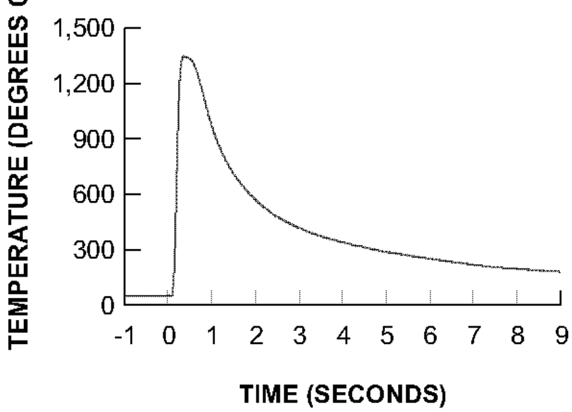
TEST 63
THERMOCOUPLE 4
BAY 4



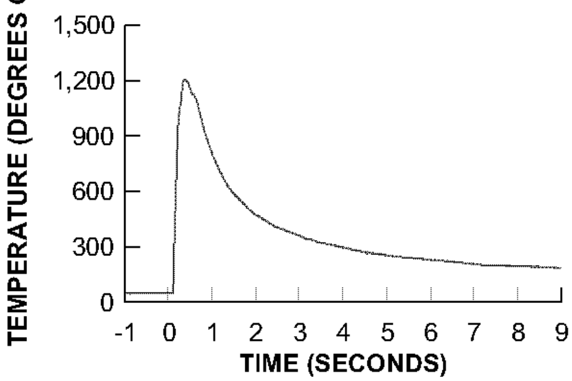
TEST 63
THERMOCOUPLE 5
BAY 2



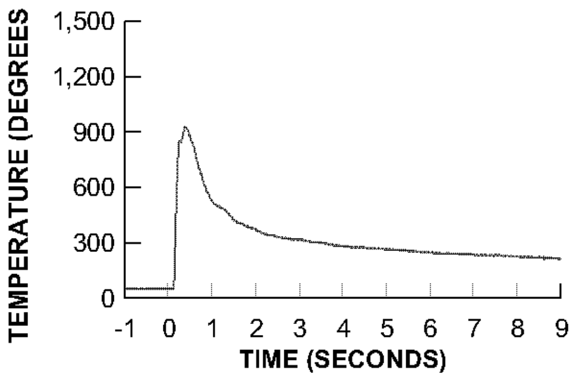
TEST 63
THERMOCOUPLE 6
BAY 1



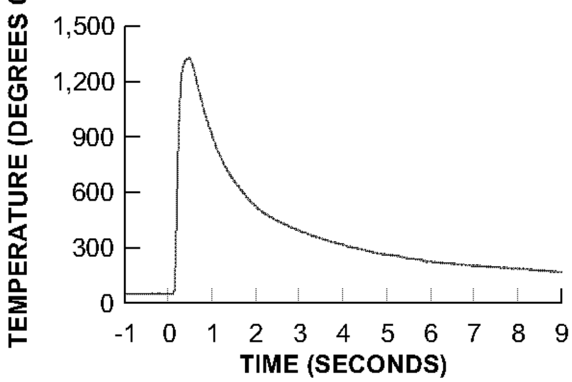
TEST 63
THERMOCOUPLE 7
BAY 5



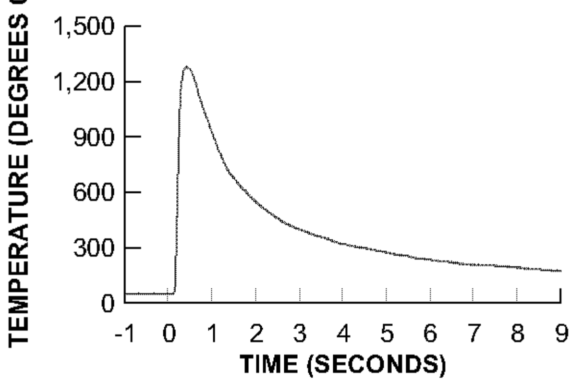
TEST 63
THERMOCOUPLE 8
BAY 6



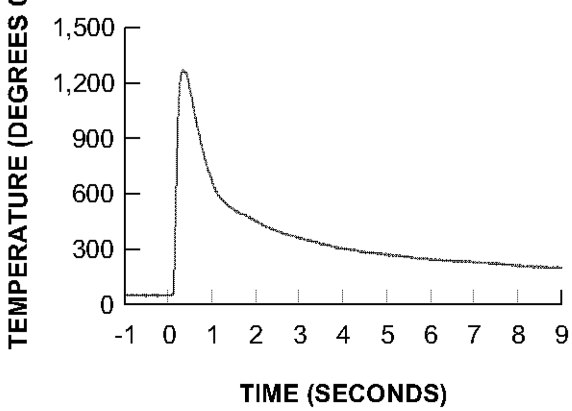
TEST 63
THERMOCOUPLE 9
BAY 3



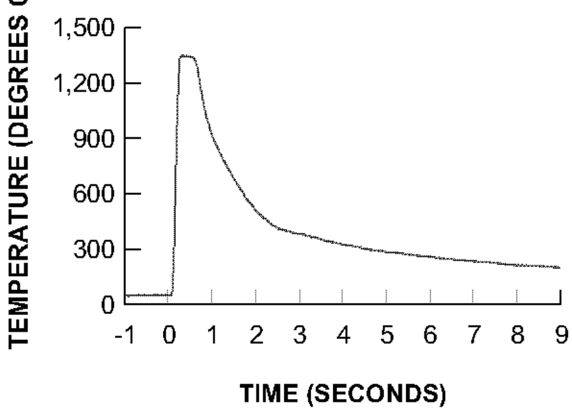
TEST 63
THERMOCOUPLE 10
BAY 4



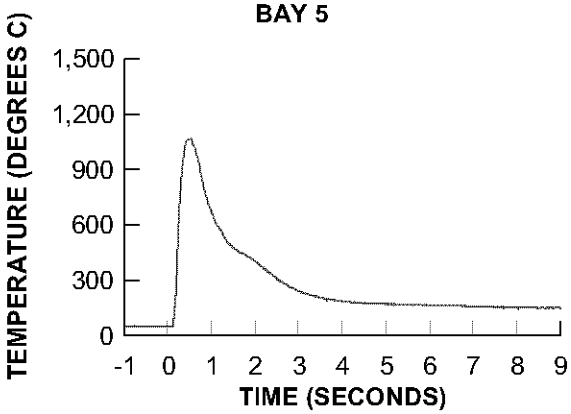
TEST 63
THERMOCOUPLE 11
BAY 2



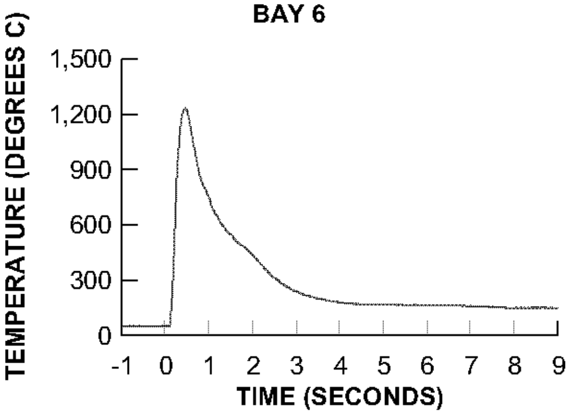
TEST 63
THERMOCOUPLE 12
BAY 1



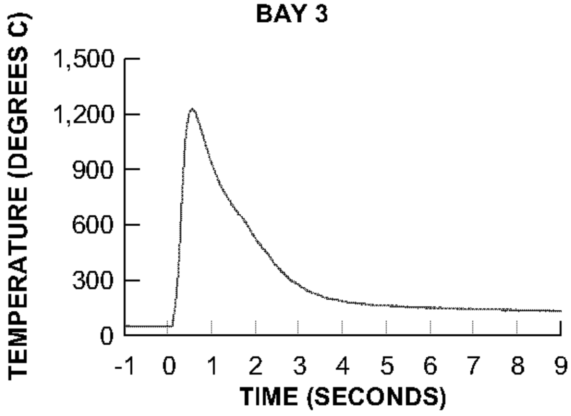
TEST 64
THERMOCOUPLE 1
BAY 5



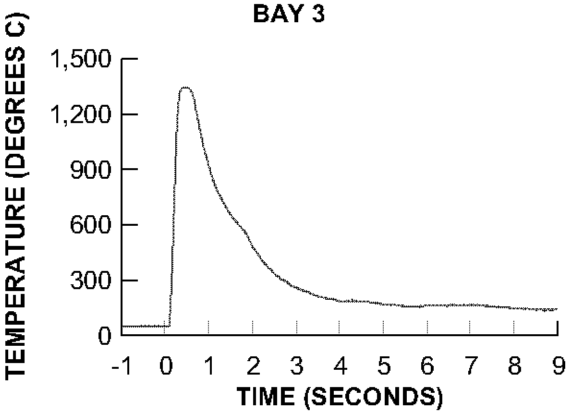
TEST 64
THERMOCOUPLE 2
BAY 6



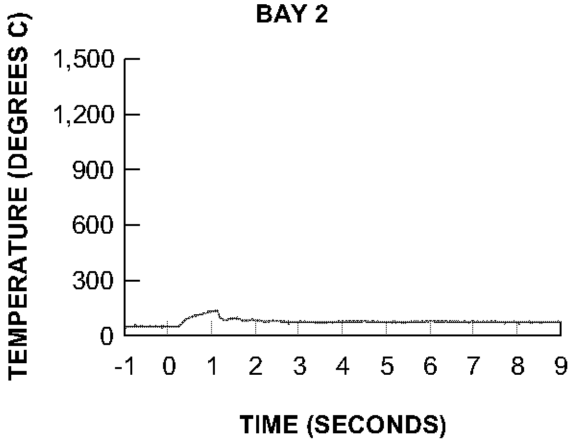
TEST 64
THERMOCOUPLE 3
BAY 3



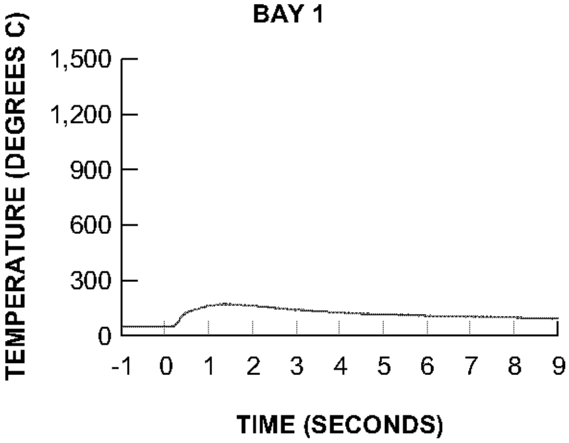
TEST 64
THERMOCOUPLE 4
BAY 3

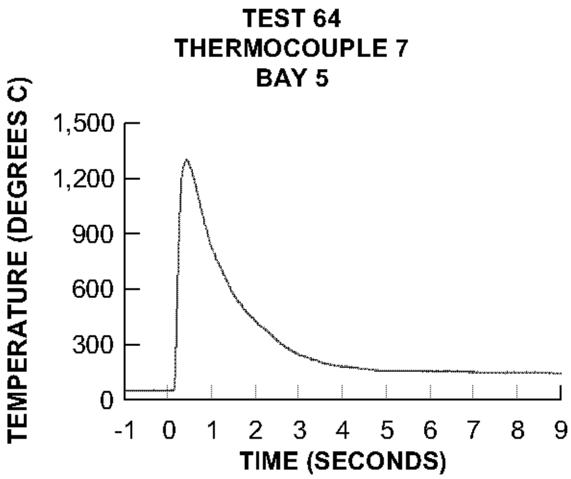


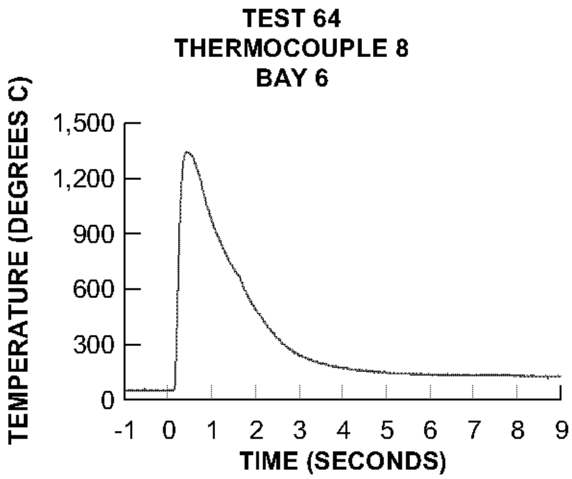
TEST 64
THERMOCOUPLE 5
BAY 2

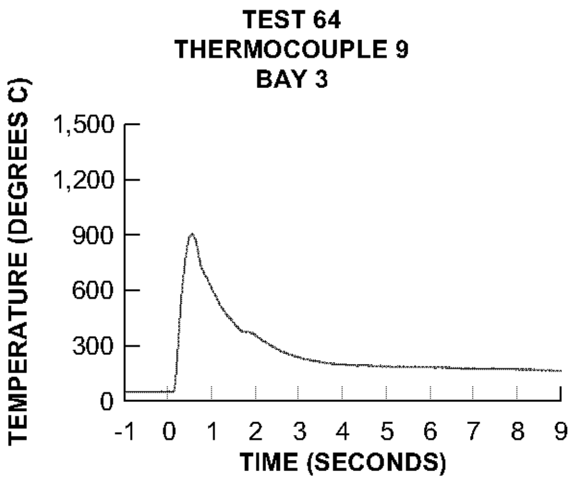


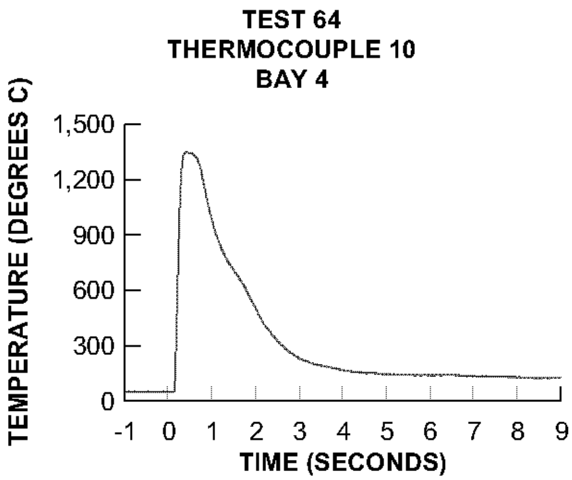
TEST 64
THERMOCOUPLE 6
BAY 1

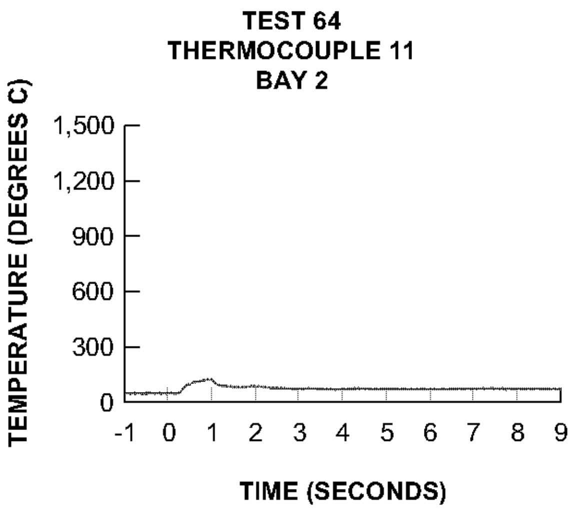


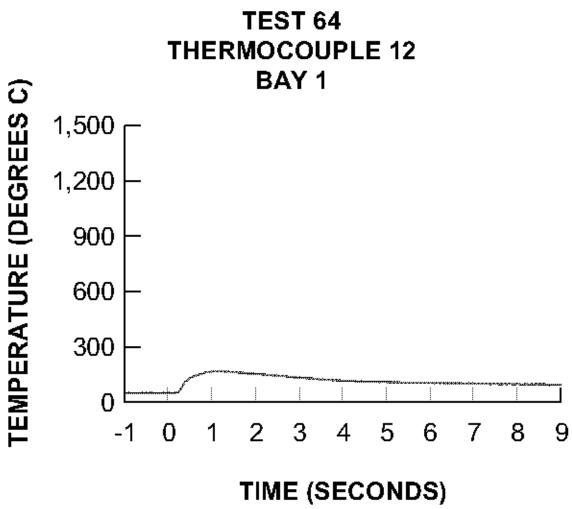

TEST 64
THERMOCOUPLE 7
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

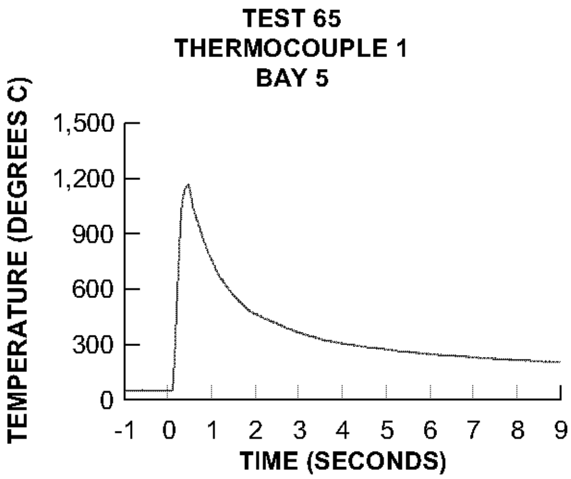

TEST 64
THERMOCOUPLE 8
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

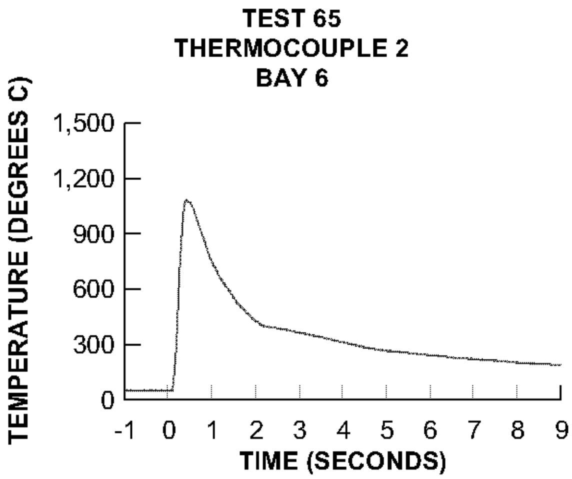

TEST 64
THERMOCOUPLE 9
BAY 3
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

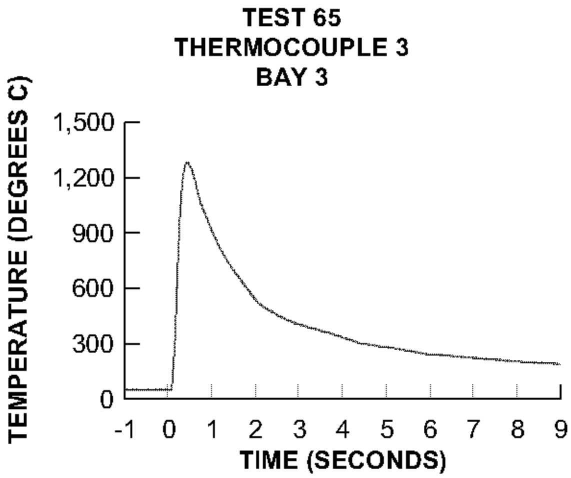

TEST 64
THERMOCOUPLE 10
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

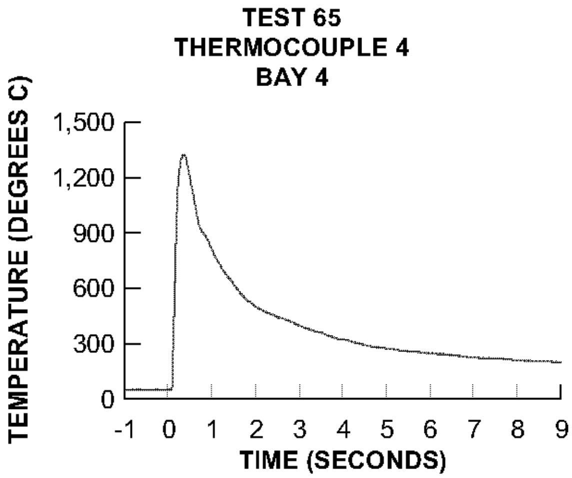

TEST 64
THERMOCOUPLE 11
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

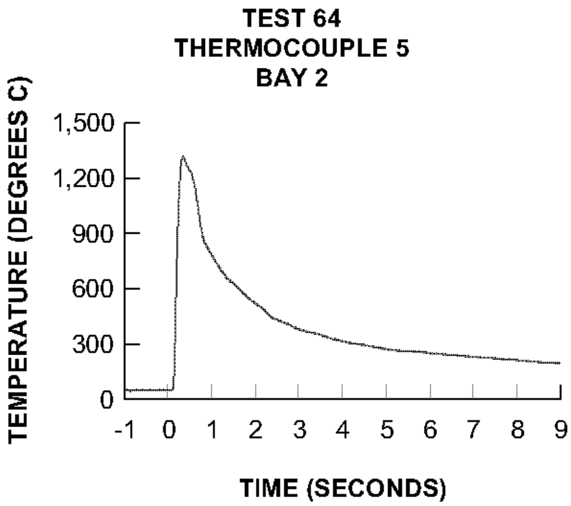

TEST 64
THERMOCOUPLE 12
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

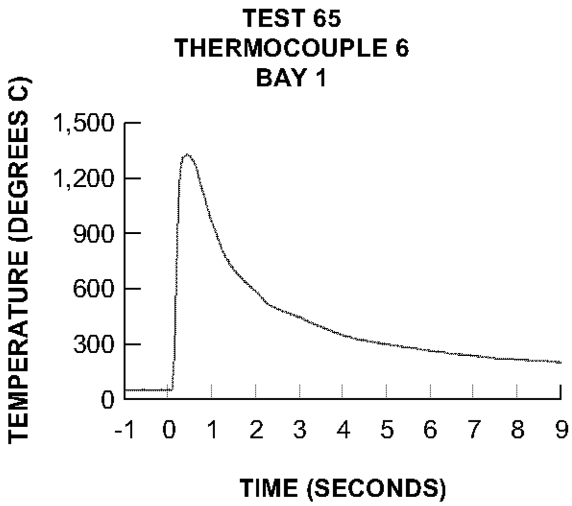

TEST 65
THERMOCOUPLE 1
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 65
THERMOCOUPLE 2
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

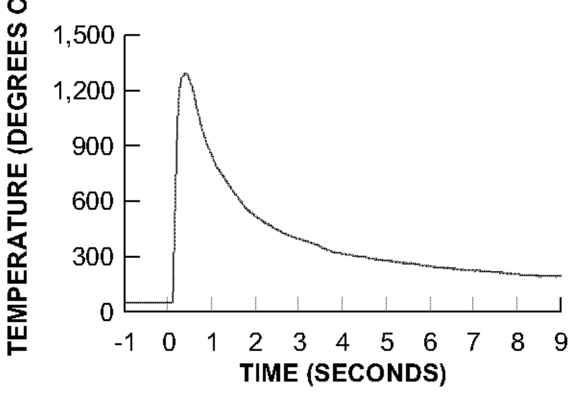

TEST 65
THERMOCOUPLE 3
BAY 3
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 65
THERMOCOUPLE 4
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

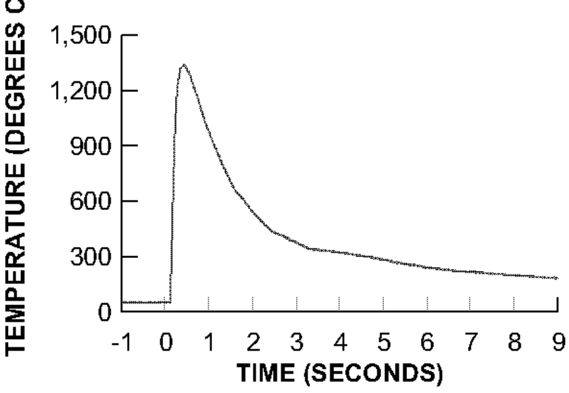

TEST 64
THERMOCOUPLE 5
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 65
THERMOCOUPLE 6
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

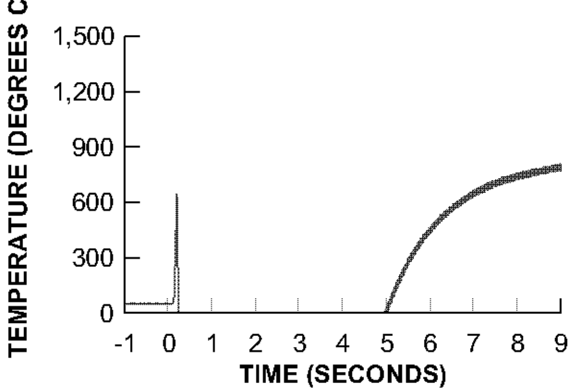
TEST 65
THERMOCOUPLE 7
BAY 5



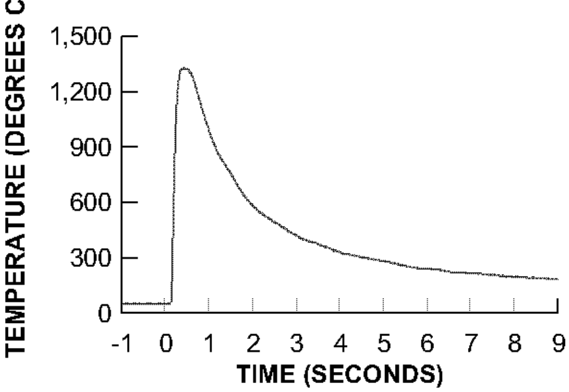
TEST 65
THERMOCOUPLE 8
BAY 6



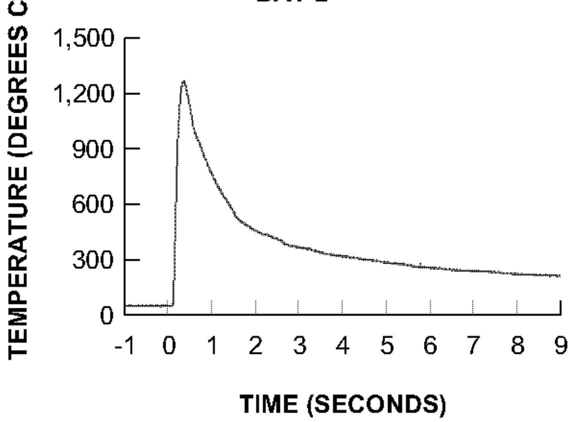
TEST 65
THERMOCOUPLE 9
BAY 3



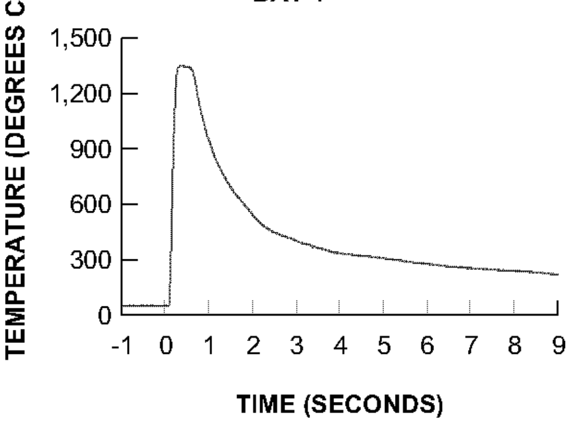
TEST 65
THERMOCOUPLE 10
BAY 4



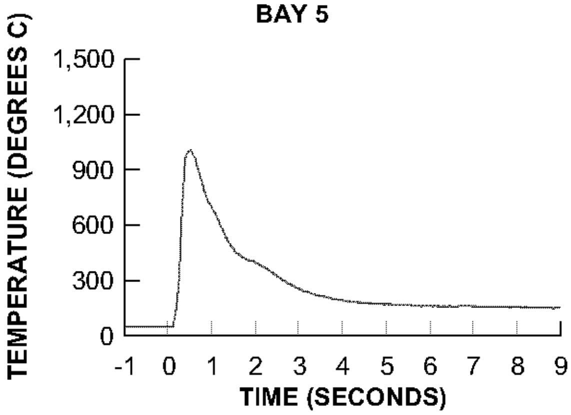
TEST 65
THERMOCOUPLE 11
BAY 2



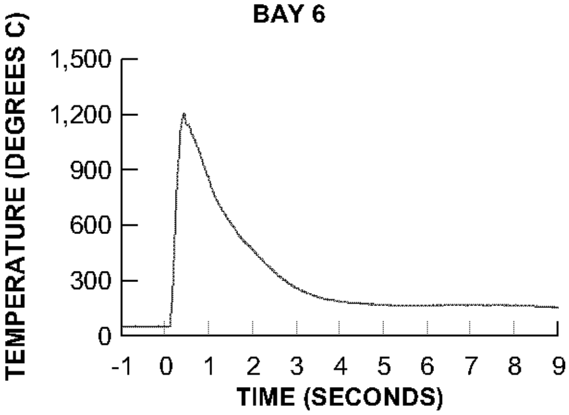
TEST 65
THERMOCOUPLE 12
BAY 1



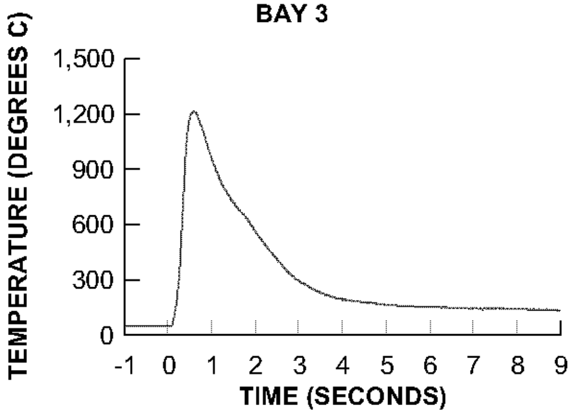
TEST 66
THERMOCOUPLE 1
BAY 5



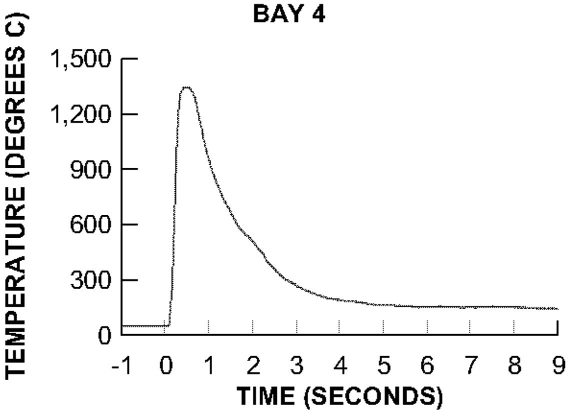
TEST 66
THERMOCOUPLE 2
BAY 6



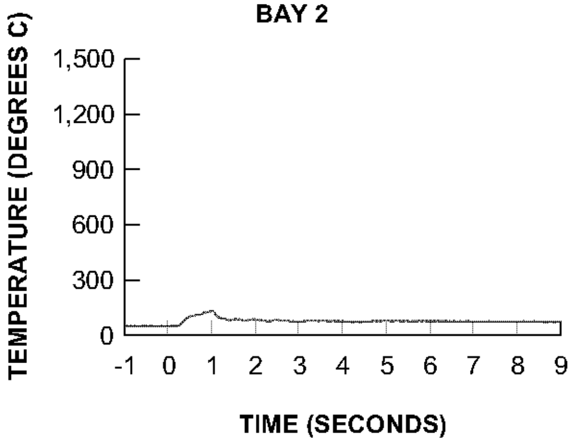
TEST 66
THERMOCOUPLE 3
BAY 3



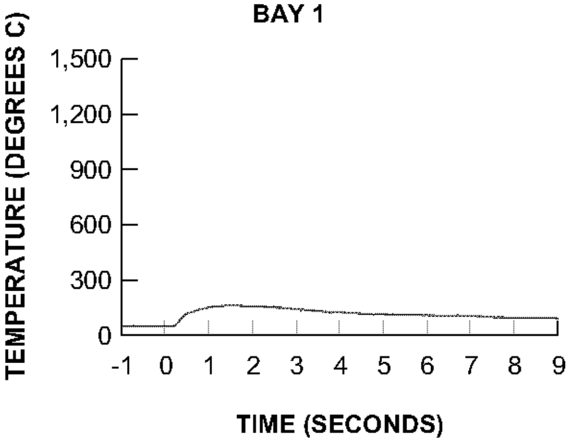
TEST 66
THERMOCOUPLE 4
BAY 4



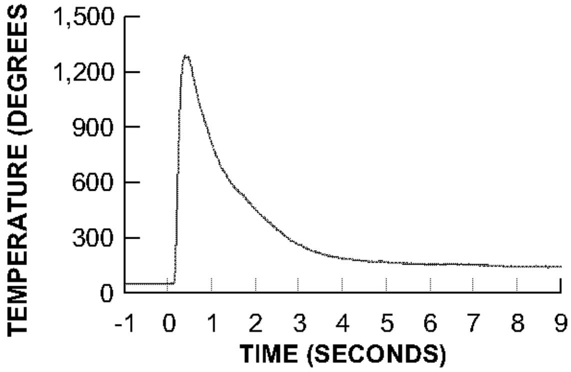
TEST 66
THERMOCOUPLE 5
BAY 2



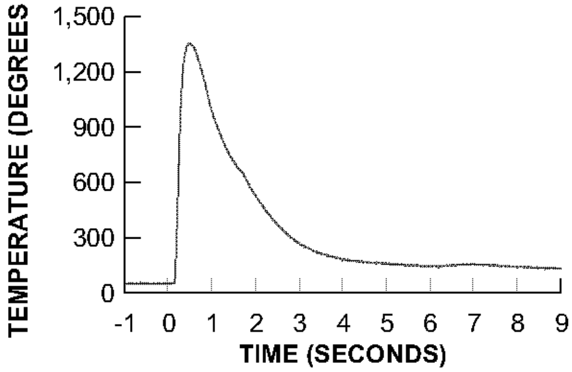
TEST 66
THERMOCOUPLE 6
BAY 1



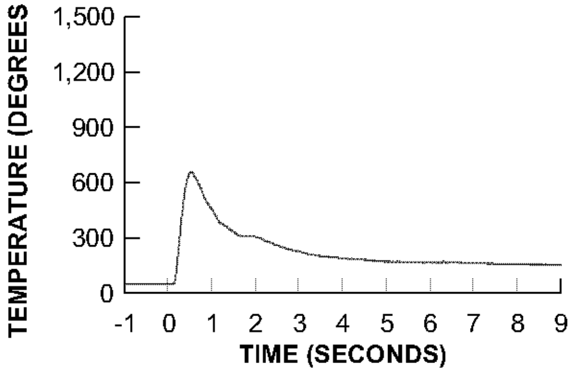
TEST 66
THERMOCOUPLE 7
BAY 5



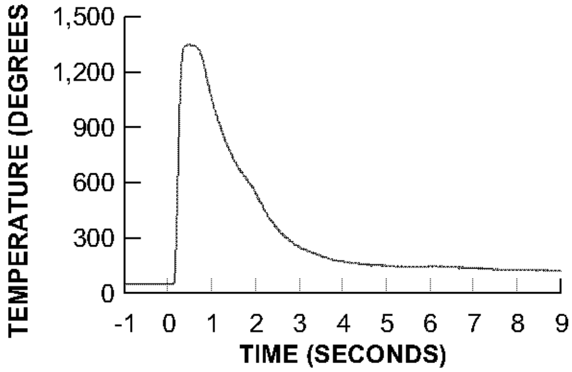
TEST 66
THERMOCOUPLE 8
BAY 6



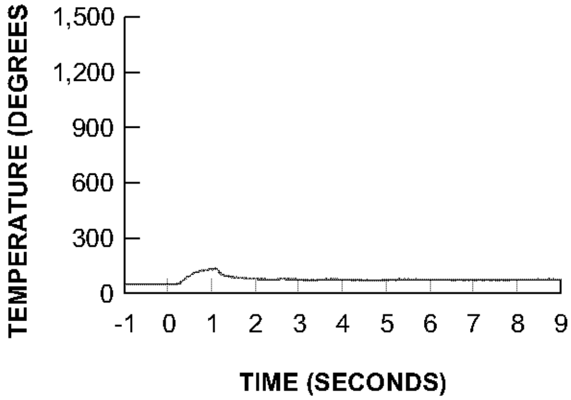
TEST 66
THERMOCOUPLE 9
BAY 3



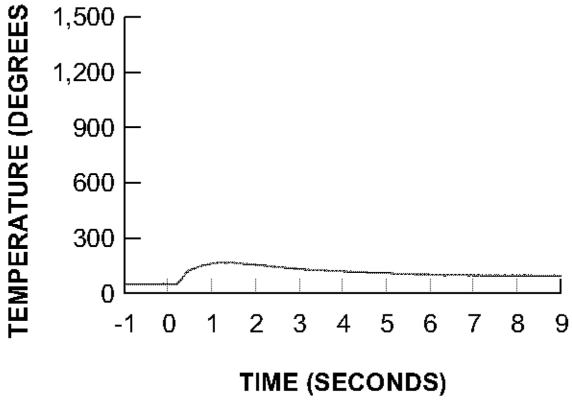
TEST 66
THERMOCOUPLE 10
BAY 2



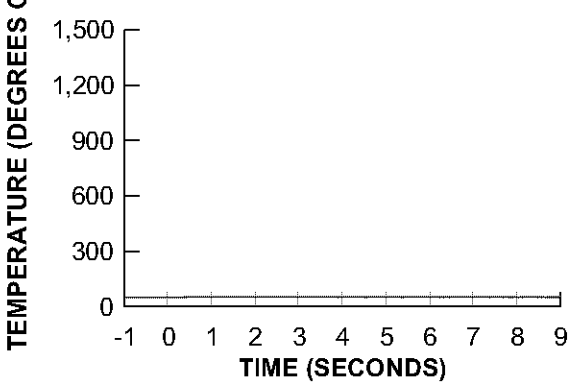
TEST 66
THERMOCOUPLE 11
BAY 2



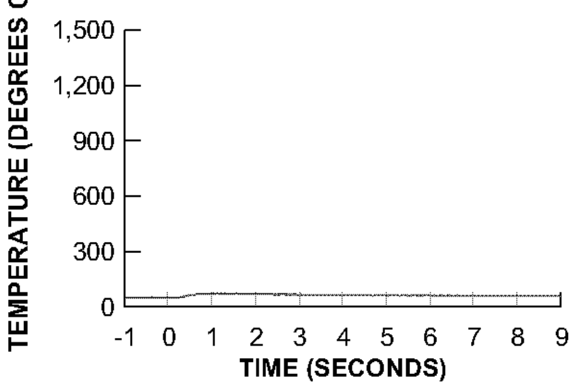
TEST 66
THERMOCOUPLE 12
BAY 1



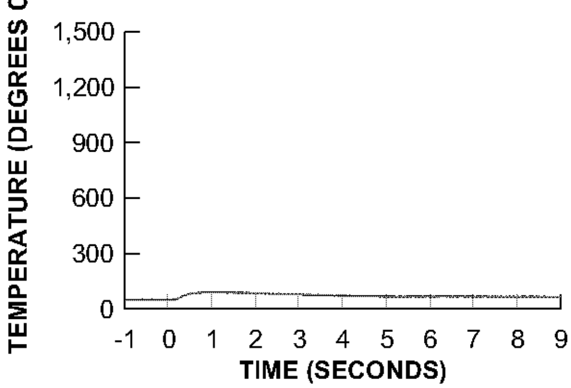
TEST 67
THERMOCOUPLE 1
BAY 5



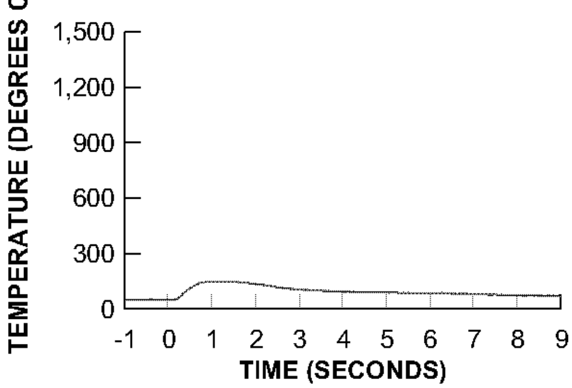
TEST 67
THERMOCOUPLE 2
BAY 6



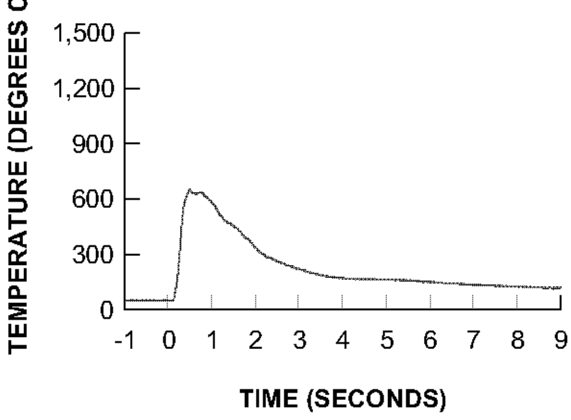
TEST 67
THERMOCOUPLE 3
BAY 3



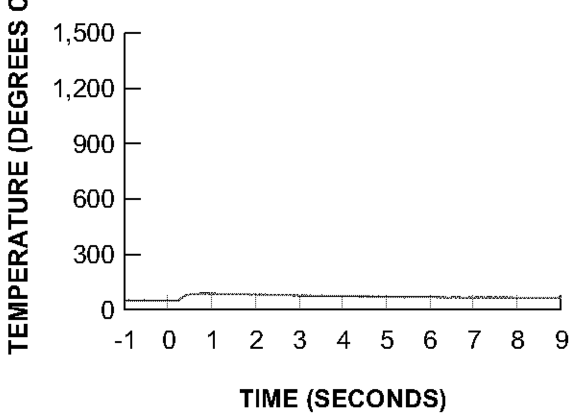
TEST 67
THERMOCOUPLE 4
BAY 4



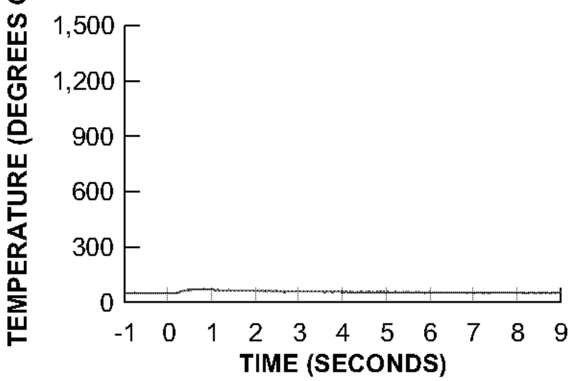
TEST 67
THERMOCOUPLE 5
BAY 2



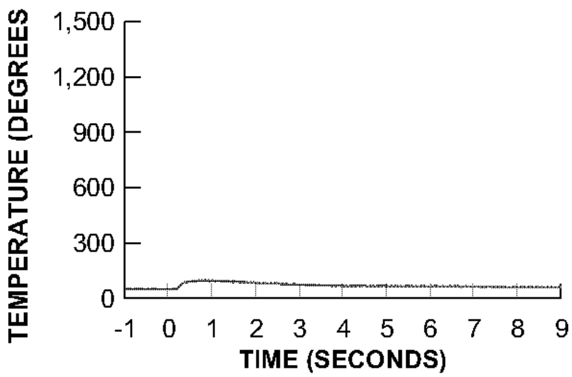
TEST 67
THERMOCOUPLE 6
BAY 1



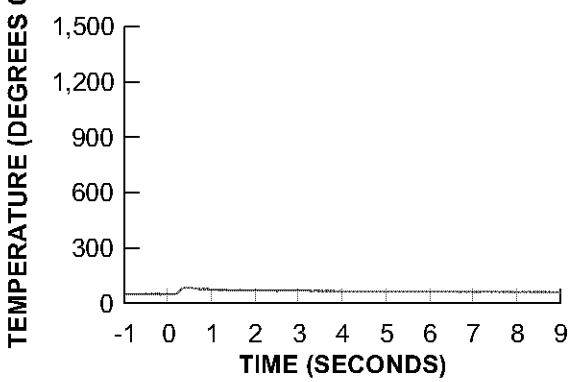
TEST 67
THERMOCOUPLE 7
BAY 5



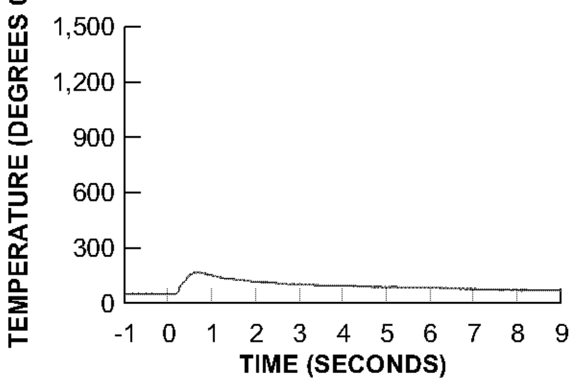
TEST 67
THERMOCOUPLE 8
BAY 6



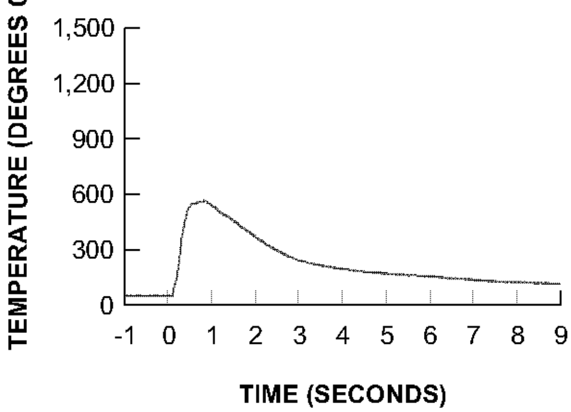
TEST 67
THERMOCOUPLE 9
BAY 3



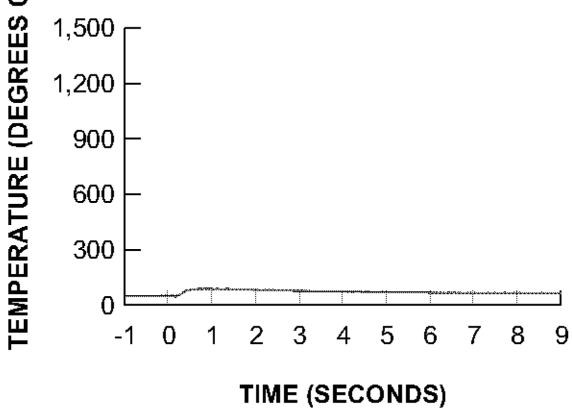
TEST 67
THERMOCOUPLE 10
BAY 4



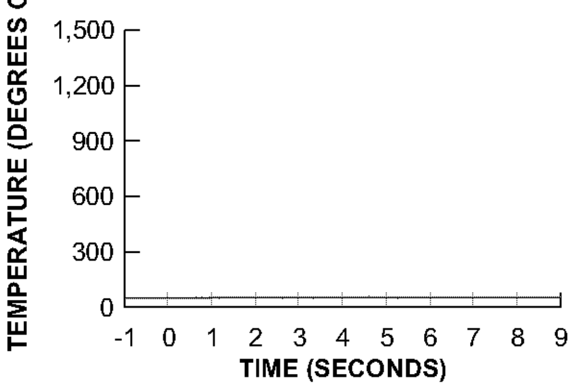
TEST 67
THERMOCOUPLE 11
BAY 2



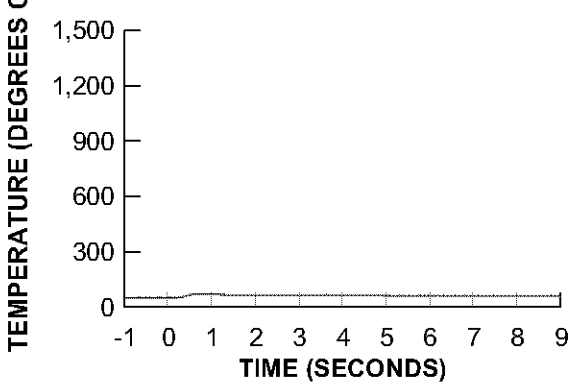
TEST 67
THERMOCOUPLE 12
BAY 1



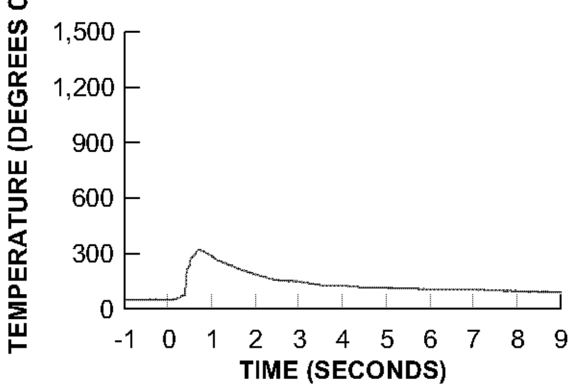
TEST 68
THERMOCOUPLE 1
BAY 5



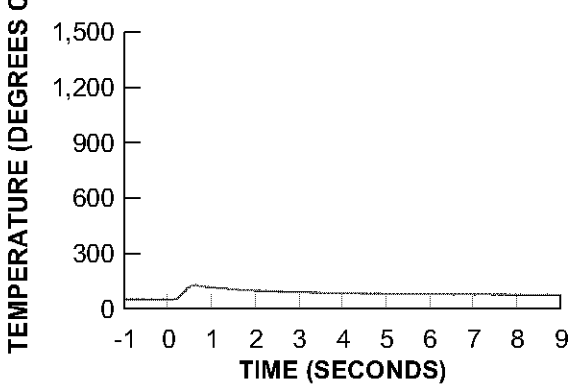
TEST 68
THERMOCOUPLE 2
BAY 6



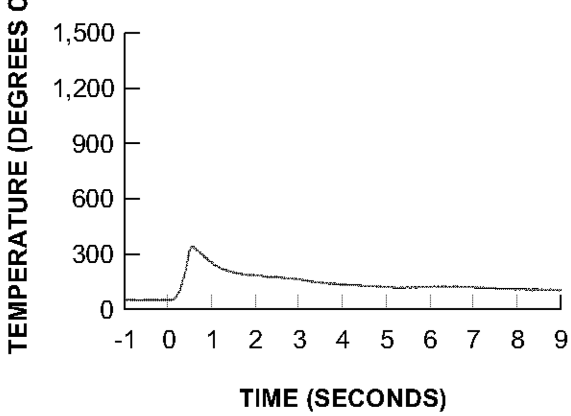
TEST 68
THERMOCOUPLE 3
BAY 3



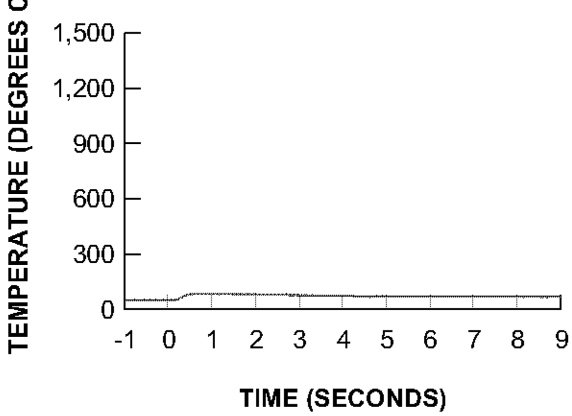
TEST 68
THERMOCOUPLE 4
BAY 4

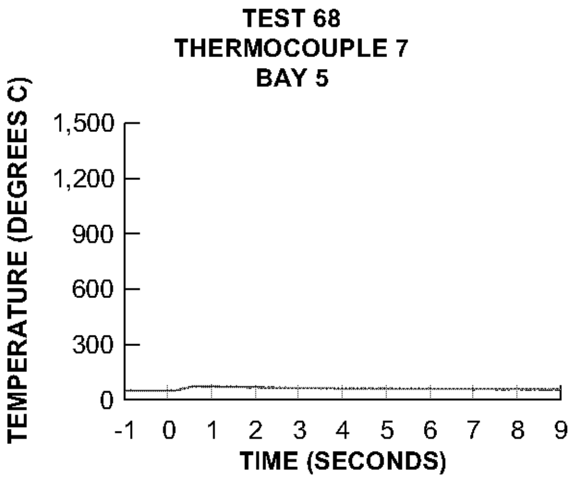


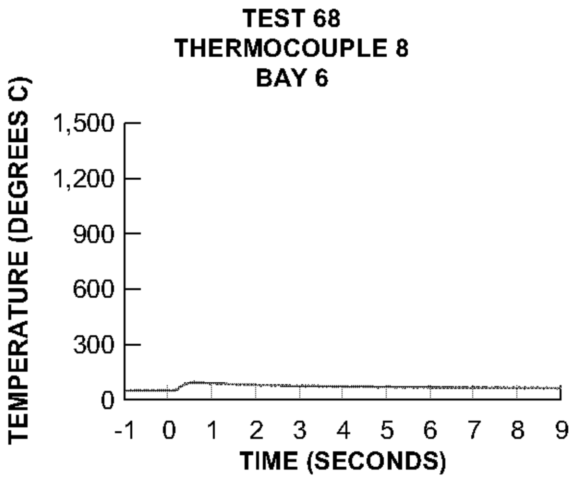
TEST 68
THERMOCOUPLE 5
BAY 2

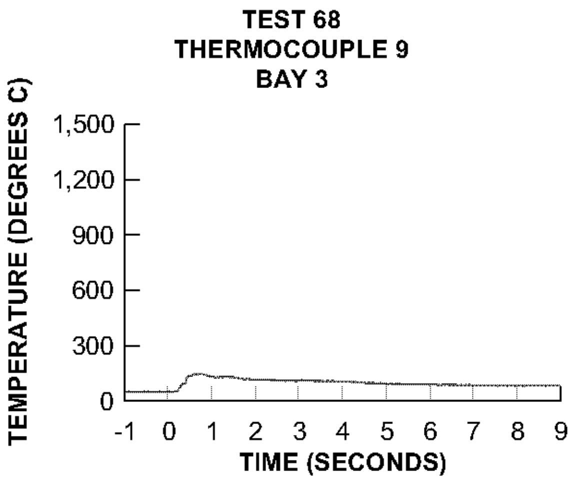


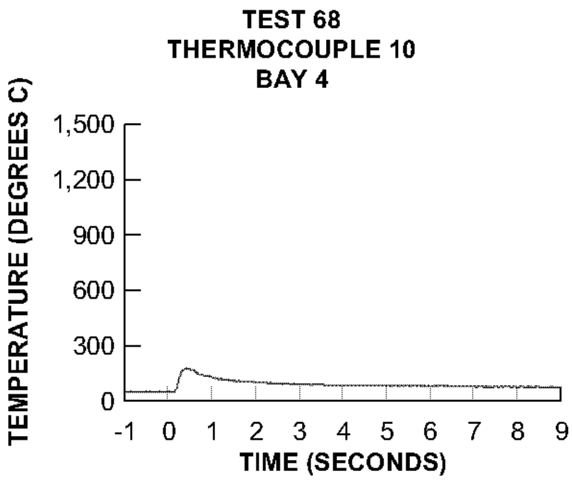
TEST 68
THERMOCOUPLE 6
BAY 1

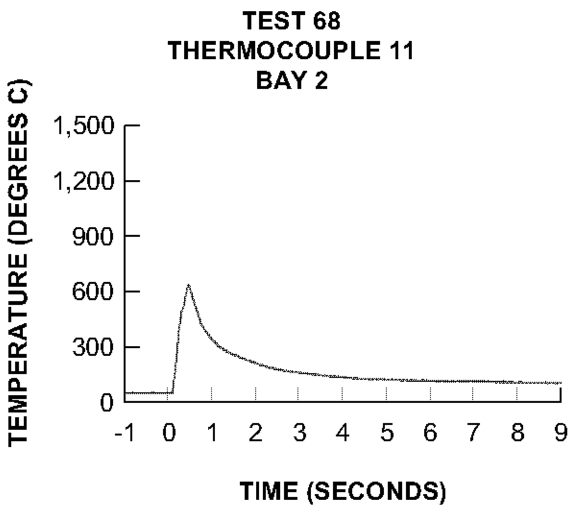


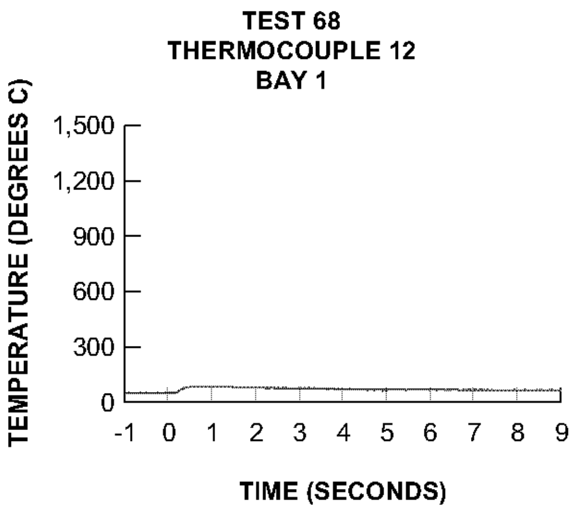

TEST 68
THERMOCOUPLE 7
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 68
THERMOCOUPLE 8
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

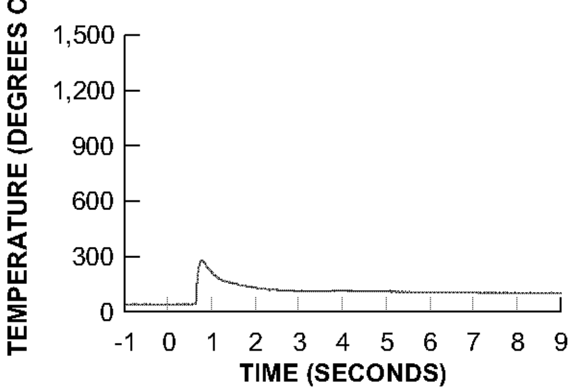

TEST 68
THERMOCOUPLE 9
BAY 3
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 68
THERMOCOUPLE 10
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

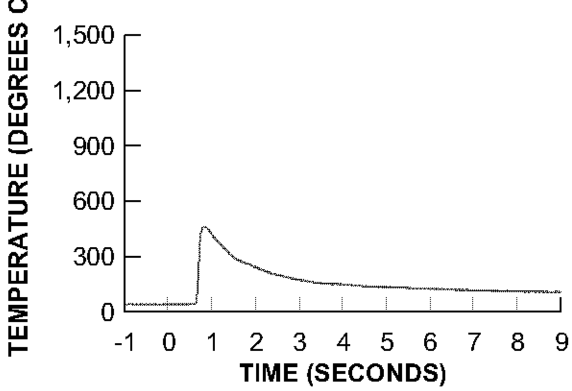

TEST 68
THERMOCOUPLE 11
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 68
THERMOCOUPLE 12
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

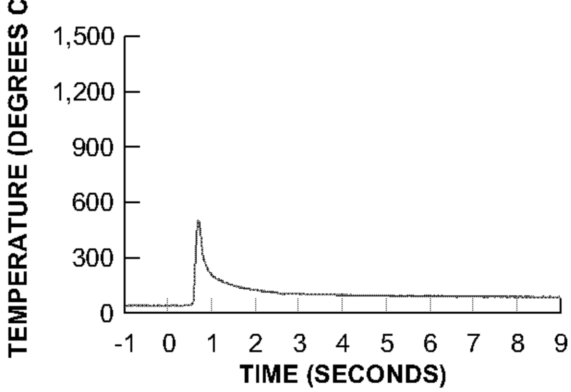
TEST 69
THERMOCOUPLE 1
BAY 5



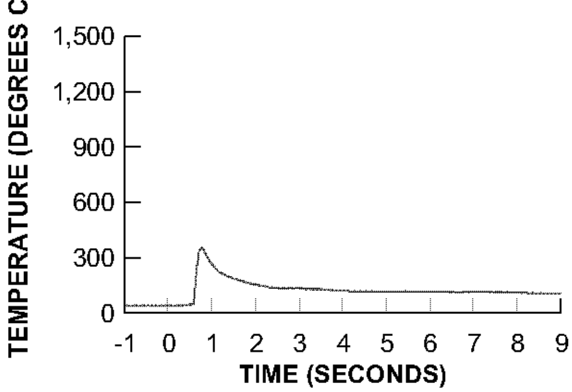
TEST 69
THERMOCOUPLE 2
BAY 6



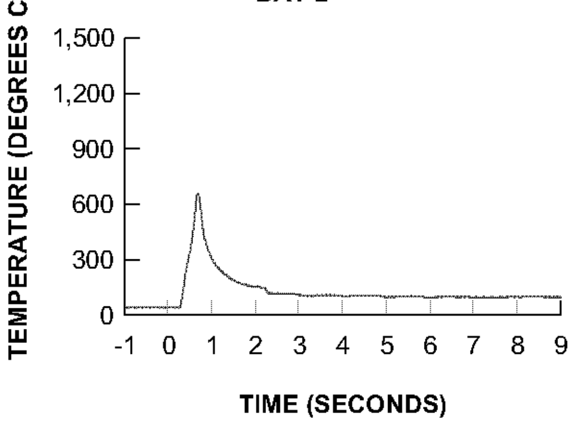
TEST 69
THERMOCOUPLE 3
BAY 3



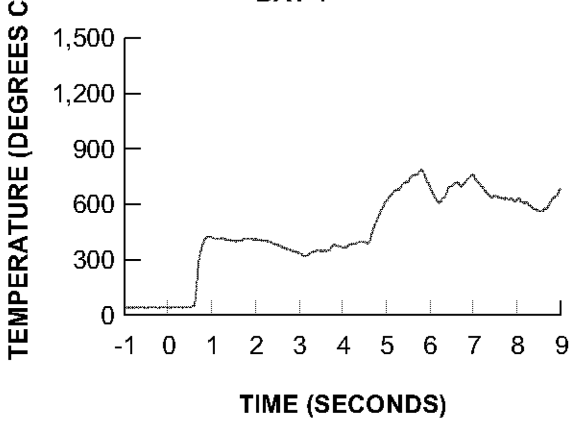
TEST 69
THERMOCOUPLE 4
BAY 4



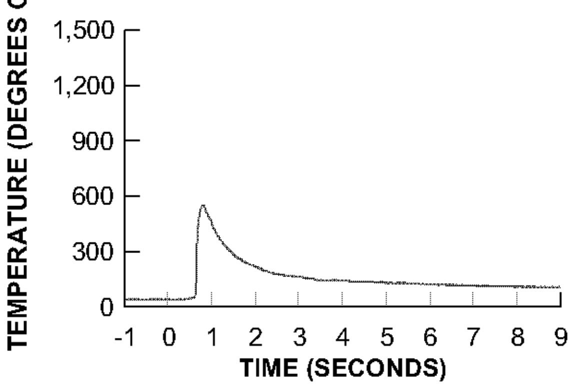
TEST 69
THERMOCOUPLE 5
BAY 2



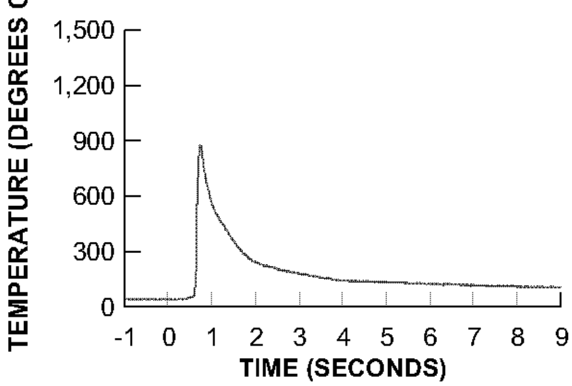
TEST 69
THERMOCOUPLE 6
BAY 1



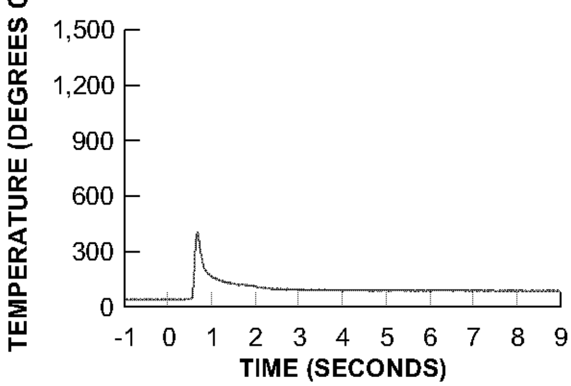
TEST 69
THERMOCOUPLE 7
BAY 5



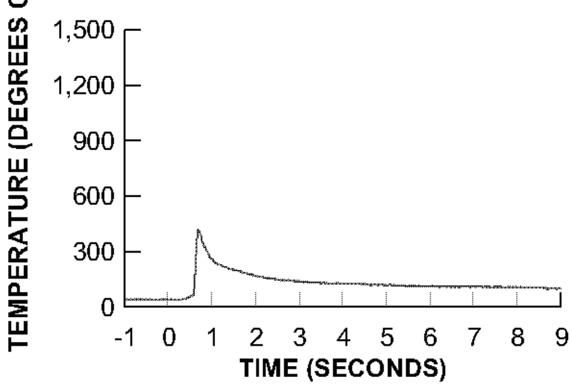
TEST 69
THERMOCOUPLE 8
BAY 6



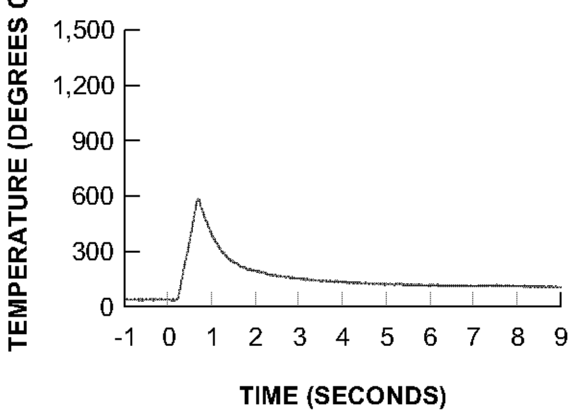
TEST 69
THERMOCOUPLE 9
BAY 3



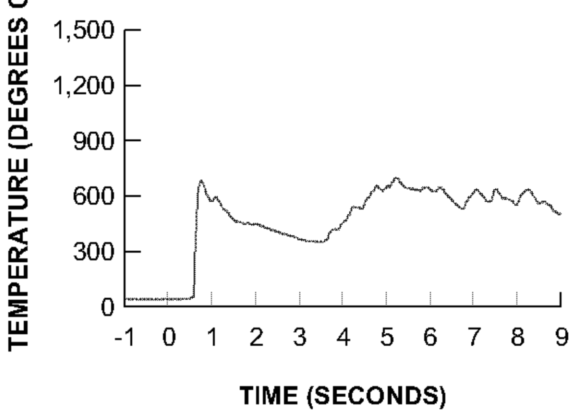
TEST 69
THERMOCOUPLE 10
BAY 4

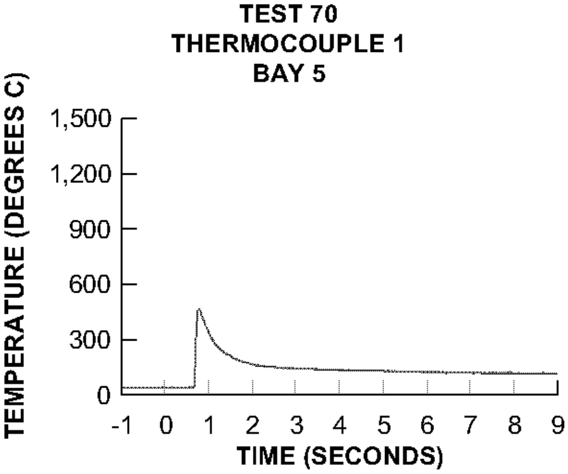


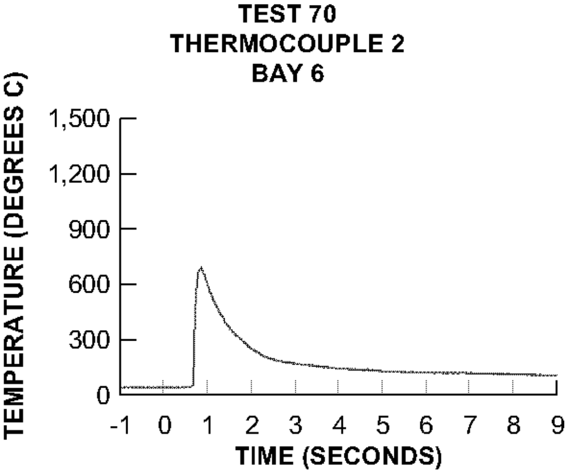
TEST 69
THERMOCOUPLE 11
BAY 2

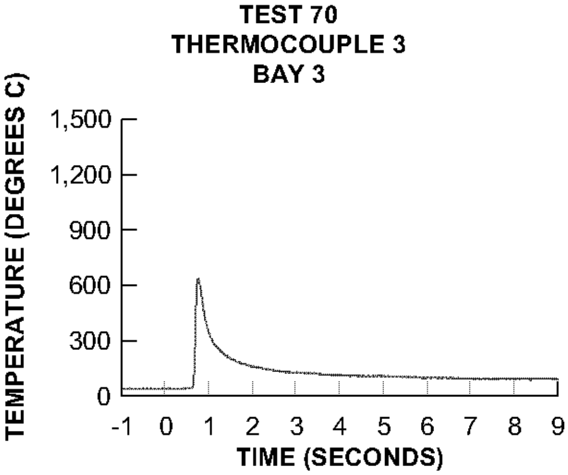


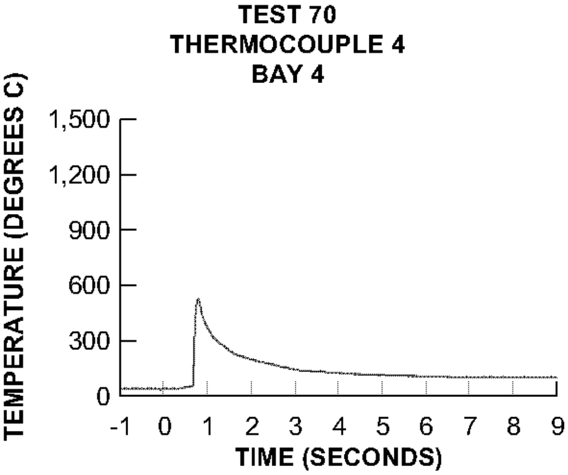
TEST 69
THERMOCOUPLE 12
BAY 1

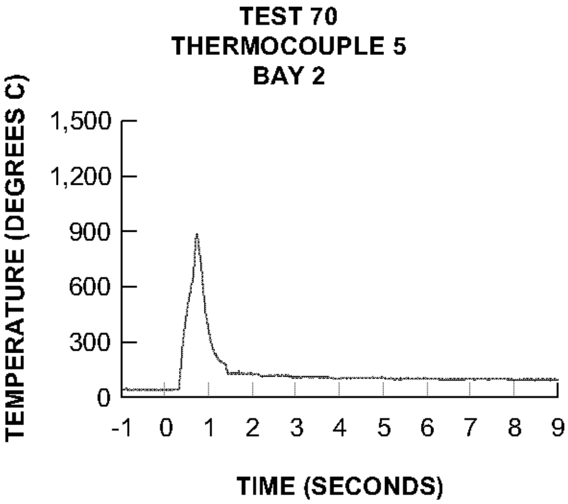


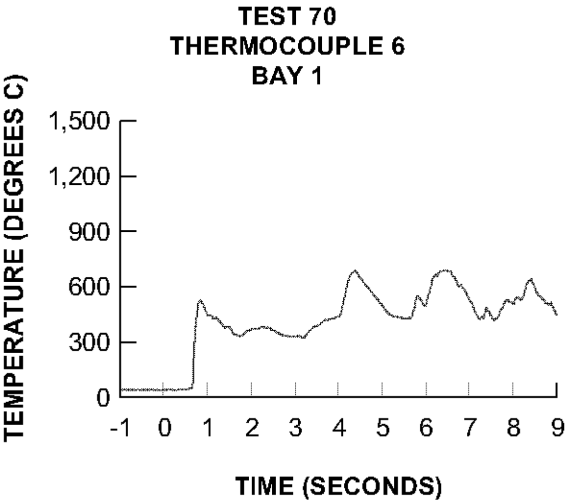

TEST 70
THERMOCOUPLE 1
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 70
THERMOCOUPLE 2
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

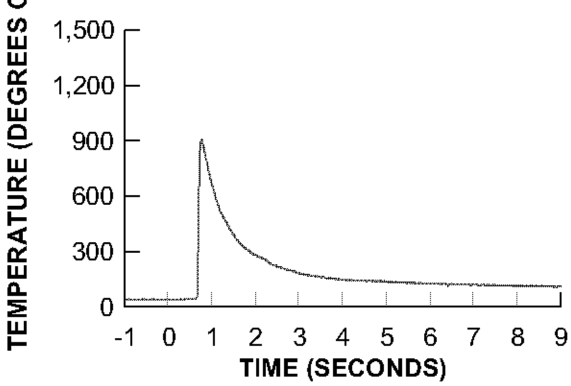

TEST 70
THERMOCOUPLE 3
BAY 3
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 70
THERMOCOUPLE 4
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

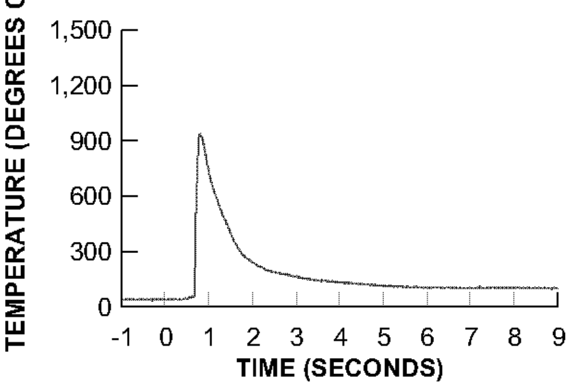

TEST 70
THERMOCOUPLE 5
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 70
THERMOCOUPLE 6
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

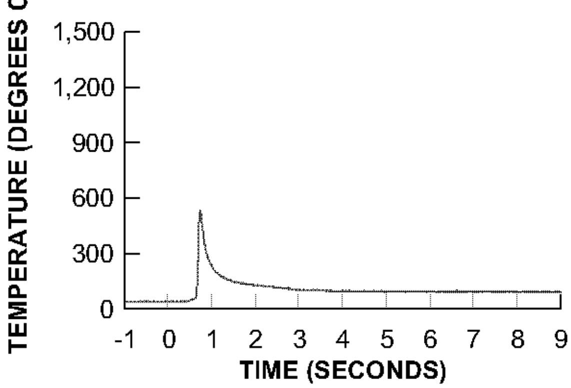
TEST 70
THERMOCOUPLE 7
BAY 5



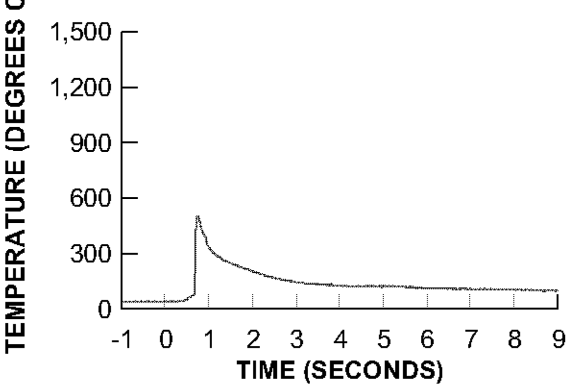
TEST 70
THERMOCOUPLE 8
BAY 6



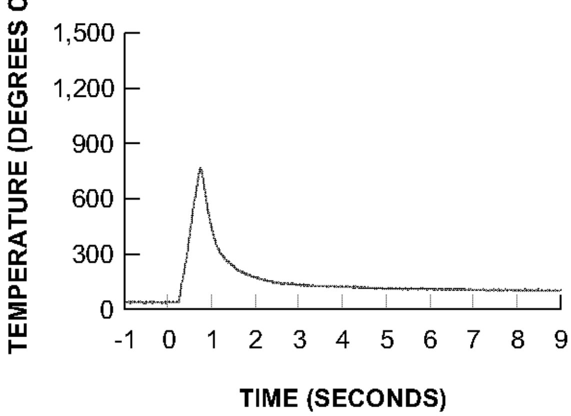
TEST 70
THERMOCOUPLE 9
BAY 3



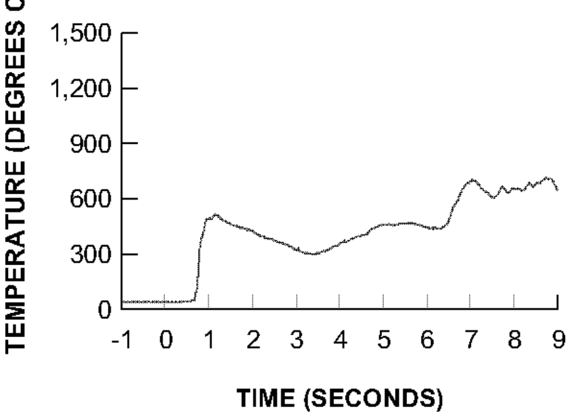
TEST 70
THERMOCOUPLE 10
BAY 4



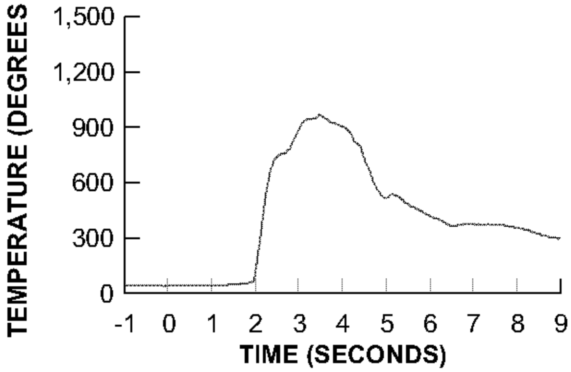
TEST 70
THERMOCOUPLE 11
BAY 2



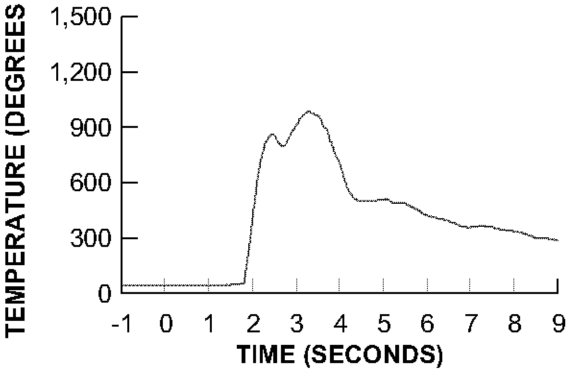
TEST 70
THERMOCOUPLE 12
BAY 1



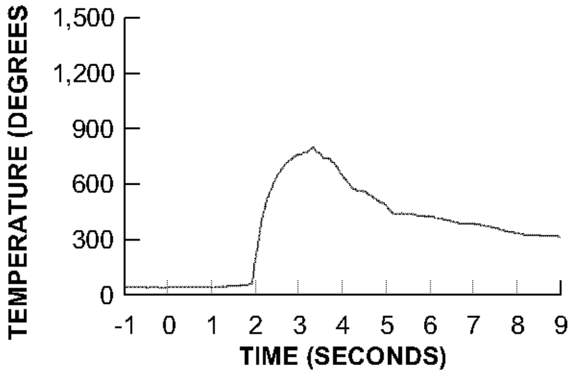
TEST 71
THERMOCOUPLE 1
BAY 5



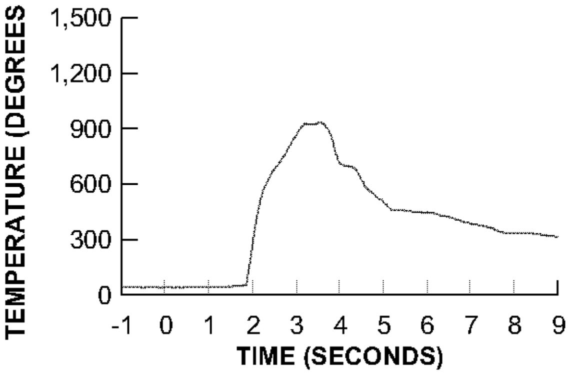
TEST 71
THERMOCOUPLE 2
BAY 6



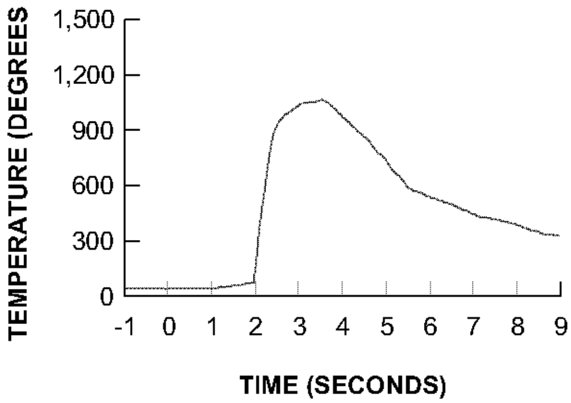
TEST 71
THERMOCOUPLE 3
BAY 3



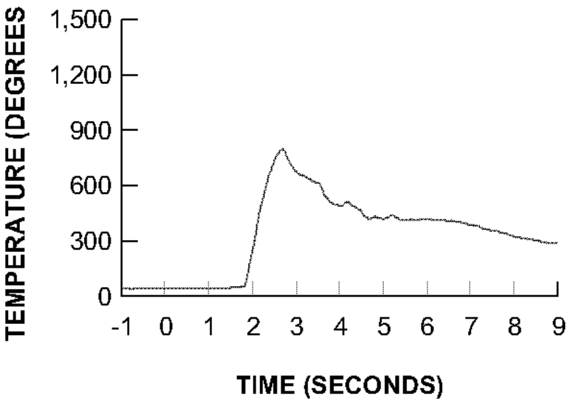
TEST 71
THERMOCOUPLE 4
BAY 4



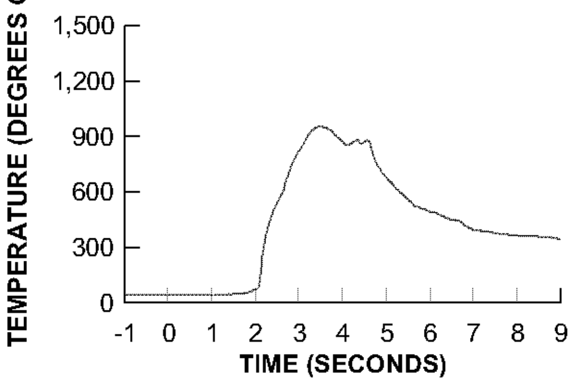
TEST 71
THERMOCOUPLE 5
BAY 2



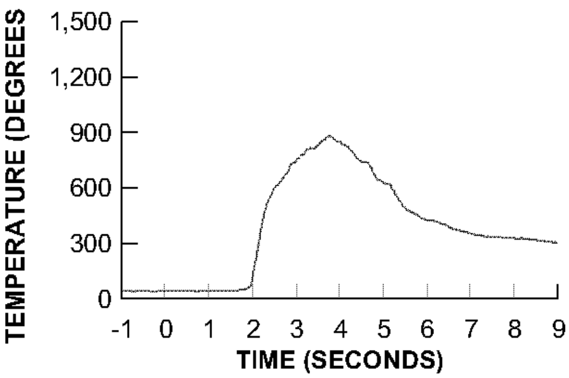
TEST 71
THERMOCOUPLE 6
BAY 1



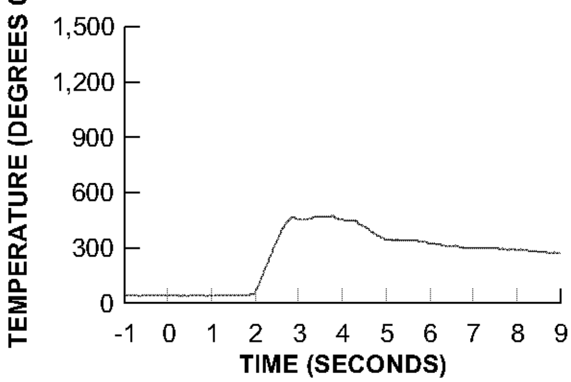
TEST 71
THERMOCOUPLE 7
BAY 5



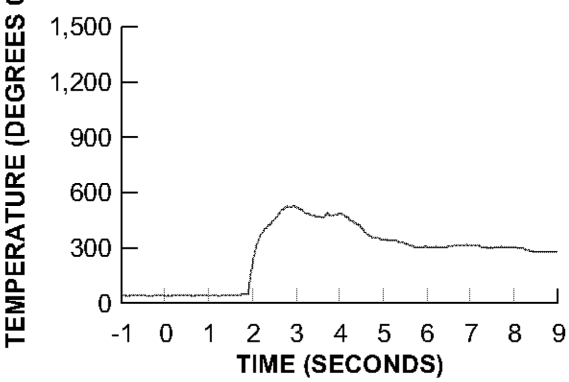
TEST 71
THERMOCOUPLE 8
BAY 6



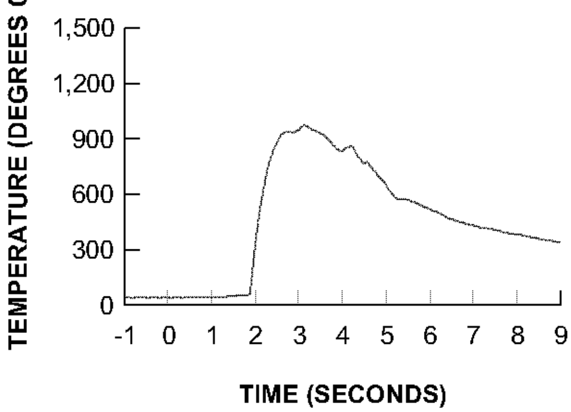
TEST 71
THERMOCOUPLE 9
BAY 3



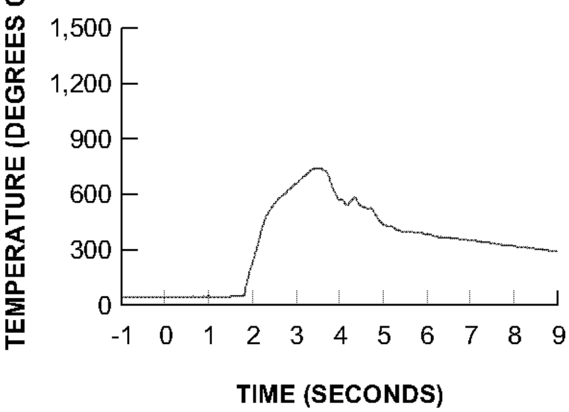
TEST 71
THERMOCOUPLE 10
BAY 4



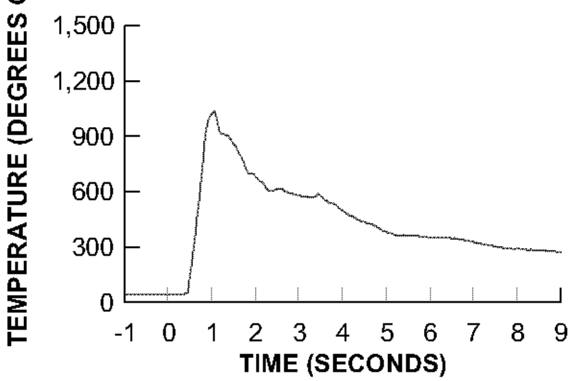
TEST 71
THERMOCOUPLE 11
BAY 2



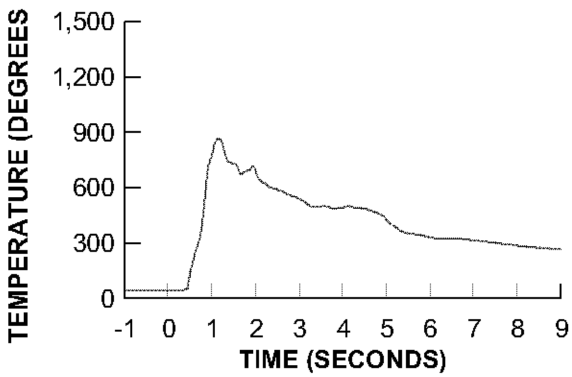
TEST 71
THERMOCOUPLE 12
BAY 1



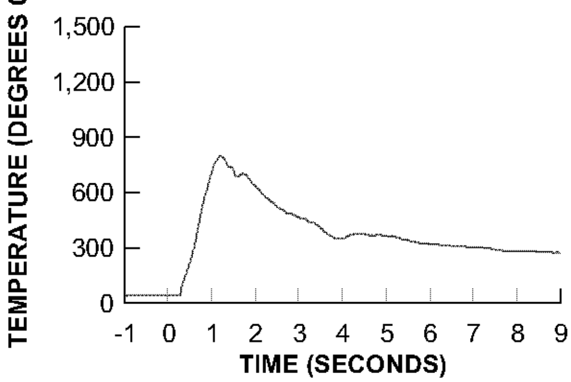
TEST 72
THERMOCOUPLE 1
BAY 5



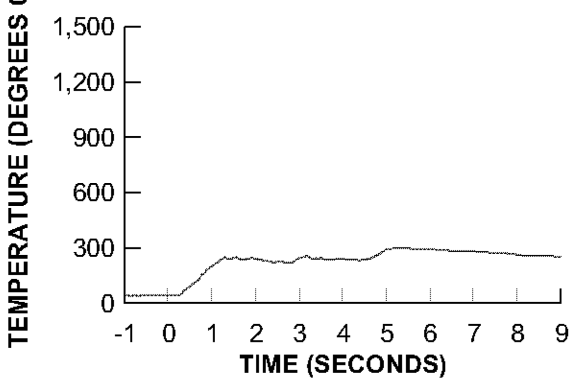
TEST 72
THERMOCOUPLE 2
BAY 6



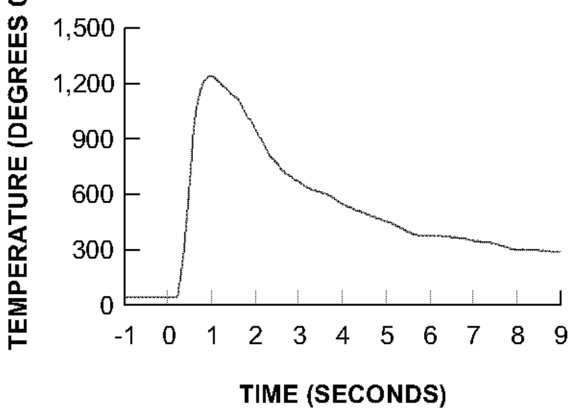
TEST 72
THERMOCOUPLE 3
BAY 3



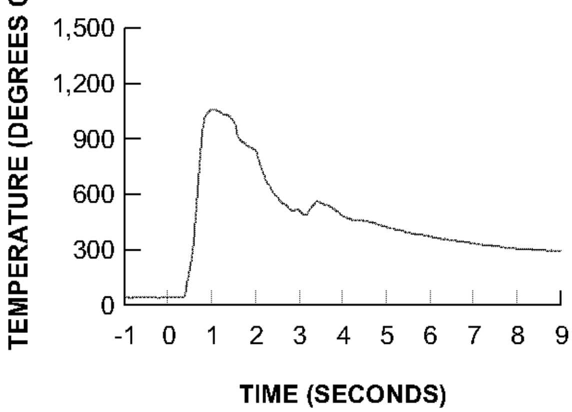
TEST 72
THERMOCOUPLE 4
BAY 4



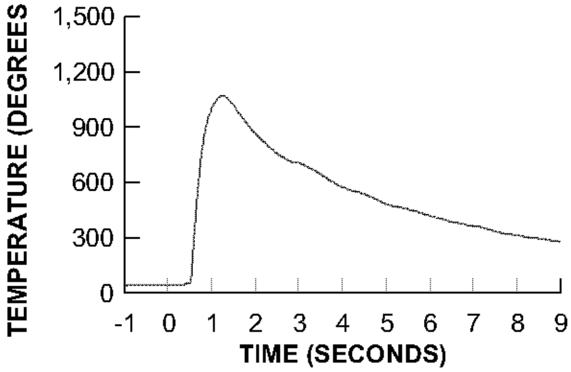
TEST 72
THERMOCOUPLE 5
BAY 2



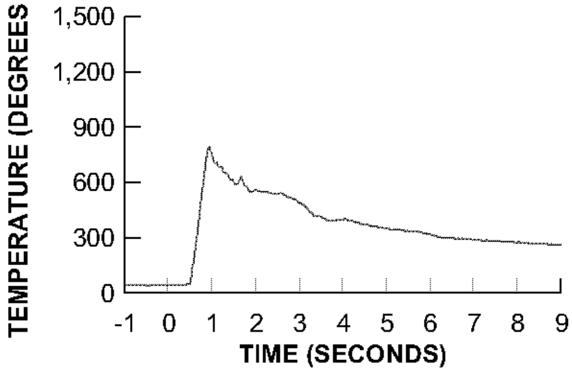
TEST 72
THERMOCOUPLE 6
BAY 1



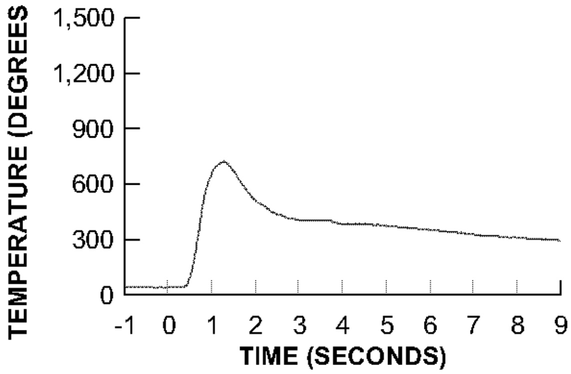
TEST 72
THERMOCOUPLE 7
BAY 5



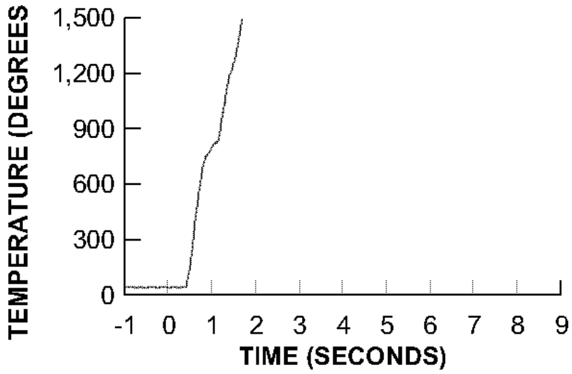
TEST 72
THERMOCOUPLE 8
BAY 6



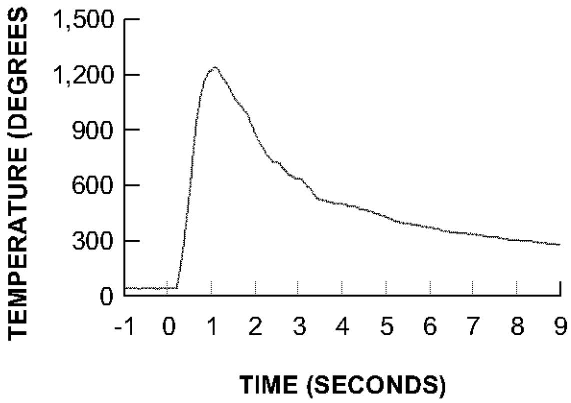
TEST 72
THERMOCOUPLE 9
BAY 3



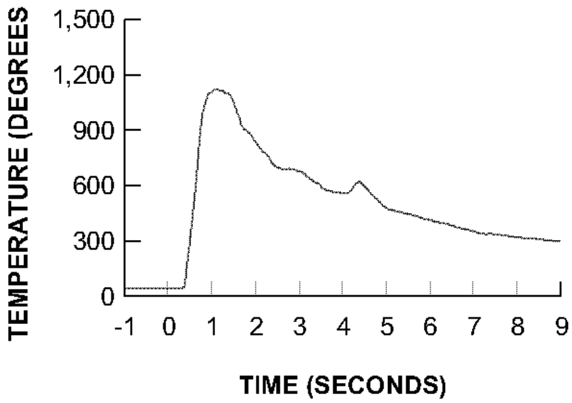
TEST 72
THERMOCOUPLE 10
BAY 4



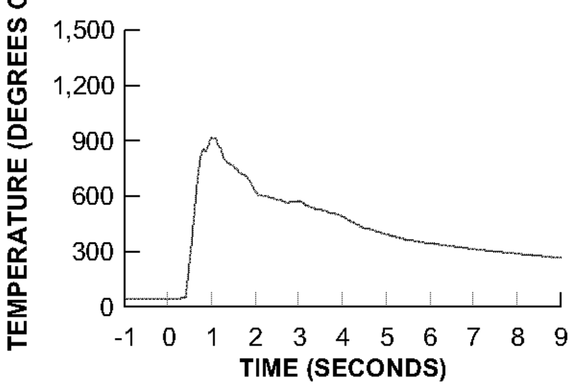
TEST 72
THERMOCOUPLE 11
BAY 2



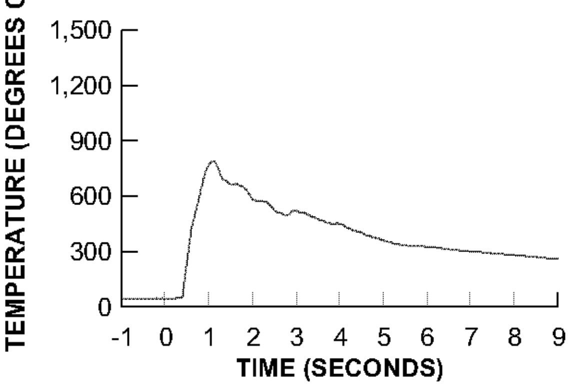
TEST 72
THERMOCOUPLE 12
BAY 1



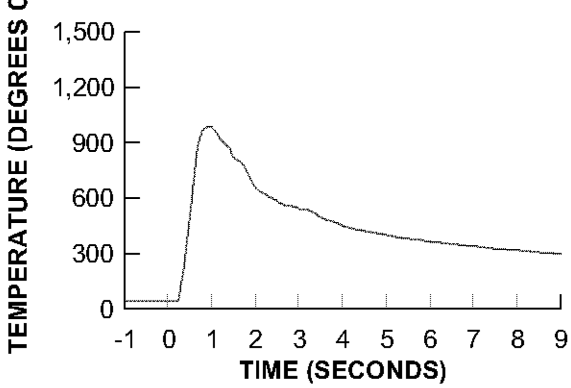
TEST 73
THERMOCOUPLE 1
BAY 5



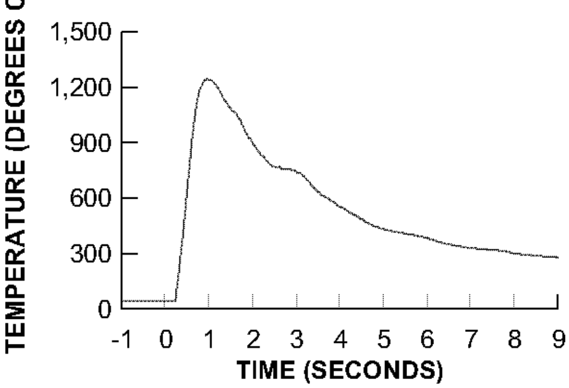
TEST 73
THERMOCOUPLE 2
BAY 6



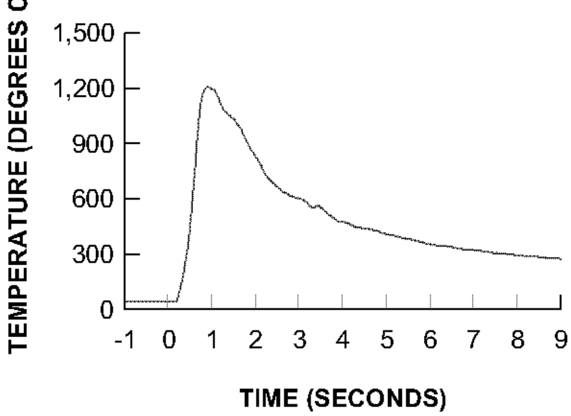
TEST 73
THERMOCOUPLE 3
BAY 3



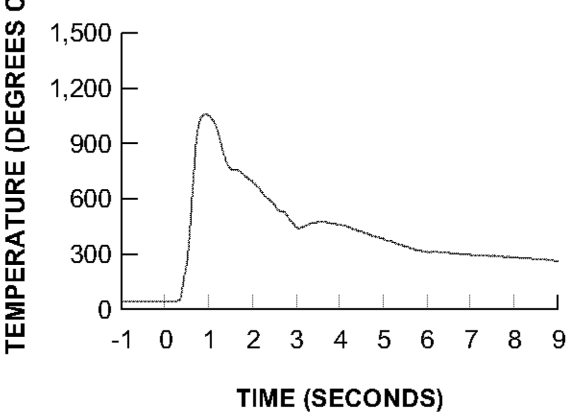
TEST 73
THERMOCOUPLE 4
BAY 4



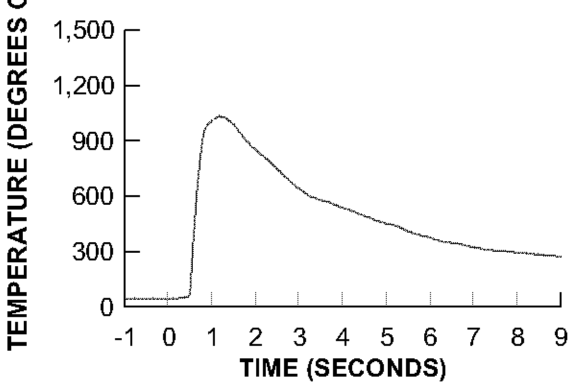
TEST 73
THERMOCOUPLE 5
BAY 2



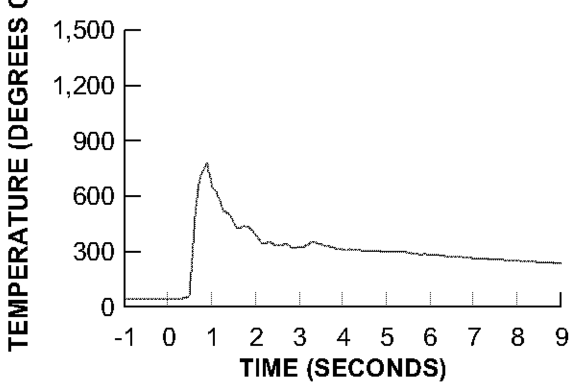
TEST 73
THERMOCOUPLE 6
BAY 1



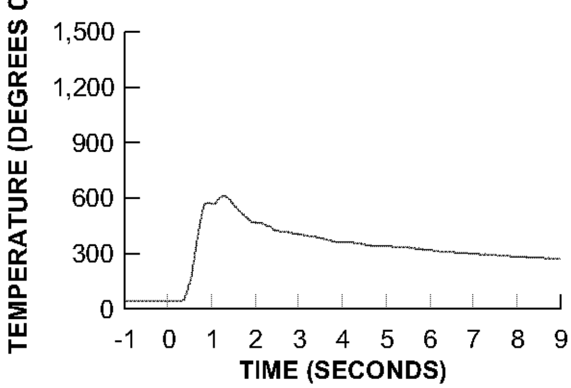
TEST 73
THERMOCOUPLE 7
BAY 5



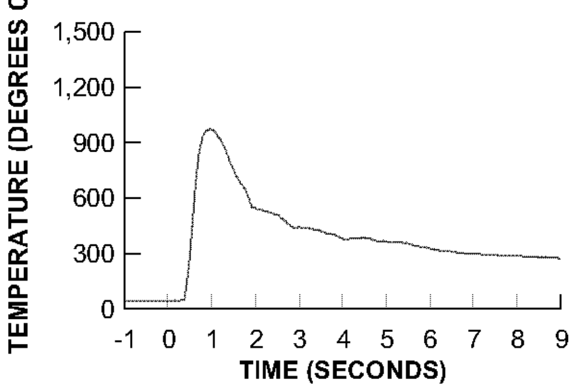
TEST 73
THERMOCOUPLE 8
BAY 6



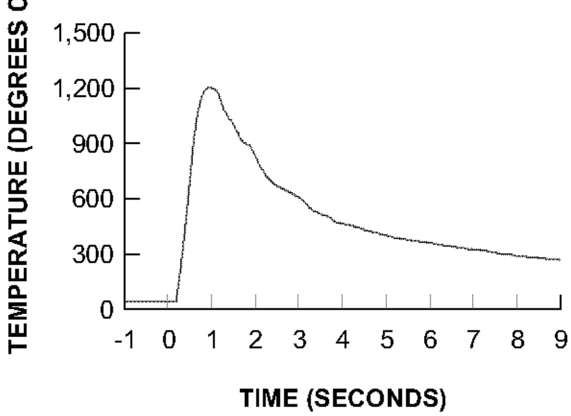
TEST 73
THERMOCOUPLE 9
BAY 3



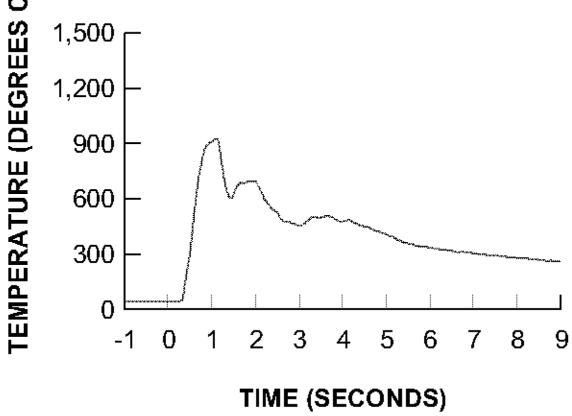
TEST 73
THERMOCOUPLE 10
BAY 4



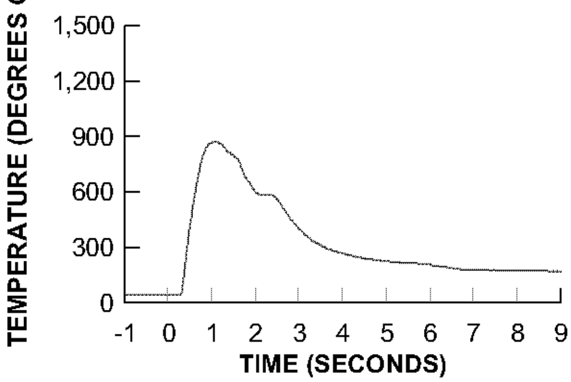
TEST 73
THERMOCOUPLE 11
BAY 2



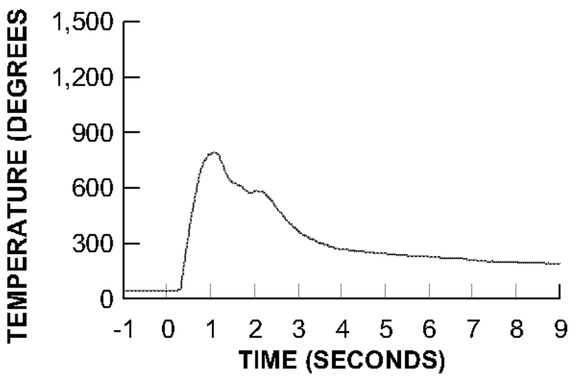
TEST 73
THERMOCOUPLE 12
BAY 1



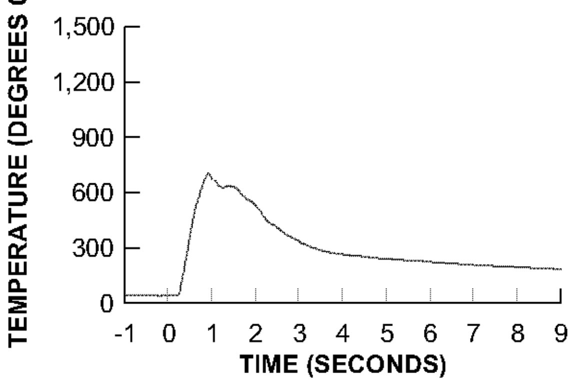
TEST 74
THERMOCOUPLE 1
BAY 5



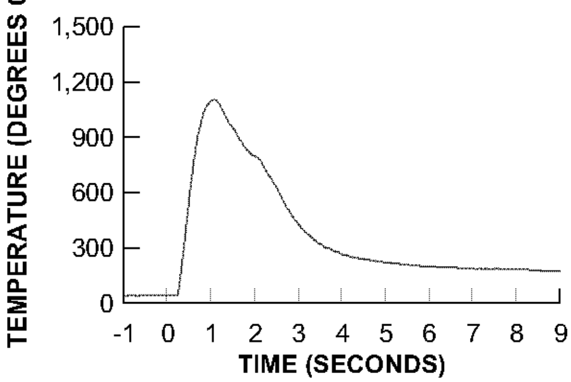
TEST 74
THERMOCOUPLE 2
BAY 6



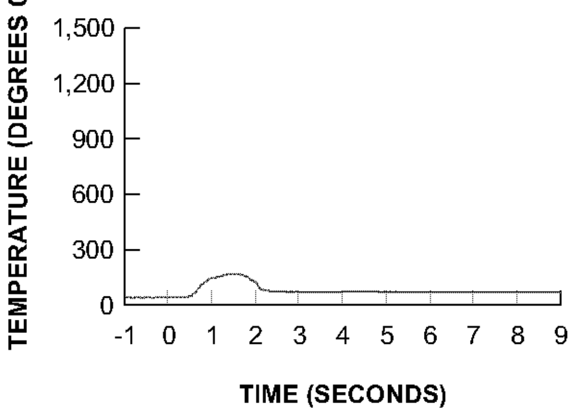
TEST 74
THERMOCOUPLE 3
BAY 3



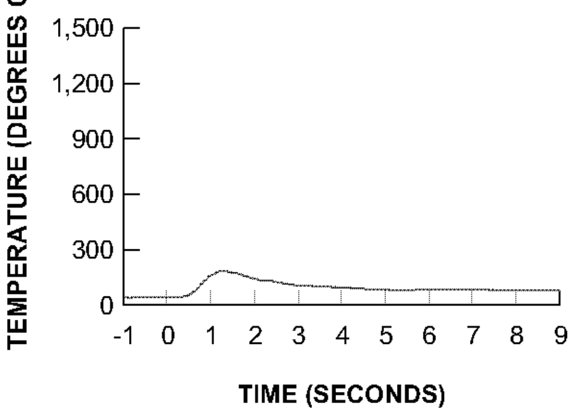
TEST 74
THERMOCOUPLE 4
BAY 4



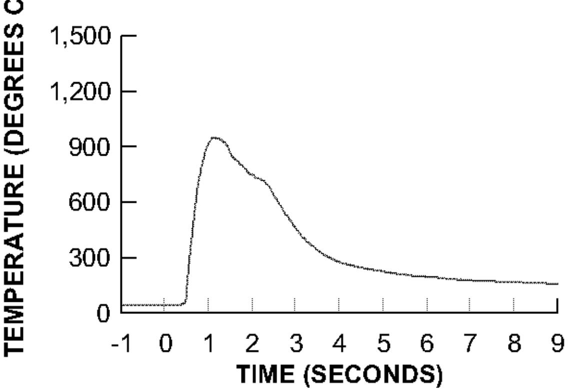
TEST 74
THERMOCOUPLE 5
BAY 2



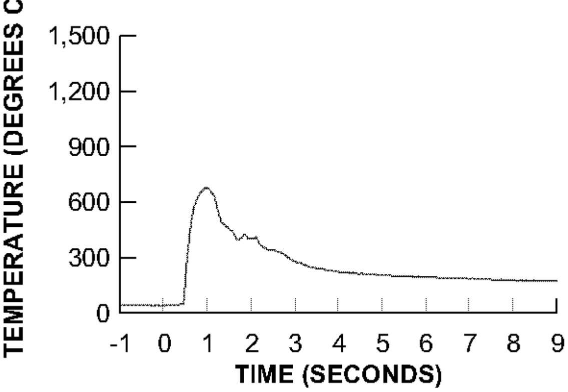
TEST 74
THERMOCOUPLE 6
BAY 1



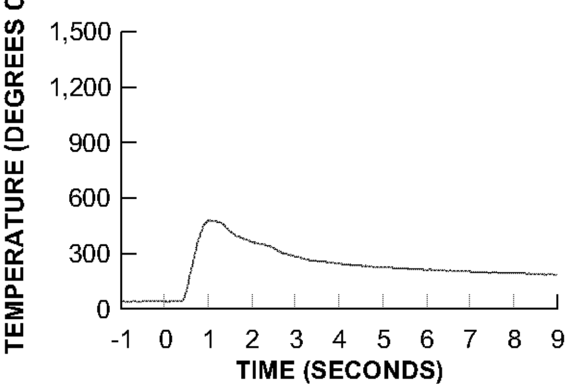
TEST 74
THERMOCOUPLE 7
BAY 5



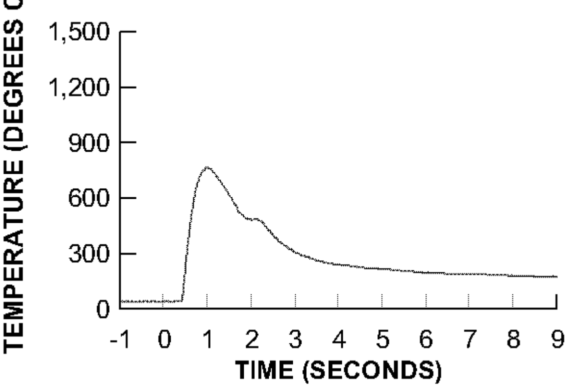
TEST 74
THERMOCOUPLE 8
BAY 6



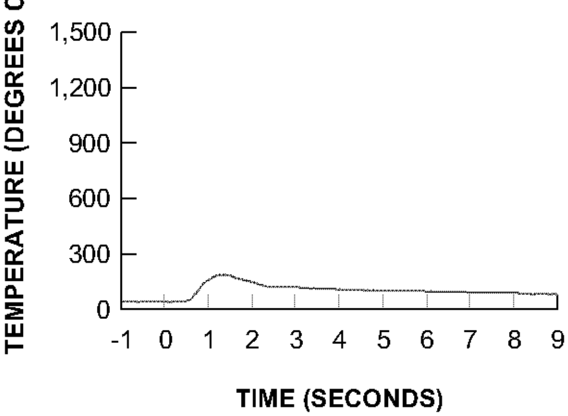
TEST 74
THERMOCOUPLE 9
BAY 3



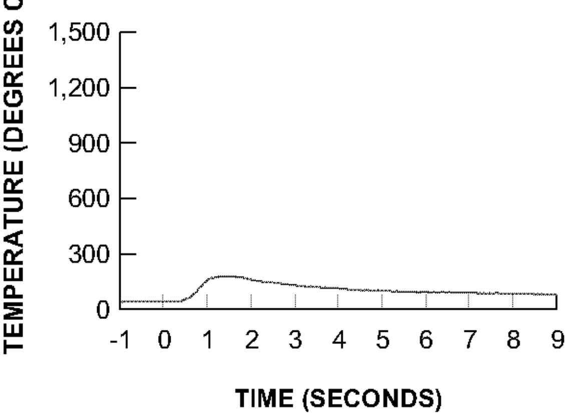
TEST 74
THERMOCOUPLE 10
BAY 4



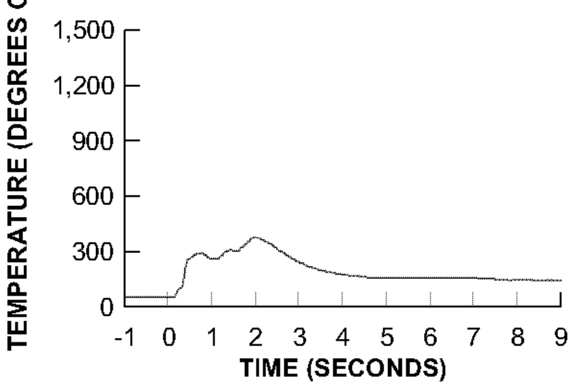
TEST 74
THERMOCOUPLE 11
BAY 2



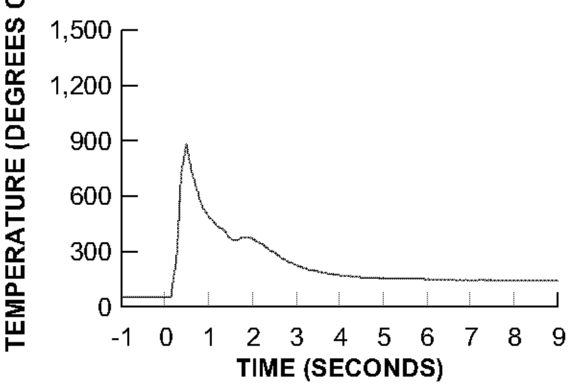
TEST 74
THERMOCOUPLE 12
BAY 1



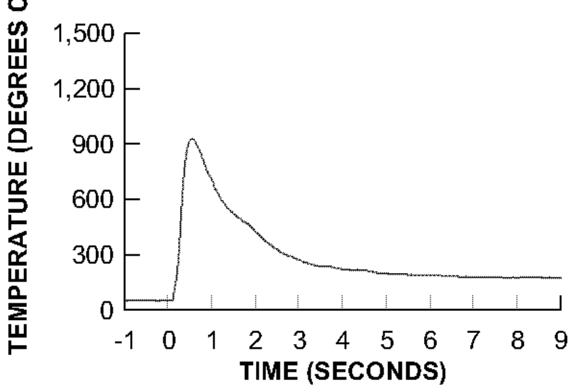
TEST 75
THERMOCOUPLE 1
BAY 5



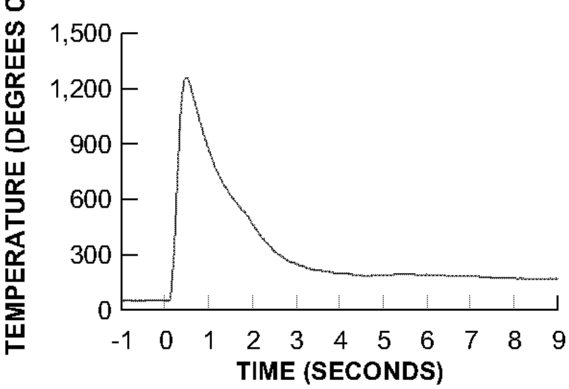
TEST 75
THERMOCOUPLE 2
BAY 6



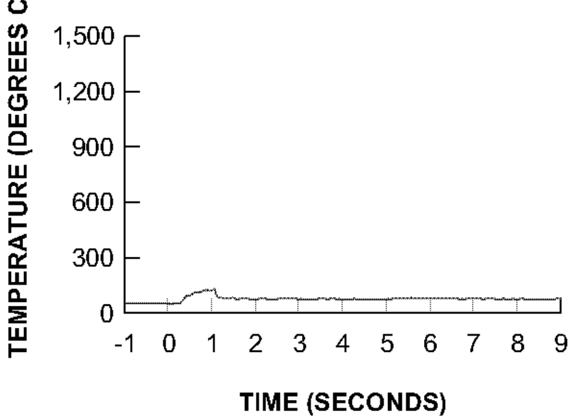
TEST 75
THERMOCOUPLE 3
BAY 3



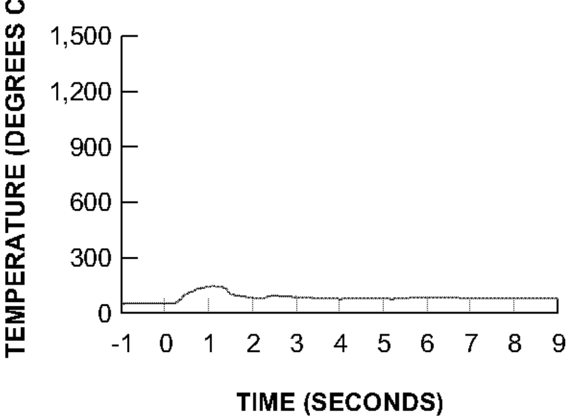
TEST 75
THERMOCOUPLE 4
BAY 4

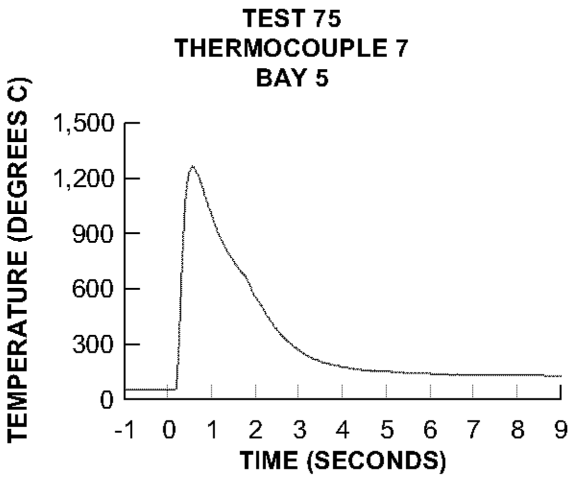


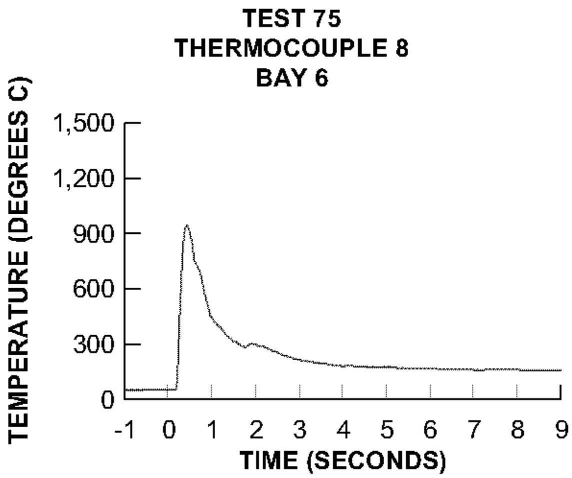
TEST 75
THERMOCOUPLE 5
BAY 2

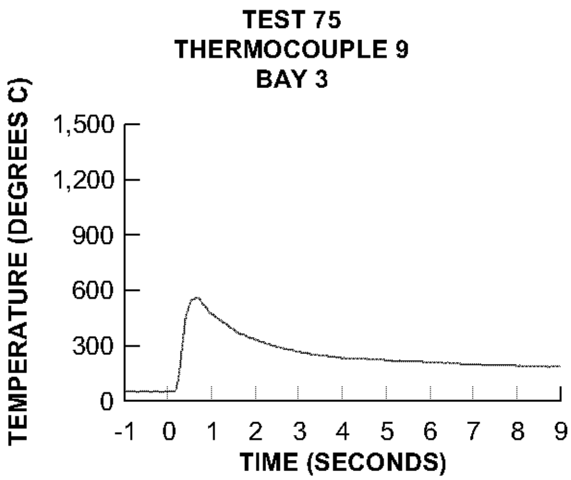


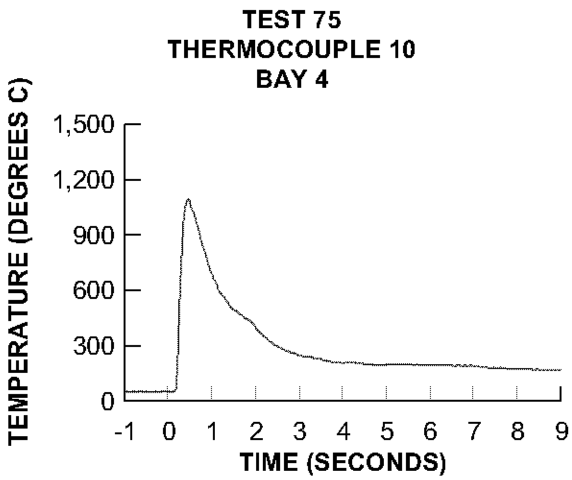
TEST 75
THERMOCOUPLE 6
BAY 1

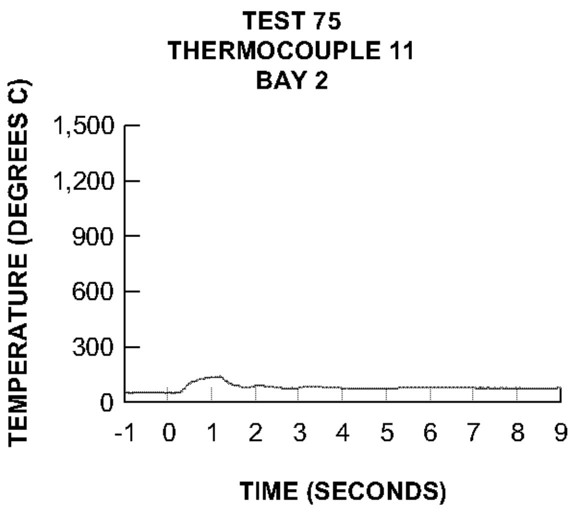


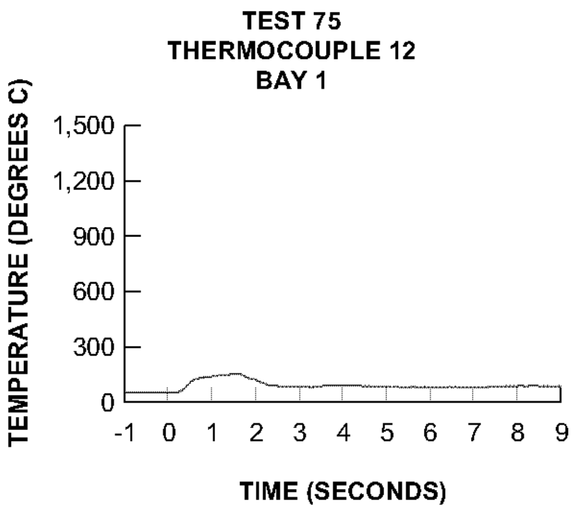

TEST 75
THERMOCOUPLE 7
BAY 5
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 75
THERMOCOUPLE 8
BAY 6
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

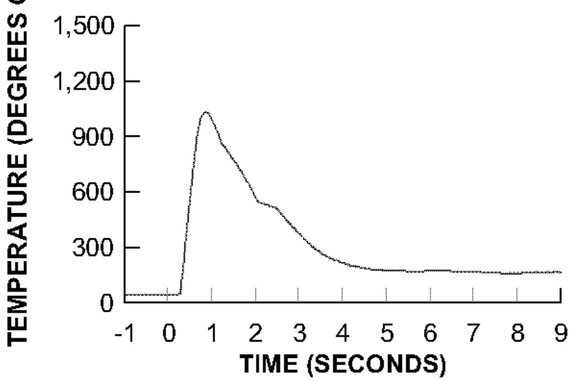

TEST 75
THERMOCOUPLE 9
BAY 3
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 75
THERMOCOUPLE 10
BAY 4
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

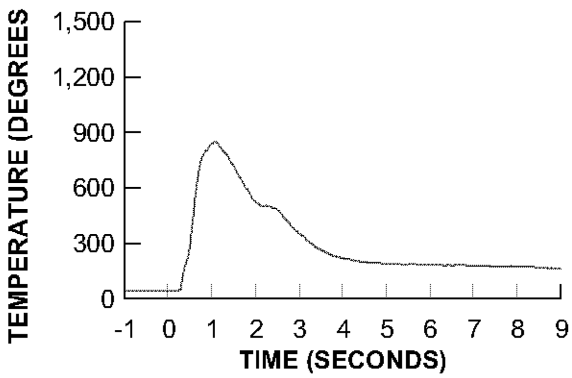

TEST 75
THERMOCOUPLE 11
BAY 2
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)


TEST 75
THERMOCOUPLE 12
BAY 1
TEMPERATURE (DEGREES C)
1,500
1,200
900
600
300
0
-1 0 1 2 3 4 5 6 7 8 9
TIME (SECONDS)

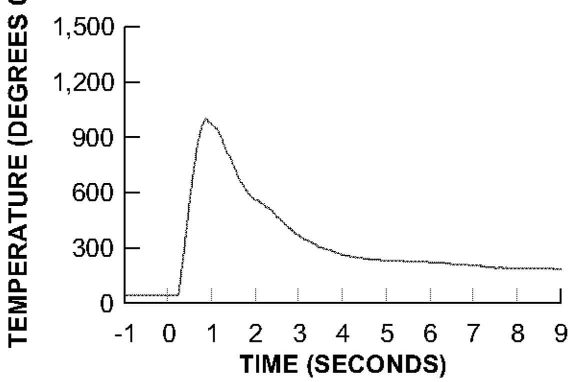
TEST 76
THERMOCOUPLE 1
BAY 5



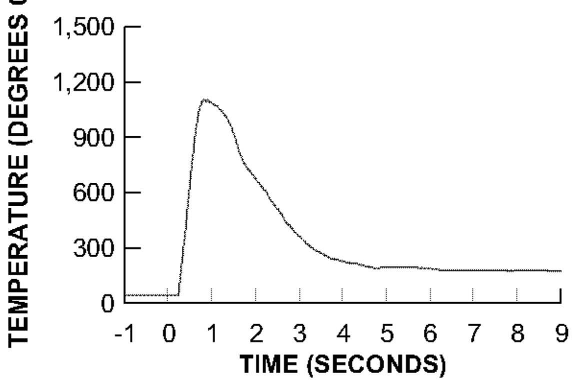
TEST 76
THERMOCOUPLE 2
BAY 6



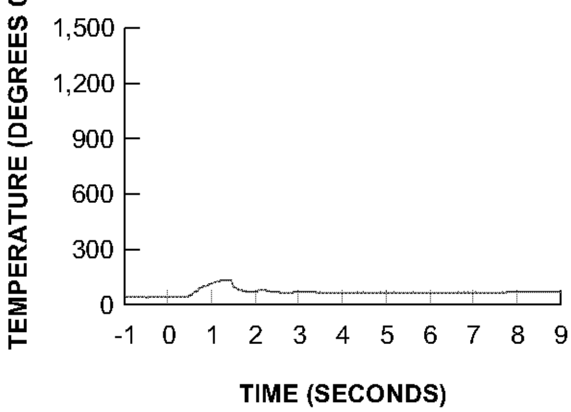
TEST 76
THERMOCOUPLE 3
BAY 3



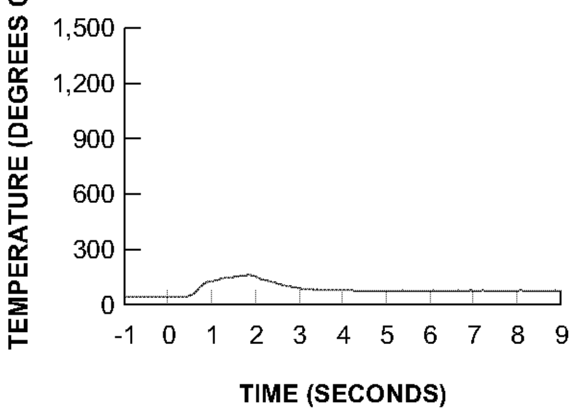
TEST 76
THERMOCOUPLE 4
BAY 4



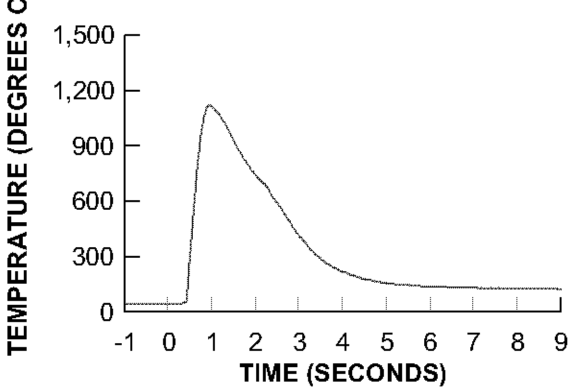
TEST 76
THERMOCOUPLE 5
BAY 2



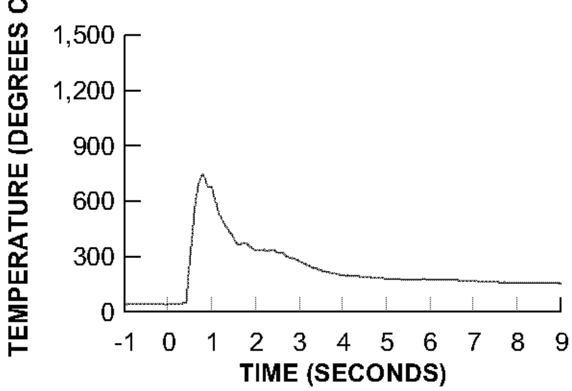
TEST 76
THERMOCOUPLE 6
BAY 1



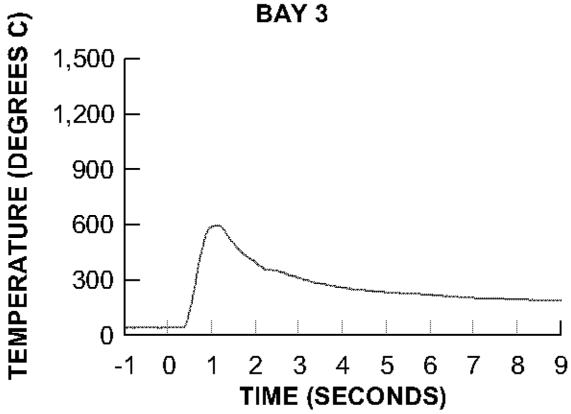
TEST 76
THERMOCOUPLE 7
BAY 5



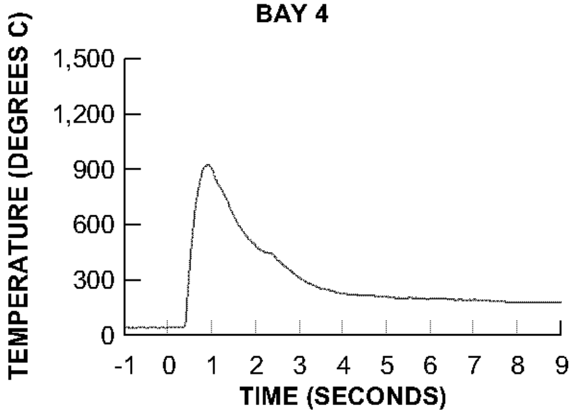
TEST 76
THERMOCOUPLE 8
BAY 6



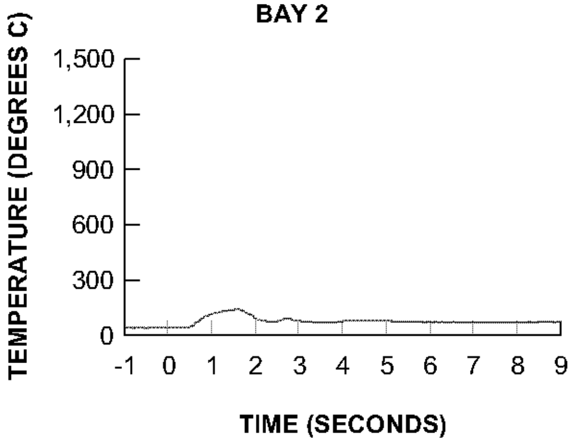
TEST 76
THERMOCOUPLE 9
BAY 3



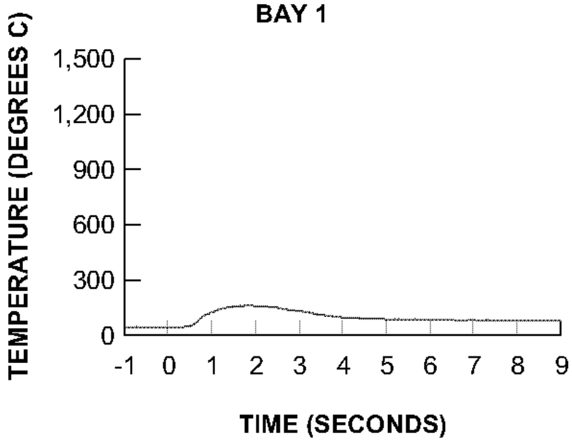
TEST 76
THERMOCOUPLE 10
BAY 4



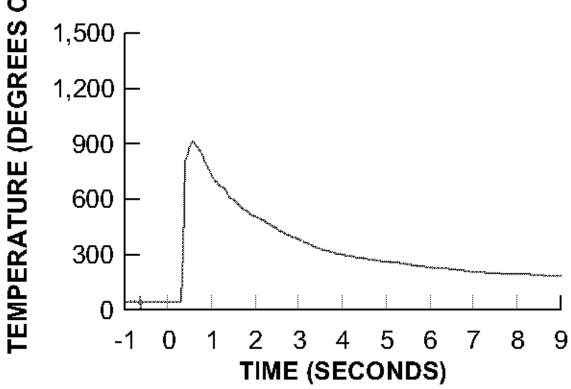
TEST 76
THERMOCOUPLE 11
BAY 2



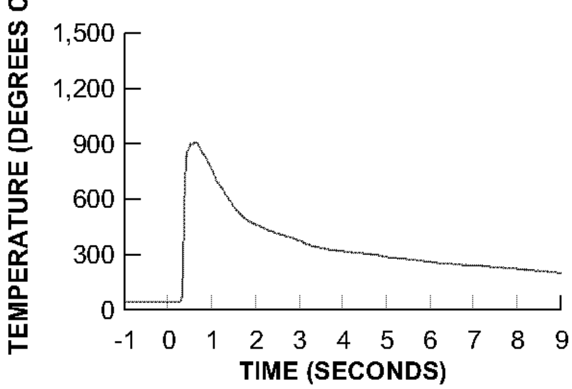
TEST 76
THERMOCOUPLE 12
BAY 1



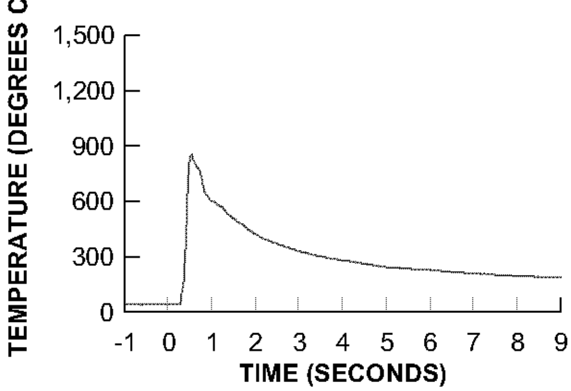
TEST 77
THERMOCOUPLE 1
BAY 5



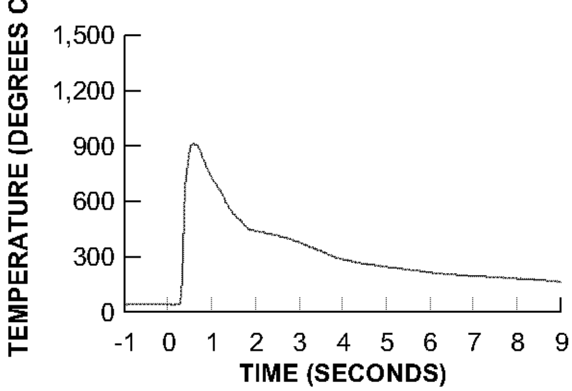
TEST 77
THERMOCOUPLE 2
BAY 6



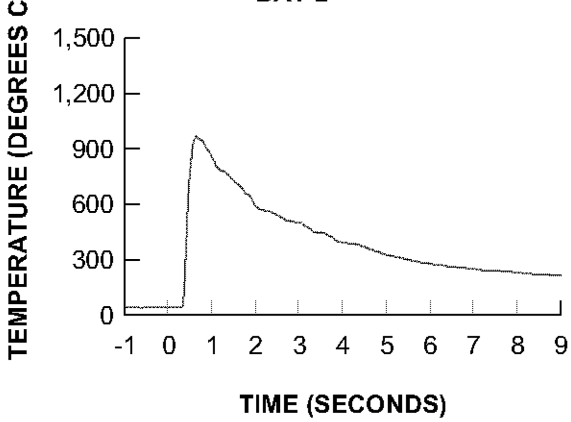
TEST 77
THERMOCOUPLE 3
BAY 3



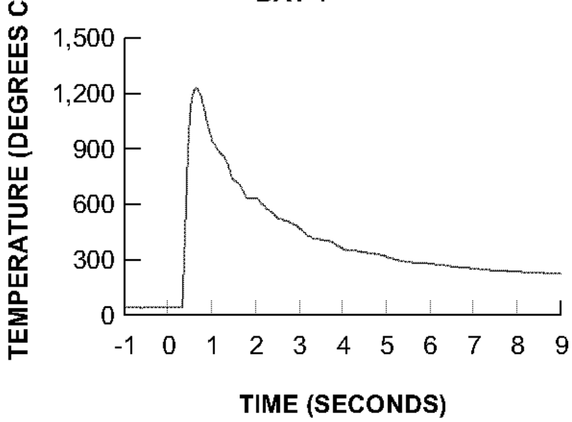
TEST 77
THERMOCOUPLE 4
BAY 4



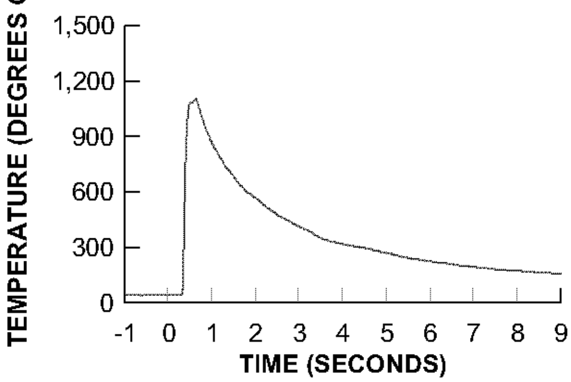
TEST 77
THERMOCOUPLE 5
BAY 2



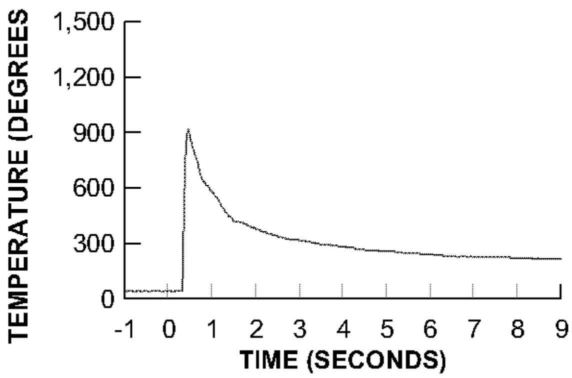
TEST 77
THERMOCOUPLE 6
BAY 1



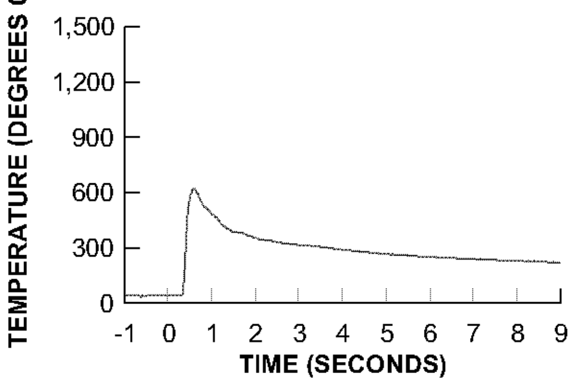
TEST 77
THERMOCOUPLE 7
BAY 5



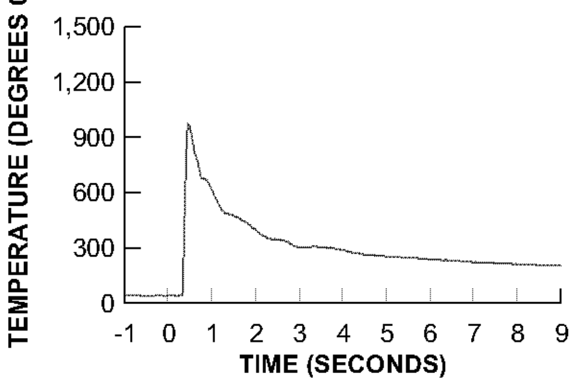
TEST 77
THERMOCOUPLE 8
BAY 6



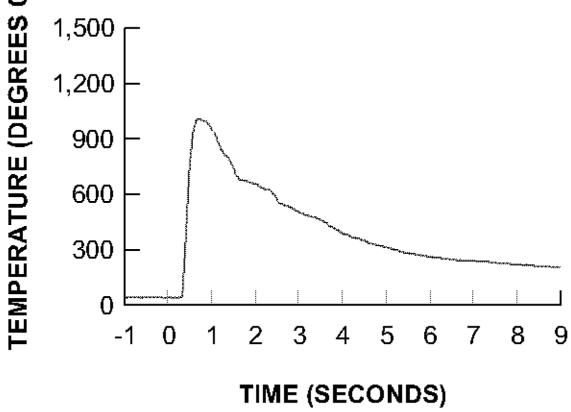
TEST 77
THERMOCOUPLE 9
BAY 3



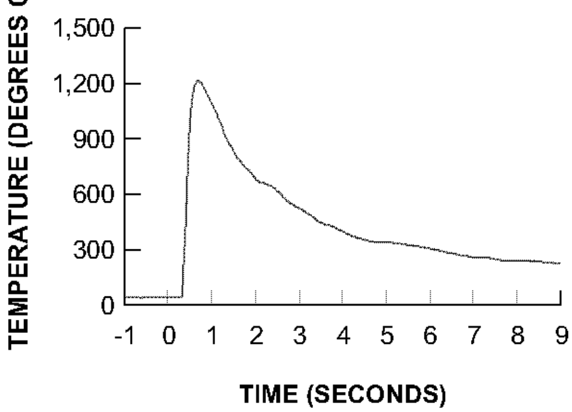
TEST 77
THERMOCOUPLE 10
BAY 4



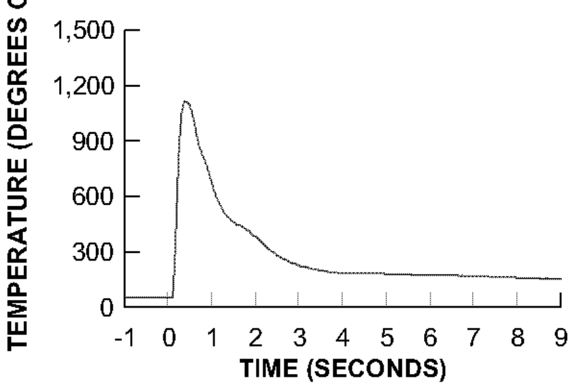
TEST 77
THERMOCOUPLE 11
BAY 2



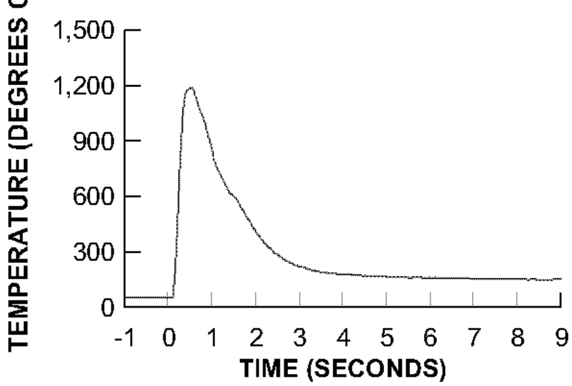
TEST 77
THERMOCOUPLE 12
BAY 1



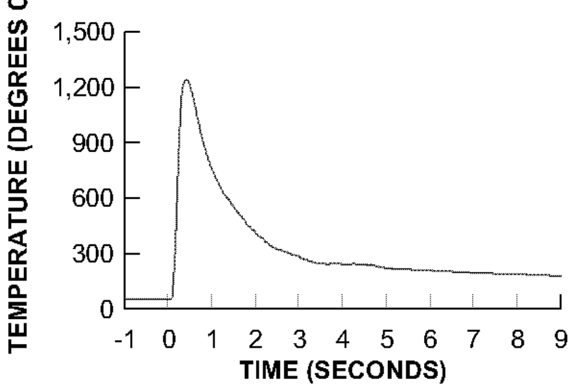
TEST 78
THERMOCOUPLE 1
BAY 5



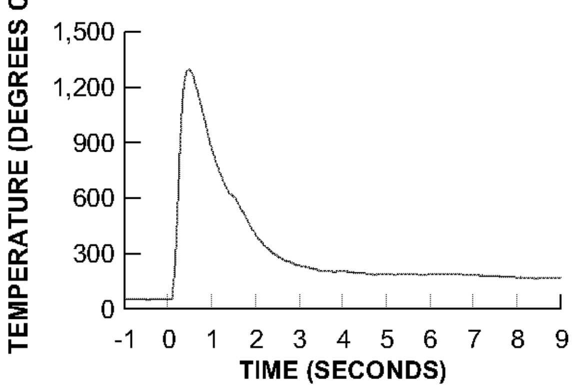
TEST 78
THERMOCOUPLE 2
BAY 6



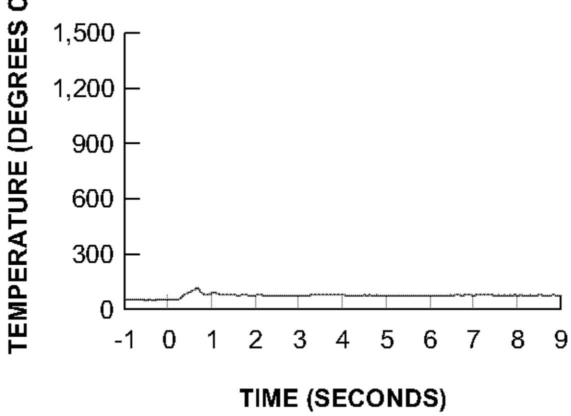
TEST 78
THERMOCOUPLE 3
BAY 3



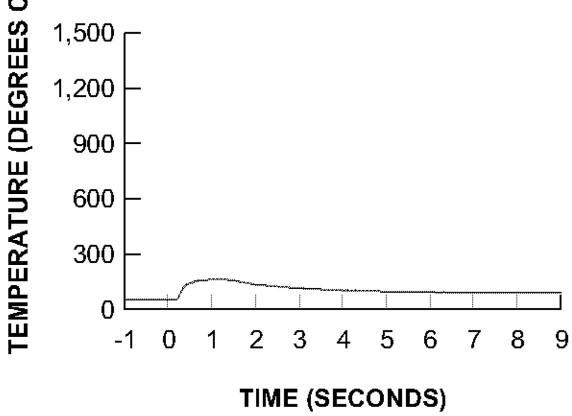
TEST 78
THERMOCOUPLE 4
BAY 4



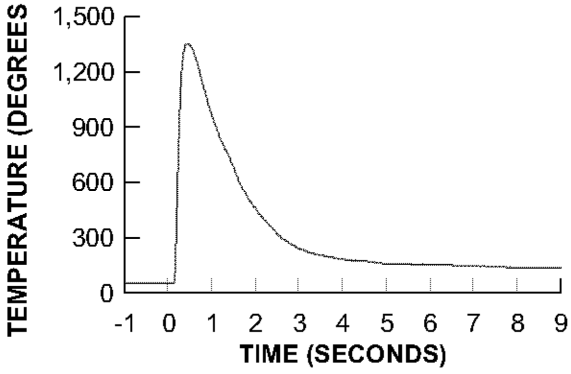
TEST 78
THERMOCOUPLE 5
BAY 2



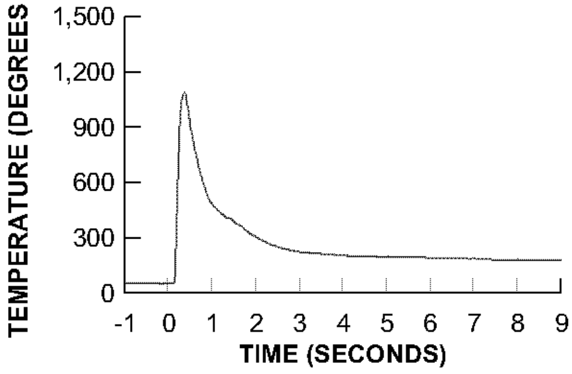
TEST 78
THERMOCOUPLE 6
BAY 1



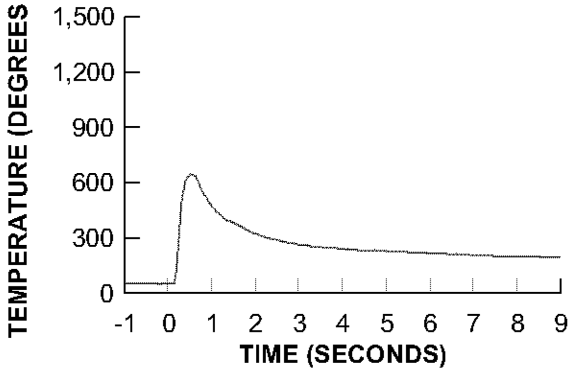
TEST 78
THERMOCOUPLE 7
BAY 5



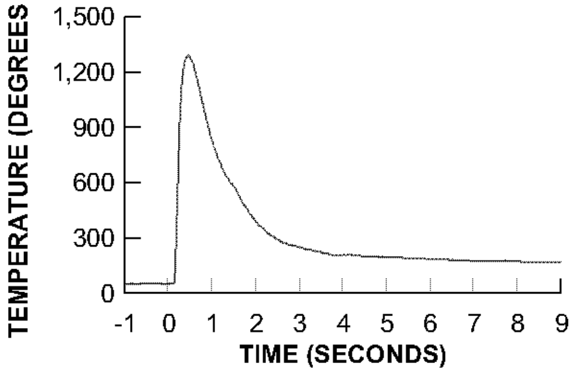
TEST 78
THERMOCOUPLE 8
BAY 6



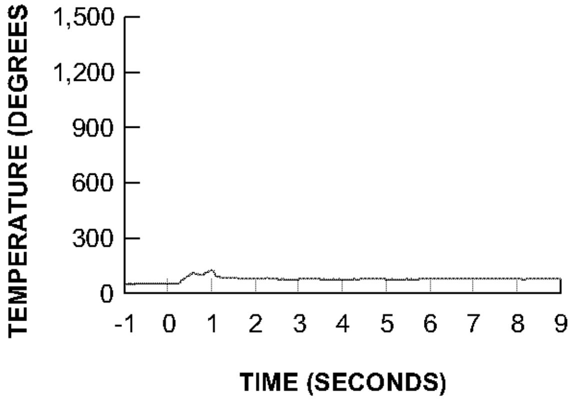
TEST 78
THERMOCOUPLE 9
BAY 3



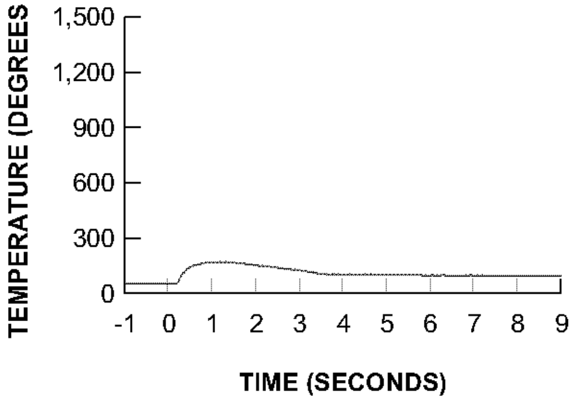
TEST 78
THERMOCOUPLE 10
BAY 4



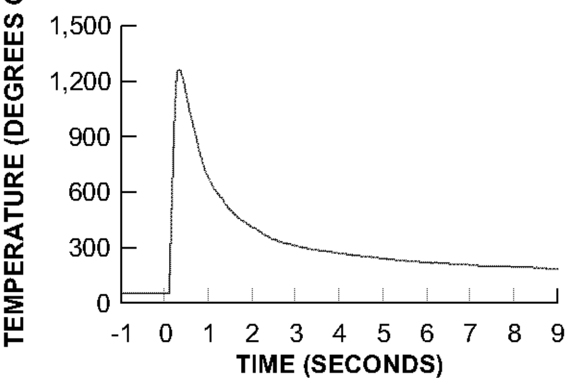
TEST 78
THERMOCOUPLE 11
BAY 2



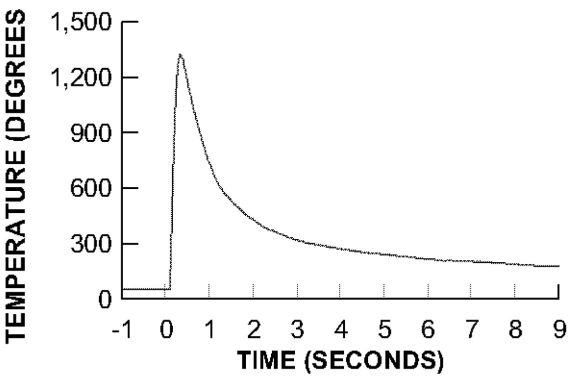
TEST 78
THERMOCOUPLE 12
BAY 1



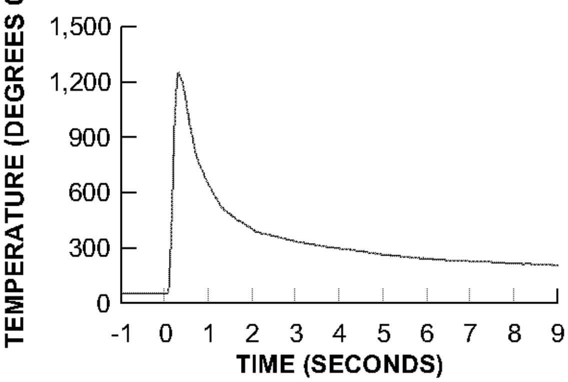
TEST 79
THERMOCOUPLE 1
BAY 5



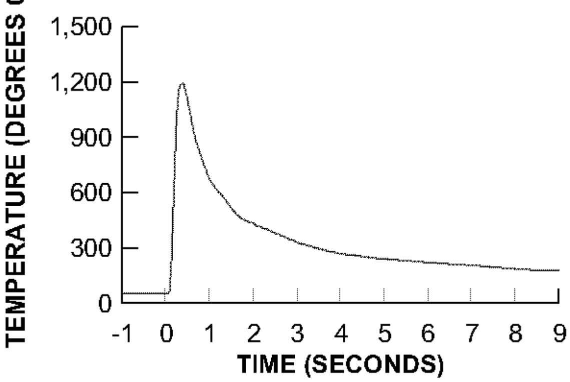
TEST 79
THERMOCOUPLE 2
BAY 6



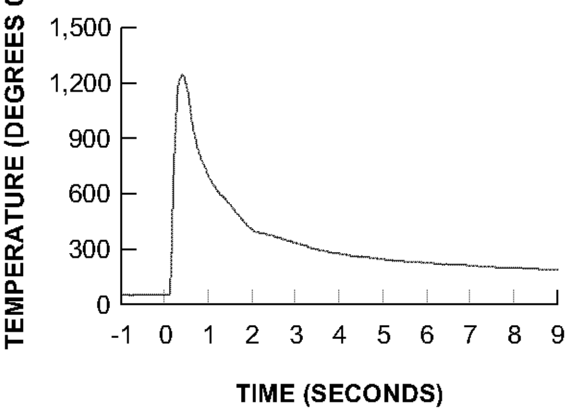
TEST 79
THERMOCOUPLE 3
BAY 3



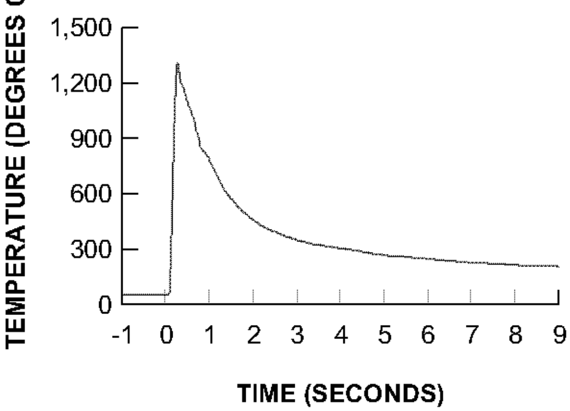
TEST 79
THERMOCOUPLE 4
BAY 4



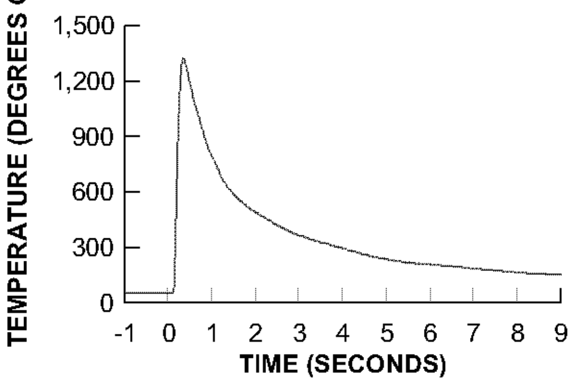
TEST 79
THERMOCOUPLE 5
BAY 2



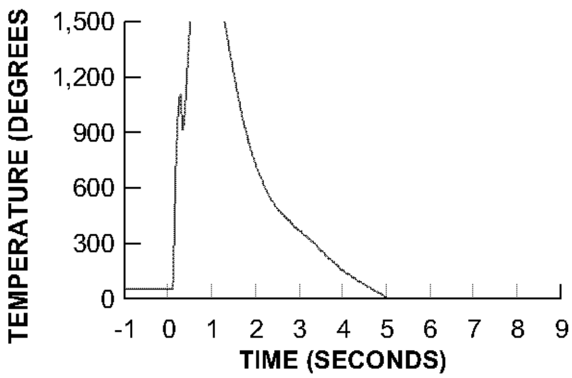
TEST 79
THERMOCOUPLE 6
BAY 1



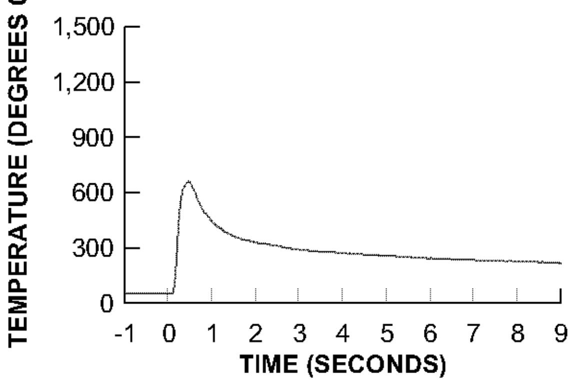
TEST 79
THERMOCOUPLE 7
BAY 5



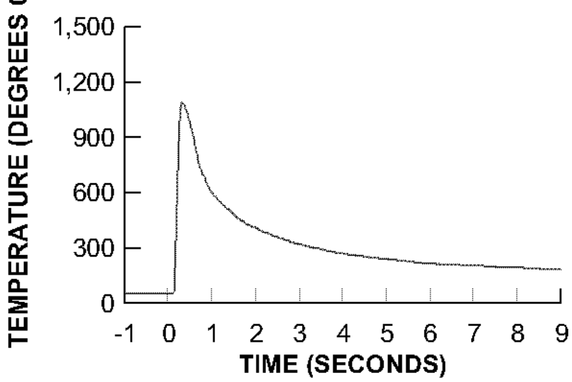
TEST 79
THERMOCOUPLE 8
BAY 6



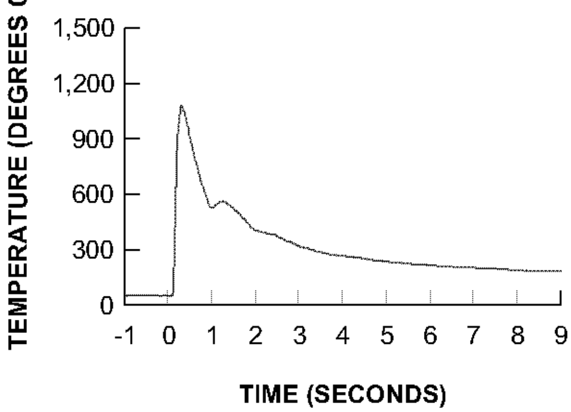
TEST 79
THERMOCOUPLE 9
BAY 3



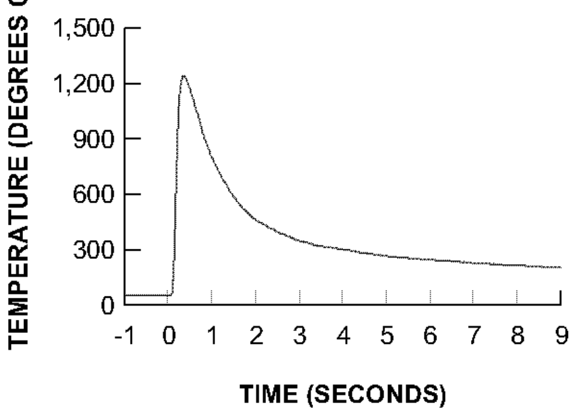
TEST 79
THERMOCOUPLE 10
BAY 4



TEST 79
THERMOCOUPLE 11
BAY 2



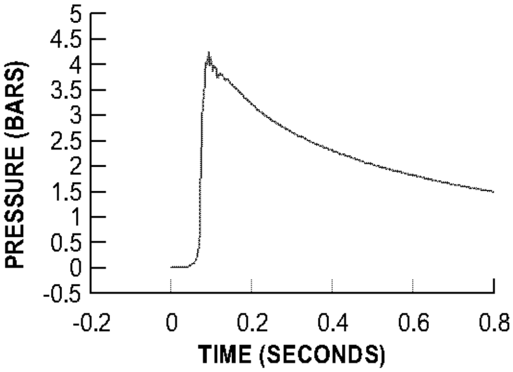
TEST 79
THERMOCOUPLE 12
BAY 1



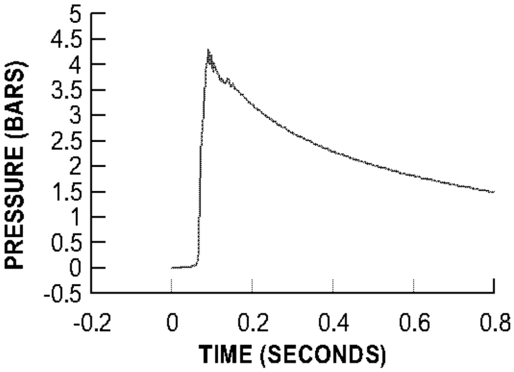
APPENDIX D

PRESSURE DATA IN BAYS

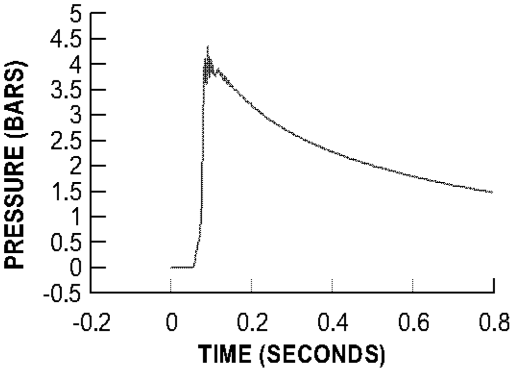
TEST 31
QUASI-STATIC PRESSURE 1
BAY 5



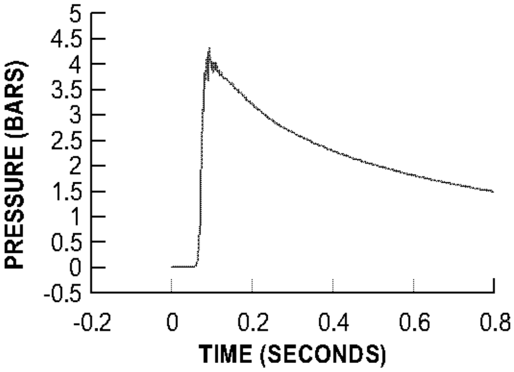
TEST 31
QUASI-STATIC PRESSURE 2
BAY 6



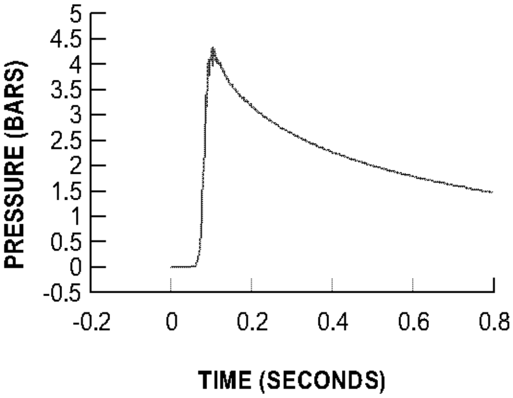
TEST 31
QUASI-STATIC PRESSURE 3
BAY 3



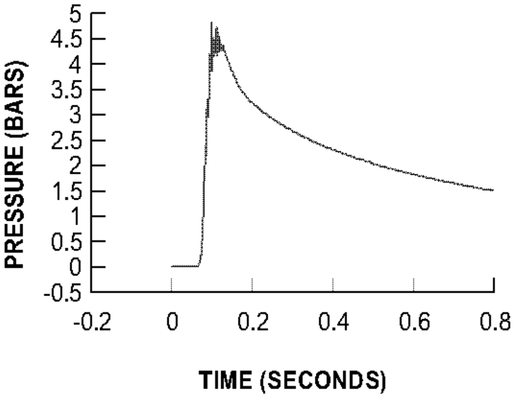
TEST 31
QUASI-STATIC PRESSURE 4
BAY 4



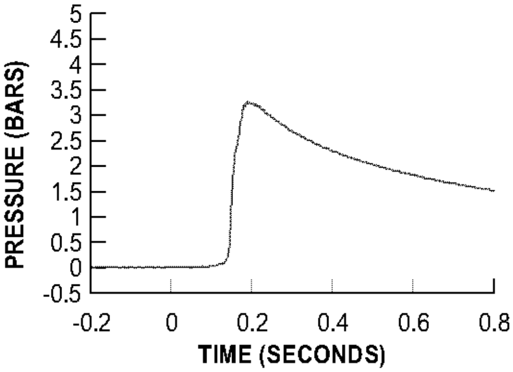
TEST 31
QUASI-STATIC PRESSURE 5
BAY 2



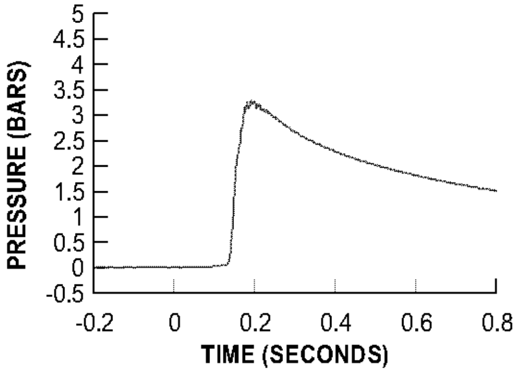
TEST 31
QUASI-STATIC PRESSURE 6
BAY 1



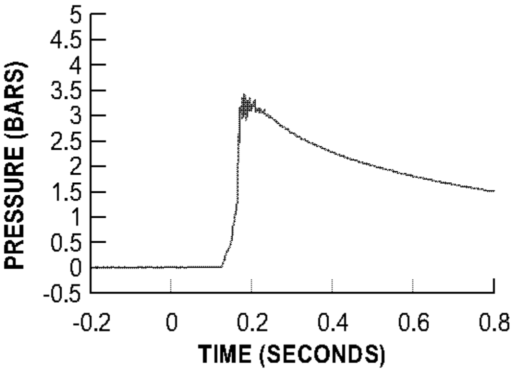
TEST 31A
QUASI-STATIC PRESSURE 1
BAY 5



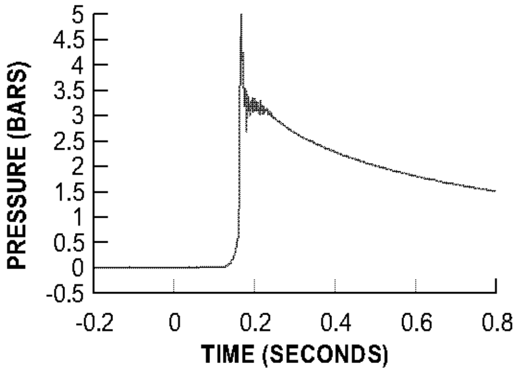
TEST 31A
QUASI-STATIC PRESSURE 2
BAY 6



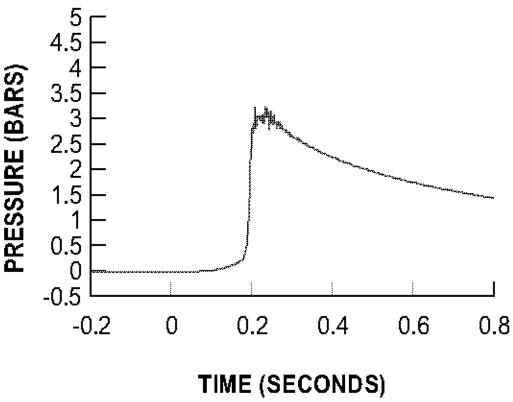
TEST 31A
QUASI-STATIC PRESSURE 3
BAY 3



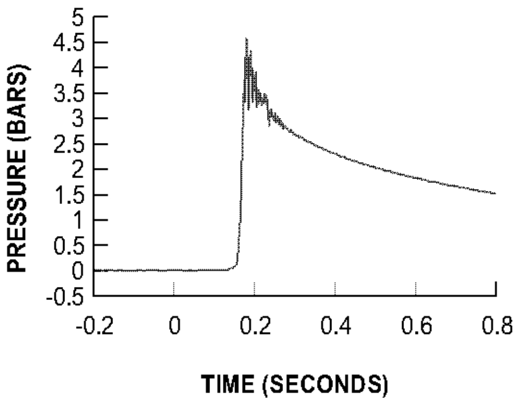
TEST 31A
QUASI-STATIC PRESSURE 4
BAY 4



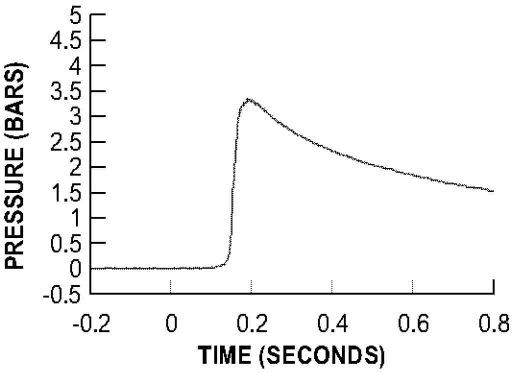
TEST 31A
QUASI-STATIC PRESSURE 5
BAY 2



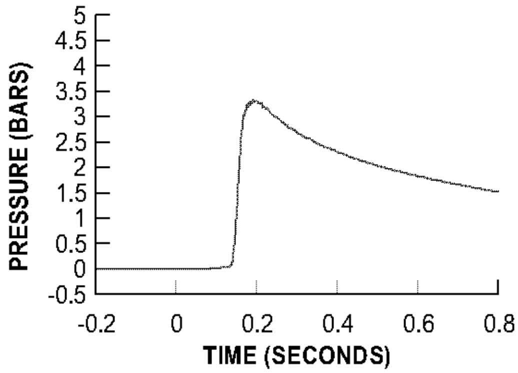
TEST 31A
QUASI-STATIC PRESSURE 6
BAY 1



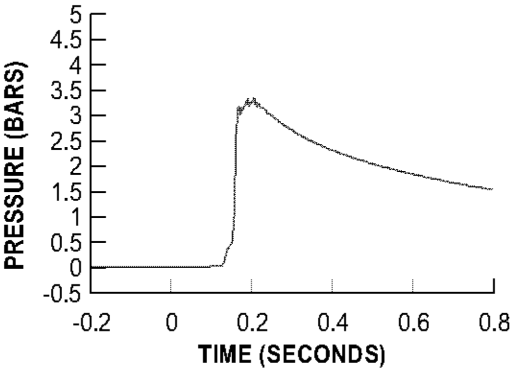
TEST 31B
QUASI-STATIC PRESSURE 1
BAY 5



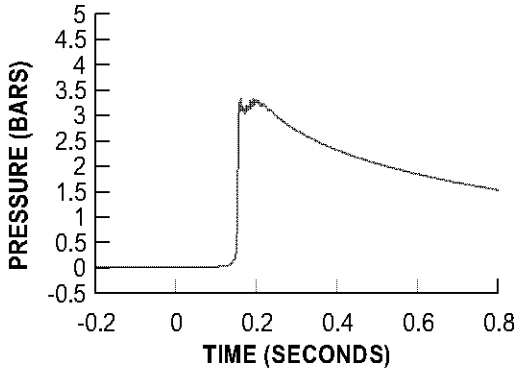
TEST 31B
QUASI-STATIC PRESSURE 2
BAY 6



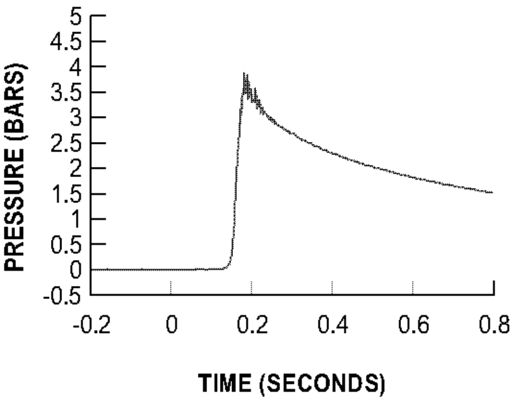
TEST 31B
QUASI-STATIC PRESSURE 3
BAY 3



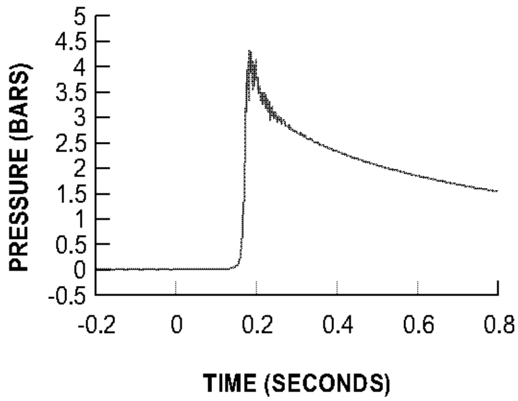
TEST 31B
QUASI-STATIC PRESSURE 4
BAY 4



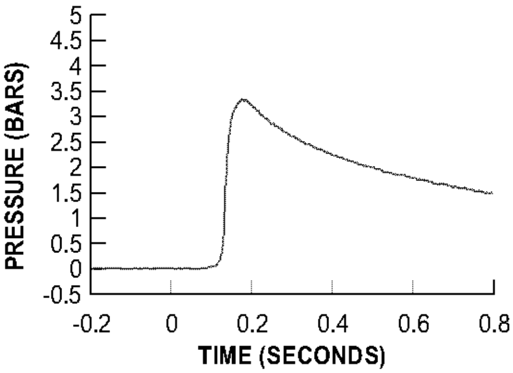
TEST 31B
QUASI-STATIC PRESSURE 5
BAY 2



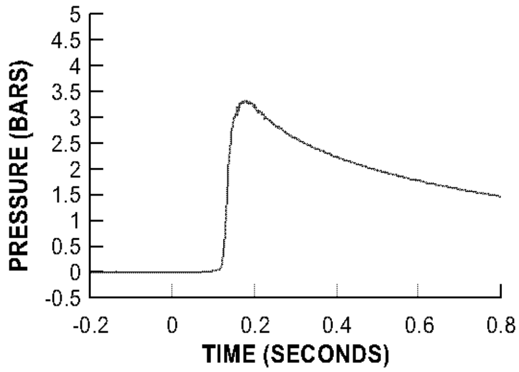
TEST 31B
QUASI-STATIC PRESSURE 6
BAY 1



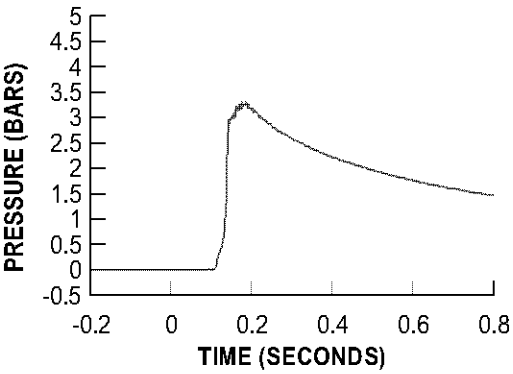
TEST 32
QUASI-STATIC PRESSURE 1
BAY 5



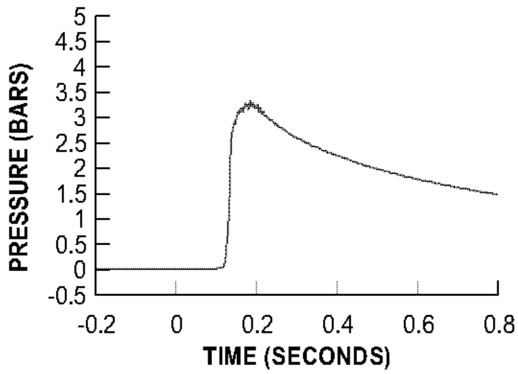
TEST 32
QUASI-STATIC PRESSURE 2
BAY 6



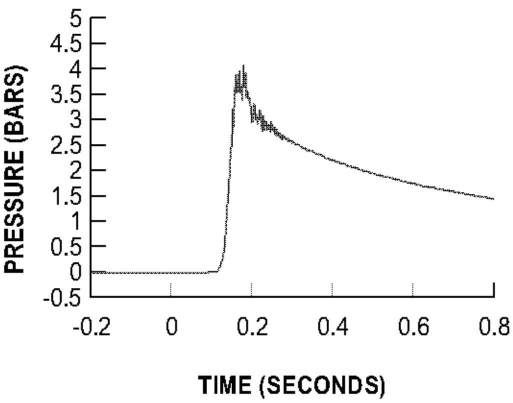
TEST 32
QUASI-STATIC PRESSURE 3
BAY 3



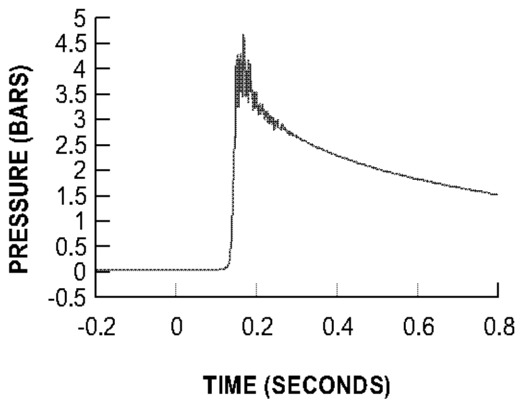
TEST 32
QUASI-STATIC PRESSURE 4
BAY 4



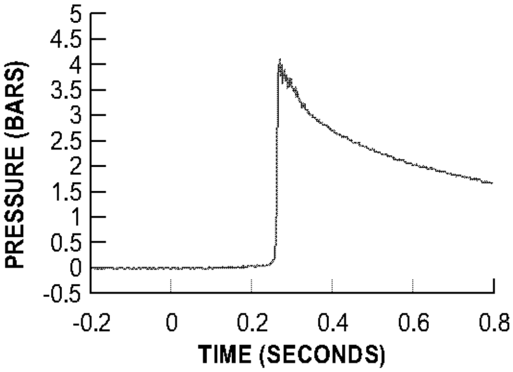
TEST 32
QUASI-STATIC PRESSURE 5
BAY 2



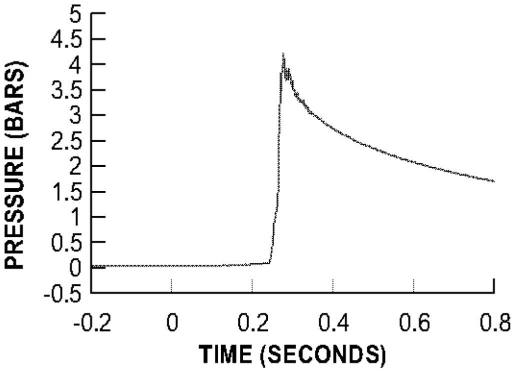
TEST 32
QUASI-STATIC PRESSURE 6
BAY 1



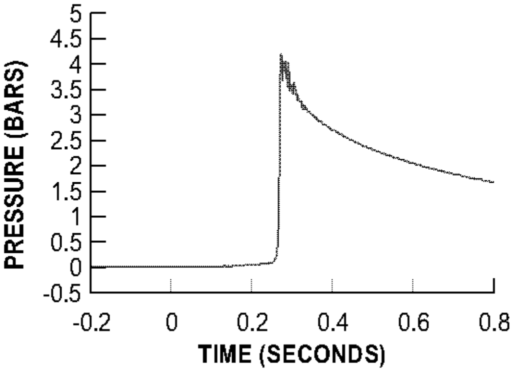
TEST 33
QUASI-STATIC PRESSURE 1
BAY 5



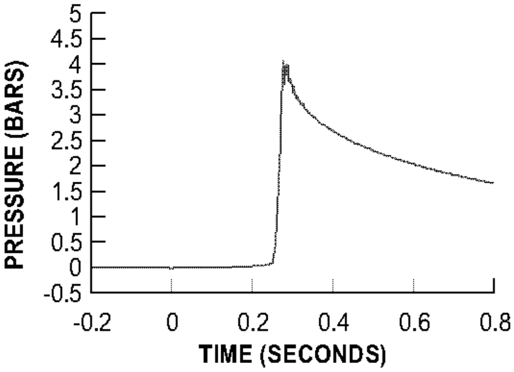
TEST 33
QUASI-STATIC PRESSURE 2
BAY 6



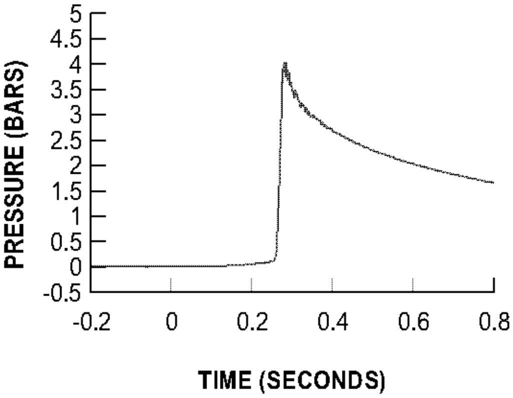
TEST 33
QUASI-STATIC PRESSURE 3
BAY 3



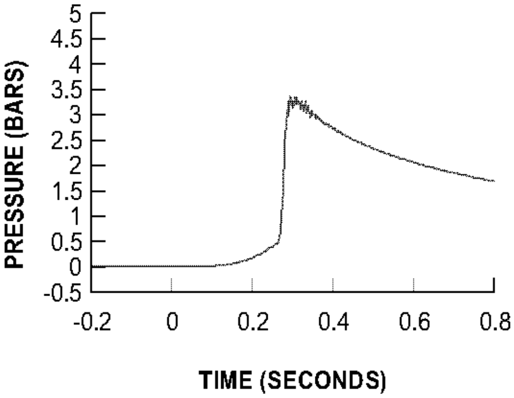
TEST 33
QUASI-STATIC PRESSURE 4
BAY 4



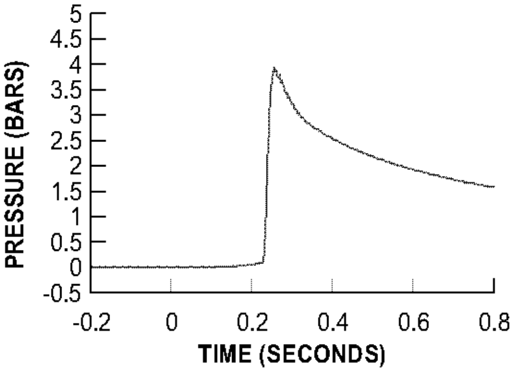
TEST 33
QUASI-STATIC PRESSURE 5
BAY 2



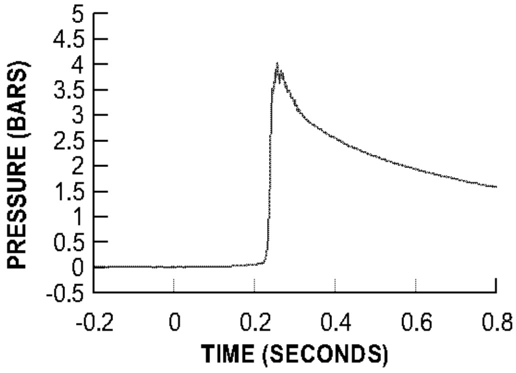
TEST 33
QUASI-STATIC PRESSURE 6
BAY 1



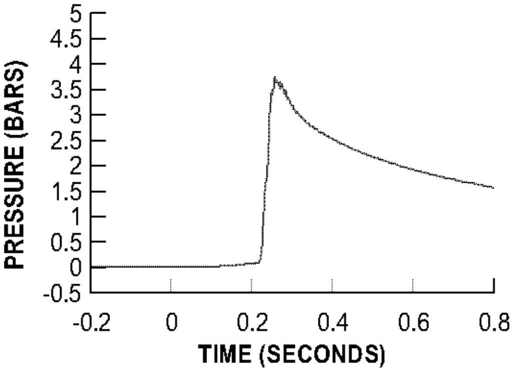
TEST 34
QUASI-STATIC PRESSURE 1
BAY 5



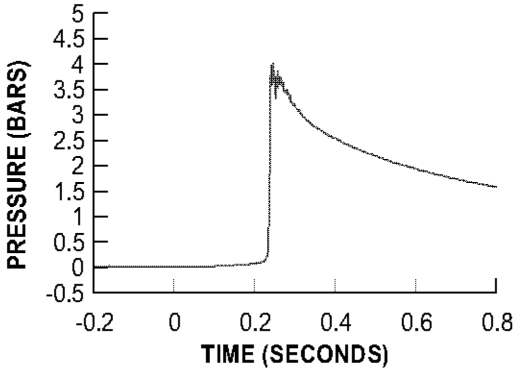
TEST 34
QUASI-STATIC PRESSURE 2
BAY 6



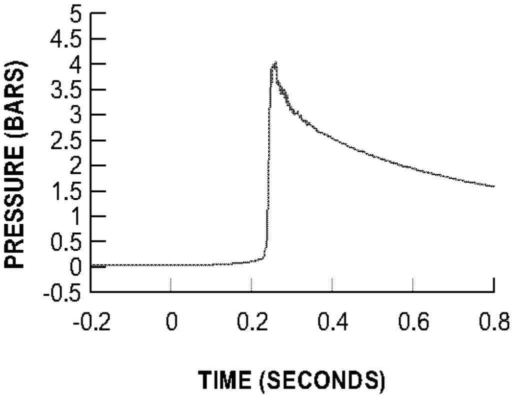
TEST 34
QUASI-STATIC PRESSURE 3
BAY 3



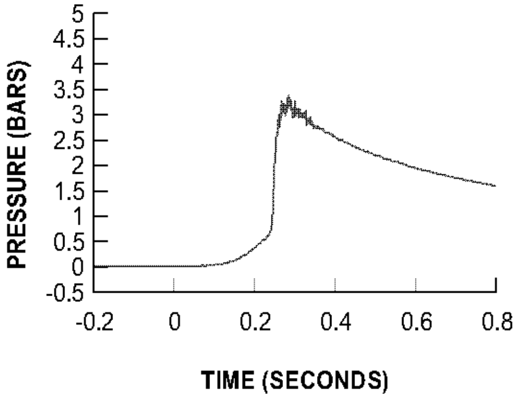
TEST 34
QUASI-STATIC PRESSURE 4
BAY 4



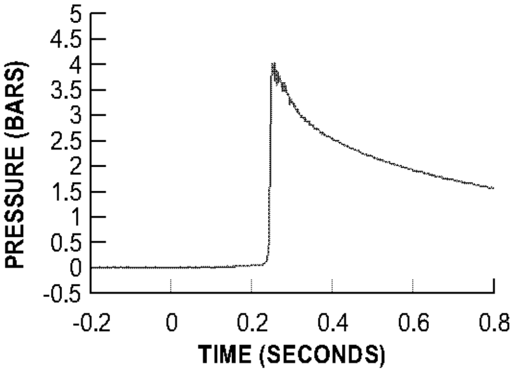
TEST 34
QUASI-STATIC PRESSURE 5
BAY 2



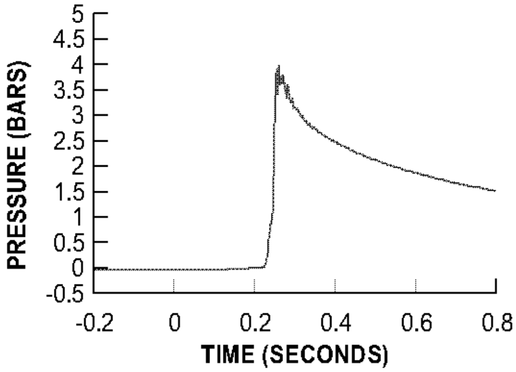
TEST 34
QUASI-STATIC PRESSURE 6
BAY 1



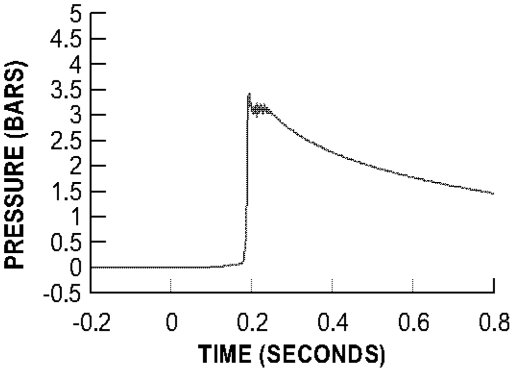
TEST 34A
QUASI-STATIC PRESSURE 1
BAY 5



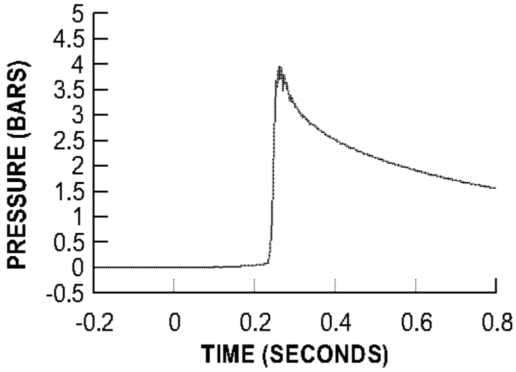
TEST 34A
QUASI-STATIC PRESSURE 2
BAY 6



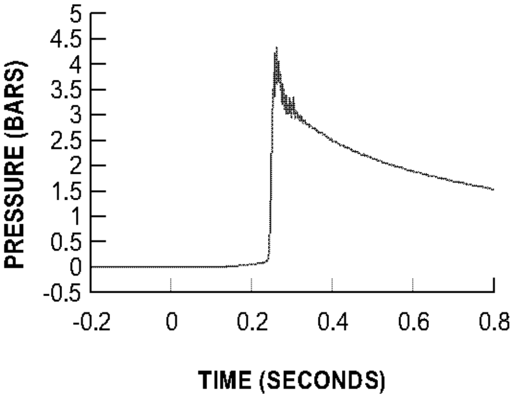
TEST 34A
QUASI-STATIC PRESSURE 3
BAY 3



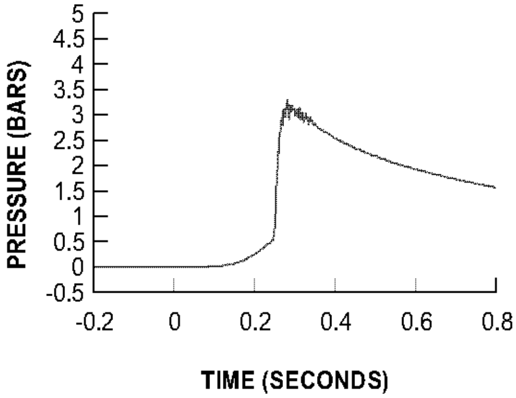
TEST 34A
QUASI-STATIC PRESSURE 4
BAY 4



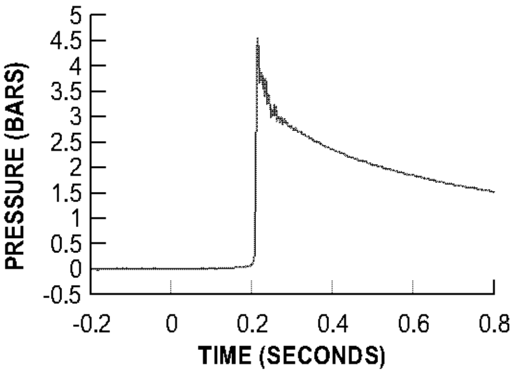
TEST 34A
QUASI-STATIC PRESSURE 5
BAY 2



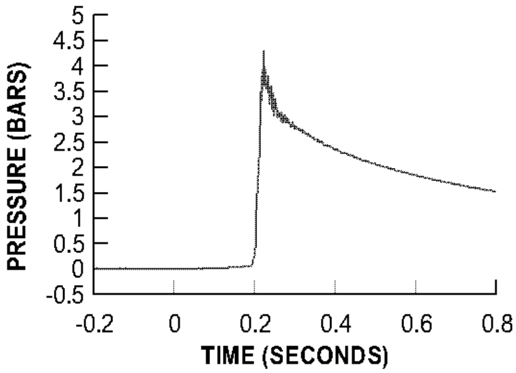
TEST 34A
QUASI-STATIC PRESSURE 6
BAY 1



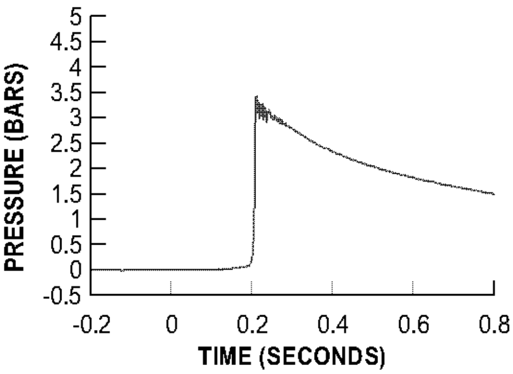
TEST 35
QUASI-STATIC PRESSURE 1
BAY 5



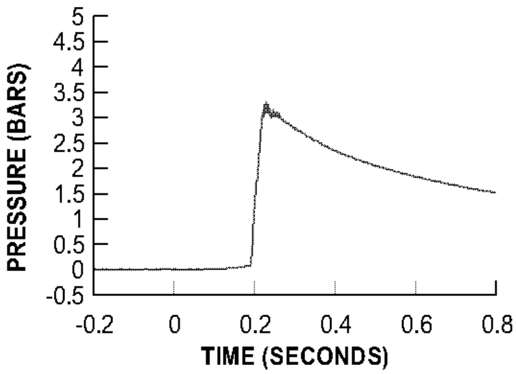
TEST 35
QUASI-STATIC PRESSURE 2
BAY 6



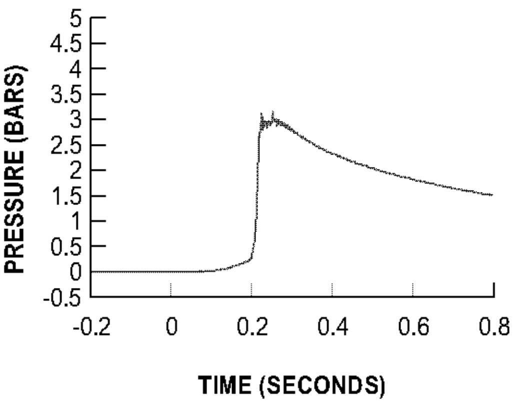
TEST 35
QUASI-STATIC PRESSURE 3
BAY 3



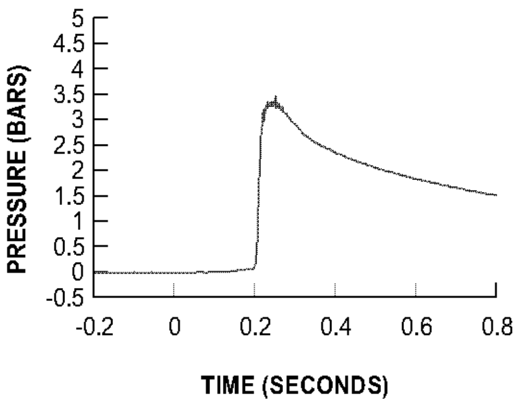
TEST 35
QUASI-STATIC PRESSURE 4
BAY 4



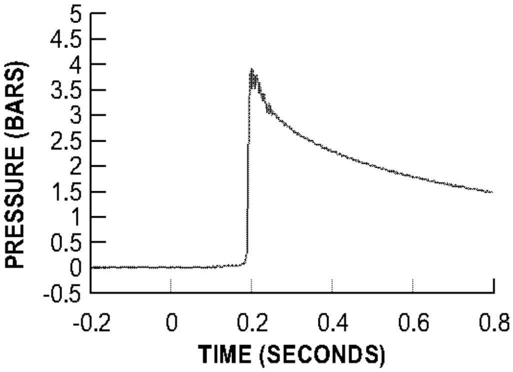
TEST 35
QUASI-STATIC PRESSURE 5
BAY 2



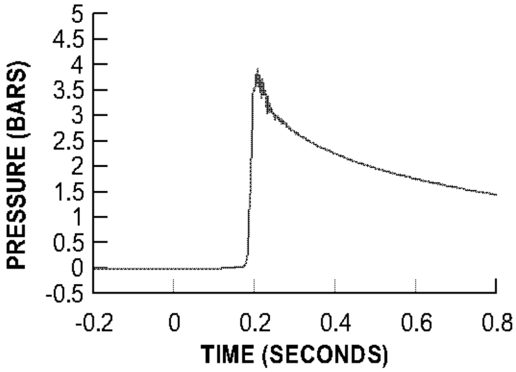
TEST 35
QUASI-STATIC PRESSURE 6
BAY 1



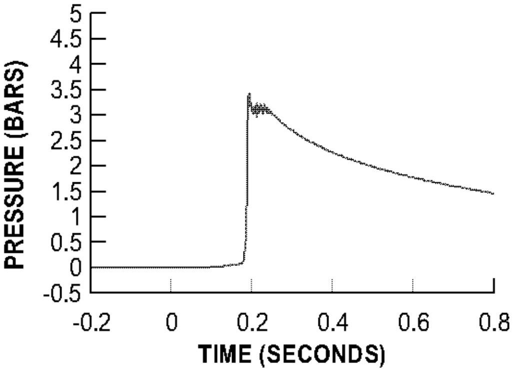
TEST 35A
QUASI-STATIC PRESSURE 1
BAY 5



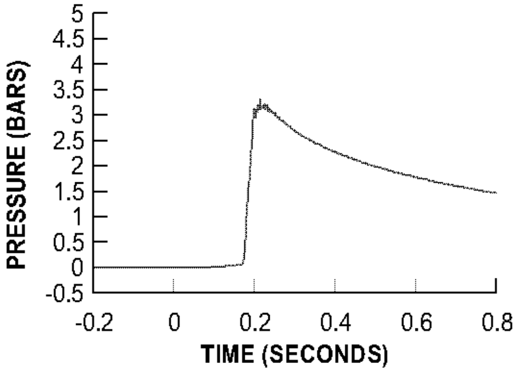
TEST 35A
QUASI-STATIC PRESSURE 2
BAY 6



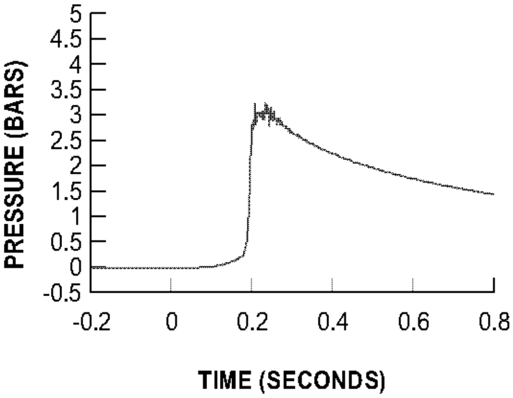
TEST 35A
QUASI-STATIC PRESSURE 3
BAY 3



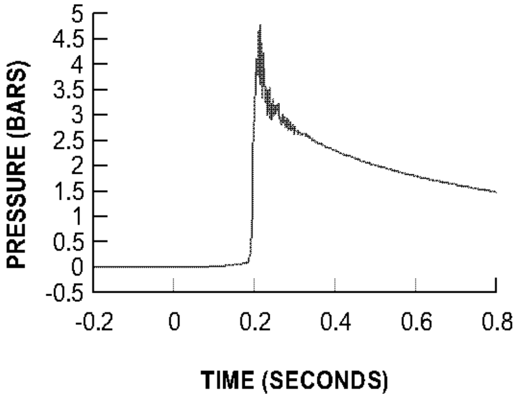
TEST 35A
QUASI-STATIC PRESSURE 4
BAY 4



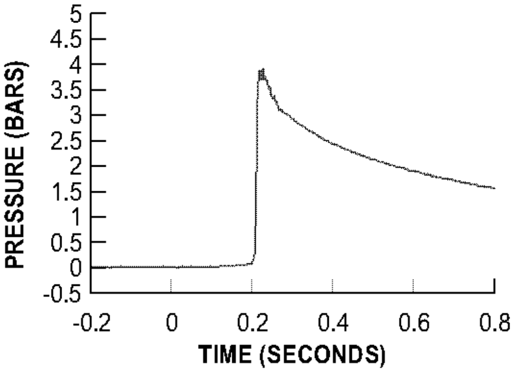
TEST 35A
QUASI-STATIC PRESSURE 5
BAY 2



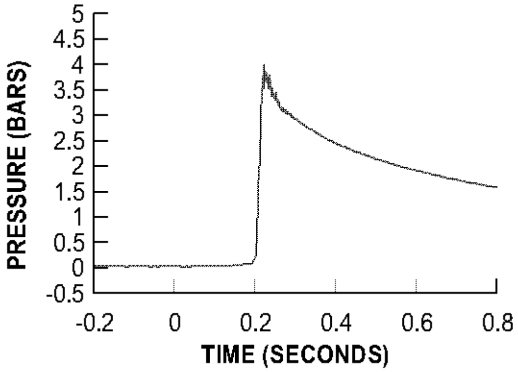
TEST 35A
QUASI-STATIC PRESSURE 6
BAY 1



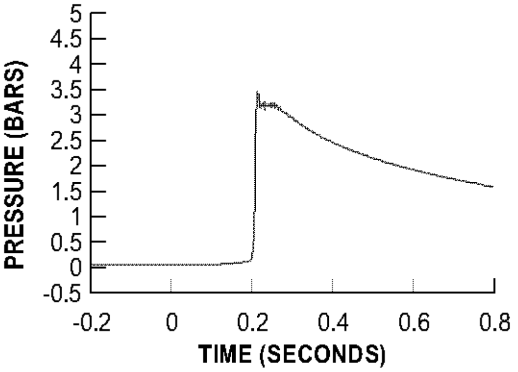
TEST 35B
QUASI-STATIC PRESSURE 1
BAY 5



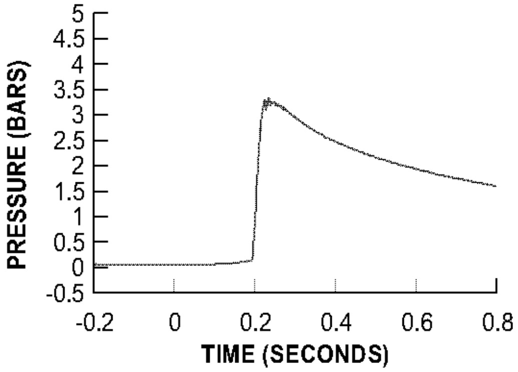
TEST 35B
QUASI-STATIC PRESSURE 2
BAY 6



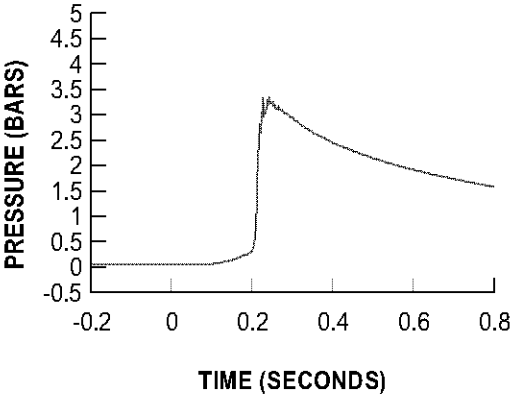
TEST 35B
QUASI-STATIC PRESSURE 3
BAY 3



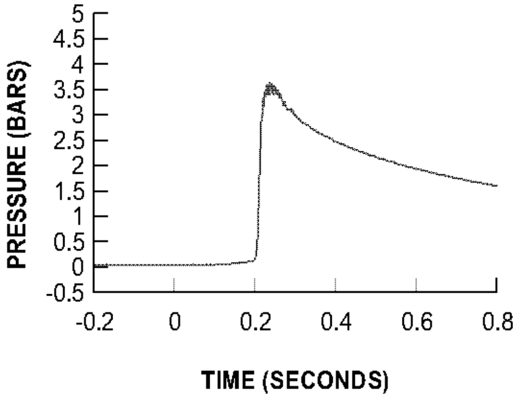
TEST 35B
QUASI-STATIC PRESSURE 4
BAY 4



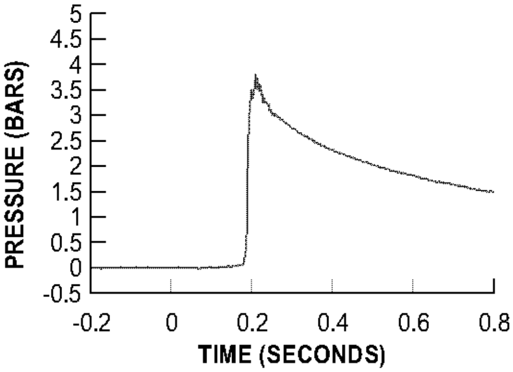
TEST 35B
QUASI-STATIC PRESSURE 5
BAY 2



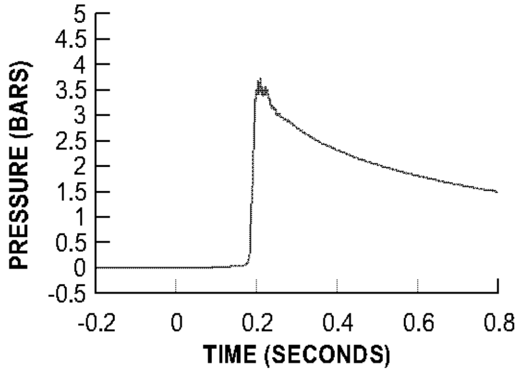
TEST 35B
QUASI-STATIC PRESSURE 6
BAY 1



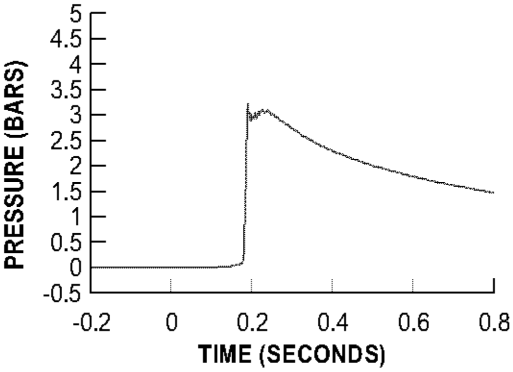
TEST 36
QUASI-STATIC PRESSURE 1
BAY 5



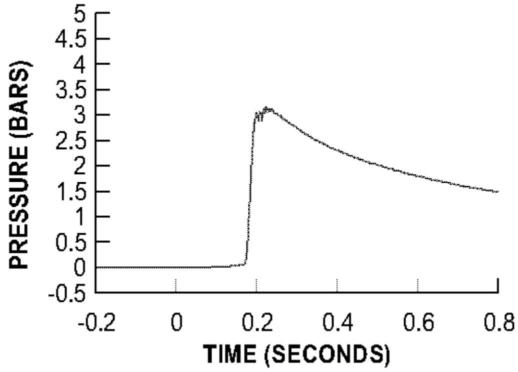
TEST 36
QUASI-STATIC PRESSURE 2
BAY 6



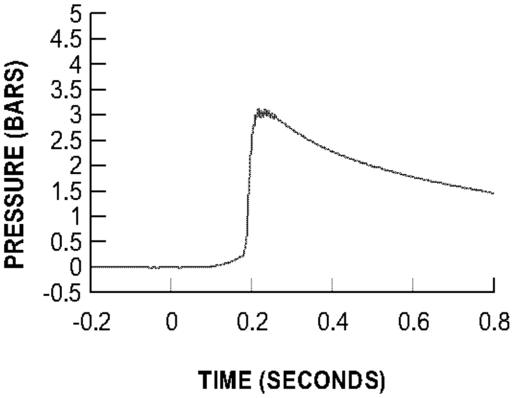
TEST 36
QUASI-STATIC PRESSURE 3
BAY 3



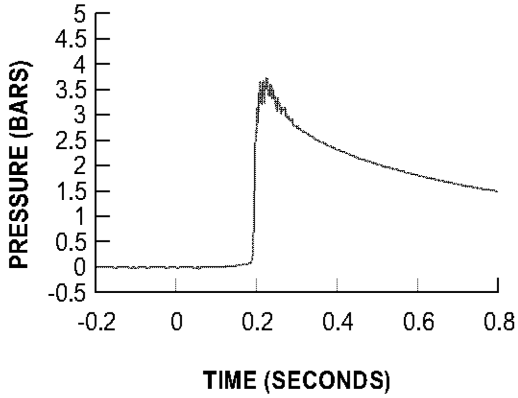
TEST 36
QUASI-STATIC PRESSURE 4
BAY 4



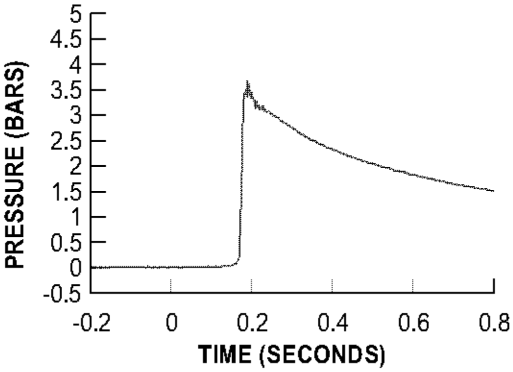
TEST 36
QUASI-STATIC PRESSURE 5
BAY 2



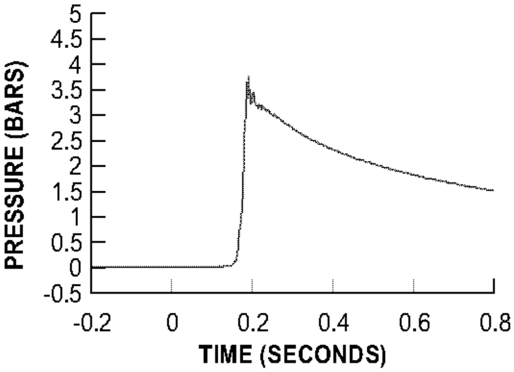
TEST 36
QUASI-STATIC PRESSURE 6
BAY 1



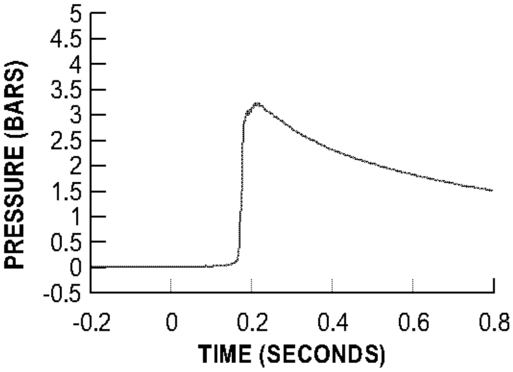
TEST 39
QUASI-STATIC PRESSURE 1
BAY 5



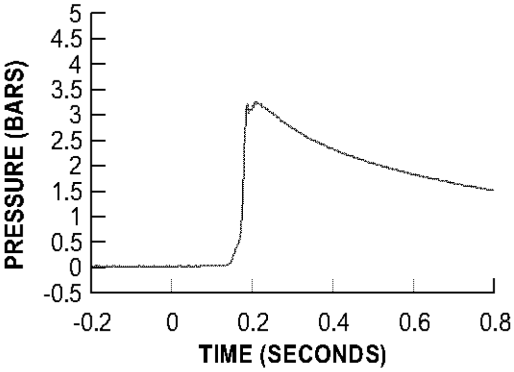
TEST 39
QUASI-STATIC PRESSURE 2
BAY 6



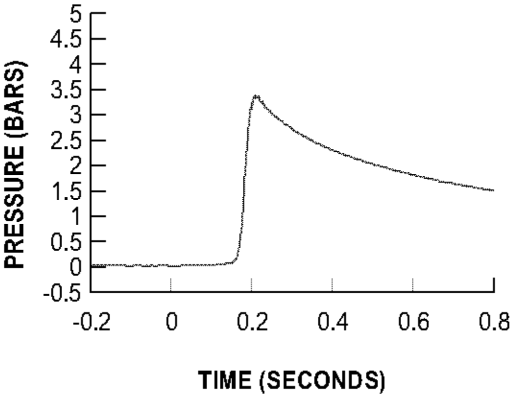
TEST 39
QUASI-STATIC PRESSURE 3
BAY 3



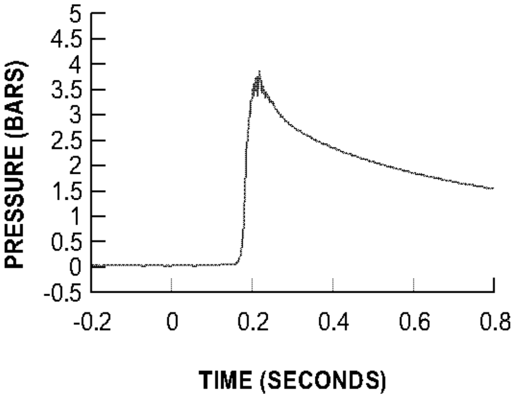
TEST 39
QUASI-STATIC PRESSURE 4
BAY 4



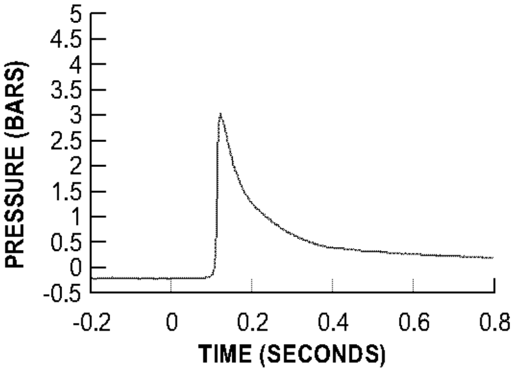
TEST 39
QUASI-STATIC PRESSURE 5
BAY 2



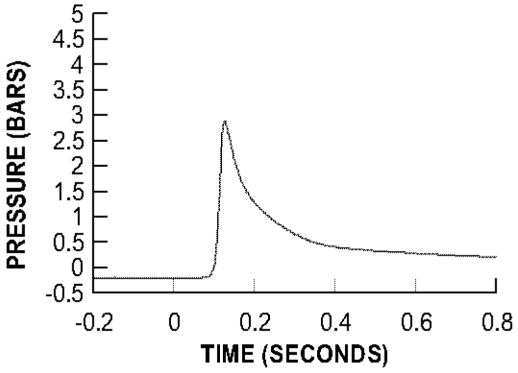
TEST 39
QUASI-STATIC PRESSURE 6
BAY 1



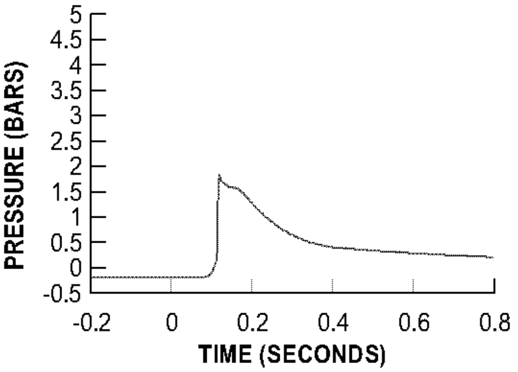
TEST 40
QUASI-STATIC PRESSURE 1
BAY 5



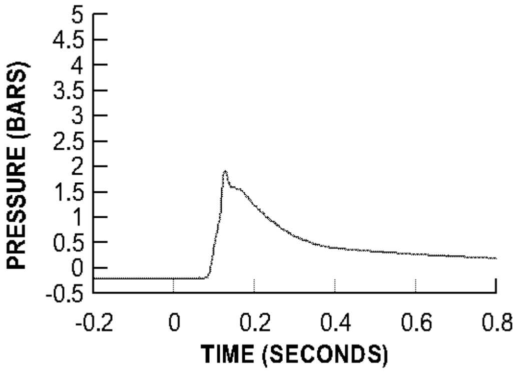
TEST 40
QUASI-STATIC PRESSURE 2
BAY 6



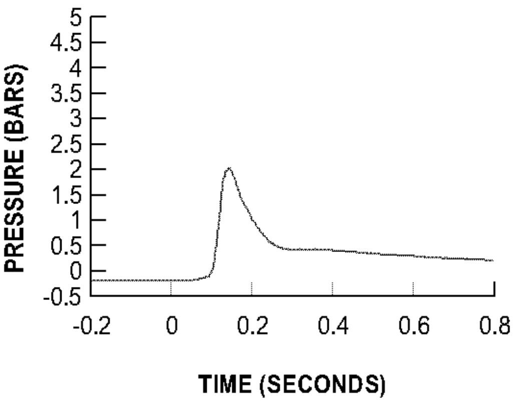
TEST 40
QUASI-STATIC PRESSURE 3
BAY 3



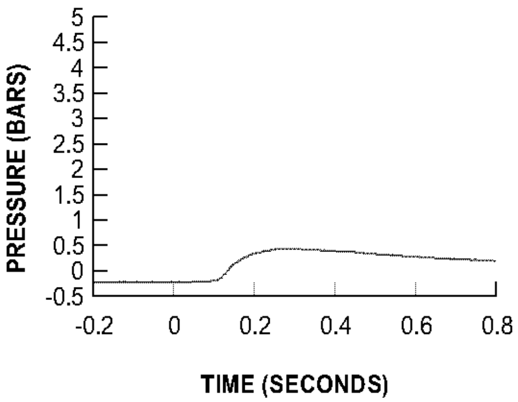
TEST 40
QUASI-STATIC PRESSURE 4
BAY 4



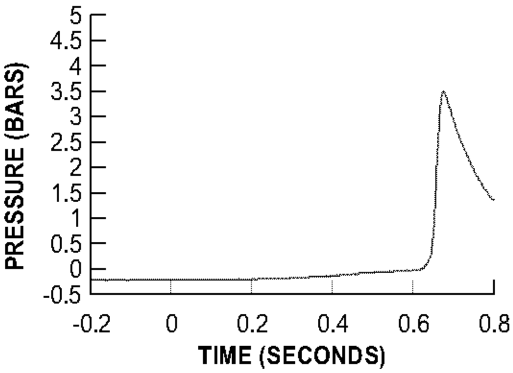
TEST 40
QUASI-STATIC PRESSURE 5
BAY 2



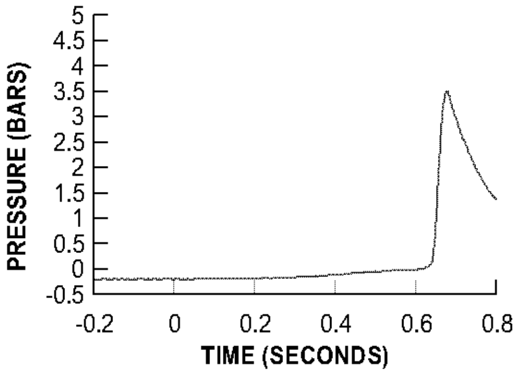
TEST 40
QUASI-STATIC PRESSURE 6
BAY 1



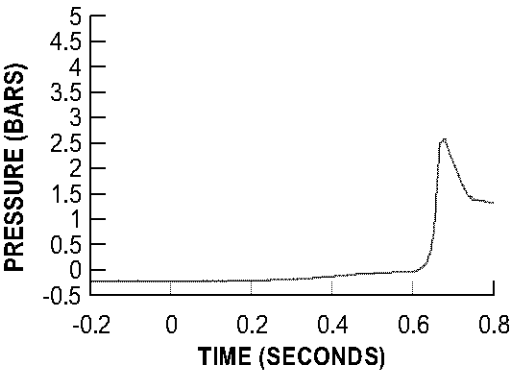
TEST 42
QUASI-STATIC PRESSURE 1
BAY 5



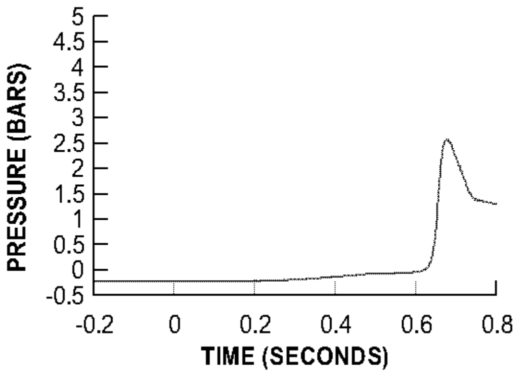
TEST 42
QUASI-STATIC PRESSURE 2
BAY 6



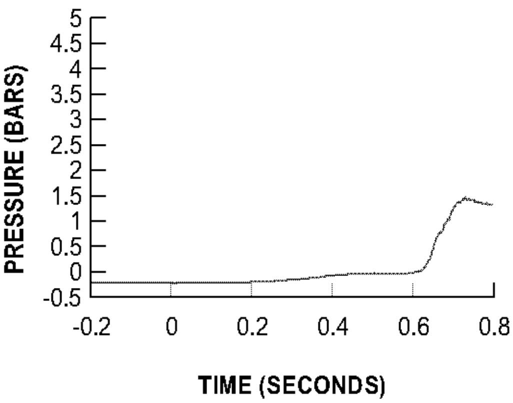
TEST 42
QUASI-STATIC PRESSURE 3
BAY 3



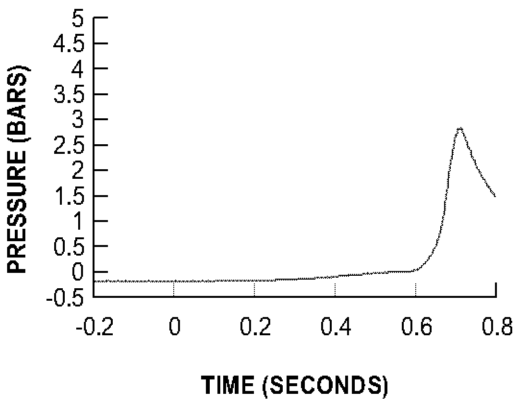
TEST 42
QUASI-STATIC PRESSURE 4
BAY 4



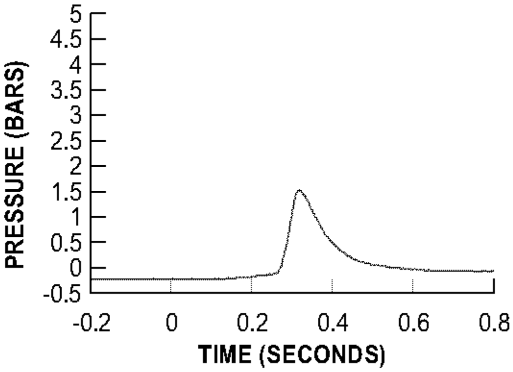
TEST 42
QUASI-STATIC PRESSURE 5
BAY 2



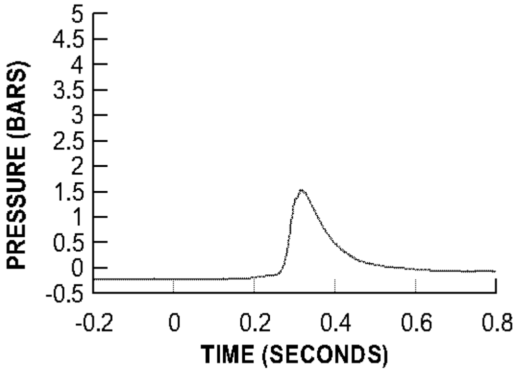
TEST 42
QUASI-STATIC PRESSURE 6
BAY 1



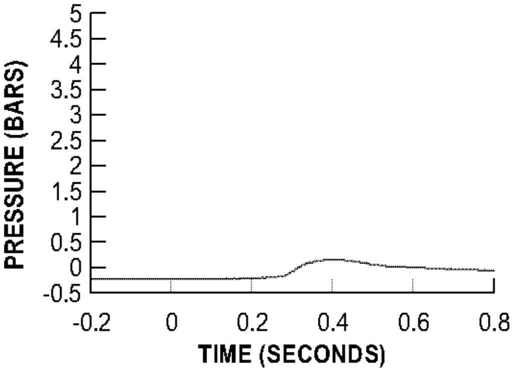
TEST 44
QUASI-STATIC PRESSURE 1
BAY 5



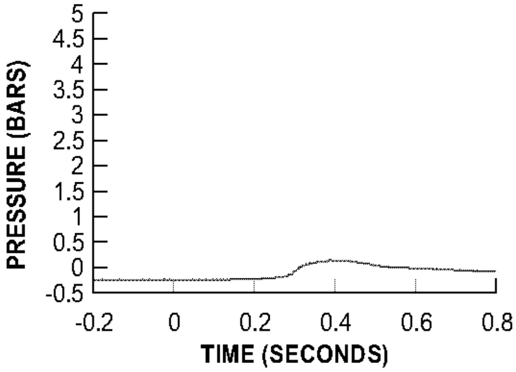
TEST 44
QUASI-STATIC PRESSURE 2
BAY 6



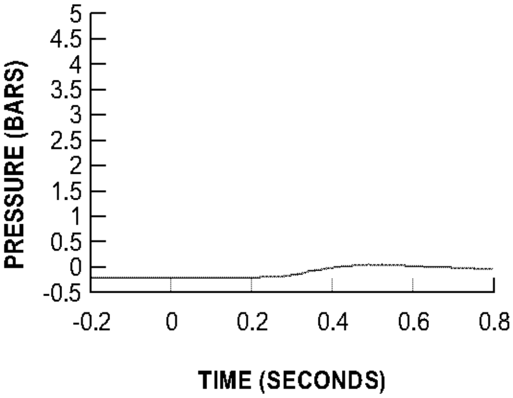
TEST 44
QUASI-STATIC PRESSURE 3
BAY 3



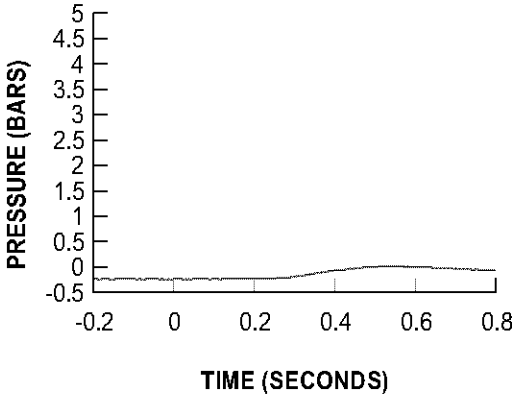
TEST 44
QUASI-STATIC PRESSURE 4
BAY 4



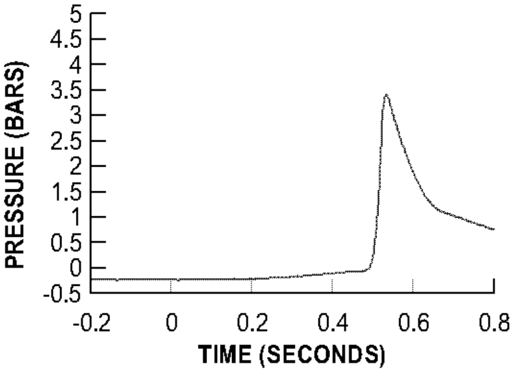
TEST 44
QUASI-STATIC PRESSURE 5
BAY 2



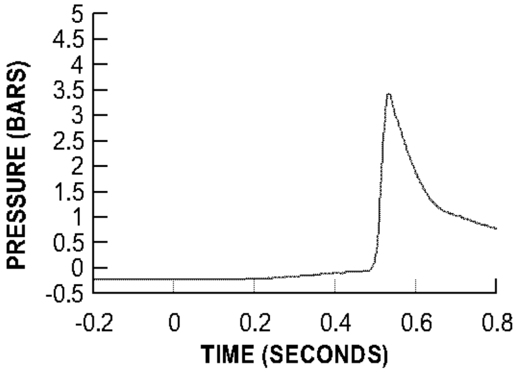
TEST 44
QUASI-STATIC PRESSURE 6
BAY 1



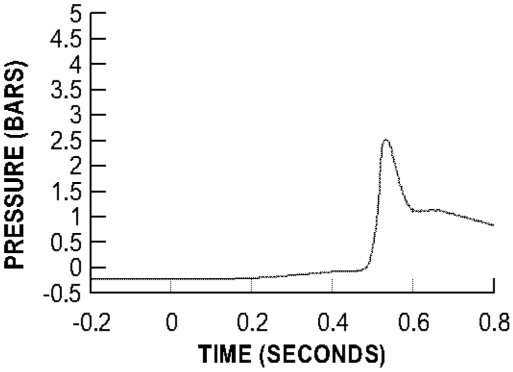
TEST 46
QUASI-STATIC PRESSURE 1
BAY 5



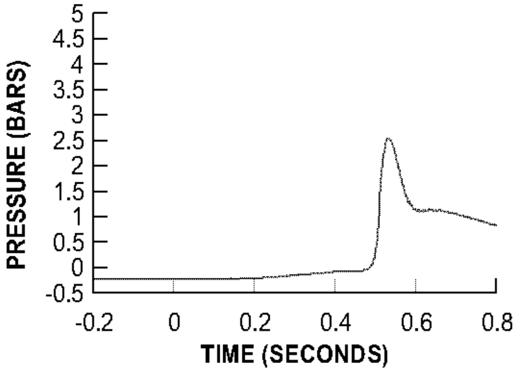
TEST 46
QUASI-STATIC PRESSURE 2
BAY 6



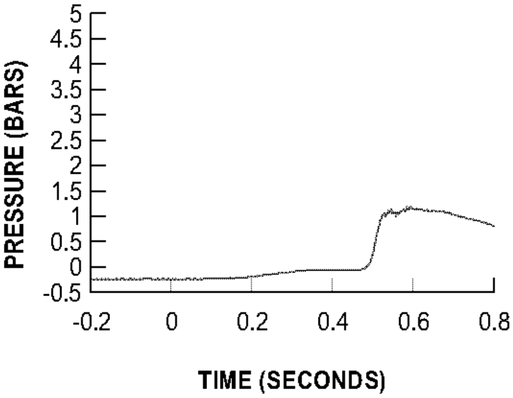
TEST 46
QUASI-STATIC PRESSURE 3
BAY 3



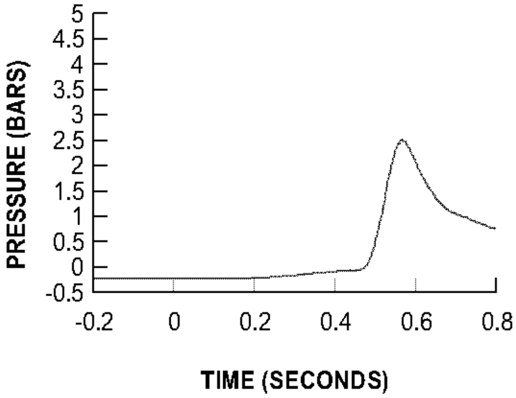
TEST 46
QUASI-STATIC PRESSURE 4
BAY 4



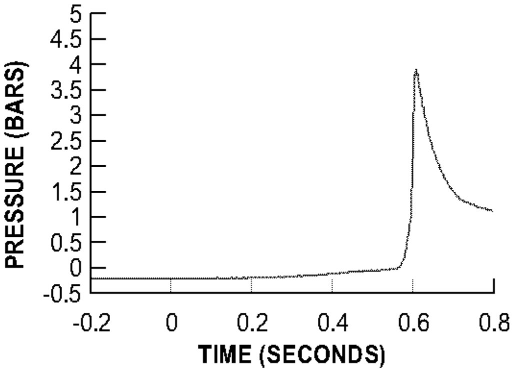
TEST 46
QUASI-STATIC PRESSURE 5
BAY 2



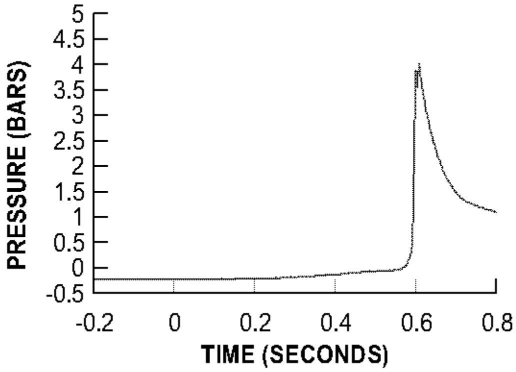
TEST 46
QUASI-STATIC PRESSURE 6
BAY 1



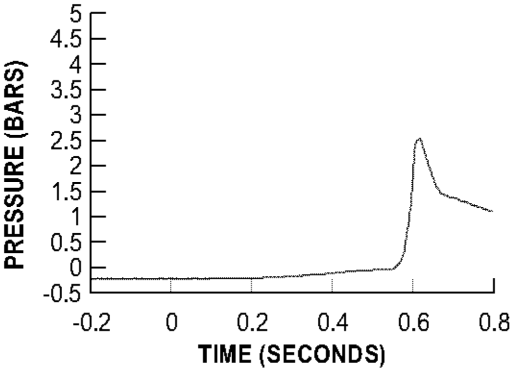
TEST 48
QUASI-STATIC PRESSURE 1
BAY 5



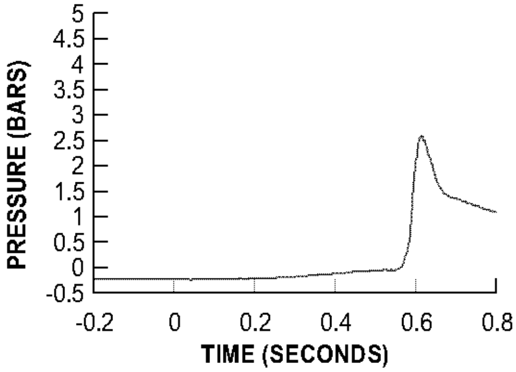
TEST 48
QUASI-STATIC PRESSURE 2
BAY 6



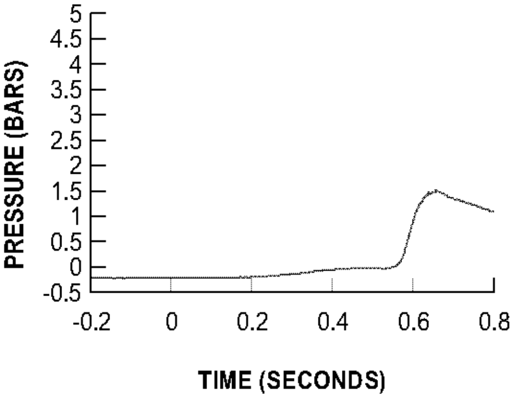
TEST 48
QUASI-STATIC PRESSURE 3
BAY 3



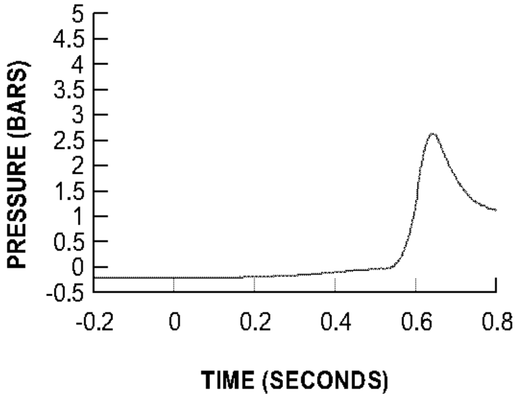
TEST 48
QUASI-STATIC PRESSURE 4
BAY 4



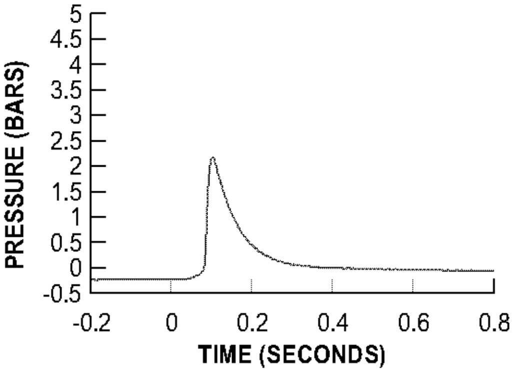
TEST 48
QUASI-STATIC PRESSURE 5
BAY 2



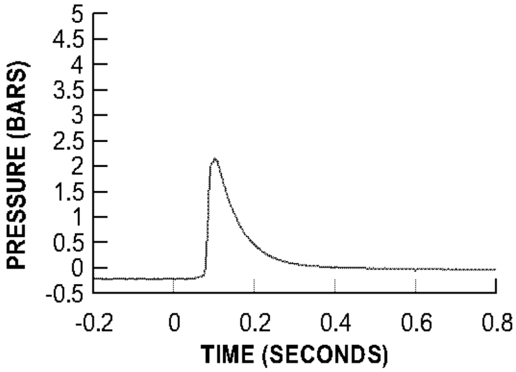
TEST 48
QUASI-STATIC PRESSURE 6
BAY 1



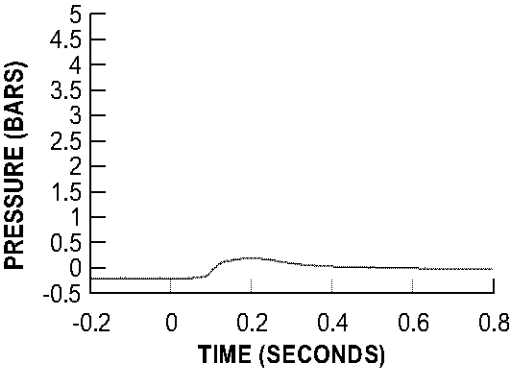
TEST 51
QUASI-STATIC PRESSURE 1
BAY 5



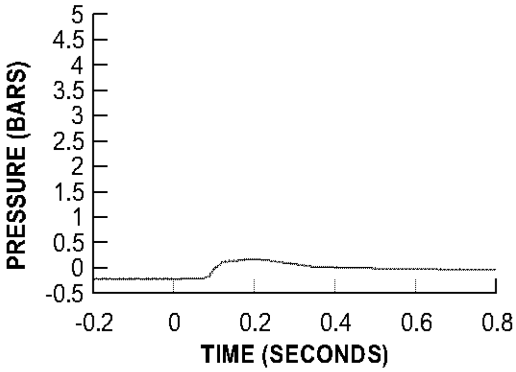
TEST 51
QUASI-STATIC PRESSURE 2
BAY 6



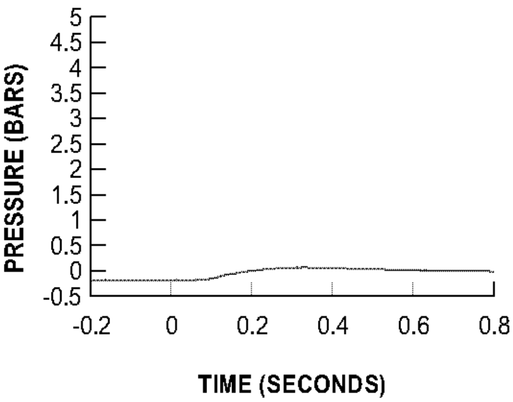
TEST 51
QUASI-STATIC PRESSURE 3
BAY 3



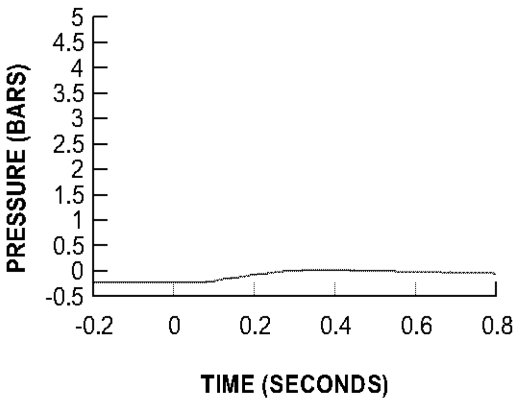
TEST 51
QUASI-STATIC PRESSURE 4
BAY 4



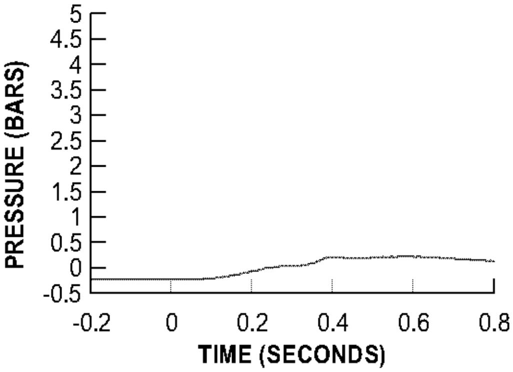
TEST 51
QUASI-STATIC PRESSURE 5
BAY 2



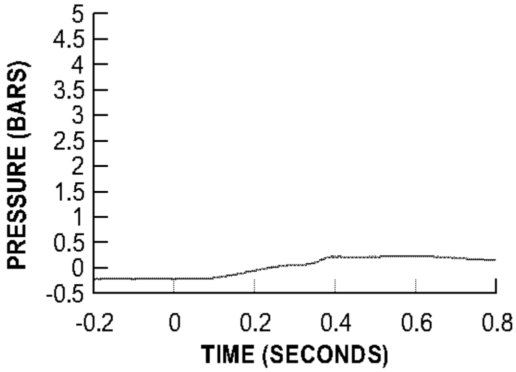
TEST 51
QUASI-STATIC PRESSURE 6
BAY 1



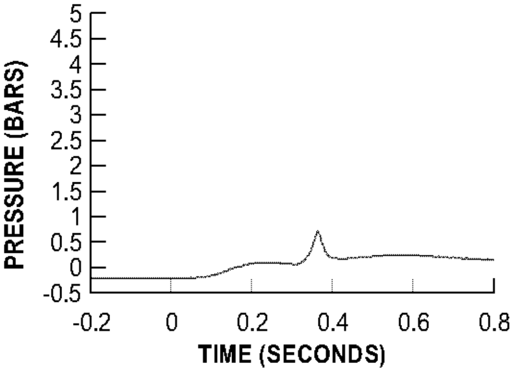
TEST 53
QUASI-STATIC PRESSURE 1
BAY 5



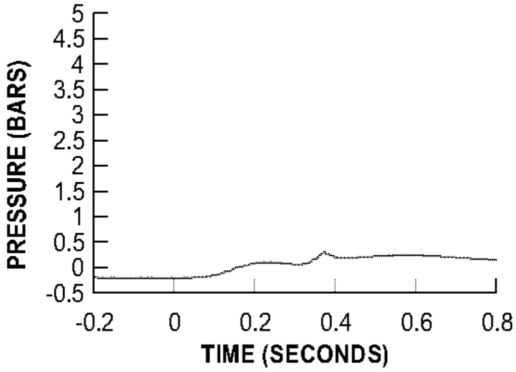
TEST 53
QUASI-STATIC PRESSURE 2
BAY 6



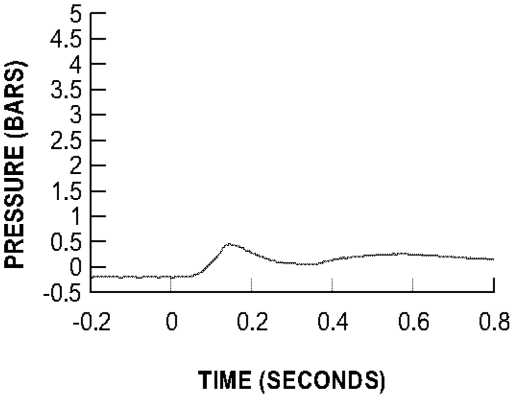
TEST 53
QUASI-STATIC PRESSURE 3
BAY 3



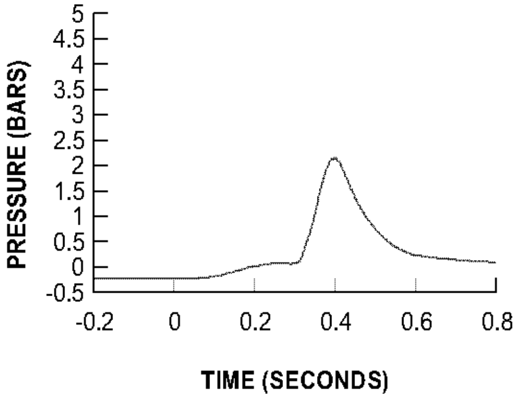
TEST 53
QUASI-STATIC PRESSURE 4
BAY 4



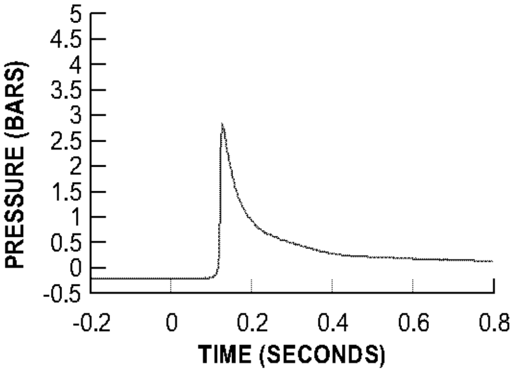
TEST 53
QUASI-STATIC PRESSURE 5
BAY 2



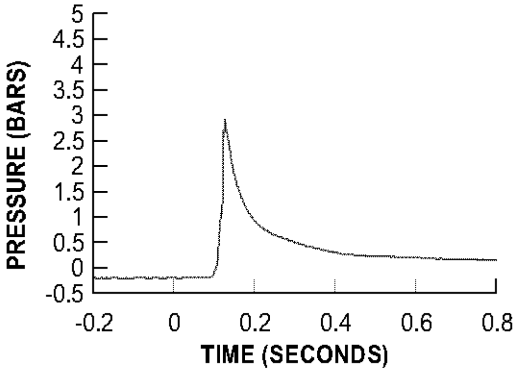
TEST 53
QUASI-STATIC PRESSURE 6
BAY 1



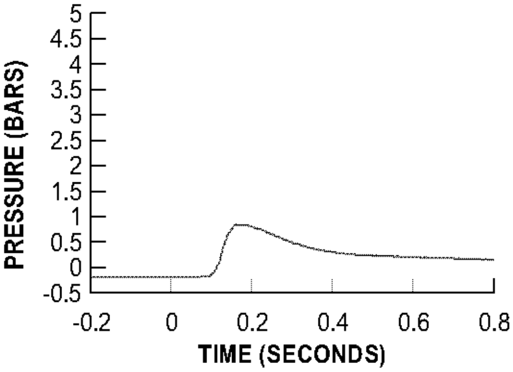
TEST 55
QUASI-STATIC PRESSURE 1
BAY 5



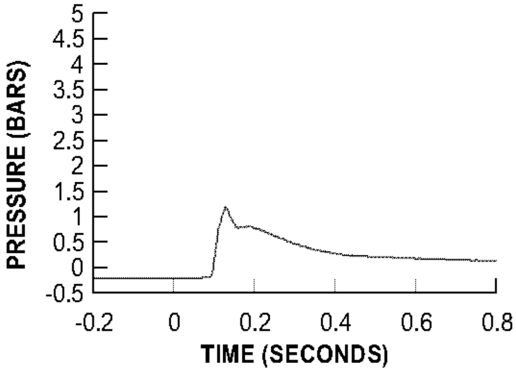
TEST 55
QUASI-STATIC PRESSURE 2
BAY 6



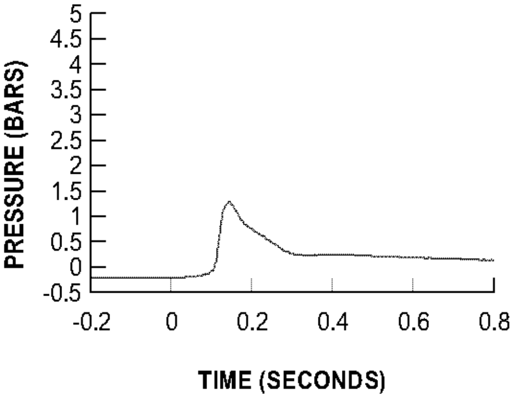
TEST 55
QUASI-STATIC PRESSURE 3
BAY 3



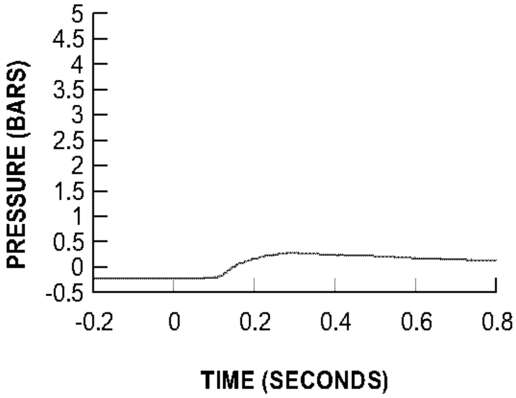
TEST 55
QUASI-STATIC PRESSURE 4
BAY 4



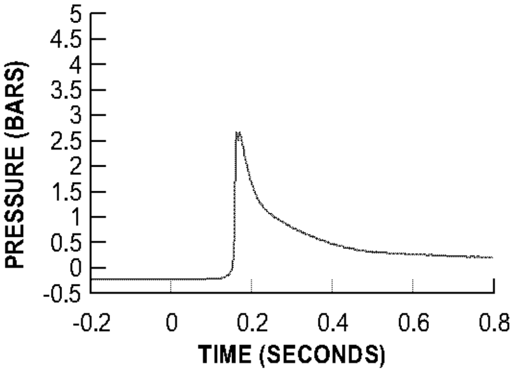
TEST 55
QUASI-STATIC PRESSURE 5
BAY 2



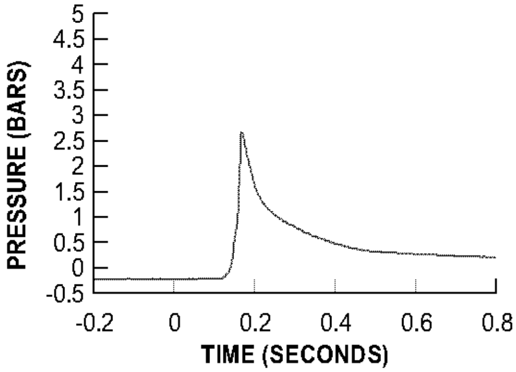
TEST 55
QUASI-STATIC PRESSURE 6
BAY 1



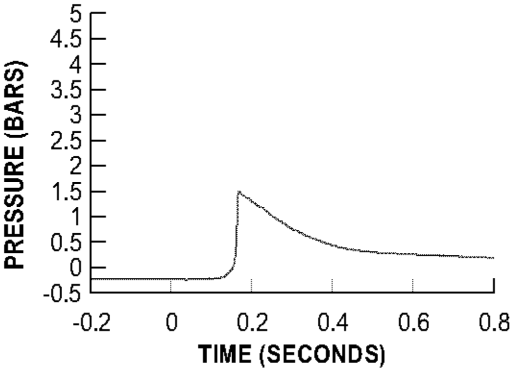
TEST 58
QUASI-STATIC PRESSURE 1
BAY 5



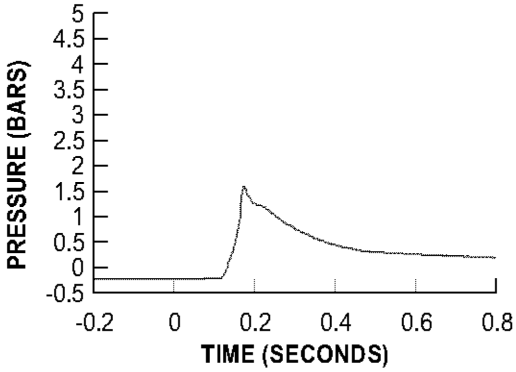
TEST 58
QUASI-STATIC PRESSURE 2
BAY 6



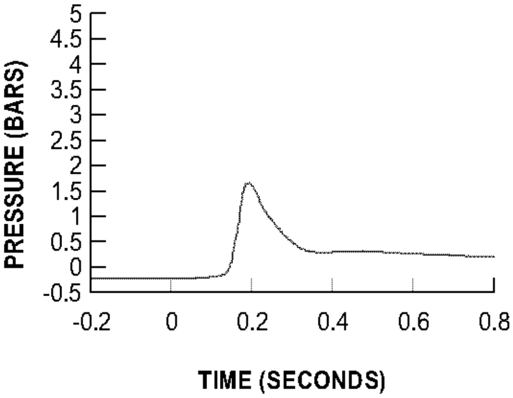
TEST 58
QUASI-STATIC PRESSURE 3
BAY 3



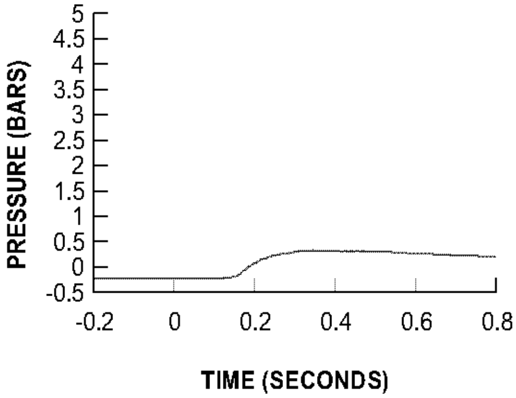
TEST 58
QUASI-STATIC PRESSURE 4
BAY 4



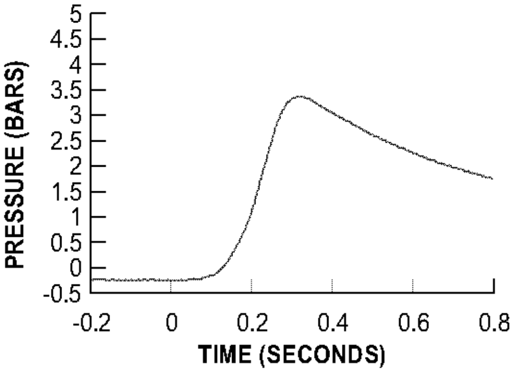
TEST 58
QUASI-STATIC PRESSURE 5
BAY 2



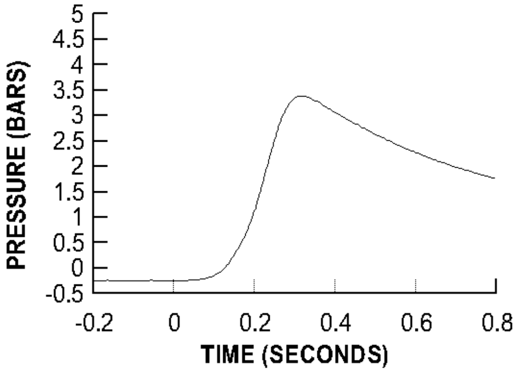
TEST 58
QUASI-STATIC PRESSURE 6
BAY 1



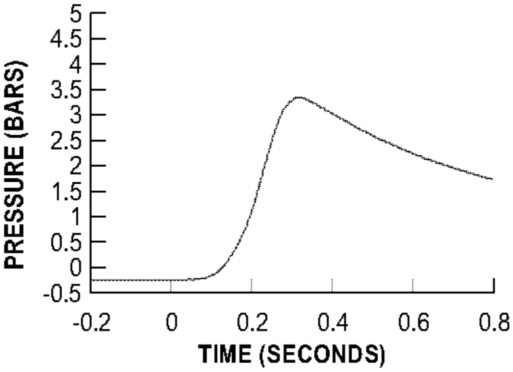
TEST 61
QUASI-STATIC PRESSURE 1
BAY 5



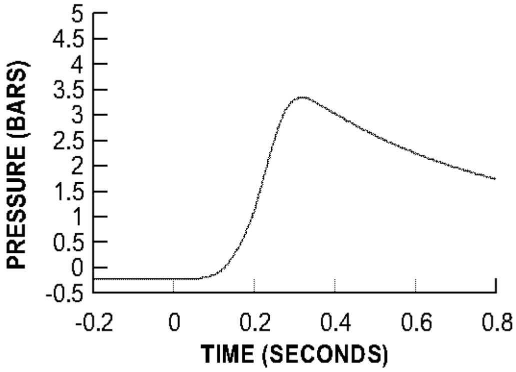
TEST 61
QUASI-STATIC PRESSURE 2
BAY 6



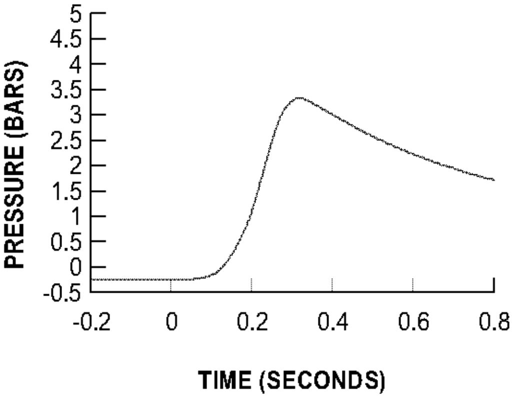
TEST 61
QUASI-STATIC PRESSURE 3
BAY 3



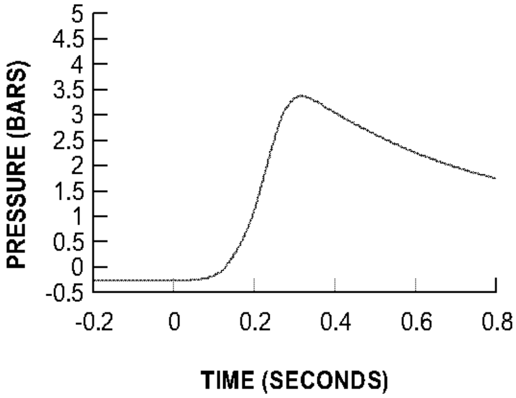
TEST 61
QUASI-STATIC PRESSURE 4
BAY 4



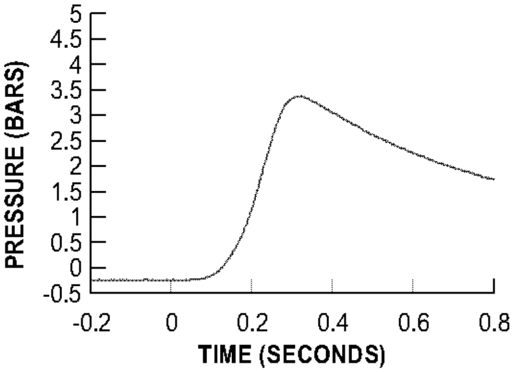
TEST 61
QUASI-STATIC PRESSURE 5
BAY 2



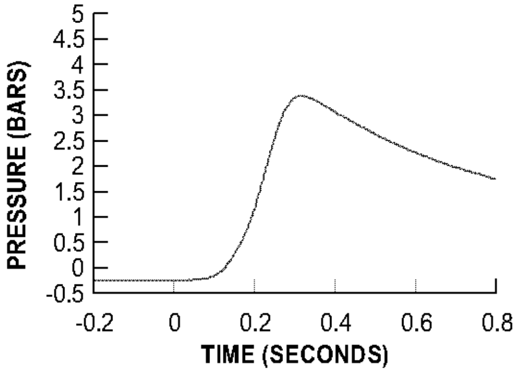
TEST 61
QUASI-STATIC PRESSURE 6
BAY 1



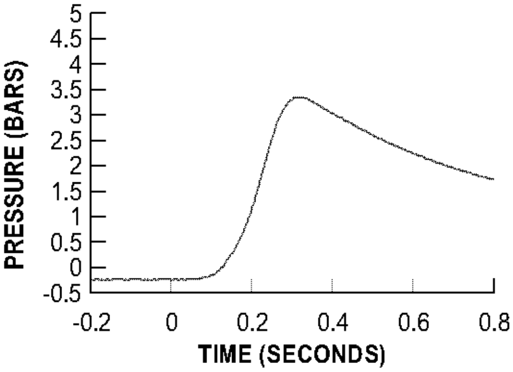
TEST 62
QUASI-STATIC PRESSURE 1
BAY 5



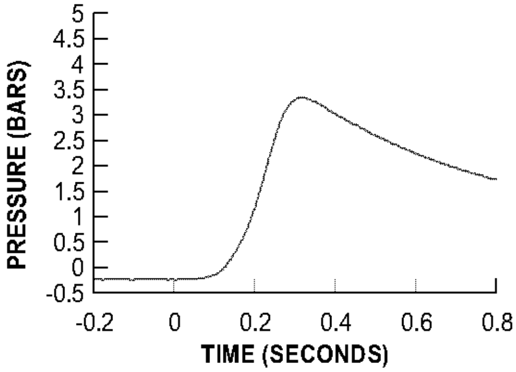
TEST 62
QUASI-STATIC PRESSURE 2
BAY 6



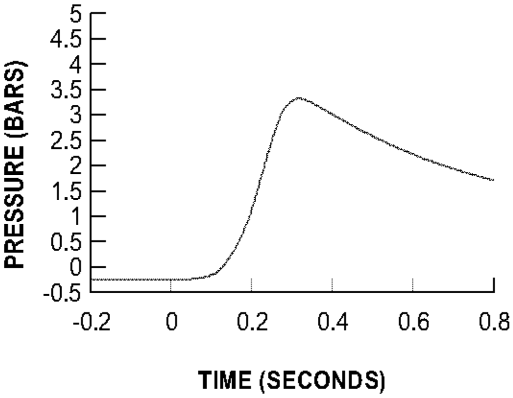
TEST 62
QUASI-STATIC PRESSURE 3
BAY 3



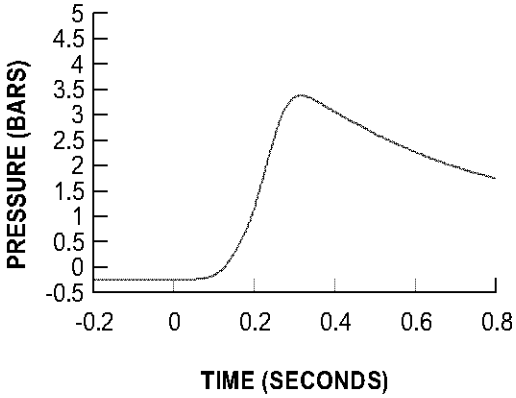
TEST 62
QUASI-STATIC PRESSURE 4
BAY 4



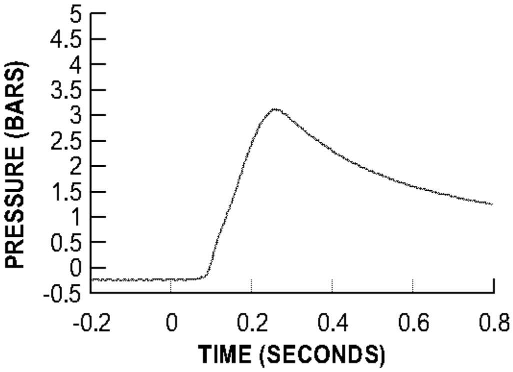
TEST 62
QUASI-STATIC PRESSURE 5
BAY 2



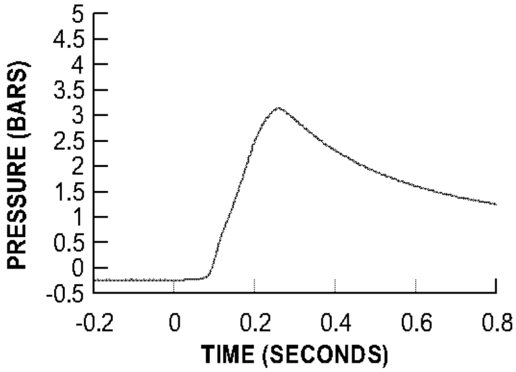
TEST 62
QUASI-STATIC PRESSURE 6
BAY 1



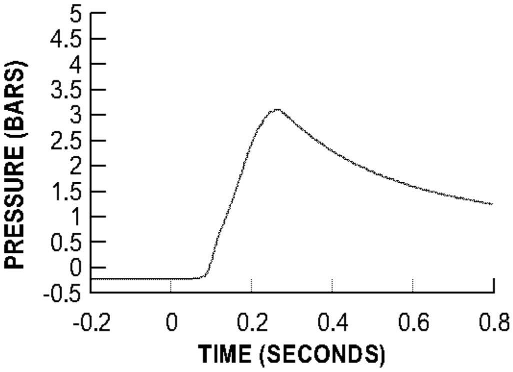
TEST 63
QUASI-STATIC PRESSURE 1
BAY 5



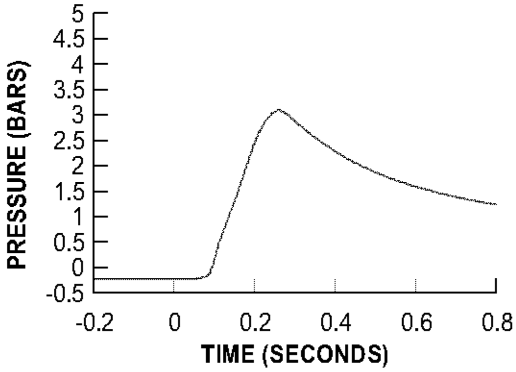
TEST 63
QUASI-STATIC PRESSURE 2
BAY 6



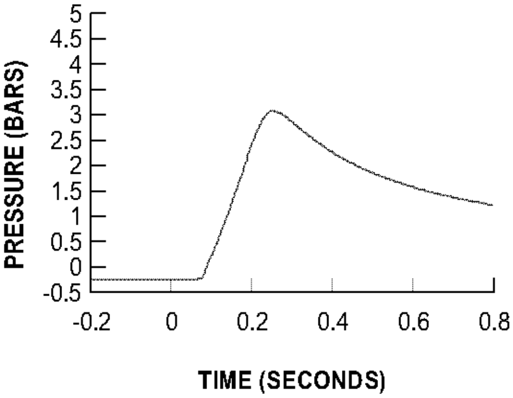
TEST 63
QUASI-STATIC PRESSURE 3
BAY 3



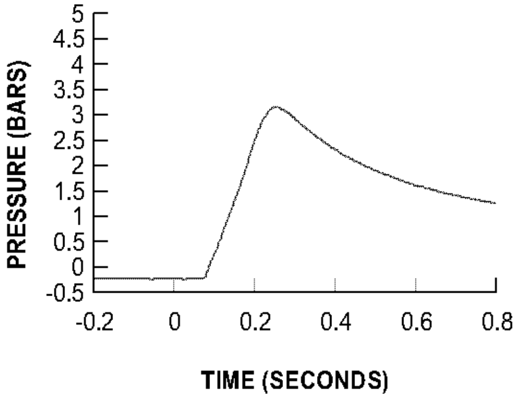
TEST 63
QUASI-STATIC PRESSURE 4
BAY 4



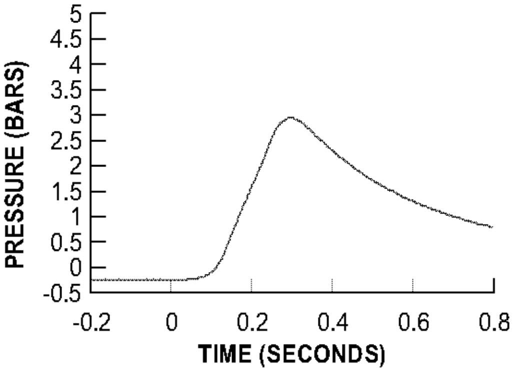
TEST 63
QUASI-STATIC PRESSURE 5
BAY 2



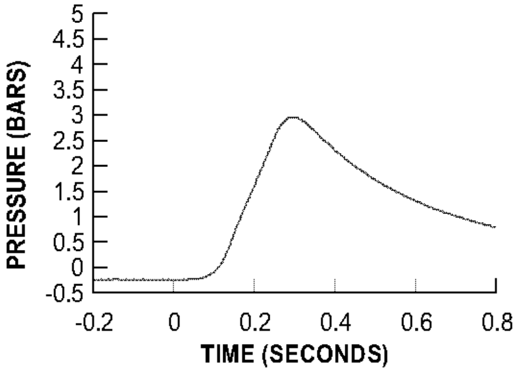
TEST 63
QUASI-STATIC PRESSURE 6
BAY 1



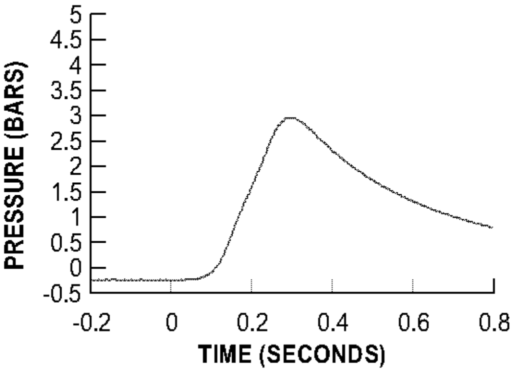
TEST 64
QUASI-STATIC PRESSURE 1
BAY 5



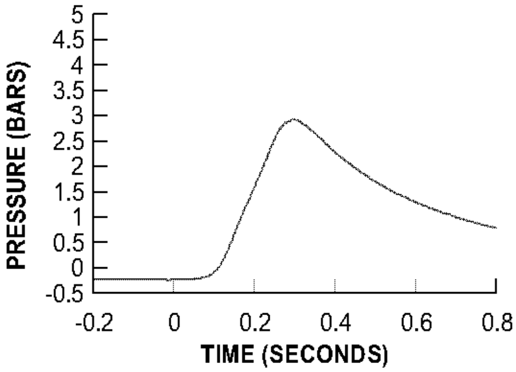
TEST 64
QUASI-STATIC PRESSURE 2
BAY 6



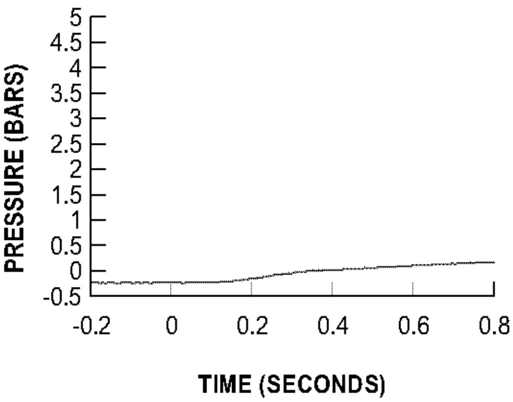
TEST 64
QUASI-STATIC PRESSURE 3
BAY 3



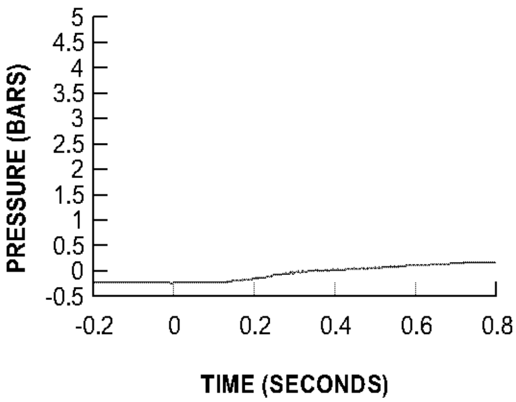
TEST 64
QUASI-STATIC PRESSURE 4
BAY 4



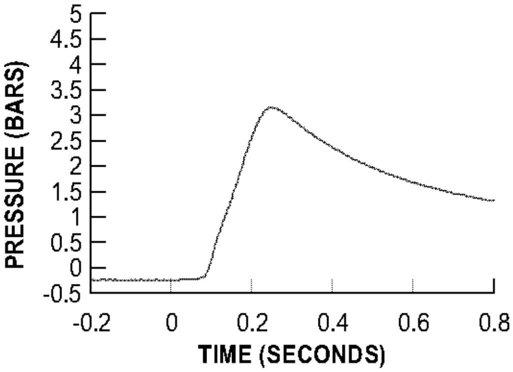
TEST 64
QUASI-STATIC PRESSURE 5
BAY 2



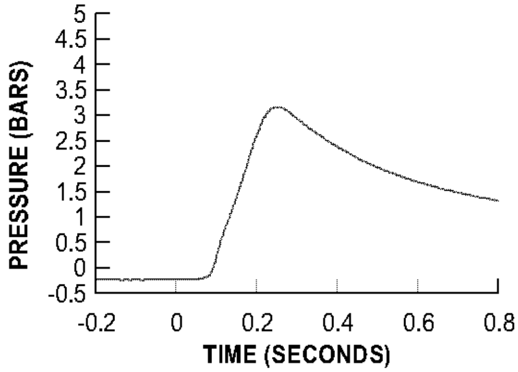
TEST 64
QUASI-STATIC PRESSURE 6
BAY 1



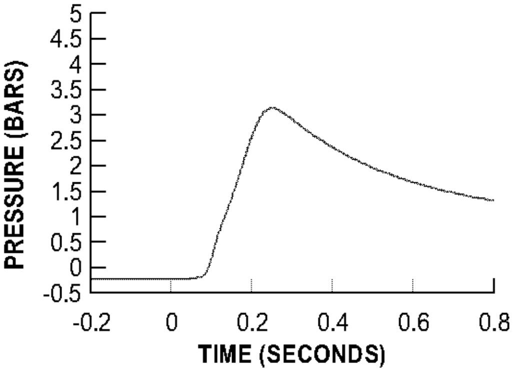
TEST 65
QUASI-STATIC PRESSURE 1
BAY 5



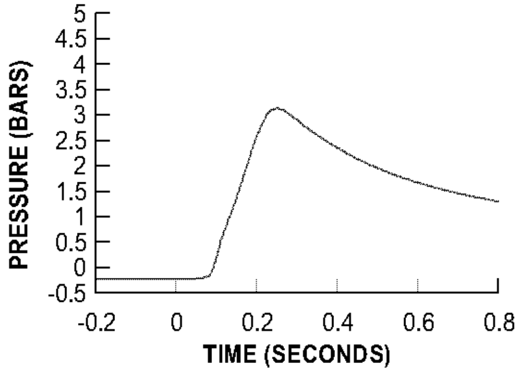
TEST 65
QUASI-STATIC PRESSURE 2
BAY 6



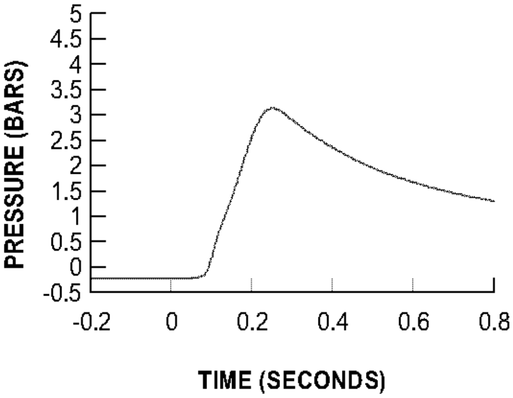
TEST 65
QUASI-STATIC PRESSURE 3
BAY 3



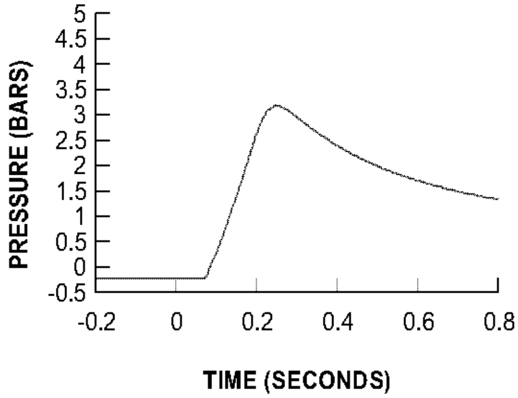
TEST 65
QUASI-STATIC PRESSURE 4
BAY 4



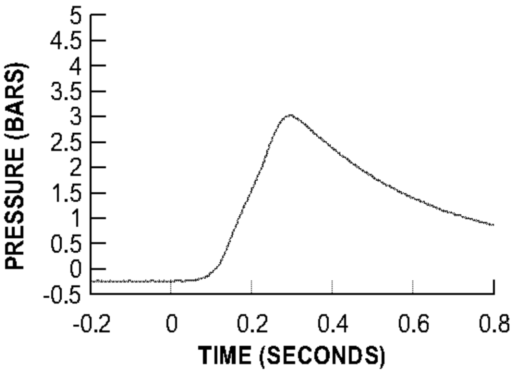
TEST 65
QUASI-STATIC PRESSURE 5
BAY 2



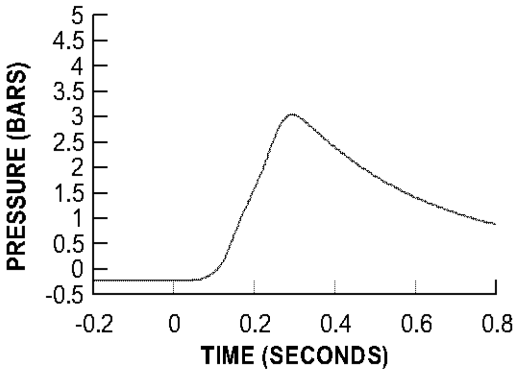
TEST 65
QUASI-STATIC PRESSURE 6
BAY 1



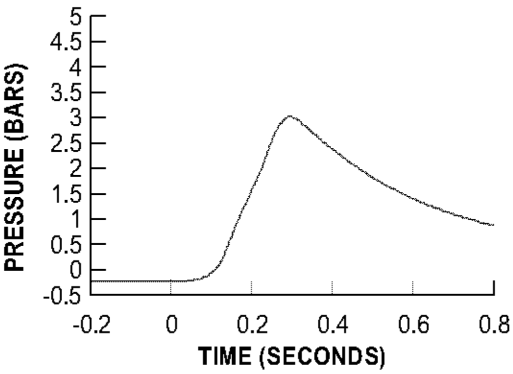
TEST 66
QUASI-STATIC PRESSURE 1
BAY 5



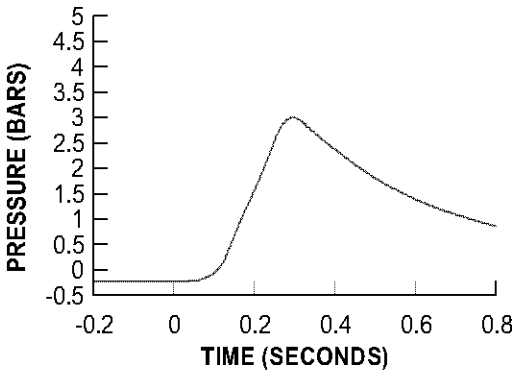
TEST 66
QUASI-STATIC PRESSURE 2
BAY 6



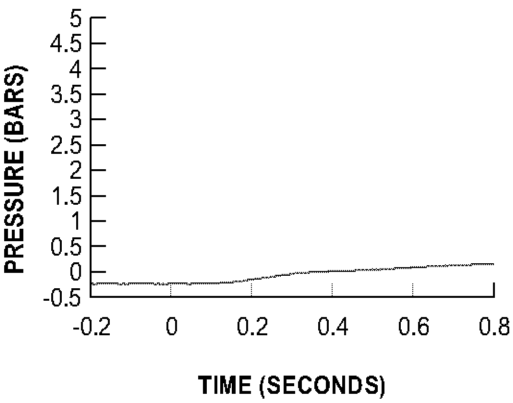
TEST 66
QUASI-STATIC PRESSURE 3
BAY 3



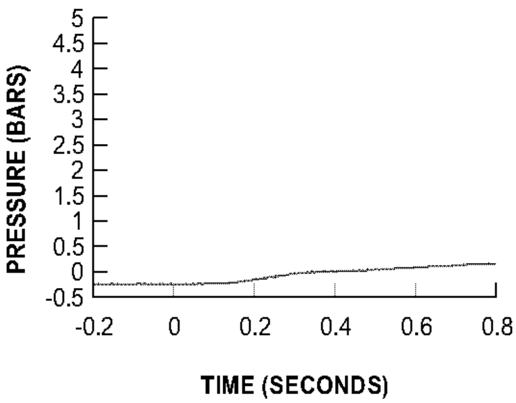
TEST 66
QUASI-STATIC PRESSURE 4
BAY 4



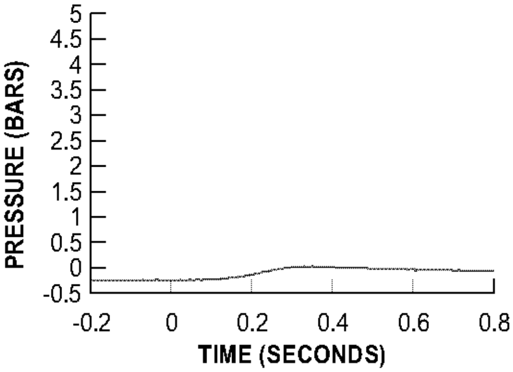
TEST 66
QUASI-STATIC PRESSURE 5
BAY 2



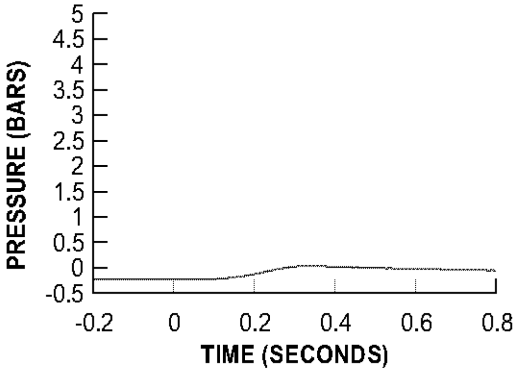
TEST 66
QUASI-STATIC PRESSURE 6
BAY 1



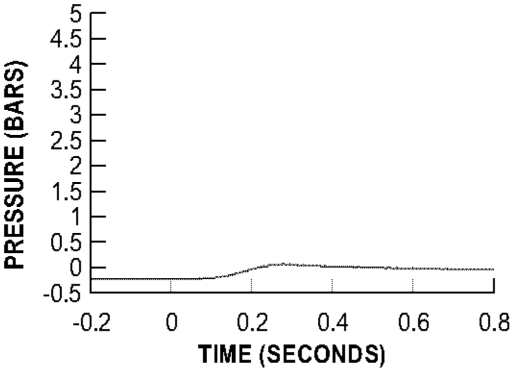
TEST 67
QUASI-STATIC PRESSURE 1
BAY 5



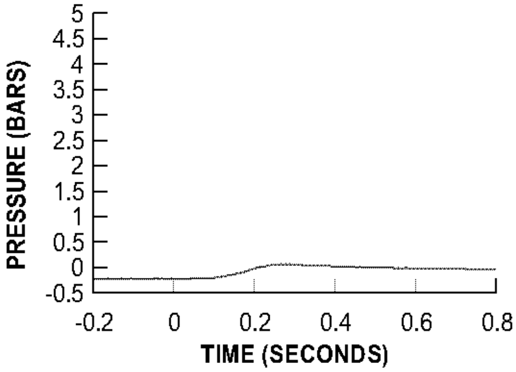
TEST 67
QUASI-STATIC PRESSURE 2
BAY 6



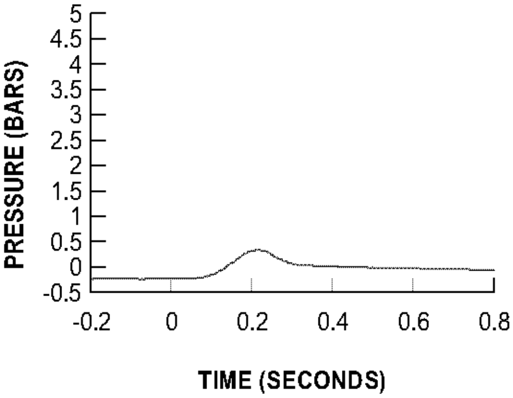
TEST 67
QUASI-STATIC PRESSURE 3
BAY 3



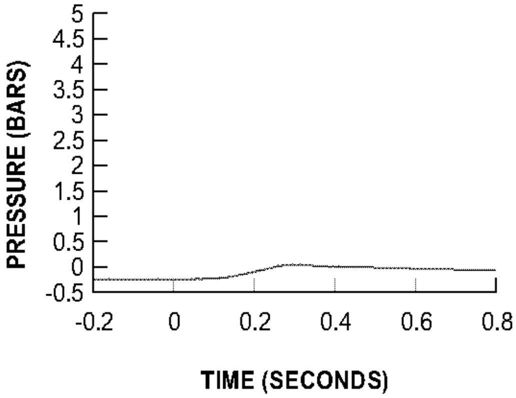
TEST 67
QUASI-STATIC PRESSURE 4
BAY 4



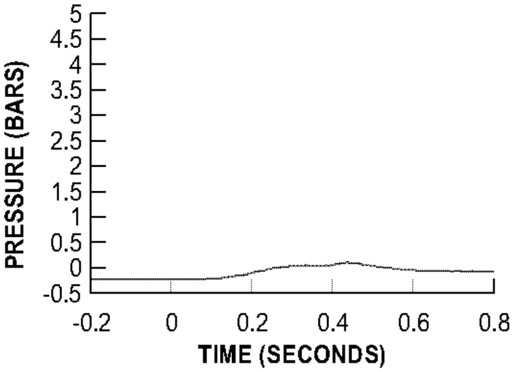
TEST 67
QUASI-STATIC PRESSURE 5
BAY 2



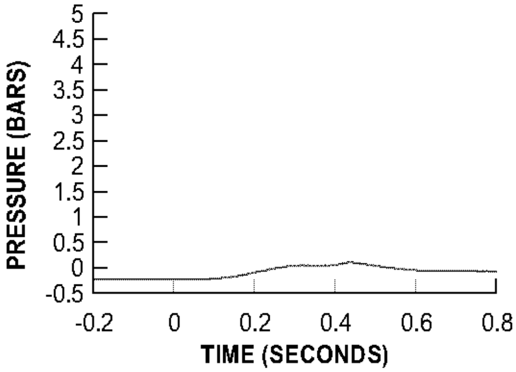
TEST 67
QUASI-STATIC PRESSURE 6
BAY 1



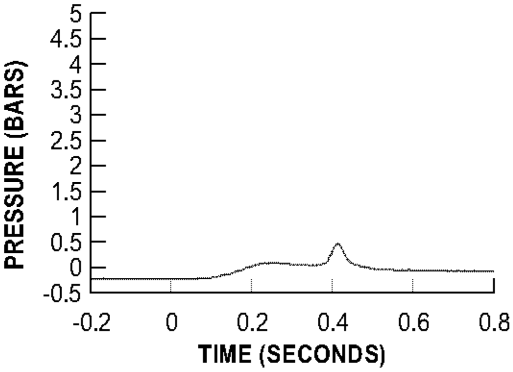
TEST 68
QUASI-STATIC PRESSURE 1
BAY 5



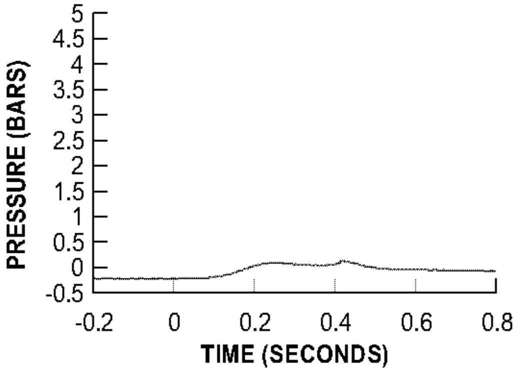
TEST 68
QUASI-STATIC PRESSURE 2
BAY 6



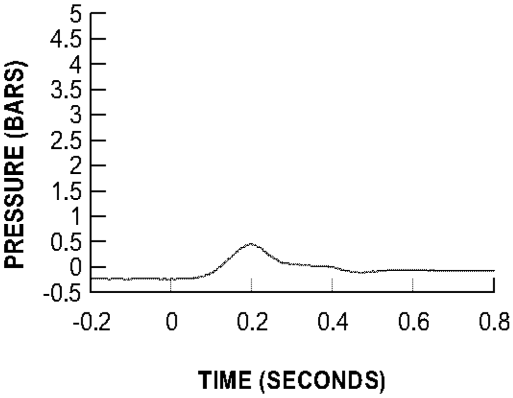
TEST 68
QUASI-STATIC PRESSURE 3
BAY 3



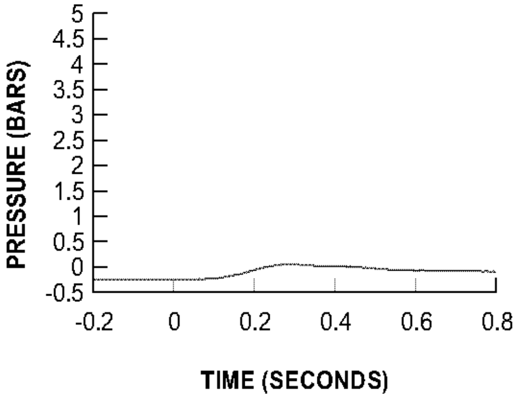
TEST 68
QUASI-STATIC PRESSURE 4
BAY 4



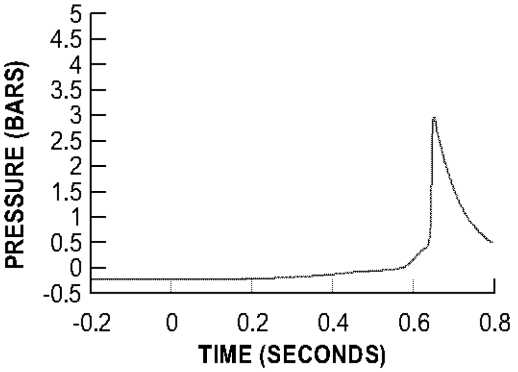
TEST 68
QUASI-STATIC PRESSURE 5
BAY 2



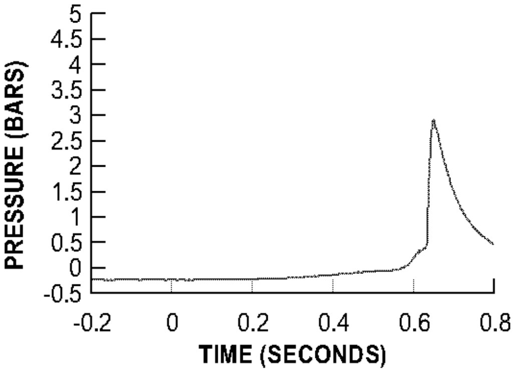
TEST 68
QUASI-STATIC PRESSURE 6
BAY 1



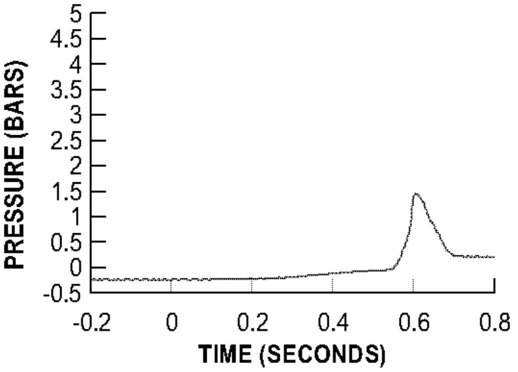
TEST 69
QUASI-STATIC PRESSURE 1
BAY 5



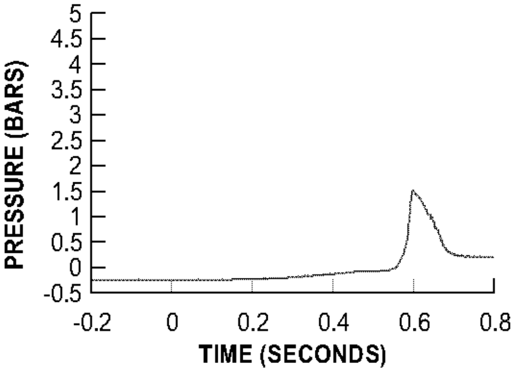
TEST 69
QUASI-STATIC PRESSURE 2
BAY 6



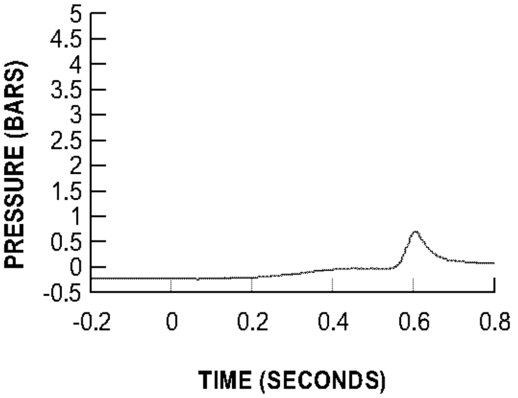
TEST 69
QUASI-STATIC PRESSURE 3
BAY 3



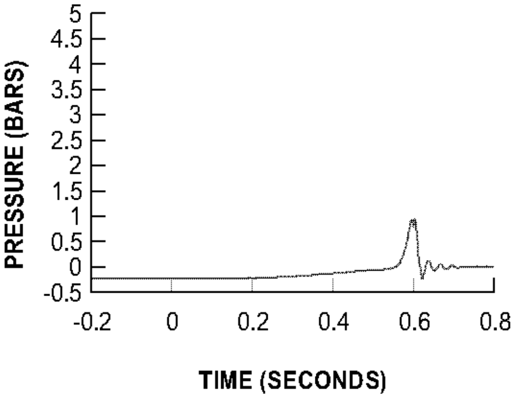
TEST 69
QUASI-STATIC PRESSURE 4
BAY 4

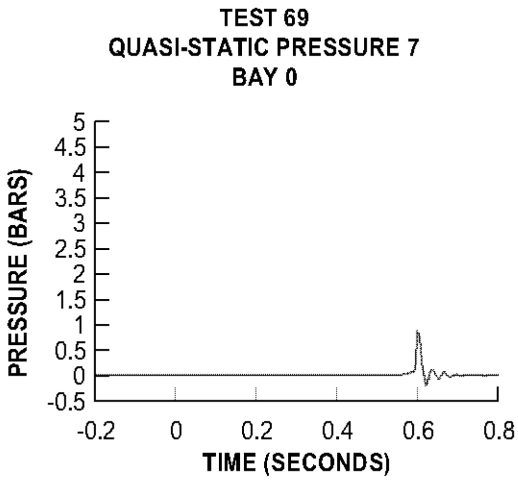


TEST 69
QUASI-STATIC PRESSURE 5
BAY 2



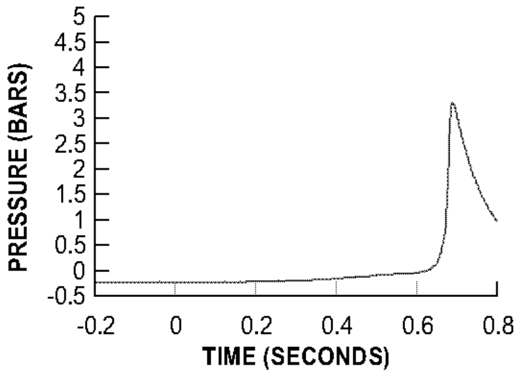
TEST 69
QUASI-STATIC PRESSURE 6
BAY 1



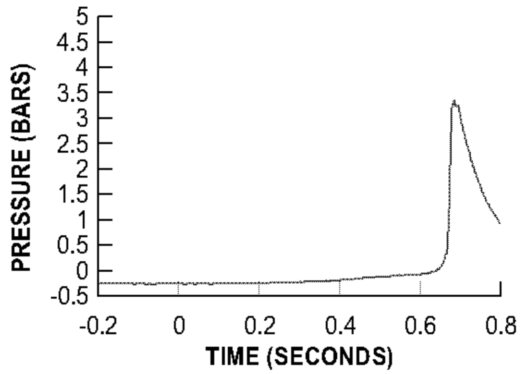


TEST 69
QUASI-STATIC PRESSURE 7
BAY 0
PRESSURE (BARS)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-0.2
0
0.2
0.4
0.6
0.8
TIME (SECONDS)

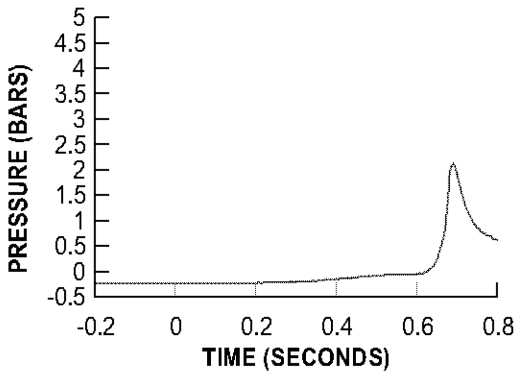
TEST 70
QUASI-STATIC PRESSURE 1
BAY 5



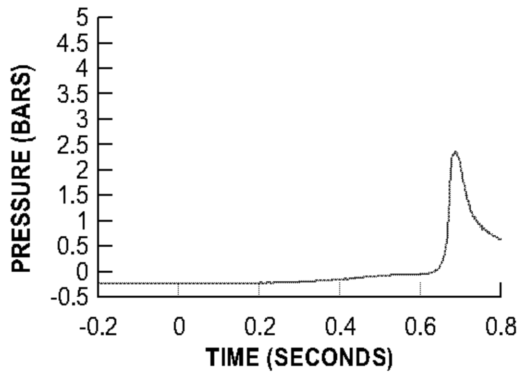
TEST 70
QUASI-STATIC PRESSURE 2
BAY 6



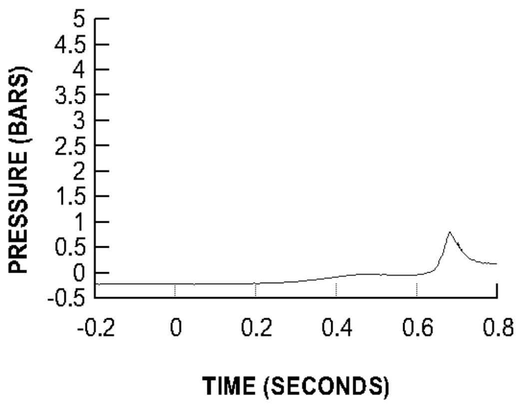
TEST 70
QUASI-STATIC PRESSURE 3
BAY 3



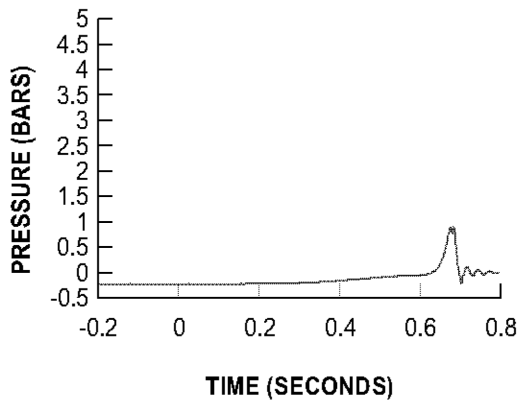
TEST 70
QUASI-STATIC PRESSURE 4
BAY 4

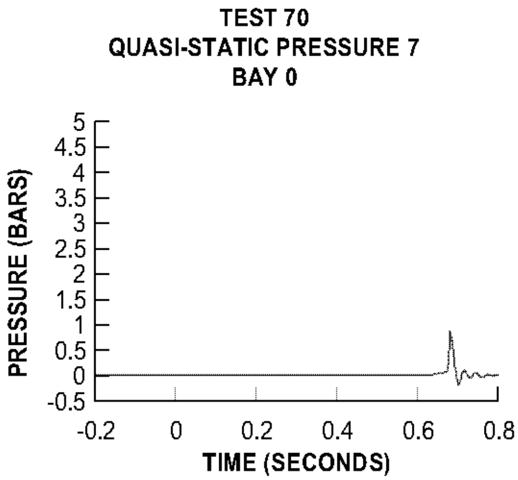


TEST 70
QUASI-STATIC PRESSURE 5
BAY 2

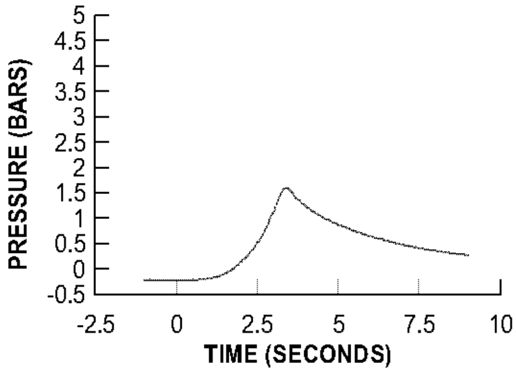


TEST 70
QUASI-STATIC PRESSURE 6
BAY 1

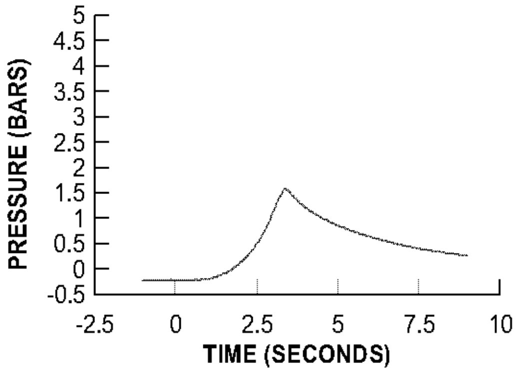



TEST 70
QUASI-STATIC PRESSURE 7
BAY 0
PRESSURE (BARS)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-0.2
0
0.2
0.4
0.6
0.8
TIME (SECONDS)

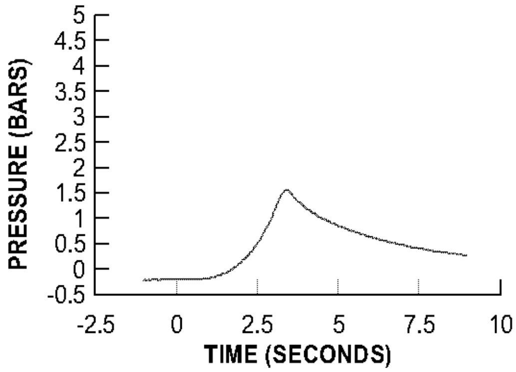
TEST 71
QUASI-STATIC PRESSURE 1
BAY 5



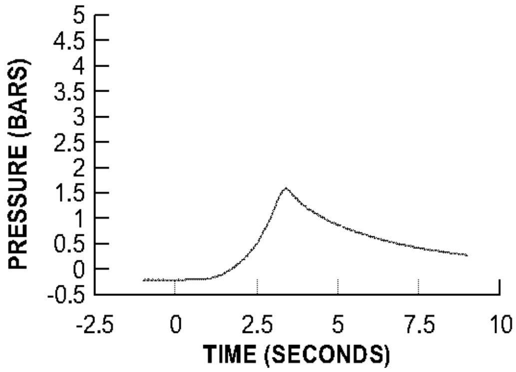
TEST 71
QUASI-STATIC PRESSURE 2
BAY 6



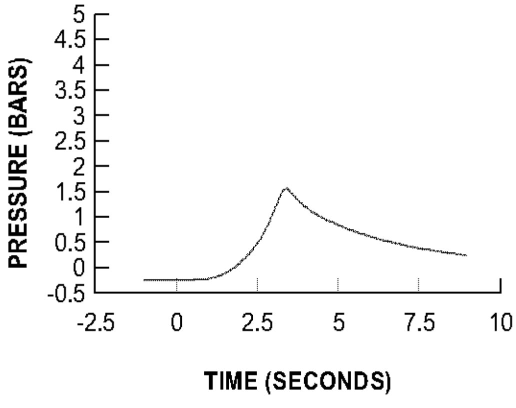
TEST 71
QUASI-STATIC PRESSURE 3
BAY 3



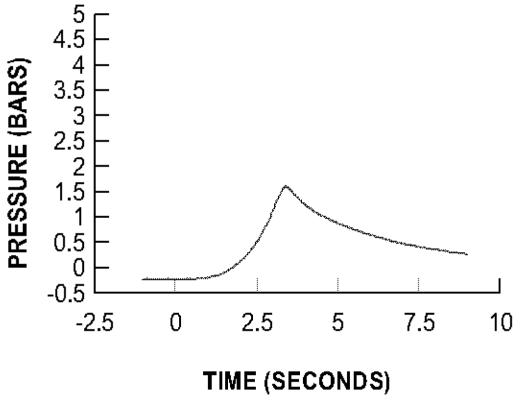
TEST 71
QUASI-STATIC PRESSURE 4
BAY 4



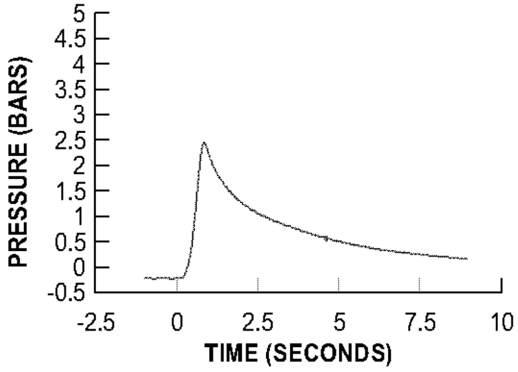
TEST 71
QUASI-STATIC PRESSURE 5
BAY 2



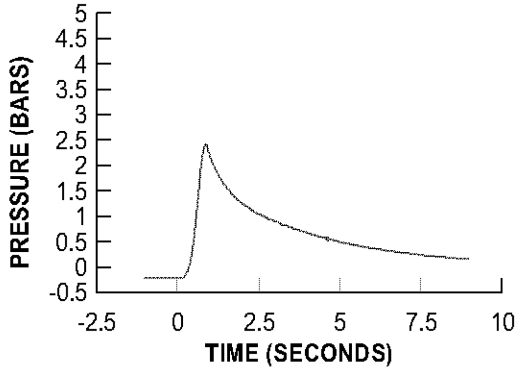
TEST 71
QUASI-STATIC PRESSURE 6
BAY 1



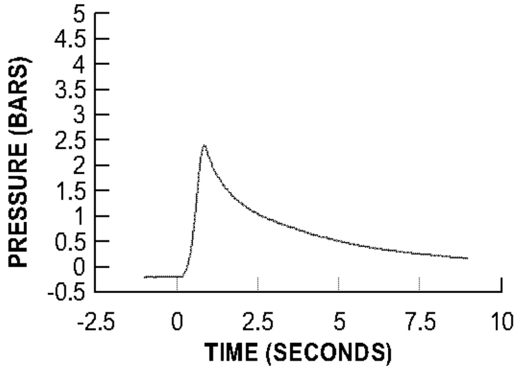
TEST 72
QUASI-STATIC PRESSURE 1
BAY 5



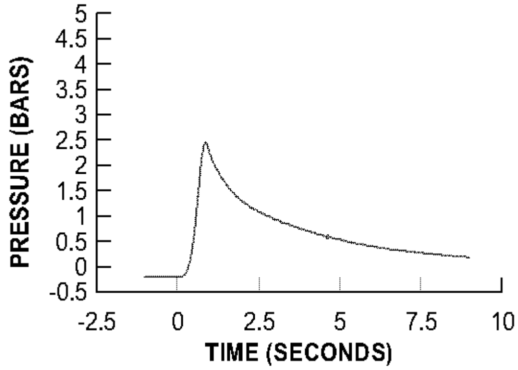
TEST 72
QUASI-STATIC PRESSURE 2
BAY 6



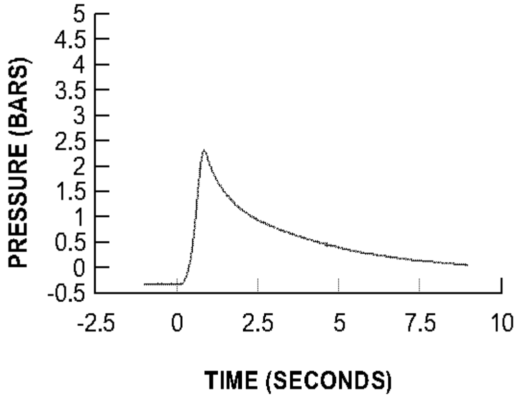
TEST 72
QUASI-STATIC PRESSURE 3
BAY 3



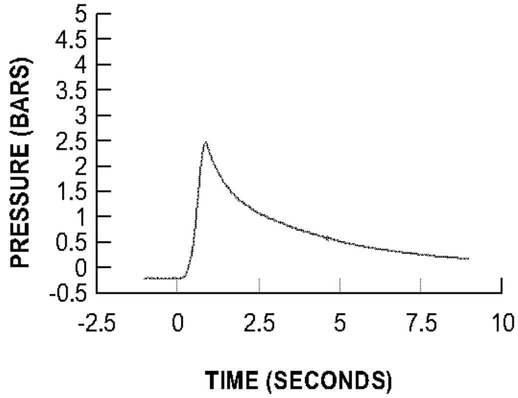
TEST 72
QUASI-STATIC PRESSURE 4
BAY 4



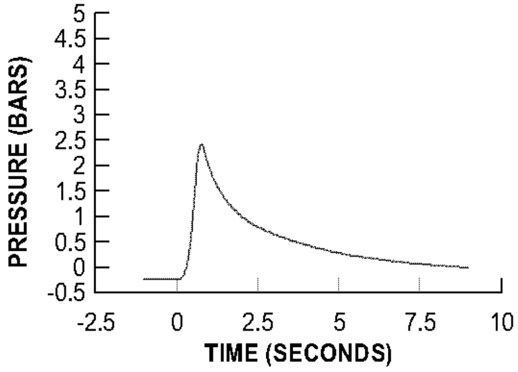
TEST 72
QUASI-STATIC PRESSURE 5
BAY 2



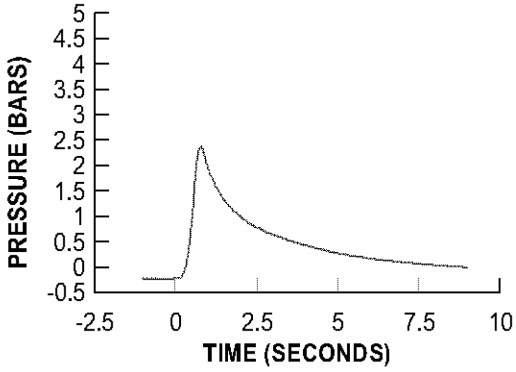
TEST 72
QUASI-STATIC PRESSURE 6
BAY 1



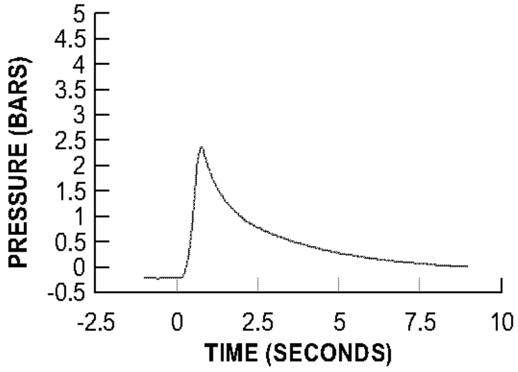
TEST 73
QUASI-STATIC PRESSURE 1
BAY 5



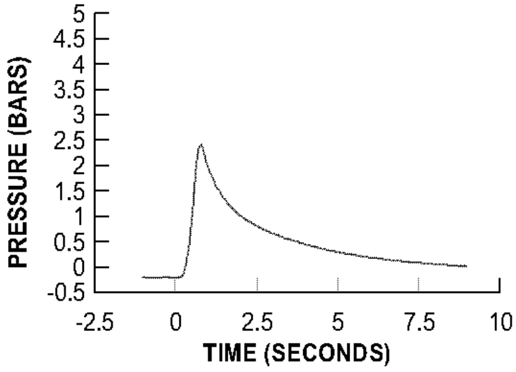
TEST 73
QUASI-STATIC PRESSURE 2
BAY 6



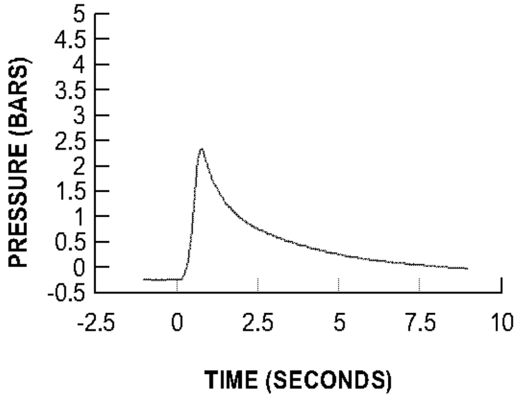
TEST 73
QUASI-STATIC PRESSURE 3
BAY 3



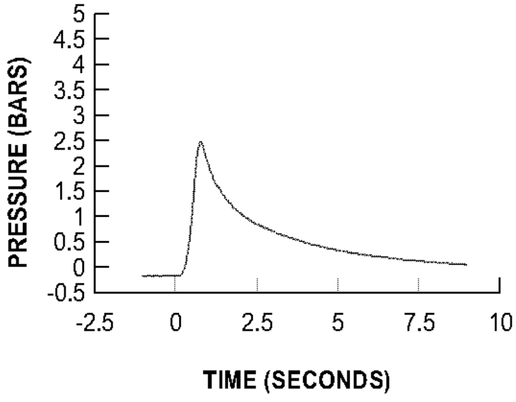
TEST 73
QUASI-STATIC PRESSURE 4
BAY 4



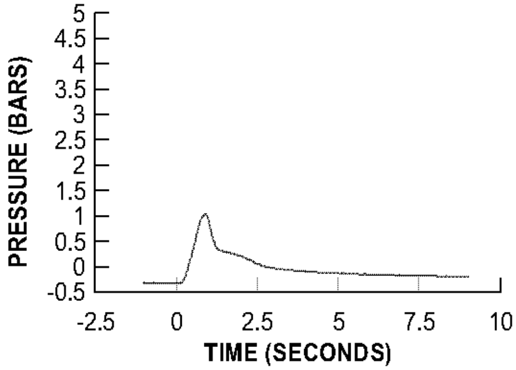
TEST 73
QUASI-STATIC PRESSURE 5
BAY 2



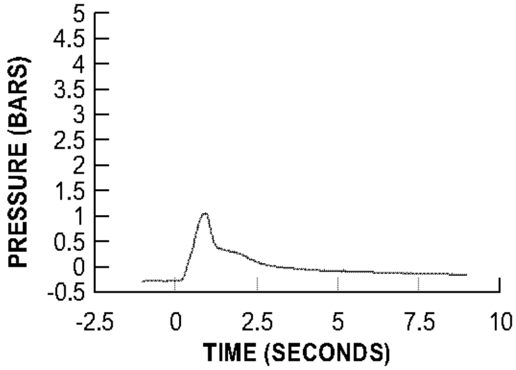
TEST 73
QUASI-STATIC PRESSURE 6
BAY 1



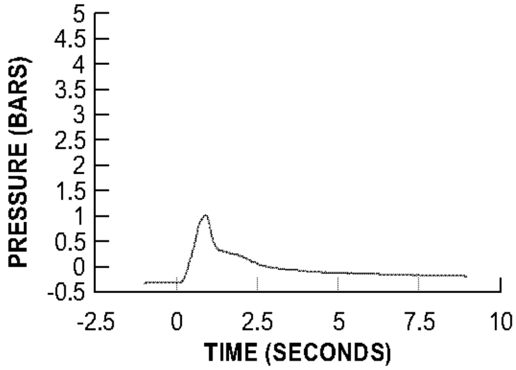
TEST 74
QUASI-STATIC PRESSURE 1
BAY 5



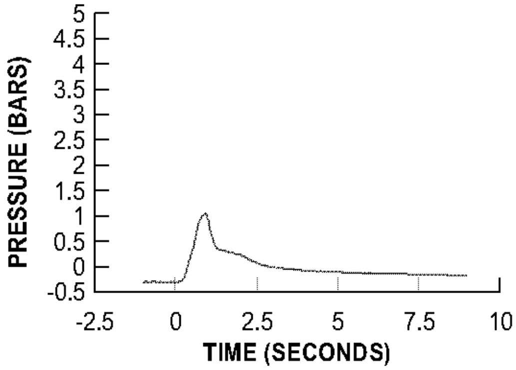
TEST 74
QUASI-STATIC PRESSURE 2
BAY 6



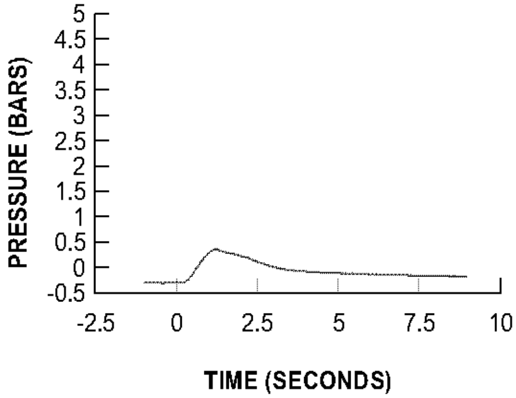
TEST 74
QUASI-STATIC PRESSURE 3
BAY 3



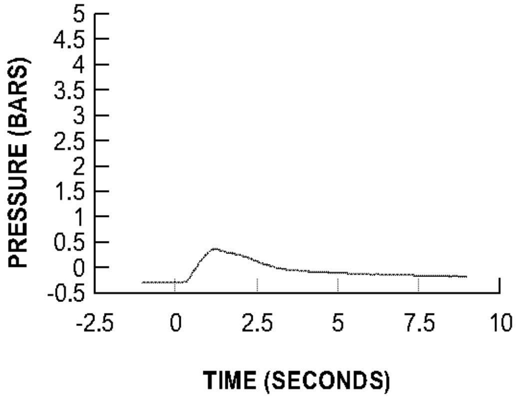
TEST 74
QUASI-STATIC PRESSURE 4
BAY 4



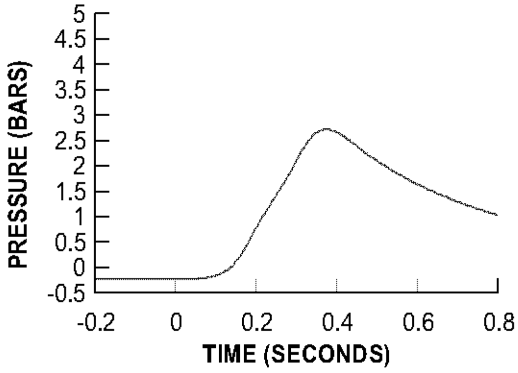
TEST 74
QUASI-STATIC PRESSURE 5
BAY 2



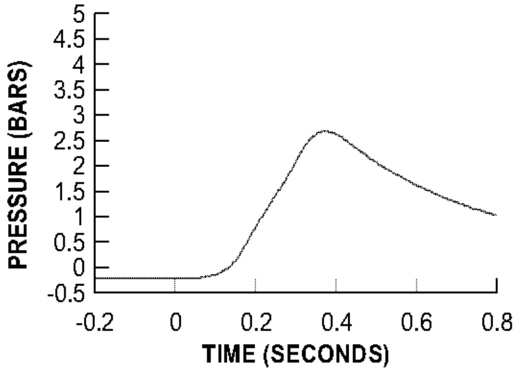
TEST 74
QUASI-STATIC PRESSURE 6
BAY 1



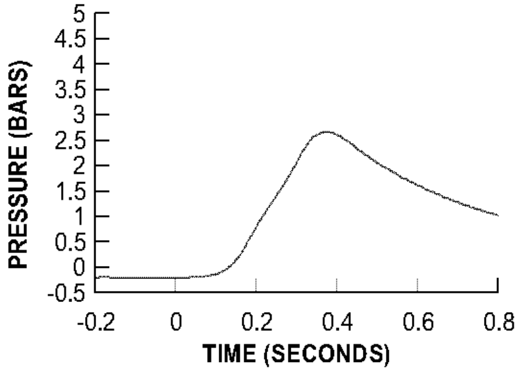
TEST 75
QUASI-STATIC PRESSURE 1
BAY 5



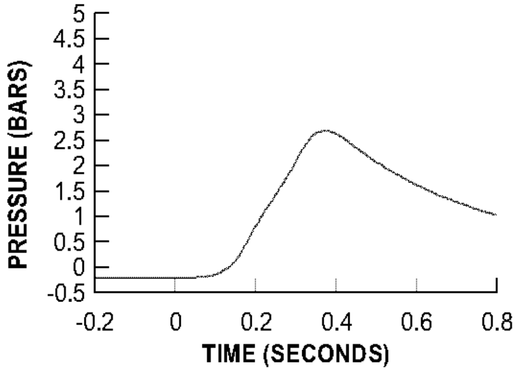
TEST 75
QUASI-STATIC PRESSURE 2
BAY 6



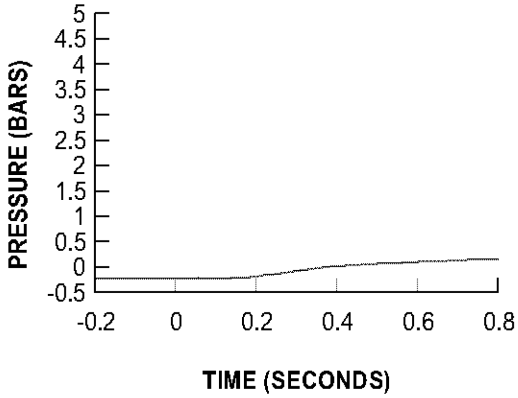
TEST 75
QUASI-STATIC PRESSURE 3
BAY 3



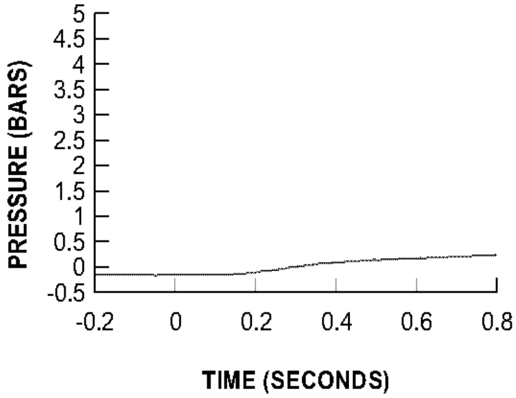
TEST 75
QUASI-STATIC PRESSURE 4
BAY 4



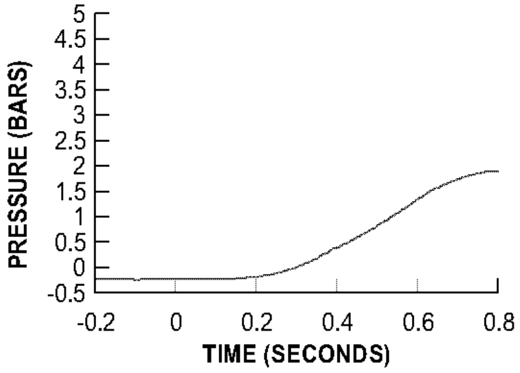
TEST 75
QUASI-STATIC PRESSURE 5
BAY 2



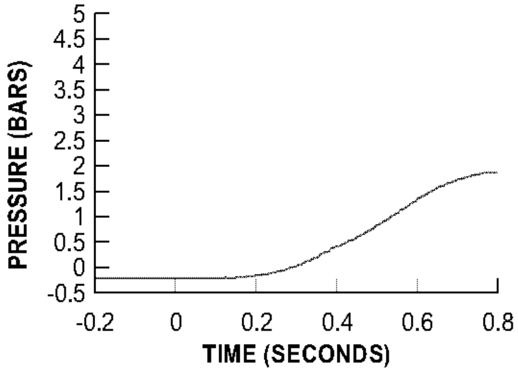
TEST 75
QUASI-STATIC PRESSURE 6
BAY 1



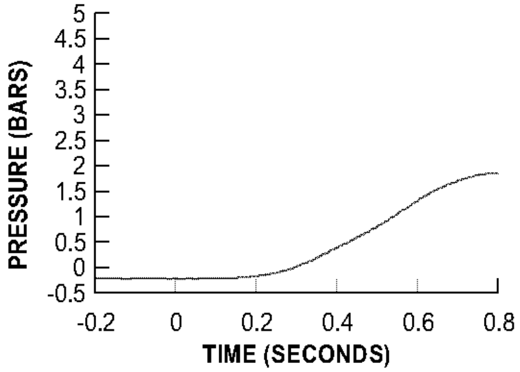
TEST 76
QUASI-STATIC PRESSURE 1
BAY 5



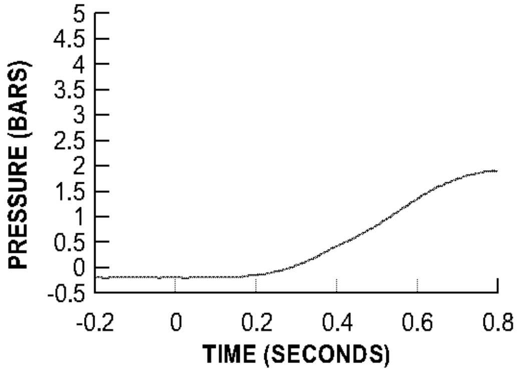
TEST 76
QUASI-STATIC PRESSURE 2
BAY 6



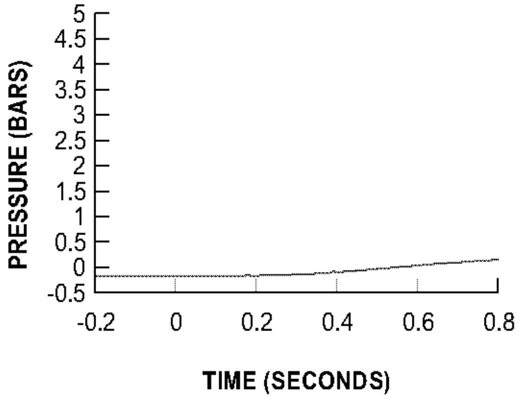
TEST 76
QUASI-STATIC PRESSURE 3
BAY 3



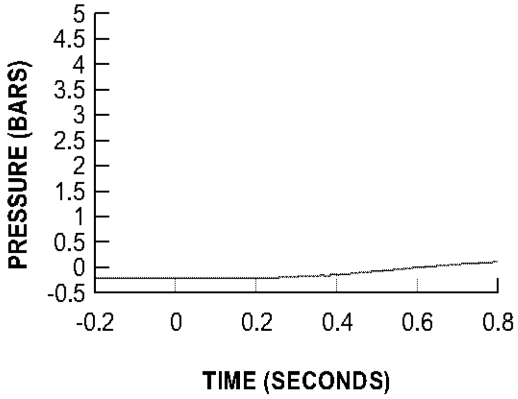
TEST 76
QUASI-STATIC PRESSURE 4
BAY 4



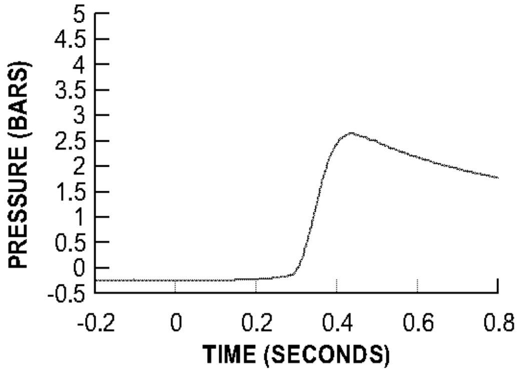
TEST 76
QUASI-STATIC PRESSURE 5
BAY 2



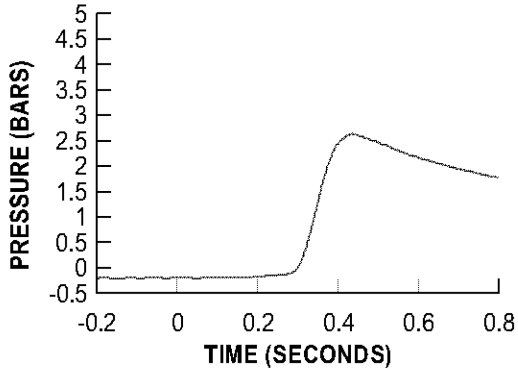
TEST 76
QUASI-STATIC PRESSURE 6
BAY 1



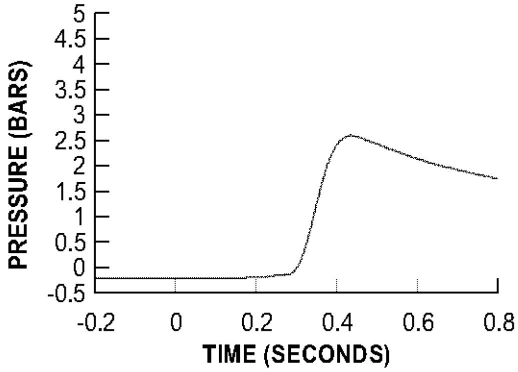
TEST 77
QUASI-STATIC PRESSURE 1
BAY 5



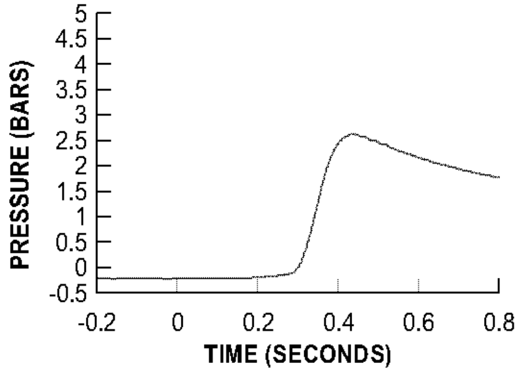
TEST 77
QUASI-STATIC PRESSURE 2
BAY 6



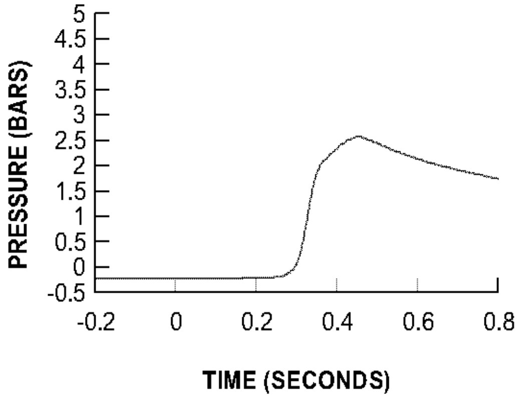
TEST 77
QUASI-STATIC PRESSURE 3
BAY 3



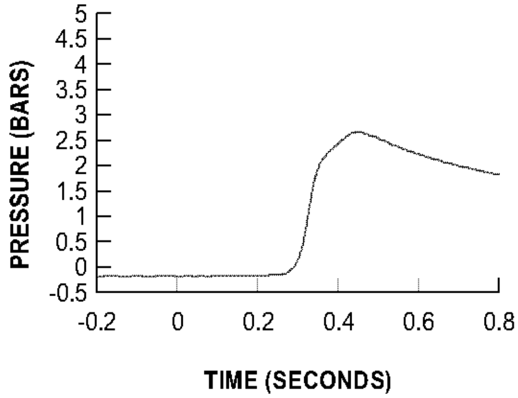
TEST 77
QUASI-STATIC PRESSURE 4
BAY 4



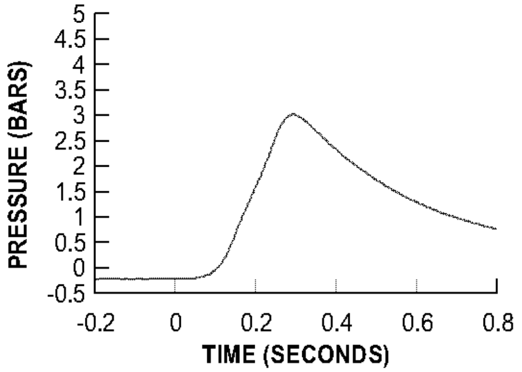
TEST 77
QUASI-STATIC PRESSURE 5
BAY 2



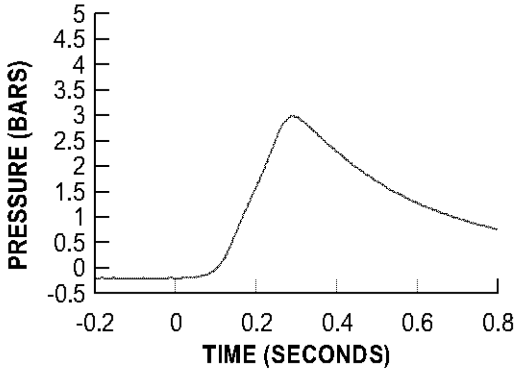
TEST 77
QUASI-STATIC PRESSURE 6
BAY 1



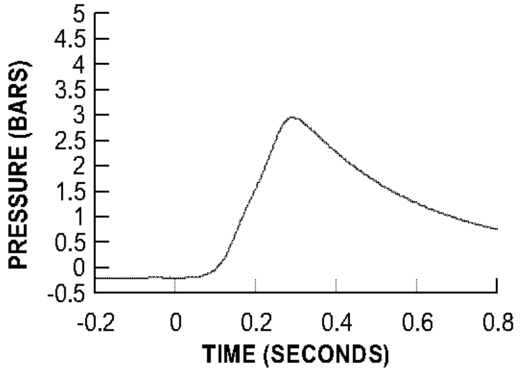
TEST 78
QUASI-STATIC PRESSURE 1
BAY 5



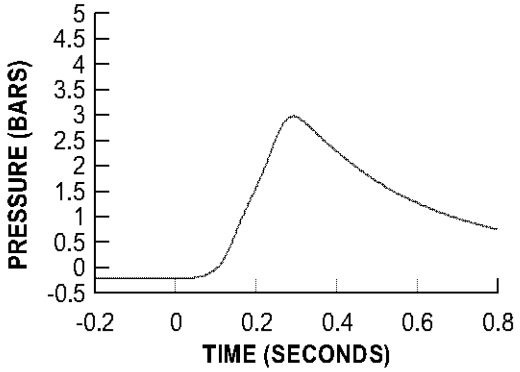
TEST 78
QUASI-STATIC PRESSURE 2
BAY 6



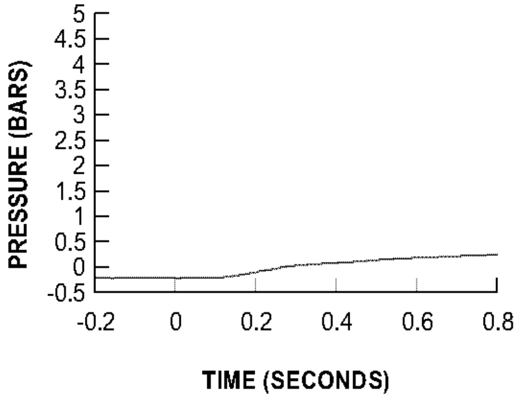
TEST 78
QUASI-STATIC PRESSURE 3
BAY 3



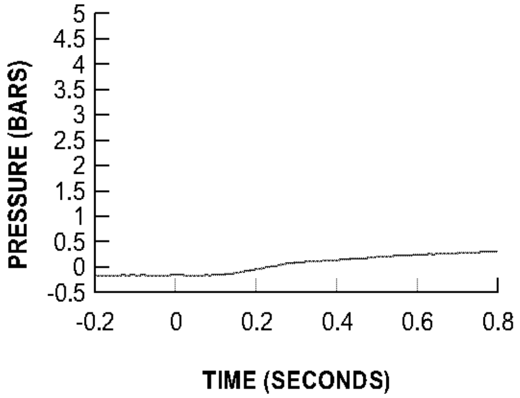
TEST 78
QUASI-STATIC PRESSURE 4
BAY 4



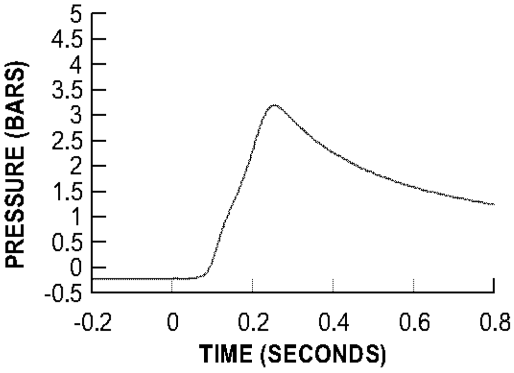
TEST 78
QUASI-STATIC PRESSURE 5
BAY 2



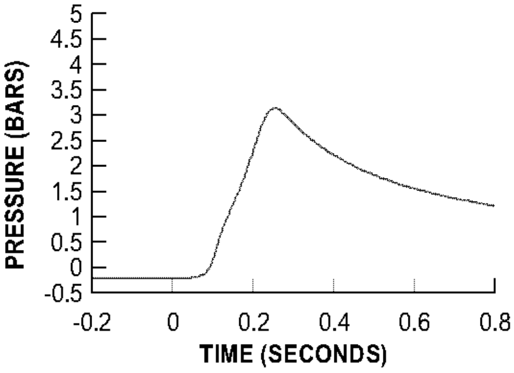
TEST 78
QUASI-STATIC PRESSURE 6
BAY 1



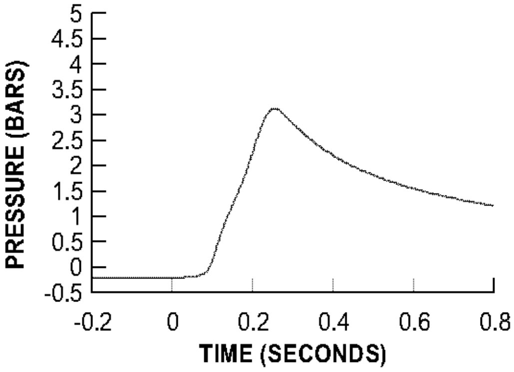
TEST 79
QUASI-STATIC PRESSURE 1
BAY 5



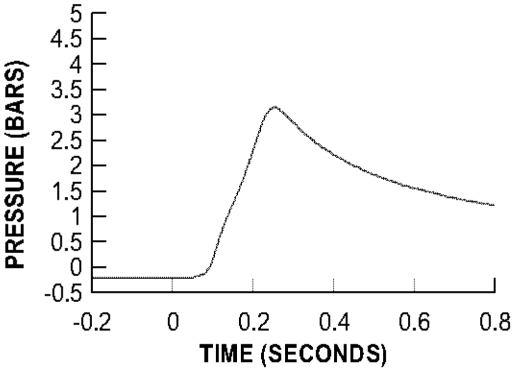
TEST 79
QUASI-STATIC PRESSURE 2
BAY 6



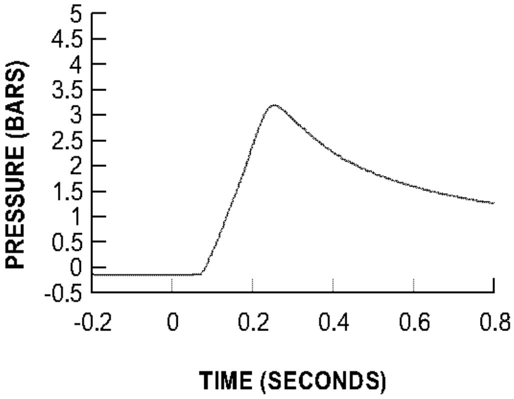
TEST 79
QUASI-STATIC PRESSURE 3
BAY 3



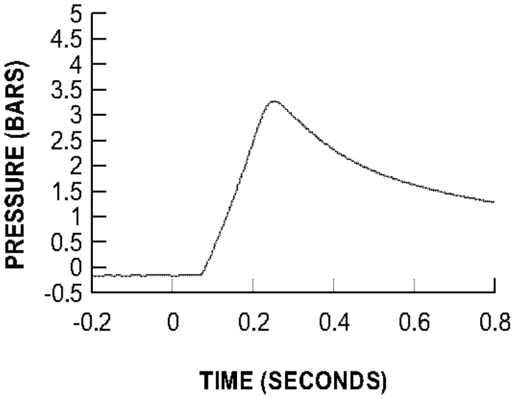
TEST 79
QUASI-STATIC PRESSURE 4
BAY 4



TEST 79
QUASI-STATIC PRESSURE 5
BAY 2



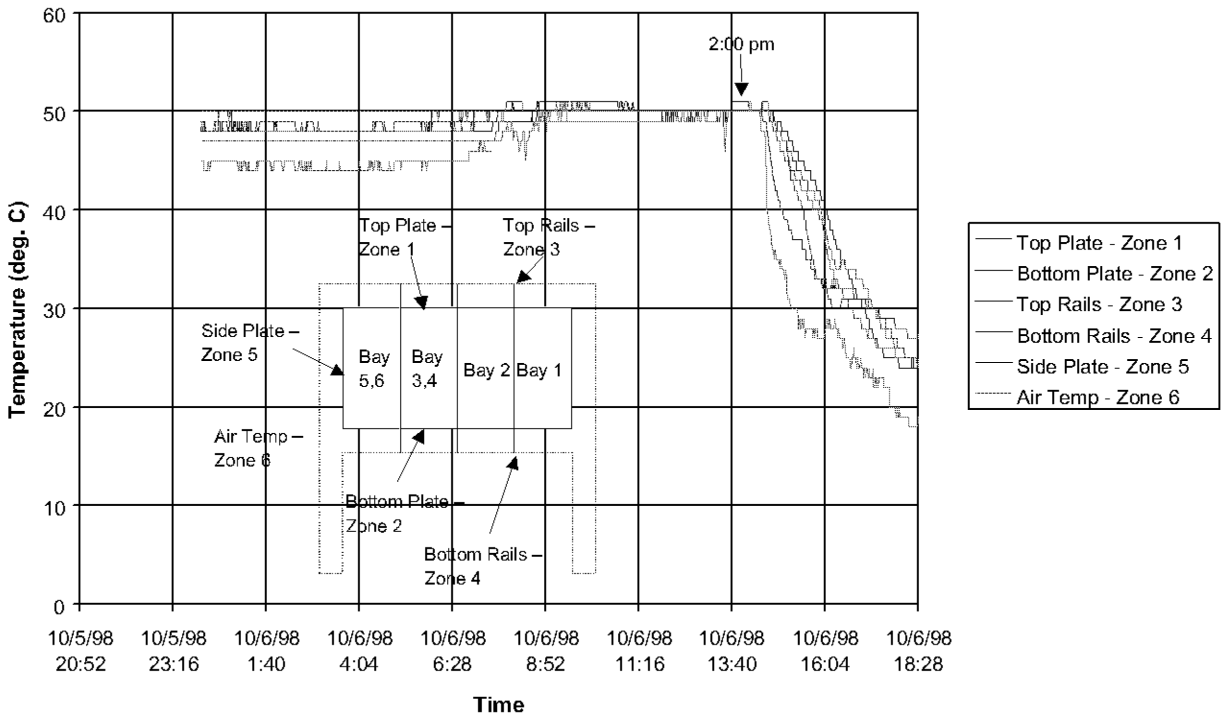
TEST 79
QUASI-STATIC PRESSURE 6
BAY 1



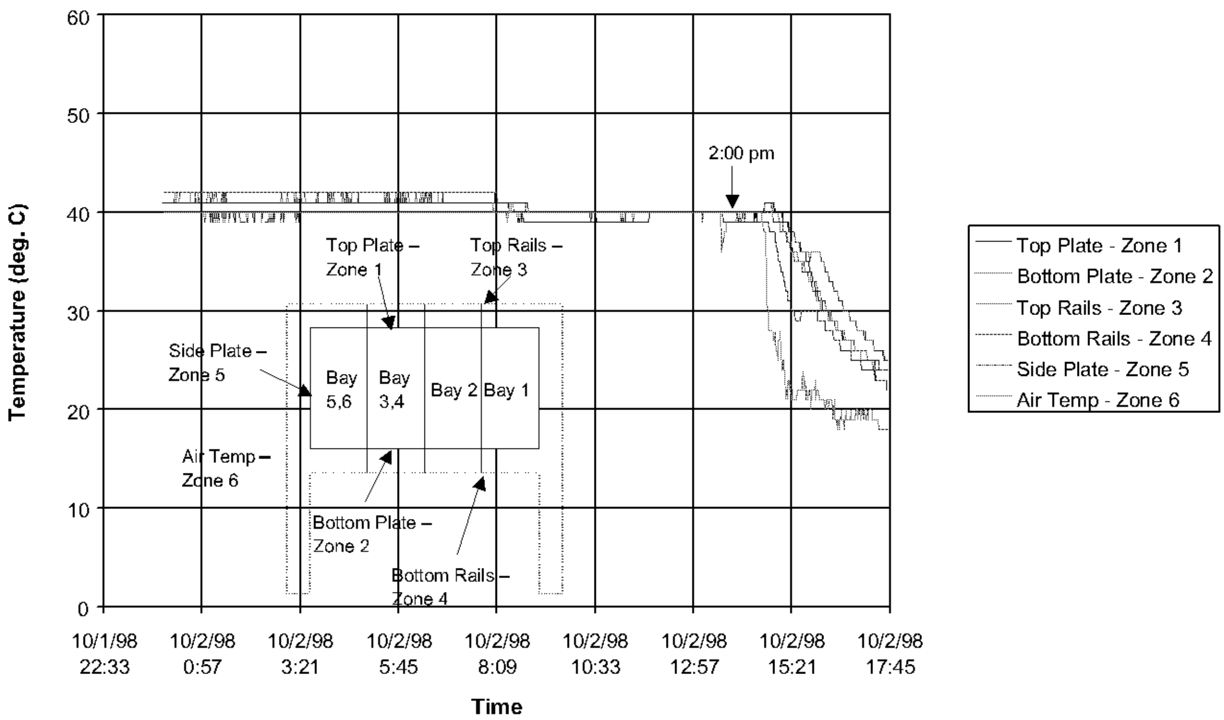
APPENDIX E

TEST FIXTURE TEMPERATURE DATA

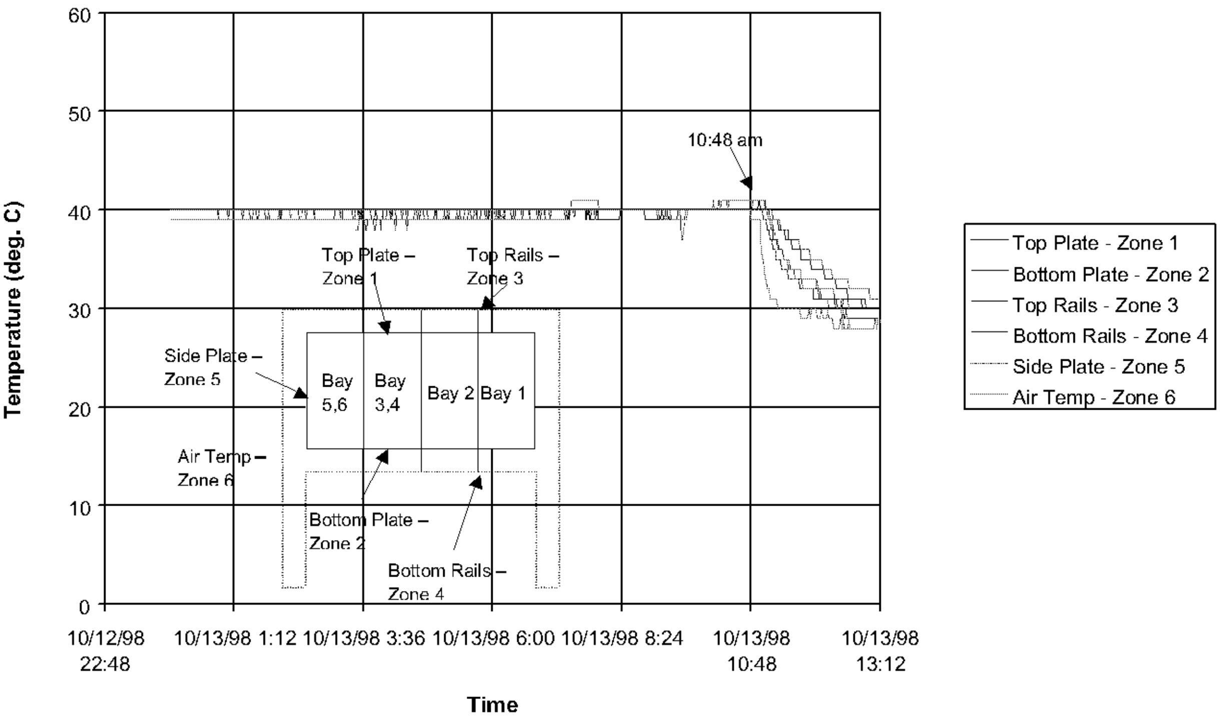
Shot 40



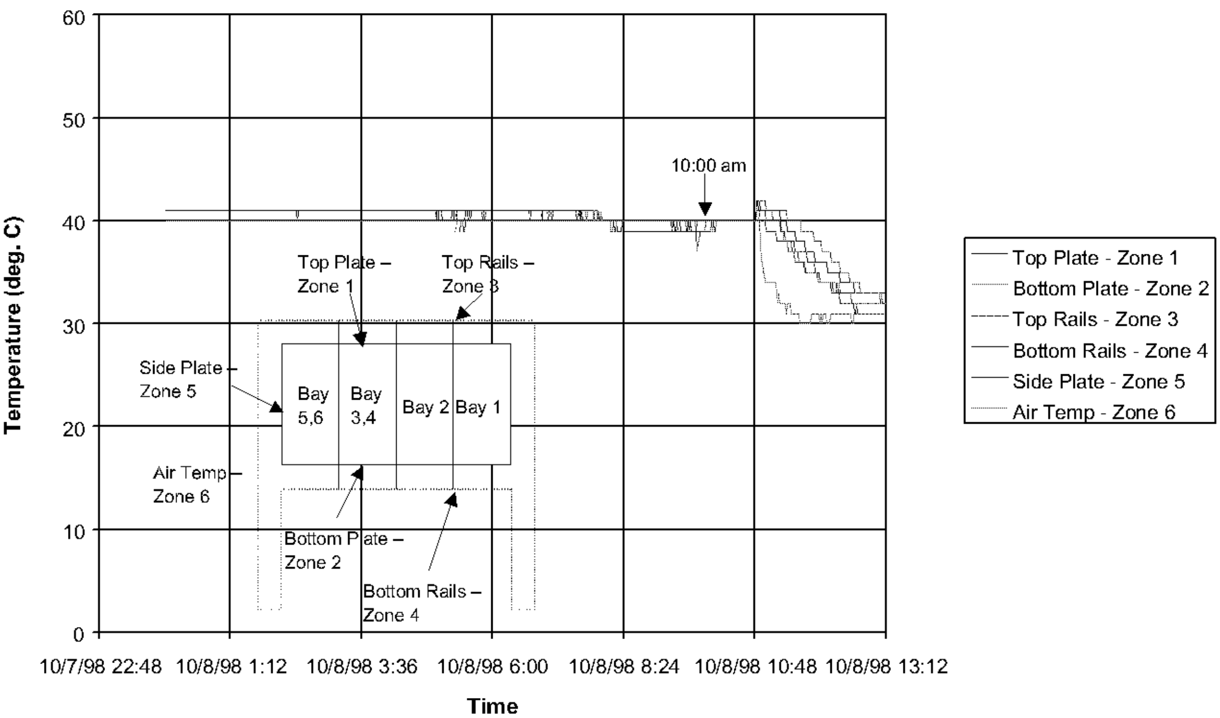
Shot 42



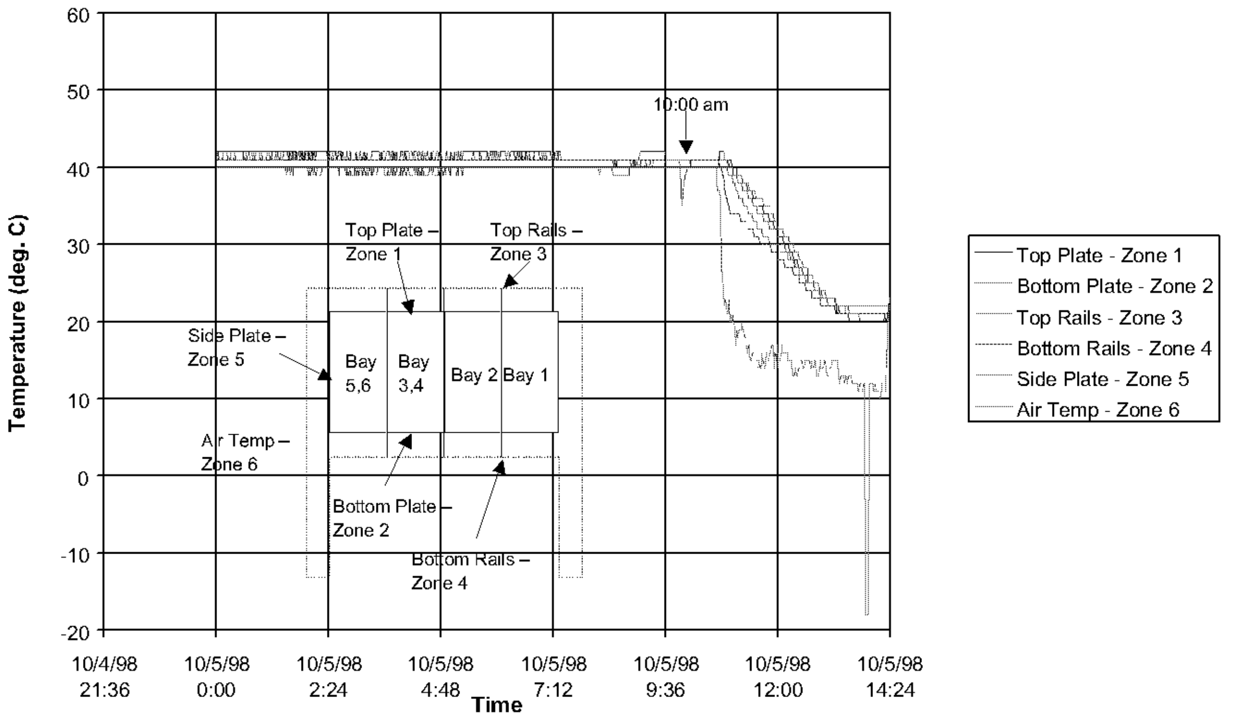
Shot 44



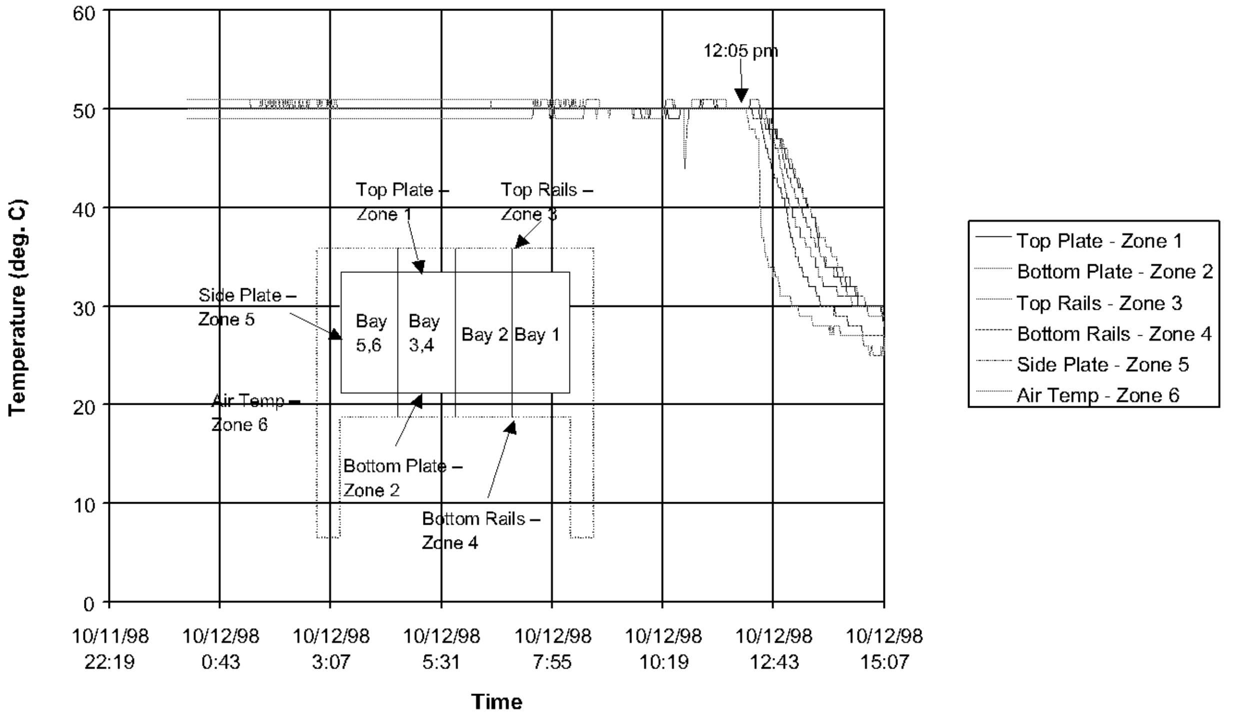
Shot 46



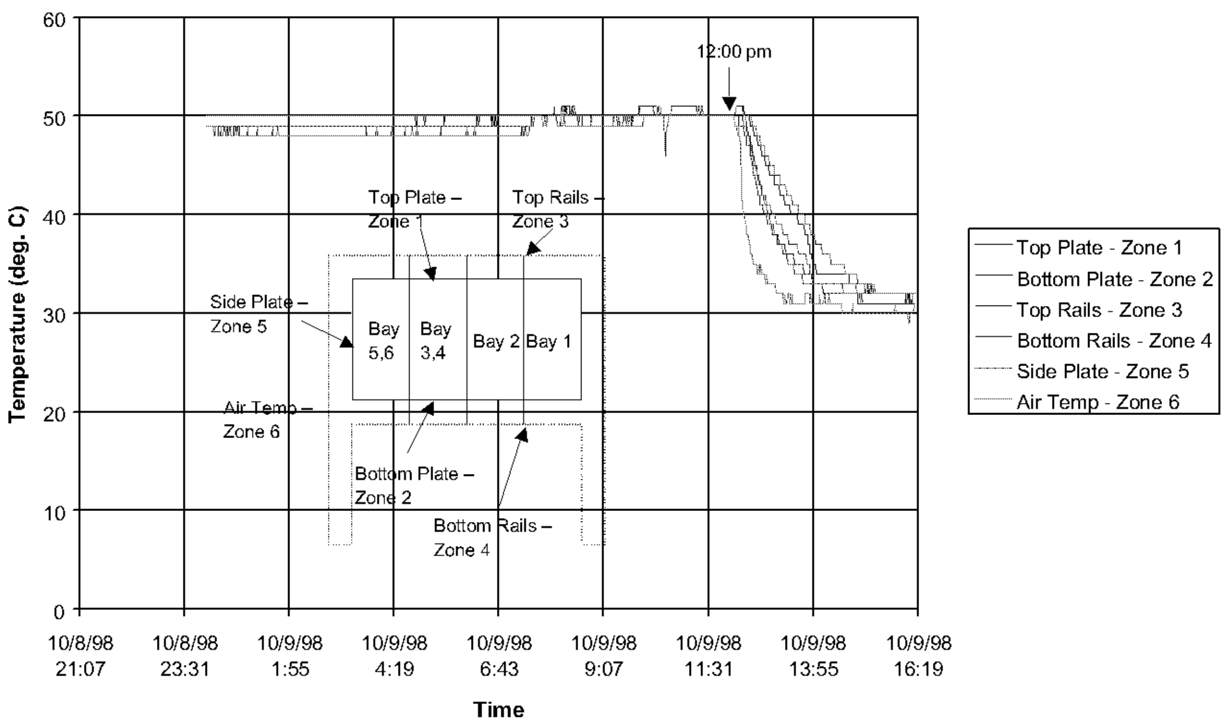
Shot 48



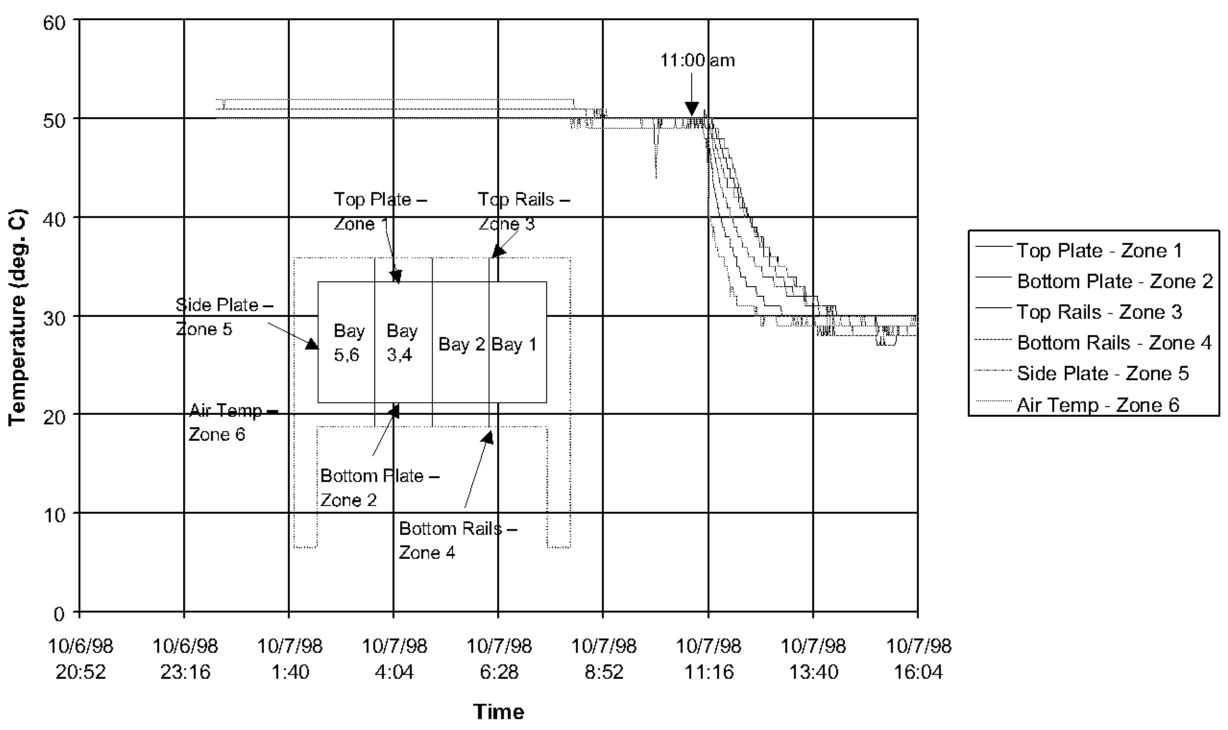
Shot 51



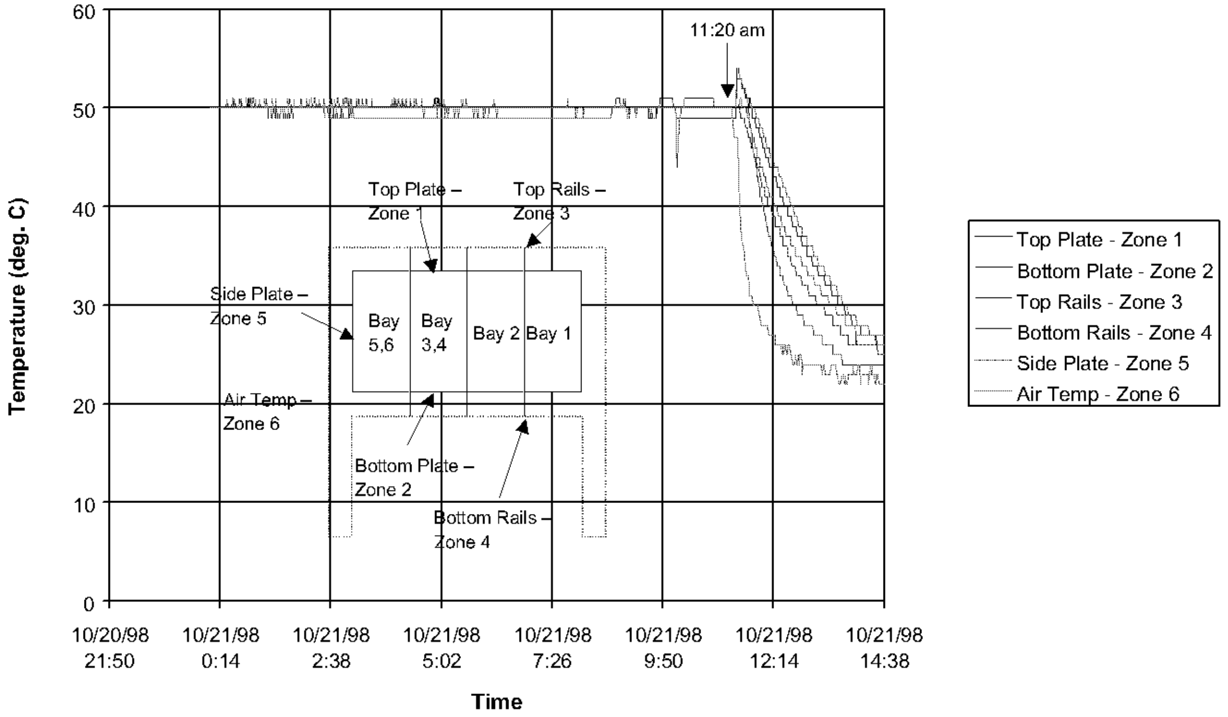
Shot 53



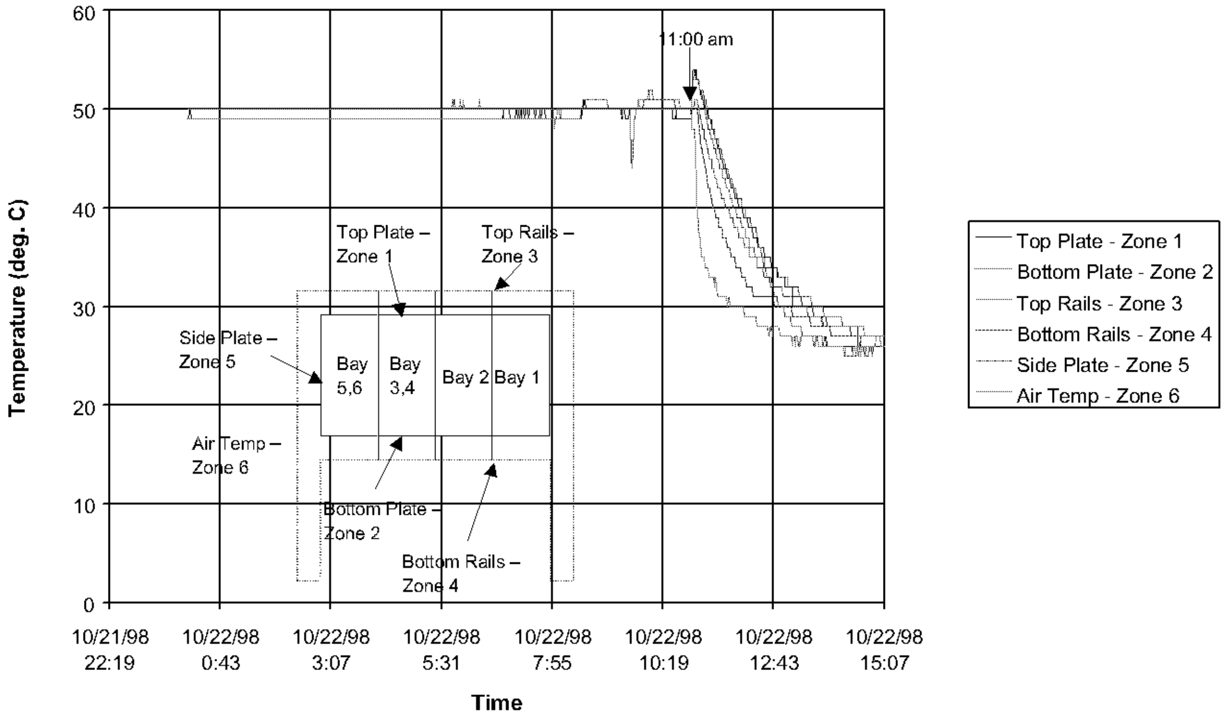
Shot 55

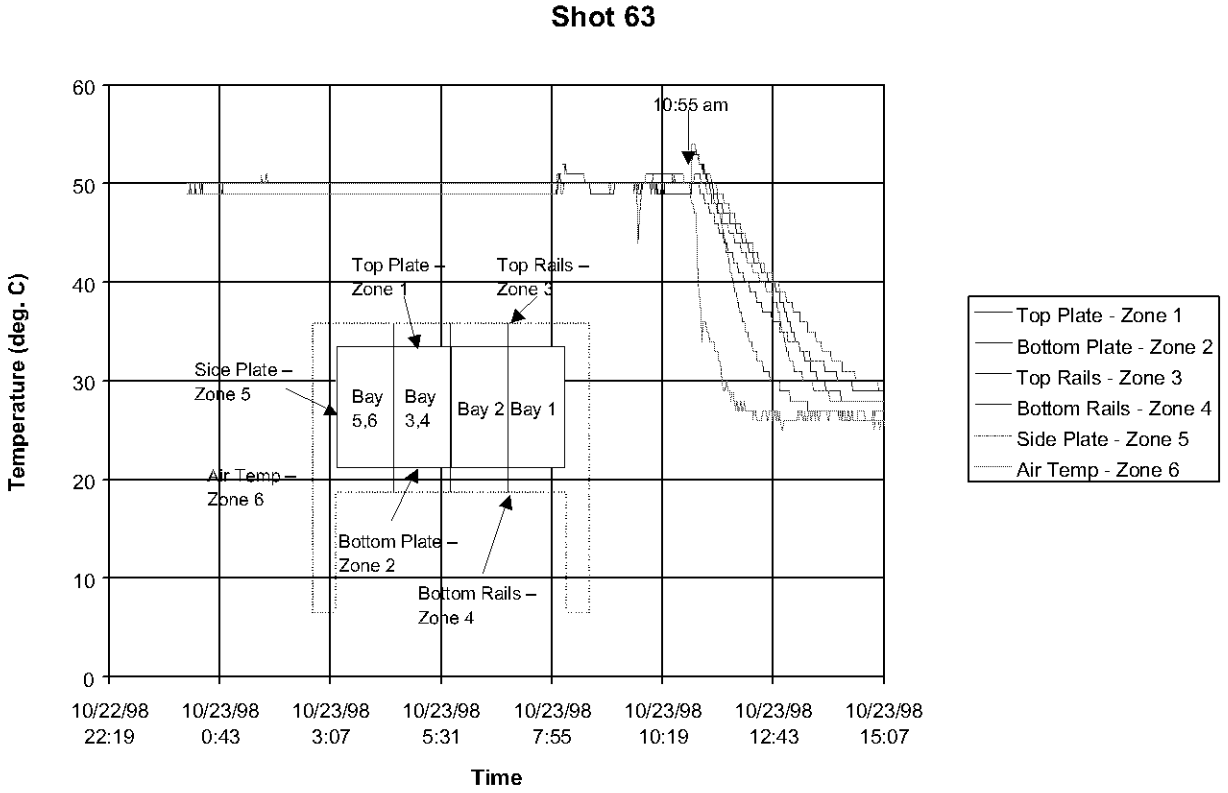


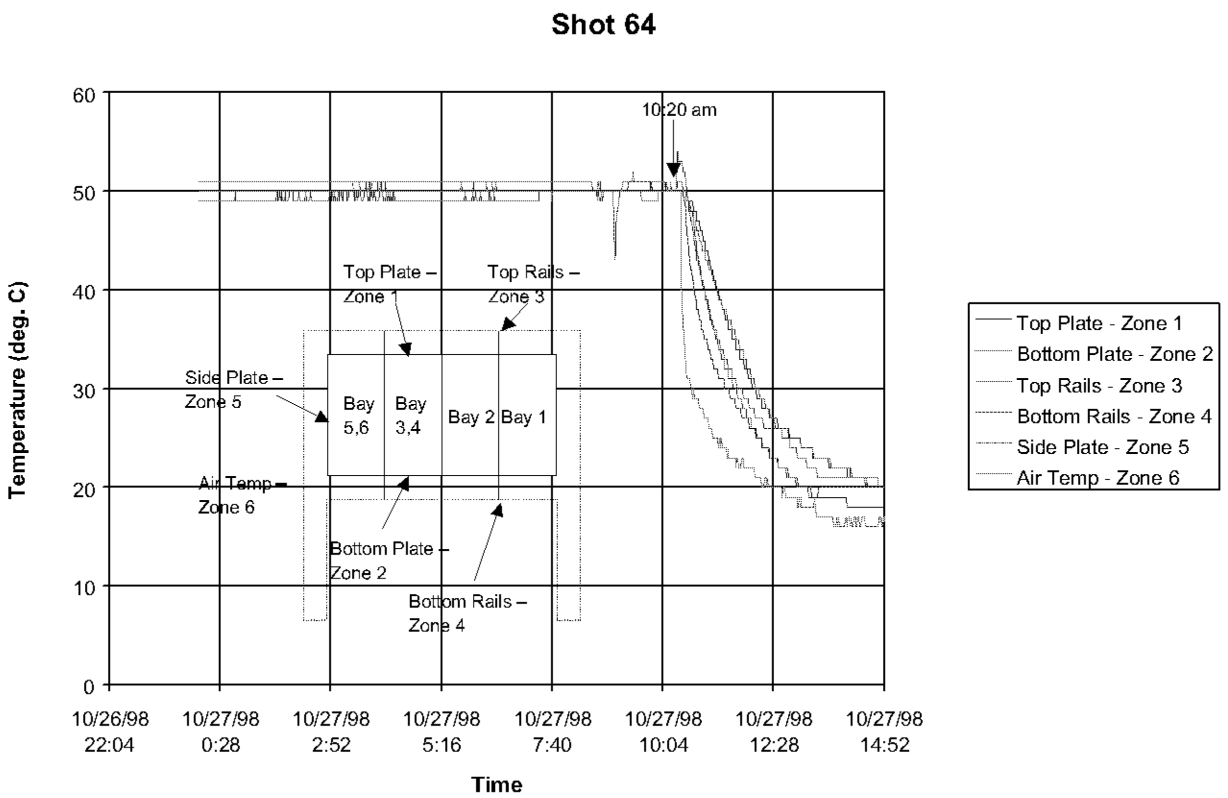
Shot 61



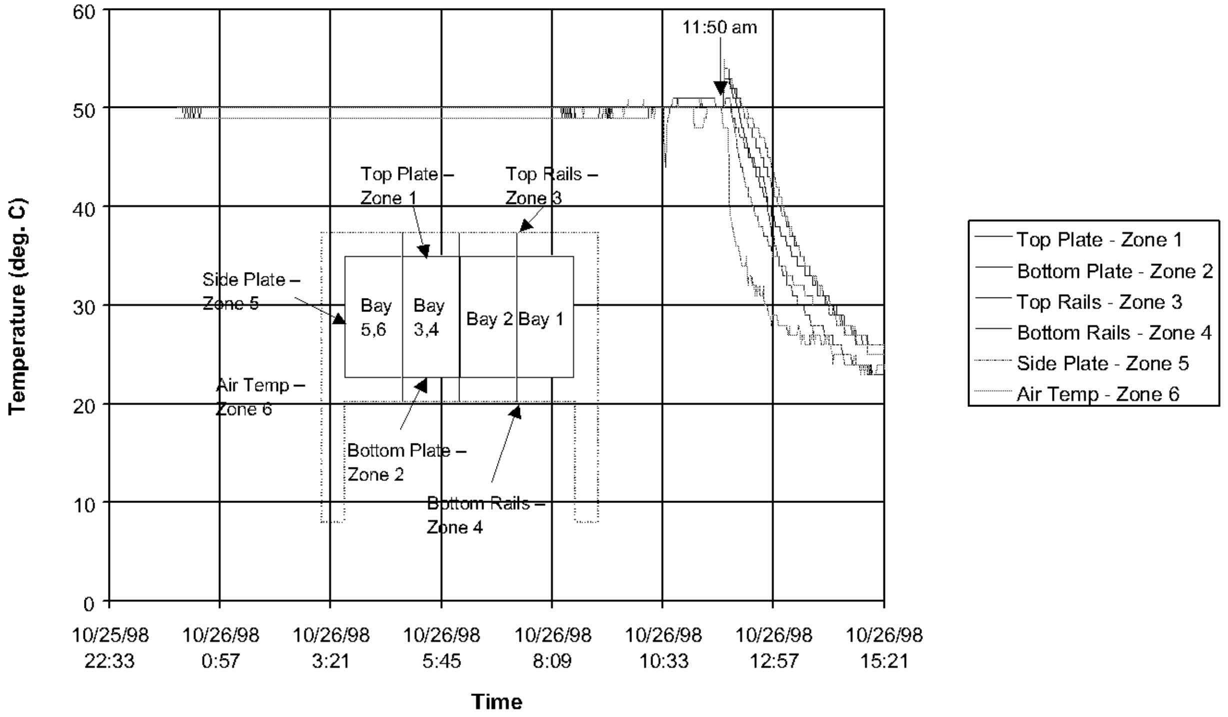
Shot 62



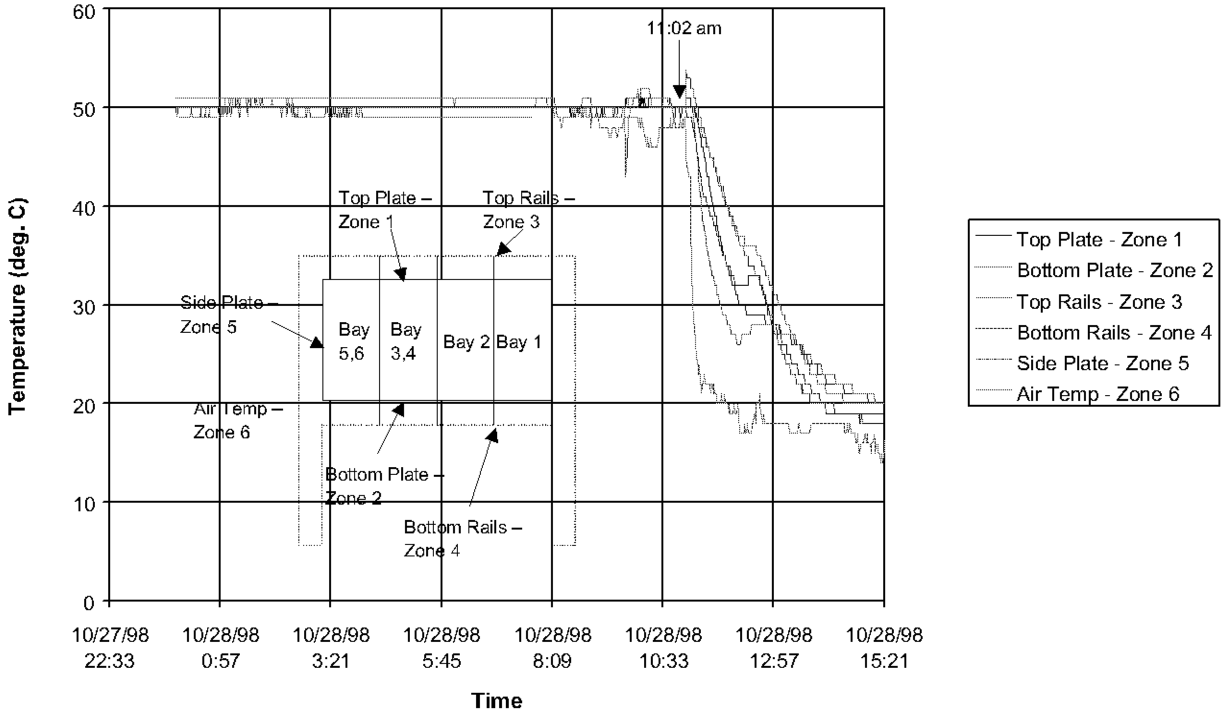

Shot 63
Temperature (deg. C)
60
50
40
30
20
10
0
10:55 am
Top Plate – Zone 1
Top Rails – Zone 3
Side Plate – Zone 5
Air Temp – Zone 6
Bay 5,6
Bay 3,4
Bay 2
Bay 1
Bottom Plate – Zone 2
Bottom Rails – Zone 4
10/22/98 22:19
10/23/98 0:43
10/23/98 3:07
10/23/98 5:31
10/23/98 7:55
10/23/98 10:19
10/23/98 12:43
10/23/98 15:07
Time
Top Plate - Zone 1
Bottom Plate - Zone 2
Top Rails - Zone 3
Bottom Rails - Zone 4
Side Plate - Zone 5
Air Temp - Zone 6


Shot 64
Temperature (deg. C)
60
50
40
30
20
10
0
10:20 am
Top Plate – Zone 1
Top Rails – Zone 3
Side Plate – Zone 5
Air Temp – Zone 6
Bay 5,6
Bay 3,4
Bay 2
Bay 1
Bottom Plate – Zone 2
Bottom Rails – Zone 4
10/26/98 22:04
10/27/98 0:28
10/27/98 2:52
10/27/98 5:16
10/27/98 7:40
10/27/98 10:04
10/27/98 12:28
10/27/98 14:52
Time
Top Plate - Zone 1
Bottom Plate - Zone 2
Top Rails - Zone 3
Bottom Rails - Zone 4
Side Plate - Zone 5
Air Temp - Zone 6

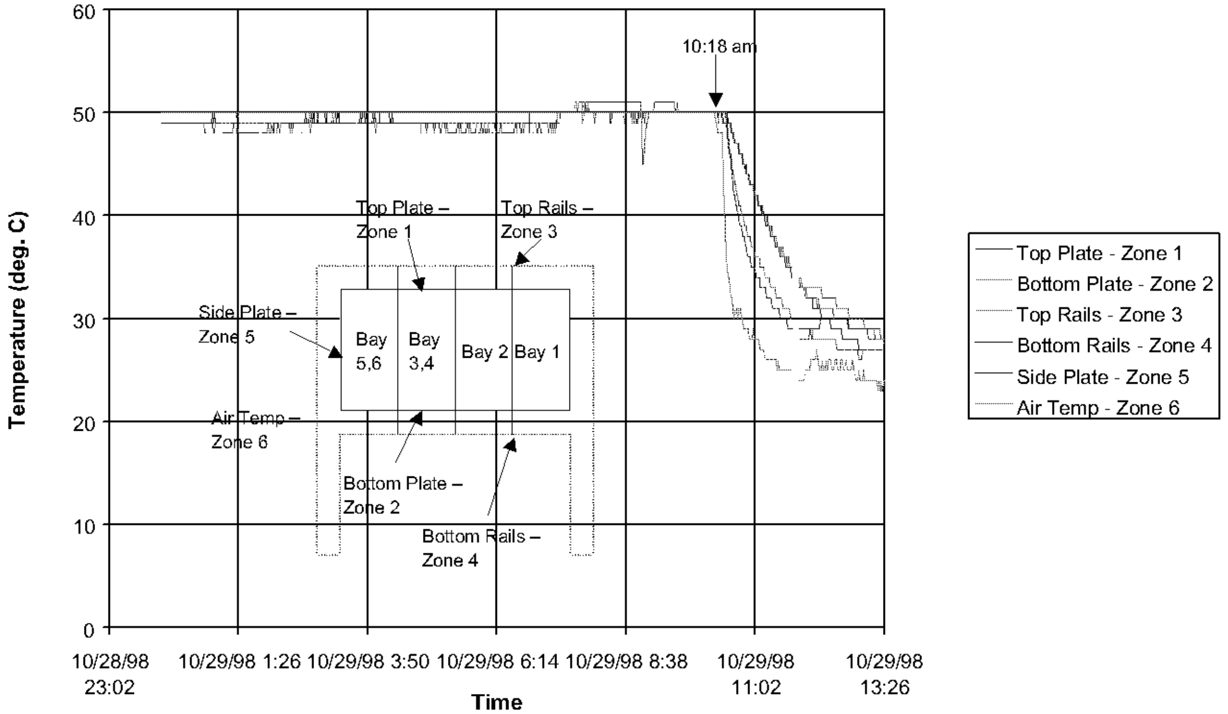
Shot 65



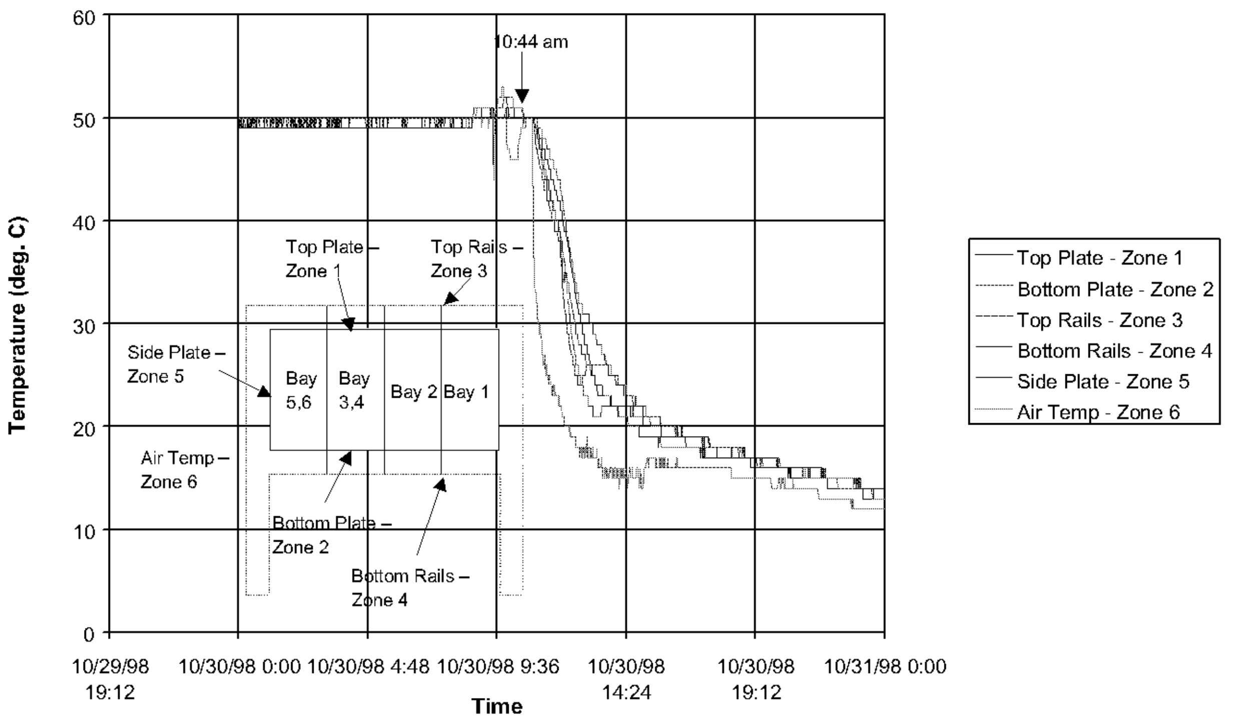
Shot 66



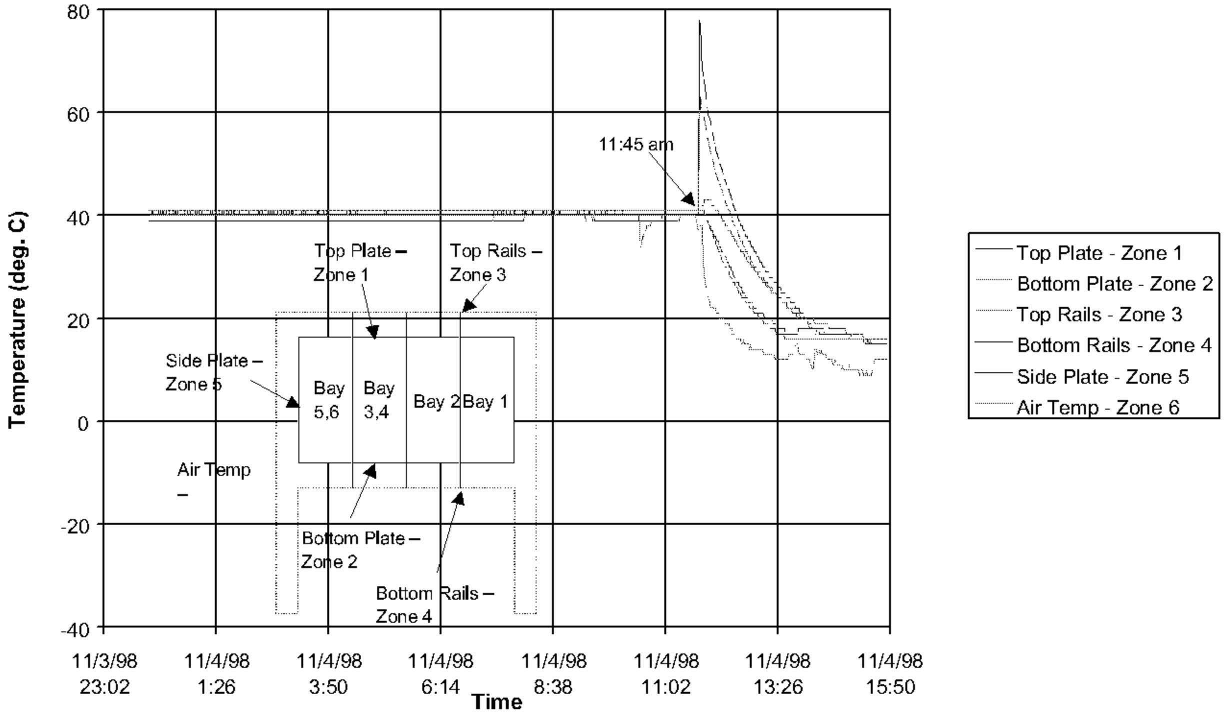
Shot 67



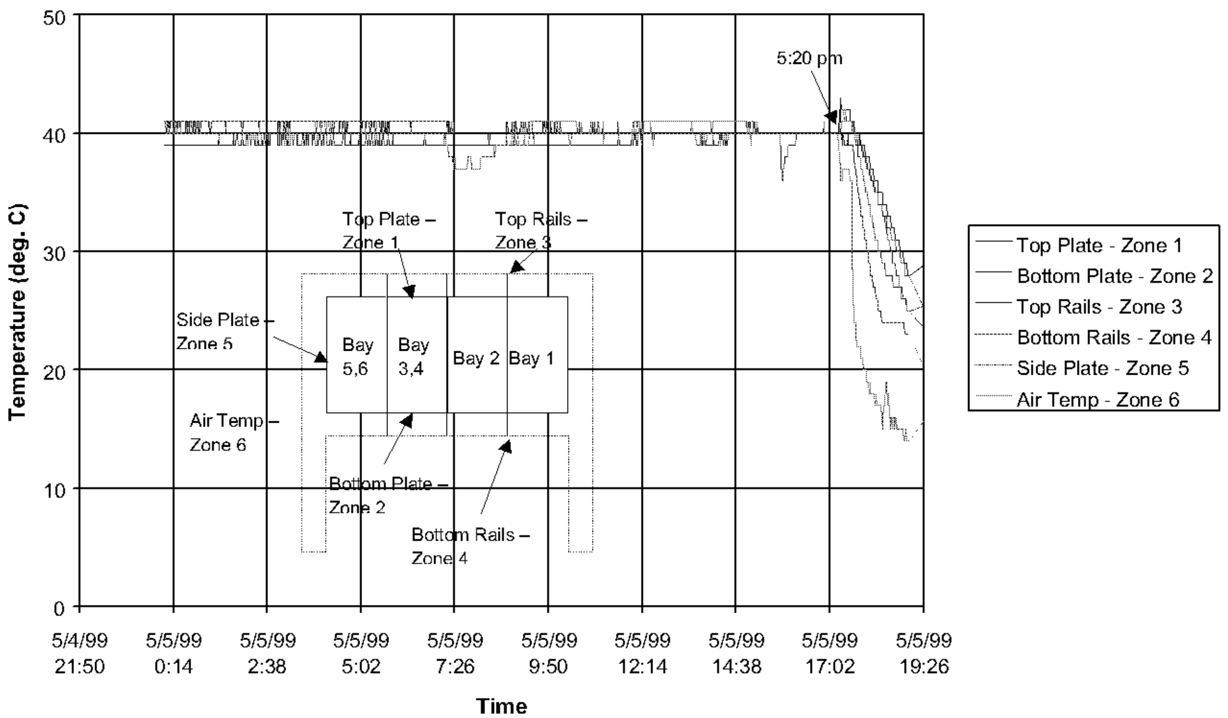
Shot 68



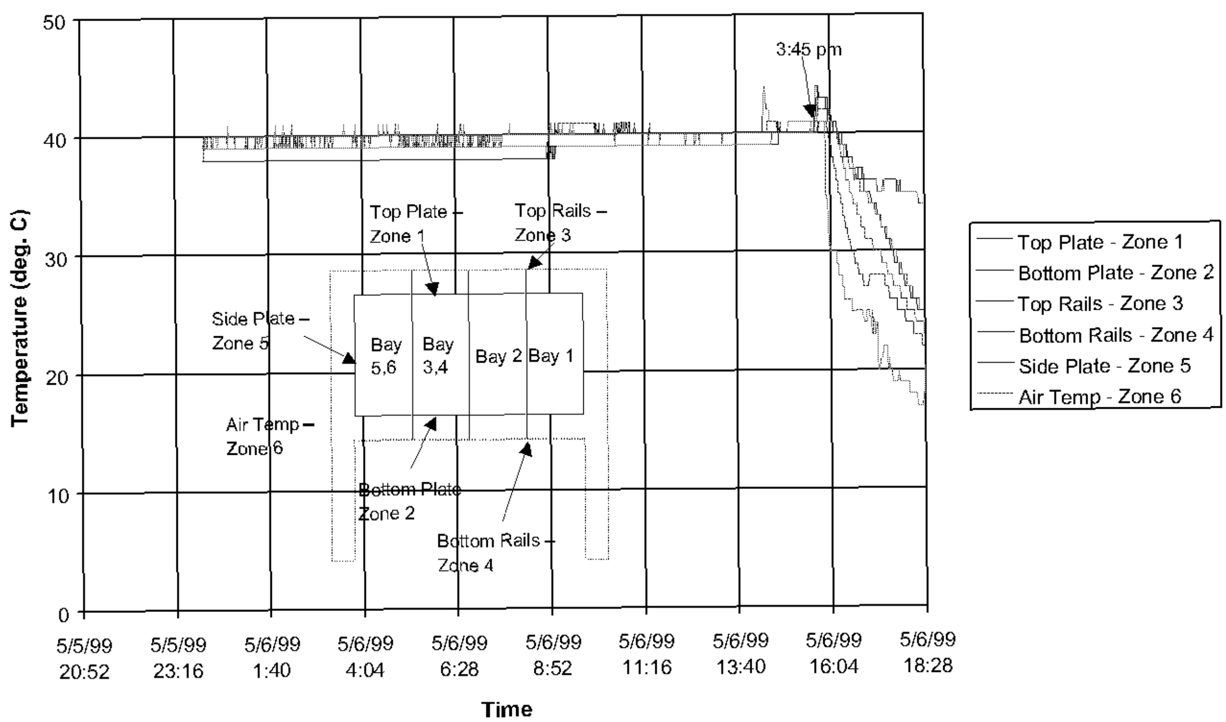
Shot 70



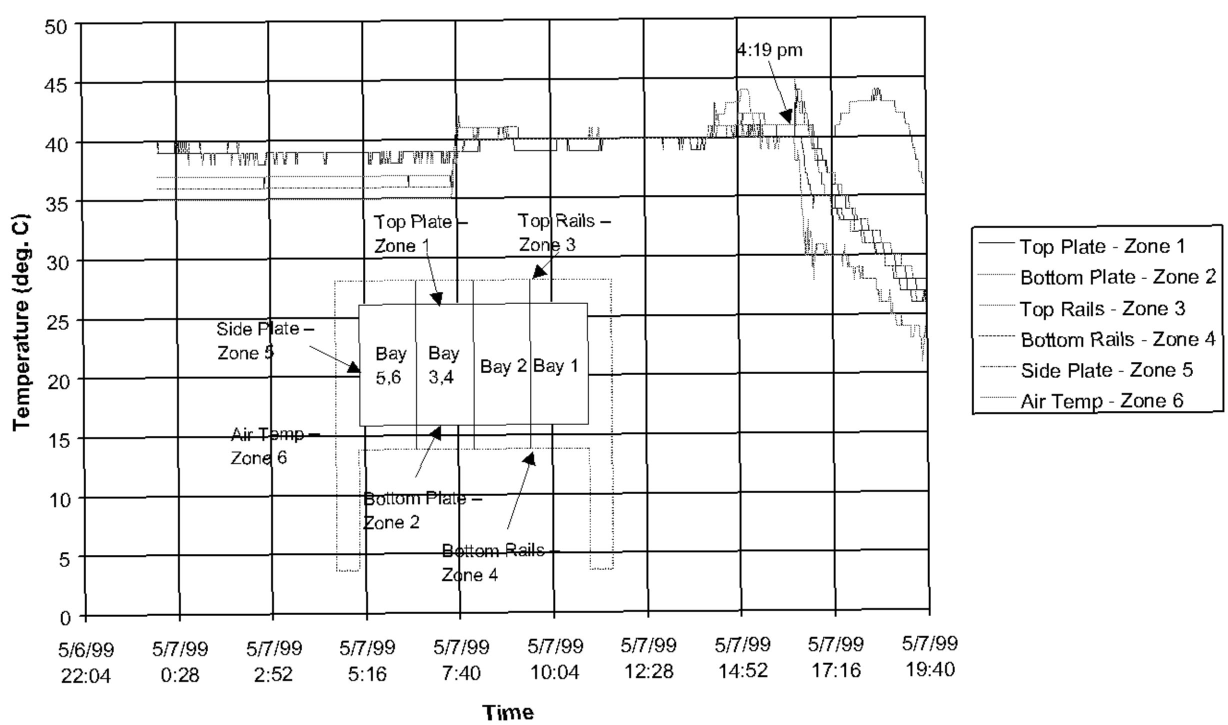
Shot 71



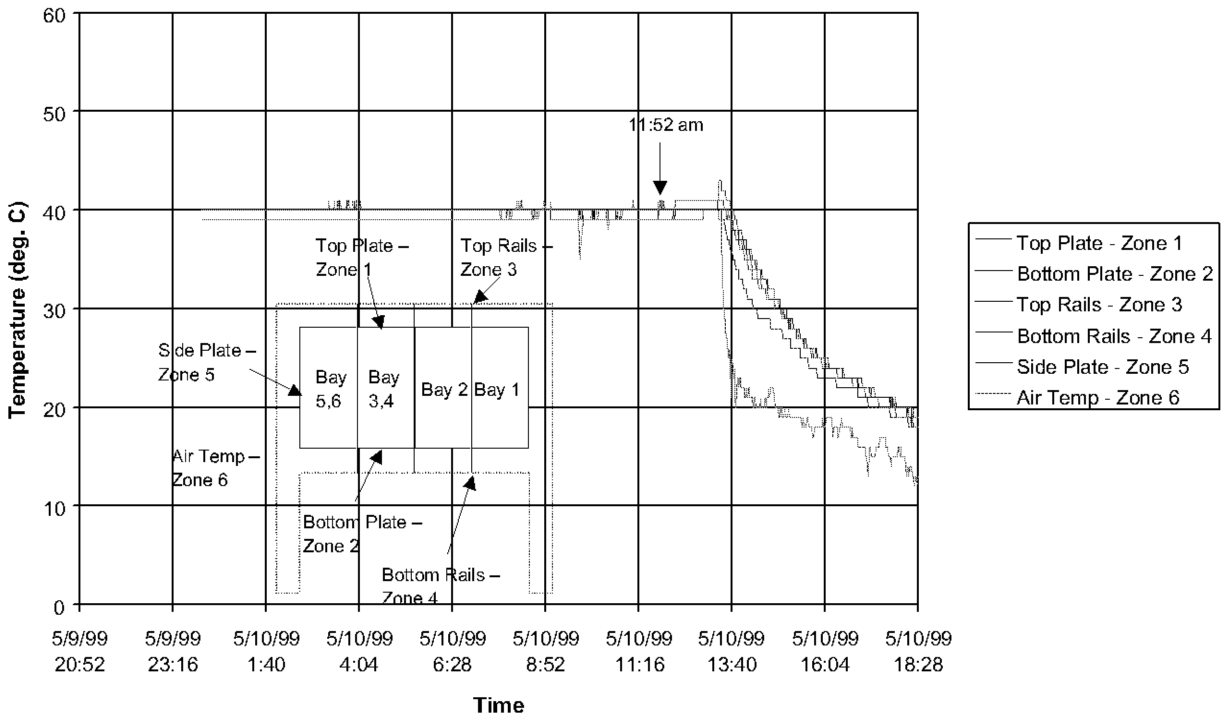
Shot 72



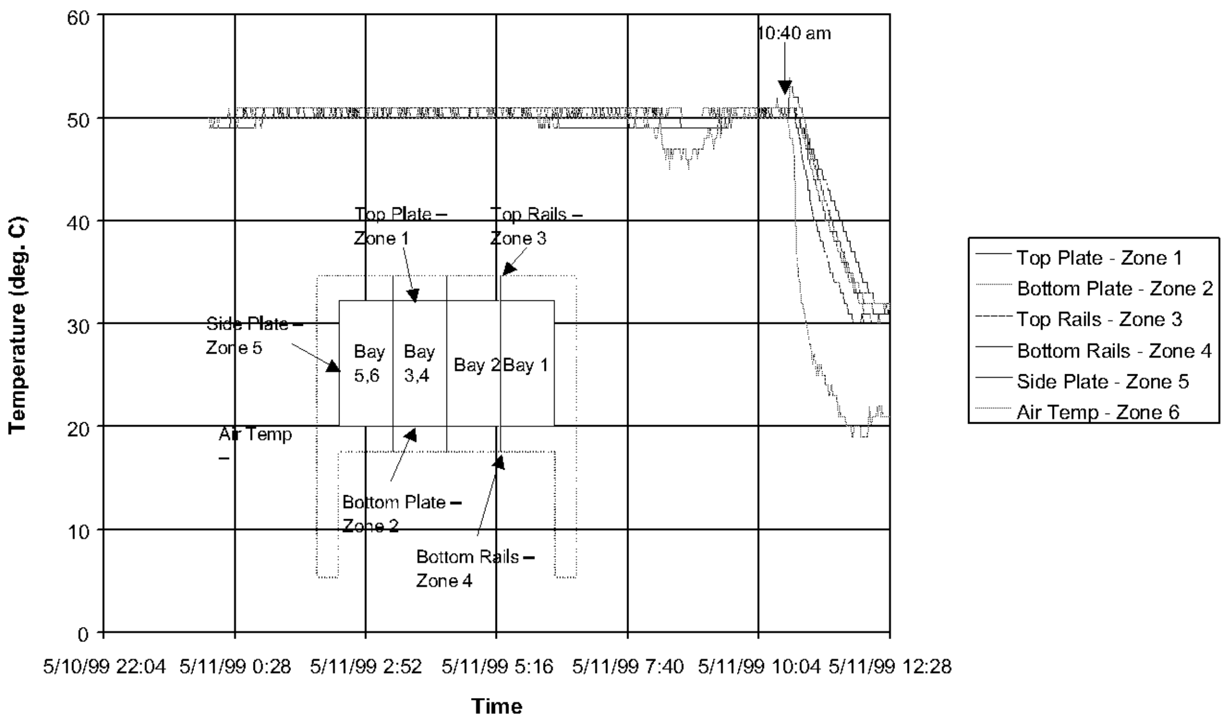
Shot 73



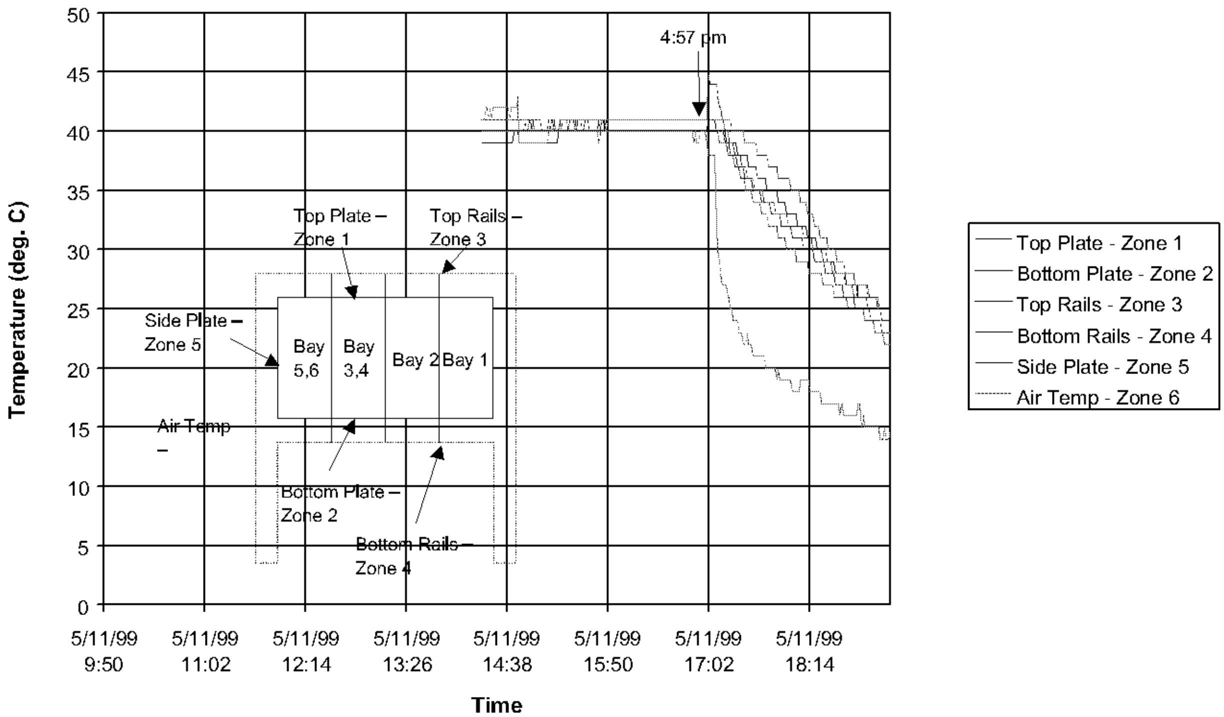
Shot 74



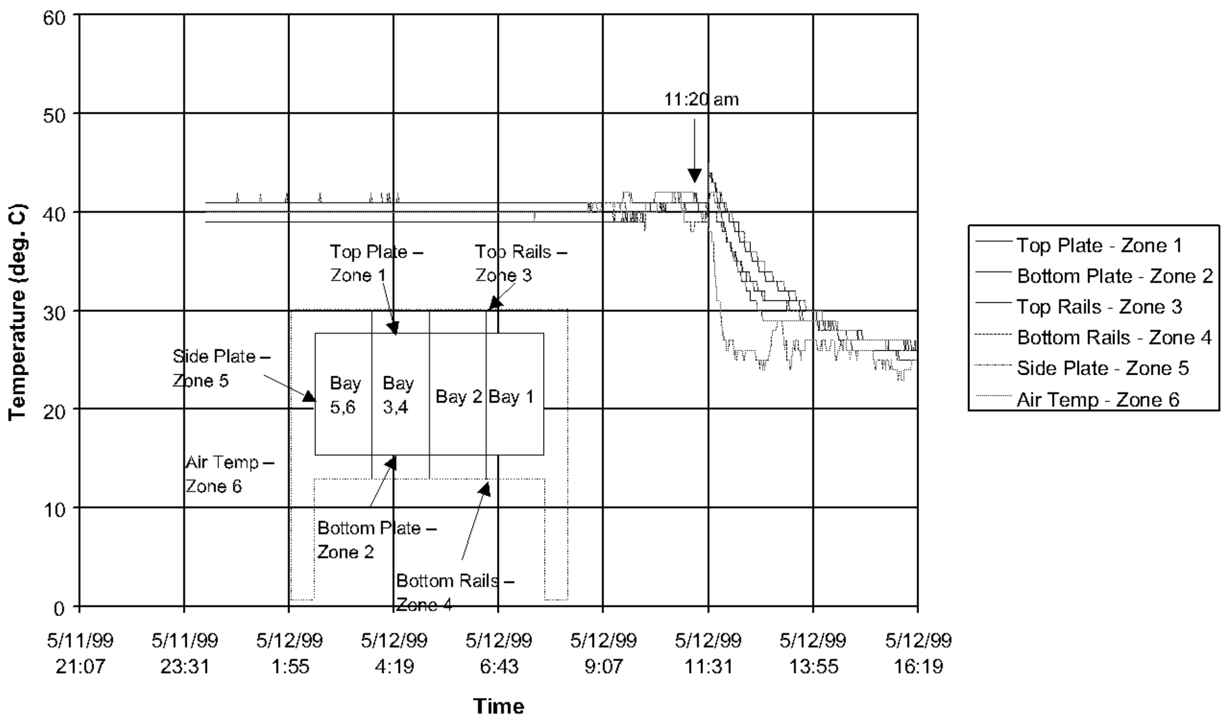
Shot 75



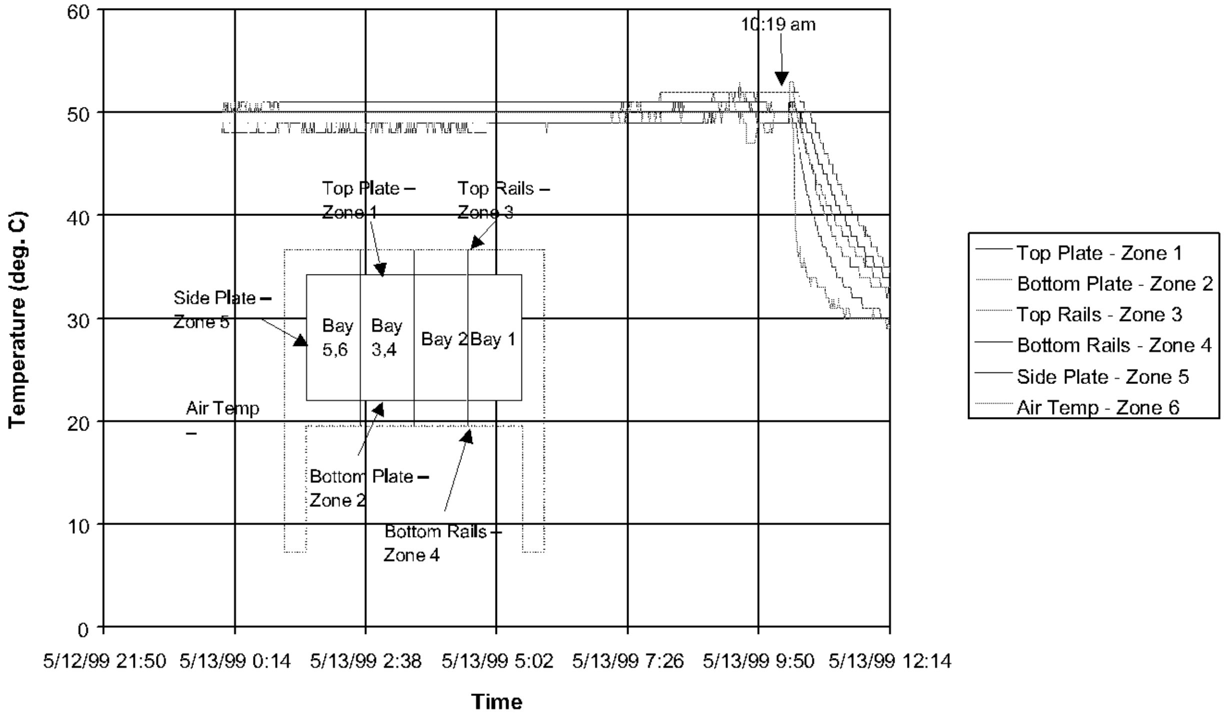
Shot 76



Shot 77



Shot 78



Shot 79