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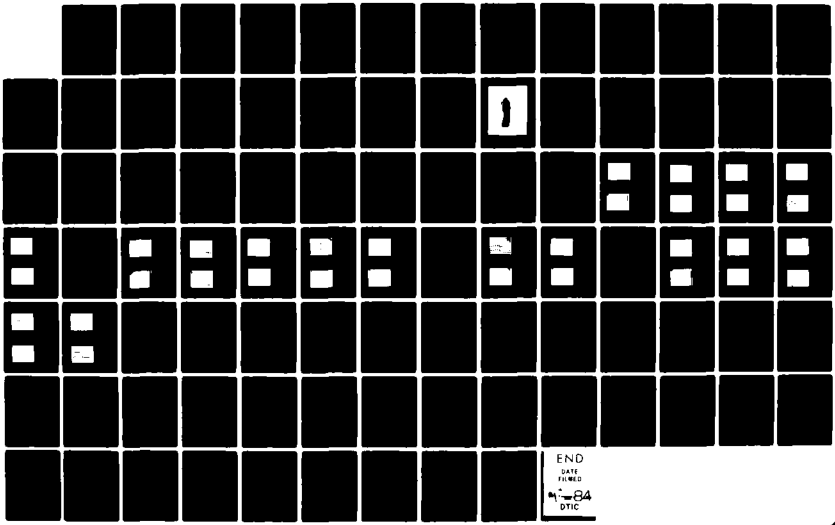

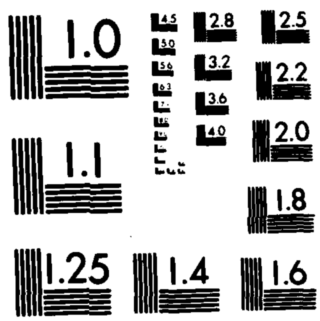

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CONSTRUCTION AND FIELDING OF TRS UNITS FOR THE MILL RACE HIGH EXPLOSIVE EVENT

Science Applications, Inc.
4615 Hawkins Street, NE
Albuquerque, New Mexico 87109

18 December 1981

Technical Report (Project Officers Report)

CONTRACT No. DNA 001-81-C-0140

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Thermal radiation simulation units were developed and fielded on the MILL RACE event. The units released over 1 billion calories of radiant energy at a peak power rate of 1.4×10^9 watts. The units were fired in conjunction with the 600 ton MILL RACE event to produce blast and thermal radiation loadings on a variety of structures.

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PREFACE

We are indebted to Mr. George Harkrider of the Defense Nuclear Agency, Field Command of Albuquerque, NM for his kind assistance in the fielding of the MILL RACE TRS system at the White Sands Missile Range. We are also grateful to Dr. Tom Kennedy, LTC Robert Flory, and LTC Ronald Bousek of the DNA for their assistance in this work.

Summary of Conversion Factors (U.S. to metric units) and Prefixes

To Convert From	To	Multiply By
mils	millimeters	0.0254
inches	centimeters	2.54
feet	meters	0.3048
miles	kilometers	1.6093
square inches	square centimeters	6.4516
square feet	square meters	0.0929
cubic inches	cubic centimeters	16.38706
cubic feet	cubic meters	0.0283
gallons (U.S.)	liters	28.349
pounds	kilograms	0.454
pounds per square inch, psi	newtons per square centimeter	0.6894757
pounds per cubic inch	kilograms per cubic centimeter	27,679.90
pounds per square foot	newtons per square meter	47.88026
inches per second	centimeters per second	2.54
Fahrenheit degrees	Celsius degrees or Kelvins[a]	5/9
kilotons	terajoules (10^{12} Joules)	4.183

1 Pa = 1 N/m^2

1 Bar = 10^5 Pa = 14.5 psi

1 psi = 6.9 KPa

1 g = acceleration of gravity = 32 F/S^2 = 9.8 m/s^2

Prefixes:

G = 10^9 = giga   M = 10^6 = mega

K = 10^3 = kilo   c = 10^{-2} = centi

μ = 10^{-6} = micro   n = 10^{-9} = nano

[a] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use C = (5/9) (F - 32). To obtain Kelvin (K) readings, use K = (5/9) (F - 32) + 273.15.

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SECTION I
INTRODUCTION AND SUMMARY

During February of 1981 Science Applications, Inc. (SAI) was funded by the Defense Nuclear Agency (DNA) under contract number DNA001-81-C-0140 to construct five (5) four-nozzle thermal radiation simulators (TRS) and to modify an existing TRS unit. The units were to be fielded on the MILL RACE high explosive event to simulate nuclear weapon thermal radiation loadings on structures.

The TRS units were constructed and field tested during the late spring and early summer of 1981. Over 50 cold and hot tests of the units were conducted during the period. The units were installed at the MILL RACE test bed during August of 1981 and were fired on every major dry run of the event. Three of the units functioned flawlessly on the MILL RACE event. The UK-1 TRS, composed of two four-nozzle units, suffered mechanical problems during the event and produced only 75% of the anticipated thermal radiation. This paper describes the construction, field testing, and performance of the MILL RACE TRS units.

SECTION II
TRS CONSTRUCTION

Background

The general TRS structure that was built for the MILL RACE event contained a single liquid oxygen (LOX) tank, two aluminum (Al) powder tanks and four burners. The substructures on each unit were inter-connected by over 5,000 individual components, nearly 1 Km of high and low pressure tubing, and an equivalent length of electrical cable. In order to properly address the construction of a TRS unit, each system is described separately in this report. A general discussion of the overall construction process is also presented.

General

TRS construction began on 1 March 1981. On this date nearly $100,000 worth of small parts were ordered to begin construction of the MILL RACE TRS units. Major component delivery schedules were formulated for vendors who had been solicited to place bids for key portions of the TRS units. Materials were to arrive on a schedule that permitted the completion of one unit per week after June 15, 1981.

Electronic subsystem designs also began on March 1. Included among these were designs for: the LOX level and LOX pressure sensing units; N_2 pressure sensing units in the Al and N_2 systems, ignition systems for each TRS burner, position switches for each critical valve, flame sensing devices for the TRS ignition system, and pre-amplifier systems for all low-level sensors.

Because only six months were allowed between the beginning of the TRS construction program and the detonation of the MILL RACE event, a crash program was required to produce the units. Frame construction was begun immediately after the "start work" for the project had been given. Three thousand pounds of steel tubing and 17,000 pounds of steel deck material were purchased for the assembly of the five units. Construction of the frames required the combined efforts of six men working for 12 weeks to finish the effort. Concurrent with the frame construction, hundreds of small plumbing fittings were assembled prior to final installation in the TRS frames. Major subcomponents, such as the LOX and Al tanks, were assembled and proof-tested as they arrived from the manufacturer. Once frame construction was complete, final mechanical and hydraulic assembly of the units was begun. Five men working over a period of two months assembled the TRS units. Concurrent with the mechanical and hydraulic assembly, the electronic assembly was completed. Electronic parts were fabricated at both the Las Vegas, Nevada and Albuquerque, New Mexico offices of SAI. These parts were examined and installed on all units by two men working for approximately two months. The first TRS unit was completed and pressure tested in June of 1981. Figure 1 is a schematic of the TRS unit. Construction on the fifth TRS was completed by August. The reconstructed TRS that was not fielded in the MILL RACE event was finished on December 15, 1981.

LOX Subsystem

The LOX subsystem of the TRS consists of four basic components. They are: the LOX tank; the LOX venting system, the LOX mixer nozzle; and the interconnecting LOX flow control plumbing. Each component is described in greater detail in subsequent sections of this chapter.

The LOX tank on each TRS unit has a nominal volume of 170 liters. The tank is constructed in two sections. The inner tank is a polished stainless steel 170-liter container that has been pressure tested to 350 psi. A second container, made of carbon steel, surrounds the inner shell. Perlite insulation has been poured into the void between the inner and outer tanks. Fittings into the tank allow: the tank to be filled with LOX, the pressure and LOX level inside the tank to be measured; the tank to be pressurized to 250 psi; and the LOX to be delivered from the tank to the TRS at a rate of 50 liters per second. The loss rate of LOX from the tank due to evaporation is approximately three liters per hour.

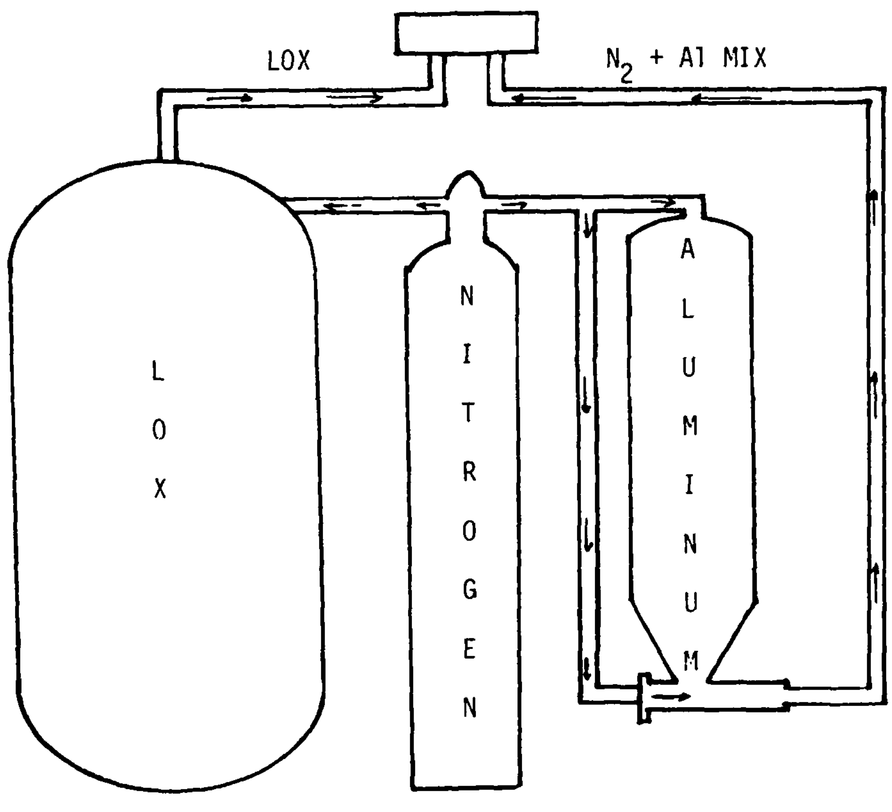


FIGURE 1. LOX TRS SCHEMATIC.

The LOX venting system provides a pathway for evaporating oxygen to be vented from the TRS. Left unvented, the LOX system would build up pressure as great as 10,000 psi. The LOX venting system provides a controlled pathway for evaporated oxygen to leave the TRS. When the TRS is activated in preparation for a test burn, the LOX tank vent is closed by pneumatically activated valves. This permits the tank to be pressurized to its full operating pressure. When electrical power is terminated to the TRS, the LOX vent valve opens, allowing pressure in the tank to be vented.

When LOX flow is initiated in the TRS, it eventually empties into the LOX mixer nozzle. In this nozzle LOX and Al powder are mixed and forced past the TRS burner assembly. The mixer nozzle is made of brass and consists of an entrance hole for Al powder, an exit hole for LOX and Al, and four jets for LOX to enter the system. Each jet has a variable orfice which is positioned so that all four streams intersect at a point 2 centimeters above the mixer. Aluminum coming into the mixer is impinged upon by LOX at four positions. The combined momentums of the LOX and Al streams carry the highly energetic mixture from the LOX mixer nozzle at a velocity of about 30 m/sec.

LOX flow from the LOX tank and to the LOX mixer nozzle is regulated by the LOX flow control plumbing. LOX leaves the tank and is subdivided into four lines at a stainless steel header. From the header each line delivers LOX towards a specific TRS burner. In the line to the burner is a specially constructed pneumatically actuated ball valve. This valve stops LOX flow when the TRS is not activated. When activated, the ball valve is opened and LOX flows towards the mixer nozzle. At the mixer nozzle LOX is again subdivided into four lines, each feeding one jet of the mixer nozzle. When electrical power is removed from the TRS, the pneumatically activated LOX flow control valves close and stop LOX flow.

Al Subsystem

The aluminum powder subsystem is composed of four sections: the venting and pressurization section; the tank and fluidization section; the flow control valve; and the acceleration and flow delivery section.

The venting and pressurization section of the aluminum powder system provides a mechanism to control pressure in the aluminum powder tank of the TRS. When the TRS system is activated, the vent to the tank is closed by a pneumatically actuated ball valve. The tank is then pressurized through two lines. The first line passes N_2 gas into fluidizer tubes located on the interior of the Al tank, the second line passes N_2 gas, at 10 psi less than the fluidizer line, into the top of the Al tank to bring it up to operating pressure. When electrical power is removed from the TRS, the Al vent opens, depressurizing the Al tank.

The tank and fluidization section of the TRS stores 30 Kg of Al powder. The tank services 2 burner nozzles and has been tested to an operating pressure of 150 psi. The tank has been specially designed to allow the flow of fluidized aluminum powder downwards to the flow control valve. Aluminum is fluidized in the tanks interior by bubbling N_2 gas through long tubes into the aluminum powder. The bubbling gas and 100 psi pressure in the tank allows the Al powder to flow easily through the Al flow control valve.

The Al flow control valve is the heart of the Al subsystem. This valve regulates the flow of aluminum powder by means of a needle-shaped plunger. The valve is specially designed to eliminate clogging and friction in its internal mechanisms. The flow control valve permits a linear increase in Al flow by linear adjustments to its stroke. With a tank pressure of 100 psi, it is capable of passing 16 Kg of Al powder per second.

The final section of the Al flow system is the acceleration and flow delivery unit. As aluminum powder exits the flow control valve, it enters a low pressure chamber. The pressure drop is created by a gas acceleration nozzle operating at 300 psi and delivering N_2 gas into the Al flow system at Mach 2. Gas from the Al tank expands, pushing the Al powder into the high speed N_2 stream. The aluminum powder is accelerated in the stream and, about 30 cm from the accelerating nozzle, is divided into two streams of equal mass. Each stream proceeds to a different LOX mixer nozzle and burner assembly.

A pressure sensor located near the accelerating nozzle measures pressure in the Al accelerator. If the pressure is below a critical threshold value, the sensor will not allow the plunger on the Al flow control valve to be activated. This feature of the unit is provided to prohibit the potential mixing of LOX and Al in the accelerator which can lead to disastrous results. By requiring a high pressure in the accelerator section of the TRS, all LOX in the Al delivery line is swept out before Al flow can start.

Nitrogen Subsystem

The nitrogen subsystem of the TRS performs all work in the unit. This subsystem is responsible for opening and closing all remote valves and driving LOX and Al to the mixer nozzle. N_2 gas is stored in four high-pressure bottles at 2,000 psi. The bottles were refitted with 2.5 cm orfices to allow high flow rates of N_2 gas when the TRS is activated. The gas is regulated to lower pressure at 7 points in the system. From these points it feeds the pneumatic valves, LOX flow system, and Al system of the TRS. Nearly 500 meters of copper and high-pressure plumbing are used on the TRS interior to conduct the gas through the unit.

Electrical Subsystem

The electrical subsystem of the TRS provides two functions: control of the unit, and monitoring of key elements of the TRS. The control function of the electrical system is three-fold. It provides power to solenoid valves which allow N_2 gas to flow to the pneumatically actuated valves that control the TRS. It provides power to solenoid valves which allow propane and O_2 gas to flow to the burner. Finally, it provides power to the electrical ignition system which in turn provides a spark to ignite the propane gas.

Key elements of the TRS unit are monitored in the electrical subsystem. Valve positions are monitored with position sensing switches. Pressure in the LOX tank, Al tank, and N_2 system are measured with pressure transducers. A manometer to sense LOX level and flame sensors to detect ignition at the TRS burner are also parts of this subsystem. The electrical function of the TRS are controlled at each unit by switching panels, amplifier circuitry and a 24-volt battery. Nearly 1 Km of wire was used to electrically connect all components of each TRS.

SECTION III
TRS TESTING

General

Once constructed, each TRS unit was examined in a five-step testing program. In the program, the unit was pressure and electrically tested in the laboratory. Once these tests were passed, Al flow tests were conducted in the lab. Upon completion of the laboratory tests, the unit was taken to the DNA TRS research site at Kirtland Air Force Base (KAFB). At KAFB the unit was examined for LOX flow characteristics, mixed cold flow characteristics, and finally for burn characteristics. Modifications of pressure settings and TRS structure were made to insure optimal heat output of each unit. Succeeding sections describe the test procedure in greater detail.

Laboratory Testing

When each unit had been constructed, it was submitted to a rigorous series of pressure tests. Manifolds connecting the high pressure tanks to regulators and actuator lines were properly fitted and tested to insure that there would be less than a 50 psi drop in pressure from 2000 psi over a period of 24 hours. The LOX system was pressure tested to insure that less than a 50 psi drop in pressure from 2000 psi would be incurred over a period of 1 hour. The Al system was pressure tested to insure that less than a 50 psi drop in pressure from 2000 psi would be incurred over a period of 30 minutes.

When a unit had passed the pressure inspection phase of the test program, it was submitted to an equally rigorous electrical inspection. All circuitry was tested in the laboratory to insure that every TRS function performed as anticipated. No unit was released for further tests until all electrical components performed perfectly when used in their firing sequence.

Aluminum flow testing was conducted in SAI's Albuquerque laboratory. Each Al tank was loaded separately with aluminum powder. Devices to catch the powder were placed over each nozzle that was serviced by the Al tank being tested. The aluminum firing sequence was initiated and aluminum powder was permitted to flow for 2 seconds. The amount of aluminum powder that was delivered to each nozzle was weighed. Using this procedure, the aluminum flow valve was adjusted until the total amount of aluminum delivered as a combined weight to the two collectors from a 2-second valve opening was equal to 20 $\pm$ 0.1 Kg. When this reading had been repeated on three consecutive trials, the valve position was marked and locked into place. Upon completion of the valve setting tests, flow diversion tests were begun. Collectors were again placed over each nozzle serviced by a given Al tank. The aluminum powder delivered to each collector by a 2-second Al flow valve opening was weighed. The amount of powder in each collector was compared. Adjustments in the alignment of the high speed accelerator cone and Al flow splitter were made until the flow to each nozzle was 10 $\pm$ 0.2 Kg during the test period.

Field Testing

Field testing of the MILL RACE units prior to the shipping of the units to the White Sands Missile Range (WSMR) was subdivided into four parts. They were: cold flow tests of LOX, cold mixed phase flow tests of LOX and Al; burn tests of individual units, and burn tests of all TRS units fired in a sequence similar to the MILL RACE event. Subsequent paragraphs describe each testing sequence in more detail.

LOX cold flow tests were performed to study the flow characteristics and flow rate of each LOX nozzle. During the tests three key parameters were studied. They were: the pressurization time of each LOX tank, the time lag between the initiation of LOX flow and the beginning of stable LOX flow, and the flow rate of LOX from the mixer nozzles after stable flow was established.

The LOX pressurization time was studied by simply setting a pressure input value on the LOX flow regulator, measuring the LOX volume in the LOX tank, and opening the LOX pressurization valve. The interval between the start of nitrogen flow and the time at which the tank reached full pressure was recorded with a stopwatch. The goal in measuring this interval was to determine the minimum amount of time that was required to pressurize the tank prior to the initiation of a TRS burn.

The time lag between LOX flow initiation and the establishment of a stable flow condition is a critical value which must be accounted for if a TRS is to be run at its peak performance level. Unstable flow at the LOX mixer can radically degrade the output of the TRS. The time lag between the start and stabilization of LOX flow can be attributed to the formation of a vapor lock in the LOX line. As LOX begins to flow from the LOX tank, it encounters pipes which have temperatures that are very close to the ambient air temperature in the TRS test area. As it flows through these pipes, the LOX begins to boil. O_2 gas begins to fill the pipes in front of the LOX and build pressure. The flow restriction orfice in the LOX mixer nozzle also restricts the exit of O_2 gas from the system. As the O_2 gas builds in pressure behind the flow restriction orfice, it eventually exceeds the LOX driving pressure and stops LOX flow. LOX flow is halted until the pressure of O_2 gas falls below the LOX tank pressure and LOX flow begins again. This cycle is repeated until the LOX flow pipes have been cooled to a point where the O_2 gas generated by boiling will no longer restrict flow. LOX flow from the TRS becomes stable at that time. The time lag is therefore dependent upon the driving pressure of the LOX tank, the diameter of the LOX jets at the mixer nozzle, the length of pipe connecting the tank to the mixer, and the ambient air temperature. Several tests of each unit were run in order to properly adjust the time lag to appropriate lengths for the MILL RACE test. During the trials, conducted at varying ambient temperatures, LOX driver pressures and orfice sizes were adjusted until a suitable mix of variables were obtained to permit a LOX flow stabilization time of less than 10 seconds.

Mixed phase flow tests of LOX and Al were conducted for each unit to examine the appox:mate homogeneity of the TRS plume. Video tapes of cold plumes were examined for qualitative estimates of proper mixing. All plumes seemed to mix well within the system. Plume heights were measured to insure that sufficient velocities of LOX and Al were being obtained during a TRS burn to produce a flame that was 5 to 7 meters in height.

Once all flow parameters had been adjusted for each TRS during cold flow tests, a series of burn tests were run for each unit. The TRS that was developed for the Ballistics Research Laboratory had nozzle spacings of 3.5 feet. Nozzles on the Navy TRS were spaced 10.5 feet from one another. All United Kingdom TRS units had nozzle spacings of 7 feet. During each burn test, video tapes were made and flux data from 9 calorimeter positions near the TRS were recorded. Data generated on each test can be found in Appendix A. Flux data and video records were used to adjust the ignition and LOX flow system of each TRS to maximize its output. Flux records from these tests were also used to adjust TRS start times and burn durations for the MILL RACE event.

Upon completion of the individual burn tests for each unit, all units were placed in tandem for a complete test of the TRS hardware as it would be used on the MILL RACE event. Appropriate timing sequences were placed into the timing and firing units to duplicate the time spacings that would be used on the MILL RACE test. Two warm tests, burn tests of the TRS units using only 500 gms of Al powder per nozzle, were conducted to examine time sequencing between the units. When proper sequencing had been assured, the TRS units were fired in tandem using the hardware, procedures, and timing that was to be used on the MILL RACE event. All units functioned flawlessly. Figure 2 is a photograph of the 20-nozzle TRS checkout test conducted at Kirtland Air Force Base on August 6, 1981.

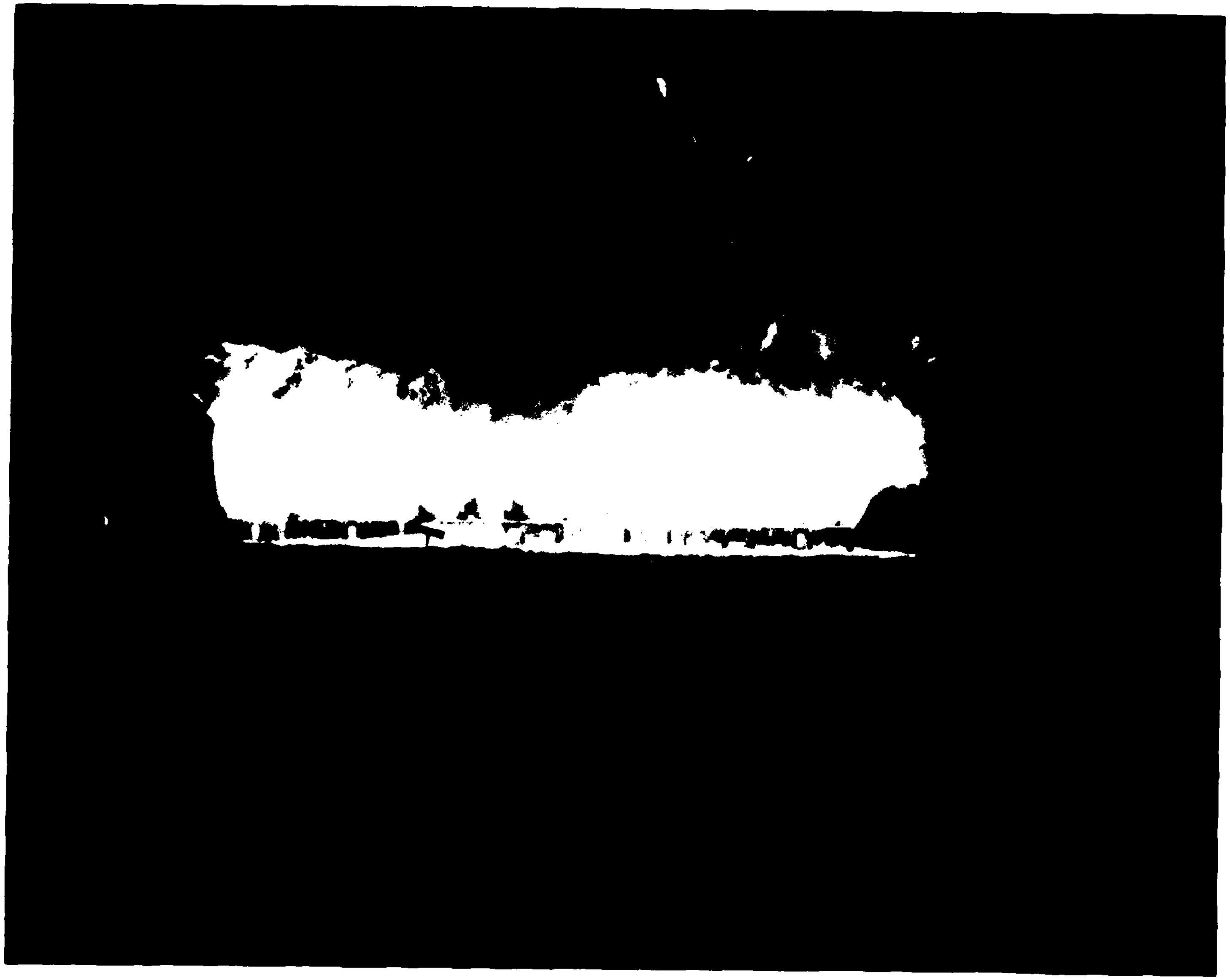


FIGURE 2. 20 NOZZLE TANDEM TEST ON AUGUST 6, 1981 AT KIRTLAND AFB.

SECTION IV
TRS FIELDING AT MILL RACE

General

Upon completion of the full scale tandem hot test at KAFB, all units were disconnected from the LOX and N_2 supplies and were shipped to the MILL RACE test bed. The instrumentation trailer was secured and also shipped to WSMR. The TRS units arrived at MILL RACE on August 7, 1981. Engineering problems concerning the N_2 gas supply, audio-visual communications system, electronic monitoring system, and pit construction, were solved during the two week period between the TRS arrival date and the first FPFF dry run of August. Warm tests of the TRS were performed on all major dry runs of the MILL RACE event. On September 16, the TRS units were fired in conjunction with the MILL RACE high explosive event concluding an intensive 7-month effort with the largest synergistic blast and thermal radiation simulation event ever con structed. Succeeding paragraphs describe the fielding and performance of the TRS units on the MILL RACE event in greater detail.

Installation of TRS Units

Pits, based roughly on a design submitted by SAI to DNA, had been constructed from concrete and were almost ready for installation of the TRS units when the units arrived on the MILL RACE test bed. Because the pits had a slight slope on the floor to allow water to flow to one end after a rain storm, the TRS units had to be mounted on wooden cross-members. These cross-members assisted in leveling the nozzle plane with the plane of the test bed. The form of bracing, however, proved to be less than desirable when surveyed after the detonation of the MILL RACE event. Some damage to units caused by the blast wave of the explosion could have been prevented if the units had been placed directly onto the concrete floor.

The nitrogen system that was designed by SAI for MILL RACE was changed by DNA field command just prior to fielding of the TRS units. The system of interconnecting plumbing between TRS pits that was designed by SAI would have eliminated several man-hours of time spent delivering N_2 gas from one TRS pit to another. The system which was used on MILL RACE, driving from one pit to another with N_2 gas, was not overly inconvenient and did perhaps save some labor dollars and time by eliminating trenching between pits.

Video Monitoring System

After some difficulties in locating positions on the test bed that were acceptable for video cameras, three video cameras were installed near the TRS units for diagnostic studies during dry runs and the MILL RACE event. The cameras were placed in steel containers at the 7 and 3 psi blast ranges from the high explosive stack. Each camera had a 12-volt battery for power. The video signal from the camera was sent via a 6000-foot fiber optic link to the instrumentation trailer park. At the trailer park video recording units stored the video signal on tape for immediate playback after the event. Real-time monitors were installed in the trailer to permit examination of the TRS area before, during, and after each TRS test. The JVC camera used on the test series required some modification prior to its use in the field. These problems were resolved before the last dry run and all cameras performed well during the MILL RACE event.

Electronic TRS Monitoring System

During the TRS construction program it was hoped that a computerized control unit, also designed by SAI, would be completed and tested during dry runs prior to the shipment of TRS units from KAFB to WSMR. Because the control unit suffered some construction set backs, it was not fielded on the MILL RACE event. In its place, the timing and firing unit used at KAFB to control earlier TRS firings was modified and fielded on the MILL RACE event.

This timing and firing unit differed from the computerized control unit in several ways. The computer unit permitted the reprogramming of various TRS functions without rewiring. The computer monitored several transducers on each TRS and provided a continuous status update on each unit. Signals from the TRS were to be digitized by a computer link near the TRS and transmitted over a single fiber optic link from the test bed to the recording trailer. Unfortunately, the computerized unit could not be fielded on the event and a simpler timing machine was used to fire the TRS units. In order to use the simpler unit, the transducers located on each TRS were reorganized to accomodate the limited number of data channels which could be transmitted over the available cables that ran from the test bed to the instrumentation trailer park. Gauges were mounted in the recording trailer to monitor the pressure of N_2 gas in the TRS LOX tanks and the presence of flames at each TRS nozzle. These two readings provided verification that the vent valves on each TRS unit had closed, that N_2 gas was pressurizing the system, and that the ignition sequence for each nozzle had been completed. Video pictures from the cameras mounted near each TRS also provided visual confirmation of burner ignition, LOX flow, and TRS ignition.

Switching systems for closing vents, pressurizing the LOX and Al tanks, and igniting the burners on each unit were rewired from a system designed for computer control to a manual control configuration. Although the electronic reconfiguration of the units required several additional man-weeks of labor, the modified firing system was operable before the first major dry run of the MILL RACE program. All systems performed well on every dry run and the final event of the MILL RACE test.

TRS Dry Runs

Five dry runs of the TRS system were conducted prior to the MILL RACE event. On each dry run, "warm" firings of all units were performed. The units were pressurized with nitrogen, partially loaded (1 lb. per nozzle) with aluminum powder, and loaded with LOX on a count down schedule which approximated the anticipated count down procedure for the MILL RACE event. In every case each TRS unit performed flawlessly. Ignition, LOX flow, and firing of each TRS was completed on time and in the desired time sequence. Even last minute changes in the timing sequence of the Navy TRS to lower the fluence at the test area were accomodated without problems and were verified during the final TRS dry run. The final time sequence on this dry run and on the MILL RACE event can be found in Appendix B. Prior to the MILL RACE event, the entire TRS system had been fully operational for four weeks and had functioned flawlessly on five dry runs.

SECTION V
MILL RACE

General

The MILL RACE event was fired at 12:36 p.m. on September 16, 1981. By the time the blast wave from the HE charge reached the thermal radiation targets, the last bit of smoke from each TRS was beginning to clear. Timing between the TRS firings and the HE detonation had been perfect. During the five seconds prior to the HE detonation, the TRS units had released over 1 billion calories of radiant energy with a continuous power output that was greater than even large nuclear reactors. Three of the five units functioned flawlessly, producing an intense thermal radiation pulse upon targets in their vicinity. The UK-1 two-unit TRS malfunctioned and produced only 75% of its peak power. Subsequent paragraphs describe the TRS portion of the MILL RACE event and the performance of the TRS units on the test.

Event Preparation

On September 15, 1981, the day prior to the MILL RACE event, all functions of the TRS units were completely cycled both manually and remotely from the control trailer. The units received their final nitrogen pressurization and were loaded with aluminum powder. SAI crews arrived on the test bed at 2:30 a.m. the morning of September 16, 1981, and began the final preparation of the TRS units for the MILL RACE event. All TRS functions, except Al flow, were cycled from the control trailer and were verified in each TRS pit. At 5:00 a.m. LOX fill began and was completed by 7:00 a.m. After a final verification that all switches were in their proper positions and that the TRS units were 100% operational, the last entrance ports to the units were sealed. Video cameras were connected to their power supplies and the MILL RACE ground zero was cleared. SAI crews returned to stations at the recording trailer park and the administration offices in anticipation of a 10:00 a.m. detonation of the MILL RACE event.

The Event

Problems with the drone aircraft that were to fly near the test area delayed the test until 12:30 p.m. After a hold at minus three minutes to allow proper positioning of the drone aircraft, the count down was resumed. TRS burners were ignited during the T-3 minutes to T-2.5 minutes period following resumption of the countdown. Vents to the TRS units were closed in the T-2.5 minutes to T-2 minutes time period. At T-30 seconds, a closure from the MILL RACE timing and firing unit to the TRS firing unit began the final time sequencing of the TRS units. A table of the TRS functions and their time sequences can be found in Table 1. All TRS functions progressed as anticipated with the ignition of the first TRS, the Navy TRS, at T-4.7 seconds. Other units ignited properly and burned for their allotted time. By T-1 second, all TRS units had been fired and extinguished, residual aluminum powder was burning out, and the TRS smoke and debris were beginning to clear. The blast wave from the HE charge arrived at the 7 psi TRS units approximately 0.5 seconds after detonation and at the 3 psi TRS approximately 0.6 seconds later. Vents were opened and burner flames extinguished at T+7 seconds. Appendix B provides a detailed list of these countdown sequences which were followed on the MILL RACE event. Appendix C provides the calorimeter data recorded as TRS diagnostics for each unit. After a short period of time, SAI and DNA safety personnel re-entered the ground zero area. Damaged TRS units were examined to determine if they presented hazards to re-entry. All units were disarmed, vented, and made harmless within 10 minutes after re-entry.

TRS Damage

All TRS units fielded on the MILL RACE event suffered some form of damage. Damage was primarily caused by overpressure loadings on the deck of the TRS unit. Decks of the units were accelerated downward, bending support members and plumbing beneath them. Rigid members beneath the deck were impacted and broken. At points where the TRS was positioned above the concrete pit floor by wooden support members, vertical support members were forced below the

TABLE 1. TIMING AND FIRING SEQUENCE FOR MILL RACE

Time (sec)	Function
T-30	Start sequence counter Pressurize tanks
T-13.3	Start NAVY LOX flow nozzles A + D
T-10.3	Start NAVY LOX flow nozzles B + C
T-8.4	Start UK-1 LOX flow
T-7.9	Start UK-2 LOX flow
T-7.8	Start BRL LOX flow
T-4.7	Start NAVY Al flow
T-3.4	Start UK-1 Al flow
T-2.9	Start UK-2 Al flow
T-2.8	Start BRL Al flow
T-2.3	NAVY OFF
T-1.9	UK-2 OFF
T-1.7	BRL OFF
T-1.4	UK-1 OFF

TRS base. Horizontal members of the support frame were also bent. In general, most damage to the units was incurred in the plumbing and support structure segments of the TRS. Major components such as the LOX tank and AL tanks were undamaged. A serious failure occurred in the vent system of the Navy TRS unit. The venting system of the LOX tank was designed to be pneumatically opened and closed in order to allow the tank to vent if an electrical power failure occurred. The pneumatic system, however, required nitrogen pressure to open the LOX vent valve. During the MILL RACE event, the nitrogen supply lines were broken and nitrogen in the system was vented before the LOX vent valve could be opened. When the command was given to vent the LOX tank, the vent valve could not be opened and pressure began to build from boiling LOX in the tank. Fortunately, a serious pressure build-up could not occur in the tank. The LOX fill cap began venting LOX and oxygen. This kept the pressure in the LOX tank at about 200 psi. In addition, a 300-psi rupture disc had been incorporated into the tank to prevent an explosive build-up of LOX gas. Because the tank pressure was only 200 psi, the disc did not rupture and the tank was not harmed. New TRS units incorporate a spring return mechanism which returns the LOX vent valve to the open position without N_2 gas.

Two nozzles of the UK-1 unit failed during the experiment due to a failure in the Al flow valve system. The aluminum powder flow valve is opened by a pneumatic actuator. The pneumatic cylinder, in turn, is actuated by an electric solenoid valve. Examination of the solenoid valve after the MILL RACE event indicated that a piece of debris had worked its way into the plunger of the solenoid and had jammed the valve shut. The failure of this valve caused the aluminum flow valve to remain closed and prohibited Al flow to nozzles 3 and 4.

A third nozzle (nozzle 6) on the UK-1 system did not function properly. The propane-oxygen flame which is responsible for ignition of the Al-LOX mixture was somehow extinguished at some time after LOX flow began but before the advent of aluminum powder flow. This prevented ignition of the mixture at the nozzle orfice. The mixture was ignited at a height of about 5' by adjacent burning plumes. Calculations show that this ignition problem did not significantly affect the flux field at the UK-1 targets.

SECTION VI
SUMMARY AND CONCLUSIONS

TRS Construction

Due to the tremendous efforts exerted by several very dedicated employees, SAI was able to construct, field, and fire in seven months a twenty-nozzle TRS system with a power rating greater than most nuclear power plants. During that time, parts for the unit were designed, manufactured, assembled, tested and fielded. Several things were learned about the construction of TRS units during this program, and are described in subsequent paragraphs.

The TRS super-structure fielded on the MILL RACE event was inadequate for blast and thermal testing. Long rectangular structures, if strengthened to withstand a 7 or 10 psi blast wave, would be very heavy and quite unwieldy on blast and thermal tests. New TRS designs have been developed which eliminate the requirement for large TRS structures. The new TRS units have small support modules which carry Al, LOX, and N_2. The fuel and oxidizers are carried through flexible hoses to nozzle units which are 25 cm x 25 cm in width, and 60 cm in length. The support modules are easily strengthened and can readily survive a 10 psi load. The nozzles can be placed in a very small pit or on tripods and are not vulnerable to 10 psi blast loads. All of these units allow for variable nozzle spacings to separation distances as great as 30 feet. We strongly suggest that these smaller, more flexible units be used on all future blast and thermal tests.

Plumbing hardware used on the MILL RACE units was, because of the compressed construction time, chosen because of its immediate availability, not because of its practicality for the work. More recent TRS units incorporate plumbing components which, although more costly, are more suited to the functions of the TRS units and provide a higher safety and reliability rating to the units.

One of the most frequent forms of operational failure experienced with the MILL RACE units was blockage of small gas orfices by debris carried through gas lines. This form of failure was responsible for the poor performance of the UK-1 TRS and for consistent ignition problems with all TRS burners. New TRS systems employ heavily filtered lines to prevent dirt and debris from entering small orfices found in the various components of the TRS system. All electrically activated pneumatic valve actuators on new TRS units are sealed in dust-proof containers to prevent dirt from jamming small sliding parts which control all functions of the TRS units.

A new and more reliable burner system has been added to TRS units constructed since the MILL RACE event. This unit employs three high precision needle valves that control propane and oxygen flow at each burner. The high precision valves allow the TRS burner and flame sensing system to be fine tuned. In addition, the spark ignition system has been replaced with a unit that utilizes conventional spark plugs. The new burner system, recently installed on two TRS units, has functioned flawlessly on over 50 tests and shows no signs of suffering the types of ignition and flame sensing problems encountered on MILL RACE.

TRS Fielding

The great attention paid to detail during the TRS construction and checkout phase of the MILL RACE program aided dramatically in the fielding phase of the program. When the TRS units arrived at WSMR, they were fully functional and required only one week of installation and 1 week of electrical connection time. The design and construction effort that went into the units and control trailer, coupled with the support of key DNA employees, allowed the TRS units to be fired on all dry runs of the MILL RACE event.

The only major improvement that can be suggested for future blast and thermal experimentation is the modification of the TRS monitoring and firing system. TRS units have several functions which should be monitored before, during and after a test. The use of a large number of TRS units on a field experiment will require a computer to provide updates on the system's performance. We suggest that DNA utilize its computer-based TRS control unit on future high explosive events. This unit, which requires the use of only one fiber optic control cable per TRS, will provide a full update capability to the control trailer and will significantly reduce cabling requirements on future tests.

TRS Performance

Flux records for all TRS events can be found in Appendixes A and C. During the testing of the TRS units, it was observed that greater burn efficiencies (calories of radiant energy/gm of Al) were achieved as the TRS nozzle spacings were increased. It is suspected that this performance improvement can be attributed to a reduction in reactant obscuration by TRS burn products. Although close spacings of TRS nozzles appear to be a technique for increasing the flux output of a TRS, research into higher velocity nozzles and nozzle spacings may improve TRS performance by as much as 50 to 100%.

APPENDIX A

FLUX AND FLUENCE DATA FROM TRS CALIBRATION TESTS

Appendix A presents the flux data collected on the calibration series for the MILL RACE event. The position of each calorimeter is given in x, y, z co-ordinates with 0, 0, 0 being the co-ordinate of the nozzle located at the east end of the TRS array at KAFB. Positive x and y co-ordinates run toward the west and south, respectively. Z co-ordinates represent altitude above the nozzle plane. Figure A-1 displays the co-ordinate system that was used.

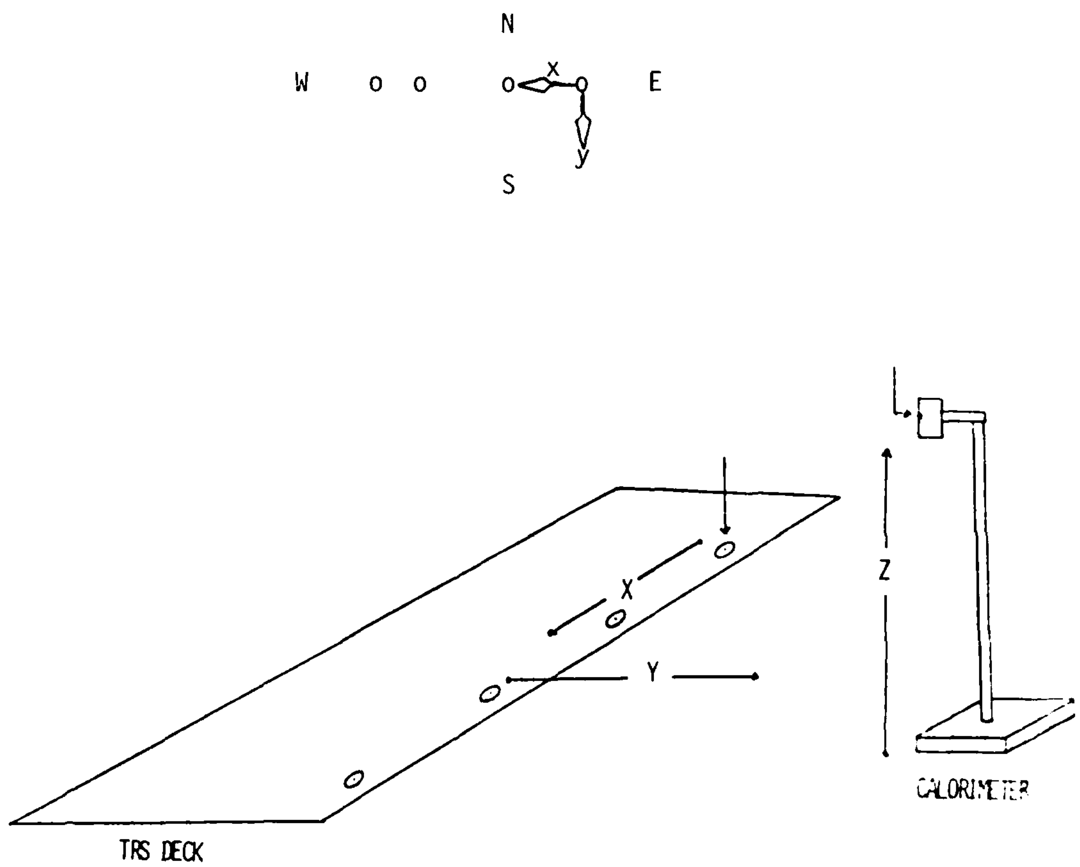


Figure A-1. Flux Gauge Co-ordinate System.

FLUX MAP - BRL TRS

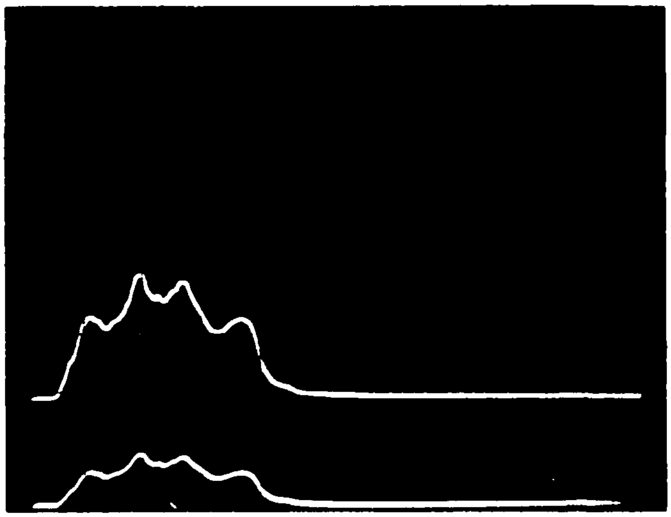
36.8	51.6	38.7
(0,1.83,3.57)	(1.87,1.83,3.57)	(3.74,1.83,3.57)
40.5	52.6	38.5
(0,1.83,2.65)	(1.87,1.83,2.65)	(3.74,1.83,2.65)
43.0	56.5	39.2
(0,1.83,1.72)	(1.87,1.83,1.72)	(3.74,1.83,1.72)

Z ↑

X →

FLUX (cal/cm^2-sec)

x,y,z (meters)



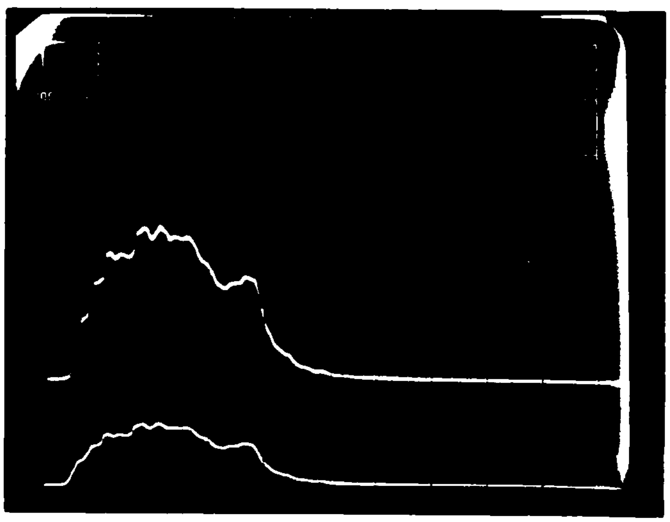
EVENT MRB-4

CALORIMETER 1

LOCATION (x,y,z) (0,1.8,1.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 43.0



EVENT MRB-4

CALORIMETER 2

LOCATION (x,y,z) (0,1.8,2.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 40.5

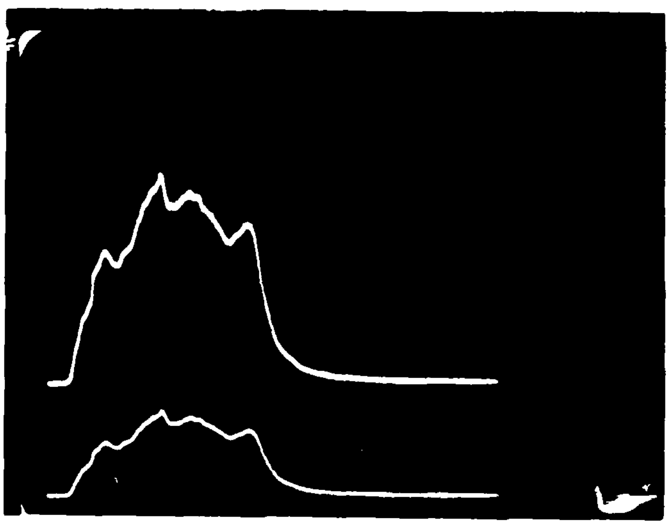
EVENT MRB-4

CALORIMETER 3

LOCATION (x,y,z) (0,1.8,3.6)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 36.8



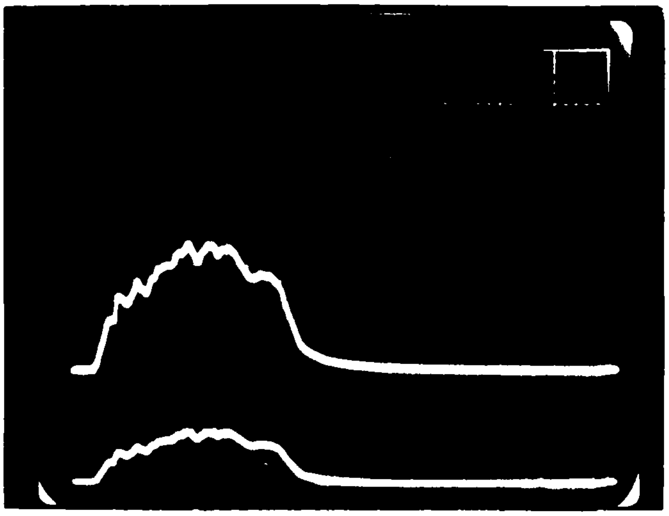
EVENT MRB-4

CALORIMETER 4

LOCATION (x,y,z) (1.9,1.8,2.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 51.6



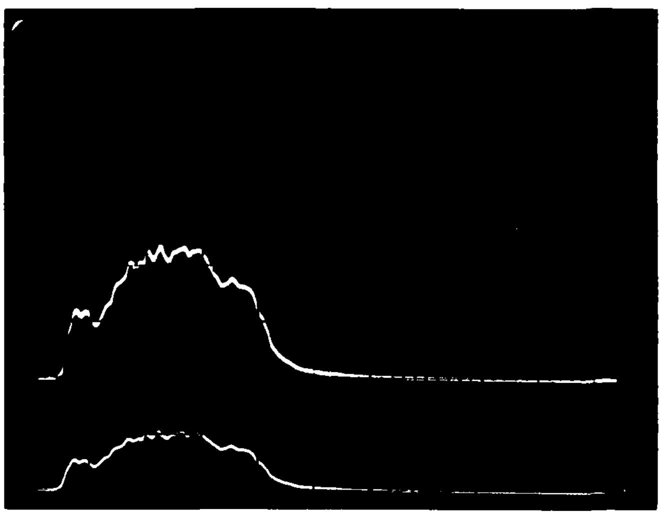
EVENT MRB-4

CALORIMETER 5

LOCATION (x,y,z) (3.7,1.8,3.6)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 38.7



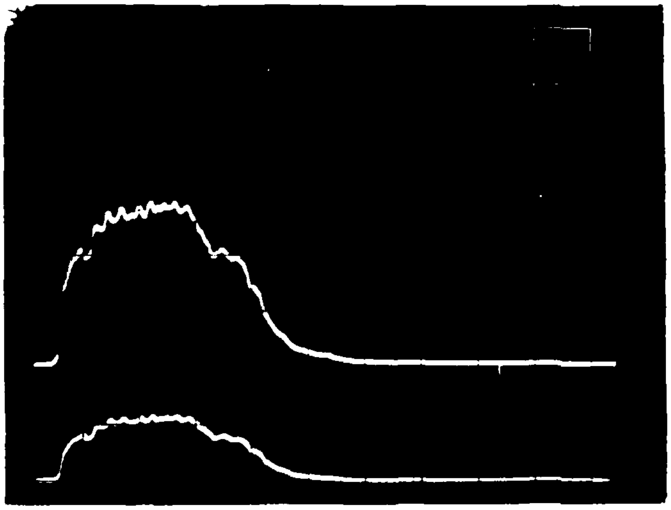
EVENT MRB-4

CALORIMETER 6

LOCATION (x,y,z) (3.7,1.8,2.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 38.5



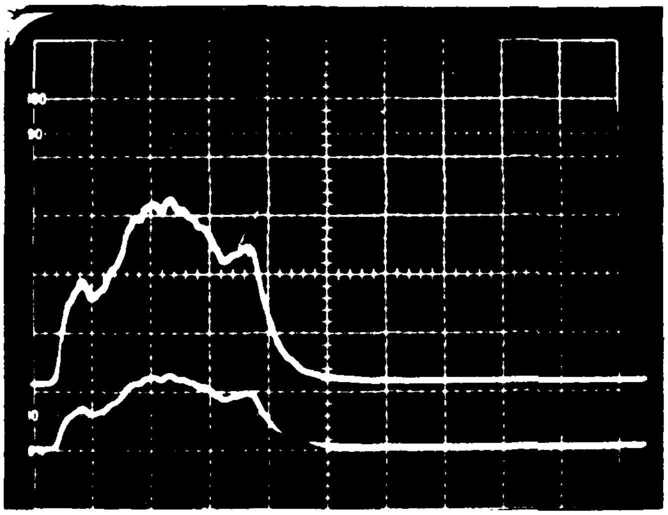
EVENT MRB-4

CALORIMETER 7

LOCATION (x,y,z) (3.7,1.8,1.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 39.2



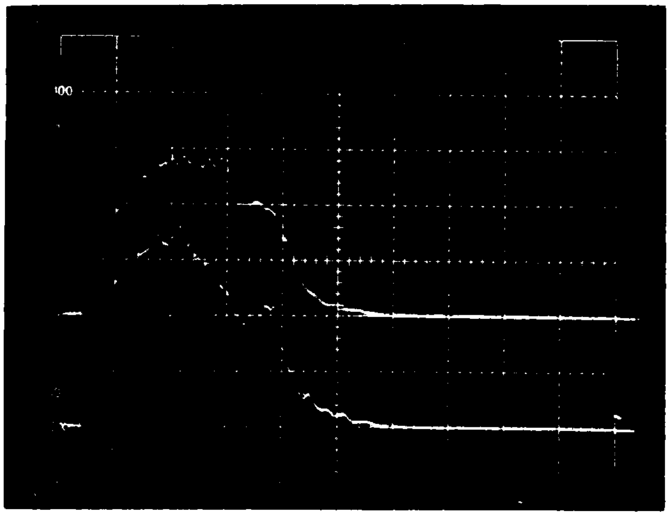
EVENT MRB-4

CALORIMETER FX-1

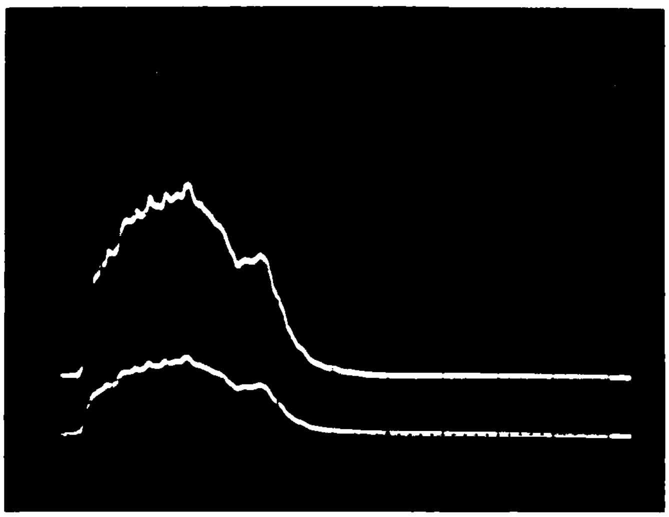
LOCATION (x,y,z) (1.9,1.8,2.7)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 52.6



EVENT	MRB-4
CALORIMETER	FX-2 FX-4
LOCATION (x,y,z)	(5.6,1.8,2.7) (-1.9,1.8,2.7)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	25.7 24.6



EVENT	MRB-4
CALORIMETER	FX-3
LOCATION (x,y,z)	(1.9,1.8,1.7)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	56.5

FLUX MAP - UK-1

x(0,3.0,1.4):26.6

x(2.2,5.9,1.4):17.7

(5.4,3.0,1.4):37.8 x

x(5.4,5.1,1.4):23.3

x(8.6,5.1,1.4):24.7

X↓

x(9.6,3.0,1.4):37.4

(11.9,2.7,1.4):40.6 x

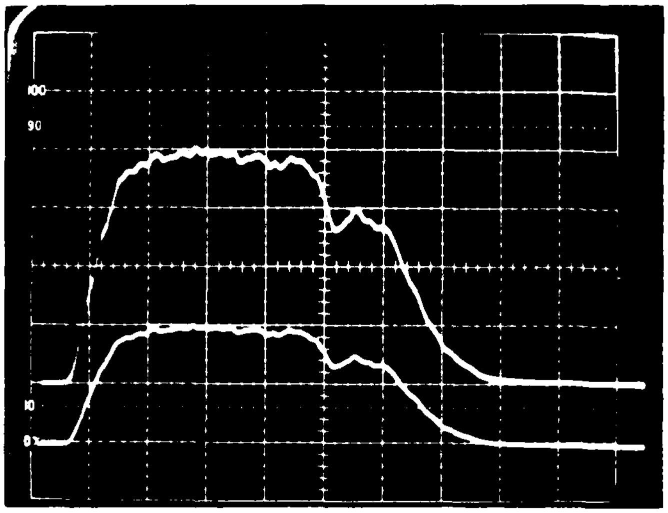
x(11.8,5.9,1.4):19.6

x(13.9,1.83,1.4):40:5

(14.9,3.0,1.4):22.3 x

Y →

.(x,y,z-meters): FLUX



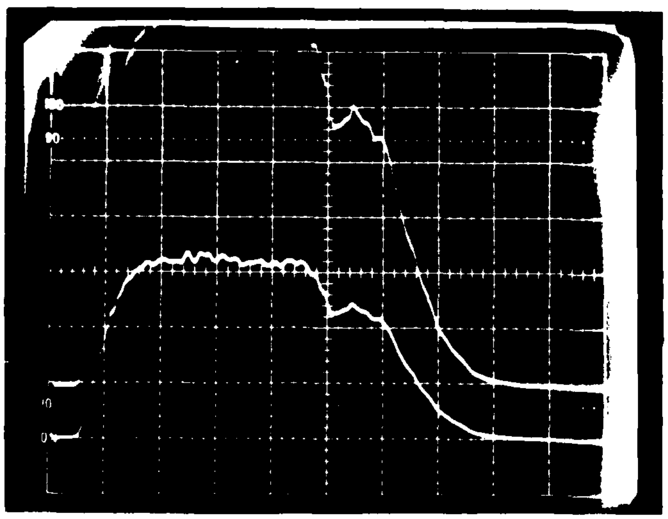
EVENT MRUKID

CALORIMETER 1

LOCATION (x,y,z) 2.2,5.9,1.4

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 17.7



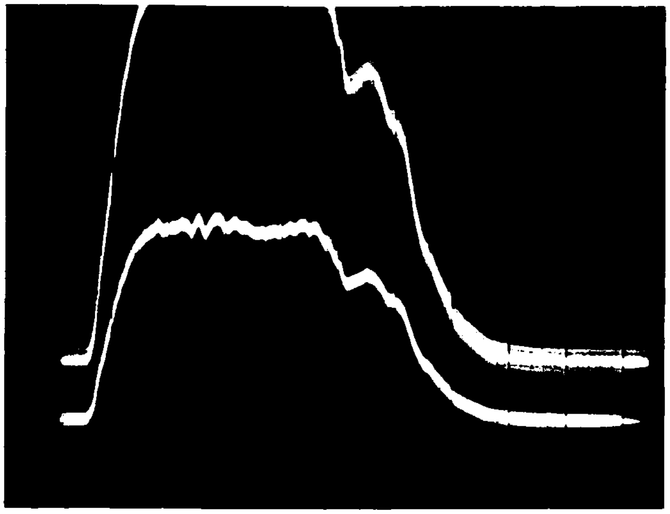
EVENT MRUKID

CALORIMETER 2

LOCATION (x,y,z) (5.4,5.1,1.4)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 23.3



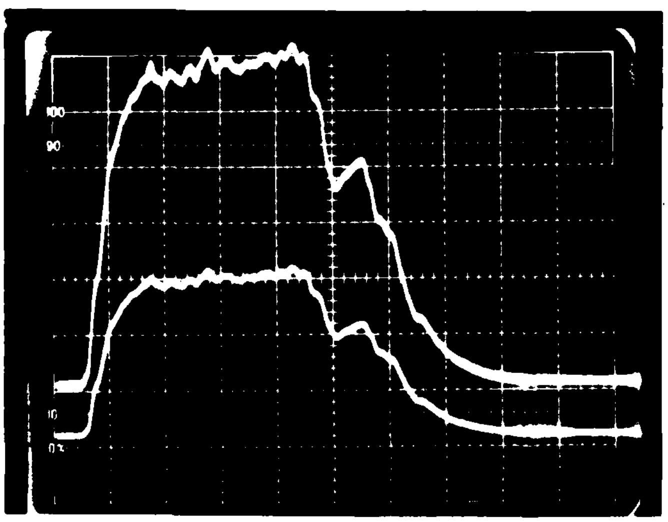
EVENT MRUKID

CALORIMETER 3

LOCATION (x,y,z) (8.6,5.1,1.4)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 24.7



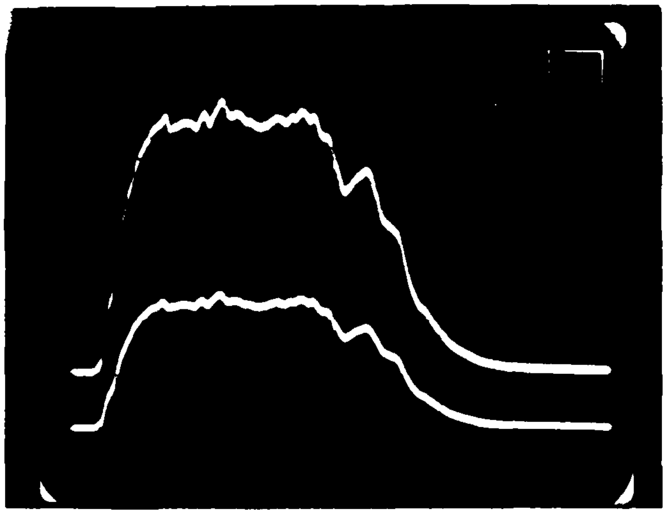
EVENT MRUKID

CALORIMETER 4

LOCATION (x,y,z) (11.9,2.7,1.4)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 40.6



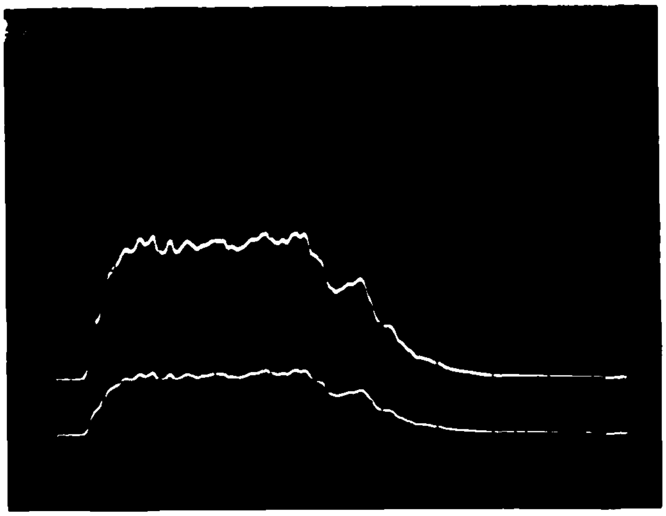
EVENT MRUKID

CALORIMETER 5

LOCATION (x,y,z) (11.8,5.9,1.4)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 19.6



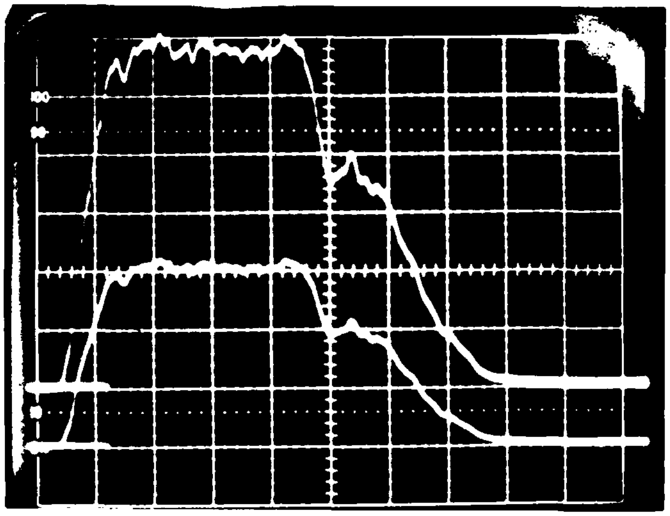
EVENT MRUKID

CALORIMETER 6

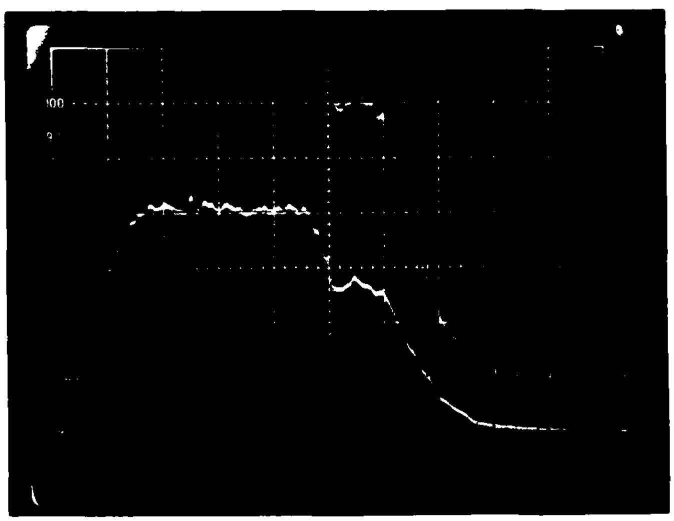
LOCATION (x,y,z) (13.9,1.83,1.4)

TIME SWEEP RATE 0.5 sec/div

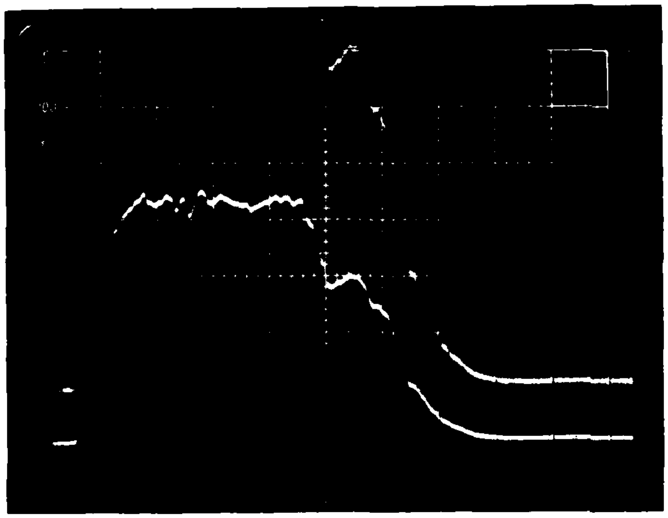
PEAK FLUX 40.5



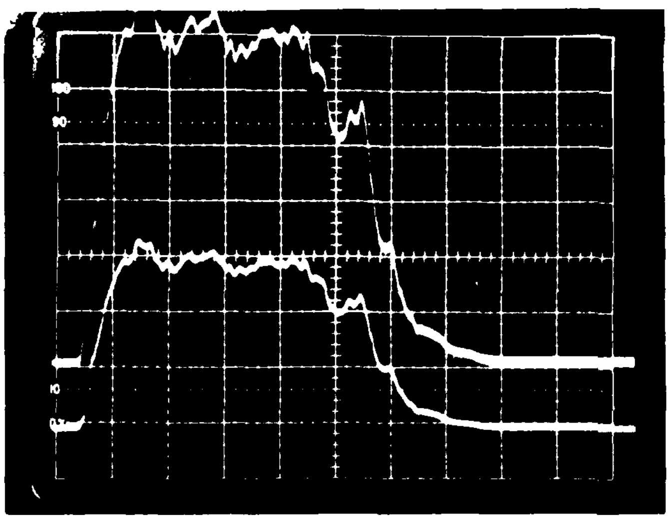
EVENT	MRUKID
CALORIMETER	FX-1
LOCATION (x,y,z)	(0,3.0,1.4)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	26.6



EVENT	MRUKID
CALORIMETER	FX-2
LOCATION (x,y,z)	(0.4,3.0,1.4)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	37.8



EVENT	MRUKID
CALORIMETER	FX-3
LOCATION (x,y,z)	(9.6,3.0,1.4)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	37.4



EVENT	MRUKID
CALORIMETER	FX-4
LOCATION (x,y,z)	(14.9,3.0,1.4)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	22.3

FLUX MAP - UK-2

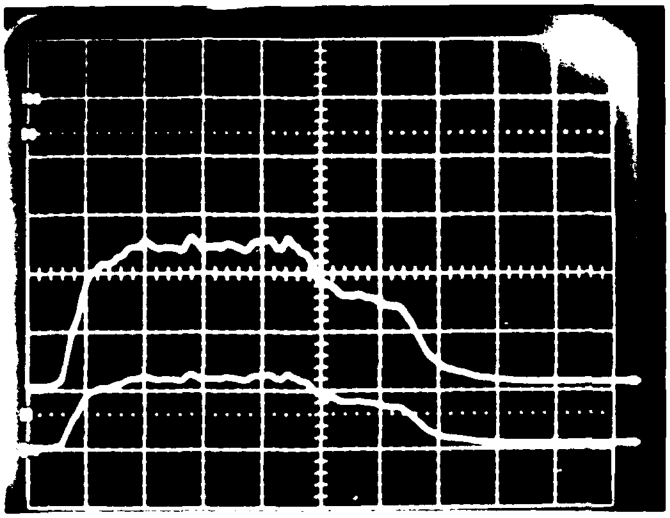
25.4 (0,2.74,3.35)	33.4 (2.13,2.74,3.35)	33.3 (4.27,2.74,3.35)	
27.2 (0,2.74,2.29)	31.3 (2.13,2.74,2.29)	30.8 (4.27,2.74,2.29)	23.1 (6.40,2.74,2.29)
21.8 (0,2.74,1.22)	29.2 (2.13,2.74,1.22)	26.7 (4.27,2.74,1.22)	19.6 (6.40,2.74,1.22)

Z ↑

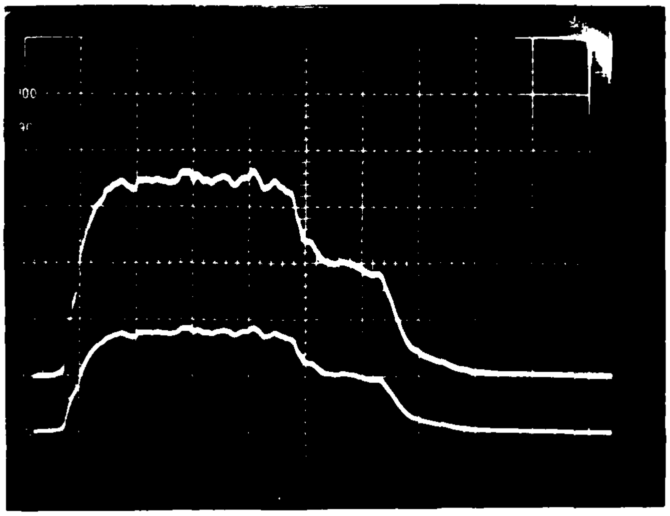
X →

FLUX (cal/cm^2-sec)

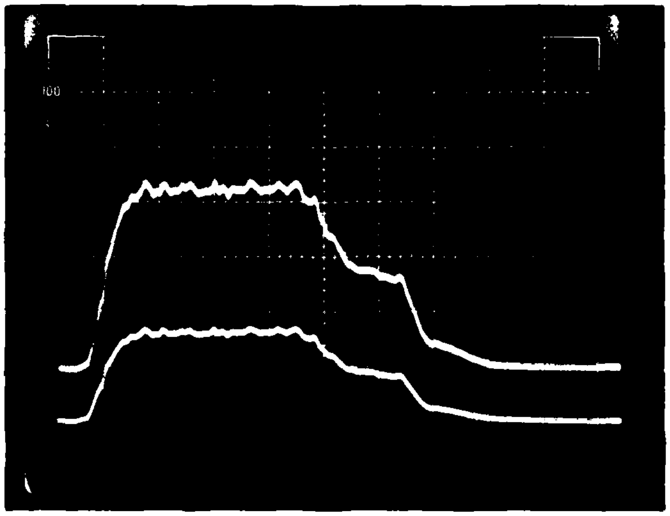
x,y,z (meters)



EVENT	MRUK2C
CALORIMETER	FX-1
LOCATION (x,y,z)	(6.4,2.7,2.3)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	23.1



EVENT	MRUK2C
CALORIMETER	FX-2
LOCATION (x,y,z)	(9.3,2.7,2.3)
TIME SWEEP RATE	0.5 sec/div
PEAK FLUX	30.8



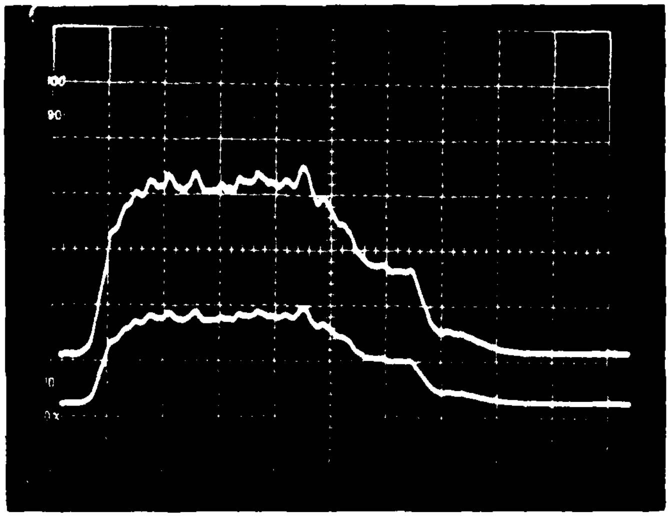
EVENT MRUK2C

CALORIMETER FX-3

LOCATION (x,y,z) (2.1,2.7,2.3)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 31.3



EVENT MRUK2C

CALORIMETER FX-4

LOCATION (x,y,z) (0,2.7,2.3)

TIME SWEEP RATE 0.5 sec/div

PEAK FLUX 27.2

FLUX MAP - NAVSEA

.(-1.6,2.4,1.4) :12.6

.(0,2.4,1.4) :23.5

.(1.6,2.4,1.4) :25.0

X ↓

.(3.2,2.4,1.4) :30.6

.(6.4,2.4,1.4) :28.0

.(9.6,2.4,1.4) :22.0

.(12.3,0,1.4) :13.1

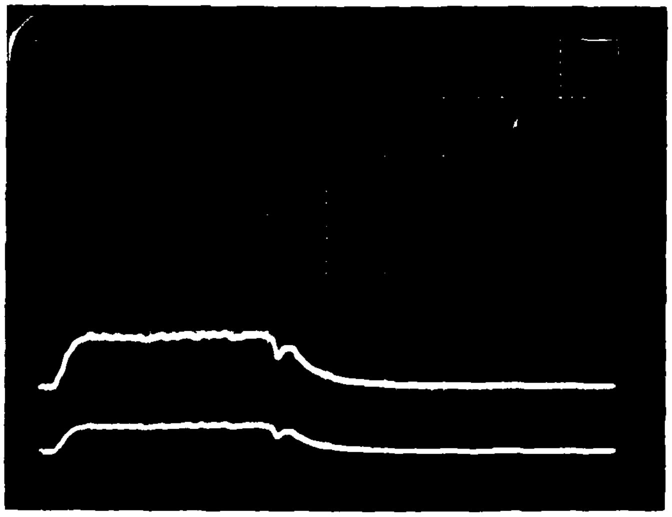
.(3.2,5.9,1.4) :12.4

.(4.8,5.9,1.4) :12.8

.(6.4,5.9,1.4) :12.9

Y ↑

.(x,y,z - meters) : FLUX



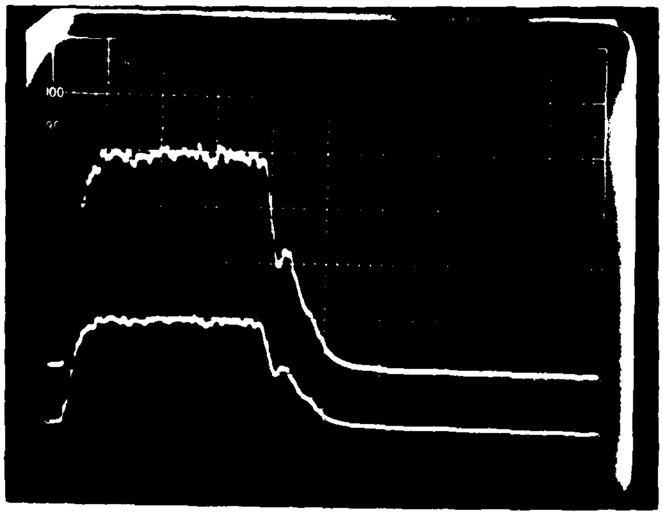
EVENT MRNAVE

CALORIMETER 1

LOCATION (x,y,z) (-1.6,2.4,1.4)

TIME SWEEP RATE 1 sec/div

PEAK FLUX 12.6



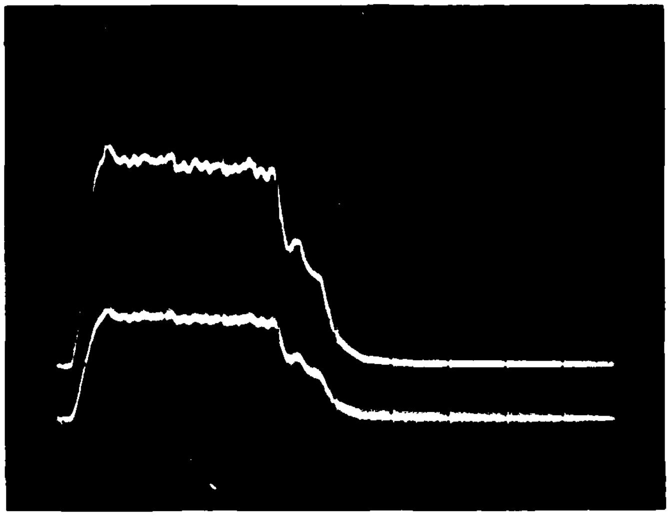
EVENT MRNAVE

CALORIMETER 2

LOCATION (x,y,z) (1.6,2.4,1.4)

TIME SWEEP RATE 1 sec/div

PEAK FLUX 25.0



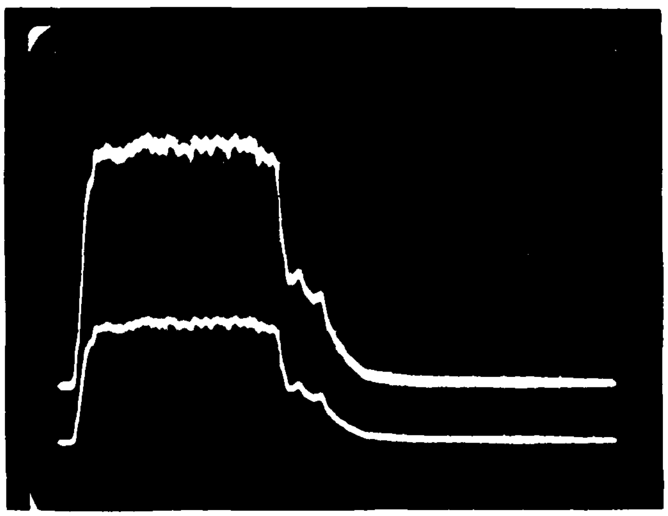
EVENT MRNAVE

CALORIMETER 3

LOCATION (x,y,z) (3.2,2.4,1.4)

TIME SWEEP RATE 1 sec/div

PEAK FLUX 30.6



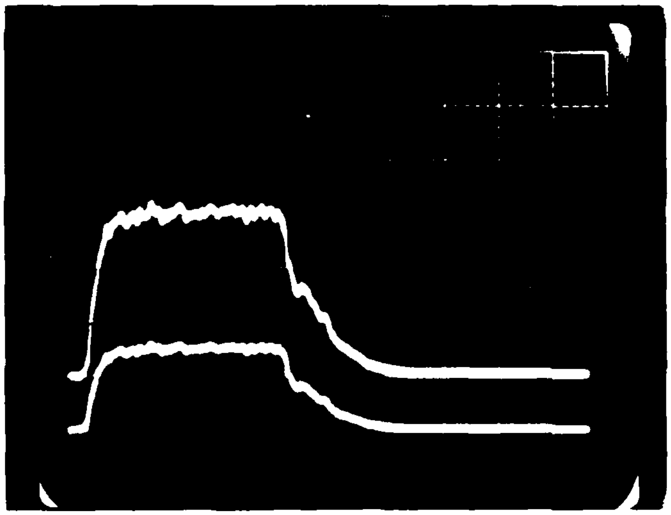
EVENT MRNAVE

CALORIMETER 4

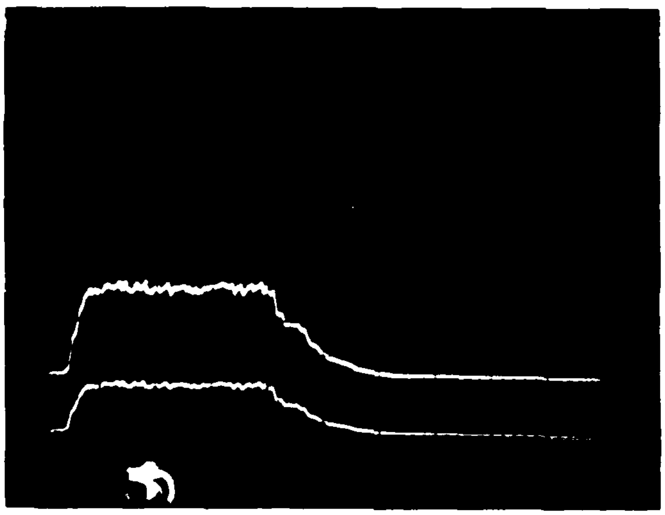
LOCATION (x,y,z) (6.4, [illegible] 4.1

TIME SWEEP RATE 1 sec/div

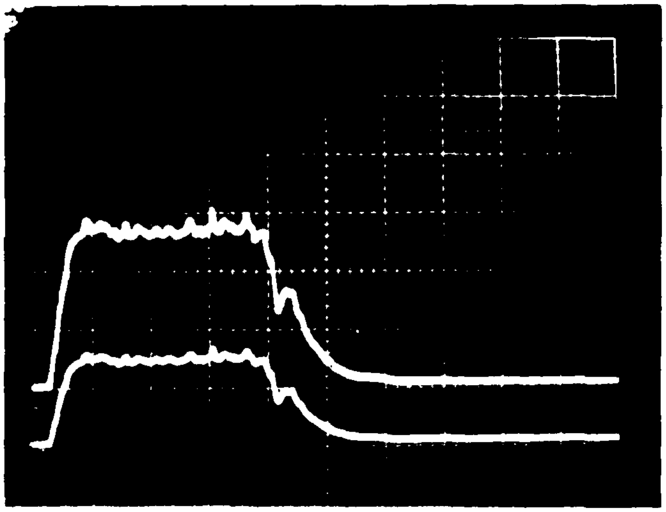
PEAK FLUX 28.0



EVENT	MRNAVE
CALORIMETER	5
LOCATION (x,y,z)	(9.6,2.4,1.4)
TIME SWEEP RATE	1 sec/div
PEAK FLUX	22.0



EVENT	MRNAVE
CALORIMETER	6
LOCATION (x,y,z)	(12.3,0,1.4)
TIME SWEEP RATE	1 sec/div
PEAK FLUX	13.1



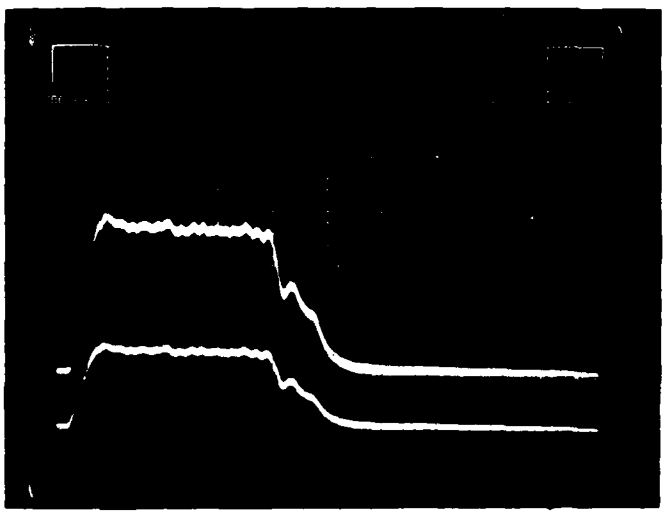
EVENT MRNAVE

CALORIMETER FX-1

LOCATION (x,y,z) (0,2.4,1.4)

TIME SWEEP RATE 1 sec/div

PEAK FLUX 23.5



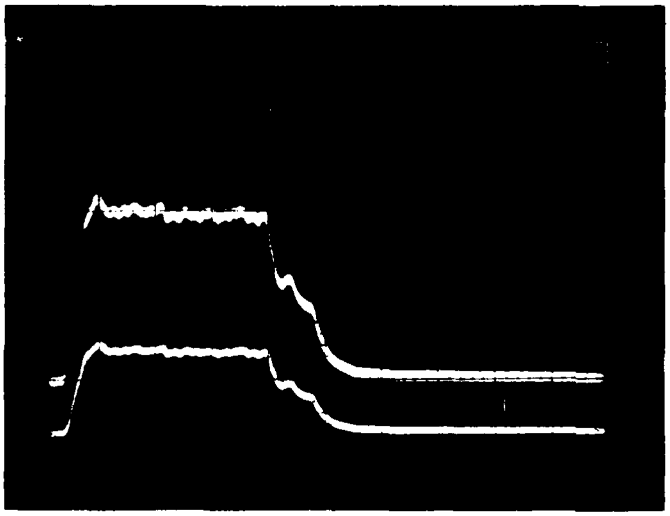
EVENT MRNAVE

CALORIMETER FX-2

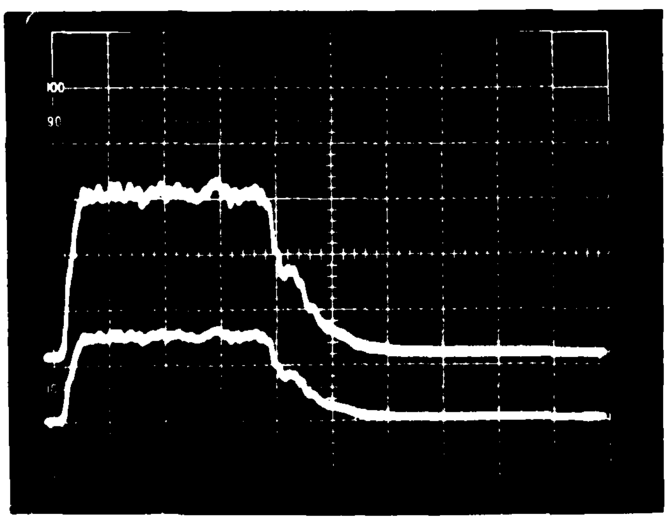
LOCATION (x,y,z) (3.2,5.9.1.4)

TIME SWEEP RATE 1 sec/div

PEAK FLUX 12.4



EVENT	MRNAVE
CALORIMETER	FX-3
LOCATION (x,y,z)	(6.4,5.9,1.4)
TIME SWEEP RATE	1 sec/div
PEAK FLUX	12.9



EVENT	MRNAVE
CALORIMETER	FX-4
LOCATION (x,y,z)	(6.4,2.4,1.4)
TIME SWEEP RATE	1 sec/div
PEAK FLUX	28.0

APPENDIX B

TRS COUNT DOWN PROCEDURE

Make sure key is removed from the keyed arming switch any time personnel are in or near the pits, unless a remote system dry run is being conducted.

FOR SHOT

Power up - shut down timer
Power up - count down timer
Power up - power supply
24 VDC "ON"
Power Pilot "RESET" (check to see that pressure switch relay light is on)
Power up - key switch panel

T-10:00 min. to 0:00

Monitor pit area with video

T-10:00

Shut down timer - reset
Count down timer - reset, "ARM SAFE" switch in "ARM" position
Key switch panel - "LOX POWER" switch armed, key switch armed

T-3:00

Roll video
Light burners
ignitors ON
propane ON for all pits
ignitors OFF
ignitors ON
ignitors OFF
oxygen ON
During the lighting of the burners - monitor the T.C. meters to see that all burners are lit

T-2:45

Close vents

Arm aluminum valve

T-0:30

Count down timer starts

Monitor LOX pressures meters to see that tanks are pressurized

T-0:15

TRS sequence starts

Monitor pit area with video

T-0:13.3

LOX flow NAVY-AD

T-0:10.3

LOX flow NAVY-BC

T-0:8.4

LOX flow UK-1

T-0:7.9

LOX flow UK-2

T-0:7.8

LOX flow BRL

T-0:4.7

Al flow on NAVY

T-0:3.4

Al flow on UK-1

T-0:2.9

Al flow on UK-2

T-0:2.8

Al flow on BRL

T-0:2.3

Al flow off NAVY

T-0:1.9

Al flow off UK-2

T-0:1.7

Al flow off BRL

T-0:1.4

Al flow off UK-1

AFTER SHOCK WAVE REACHES TRAILER

Power Supply

- burner oxygen OFF
- propane for each pit OFF
- vents OPEN
- Aluminum valve enable OFF

Key Switch Panel

key switch OFF

remove key

LOX power toggle switch OFF

Count Down Timer

arm safe switch "SAFE"

push RESET button

Before leaving CP to re-enter area, monitor pit area on video for any signs of damage to the TRS.

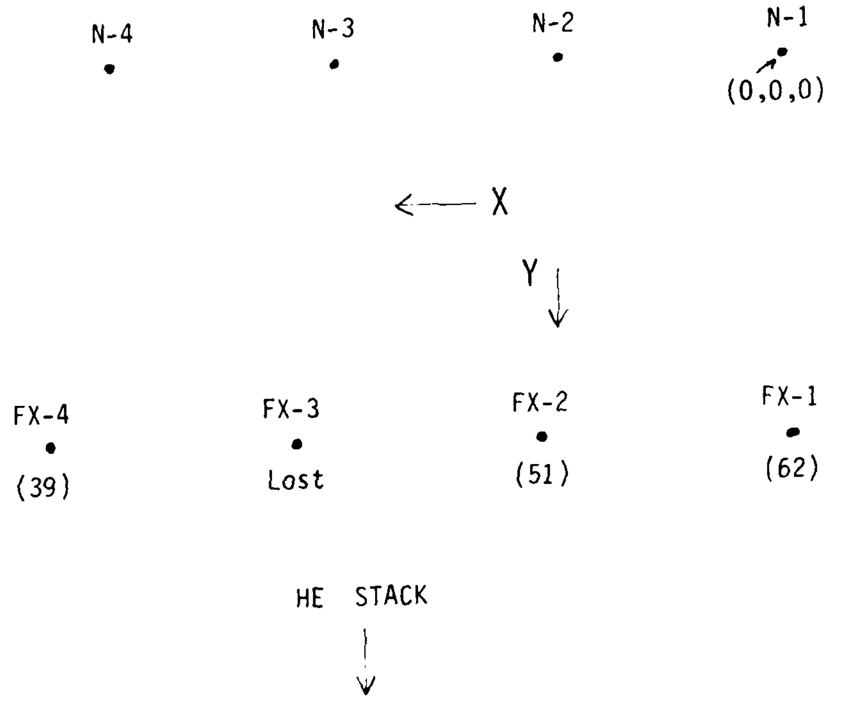
APPENDIX C

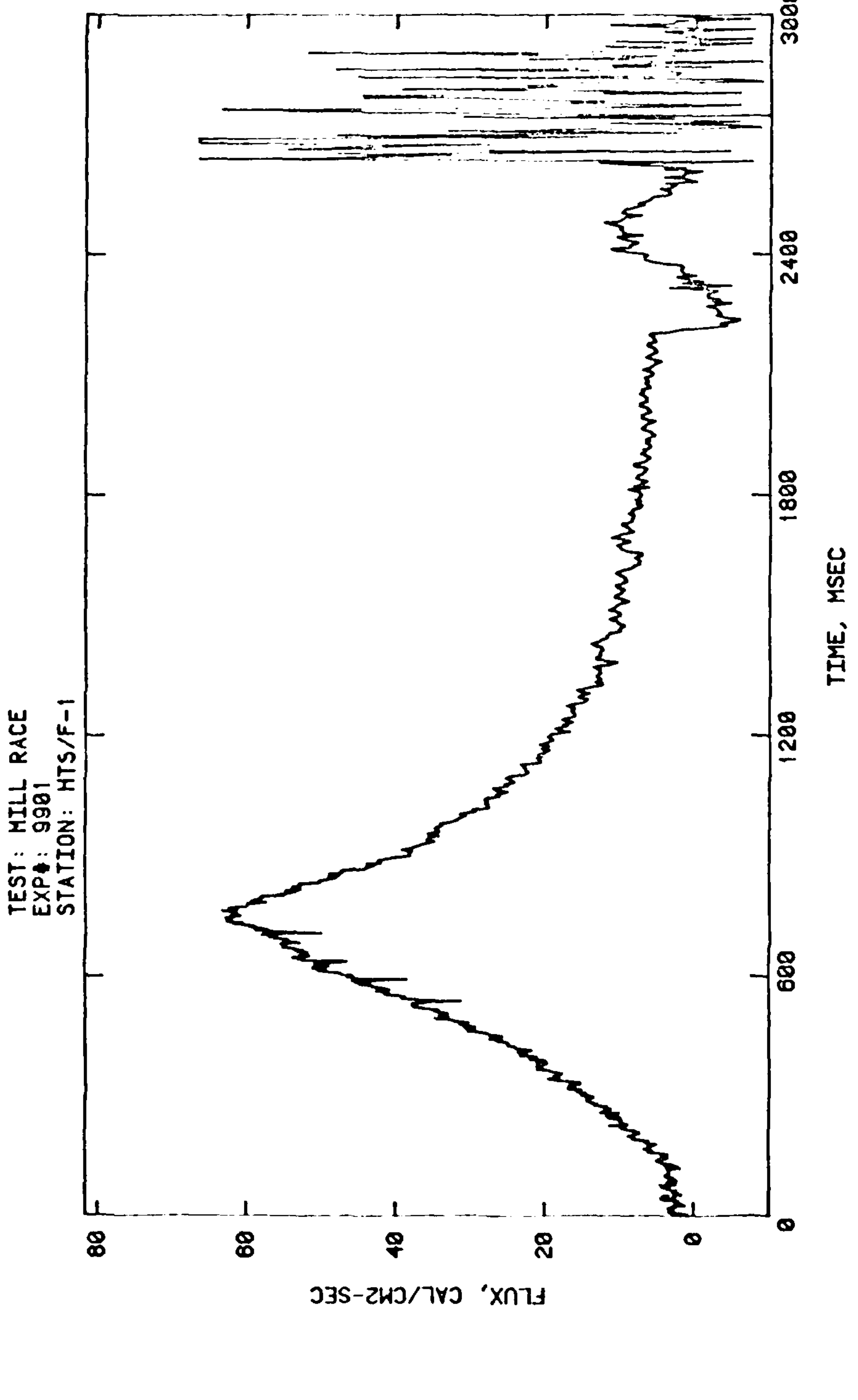
FLUX DATA FROM THE MILL RACE TEST

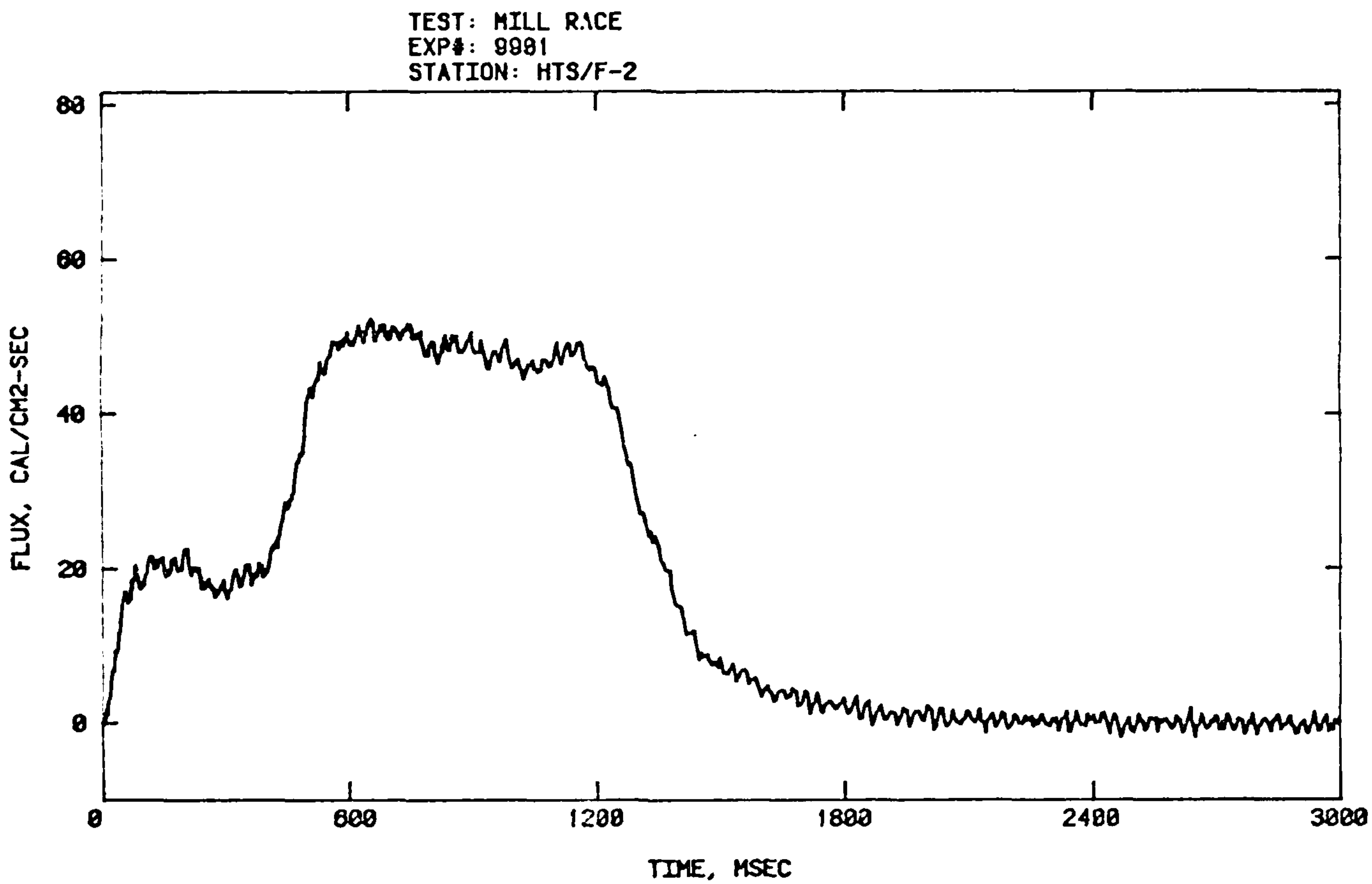
Appendix C presents the flux data for free field calorimeters placed on each TRS test bed by the Ballistics Research Laboratory (BRL). Positions for each calorimeter are given in x, y, and z co-ordinates with 0, 0, 0 being the co-ordinates of the TRS nozzle located at the north end of the array. Positive x and y co-ordinates run toward the south and west, respectively. Z co-ordinates represent calorimeter elevation above the test bed. Fluences were determined by BRL by computer integration of fluxes.

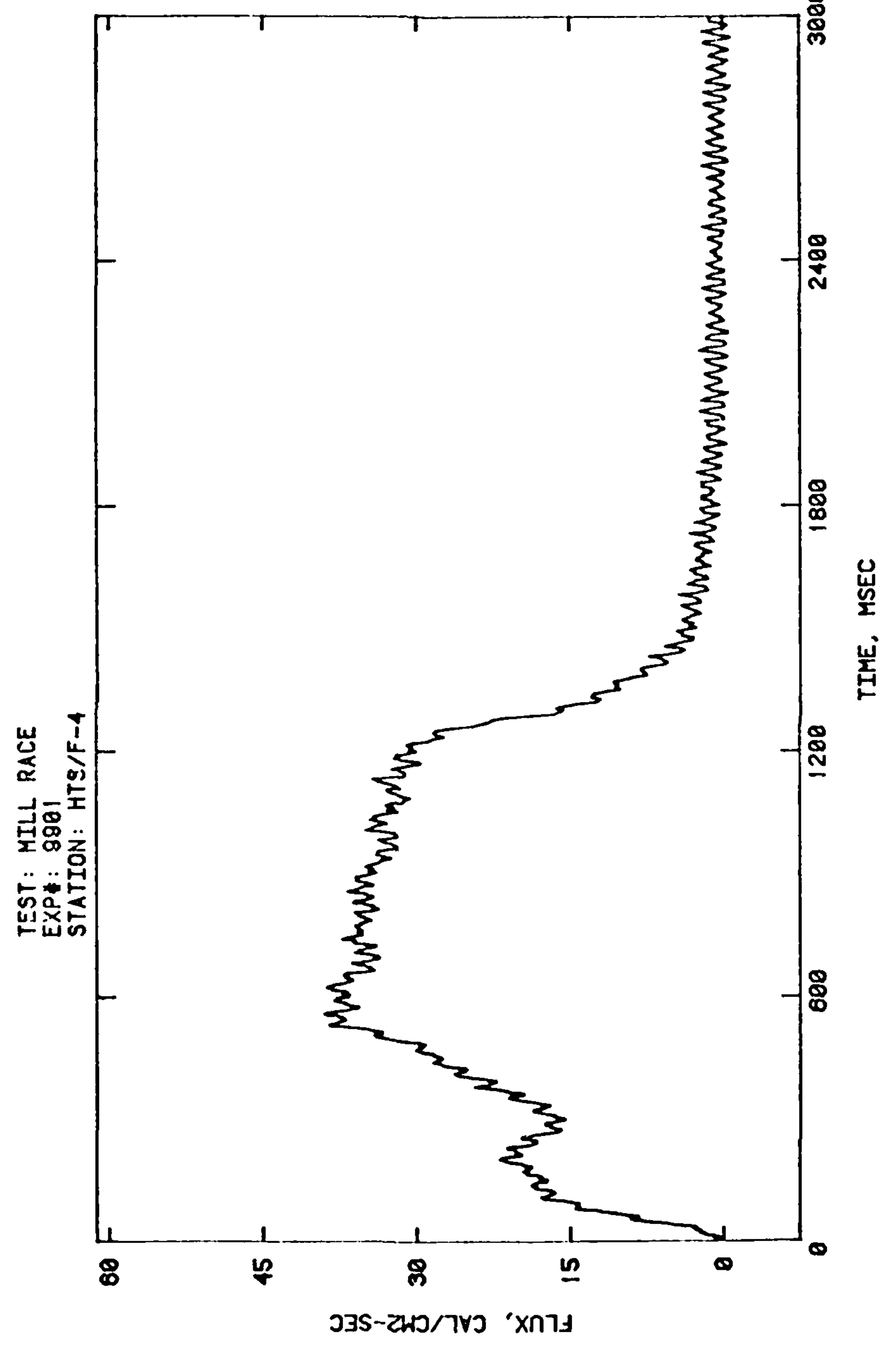
FLUX FIELD -- BRL

Calorimeter	Location (X,Y,Z) Meters	Peak Flux (cal/cm^2-sec)	Fluence (cal/cm^2)
FX-1	(-.20,1.90,2.0)	62	38.7
FX-2	(.99,1.90,2.0)	51	52.1
FX-3	(2.16,1.90,2.0)	Lost Data	Lost Data
FX-4	(3.35,1.90,2.0)	39	37.6



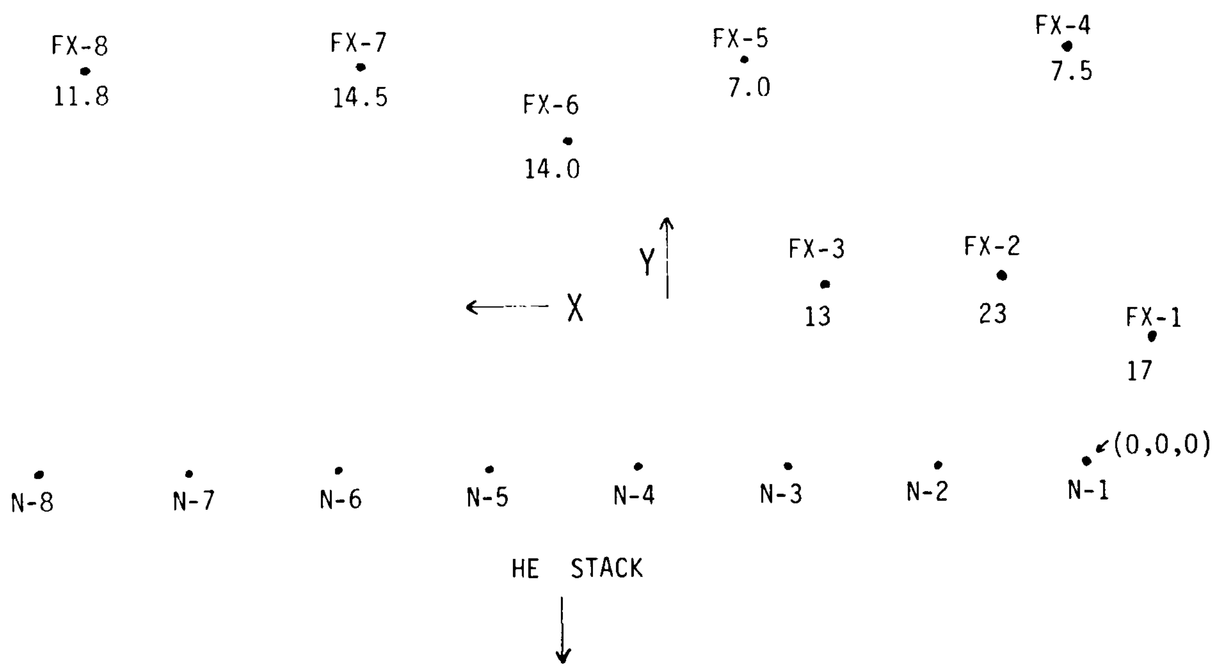

TEST: MILL RACE
EXP#: 9901
STATION: HTS/F-1
FLUX, CAL/CM2-SEC
80
60
40
20
0
0
600
1200
1800
2400
3000
TIME, MSEC

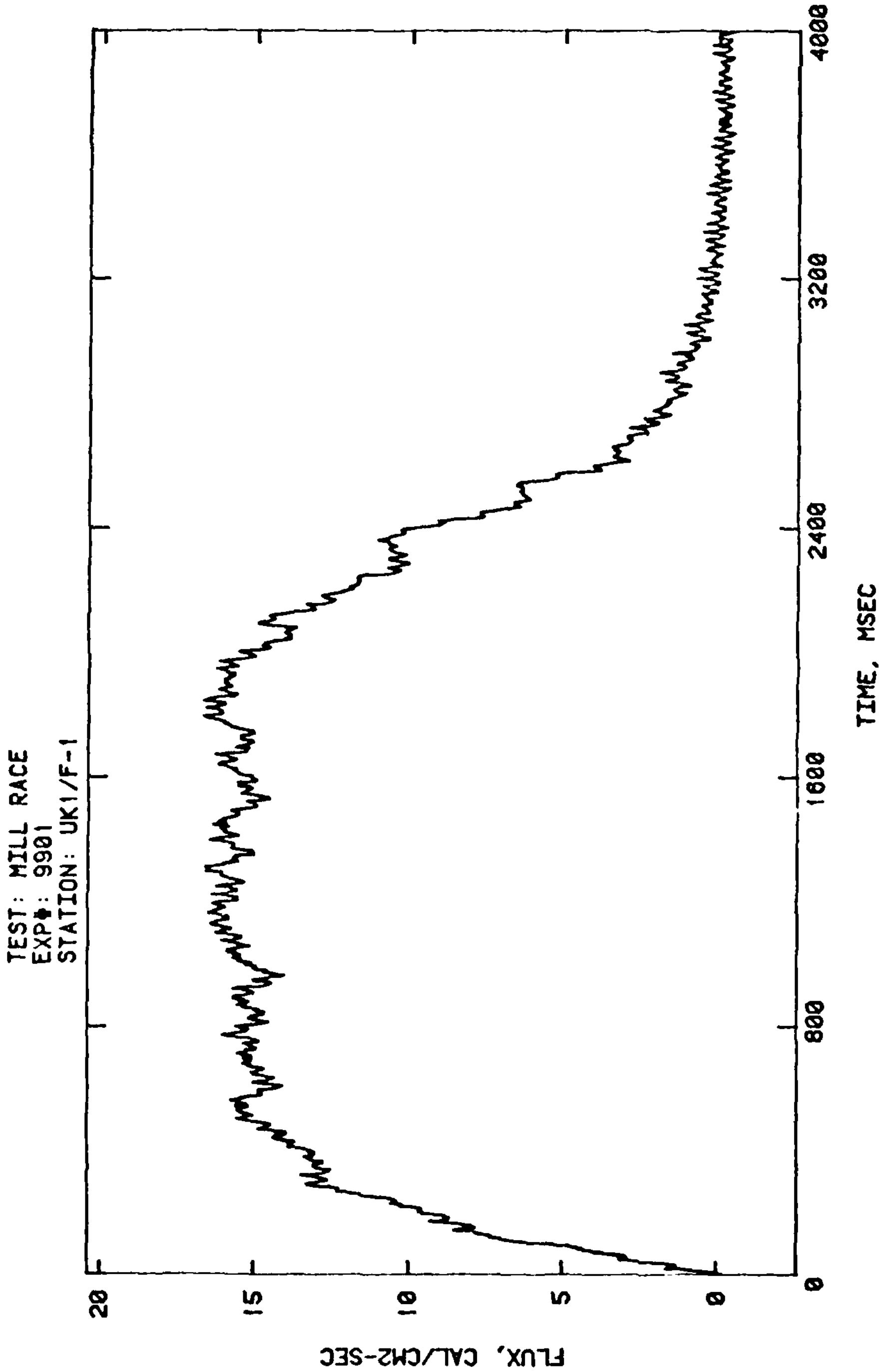

TEST: MILL RACE
EXP#: 9901
STATION: HTS/F-2
FLUX, CAL/CM2-SEC
80
60
40
20
0
0
600
1200
1800
2400
3000
TIME, MSEC

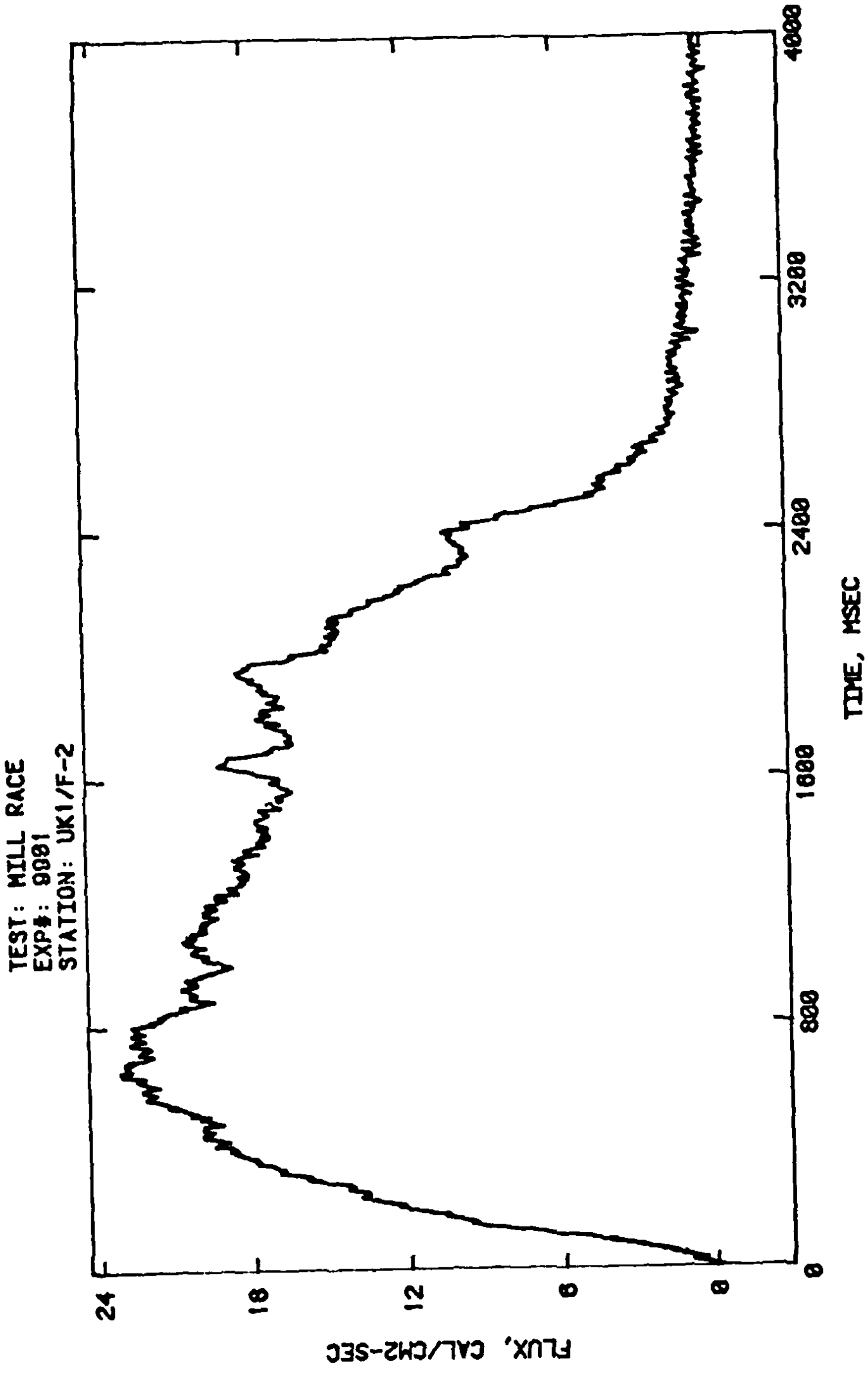

TEST: MILL RACE
EXP#: 9901
STATION: HTS/F-4
FLUX, CAL/CM2-SEC
60
45
30
15
0
TIME, MSEC
0
600
1200
1800
2400
3000

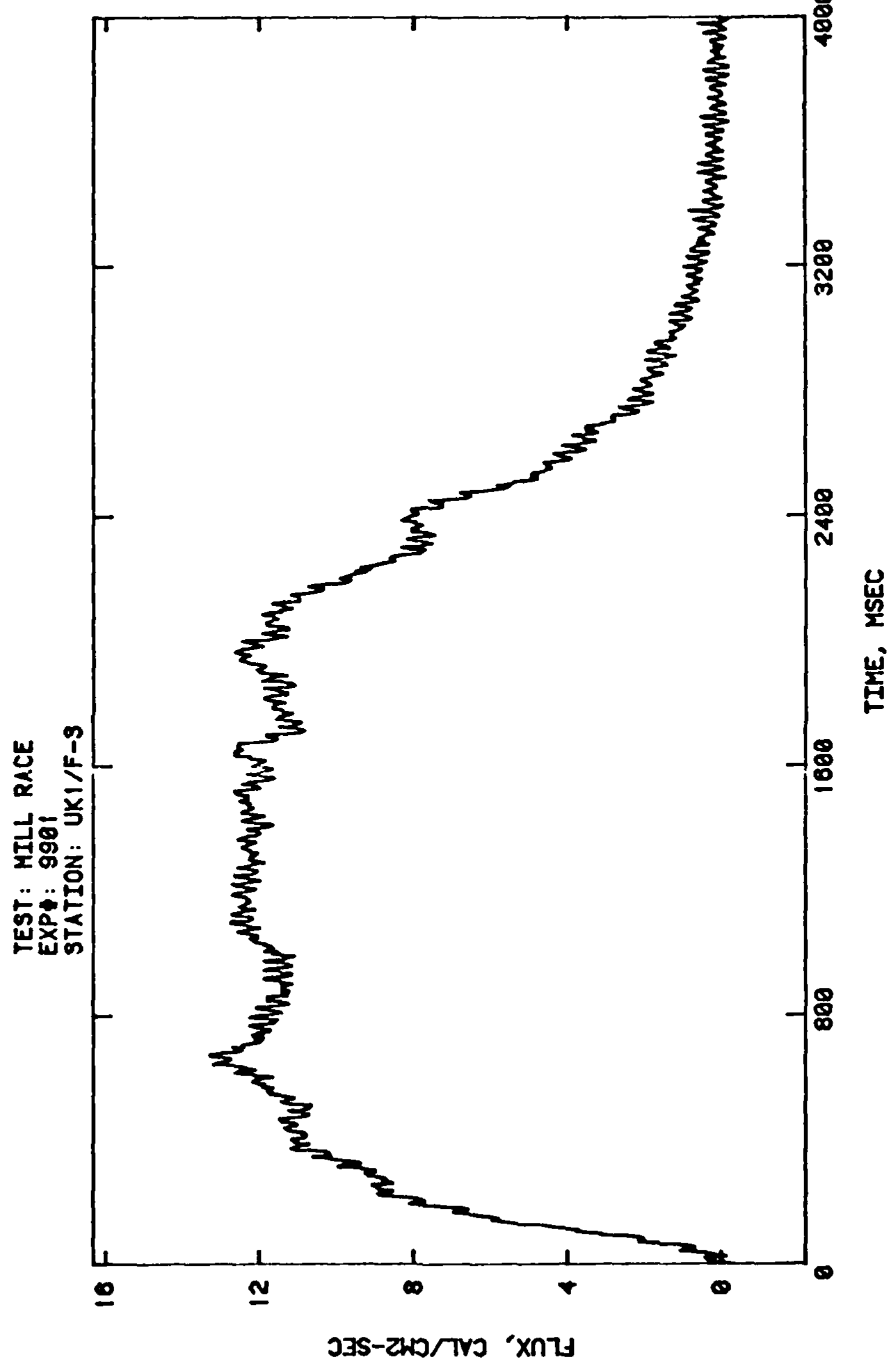
FLUX FIELD -- UK-1

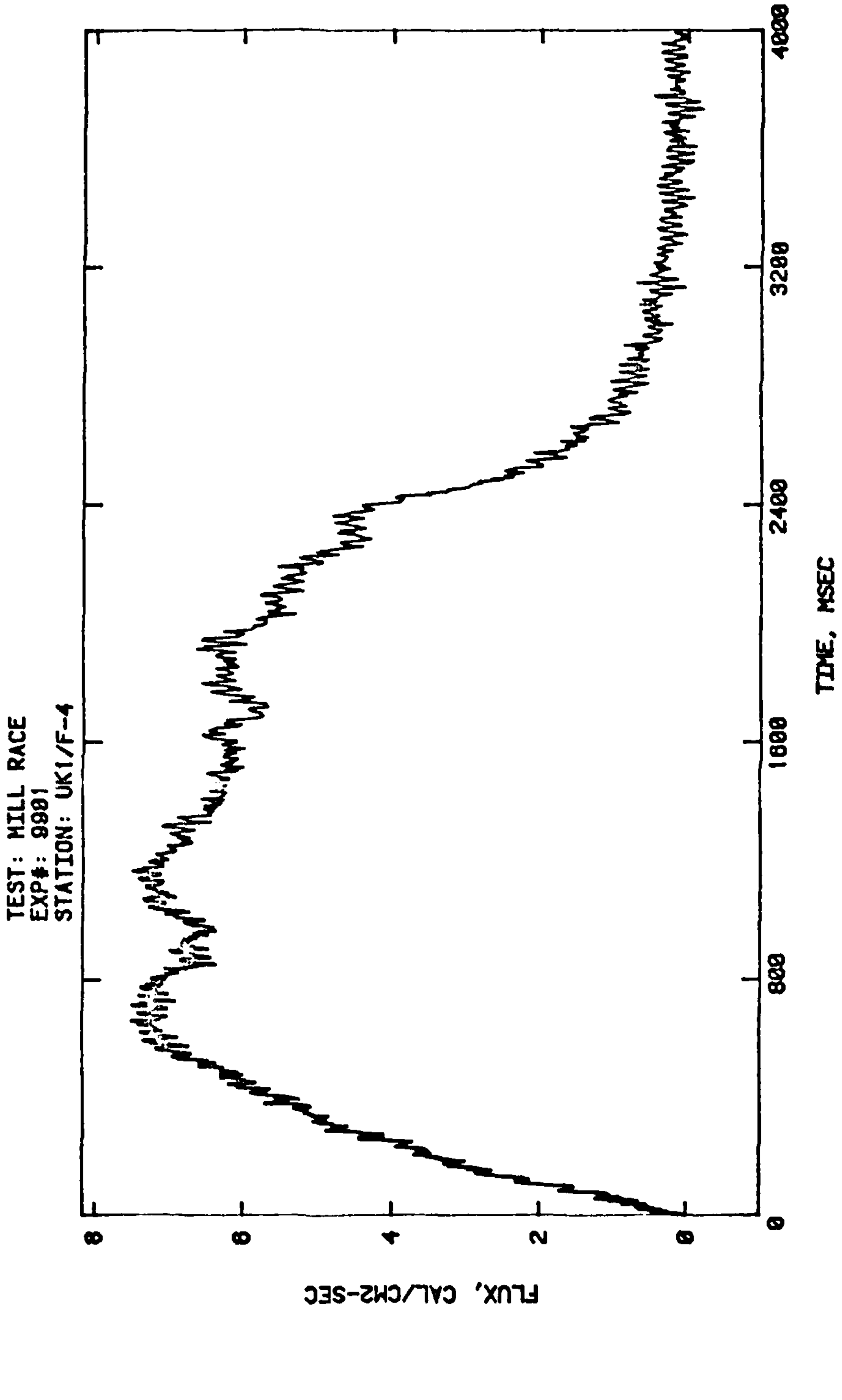
Calorimeter	Location (X,Y,Z) Meters	Peak Flux (cal/cm^2-sec)	Fluence (cal/cm^2)
FX-1	(-0.91,1.8,1.16)	17	35.2
FX-2	(1.47,2.71,1.65)	23	41.9
FX-3	(3.97,2.62,1.40)	13	27.7
FX-4	(0.51,5.97,2.29)	7.5	14.8
FX-5	(5.18,5.91,2.32)	7.0	13.8
FX-6	(7.73,4.66,1.68)	14	30.0
FX-7	(10.7,5.76,2.29)	14.5	30.2
FX-8	(14.7,5.76,2.29)	11.8	24.6

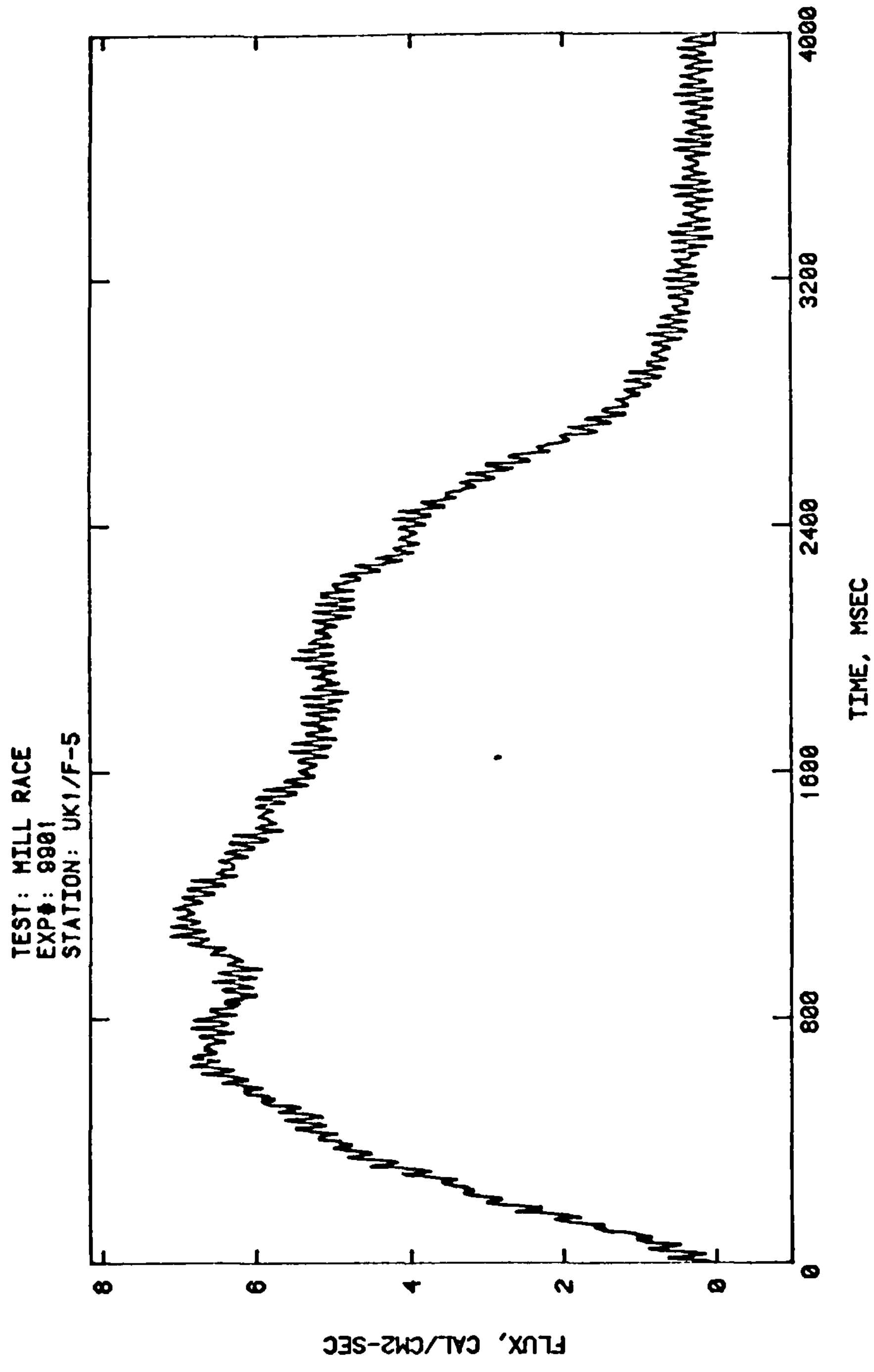


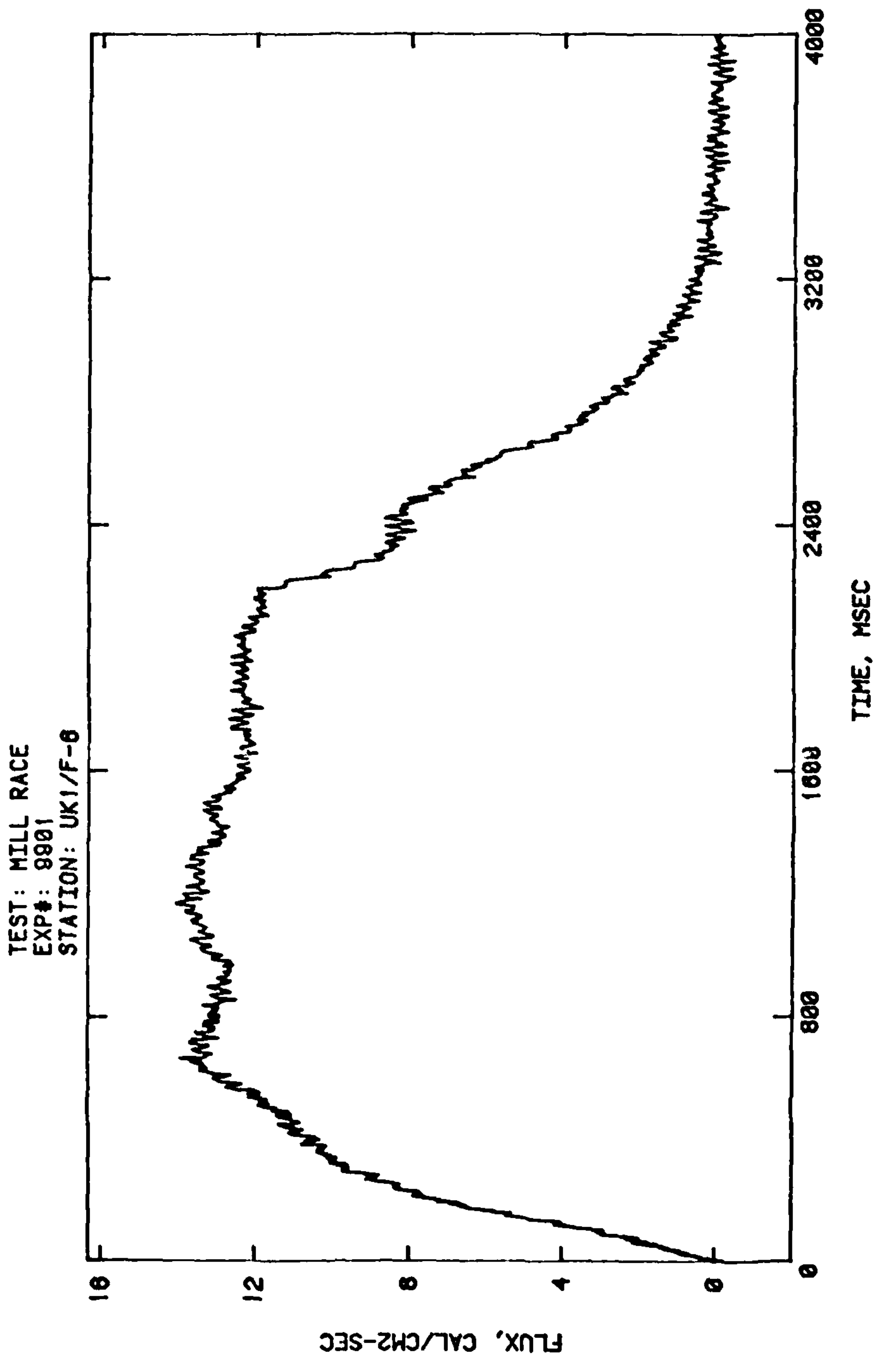

TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-1
FLUX, CAL/CM2-SEC
20
15
10
5
0
0
800
1600
2400
3200
4000
TIME, MSEC

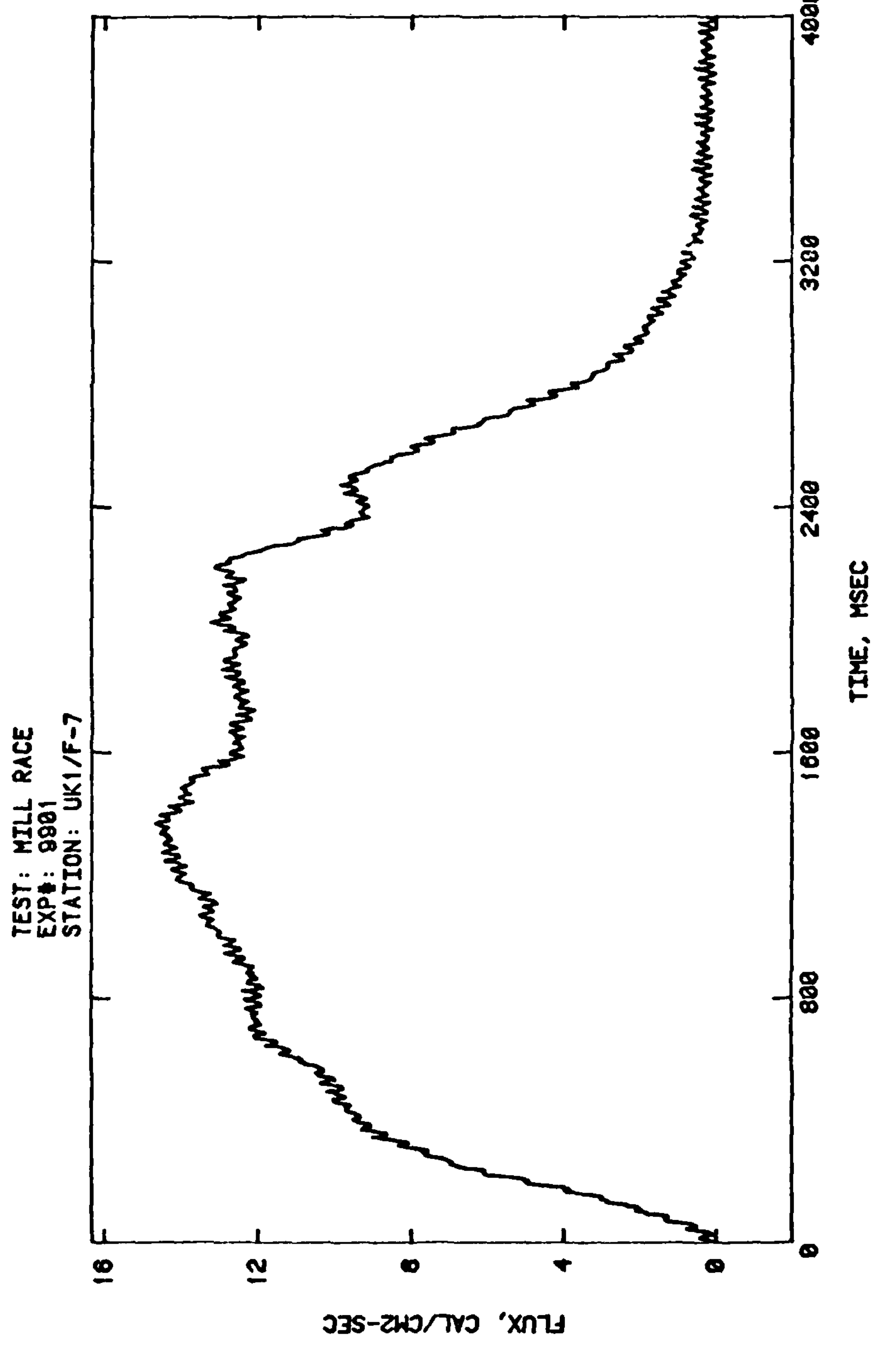

TEST: MILL RACE
EXP#: 0001
STATION: UK1/F-2
FLUX, CAL/CM2-SEC
24
18
12
6
0
0
800
1600
2400
3200
4000
TIME, MSEC

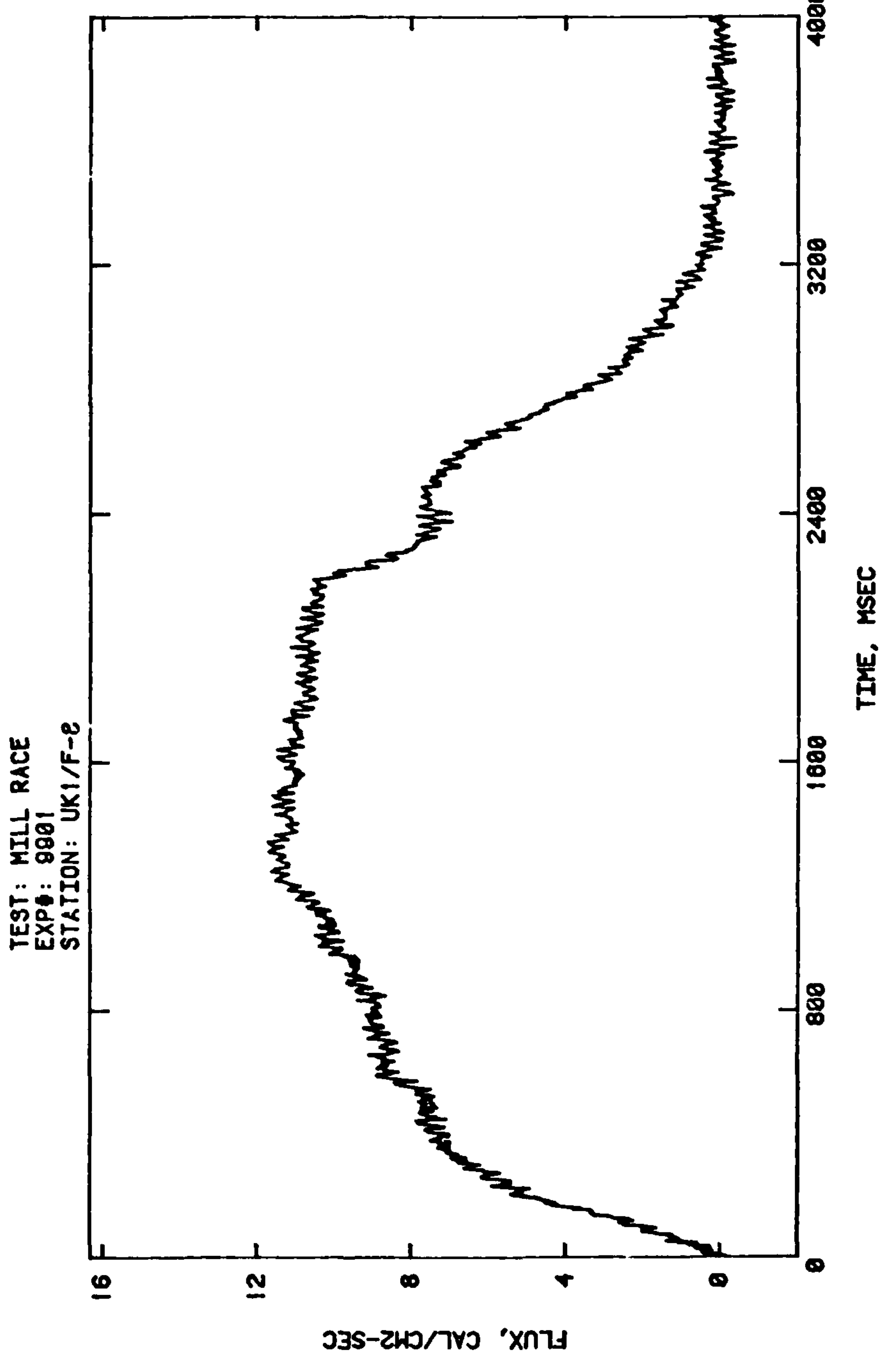

TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-3
FLUX, CAL/CM2-SEC
TIME, MSEC
0
4
8
12
16
0
800
1600
2400
3200
4000


TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-4
FLUX, CAL/CM2-SEC
8
6
4
2
0
0
800
1600
2400
3200
4000
TIME, MSEC


TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-5
FLUX, CAL/CM2-SEC
TIME, MSEC
0
2
4
6
8
0
800
1600
2400
3200
4000

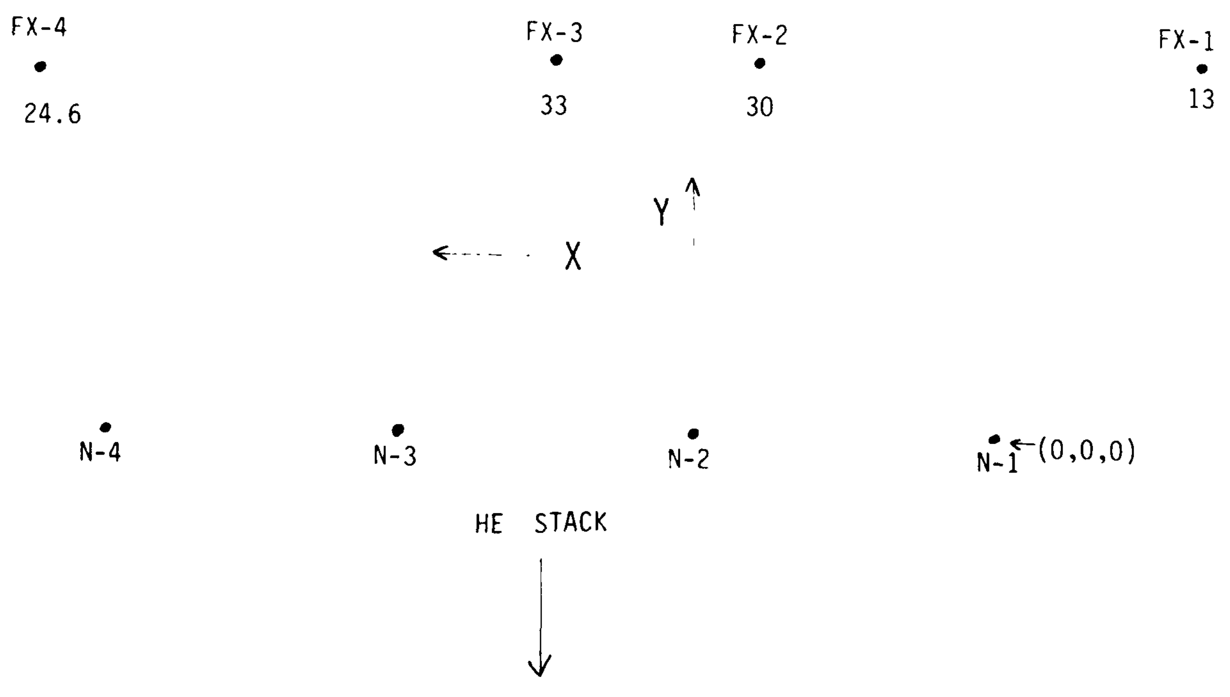

TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-6
FLUX, CAL/CM2-SEC
0
4
8
12
16
TIME, MSEC
0
800
1600
2400
3200
4000

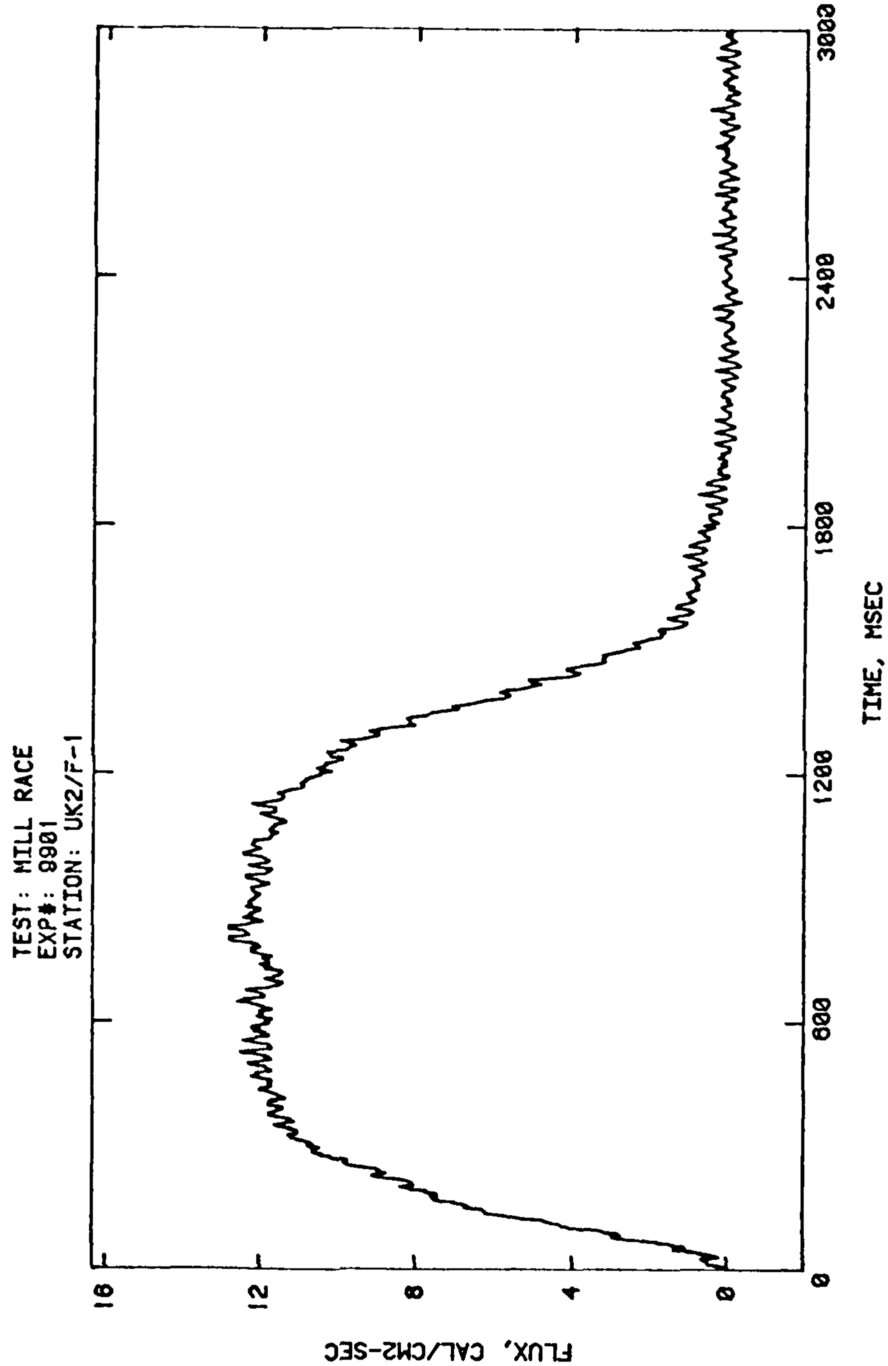

TEST: MILL RACE
EXP#: 9901
STATION: UK1/F-7
FLUX, CAL/CM2-SEC
TIME, MSEC
0
4
8
12
16
0
800
1600
2400
3200
4000

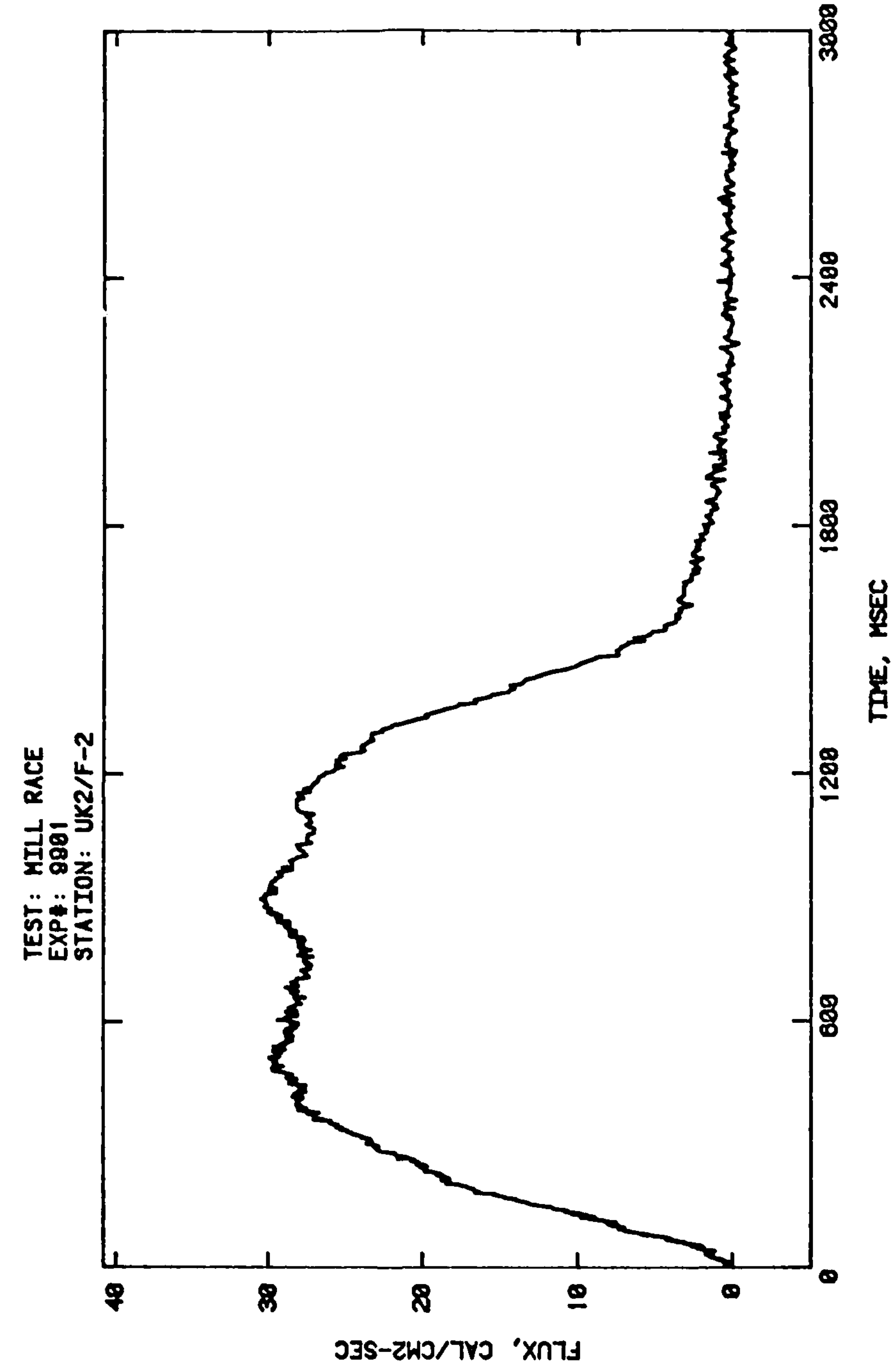

TEST: MILL RACE
EXP#: 9001
STATION: UK1/F-8
FLUX, CAL/CM2-SEC
0
4
8
12
16
TIME, MSEC
0
800
1600
2400
3200
4000

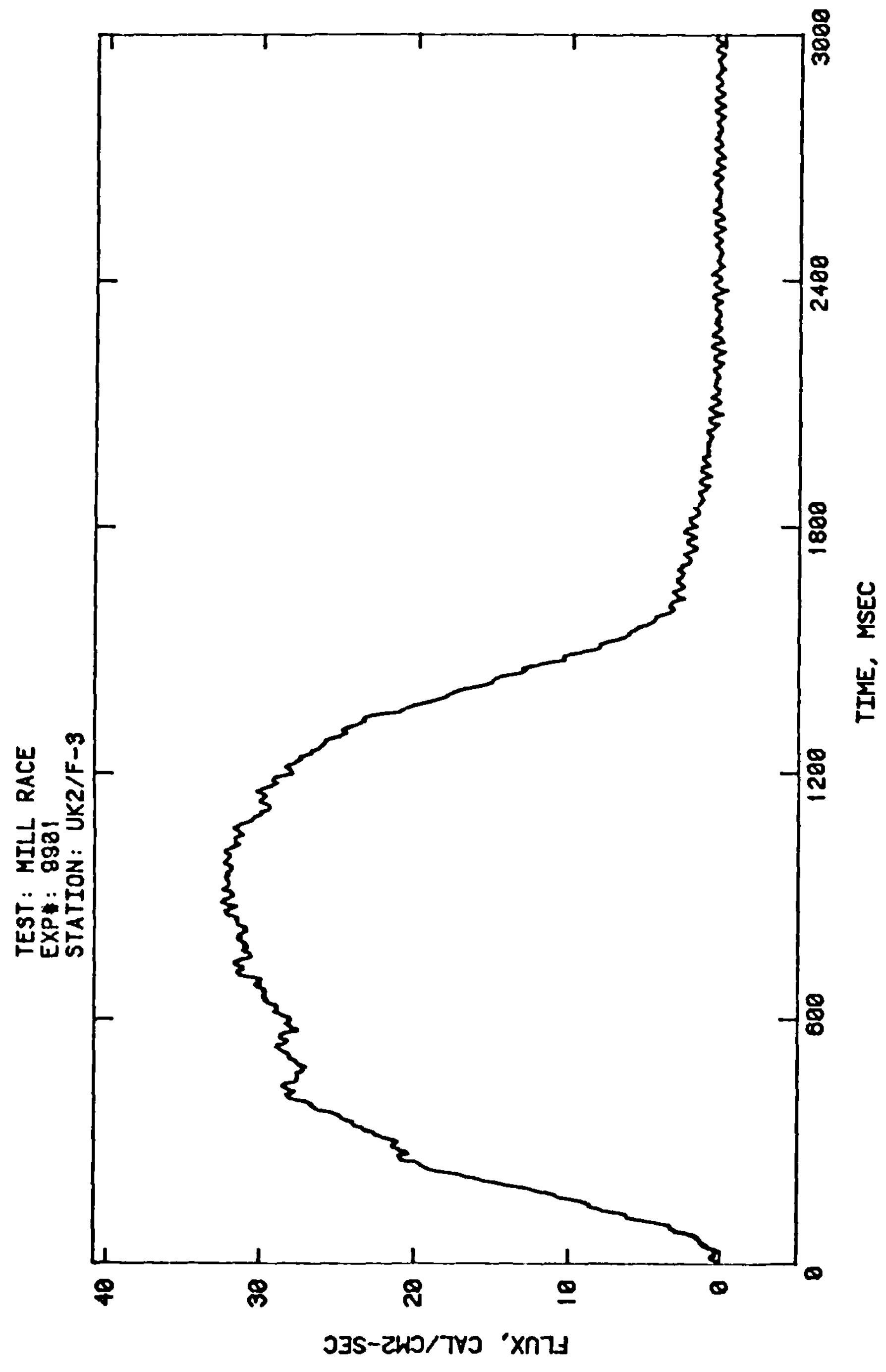
FLUX FIELD -- UK-2

Calorimeter	Location (X,Y,Z) Meters	Peak Flux (cal/cm^2-sec)	Fluence (cal/cm^2)
FX-1	(-1.49,2.68,1.77)	13	14.7
FX-2	(1.71,2.68,1.77)	30	34.8
FX-3	(3.17,2.68,1.89)	33	36.3
FX-4	(6.86,2.59,1.77)	22	25.1




TEST: MILL RACE
EXP#: 9901
STATION: UK2/F-1
FLUX, CAL/CM2-SEC
16
12
8
4
0
TIME, MSEC
0
600
1200
1800
2400
3000


TEST: MILL RACE
EXP#: 9001
STATION: UK2/F-2
FLUX, CAL/CM2-SEC
0
10
20
30
40
TIME, MSEC
0
600
1200
1800
2400
3000


TEST: MILL RACE
EXP#: 8901
STATION: UK2/F-3
FLUX, CAL/CM2-SEC
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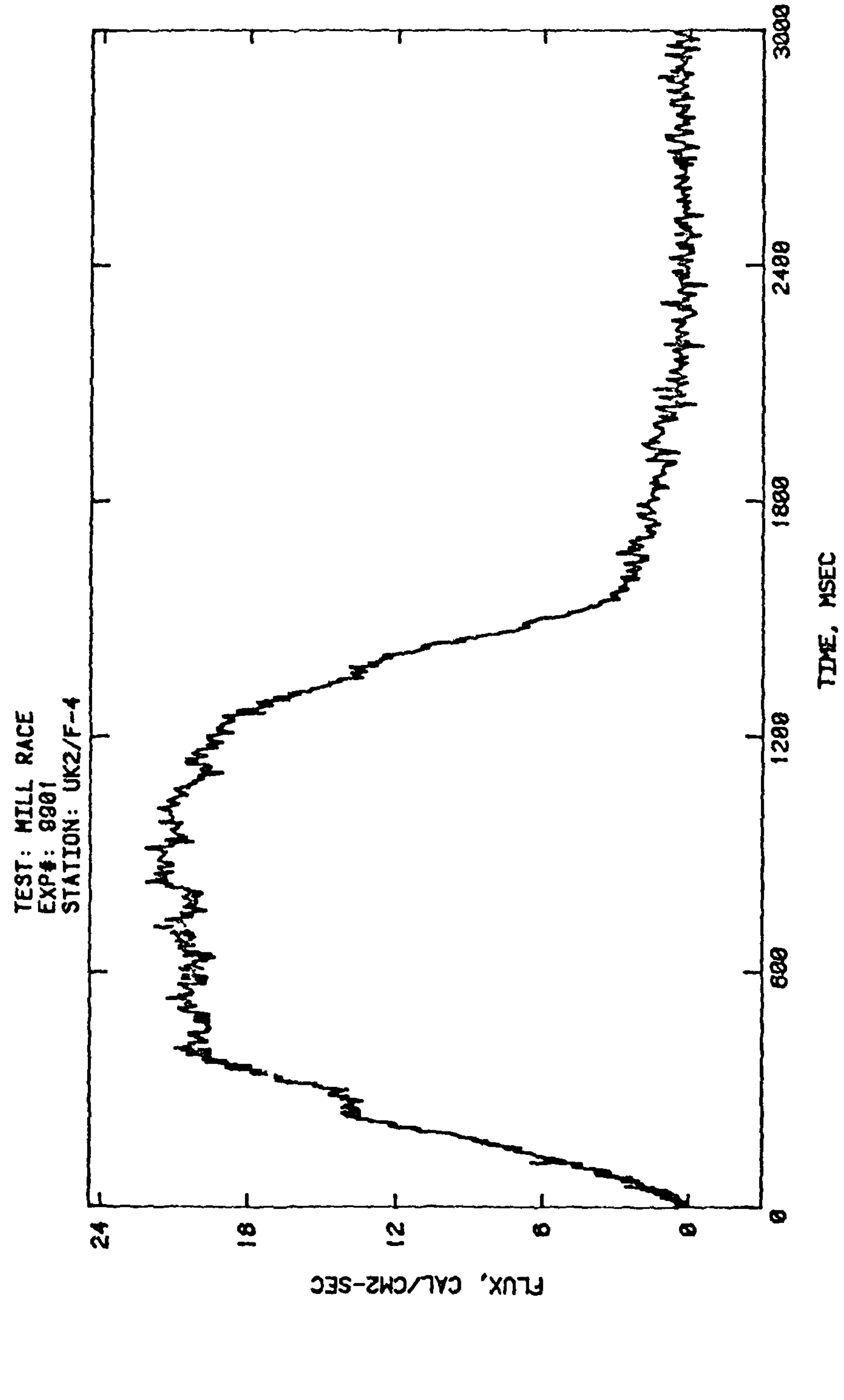
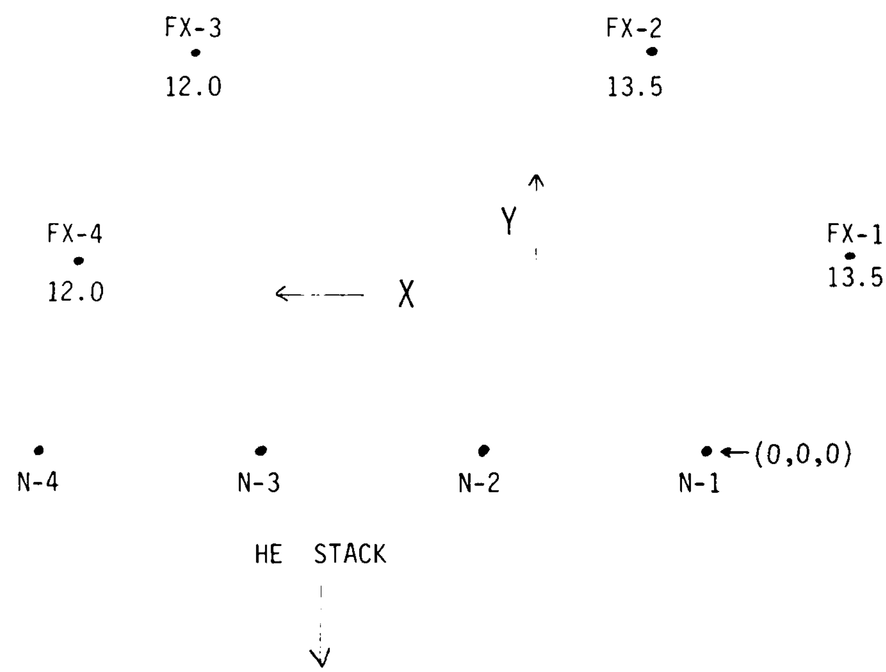
30
20
10
0
0
600
1200
1800
2400
3000
TIME, MSEC

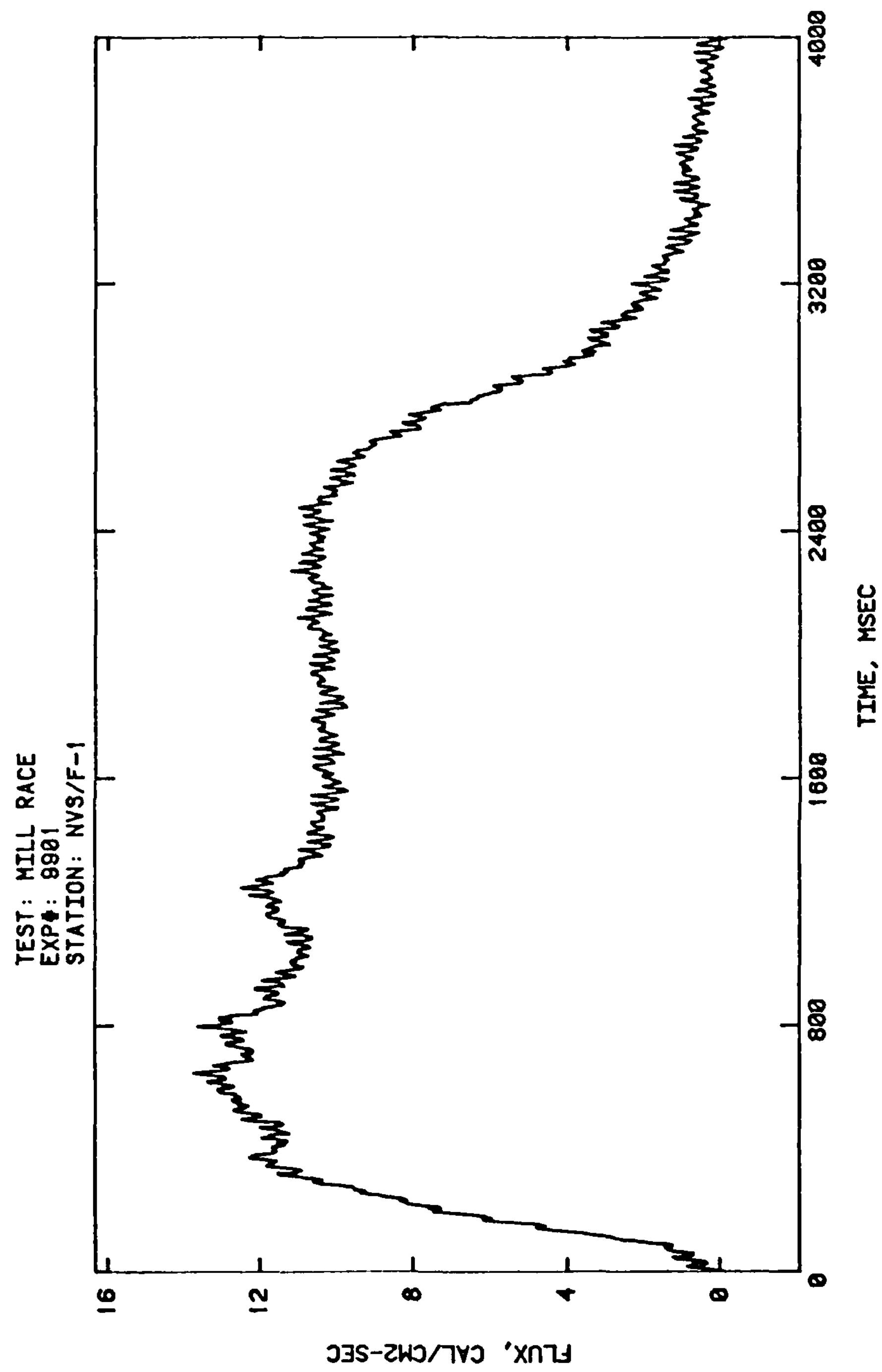


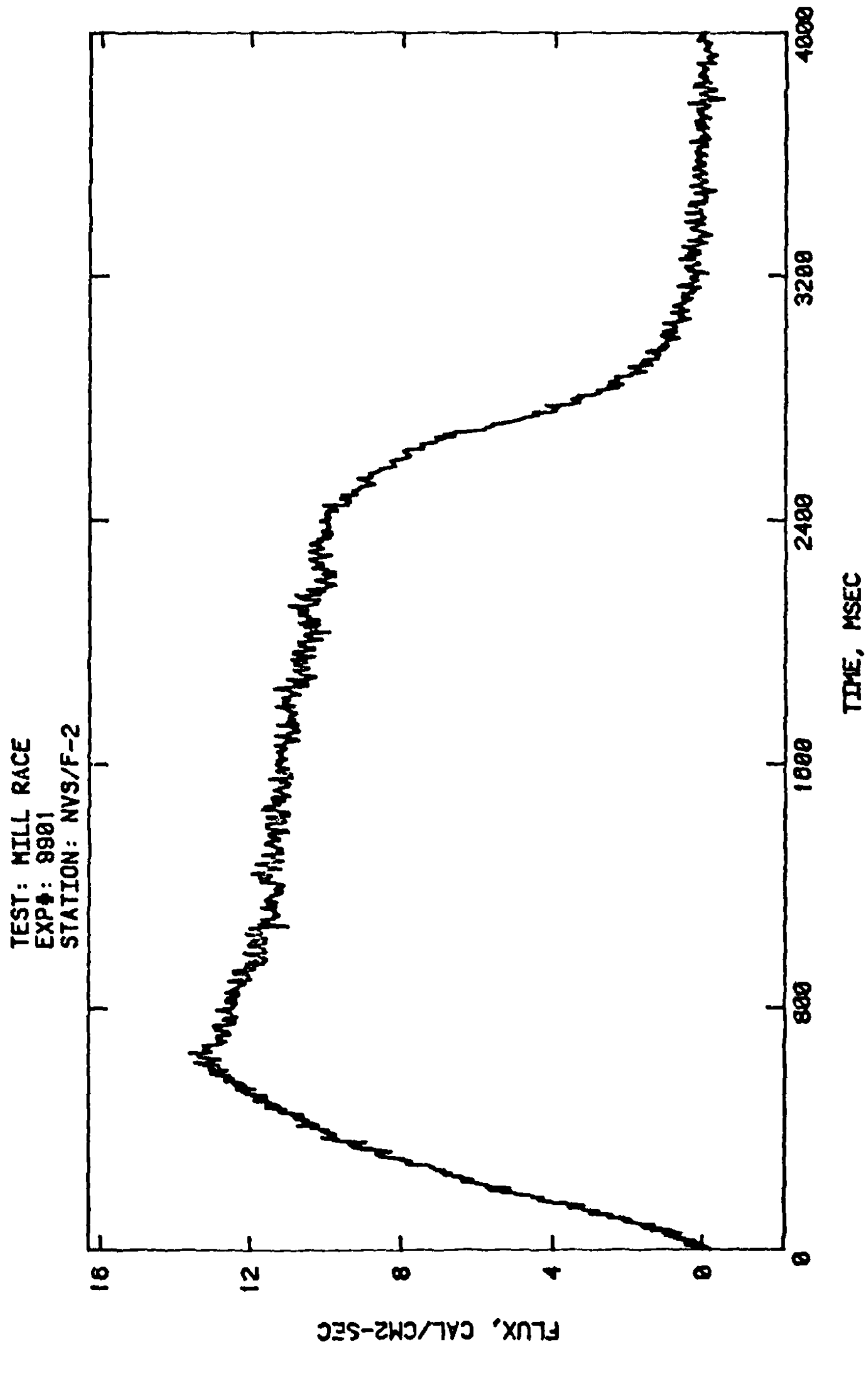
TEST: MILL RACE
EXP#: 8001
STATION: UK2/F-4
FLUX, CAL/CM2-SEC
24
18
12
6
0
TIME, MSEC
0
600
1200
1800
2400
3000

FLUX FIELD -- NAVSEA

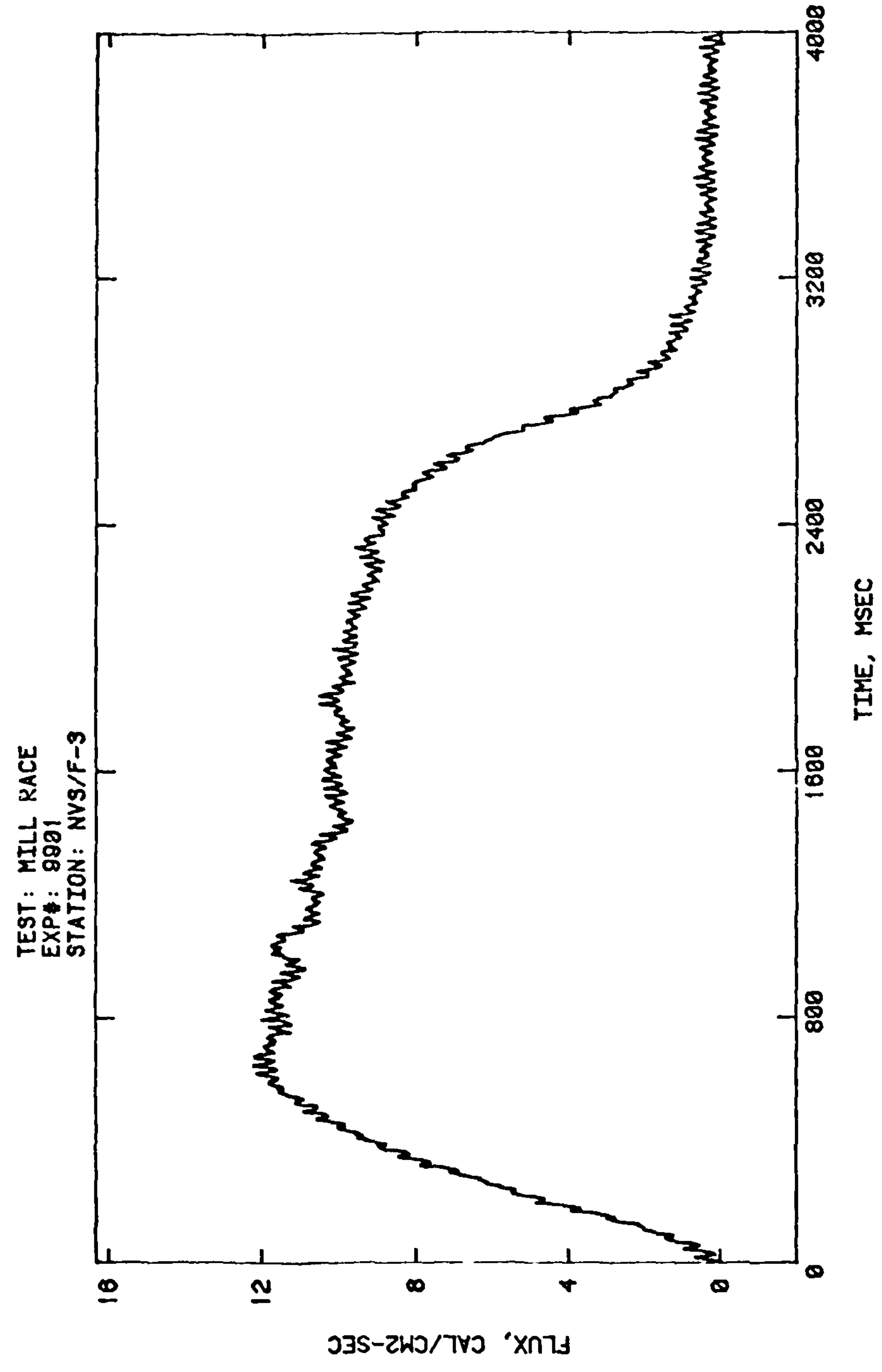
Calorimeter	Location (X,Y,Z) Meters	Peak Flux (cal/cm^2-sec)	Fluence (cal/cm^2)
FX-1	(-.66,2.77,0.91)	13.5	30.1
FX-2	(2.16,5.76,1.83)	13.5	28.3
FX-3	(7.35,5.76,1.77)	12.0	25.9
FX-4	(8.94,2.46,0.91)	12.0	28.2

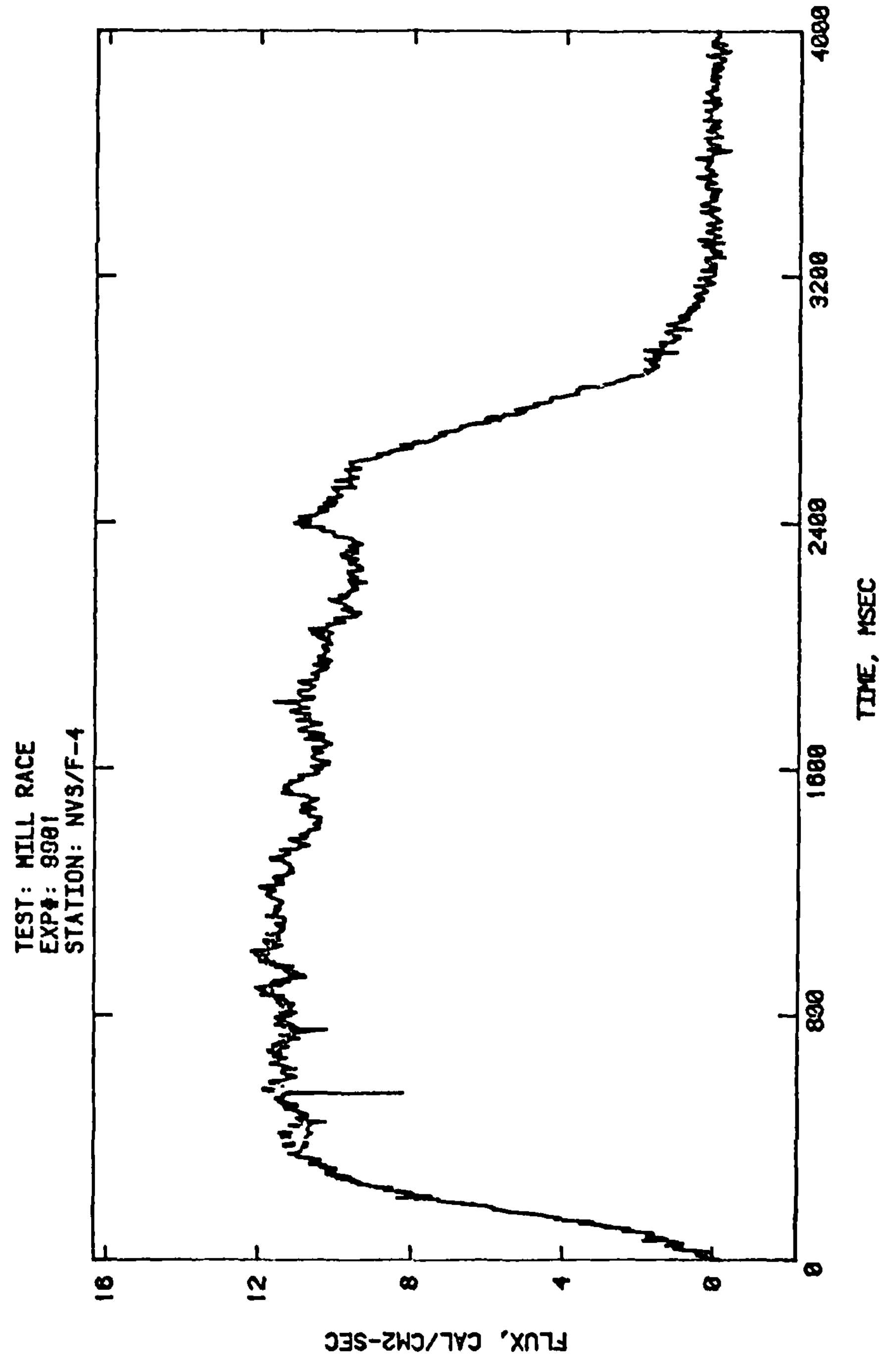



TEST: MILL RACE
EXP#: 8901
STATION: NVS/F-1
FLUX, CAL/CM2-SEC
16
12
8
4
0
TIME, MSEC
0
800
1600
2400
3200
4000



TEST: MILL RACE
EXP#: 8901
STATION: NVS/F-2
FLUX, CAL/CM2-SEC
16
12
8
4
0
TIME, MSEC
0
800
1600
2400
3200
4000


TEST: MILL RACE
EXP#: 9901
STATION: NVS/F-3
FLUX, CAL/CM2-SEC
TIME, MSEC
0
4
8
12
16
0
800
1600
2400
3200
4000



TEST: MILL RACE
EXP#: 9901
STATION: NVS/F-4
FLUX, CAL/CM2-SEC
TIME, MSEC
0
4
8
12
16
0
800
1600
2400
3200
4000

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