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TORY IIC TEST OPERATIONS

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TORY IIC TEST OPERATIONS

(Title: Unclassified)

Charles Barnett

March 12, 1965

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TORY IIC TEST OPERATIONS*

Charles Barnett

Lawrence Radiation Laboratory, University of California
Livermore, California

March 12, 1965

INTRODUCTION

This paper discusses the Tory IIC test program that led to sucessful test of the Tory IIC reactor at design conditions on May 20, 1964. Included are: (1) discussion of the facility qualification test program, (2) description of low power tests, and (3) description of the high power runs and a brief discussion of results derived from them.

TEST FACILITY CHECKOUT

A large test facility such as the Pluto facility requires considerable qualification testing both of components and the integrated whole. An attempt is made here to give some idea of the number and nature of the tests that were required and to discuss some of the problems which the tests revealed. A very brief description of the test facility is included.

Description of Facility

The Pluto test facility is located at the Atomic Energy Commission's Nevada Test Site. The Pluto site is approximately 8 square miles in area and consists of essentially three groups of facilities: the control area, the disassembly building, and the test area.

The control area consists of the test control building, the data reduction building, a warehouse, and a shop. In close proximity is the hot critical test facility which was deactivated before the beginning of Tory IIC tests.

*Work done under the auspices of the U. S. Atomic Energy Commission.

The disassembly building contains a large disassembly bay and two smaller disassembly shops used for the remote dismantling and inspection of the radioactive or "hot" reactors. It also contains an assembly bay.

The test area consists of the test bunker, air heating facility, air storage farm, and compressor building. The heating facility includes four heaters containing approximately 2 million pounds of 1-in.-diam steel balls, which are preheated to raise the test air temperature to about 1000°F. The heated air is supplied to the test vehicle at a flow rate up to 2000 lb/sec. The air storage farm is composed of approximately 25 miles of 10-in. oil well casing. It holds 1.2 million pounds of air at 3600 psia, which is sufficient for a 5-min test run. The compressor building houses three compressors which can pump up the air farm in 5 days.

In addition, there is a railroad connecting the disassembly building with the test bunker. A check station located between the control building and the disassembly building is used for limiting access to the test area during a test and is also used as a control point for health physics and other aspects of safety.

Figures 1 and 2 show the test facility layout.

Facility Qualification Testing

The facility testing program began on November 17, 1962, and ended on March 5, 1964. Eighty-two major tests were performed during this period. Facility construction was not complete when the testing began. In fact, much of the early testing was in support of the construction program.

It is convenient to break the tests into four groups: (1) air supply cleanup tests, (2) facility component qualification tests, (3) test vehicle qualification tests, (4) operator training tests.

Air Supply Cleanup Tests

During construction of the air supply system, many miles of 10-in. oil well casing were joined together and many lengths of large pipes and large vessels were joined together. Steps were taken to minimize the dirt and slag that was built into the system, but considerable effort was still required to clean the system to an acceptable level. Repeated blowdowns were made until the severity of pitting of an aluminum target was below the specified level. Some idea of the effort involved in cleanup by blowdowns is given in the following listing:

Item	No. of cleanup blowdowns
Section 2 of tank farm	13
Heater inlet pipes	4
Nozzle cooling line	12
Purge fitting	9
Section 1 of tank farm	4
Actuator air line	1

In addition to cleaning up the system these "dirt blowdowns" were useful in showing up weaknesses in various pressure and temperature measuring probes. Also a major fault in one of the large (36-in.) valves was uncovered during these tests.

Facility Component Qualification Tests

Several of the larger facility components required acceptance testing and adjustments after installation at the site. Notable among these were furnace and heat mass acceptance tests and large relief valve tests. The more important component tests are listed below:

Test	No. of tests
Large relief valves	7
Low pressure blowers	1
Heater and heat mass performance	10
Post-facility-repair hot blowdown	1

The facility tests listed above were made by blowing the supply air through a bypass outlet; air was not blown through the test vehicle.

These facility component tests exposed many minor weaknesses in equipment which were readily corrected. One major problem was exposed which required a three-month delay in schedule for repair. An inspection of the large hot air piping expansion joints conducted during the heater performance tests showed that extensive cracking had occurred. Removal of all heat insulation and further inspection showed the problem to be serious. The solution of the problem consisted of redesign of a portion of the piping so that some joints could be eliminated and a "beefing up" of those joints which remained. During the piping and joint repair, the heat mass liners were also modified to prevent warping.

Test Vehicle Qualification Tests

In the later stages of facility qualification, attention was shifted to qualifying the test vehicle. The test vehicle consisted of a railroad flatcar on which was mounted the ducting that contained the reactor core and control rod actuators (see Fig. 3). Several blowdowns through the test vehicle were made before installing the core in the ducting. The general purpose of these tests was to make certain that all test vehicle components would survive blowdowns and perform properly.

Reactor behavior was simulated electronically during several of these runs. The simulator moved the control rods in the same fashion that would be required in a power run. Some of the blowdowns were made with an orifice plate mounted in the duct to simulate core pressure drop.

Several problems were uncovered by the test vehicle blowdowns. Notable among these were: (1) high temperature connector faults in control rod actuator packages, (2) insufficient nozzle cooling flow, (3) discovery of foreign material in an actuator servo valve, (4) need for design changes in the pressure and temperature probe mount which was located downstream of the core (PT_{10} rake).

The following list summarizes test vehicle blowdowns:

Test	No. of tests
Cold blowdown without pressure drop simulator	1
Hot blowdown without pressure drop simulator	1
Cold blowdown through nozzle cooling line	4
Hot blowdown with core pressure drop simulator	6
Cold blowdown with core pressure drop simulator	5
Blowdown of actuator air lines	2

Operator Training Tests

Many persons were required for prerun preparation and execution of a test, and considerable teamwork and coordination were required. During the planning stage it was thought that several training runs would be required to develop the necessary teamwork to run a test. This turned out to be unnecessary because the required training was obtained during the facility qualification runs. This was to a considerable degree a result of the fact that test procedures were formalized early in the qualification testing phase.

Not all tests are listed above and not all the reasons for any given test are clear from their names. Almost all tests had multiple purposes. For example, many of the blowdowns served as dynamic checks of the main airflow control and temperature valves and as calibration runs for the air mass flow rate meters.

PRELIMINARY REACTOR RUNS

After shipment of the reactor to the Nevada Test Site and before high power operation, five major tests were performed. This section discusses briefly the purpose and achievements of these tests.

Subcritical Experiment (March 23, 1964)

During the test planning phase, it was known that extensive checkouts of integrated subsystems would have to be made after the reactor and test vehicle were connected to the test bunker. In particular, extensive testing of the reactor power control system would be necessary. This would require ganged motion of all the operational control rods. The reactor core was equipped with 12 auxiliary hand-insertable and 6 auxiliary electrically actuated rods for extra shutdown margin. The purpose of the subcritical experiment was to verify that all operational rods could be withdrawn if all auxiliary rods were inserted without causing dangerous increase in multiplication. If this were the case, then it would be unnecessary to evacuate personnel from the test bunker area during control system checkout, and other important checkout work could continue simultaneously.

It had already been established in critical experiments conducted at Livermore that the multiplication was acceptable ($M \approx 15$) with all operational rods out, the 6 L-ring rods in and the 12 N-ring hand-inserted rods in. ("L" means rods on innermost available radius. "N" means third available radius.) Nevertheless, it was felt that a verification in the field would be desirable. It would make possible a shakedown of criticality approach procedures under safe conditions and establish that no core configuration changes had occurred during shipment from Livermore to Nevada.

The subcritical experiment was treated as a critical experiment, i. e., personnel were evacuated from the test area and all operations were conducted from the control building. The experiment verified the Livermore results, so it was possible to conduct control system checkouts as planned. This test had two significant by-products: the first complete checkout was made of the nuclear counting system, and valuable operator training was obtained.

Cold Critical Experiment (March 24, 1964)

The objectives of the first field critical experiment were as follows:

1. Verify the critical shim bank position required for room temperature criticality. This had been previously established in the Livermore critical experiment.

2. Position the BF_3 detectors, fission detectors, and low-level ion chambers relative to the reactor so that proper range overlap between detectors is obtained.

3. Determine the open loop reactivity-power transfer function by vernier rod oscillation tests.

4. Close the reactor power control loop on low log ion chamber current for the first time.

5. Calibrate neutron detectors in terms of nuclear power using fission foils and a previously calibrated ion chamber.

6. Gain valuable operating experience with the reactor and associated systems before the approach to high power operation.

Except for a minor qualification concerning objective 3 above, all objectives were achieved and the measurements agreed well with expected values. The power calibration according to the fission foils was within 10% of that indicated by the previously calibrated ion chamber. The low log chamber power control loop was closed without incident, and the response to power demand behaved better than could be expected. The operational aspects of the test went smoothly, indicating adequate training of the operating crew.

Objective 3, transfer function determination, was very nearly completed; a few points at the higher frequencies were missed. To obtain each point an oscillating voltage was superimposed on the direct demand voltage which holds the vernier rod at its center position. Before the oscillating voltage is applied, the direct voltage component from the oscillator must be balanced against the existing direct demand voltage. Just as the oscillator was turned on to obtain data at one of the higher frequencies, the reactor scrammed on a low period signal. Study of data showed that the vernier rod had made a small outward step because the voltages had not been exactly balanced. It was decided that enough data had been obtained to verify that the system would be stable under closed loop control, so the transfer function test was terminated.

Although it had not been planned to do so, the power loop was closed on the high-range ion chambers as well as on the low-range ion chambers. This was possible because the high range detectors were somewhat more sensitive than had been calculated. This maneuver eliminated one entire run which had been planned.

Hot Zero-Power Tests (April 9 and 23, 1964)

The general objective of these tests was to study the dynamic behavior of the core and test vehicle under flow conditions approaching those characteristic of a high power run. Special temperature, pressure, and vibration transducers were installed for the test. Possible axial and radial dynamic motion of the core relative to the pressure vessel were of particular concern. Also of special interest was the behavior of the control rod actuators under dynamic flow conditions. Although the reactor was not brought critical during this run, the control rods were exercised during the blowdown so that their behavior could be observed.

The plan for the first run was to flow 800°F air up to a rate of 600 lb/sec for 1 min. Plans had been made to abort the run if vibration levels exceeded a preset level. The first run was aborted after reaching a level of 400 lb/sec. The shim rods scrammed at approximately the same level from a period signal. The abort was a result of what looked like excessive axial motion of the core and excessive axial motion of the reactor duct.

The data from the run were studied and the evidence indicated that the transducers which caused the abort were not operating properly. The scram was caused by a noisy counter channel; some loose connections were repaired. It was decided to make a second hot zero-power test with more extensive and carefully designed special vibration transducers.

The plan for the second hot zero-power test called for flow plateaus at 200, 400, 600, 800, 1200 and 1800 lb/sec. All these levels were reached, and no vibration was observed. It had been demonstrated that the core and test vehicle were dynamically sound.

These two tests also made it possible to determine which core thermocouples were good enough to qualify for core temperature control thermocouples.

Hot Low-Power Test (May 7, 1964)

The plan for this test called for bringing the reactor critical at low power, closing the reactor power control loop, and flowing 850°F air at 1800 lb/sec through the core. The purpose was twofold: (1) establish that the power control system would maintain steady power control when the actuators and nuclear detectors were exposed to the design vibration, temperature, and pressure environment; (2) obtain a good plot of critical shim rod bank position vs reactor core temperature for comparison with calculated reactivity temperature coefficient behavior.

The main events of the run were as follows: As the airflow was being increased up to the 1800-lb/sec plateau the position feedback signal from shim actuator B2 became noisy and was manually placed in the "hold" mode. In this mode an actuator remains in one position. Just as the plateau was reached, actuator A1 scrammed due to an apparent loss of air supply pressure. When A1 scrammed, the other actuators (A2, B1) began to move outward rapidly to compensate for loss of reactivity. In the excitement of the moment a manual scram was initiated although the outward motion of actuators A2 and B1 was exactly what the system design required. The nuclear part of the run was aborted but the flow program was completed as planned.

Very good temperature coefficient data were obtained, and the results agreed much better with calculations than those obtained during the Livermore critical experiment. The Livermore experiment was marginal since only a small temperature difference was available.

Obviously it was not directly demonstrated in this run that the nuclear control system would control power without any perturbations. However, postrun study of the data and component checkout work revealed that all malfunctions could be explained and corrected. The noise in B2 was due to a small wire whisker which was found in a high-temperature electrical connector. Actuator A1 had scrammed because of a faulty pressure switch. Had we not manually scrammed the reactor, the power control system would have overcome the scramming of A1.

Since all malfunctions had been explained and corrected, it was decided to proceed with high power operation.

INTERMEDIATE POWER TEST (MAY 12, 1964)

The reactor was taken to its first significant power level in this run. Conditions of a Mach 2.8, hot-day flight at 10,000 ft altitude were simulated. Two major uncertainties had to be resolved at a low but substantial power. The first concerned the neutron counters, which were retractable into a large concrete shield in order to reduce the neutron intensity at full power so that the counters would not be saturated. Thus the counter response had to be measured as a function of position at a power level large enough to give an on-scale reading for the fully retracted counters. Then the counters could be placed to give a full coverage of the reactor power.

The second problem involved the measurement of core temperature. In order to place thermocouples in the core it was necessary to pass the leads down unfueled tube columns. These unfueled columns would operate at low temperature and reduce the temperature of the adjoining fueled column which contained the tip of the thermocouple. This temperature reduction was difficult to estimate because of the uncertainty in heat transfer between adjoining tube columns and the partial blockage of unfueled columns by the thermocouple lead wires. In addition the gamma-ray heating of the thermocouple tip was difficult to evaluate. Therefore the possible error in temperature measurement was several hundred degrees. Since the operator controlled the reactor by observing core temperature and changing power to obtain the appropriate temperature, it was obviously necessary to calibrate the core temperature. This was done by stopping at an intermediate temperature and using the limited number of gas exit temperature thermocouples to determine the core temperature by means of thermodynamic calculations. The operator was then directed to go to a final indicated core temperature. This procedure was satisfactory as will be demonstrated.

Brittle fractures of the facility piping expansion joints had been detected before the reactor runs and had been repaired. It was felt desirable for the first few runs to heat the piping slowly and to also preheat the actuators and reactor slowly until experience had been gained with the system. Therefore the facility blowers delivered about 25 lb/sec of hot air to the piping and reactor for about 10 min before each run. The reactor temperature rose to about 400°F during this process.

The run was carried out in the following manner. The reactor was taken critical and switched to automatic power control on low level counters at about 1 kW. The power was then increased to 80 kW. At this power level the neutron counter mapping took place and the counters were stationed at the appropriate positions. This operation required about 40 min.

When these steps were completed the inlet air from the low pressure blowers was shunted through the heaters and the 10-min "heat soak" completed. Blower air was then valved out of the reactor (reactor inlet air temperature had reachd 525°F on blowers). Reactor power was then increased to about 750 kW and the automatic control loop closed on high log detector signal.

From this point on, the reactor power was adjusted using the automatic power control system with feedback signals supplied by the median signal from the three high-power-range compensated ion chambers. Core temperature information was supplied to the nuclear operator by an averaging network which selected the "weighted" average of up to 12 core thermocouple signals and displayed the result on a stripchart. The network weighted the input signals by their relative distance from the mean and computed a weighted mean accordingly.

After the power control loop was closed, tank farm air was valved through the reactor with maximum inlet air temperature demanded. A flow rate of 205 lb/sec was held for 250 sec, then the automatic airflow programmer was started. At 440 lb/sec the programmer was stopped and reactor power increased to bring the peak core temperature (as displayed on the nuclear operator's stripchart) to 1730°F. This yielded a steady-state calorimetric power of 76 MW. At this point there was a pause to verify that reactor power, flow rate, and core component temperatures were consistent with predictions. The nuclear operator was in constant voice communication with observers on the various data systems to insure that his temperature information was correct and that the exit gas temperature was running at acceptable levels. The target indicated core temperature was determined to be 2070°F which implied an estimated peak wall temperature of 2200°F.

After it had been determined that all systems were performing properly, the automatic airflow program was resumed and the flow rate taken to 1260 lb/sec. As this was done the reactor power was gradually adjusted upward to prevent the temperature from dropping. When the plateau was reached, the nuclear operator increased power until the target core temperature was reached. Again all parameters were correlated continuously on the plateau and found to be consistent with predictions.

The airflow plateau was scheduled to last for 5 min. However, a good deal of air had been expended on the lower plateaus. This situation was anticipated, so a tank farm pressure of 900 psia or 5 min of high-flow operation was set as the termination point of the plateau. At lower air supply pressures, automatic control of the airflow becomes difficult; also, it was necessary to insure that there was sufficient air remaining for postrun cooling to counteract fission-product gamma heating.

When the tank farm pressure dropped to 900 psia, airflow control was transferred to the manual servo mode and the flow was reduced to 200 lb/sec. A few seconds before this occurred, the nuclear operator transferred the nuclear control system to manual servo and ran in the shims. When they were seated the reactor was scrammed manually.

Five minutes after the scram all coolant flow through the reactor was stopped so that the resultant effect on core temperature could be examined. After 4 min the temperature increase was about 100°F (from 855°F to 955°F) on the nuclear operator's stripchart. The low pressure blowers were then valved through the reactor. It was demonstrated that the blowers alone were adequate for shutdown cooling.

The duration of the run was 1 hour and 45 minutes. Plateau intervals (defined here as the length of time the magnitude of a given parameter remained above an approximate value of 95% of its "steady-state mean value") were as follows:

Item	95% SSMV	Plateau length (sec)
Calculated flow rate at grid	1199 lb/sec	298
High log ion chamber power	297 MW	242
Ion chamber R2 power	297 MW	247
Inlet air temperature	822°F	825
Average fuel temperatures		
(x/L = 0.7, uncorrected)	1995°F	248

Steady-state mean values for this run were calculated over the interval from 49,075 to 49,289 sec, which defines a fairly steady section of the high flow plateau. This run is illustrated in Fig. 4. The inlet gas temperature, exit gas temperature, core temperature, flow rate, and power are plotted.

A detailed analysis of the data is not appropriate for the present discussion, but a brief summary of the data is given below.

The corrected fuel-element wall temperature at the 0.7 axial station was 2268°F, which is 68°F above the objective. Since the thermocouple reading at this point requires large and uncertain corrections, this temperature was determined indirectly by using the accurately known exit gas temperature and calculating the core temperature. The radial temperature distribution of the exit gas was flat to within 3%. The temperatures of the metal parts of the reactor were in good agreement with calculation, with the exception of the reactor duct. The calculations of the duct temperature did not include external convection because of the difficulty in predicting the external airflow and a desire to be conservative. Therefore the duct temperature was several hundred degrees cooler than calculated, indicating a relatively high velocity external airflow (~ 30 mph), presumably caused by aspiration by the nozzle. Axial and radial motions of the core due to thermal expansion were as expected. There was no axial or radial vibration of the core greater than 2 mils, the resolution of the position transducers.

The control rod position as a function of temperature is in good agreement with calculation, indicating that our understanding of the temperature coefficient of reactivity is adequate.

It was expected that the major loss of radioactivity would be those fission fragments which left the fuel elements by direct recoil and stopped in the gas. Estimates indicate that approximately 0.2% of the fission fragments would leave by this process. Radiochemical measurements of the effluent and observation of the resulting cloud give values somewhat below this estimate.

After the run a telescopic inspection of the vehicle and base plates was made. There was no change in appearance of any parts of the reactor. No losses of reactivity or any other unusual events occurred during the run. All measured parameters were in agreement with predictions or fell on the conservative side. It was therefore concluded that the run was completely successful, and preparations were begun for the full power run.

FULL POWER TEST (MAY 20, 1964)

This test was planned to simulate Mach 2.8, sea level, hot day (100°F) design conditions. Test procedures were similar to those used in the intermediate power test, with the primary difference being the deletion of the neutron detector mapping exercise and the use of a new set of target values for flow rate and core temperature.

A good calorimetric-versus-ion-chamber power correlation was obtained from the previous test, so detector positions were not changed from the previous run and high-power scram levels could be set with some certainty. There was also increased confidence in the use of median core temperature for control purposes. The high-power target indicated temperature for the nuclear operator was 2360°F, which was expected to yield a peak wall temperature of 2500°F. The target temperatures are less than the desired wall temperature for reasons given in the previous chapter.

The reactor power was raised to about 700 kW in high log power control before introducing tank farm air through the reactor. After a brief pause at 200 lb/sec the air-flow rate was taken to 410 lb/sec. At this point the nuclear operator increased the reactor power to get a target core temperature of 1730°F. This level (~76 MW) was held just long enough to verify that crucial parameters were close to predicted values. All systems appeared to be operating properly so flow rate was increased to its final value of 1663 lb/sec. Reactor power was immediately increased until the target core temperature of 2360°F was reached. The temperature came up smoothly with no perceptible overshoot in any region of the reactor.

Temperature and pressure data were continuously compared on the plateau and found to lie very close to predicted values. Because of limitations in the heater system the temperature of the air delivered to the reactor could not be held constant over the entire plateau. The automatic programmer demanded a constant flow rate all this time so changes in gas temperature were compensated for, but the power and core temperature would be expected to reflect the variation of inlet air temperature.

Figure 5 is a plot of the reading of the nine control thermocouples used in the nuclear operator's median signal network during the high power portion of the run. One of the thermocouples (10751, No. 8 in Fig. 5) exhibited anomalous behavior: rather than holding steady, it climbed up 70°F by the middle of the plateau. The median network apparently weighted this thermocouple rather heavily (since it ran closest to the mean), and the nuclear operator adjusted power to correct what was an apparent upward drift in core temperature. The power variations involved were less than 4%.

The flow rate plateau was terminated automatically after 5 min as planned. Shortly before this point was reached the shims were inserted at constant speed in manual servo control. When the shims were seated the reactor was scrammed manually. The airflow was reduced to 200 lb/sec and held for about 2 min. Shutdown cooling was completed with the low pressure blowers.

The duration of the test was 1 hour. No serious difficulties were experienced in any phase of reactor operation and no loss of reactivity could be detected at any time. A small limit cycle was noted in the log power control loop which caused the vernier rod (C1) to oscillate ±1/4 in. at 2 cps during intervals of short period demand (the effect on the shims was imperceptible). During the power ramp up to 76 MW (with period demand at 10 sec) the oscillations became greater, so rod C2 was selected as the vernier. The amplitude of the oscillation was reduced and the run was completed without further difficulty.

Plateau intervals (defined here as the length of time the magnitude of a given parameter remained above an approximate value of 95% of its "steady-state mean value") for several test parameters are listed below:

Item	95% SSMV	Plateau length (sec)
Calculated flow rate at grid	1580 lb/sec	303
High log ion chamber power	461 MW	280
Ion chamber R2 power	461 MW	292
Inlet air temperature	882°F	388
Average fuel temperature (x/L = 0.7, uncorrected)	2246°F	286

The steady state portion of the high power plateau used for correlating data from this run is the time span covering 50,050 to 50,170 sec. The run is illustrated in Fig. 6. The inlet gas temperature, exit gas temperature, core temperature, flow rate, and power are plotted.

A brief summary of the data is given below.

The fuel element temperature at the 0.7 axial station was 2590°F, which is 90° above the objective. The reactor was designed neutronically for an operating point at 5 hours of life. At this time the xenon poisoning would require removal of the rods approximately 5 in. Thus for the short time run, the insertion of the rods 5 in. farther into the reactor than for the 5-hour case depresses the power density and temperature in the front end of the core. To compensate and obtain the proper exit gas temperature and thrust, the center of the reactor must go to a higher power density and temperature. The radial exit gas temperature was flat to within 3% as in the previous run. Temperatures of core components were consistent with estimates, with the previously mentioned exception of the duct. Core vibrations were less than 2 mils and the fission product effluent was again about 0.2% of the produced fragments. The control rod positions were consistent with those observed in the previous run.

Since the reactor was taken to the disassembly building after this run, a detailed examination could be made of those reactor parts that could be observed without disassembly. Figure 7 is a photograph of the core baseplates taken after the full power test. Other than slight changes in shading there has been no change in the base plates. By removing the manhole covers forward of the reactor, a detailed examination of the control actuators and front of the reactor was made utilizing a television camera and recorder. No changes were observed in this part of the system. A light placed in front of the reactor allowed sightings to be made through a majority of the reactor flow holes. Detailed examination of these holes failed to show any blockage or anomalies. All control rods were observable in place and there was no evidence of corrosion or damage. Figure 8 is a typical picture of a sighting through some of the flow holes. Only a limited part of the core could be covered in each picture because of the necessary alignment of the light, the holes, and the camera.

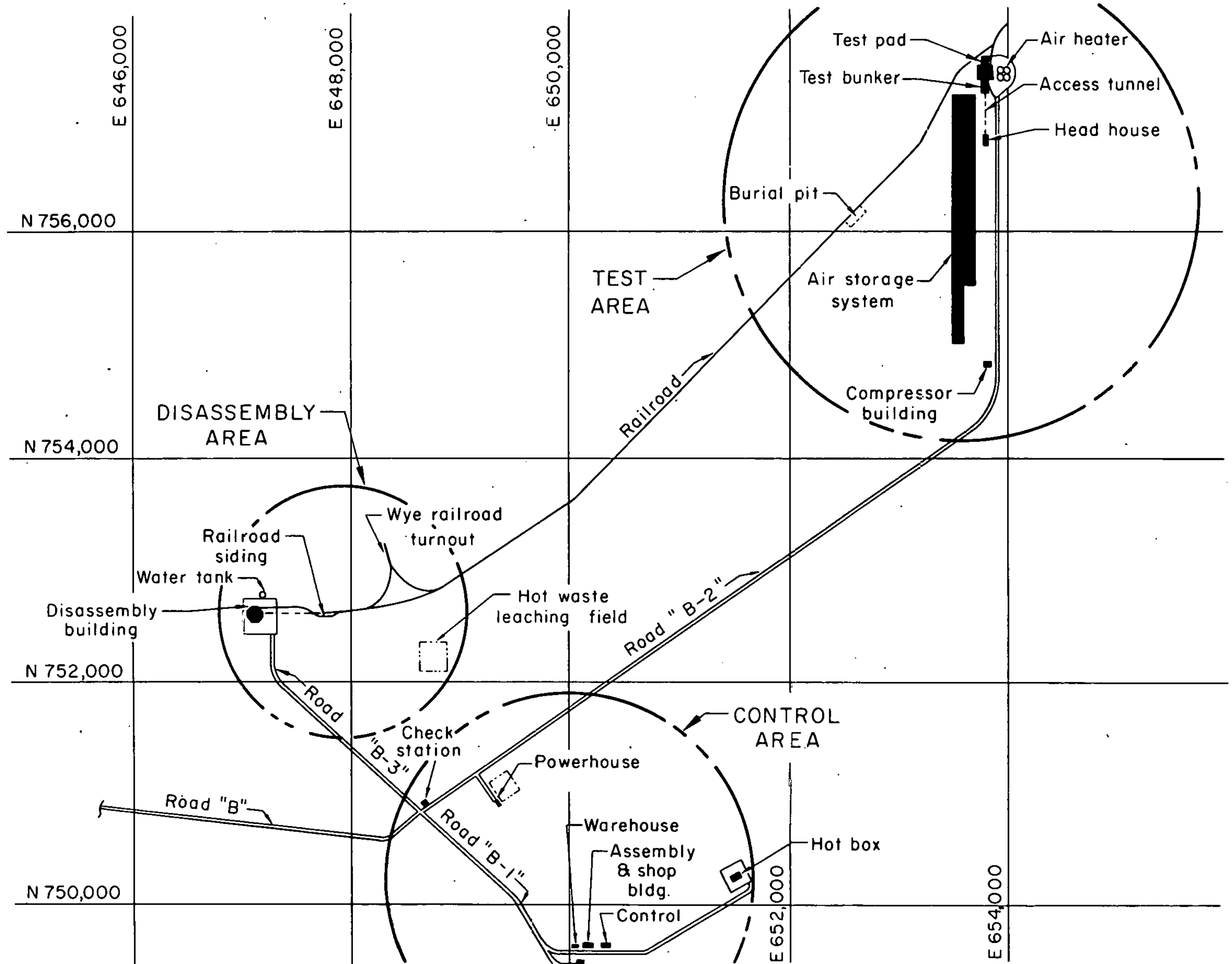

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Fig. 1. Area and building location map of Pluto test facility.

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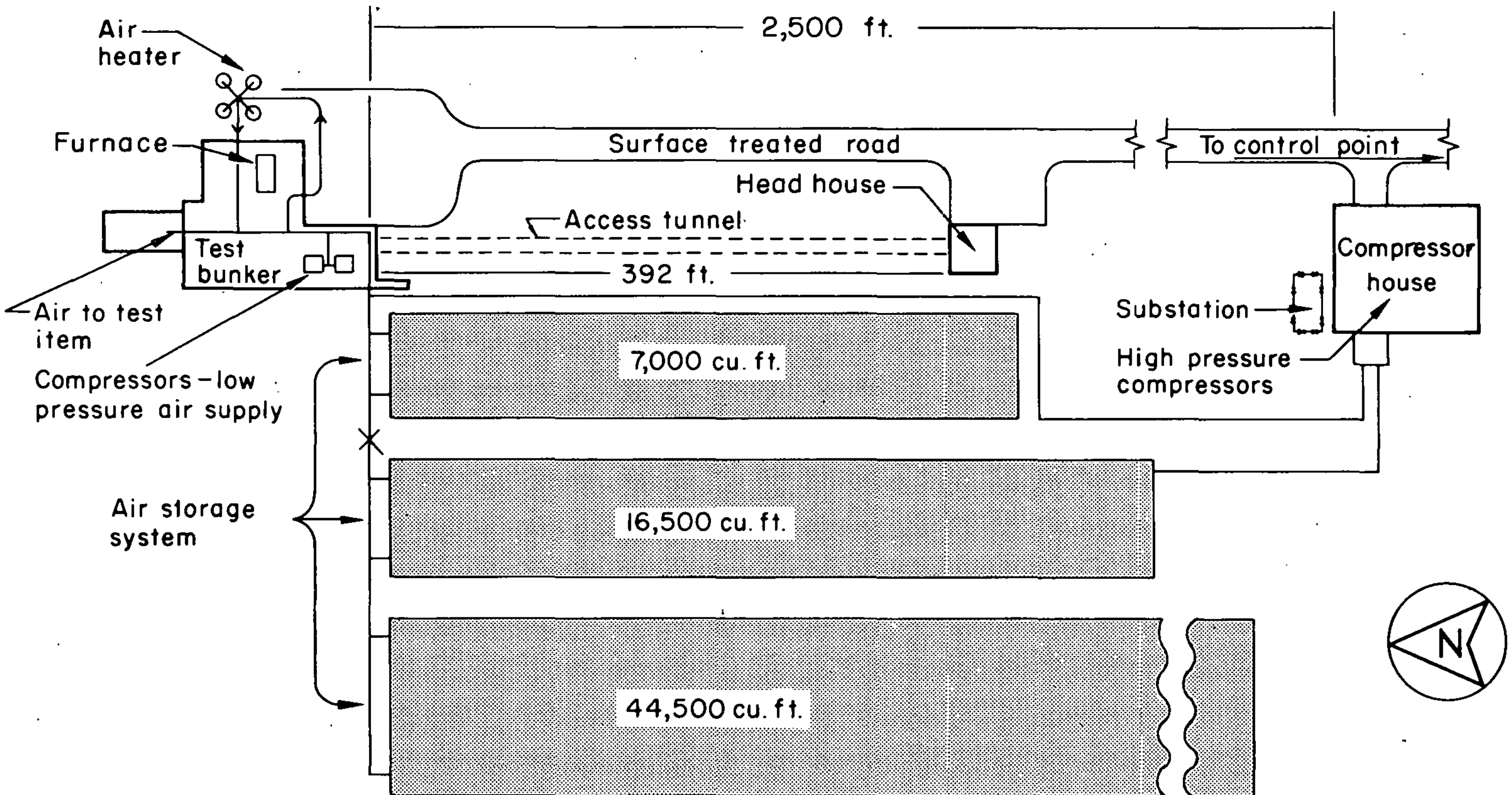

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Fig. 2. Test area arrangement.

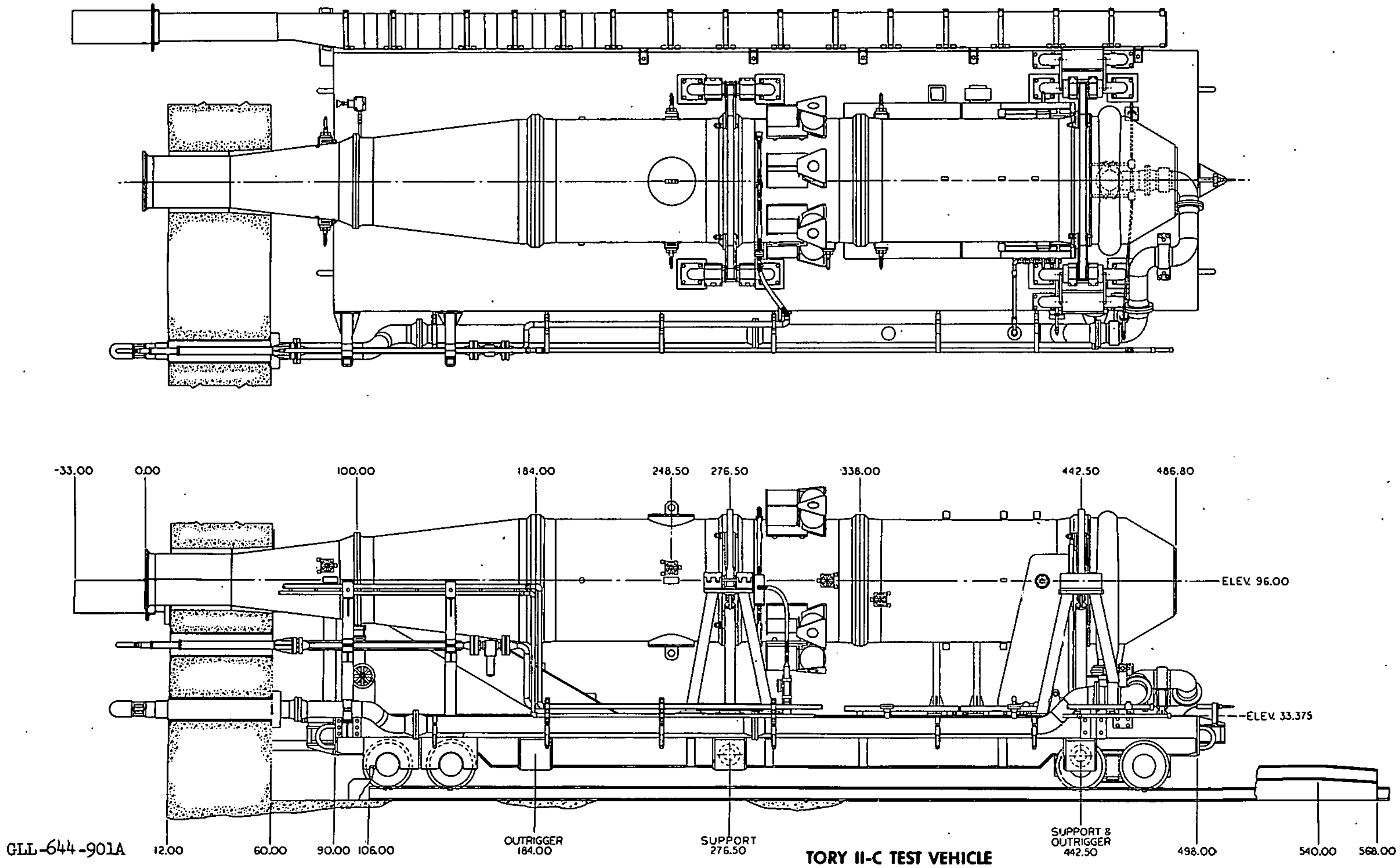

Fig. 3. Schematic of Tory IIC test vehicle.

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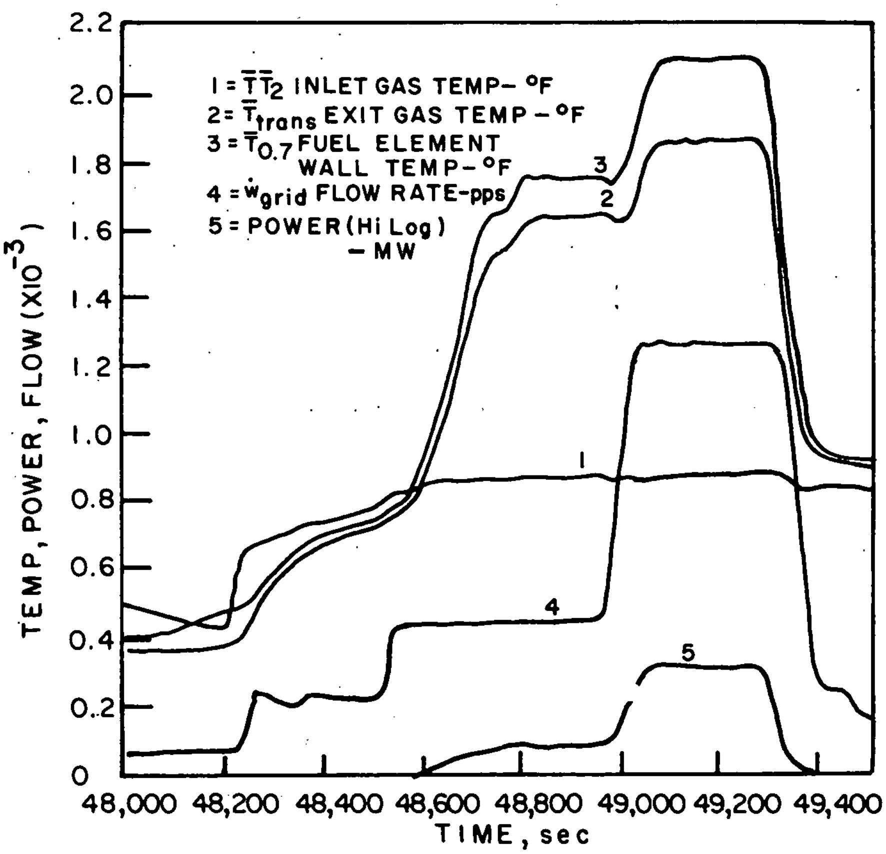

Fig. 4. Parameter measurements during intermediate power run.

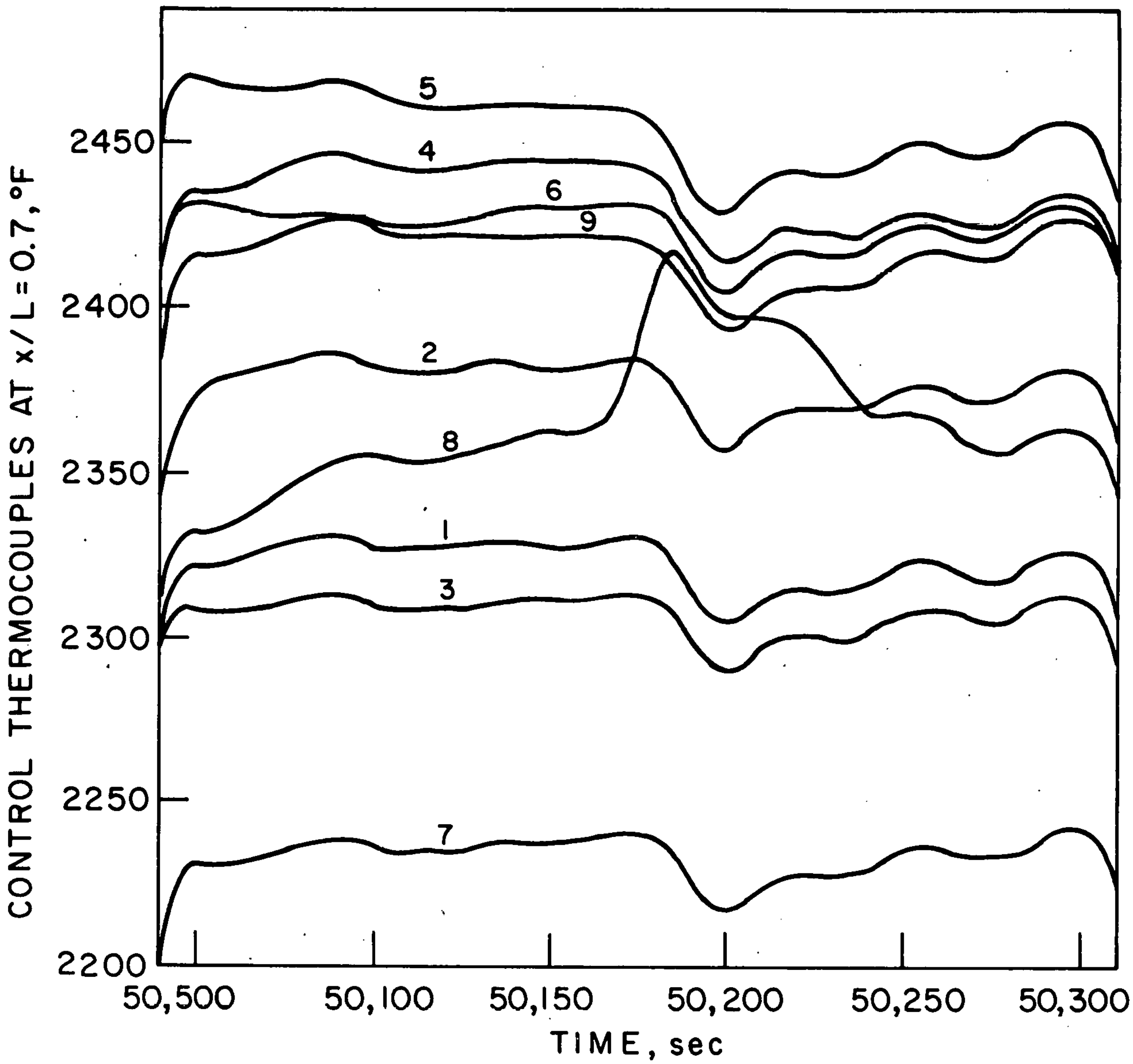

Fig. 5. Control thermocouple readings for high power test, run 89 (x/L = 0.7).

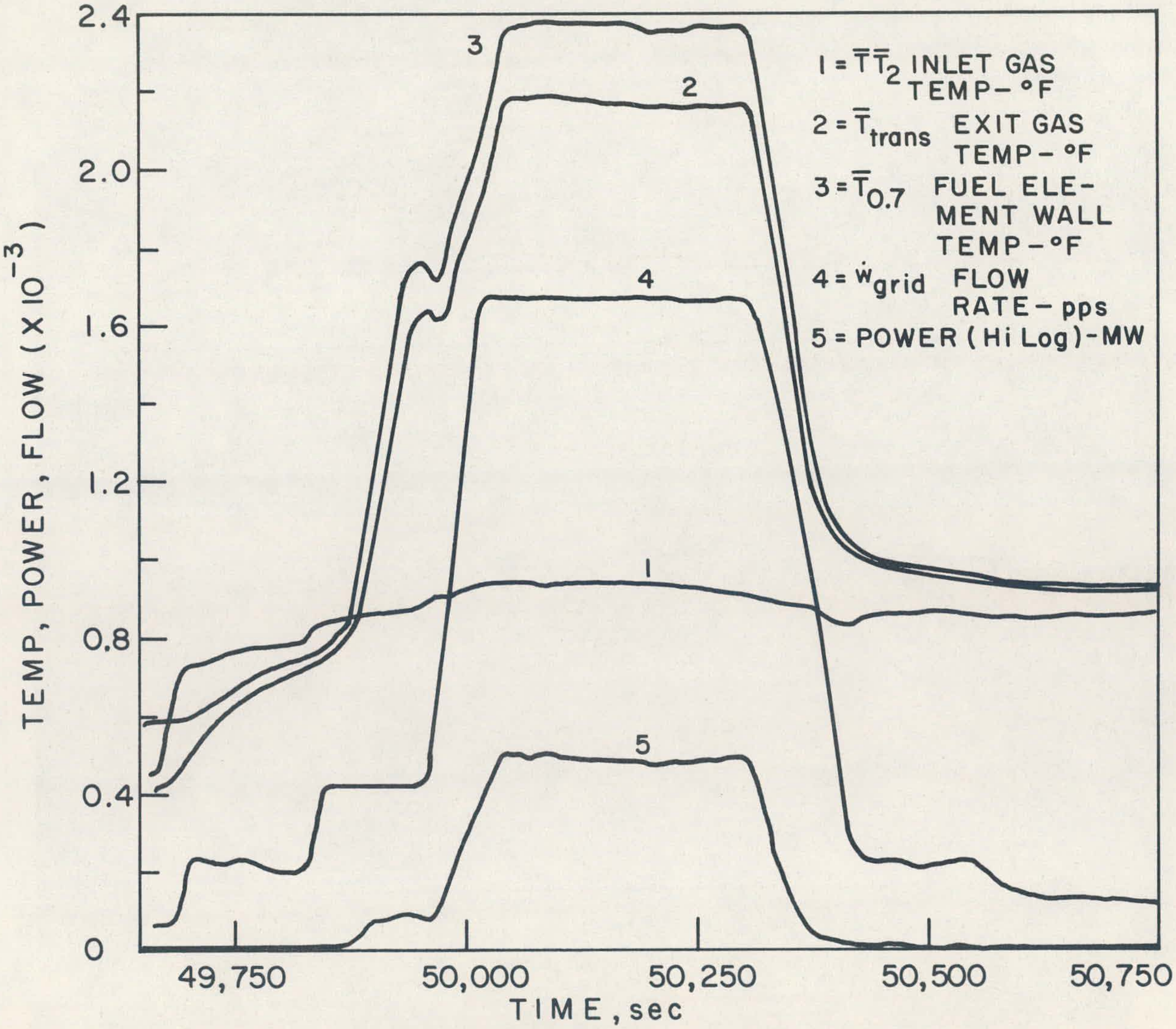

Fig. 6. Uncorrected major parameters during run 89.

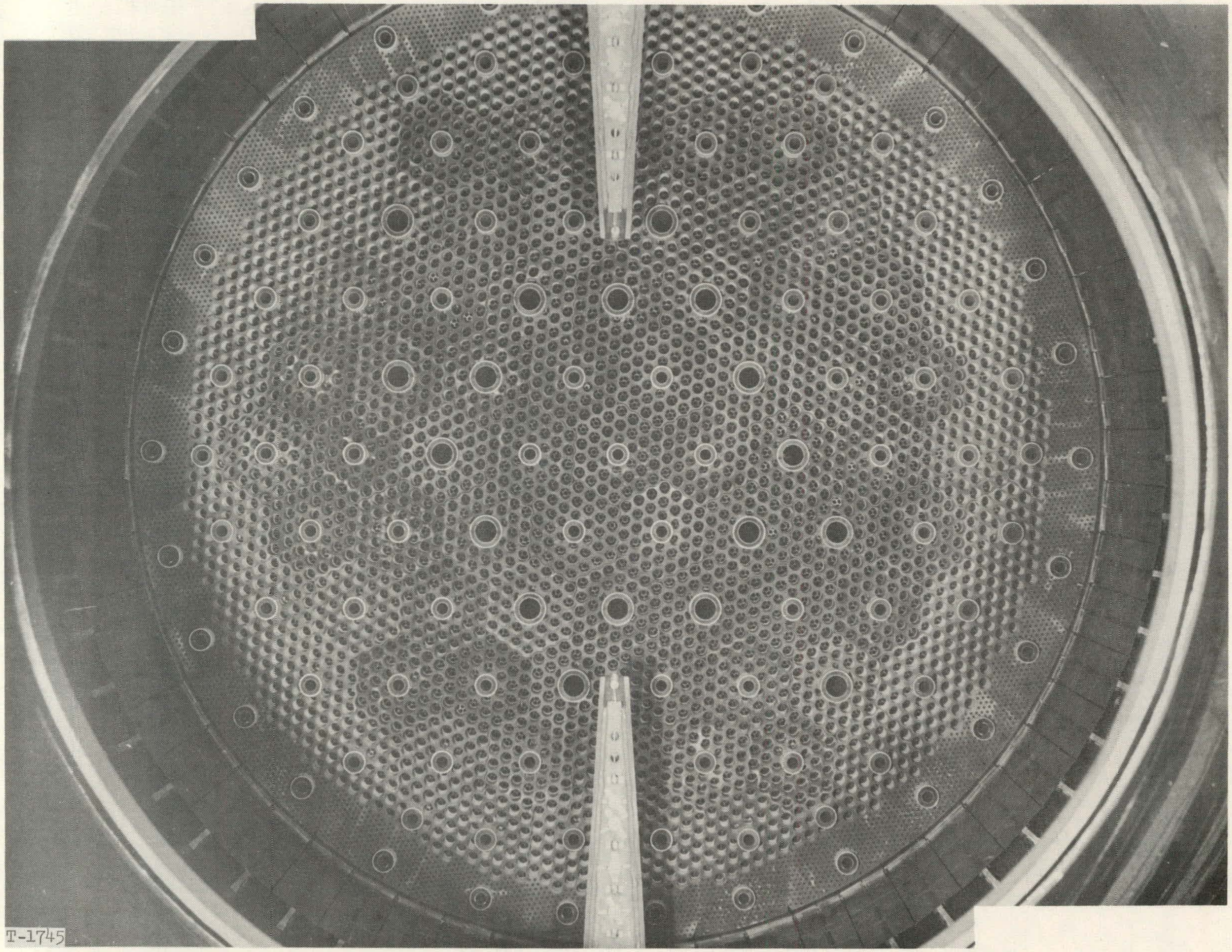

Fig. 7. View of base blocks after run 89

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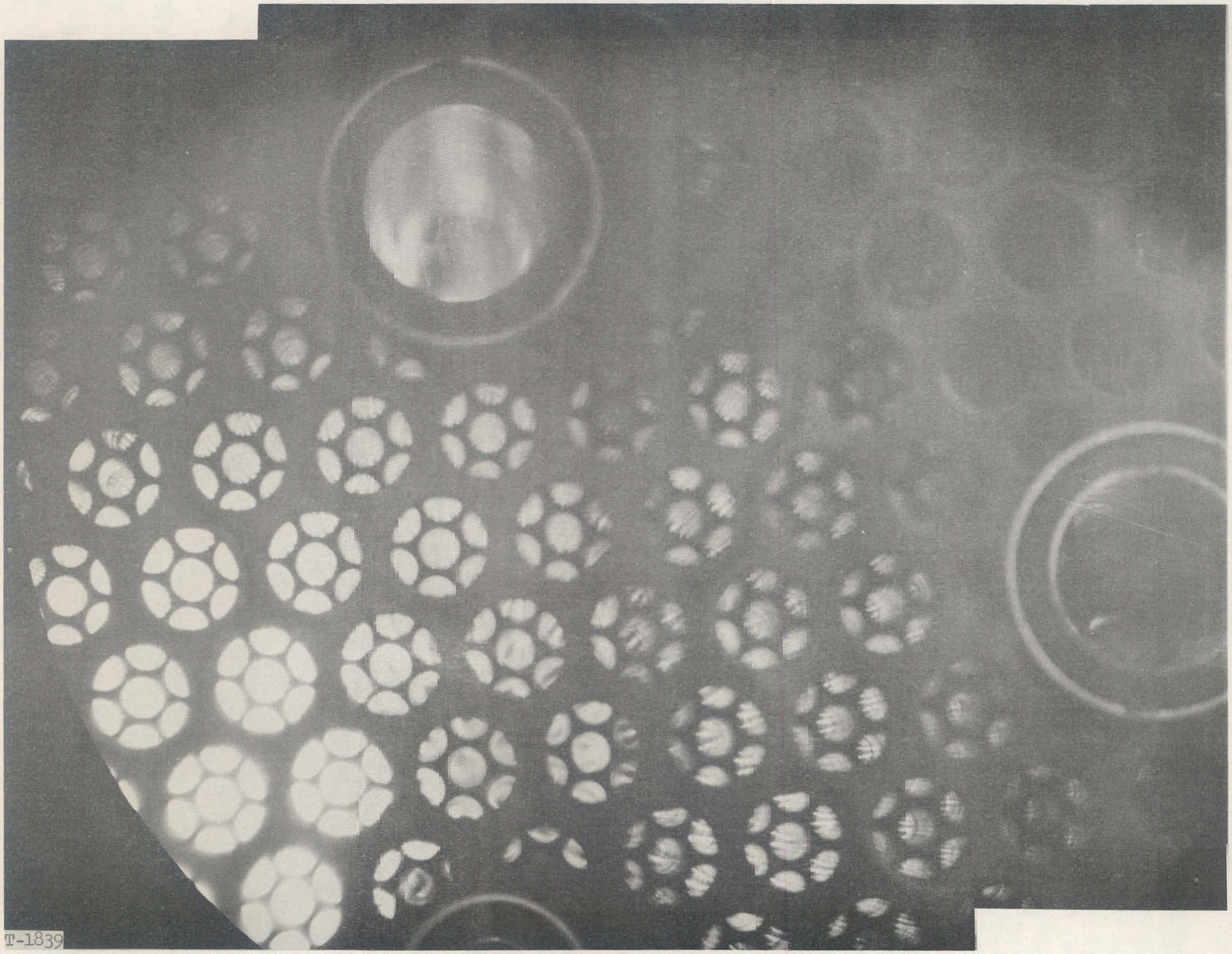

Fig. 8. View through reactor flow channels after run 89. Light is forward of reactor, and camera must be in close alignment to observe through the holes.

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