5.1.2 Commissioning Test Run CR02

5.1.2.1 Introduction and Test Objectives

Commissioning test run CR02 was conducted between June 11 and June 15, 1996. During this test run the transport reactor and associated refractory-lined pipe joints refractory were cured to about 1000°F. The reactor system had no solids inventory to begin with and no solids were added during the test run. The temperature, pressure, and flow rate trends observed during the run are shown in figure 5.1.2-1 through figure 5.1.2-7. After addressing a number of problems identified during the CR01 test run with the BR0201 the burner performed well during the CR02 commissioning test run.

5.1.2.2 Test Chronology

On June 10 the thermal oxidizer was started in preparation for the reactor start-up. The following day the main air compressor was started and the reactor pressure was set at 50 psig. As shown in figure 5.1.2-7, the CO0201 compressor discharge pressure for this and other test runs usually was set and occasionally was varied between 330 and 350 psig as necessary. The CO0201 exit temperature was between 340 and 350°F. The BR0201 pilot was lit (event 1, figure 5.1.2-1) and the cooling ignitor purge flow was set. The propane flow rate was about 18 lb/hr and the burner exit temperature reached about 500°F on start-up. Over the next 24 hours, the burner exit temperature was slowly increased to about 750 to 790°F by lowering the quench gas flow (event 2, figure 5.1.2-1). Since this was the first test run in which the reactor refractory was being heated up, the initial refractory cure procedure was followed for heat-up rates. The reactor refractory was held between 250 and 300°F during the first 24-hour period (event 2, figures 5.1.2-2 and -3) to slowly evaporate the moisture in the refractory.

On June 12 the main burner was lit (event 3, figure 5.1.2-1). The propane flow rate was increased from 18 to 70 lb/hr, and the burner exit temperature increased from about 750 to 1,050°F. After holding steady for about 6 hours, the propane flow rate and the outlet temperature were gradually ramped to about 140 lb/hr and 1,500°F respectively (event 4, in figure 5.1.2-1). The reactor loop skin temperatures were taken and were found acceptable. The propane flow and quench gas flows were increased simultaneously to maintain the burner exit at between 1,400 and 1,500°F (event 5, figure 5.1.2-1). Proper aeration of J-legs allowed uniform distribution of temperatures in various legs of the reactor. The reactor mixing zone temperature approached 1,200°F and the riser, standpipe, and cyclone exit temperatures were close to 1,000°F.

After reaching the desired cyclone exit temperature (1,000°F), the conditions were held steady to complete the cureout. At this time the burner tripped due to a loss of propane flow. Thirty minutes later the burner was relit. The propane firing was held at 140 lb/hr due to the frequent trips (event 6, figure 5.1.2-1). The quench air flow was gradually decreased to increase the outlet temperature. A few hours later the propane fell from 140 to 132 lb/hr and the burner tripped again. The main burner was lit again and the propane flow was set to about 140 lb/hr and held constant. The refractory cureout was completed at 0530 on June 15. The start-up burner's discharge temperature was 1,750°F at a firing rate of about 2.8 MBtu/hr before ramping the temperatures down in preparation for a gradual shutdown (event 7, figure 5.1.2-1). The momentary drop and loss of propane flow was later attributed to operation of the propane vaporizer. The operation of the vaporizer was far from smooth since less than 1 percent of its capacity was being utilized to vaporize liquid propane.

5.1.2.3 Test Run CR02 Observations

Several problems identified with the reactor start-up burner were corrected and the transport reactor refractory joints were successfully cured to 1,000°F. Proper aeration of the reactor J-legs allowed uniform distribution of temperatures in various legs of the reactor. There were minor problems with the operation of the propane vaporizer due to its running at a low load (~1 percent of its capacity), which caused the burner to trip periodically.

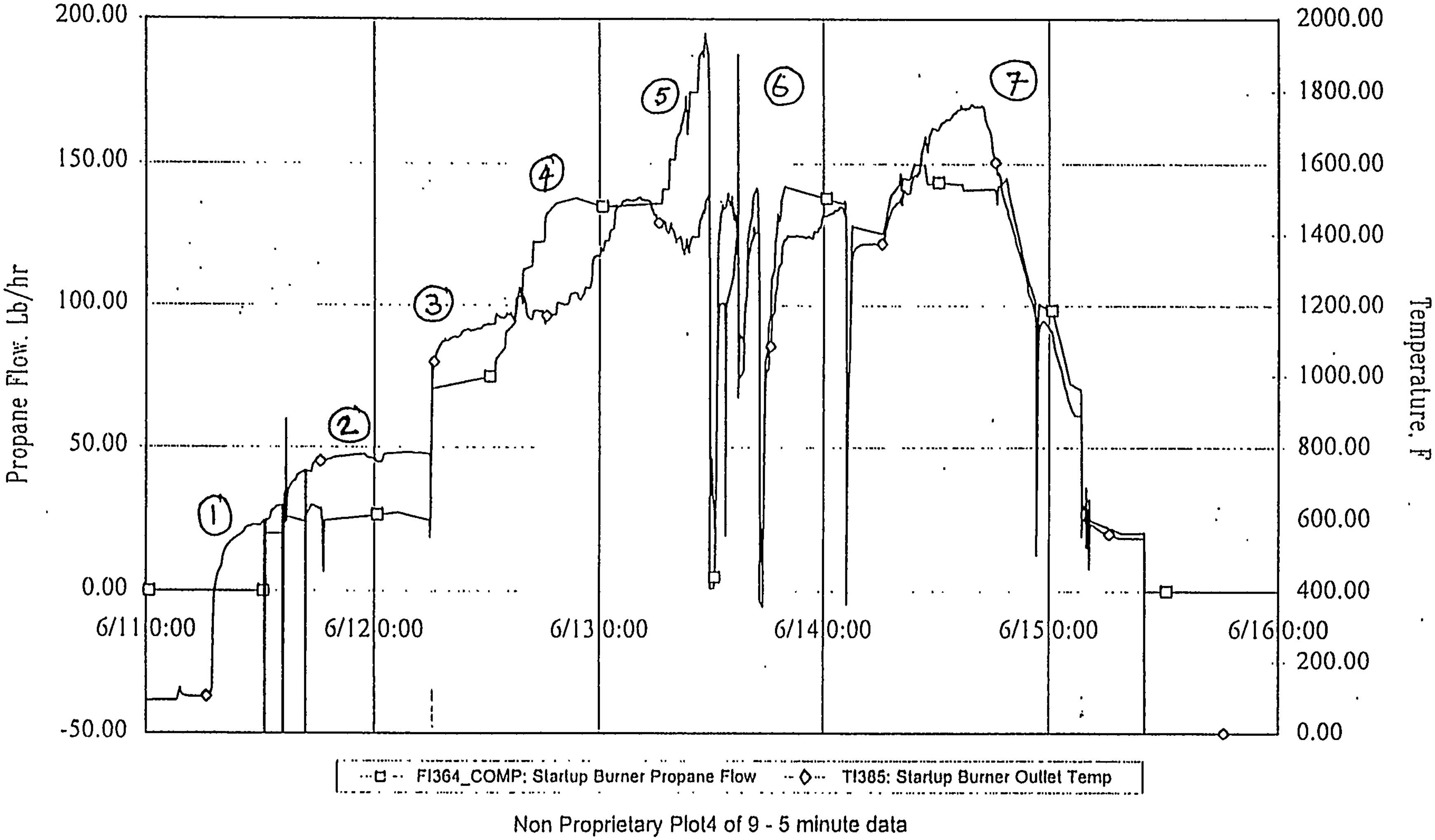


Figure 5.1.2-1 Start-up Burner Flow/Temperature for June 11 through 15, 1996

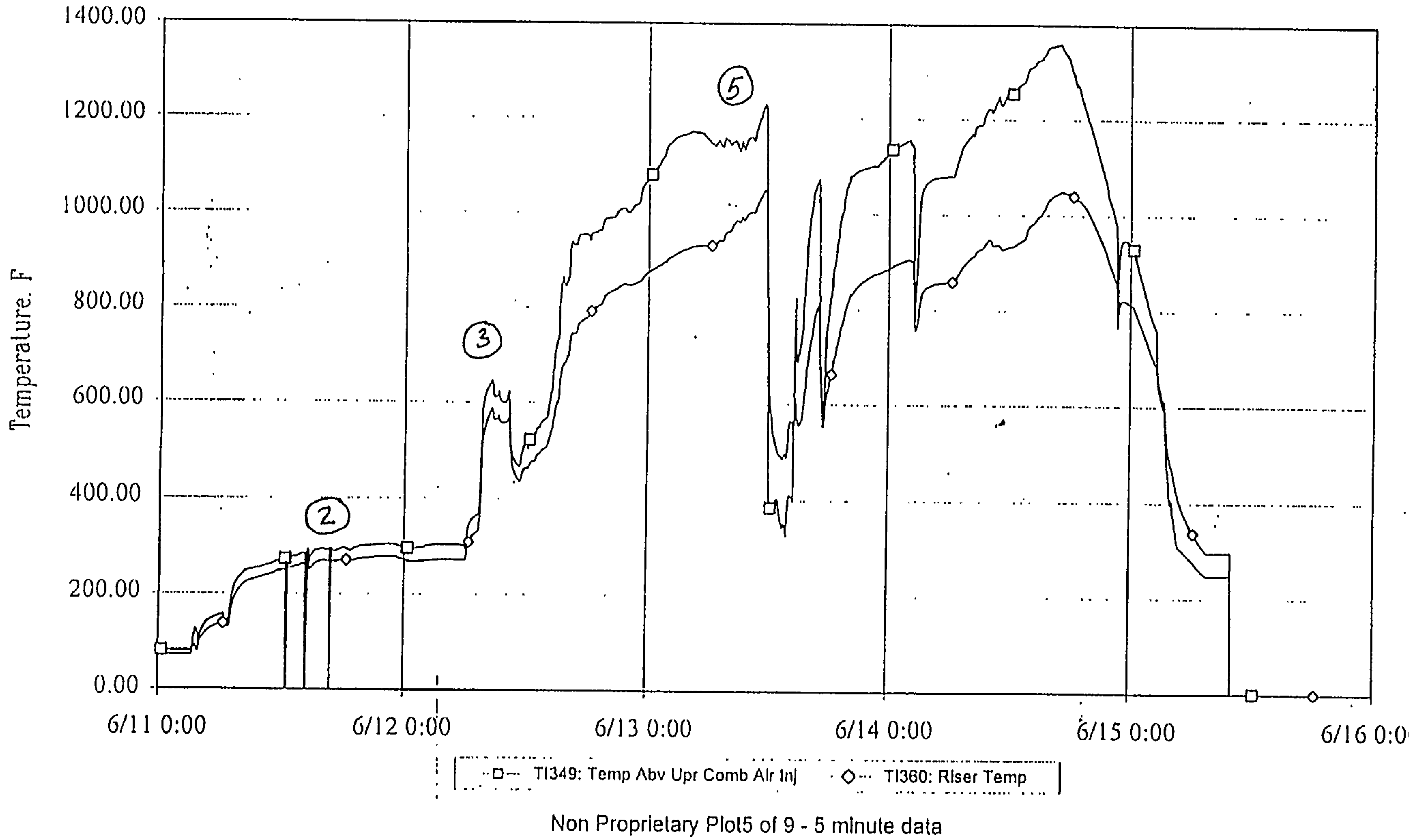


Figure 5.1.2-2 Reactor Mixing Zone and Riser Temperatures for June 11 through 15, 1996

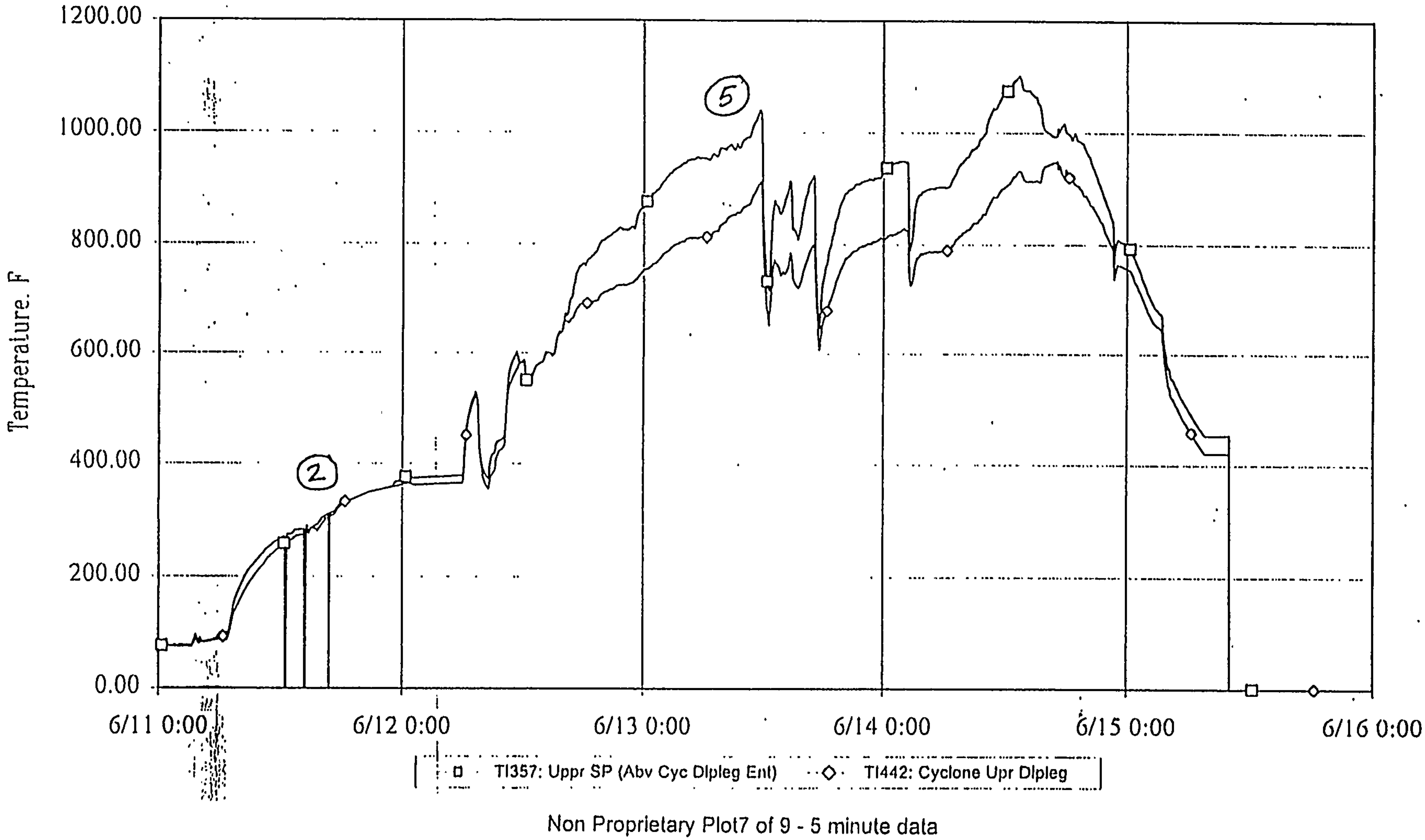


Figure 5.1.2-3 Standpipe/Dipleg Temperatures for June 11 through 15, 1996

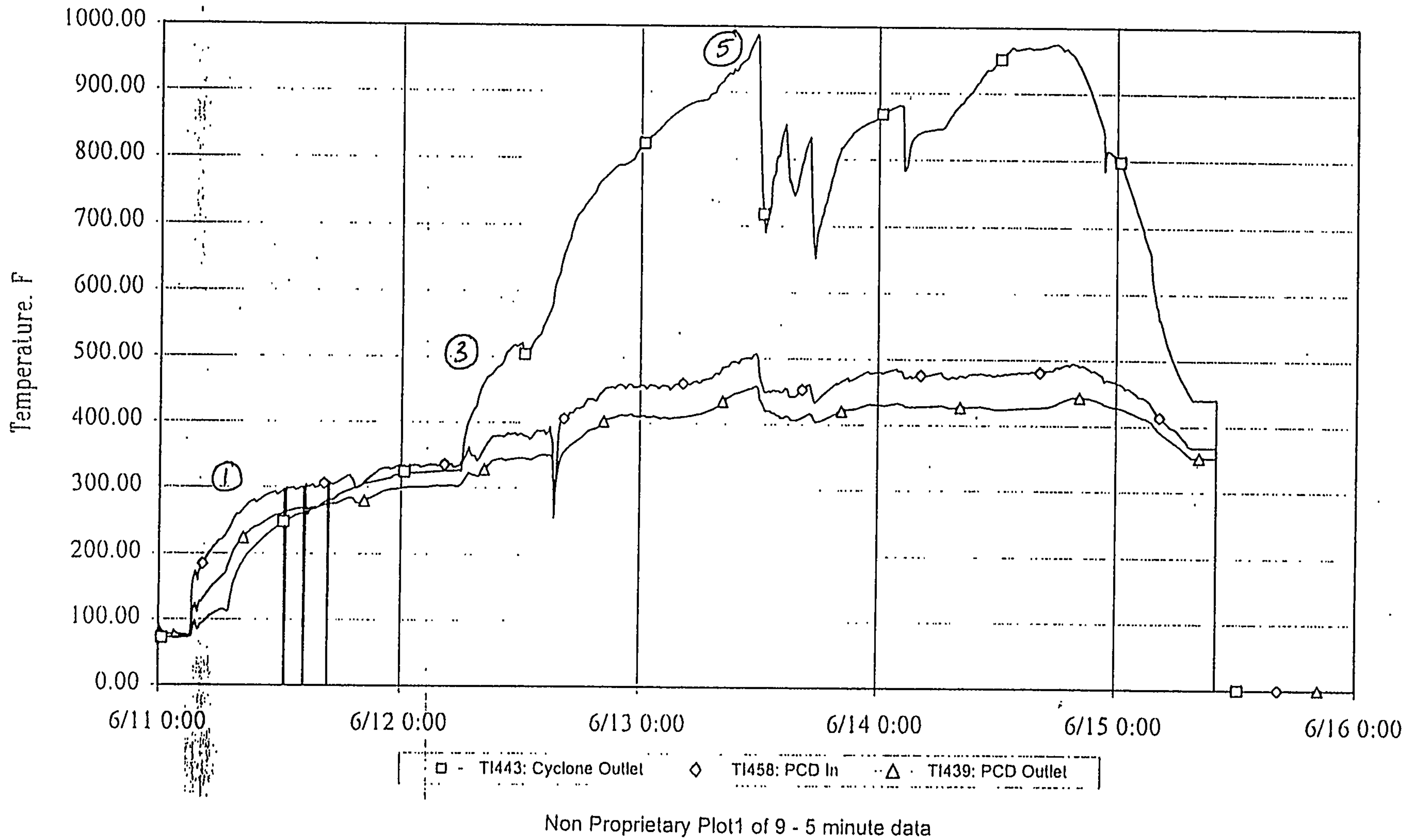
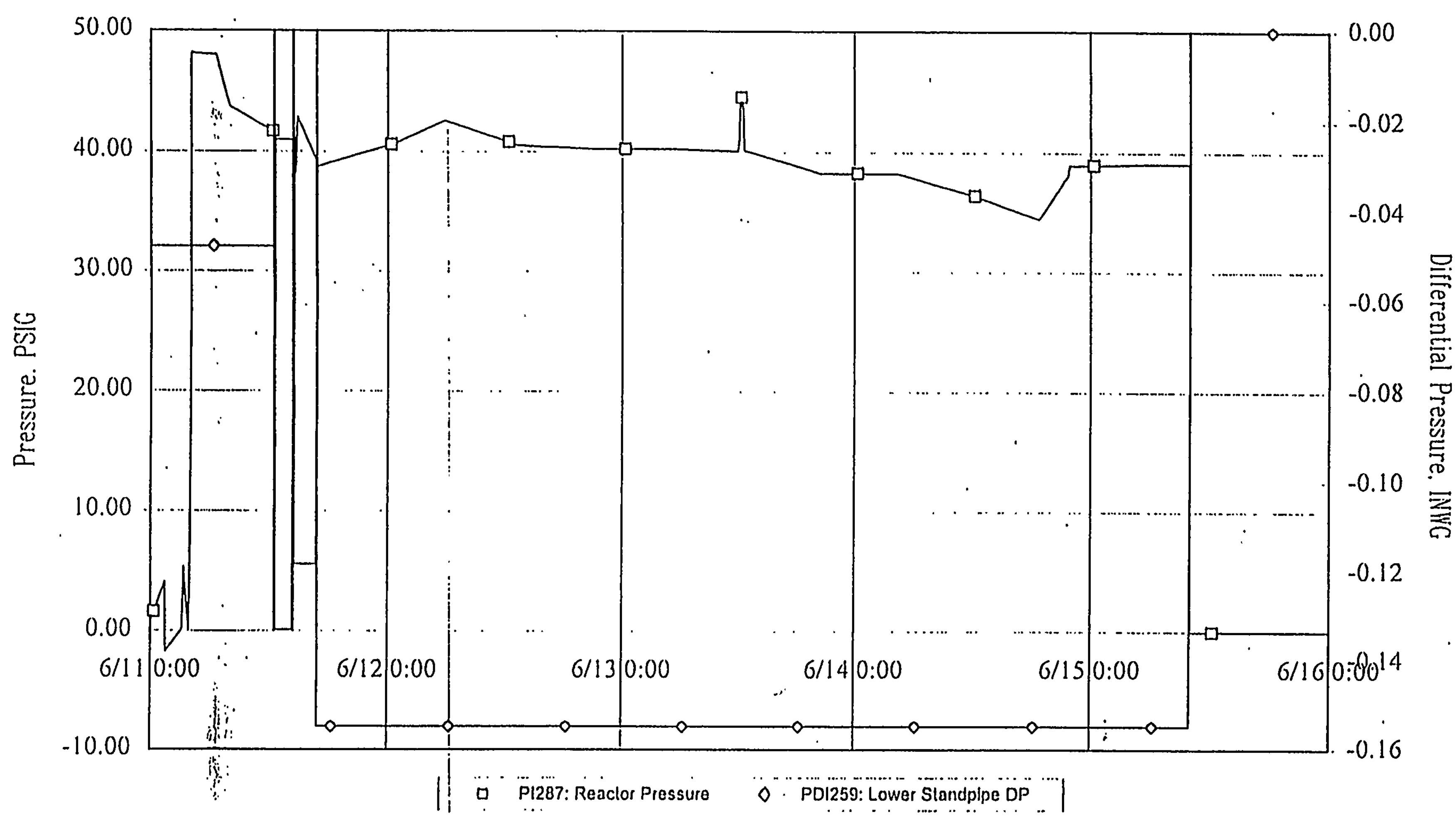


Figure 5.1.2-4 PCD Temperatures for June 11 through 15, 1996



Non Proprietary Plot6 of 9 - 5 minute data

Figure 5.1.2-5 Reactor Pres/Standpipe DP for June 11 through 15, 1996

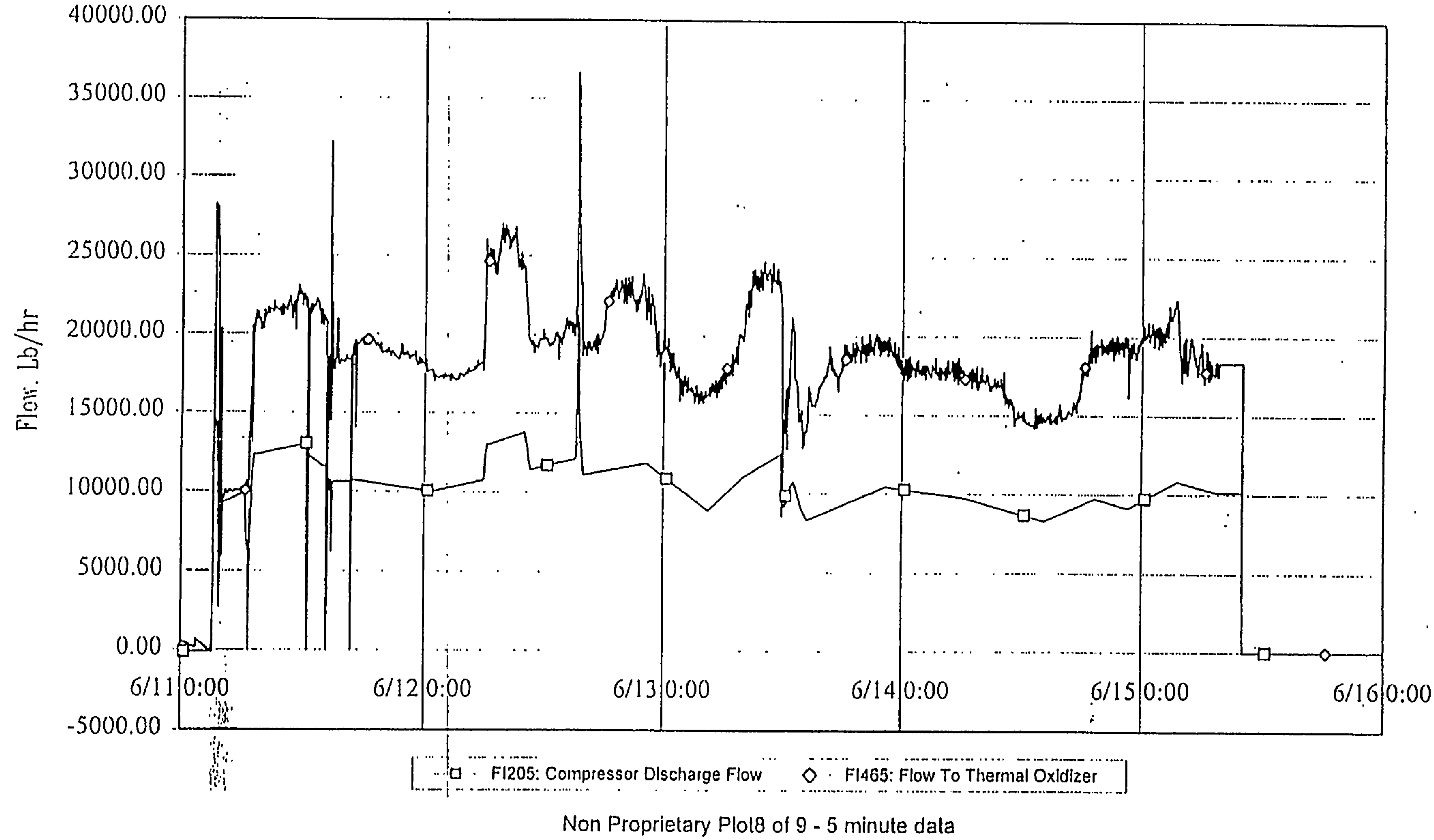
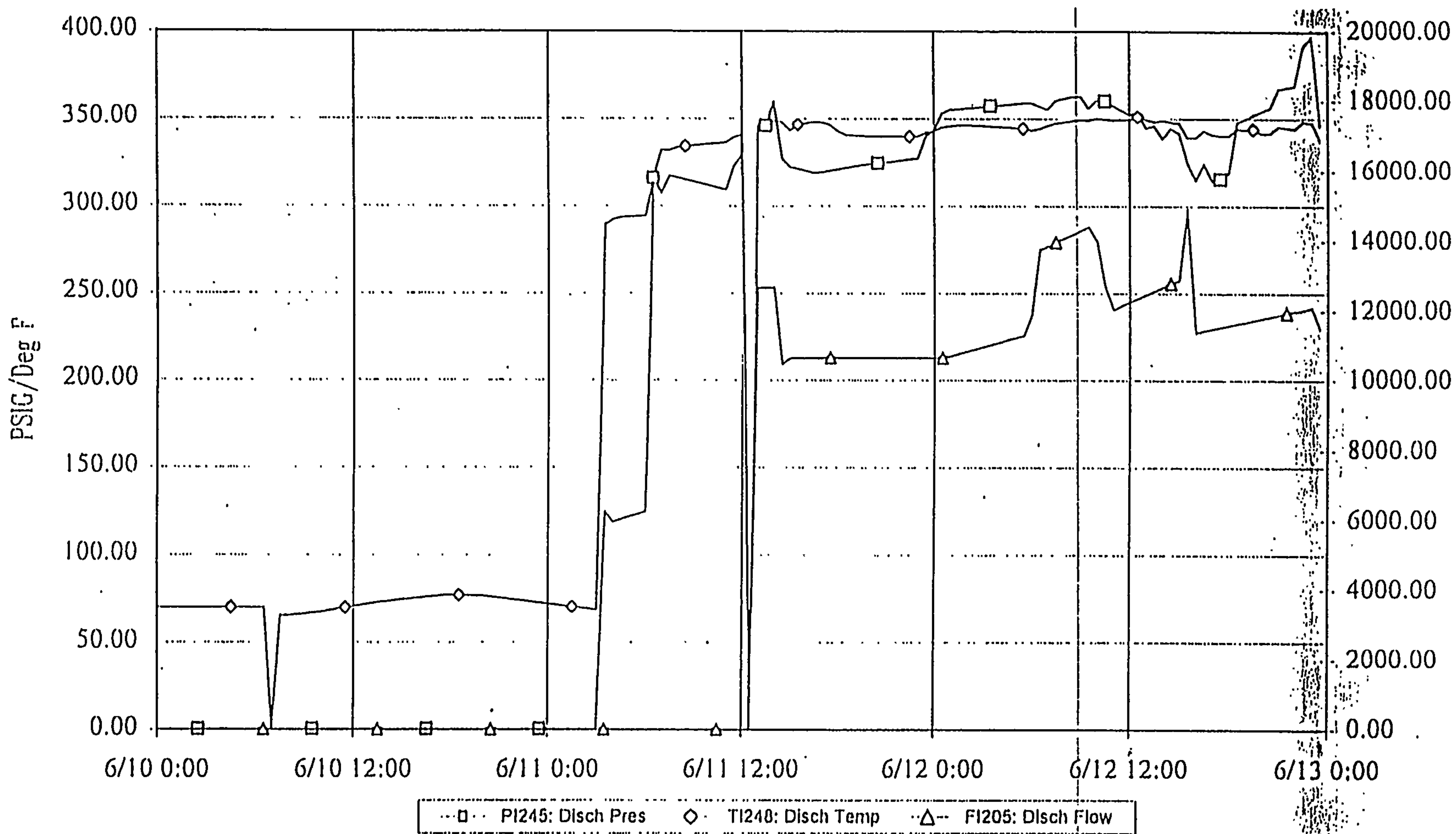


Figure 5.1.2-6 Reactor Flows for June 11 through 15, 1996



MWK Transport Reactor Plot 1 of 75 - 30 minute data

Figure 5.1.2-7 C00201 System Profile for June 10 through 12, 1996

5.1.3 Commissioning Test Run CR03

5.1.3.1 Introduction and Test Objectives

Test run CR03 was conducted from June 17 to June 20, 1996. Figures 5.1.3-1 through 5.1.3-19 show the operating graphs during this run. This test run consisted of the transport reactor undergoing a hot fluidization test with alumina circulating while the start-up burner was heating the reactor. The start-up burner was inspected and cleaned in preparation for this run.

The following summarizes addition of alumina to the reactor system and initial attempts to circulate solids before the process was shutdown.

The pressure differential transmitter (PDT) purge bleeds on the reactor system were balanced at three different pressures: 50, 160, and 294 psig. The pressure transmitter (PT) bleed flow rates were set at 3 lb/hr for 50 psig operation. The PT bleed flow rates had no effect on the instrument readings.

The FD0210 was loaded with 4,000 lb of alumina, the start-up bed material (event 1, figure 5.1.3-4). During the initial start of circulation, solids filled the HX0203 J-leg, reactor J-leg, and the lower portion of the mixing chamber, resulting in a decrease in the solids height in the standpipe.

The FD0140 was loaded with 2,640 lb of alumina to be transferred into the standpipe through the fill nozzle. As per procedure, minimum aeration and process air flow rates were set. Instrument purge rates were also set for 50 psig operation. The reactor pressure was set to zero psig to facilitate transfer of alumina through the fill nozzle in the standpipe. The alumina was conveyed into the standpipe between 01:30 and 03:14 on June 18, 1996. Five 1,650 lb batches of alumina were added to the reactor system between 19:20 and 23:49. The addition of solids in the reactor standpipe, HX0203 standpipe and J-legs was confirmed by the PDTs (event 2, figure 5.1.3-14 and -16).

While solids were being transferred to the reactor system, circulation of solids was confirmed by the upper riser differential pressure indicator, DI202 (event 2, figure 5.1.3-15). The solids that were added to the reactor standpipe were being transferred to the J-legs and the lower portion of the mixing zone because the J-legs were over-aerated. However, the aeration rates that were set for the J-legs were the minimum that could be obtained through the flow indicator controllers (FICs) and flow indicators (FIs).

5.1.3.2 Test Chronology

At 1400 on June 18, 1996, the reactor system was pressurized to 50 psig (event 3, figure 5.1.3-15). The combustion air flow through the BR0201 was increased in preparation for lighting the start-up burner pilot. The burner chamber pressure was swinging from 45 to 60 psig and the PDT across the burner J-leg was also swinging. The aeration nozzles on the burner J-leg were all cold indicating that there was no flow. So, the nozzles and the burner J-leg were cleared of solids by temporarily increasing the flow rates through these nozzles and simultaneously decreasing the reactor pressure to 38 psig. This resulted in a small pressure fluctuation (less than 1 psi) in the burner chamber.

On the second try the pilot was lit at 15:14. The burner exit temperature was maintained at 515°F by using the quench air (event 4, figure 5.1.3-6). The aeration and process air flow rates were increased as per procedure to initiate circulation through the reactor J-leg only. Since the solids level in the reactor standpipe was just below the HX0203 solids inlet, addition of solids through FD0210 was attempted.

Due to a number of problems (including damp solids) further addition of solids could not be achieved from the FD0210 system. The system logic was checked and the mechanical failures in the FD0210 system were corrected. After the unit was pressurized to 50 psig, a white plume was noticed coming from the stack. The thermal oxidizer flue gases and the process gas were set to bypass the baghouse as the bags were not in place. When the pressure letdown valve was closed temporarily, the plume disappeared, confirming the source of the plume was through the reactor system. A steam leak through the heat exchanger in the process was precluded. Through a process of elimination and through samples, it was concluded that the plume was caused by alumina. It was assumed at this time that the alumina was carried over to the Combustion Power Company (CPC) filter vessel during loading of solids in the standpipe. Samples of alumina obtained later from the CPC vessel contained higher proportions of fines below 100 microns than the virgin alumina and samples from various parts in the reactor system.

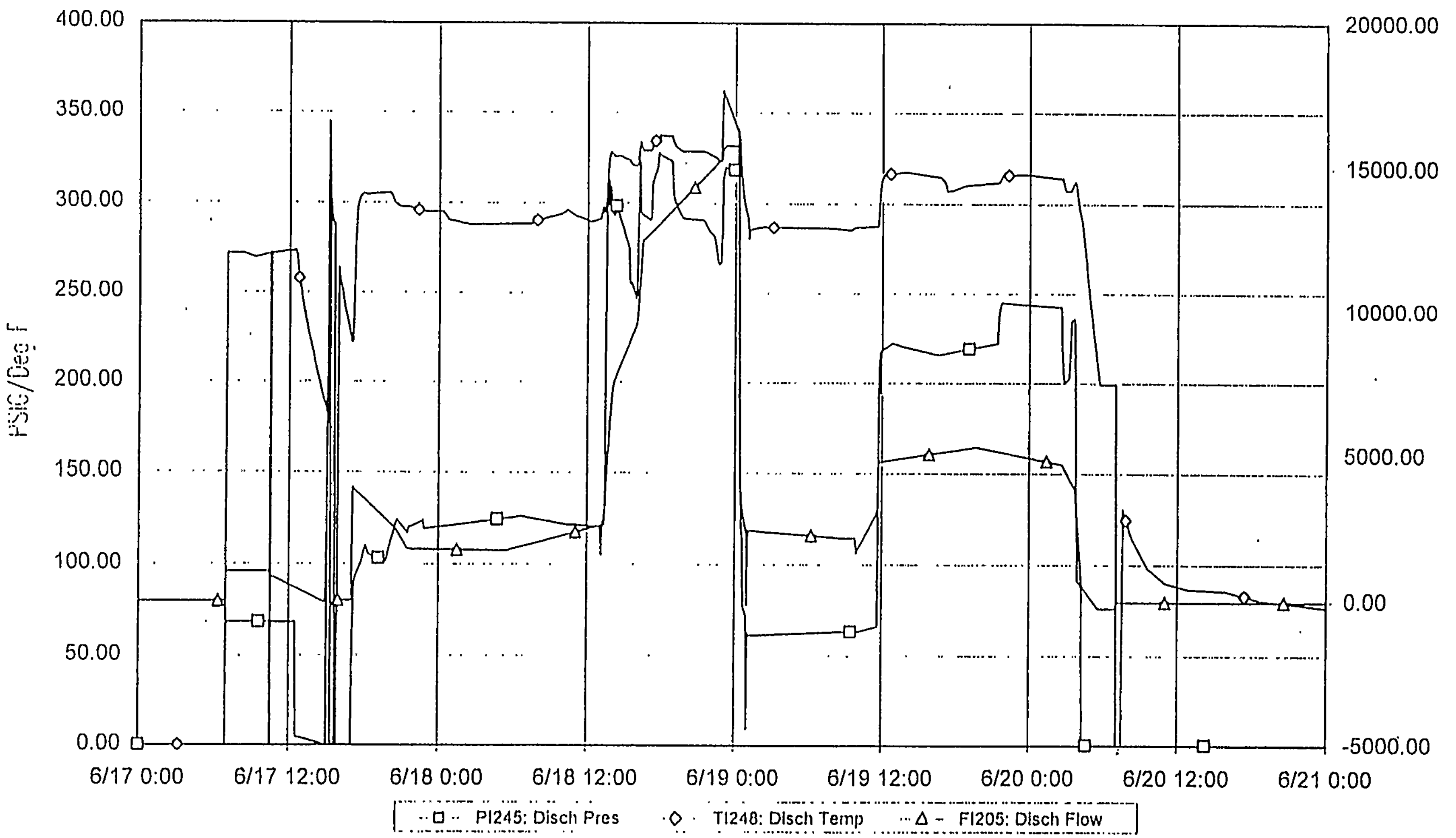
At 23:25 on June 18, 1996, while FD0210 problems were being solved, solid circulation was initiated through the HX0203 J-leg by increasing the HX0203 J-leg flow, closing the HX0203 vent valve (PDV384), and slightly decreasing the reactor J-leg flow. The riser pressure differential transmitter, DI202 increased from 0.0 to 2.7 inH_2O (event 5, figure 5.1.3-15). At 23:50 the HX0203 flow was further increased and the reactor J-leg flow was also increased. The DI202 indication fluctuated between 2.7 and 5 inH_2O.

Over the 5-hour period before the start of solid circulation, the standpipe temperatures were increasing at a rate of 10°F/hr, and during solid circulation, these temperatures increased at a rate of 50°F/hr (event 6, figure 5.1.3-10). These temperature and differential pressure increases confirm transport of solids through the riser and circulation of solids. The riser superficial gas velocity was approximately 32 ft/sec. The higher gas flow rates during solid circulation caused an increase in the plume intensity out of the stack. As a result the BR0201 and the reactor system were shutdown and depressurized (event 7, figure 5.1.3-15).

This test was ended prematurely because the pressure letdown valve body and trim were eroded by the alumina. This valve was subjected to solids because the flow path was routed through the empty Combustion Power Company Granular Bed Filter to protect the candles from high moisture in the gas/air during the cure. This failure occurred after sufficient flow, circulation, and temperatures were achieved to relieve concerns of moisture fouling the PCD candles.

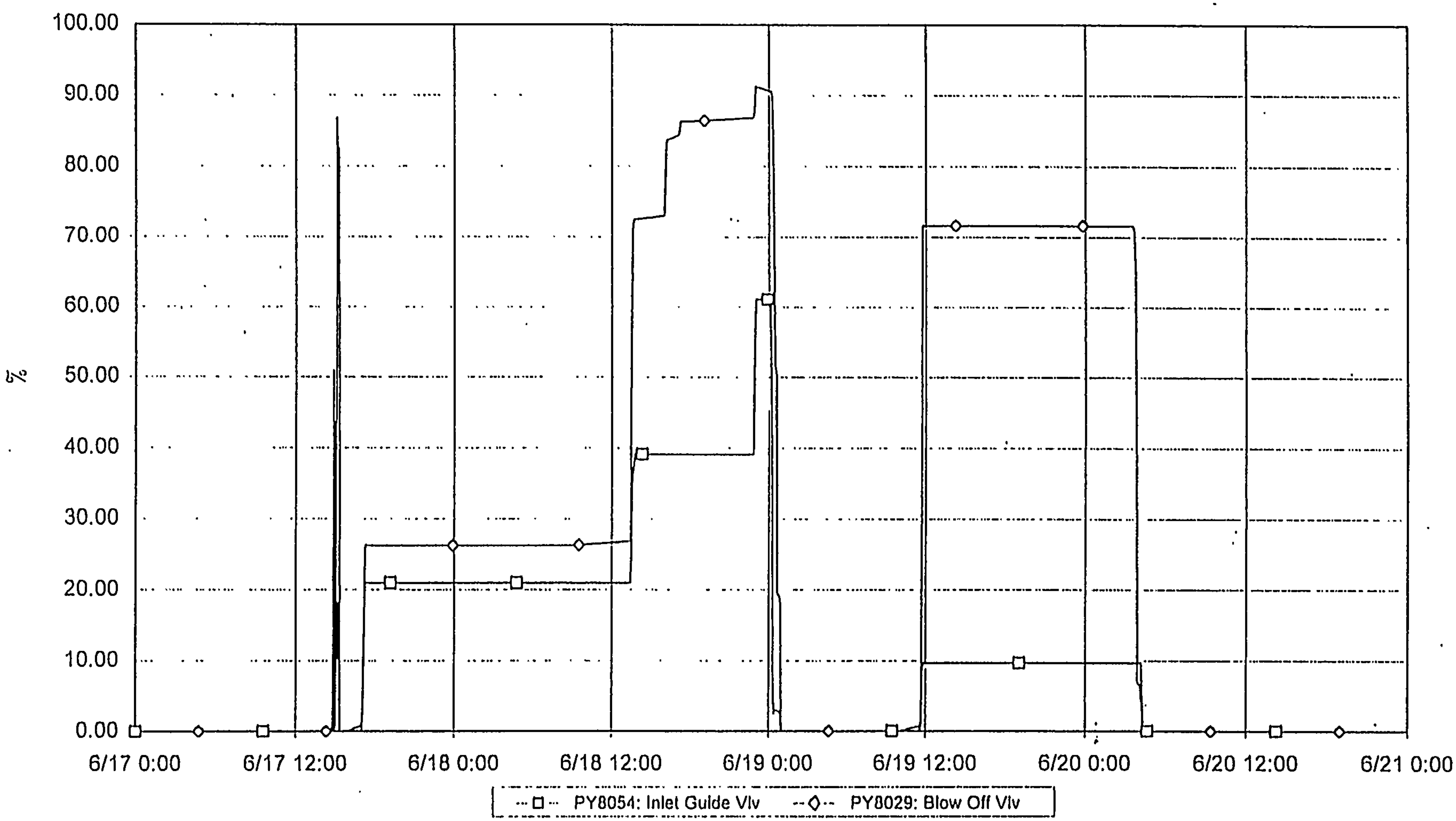
5.1.3.3 Test Run CR03 Observations

The alumina inert bed material was added to the reactor under ambient conditions. Solid circulation in the reactor loop was successfully established. Due to a dust plume in the stack the run was prematurely ended. It was concluded that there was a high carryover of alumina to the downstream equipment since the flow path was through the empty Combustion Power Company granular bed filter.



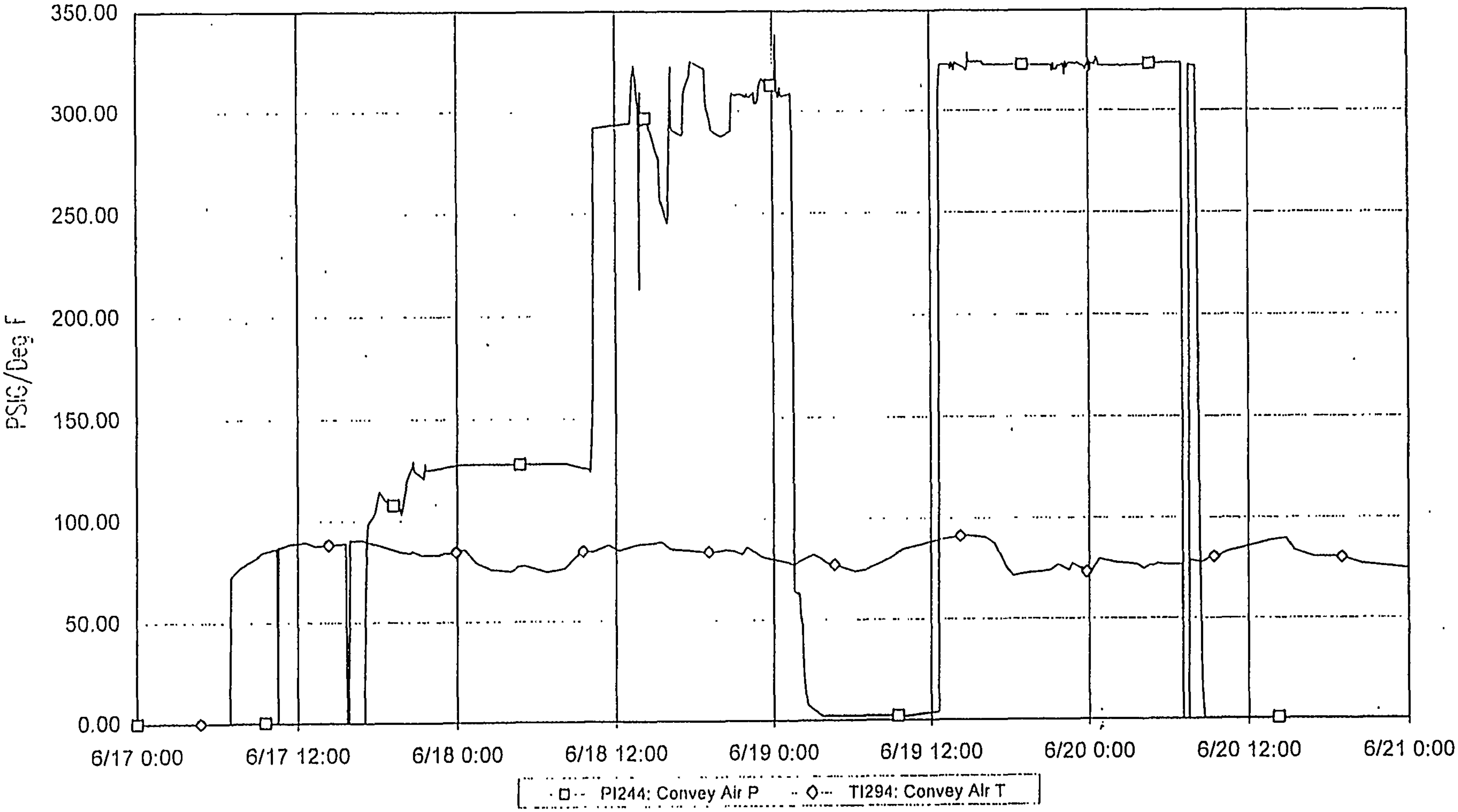
DOE Plot 1 of 45 - 5 minute data

Figure 5.1.3-1 C00201 System Profile for June 17 Through 20, 1996



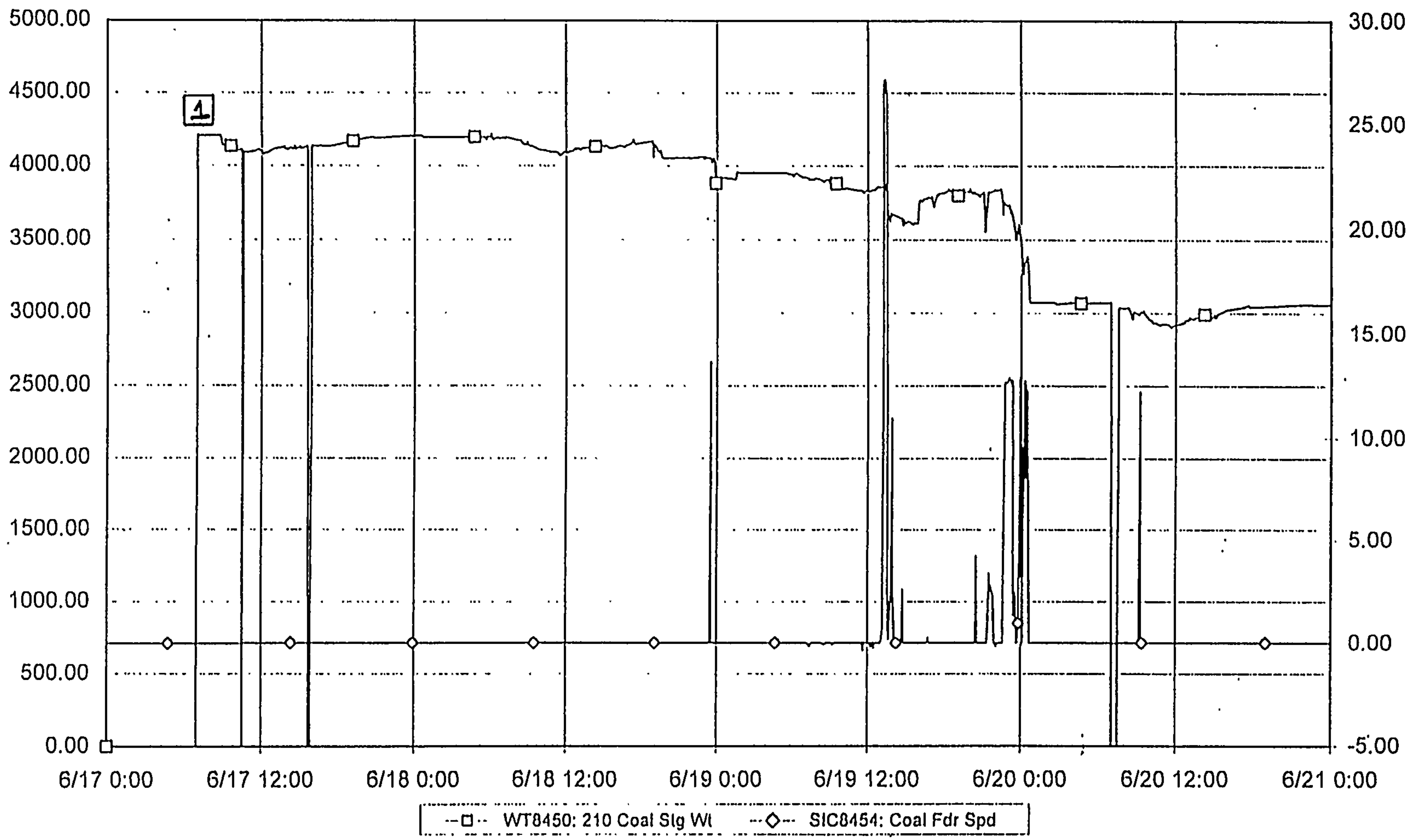
DOE Plot 2 of 45 - 5 minute data

Figure 5.1.3-2 C00201 Fourth Stage Vane Position for June 17 Through 20, 1996



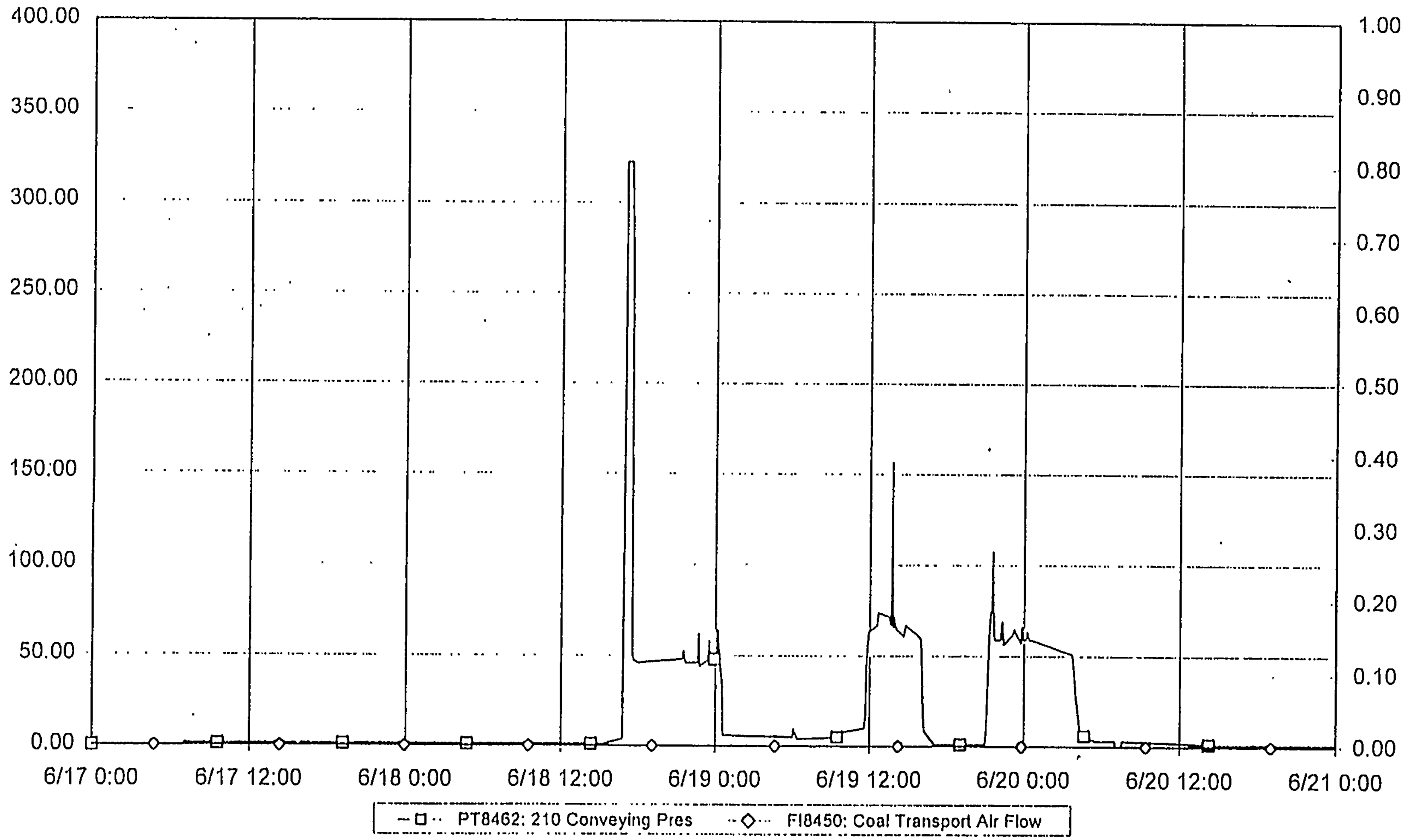
DOE Plot 5 of 45 - 5 minute data

Figure 5.1.3-3 Transsport Air System for June 17 Through 20, 1996



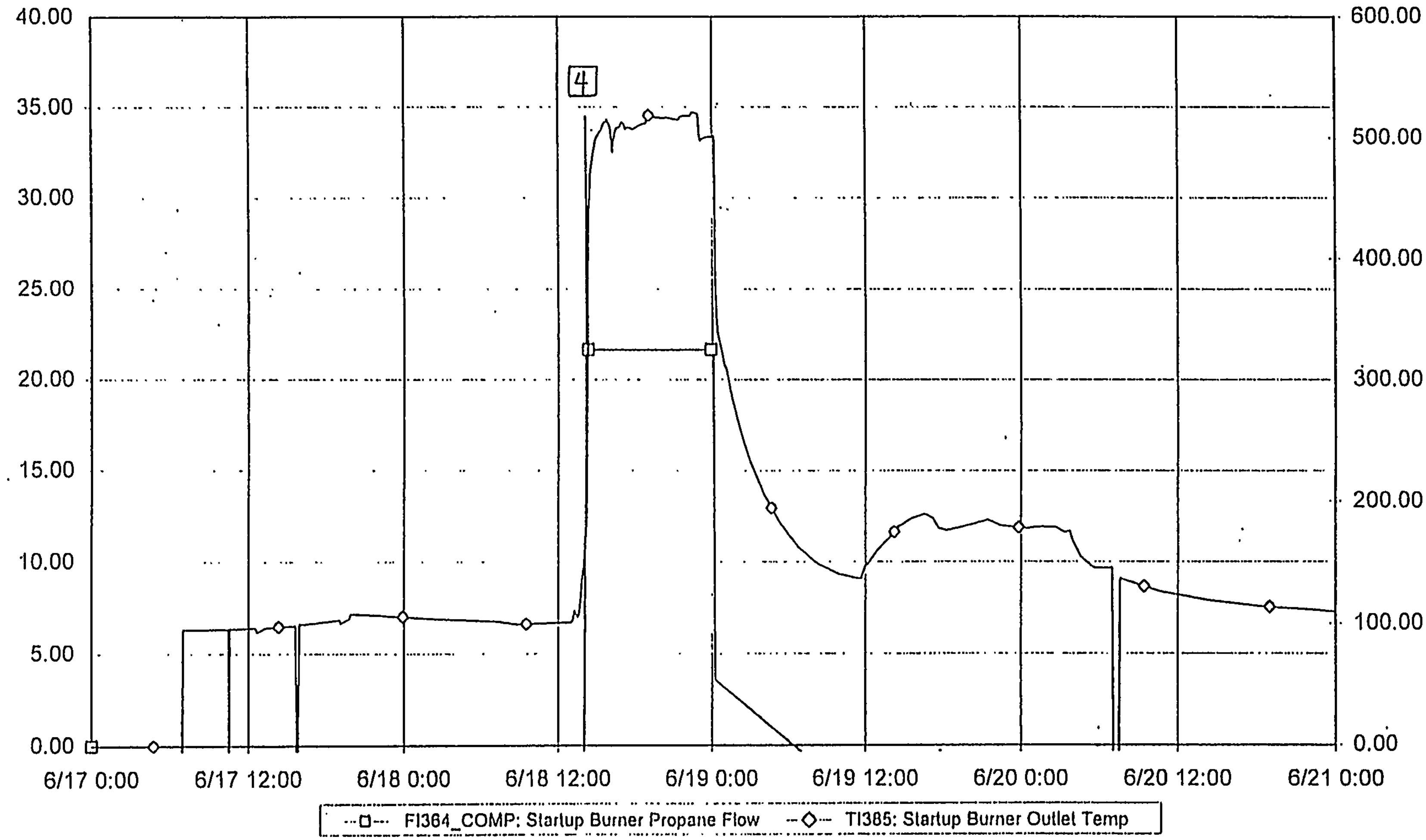
DOE Plot 7 of 45 - 5 minute data

Figure 5.1.3-4 Coal Feed for June 17 Through 20, 1996



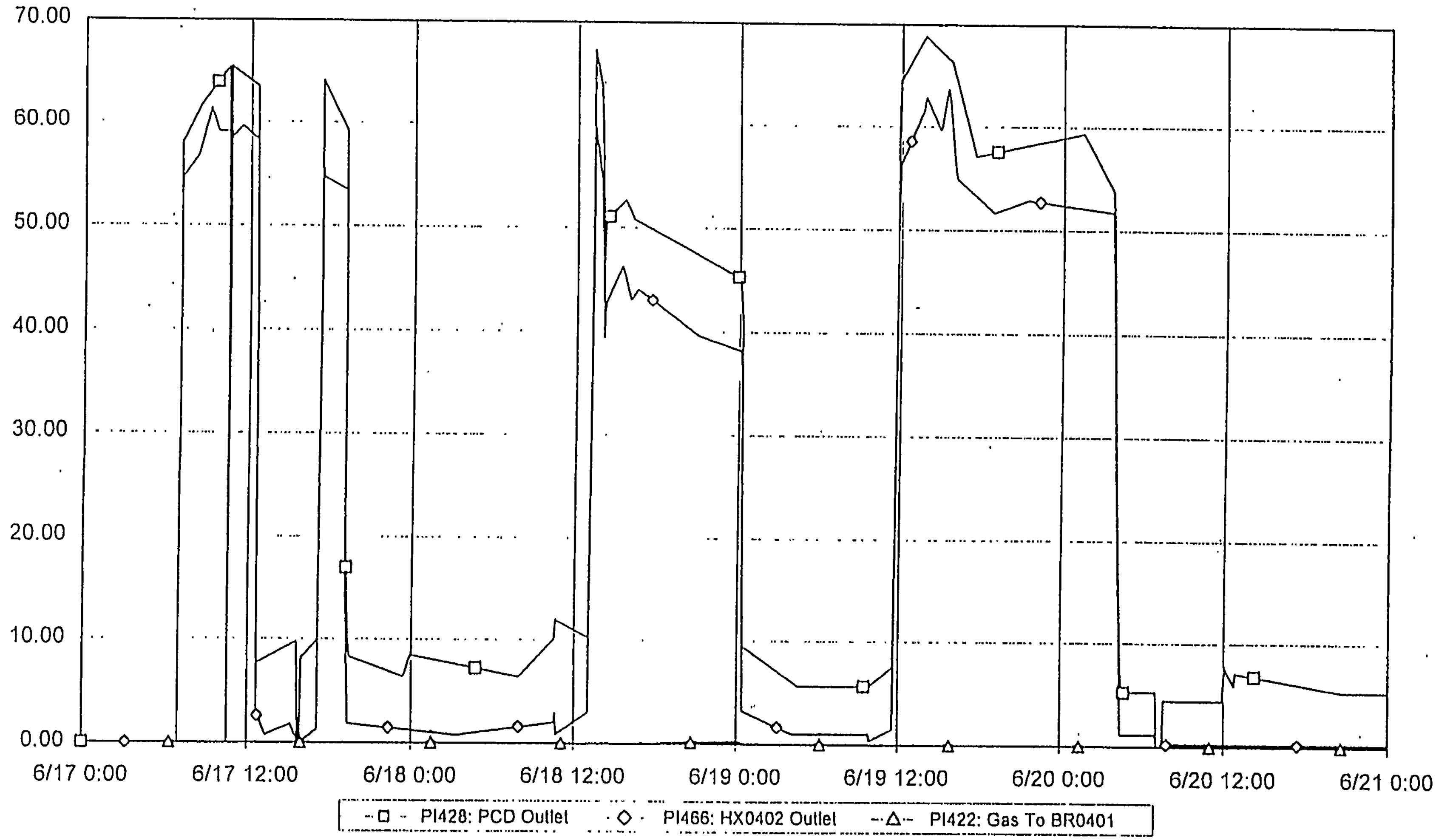
DOE Plot 8 of 45 - 5 minute data

Figure 5.1.3-5 FD0210 Conveying line Pres/Flow for June 17 Through 20, 1996



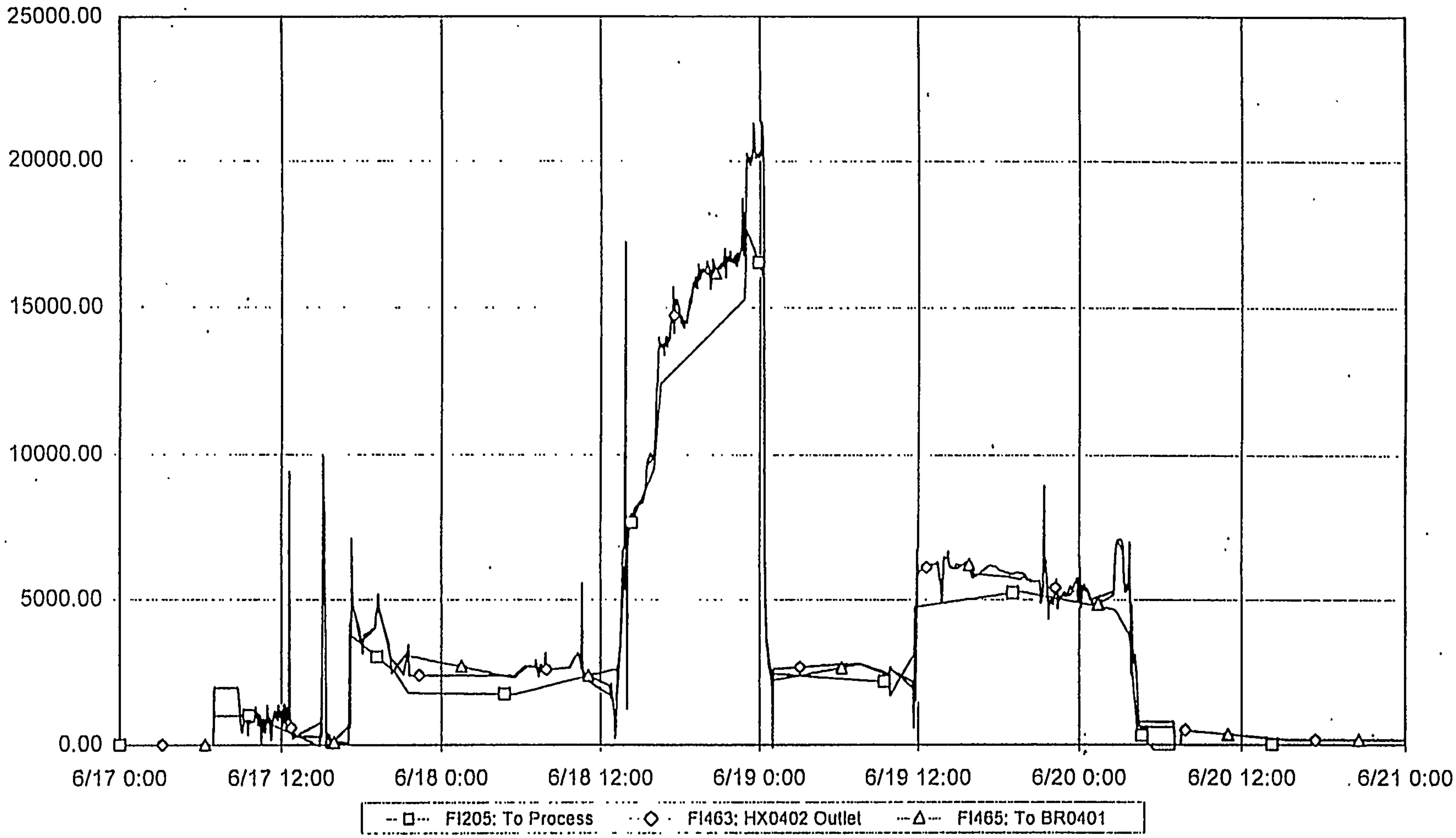
DOE Plot 11 of 45 - 5 minute data

Figure 5.1.3-6 Start-up Burner Flow/Temperature for June 17 Through 20, 1996



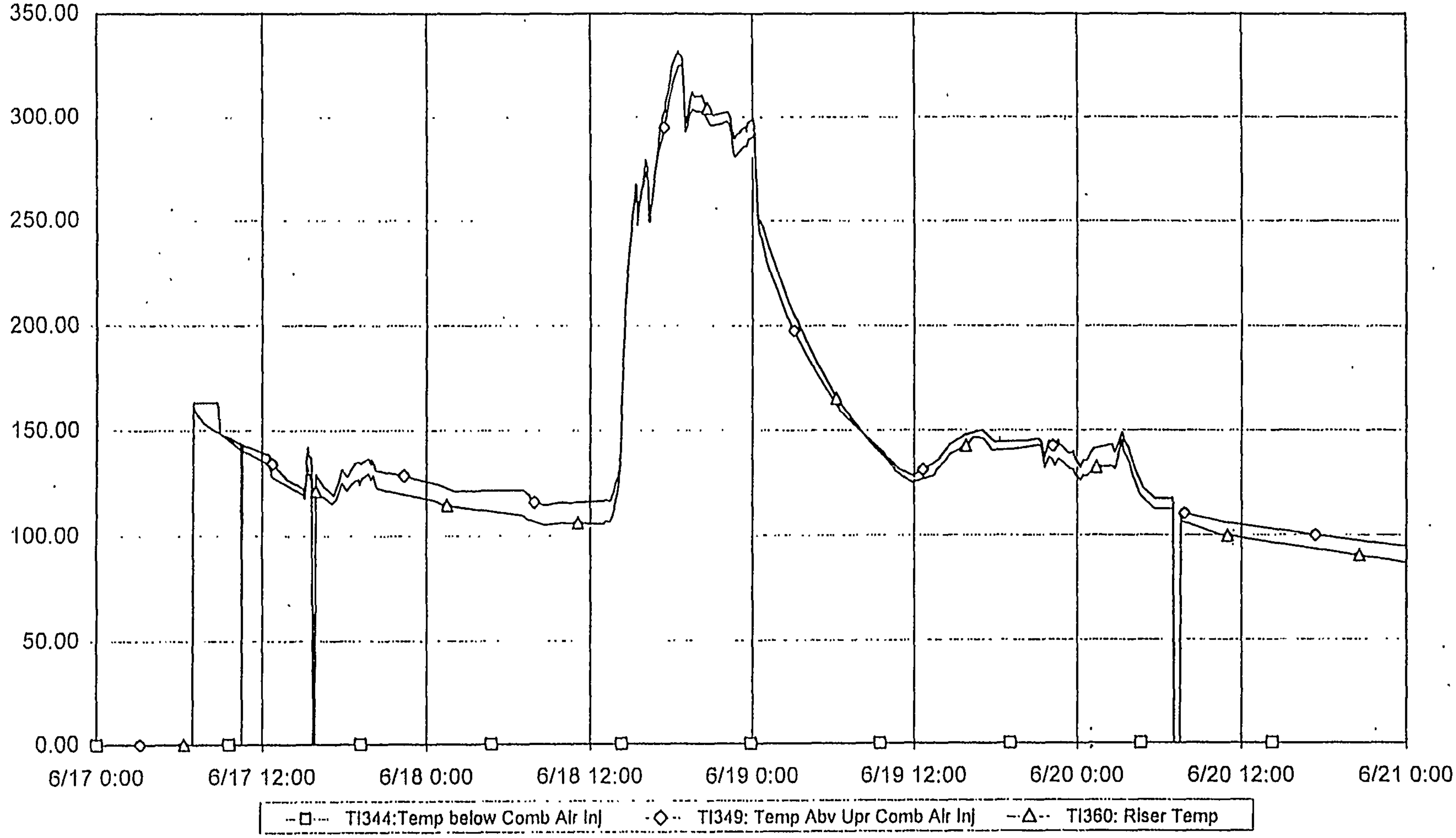
DOE Plot 12 of 45 - 5 minute data

Figure 5.1.3-7 System Pressures Downstream of PCD for June 17 Through 20, 1996



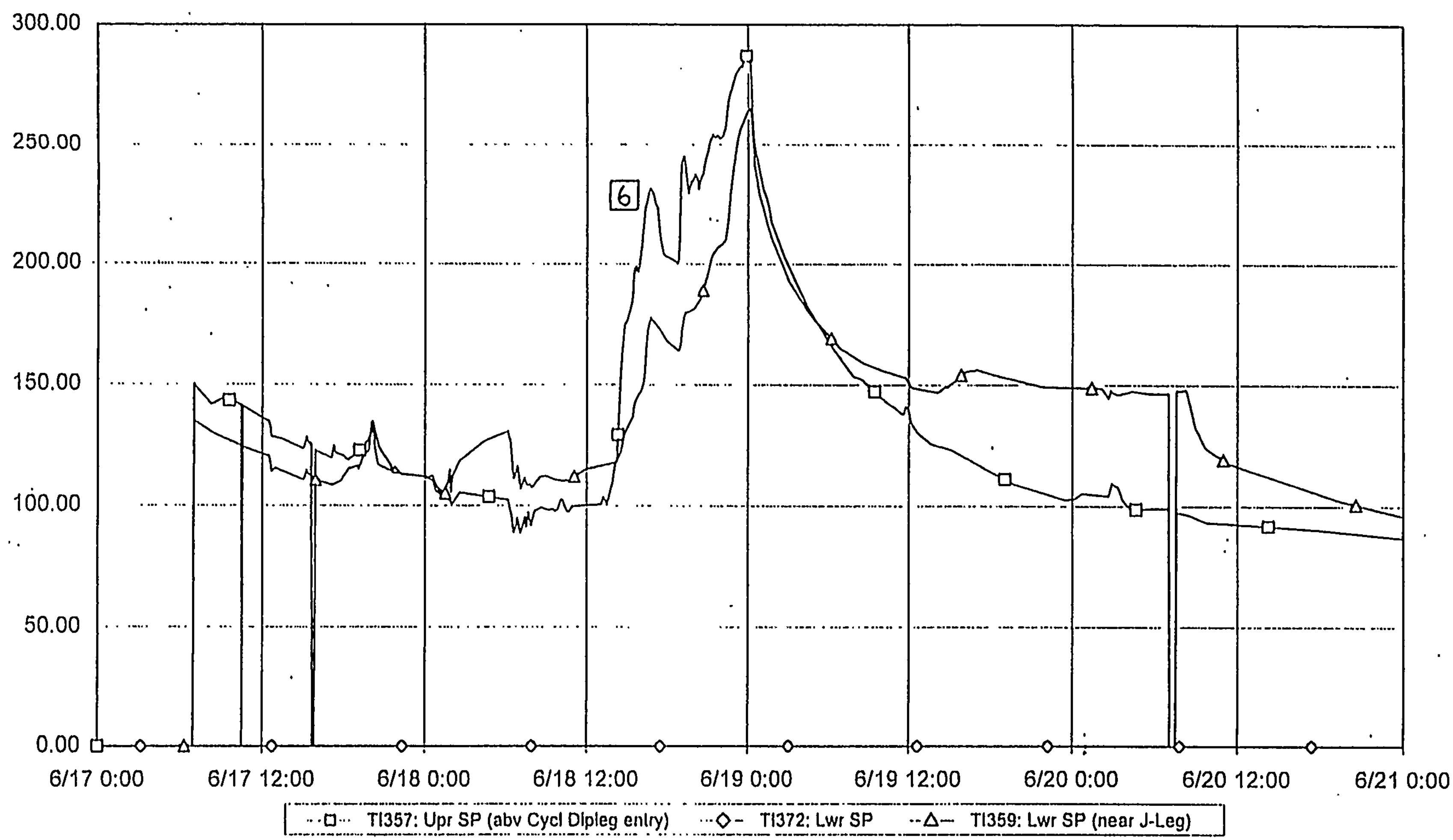
DOE Plot 13 of 45 - 5 minute data

Figure 5.1.3-8 Total Gas In/Out Flow Rates for June 17 Through 20, 1996



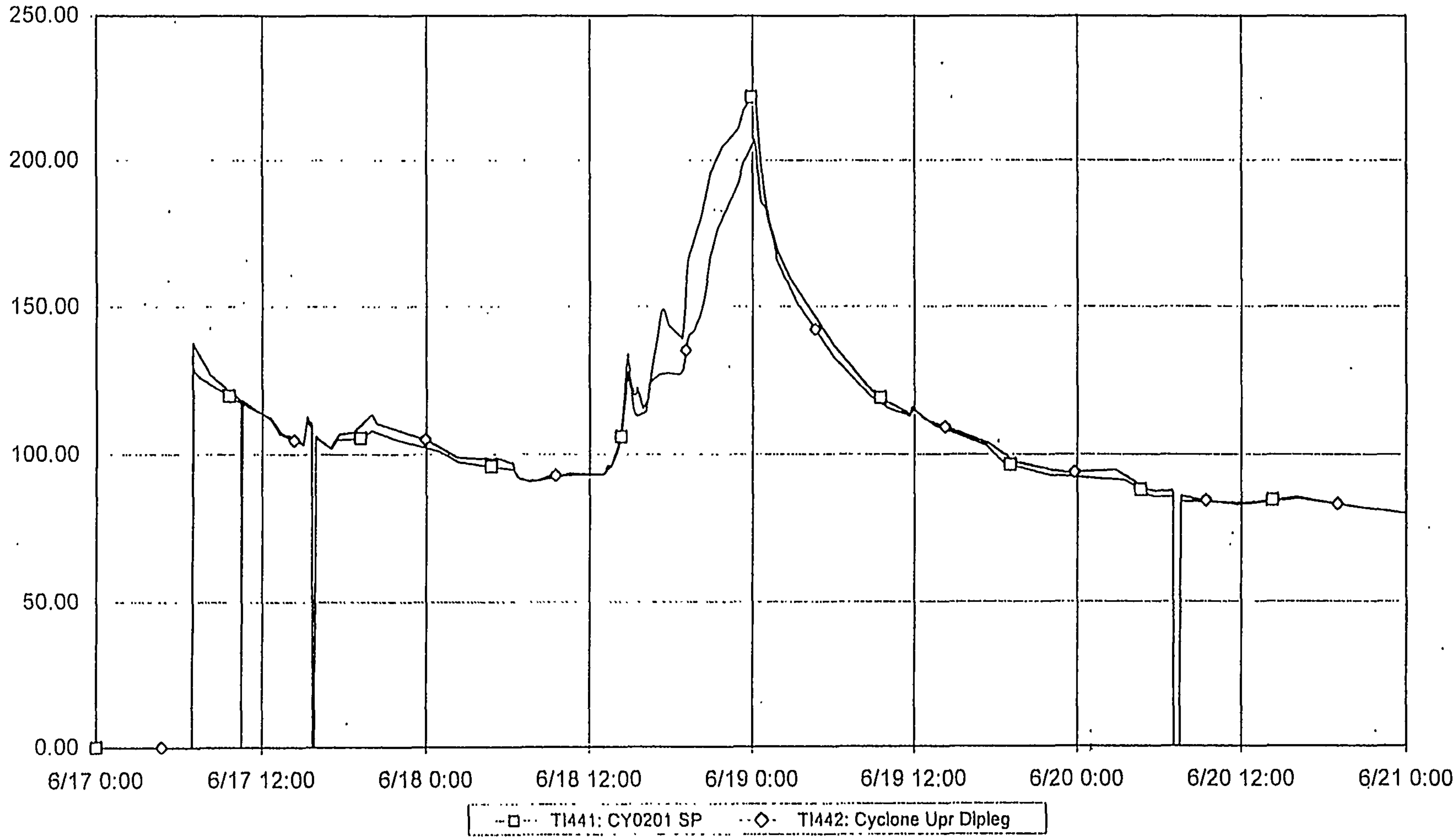
DOE Plot 14 of 45 - 5 minute data

Figure 5.1.3-9 Reactor Mixing Zone and Riser Temperatures for June 17 Through 20, 1996



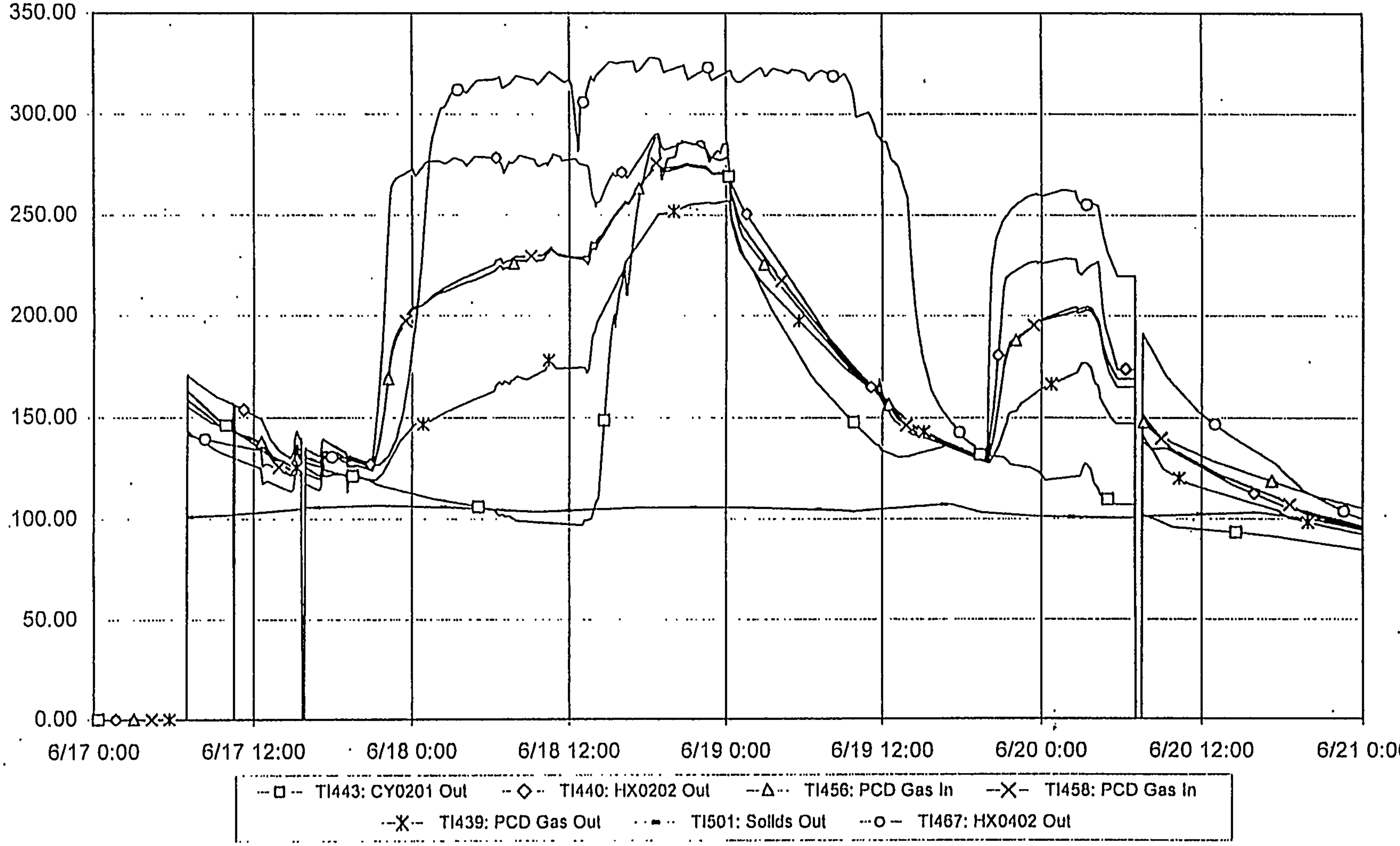
DOE Plot 15 of 45 - 5 minute data

Figure 5.1.3-10 Staandpipe Temperatures for June 17 Through 20, 1996



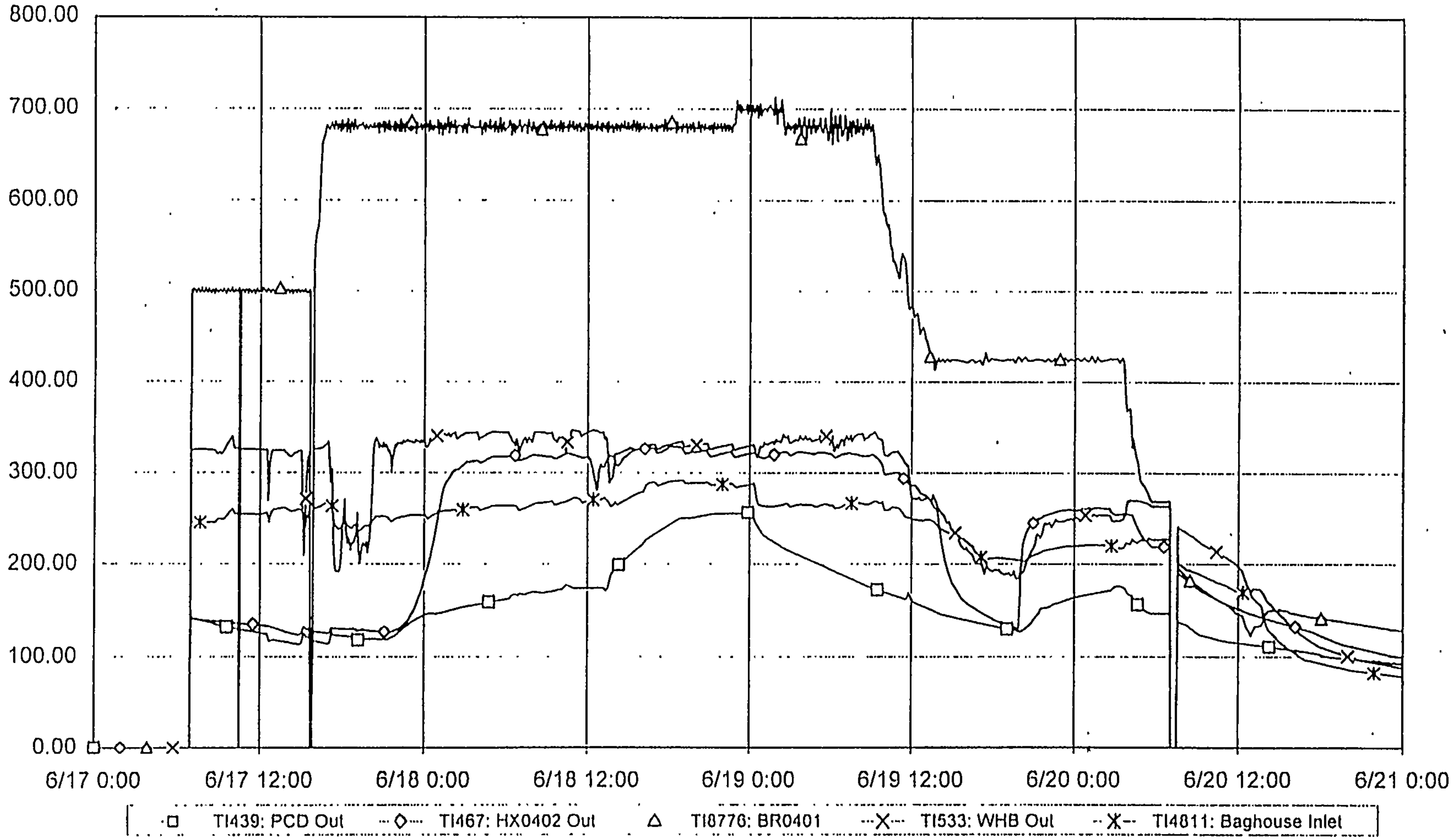
DOE Plot 16 of 45 - 5 minute data

Figure 5.1.3-11 Cyclone Dipleg Temperatures for June 17 Through 20, 1996



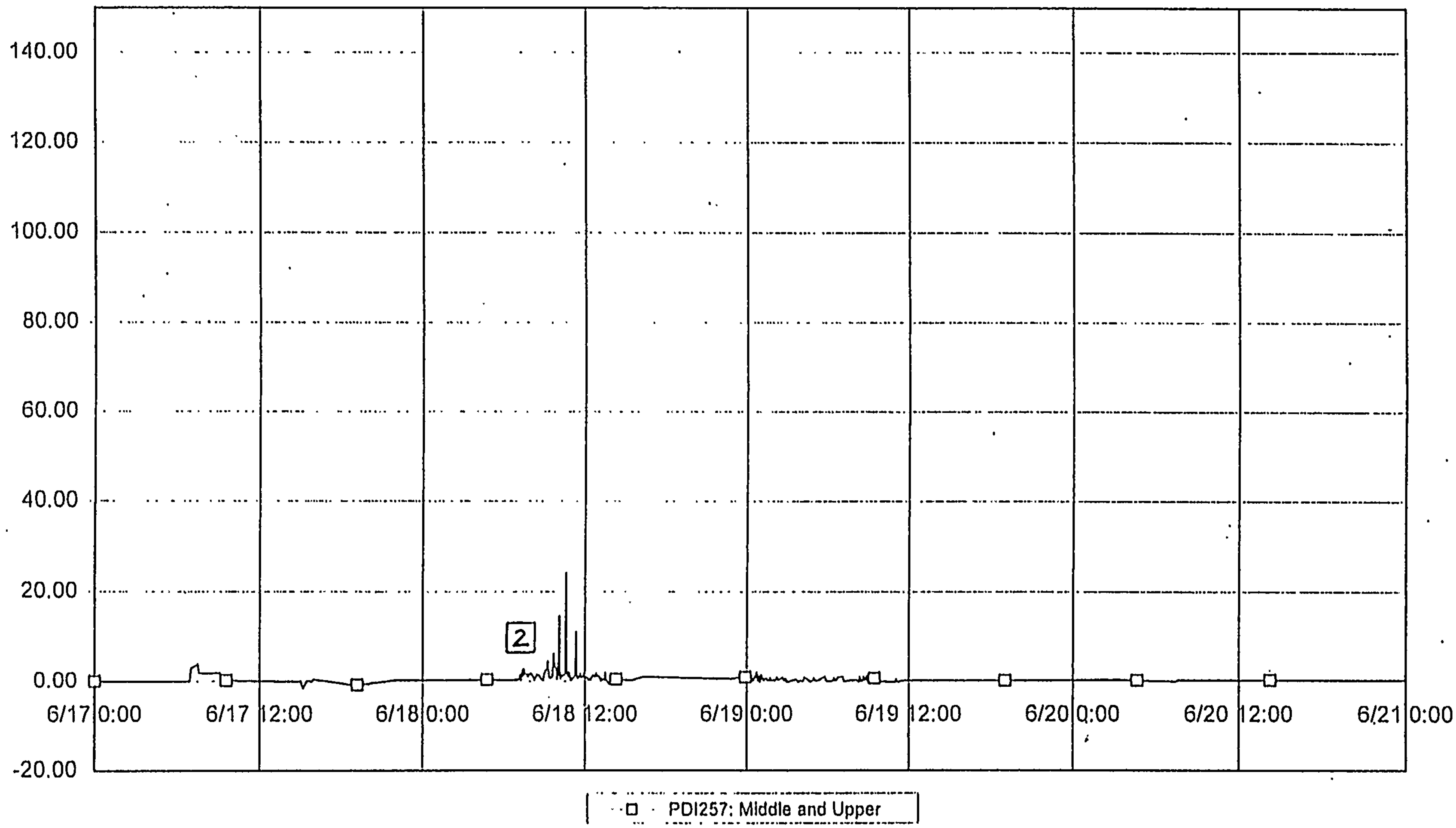
DOE Plot 17 of 45 - 5 minute data

Figure 5.1.3-12 Temperature Profiles Downstream of Reactor for June 17 Through 20, 1996



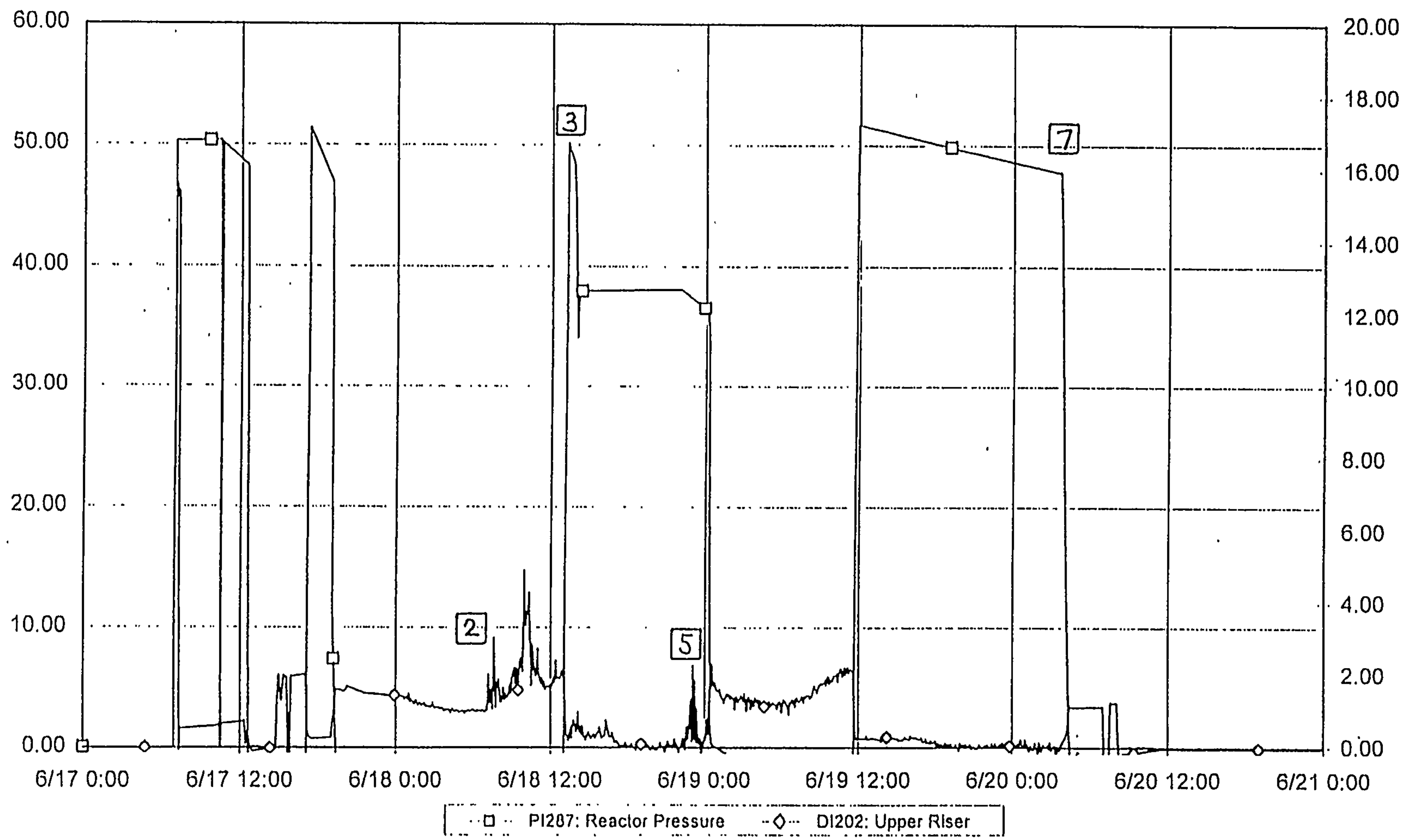
DOE Plot 19 of 45 - 5 minute data

Figure 5.1.3-13 System Temperatures Downstream of PCD for June 17 Through 20, 1996



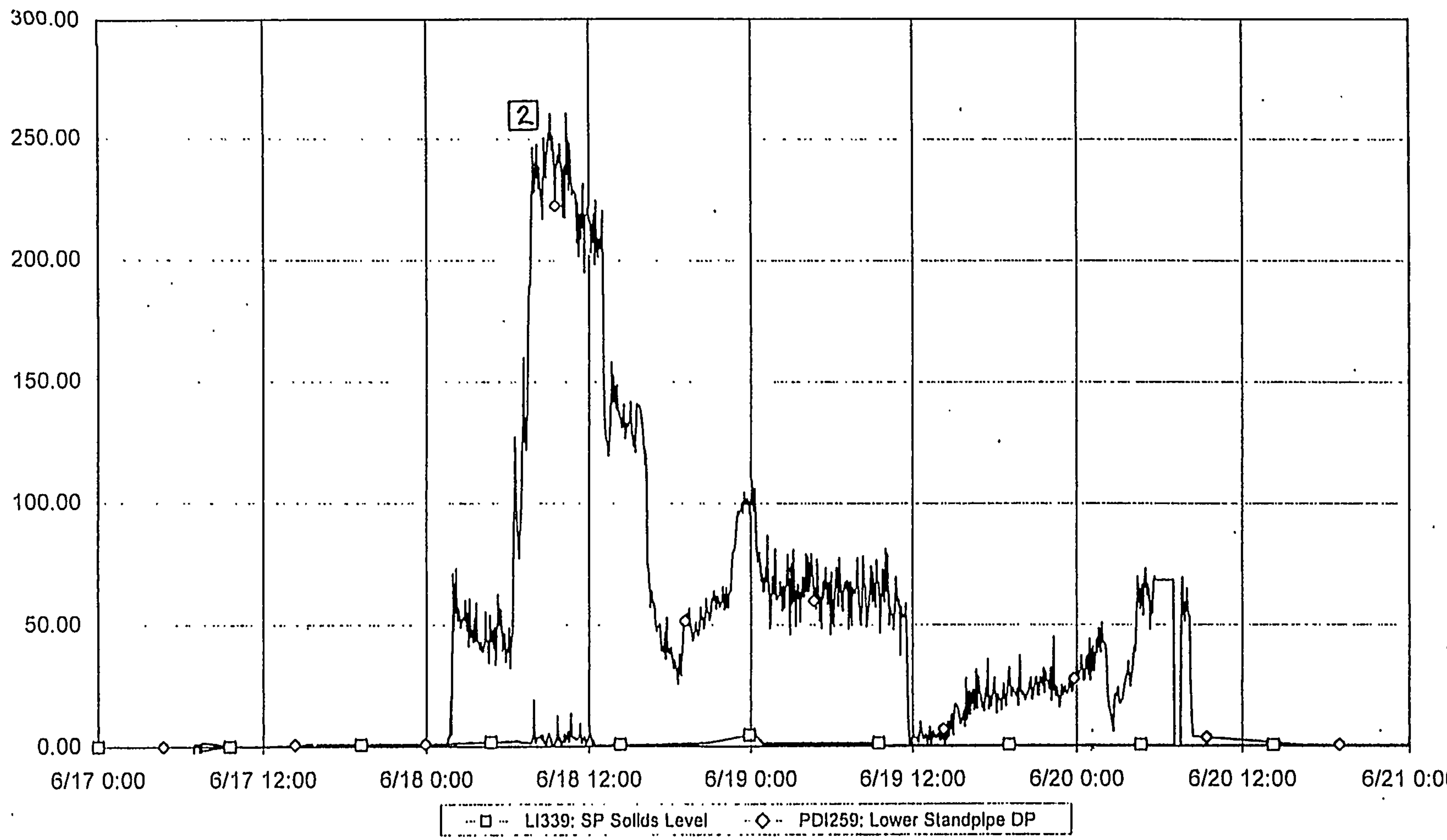
DOE Plot 20 of 45 - 5 minute data

Figure 5.1.3-14 Mixing Zone DP Profile for June 17 Through 20, 1996



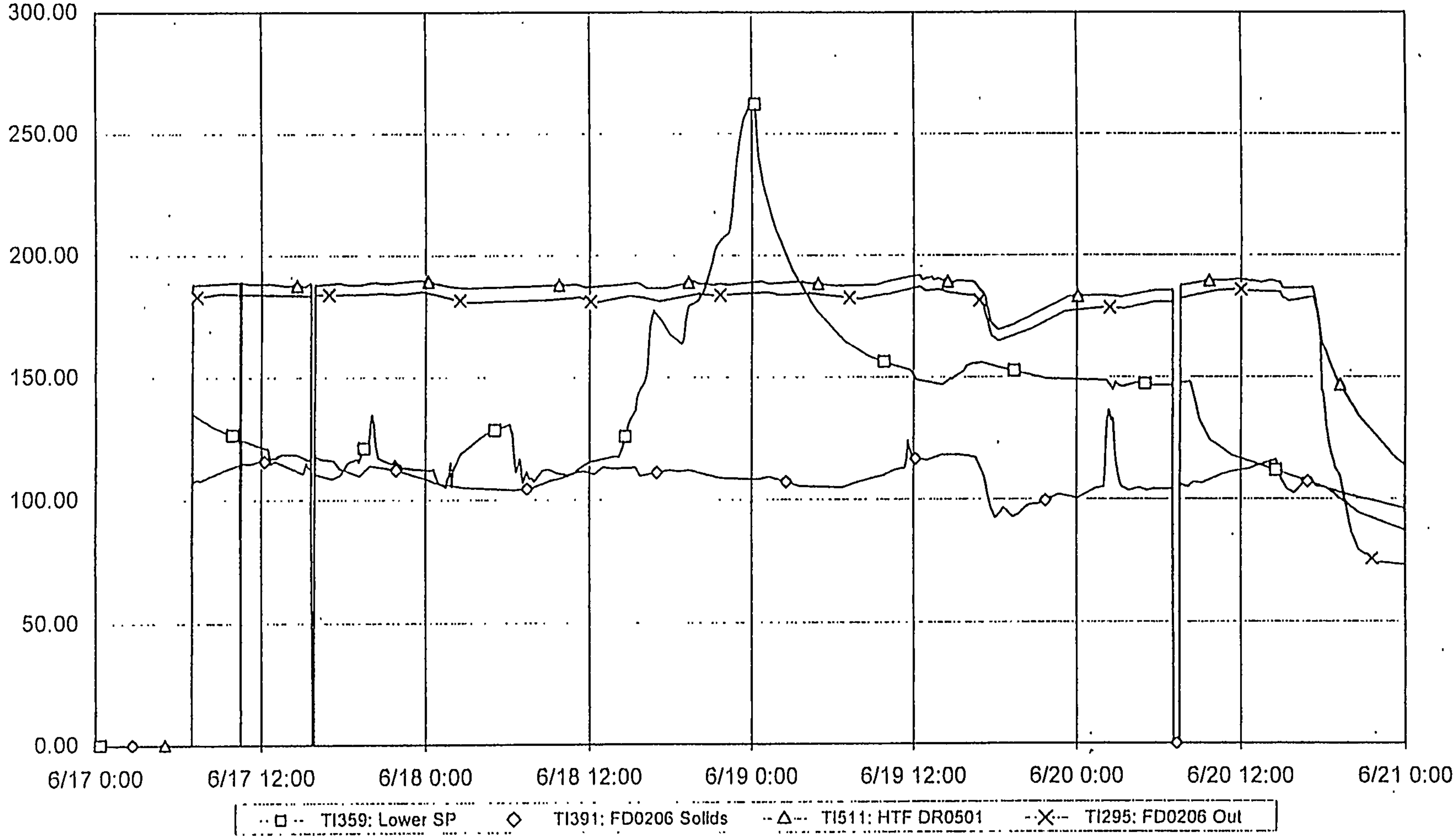
DOE Plot 21 of 45 - 5 minute data

Figure 5.1.3-15 Reactor Pressure/Riser DP Profiles for June 17 Through 20, 1996



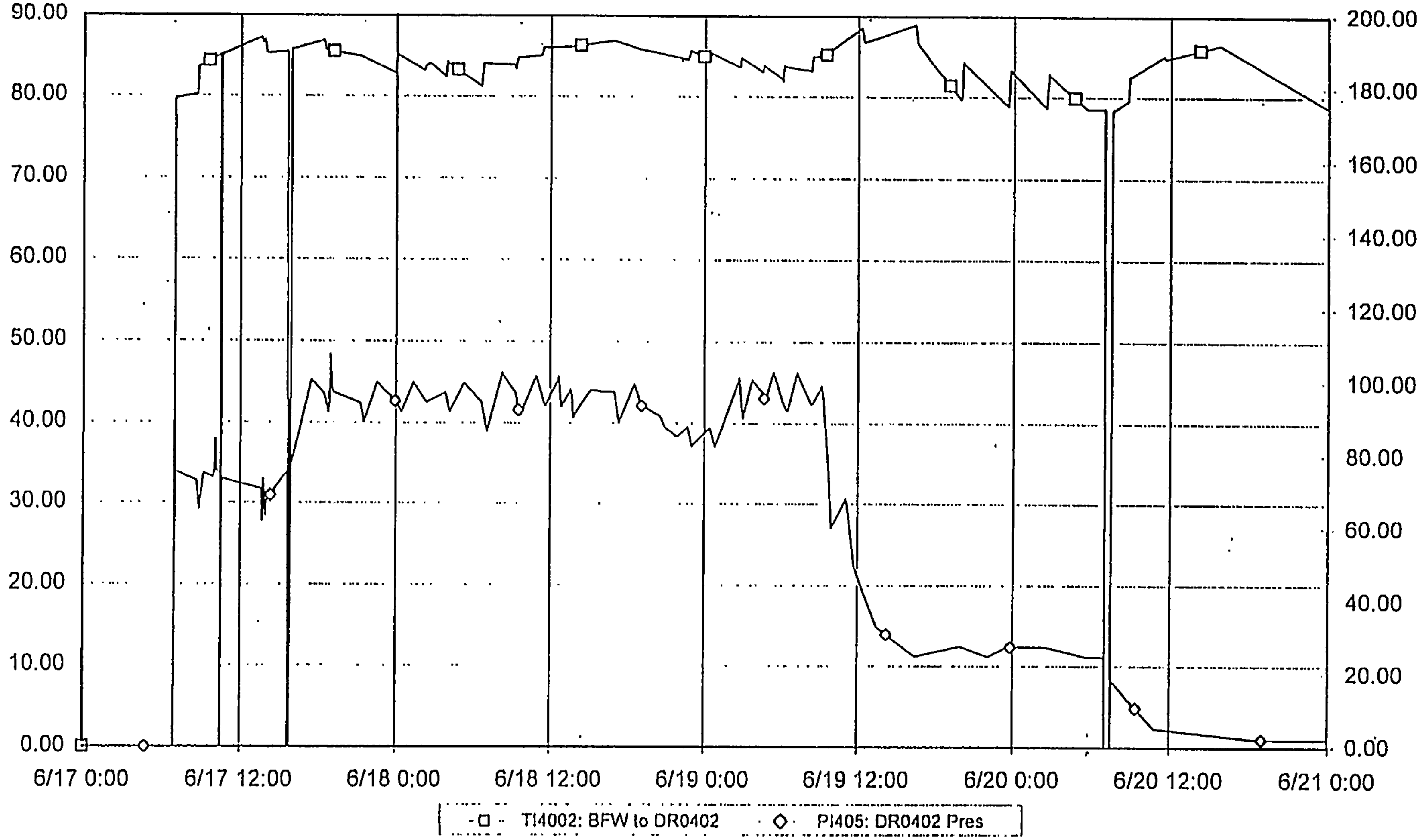
DOE Plot 22 of 45 - 5 minute data

Figure 5.1.3-16 Standpipe DP Profiles for June 17 Through 20, 1996



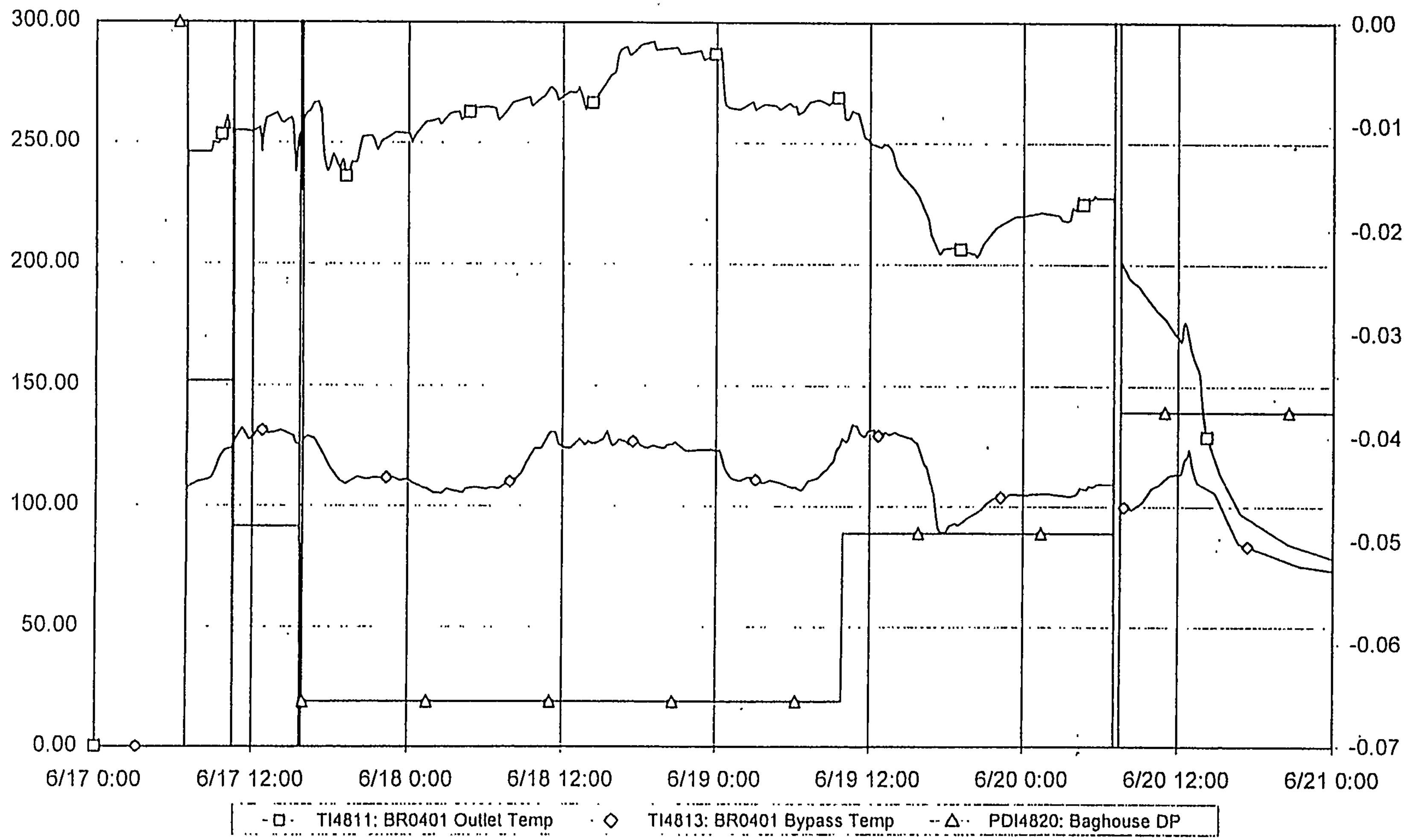
DOE Plot 30 of 45 - 5 minute data

Figure 5.1.3-17 FD0510 Temperature Profiles for June 17 Through 20, 1996



DOE Plot 36 of 45 - 5 minute data

Figure 5.1.3-18 Steam Drum Pressure and BFW Temperature for June 17 Through 20, 1996



DOE Plot 43 of 45 - 5 minute data

Figure 5.1.3-19 Baghouse Temperatures and Differential Pressures for June 17 Through 20, 1996

Psd05_1_3

5.1.4 Commissioning Test Run CR04

5.1.4.1 Introduction and Test Objectives

Test run CR04 was conducted from June 26 to July 1, 1996. This test run consisted of circulating hot solids in the transport reactor. Figures 5.1.4-1 through -18 show the operating graphs for this time period.

For this test, the gas from the reactor was directed through the empty CPC filter vessel bypassing the thermal oxidizer and passed through the baghouse to the stack. Prior to the recycle gas booster compressor test, almost all of the solids were drained from the transport reactor to avoid solids carryover from the reactor during the test. The reactor J-leg and standpipe were emptied of solids. The solids remaining inside HX0203 filled its J-leg and standpipe up to its boot. In preparation for hot solids circulation, the withdrawn solids were loaded into the reactor through FD0210.

5.1.4.2 Test Chronology

On June 26 the thermal oxidizer and HTF systems were started in preparation for start-up of the transport reactor system (event 1, figure 5.1.4-1). The following day the main air compressor was started and the reactor was leak tested at 75 psig. All purge and aeration flows were set to minimum standby rate. By 10:30 the steam drum pressure reached 50 psig. At 19:45, solids withdrawal from the reactor standpipe began using FD0206. The solids were removed from the reactor and heat exchanger in preparation for testing the recycle gas booster compressor. This was done to avoid solids carryover from the reactor during the test.

On June 28, 1996, as much solids as possible were transferred from HX0203 to the reactor standpipe for withdrawal using FD0206. The withdrawal of solids from reactor standpipe and reactor J-leg was completed. At 04:20 the HX0202 and HX0402 risers were opened, the downcomers remained closed, and the blowdowns were cracked opened. This was done to preheat the gas passing through the Westinghouse PCD to prevent any condensation. The HX0203 riser and downcomer were also opened. At 13:00 on June 28, 1996, the recycle gas booster compressor tests were started. By 13:01 the following day (June 29) the recycle gas booster compressor tests were completed.

The reactor was pressurized to 50 psig and the instrument purge flows and all aeration flows were set to standby rates. Solids transfer into the reactor was initiated at 17:20 on June 29, 1996. This method of feeding inert materials into the reactor is preferred to the alternate method of feeding through the fill nozzle on the reactor standpipe. In the latter method, the reactor has to be at atmospheric pressure.

Since the reactor J-leg was not sealed initially, all the reactor aeration and fluidization flows were set to standby (minimum) flows. Alumina was fed into the reactor mixing zone where it moved by gravity into the reactor J-leg and the burner J-leg. Once the J-legs were sealed, gas flow through the reactor was increased (event 2, figure 5.1.4-9). Subsequent alumina fed into the mixing zone was transported through the riser (separated by the cyclone system) and into the reactor standpipe. The transport air was supplied through the primary combustion nozzles located in the mixing zone. When the solids level in the reactor standpipe was close to the HX0203 solids, there were additional solids fed by gravity from FD0210 into HX0203. When FD0210 was emptied of solids at 23:00, the solid levels in HX0203 and reactor standpipe were below the desired normal operating levels because the amount of solids inventoried was less than the amount of solids required to fill the reactor to the desired operating levels. Despite this shortfall it was estimated that hot solids circulation could be achieved at a reasonable circulation rate. The only drawback was an increase in solids loss through the primary cyclone since the cyclone dipleg would not seal.

During the solids transfer from FD0210 into the reactor several operational problems were experienced with the FD0210 rotorfeeder. The higher alumina bulk density (compared to that of coal) caused some of the problems. This was the first time solids were transferred from FD0210 into the reactor under pressure. Once the problems were solved, the solids transfer was very smooth.

Solids circulation was initiated through the reactor J-leg and HX0203 at 00:20 on June 30, 1996, by increasing the fluidization/aeration flows to the J-legs.

PDI259 increased from 0.0 to 320 inH_2O when the reactor standpipe was being filled with the solids using minimum aeration in the standpipe (event 3, figure 5.1.4-17). Further addition of solids resulted in transfer of solids from standpipe to HX0203 as PDI259 approximately stayed constant at 320 inH_2O (event 4, figure 5.1.4-17). At the same time, the HX0203 PDIs showed an increase. Fluidization of the reactor standpipe caused the bed in the standpipe to expand, and thereby, transfer more solids into the HX0203. PDI259 decreased from 320 to about 160 inH_2O and the HX0203 PDIs showed a corresponding increase (event 5, figure 5.1.4-17).

During this initial circulation of solids, the mid-standpipe differential pressure did not show any indication. The higher leg of this PDI is located just above the solids inlet to the HX0203, indicating that the solids level in the reactor standpipe was never above the inlet to the HX0203. The PDI in the riser showed 2 inH_2O on DI202 (upper riser) (event 6, figure 5.1.4-16). This and other differential pressures indicated the transport of solids through the riser and circulation through the J-legs.

At 08:10 in preparation for lighting the start-up burner pilot, the solids that accumulated inside the burner J-leg were conveyed into the reactor mixing zone by increasing the burner quench air flow, aided by fluidization flow from the aeration nozzles located on the burner J-leg. After the burner leg was cleared of solids, the burner pilot was lit at 02:30. The propane flow rate was 21 lb/hr. The combustion and quench air flows were set to give a flue gas temperature of 500°F (event 7, figure 5.1.4-7). The burner exit temperature was held for approximately 4 hours in accordance with the refractory heat-up guidelines. The baghouse screw conveyor was run after the burner hold period to convey solids captured by the baghouse into the ash silo. The ash silo, which was later drained, produced an insignificant quantity of alumina.

In preparation for lighting the main burner, the reactor and HX0203 J-leg aeration rates were reduced in order to increase the air flow through the burner. Because solids circulation was initiated at 50 psig reactor pressure and at approximately 200°F, a considerable quantity of air was required to maintain solids circulation through the J-legs. The air flow rate required to fire the main burner, maintain the minimum burner exit temperature (850°F), and also maintain J-leg aeration at the current level would exceed targeted riser superficial velocity. To prevent this from happening, the J-leg aeration flows were reduced and the excess air was supplied through the burner. The main burner was lit at 08:30, and the burner exit temperature immediately increased from 500 to 850°F.

The burner firing rate (70 lb/hr total propane flow rate) at minimum turndown was much higher than design due to problems in operating the burner at lower firing rates. The higher firing rate required higher combustion and quench air flow rates through the burner in order to minimize the increase in the flue gas exit temperature at start-up. Such high air flow rates through the burner along with lower reactor and HX0203 J-legs aeration rates resulted in riser velocities much higher than desired.

At 09:15 the HX0202 and HX0402 downcomers were opened and the blowdown valves were closed. Prior to loading solids into the reactor, the heat exchanger was used to preheat the gas stream downstream of the reactor by condensing steam from the steam drum in the heat exchangers so that a higher inlet temperature to the PCD could be maintained. To accomplish this the valves on the risers were opened and the blowdown valves were cracked open. After the main burner was lit, the gas temperature downstream of the reactor was adequate for steam generation inside the heat exchangers. By closing the blowdown valve and opening the downcomer, the heat exchangers were put in steam generation mode.

At 11:30 aeration flow through the reactor J-leg was reduced further and the flow through HX0203 J-legs was increased to induce more solids circulation through HX0203. This was done due to the presence of more solids in HX0203 than in the reactor standpipe. Also, as the solids in the reactor standpipe expanded, they overflowed into HX0203 resulting in the transfer of solids from the reactor J-leg into HX0203. An additional 700 lb of alumina was added later, but this was too little to improve solids circulation.

At 13:00 the thermal oxidizer firing rate was reduced to maintain the steam drum pressure because of steam production from HX0202 and HX0402. The baghouse dilution fan was started soon afterwards to reduce the flue gas temperature entering the baghouse.

The riser differential pressures were increased by increasing the aeration flow rate through the bottom of the mixing zone (event 8, figure 5.1.4-16). During the entire run, PDI254 read low which indicated that the primary cyclone dipleg was empty of solids. The temperature profiles in the primary cyclone dipleg (event 9, figure 5.1.4-12) show that there was a gas flow up through the dipleg from the reactor standpipe. This gas flow through the cyclone would have resulted in spoiling of the cyclone with a reduction in its efficiency.

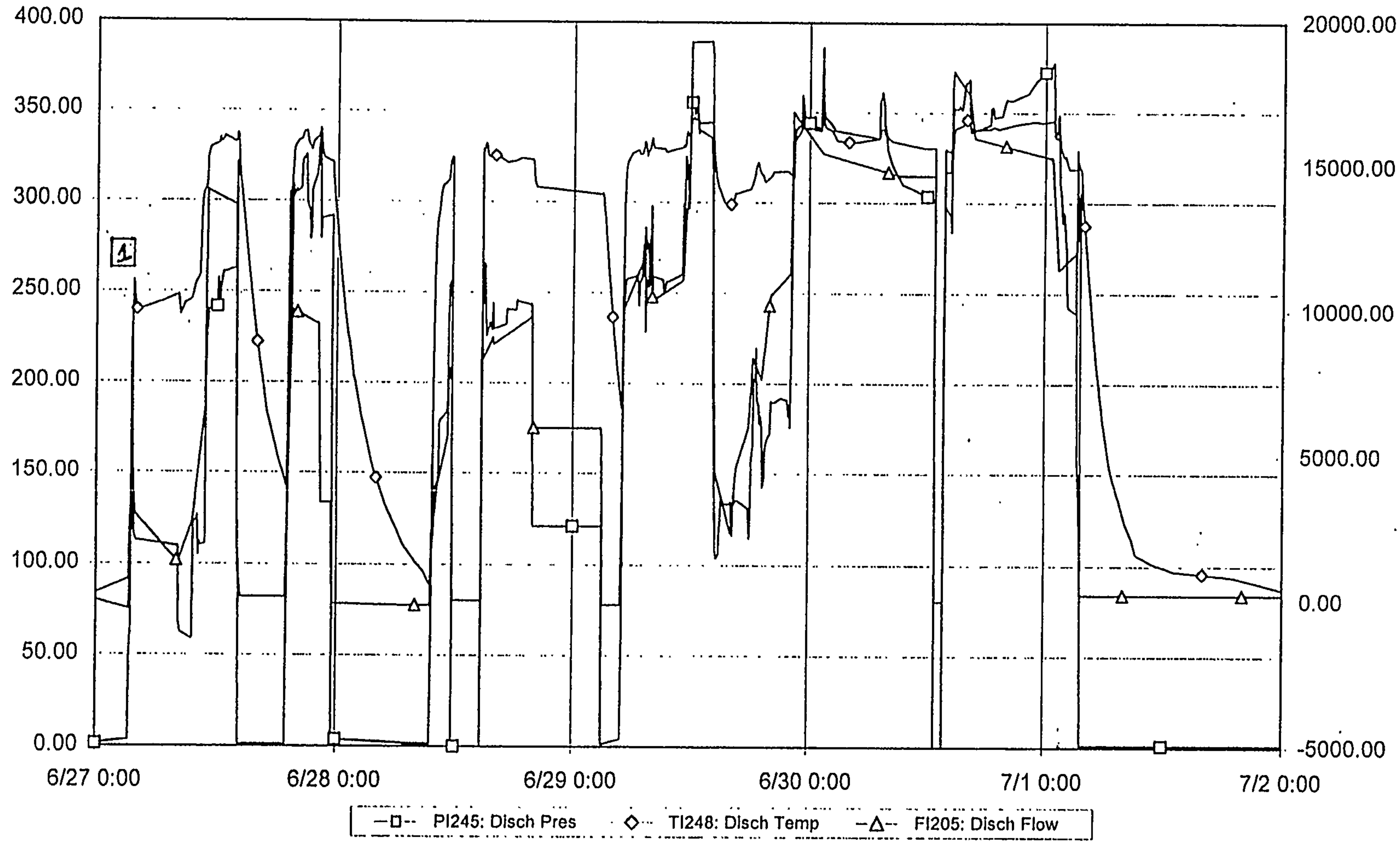
The burner quench air flow was reduced to increase the burner exit temperature from 850 to 1,000°F. The quench flow was further reduced after about a 2-hour hold at 1,000°F, and the firing rate of the burner was gradually increased from 70 to 118 lb/hr over a period of 5 hours. The burner exit temperature increased from 1,000 to 1,600°F. The cyclone exit temperature (TI443) increased from 450 to 610°F (event 10, figure 5.1.4-13). The TI443 was still rising when, due to a leak in the pressure letdown valve (PV287), the burner firing rate was reduced at 02:00 on July 1, 1996.

Before the unit was shutdown, the main burner turndown was tested by reducing the propane flow rate from 50 to 32 lb/hr. The burner was steady at the low propane flow rate. The solid circulation through the reactor and heat exchanger J-legs was stopped by decreasing the aeration rates. The spent solids screw cooler was briefly tested by withdrawing about 700°F solids from the reactor standpipe. The screw cooler operated well running at 2 rpm at these conditions with a solids exit temperature of about 150°F.

The system was shutdown at 08:10 on July 1, 1996. Upon inspection, the PV287 control valve showed severe erosion due to high velocity jetting by alumina-laden gas. About 5,600 lb of alumina was drained from the CPC filter vessel. The reactor riser pillow top, primary cyclone, cyclone dipleg, FD0502 inlet transition spool piece, HX0202, and HX0402 were inspected with a borescope. The reactor and cyclone refractories were in good condition. A part of the refractory plugs (attached to the flanges) at the top of the riser and primary cyclone were missing. These broken plugs are likely in the cyclone dipleg and HX0203 J-leg dead-legs. The ceramic ferrules in both HX0202 and HX0402 were found to be in good condition with no observable erosion due to alumina. The HX0202 tubes were also in good condition. However, the HX0402 tubes showed abnormal signs of corrosion. The tube thickness was measured and was found to be within acceptable range.

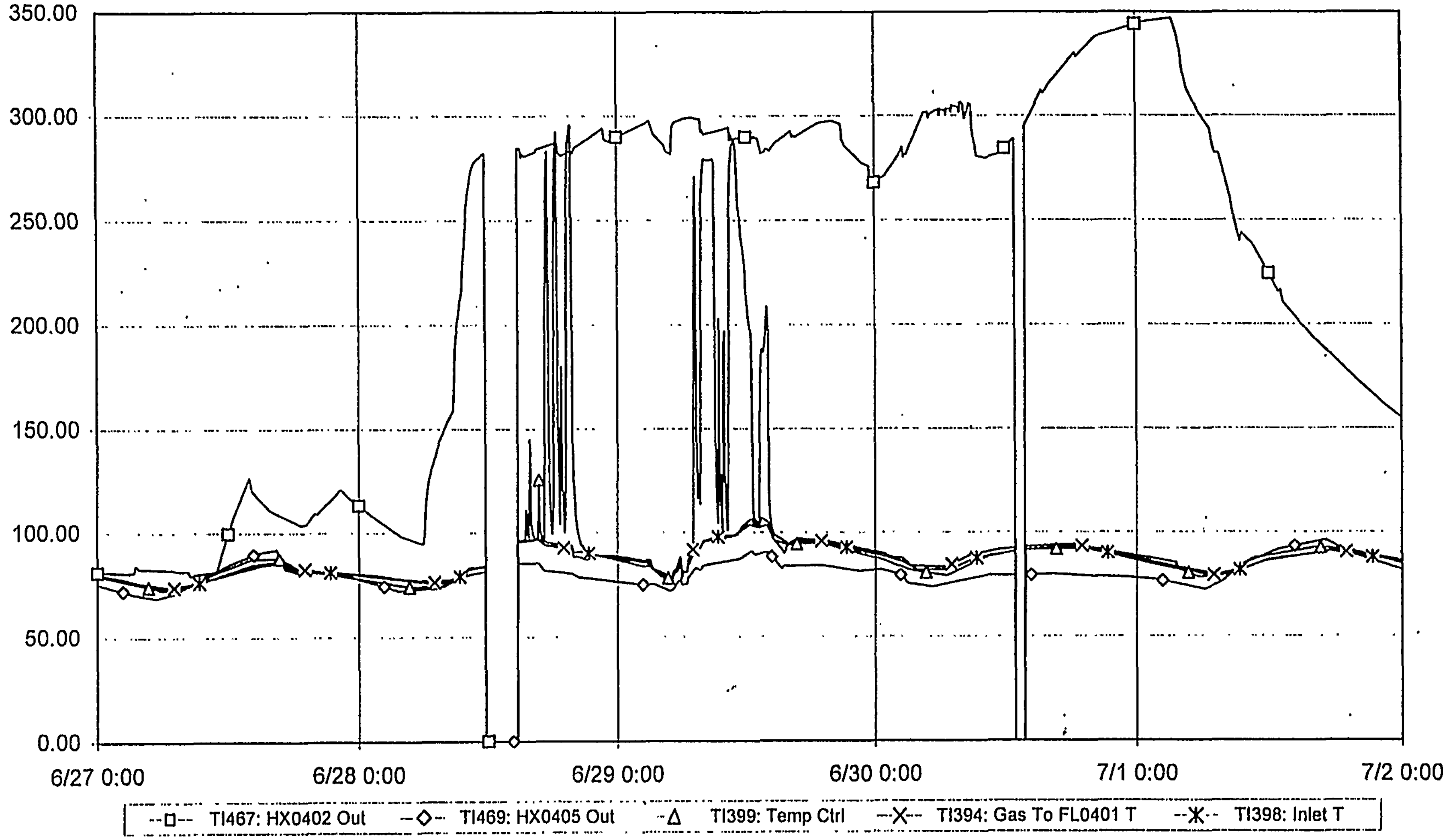
5.1.4.3 Test Run CR04 Observations

The alumina inert bed material was successfully added using the coal feed system with the reactor under pressure. The start-up burner was fired and the solid circulation was successfully established. The start-up burner firing rate at minimum turndown was observed to be much higher than design. The spent solids screw cooler was briefly tested by withdrawing hot solids. Due to the erosion of the pressure letdown valve, the run was prematurely ended. During this run the recycle gas booster compressor was successfully operated.



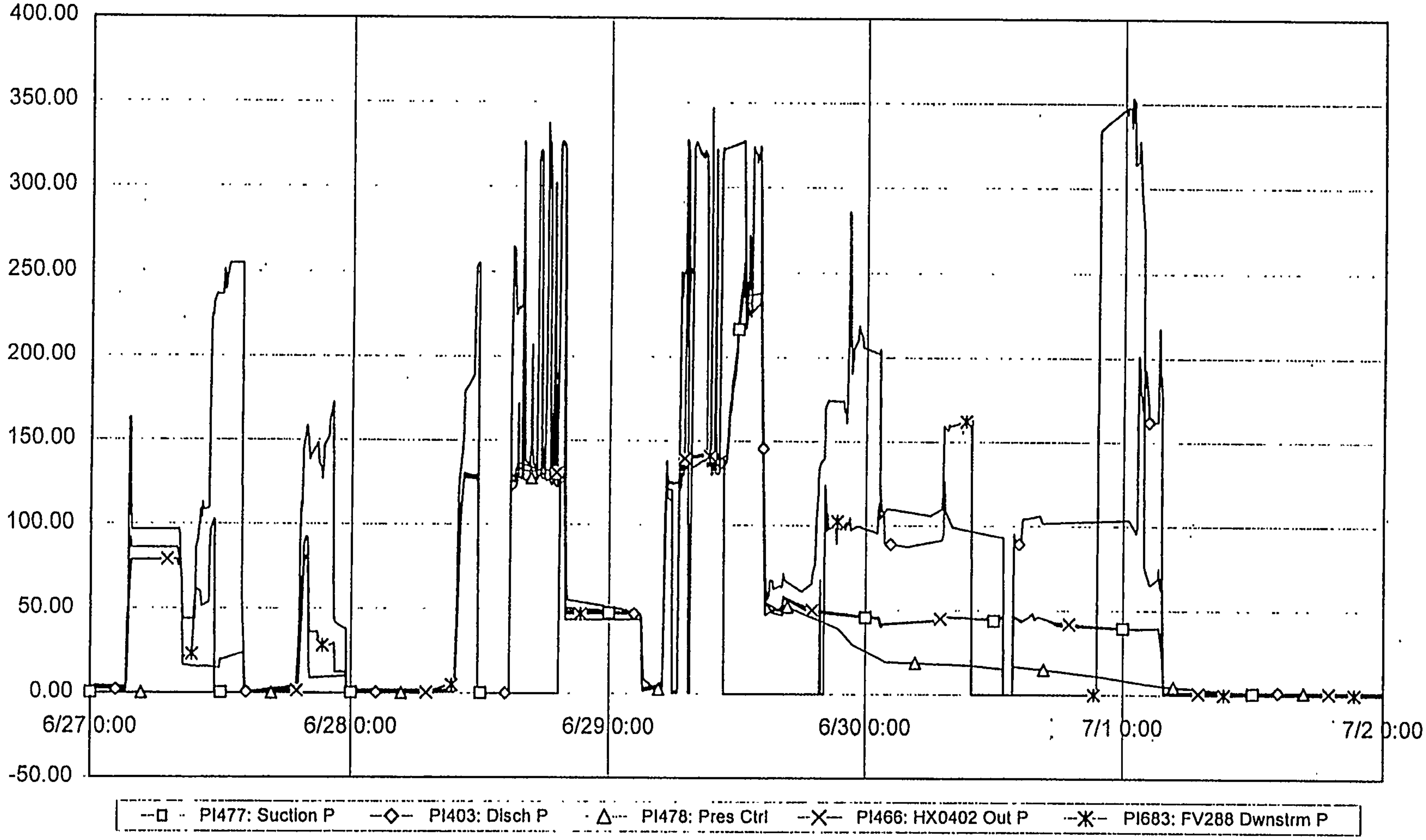
DOE Plot 1 of 45 - 5 minute data

Figure 5.1.4-1 C00201 System Profile for June 27 Through July 1, 1996



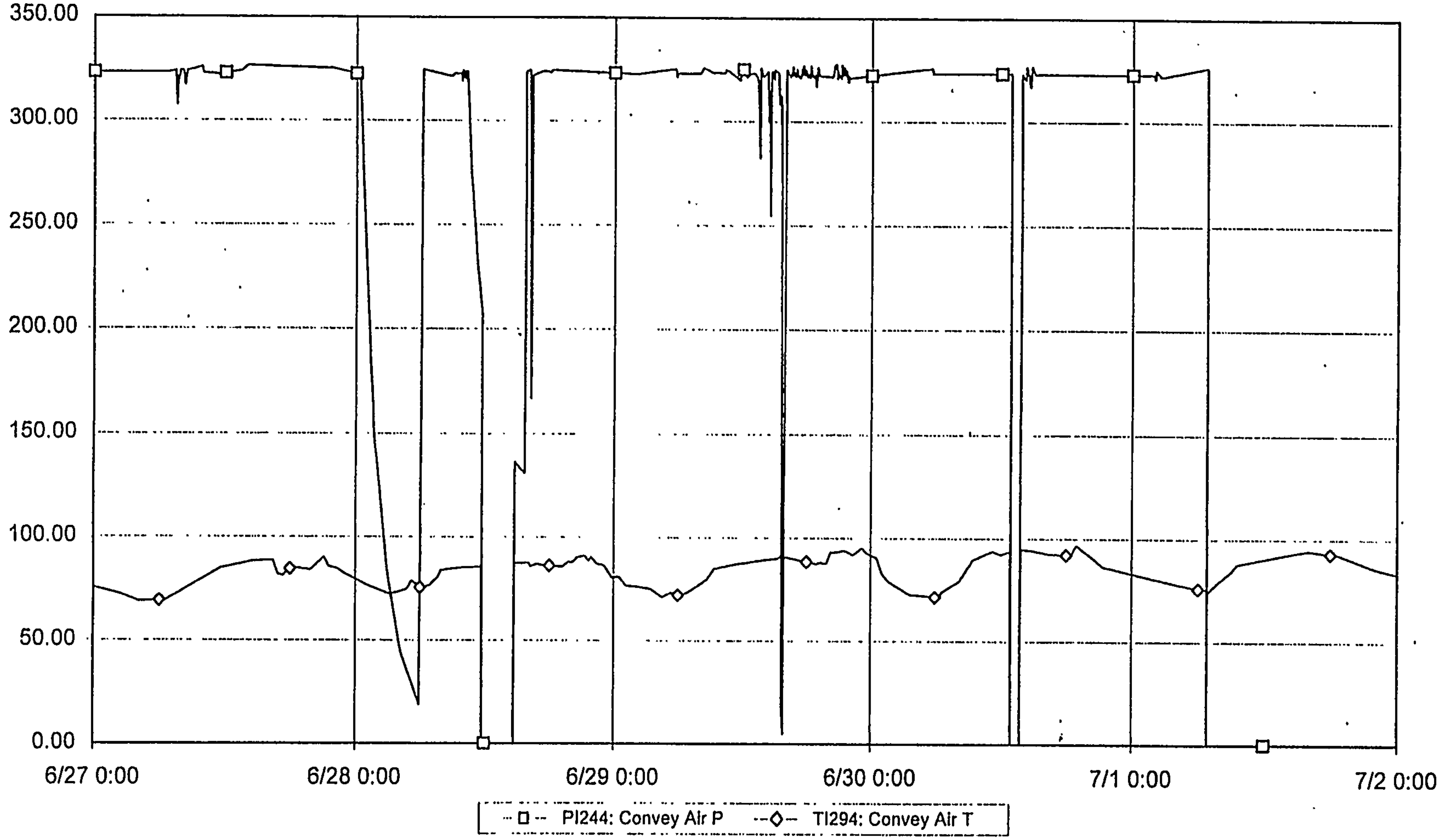
DOE Plot 3 of 45 - 5 minute data

Figure 5.1.4-2 Recycle Gas System Temperatures for June 27 Through July 1, 1996



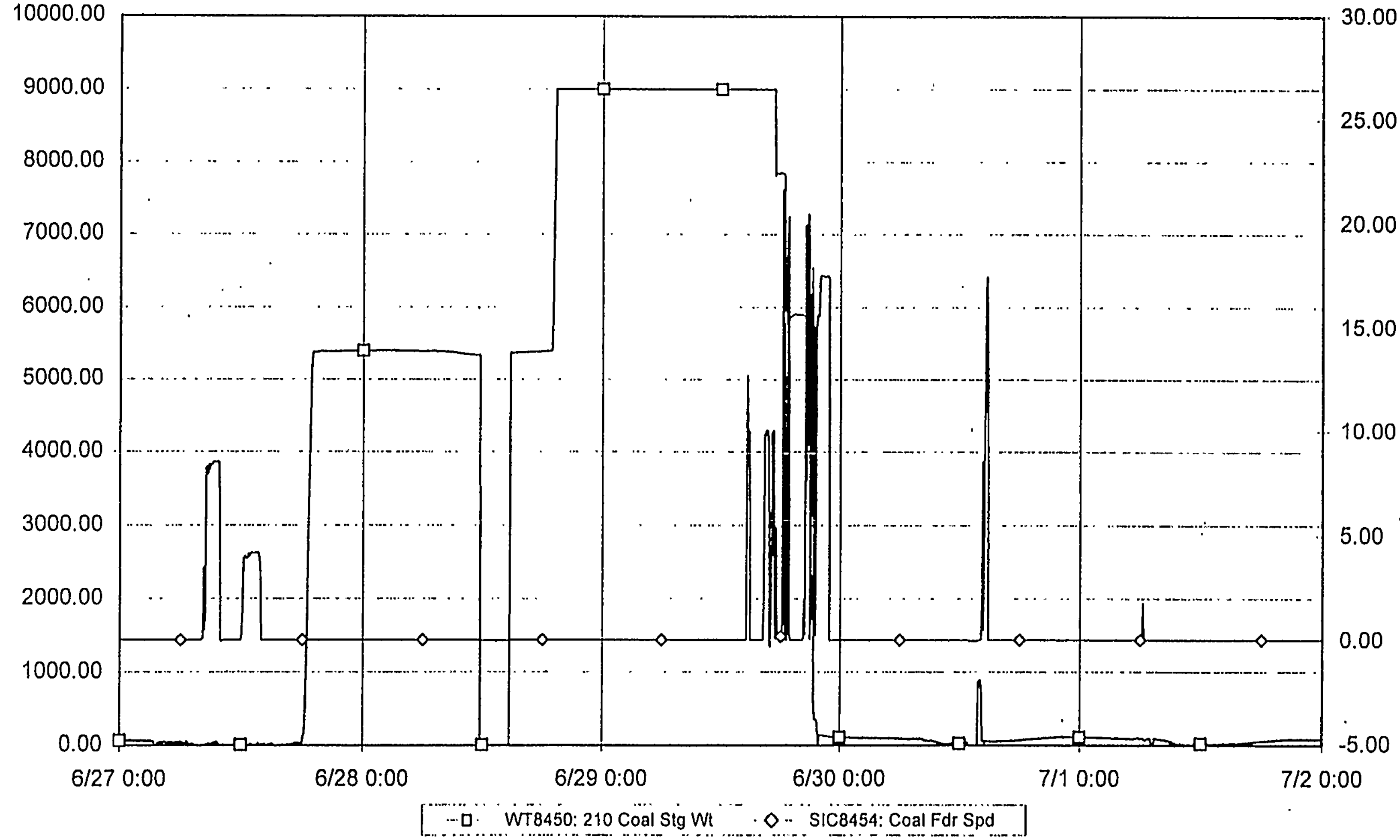
DOE Plot 4 of 45 - 5 minute data

Figure 5.1.4-3 Recycle Gas System Pressure for June 27 Through July 1, 1996



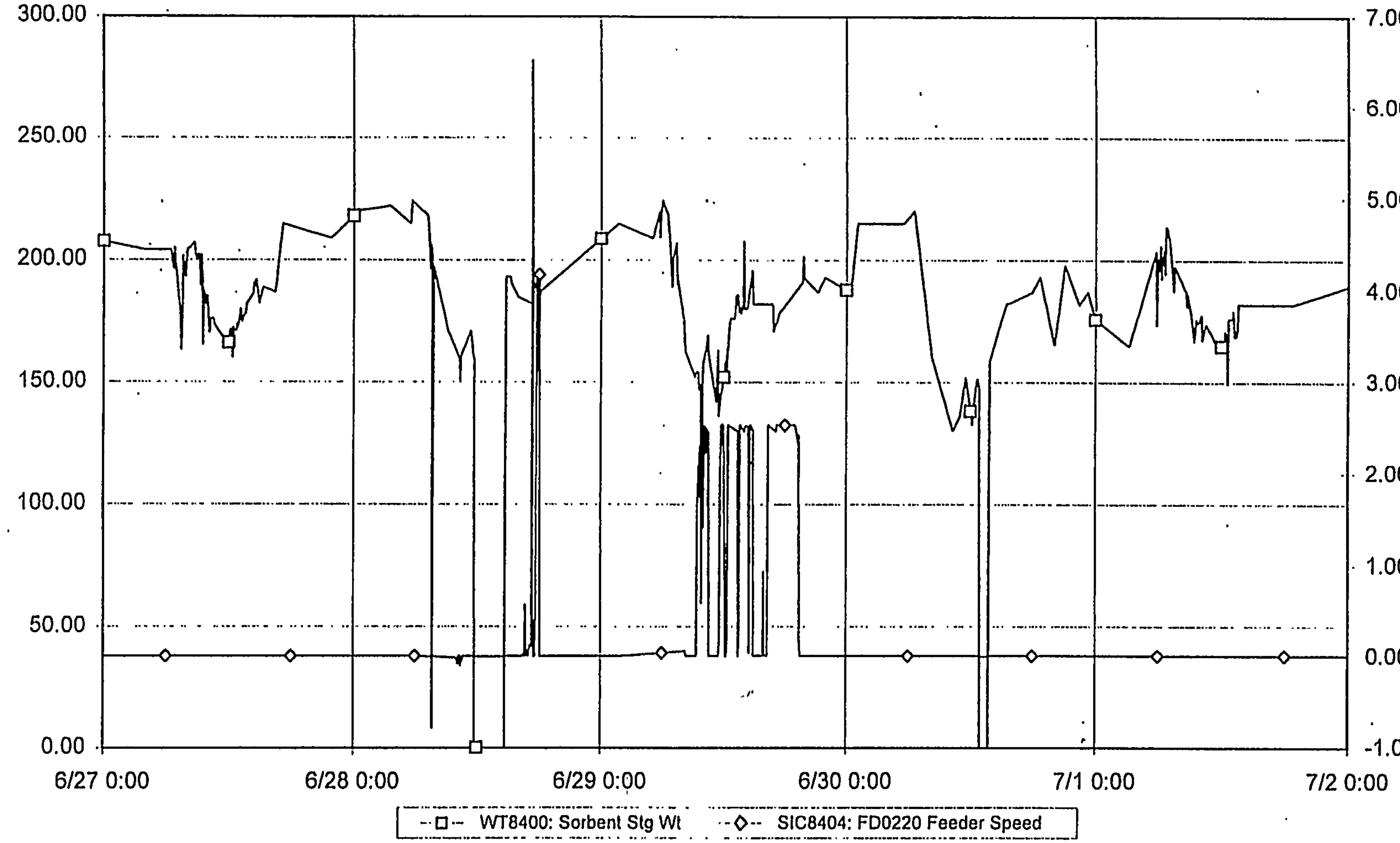
DOE Plot 5 of 45 - 5 minute data

Figure 5.1.4-4 Transport Air System for June 27 Through July 1, 1996



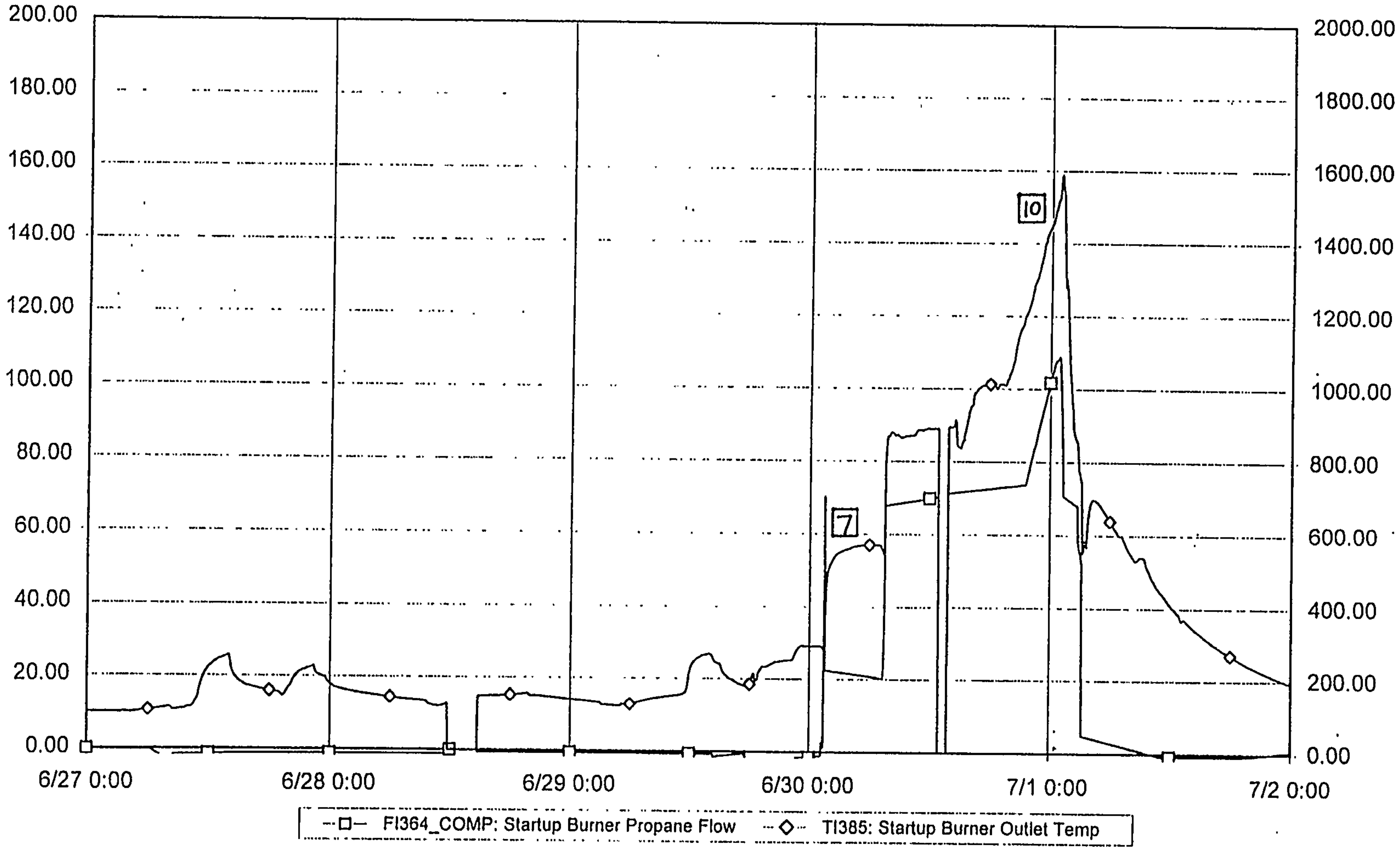
DOE Plot 7 of 45 - 5 minute data

Figure 5.1.4-5 Coal Feed for June 27 Through July 1, 1996



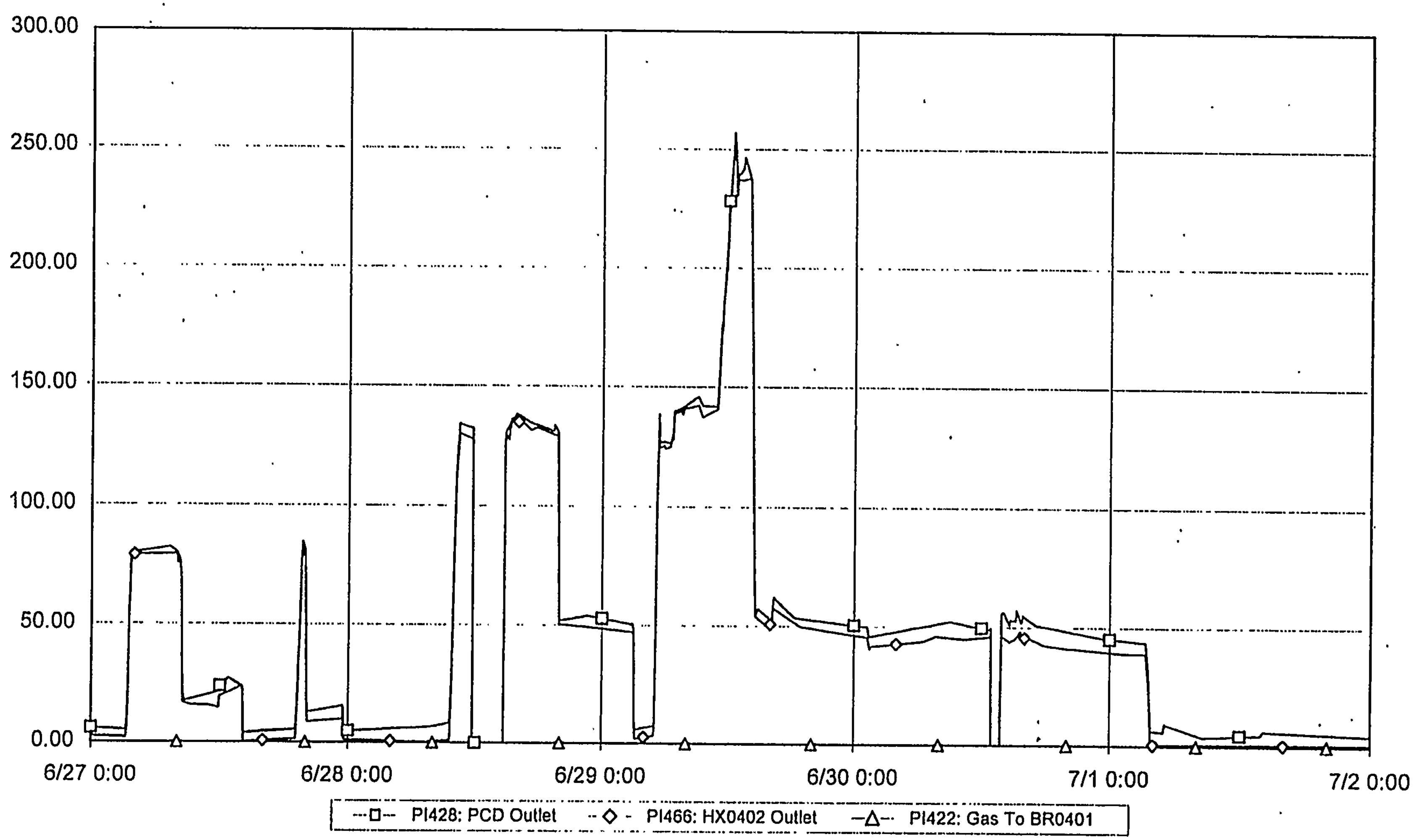
DOE Plot 9 of 45 - 5 minute data

Figure 5.1.4-6 Sorbent Feed for June 27 Through July 1, 1996



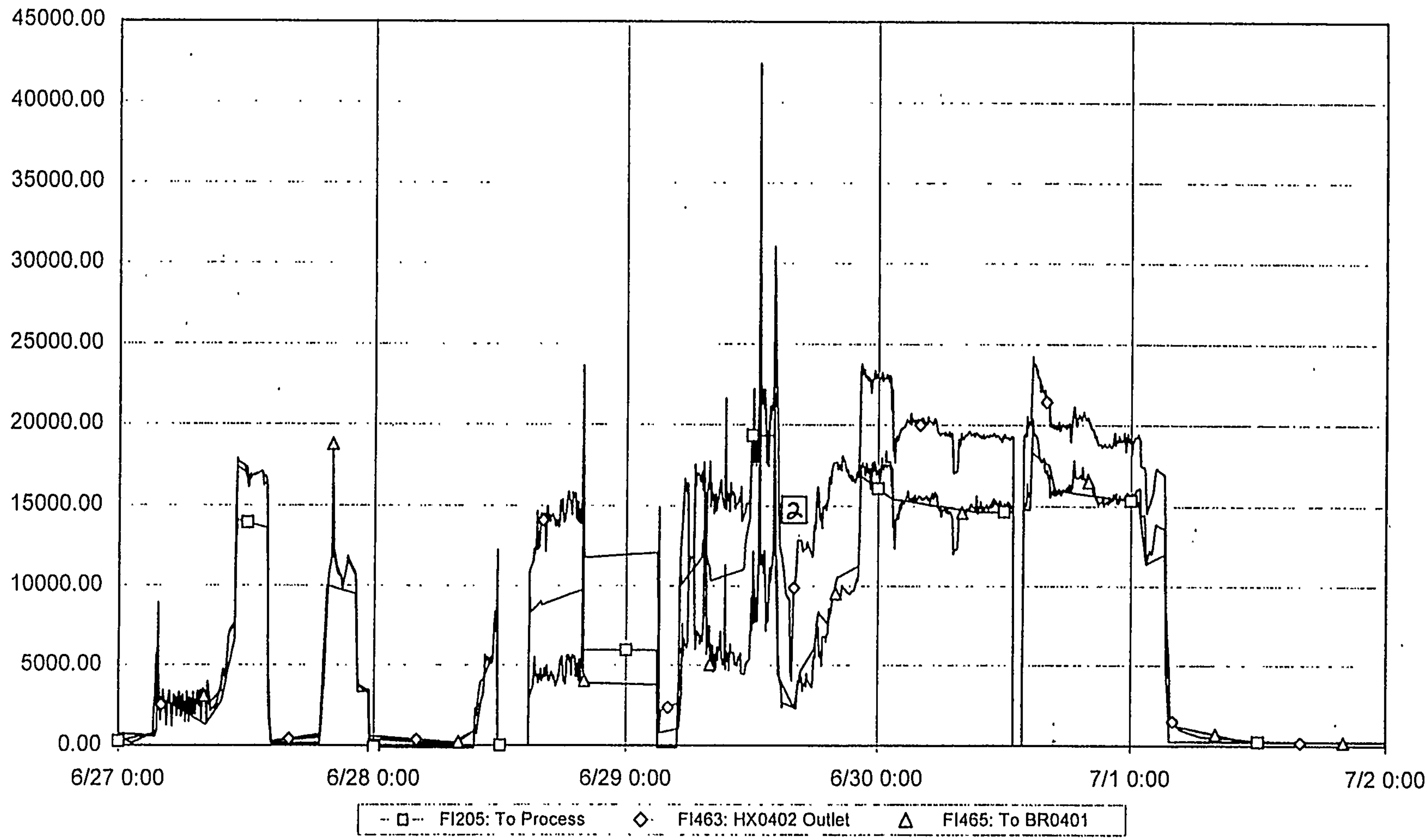
DOE Plot 11 of 45 - 5 minute data

Figure 5.1.4-7 Start-up Burner Flow/Temperature for June 27 Through July 1, 1996



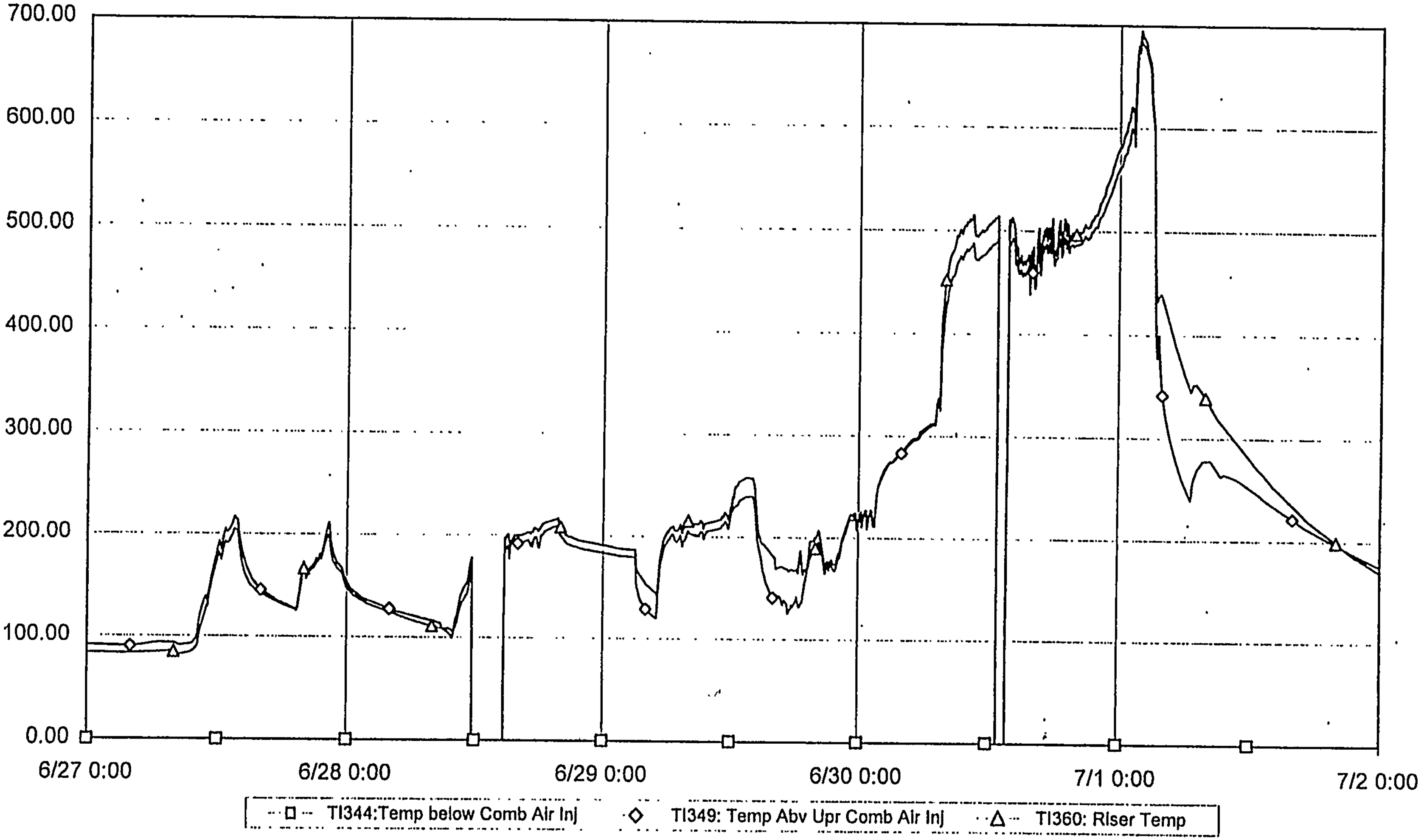
DOE Plot 12 of 45 - 5 minute data

Figure 5.1.4-8 System Pressures Downstream of PCD for June 27 Through July 1, 1996



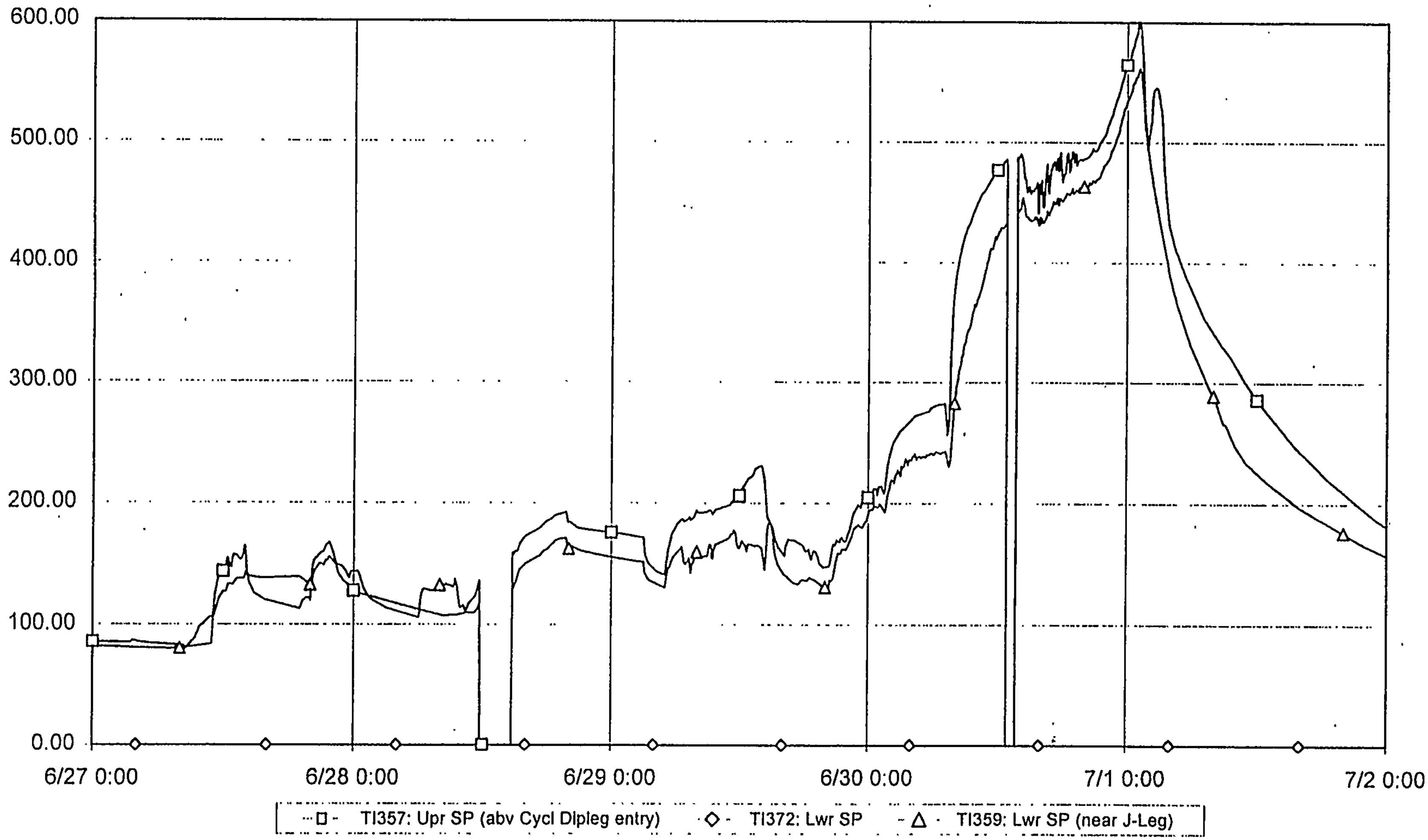
DOE Plot 13 of 45 - 5 minute data

Figure 5.1.4-9 Total Gas In/Out Flow Rates for June 27 Through July 1, 1996



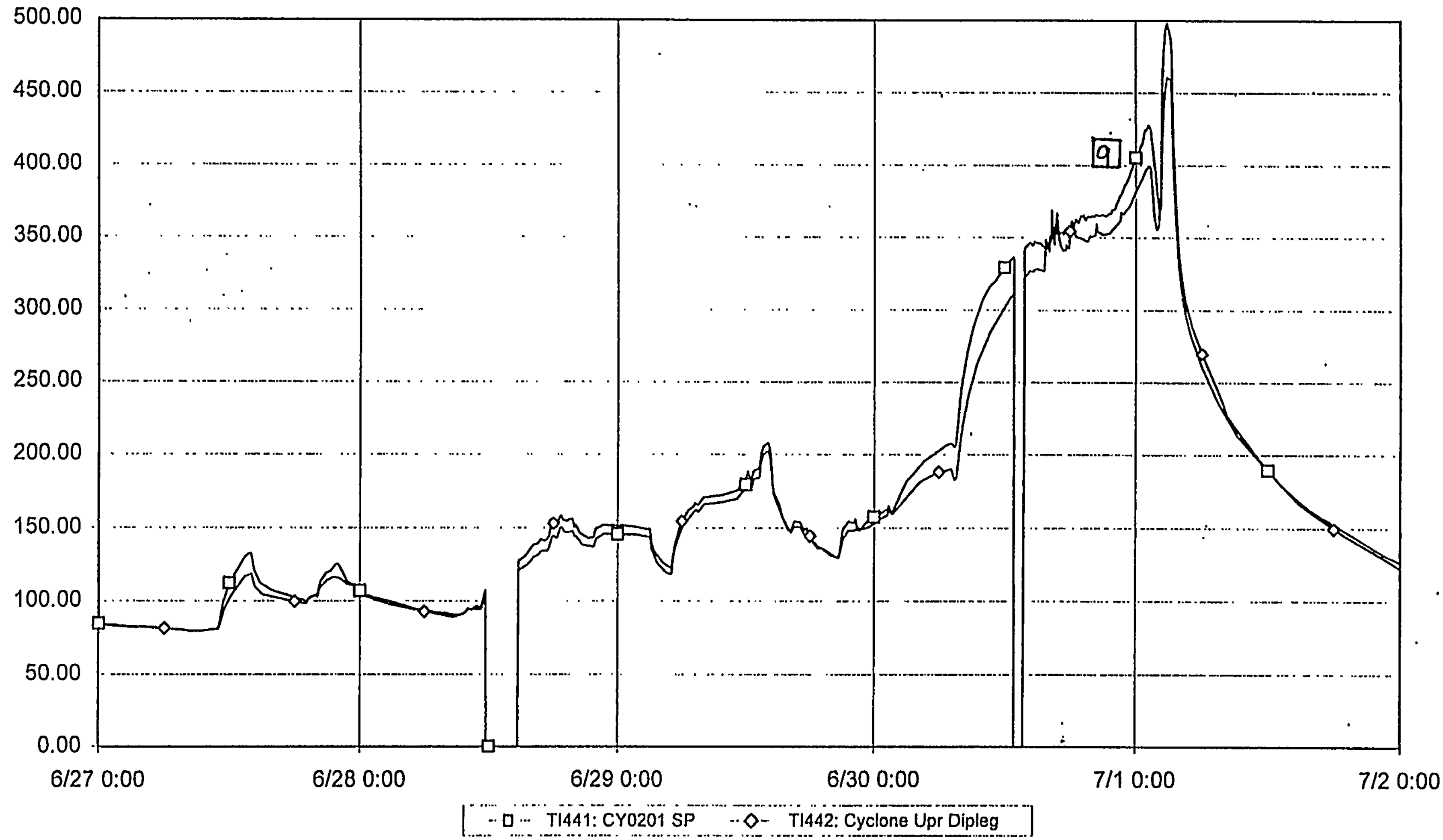
DOE Plot 14 of 45 - 5 minute data

Figure 5.1.4-10 Reactor Mixing Zone and Riser Temperatures for June 27 Through July 1, 1996



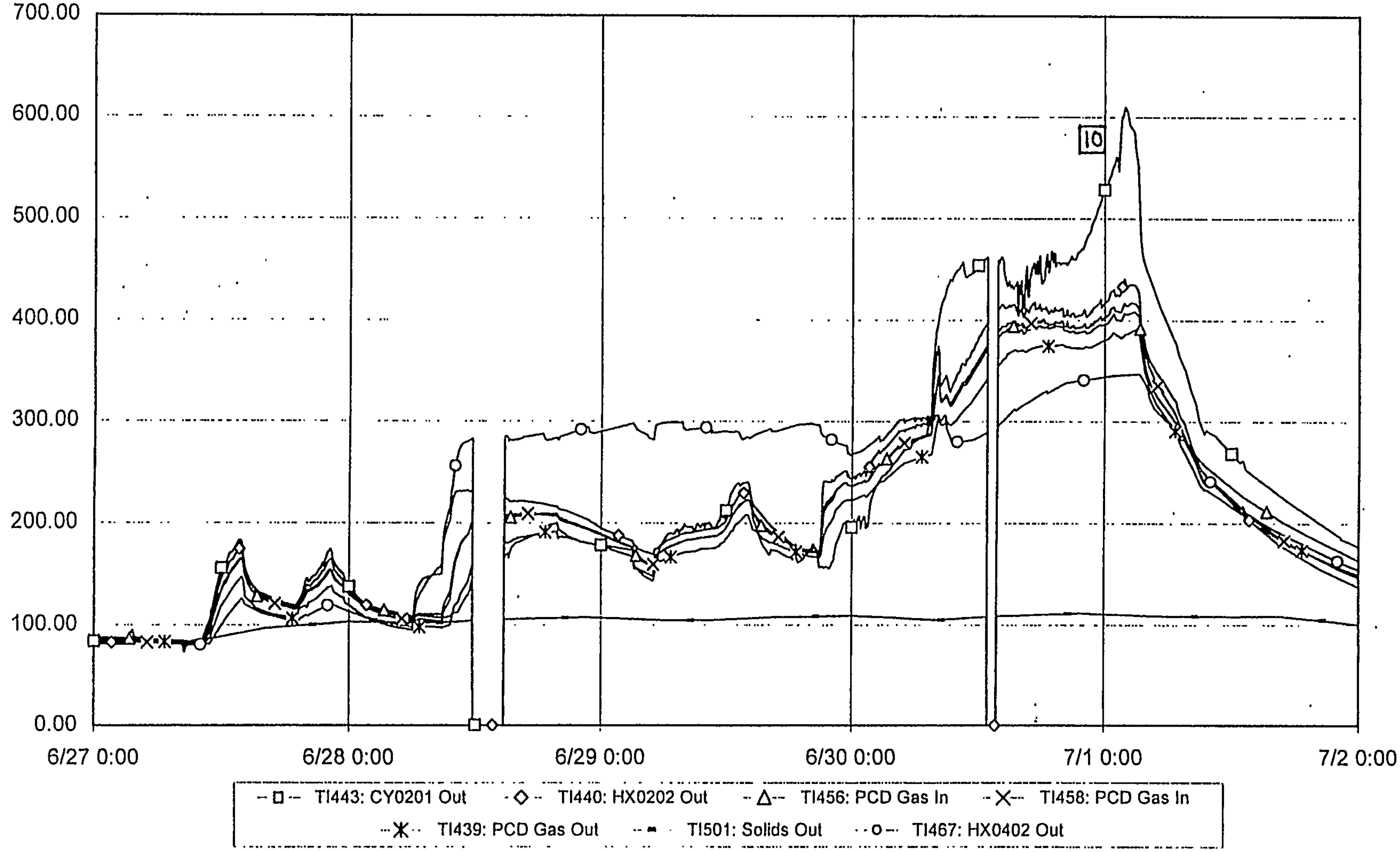
DOE Plot 15 of 45 - 5 minute data

Figure 5.1.4-11 Standpipe Temperatures for June 27 Through July 1, 1996



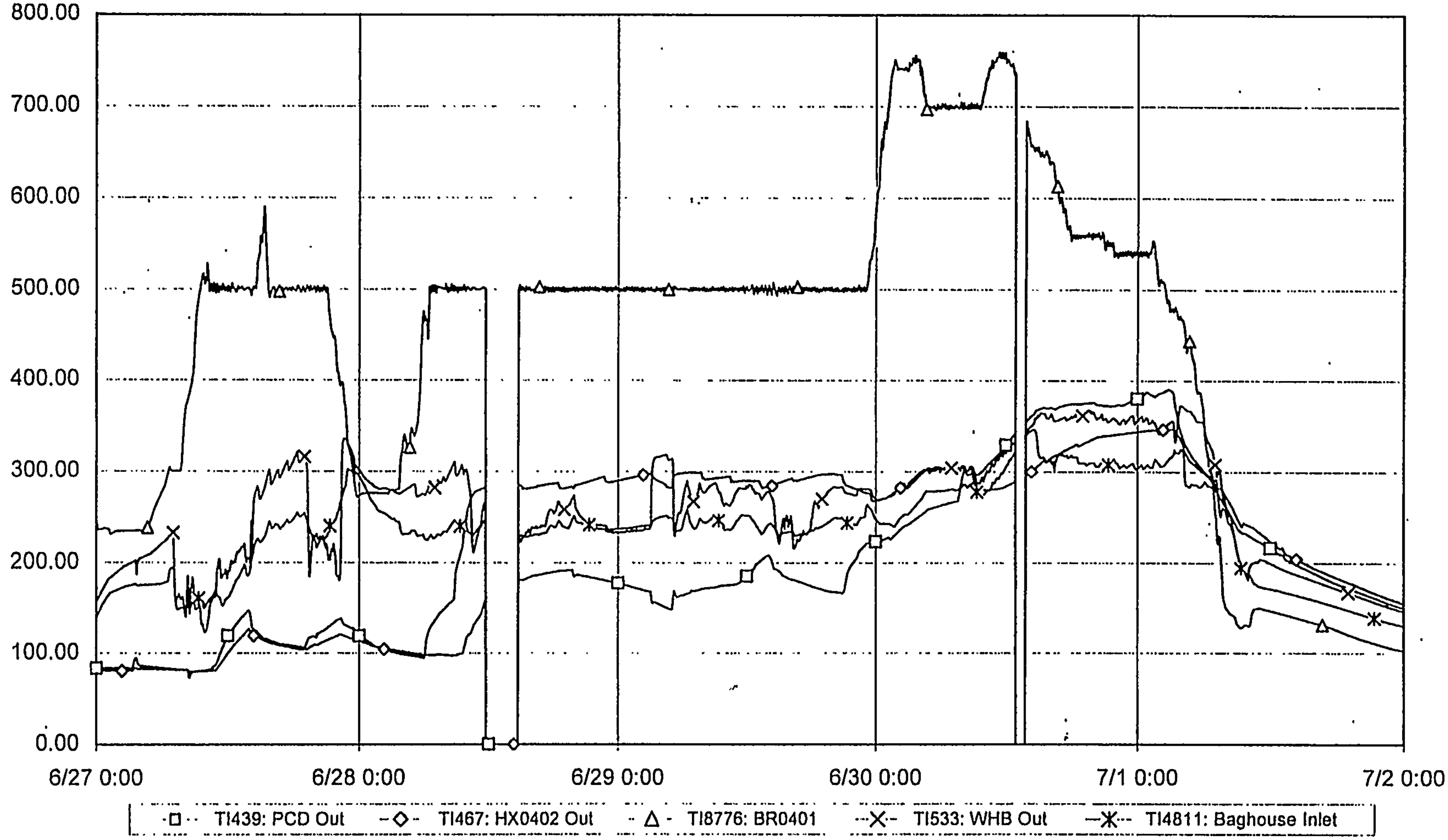
DOE Plot 16 of 45 - 5 minute data

Figure 5.1.4-12 Cyclone Dipleg Temperatures for June 27 Through July 1, 1996



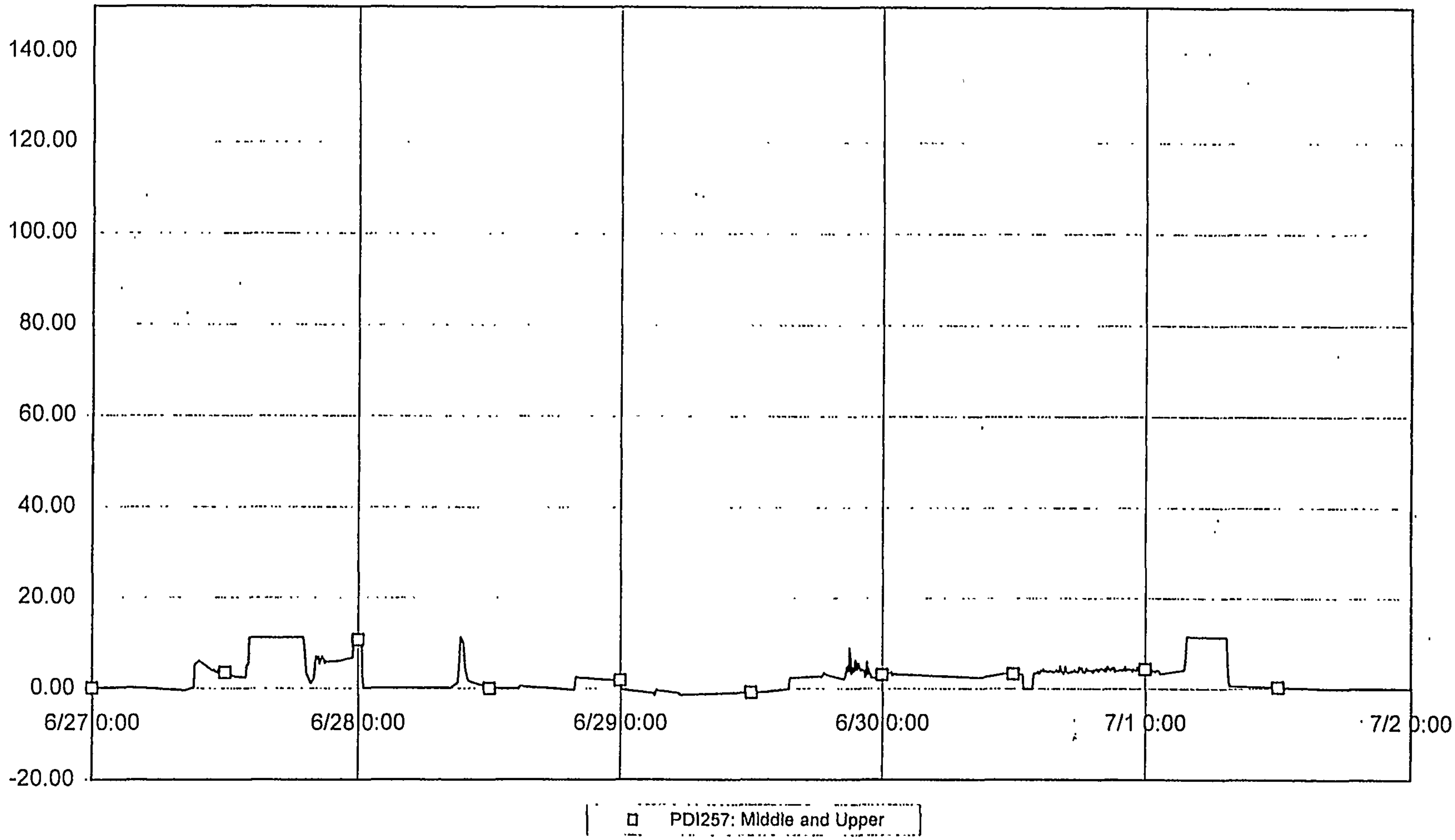
DOE Plot 17 of 45 - 5 minute data

Figure 5.1.4-13 Temperature Profile Downstream of Reactor for June 27 Through July 1, 1996



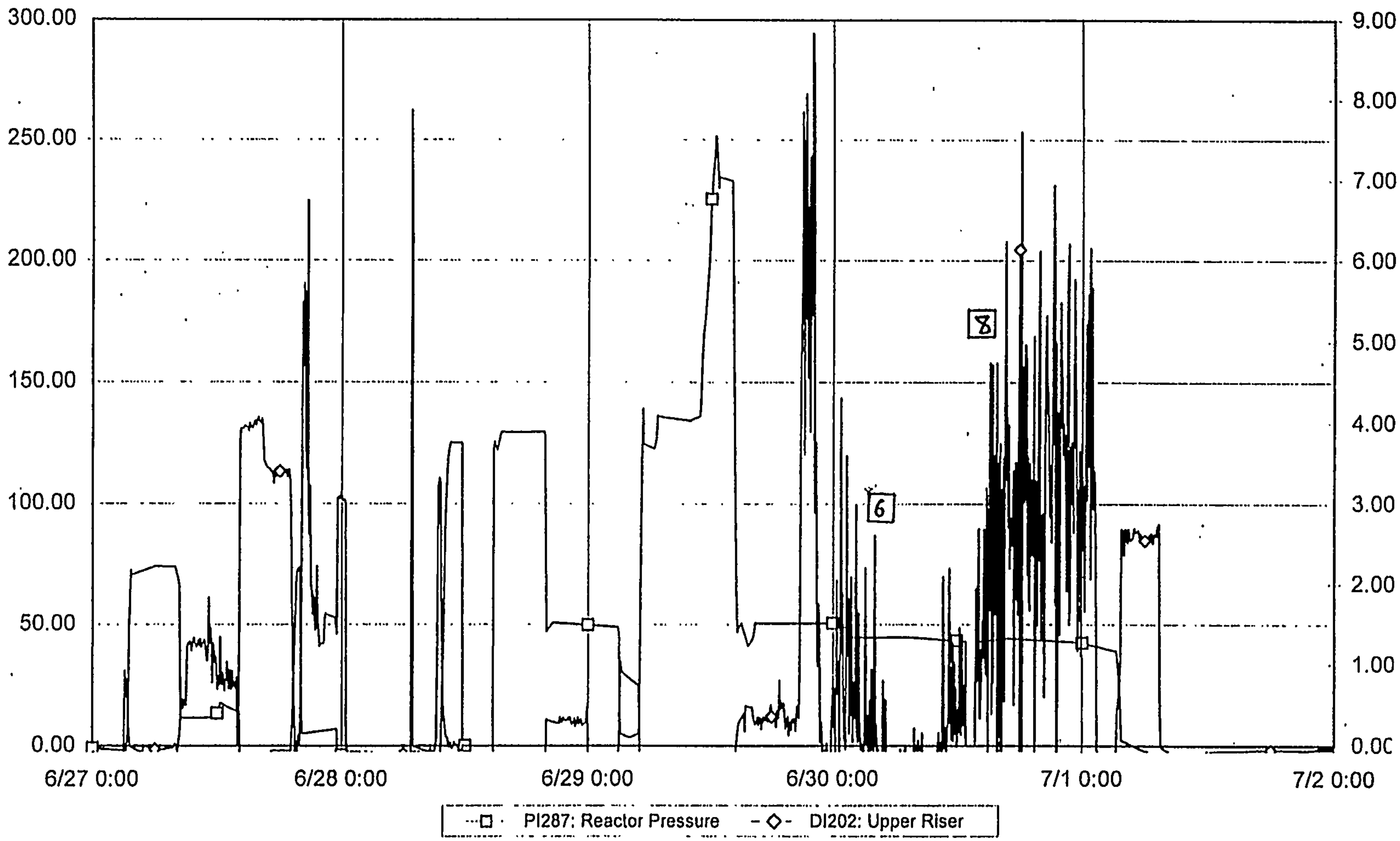
DOE Plot 19 of 45 - 5 minute data

Figure 5.1.4-14 System Temperatures Downstream of PCD for June 27 Through July 1, 1996



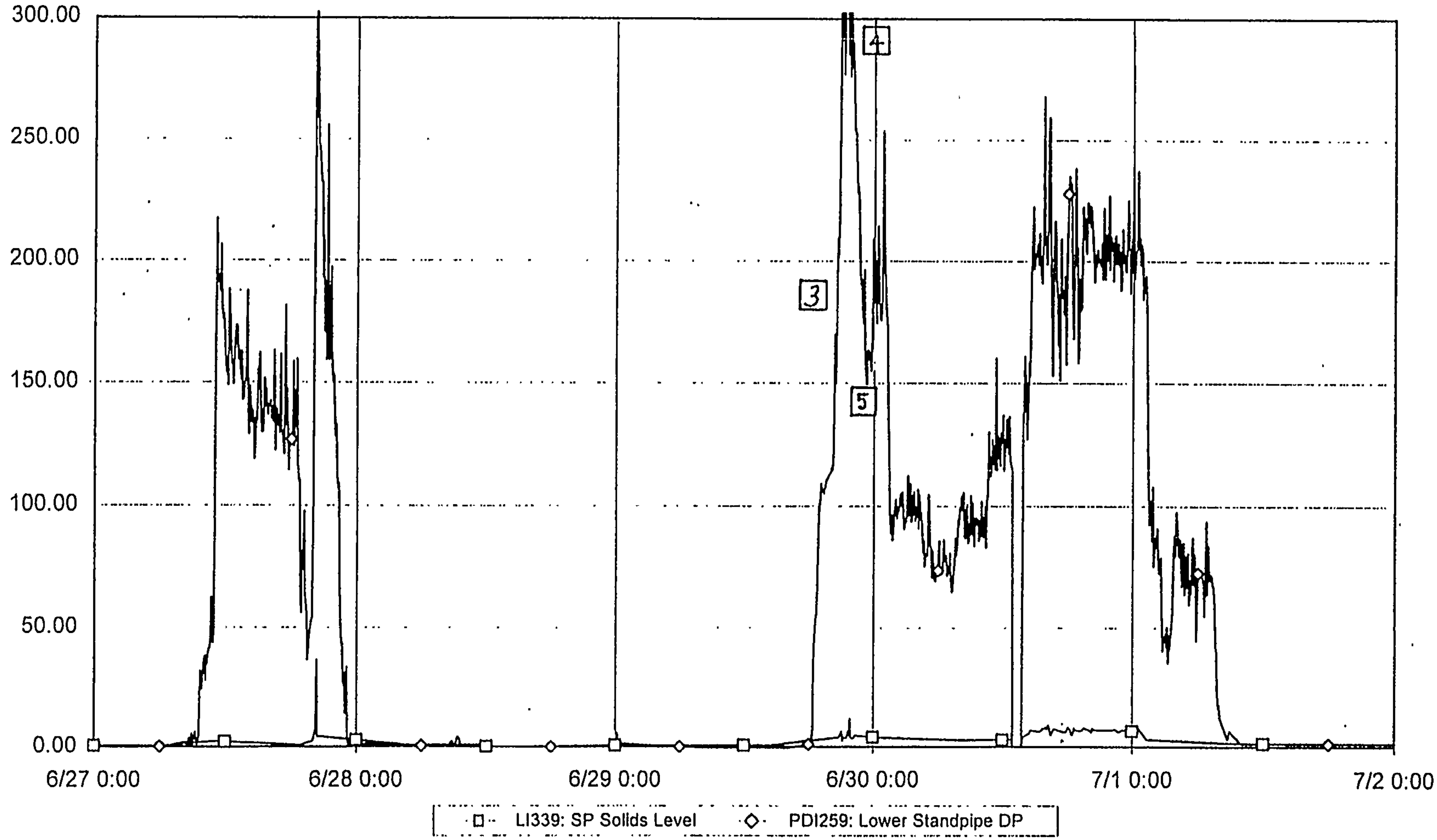
DOE Plot 20 of 45 - 5 minute data

Figure 5.1.4-15 Mixing Zone DP Profile for June 27 Through July 1, 1996



DOE Plot 21 of 45 - 5 minute data

Figure 5.1.4-16 Reactor Pressure/Riser DP Profiles for June 27 Through July 1, 1996



DOE Plot 22 of 45 - 5 minute data

Figure 5.1.4-17 Standpipe DP Profiles for June 27 Through July 1, 1996

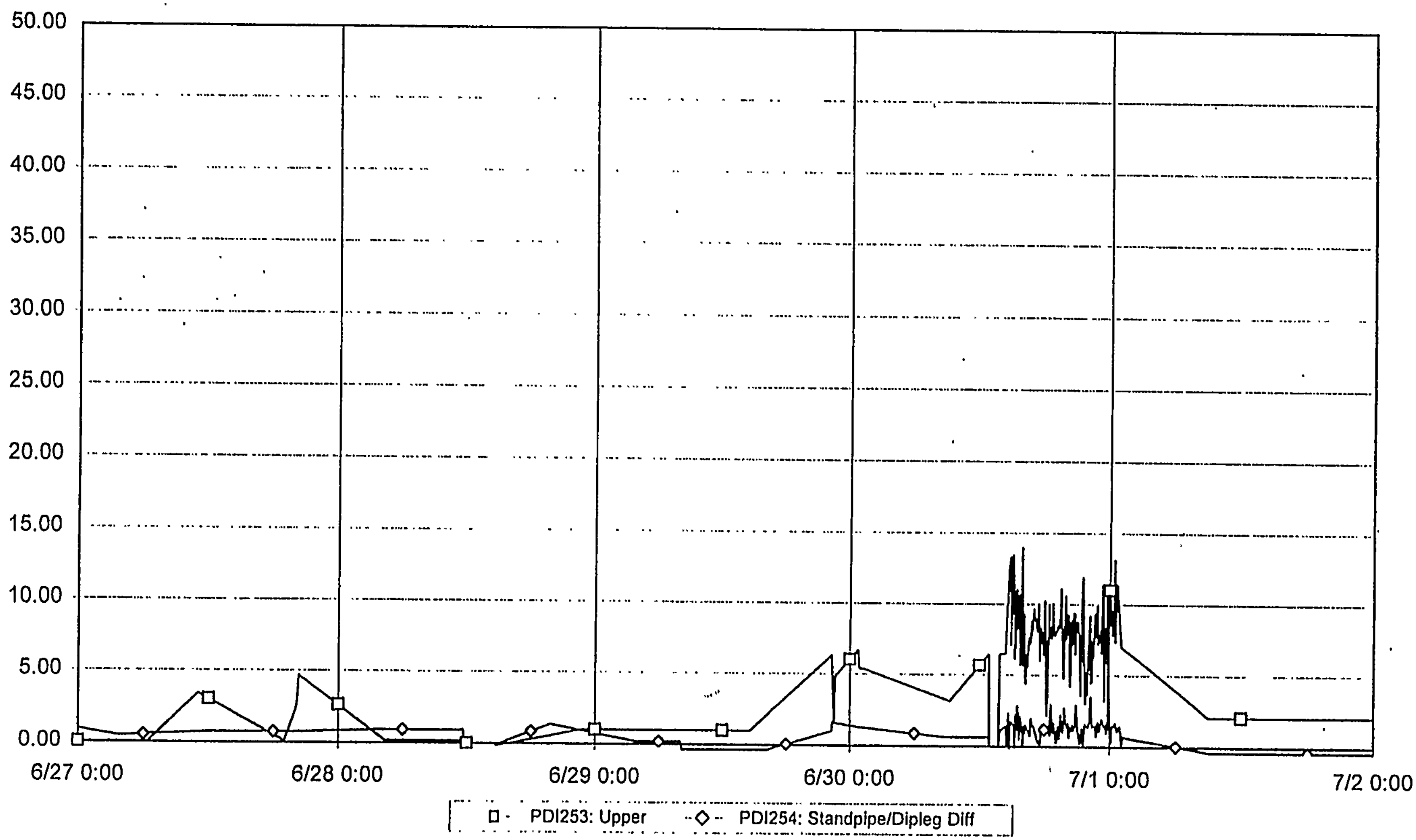


Figure 5.1.4-18 CY0301 Dipleg DP Profiles for June 27 Through July 1, 1996

5.1.5 Characterization Test Run CCT1A

5.1.5.1 Introduction and Test Objective

The objective of this test was to demonstrate coal combustion in the transport reactor at high operating pressures. This was the first coal combustion test scheduled after hot shakedown with solids circulation. The gas flow path was lined up through the Westinghouse PCD. Test run CCT1A was conducted between July 20 and July 27, 1996. Operating plots are shown in figures 5.1.5-1 to -36.

The pressure letdown valve (PV287) that was eroded during the previous run was replaced prior to this run. Also, the main air compressor (CO0201) was tuned and the safety interlocks in the reactor loop were tested and proven to be functional. The pressure relief valves were calibrated, installed, and tested. The relief valve on the discharge of the recycle gas compressor (CO0401) was found to lift prematurely probably due to vibration from CO0401, which is a reciprocating compressor. The pilot of the relief valve was relocated upon recommendations from MWK and the supplier.

A transport reactor capacity test was performed to determine the maximum air flow that could be passed through the reactor at 290 psig cyclone exit pressure (maximum operating pressure), with an operating compressor discharge pressure of 330 psig. The results show that at 287 psig (cyclone exit pressure), the maximum air flow rate obtained was 13,600 lb/hr compared to 17,000 lb/hr required for coal combustion at 290 psig. By lowering the reactor pressure to 267 psig, about 17,800 lb/hr air flow was achieved. The data was later reviewed by the M. W. Kellogg Company (MWK). MWK recommended the test be repeated at a compressor discharge pressure of 350 psig. At this compressor discharge pressure, the design flow through the reactor would be achieved.

Prior to the run, the starting bed material was drained from the transport reactor standpipe and transport reactor J-leg to permit borescope inspection of the inlet to the spent solids screw cooler (FD0206). Also, the fines screw cooler (FD0502) under the PCD was inspected with the borescope. Both the transition pieces upstream of the screw coolers and the entrance to the coolers were found to be free of debris. The refractory surface was found to be in excellent condition.

In preparation for the run, the heat transfer fluid system and the thermal oxidizer in addition to other miscellaneous systems required for the run were started. The reactor was also leak tested. During the leak test, the Westinghouse PCD head was found to leak between the vessel flanges and the tubesheet. The reactor loop was again leak tested after the Westinghouse PCD vessel was reassembled. The PCD was found to leak at two locations around the head at pressures higher than 180 psig. It was decided to proceed with the test but operate the reactor at a maximum pressure of 160 psig instead of 260 psig as planned.

5.1.5.2 Test Chronology

On July 22, 1996, after the leak test was completed, the PT and PDT instruments bleeds were balanced at 260, 210, and 50 psig. The reactor pressure was held at 50 psig to begin the run (event 1, figure 5.1.5-14). The steam drum vent was closed to begin pressurization of the drum. When the drum pressure reached 50 psig, the riser on HX0202 and HX0402 were opened and their downcomers were cracked open. At 12:00 all process aeration flows were set to normal operating flows. The preheating of the PCD was completed at 14:45 and the process flow rates were reduced to allow solids addition into the reactor through the coal feeder (FD0210). This was done to allow the solids fed into the mixing zone to fill the reactor J-leg creating a seal between the mixing zone and reactor standpipe. The PCD back-pulse system, FD0502, FD0520 and FD0530 were started at 16:40 prior to feeding solids from FD0210. The FD0530 was lined up to transfer solids captured in the PCD into FD0220 for subsequent feeding into the reactor.

Solids transfer from FD0210 into the reactor mixing zone was initiated at 17:05 (event 2, figure 5.1.5-3). The J-leg was sealed after a half-hour transfer of solids as evidenced from the lower standpipe differential pressure (PDI259) profile (event 3, figure 5.1.5-15). Once the reactor J-leg was sealed, the transport air flow rate was increased to convey additional starting bed material, added into the mixing zone, into the reactor standpipe and then into HX0203. At 23:00 approximately 8,500 lb of alumina was transferred from FD0210 into the reactor. The total amount of starting bed material loaded did not fill the reactor standpipe and HX0203 to the desired operating levels. However, the levels were adequate to start solids circulation in the reactor. More solids were planned to be added later during the preheat period.

The start-up burner (BR0201) pilot was lit at 03:16 on July 23, 1996. The quench air flow to the burner was adjusted to produce a burner exit temperature at approximately 500°F (event 4, figure 5.1.5-5). Solids circulation through HX0203 and reactor J-legs was started approximately an hour after the burner pilot was lit. After establishing solids circulation, the reactor pressure was increased from 50 to 60 psig. Shortly thereafter, FD0520 outlet was plugged. Unable to transfer solids collected inside the PCD into the reactor, the solids circulation in the reactor was decreased to reduce the carryover to the PCD while FD0520 was being fixed. Meanwhile, the spent solids transporter was run every 2 hours to prevent moisture condensation. Solids circulation through the reactor was further reduced and the reactor pressure was lowered from 60 to 50 psig. Later at 08:05, BR0201 was shut down, solids circulation stopped, and the aeration reduced to standby flows. The PCD back-pulse system was shut off and the reactor was depressurized to 5 psig to permit maintenance work to be done on FD0520. The main air compressor discharge pressure was lowered to 70 psig (event 5, figure 5.1.5-1).

A spool piece at the exit of FD0520 was removed and refractory pieces that plugged the discharge line were removed. The PCD back-pulse was started and FD0502 and FD0520 systems were run for an hour to verify their operation and ensure that all the refractory pieces were removed.

The reactor loop was pressurized back to 60 psig. The solids that collected inside the BR0201 J-leg were blown out into the mixing zone in preparation for lighting the burner pilot. The reactor pressure was reduced to 50 psig and the burner pilot was lit at 17:39 on July 23, 1996. During troubleshooting of FD0520, moisture condensation in the feeder was suspected to be the cause of the plug. Because of this, it was decided that the PCD must be preheated to at least 350°F before solids circulation in the reactor was started. The PCD preheat therefore started with lighting of the burner pilot. At 20:40 the reactor pressure was increased to 60 psig and the main burner gun lit (event 6, figure 5.1.5-5 and -14). During the PCD preheat, both HX0202 and HX0402 were lined up for steam production because the gas temperature at their inlet was higher than the steam drum temperature. The burner exit temperature at this time was approximately 940°F.

Around 22:00 the FD0520 outlet plugged several times. Each time the sample port at the exit of FD0520 was removed and the discharge line was rodded out to clear the pluggage. At 23:30 the PCD preheat was completed and additional 2,000 lb of alumina was added into the reactor from FD0210. Solids circulation through both reactor and HX0203 J-legs was started an hour later. While starting solids circulation, the plant information (PI) data collecting computer system went down (event 7, figure 5.1.5-1 and -2).

At 01:00 on July 24, 1996, the burner firing rate was increased to increase the burner exit temperature at 150°F/hr and to increase the solids heat up rate. Approximately 2,215 lb of alumina were added into the reactor to increase the solids level in the standpipe and HX0203. At 13:23 the start-up burner tripped but it was immediately relit. At this time, the burner exit temperature (TI385) was 1,582°F, propane flow rate (FIC364) was 126 lb/hr, with high combustion air flow rate through the burner. The reactor was operating at 70 psig pressure and the riser exit temperature was approximately 600°F (event 8, figure 5.1.5-5, -8, and -14). At approximately 14:00 the regulator on the Westinghouse PCD back-pulse skid failed. To reduce solids carryover from the reactor to the PCD while the regulator was being worked on, the solids circulation rate in the reactor was reduced by decreasing the reactor J-leg aeration and the HX0203 J-leg aeration. While the regulator was being changed, cooling water flow to the facility was momentarily interrupted. This caused the main air compressor to trip which in turn tripped the solids conveying systems and the fines screw cooler.

At 15:30 the PCD back-pulse regulator was replaced and solids circulation in the reactor was started by increasing the J-leg aerations. Between 15:30 and 22:00, the burner propane flow was steadily increased from 126 to 165 lb/hr to increase the heat input into the system. The reactor pressure was also increased to reduce the riser velocity. At 20:25 the riser exit temperature was 700°F (event 9, figure 5.1.5-8) and preparations were started for loading coke breeze into the coal feeder (FD0210) to be used for raising the reactor temperature to between 1,300 and 1,400°F prior to coal injection. Approximately 300 lb of coal breeze were inventoried into FD0210 to avoid dumping a lot of coke breeze into the reactor since it was difficult to know the instantaneous feeding rate. At 22:05 BR0201 tripped again. It was relit after 5 minutes.

At 0110 on July 25, 1996, coke breeze was fed into the reactor for approximately 1 minute. This was repeated after 20 minutes. During each feeding period, the temperatures in the mixing zone and riser did not increase (event 10, figure 5.1.5-26). At 01:50, solids circulation through HX0203 were reduced to increase the mixing zone temperature (event 11, figure 5.1.5-26). Coke breeze feeding was repeated at 03:10 for 1 minute. This time, the mixing zone and riser exit temperatures dropped by 30°F (event 12, figure 5.1.5-26), an indication of low solids circulation in the reactor. After this, solids circulation was established through HX0203 and the mixing zone temperatures dropped (event 13, figure 5.1.5-26). Shortly after, the propane firing rate dropped steadily from 178 lb/hr (event 14, figure 5.1.5-23 and -26) and finally the burner tripped 2 hours later. The burner was relit 20 minutes after it tripped. However, the propane flow could not be increased beyond 168 lb/hr. Also, difficulties were experienced in feeding the material collected by the PCD into the reactor. This was caused by a FD0220 Spheri valve failing to close.

The reduction in propane flow resulted in a decrease in burner heat input into the reactor that caused the reactor (mixing zone and riser) temperatures to drop. Between 06:15 and 10:15 the solids circulation rate through the reactor was manipulated to increase the mixing zone temperature by reducing solids circulation through HX0203 to a minimum. At 11:28, to counteract the continuous decrease in the propane flow, the liquid propane pump was started and the propane flow increased from 154 to 164 lb/hr (event 15, figure 5.1.5-23). Prior to this, it was decided to raise the maximum burner exit temperature from the initial vendor recommendation of 1800 to 1900°F.

When the mixing zone temperatures reached about 900°F, coke breeze was fed in batches into the reactor. Feeding of coke breeze into the reactor was stopped because all the coke breeze inventoried into FD0210 had been used. The mixing zone bottom temperature increased from 900 to 945°F (event 16, figure 5.1.5-26) after two batches of coke breeze were fed each lasting approximately 1 minute. The riser exit temperature increased to 820°F. Approximately 900 lb of alumina were added into the reactor at 13:56. Another 250 lb of coke breeze were loaded into FD0210.

The coke breeze loaded into FD0210 was injected into the reactor between 14:30 and 15:30. There was not a noticeable increase in the reactor temperature. The FD0210 was inventoried with approximately 2,000 lb of coke breeze to be added later into the reactor. The burner firing rate was increased from 164 to 182 lb/hr to increase the heat input into the system and to help raise the reactor temperature as high as possible to ignite the coke breeze.

By decreasing the solids circulation rate in the reactor, the reactor temperature continued to increase to as high as 930°F at 20:20. Coke breeze was injected into the reactor for

5 minutes. The temperature profile in the reactor indicated that the coke breeze was burning (event 17, figure 5.1.5-26). Between 20:30 on July 25, 1996, and 04:25 on July 26, 1996, the 2,000 lb of coke breeze loaded into FD0210 were added in batches (feeding for 2 minutes at a time) into the reactor. Each addition was accompanied by a reactor temperature increase. However, at 04:10 on July 26, 1996, the propane flow rate suddenly dropped from 174 to 148 lb/hr (event 18, figure 5.1.5-23). This caused the reactor temperatures to drop and the heat released from coke breeze combustion was too low to compensate for the drop in heat input from the start-up burner. Attempts to increase the propane flow rate by increasing the propane supply pressure were unsuccessful. Also, the circulation through the reactor was periodically reduced and then increased to increase the mixing zone temperature. However, due to the lower heat input, the mixing zone temperature was not high enough for coke breeze injection. After approximately 7 hours the highest mixing zone temperature was 863°F.

Starting the spent solids screw cooler (FD0206) was attempted at 14:46. The screw appeared jammed and would not start. The problems with starting FD0206 coupled with propane flow problems to BR0201 caused shutdown of the facility.

5.1.5.3 Post Test Inspection

The main burner gun was removed after the reactor had cooled down, and approximately 19 grams of carbon (coke) deposits were removed. The main burner holes were cleaned and the burner was reinstalled with strainers on the propane line upstream of burner gun to minimize plugging due to pipe scales.

Nitrogen was blown through a nozzle close to the drive end of FD0206. This appeared to clear the pluggage and the screw started without any difficulty. However, to ascertain that the jamming was not caused by refractory pieces, the solids in reactor J-leg and standpipe were drained and FD0206 inlet was inspected with a borescope. There were no refractory pieces or foreign debris found.

The limestone feeder (FD0220) middle Spheri valve was removed and was examined, and reassembled with higher tolerances to prevent binding problems experienced during the run. The seal ring was found corroded and pitted in some places.

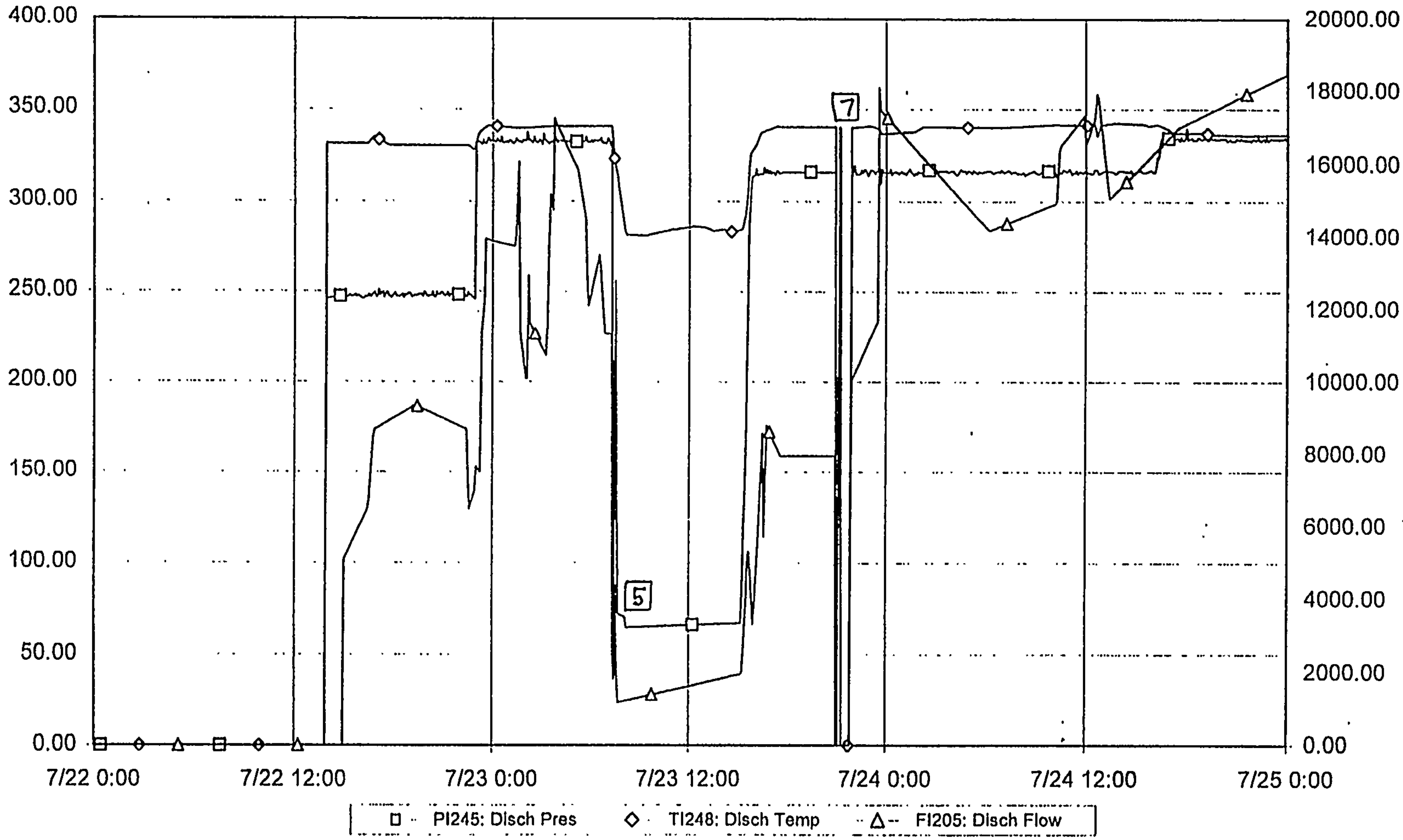
Rainwater leaks in the baghouse were repaired. Several refractory-lined areas (riser crossover, between the standpipe and solids cooler, exit of Westinghouse PCD and mixing zone) were inspected with a borescope. The refractory in these areas did not show any signs of erosion.

Thermowells in high erosion areas were removed and checked. The thermowell and its associated thermocouple (TI-356) in the riser crossover were eroded. The eroded tip was grounded off, capped, and reinstalled. Several thermowells in the riser and mixing zone showed erosion wear. These were rotated 180° and reinstalled.

A review meeting was held to discuss how the system was operated and the lessons learned from the operation. High carbon inventory was built-up in the reactor with coke breeze as the reactor temperatures were low and not sufficient to ignite the coke breeze. The coal combustion procedure was revised to incorporate lessons learned from the previous run. Subbituminous coal was procured and prepared as an alternative to coke breeze for the next combustion start-up. Subbituminous coal contains more volatile matter than coke breeze and would therefore ignite at a lower temperature than coke breeze.

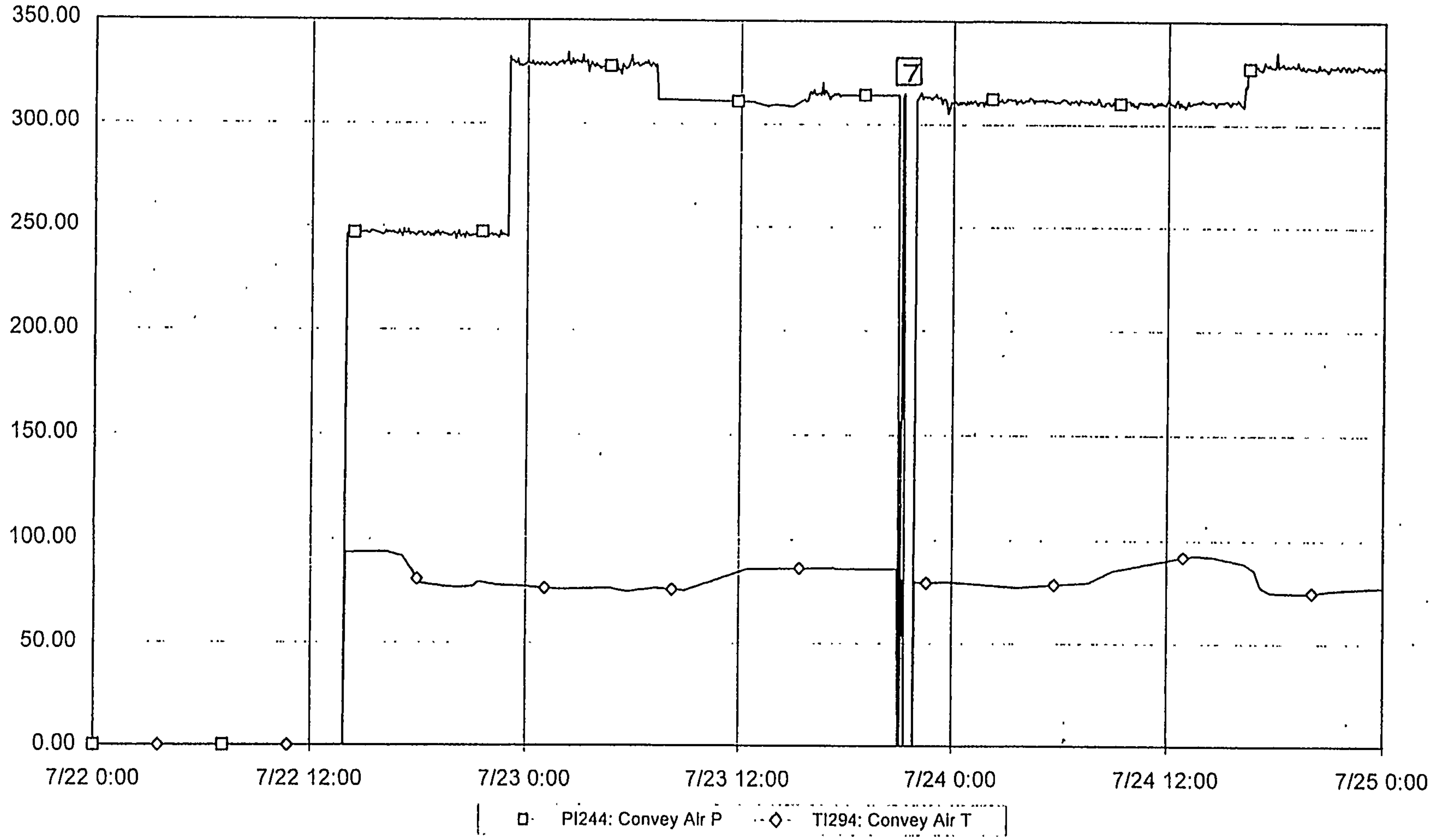
5.1.5.4 Test Run CCT1A Observations

A high carbon inventory with coke breeze was built up in the reactor because the reactor temperatures were low and not sufficient to ignite the coke breeze. Subbituminous coal will be procured and prepared as an alternative to coke breeze for the next combustion start-up. Inspections found that the pressure letdown valve was eroded again. Since the gas flow path was through the Westinghouse PCD, the pressure letdown valve erosion problem was further analyzed. It was decided to use sand as the startup bed material instead of alumina in subsequent test runs. With alumina, the solids carryover from the reactor was excessive and the abrasive nature of alumina was probably causing the pressure letdown valve to erode.



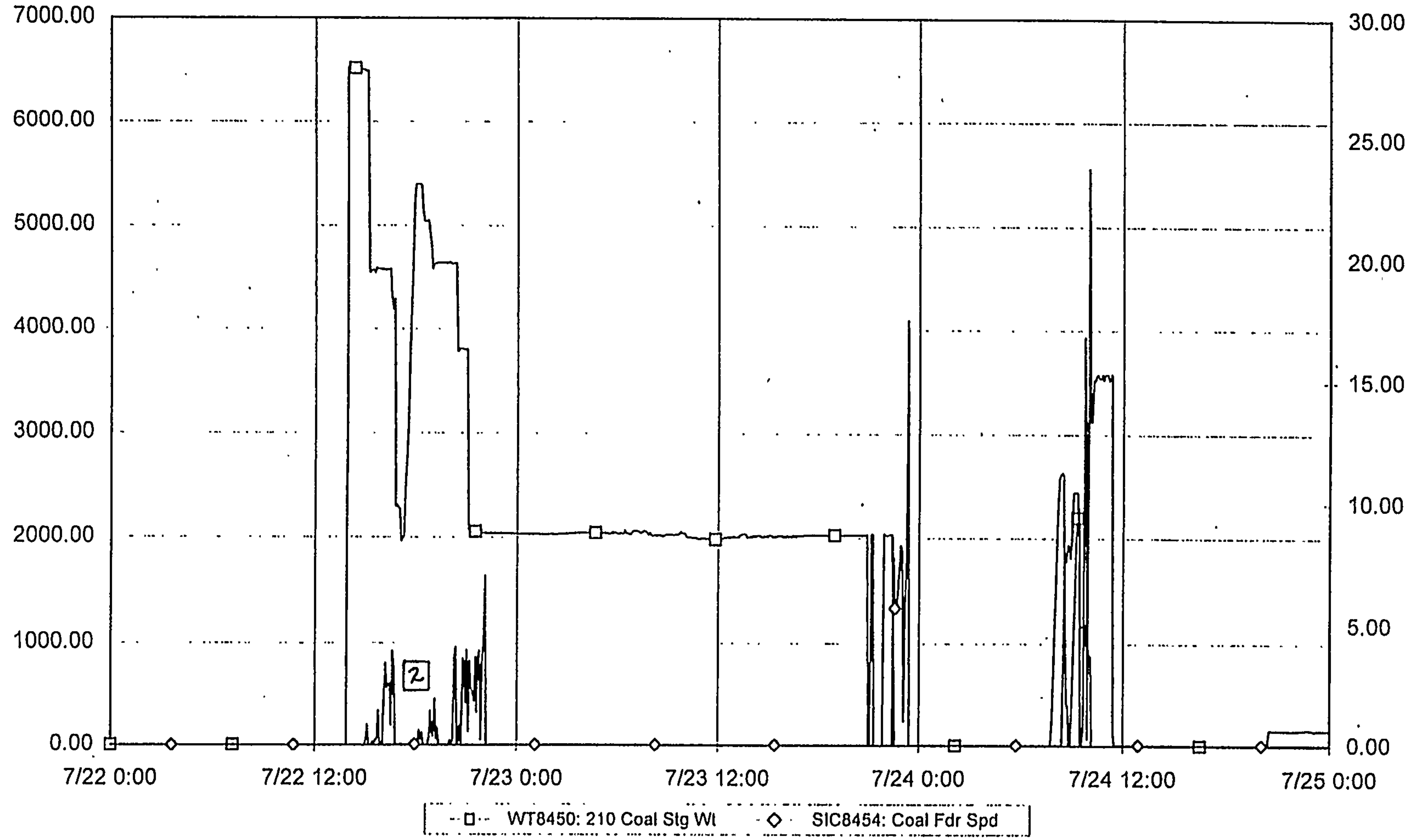
DOE Plot 1 of 45 - 5 minute data

Figure 5.1.5-1 C00201 System Profile for July 22 Through July 24, 1996



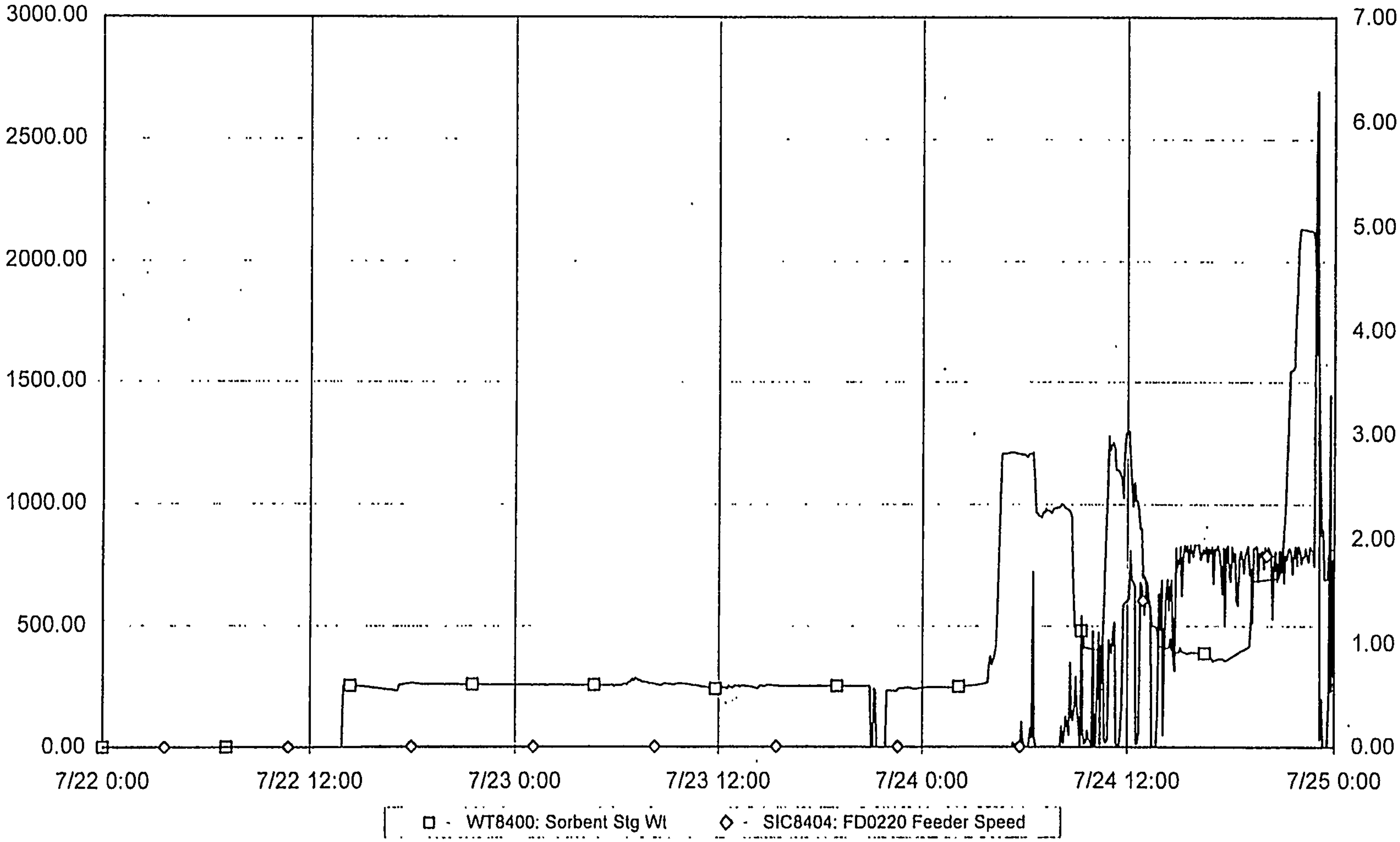
DOE Plot 5 of 45 - 5 minute data

Figure 5.1.5-2 Transport Air System for July 22 Through July 24, 1996



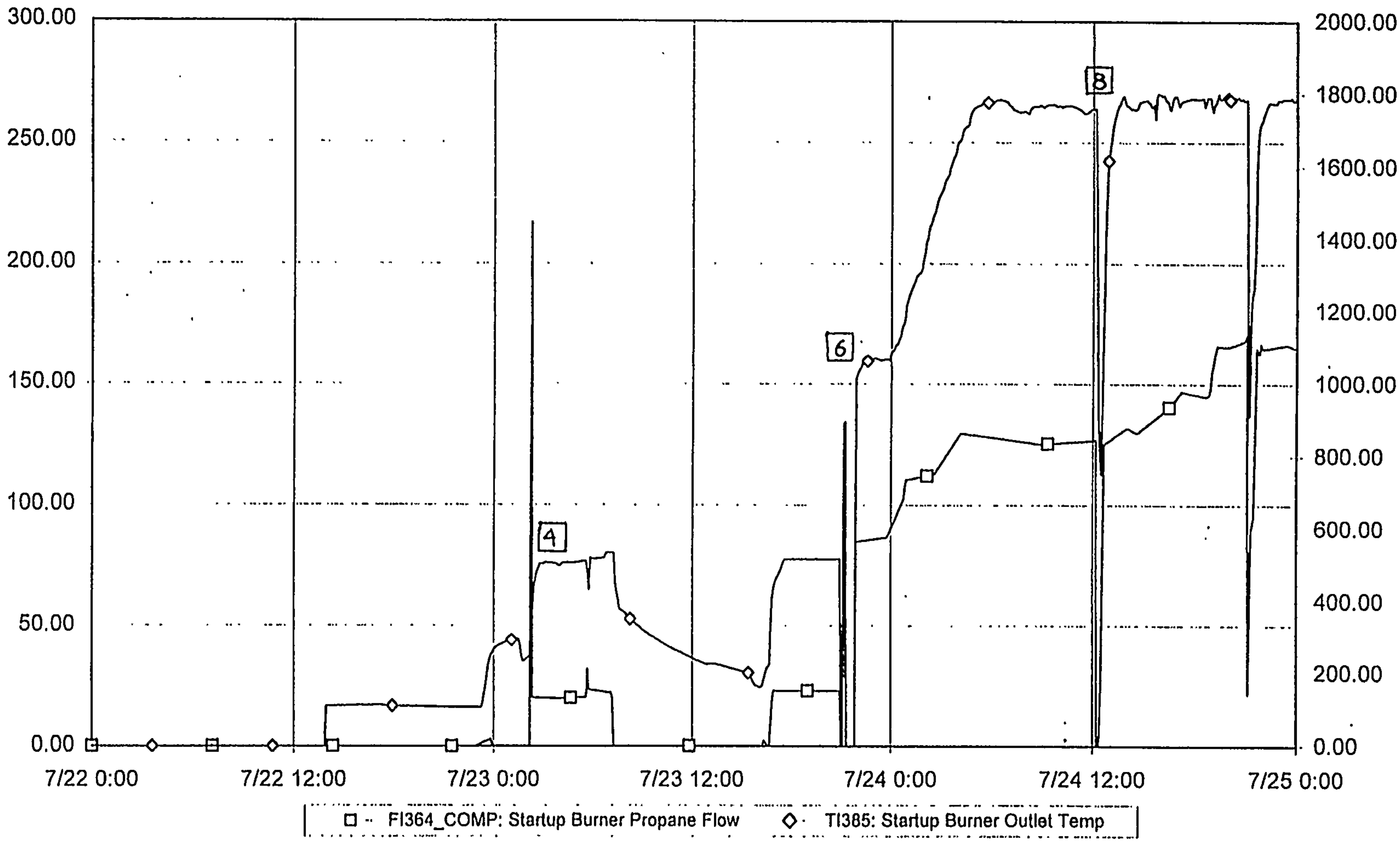
DOE Plot 7 of 45 - 5 minute data

Figure 5.1.5-3 Coal Feed for July 22 Through July 24, 1996



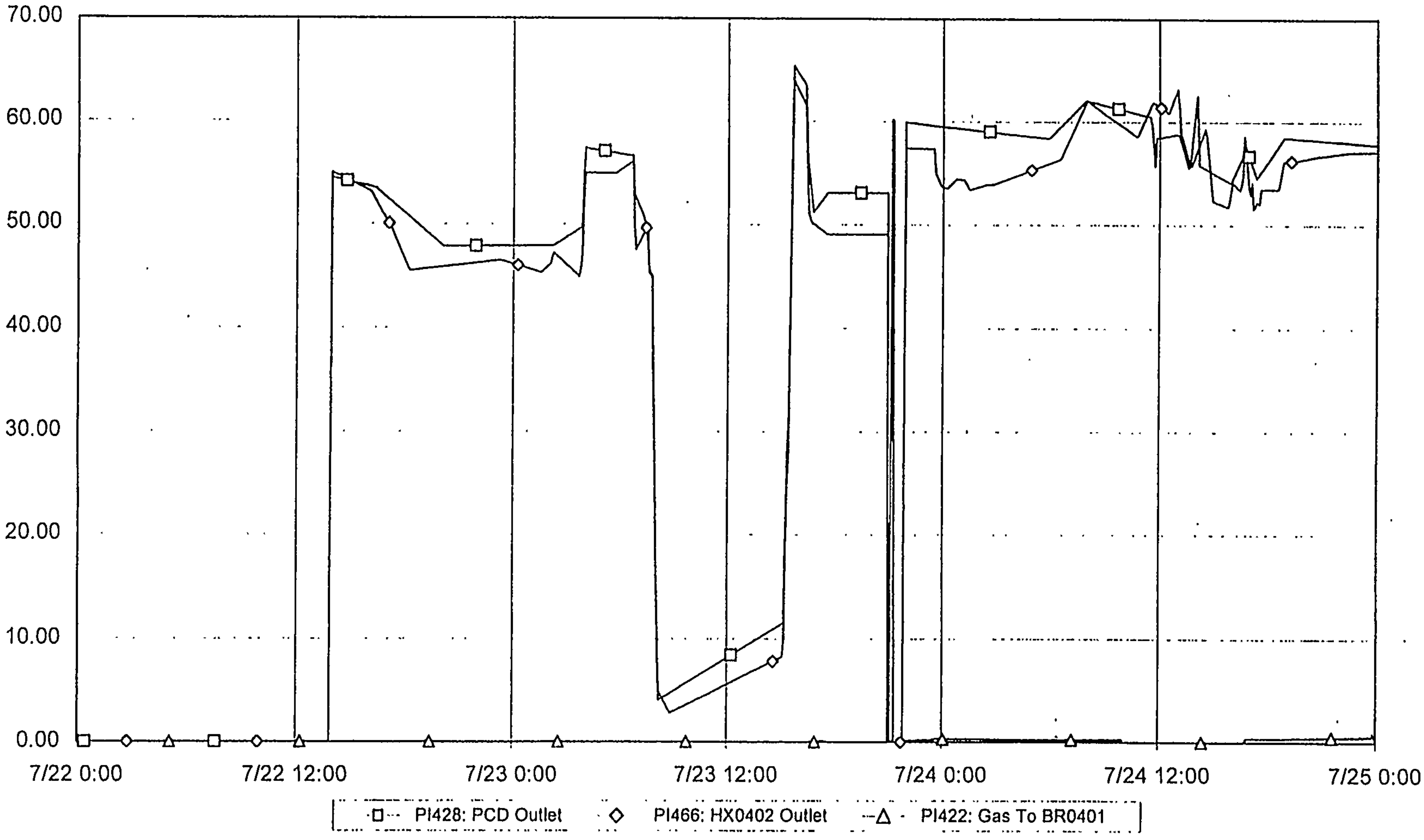
DOE Plot 9 of 45 - 5 minute data

Figure 5.1.5-4 Sorbent Feed for July 22 Through July 24, 1996



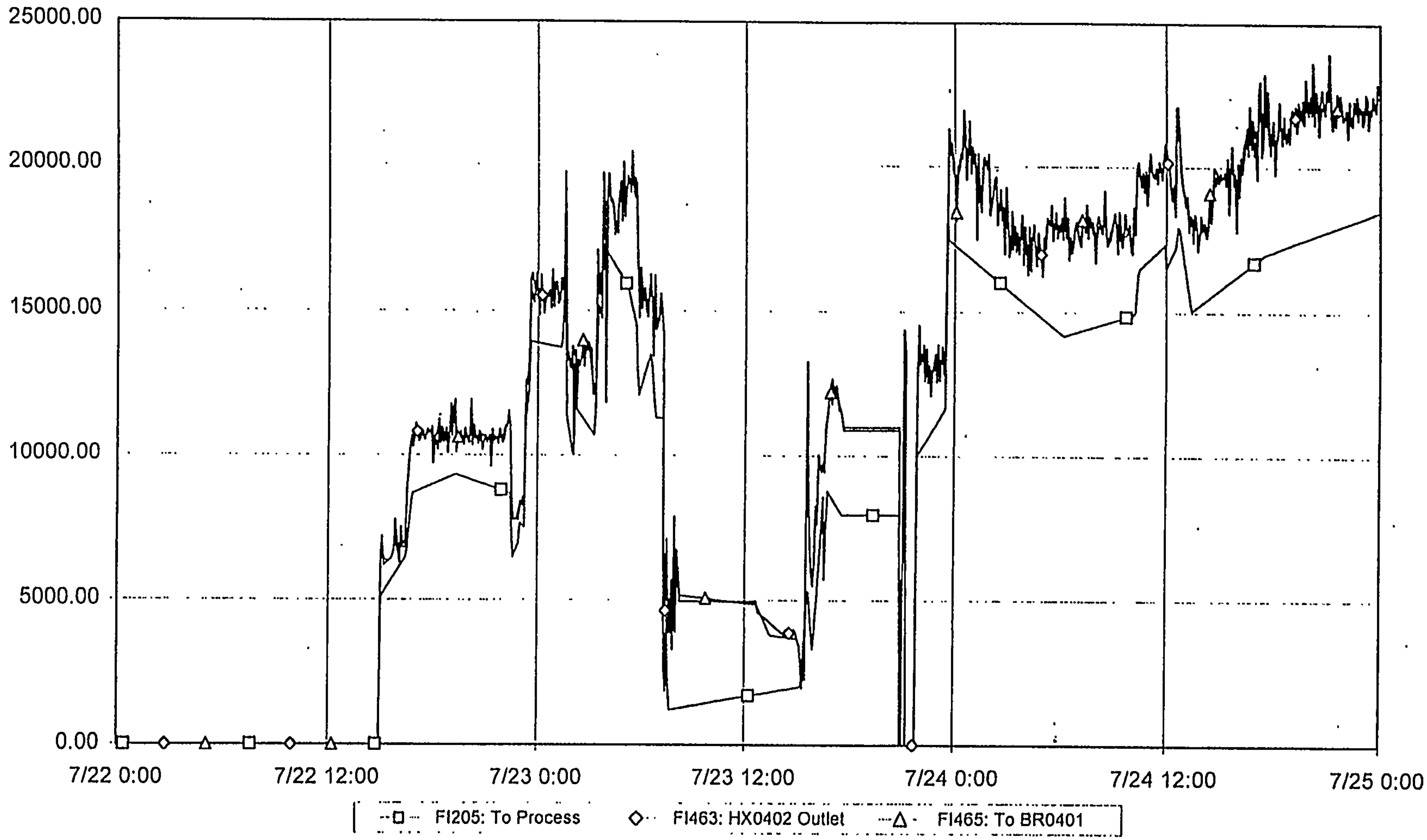
DOE Plot 11 of 45 - 5 minute data

Figure 5.1.5-5 Start-up Burner Flow/Temperature for July 22 Through July 24, 1996



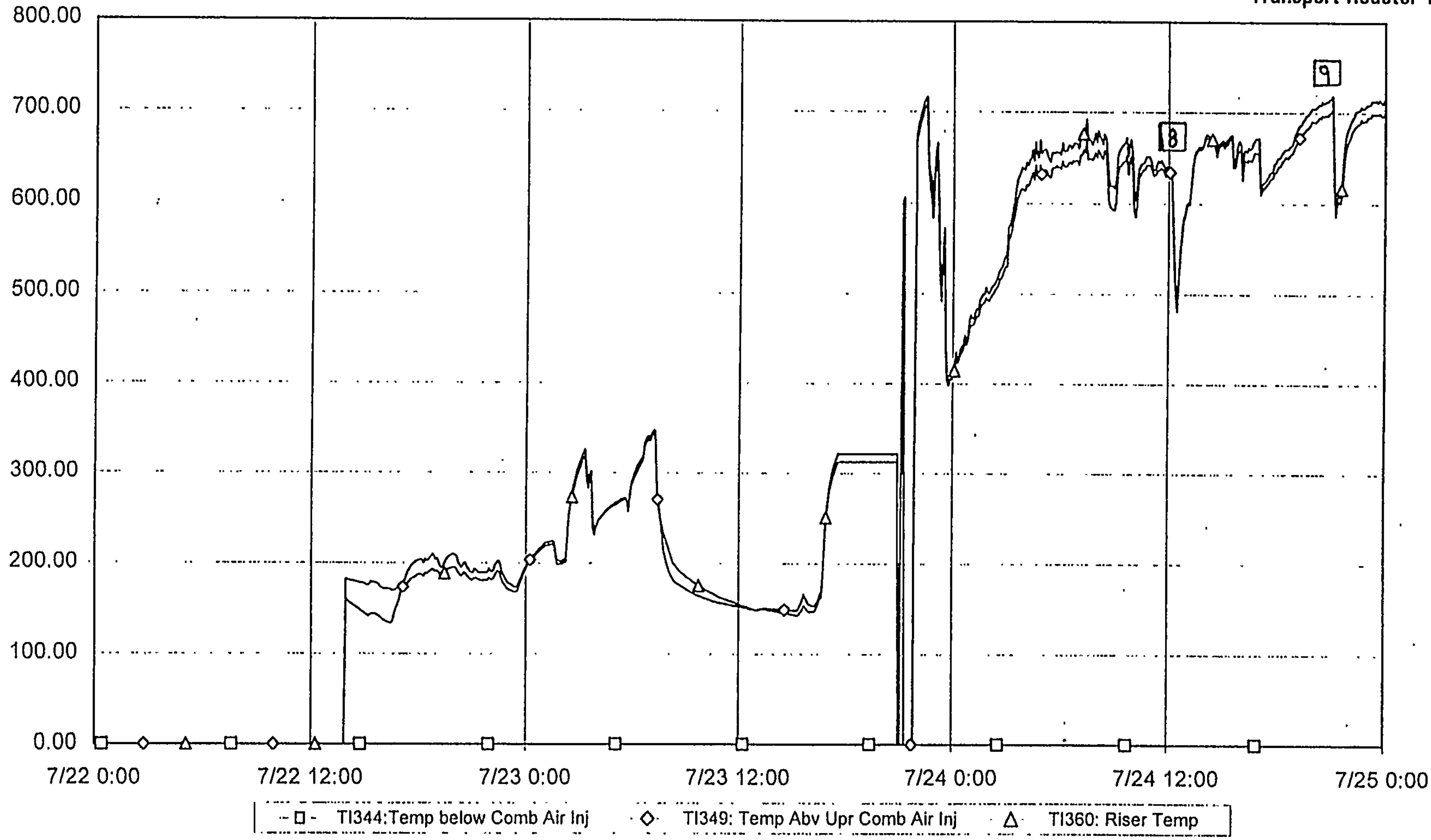
DOE Plot 12 of 45 - 5 minute data

Figure 5.1.5-6 System Pressures Downstream of PCD for July 22 Through July 24, 1996



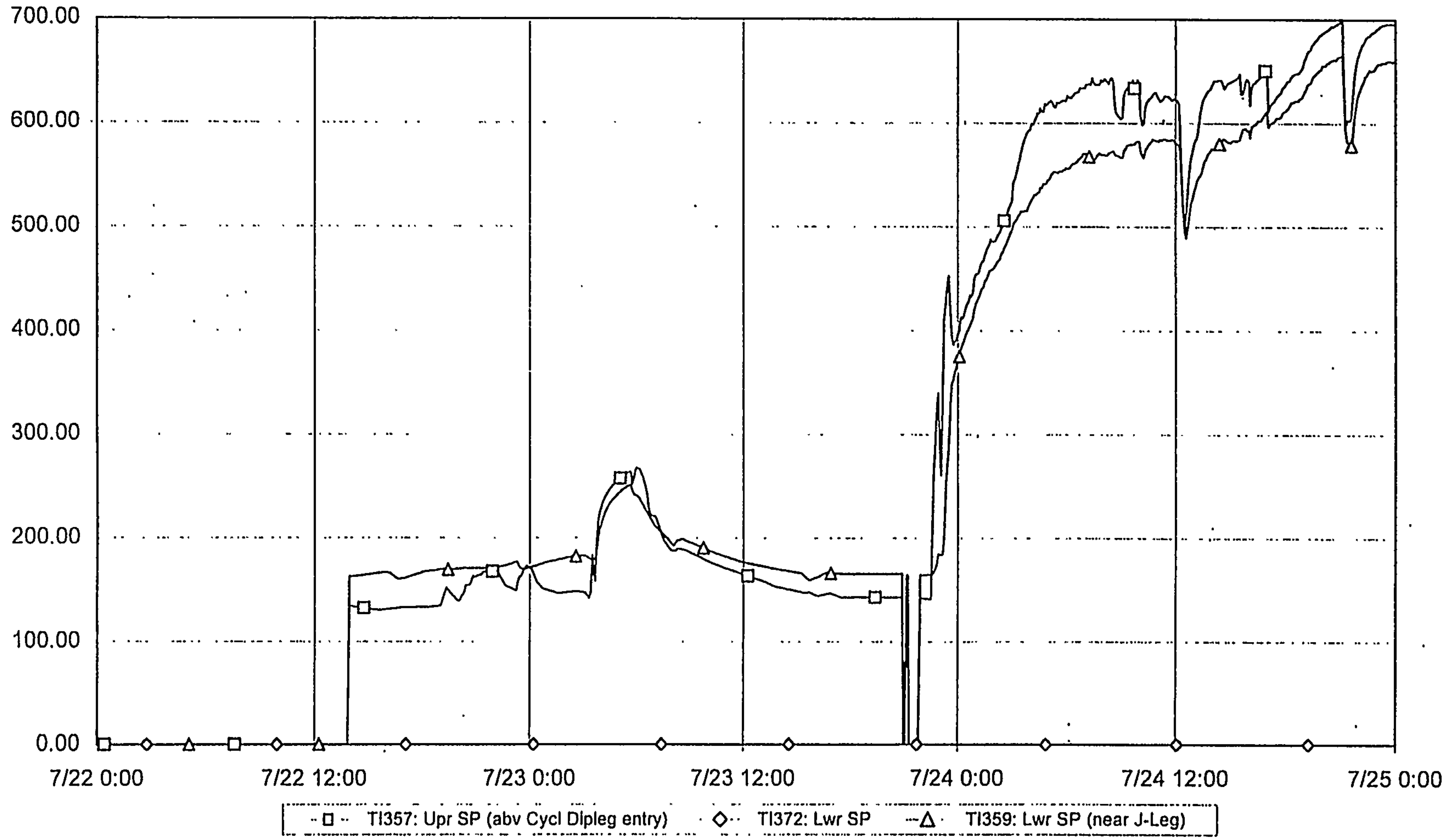
DOE Plot 13 of 45 - 5 minute data

Figure 5.1.5-7 Total Gas In/Out Flow Rates for July 22 Through July 24, 1996



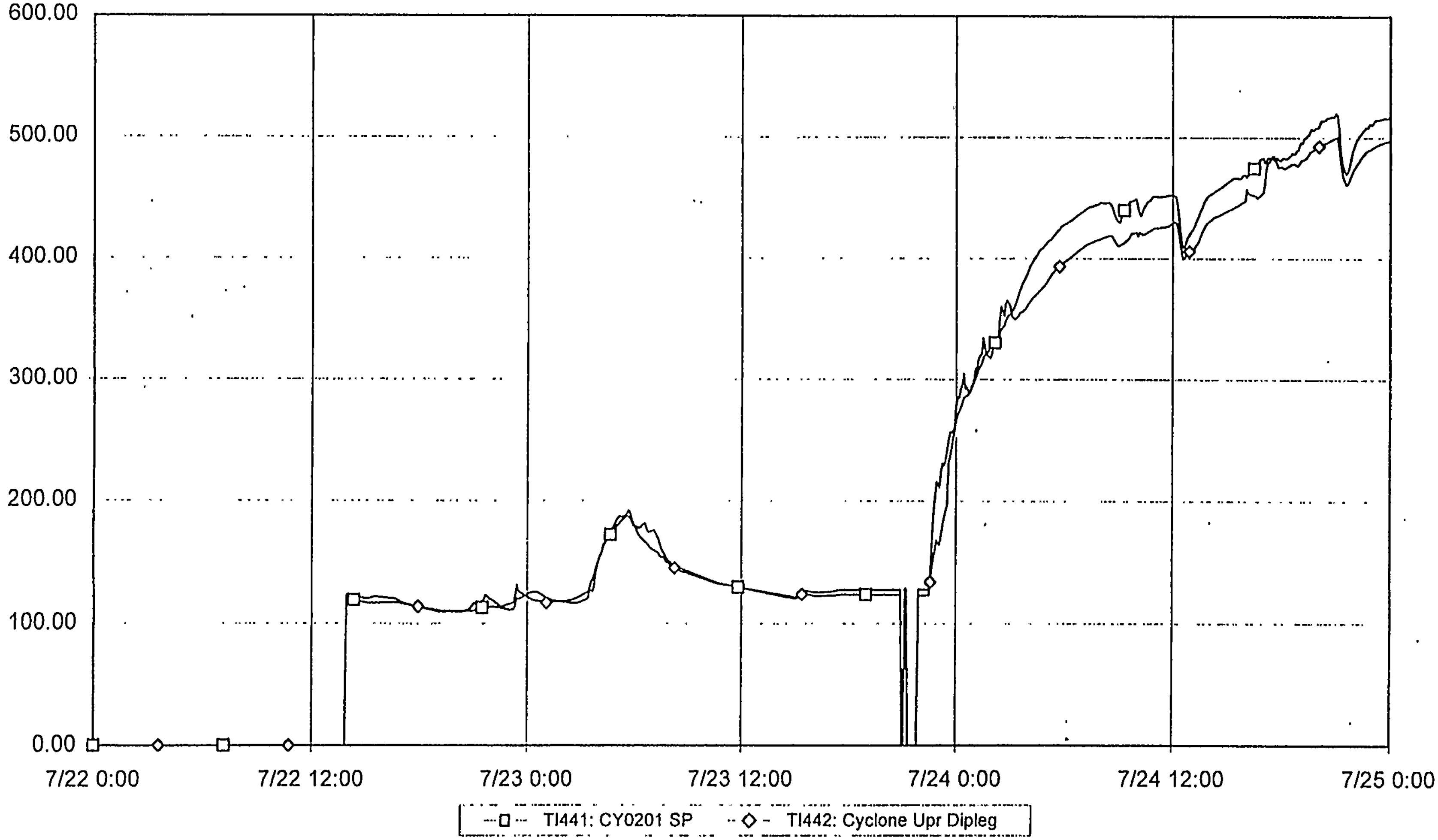
DOE Plot 14 of 45 - 5 minute data

Figure 5.1.5-8 Reactor Mixing Zone and Riser Temperatures for July 22 Through July 24, 1996



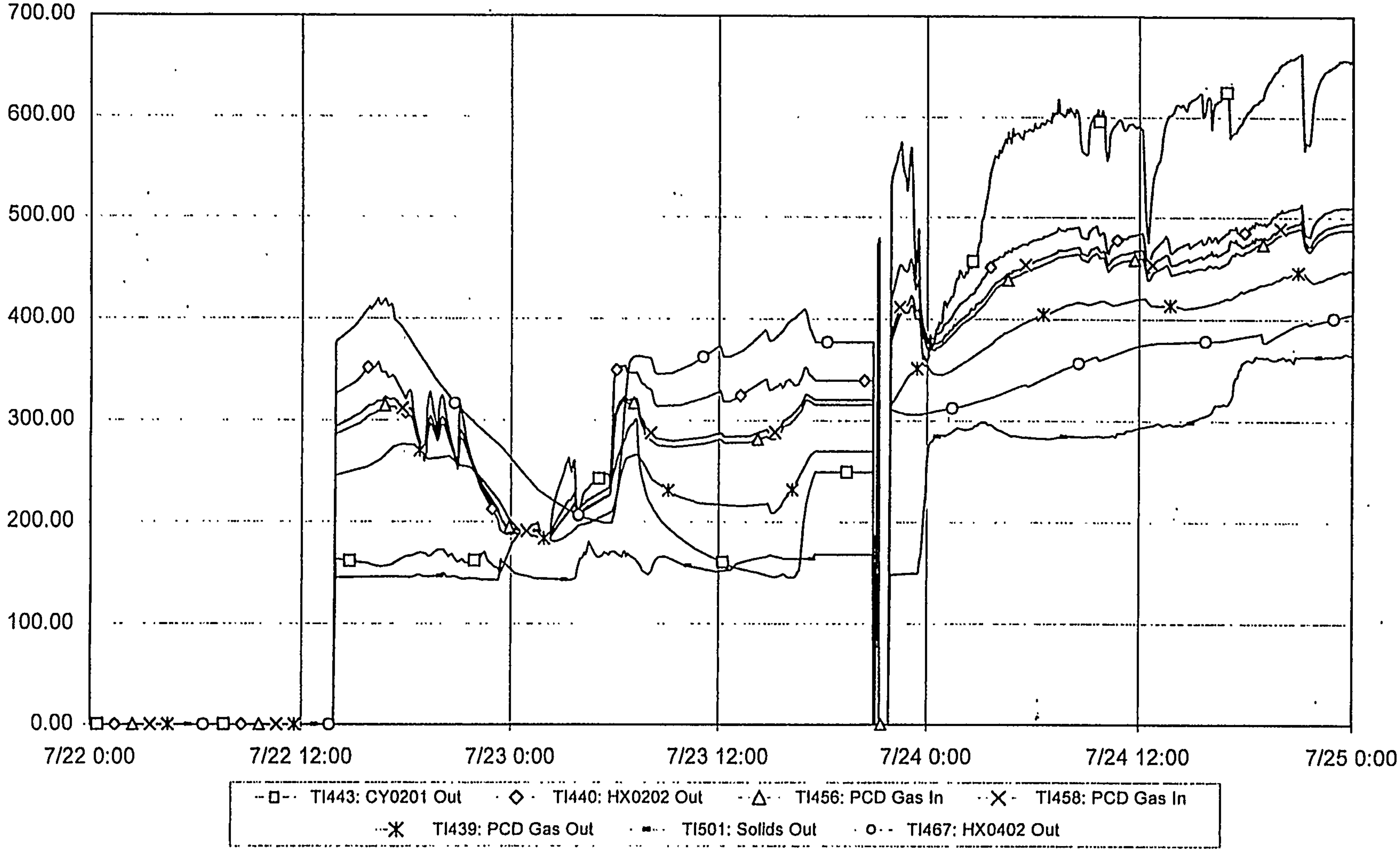
DOE Plot 15 of 45 - 5 minute data

Figure 5.1.5-9 Standpipe Temperatures for July 22 Through July 24, 1996



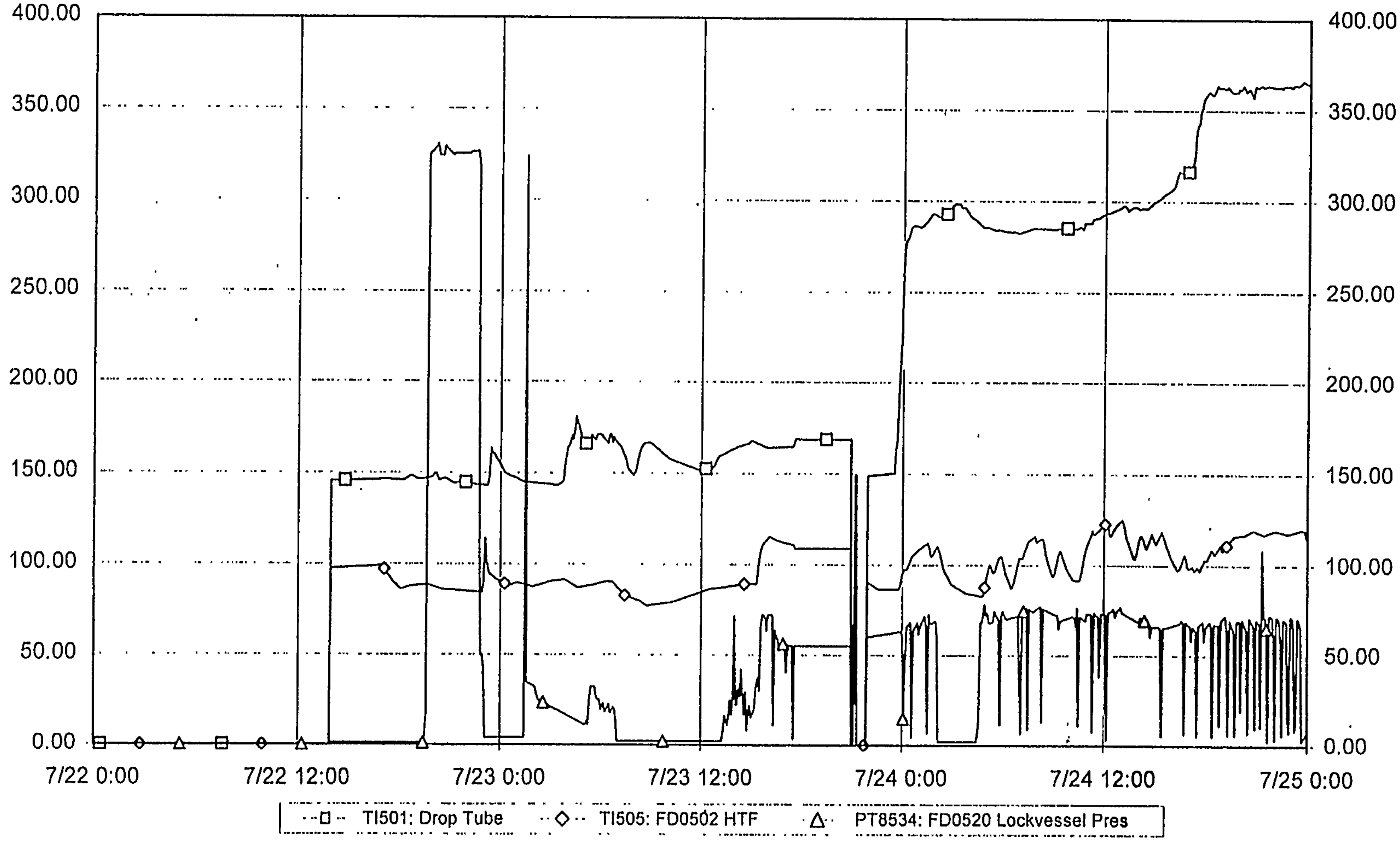
DOE Plot 16 of 45 - 5 minute data

Figure 5.1.5-10 Cyclone Dipleg Temperatures for July 22 Through July 24, 1996



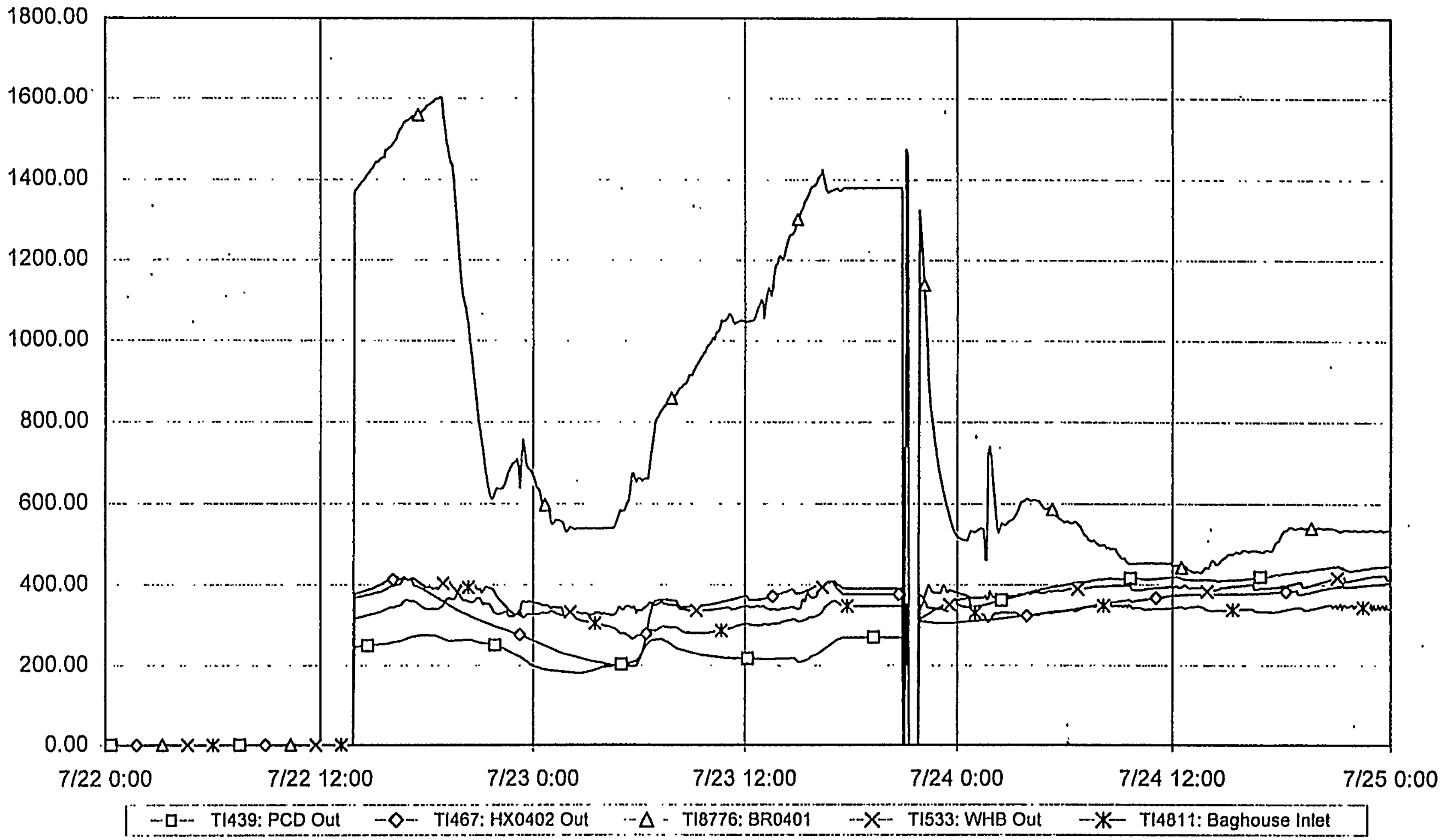
DOE Plot 17 of 45 - 5 minute data

Figure 5.1.5-11 Temperature Profiles Downstream of Reactor for July 22 Through July 24, 1996



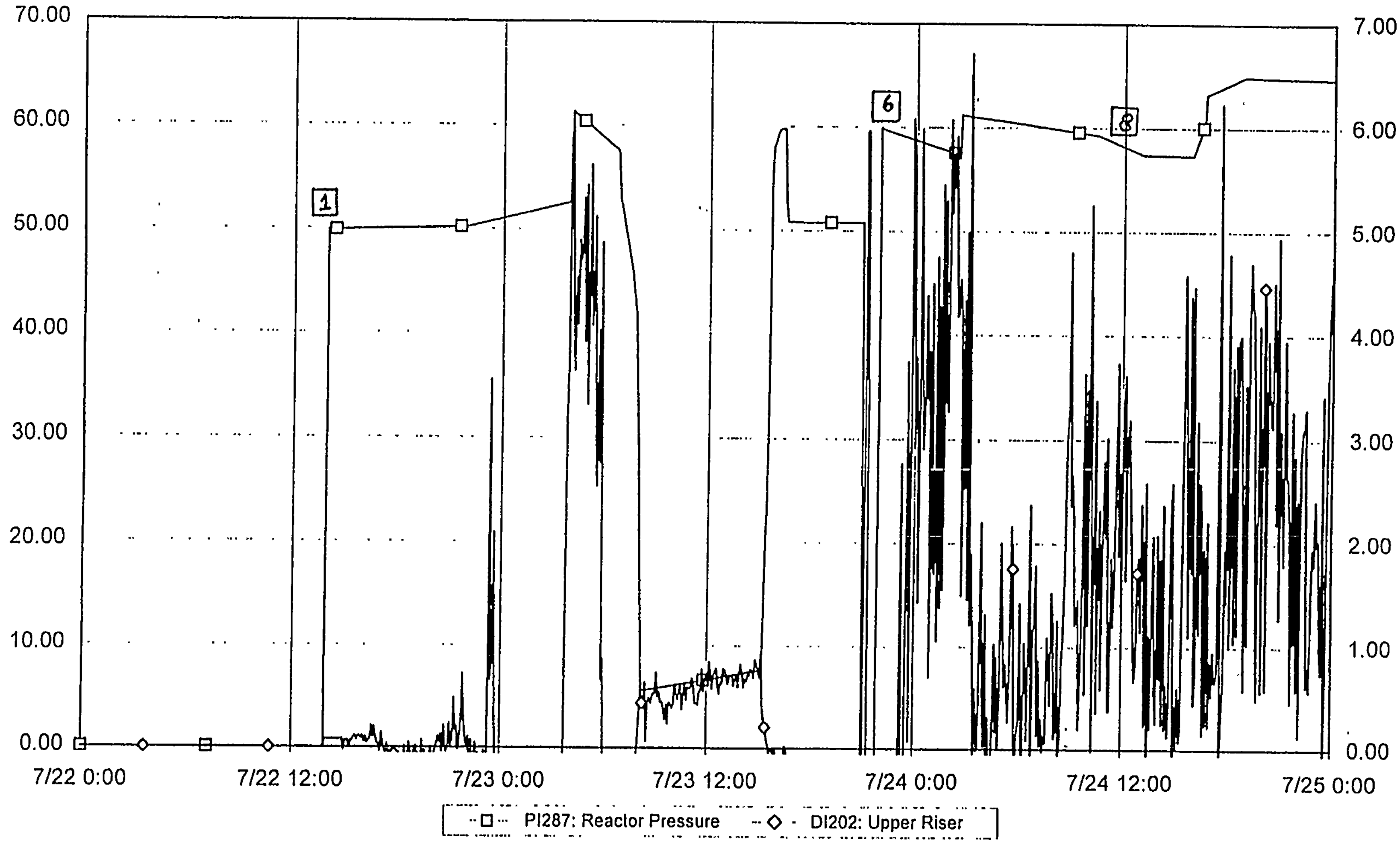
DOE Plot 18 of 45 - 5 minute data

Figure 5.1.5-12 PCD Ash Temperatures for July 22 Through July 24, 1996



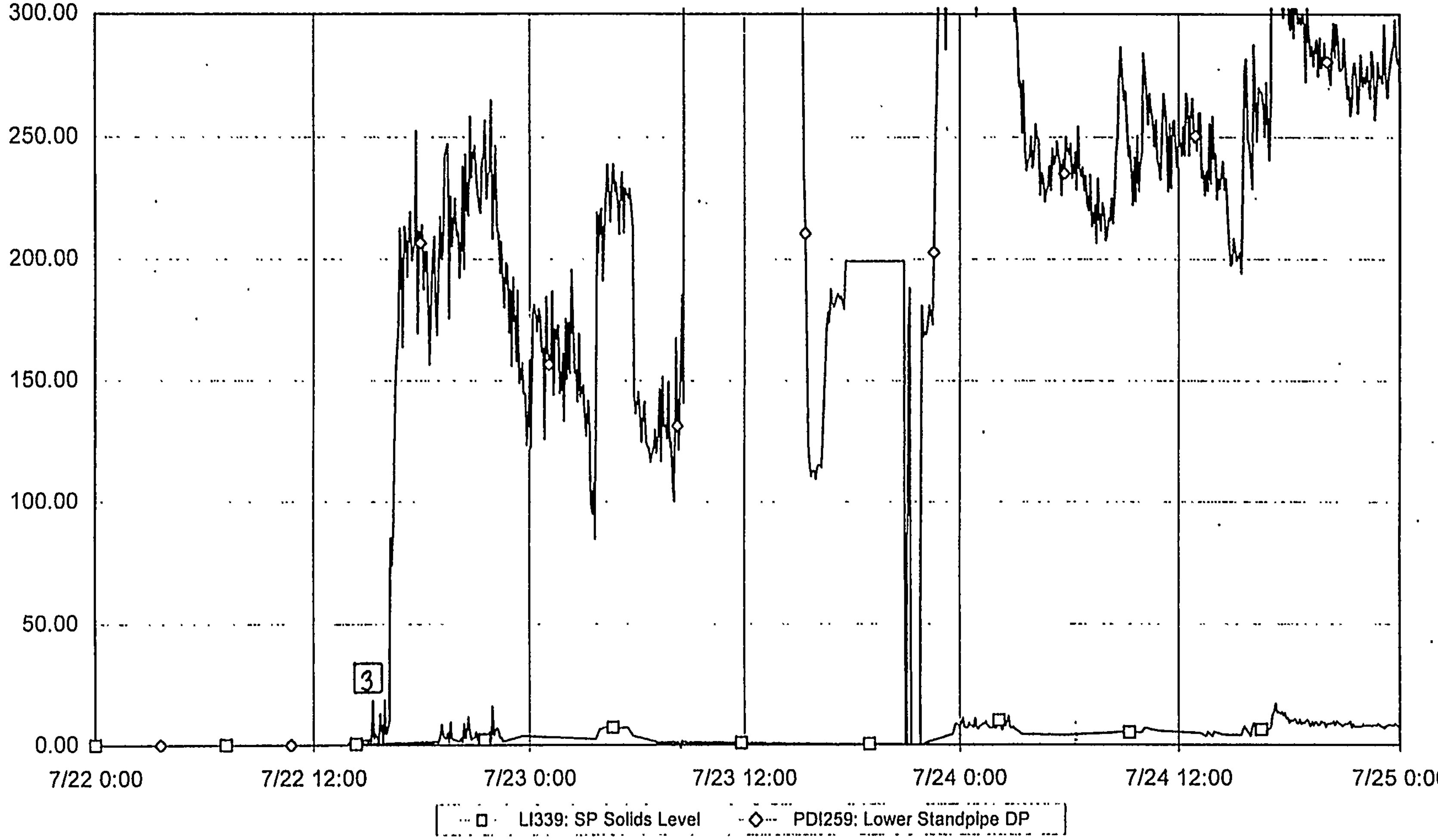
DOE Plot 19 of 45 - 5 minute data

Figure 5.1.5-13 System Temperatures Downstream of PCD for July 22 Through July 24, 1996



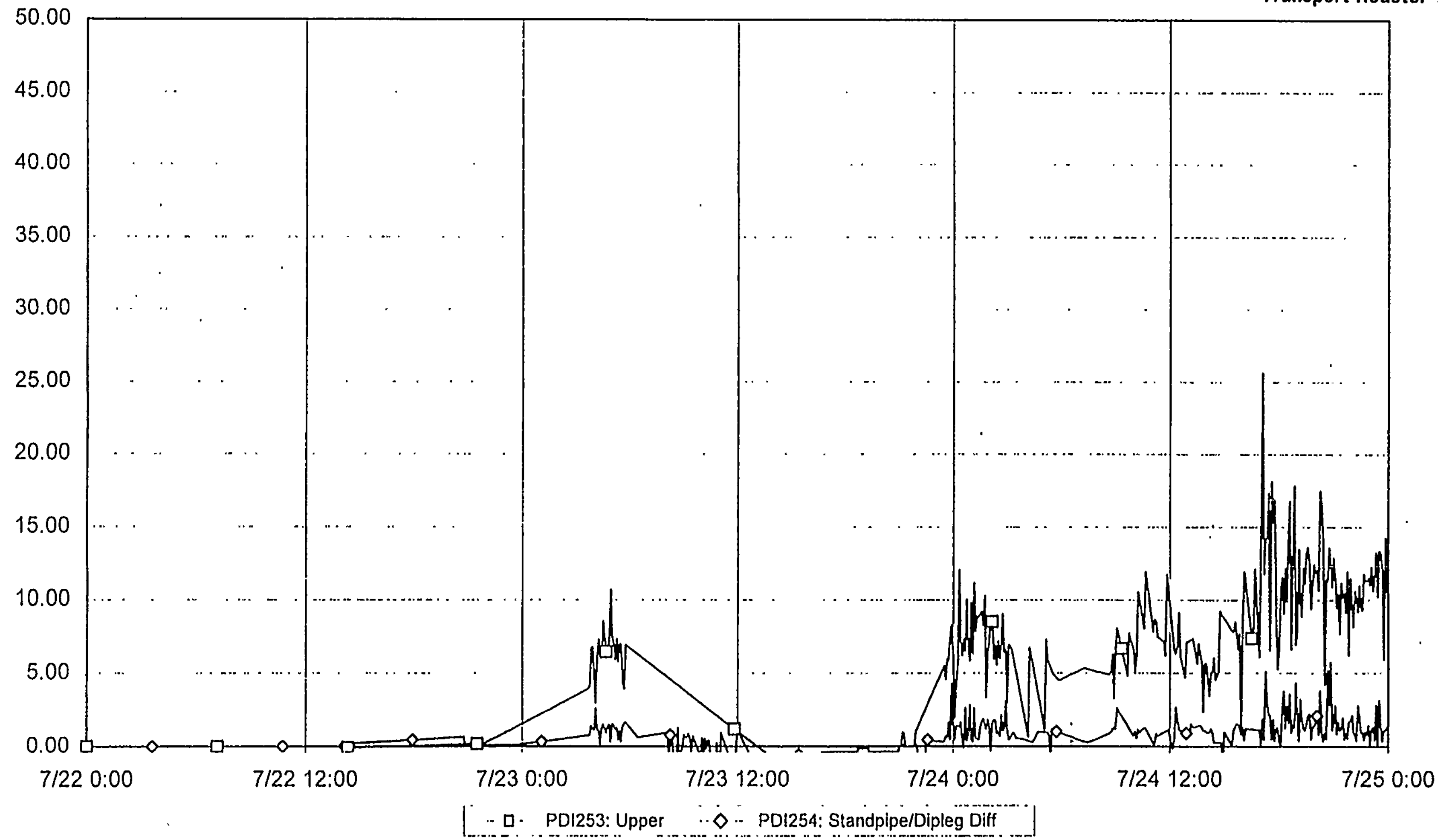
DOE Plot 21 of 45 - 5 minute data

Figure 5.1.5-14 Reactor Pressure/Riser DP Profiles for July 22 Through July 24, 1996



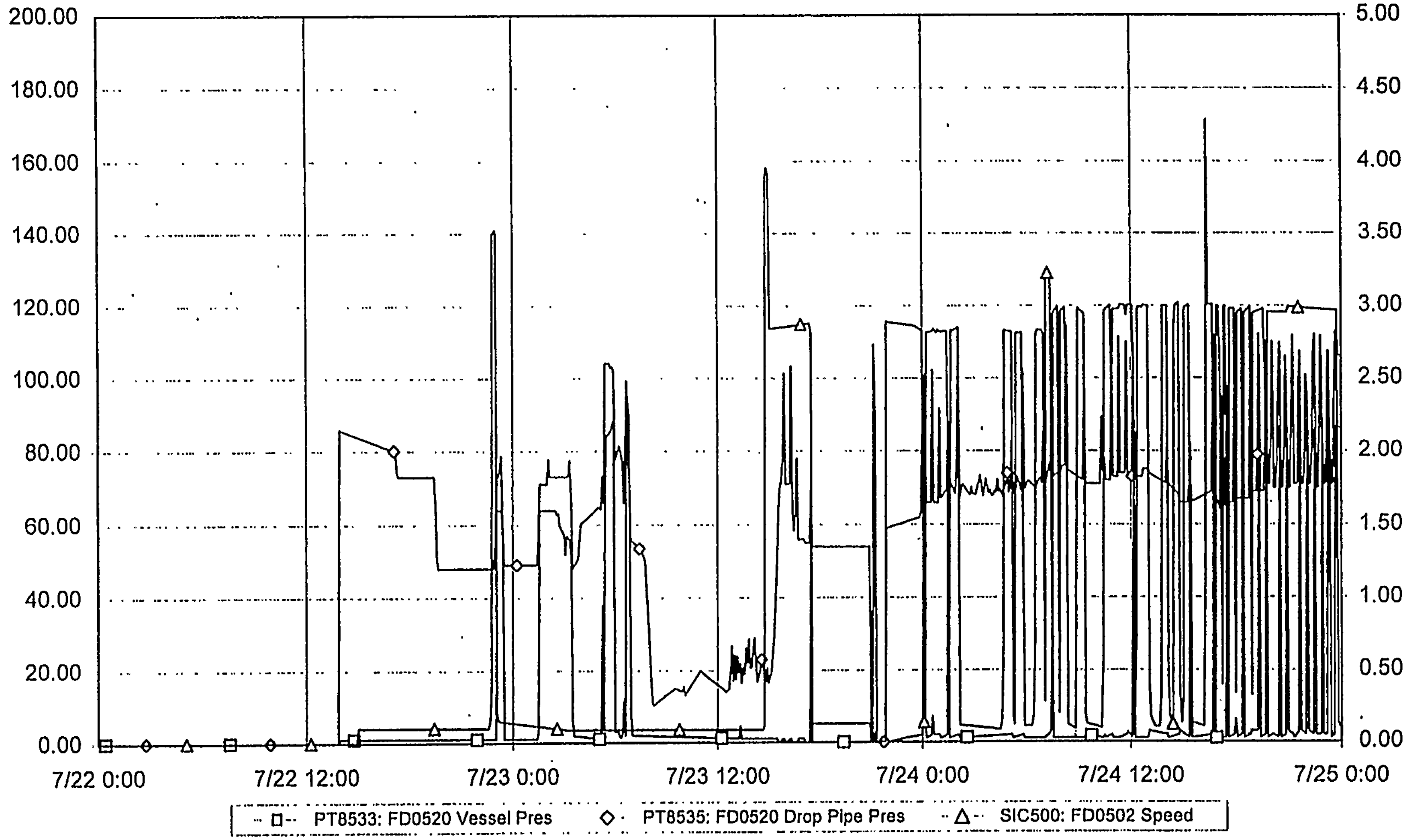
DOE Plot 22 of 45 - 5 minute data

Figure 5.1.5-15 Standpipe DP Profiles for July 22 Through July 24, 1996



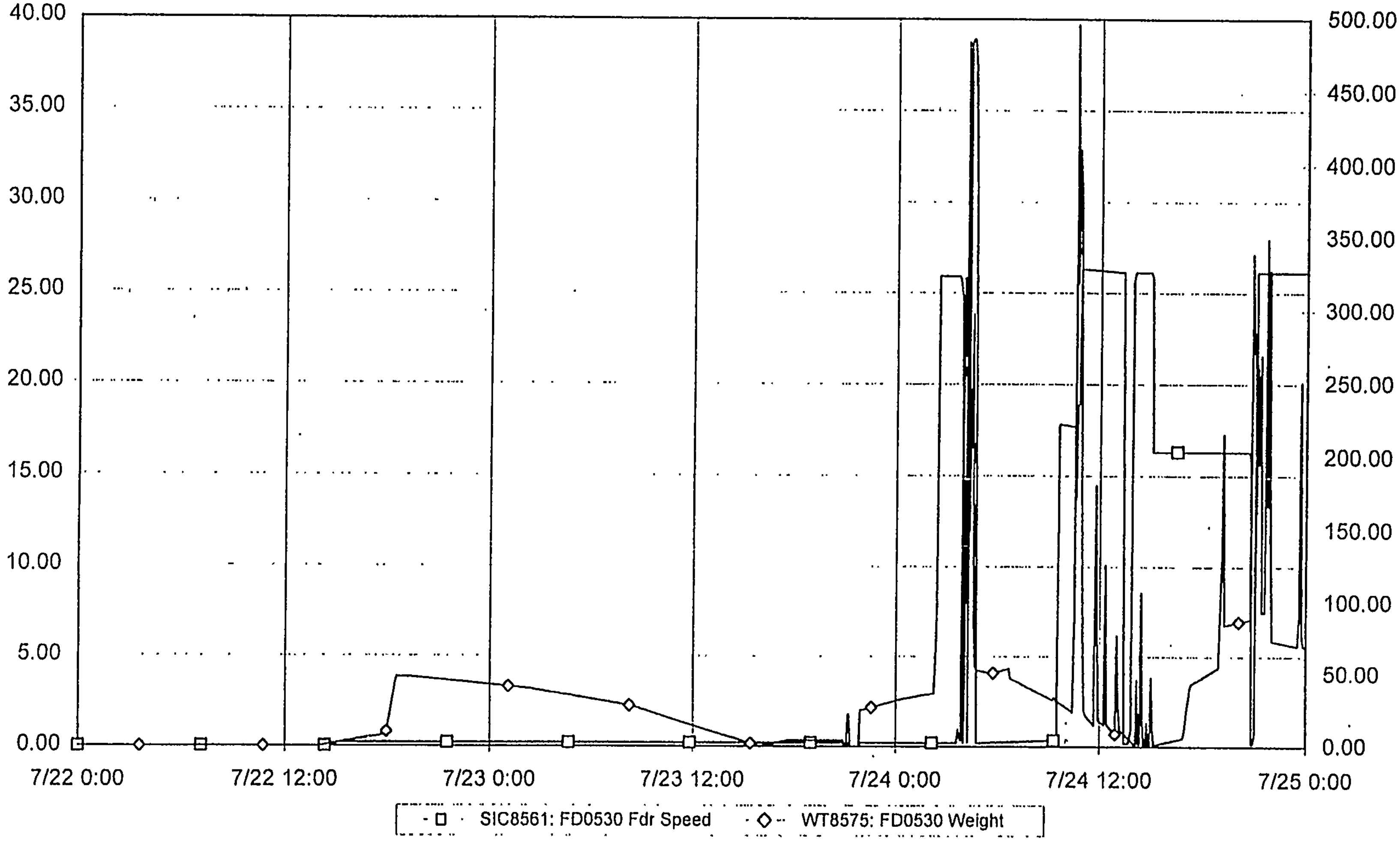
DOE Plot 23 of 45 - 5 minute data

Figure 5.1.5-16 CY0201 Dipleg DP Profiles for July 22 Through July 24, 1996



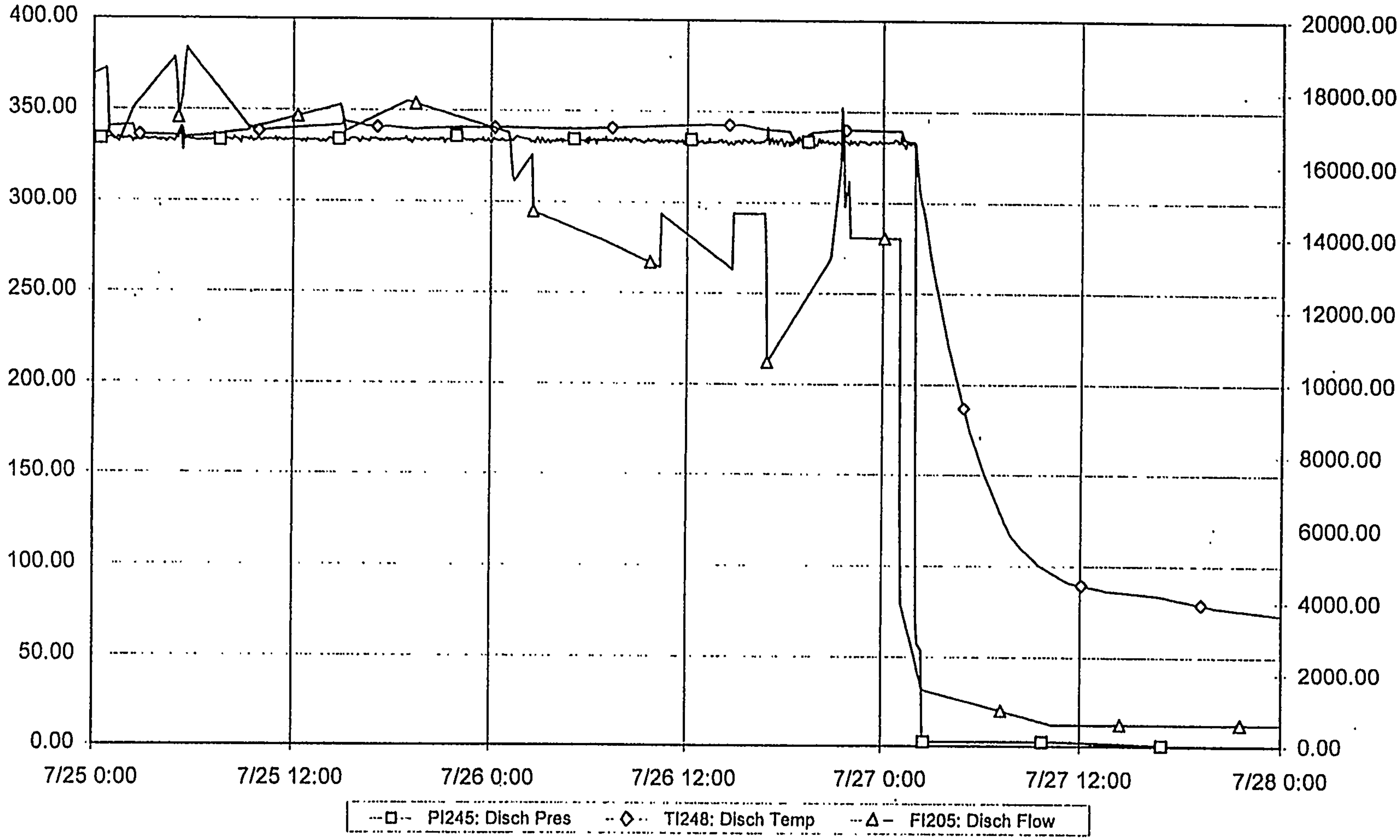
DOE Plot 32 of 45 - 5 minute data

Figure 5.1.5-17 FD0520 Pressures for July 22 Through July 24, 1996



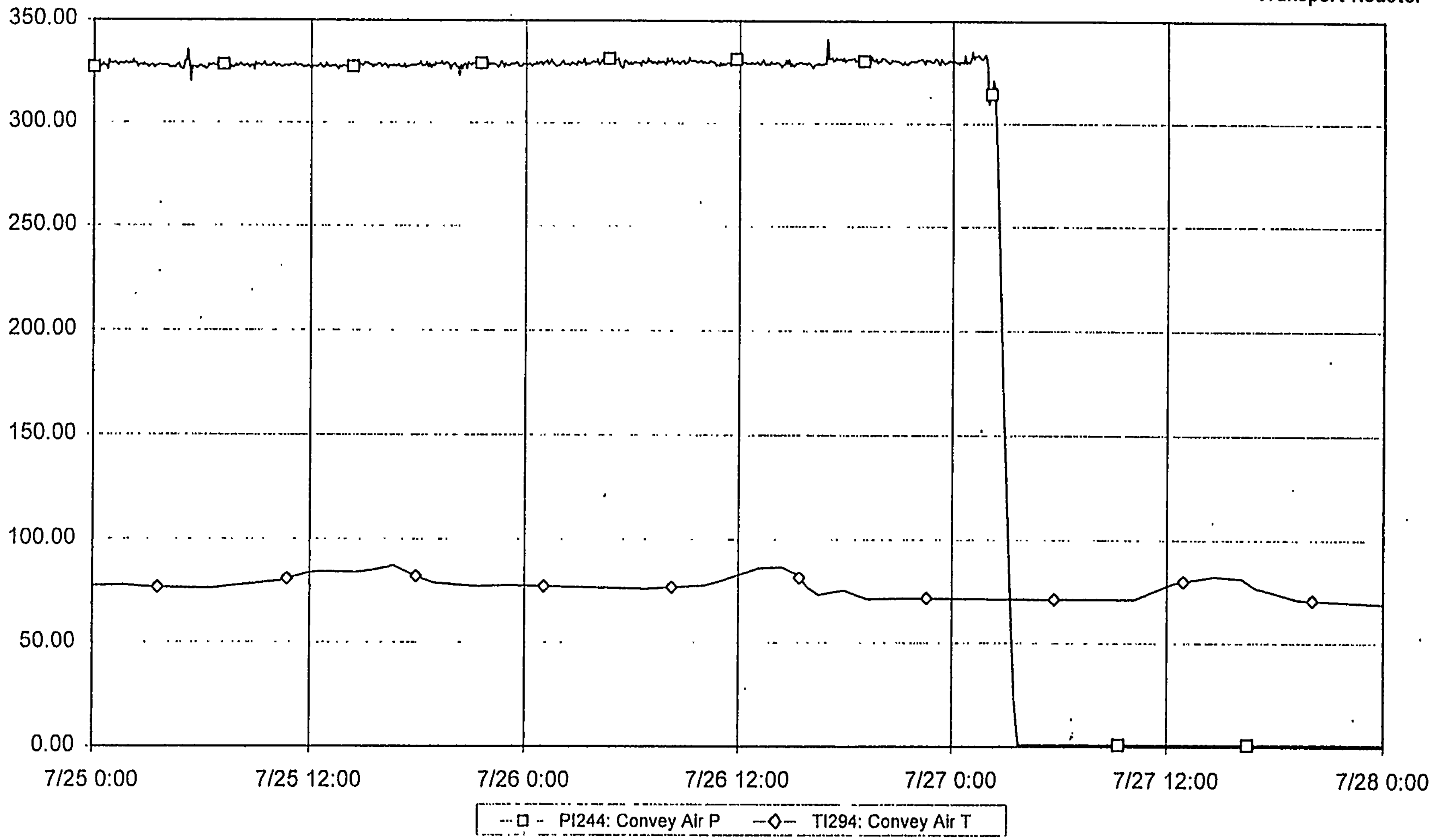
DOE Plot 33 of 45 - 5 minute data

Figure 5.1.5-18 FD0530 Feeder for July 22 Through July 24, 1996



DOE Plot 1 of 45 - 5 minute data

Figure 5.1.5-19 C00201 System Profile for July 25 Through July 27, 1996



DOE Plot 5 of 45 - 5 minute data

Figure 5.1.5-20 Transport Air System for July 25 Through July 27, 1996