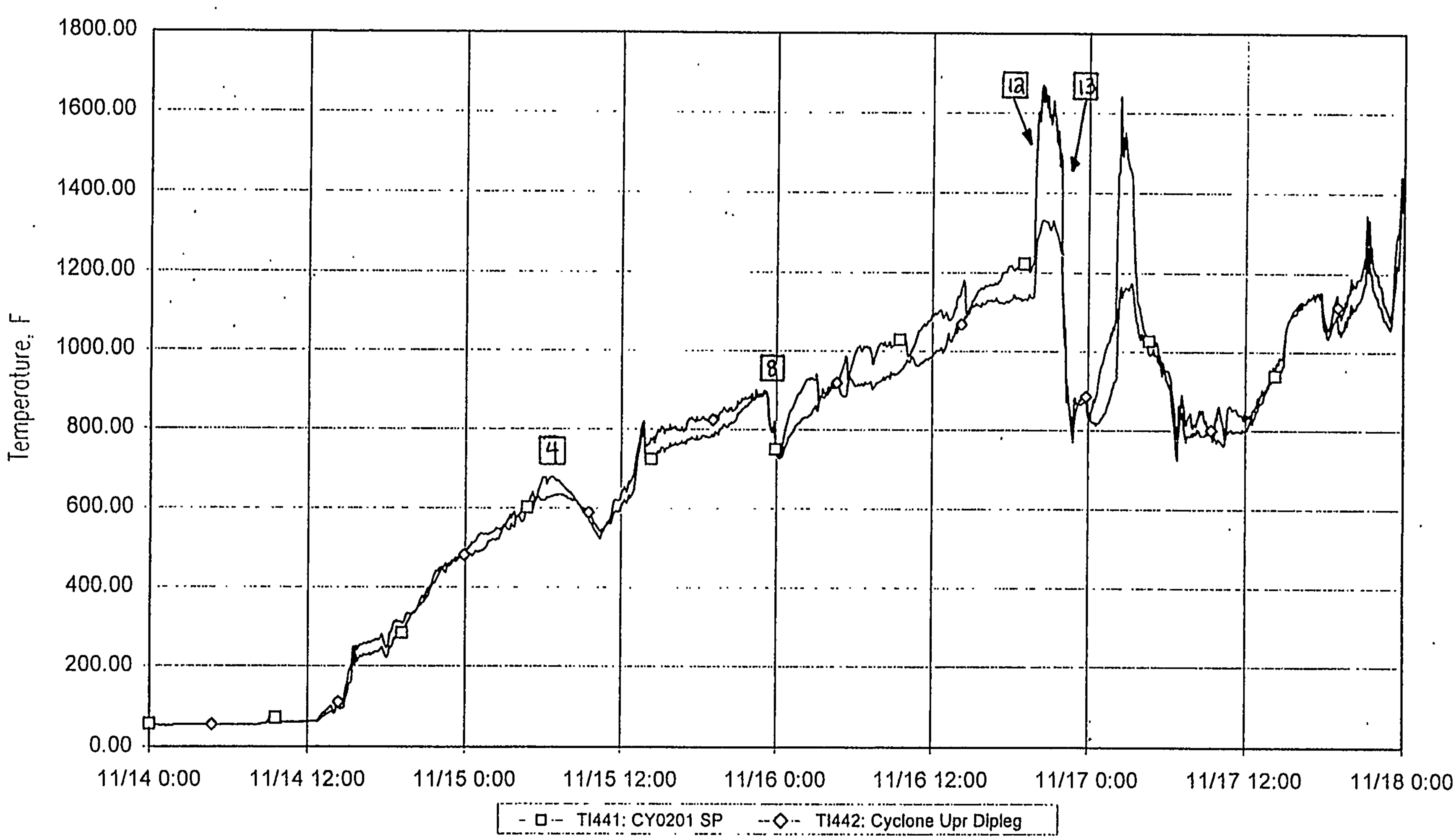

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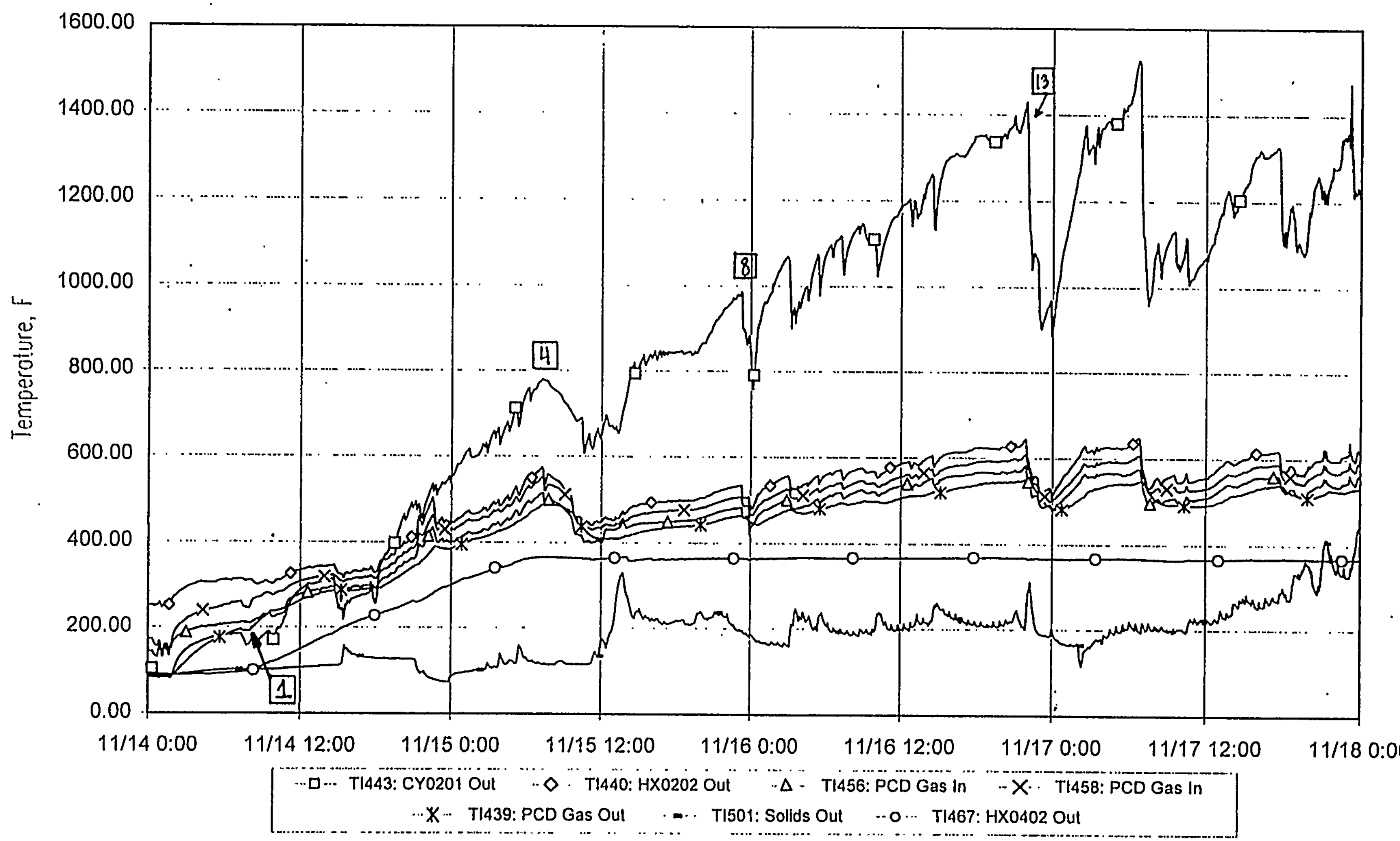
5.1.10-10 Cyclone Dipleg Temperatures for November 14 Through November 17, 1996



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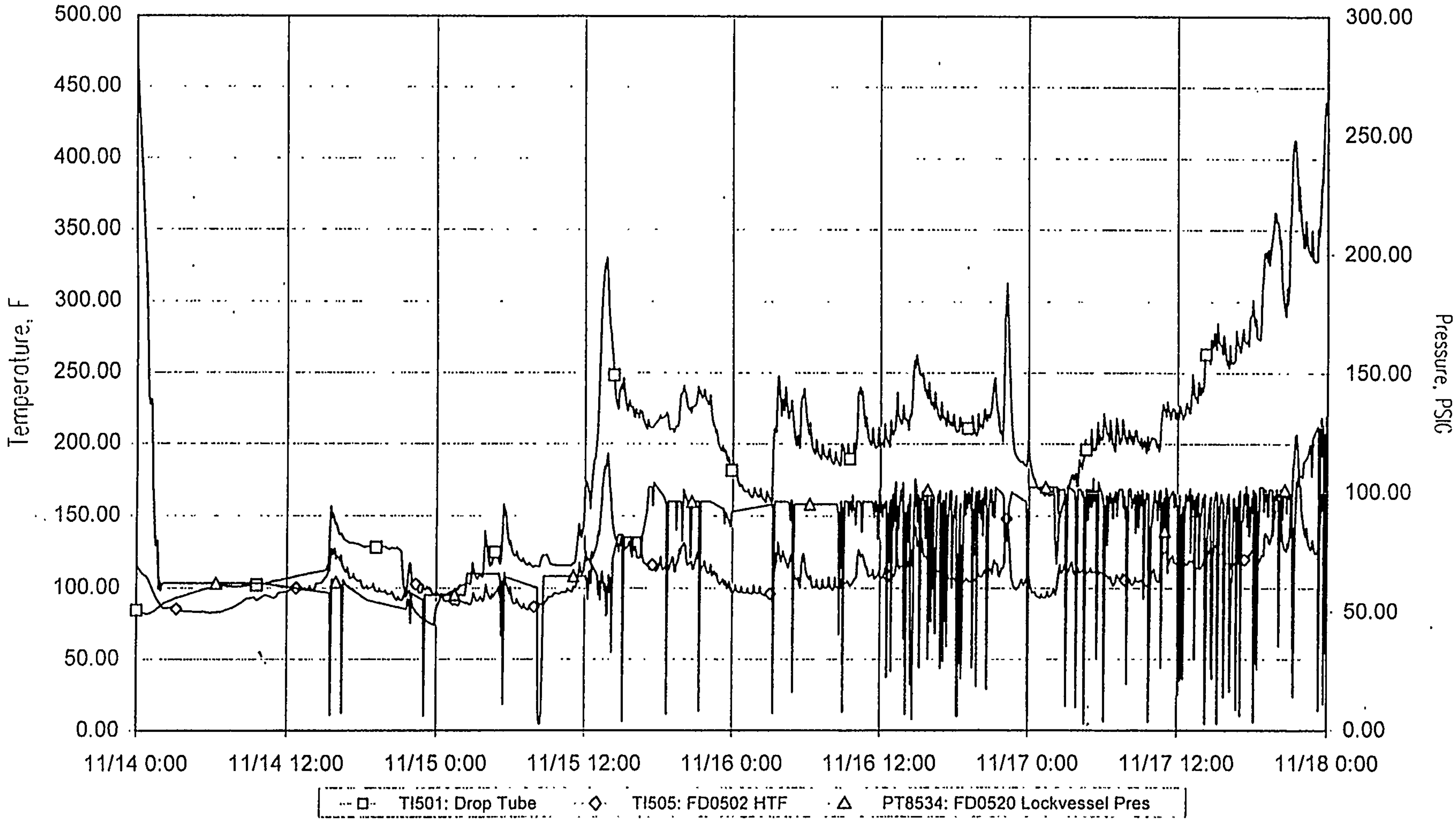
5.1.10-11 Temperature Profiles Downstream of Reactor for November 14 Through November 17, 1996



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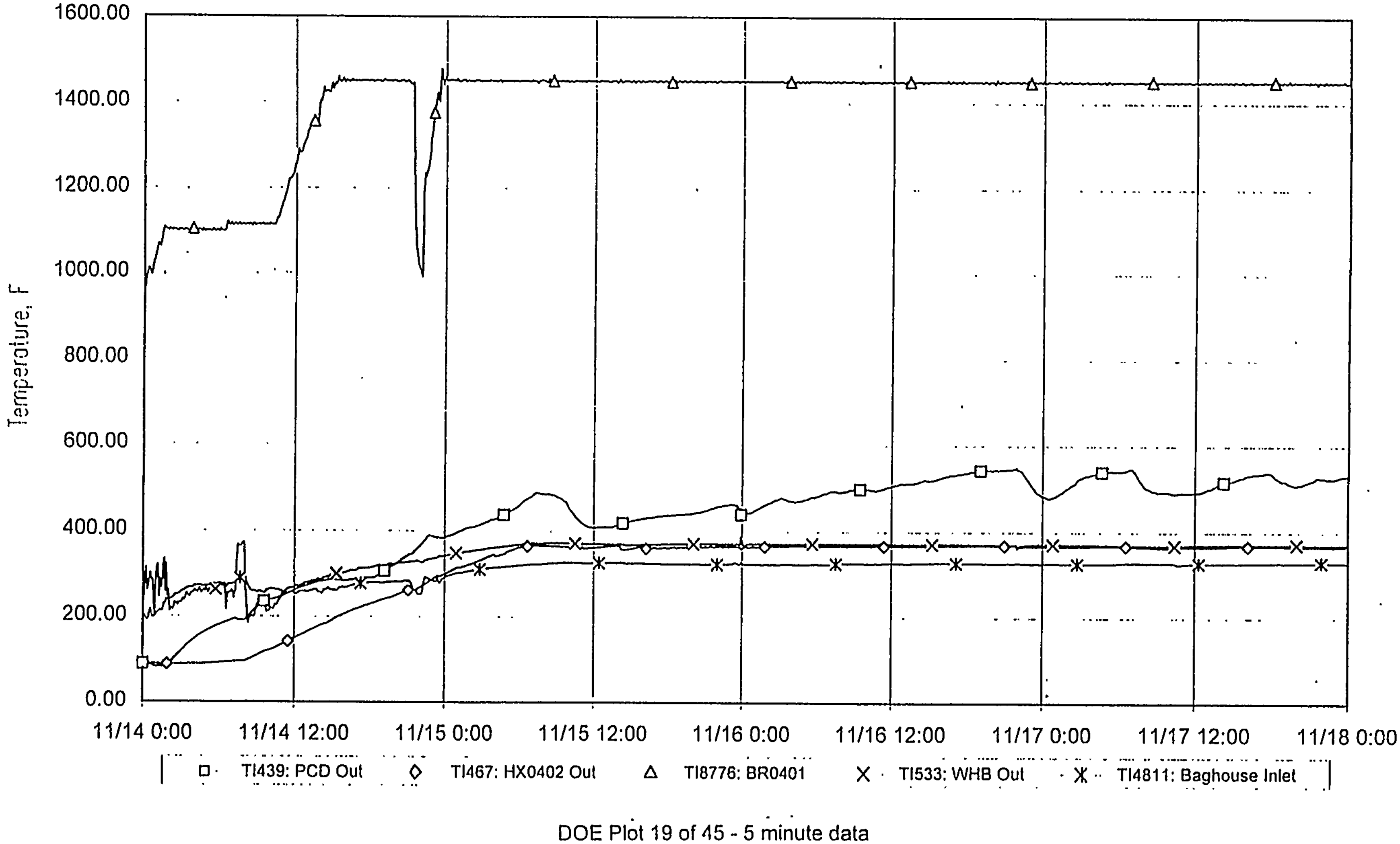
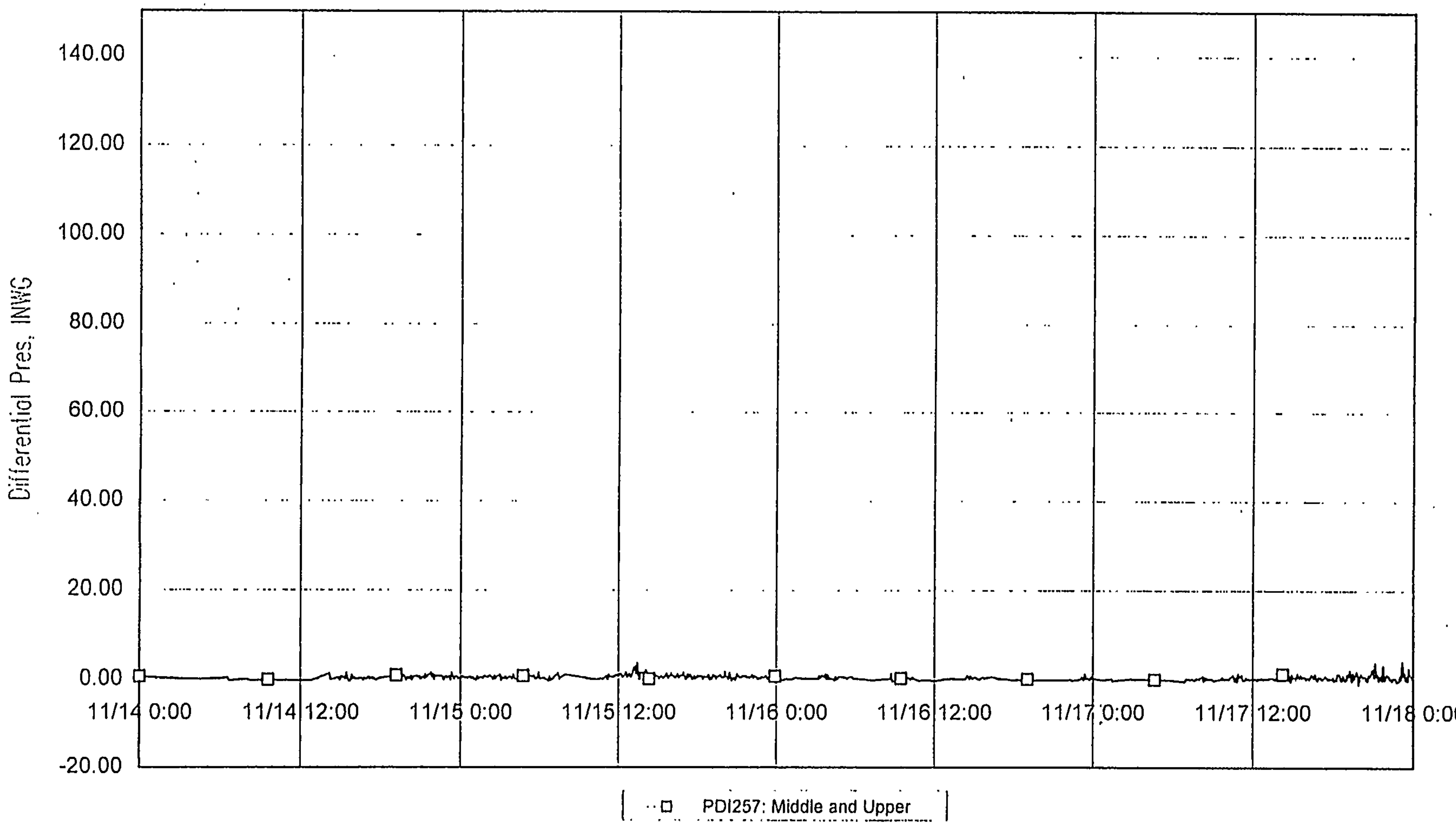
5.1.10-12 PCD Ash Temperatures for November 14 Through November 17, 1996



5.1.10-13 System Temperatures Downstream of PCD for November 14 Through November 17, 1996



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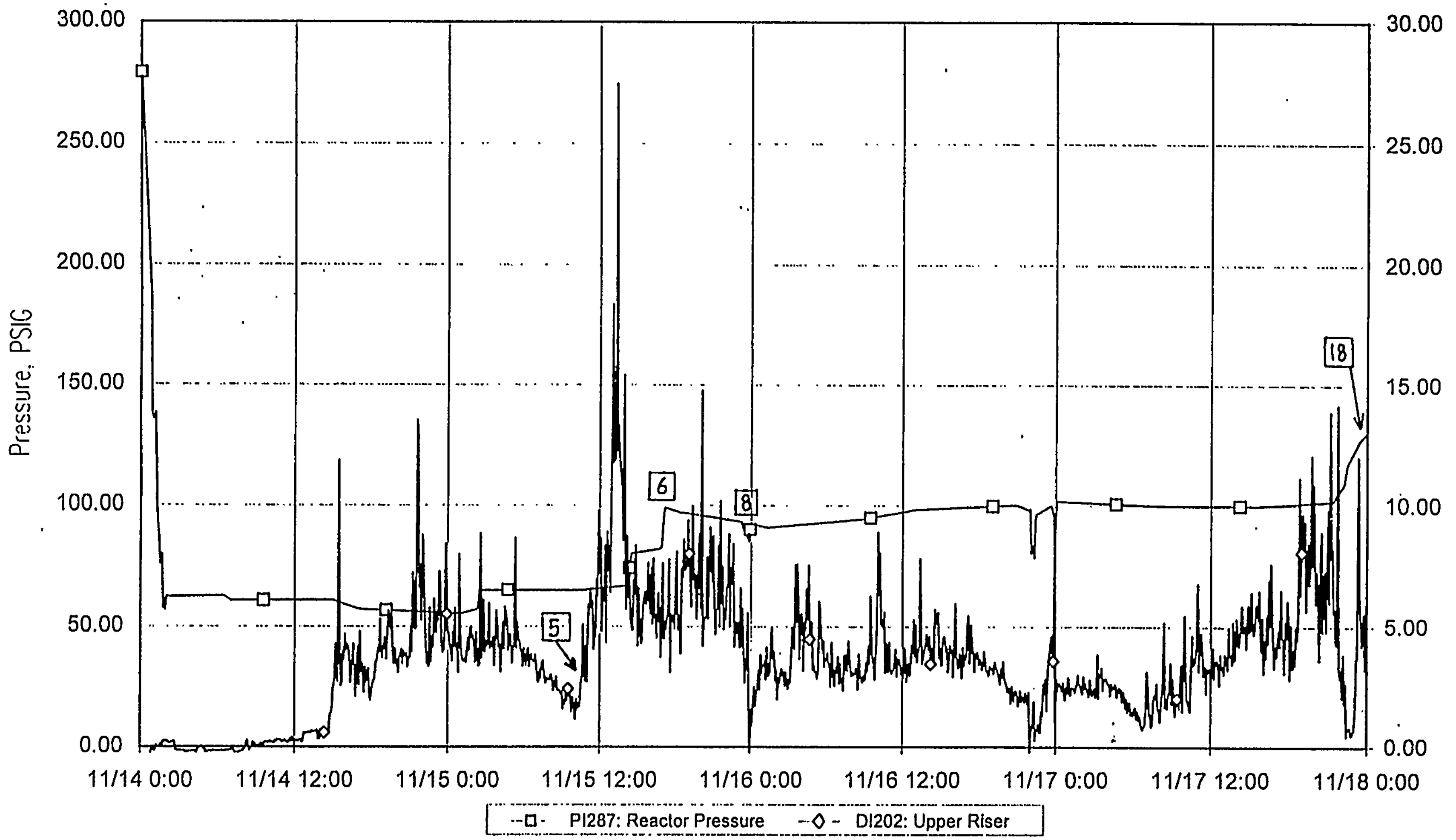
5.1.10-14 Mixing Zone DP Profile for November 14 Through November 17, 1996



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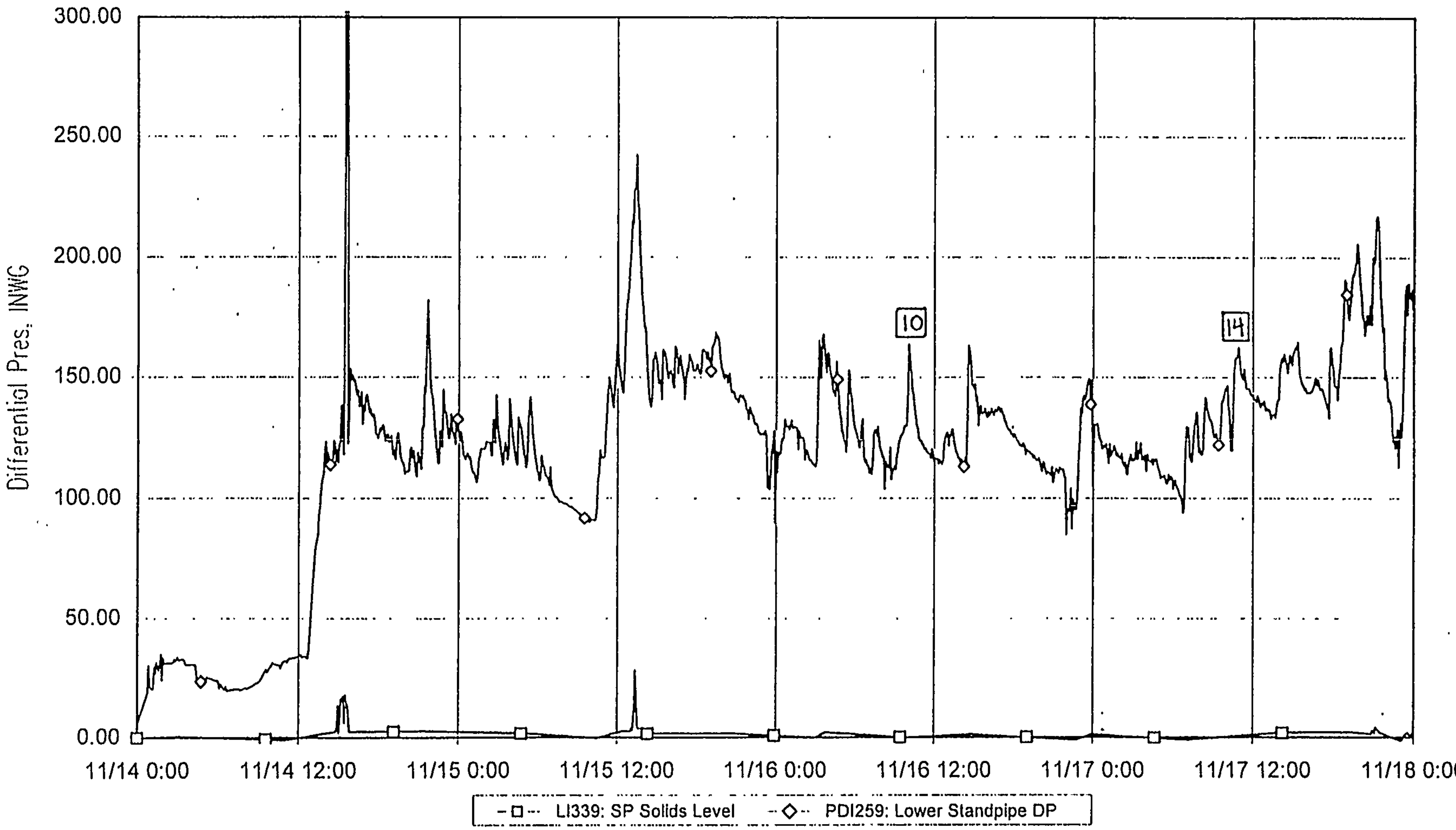
5.1.10-15 Reactor Pressure/Riser DP Profiles for November 14 Through November 17, 1996



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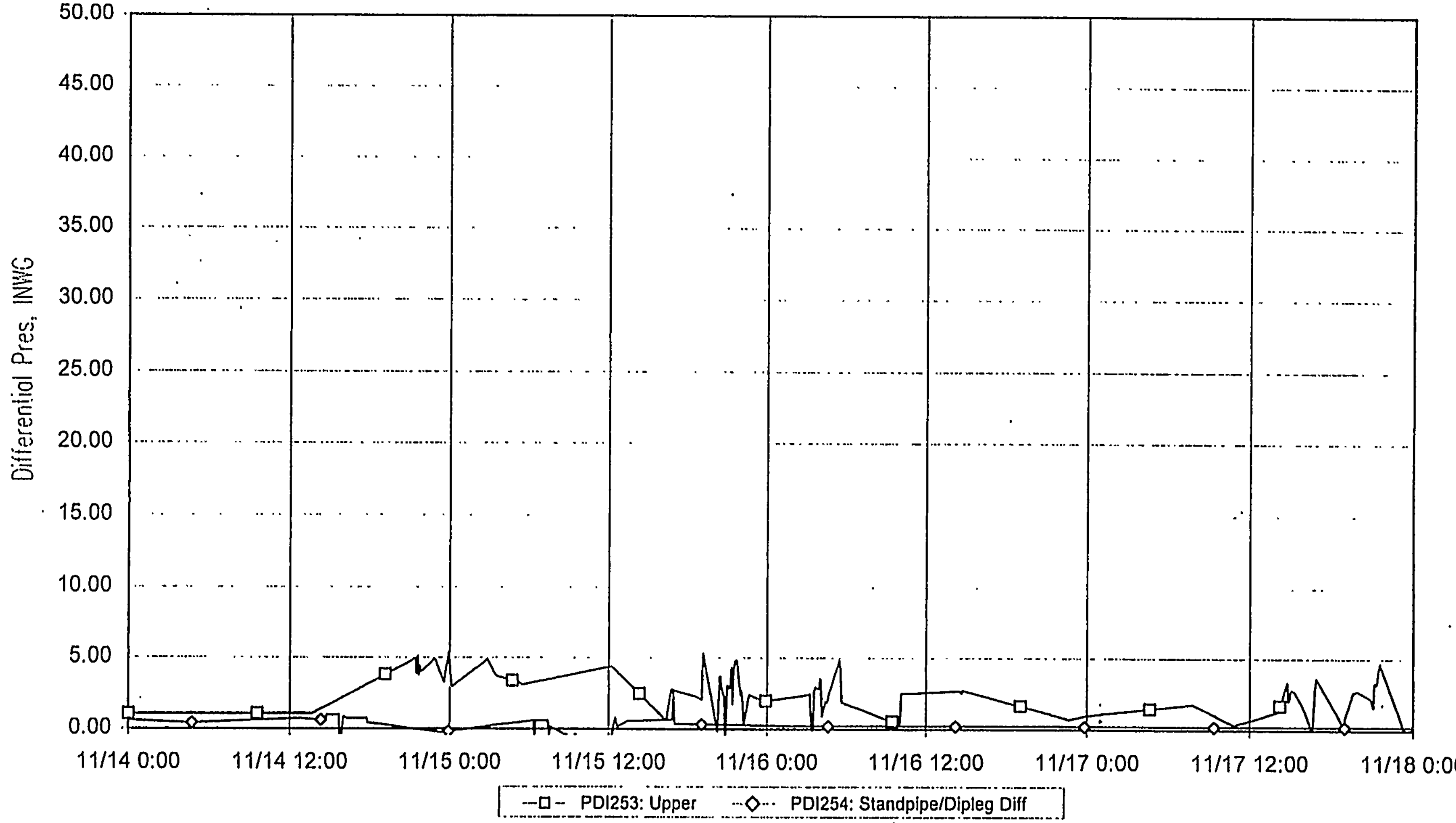
5.1.10-16 Standpipe DP Profiles for November 14 Through November 17, 1996



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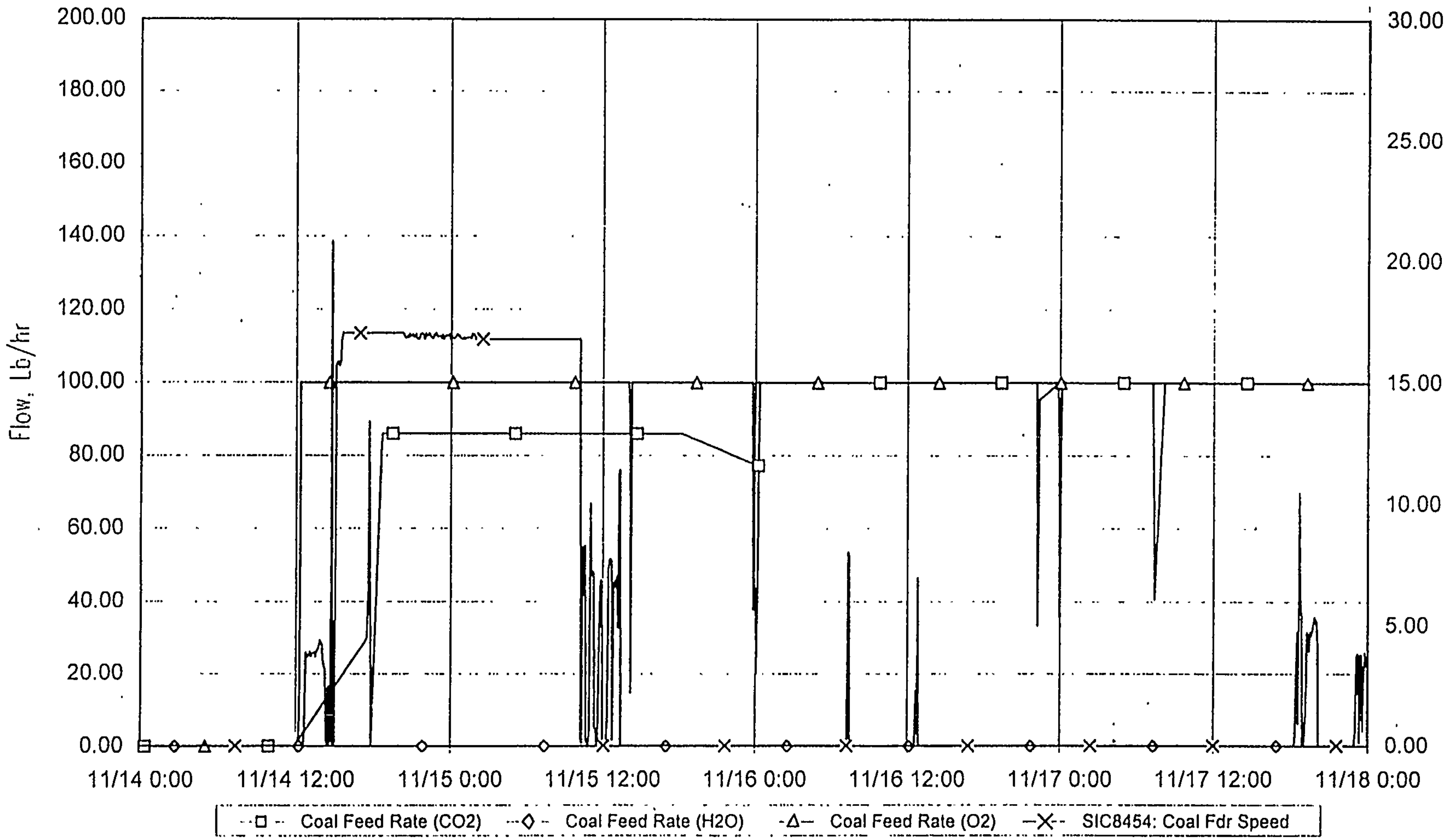
5.1.10-17 CY0201 Dipleg DP Profiles for November 14 Through 17, 1996



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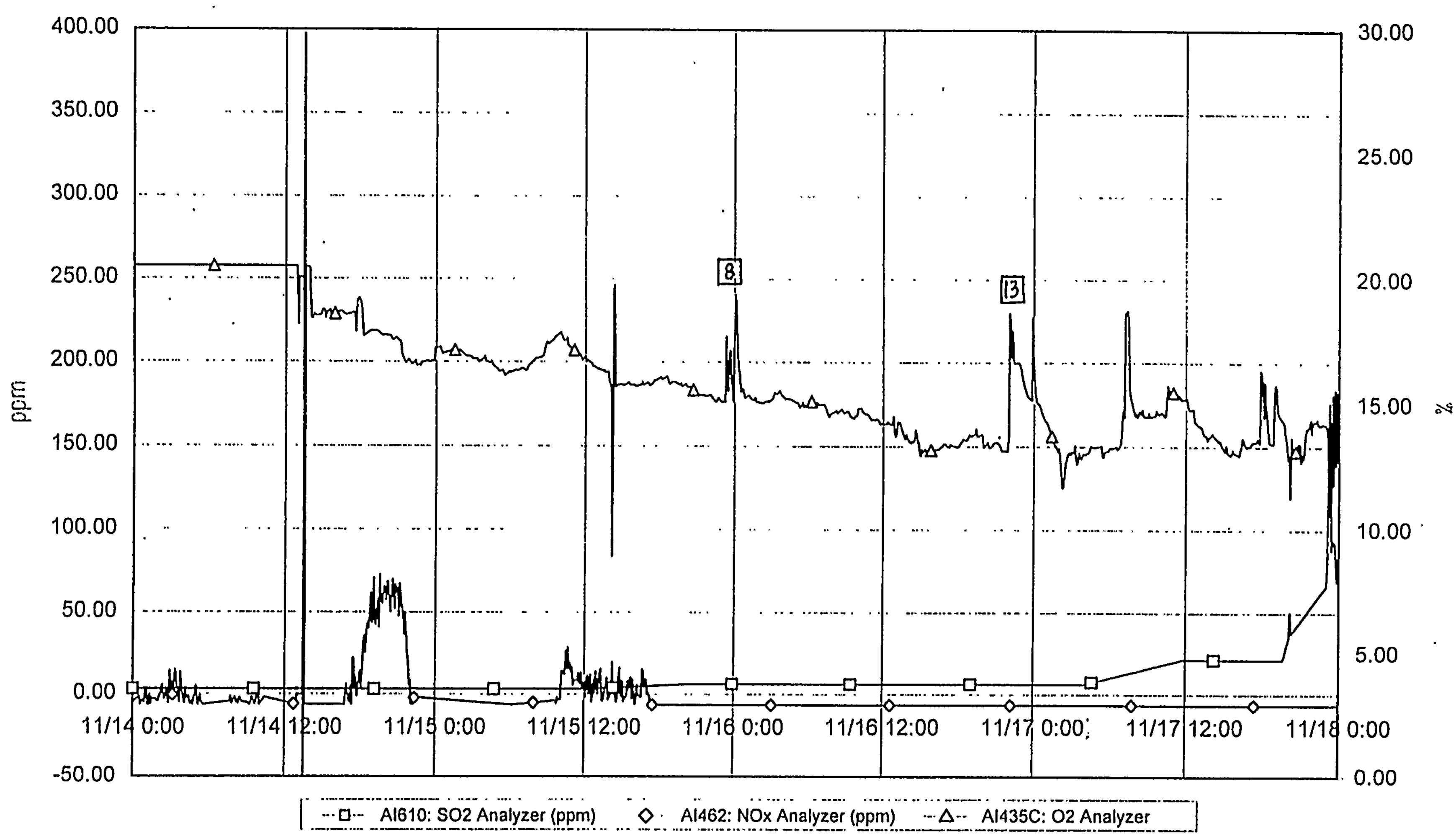

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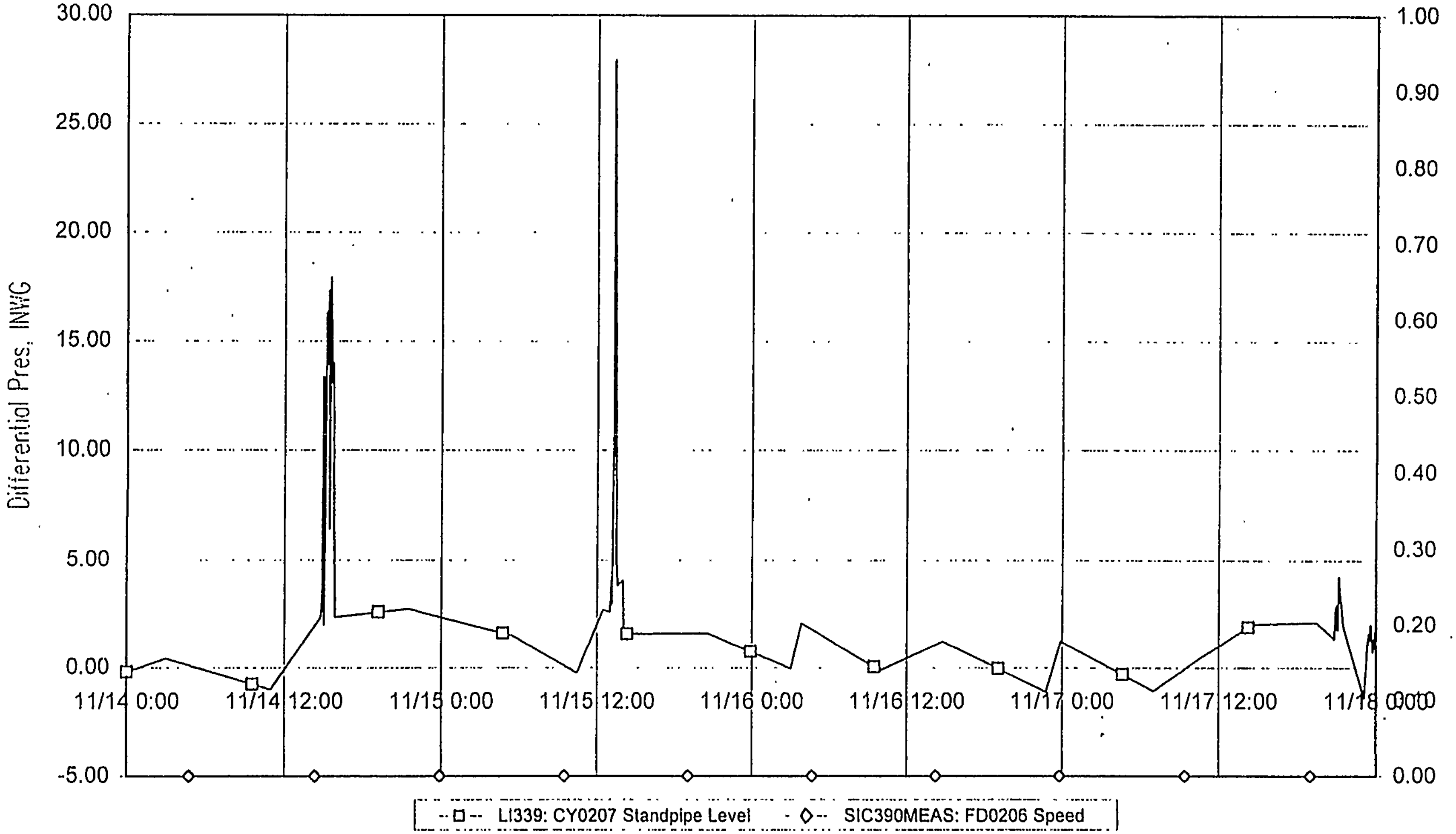

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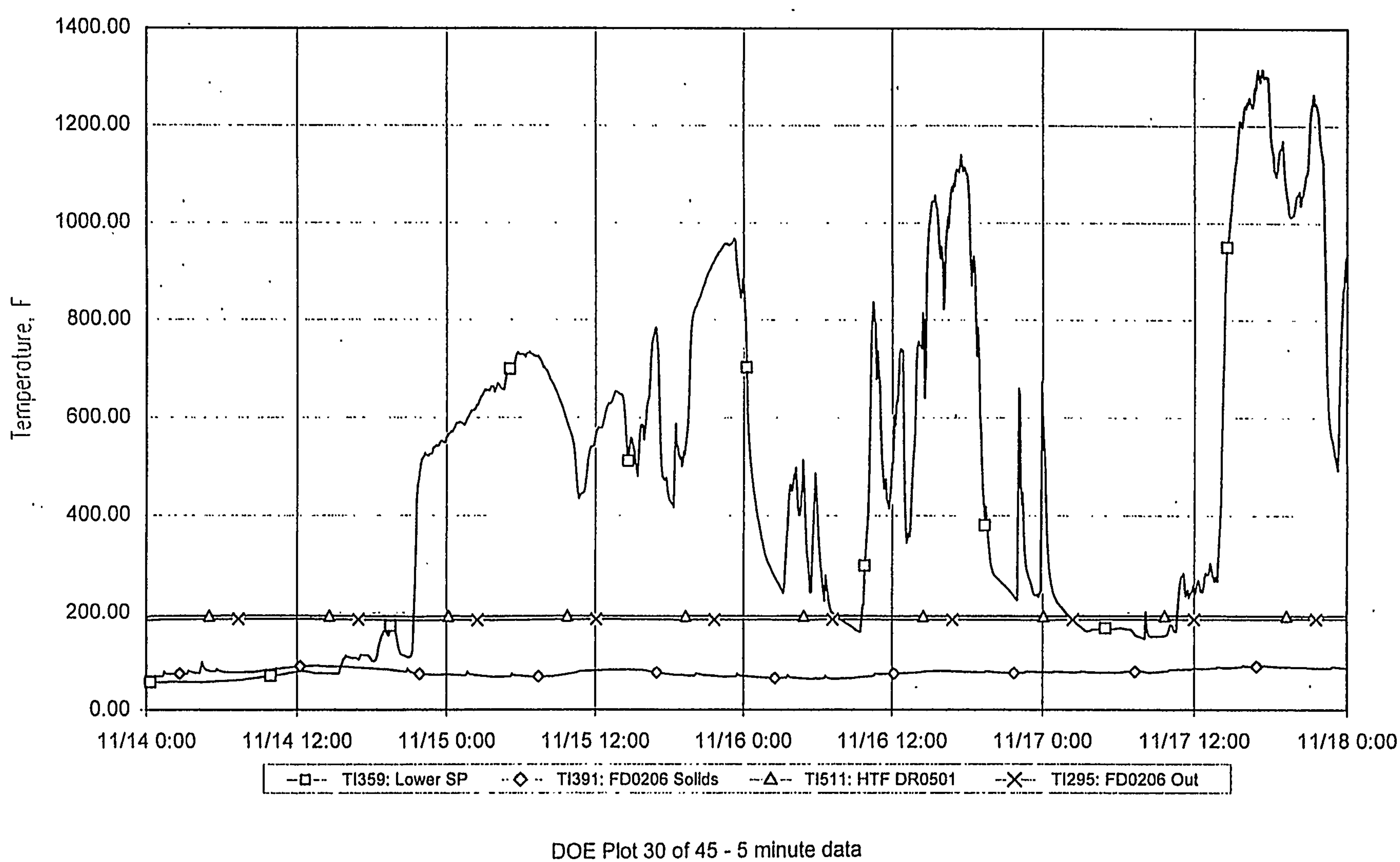

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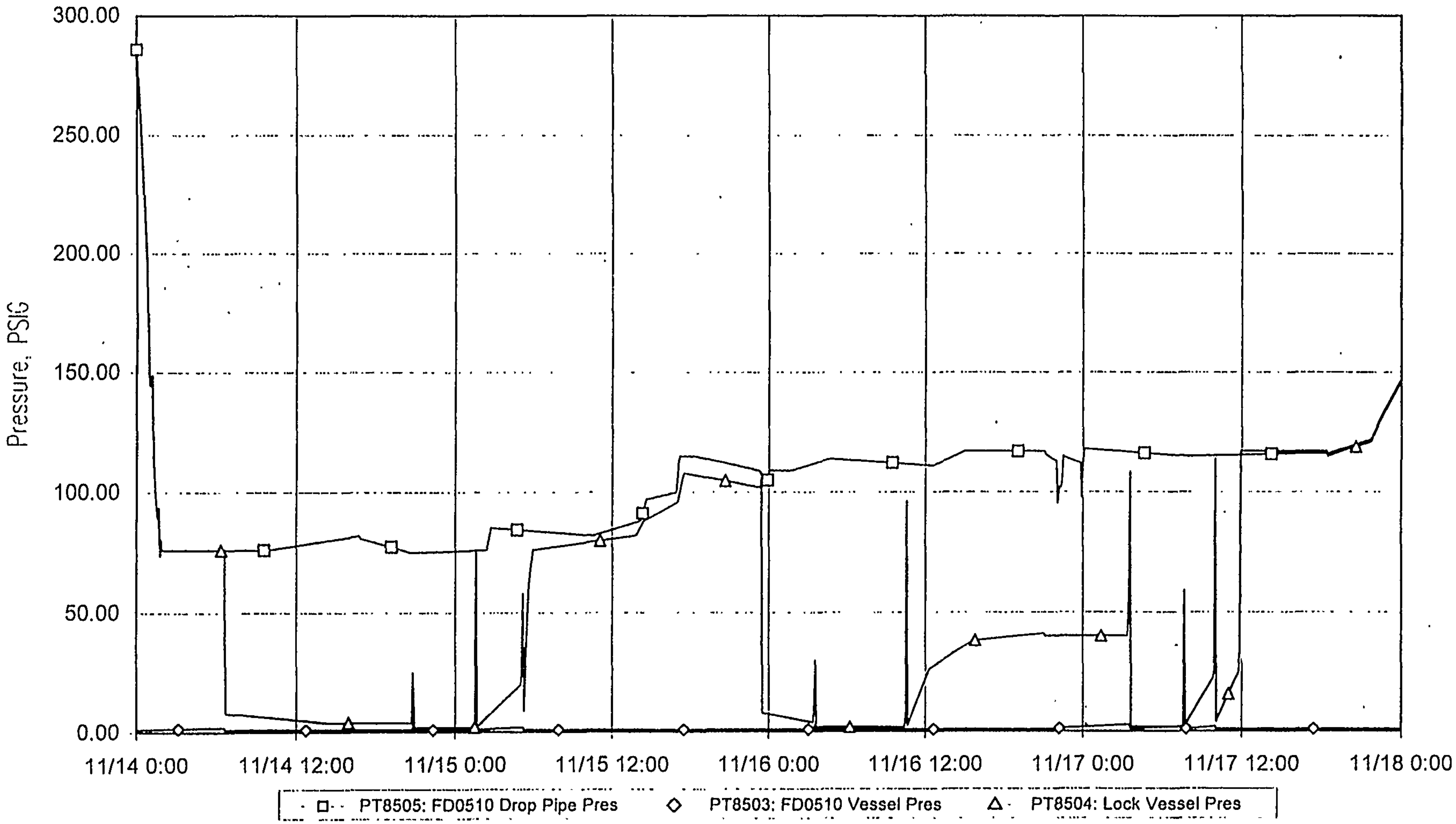

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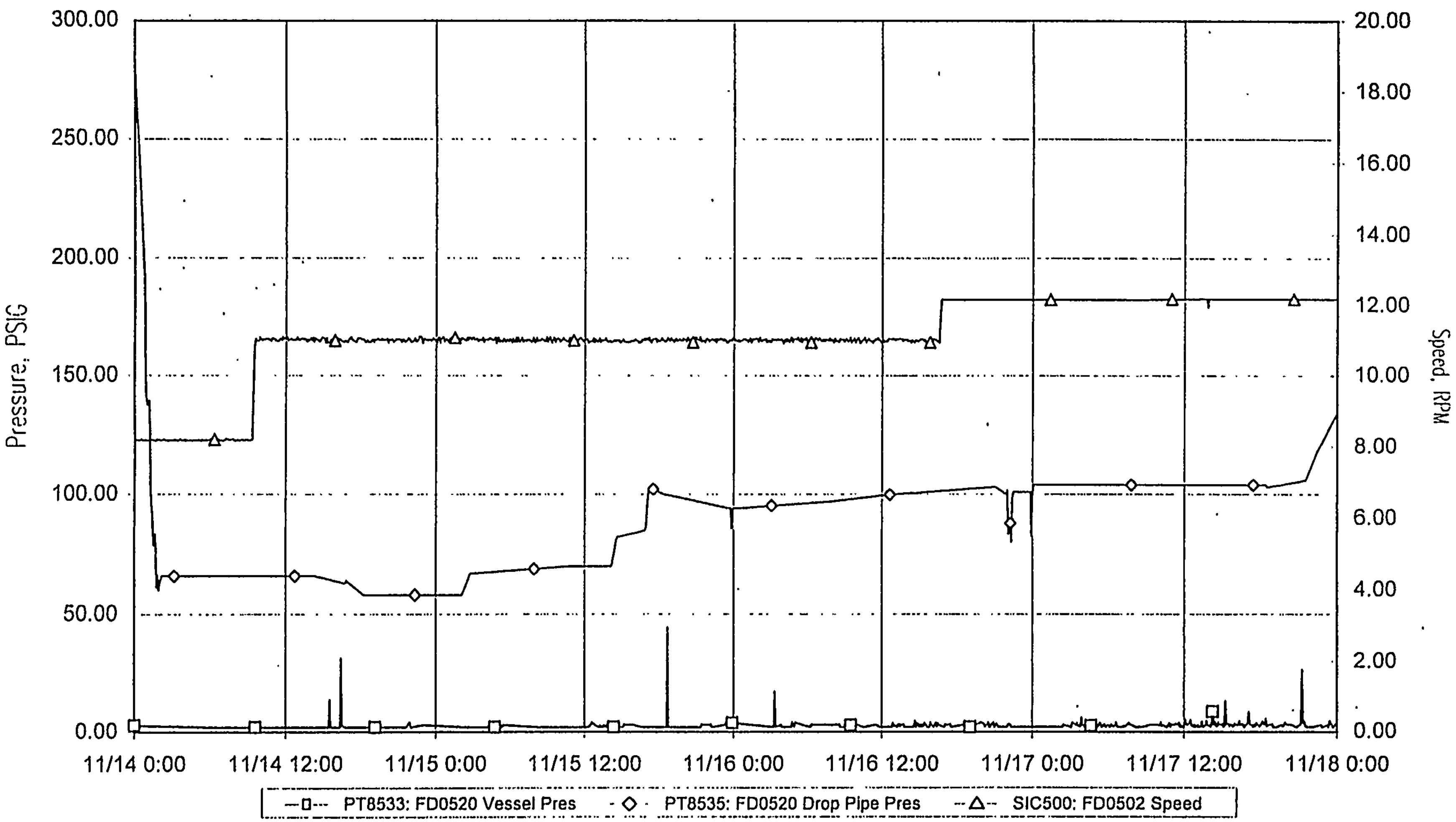

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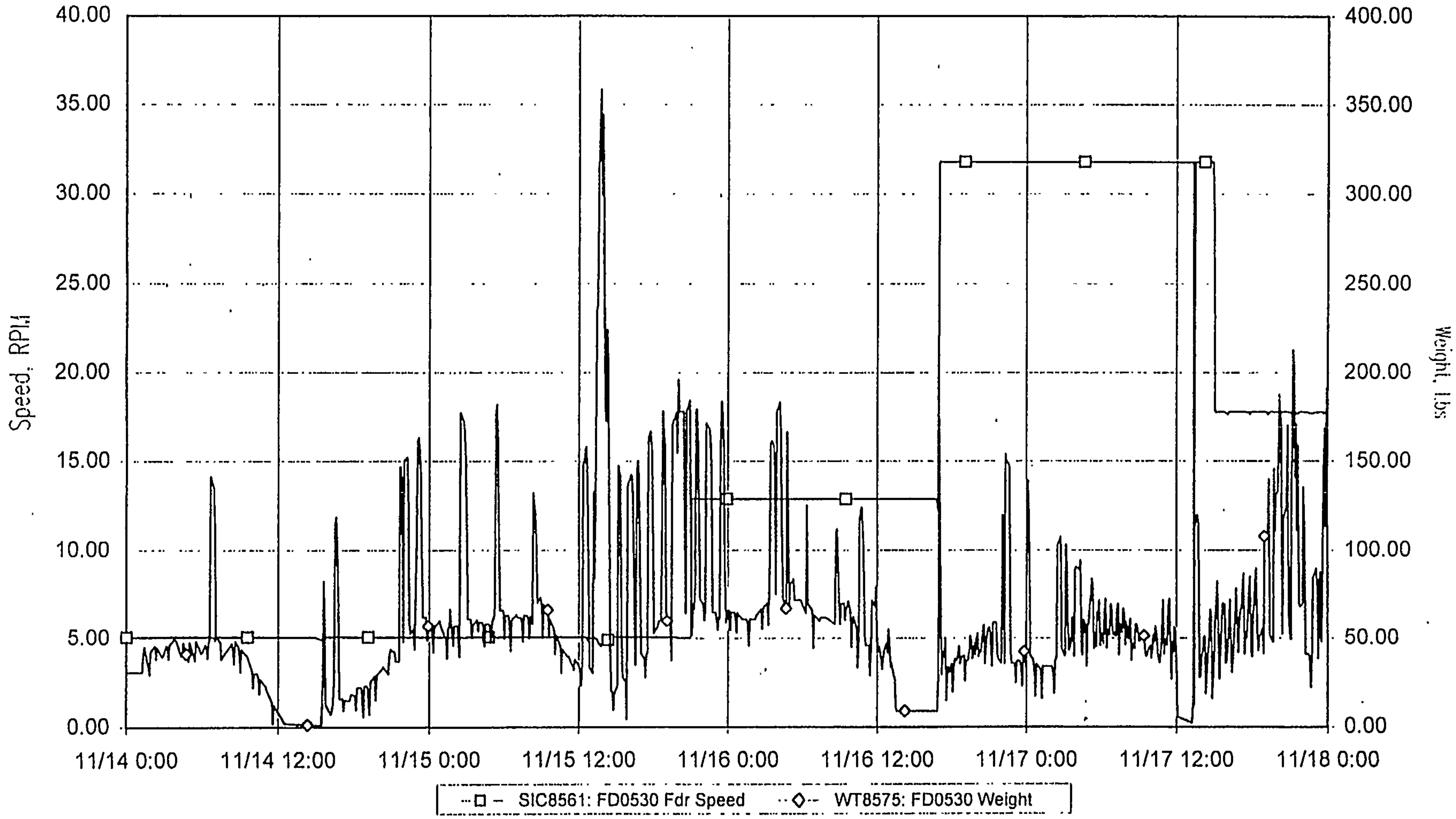

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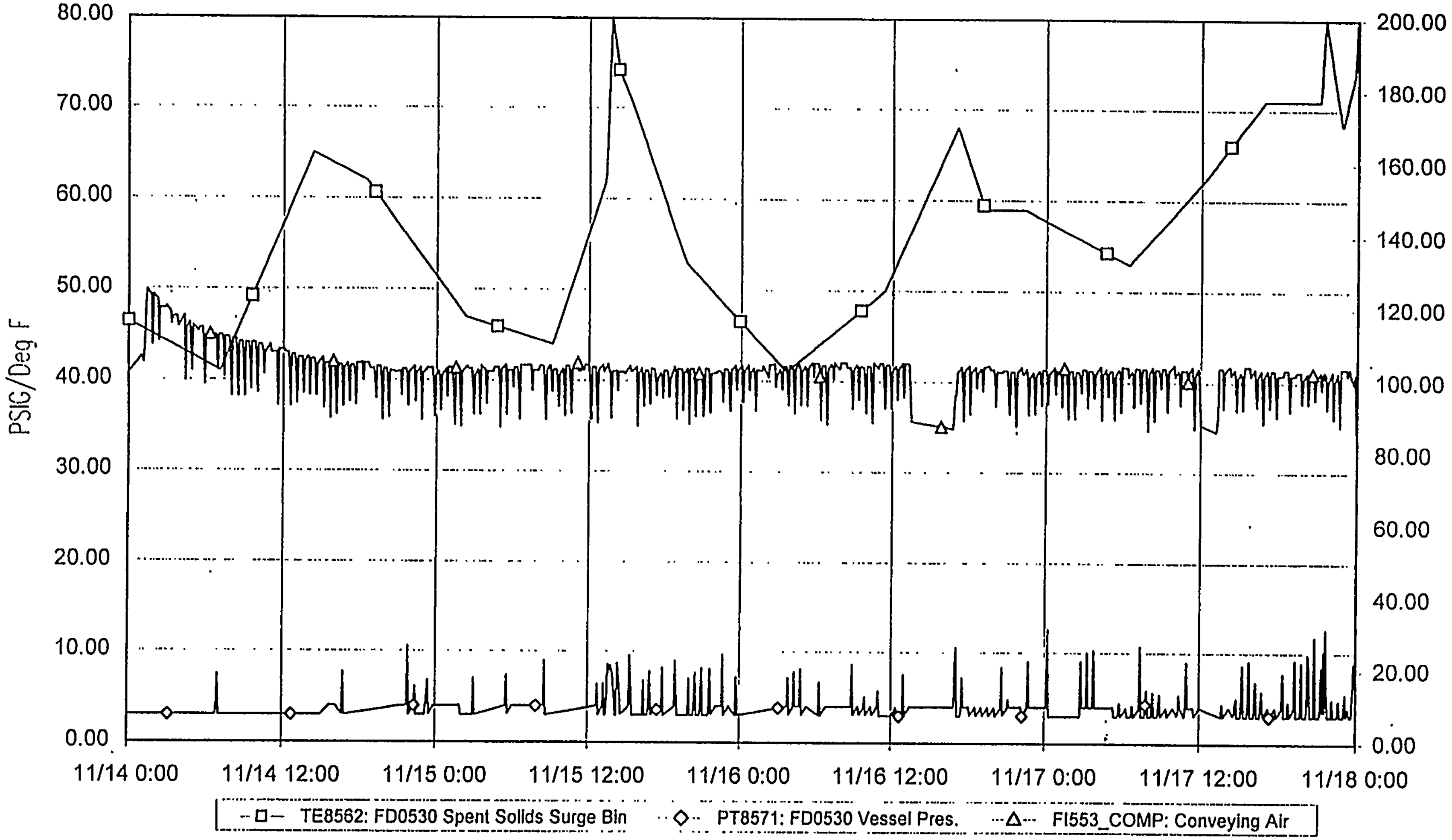

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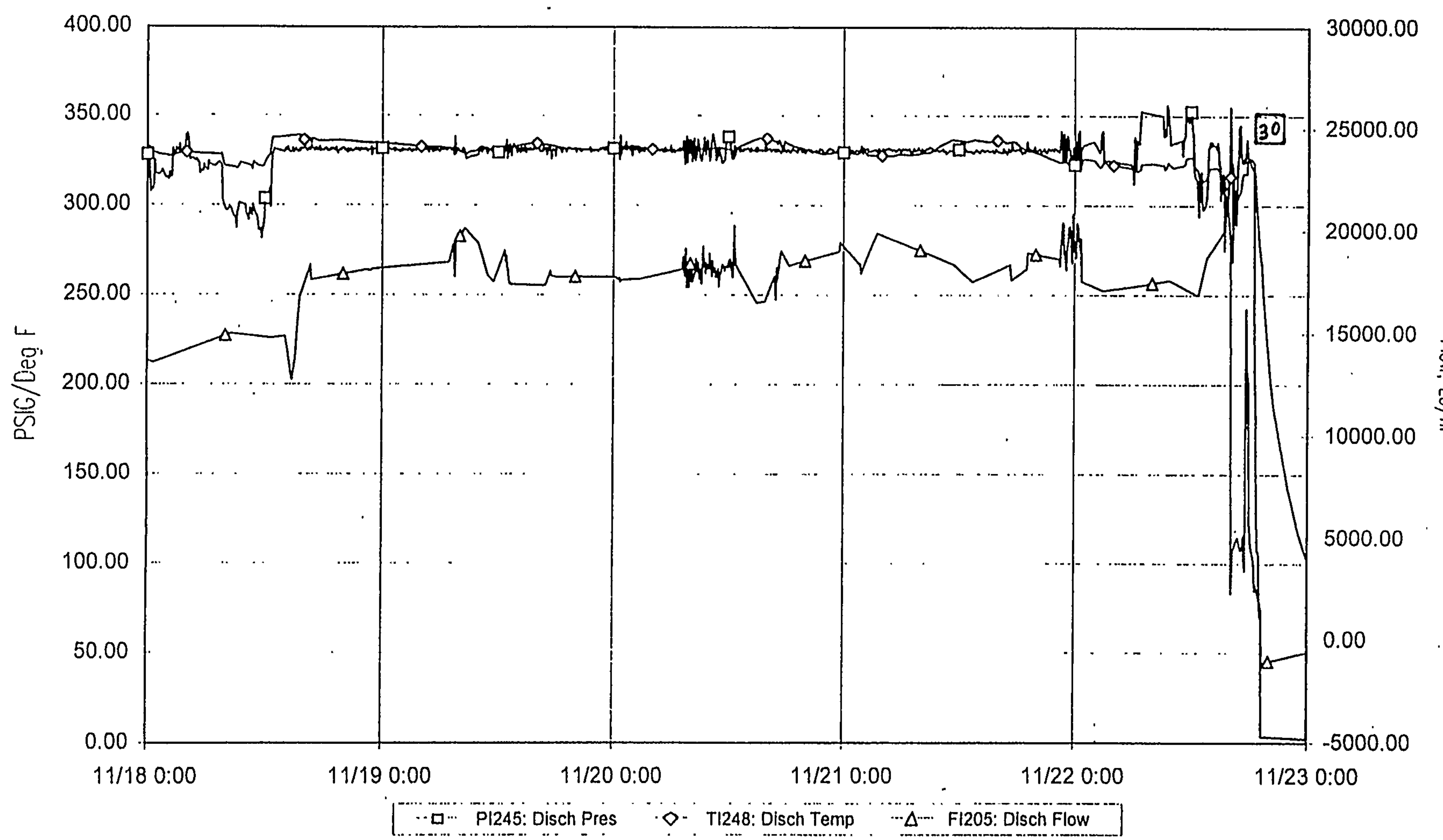
5.1.10-25 FD0530 Feeder for November 14 Through November 17, 1996



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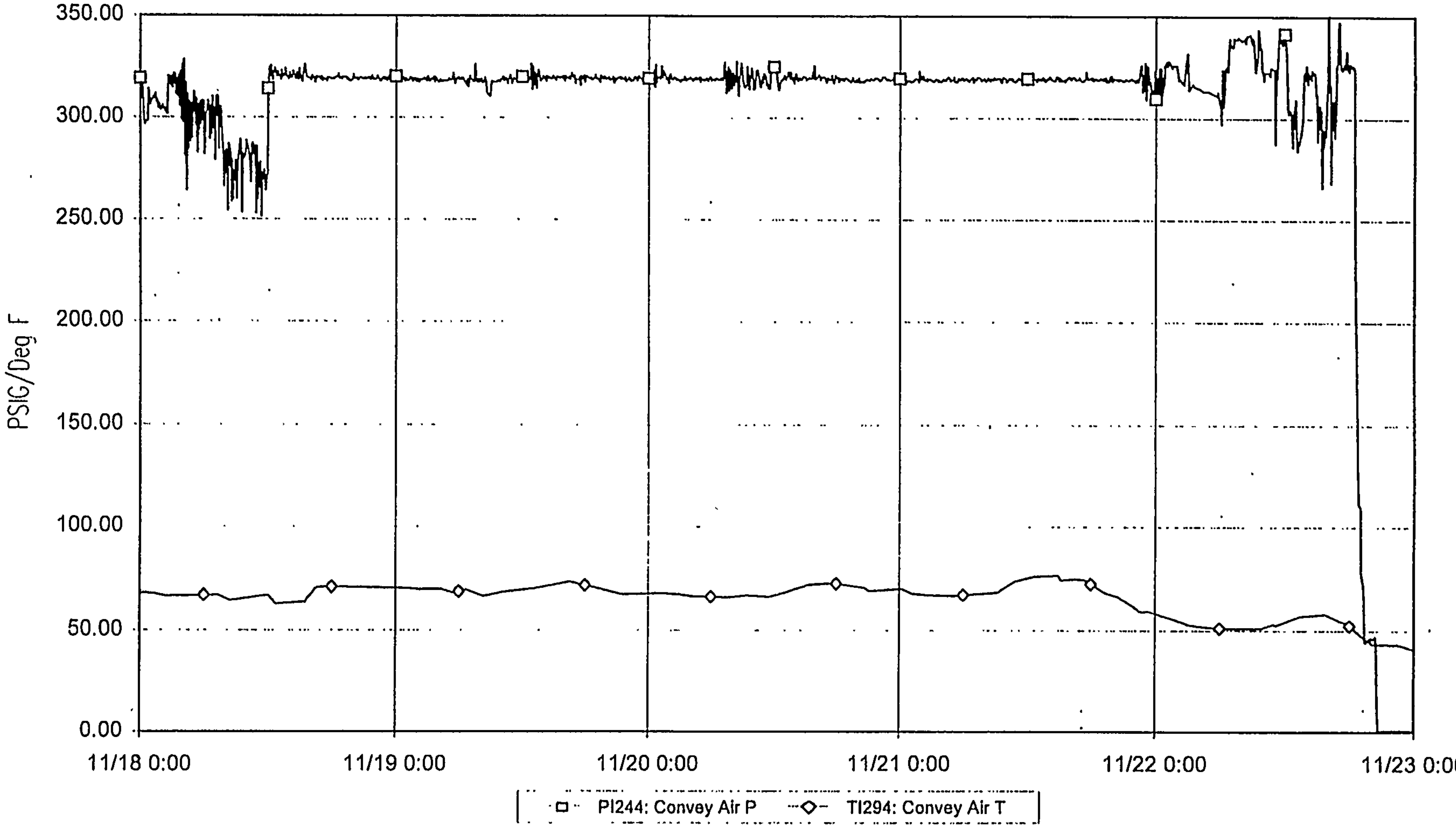

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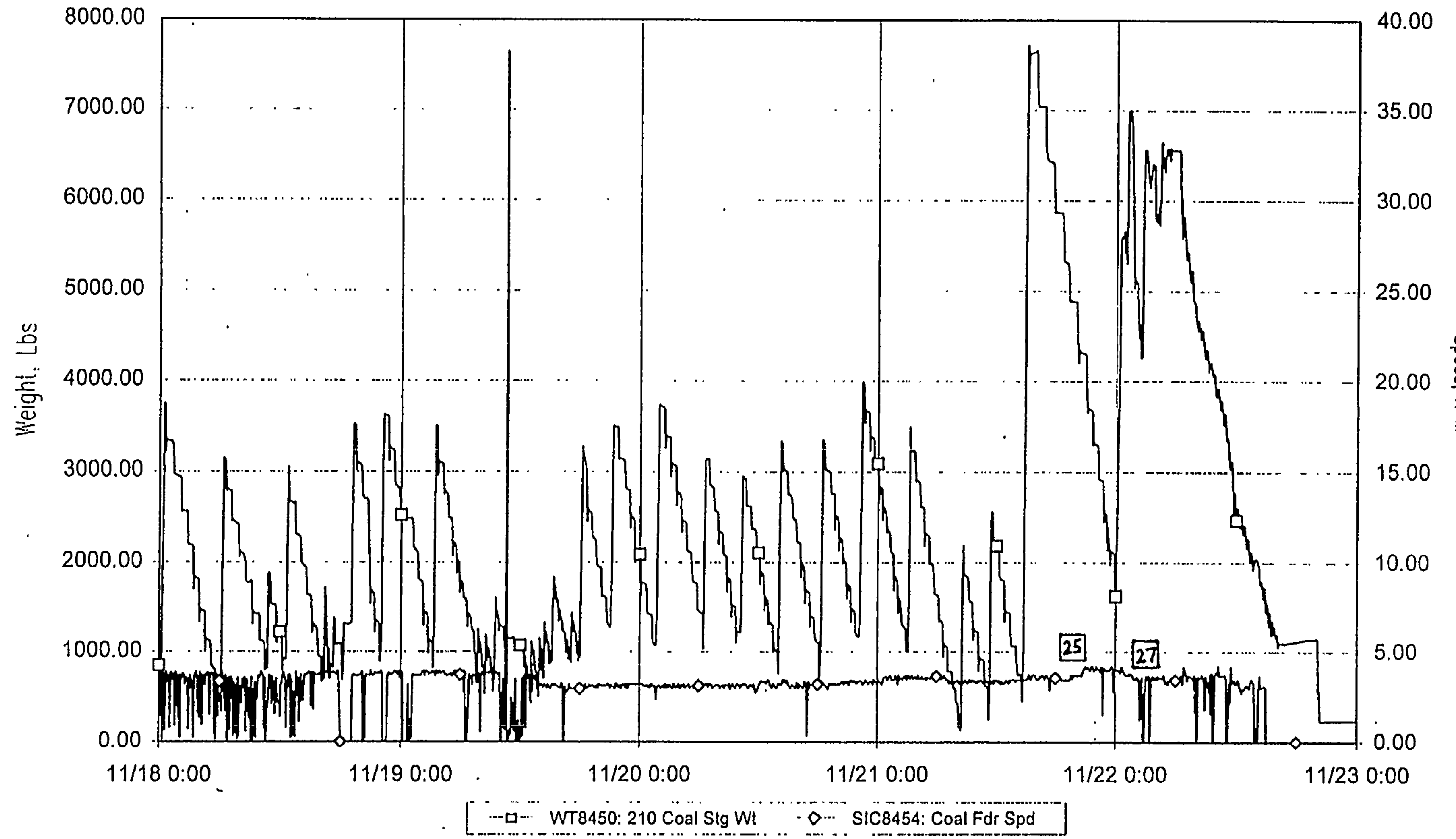

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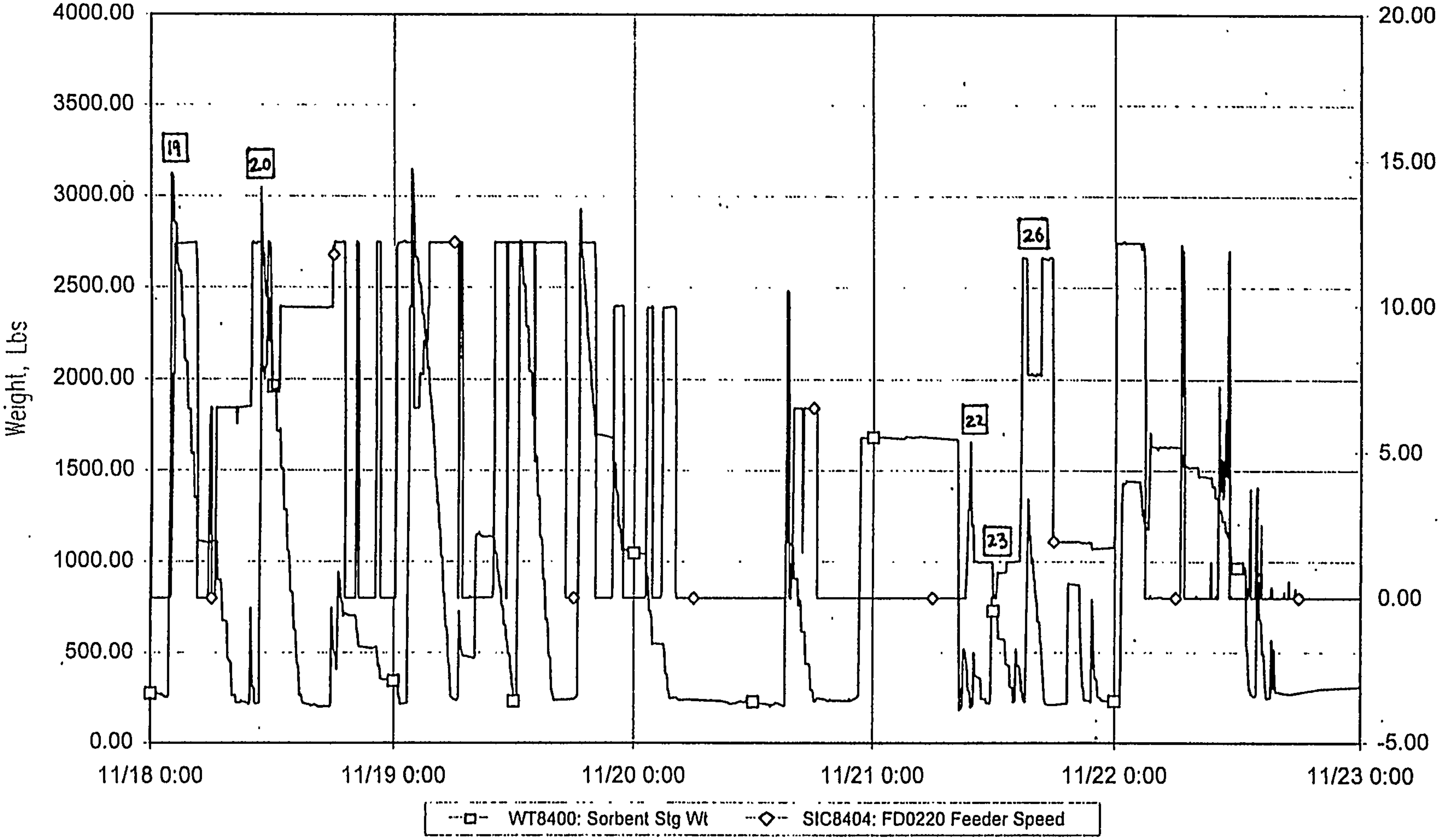

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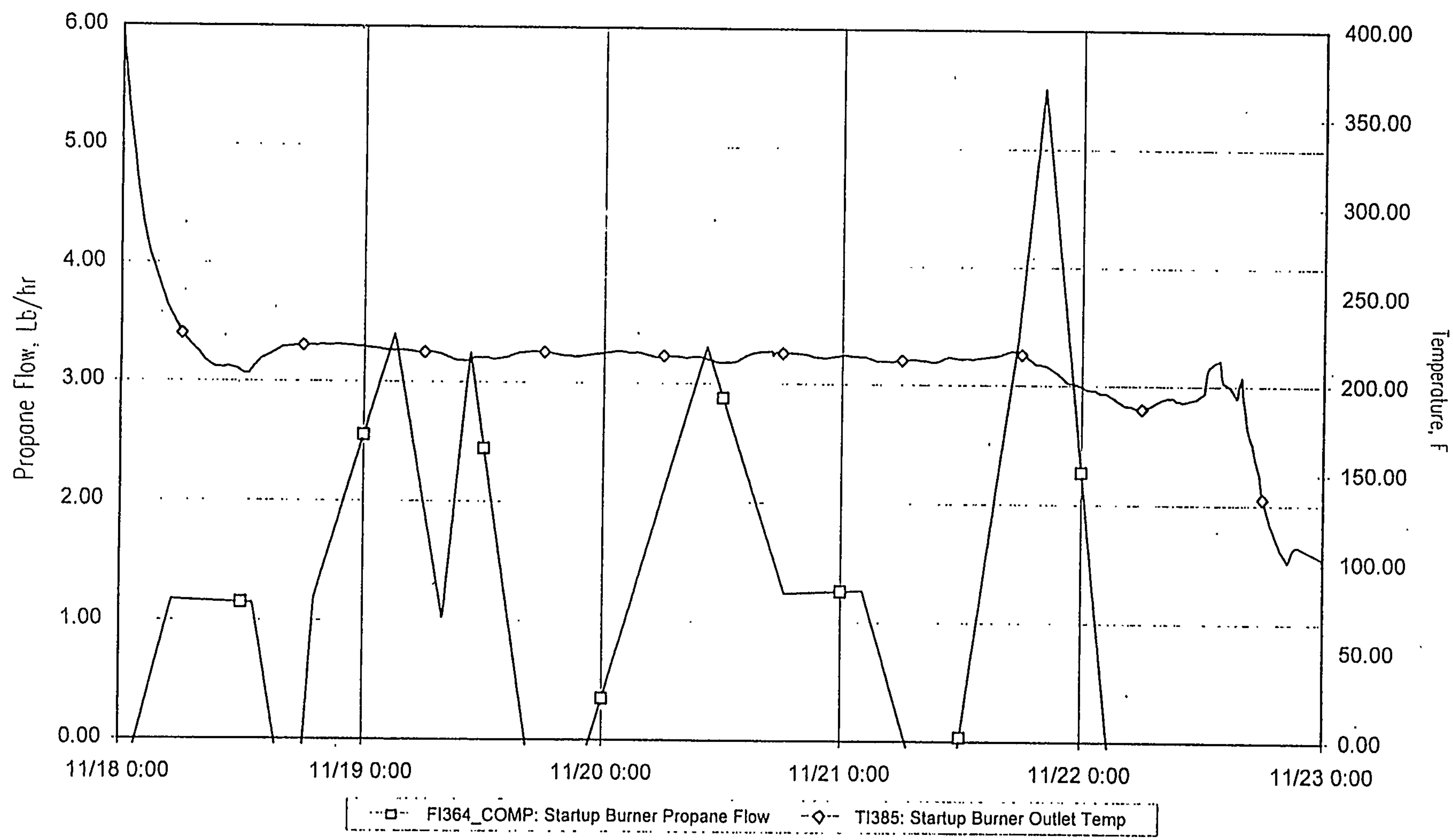

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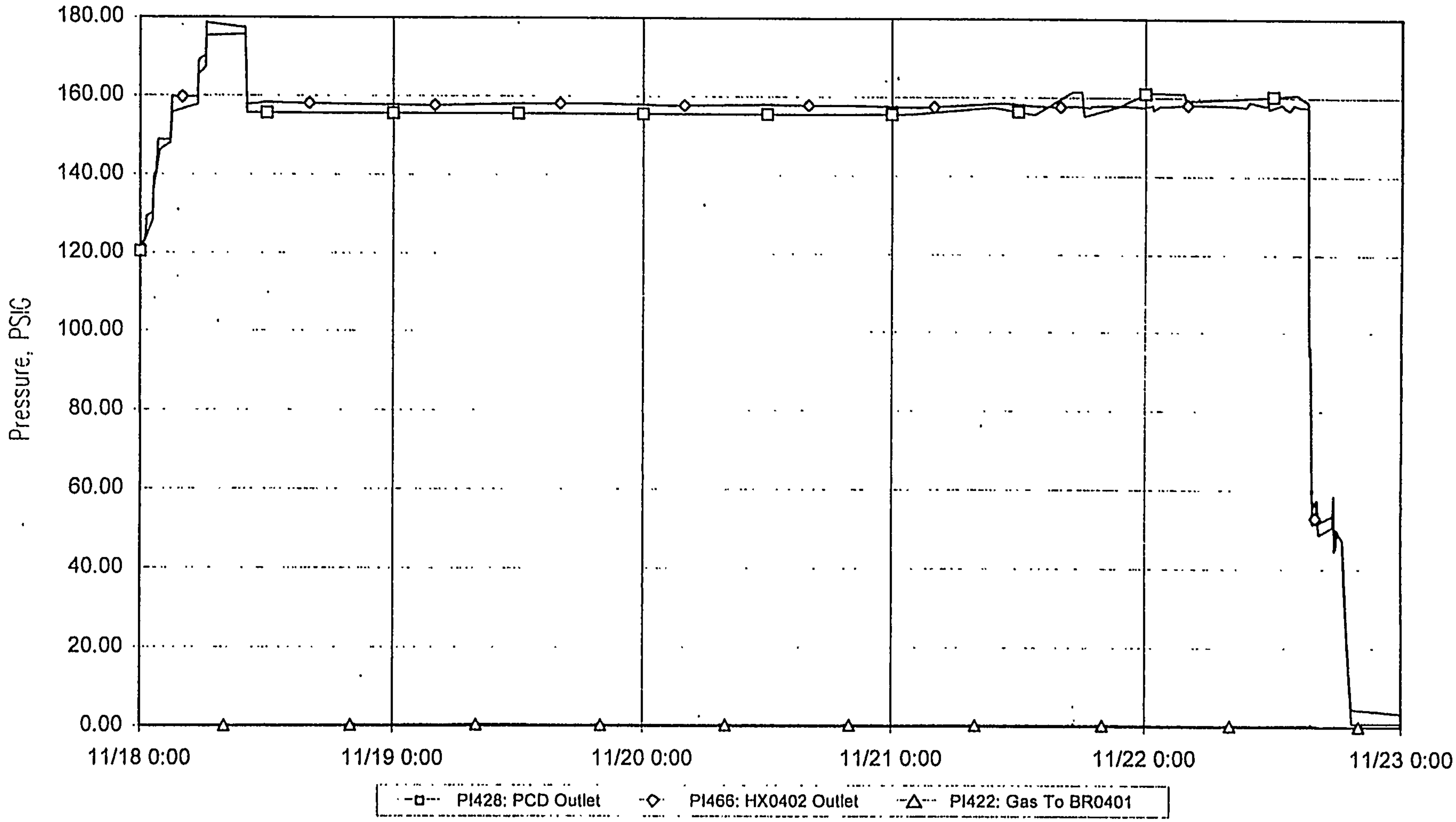

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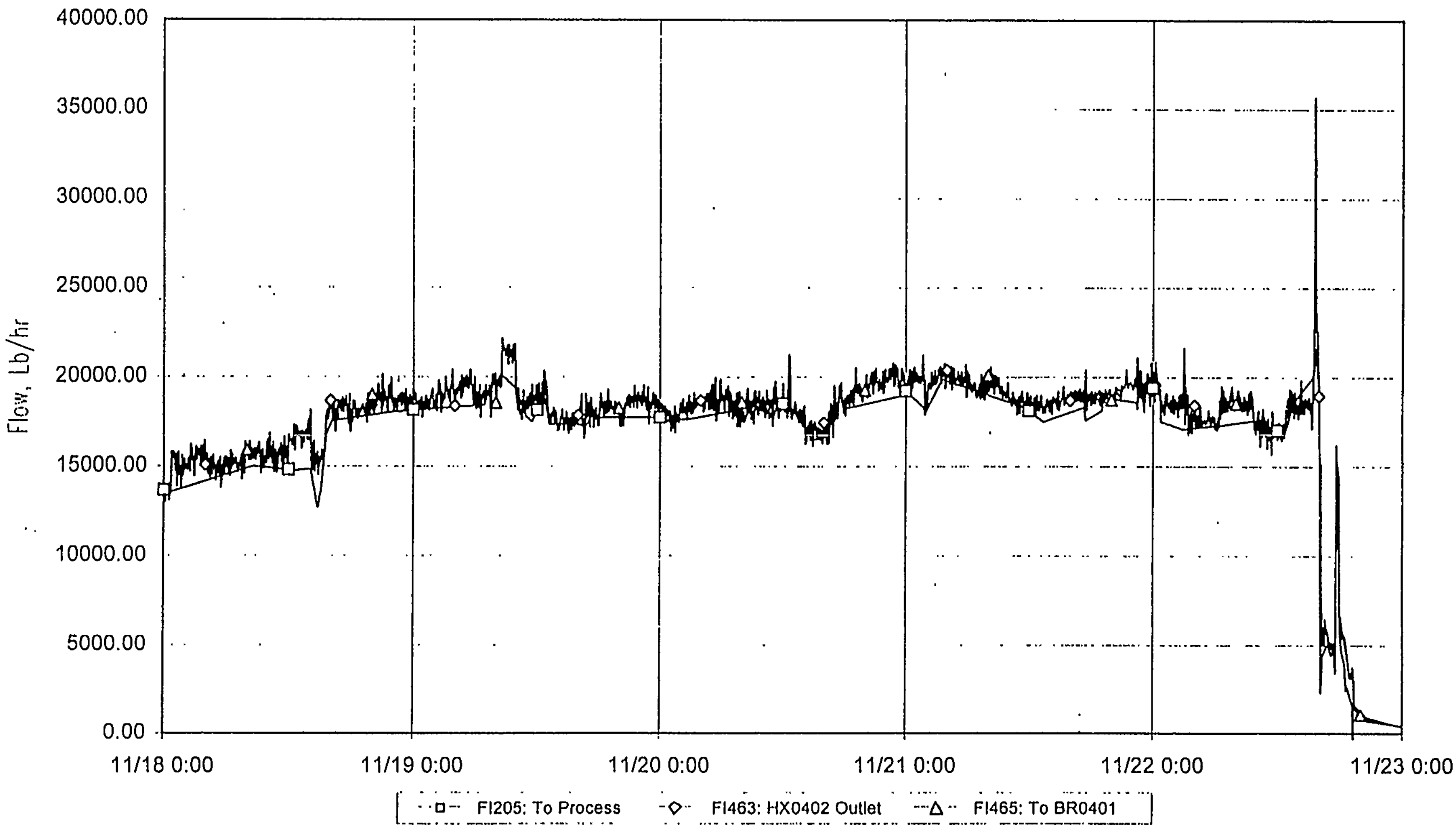

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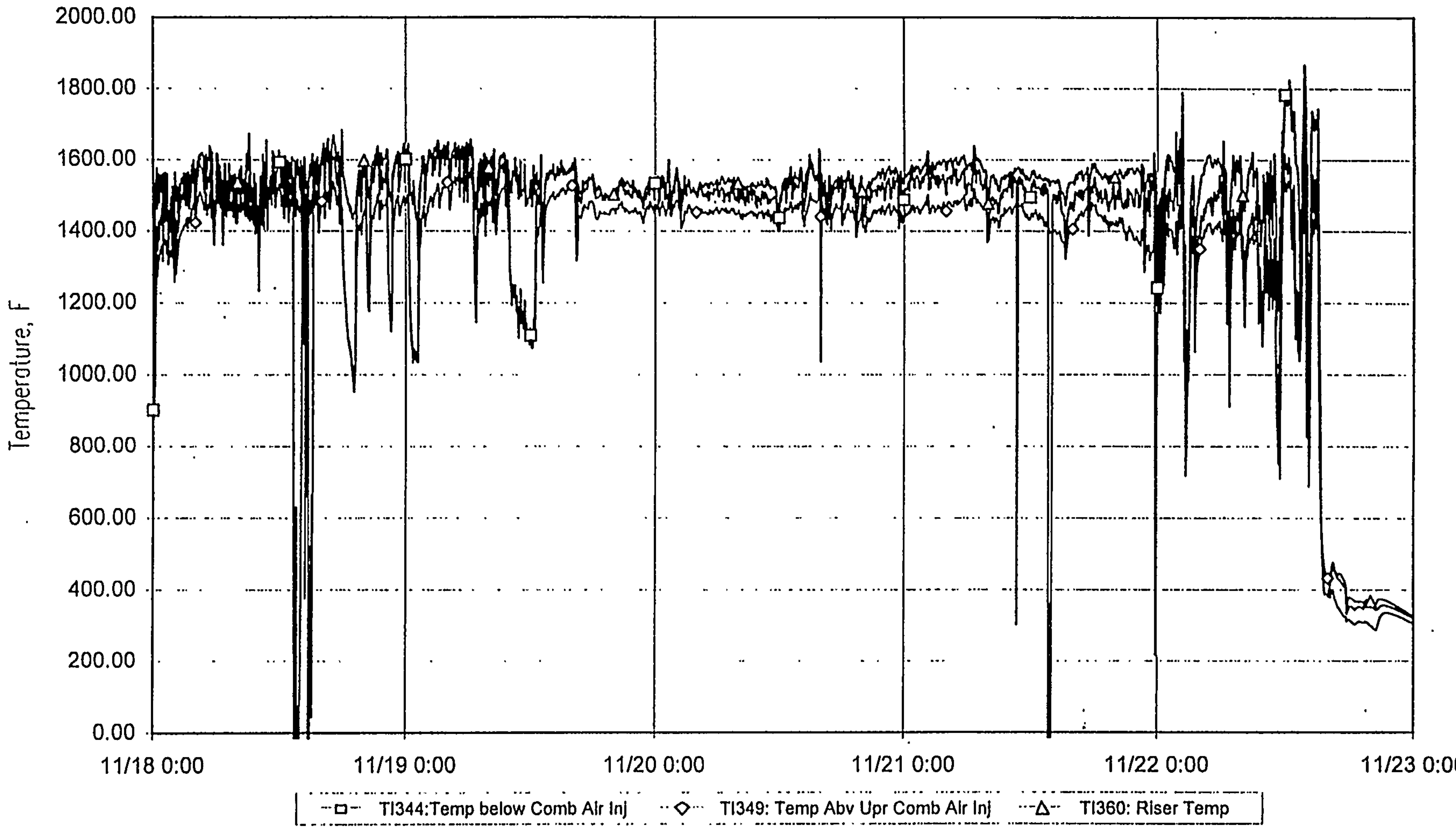
5.1.10-32 Total Gas In/Out Flow Rates for November 18 Through November 22, 1996



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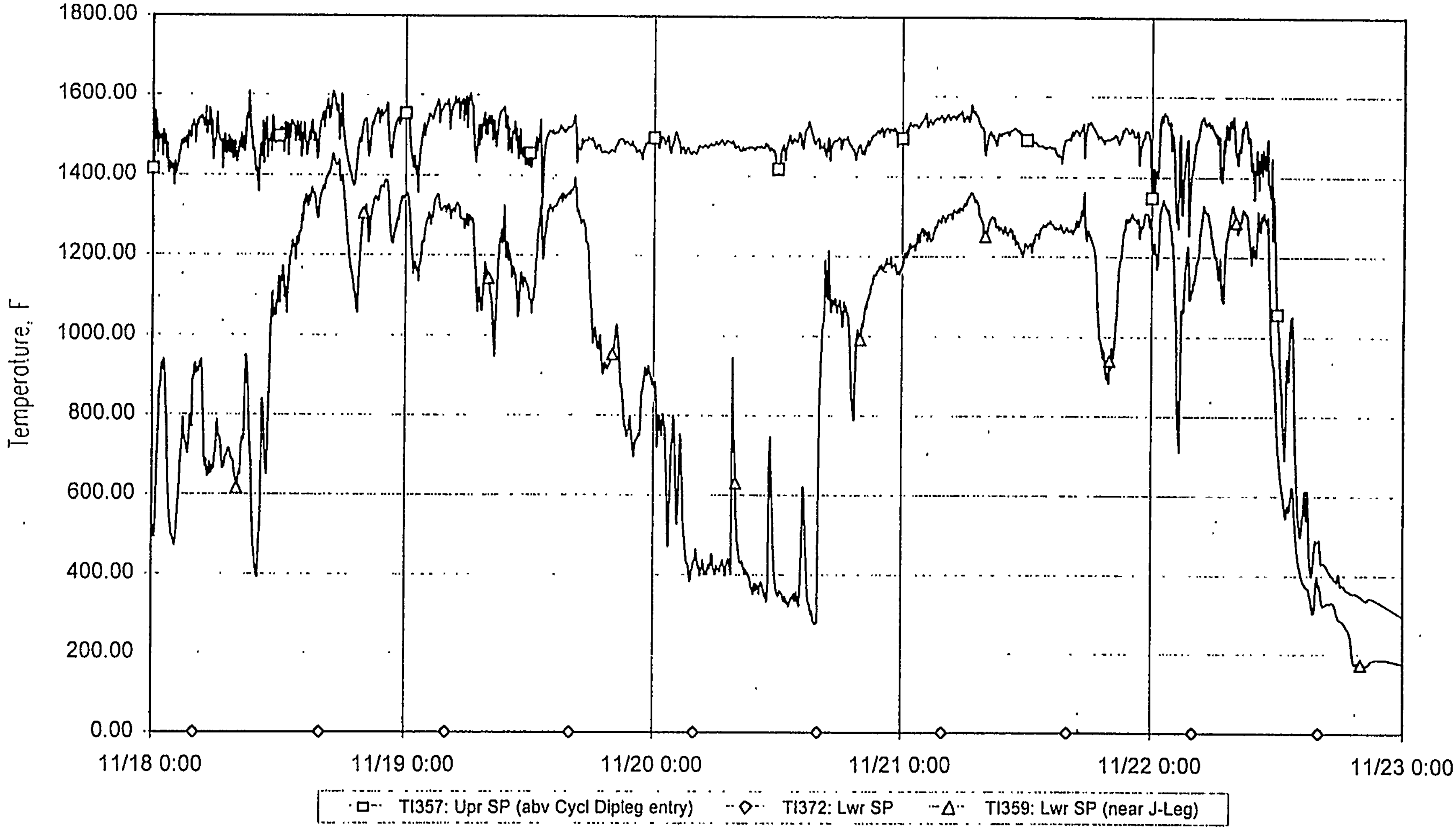

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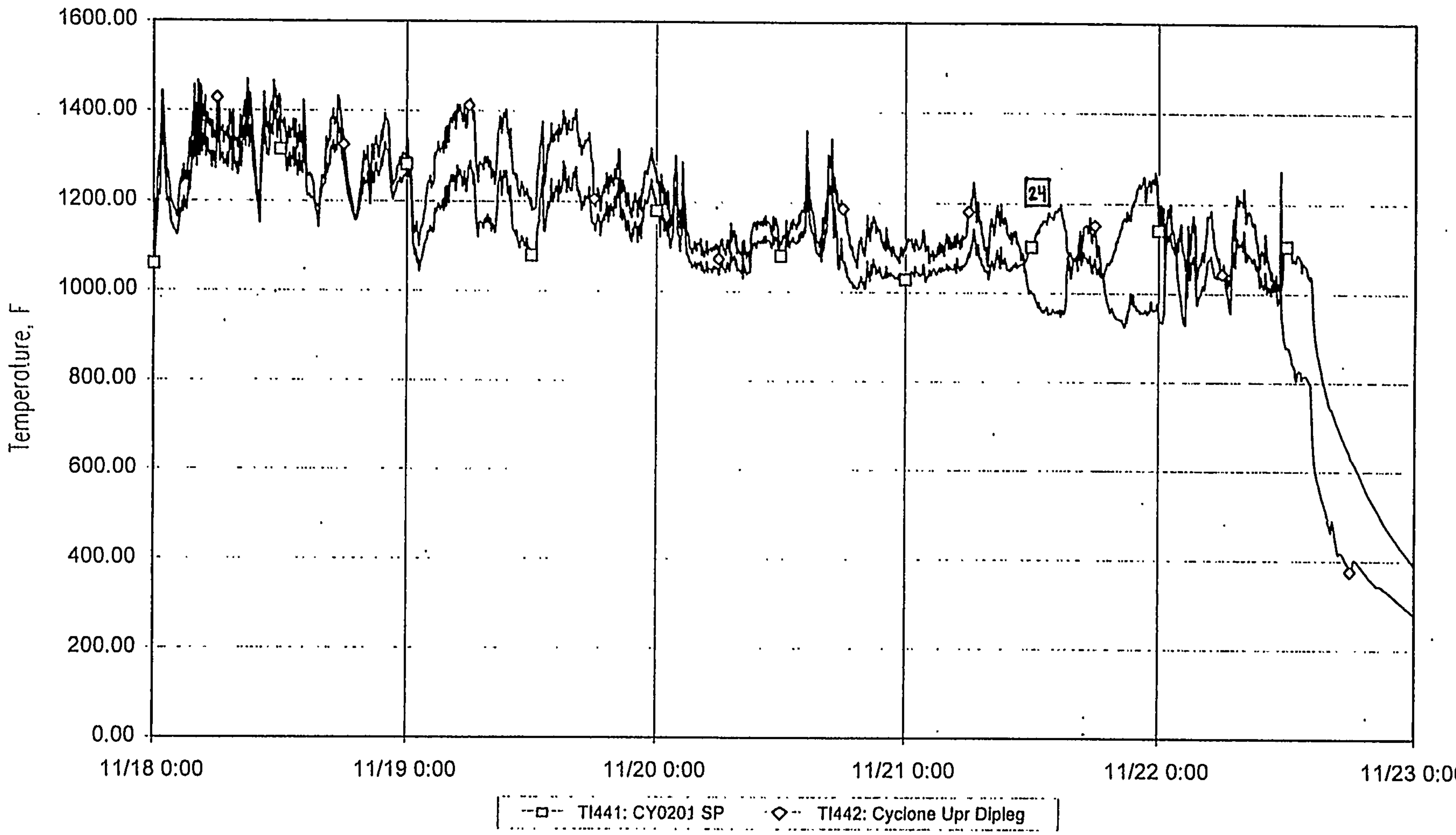
5.1.10-34 Standpipe Temperatures for November 18 Through November 22, 1996



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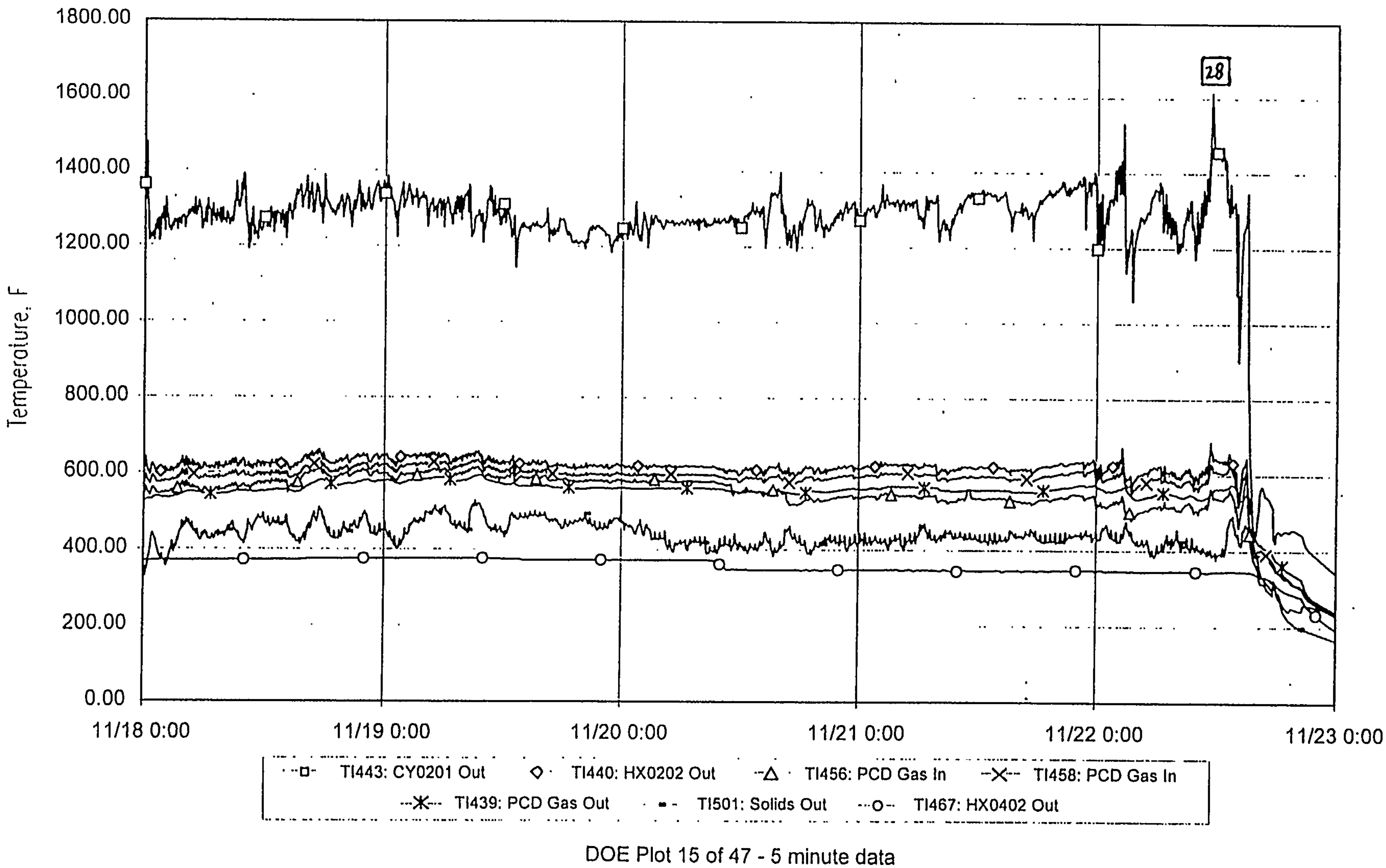
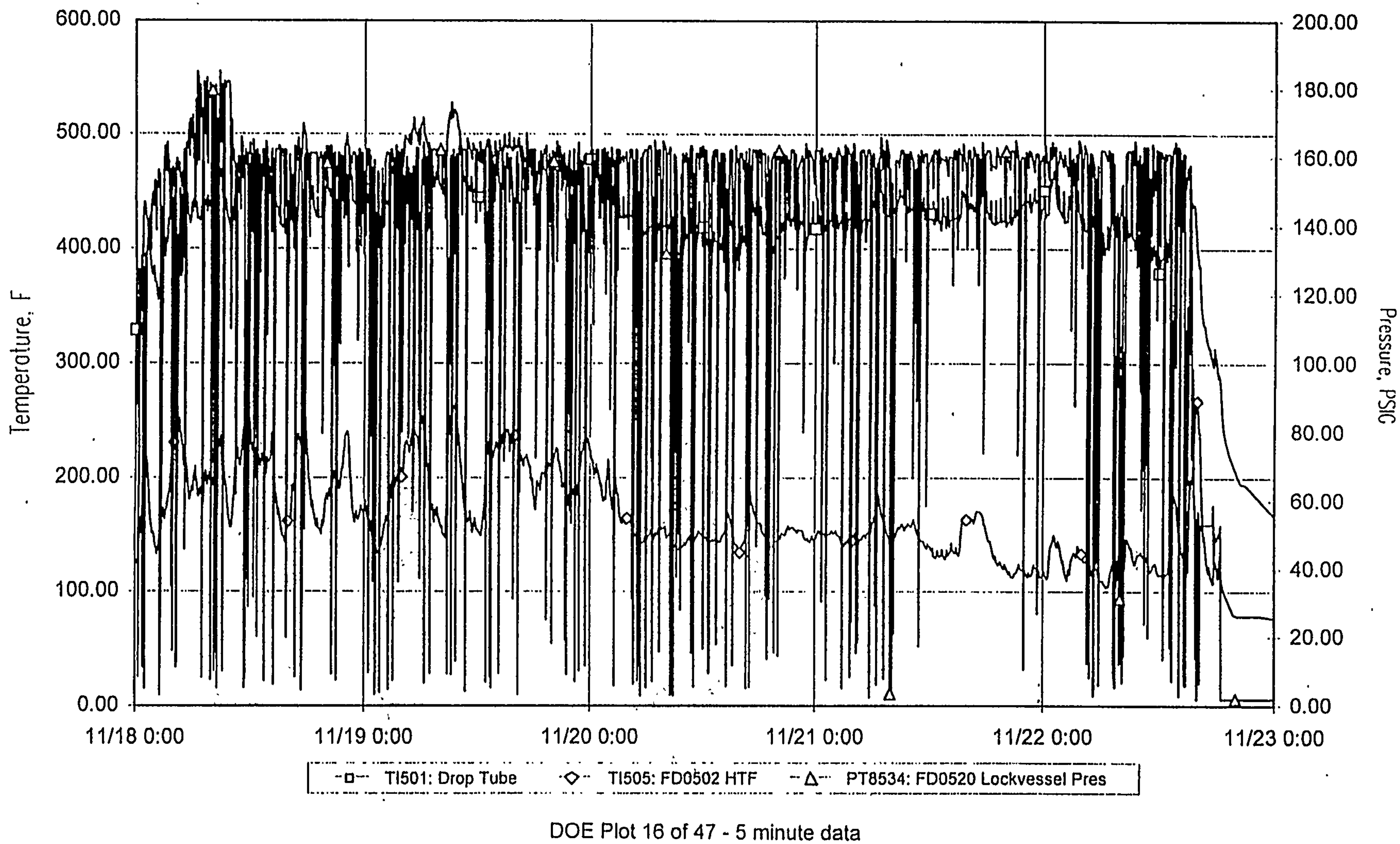
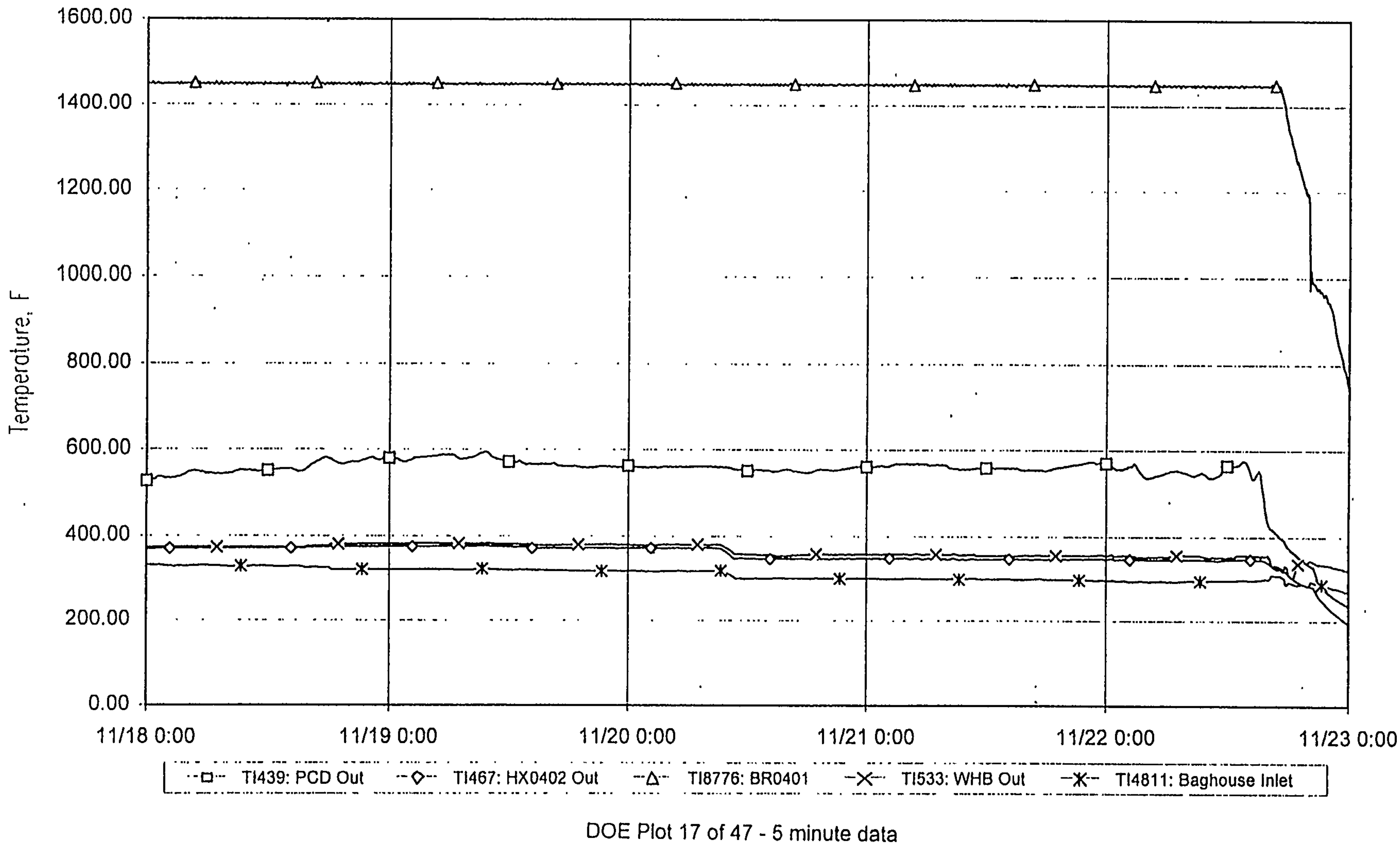


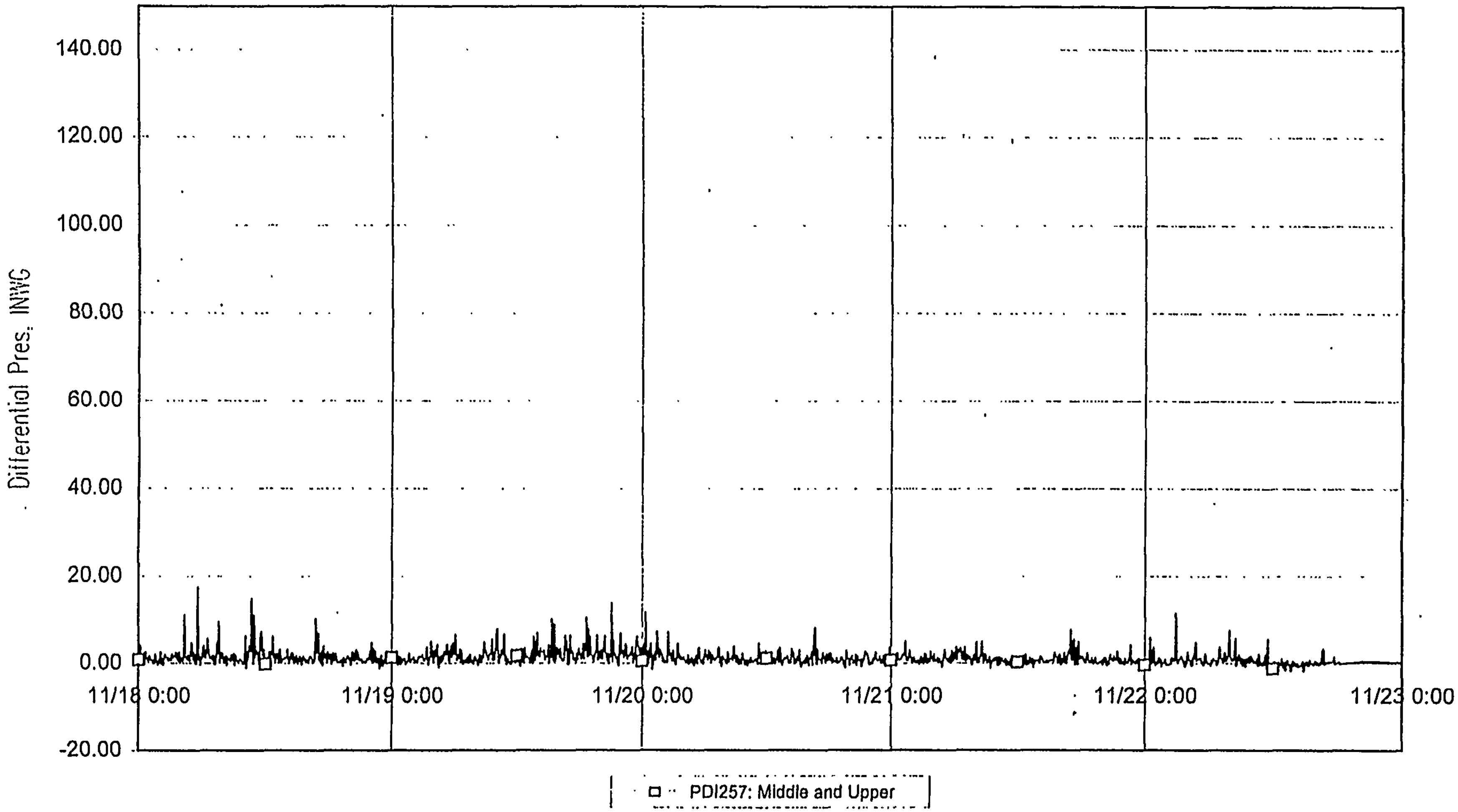
5.1.10-36 Temperature Profiles Downstream of Reactor for November 18 Through November 22, 1996



5.1.10-37 PCD Ash Temperatures for November 18 Through November 22, 1996



5.1.10-38 System Temperatures Downstream of PCD for November 18 Through November 22, 1996



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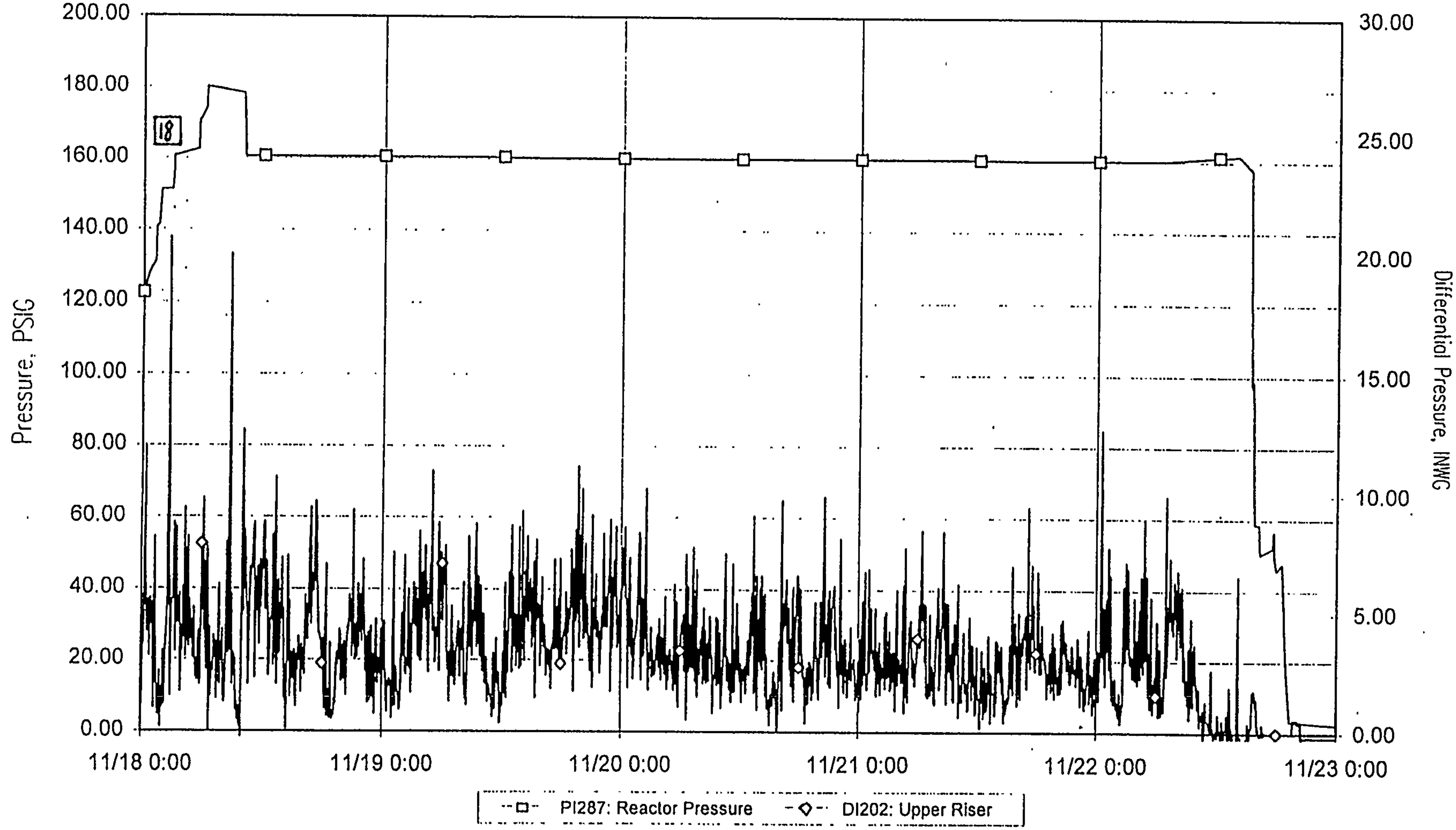

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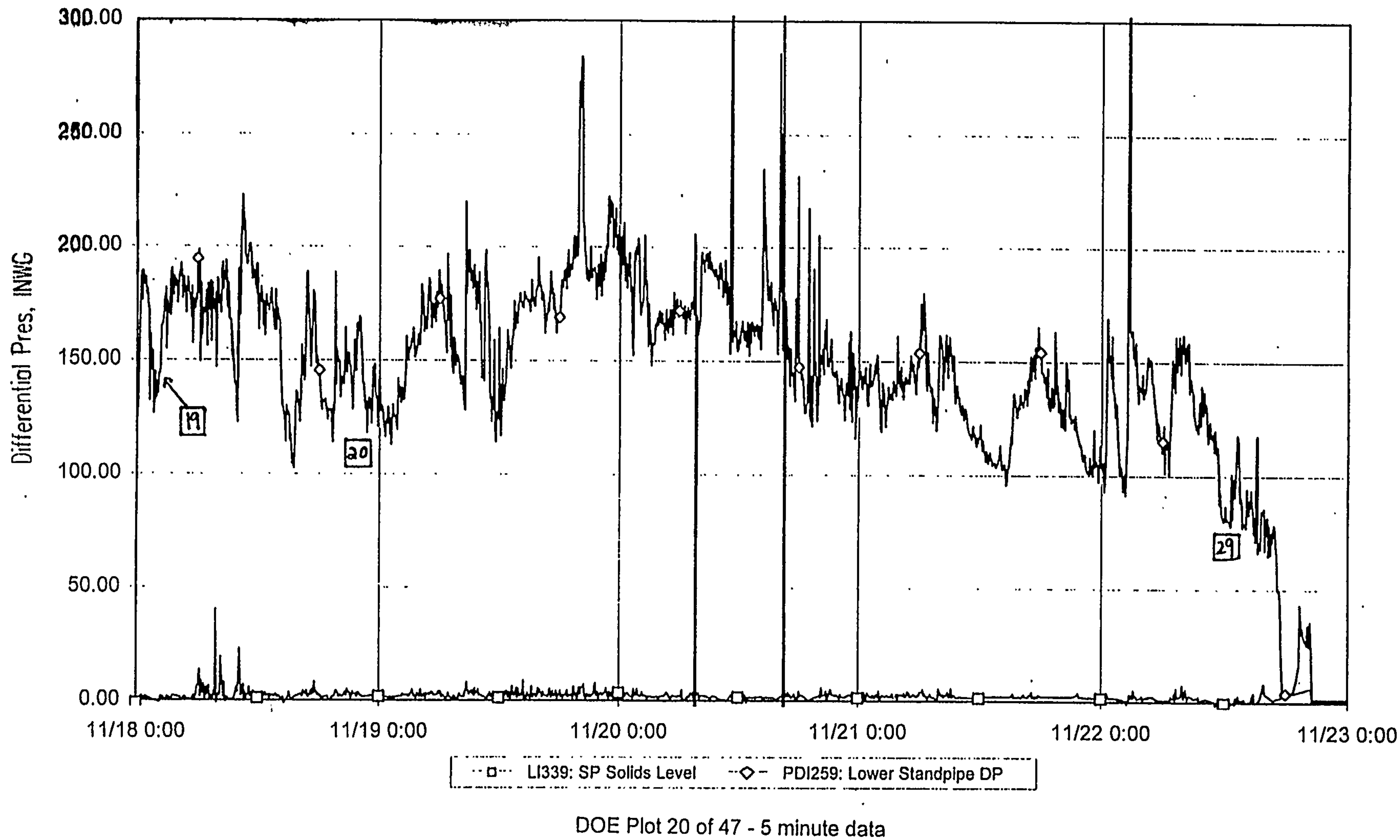
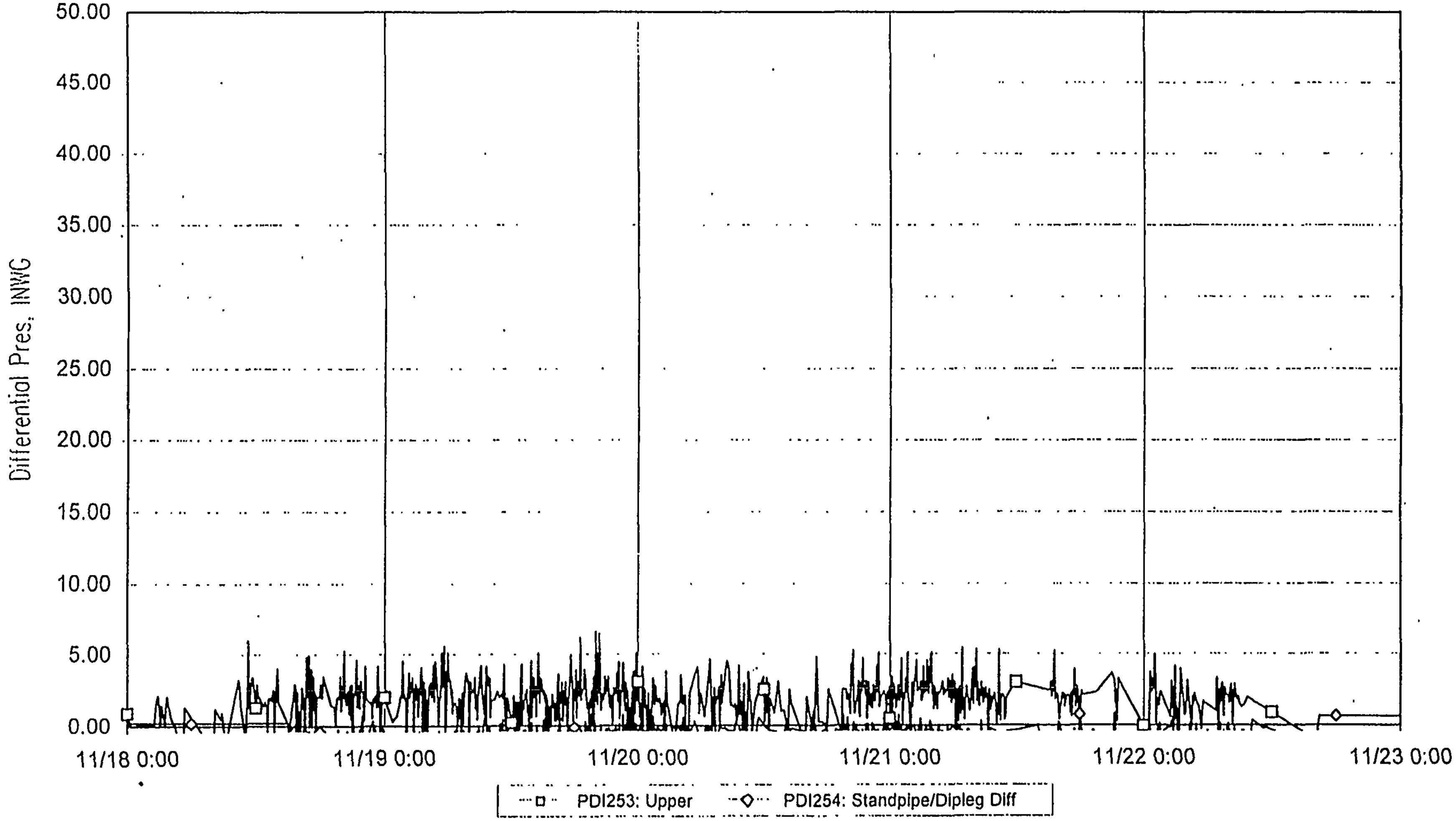
5.1.10-40 Reactor Pressure/Riser DP Profiles for November 18 Through November 22, 1996



5.1.10-41 Standpipe DP Profiles for November 18 Through November 22, 1996



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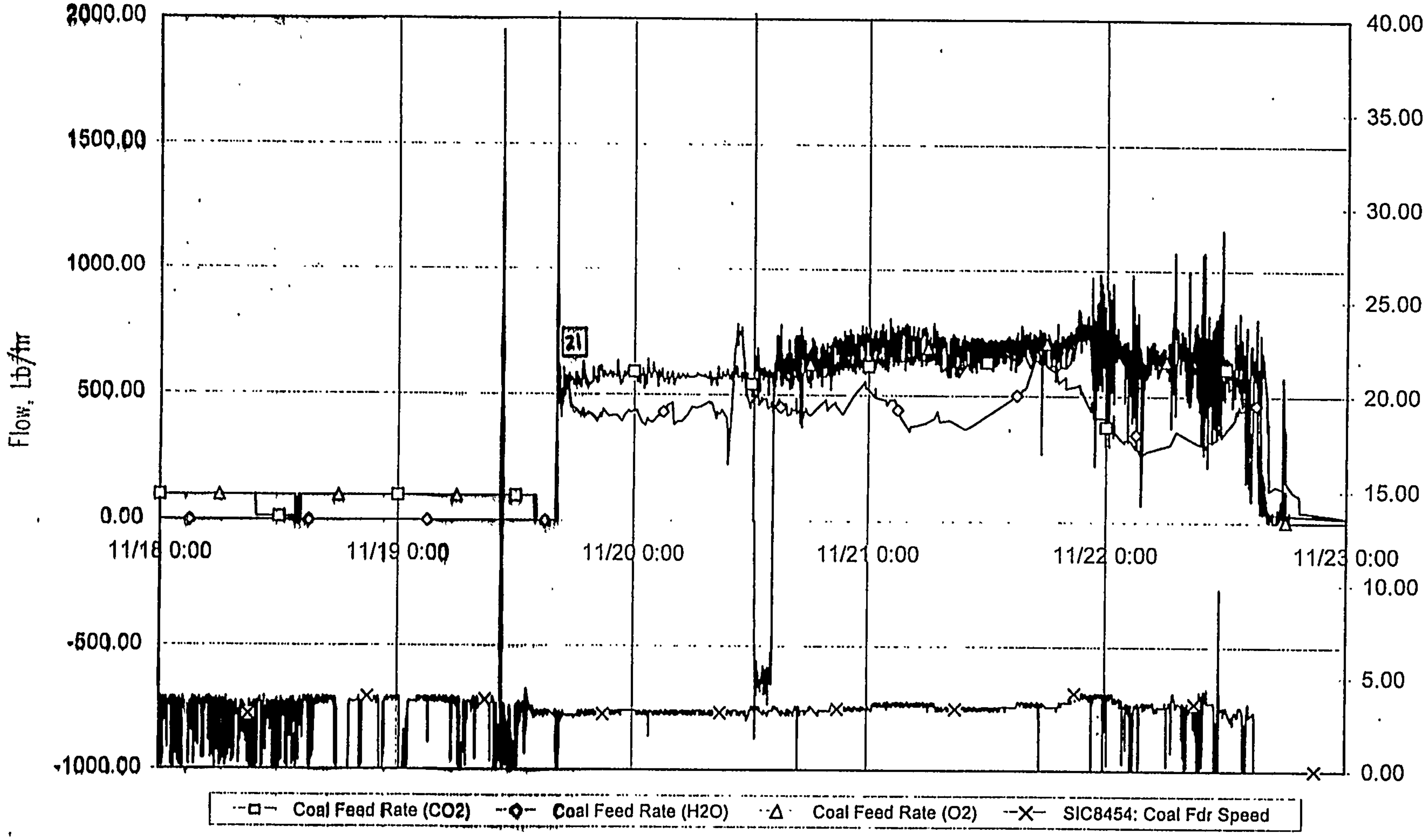
5.1.10-42 CY0201 Dipleg DP Profiles for November 18 Through November 22, 1996



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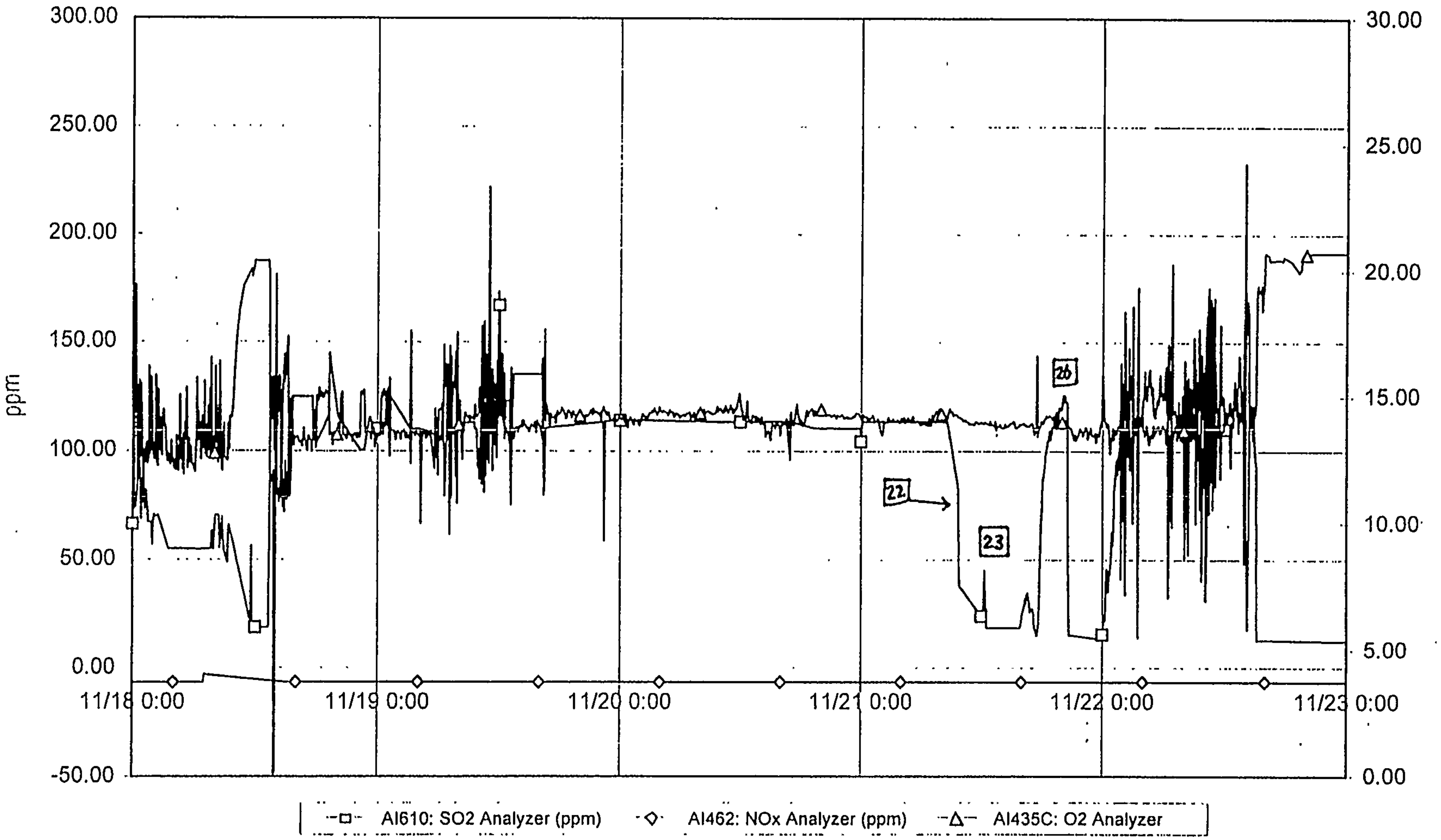
5.1.10-43 **Coal** Feed Rate for November 18 Through November 22, 1996



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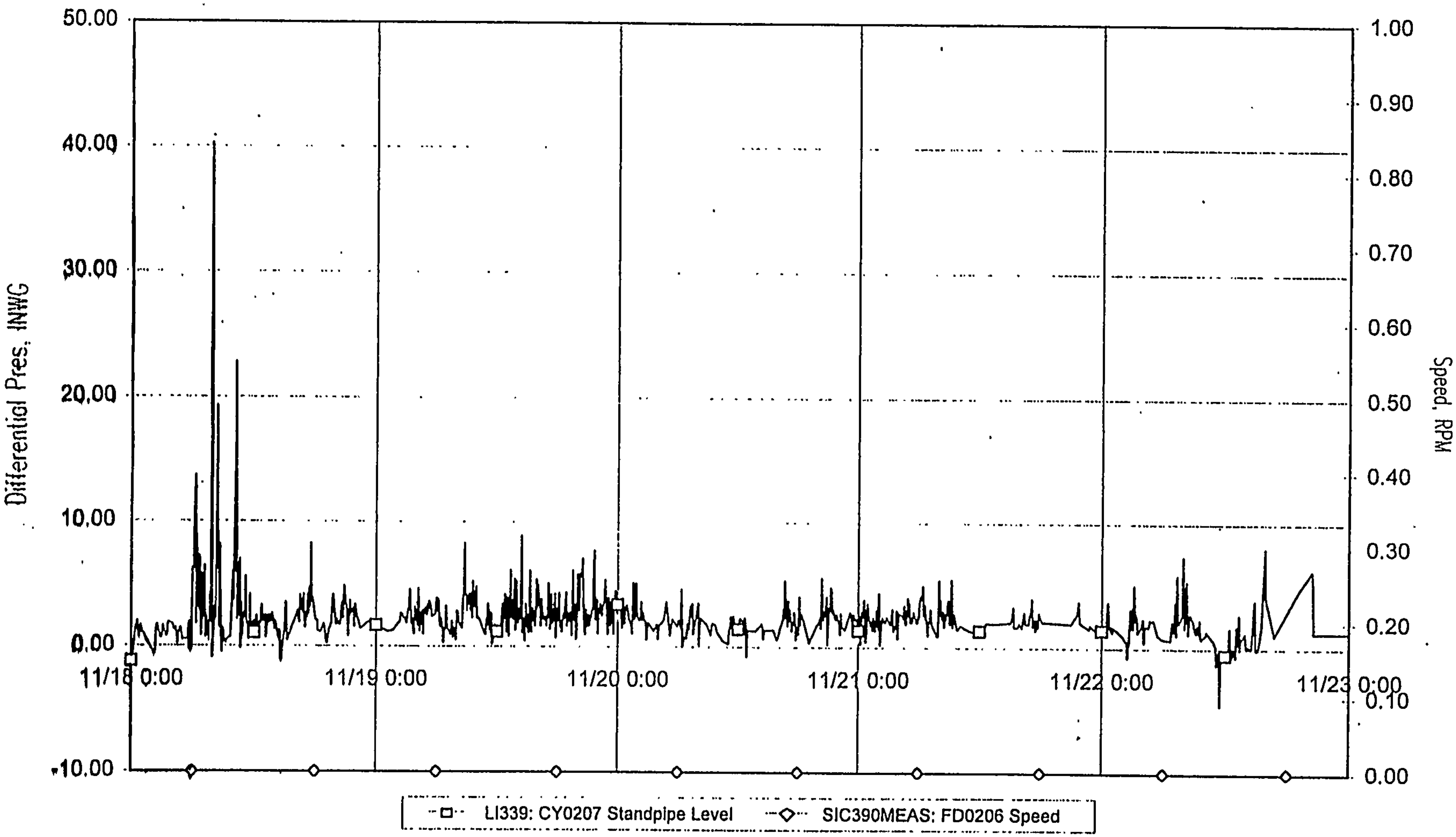
5.1.10-44 O_2, SO_2, and NO_x Analyzers for November 18 Through November 22, 1996



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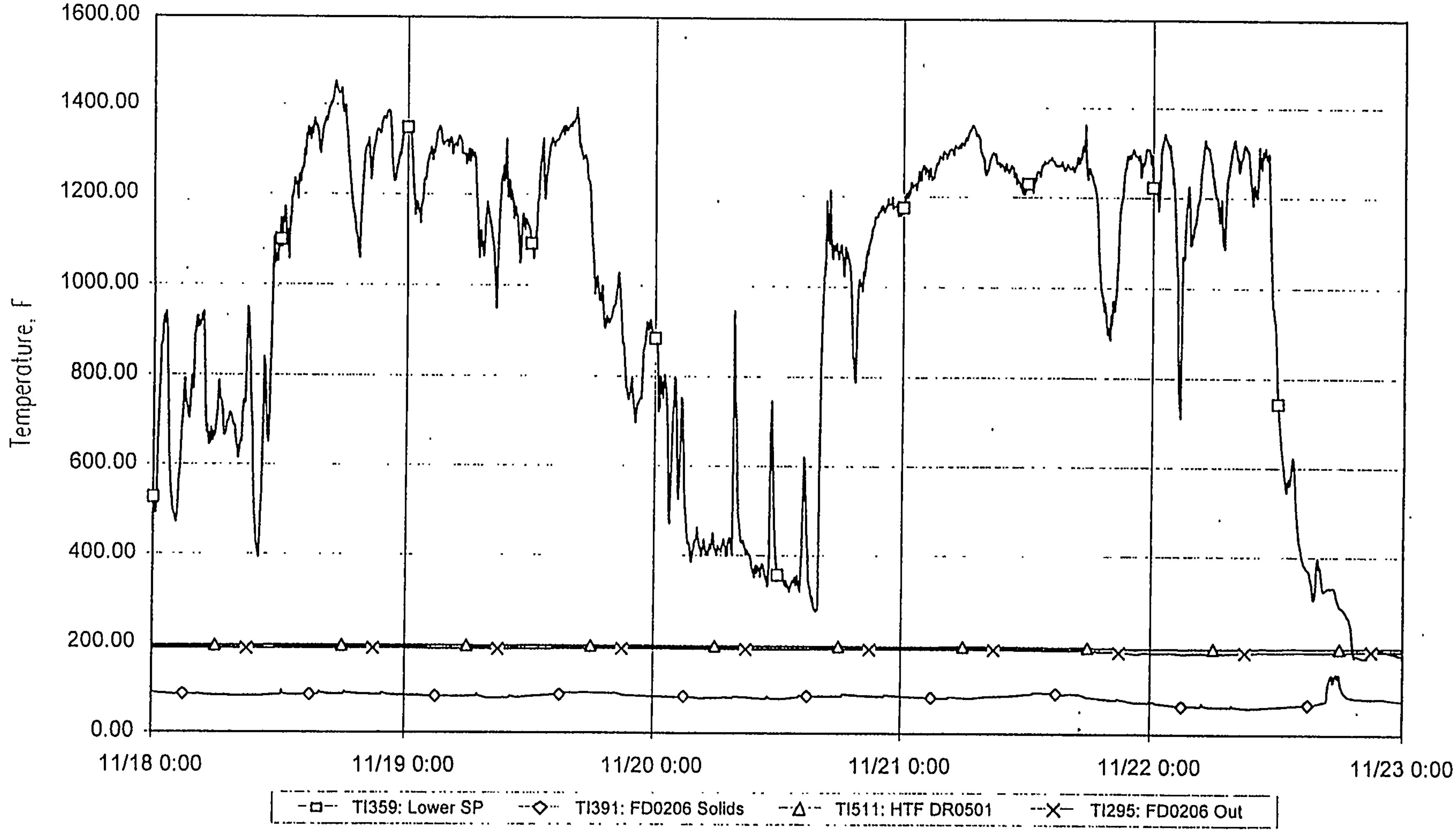

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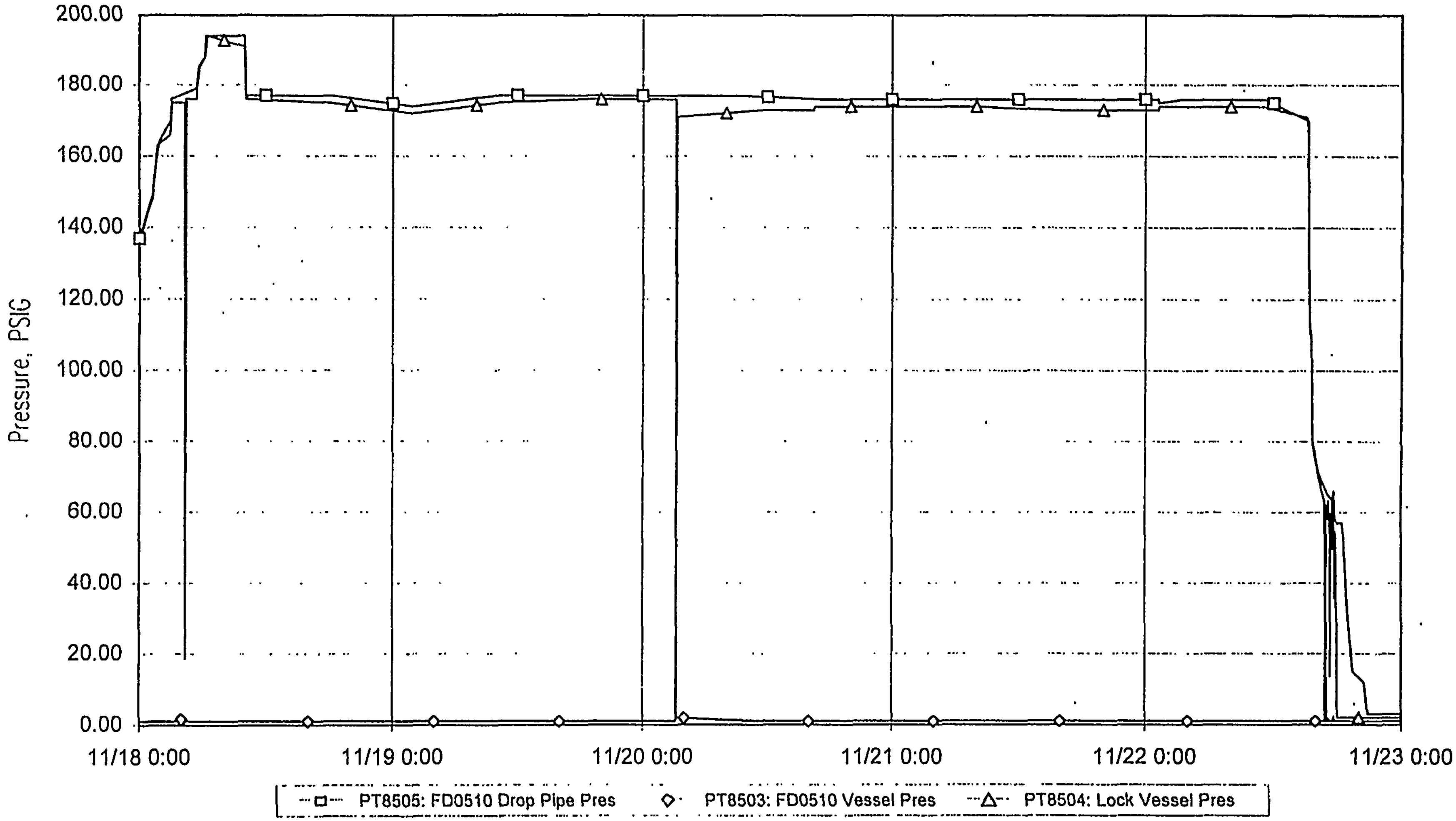

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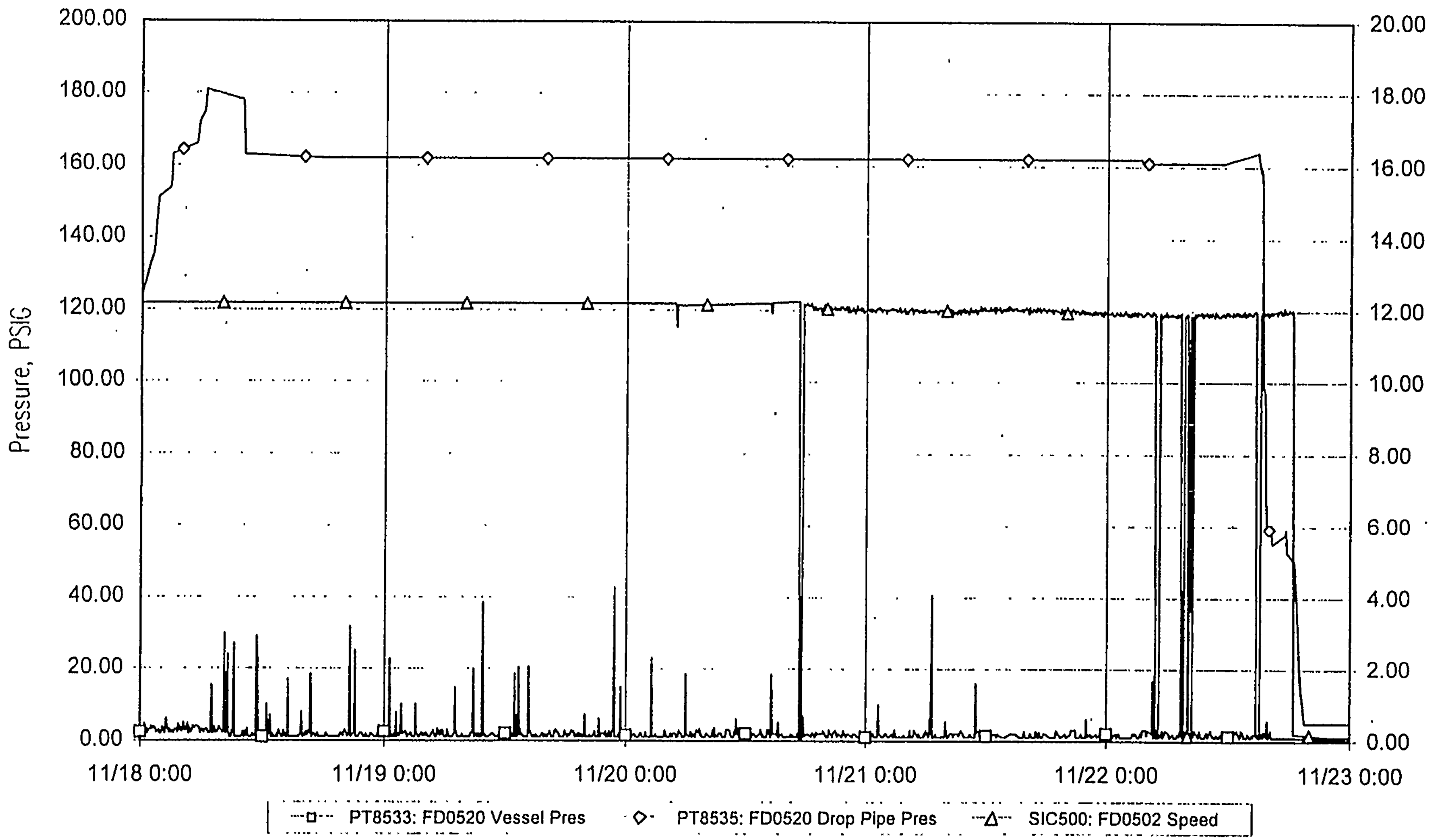

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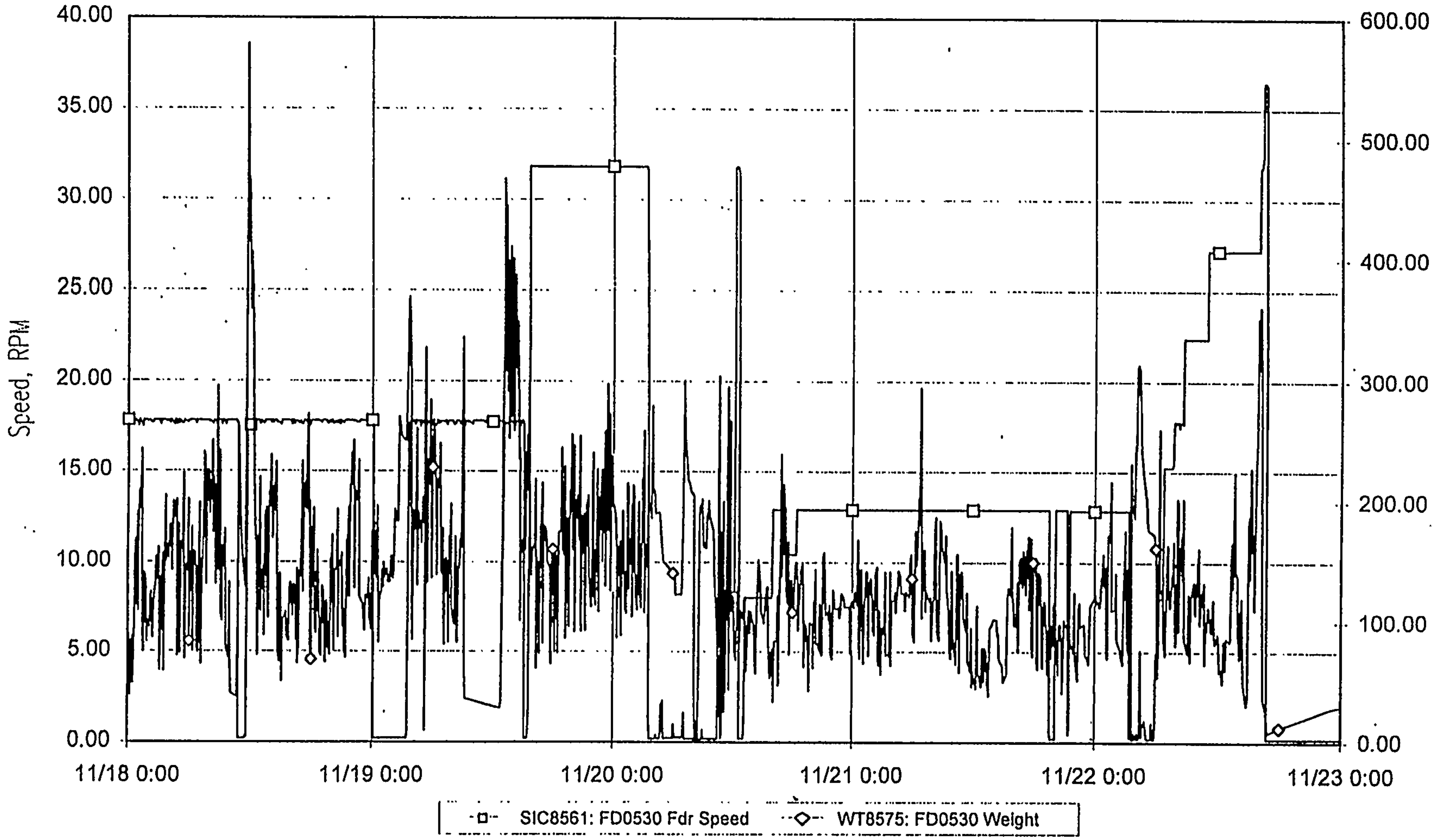

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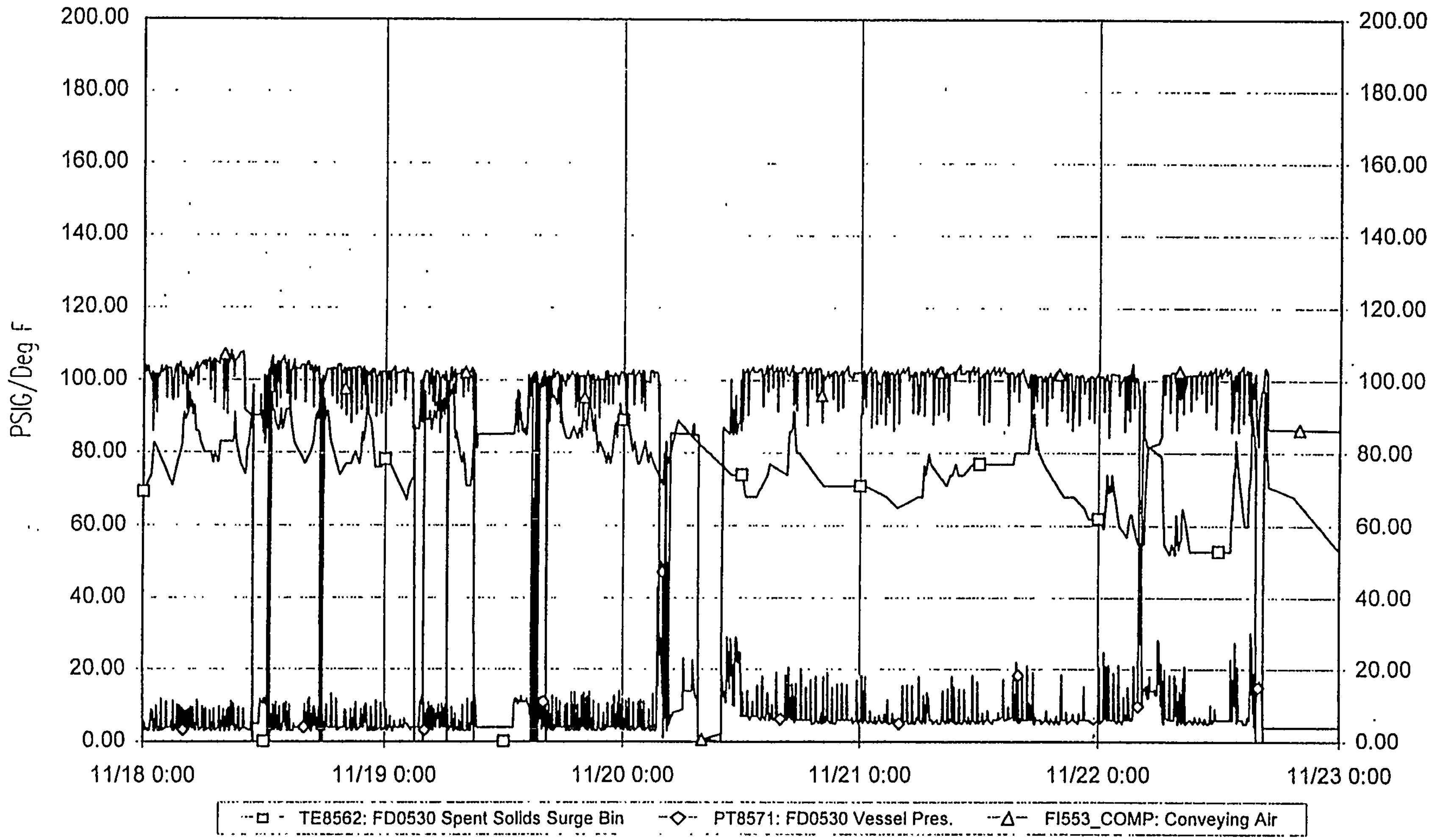

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5.1.10-50 FD0530 Feeder for November 18 Through November 22, 1996

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TERMS

List of Abbreviations

AAS	Automated Analytical Solutions
ADEM	Alabama Department of Environmental Management
APFBC	Advance Pressurized Fluidized-Bed Combustion
ASME	American Society of Mechanical Engineers
AW	Application Workstation
BFI	Browning-Ferris Industries
BFW	Boiler Feed Water
BMS	Burner Management System
BOC	BOC Gases
BOP	Balance-of-Plant
BPIR	Ball Pass Inner Race, Frequencies
BPOR	Ball Pass Outer Race, Frequencies
BSF	Ball Spin Frequency
CAD	Computer-Aided Design
CEM	Continuous Emissions Monitor
CFB	Circulating Fluidized Bed
CFR	Code of Federal Regulations
CHE	Combustor Heat Exchanger
CPC	Combustion Power Company
CPR	Cardiopulmonary Resuscitation
DC	Direct Current
DCS	Distributed Control System
DOE	U.S. Department of Energy
E & I	Electrical and Instrumentation
EERC	Energy and Environmental Research Center
EPRI	Electric Power Research Institute
FCC	Fluidized Catalytic Cracker
FETC	Federal Energy Technology Center
FFG	Flame Front Generator
FI	Flow Indicator
FIC	Flow Indicator Controller
FOAK	First-of-a-Kind
FTF	Fundamental Train Frequency
FW	Foster Wheeler
GBF	Granular Bed Filter
GC	Gas Chromatograph
GEESI	General Electric Environmental Services, Inc.
HTF	Heat Transfer Fluid
HTHP	High-Temperature, High-Pressure
I/O	Inputs/Outputs
ID	Inside Diameter
IF&P	Industrial Filter & Pump
IGV	Inlet Guide Vanes
IR	Infrared

LAN	Local Area Network
LIMS	Laboratory Information Management System
LOC	Limiting Oxygen Concentration
LOI	Loss on Ignition
LPG	Liquefied Propane Gas
LSLL	Level Switch, Low Level
MAC	Main Air Compressor
MCC	Motor Control Center
MS	Microsoft Corporation
MWK	The M. W. Kellogg Company
NDIR	Nondestructive Infrared
NFPA	National Fire Protection Association
NOx	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NPS	Nominal Pipe Size
OD	Outside Diameter
OSHA	Occupational Safety Health Administration
OSI	OSI Software, Inc.
P&IDs	Piping and Instrumentation Diagrams
PC	Pulverized Coal
PCD	Particulate Control Device
PDI	Pressure Differential Indicator
PDT	Pressure Differential Transmitter
PFBC	Pressurized Fluidized-Bed Combustion
PI	Plant Information
PLC	Programmable Logic Controller
PPE	Personal Protection Equipment
PSD	Particle Size Distribution
PSDF	Power Systems Development Facility
PT	Pressure Transmitter
RFQ	Request for Quotation
RO	Restriction Orifice
RSSE	Reactor Solid Separation Efficiency
SCS	Southern Company Services, Inc
SRI	Southern Research Institute
TCLP	Toxicity Characteristic Leaching Procedure
TR	Transport Reactor
TRDU	Transport Reactor Demonstration Unit
TSS	Total Suspended Solids
UND	University of North Dakota
UPS	Uninterruptible Power Supply
UV	Ultraviolet
VOCs	Volatile Organic Compounds
WPC	William's Patent Crusher
XXS	Extra, Extra Strong

List of Units

acfm	Actual Cubic Feet Per Minute
Btu	British Thermal Units
°F	Degrees Fahrenheit
°C	Degrees Celsius or Centigrade
ft	Feet
gpm	Gallons Per Minute
hp	Horsepower
hr	Hour
inWG	Inches, Water Gauge
mA	milliamps
MB	Megabytes
MW	Megawatts
m/s	Meters per second
μ or μm	Microns or Micrometers
dp_{50}	Particle Size Distribution at 50 Percentile
ppm (W or V)	Parts Per Million (by weight (w) or volume(v))
lb	Pounds
pph	Pounds per hour
psia	Pounds Per Square Inch Gauge
psig	Pounds Per Square Inch Gauge
ΔP	Pressure Drop
rpm	Revolutions Per Minute
s or sec	Seconds
scf	Standard Cubic Feet
scfm	Standard Cubic Feet Per Minute
V	Volts
W/PPPM	weight/parts per million

Power Systems Development Facility

Commissioning Report of M.W. Kellogg Transport Reactor Train, Westinghouse Particulate Control Device, and Associated Balance-of-Plant Equipment: September 1995 - December 1996

DOE Cooperative Agreement Number
DE-FC21-90MC25140

Volume II

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POWER SYSTEMS DEVELOPMENT FACILITY

COMMISSIONING REPORT OF M.W. KELLOGG TRANSPORT REACTOR TRAIN, WESTINGHOUSE PARTICULATE CONTROL DEVICE, AND ASSOCIATED BALANCE-OF-PLANT EQUIPMENT: SEPTEMBER 1995 - DECEMBER 1996

DOE Cooperative Agreement Number
DE-FC21-90MC25140 --25b

VOLUME II

Prepared by:
Southern Company Services, Inc.
Power Systems Development Facility
P.O. Box 1069
Wilsonville, AL 35186

August 1998

POWER SYSTEMS DEVELOPMENT FACILITY

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5.0 Commissioning of M.W. Kellogg Transport Reactor Train

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are contained in Volume I

of this report

5.1.11 Disengager Performance Tests

5.1.11.1 Background

During the October 1996 test run CCT2A, a high level of solids carryover from the reactor loop was observed when the system began operating with silica sand as start-up bed material. The geometric mean size of the sand was approximately 290 μm, with the top and bottom sizes of 500 and 45 μm, respectively. The solids separation system installed on the M. W. Kellogg Company (MWK) transport train was designed to separate ash and char with geometric mean sizes of less than 60 and 100 microns, respectively, with overall collection efficiencies of 99.96 percent with ash and 99.95 percent with char. Analysis of the test data collected indicated that the overall collection efficiency achieved ranged from 87 to 99.4 percent. The low collection efficiency resulted in greater than desired dust loading to the particulate control device (PCD). The excessive loss of solids from the reactor loop required frequent makeup of bed material to maintain a reasonable level of solids circulation in the reactor to permit the reactor to be operated at a lower than desired coal throughput.

A technical meeting held at Wilsonville on November 15, 1996, which was attended by representatives from GEESI (the cyclone system designer), MWK, SCS, and DOE who reviewed the performance of the solids separation system. It also provided an opportunity for GEESI to witness first hand the solids carryover from the reactor loop. At the meeting, the performance of the disengager was suspected to be the cause of the excessive solids carryover. It was speculated that difficulties of separated solids draining out of the disengager cone (cone angle of 8° to vertical) resulted in solids reentrainment out of the disengager. The design of the disengager was also discussed.

From operations to date, it was clear that solids carryover from the reactor loop increased whenever the solids circulation rate increased beyond a certain threshold, and it did not seem to be influenced very much by gas velocity. Also solids carryover at high-solids loading to the disengager did not seem to be affected by the particle size distribution. The material escaping the cyclone had geometric mean size comparable with the feed. The high solids loss as the standpipe solids level builds up does not permit filling the standpipe to the desired operating level. The excessive solids carryover makes it difficult to maintain the bed level in standpipe and more importantly it overwhelms the solids discharge system under the PCD, causing solids to accumulate in the PCD cone.

It was agreed at the meeting that GEESI would perform solids flowability test on the start-up bed material and that a test would be conducted at Wilsonville to characterize the performance of the disengager at high solids circulation rates approaching the design solids circulation rate of 250,000 lb/hr (combustion mode), at approximately 25 to 35 ft/s riser superficial gas velocity, ambient temperature (~200 to 300°F), and at 60 psig reactor pressure. To accomplish this, the dipleg of the primary cyclone was isolated from the solids traffic by inserting a plug inside the dipleg. This temporary modification essentially eliminated the primary cyclone from the circuit to test the performance of the disengager without interaction with the cyclone dipleg perturbations. The test was identified as CCT3A.

5.1.11.2 Disengager Performance Tests CCT3A

The disengager efficiency tests were performed on December, 12, 1996, using silica sand with a geometric mean diameter of approximately 400 μm. The riser velocity and solids loading to the disengager were varied to investigate their effect on disengager operation. The reactor was operated at approximately 60 psig and nominal 200°F. Sand was continuously fed into the reactor during the test except during the last period of testing when sand was not fed. Solid samples were taken from the reactor and the discharge of the PCD to represent the size distribution exiting the disengager. The PCD solids at the end of each test run period were transferred to the ash silo and a solid sample was taken for analysis. The amount of material lost to the PCD was estimated from the transfer bin weigh cell differentials. The particle size distribution at the inlet to the disengager was calculated from the standpipe and PCD solid flow rates and their size distributions. The average test operating conditions are presented in table 5.1.11A-1. The average solids circulation rate was calculated by assuming a gas-solid slip factor of 2. The particle size distribution was relatively finer at the beginning of the test.

Except for test period 3, the HX0203 vent valve (PDV384) was 100-percent open. During period 3, HX0203 vent valve was closed to prevent gas entrained from the disengager with the particles from bypassing through the HX0203 vent into the primary cyclone. The results from test period 3 will indicate whether this type of gas bypassing affects the disengager efficiency.

Experimental Findings

During the test, makeup sand was added intermittently into the reactor. The amount of sand fed and the average feed rate during the periods analyzed are presented in table 5.1.11A-2. Using the solids circulation rate and the solids collected by the PCD, the average disengager efficiency was estimated. The results are presented in table 5.1.11A-3.

From the particle size distribution of the circulating solids and the solids captured by the PCD (using ash silo solids size distribution), the grade efficiencies were calculated for each period.

The grade efficiencies for all test periods (except for period 4) were plotted as a function of particle size distribution as shown in figure 5.1.11A-1. The disengager cut diameters were read from figure 5.1.11A-1 and the results are presented in table 5.1.11A-3. The disengager grade efficiency curve was replotted using the normalized particle size as shown in figure 5.1.11A-2.

The following general conclusions can be drawn from the test results:

A. The disengager efficiency is lower than expected for the coarser particle size distribution used for this test.

B. Within the operational range of aeration/fluidization flow through HX0203, closing off PDV384 does not appear to affect the disengager performance.

C. The disengager appears to be more efficient at low riser superficial velocity at lower circulation rates.

D. Comparing results from test periods 1 and 5, it appears that the disengager efficiency is not very sensitive to solids loading. However, comparison of test period 2 and test period 5 data indicates some dependency of disengager efficiency on inlet solids loading.

E. The performance of the disengager during this test does not appear to be significantly different from its performance during previous test runs.

5.1.11.3 Cold Flow Testing of Disengager at GEESI (CCT3B)

From February 6 to 7, 1997, a full-scale cold-flow model of the disengager constructed from sheet metal with a Plexiglas top was tested at the GEESI facilities located in Lebanon, Penn. Representatives from GEESI, SCS, and MWK conducted the testing. The objective of the test was to characterize the efficiency of the disengager with sand, and to understand and identify the cause of the low solids separation efficiencies at the PSDF. Prior to the test, performance of the disengager was suspected as the cause of the dust carryover.

A schematic drawing of the experimental setup is shown in figure 5.1.11B-1. The test solid was silica sand from the PSDF with size distribution as shown in figure 5.1.11B-2. A screw feeder with maximum feed rate of ~350 lb/min was used to feed the solids into the disengager. An induction fan was used to convey the solids through the disengager and the secondary cyclone. The solids separated in the disengager and cyclone were collected in 55-gallon drums. The capacity of the drum under the disengager limited the duration of the test. If the disengager collected all the solids, it would hold approximately 700 to 800 lb of solids corresponding to a maximum test duration of 2.3 minutes.

Prior to February 2, 1997, GEESI completed a trial test (test 1). Samples from this test were sent to SCS for particle size distribution determination. The results are shown in figure 5.1.11B-2.

Discussions were held with GEESI regarding the possibility of increasing the feed rate into the disengager by either modifying the feeder motor-gear arrangement (which was later found to be impossible) or renting another feeder with a higher feed rate. The blower had enough capacity to allow the velocity through the disengager to be increased from 26 ft/s to 45 ft/s. In addition to sand, fly ash was also run through the disengager. Being of a lower density than sand, the maximum fly ash feed rate obtained was approximately a third of that of sand. Between February 6 and 7, 1997, nine test runs were completed. The results of the tests, including test 1, are summarized in table 5.1.11B-1. In test 2, two buckets of sand (each bucket containing ~50 lb of sand) were manually dumped directly into the disengager through the funnel while the screw was running at maximum speed. In test 4, the screw feeder was shut off and buckets of sand were manually dumped into the disengager in an attempt to increase the feed rate and also simulate slugs of solids entering the disengager. In test 5, the screw was not run. The solids were fed directly from the spout dumped from the bottom of the supersack. This run simulated a very high feed rate into the disengager. This test lasted for only 6.5 seconds. In tests 7 and 8, fly ash was used instead of sand.

The collection efficiencies are plotted in figure 5.1.11B-3 as a function of solid/gas weight ratio. Also included on the graph are data from the December 1996 test of the PSDF disengager with the cyclone dipleg blocked and test data from November 1996 operation of the PSDF transport reactor with the primary cyclone functional (dipleg not blocked off).

It appears from figure 5.1.11B-3 that the performance of the disengager during the cold flow tests at GEESI is similar to what had been observed during the PSDF disengager tests in December 1996. The data from the November 1996 test suggests strongly that the primary cyclone was not capturing solids since the disengager efficiency seemed to follow the same trend as the cold flow results. During all test campaigns at PSDF the cyclone dipleg was not sealed with solids in the standpipe. However, it is possible that gas was bypassing up through the dipleg into the cyclone causing the cyclone's efficiency to be penalized. It is also plausible that a hole (or gap) might have developed in the roof of the cyclone allowing gas and solids to bypass the gas outlet tube. Either of these scenarios would be consistent with the low-cyclone-pressure drop observed during the PSDF test runs.

The collection efficiency of the disengager with fly ash is significantly lower than with sand. Based on the fly ash and sand data, it could be speculated that the actual disengager efficiency with char and transport reactor ash may be significantly lower than the design values of 97.6 and 96.4 percent for combustion and gasification operations, respectively.

From the results of the disengager tests, the following recommendations and implementations were made:

A. Review the cyclone trend data from previous tests and compare the cyclone differential pressures with those of the December 1996 tests when the cyclone dipleg was blocked off. Trending should include cyclone dipleg temperature profile displayed with differential pressure.

   This was done and there was no evidence of significant gas bypass up the cyclone dipleg.

B. Provide GEESI with an alternate test material with properties close to the ash and char to be generated from the PSDF transport reactor for testing.

   Plans were drawn to test coke breeze at a later date.

C. Inspect the roof of the cyclone for cracks or holes that could provide a bypass path, especially around the gas outlet tube. It is possible that a dye test would be required to detect cracks that could seal when the unit is cold and open when the cyclone is heated up.

   Borescope inspection of the gas outlet pipe did not reveal any gross defects.

D. Conduct test at PSDF, with the cyclone dipleg sealed with solids, to investigate possible cyclone inefficiency caused by standpipe disengager gas venting up the cyclone dipleg. This test may require manually filling the dipleg.

E. Review data with GEESI and determine options available and action to take.

Modifications to cyclone gas inlet and outlet were suggested by GEESI. Cyclone inlet modifications (restriction of cross sectional area and change from a circular to a rectangular cross section) were carried out. Plans were made to move the disengager cold-flow model from GEESI to Wilsonville. This decision was made because more tests could be needed and since the disengager performance is expected to be very different in gasification than in combustion.

Table 5.1.11A-1

Average Test Conditions

Test No.	Average Riser Velo., ft/s	Average Solids Circ. Rate, lb/hr	Average Disengager DP, inH_2O	Average Cyclone DP, in H_2O	Average Riser Exit Temp. (TI355), °F	Average Reactor Pressure, psig
1	36	4,148	2.2	4.0	208	59
2	37	4,027	2.5	4.2	218	62
3	38	9,539	2.8	6.7	216	61
4	28	42,888	3.1	2.5	191	61
5	37	72,325	8.4	6.4	202	62

Table 5.1.11A-2

Sand Makeup Into Reactor

Test No.	Duration of External Feeding	Total Sand Fed, lb	Average Feed Rate, lb/hr
1	10:53 to 11:40	1,171	1,731
2	12:47 to 14:35	1,175	1,438
3	14:40 to 15:39	2,059	2,094
4	15:50 to 16:40	3,214	3,857
5	No External Feeding	0	0

Table 5.1.11A-3

Summary of Results

Test No.	Period Analyzed	Average Riser Velocity, ft/s	Average Solids Circ. Rate, lb/hr	Average Solids Loss Rate From Disengager lb/hr	Estimated Disengager Cut Diameter, μm	Disengager Efficiency Percent
1	10:37 to 11:40	36	4,148	213	72	94.5
2	12:39 to 14:35	37	4,027	556	82	86.2
3*	14:40 to 15:39	38	9,539	1,478	144	84.5
4	15:50 to 16:40	28	42,888	112	N/A	99.74*
5**	17:20 to 18:05	37	72,325	5,032	146	93

* Only one PCD dump cycle was observed in approximately 1 hour.
** With HX0203 solids circulation.
# PDV384 was closed.
N/A Not estimated.