Stoner Associates
Suite 900
5177 Richmond Ave.
Houston, TX 77056-6736
Tel. 713 626 1600
Fax. 713 622 7832

TRANSIENT REPORT FOR

OLYMPIC PIPE LINE COMPANY

SURGE ANALYSIS OF THE OLYMPIC PIPE LINE

ARCO PUMP STATION to
RENTON TERMINAL and
SEATTLE DELIVERIES

16 INCH LINE ONLY

STONER PROJECT NO. MAR9916

STONER ASSOCIATES, INC.
HOUSTON, TEXAS

DATE: **September 21, 1999**

PREPARED BY: **Gerald T. Moreland, P.E., Chief Engineer**
Jim McIvor, Senior Pipeline Engineer

TABLE OF CONTENTS

SA 002970

1.0 INTRODUCTION

This final report is issued to summarize and outline the hydraulic transient study on the Olympic Pipe Line from ARCO to Renton/Seattle Terminals, herein referred to as the Olympic System in this document. The scope of work was authorized by Subcontract Agreement with MARMAC Engineering on behalf of Olympic Pipe Line Company.

2.0 RESULTS of SIMULATIONS

The results of the transient simulations are presented in two parts. The first part is a set of simulations for closure of inlet valves in 4.0 seconds at four critical points. The second part is a set of simulations for the events of June 10, 1999, which resulted in a release at Milepost 15.9 on Olympic's 16-inch pipeline.

The maximum pressures at the following four locations on the 16-inch mainline based on these simulations were:

	REFERENCE LOCATION			
CASE Number	DISCHARGE FERNDALE V.327	RELEASE POINT MP 15.9	ALLEN JUNCTION MP 37.4	INLET BAYVIEW MV.1902
MAOP	1370 psig	1456 psig	1419 psig	1440 psig
MASP	1507 psig	1602 psig	1560 psig	1584 psig
1	1400 psig	1424 psig	1532 psig	1520 psig
2	1400 psig	1424 psig	1532 psig	1520 psig
3	1051 psig	608 psig	437 psig	434 psig
4	1262 psig	1040 psig	847 psig	810 psig
5	1402 psig	1422 psig	1521 psig	1515 psig
6	1283 psig	1108 psig	989 psig	962 psig
7	1081 psig	752 psig	456 psig	411 psig
8	1296 psig	1154 psig	1034 psig	1006 psig
9	1399 psig	1382 psig	1475 psig	1466 psig

MAOP = Maximum Allowable Operating Pressure
MASP = Maximum Allowable Surge Pressure (MAOP * 1.1)

SA 002971

2.1 INLET VALVE CLOSURE CASES

The four cases described below were simulated for the maximum flow rate for gasoline:

CASE 1 - Closure of Inlet Valve – Bayview Terminal, Q=9117 bbl/hr

CASE 2 - Closure of Inlet Valve – Bayview Terminal, Q=9228 bbl/hr

CASE 3 - Closure of Inlet Valve –Ferndale Pump Sta., Q=9117 bbl/hr

CASE 4 - Closure of Inlet Valve –Allen Pump Station, Q=9117 bbl/hr

2.2 EVENT of JUNE 10, 1999

The five cases described below were simulated for the flow rate on June 10, 1999 and the pressure conditions at 15:03:00 hours from Arco to Renton-Seattle Terminals.

**CASE 5 – Event of June 10, 1999, Original Sequence,
Mal-Function of RV1919**

**CASE 6 - Event of June 10, 1999, Original Sequence,
Proper Function of RV1919**

**CASE 7 - Event of June 10, 1999, Trip of ARCO first,
Mal-Function of RV1919**

**CASE 8 - Event of June 10, 1999, Original Sequence,
NEW RV2229 @ 1000 psig, Flow Switch
Trips Ferndale with 45 seconds delay,
Mal-Function of RV1919, New Set Points
CV1904 @ 500 psig, RV1919 @ 580psig,
No Mechanical Stop on CV1904**

**CASE 9 - Event of June 10, 1999, Original Sequence,
Proper Function of RV1919,
NO Flow Switch to Ferndale,
Mal-Function of RV2229, New Set Points
CV1904 @ 500 psig, RV1919 @ 580psig,
No Mechanical Stop on CV1904**

SA 002972

3.0 ANALYSIS SUMMARY

The system was simulated using the Stoner Pipeline Simulator (SPS) computer package. The numerical models emulated the piping, pumps, valves and the physical pipe profile. Using the input requirements for SPS, information from drawings and piping data provided by MARMAC Engineering and Olympic Pipe Line Company, several hydraulic models were developed for the Olympic System.

The naming convention of the model for the Olympic Pipe Line 16-inch system is primarily based on the station numbers and the pump station designation number. The 16" main line devices were named based on milepost (location). All block and control valves were named based on the flow diagrams and P&IDs provided ("device name"). The data sets reflect the device names used in the drawings and field tags. The variable naming convention is as follows:

NAME CONVENTION	MEANING
"device name":P-	Upstream Pressure - psig
"device name":P+	Downstream Pressure - psig
"device name":Q-	Upstream Flow – bbl/hr
"device name":Q+	Downstream Flow – bbl/hr
"device name":RPM	Rotational Speed – rpm
"device name":FR	Fraction Open
'device name":CF	Accumulative Volume – mbbl
Example:	
MV.1902:P-	Block Valve MV1902 at Bayview Inlet, Upstream Pressure in psig

The schematic diagrams for the model with device names and selected data are provided in the section labeled "FIGURES".

The SPS computer simulations assume primed systems (systems which are completely filled with liquid). Additional details on modeling parameters and assumptions are outlined in Section 4 and Appendix A.

Each section of the appendix corresponds to a particular case and consists of a table and reference to several plots in the corresponding appendix. The plots in the appendix include maximum pressure envelope for the modeled pipelines, pressure-time curves for selected pipeline locations, and flow-time curves for selected locations. Time plots show time on the x-axis versus one or more parameter(s), such as pressure or flow rate, on the y-axis. These plots illustrate the change with respect to time for the selected parameter(s).

SA 002973

MATRIX OF CASE STUDIES FOR OLYMPIC PIPE LINE
MAR9916

CASE DESCRIPTION		NOTES
Closure of Inlet valve at Bayview in 4 seconds; Flow Rate = 9117 bbl/hr	CASE 1	All Models / Cases on this page include the following:
Closure of Inlet valve at Bayview in 4 seconds; Flow Rate = 9228 bbl/hr	CASE 2	PUMPS: ARCO Pumps
Closure of Inlet valve at Ferndale in 4 seconds; Flow rate = 9117 bbl/hr	CASE 3	Cherry Point Pumps Ferndale Booster Pumps
Closure of Inlet valve at Allen in 4 seconds; Flow rate = 9117 bbl/hr	CASE 4	Ferndale Pumps Bayview Pumps Allen Pumps Woodinville Pumps
JUNE 10, 1999 CASE - Actual Flow Rate	**CASE 5**	**PIPELINE:**
June 10, 1999 - Original Sequence Commanded Trip ALLEN P2 ;Mal-Function of RV1919; CV1904 @ 600 psig; MV9102 triggered @ 730 psig; Flow rate = 8748 bbl/hr	CASE - EVENT with failed RV	Pipe - Allen to Woodin. Pipe - Cherry Pt to Fern. Pipe - Fern. To Bayview Pipe - Bayview to Allen Pipe - Allen to Woodin. Pipe - Woodin. To Renton Pipe - Renton to Seattle Pipe - Renton to Tosco
June 10, 1999 - Original Sequence Commanded Trip ALLEN P2 ; Functional RV1919; CV1904 @ 600 psig; MV9102 triggered @ 730 psig; Flow rate = 8748 bbl/hr	CASE 6 CASE - NORMAL with working RV	
June 10, 1999 - Trip ARCO Pumps First Allen on High Discharge Trip Control (1600 psig); Mal-Function of RV1919; CV1904 @ 600 psig; MV9102 triggered @ 730 psig; Flow rate = 8748 bbl/hr	CASE 7 ARCO Trip Instead of ALLEN	VALVES: Switching Valves - Renton ESD Valves Suction/Discharge Control Mainline Block Valves
June 10, 1999 - Original Sequence New RV2229 upstream MV1902 @ 1000 psig; Mal-Function of RV1919; CV1904 @ 500 psig; MV9102 triggered @ 700 psig; Flow rate = 8748 bbl/hr Mechanical Stop on CV1904 removed	CASE 8 NEW RV2229 RV1919 fails	RELIEF VALVES: Bayview - 8" Brooks RV1919, RV1932, New RV2229 Renton - 12" Brodie
June 10, 1999 - Original Sequence New RV2229 upstream MV1902 @ 1000 psig Mal-functions; Functional; RV1919 @ 580 psig & CV1904 @ 500 psig (maximum pressure) MV9102 triggered @ 700 psig; Flow rate = 8748 bbl/hr Mechanical Stop on CV1904 removed	CASE 9 FAIL NEW RV RV1919 working RV2229 fails	

SA 002974

The following is a summary of the starting conditions at the start of the transient for Cases 1 to 4:

LOCATION	MODEL DATA Case 1, 3, and 4	MODEL DATA Case 2
Cherry Point Discharge	267 psig	264 psig
Ferndale Flow Rate	9117 bbl/hr	9228 bbl/hr
Ferndale Suction	106 psig	103 psig
Ferndale Discharge	1051 psig	1039 psig
Bayview Suction	45 psig	10 psig
Bayview Discharge	111 psig	To Tanks
Allen Suction	60 psig	------
Allen Discharge	1152 psig	------

The following is a summary of the starting conditions at the start of the transient for Cases 5 to 9 (Event of June 10, 1999):

LOCATION	OLYMPIC DATA June 10, 1999 at 15:03	MODEL DATA	Error
Cherry Point Suction	19.0 psig	20.9 psig	+10.0%
Cherry Point Discharge	211.0 psig	212.8 psig	+0.8%
Ferndale Flow Rate	8748 bbl/hr	8748 bbl/hr	+ 0.0%
Ferndale Suction	65.0 psig	65.2 psig	+ 0.3%
Ferndale Discharge	993.0 psig	994.2 psig	+ 0.1%
Bayview Suction	72.0 psig	70.0 psig	- 1.4%
Bayview Discharge	217.0 psig	219.0 psig	+ 0.9%
Allen Suction	173.0 psig	173.0 psig	+ 0.0%
Allen Discharge	1437.0 psig	1437.3 psig	+ 0.0%
Woodinville Suction	419.0 psig	419.2 psig	+ 0.0%
Woodinville Discharge	552.0 psig	553.5 psig	+ 0.3%
Renton Inlet	248.0 psig	249.0 psig	+ 0.4%
Tosco Terminal	35.0 psig	35.0 psig	+ 0.0%
Seattle Terminal	40.0 psig	40.0 psig	+ 0.0%

SA 002975

3.2.1 CASE 1 - Closure of Inlet Valve – Bayview Terminal in 4.0 seconds Flow Rate = 9117 bbl/hr

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1400 psig
Release Point (MP 15.9)	1424 psig
Allen Junction (MP 37.4)	1532 psig
Inlet – Bayview	1520 psig

RELIEF OPERATION –

Device	Operation
RV1919	Closed
RV1932	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	Trip - Low Suction
Allen	Trip - Low Suction

Detailed Results

Appendix 1 contains plots of selected parameters versus time and distance

SA 002976

3.3.2 CASE 2 - Closure of Inlet Valve – Bayview Terminal in 4.0 seconds Flow Rate = 9228 bbl/hr

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1400 psig
Release Point (MP 15.9)	1424 psig
Allen Junction (MP 37.4)	1532 psig
Inlet – Bayview	1520 psig

RELIEF OPERATION –

Device	Operation
RV1919	Closed
RV1932	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	Trip – Low Suction
Allen	Trip - Low Suction

Detailed Results

Appendix 2 contains plots of selected parameters versus time and distance

SA 002977

3.2.3 CASE 3 - Closure of Inlet Valve – Ferndale Pump Station in 4.0 seconds Flow Rate = 9117 bbl/hr

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1051 psig
Release Point (MP 15.9)	608 psig
Allen Junction (MP 37.4)	437 psig
Inlet – Bayview	434 psig

RELIEF OPERATION –

Device	Operation
RV1919	Closed
RV1932	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	Trip – Low Suction
Bayview	CV.1963 closed

Detailed Results

Appendix 3 contains plots of selected parameters versus time and distance

3.2.4 CASE 4 - Closure of Inlet Valve – Allen Pump Station in 4.0 seconds Flow Rate = 9117 bbl/hr

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1262 psig
Release Point (MP 15.9)	1040 psig
Allen Junction (MP 37.4)	847 psig
Inlet – Bayview	810 psig
Inlet – Allen	620 psig

RELIEF OPERATION –

Device	Operation
RV1919	Opened
RV1932	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	Trip – High Discharge CV.1963 closed
Allen	Trip – Low Suction

Detailed Results

Appendix 4 contains plots of selected parameters versus time and distance

3.2.5 CASE 5 – Event of June 10, 1999, Original Sequence, Mal-Function of RV1919

CASE 5 was the simulation of the event on June 10, 1999 for the Olympic Pipe Line System from the 16-inch segment at ARCO / Cherry Point to the suction of Woodinville Station.

This case outlines the results for the simulation of the surge event of June 10, 1999 based on data and timeline of actions provided to Stoner by Olympic Pipe Line. The event of June 10, 1999 has simulation by the switching of flow at Renton from delivery to Tosco to Seattle. The simulation used the time sequence of valve operations and set point ramps provided by Olympic Pipe Line. The temporary flow reduction/stoppage at Renton caused the flow to "back-up" in the 16-inch line between Allen Pump Station and Renton. With this flow "back-up" and the increase in pressure at Allen, pump #2 at Allen Pump Station was commanded to shutdown at 15:23:35. The Bayview pump (P.301) had shutdown 35 seconds earlier (15:23:00) for unknown reasons. The simulation modeled all these events.

After the trip of Allen and Bayview pumps, CV1904 reacted to the pressure increase and started closing to hold the set point of 600 psig. CV1904 could not close completely due to mechanical stop on the operator at about 10% rotation (Valve Cv of 135).

RV1919 was set to open at 650 psig; however, it did not response as programmed. RV1919 failed to open fast enough or failed to open wide enough. Some mechanism or other malfunction prevented RV1919 from operating properly. It is not the purpose of this report to investigate the mechanical reasons for the malfunction. This case was to investigate the hydraulic response of the Olympic Pipe Line after the malfunction of RV1919. Regardless of how or why RV1919 malfunctioned, the pressure continued to rise between CV1904 and RV1919 after CV1904 was closed against its mechanical stop.

When the pressure between CV1904 and RV1919 exceeded 730 psig, MV1902 was commanded to close (set for 730 psig closure) in 62 seconds. After closure of MV1902, the pressure at the inlet (upstream of MV1902) to Bayview rose to a predicted 1515 psig (based on the simulation) due to effect of surge and line pack. This is 1.0% of the recorded pressure rise (1515/1500). The 1500 psig maximum pressure was the maximum pressure reported from a 1-second scan of the Olympic PLC records of the event.

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1402 psig
Release Point (MP 15.9)	1422 psig
Allen Junction (MP 37.4)	1521 psig
Inlet – Bayview	1515 psig
Allen Discharge	1450 psig

RELIEF OPERATION –

Device	Operation
RV1919	Mal-Function
RV1932	Closed
RV682	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	P.201 tripped – Unknown cause at 15:23:00
Allen	Unit 2 – manual trip at 15:23:35
Woodinville	No Trip

Detailed Results

Appendix 5 contains plots of selected parameters versus time and distance.

3.2.6 CASE 6 – Event of June 10, 1999, Original Sequence, Proper Function of RV1919

CASE 6 was the simulation of the event on June 10, 1999 with a properly functioning RV1919 for the Olympic Pipe Line System from the 16-inch segment at ARCO / Cherry Point to the suction of Woodinville Station. This case outlines the results for the simulation of the surge event of June 10, 1999 based on data and timeline of actions provided to Stoner by Olympic Pipe Line. All sequences of events were the same as CASE 5.

After the trip of Allen and Bayview pumps, CV1904 reacted to the pressure increase and started closing to hold the set point of 600 psig. CV1904 could not close completely due to mechanical stop on the operator at about 10% rotation (Valve Cv of 135). RV1919 was set to open at 650 psig and responded as programmed. The pressure between CV1904 and RV1919 did exceed 730 psig; therefore, MV1902 did not close (set for 730 psig closure).

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1283 psig
Release Point (MP 15.9)	1108 psig
Allen Junction (MP 37.4)	989 psig
Inlet – Bayview	962 psig
Allen Discharge	1450 psig

RELIEF OPERATION –

Device	Operation
RV1919	Opened – Maximum Flow 5700 bbl/hr
RV1932	Closed
RV682	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	P.201 tripped – Unknown cause at 15:23:00
Allen	Unit 2 – manual trip at 15:23:35
Woodinville	No Trip

Detailed Results

Appendix 6 contains plots of selected parameters versus time and distance.

3.2.7 CASE 7 – Event of June 10, 1999, Trip of ARCO first, Mal-Function of RV1919

CASE 7 was the simulation of the event on June 10, 1999 with the trip of ARCO pumps instead of Allen Unit #2 for the Olympic Pipe Line System from the 16-inch segment at ARCO / Cherry Point to the suction of Woodinville Station.

This case outlines the results for the simulation of the surge event of June 10, 1999 based on data and timeline of actions provided to Stoner by Olympic Pipe Line. The only change was the call for shutdown Allen Unit #2. The different sequence was to call for shutdown of ARCO pump instead. The event of June 10, 1999 has simulation by the switching of flow at Renton from delivery to Tosco to Seattle. The simulation used the time sequence of valve operations and set point ramps provided by Olympic Pipe Line. The temporary flow reduction/stoppage at Renton caused the flow to "back-up" in the 16-inch line between Allen Pump Station and Renton. With this flow "back-up" and the increase in pressure at Allen, the pumps (both) at ARCO Pump Station were commanded to shutdown at 15:23:35. The Bayview pump (P.301) had shutdown 35 seconds earlier (15:23:00) for unknown reasons. The simulation modeled all these events.

After the trip of ARCO, the inflow was stopped. CV1904 had no high pressure to react on and remained open. RV1919 did not need to open and was not a factor in the transient. Because the pressure at Bayview did not exceed 730 psig, MV1902 was not triggered and remained open.

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1081 psig
Release Point (MP 15.9)	752 psig
Allen Junction (MP 37.4)	456 psig
Inlet – Bayview	411 psig
Allen Discharge	1450 psig

RELIEF OPERATION –

Device	Operation
RV1919	Mal-Function – Not a factor
RV1932	Closed
RV682	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	Both Units – manual trip at 15:23:35
Cherry Point	No Trip
Ferndale	No Trip
Bayview	P.201 tripped – Unknown cause at 15:23:00
Allen	No Trip
Woodinville	No Trip

Detailed Results

Appendix 7 contains plots of selected parameters versus time and distance.

3.2.8 CASE 8 – Event of June 10, 1999, Original Sequence, NEW RV2229 @ 1000 psig, Flow Switch Trips Ferndale with 45 seconds delay, Mal-Function of RV1919, New Set Points CV1904 @ 500 psig, RV1919 @ 580psig, No Mechanical Stop on CV1904

CASE 8 was the simulation of the event on June 10, 1999 with a new relief valve upstream of MV1902 for the Olympic Pipe Line System from the 16-inch segment at ARCO / Cherry Point to the suction of Woodinville Station. This case outlines the results for the simulation of the surge event of June 10, 1999 based on data and timeline of actions provided to Stoner by Olympic Pipe Line. All sequences of events were the same as CASE 5. The new relief valve (RV2229) upstream of MV1902 was the same as RV1919 and was set to open at 1000 psig. A flow switch was modeled downstream of RV2229 to trigger the shutdown of all Ferndale pumps after a 45 seconds time delay.

After the trip of Allen and Bayview pumps, CV1904 reacted to the pressure increase and started closing to hold the set point of 500 psig. CV1904 closed completely trying to hold a downstream pressure of 500 psig. The mechanical stop on CV1904 was removed for this case.

RV1919 was set to open at 580 psig; however, it did not response as programmed. RV1919 failed to open fast enough or failed to open wide enough. Regardless of how or why RV1919 malfunctioned, the pressure rose above 500 psig and CV1904 completely closed.

MV1902 was not triggered and commanded to close (set for 700 psig closure) because the Bayview inlet pressure did not exceed 700 psig. After closure of Cv1904, the pressure at the inlet (upstream of MV1902) to Bayview rose to over 1000 psig and triggered the opening of the new relief valve (RV2229).

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1296 psig
Release Point (MP 15.9)	1154 psig
Allen Junction (MP 37.4)	1034 psig
Inlet – Bayview	1006 psig
Allen Discharge	1450 psig

RELIEF OPERATION –

Device	Operation
RV2229 (new)	Opened – Maximum flow was 5100 bbl/hr
RV1919	Mal-Function
RV1932	Closed
RV682	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	Trip by signal for Flow Switch on RV2229
Bayview	P.201 tripped – Unknown cause at 15:23:00
Allen	Unit 2 – manual trip at 15:23:35
Woodinville	No Trip

Detailed Results

Appendix 8 contains plots of selected parameters versus time and distance.

3.2.9 CASE 9 – Event of June 10, 1999, Original Sequence, Proper Function of RV1919, NO Flow Switch to Ferndale, Mal-Function of RV2229, New Set Points CV1904 @ 500 psig, RV1919 @ 580psig, No Mechanical Stop on CV1904

CASE 9 was the simulation of the event on June 10, 1999 with a mal-function of the new relief valve upstream of MV1902 for the Olympic Pipe Line System from the 16-inch segment at ARCO / Cherry Point to the suction of Woodinville Station. This case outlines the results for the simulation of the surge event of June 10, 1999 based on data and timeline of actions provided to Stoner by Olympic Pipe Line. All sequences of events were the same as CASE 5. The new relief valve (RV2229) upstream of MV1902 was the same as RV1919

and was set to open at 1000 psig. No flow switch was modeled downstream of RV1919 to trigger the shutdown of all Ferndale pumps. RV2229 failed to operate and did not open as programmed.

After the trip of Allen and Bayview pumps, CV1904 reacted to the pressure increase and started closing to hold the set point of 500 psig. CV1904 closed completely trying to hold a downstream pressure of 500 psig. The mechanical stop on CV1904 was removed for this case. RV1919 was set to open at 580 psig and responded as programmed.

MV1902 was not triggered and commanded to close (set for 700 psig closure) because the Bayview inlet pressure did not exceed 700 psig.

Summary of Results

MAXIMUM PRESSURES -

Location	Maximum Pressure
Ferndale Discharge	1399 psig
Release Point (MP 15.9)	1382 psig
Allen Junction (MP 37.4)	1475 psig
Inlet – Bayview	1466 psig
Allen Discharge	1450 psig

RELIEF OPERATION –

Device	Operation
RV2229 (new)	Mal-Function
RV1919	Opened – Maximum flow was 1600 bbl/hr
RV1932	Closed
RV682	Closed

PUMP OPERATION -

Device	Operation
ARCO Pumps	No Trip
Cherry Point	No Trip
Ferndale	No Trip
Bayview	P.201 tripped – Unknown cause at 15:23:00
Allen	Unit 2 – manual trip at 15:23:35
Woodinville	No Trip

Detailed Results

Appendix 9 contains plots of selected parameters versus time and distance.

4.0 MODELING PARAMETERS AND ASSUMPTIONS

4.1 MODELING ASSUMPTIONS for PIPES

The following assumptions were used in the simulations for the above cases. The Stoner Pipeline Simulator (SPS) was used for all simulations.

Pipe Conditions (Mainline) -

Nominal Size = 16 inch
Outside Diameter = 16.0 inch
Wall Thickness = 0.312 inch (nominal thickness)
Internal Diameter = 15.376 inch
Roughness = 0.0003 inch
MAOP = Maximum Allowable Operating Pressure
MASP = Maximum Allowable Surge Pressure (1.1 * MAOP)

Elevation Profiles = As provided by and modified by Olympic Pipe Line

LOCATION POINT	MAOP Psig	MASP Psig
Cheery Point Discharge	716.0	788.0
Ferndale Discharge		
Actual	1394.0	1533.0
Procedural	1370.0	1507.0
Release Point (MP 15.9)	1456.0	1602.0
Allen Junction Tie-in		
MP37.4	1419.0	1560.0
Bayview Inlet	1440.0	1584.0
Bayview Discharge	740.0	814.0
Allen Discharge	1440.0	1584.0
Woodinville Discharge	1298.0	1427.0
Renton Inlet	1440.0	1584.0

APPENDIX A contains a complete, detail listing of all model input data.

4.2 FLUID PROPERTIES AND CHARACTERISTICS

Fluid Properties –

Weight Density = 47.07 lbs/cf. @ 60 °F
Dynamic Viscosity = 0.55 centipoise @ 60 °F

Dynamic Viscosity = 0.50326 centipoise @ 70 °F
Bulk Modulus = 150000 psi @ 60 °F
Nominal Flowing Temperature = 70 °F
Vapor Pressure = 8.7 psia @ 70 °F

4.3 PUMP PERFORMANCE DATA

4.3.1 Equipment –

Pumps = Curves As provided by Olympic Pipe Line
All pump performance curves were
at 100% manufacturer's stated performance.

4.3.2 Controls –

ARCO Pumps were used in the model in this case.

Cherry Point Pump Shutdown -Pump Suction Pressure less than or equal 5 psig
Pump Discharge Pressure greater than 575 psig
Pump High Case shutdown greater than 600 psig

Ferndale Pump Shutdown - Suction Pressure less than 20 psig
Discharge Pressure greater than or equal 1400 psig
Pump High Case shutdown greater than 1500 psig

Bayview Pump Shutdown - Low Flow less than or equal 37.15 gpm
Pump Suction Pressure less than or equal 2 psig
Pump High Case shutdown greater than 700 psig
CV1963 Pressure greater than 600 psig

Allen Pump Station: Suction Pressure less than 20 psig
Discharge Pressure greater than or equal 1550 psig
Pump High Case shutdown greater than 1600 psig

Woodinville Pump Sta. Suction Pressure less than 20 psig
Discharge Pressure greater than or equal 1400psig
Pump High Case shutdown greater than 1500 psig

4.4 CONTROL VALVES

Control Valves (CV) = As provided by Olympic Pipe Line

APPENDIX A contains additional information.

4.5 BLOCK VALVES and RELIEF VALVES

Motor Valves (MV) = As provided by Olympic Pipe Line

Relief Valves (RV) = As provided by Olympic Pipe Line

APPENDIX A contains additional information.

	ARCO	TOSCO	CHENEY POINT	PENNDALE	BAYVIEW	ALLEN	WOODINVILLE	RENTON	SEATTLE
	PUMP STATION	PUMP STATION	PUMP STATION	PUMP STATION	PUMP STATION	PUMP STATION	PUMP STATION	STATION	DELIVERY
PUMP CONFIGURATION	SERIES	ONE ONLY	ONE ONLY	SERIES	SERIES	SERIES	SERIES	NONE	NONE
PUMP #1	ARCO.P1	P.300A	CP.PUMP	P.301	P.201	ALLEN.P1	WOODINVILLE.P1	********	********
SUCTION BLOCK	ARCO.P1.SB	V.301	V.1412	C.373	MV.1981	V.521	V.1510	********	********
DISCHARGE BLOCK	ARCO.P1.DB	V.307	V.1414	V.323	MV.1983	V.520	V.1511	********	********
BYPASS CHECK	ARCO.P1.CK	NONE	CP.PUMP.BC	CV.300	CK.1982	CK.506	CK.1501	********	********
PUMP #2	ARCO.P2	NONE	NONE	P.302	P.202	ALLEN.P2	WOODINVILLE.P2	********	********
SUCTION BLOCK	ARCO.P2.SB	********	********	V.324	MV.1986	V.519	V.1516	********	********
DISCHARGE BLOCK	ARCO.21.DB	********	********	V.325	MV.1990	V.518	V.517	********	********
BYPASS CHECK	ARCO.2.CK	********	********	CV.301	MV.1985	CK.506	CK.1500	********	********
PUMP #3	NONE	NONE	NONE	P.303	NONE	ALLEN.P3	NONE	********	********
SUCTION BLOCK	********	********	********	V.360	********	V.566	********	********	********
DISCHARGE BLOCK	********	********	********	V.361	********	V.565	********	********	********
BYPASS CHECK	********	********	********	CV.302	********	CK.508	********	********	********
STATION BYPASS	NONE	NONE	NONE	NONE	NONE	CK.515	CK.1503	NONE	NONE
PUMP STATION CONTROL	UNKNOWN	OFF	ON	ON	ON	ON	ON	********	********
LOW SUCTION TRIP	********	5	5	20	2	20	20	********	********
HIGH DISCHARGE TRIP	********	********	575	1400	NONE	1550	1400	********	********
HIGH CASE TRIP	********	********	600 (EVENT)	1500 (EVENT)	700	1600	1500	********	********
LOW FLOW SWITCH -gpm	********	********	NONE	NONE	26	NONE	NONE	********	********
								SEATTLE	
INLET BLOCK VALVE	UNKNOWN	CLOSED	NOT MODELED	V.373	MV.1902	MV.503	MV.1501	MV.602 V.667	V.702
SET POINT					700			CK.667	Override ●
								V.608	275 psig
STATION CONTROL VALVE	ARCO.FCV	NONE	V.1408	V.327	CV.1963	CV.517	CV.1508	TOSCO	V.704
SUCTION CONTROL	FLOW	CLOSED	20	60	45	60	60	V.669	Variable UPST
DISCHARGE CONTROL	8748 BBL/HR	CLOSED	450	1320	230 (EVENT)	1440	1320	CK.669	Set Point
					CV.1904			V.636	Override ●
					600 (EVENT)			Variable UPST	100 psig
								Set Point	
DISCHARGE CHECK VALVE	ARCO.CK	CV.352	CP.CHK	CV.303	NONE	CK.516	CK.1502	Override ●	
DISCHARGE BLOCK VALVE	ARCO.BD	********	V.1409	V.330	NOT MODELED	MV.509	MV.1504	175 psig	
RELIEF VALVE	NONE	NONE	NONE	NONE	RV.1919	NONE	NONE	V.662	V1901
SET POINT					650 (EVENT)			1200	NOT MODELED
					RV.1932				
					650				
					RV.2229				
					(PROPOSED)				

APPENDIX A

MODEL INPUT LISTING

Properties of Gasoline
- density @ 60°F = 47.07 pounds per cubic foot
- bulk modulus = 150,000 psi
- viscosity @ 60°F = 0.55 centipoise
- viscosity @ 71°F = .50326 centipoise
- vapor pressure = 8.7 psia

Default pipe roughness = 0.00025 inches

All block valves, Cv = 41,551 gallons per minute
All check valves, Cv = 6,061 gallons per minute

ARCO, 2 pumps in series, same data for both pumps
- pump suction fixed at 19 psig
- pump motor power = 350 horsepower
- pump motor speed = 1150 rpm
- pump speed = 1150 rpm
- pump head at best efficiency point = 163 feet
- pump power at best efficiency point = 401.6 horsepower based on water
- pump flow rate at best efficiency point = 8500 gallons per minute
- station suction/discharge pressure control valve Cv = 3100 gallons per minute
- control valve used equal percentage curve
- control valve actuator speed, full travel = 4 seconds

Pipe from ARCO to Cherry Point
- length = 4.0 miles
- inlet elevation = 102 feet
- outlet elevation = 119 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch
- pipe roughness = 0.0018 inch

Cherry Point
- United 14X24 DVS
- pump motor power = 1000 horsepower
- pump motor speed = 1782 rpm, pump speed = 1782 rpm
- pump head at best efficiency point = 568.3 feet
- pump power at best efficiency point = 1415 horsepower based on water
- pump flow rate at best efficiency point = 8500 gallons per minute
- station suction/discharge pressure control valve Cv = 3100 gallons per minute
- control valve used equal percentage curve and Set Pressure = 450 psig
- control valve actuator speed, full travel = 4 seconds
- suction controller set point = 19 psig
- discharge controller set point = 450 psig

Pipeline from Cherry Point to TOSCO
- length = 5.0695 miles
- inlet elevation = 119 feet
- outlet elevation = 180 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch

Pipeline from TOSCO to Ferndale
- length = 0.07575 miles, 400 feet
- inlet elevation = 180 feet
- outlet elevation = 180 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch

FERNDALE UNIT #1
- United 10 DVS, EX single stage
- pump motor power = 800 horsepower
- pump motor speed = 1782 rpm, pump speed = 1782 rpm
- pump head at best efficiency point = 481 feet
- pump power at best efficiency point = 691 horsepower based on water
- pump flow rate at best efficiency point = 4900 gallons per minute
- head curve correction = 0.8896
- flow correction = 0.9432
- power curve correction = 0.8390
- impeller changed from 22-inch to 20.75-inch diameter

FERNDALE UNIT #2
- United 10 x 19 DVS single stage
- General Electric, 2000-horsepower, 3600 RPM
- pump motor power = 2000 horsepower
- pump motor speed = 3570 rpm, pump speed = 3570 rpm
- pump head at best efficiency point = 1296 feet
- pump power at best efficiency point = 2994 horsepower based on water
- pump flow rate at best efficiency point = 8000 gallons per minute
- head curve correction = 0.9452
- flow correction = 0.9722
- power curve correction = 0.9190
- impeller changed from 18-inch to 17.5-inch diameter

FERNDALE UNIT #3

- United 10 x 19 DVS single stage
- General Electric, 2000-horsepower, 3600 RPM
- pump motor power = 2000 horsepower
- pump motor speed = 3570 rpm, pump speed = 3570 rpm
- pump head at best efficiency point = 1296 feet
- pump power at best efficiency point = 2994 horsepower based on water
- pump flow rate at best efficiency point = 8000 gallons per minute
- head curve correction = 0.9318
- flow correction = 0.9653
- power curve correction = 0.8994
- impeller changed from 18-inch to 17.375-inch diameter

Ferndale Pump Station

- station suction/discharge pressure control valve Cv = 4480 gallons per minute
- control valve used equal percentage curve
- control valve actuator speed, full travel = 4 seconds
- suction controller set point = 63 psig
- discharge controller set point = 1320 psig

Pipeline from Ferndale to Line Break location

- length = 15.9199 miles
- inlet elevation = 180 feet
- outlet elevation = 255 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch

Pipeline from Line Break location to Bayview

- length = 23.25774 miles
- inlet elevation = 255 feet
- outlet elevation = 60 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch

Bayview Pump Station/Terminal

- MV.1902
  set to close at downstream pressure (downstream of CV.1904) > 700 psig
  Cv closed = 0.001
  Cv open = 41551
  linear operator
  closing/opening time = 60-62 seconds
- inlet control valve, CV.1904,
  Cv open = 6778 gallons per minute
  Cv closed = 300 gallons per minute
  control valve used equal percentage curve
  control valve actuator speed, full travel = 4 seconds
  valve controlled on downstream pressure
  set to close when pressure > 600 psig
  pressure above set point to cause valve to fully close = 120 psig

Bayview Pump #202

- BAYVIEW PUMP P-202, SULZER 14 X 14 X 26 HSA
- TECO, 1250 HP, 1800 RPM
- pump motor power = 1250 horsepower
- pump motor speed = 1780 rpm, pump speed = 1780 rpm
- pump head at best efficiency point = 500 feet
- pump power at best efficiency point = 1139 horsepower based on water
- pump flow rate at best efficiency point = 7500 gallons per minute

Bayview Pump #201

- BAYVIEW PUMP P-201, SULZER 14 X 14 X 26 HSA
- TECO, 1250 HP, 1800 RPM
- pump motor power = 1250 horsepower
- pump motor speed = 1800 rpm, pump speed = 1780 rpm
- pump head at best efficiency point = 495 feet
- pump power at best efficiency point = 1148 horsepower based on water
- pump flow rate at best efficiency point = 7500 gallons per minute

Bayview Discharge (CV.1963)

- station suction/discharge pressure control valve Cv = 3100 gallons per minute
- control valve used equal percentage curve
- control valve actuator speed, full travel = 4 seconds
- suction controller set point = 66 psig

Brooks surge relief valve RV.1919

- Cv = 1296 gallons per minute
- set point = 650 psig
- lag time between set point recognition and valve action = 1.5 seconds
- pressure above set point to cause valve to fully open = 17.5 psig
- control valve actuator speed, full travel = 0.5 seconds

RV1919 was model to malfunction and only crack open (lift disk).
Therefore, the Cv was limited to about 40-50 maximum.
The total relieved volume was about 42+/- barrels

Brooks surge relief valve RV.1932

- Cv = 1296 gallons per minute
- set point = 650 psig
- lag time between set point recognition and valve action = 1.5 seconds
- pressure above set point to cause valve to fully open = 17.5 psig
- control valve actuator speed, full travel = 0.5 seconds

RV1932 did not operate in the simulation of the June 10, 1999 event

RELIEF HEADER

- relief header from surge relief valve to 16" line
- length = 28 feet
- inlet elevation = 60 feet
- outlet elevation = 60 feet
- outer diameter = 8.625 inch
- wall thickness = 0.25 inch

- relief header from 16" line to check valve
- length = 0.0481 miles, 254 feet
- inlet elevation = 60 feet
- outlet elevation = 60 feet
- outer diameter = 16.0 inch
- wall thickness = 0.375 inch

- relief header from check valve to tk-209
- length = 0.05833 miles, 308 feet
- inlet elevation = 60 feet
- outlet elevation = 60 feet
- outer diameter = 16.0 inch
- wall thickness = 0.375 inch
- tank 209 constant pressure = 12.625 psig

Pipeline from Line Bayview to Allen

- length = 2.026 miles
- inlet elevation = 60 feet
- outlet elevation = 25 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch
- roughness = 0.0018 inches

Allen Pump #1

- United, 10x19 DVS, single stage
- General Electric, 3600 RPM, 2500 horsepower
- pump motor power = 2500 horsepower
- pump motor speed = 3560 rpm, pump speed = 3560 rpm
- pump head at best efficiency point = 1454.67 feet
- pump power at best efficiency point = 3579.8 horsepower based on water
- pump flow rate at best efficiency point = 8500 gallons per minute
- head curve correction = 0.9467
- flow correction = 0.9730
- power curve correction = 0.9211
- impeller changed from 18.5-inch to 18.0-inch diameter

Allen Pump #2

- United, 10x16 DVS, single stage
- General Electric, 3600 RPM, 1500 horsepower
- pump motor power = 1500 horsepower
- pump motor speed = 3560 rpm, pump speed = 3560 rpm
- pump head at best efficiency point = 992.07 feet
- pump power at best efficiency point = 2199.35 horsepower based on water
- pump flow rate at best efficiency point = 7500 gallons per minute

Allen Pump #3

- United, 10x19 DVS, single stage
- General Electric, 3600 RPM, 2500 horsepower
- pump motor power = 2500 horsepower
- pump motor speed = 3560 rpm, pump speed = 3560 rpm
- pump head at best efficiency point = 1449.27 feet
- pump power at best efficiency point = 3561.29 horsepower based on water
- pump flow rate at best efficiency point = 8500 gallons per minute
- head curve correction = 0.9732
- flow correction = 0.9865
- power curve correction = 0.9600
- impeller changed from 18.5-inch to 18.25-inch diameter

Pipeline from Allen to Woodinville

- Friction factor adjusted to match delta p from recorded data
- length = 49.53 miles
- inlet elevation = 5 feet
- outlet elevation = 430 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch
- the friction factor has been adjusted to model the effects of DRA in this section of line

Woodinville Pump #1

- United, 10x16 DVS, single stage
- General Electric, 3600 RPM, 2500 horsepower
- pump motor power = 1000 horsepower
- pump motor speed = 3560 rpm, pump speed = 3560 rpm
- pump head at best efficiency point = 618.18 feet
- pump power at best efficiency point = 1389.8 horsepower based on water
- pump flow rate at best efficiency point = 7750 gallons per minute

Woodinville Pump #2

- United, 10x19 DVS, single stage
- General Electric, 3600 RPM, 1500 horsepower
- pump motor power = 2000 horsepower
- pump motor speed = 3560 rpm, pump speed = 3560 rpm
- pump head at best efficiency point = 1302.57 feet
- pump power at best efficiency point = 2155.2 horsepower based on water
- pump flow rate at best efficiency point = 8000 gallons per minute

Pipeline from Woodinville to Renton

- Friction factor adjusted to match delta p from recorded data
- length = 26.10 miles
- inlet elevation = 430 feet
- outlet elevation = 10 feet
- outer diameter = 16.0 inch
- wall thickness = 0.312 inch
- the friction factor has been adjusted to model the effects of DRA in this section of line

Surge Relief Valve at Renton

- Brodie 16-inch, Cv = 5360

Renton Station

- Renton station has been modeled to allow switching and flow/pressure control to either TOSCO or Seattle

Pipeline from Renton to Seattle

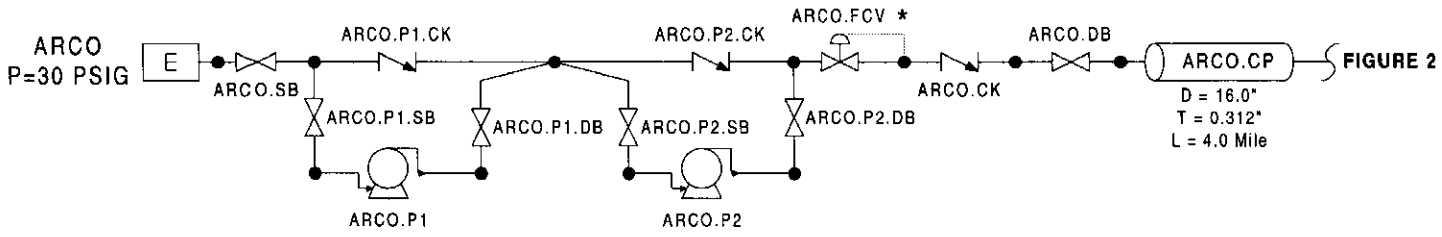
- Friction factor adjusted to match delta p from recorded data
- length = 12.27 miles
- inlet elevation = 10 feet
- outlet elevation = 4 feet
- outer diameter = 12.75 inch
- wall thickness = 0.281 inch
- the friction factor has been adjusted to model the effects of DRA in this section of line

Seattle

- Seattle terminal has been modeled as an external with a flow/pressure control valve

FIGURES 1 to 10

SCHEMATIC DIAGRAMS



ARCO PUMP STATION

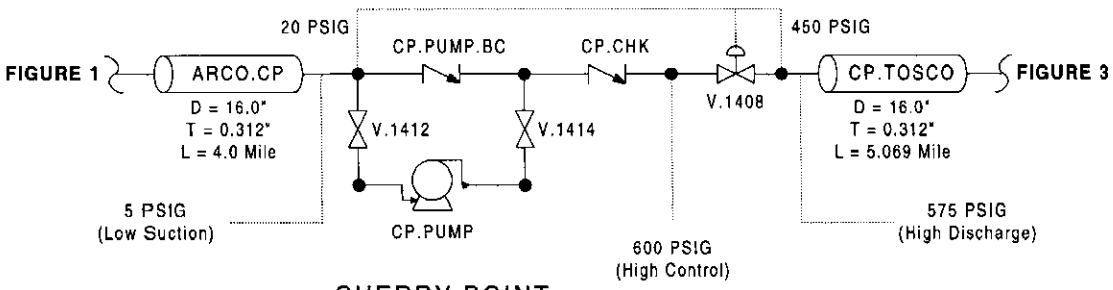
* NOTE: For control of ARCO pumps only; Model requirement

SA 003001

OLYMPIC PIPELINE

ARCO Pump Station
FIGURE 1

September 1999 #MAR9916



CHERRY POINT
PUMP STATION

Control set points
are maximum values.

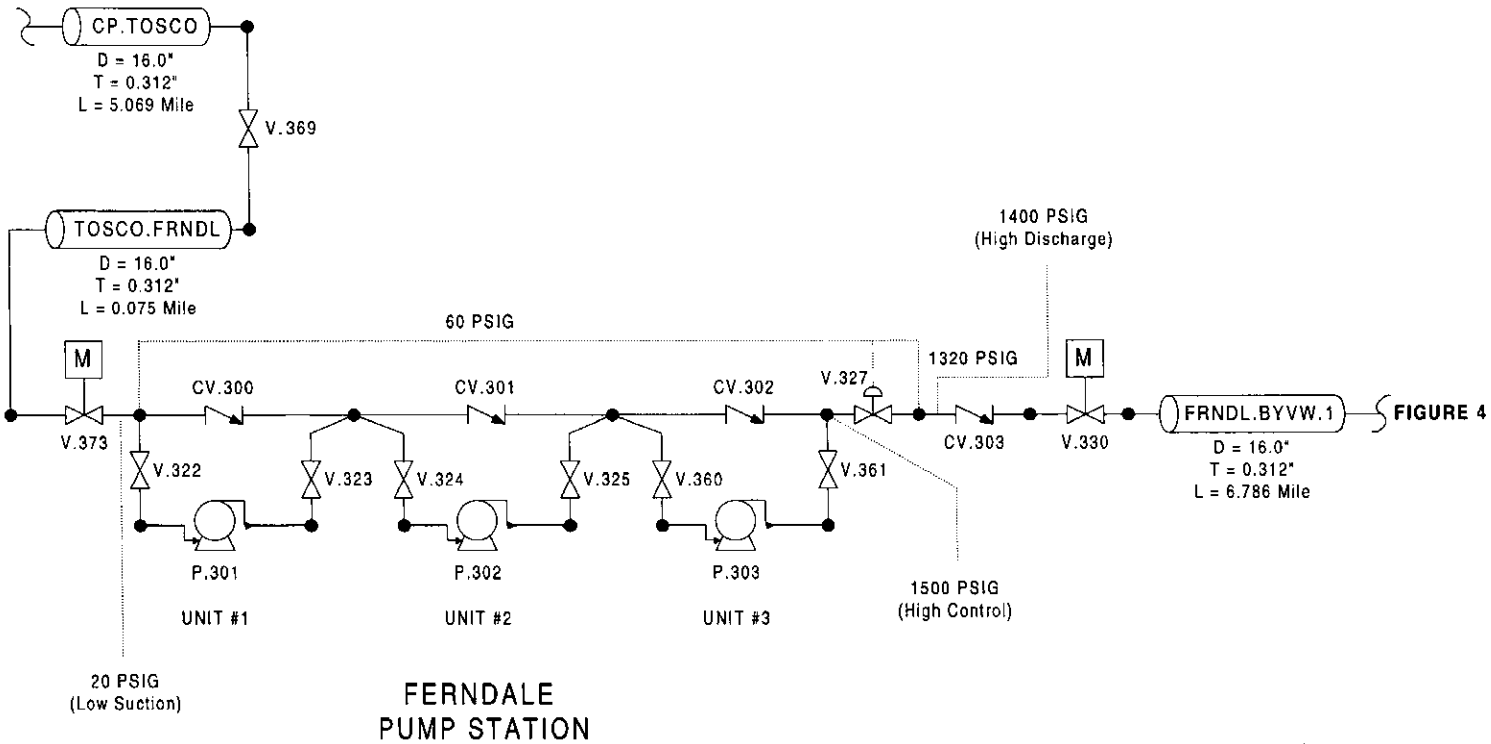
SA 003002

OLYMPIC PIPELINE

Cherry Point Pump Station
FIGURE 2

September 1999 #MAR9916

FIGURE 2



FERNDALE
PUMP STATION
Mile Post 0.00

Normal Shutdown
Does Not Close:
V.322, V.323
V.324, V.325
V.360, V.361

M - Motor Operator

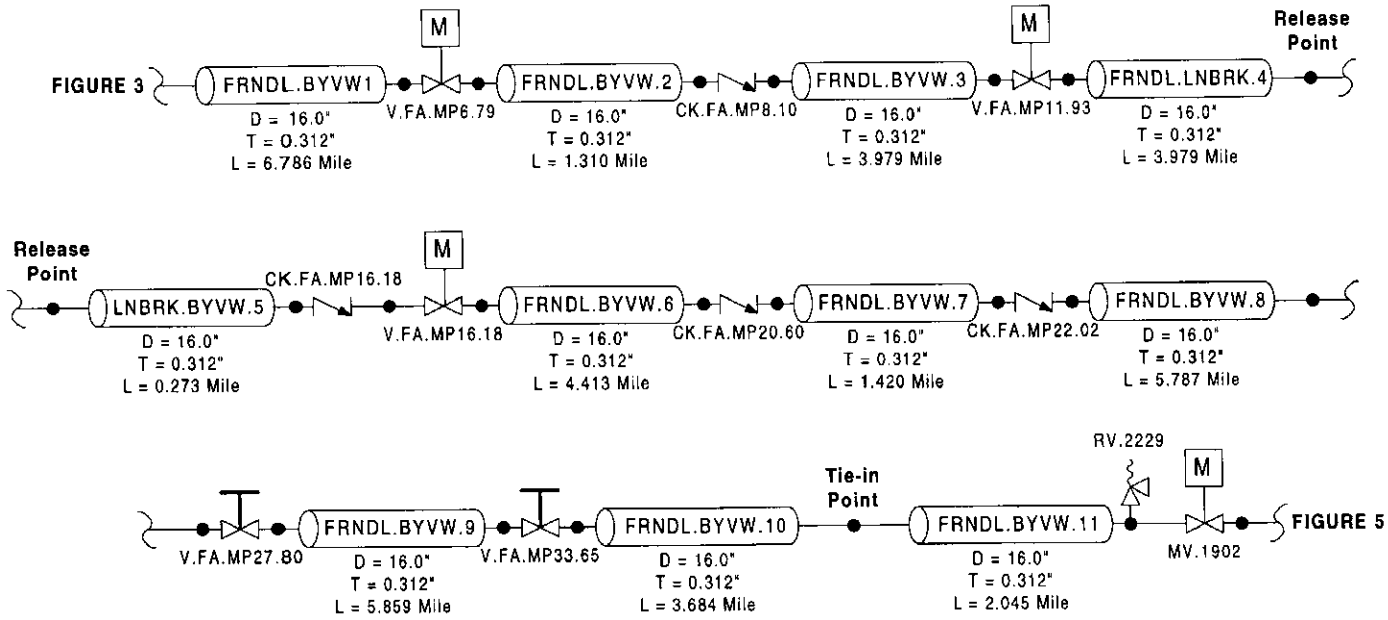
Control set points
are maximum values.

SA 003003

OLYMPIC PIPELINE

Ferndale Pump Station
FIGURE 3

September 1999 #MAR9916

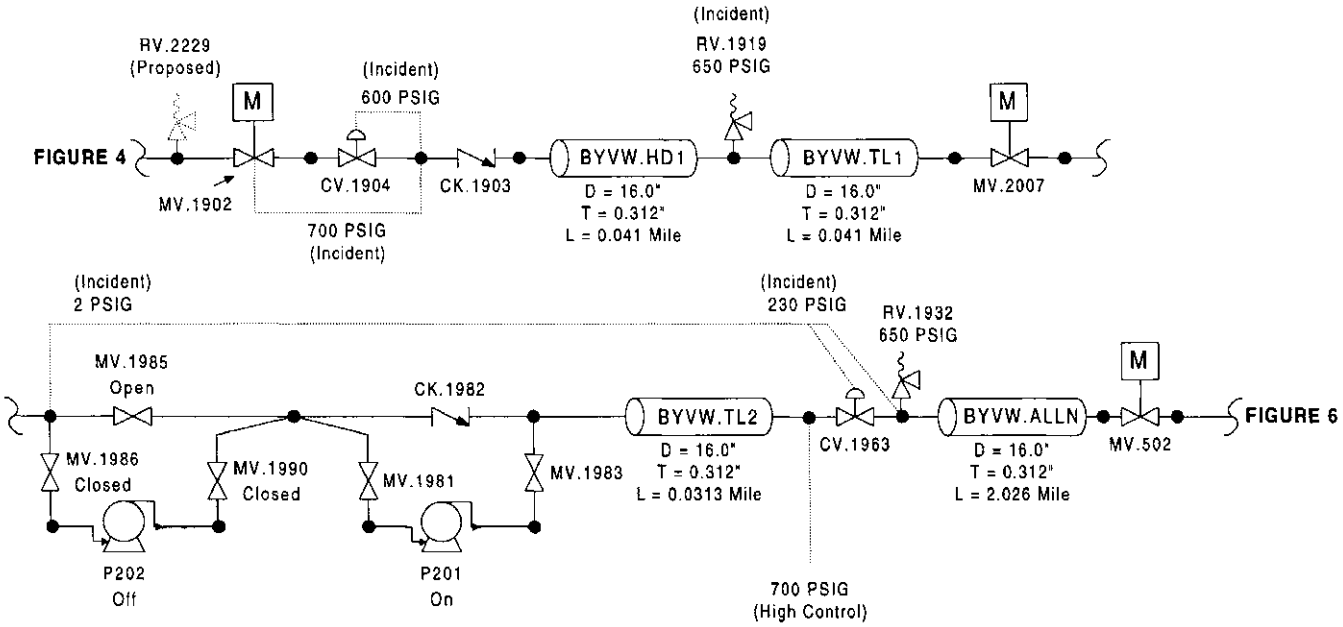


SA 003004

OLYMPIC PIPELINE

Ferndale to Bayview
FIGURE 4

September 1999 MAR9916



BAYVIEW
PUMP STATION
Mile Post 39.39

SA 003005

All Shutdowns
Close:
MV.1986, MV.1990
MV.1981, MV.1983

M - Motor Operator

Control set points
are maximum values.
"Incident" means June 10, 1999 event.

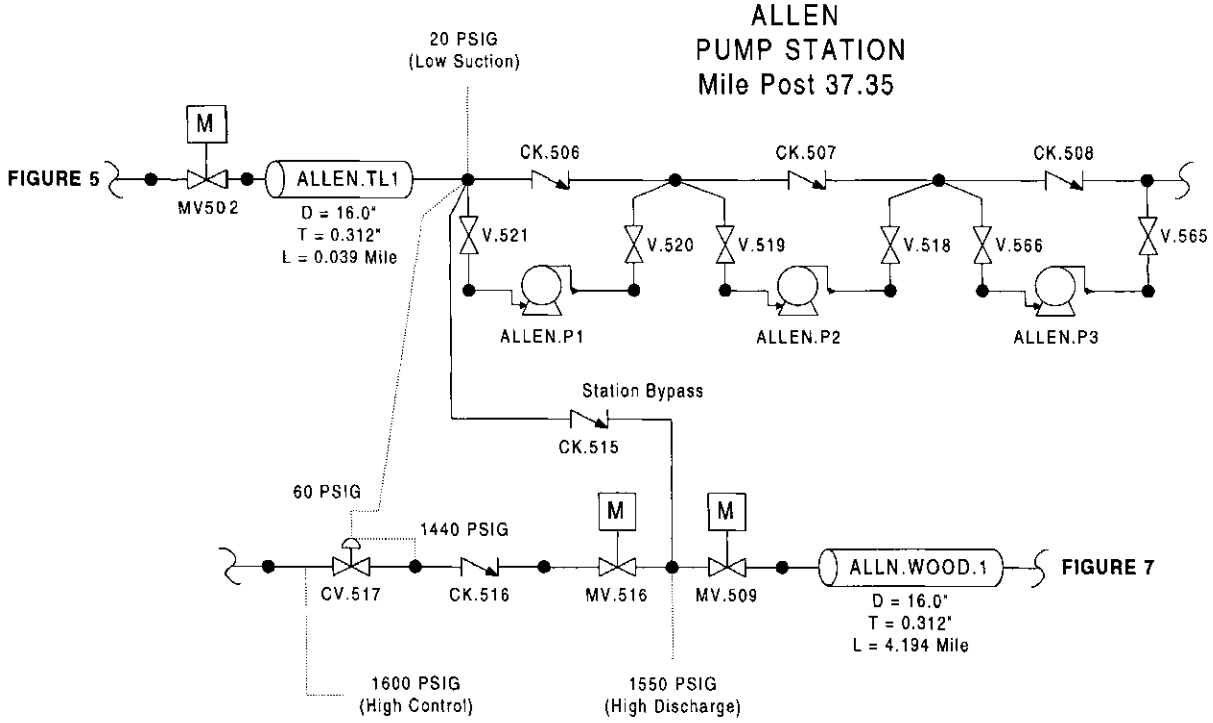
OLYMPIC PIPELINE

Bayview Terminal
FIGURE 5

September 1999 #MAR9916

Stoner Associates

ALLEN
PUMP STATION
Mile Post 37.35



Normal Shutdown
Does Not Close:
V.521, V.520
V.519, V.518
V.566, V.565

M - Motor Operator

Control set points
are maximum values.

SA 003006

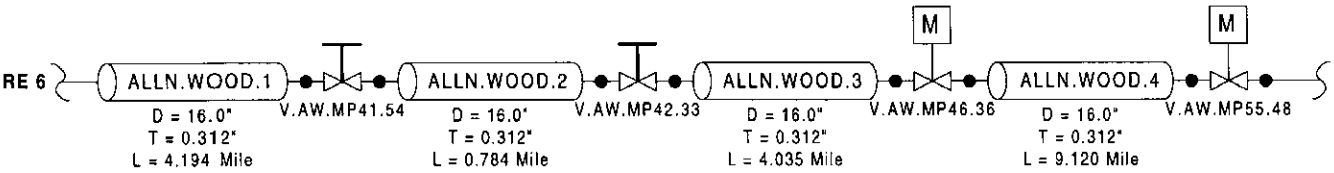
OLYMPIC PIPELINE

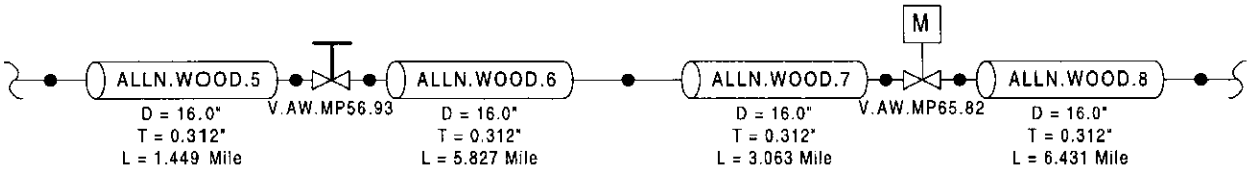
Allen Pump Station
FIGURE 6

September 1999 #MAR9916

Stoner Associates

FIGURE 6





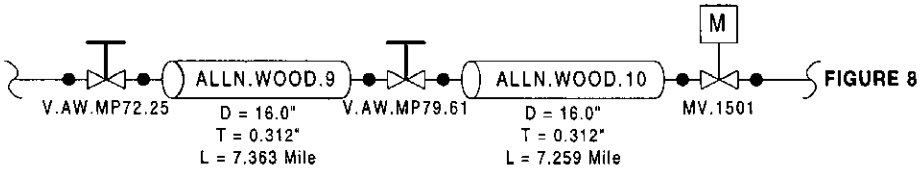


FIGURE 8

M - Motor Operator

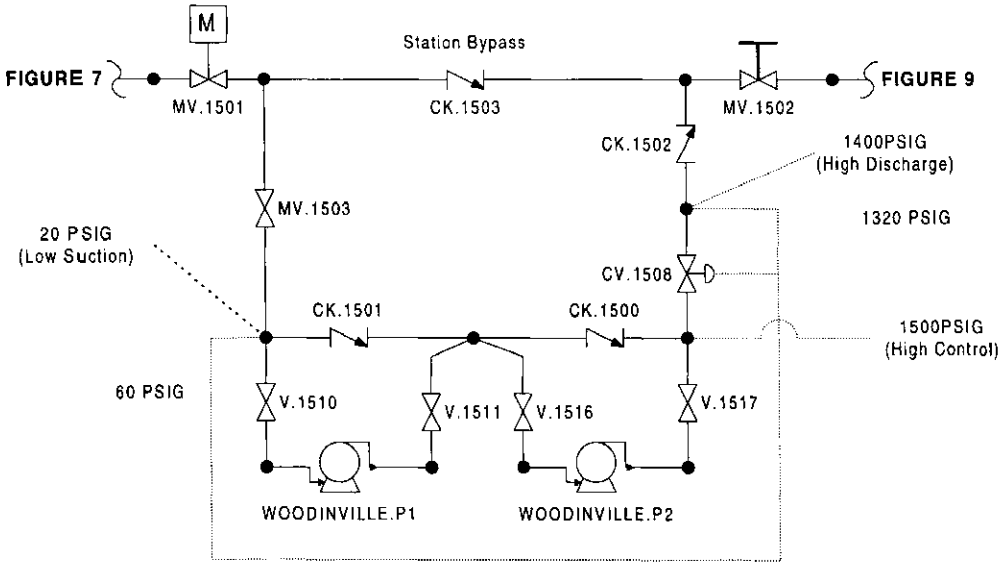
T - Hand Operator

SA 003007

OLYMPIC PIPELINE

Allen to Woodinville
FIGURE 7

September 1999 #MAR9916



WOODINVILLE
PUMP STATION
Mile Post 86.87

Normal Shutdown
Does Not Close:
V.510, V.511
V.516, V.517

M - Motor Operator

T - Hand Operator

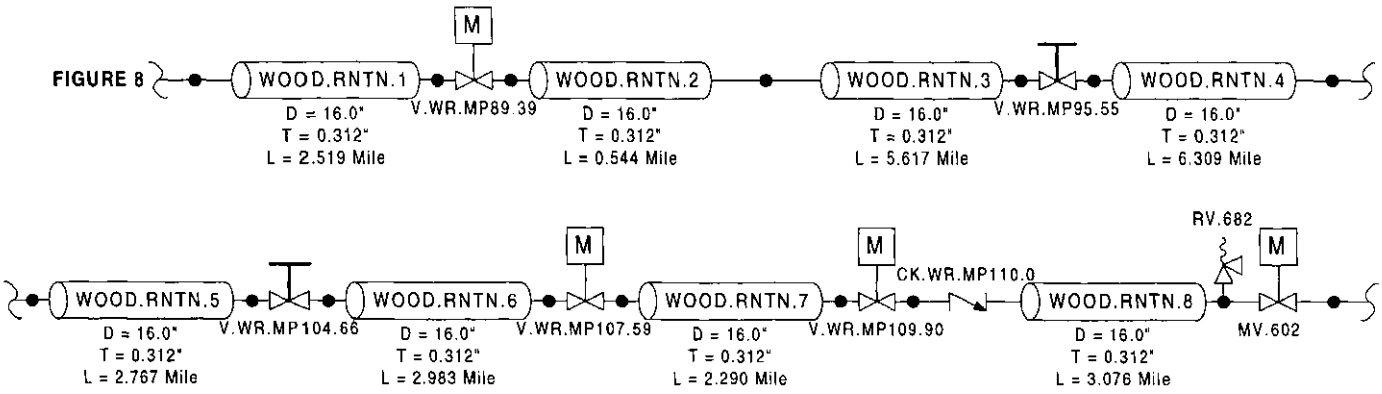
Control set points
are maximum values.

OLYMPIC PIPELINE

Woodinville Pump Station
FIGURE 8

September 1999 #MAR9916

SA 003008



M - Motor Operator

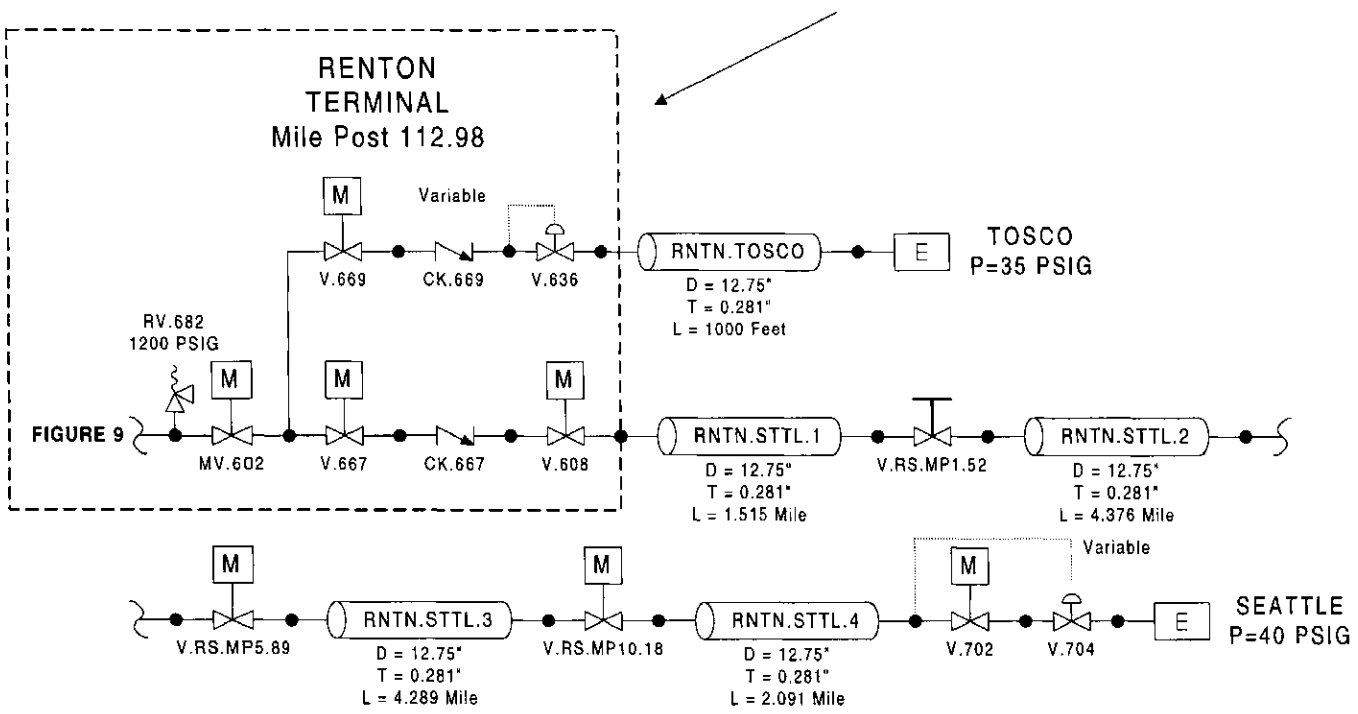
T - Hand Operator

SA 003009

OLYMPIC PIPELINE

Woodinville to Renton
FIGURE 9

September 1999 #MAR9916



SA 003010

OLYMPIC PIPELINE

Renton Station to Seattle
FIGURE 10

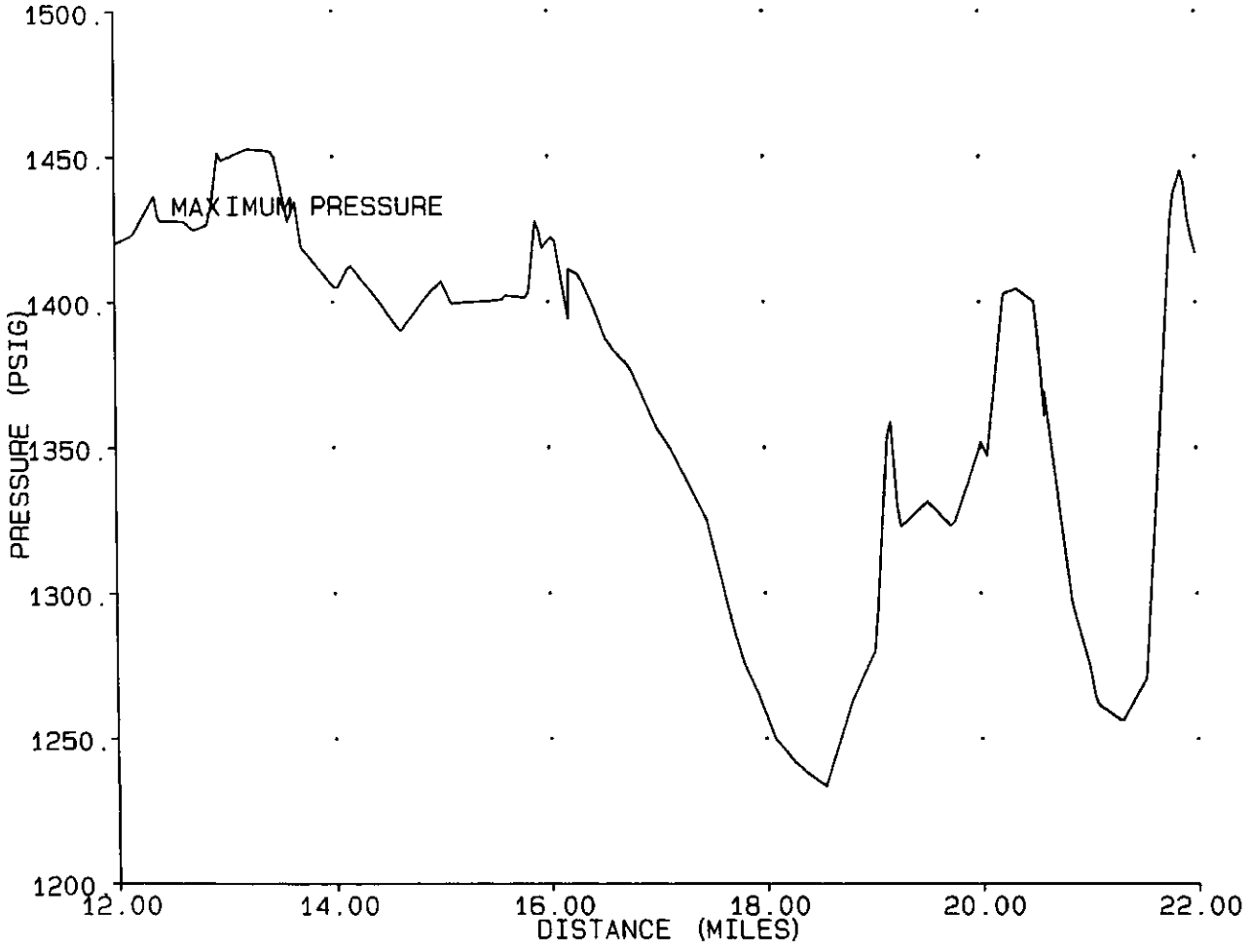
September 1999 #MAR9916

APPENDIX 1

CASE 1 - Closure of Inlet Valve – Bayview Terminal

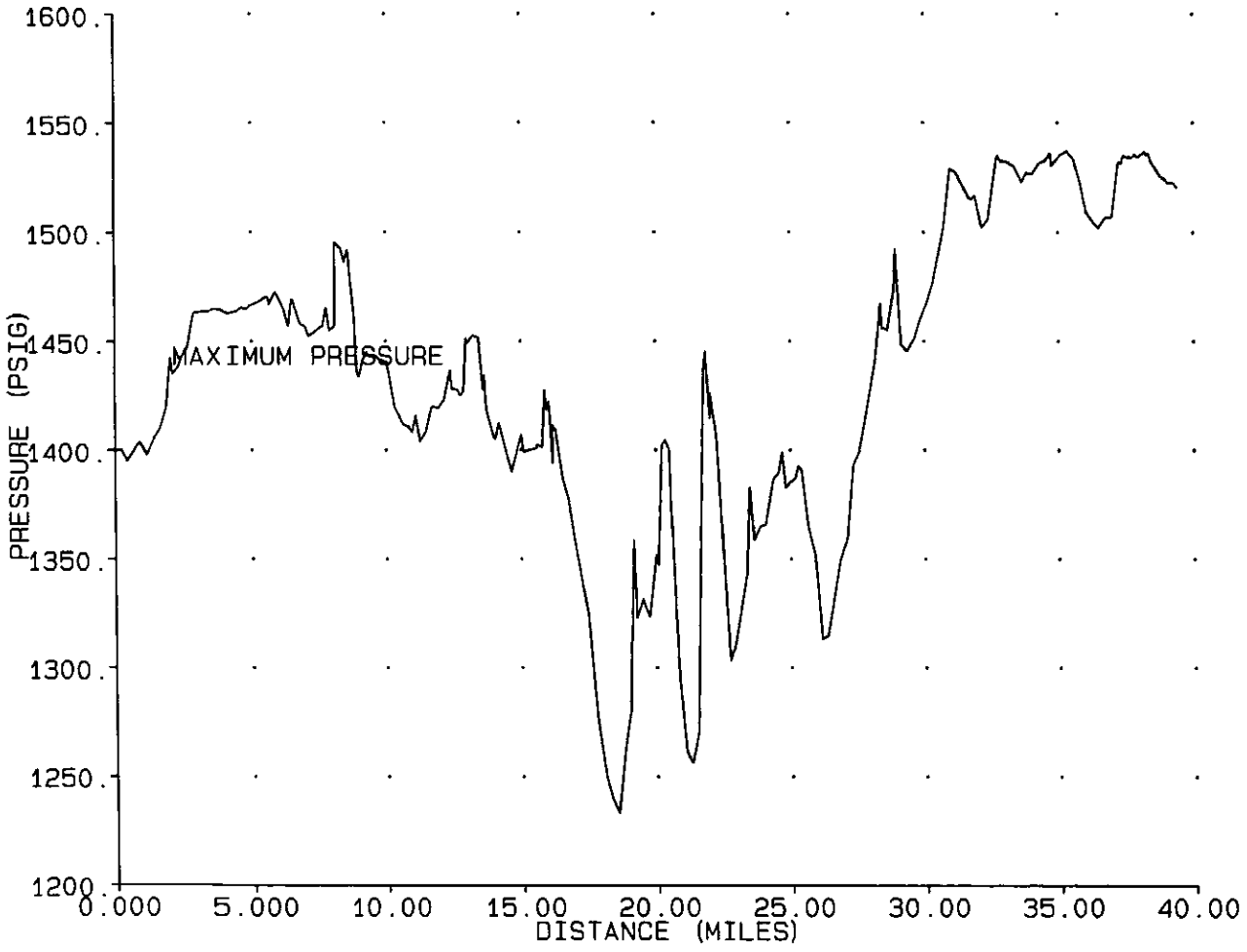
Flow Rate = 9117 bbl/hr

CASE 1, FIGURE 1, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINHAM CITY LIMITS



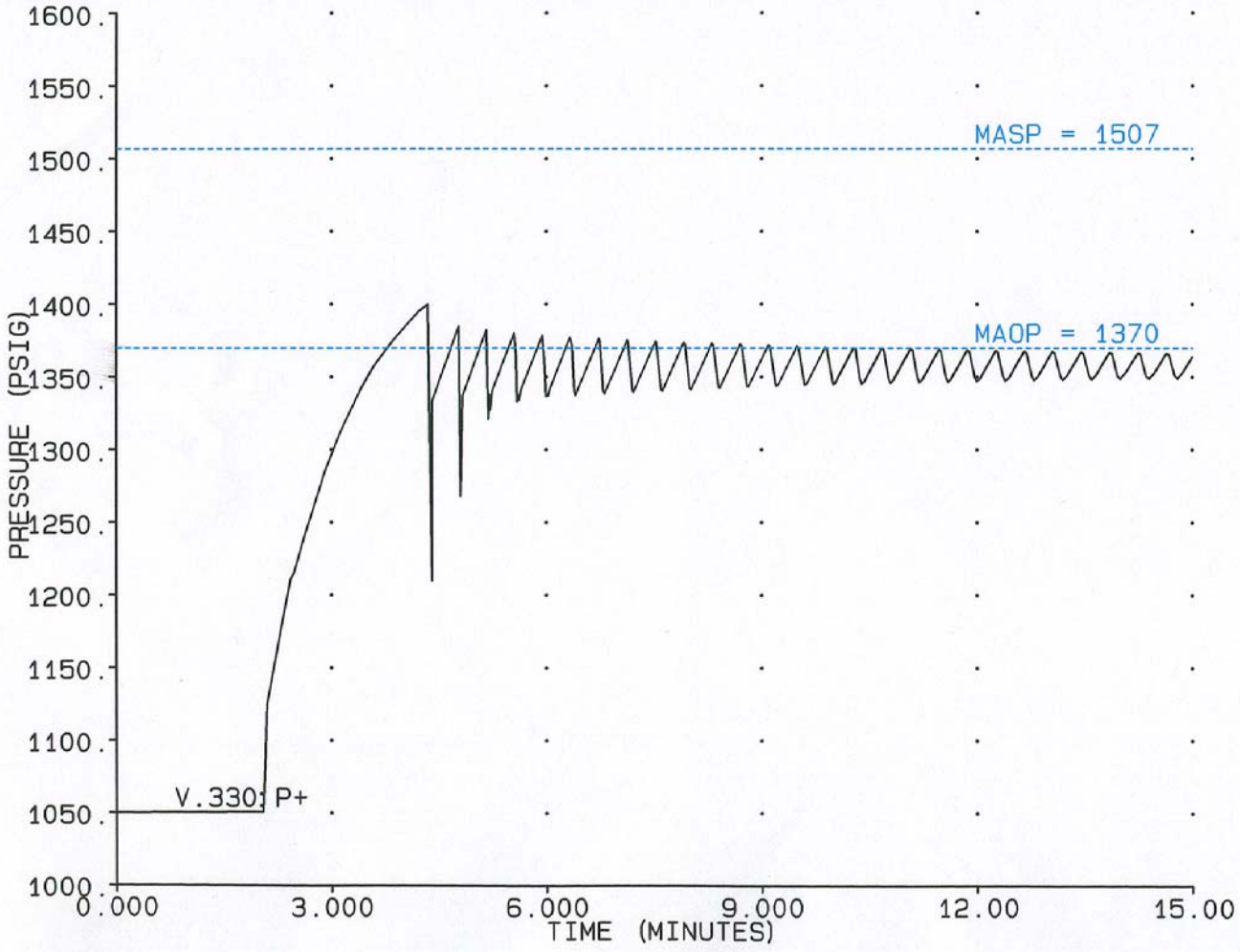
SA 003012

CASE 1, FIGURE 2, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW

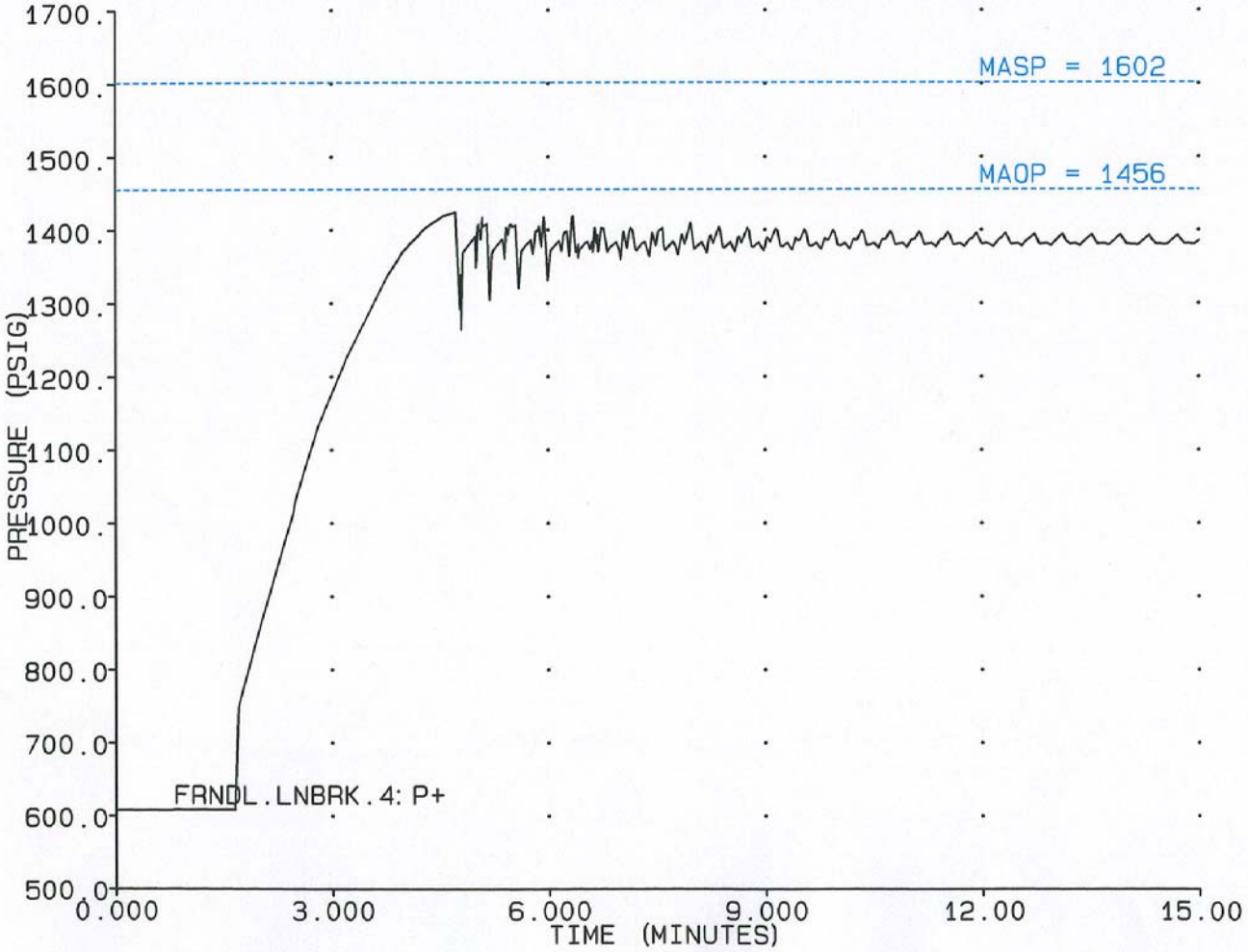


SA 003013

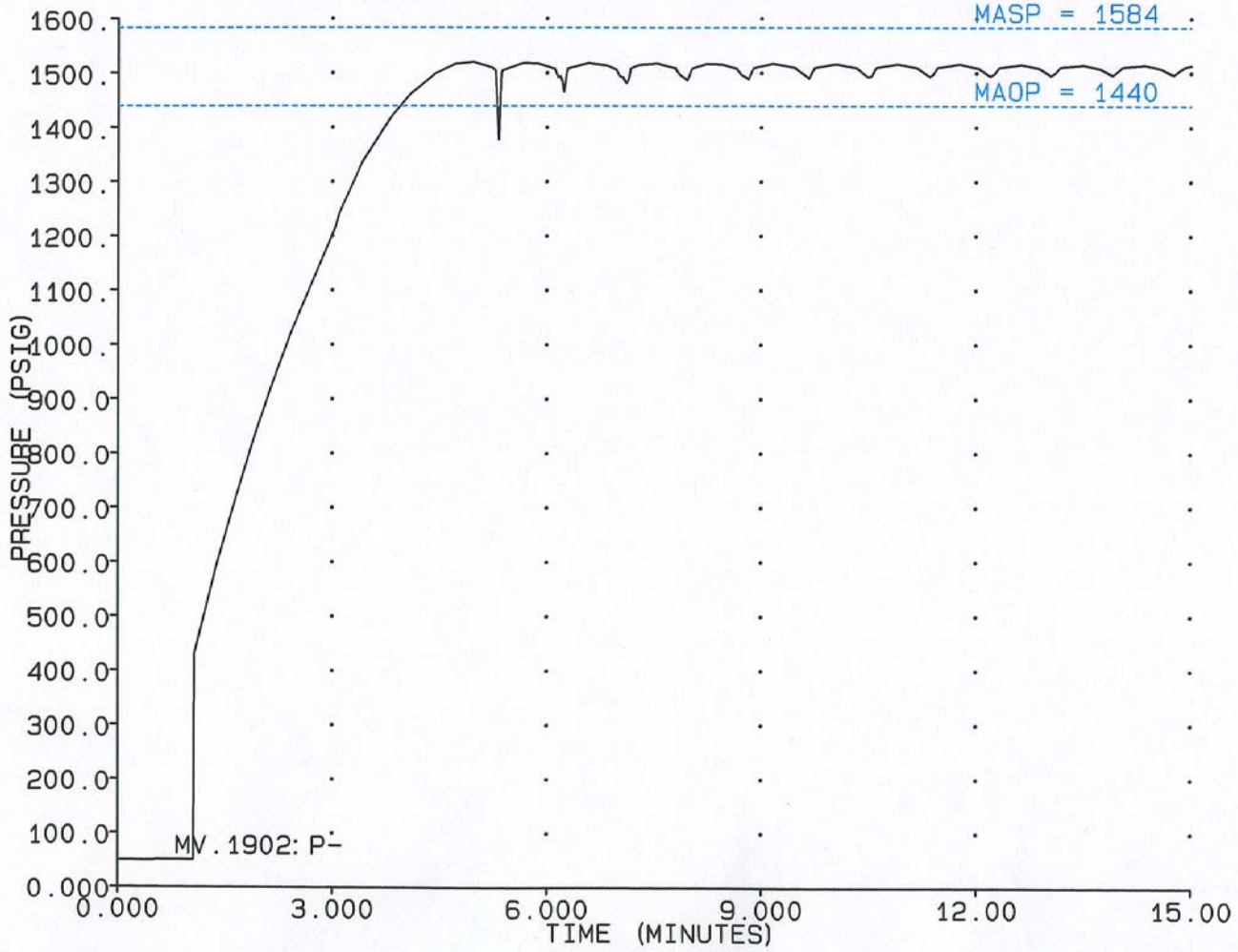
CASE 1, FIGURE 3, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
FERNDALE, V.330, DOWNSTREAM PRESSURE AT DISCHARGE BLOCK VALVE



CASE 1, FIGURE 4, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



CASE 1, FIGURE 5, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
BAYVIEW, MV.1902, UPSTREAM PRESSURE AT INLET BLOCK VALVE

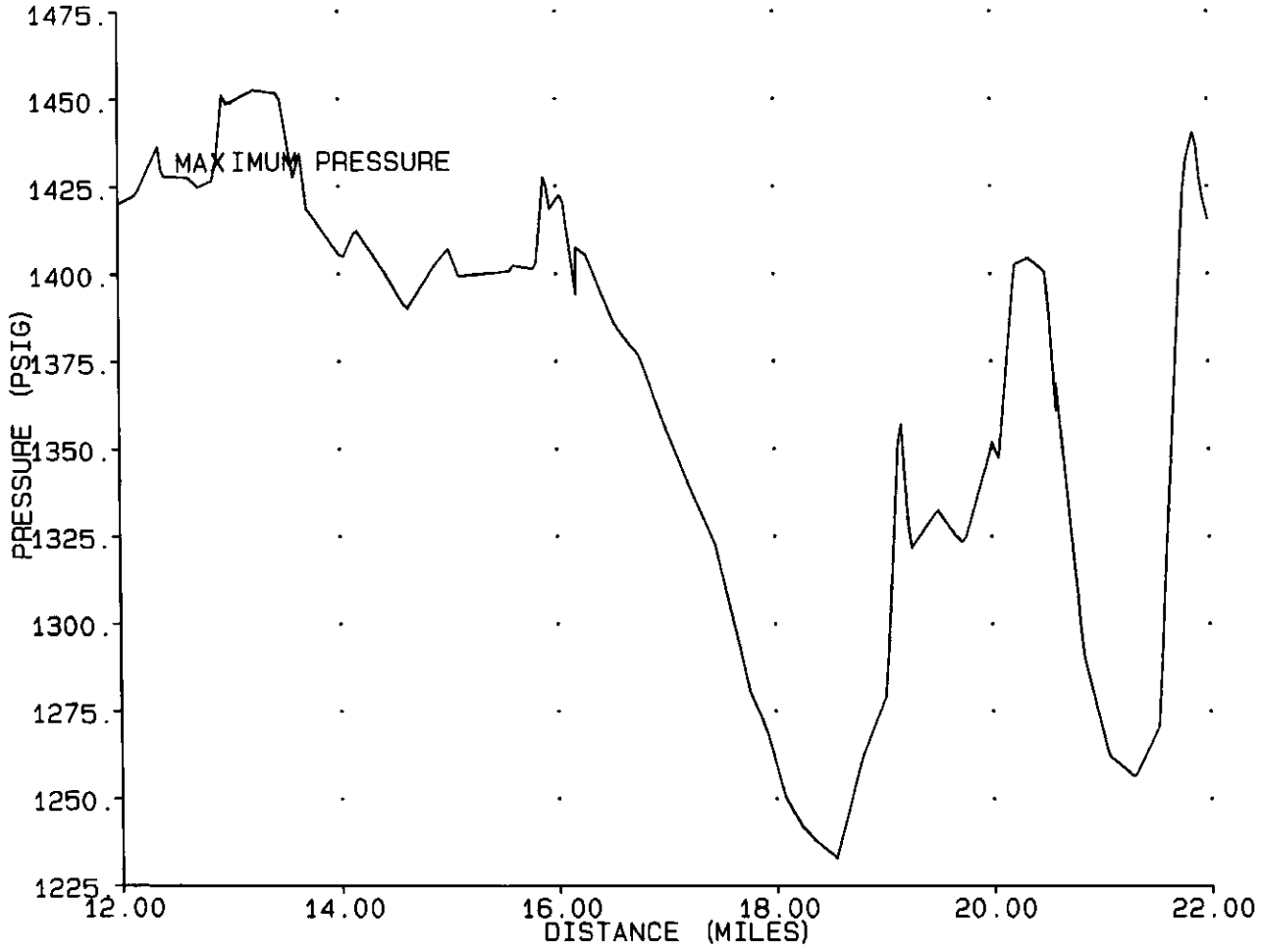


APPENDIX 2

CASE 2 - Closure of Inlet Valve – Bayview Terminal

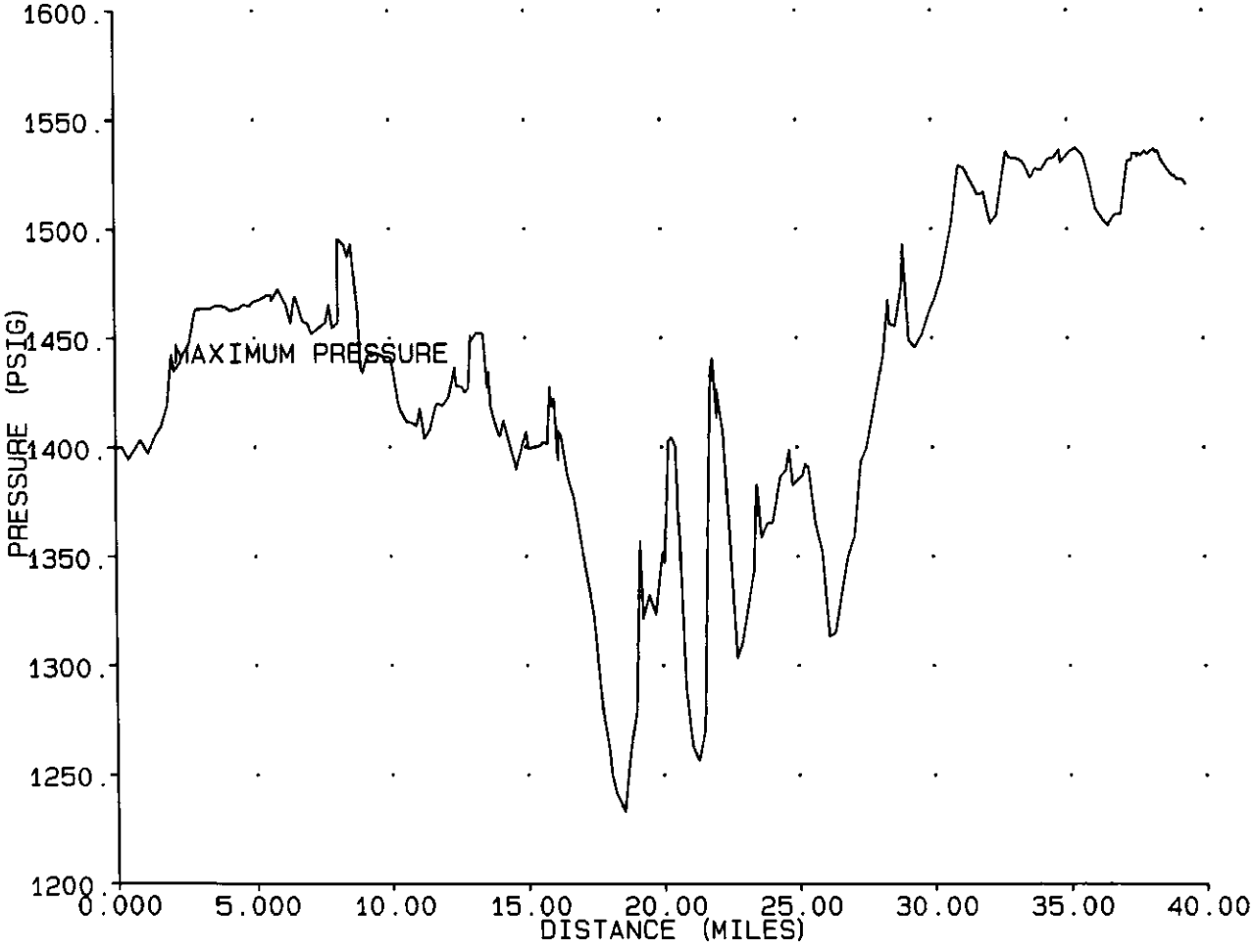
Flow Rate = 9228 bbl/hr

CASE 2, FIGURE 1, GASOLINE FLOW RATE 9228 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



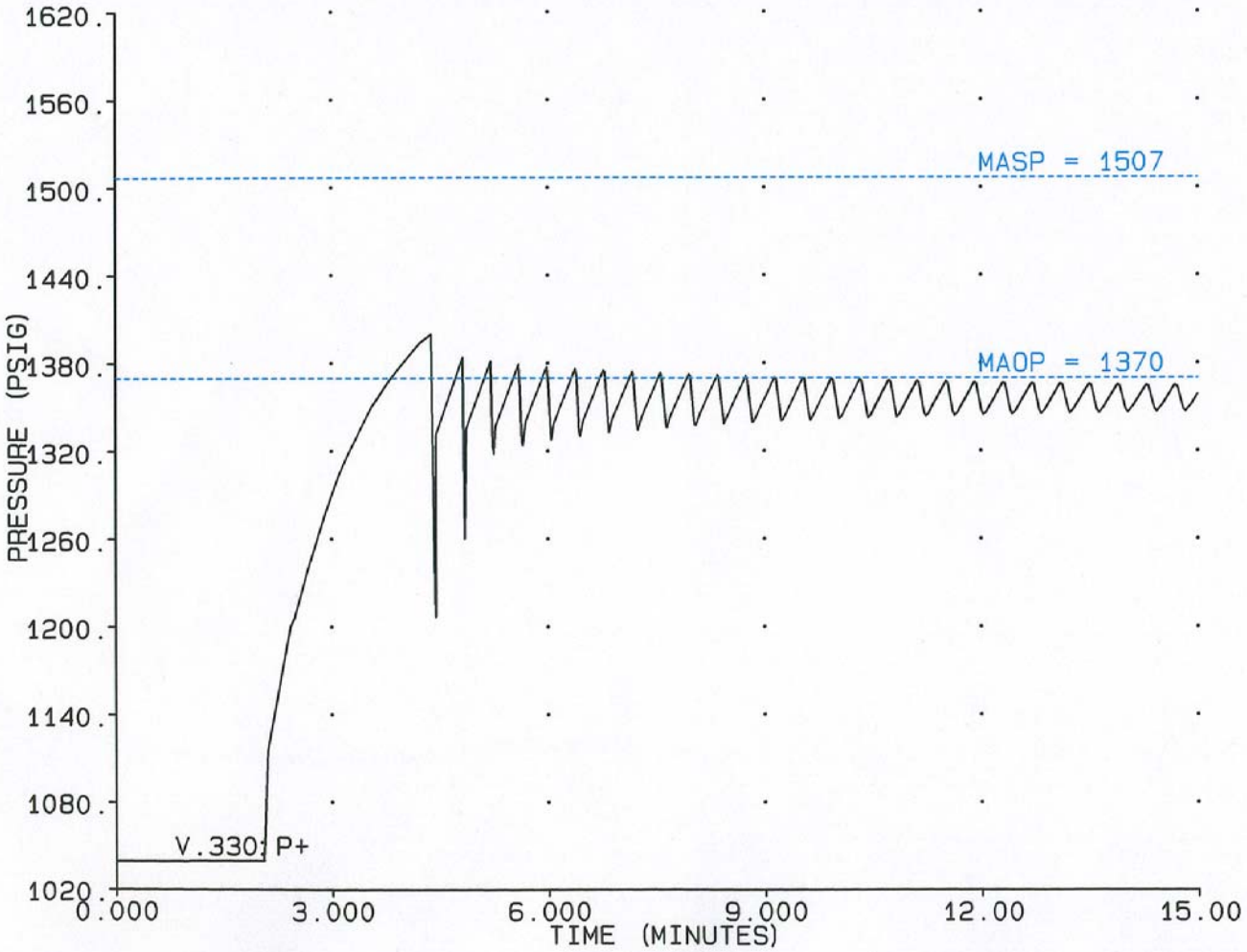
SA 003018

CASE 2, FIGURE 2, GASOLINE FLOW RATE 9228 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW



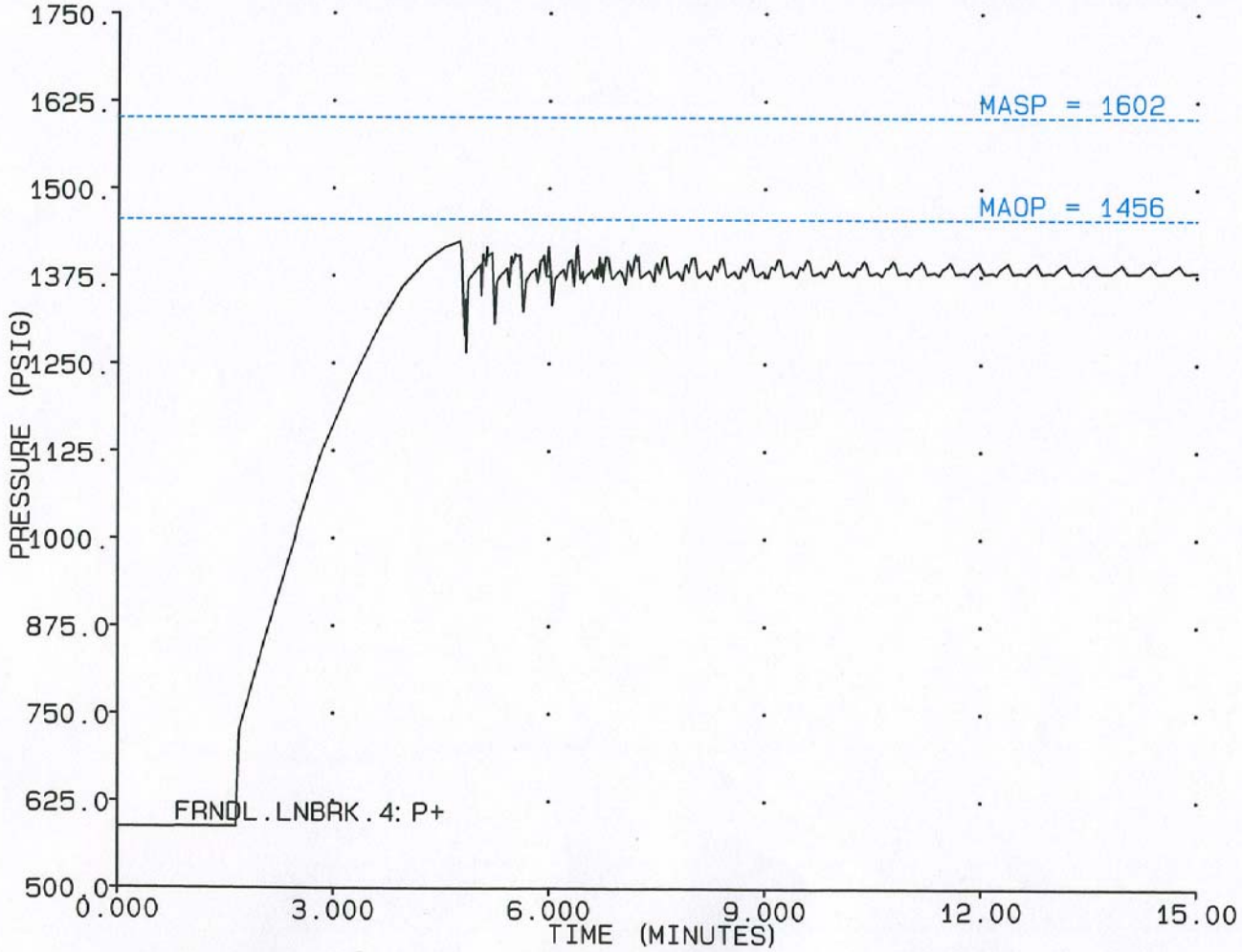
SA 003019

CASE 2, FIGURE 3, GASOLINE FLOW RATE 9228 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
FERNDALE, V.330, DOWNSTREAM PRESSURE FOR DISCHARGE BLOCK VALVE

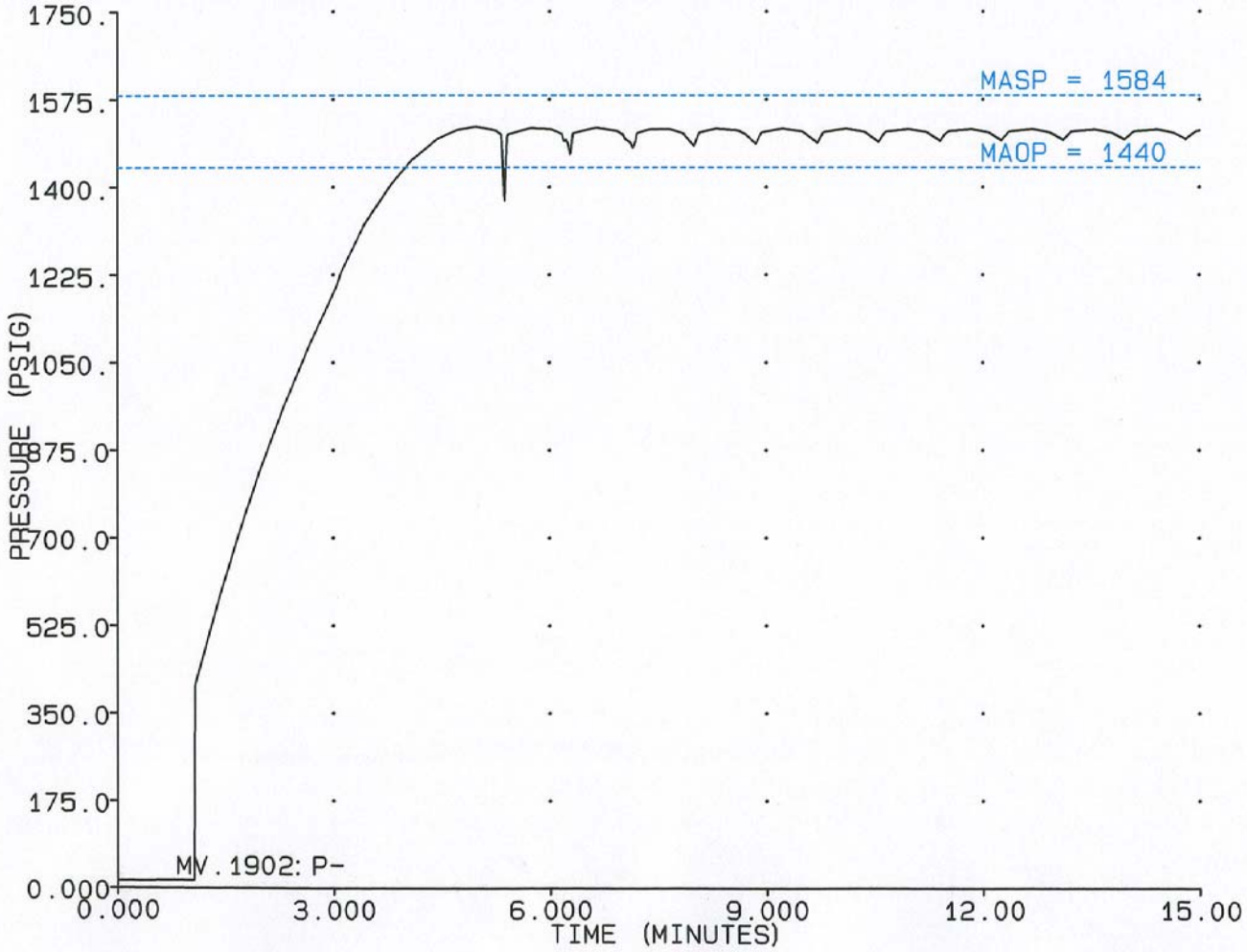


SA 003020

CASE 2, FIGURE 4, GASOLINE FLOW RATE 9228 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



CASE 2, FIGURE 5, GASOLINE FLOW RATE 9228 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT BAYVIEW TERMINAL
BAYVIEW, MV.1902, UPSTREAM PRESSURE FOR INLET BLOCK VALVE

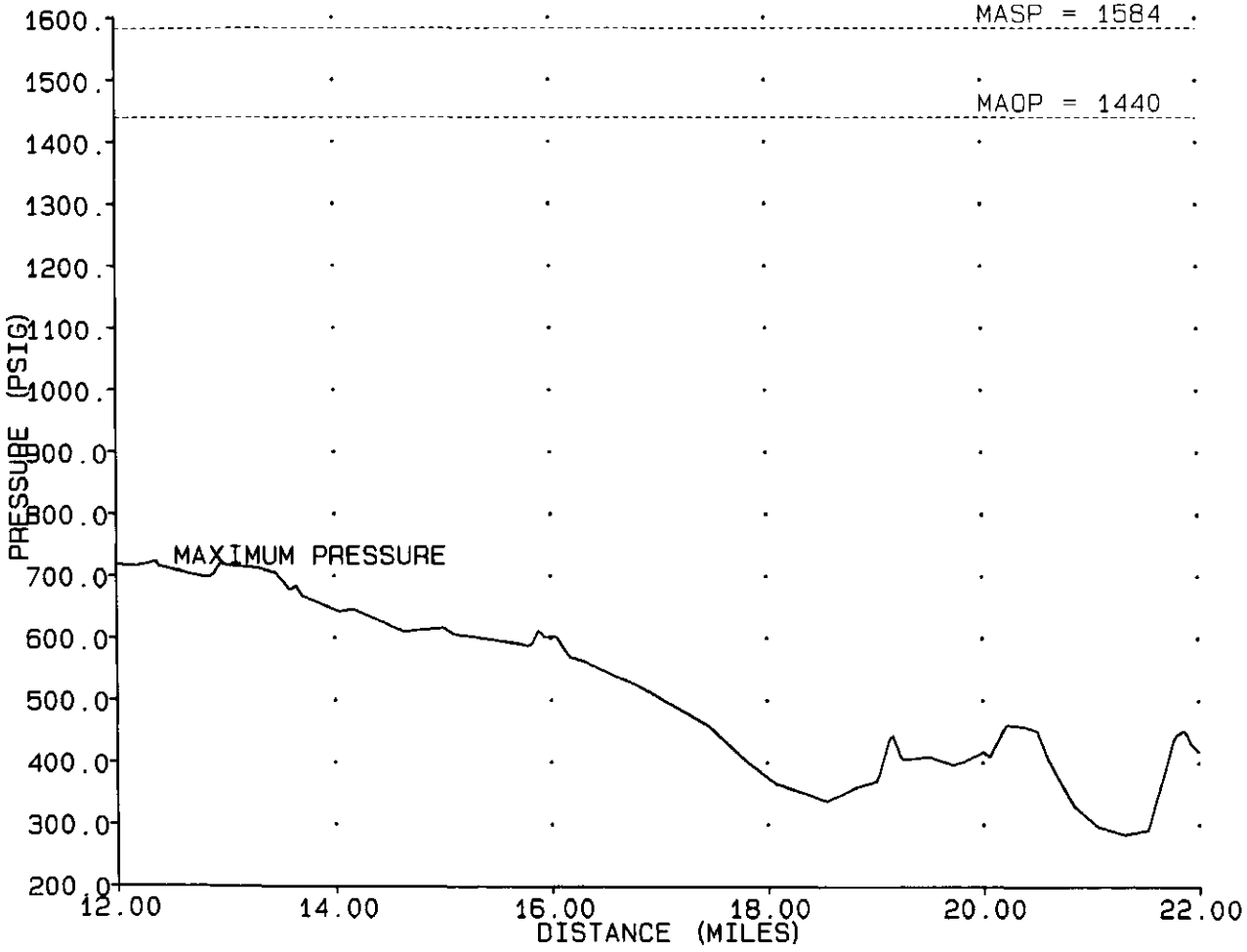


APPENDIX 3

CASE 3 - Closure of Inlet Valve – Ferndale Pump Station

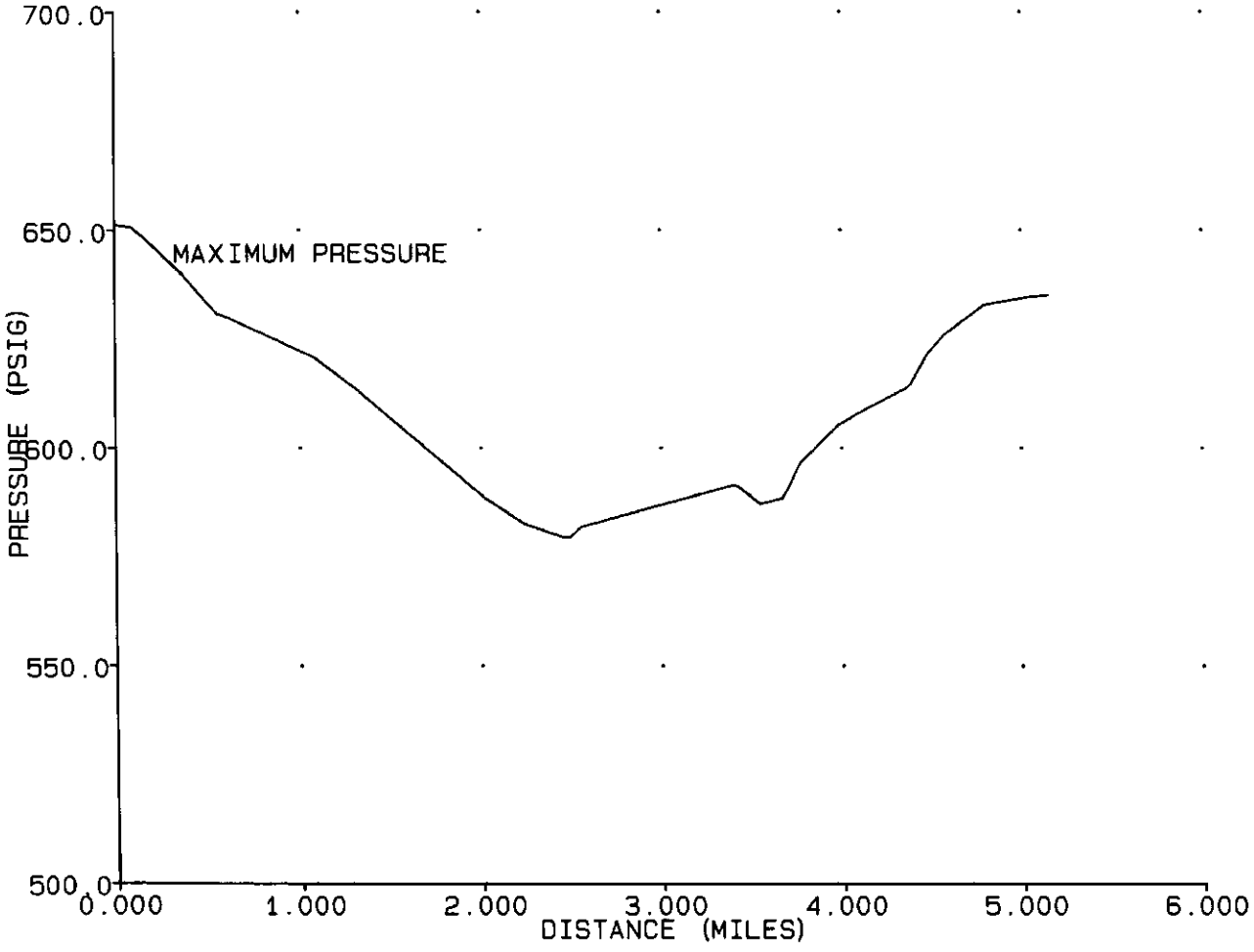
Flow Rate = 9117 bbl/hr

CASE 3, FIGURE 1, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS

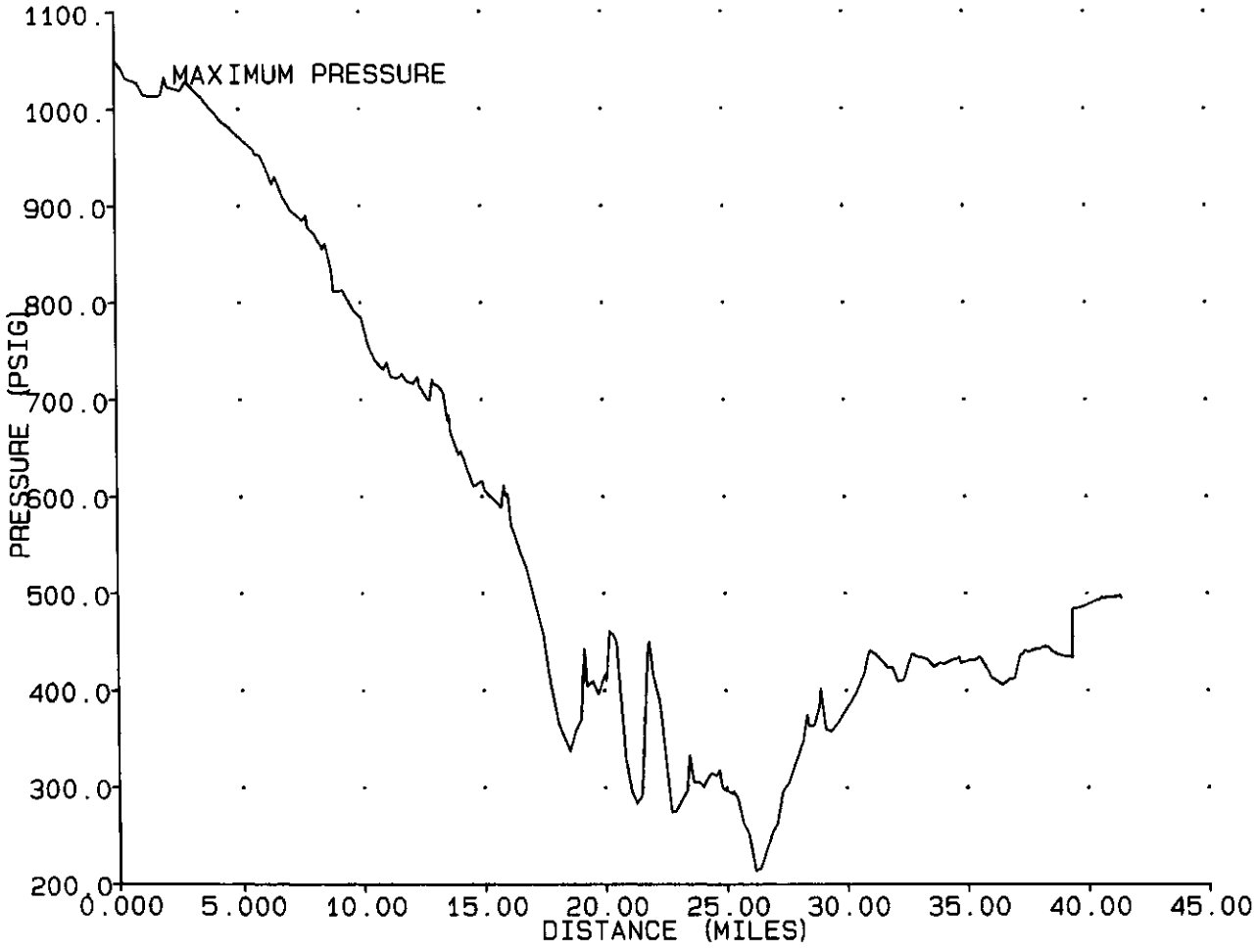


SA 003024

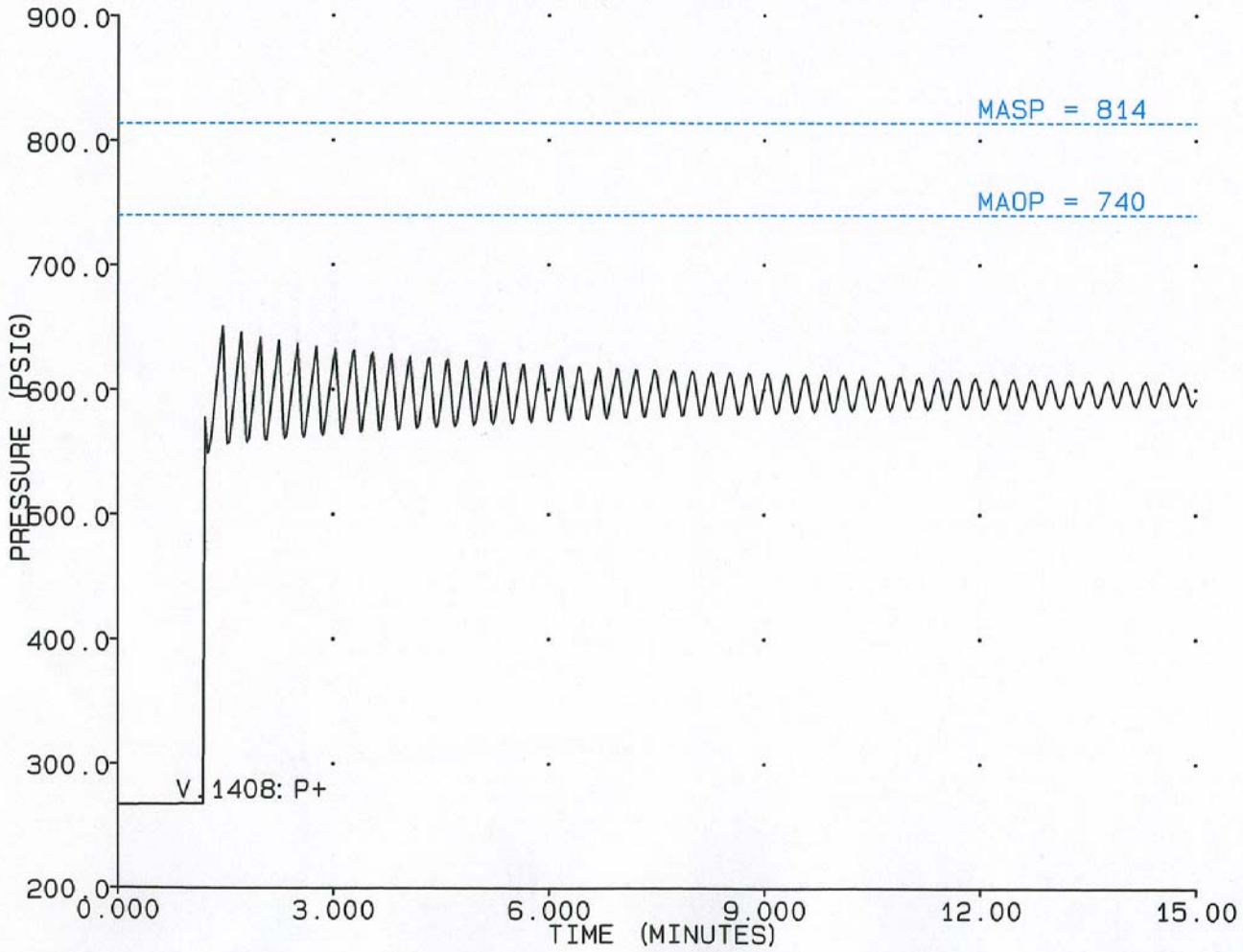
CASE 3, FIGURE 2, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM CHERRY POINT TO FERNDALE



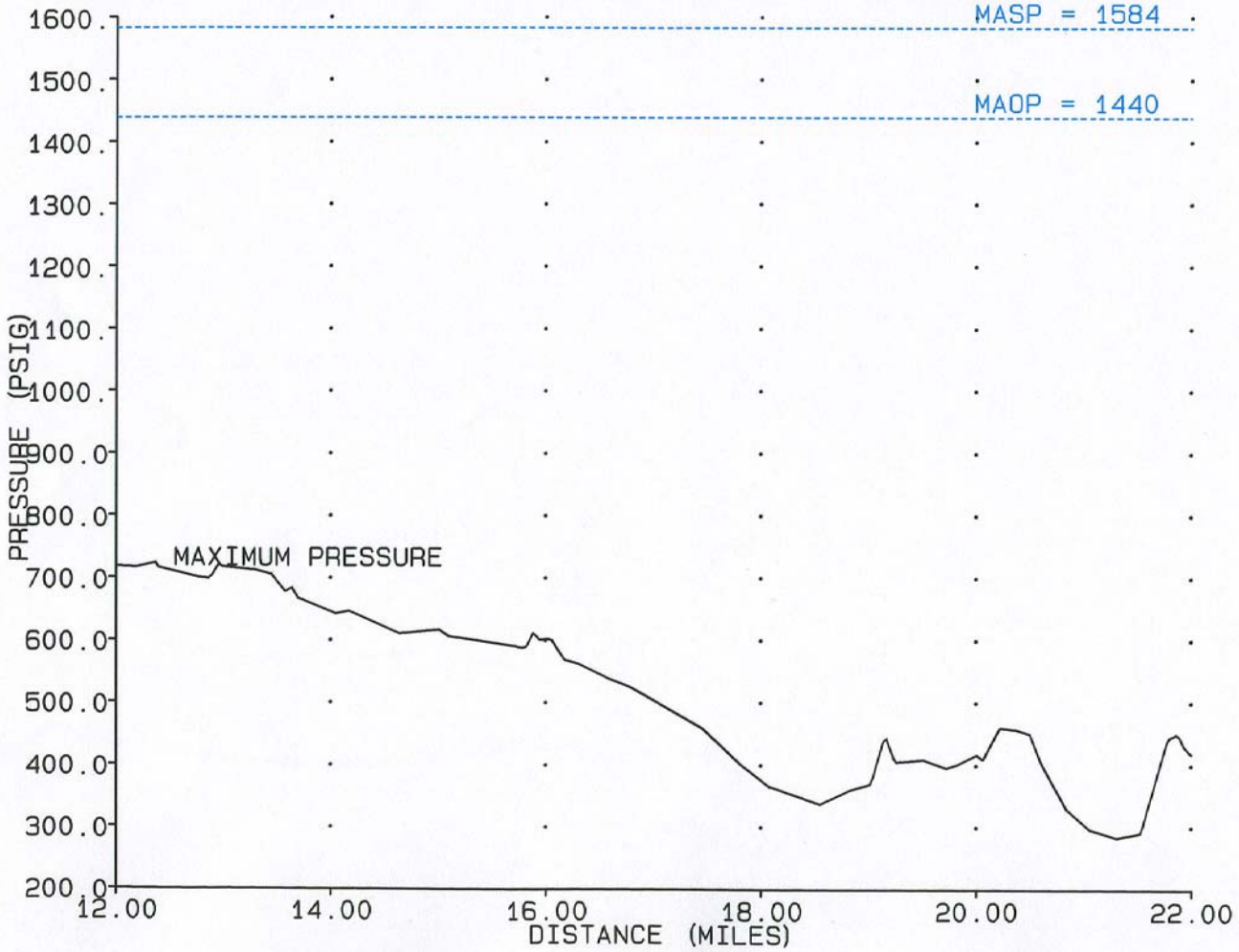
CASE 3, FIGURE 3, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW



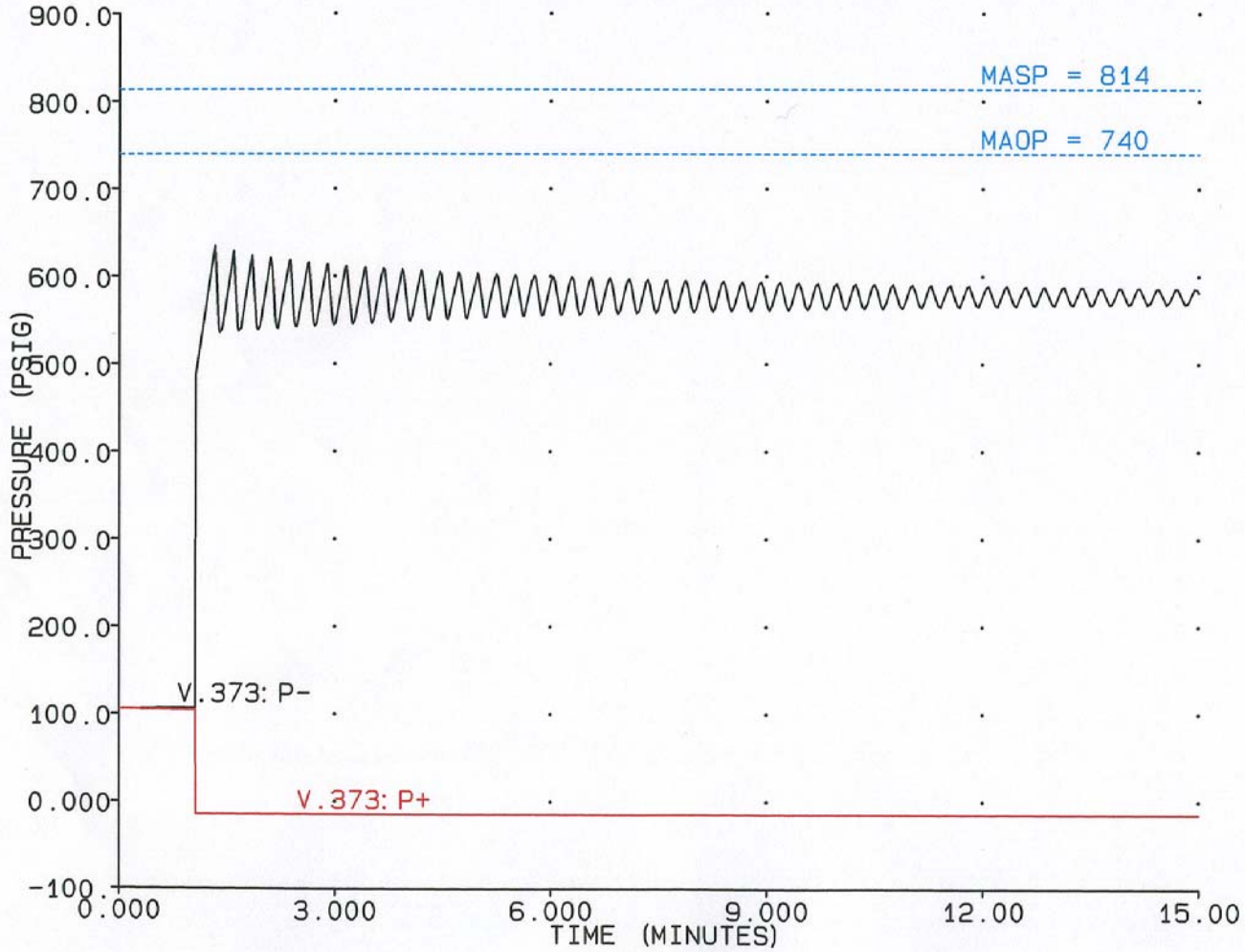
CASE 3, FIGURE 4, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
CHERRY POINT, V.1408, DOWNSTREAM OF DISCHARGE CONTROL VALVE



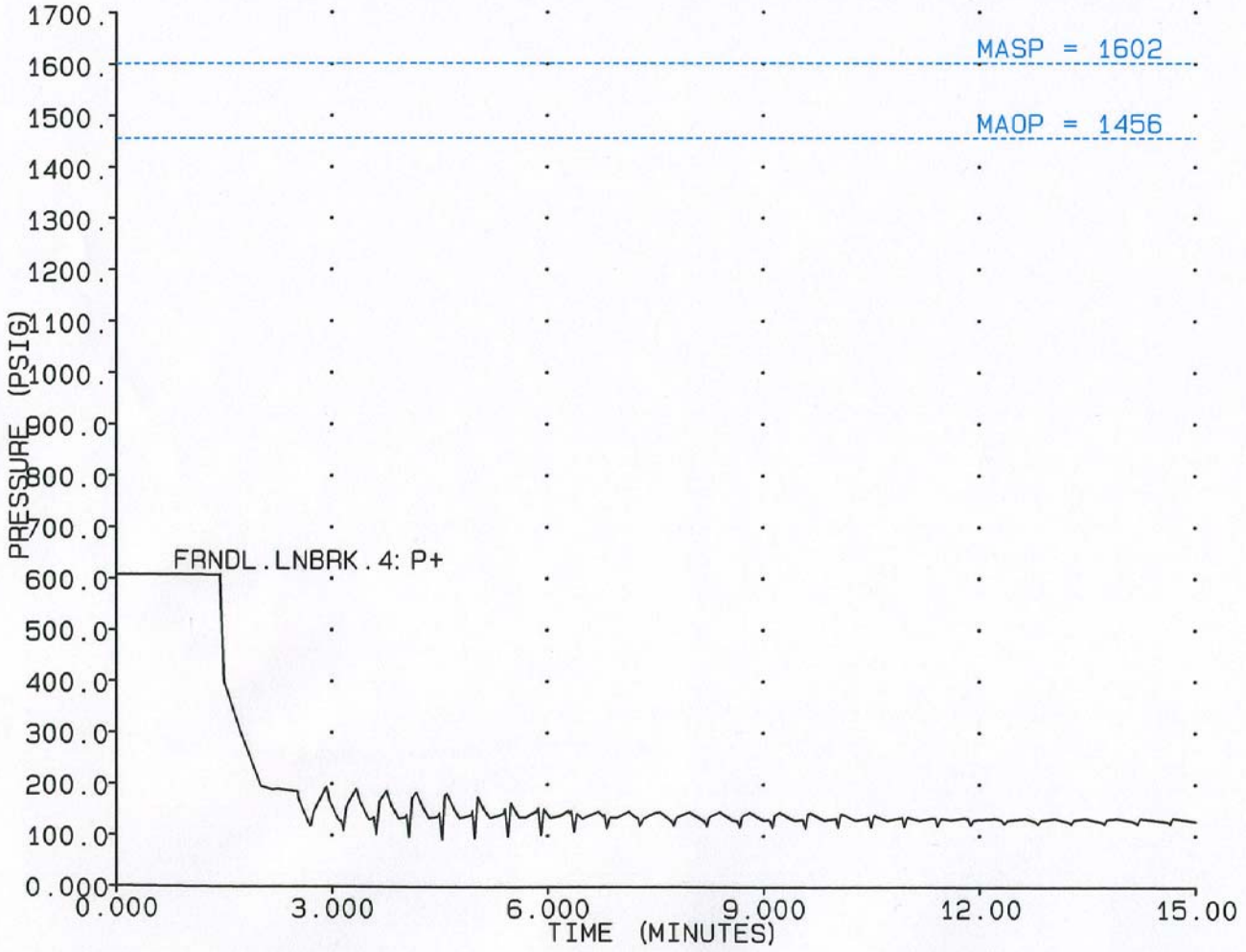
CASE 3, FIGURE 1, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



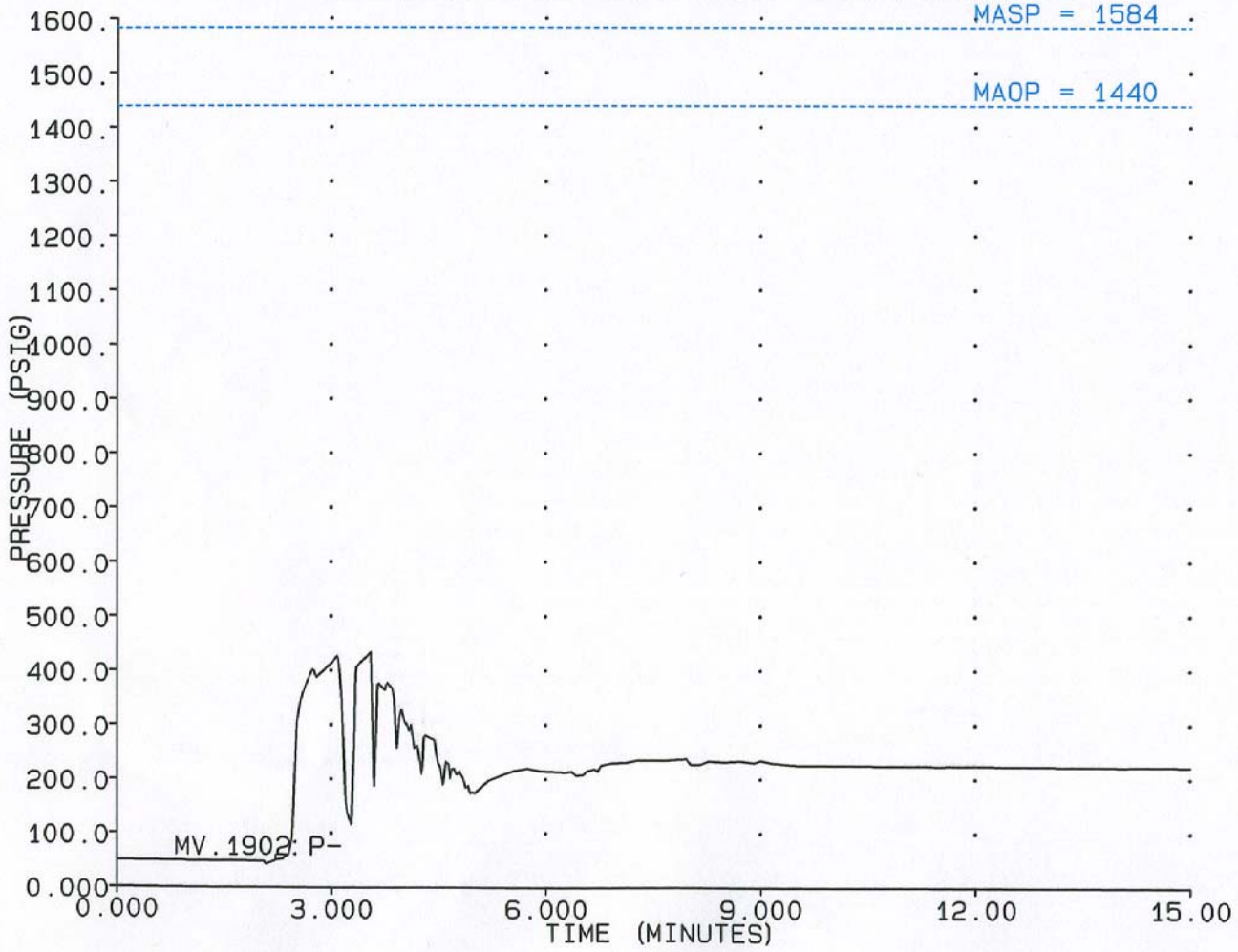
CASE 3, FIGURE 5, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
FERNDALE, V.373, UPSTREAM & DOWNSTREAM PRESSURES FOR INLET BLOCK VALVE



CASE 3, FIGURE 6, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



CASE 3, FIGURE 7, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT FERNDALE PUMP STATION
BAYVIEW, MV.1902, UPSTREAM OF INLET BLOCK VALVE

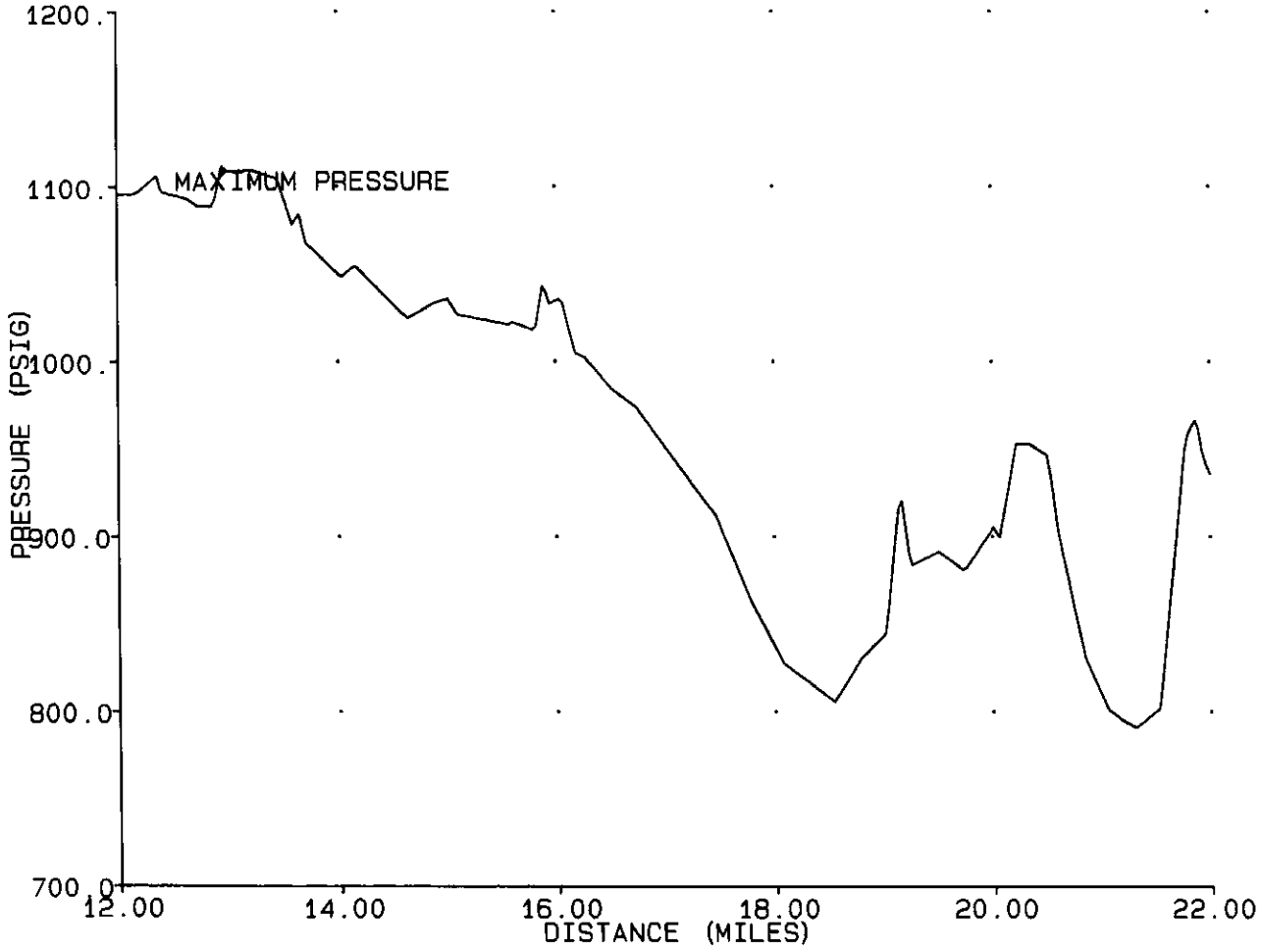


APPENDIX 4

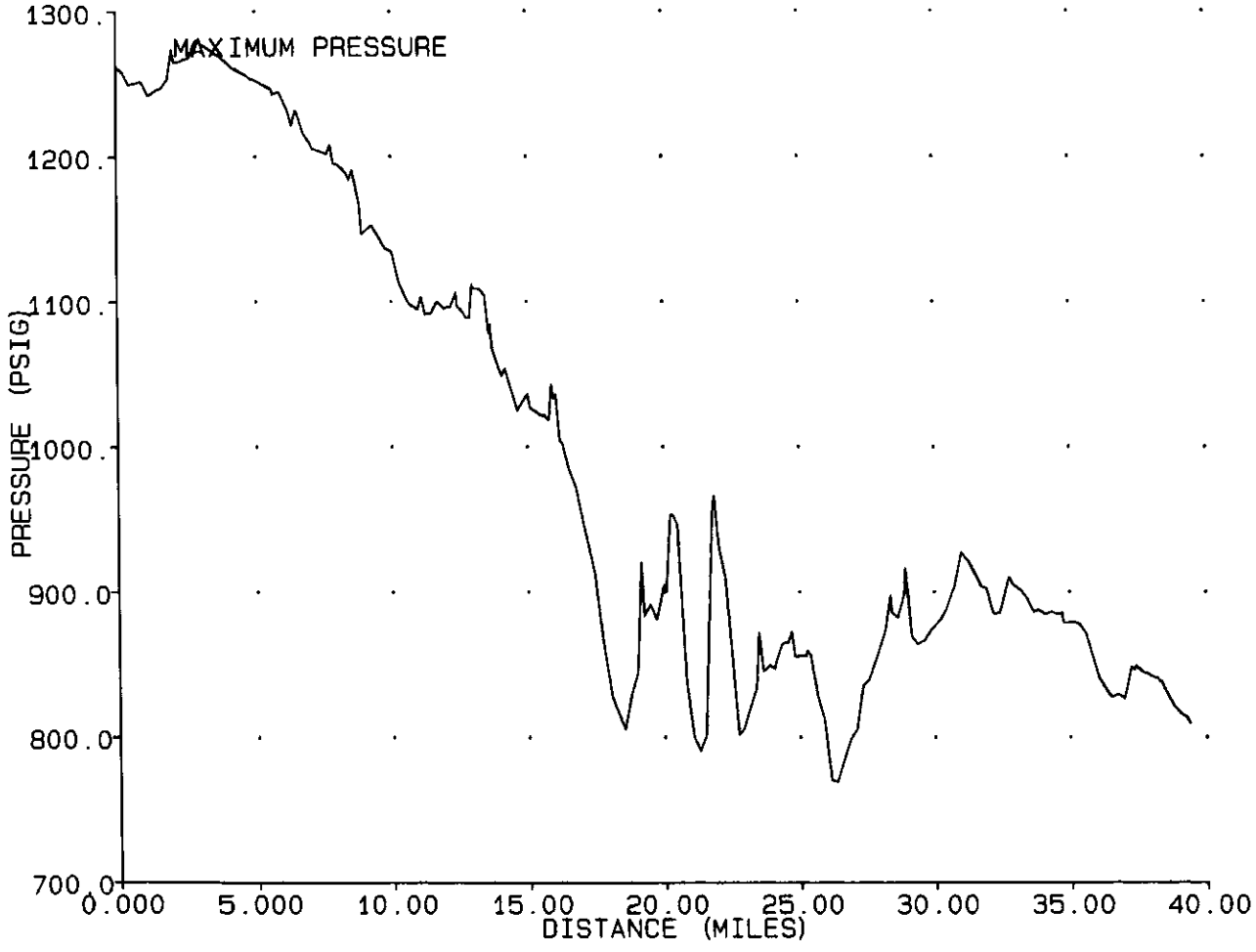
CASE 4 - Closure of Inlet Valve – Allen Pump Station

Flow Rate = 9117 bbl/hr

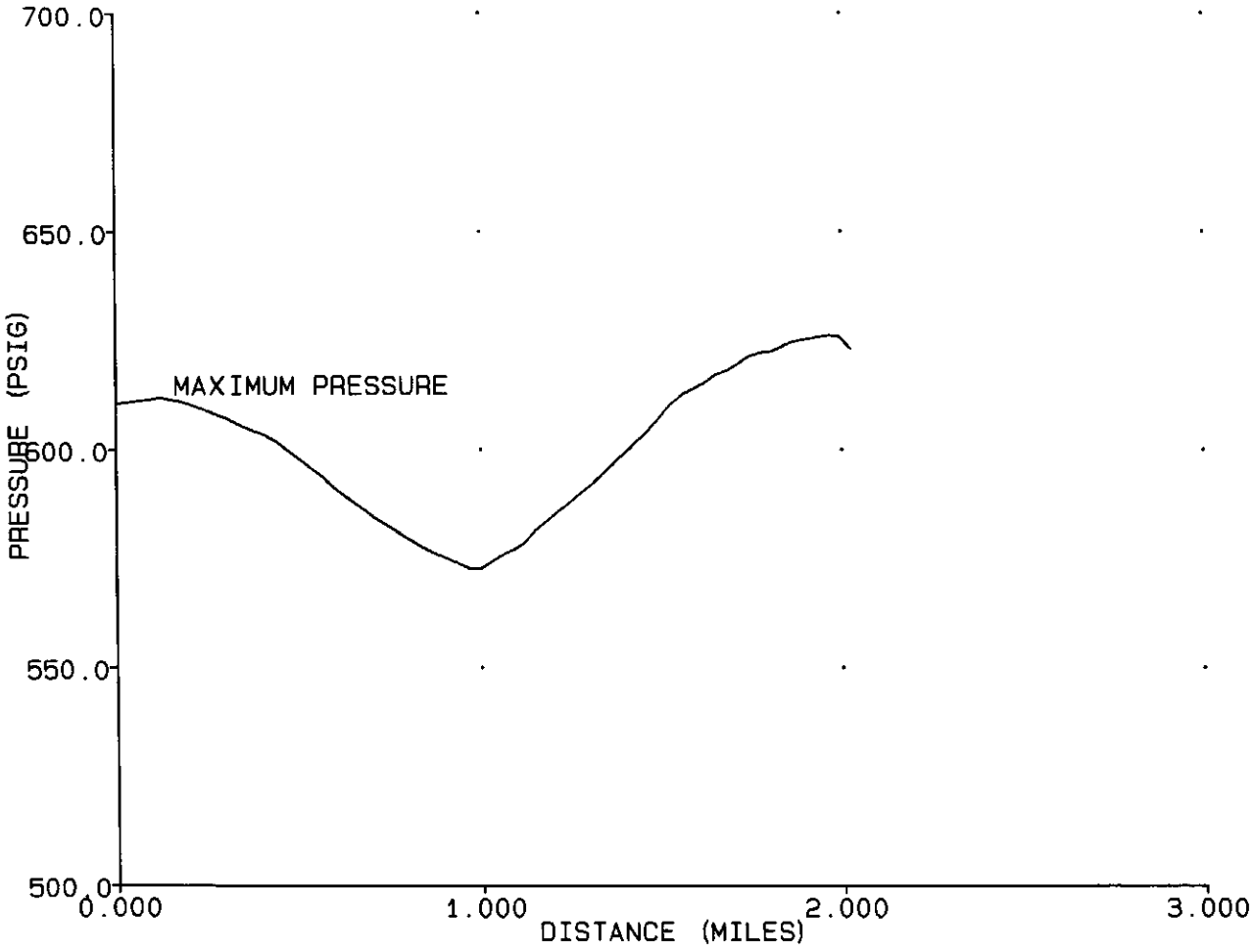
CASE 4, FIGURE 1, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



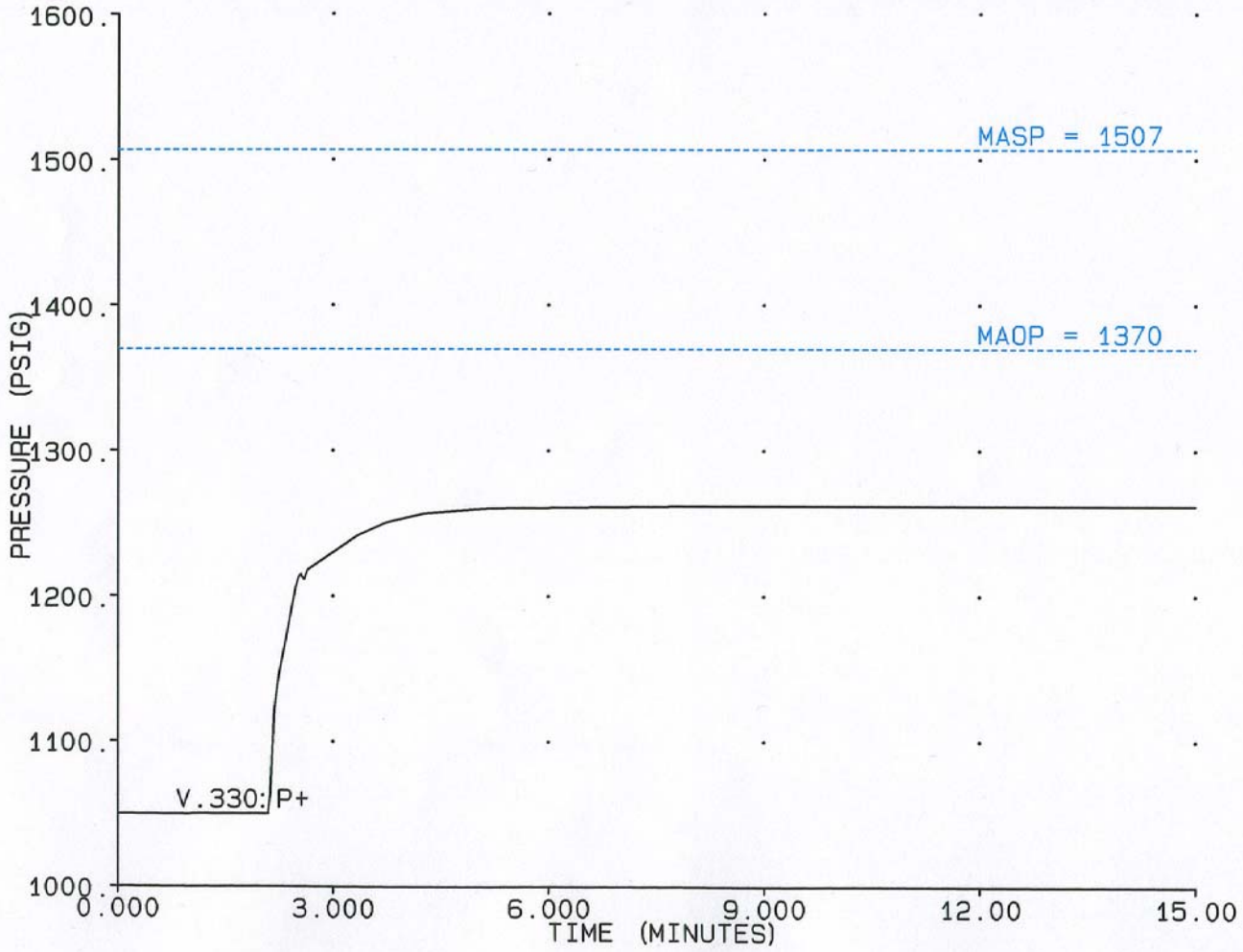
CASE 4, FIGURE 2, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW



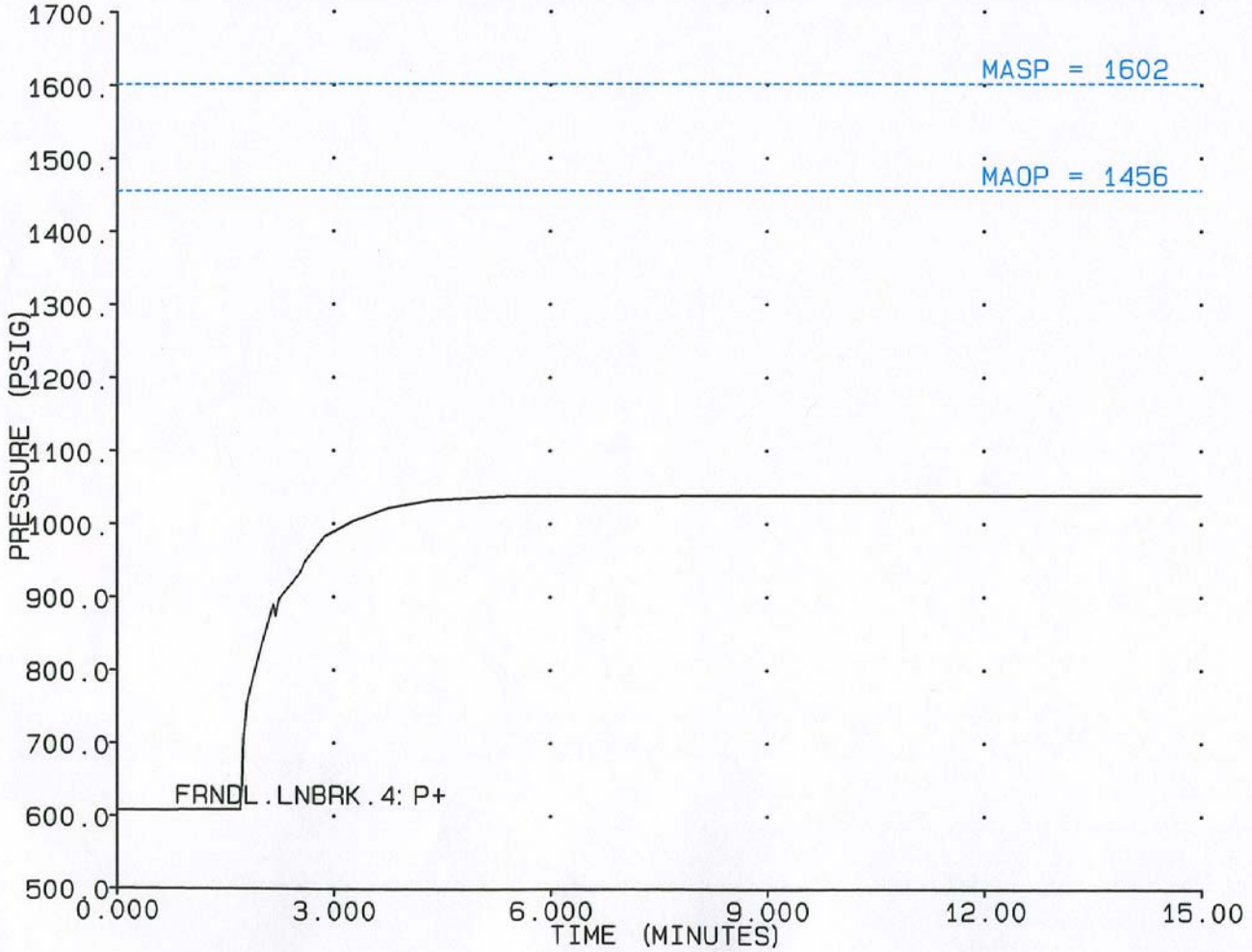
CASE 4, FIGURE 3, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM BAYVIEW TO ALLEN



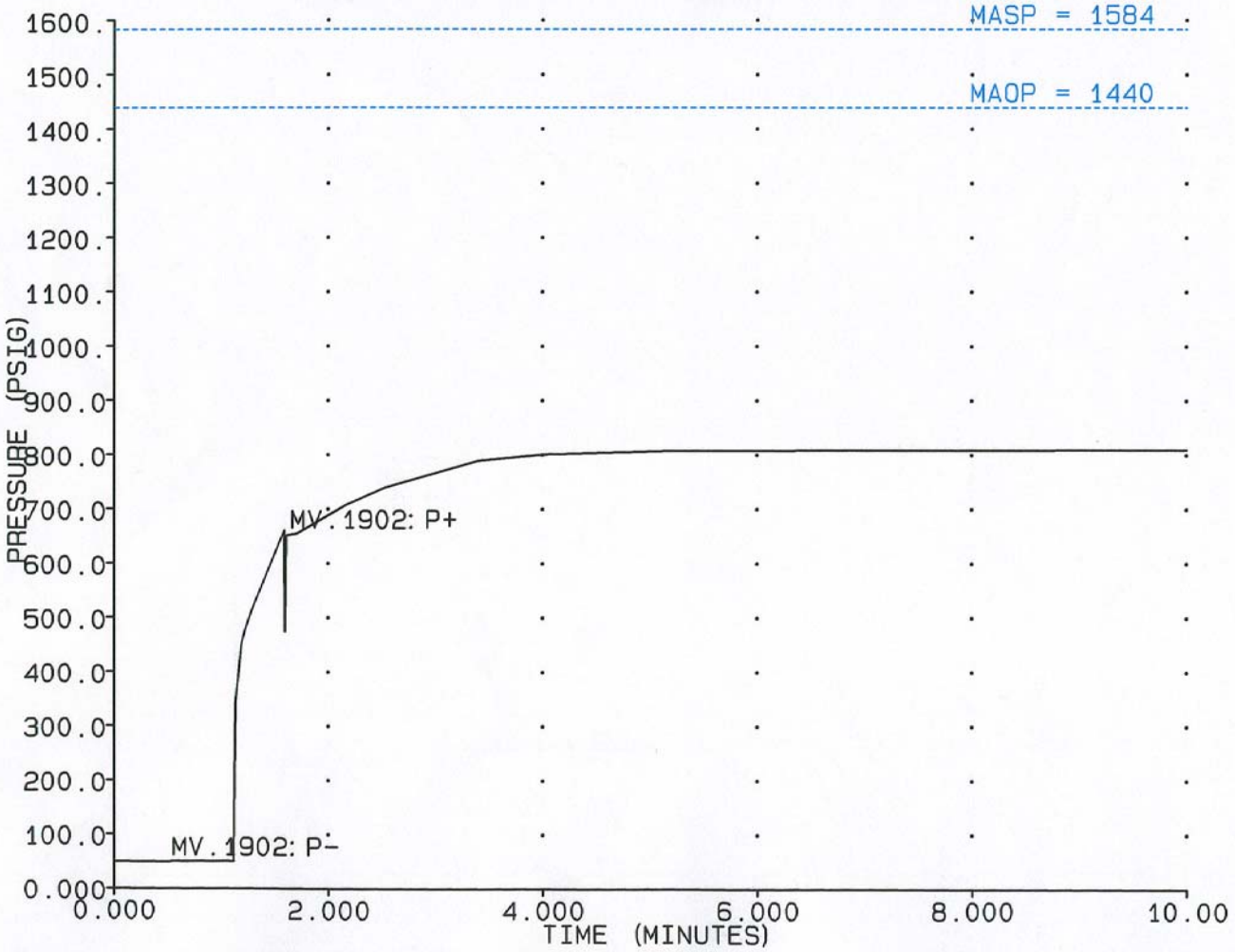
CASE 4, FIGURE 4, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
FERNDALE, V.330, DOWNSTREAM PRESSURE AT DISCHARGE BLOCK VALVE



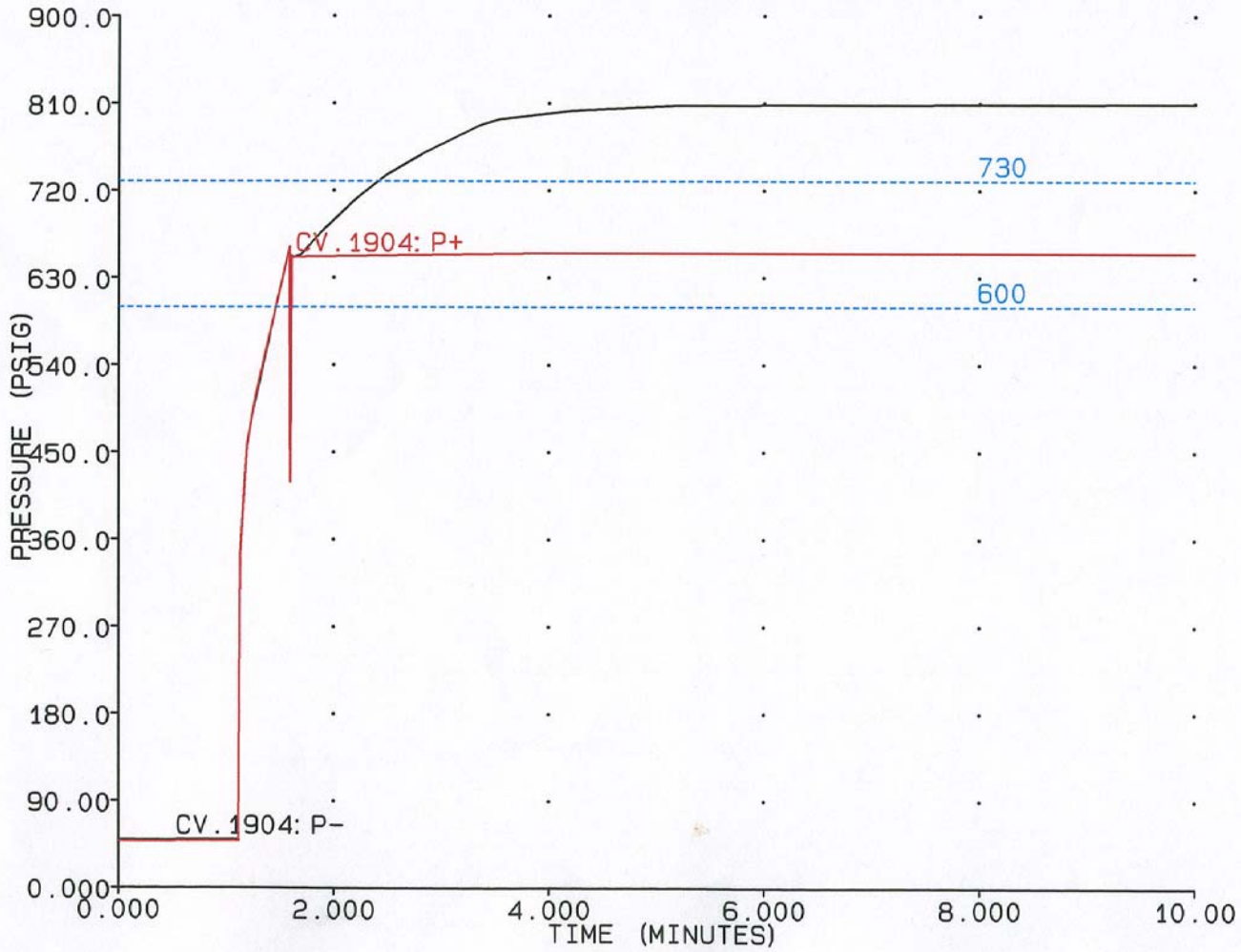
CASE 4, FIGURE 5, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



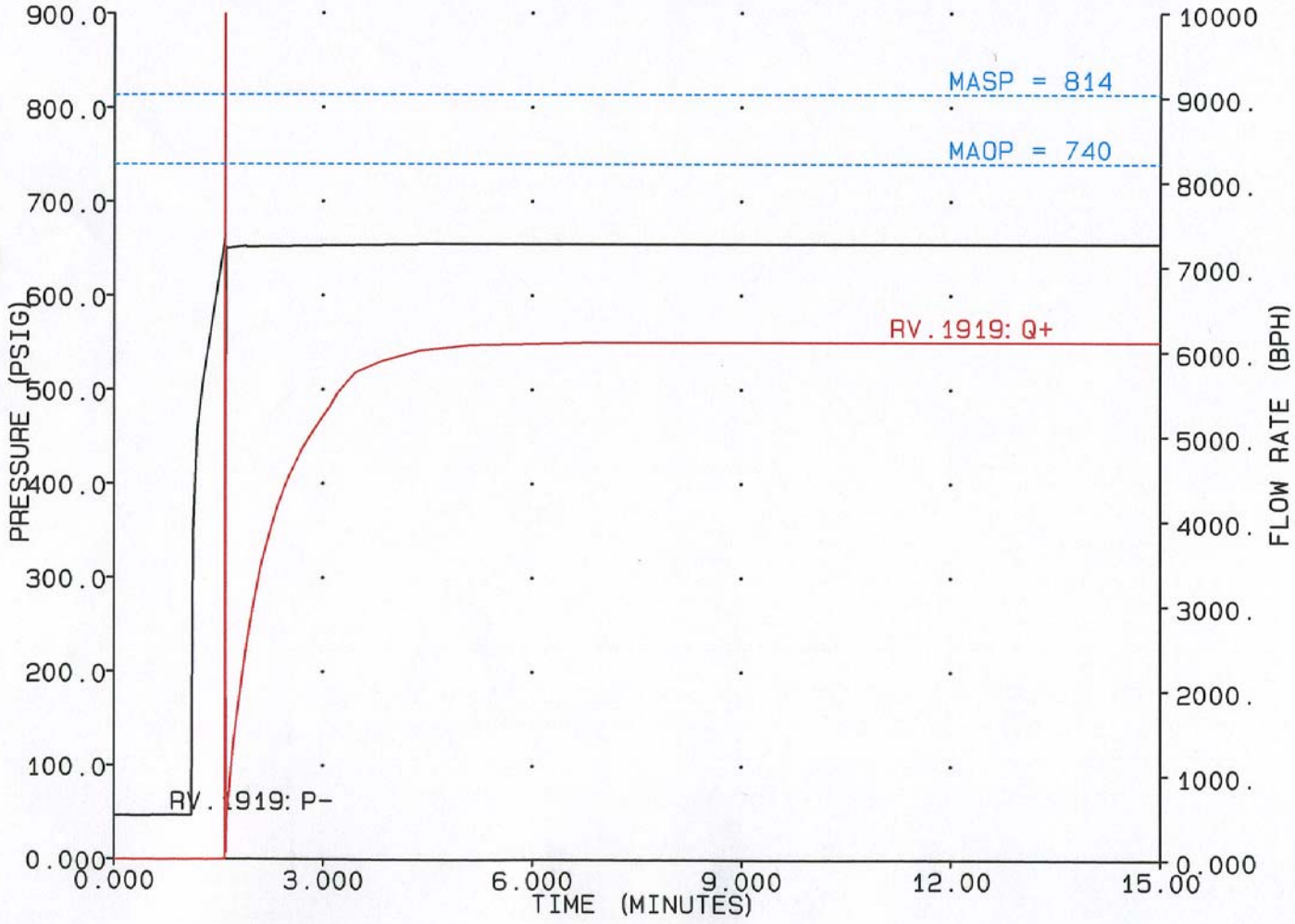
CASE 4, FIGURE 6, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
BAYVIEW, MV.1902, UPSTREAM OF INLET BLOCK VALVE



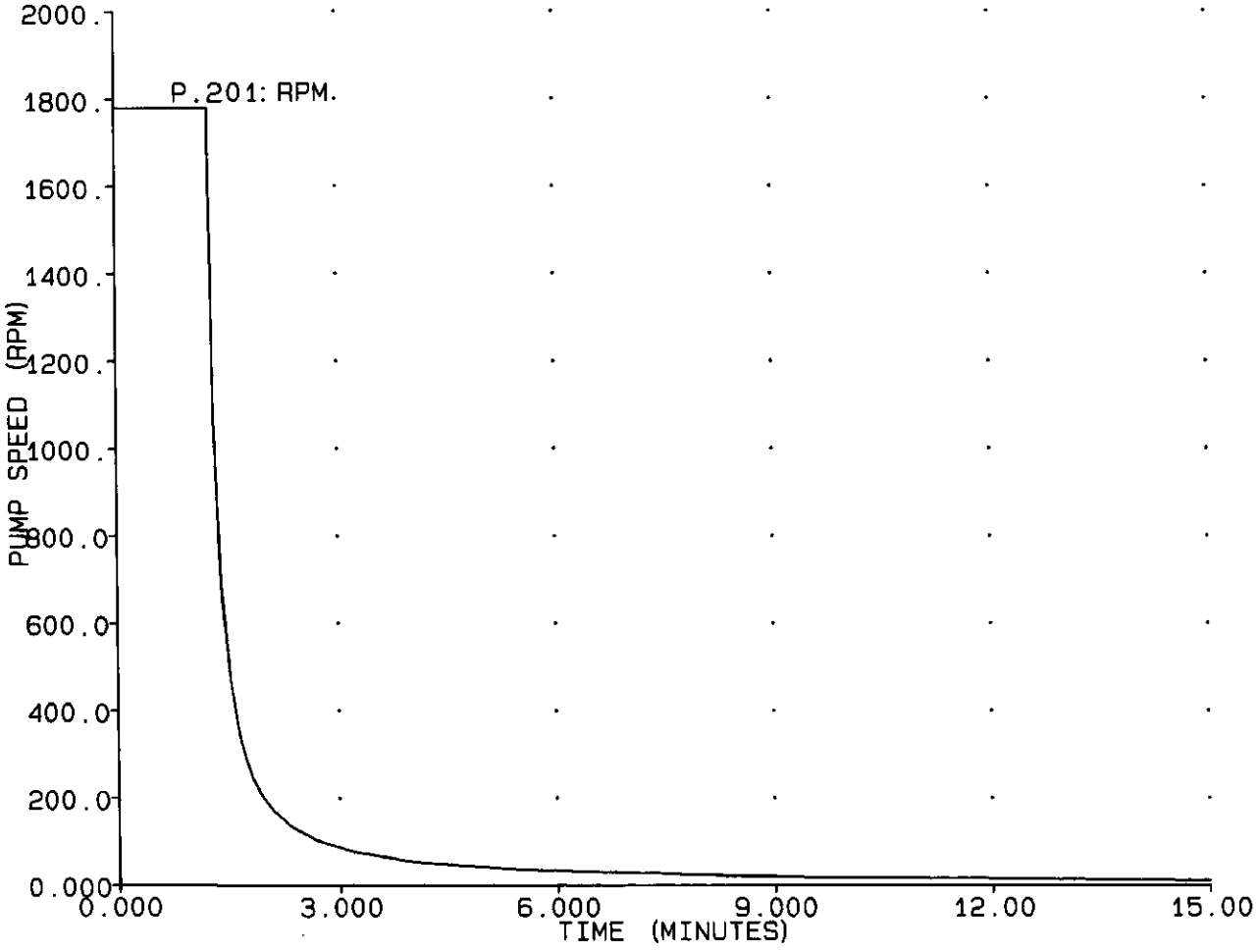
CASE 4, FIGURE 7, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
BAYVIEW, CV.1904, UPSTREAM & DOWNSTREAM PRESSURE OF INLET CONTROL VALVE



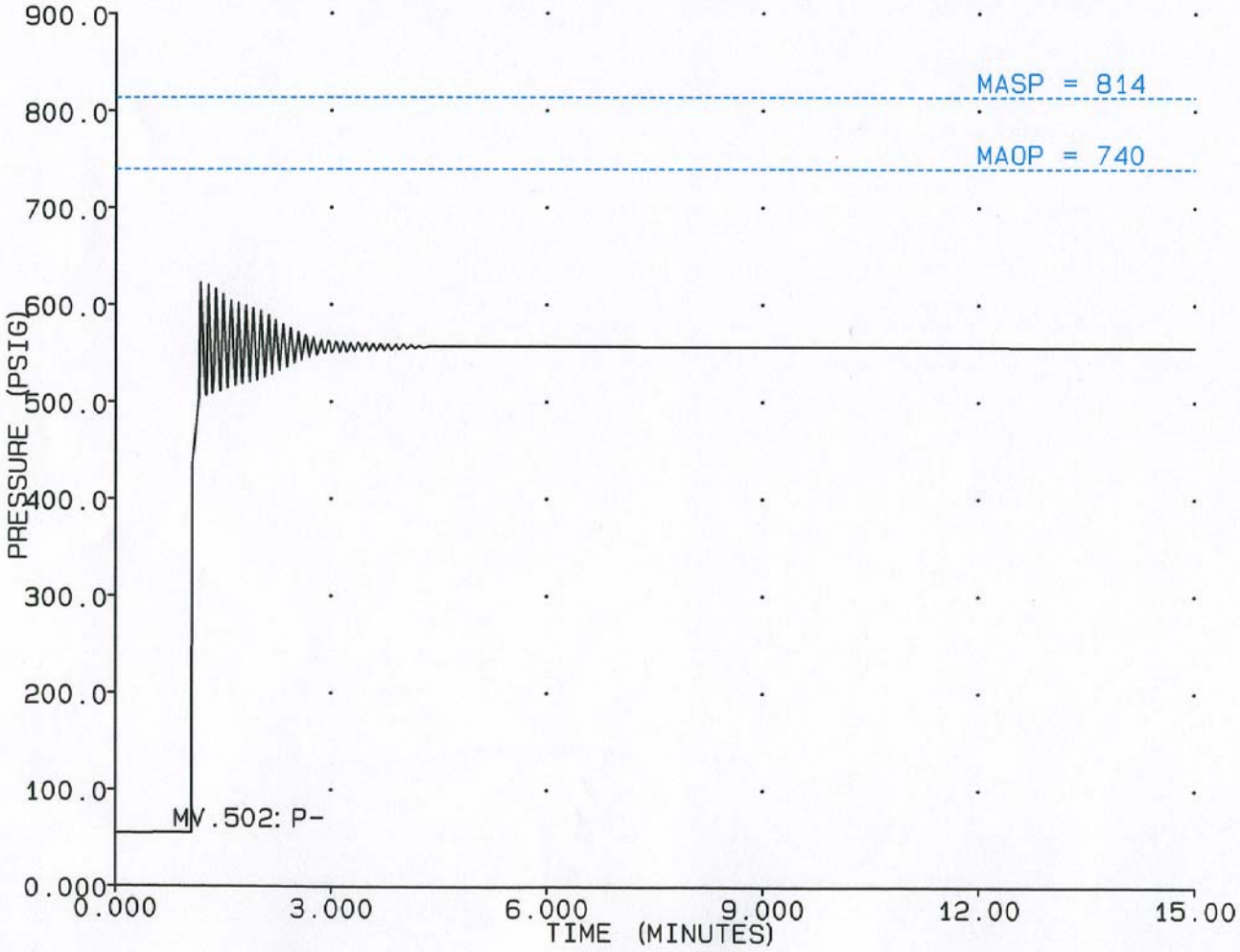
CASE 4, FIGURE 8, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
BAYVIEW, RV.1919, UPSTREAM PRESSURE & FLOW OF INLET RELIEF VALVE



CASE 4, FIGURE 9, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
BAYVIEW, P.201, PUMP SPEED OF BAYVEW UNIT #1



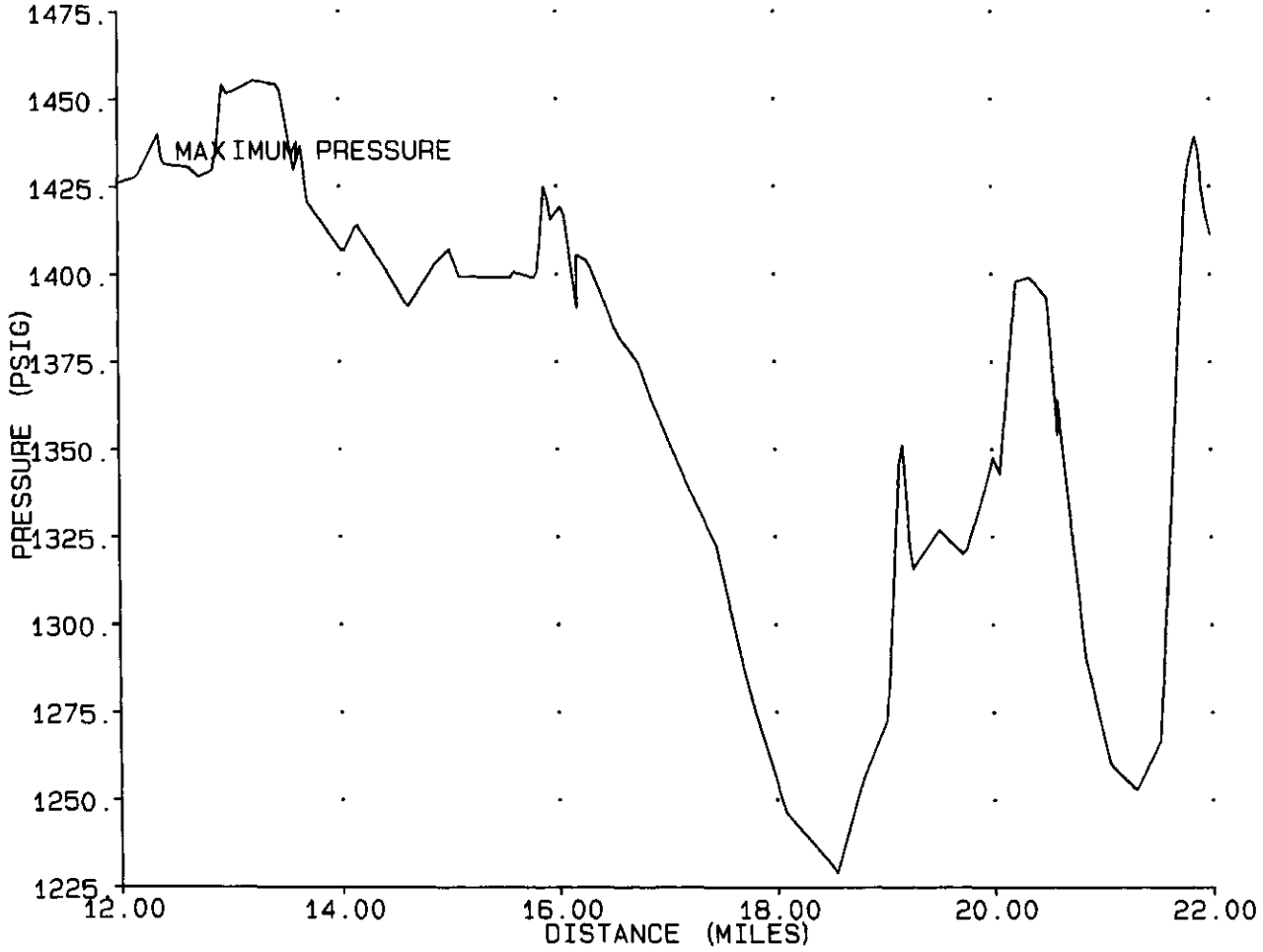
CASE 4, FIGURE 10, GASOLINE FLOW RATE 9117 BBL/HR FROM ARCO, 10 SEP 1999
EVENT CAUSED BY CLOSURE OF INLET BLOCK VALVE AT ALLEN PUMP STATION
ALLEN, MV.502, UPSTREAM PRESSURE OF INLET BLOCK VALVE



APPENDIX 5

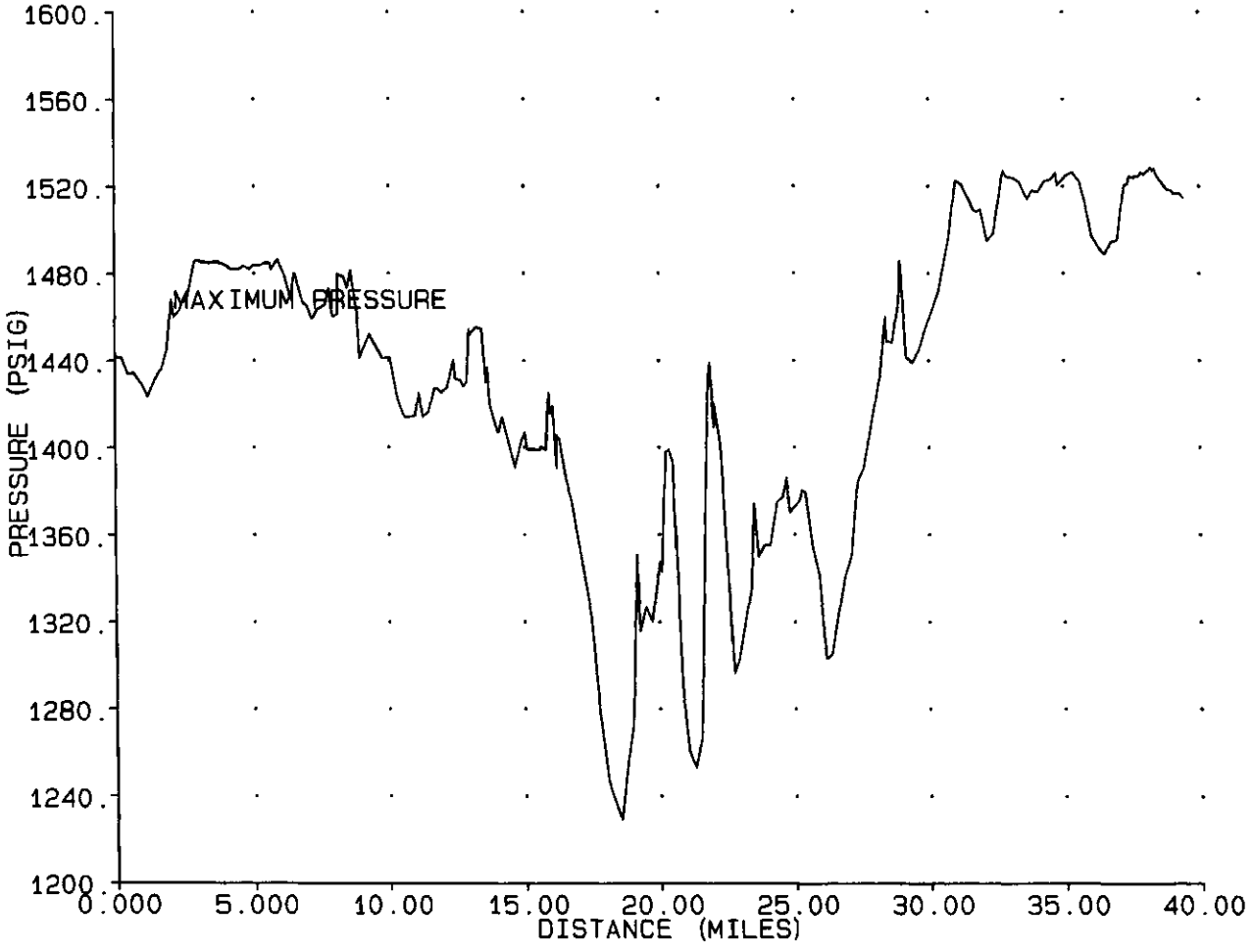
CASE 5 – Event of June 10, 1999, Original Sequence, Mal-Function of RV1919

CASE 5, FIGURE 1, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



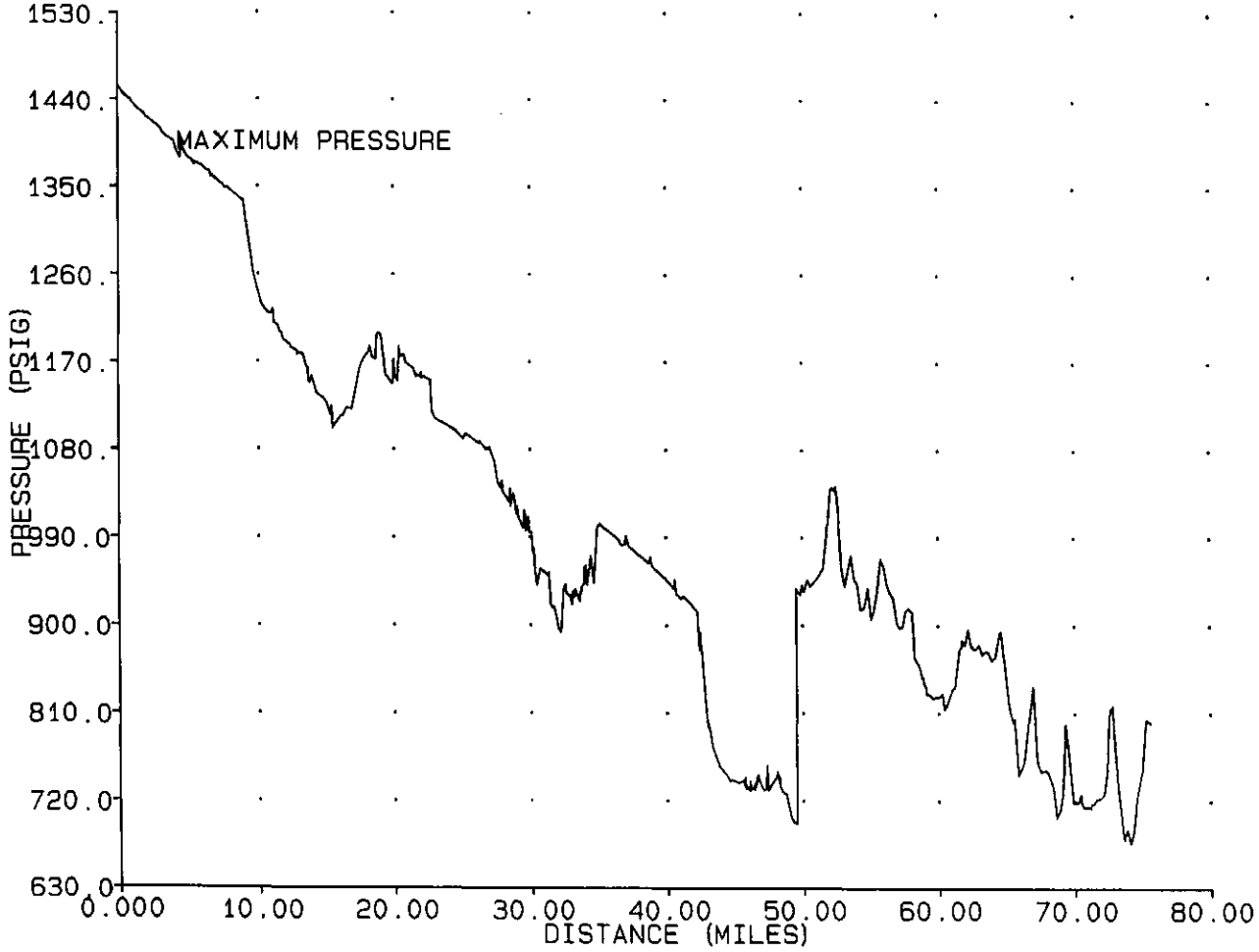
SA 003043

CASE 5, FIGURE 2, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW

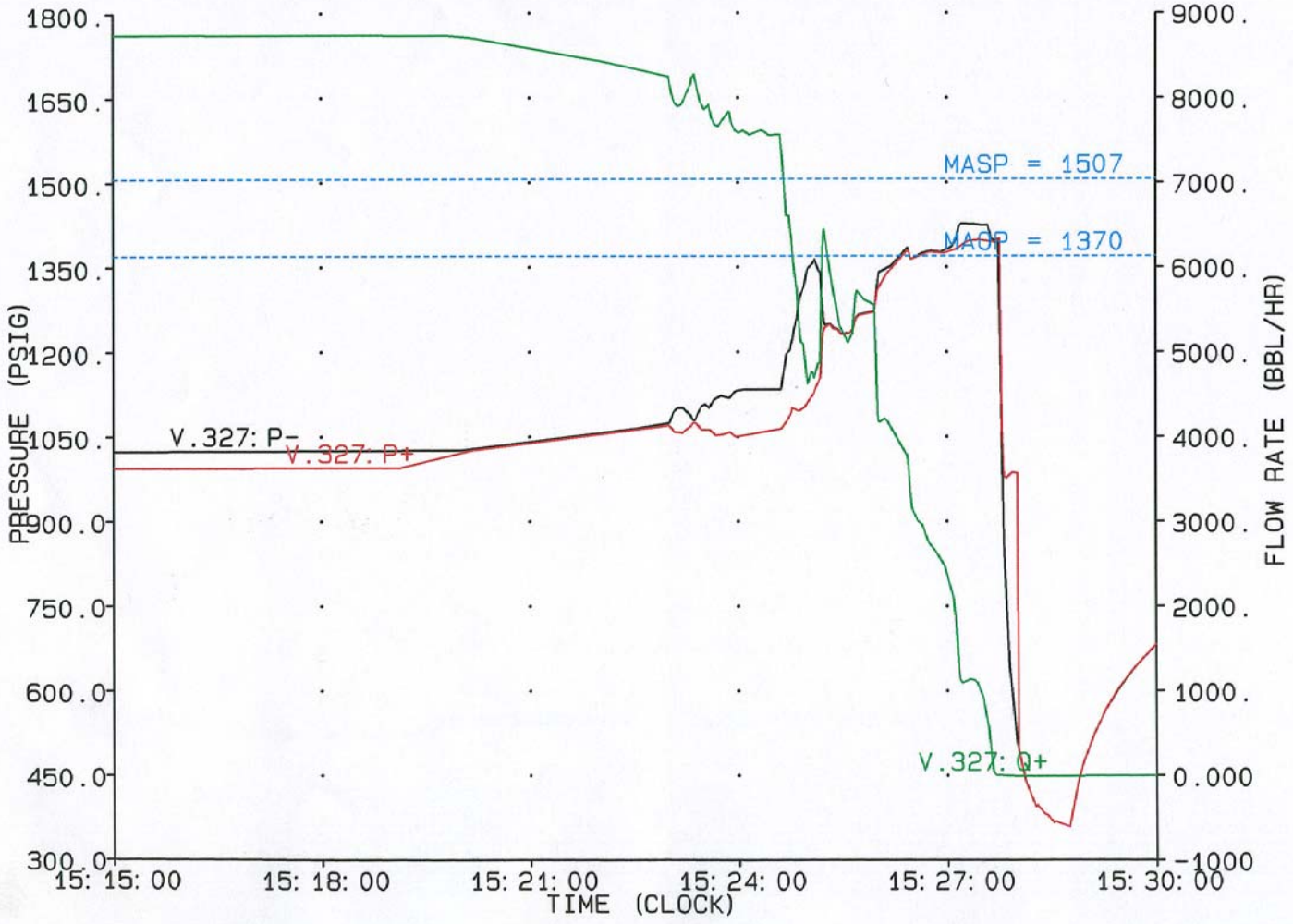


SA 003044

CASE 5, FIGURE 3, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM ALLEN TO RENTON

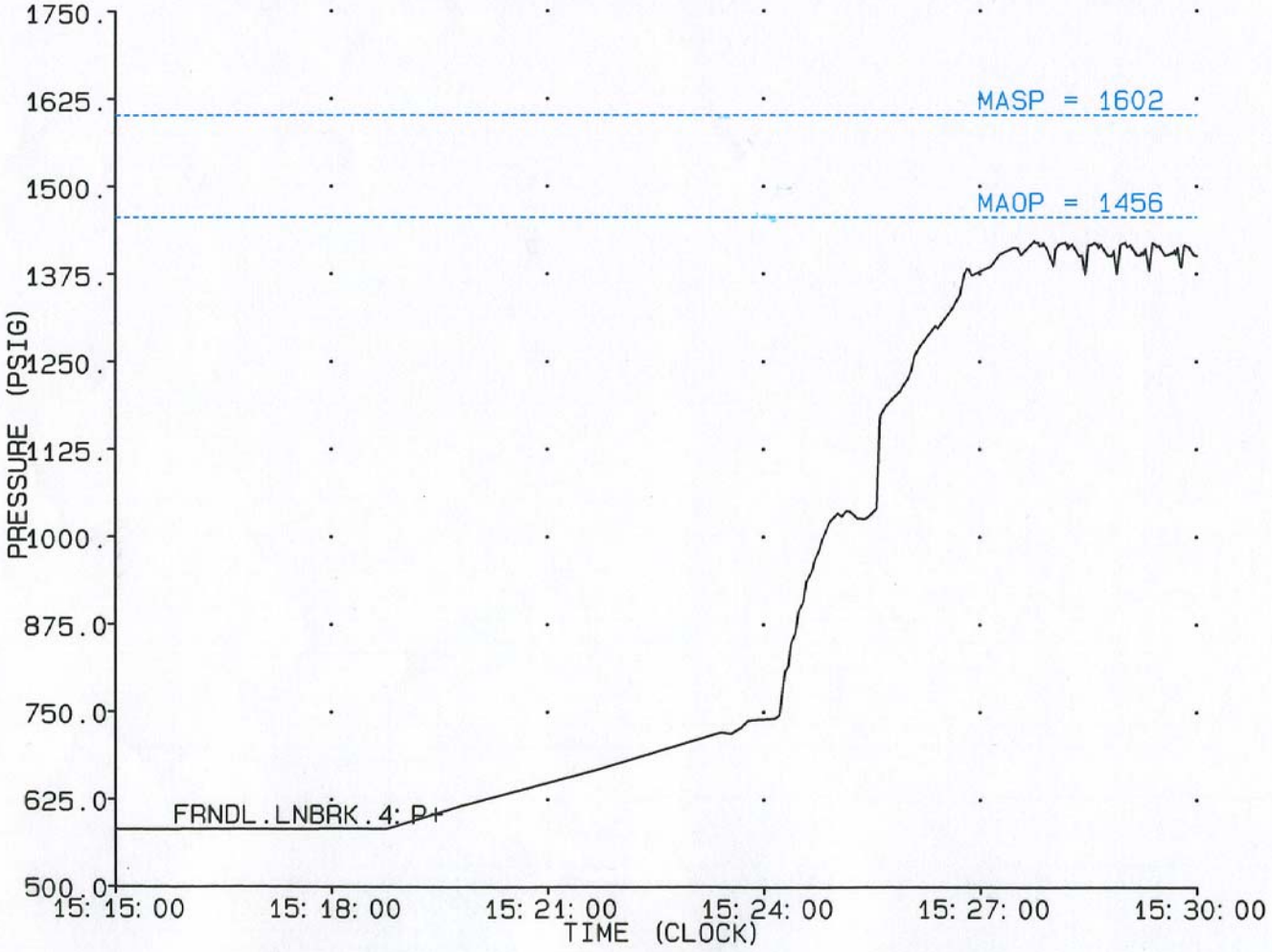


CASE 5, FIGURE 4, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
FERNDALE , V.327, PUMP DISCHARGE CONTROL VALVE PRESSURE & FLOW



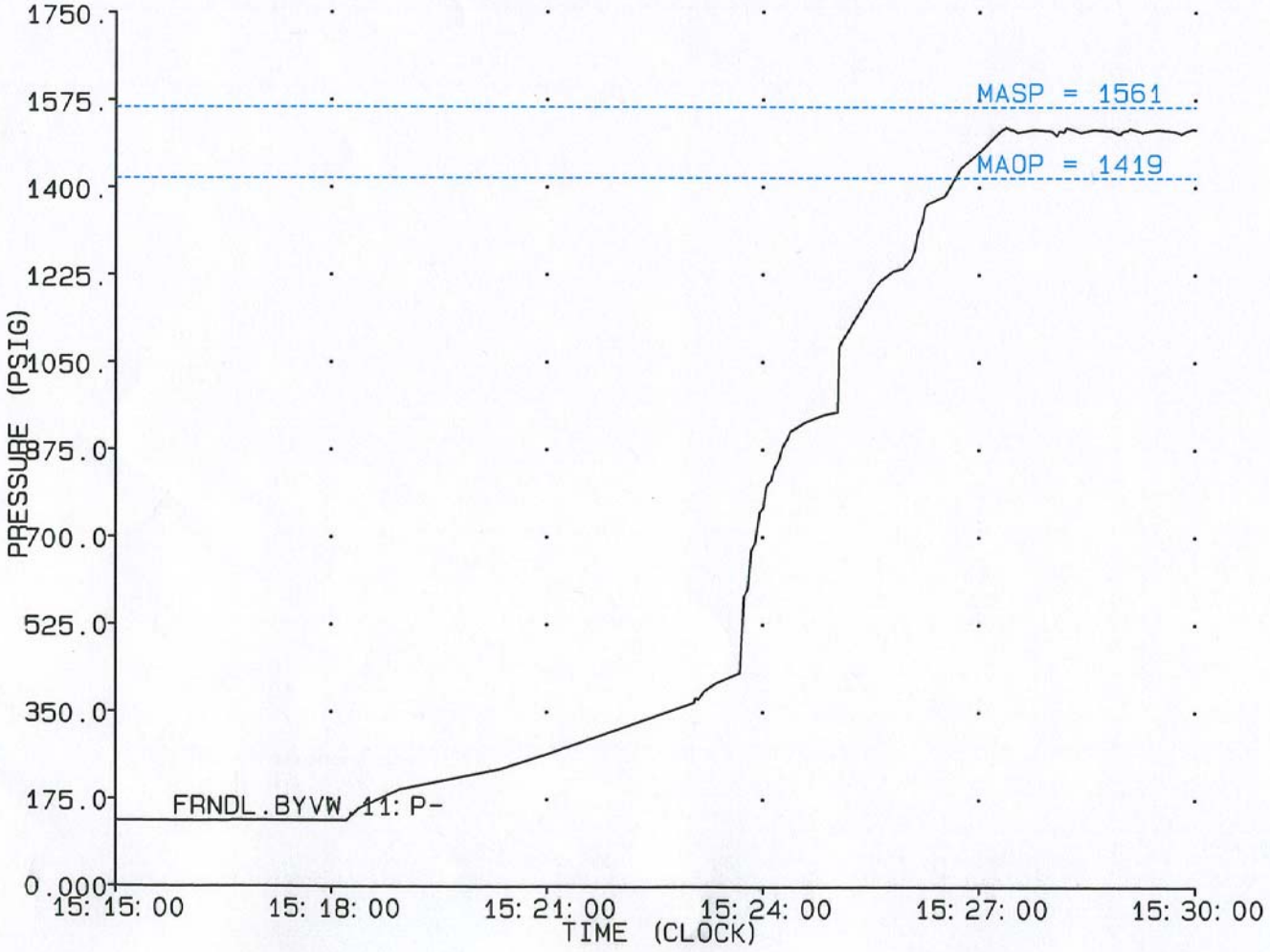
SA 003046

CASE 5, FIGURE 5, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



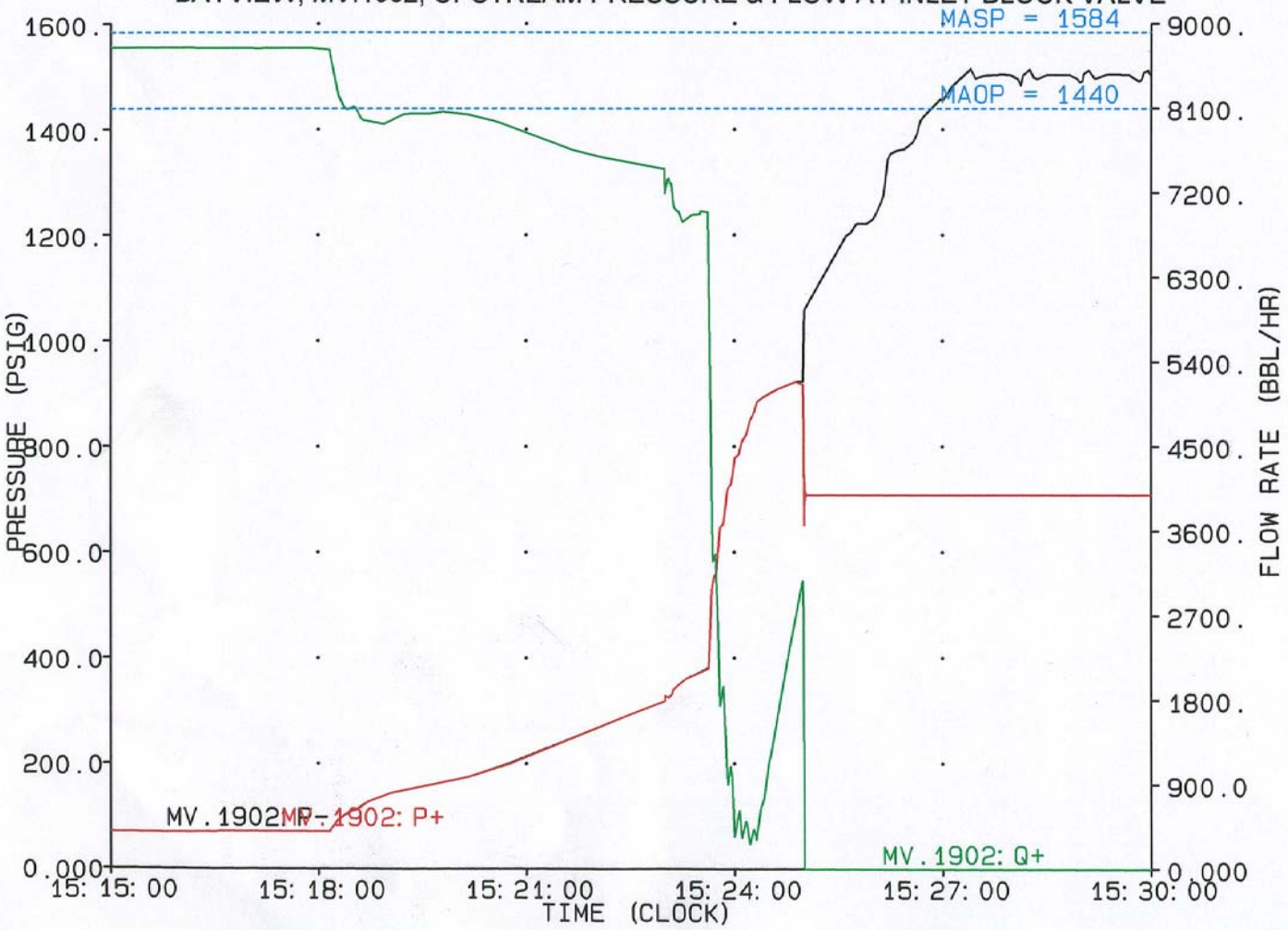
SA 003047

CASE 5, FIGURE 6, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
PRESSURE AT ALLEN JUNCTION



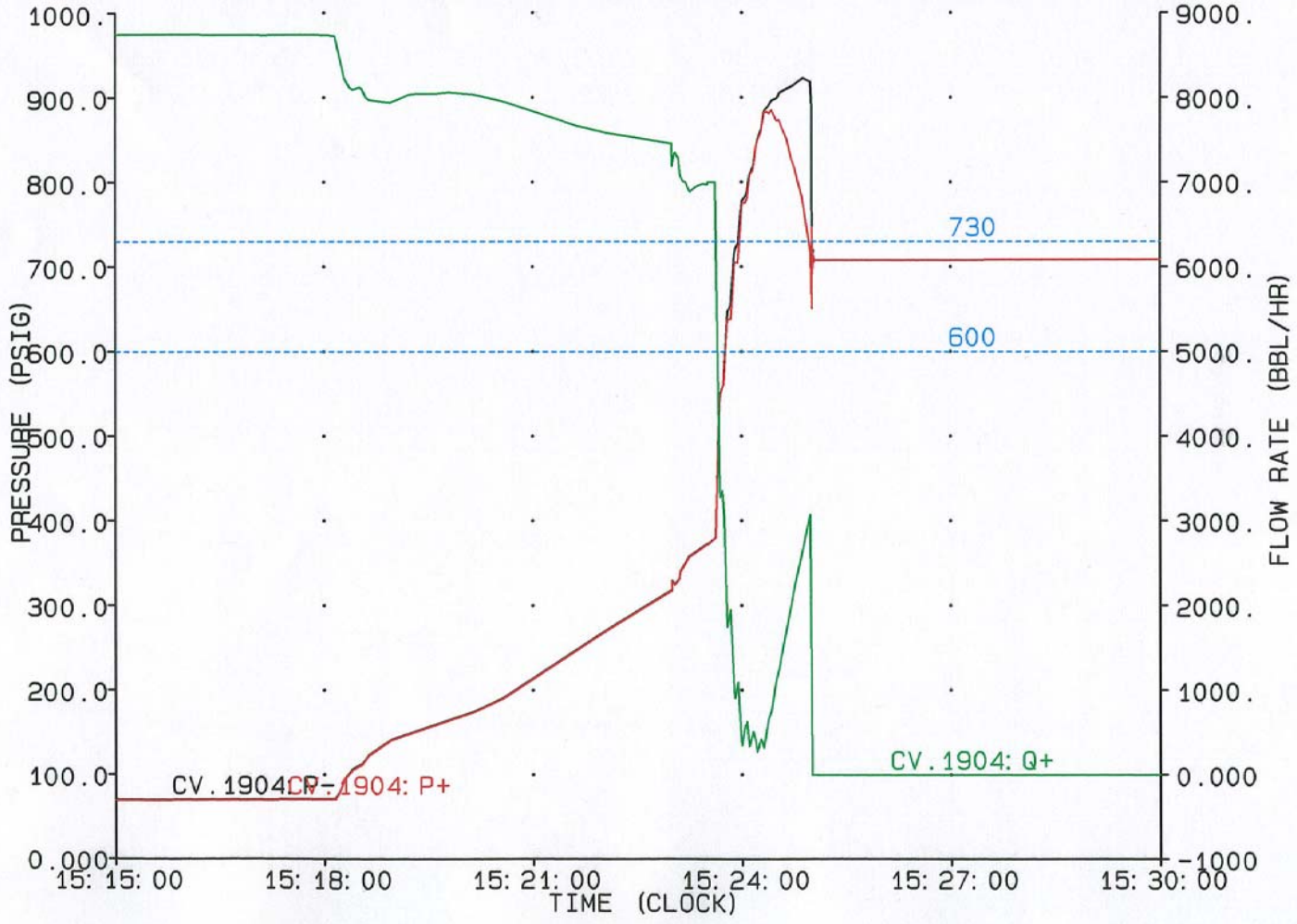
SA 003048

CASE 5, FIGURE 7, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, MV.1902, UPSTREAM PRESSURE & FLOW AT INLET BLOCK VALVE

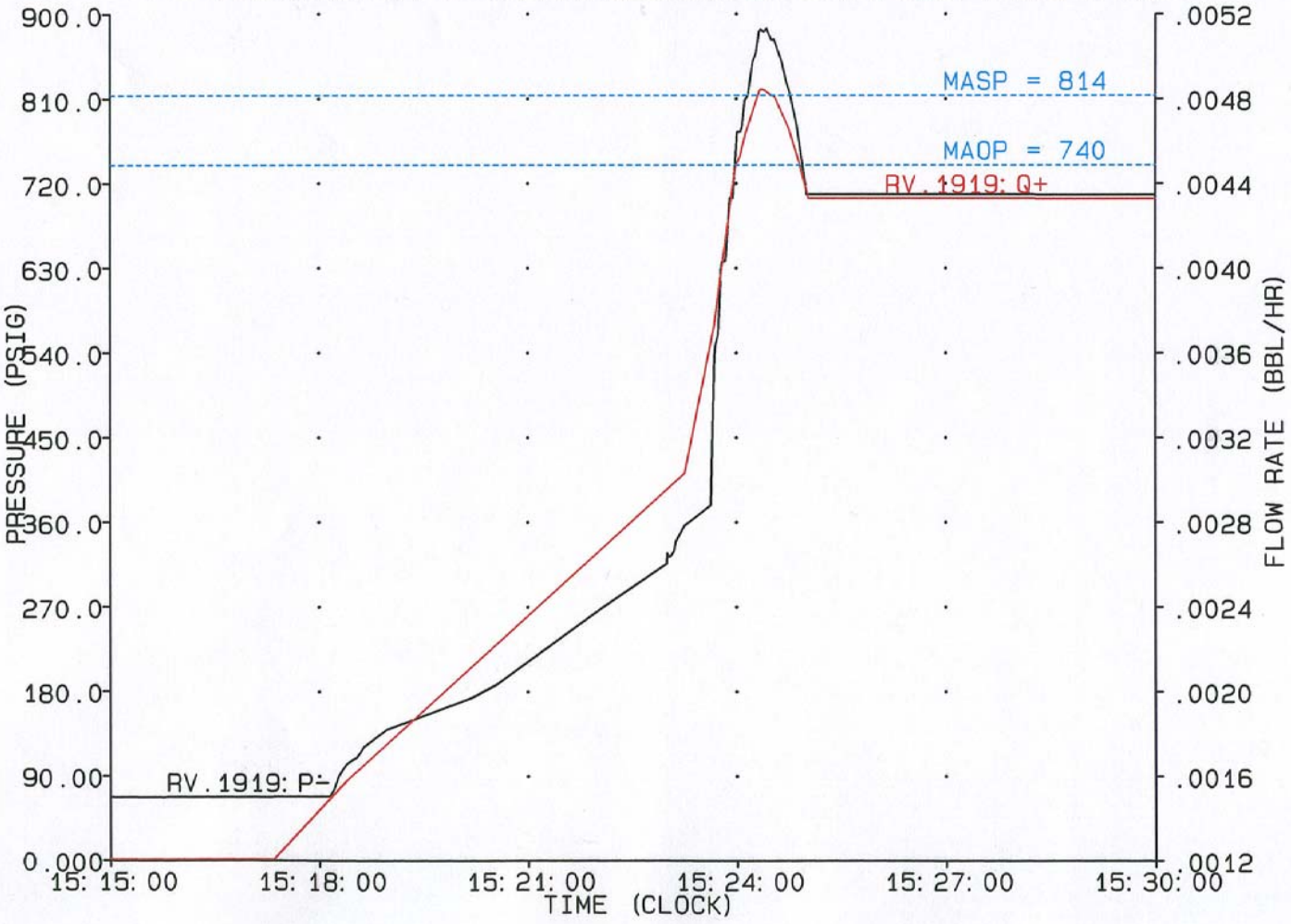


SA 003049

CASE 5, FIGURE 8, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, CV.1904, UPSTREAM PRESSURE & FLOW AT INLET CONTROL VALVE

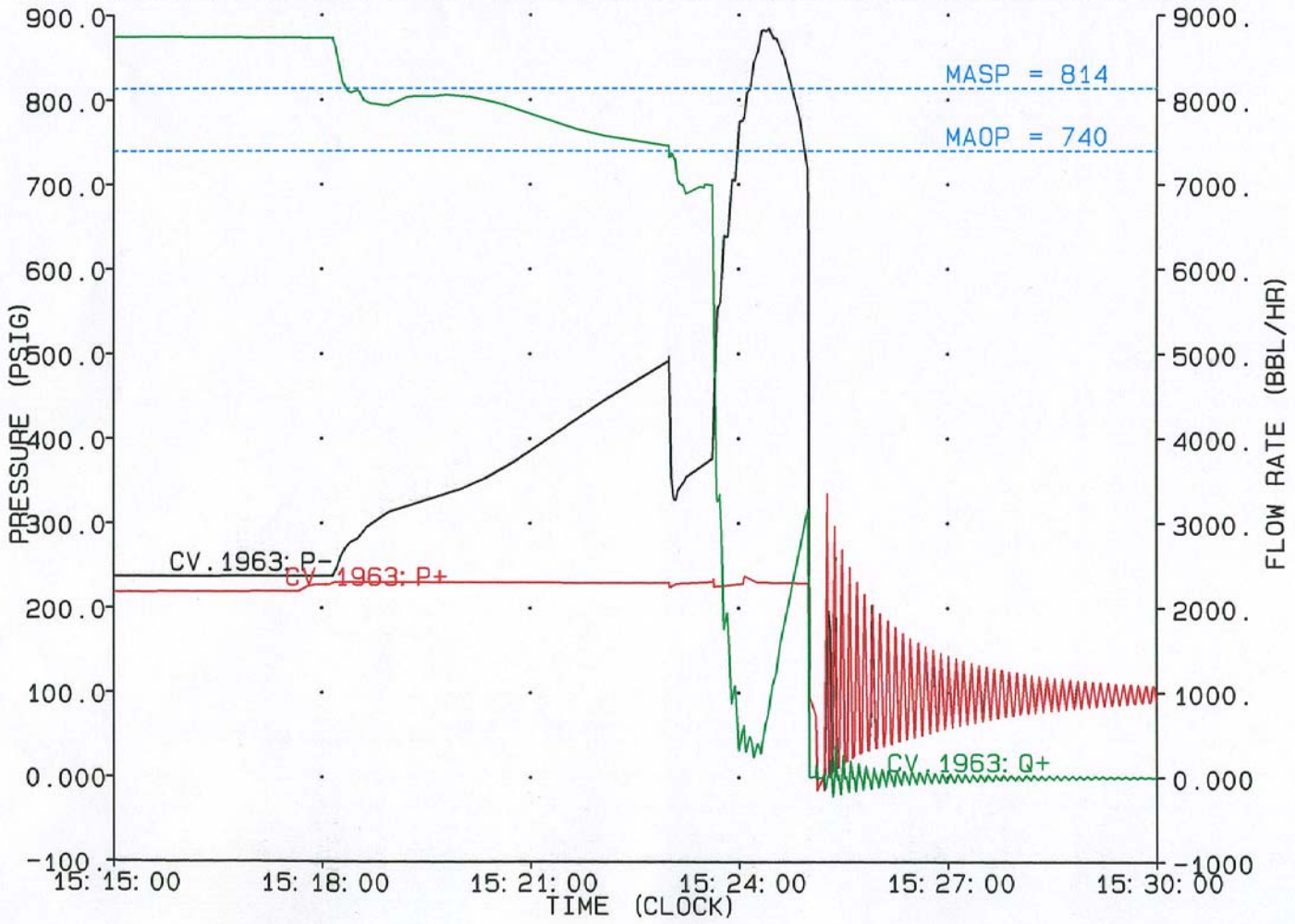


CASE 5, FIGURE 9, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, RV.1919, UPSTREAM PRESSURE & FLOW AT INLET RELIEF VALVE



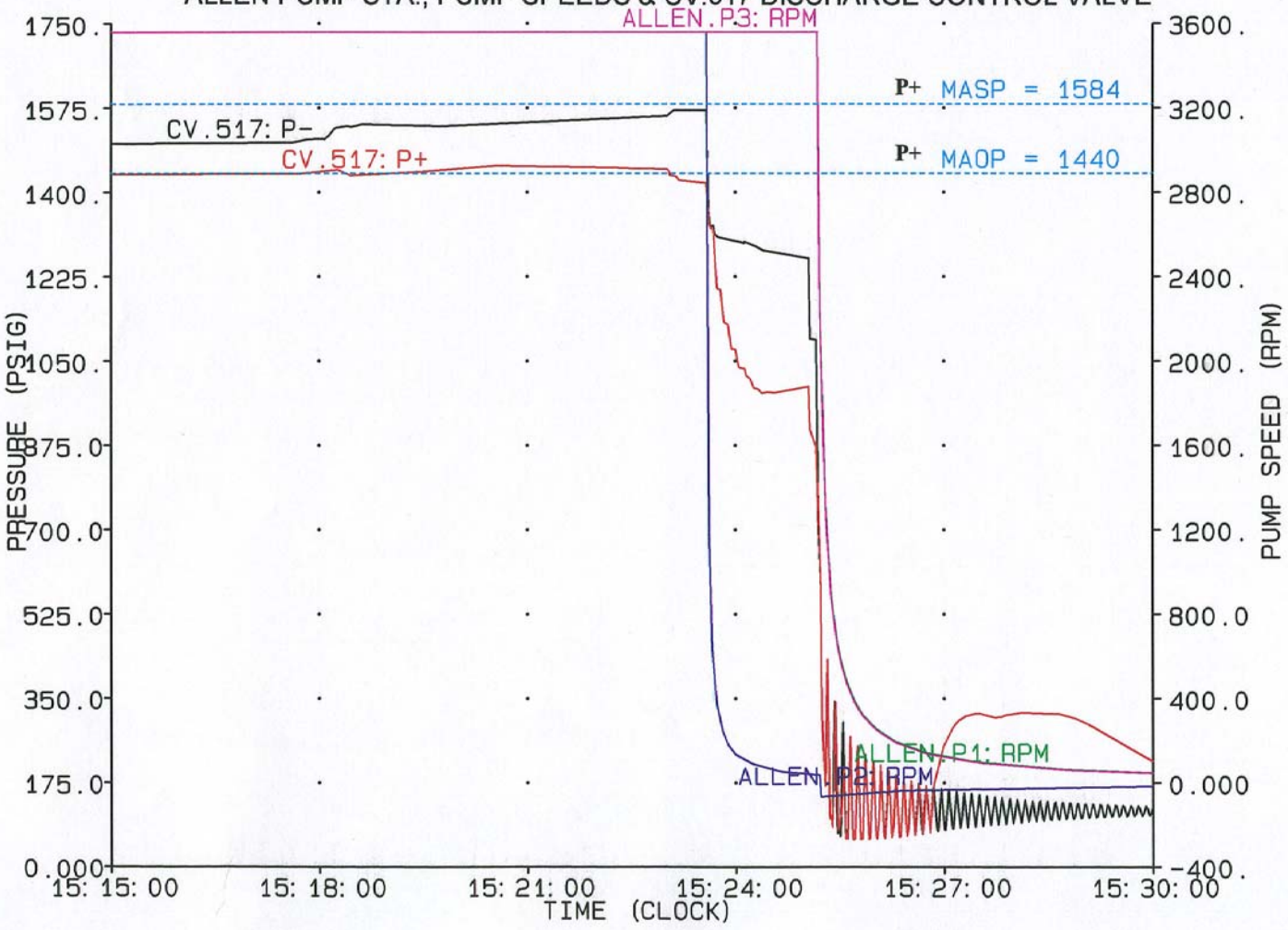
SA 003051

CASE 5, FIGURE 10, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, CV.1963, UPSTREAM PRESSURE & FLOW AT DISCHARGE CONTROL VALVE



SA 003052

CASE 5, FIGURE 11, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, MAL-FUNCTION OF RV.1919 AT BAYVIEW
ALLEN PUMP STA., PUMP SPEEDS & CV.517 DISCHARGE CONTROL VALVE

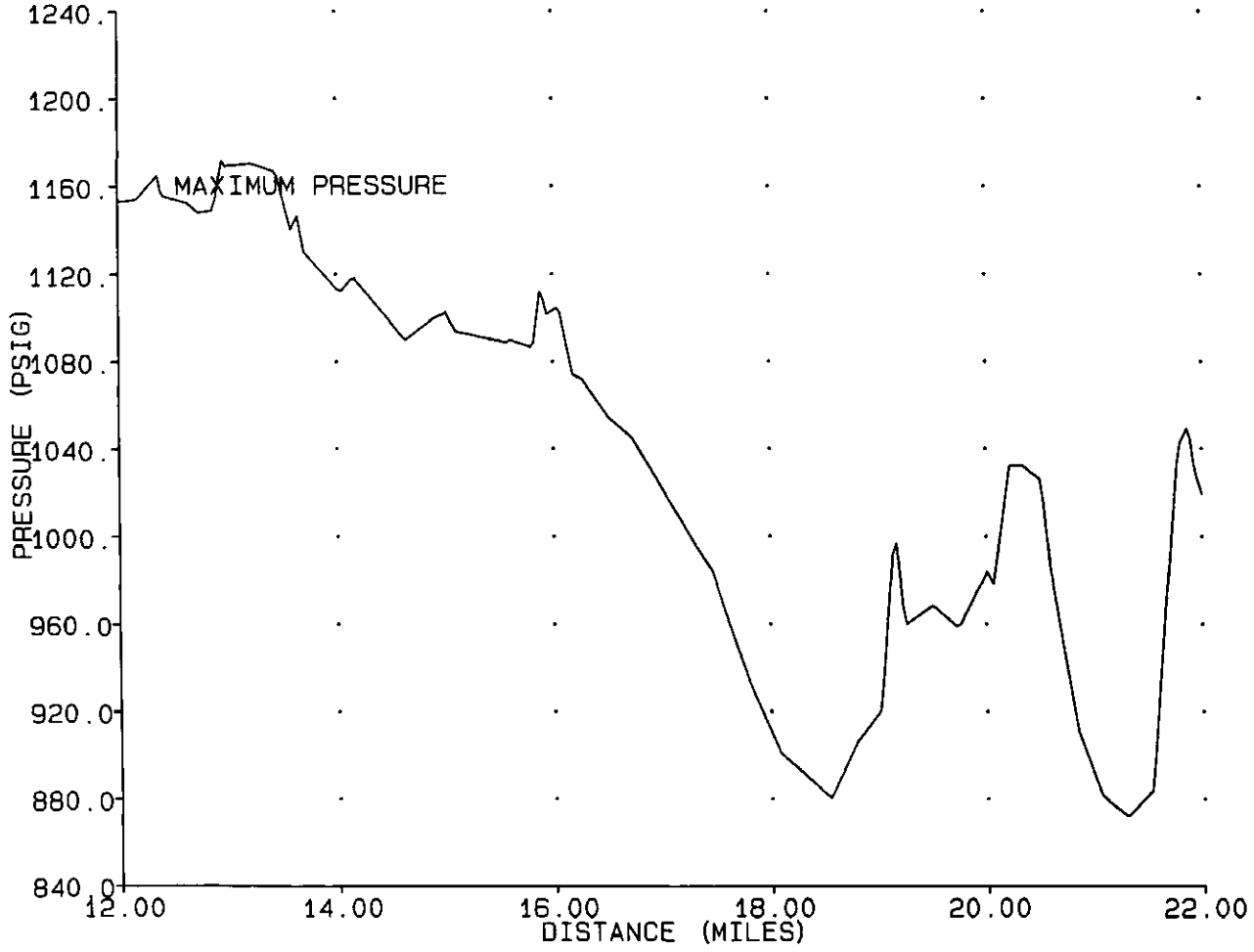


SA 003053

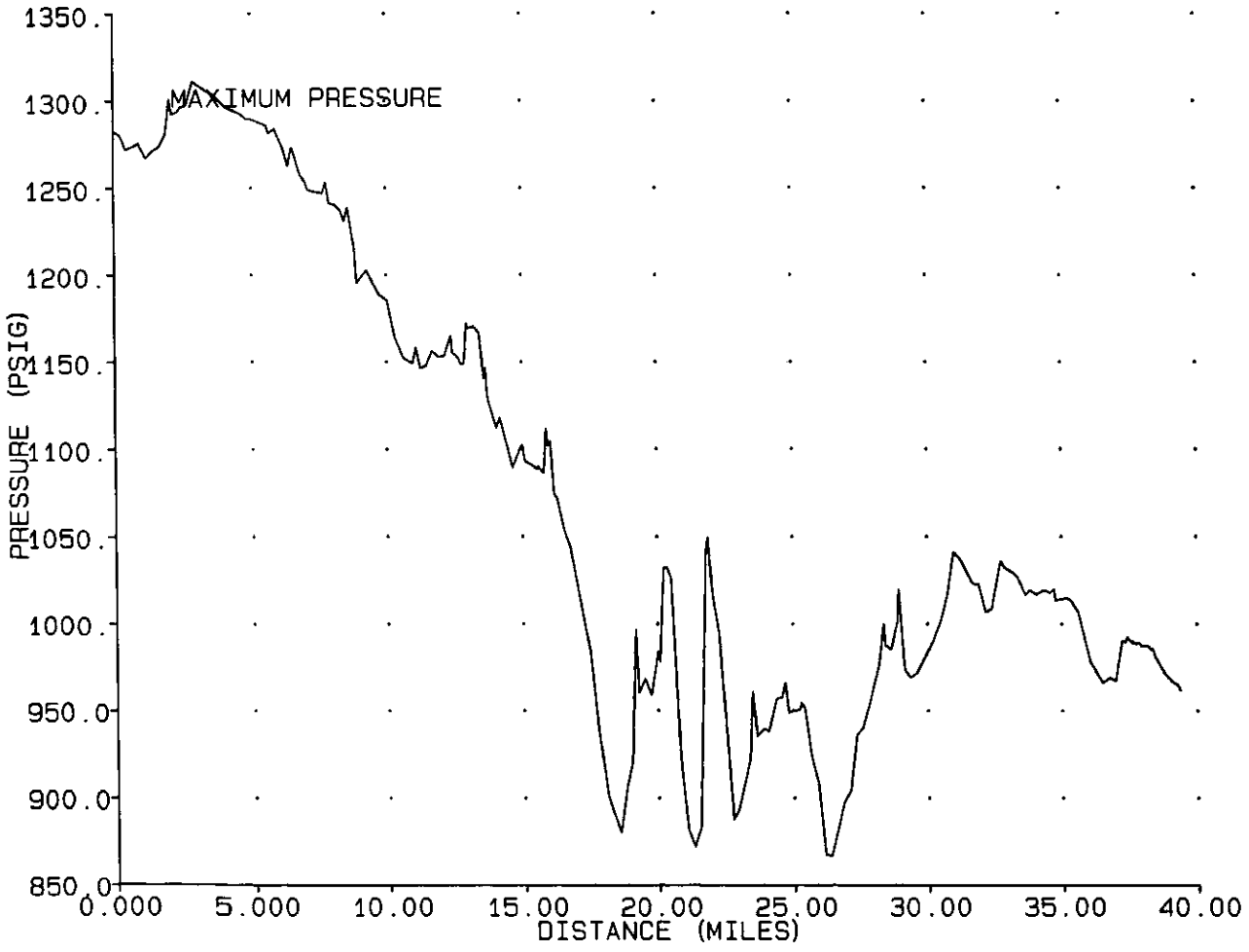
APPENDIX 6

CASE 6 - Event of June 10, 1999, Original Sequence, Proper Function of RV1919

CASE 6, FIGURE 1, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS

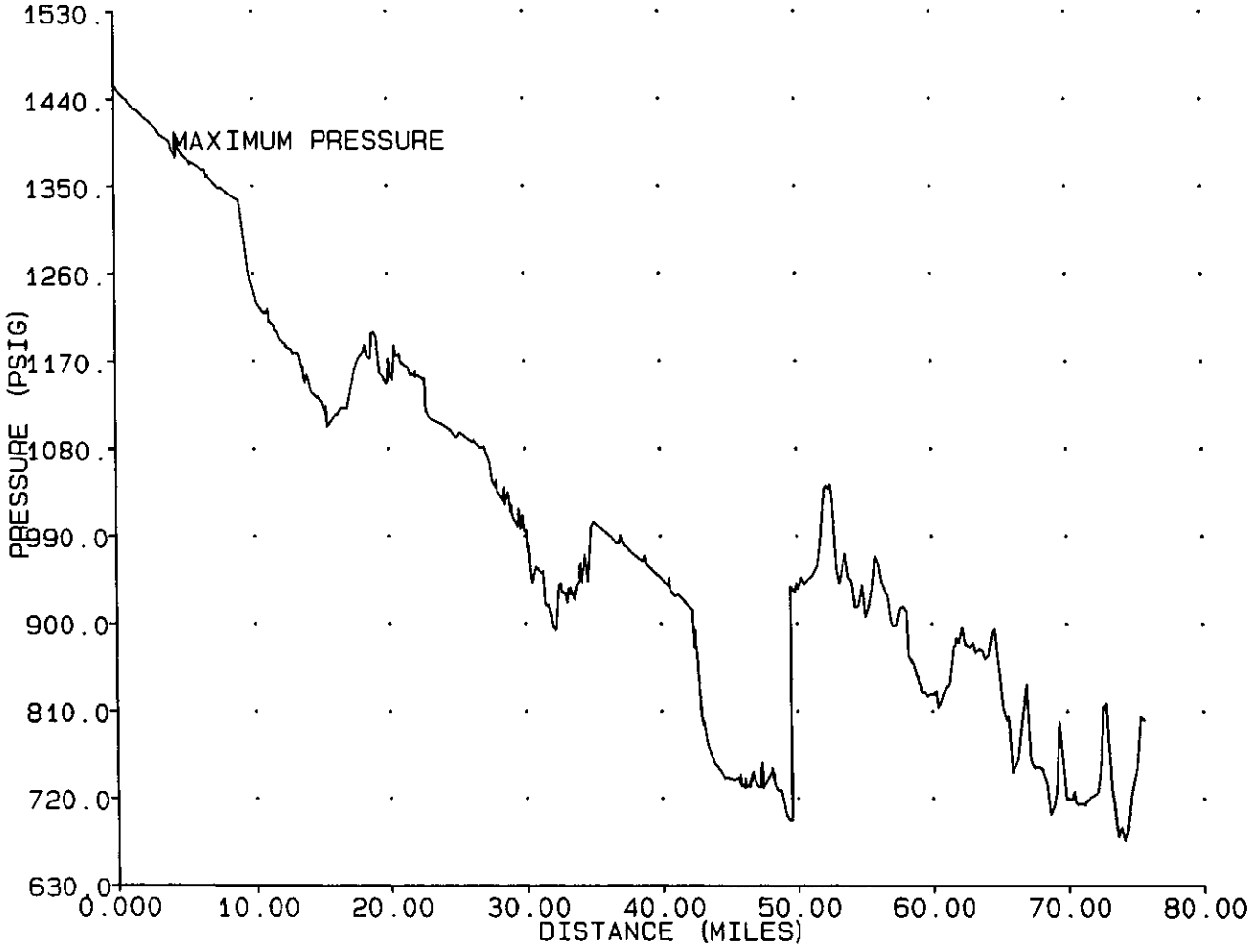


CASE 6, FIGURE 2, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW

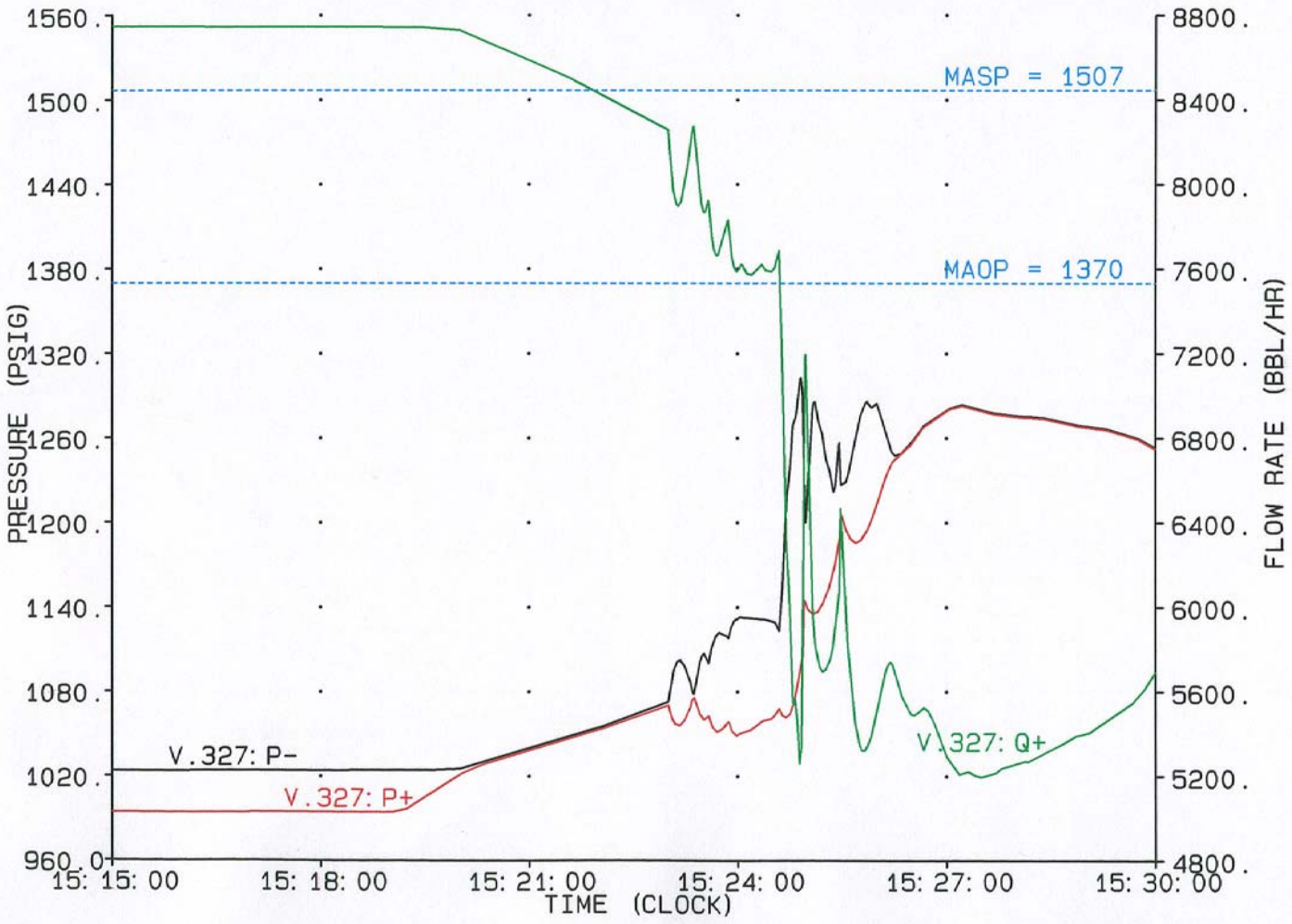


SA 003056

CASE 6, FIGURE 3, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM ALLEN TO RENTON

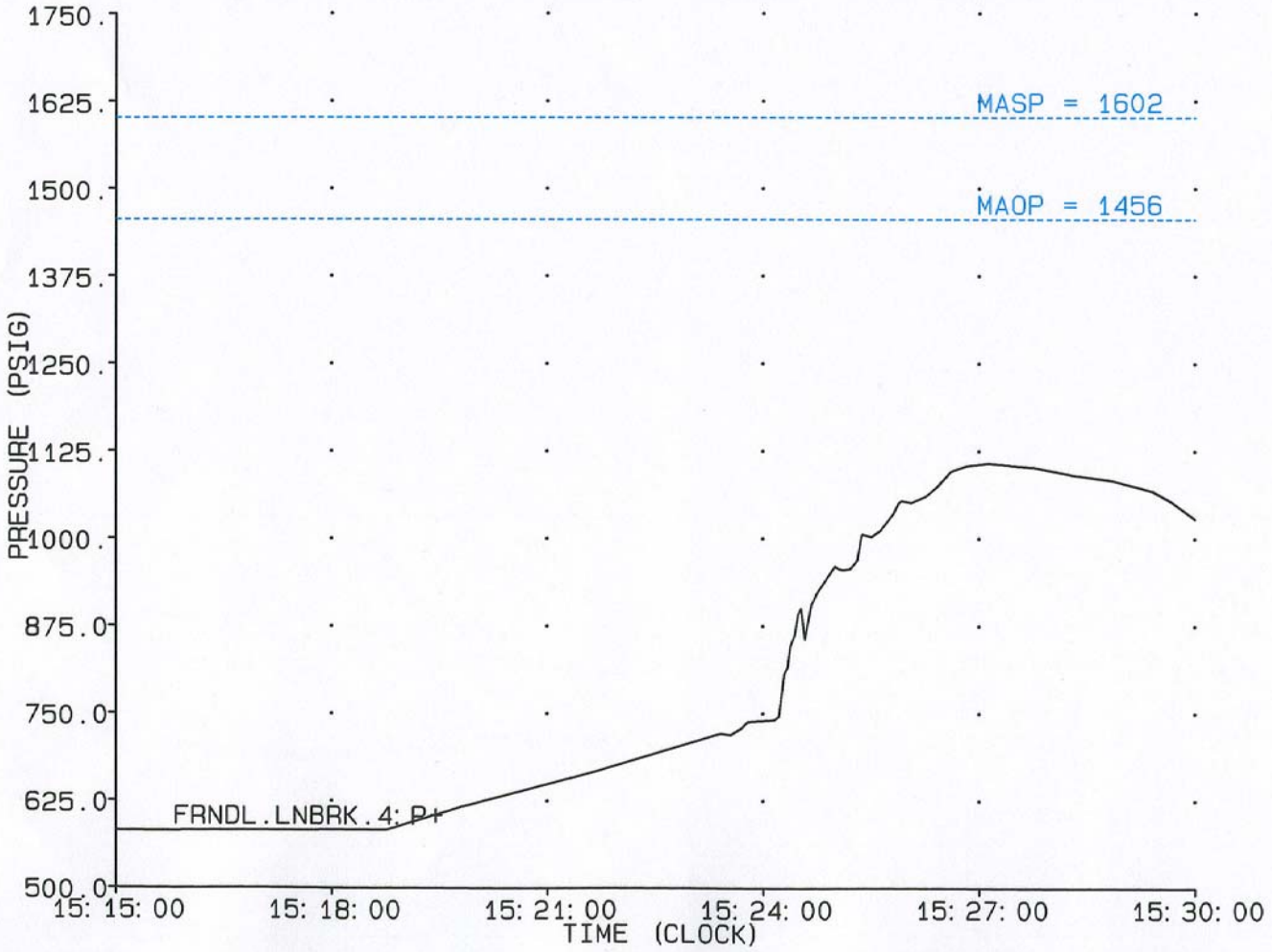


CASE 6, FIGURE 4, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
FERNDALE, V.327, PUMP DISCHARGE CONTROL VALVE PRESSURE & FLOW



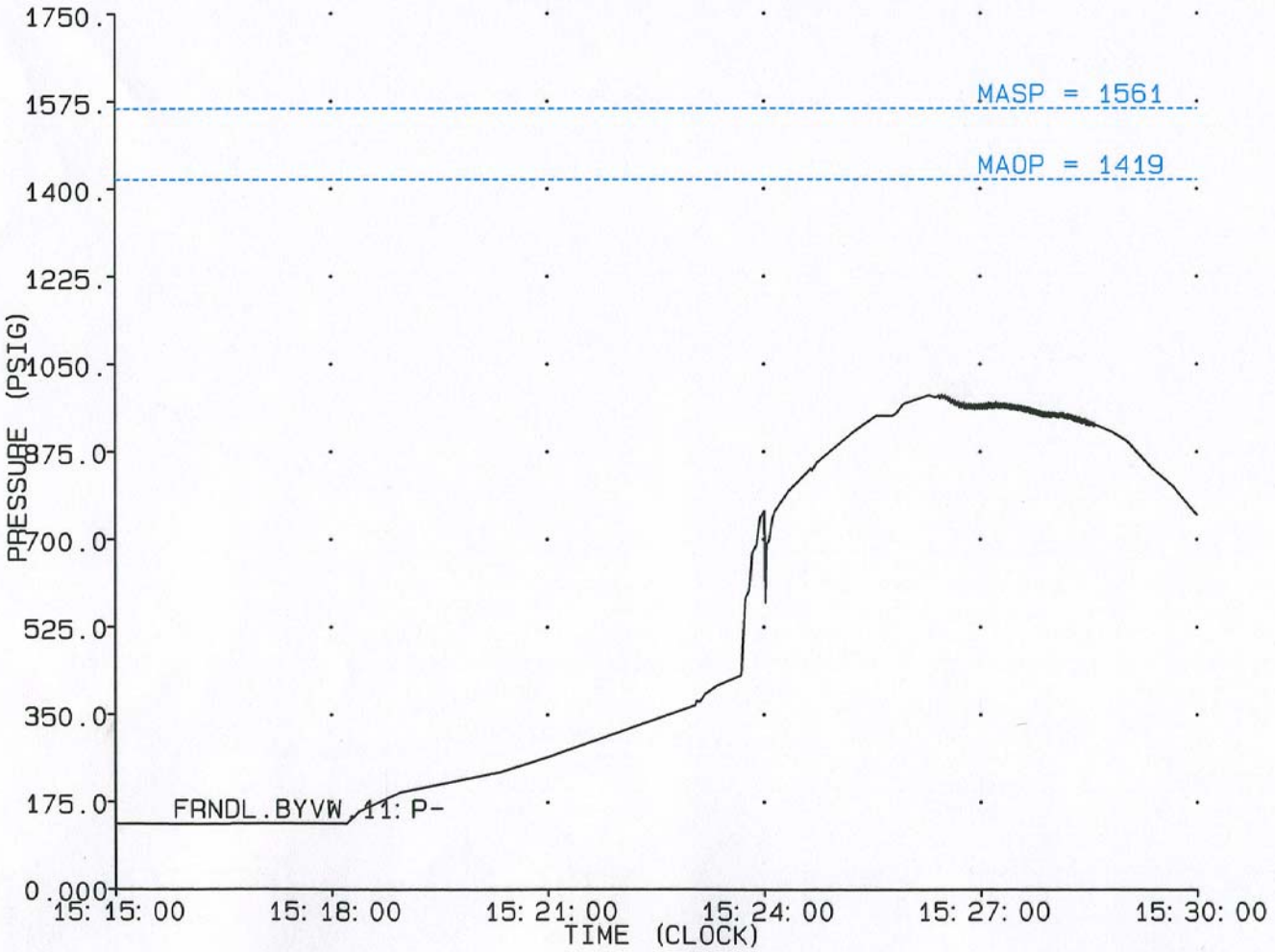
SA 003058

CASE 6, FIGURE 5, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



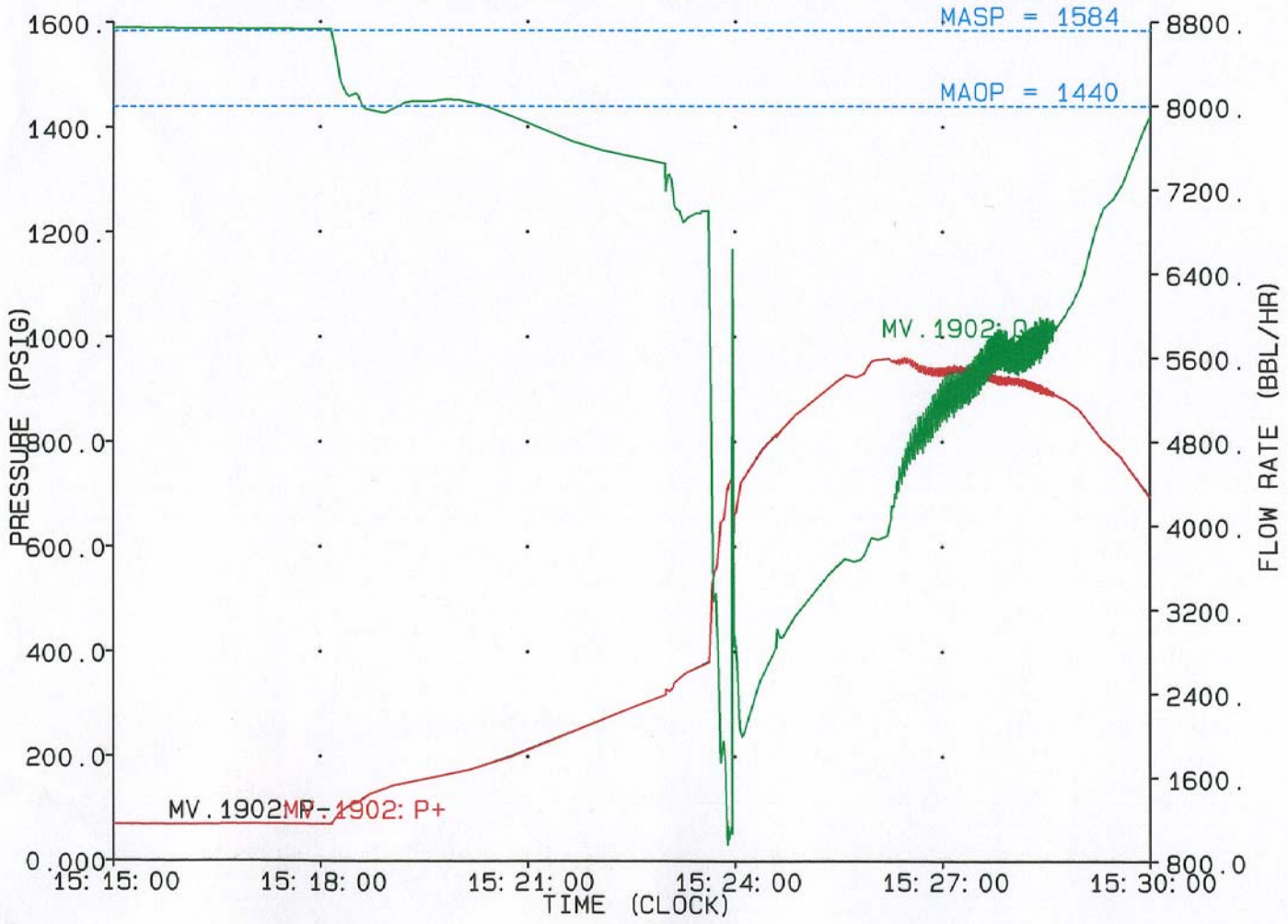
SA 003059

CASE 6, FIGURE 6, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
PRESSURE AT ALLEN JUNCTION



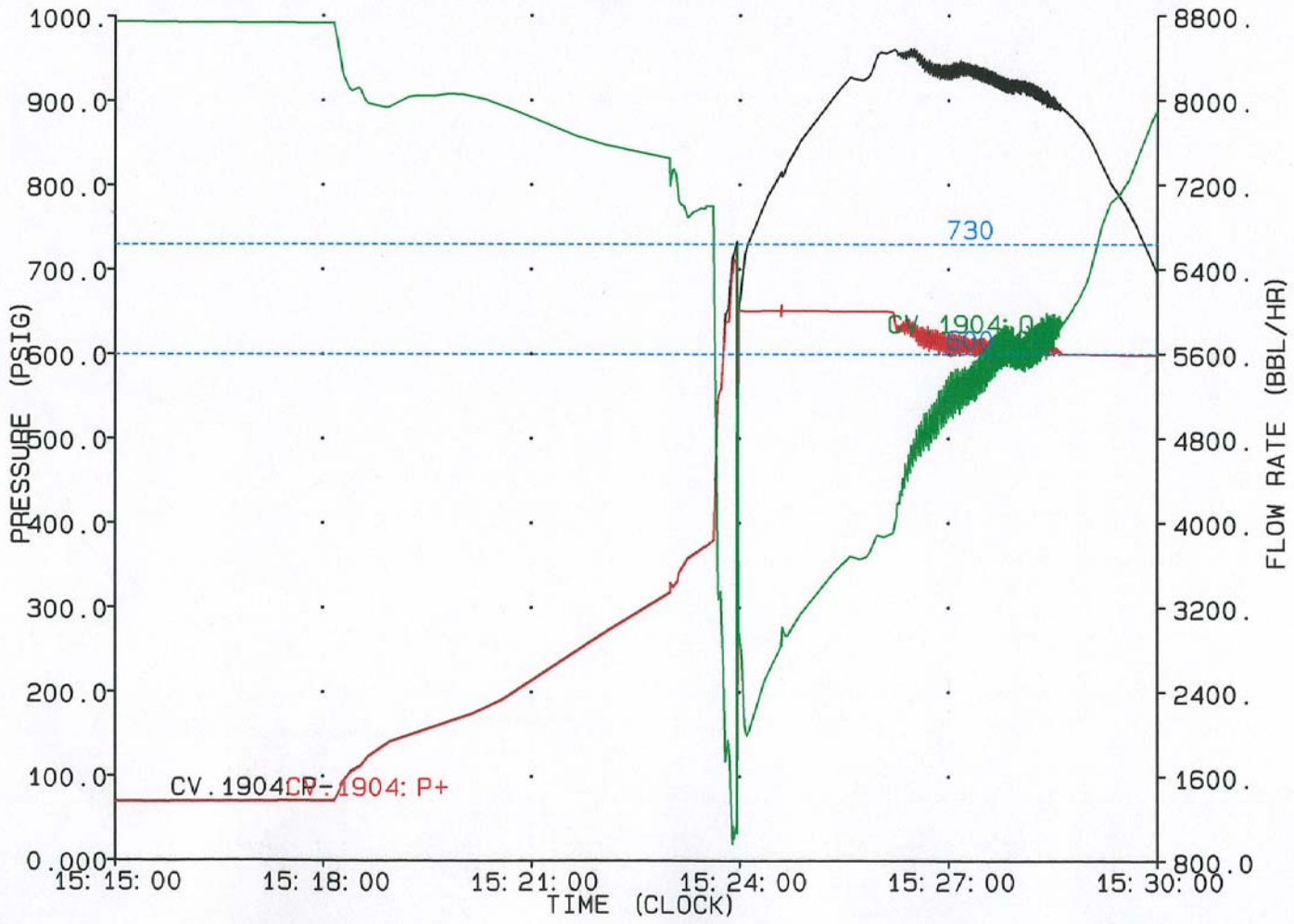
SA 003060

CASE 6, FIGURE 7, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, MV.1902, UPSTREAM PRESSURE & FLOW AT INLET BLOCK VALVE

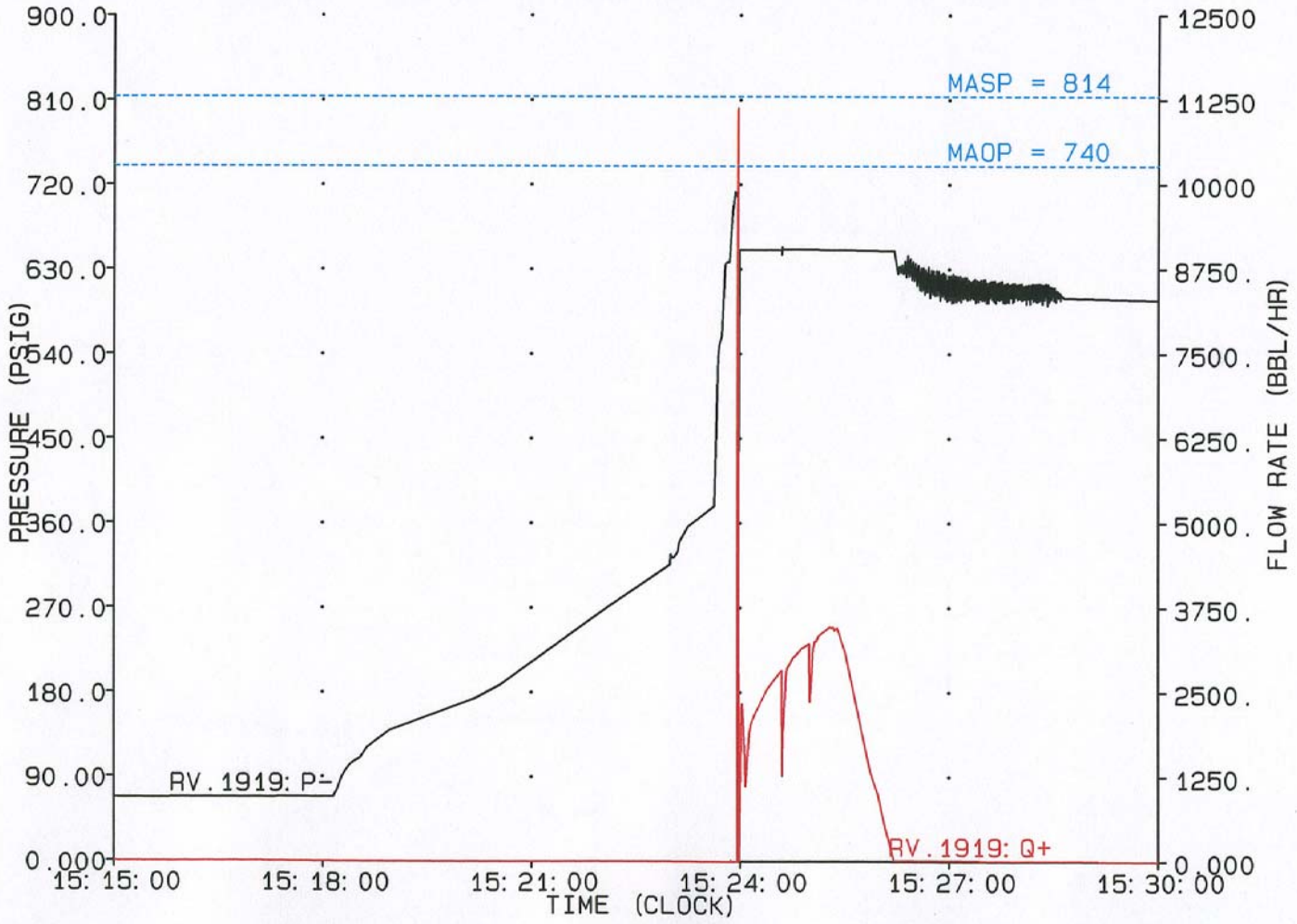


SA 003061

CASE 6, FIGURE 8, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, CV.1904, UPSTREAM PRESSURE & FLOW AT INLET CONTROL VALVE

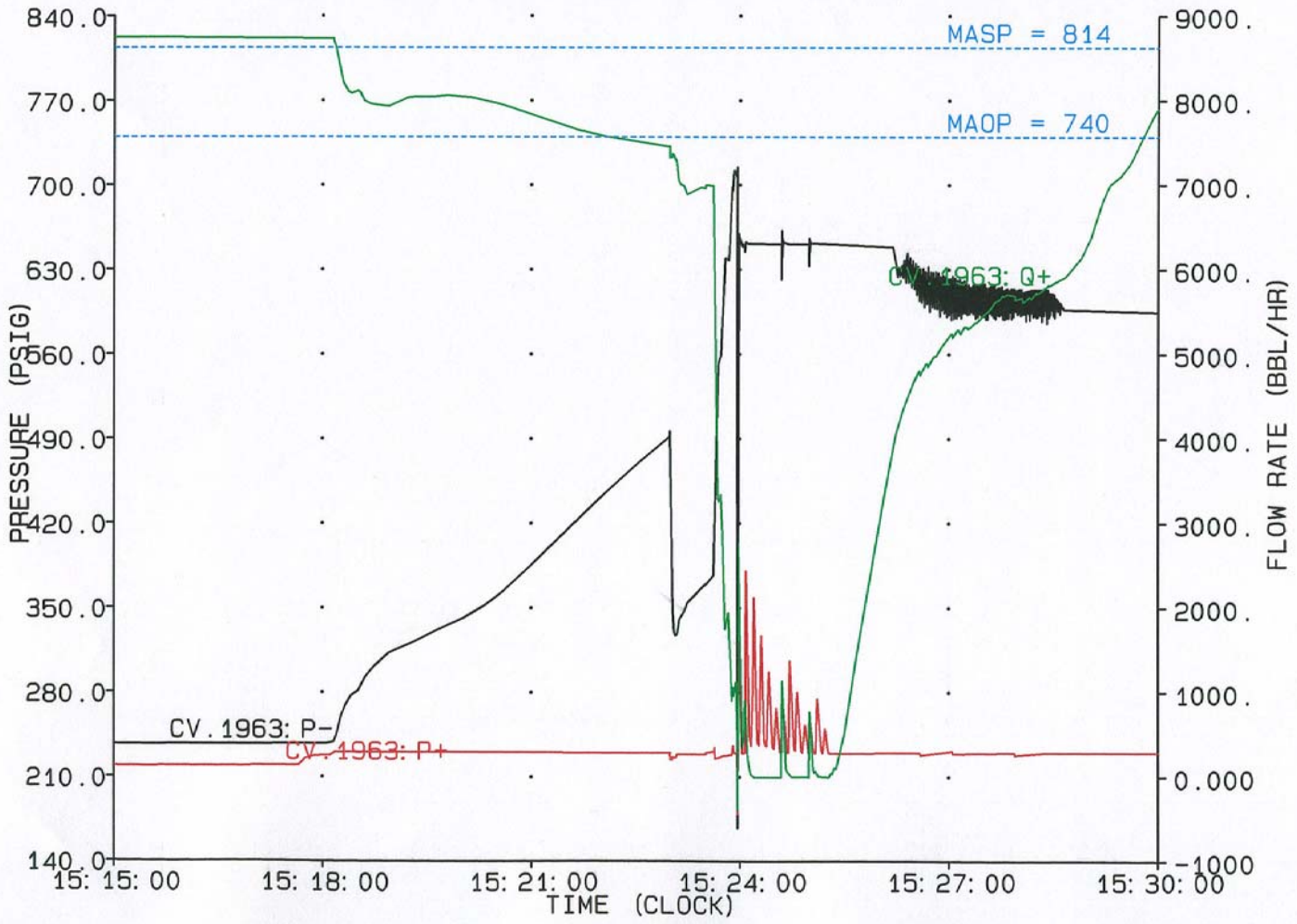


CASE 6, FIGURE 9, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, RV.1919, UPSTREAM PRESSURE & FLOW AT INLET RELIEF VALVE

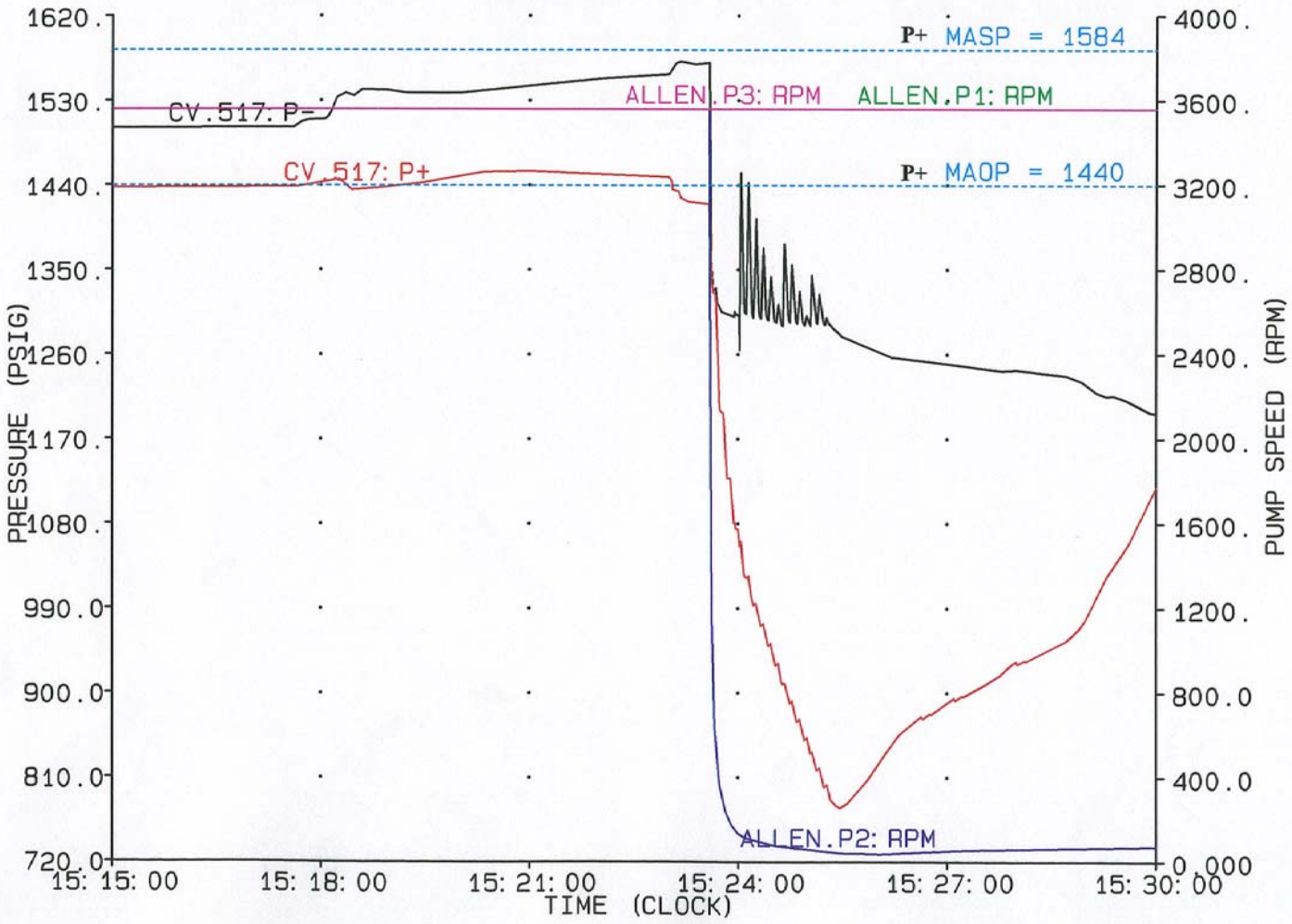


SA 003063

CASE 6, FIGURE 10, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
BAYVIEW, CV.1963, UPSTREAM PRESSURE & FLOW AT DISCHARGE CONTROL VALVE



CASE 6, FIGURE 11, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION OF RV.1919 AT BAYVIEW
ALLEN PUMP STA., PUMP SPEEDS & CV.517 DISCHARGE CONTROL VALVE

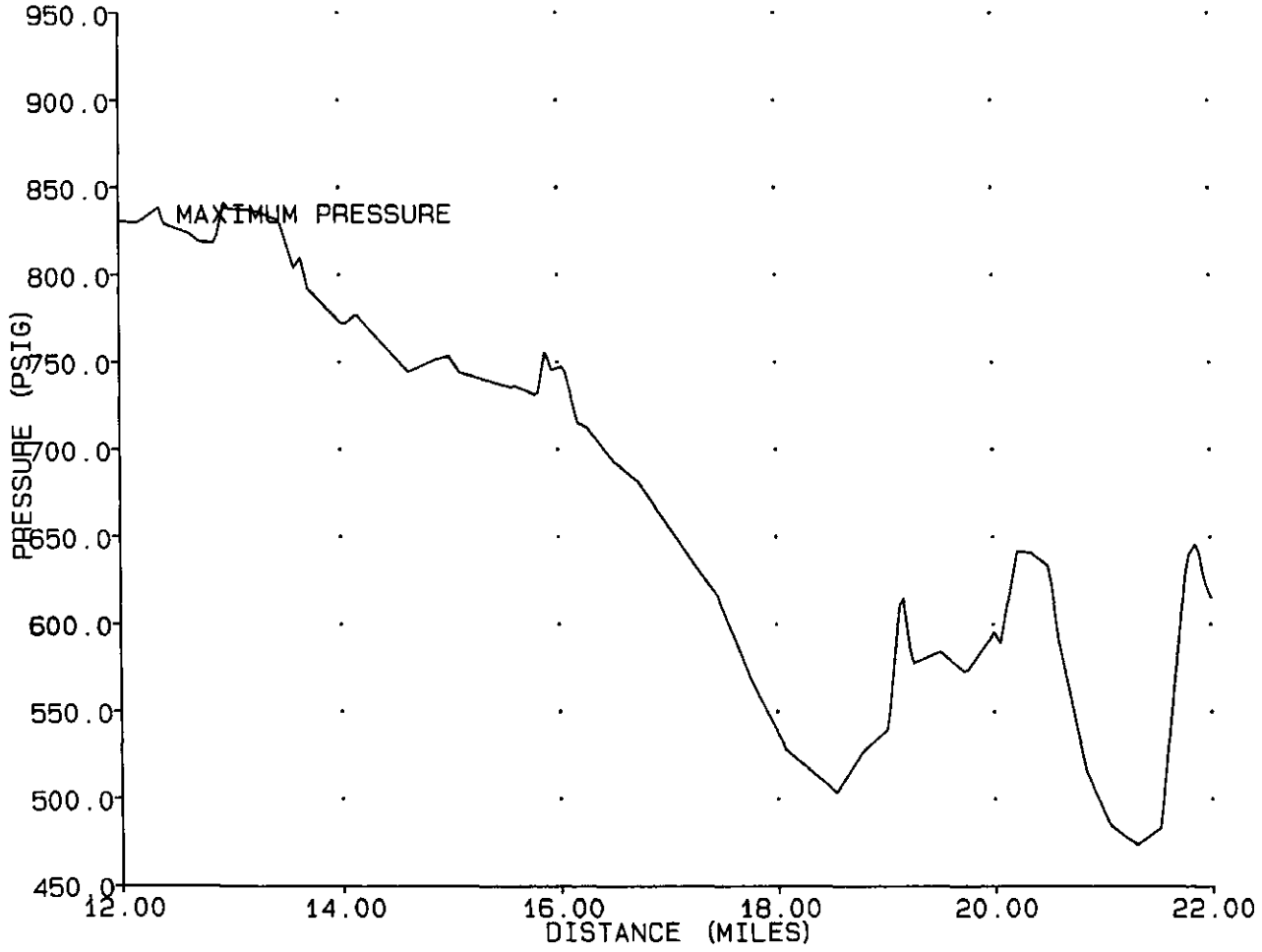


SA 003065

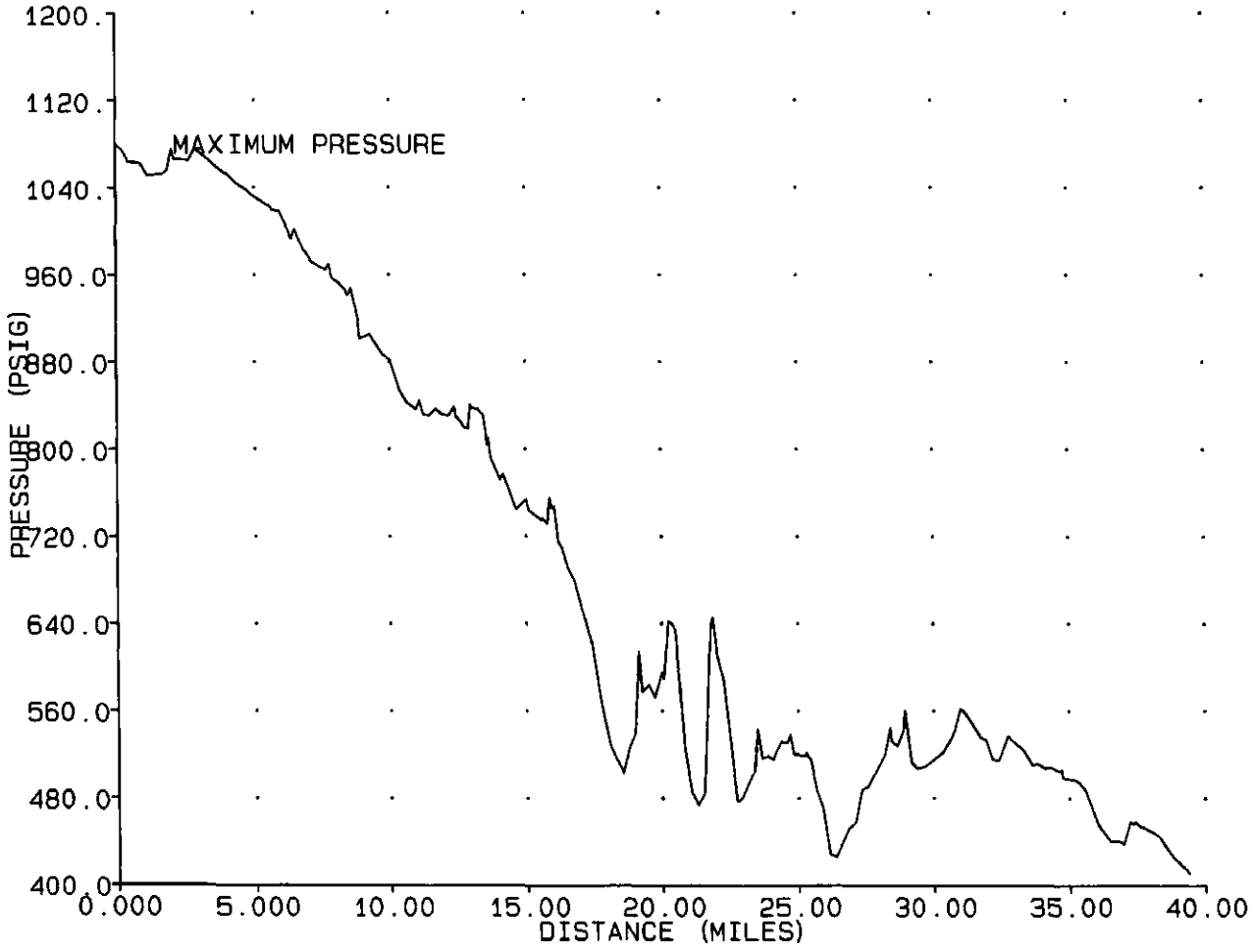
APPENDIX 7

CASE 7 - Event of June 10, 1999, Trip of ARCO first, Mal-Function of RV1919

CASE 7, FIGURE 1, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS

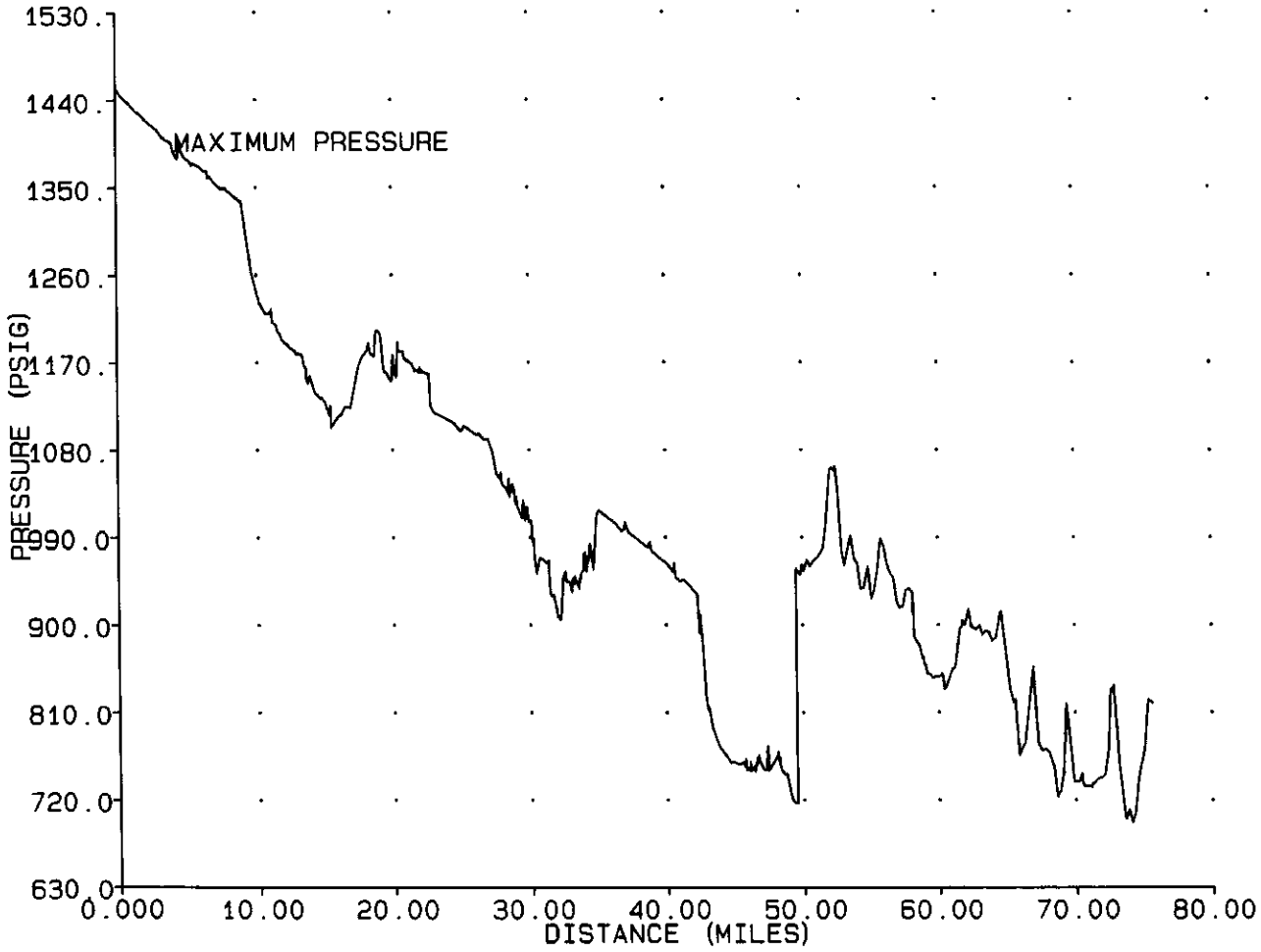


CASE 7, FIGURE 2, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW

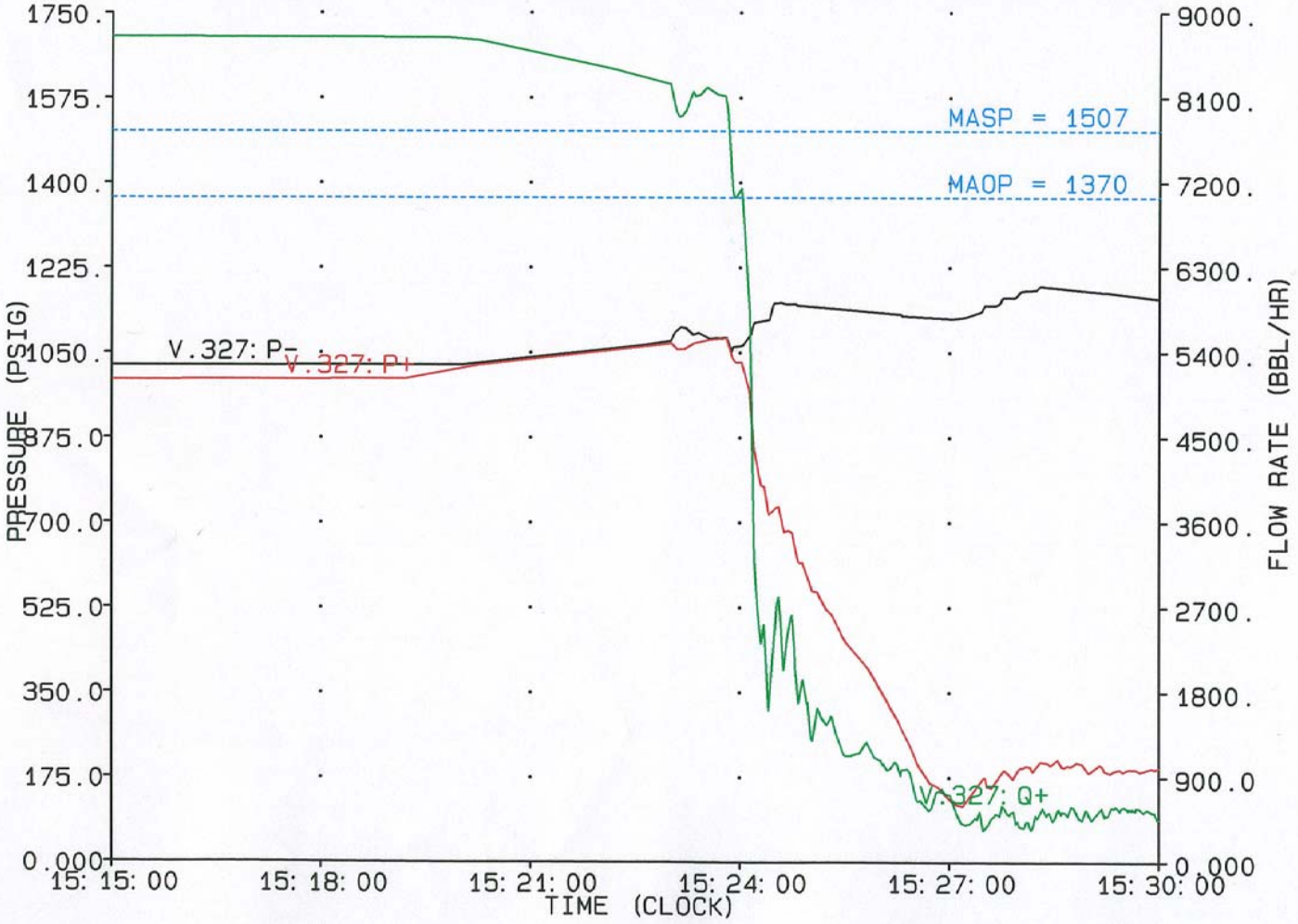


SA 003068

CASE 7, FIGURE 3, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM ALLEN TO RENTON

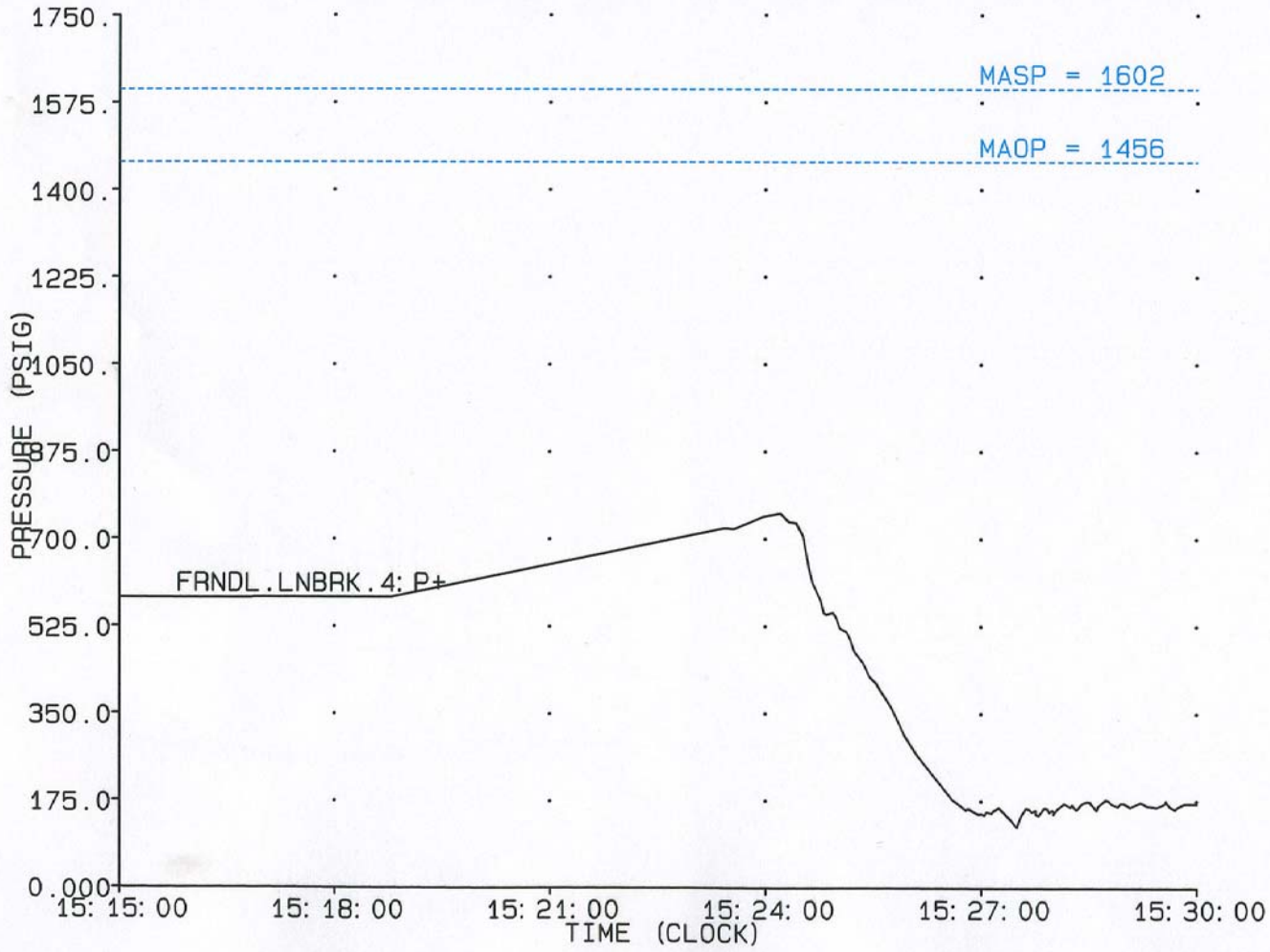


CASE 7, FIGURE 4, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
FERNDALE, V.327, PUMP DISCHARGE CONTROL VALVE PRESSURE & FLOW

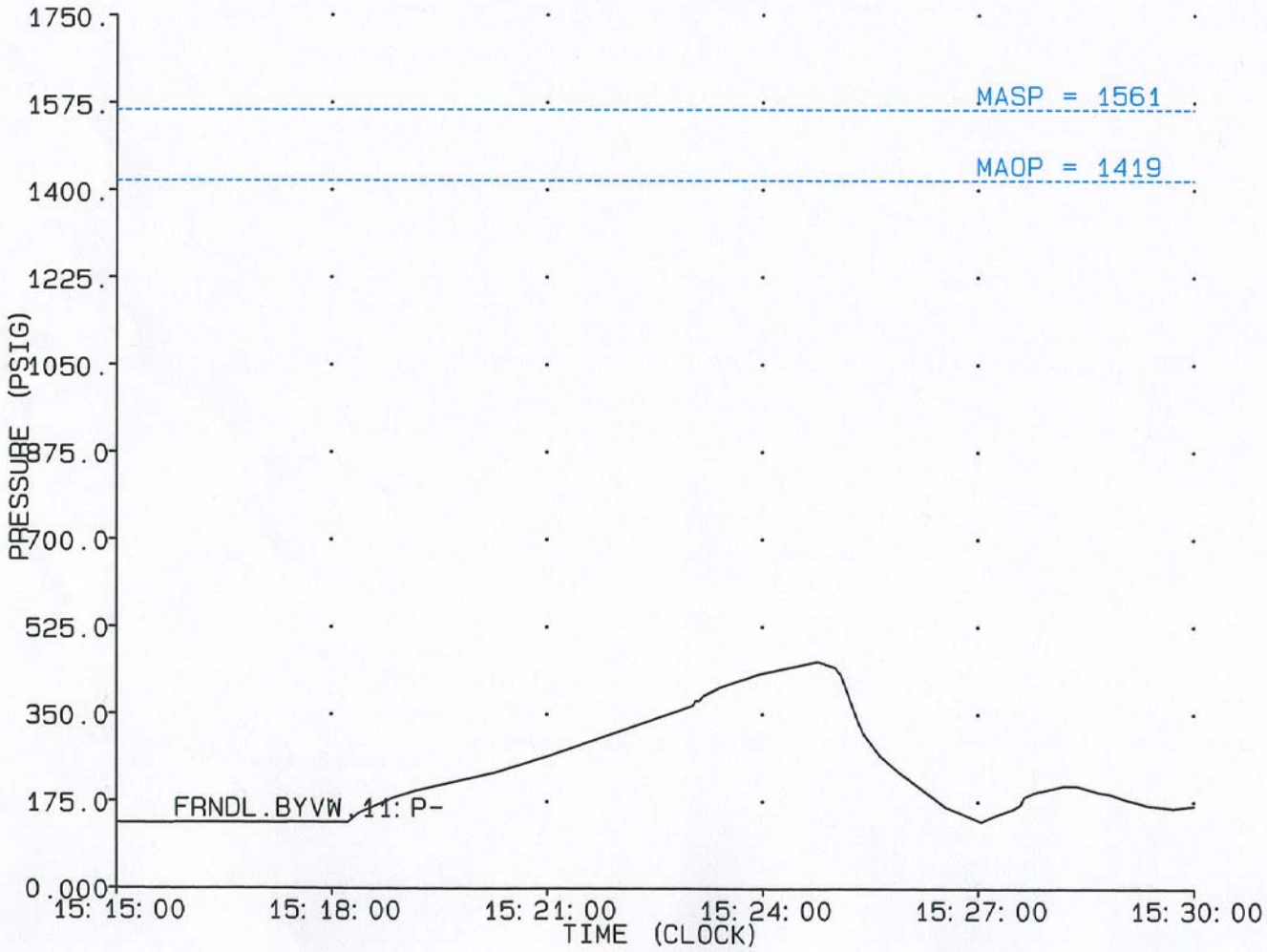


SA 003070

CASE 7, FIGURE 5, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE

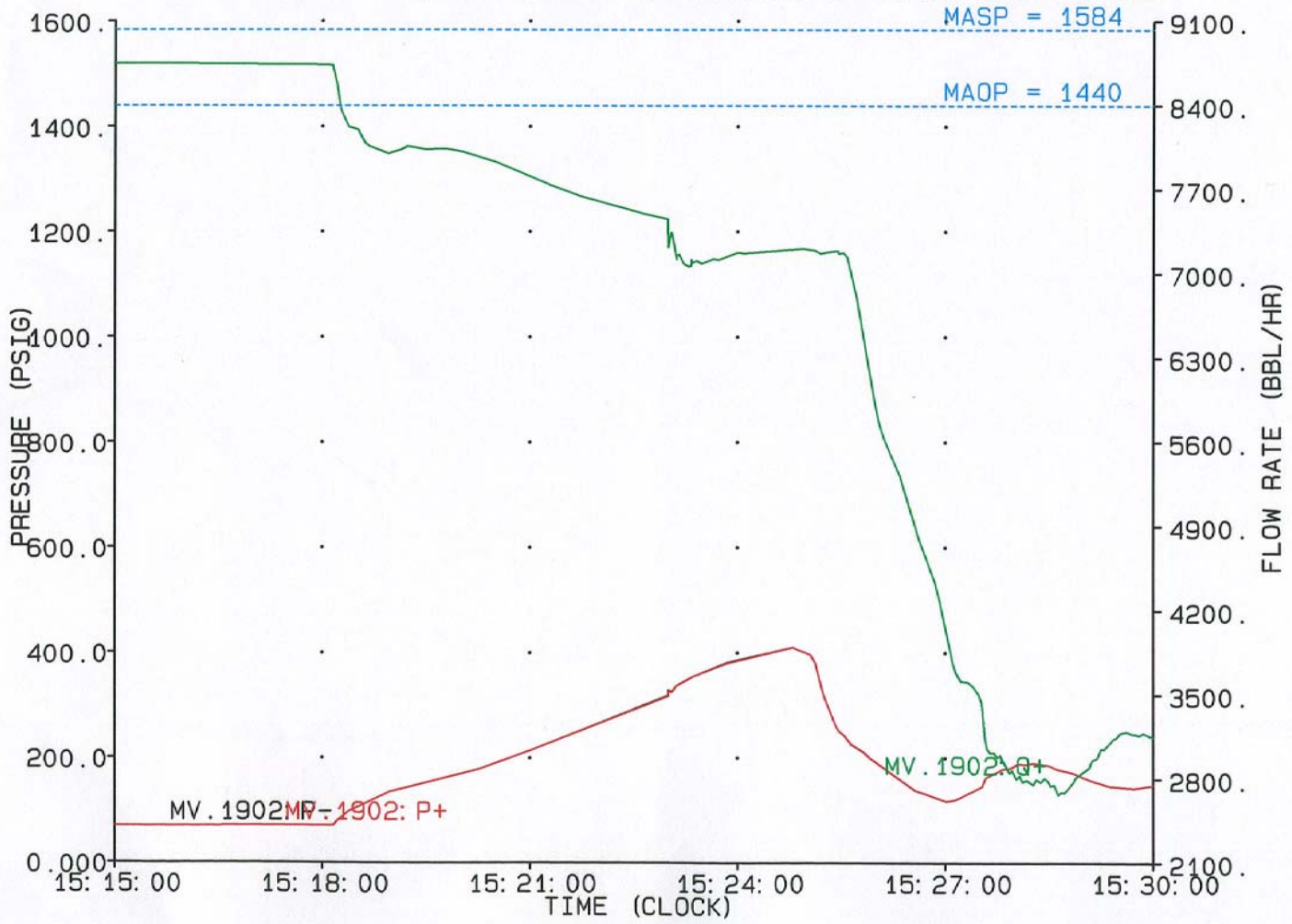


CASE 7, FIGURE 6, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
PRESSURE AT ALLEN JUNCTION



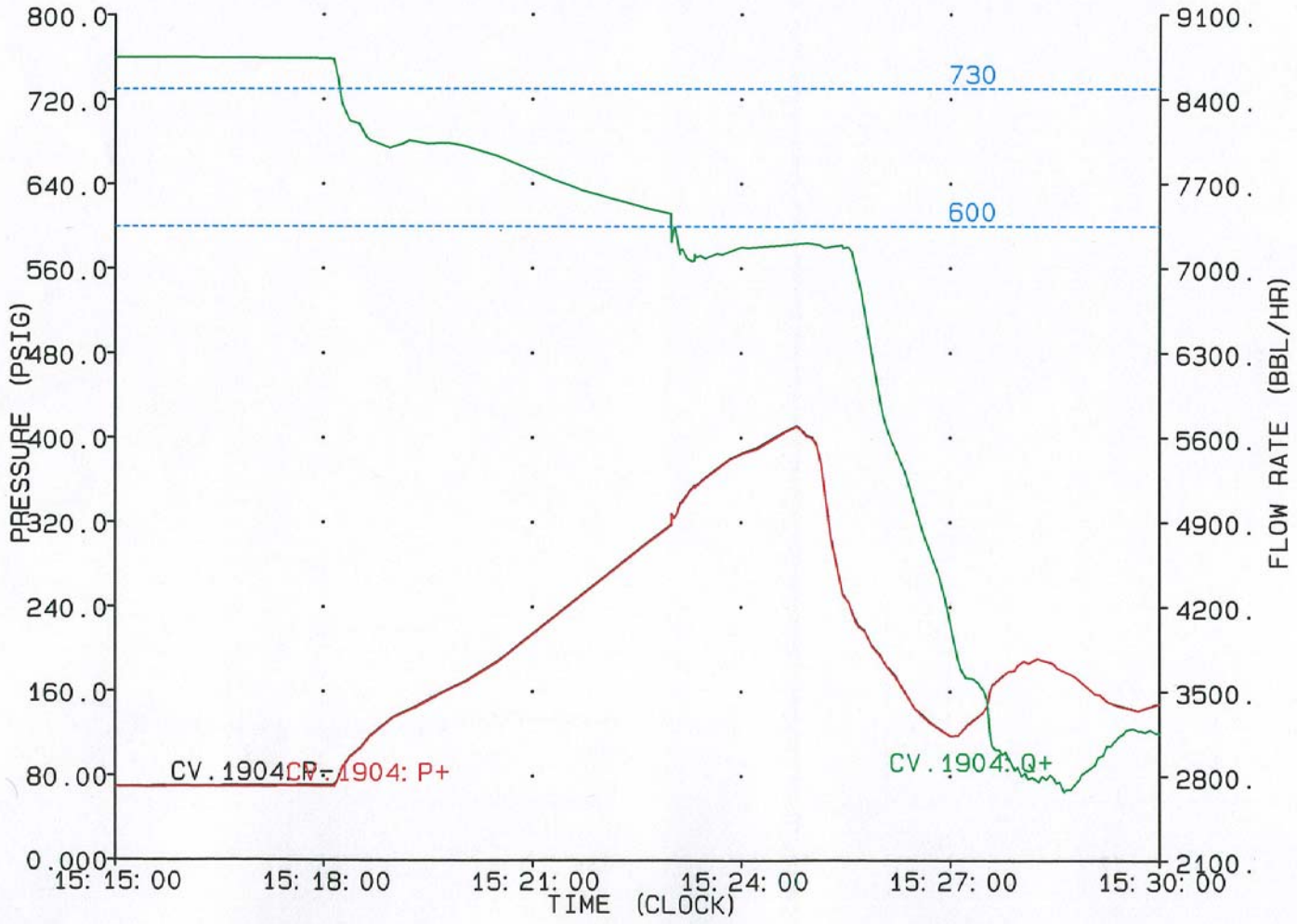
SA 003072

CASE 7, FIGURE 7, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
BAYVIEW, MV.1902, UPSTREAM PRESSURE & FLOW AT INLET BLOCK VALVE



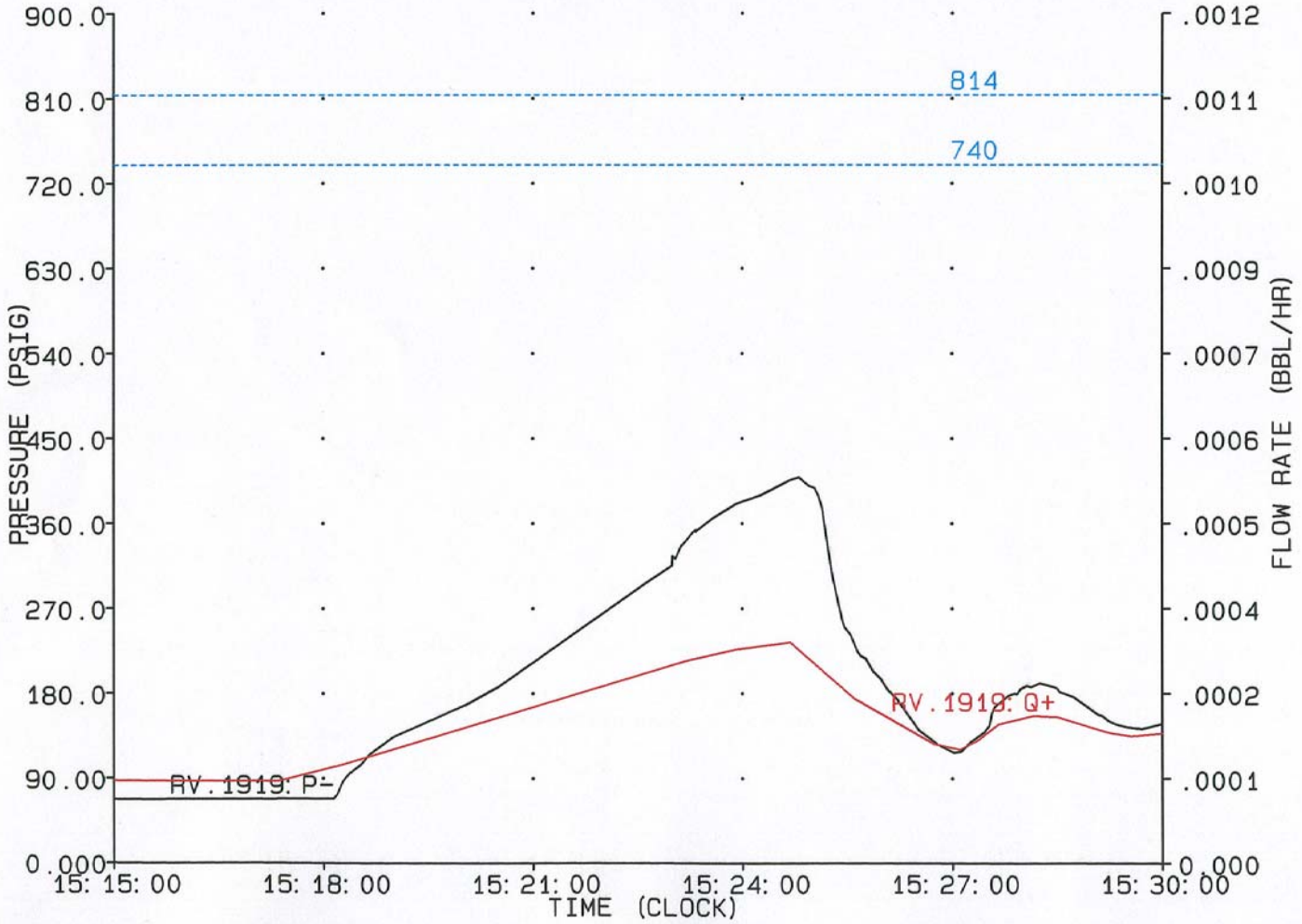
SA 003073

CASE 7, FIGURE 8, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
BAYVIEW, CV.1904, UPSTREAM PRESSURE & FLOW AT INLET CONTROL VALVE



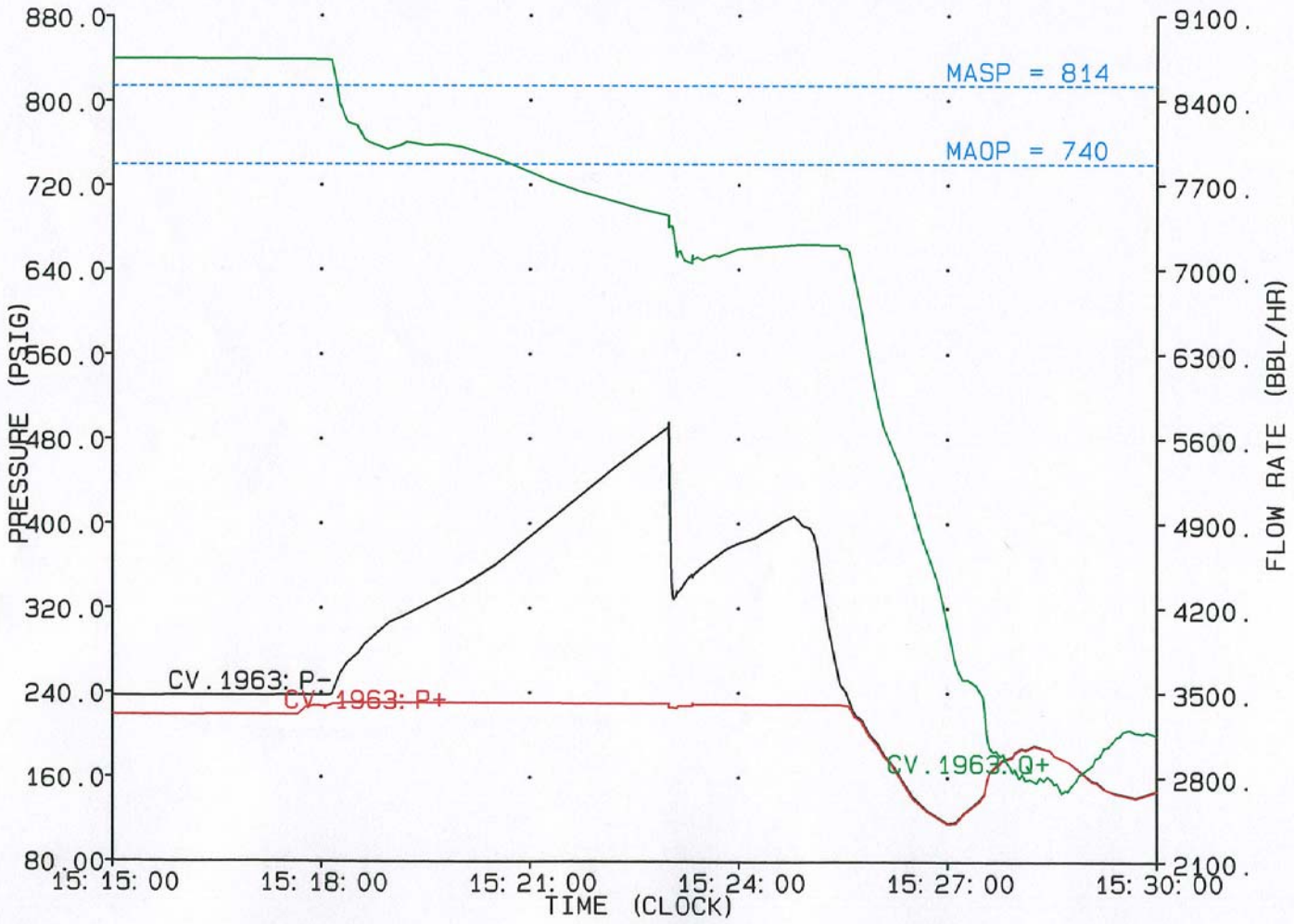
SA 003074

CASE 7, FIGURE 9, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
BAYVIEW, RV.1919, UPSTREAM PRESSURE & FLOW AT INLET RELIEF VALVE



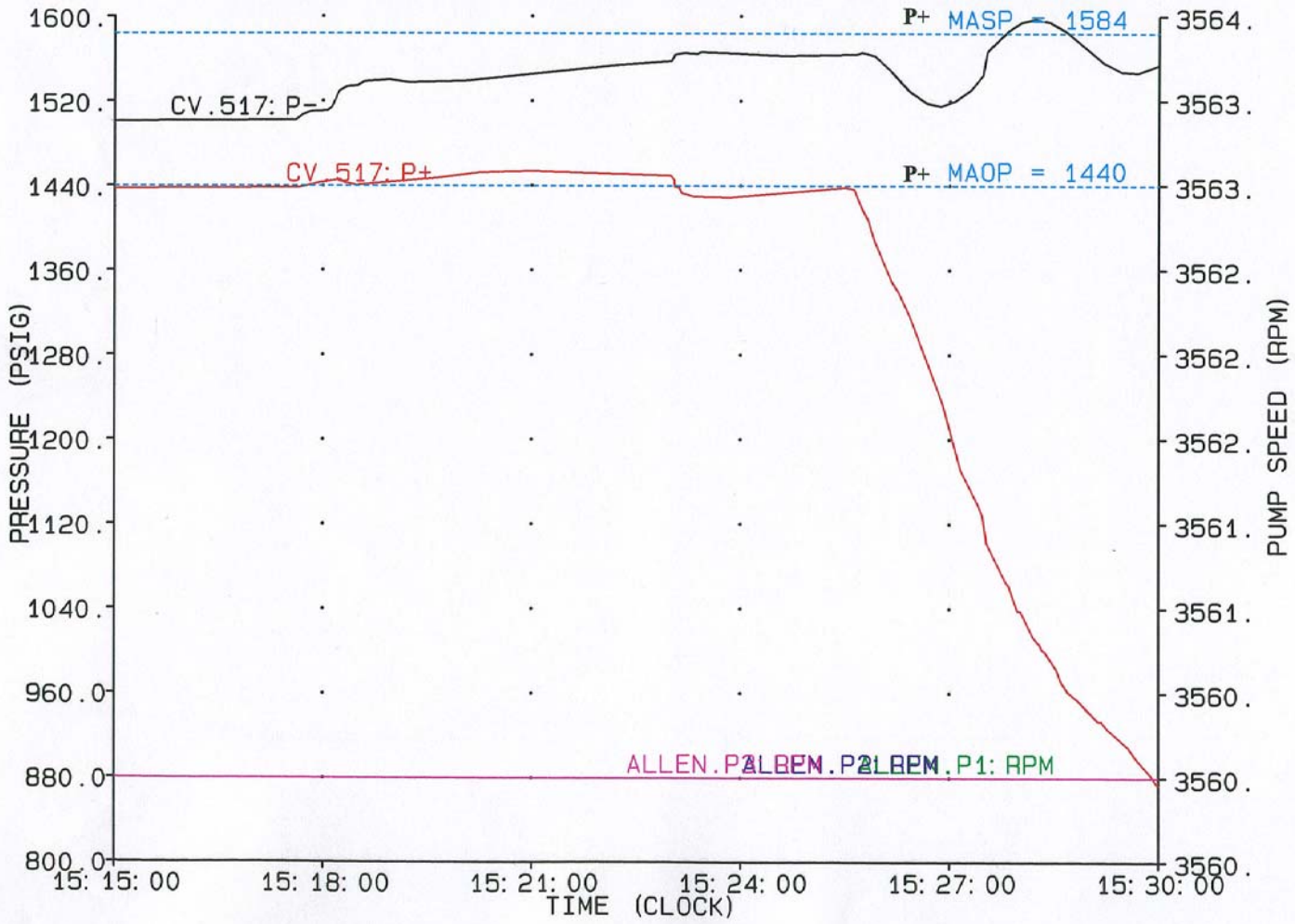
SA 003075

CASE 7, FIGURE 10, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
BAYVIEW, CV.1963, UPSTREAM PRESSURE & FLOW AT DISCHARGE CONTROL VALVE



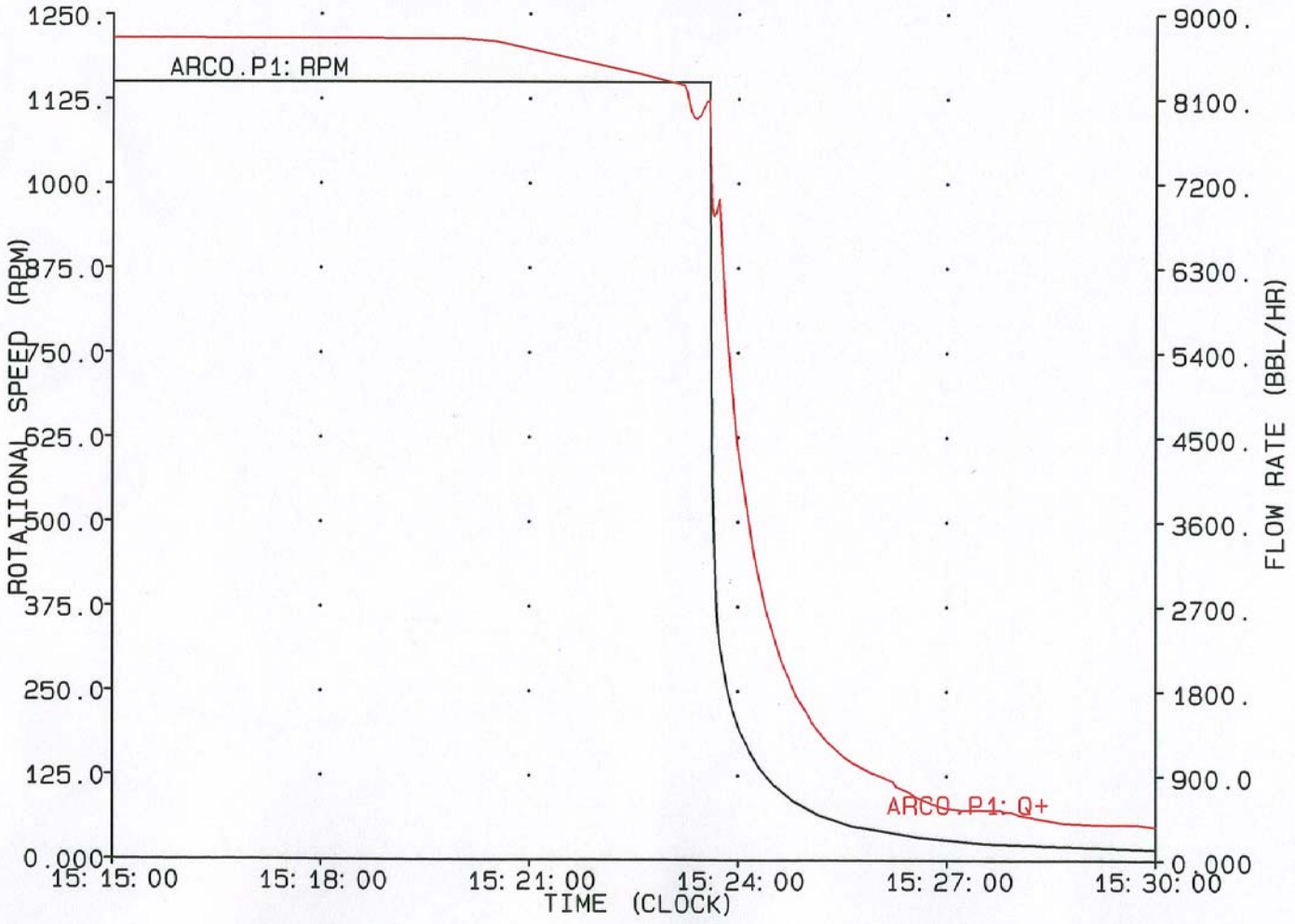
SA 003076

CASE 7, FIGURE 11, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
ALLEN PUMP STA., PUMP SPEEDS & CV.517 DISCHARGE CONTROL VALVE

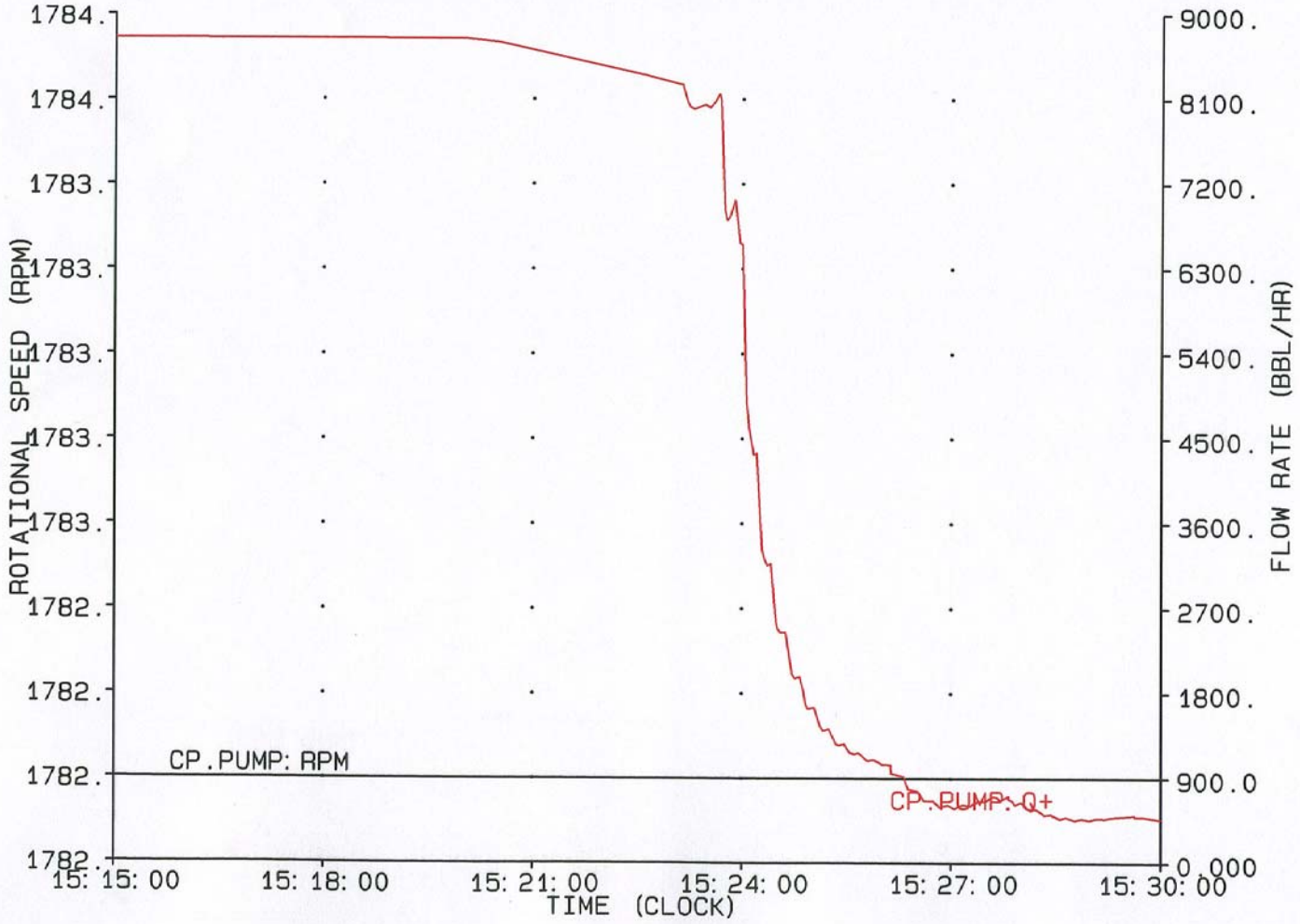


SA 003077

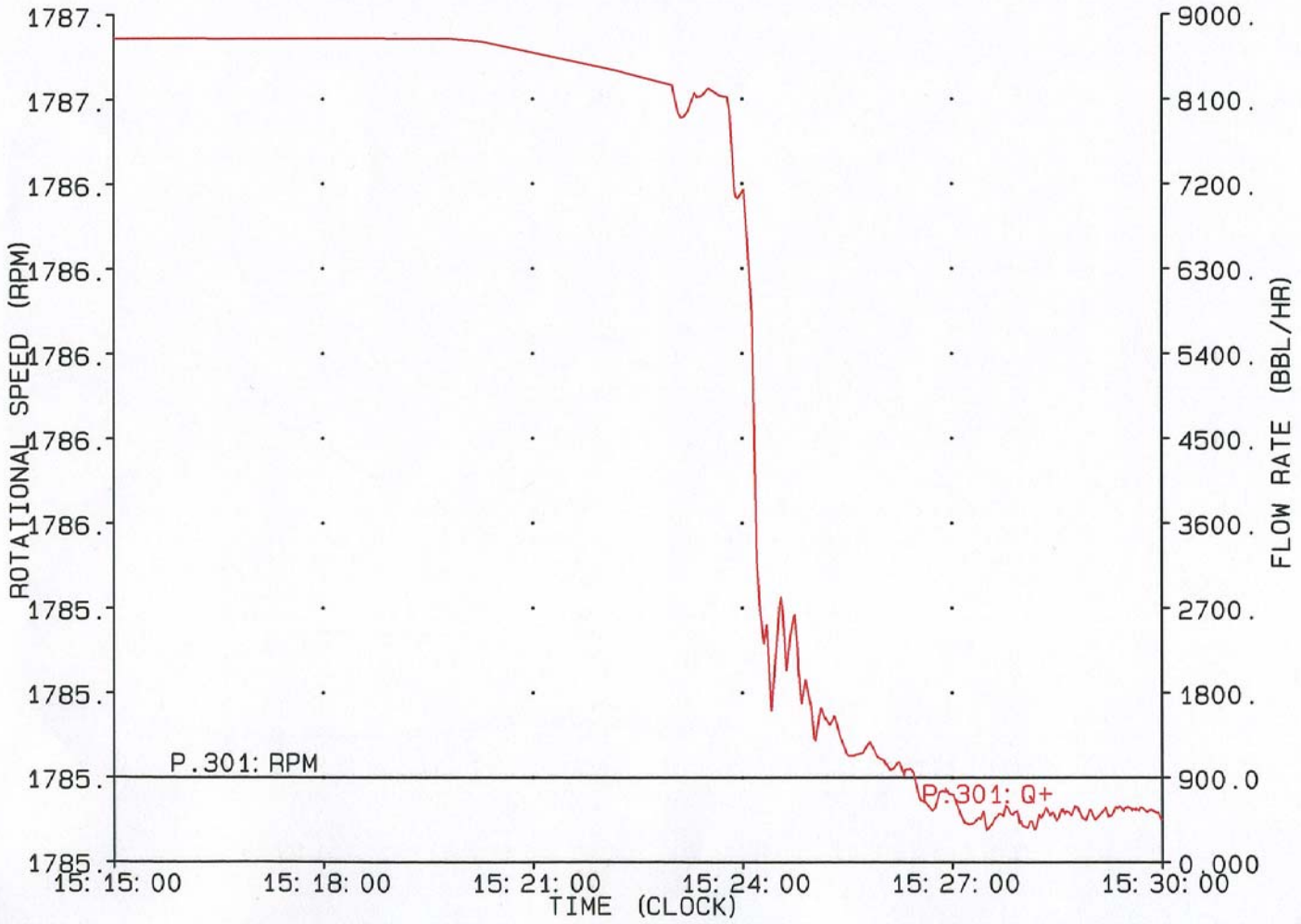
CASE 7, FIGURE 12, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
ARCO PUMP STA., PUMP SPEEDS & FLOW RATE



CASE 7, FIGURE 13, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
CHERRY POINT PUMP STA., PUMP SPEEDS & FLOW RATE



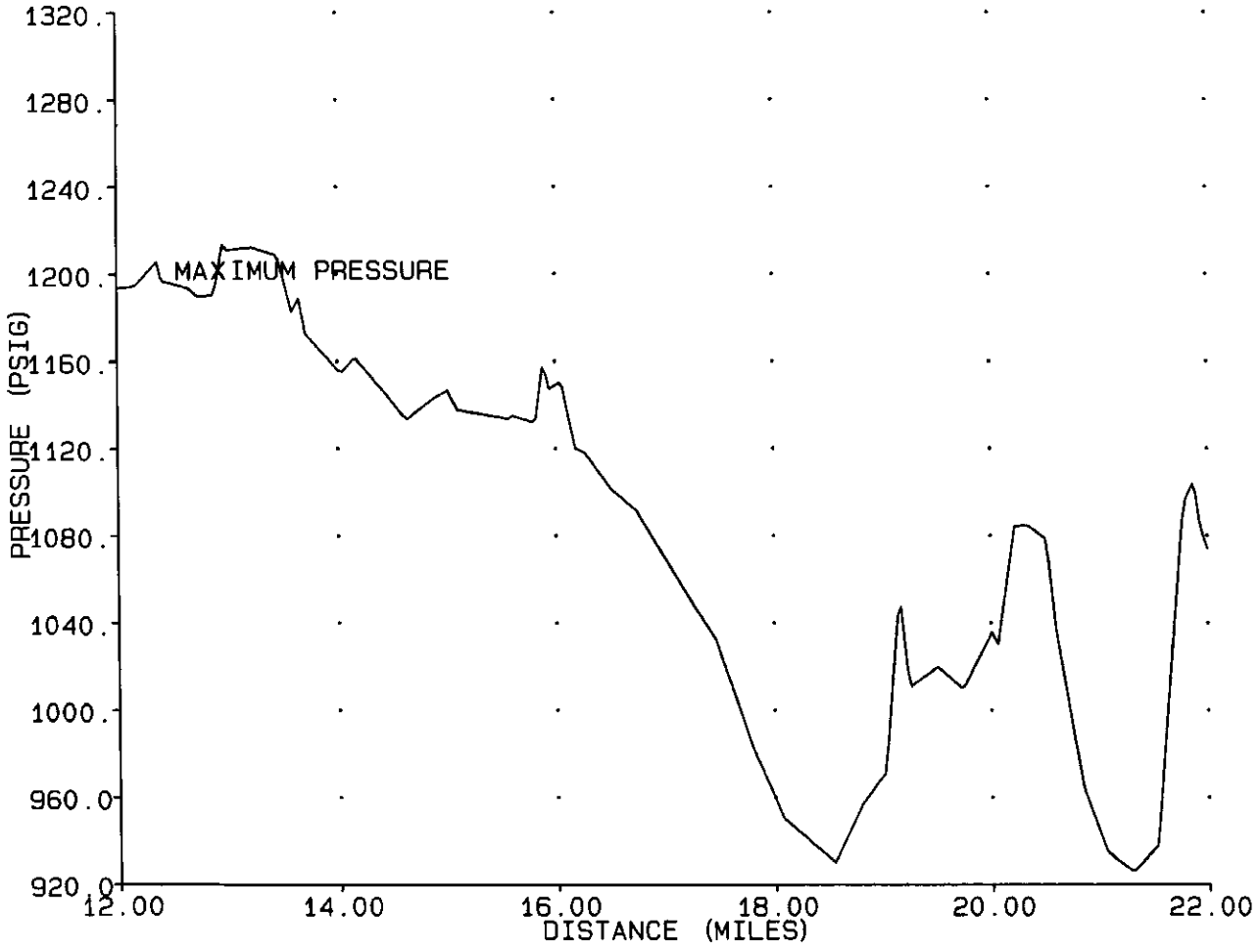
CASE 7, FIGURE 14, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, TRIP OF ARCO PUMPS FIRST & MAL-FUNCTION RV.1919
FERNDALE PUMP STA., PUMP SPEEDS & FLOW RATE



APPENDIX 8

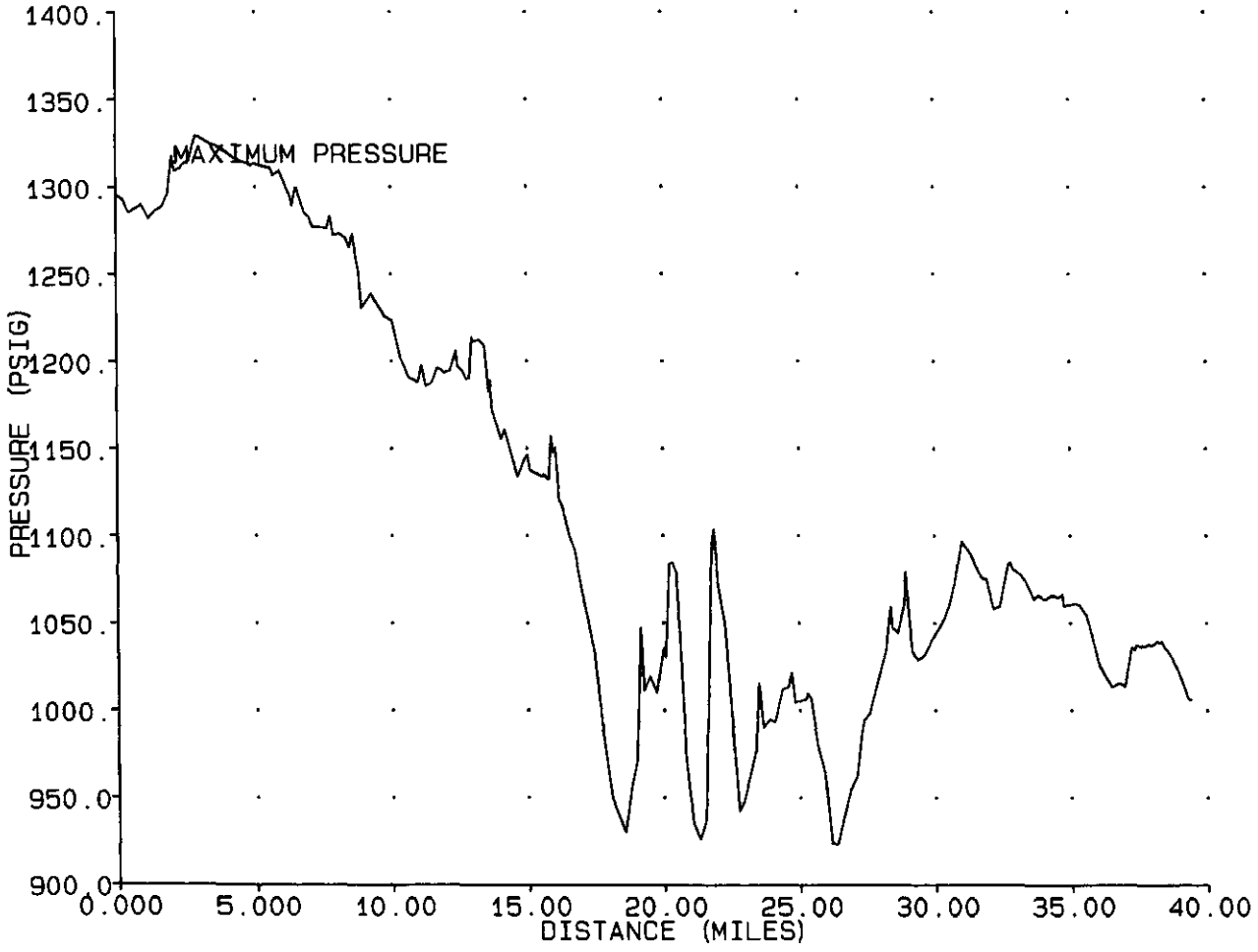
**CASE 8 - Event of June 10, 1999, Original Sequence,
NEW RV2229 @ 1000 psig, Flow Switch
Trips Ferndale with 45 seconds delay,
Mal-Function of RV1919, New Set Points
CV1904 @ 500 psig, RV1919 @ 580psig,
No Mechanical Stop on CV1904**

CASE 8, FIGURE 1, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



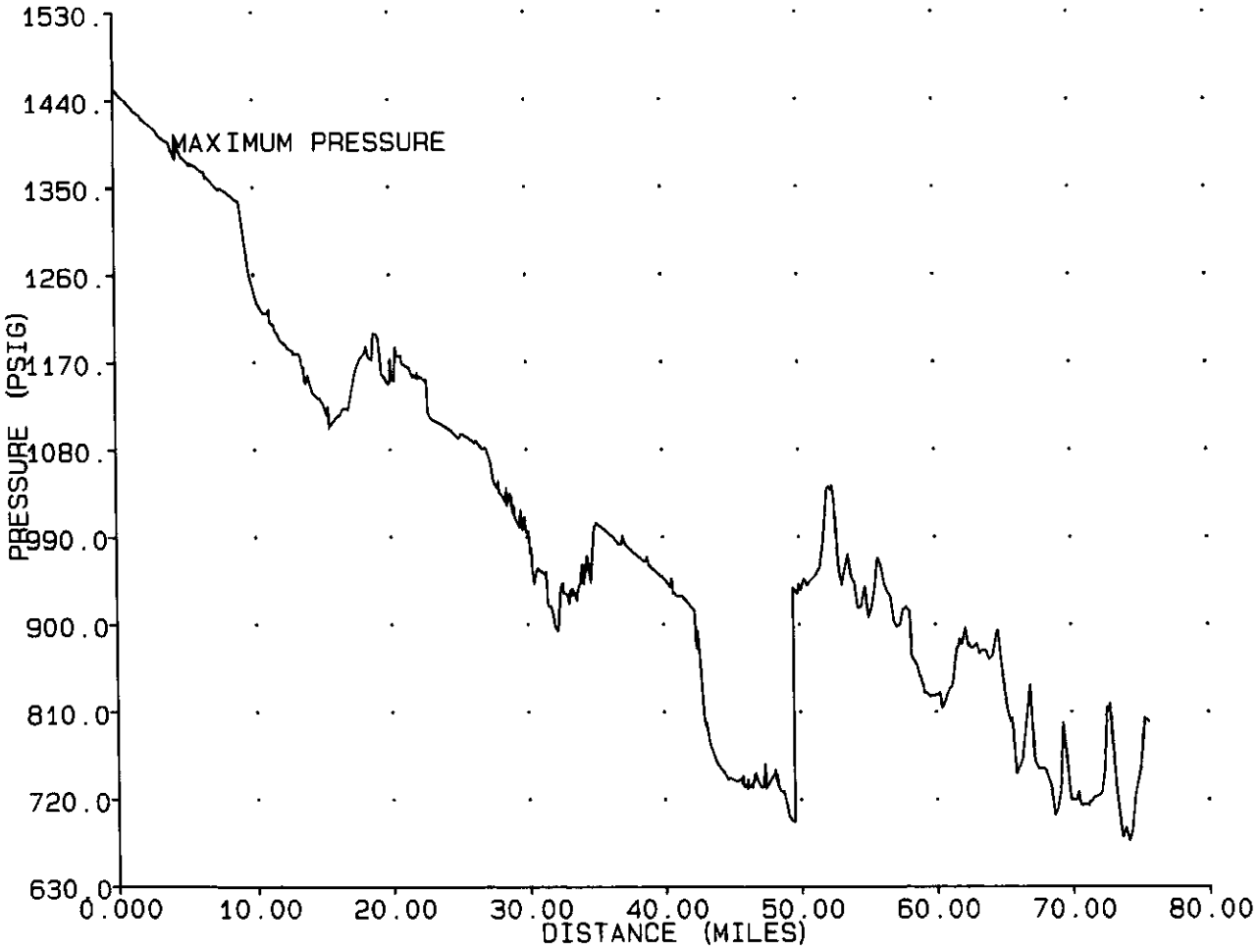
SA 003082

CASE 8, FIGURE 2, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW



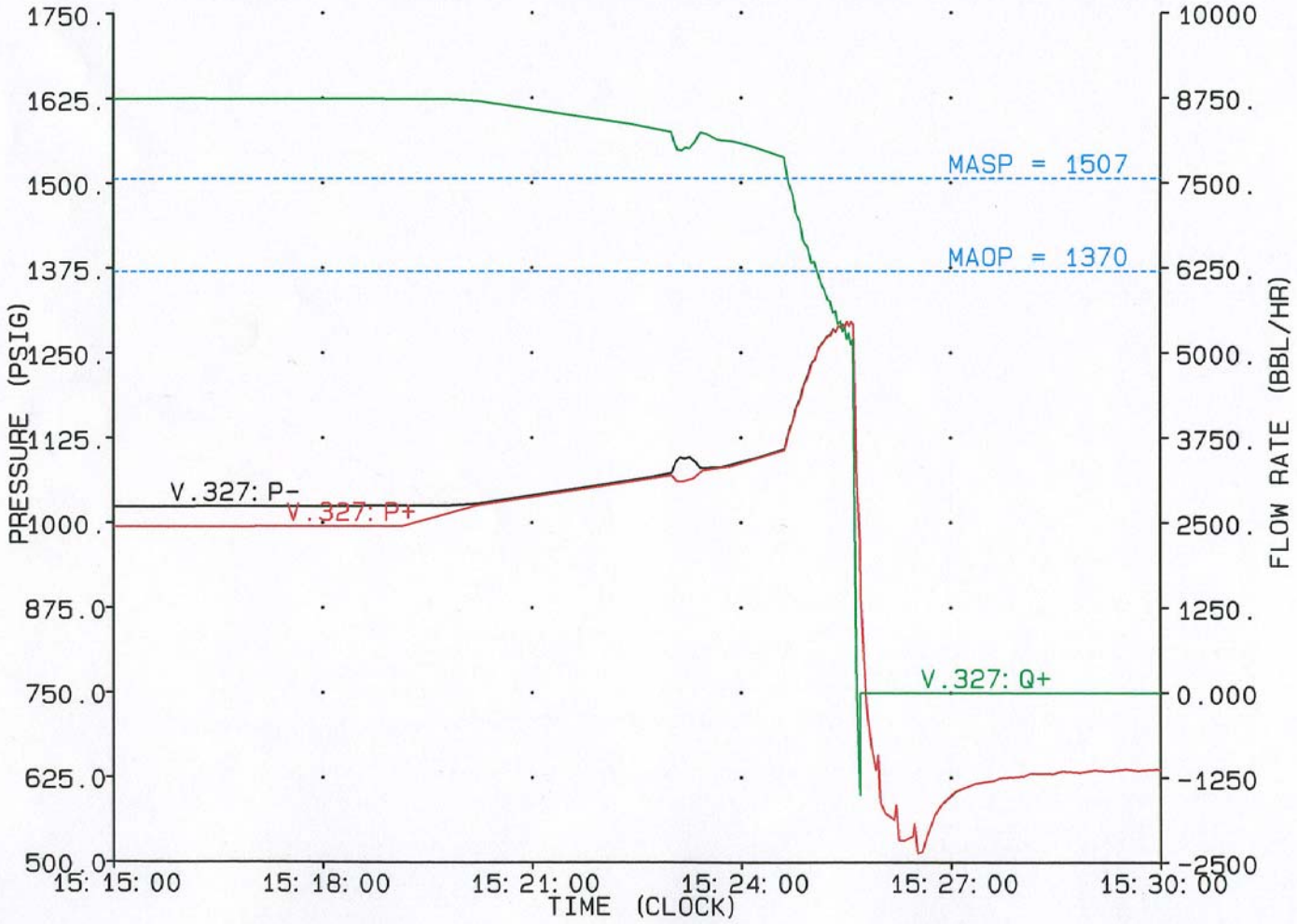
SA 003083

CASE 8, FIGURE 3, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM ALLEN TO RENTON



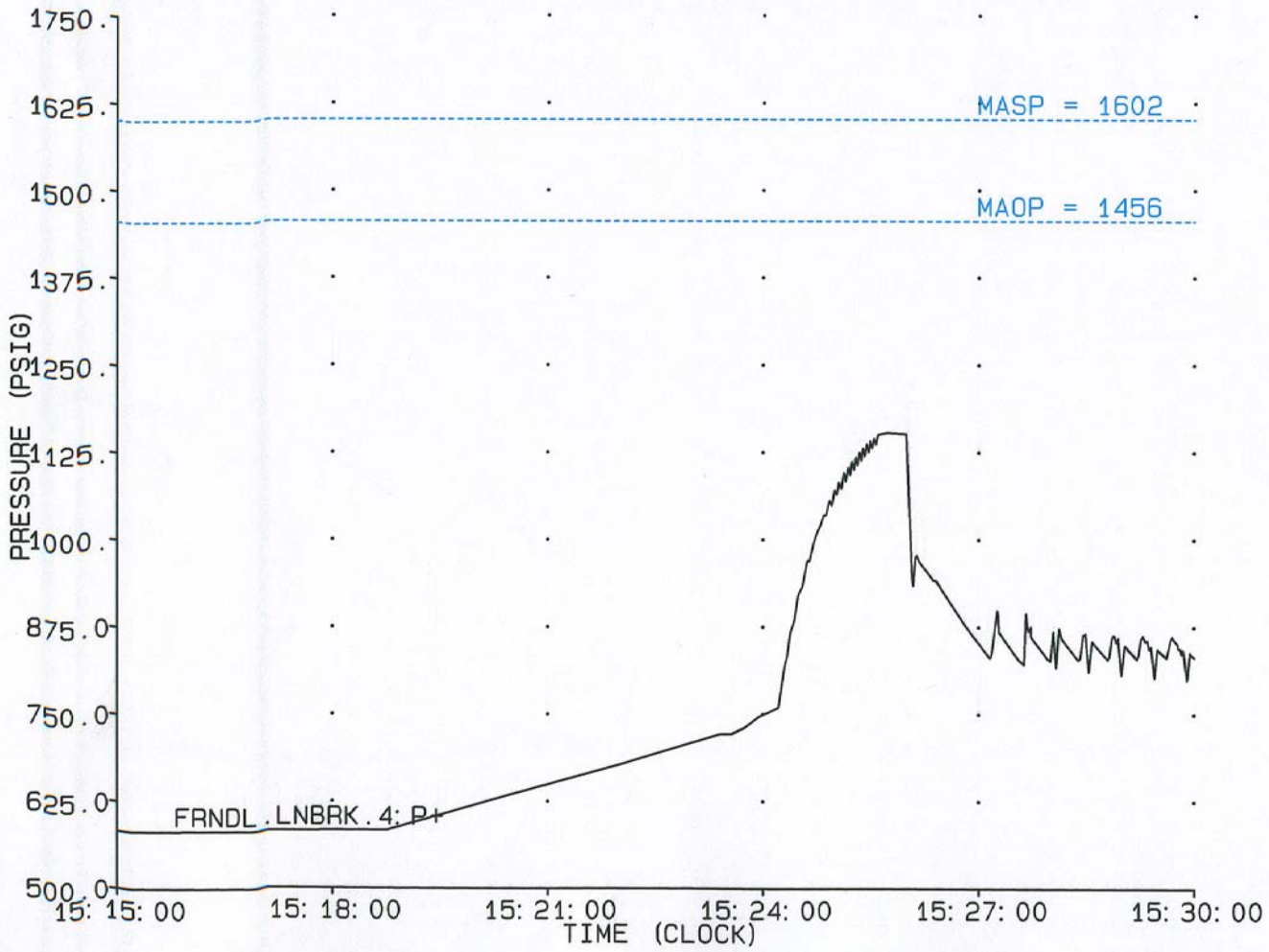
SA 003084

CASE 8, FIGURE 4, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
FERNDALE, V.327, PUMP DISCHARGE CONTROL VALVE PRESSURE & FLOW

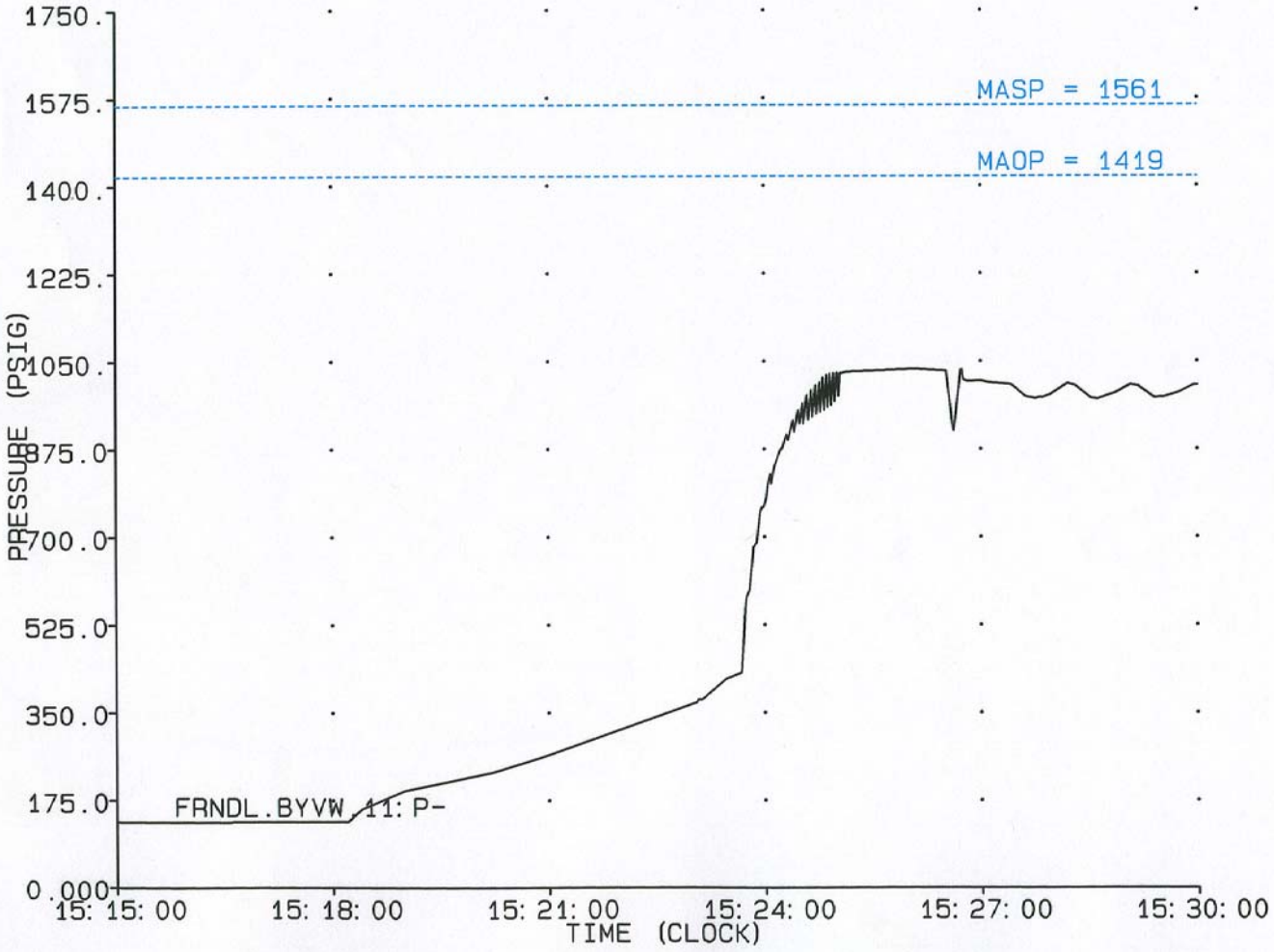


SA 003085

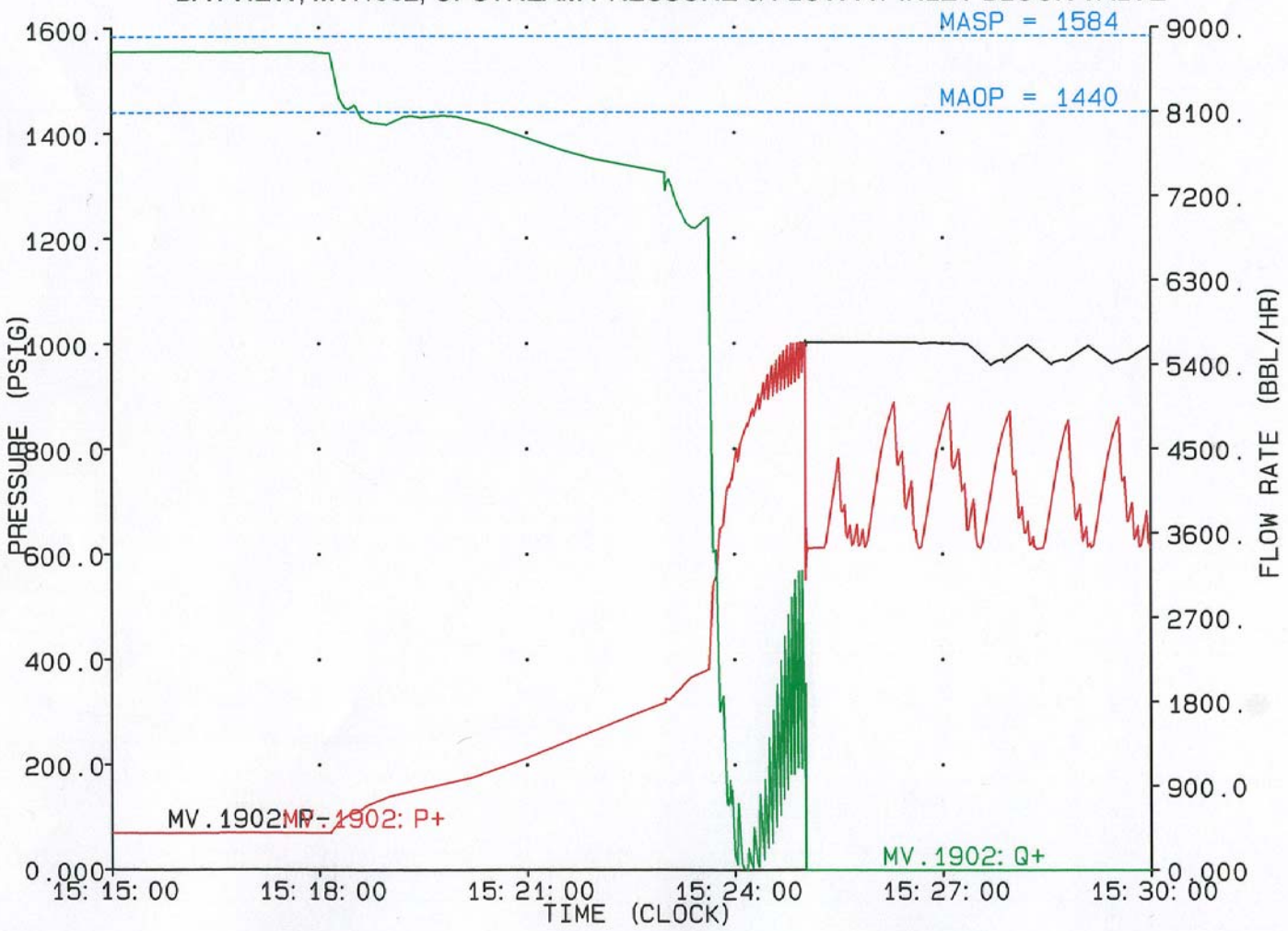
CASE 8, FIGURE 5, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE



CASE 8, FIGURE 6, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
PRESSURE AT ALLEN JUNCTION

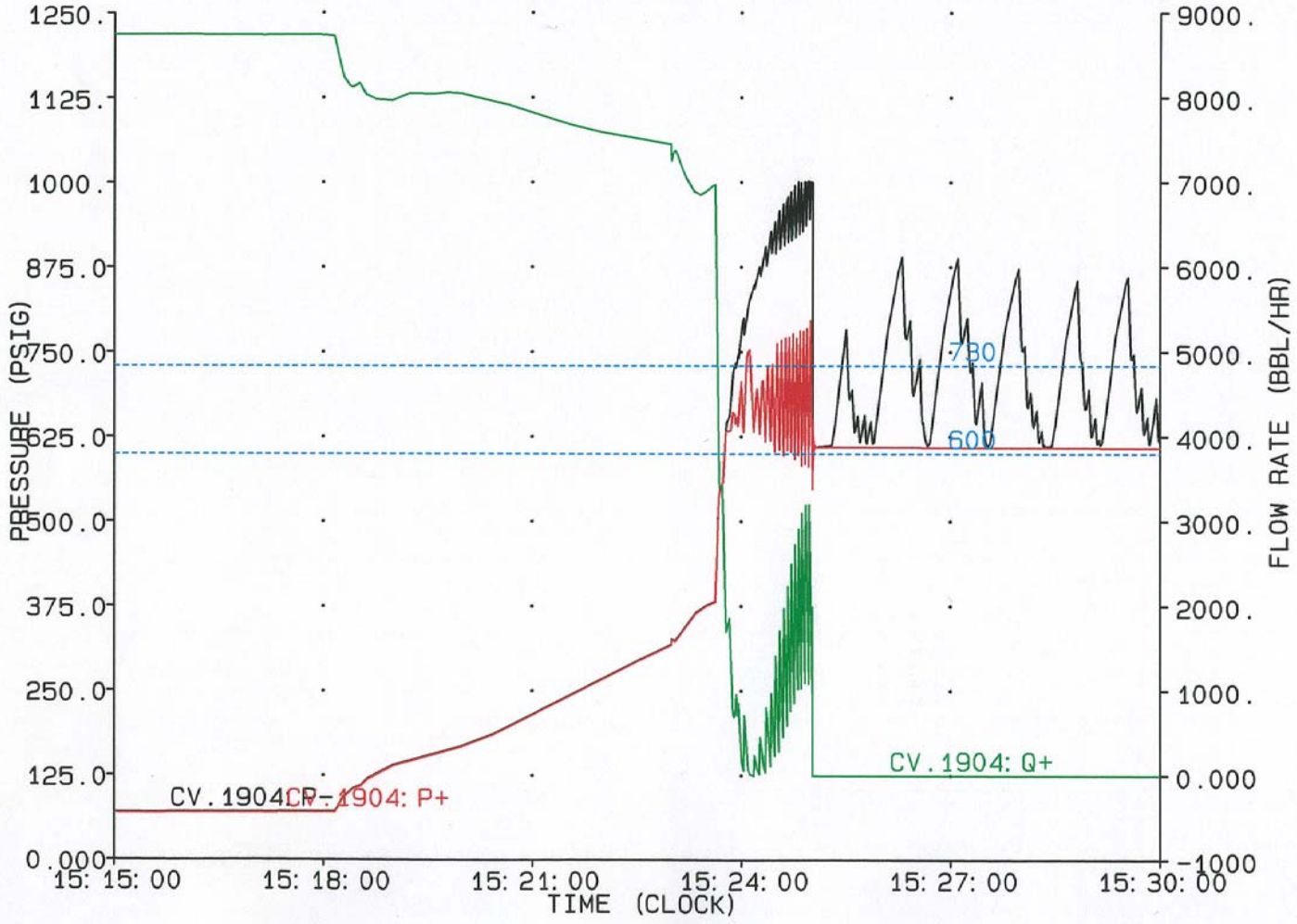


CASE 8, FIGURE 7, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
BAYVIEW, MV.1902, UPSTREAM PRESSURE & FLOW AT INLET BLOCK VALVE



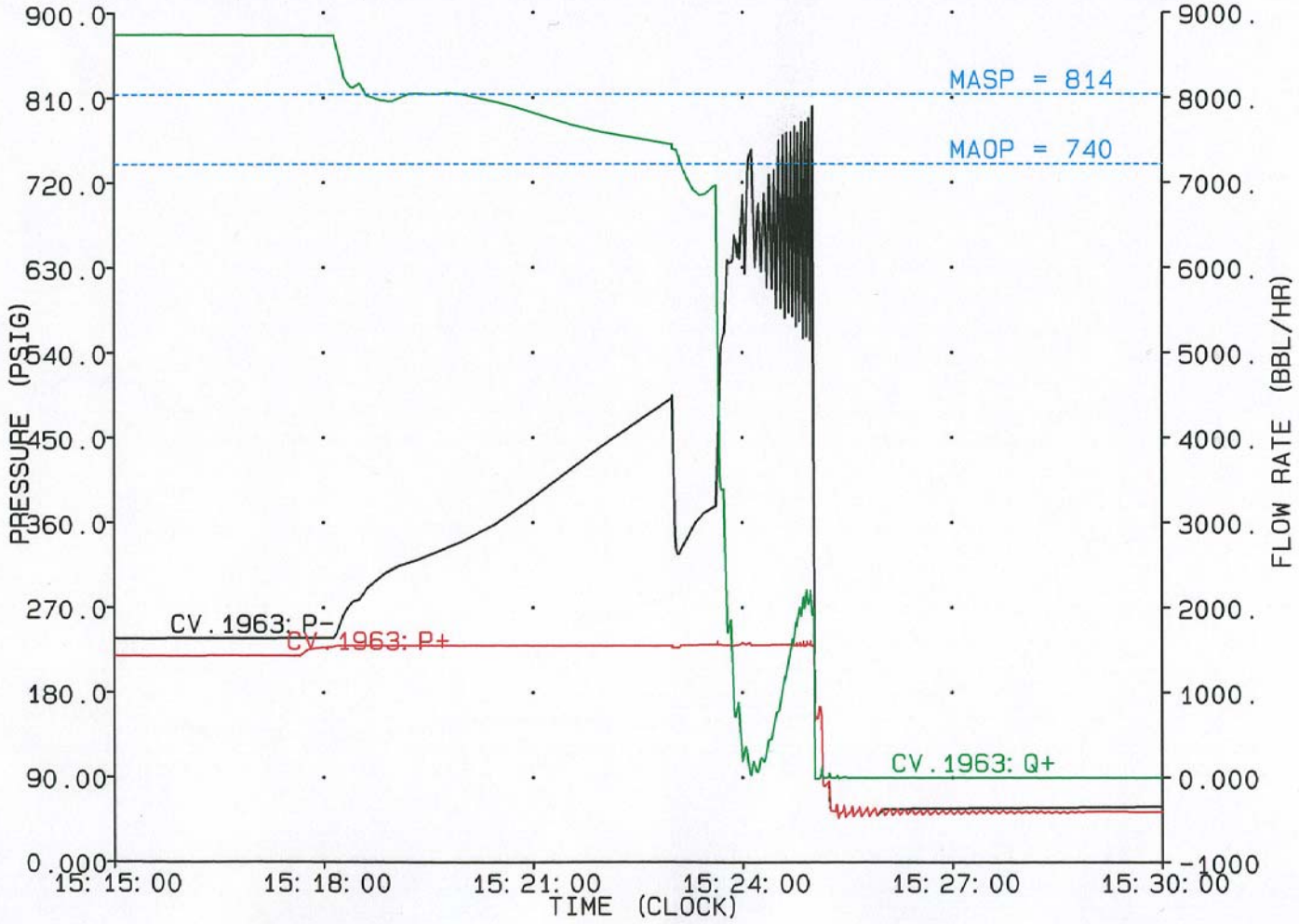
SA 003088

CASE 8, FIGURE 8, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
BAYVIEW, CV.1904, UPSTREAM PRESSURE & FLOW AT INLET CONTROL VALVE

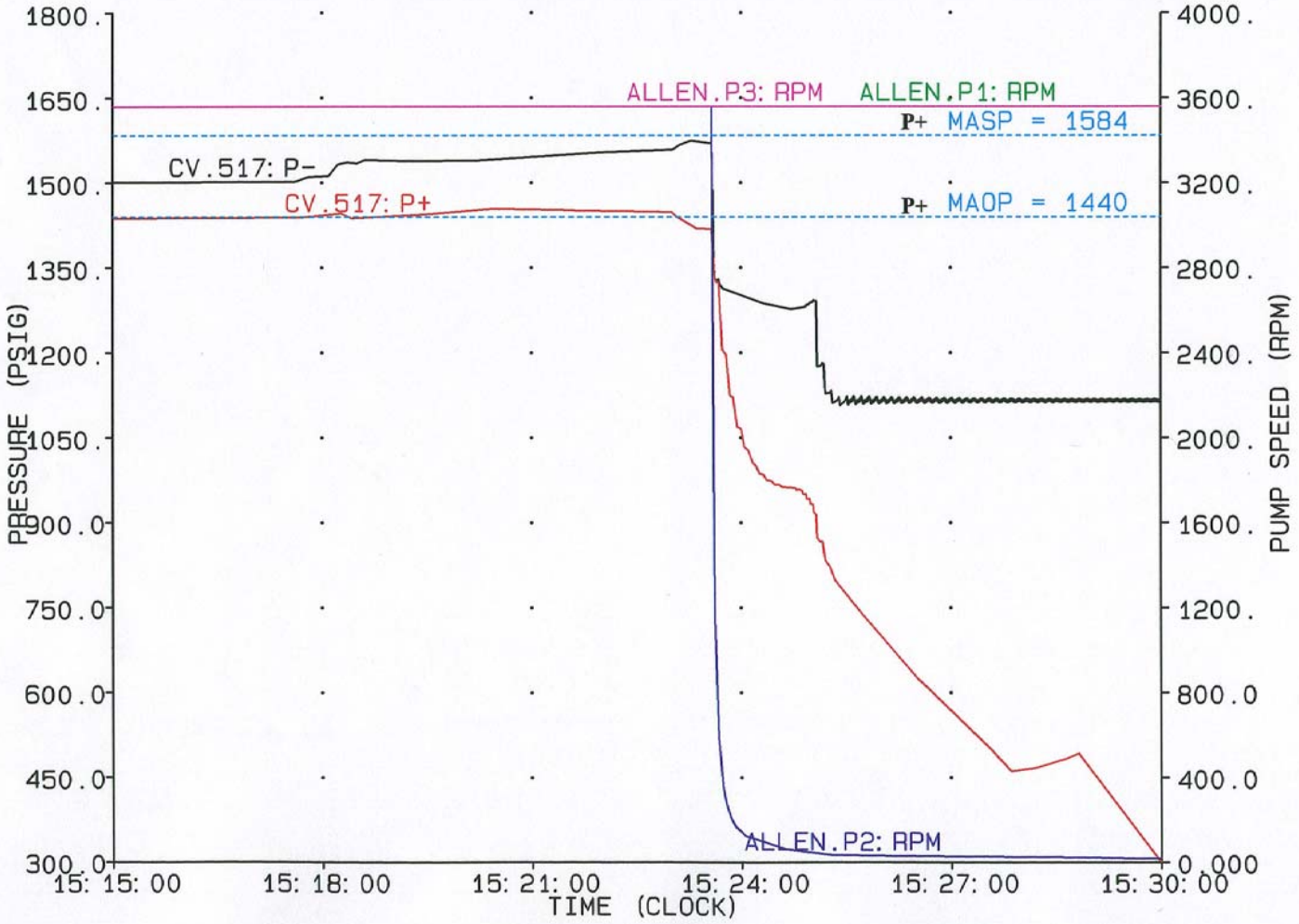


SA 003089

CASE 8, FIGURE 9, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
BAYVIEW, CV.1963, UPSTREAM PRESSURE & FLOW AT DISCHARGE CONTROL VALVE

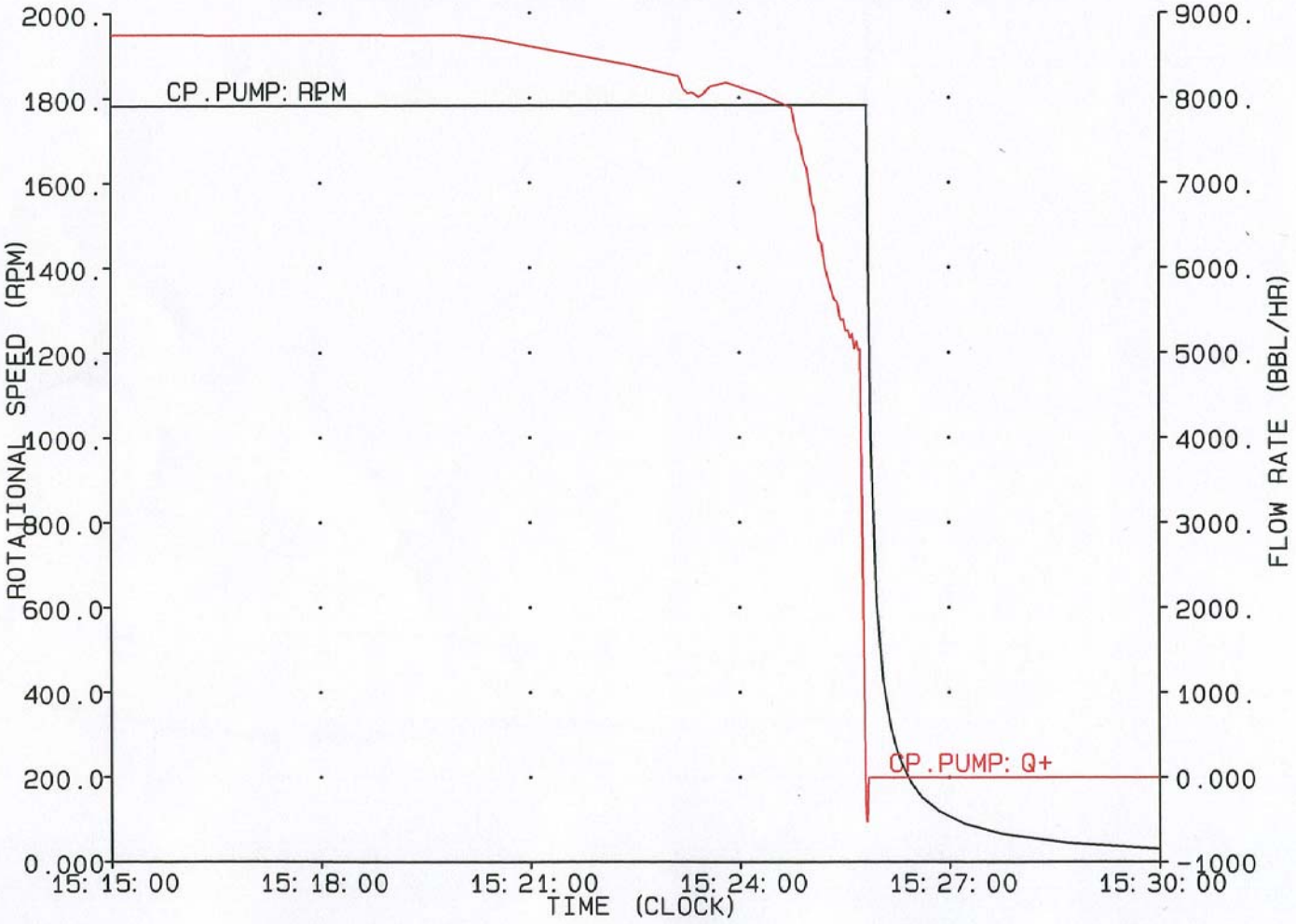


CASE 8, FIGURE 10, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
ALLEN PUMP STA., PUMP SPEEDS & CV.517 DISCHARGE CONTROL VALVE

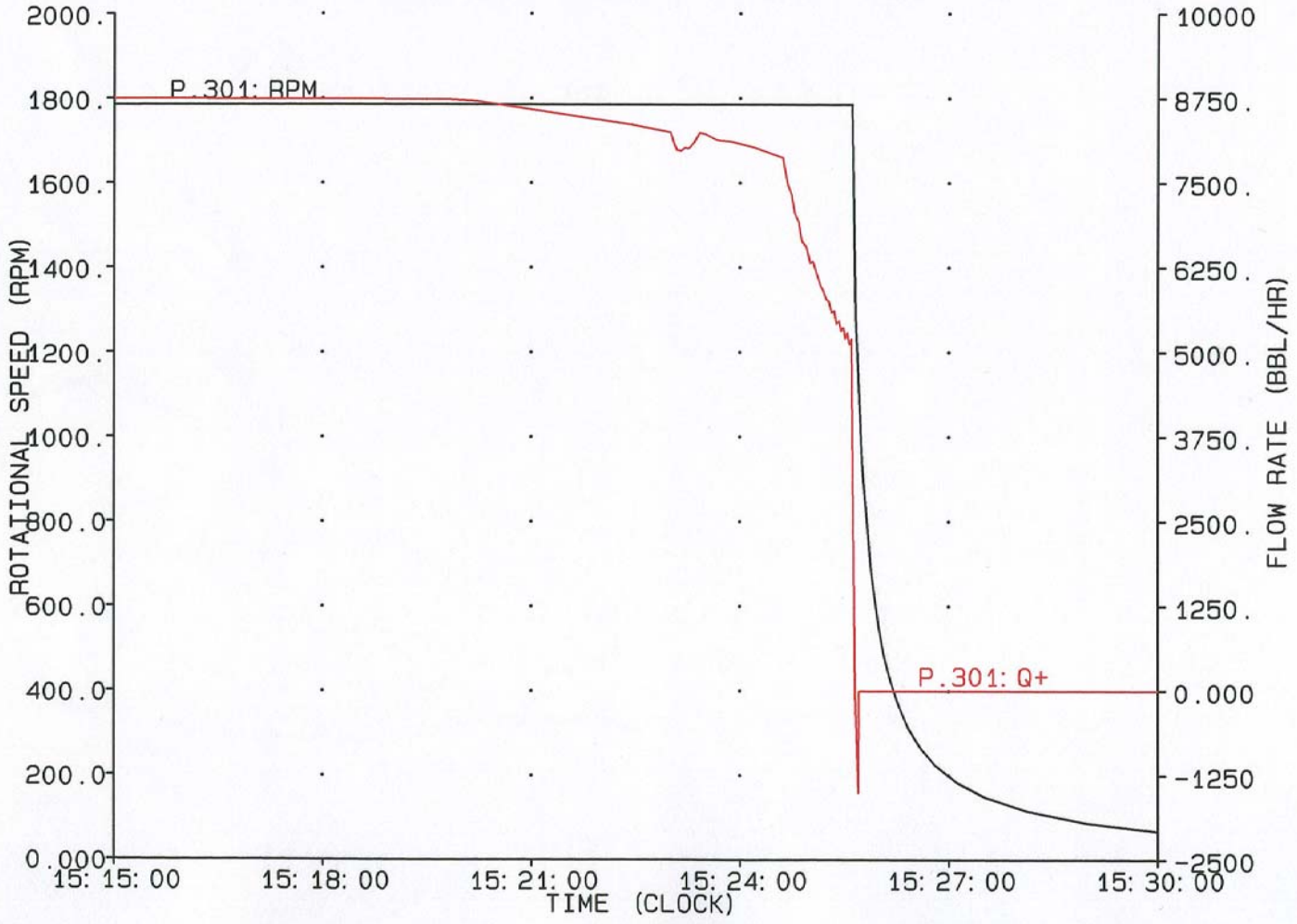


SA 003091

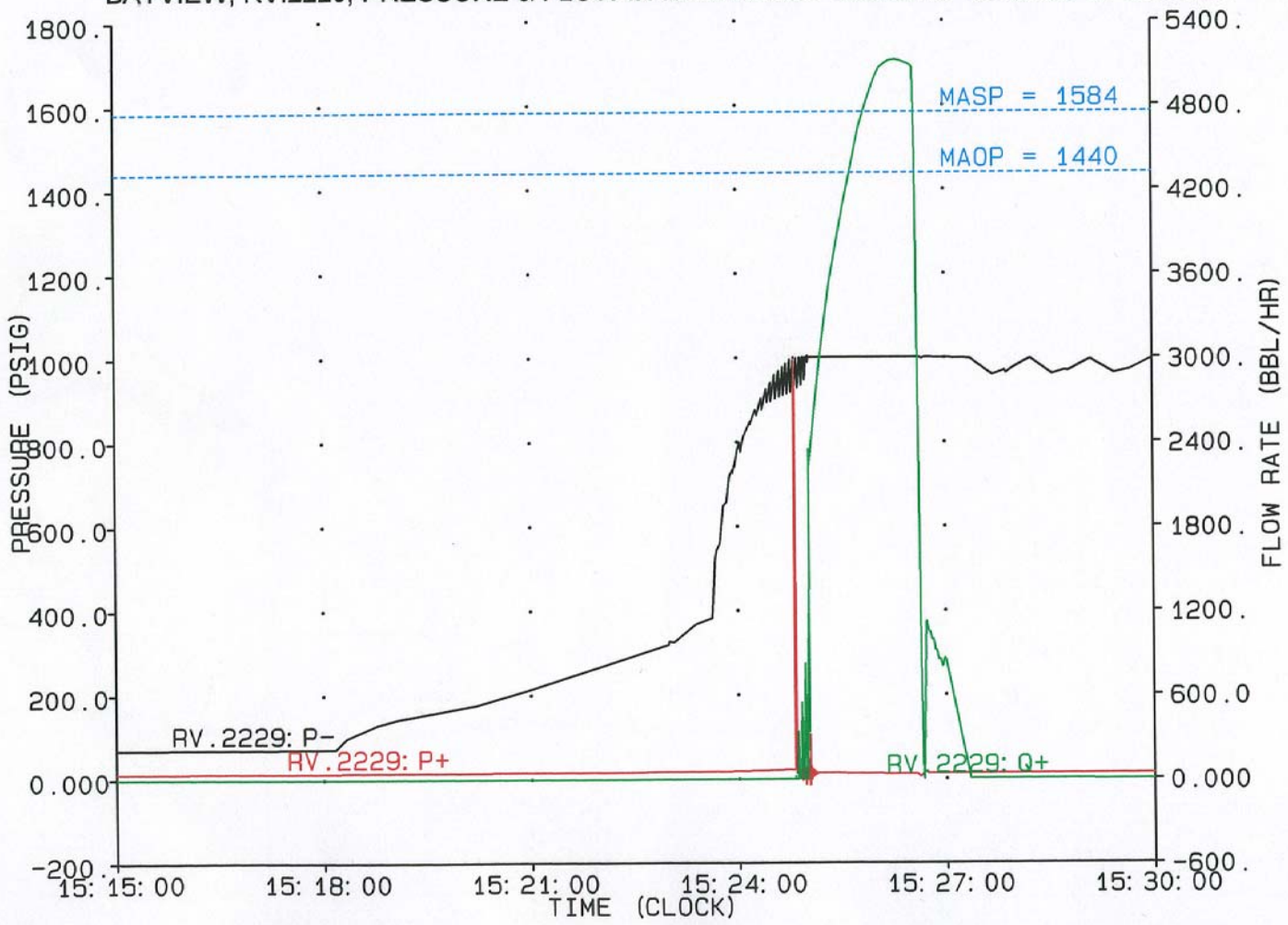
CASE 8, FIGURE 11, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
CHERRY POINT PUMP STATION., PUMP SPEED & FLOW RATE



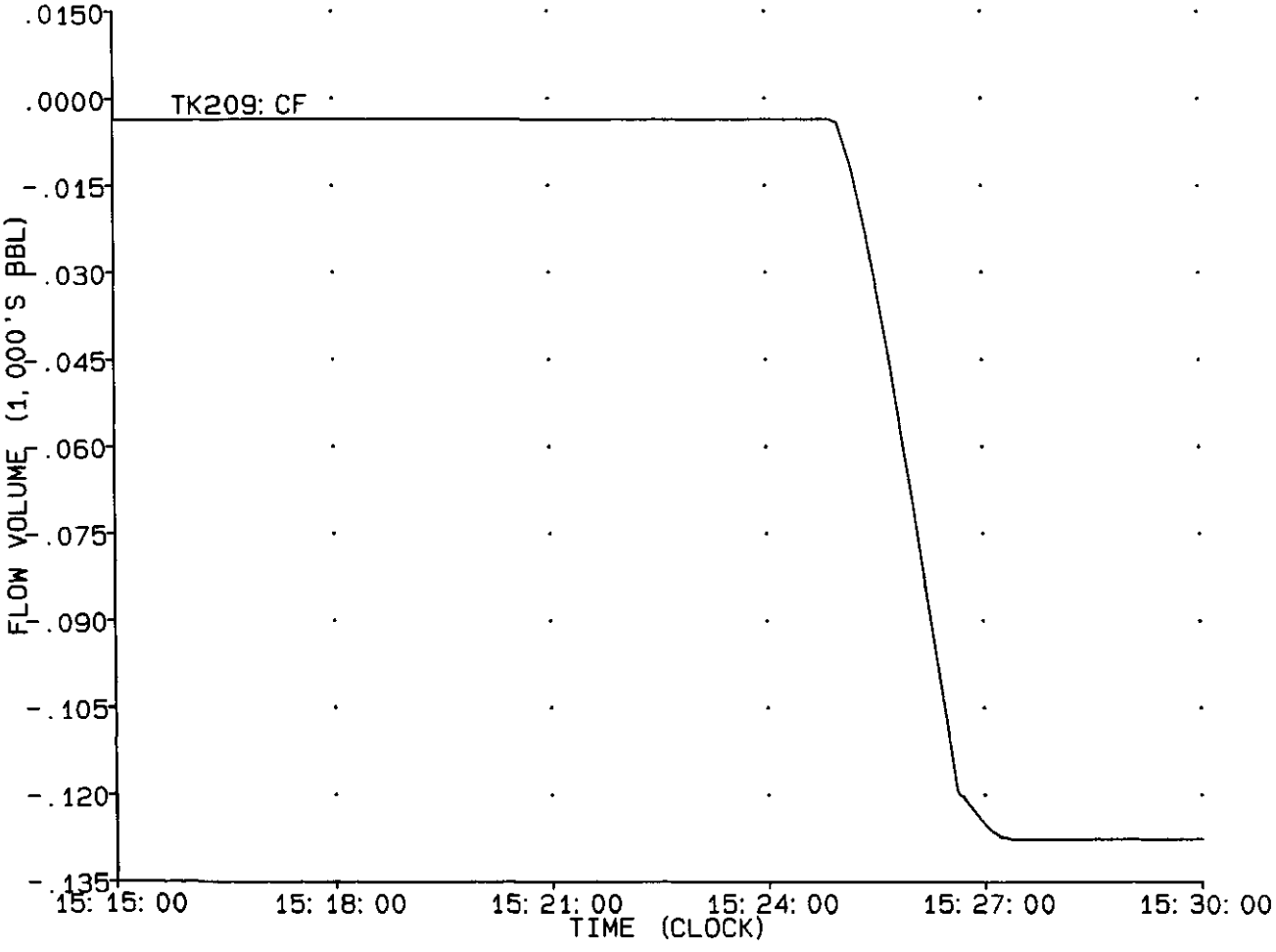
CASE 8, FIGURE 12, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
FERNDALE PUMP STA., PUMP SPEEDS & FLOW RATE



CASE 8, FIGURE 13, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
BAYVIEW, RV.2229, PRESSURE & FLOW IN NEW RELIEF VALVE UPSTREAM OF MV.1902



CASE 8, FIGURE 14, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, NEW RELIEF VALVE (RV.2229) @ 1000 PSIG & MAL-FUNCTION RV.1919
BAYVIEW, TK.209, RELIEF VOLUME FROM RV.2229

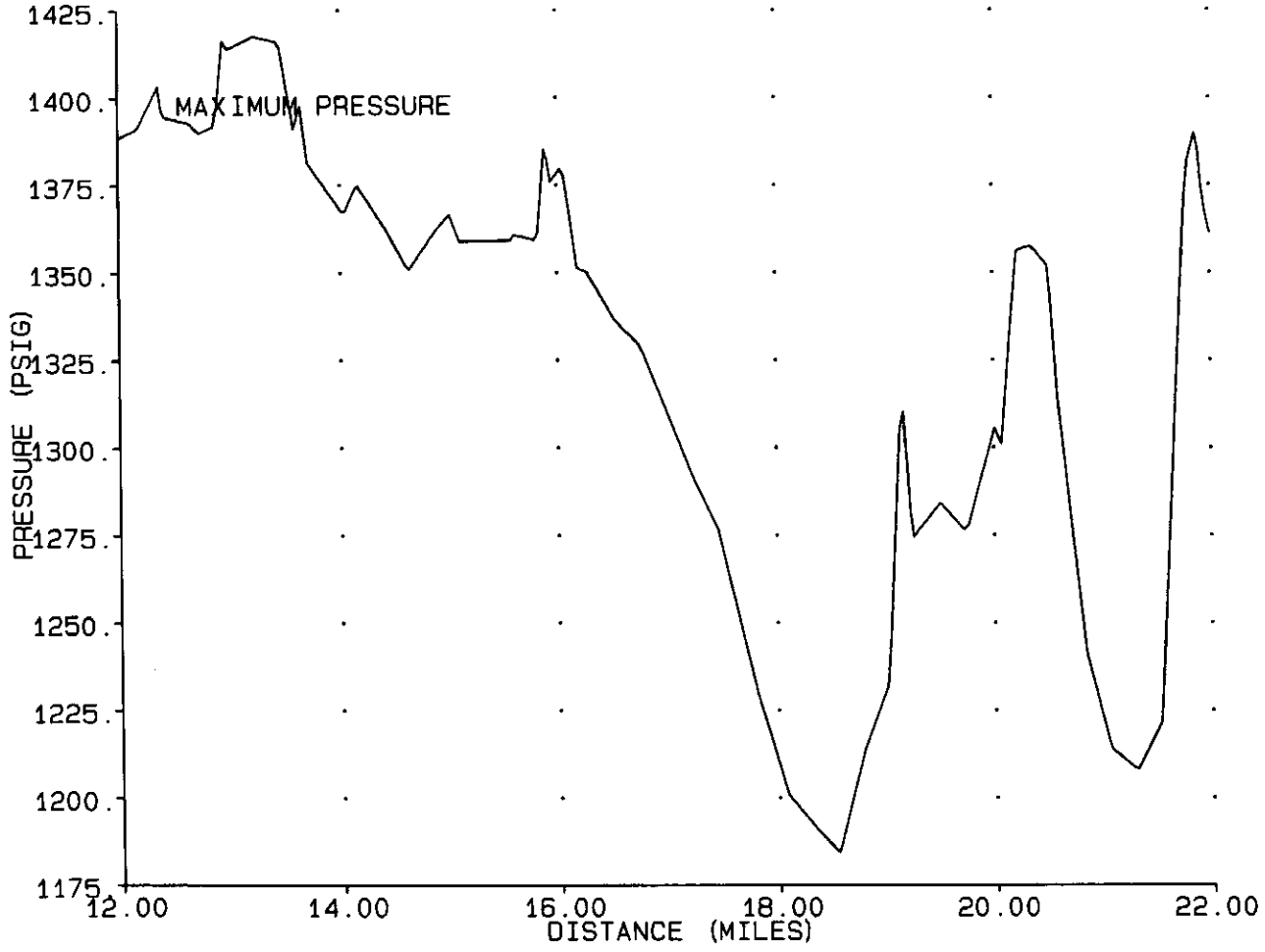


SA 003095

APPENDIX 9

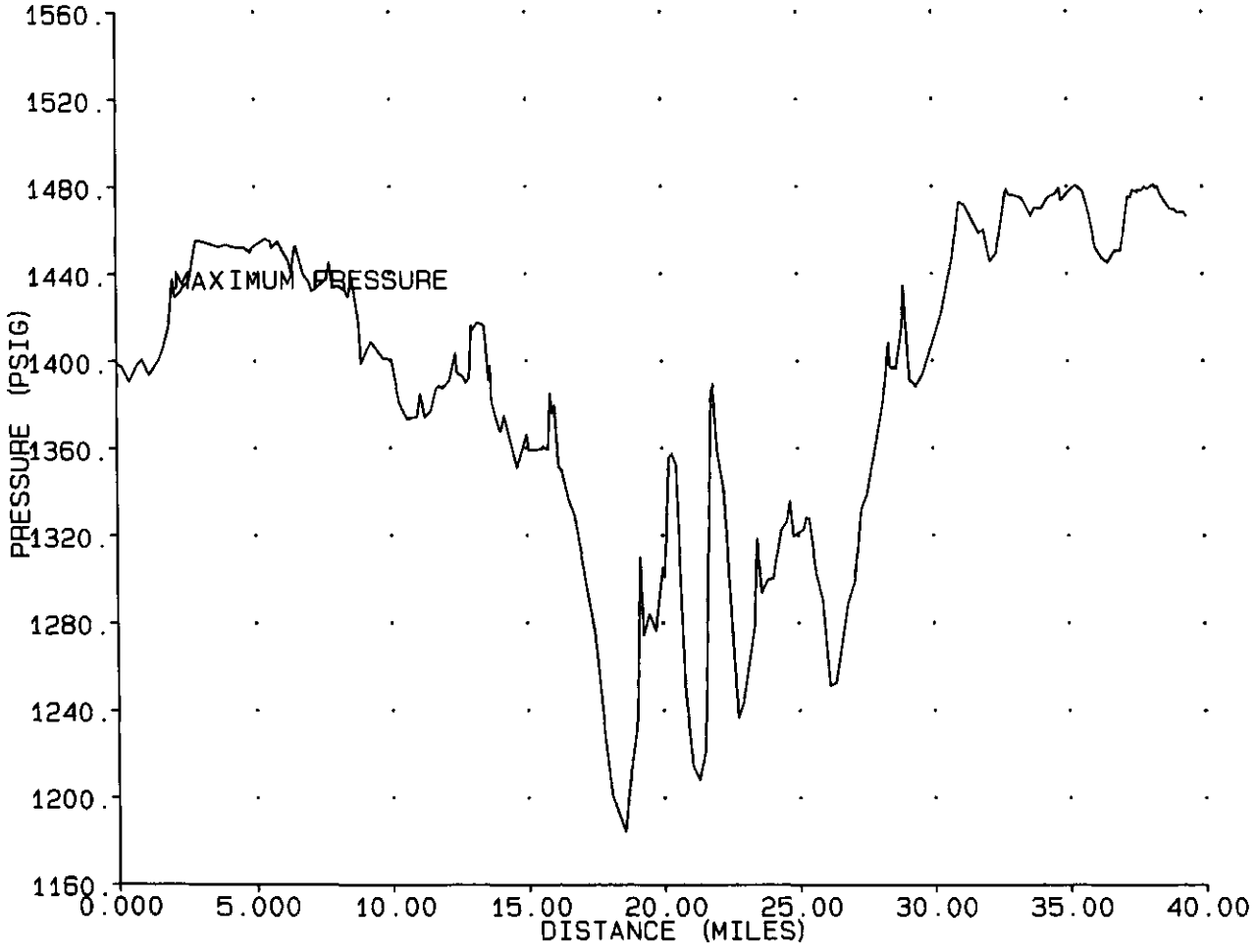
CASE 9 - Event of June 10, 1999, Original Sequence, Proper Function of RV1919, NO Flow Switch to Ferndale, Mal-Function of RV2229, New Set Points CV1904 @ 500 psig, RV1919 @ 580psig, No Mechanical Stop on CV1904

CASE 9, FIGURE 1, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE WITHIN BELLINGHAM CITY LIMITS



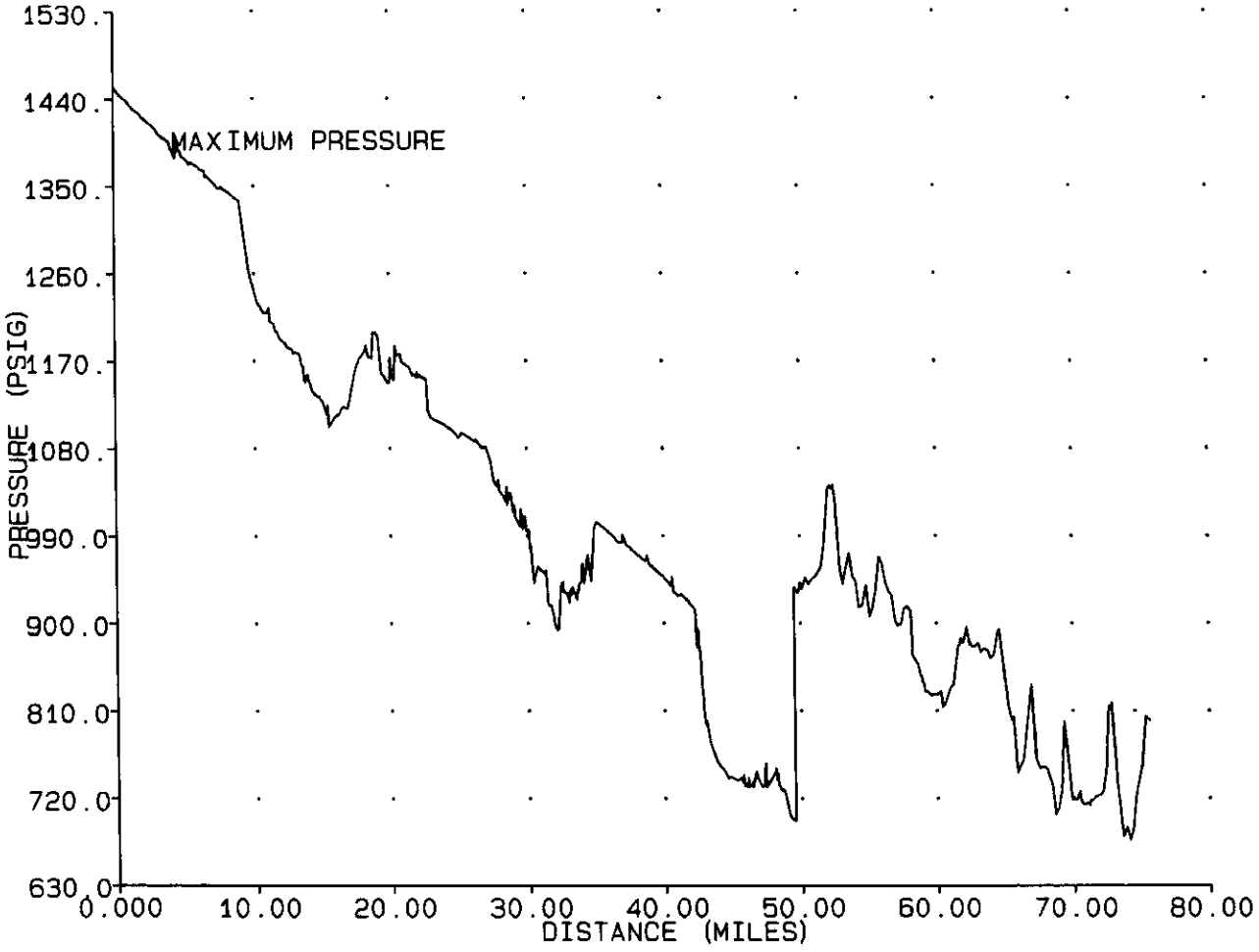
SA 003097

CASE 9, FIGURE 2, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM FERNDALE TO BAYVIEW



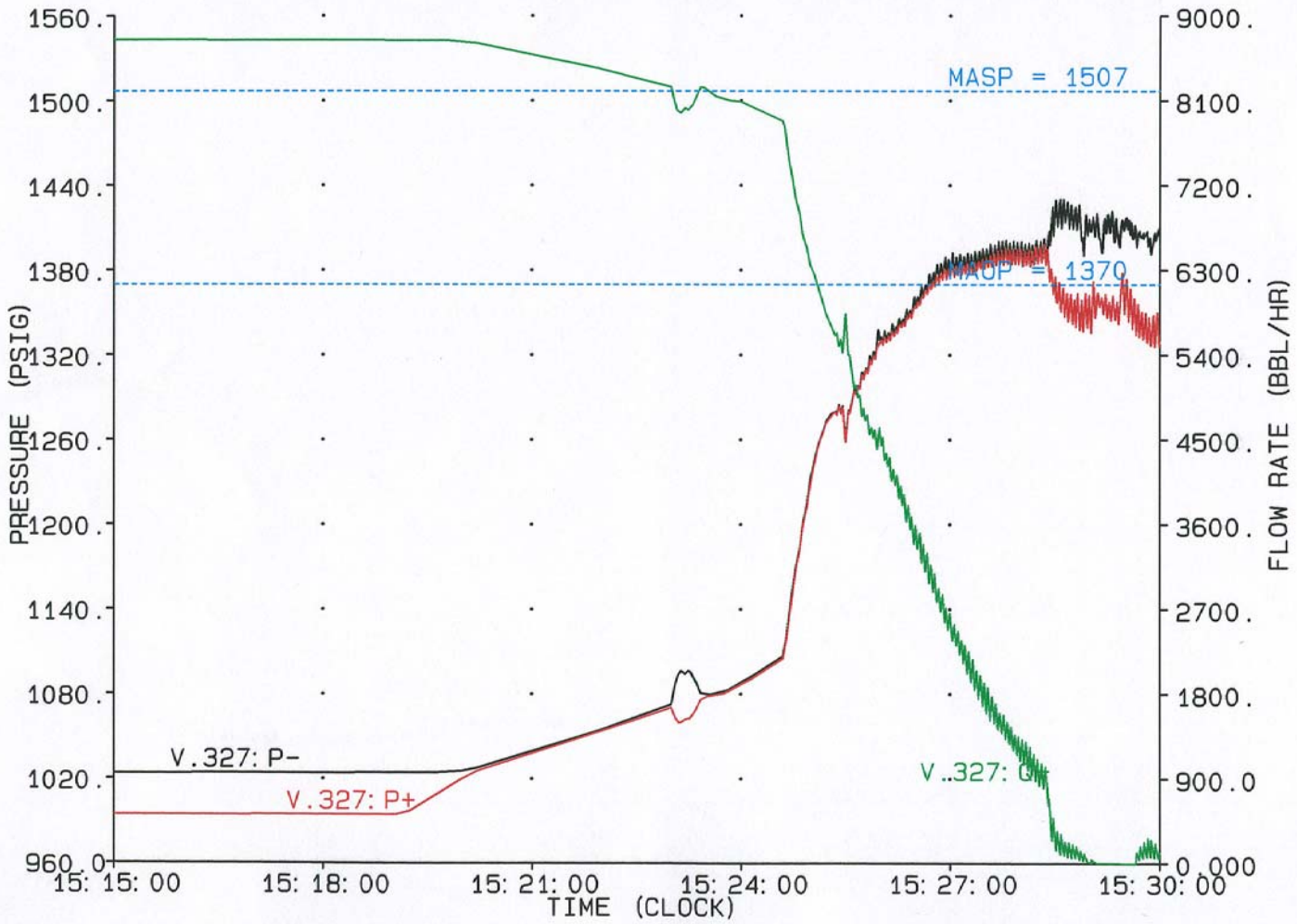
SA 003098

CASE 9, FIGURE 3, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
MAXIMUM TRANSIENT PRESSURE PROFILE FOR PIPELINE FROM ALLEN TO RENTON



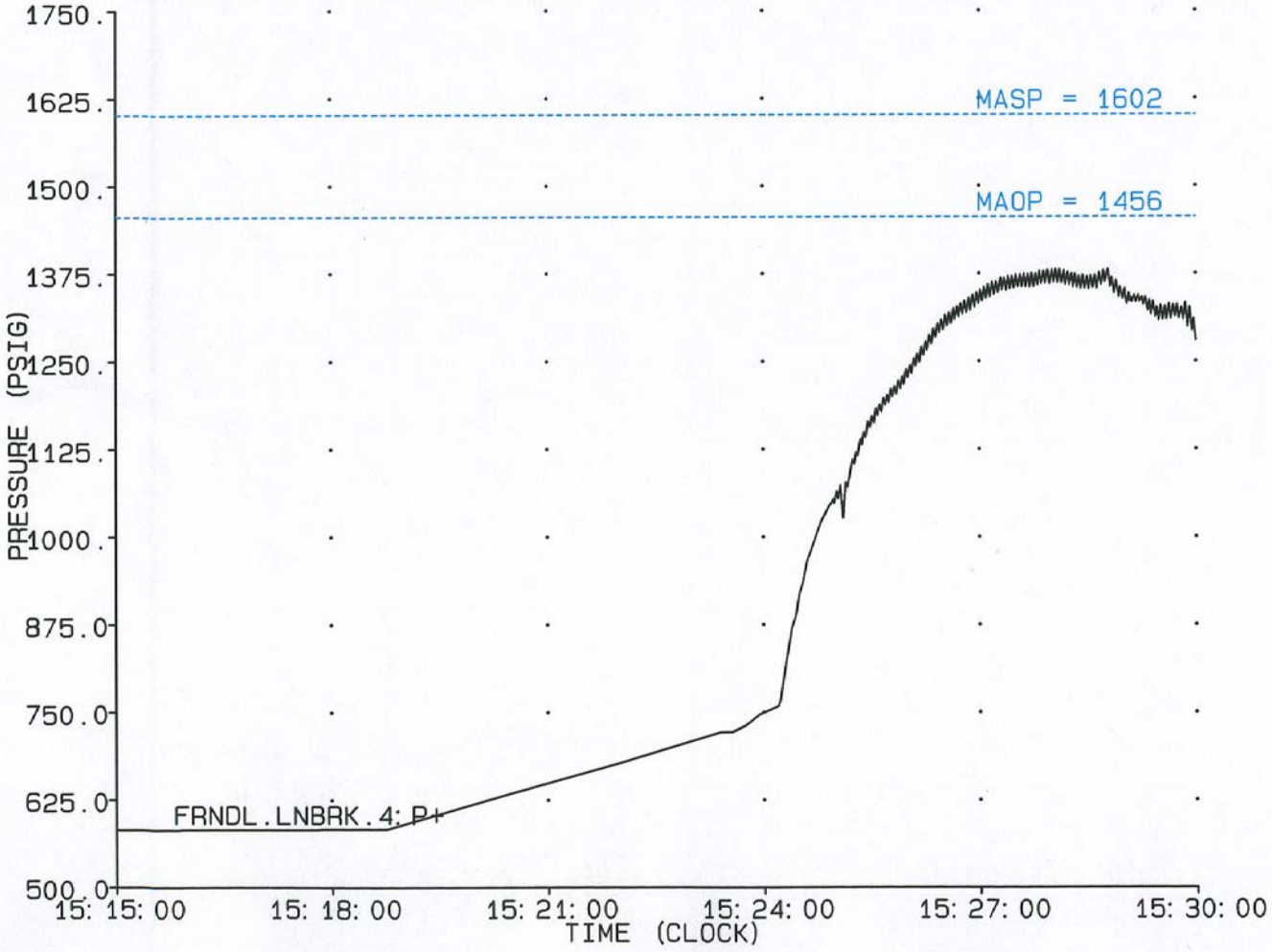
SA 003099

CASE 9, FIGURE 4, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
FERNDALE, V.327, PUMP DISCHARGE CONTROL VALVE PRESSURE & FLOW

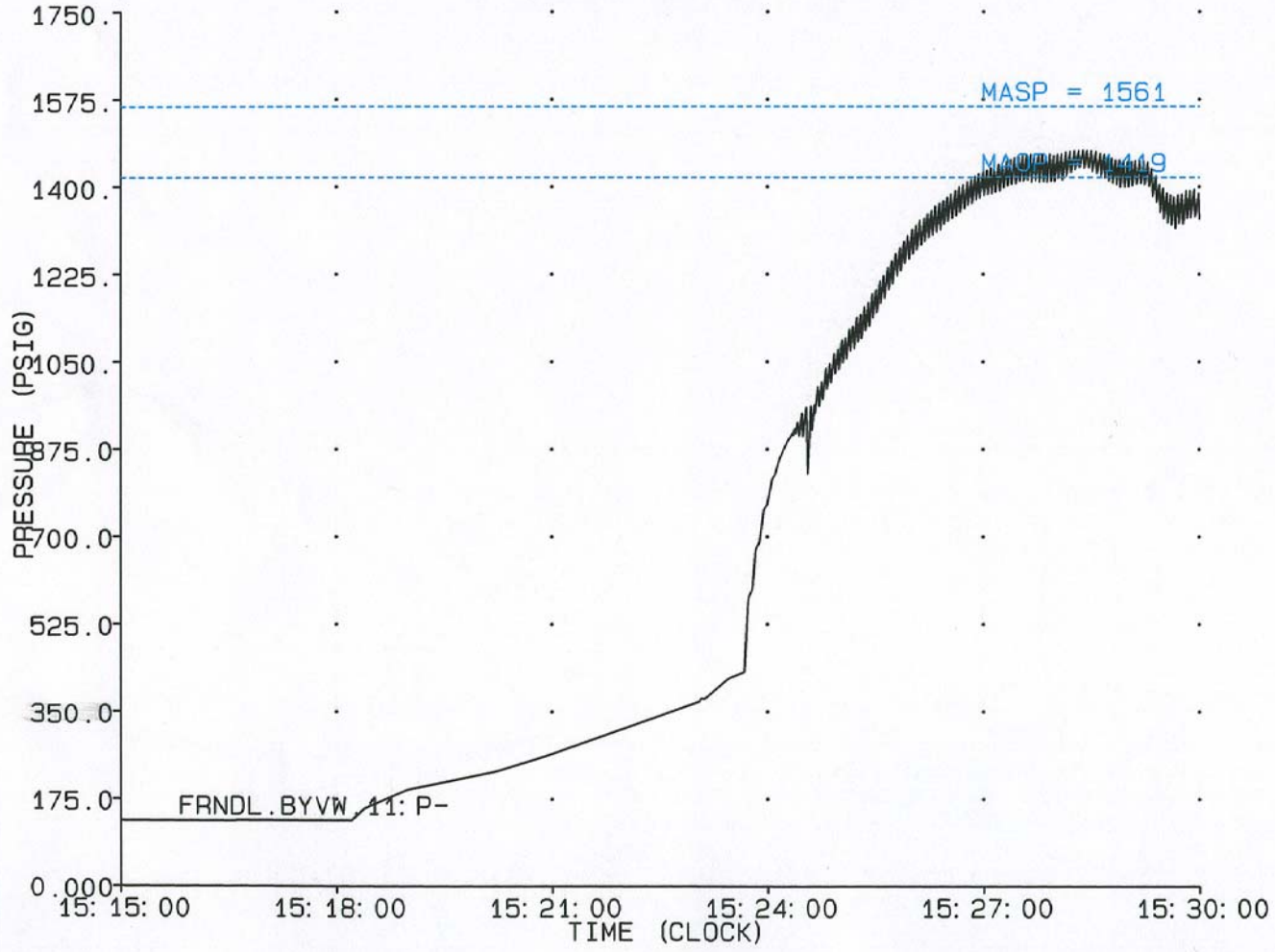


SA 003100

CASE 9, FIGURE 5, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
PRESSURE AT LINE BREAK LOCATION, 15.9 MILES DOWNSTREAM OF FERNDALE

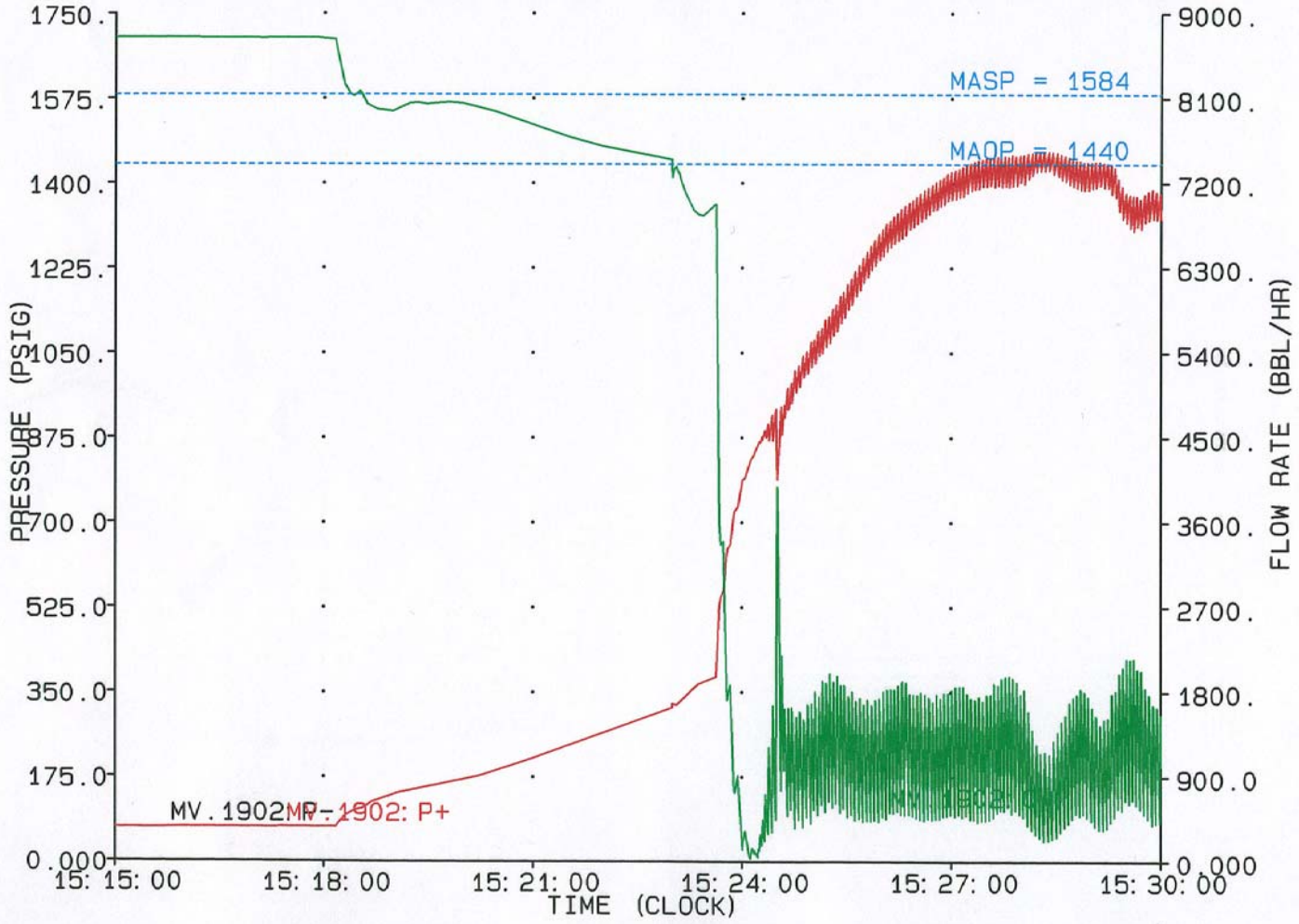


CASE 9, FIGURE 6, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
PRESSURE AT ALLEN JUNCTION



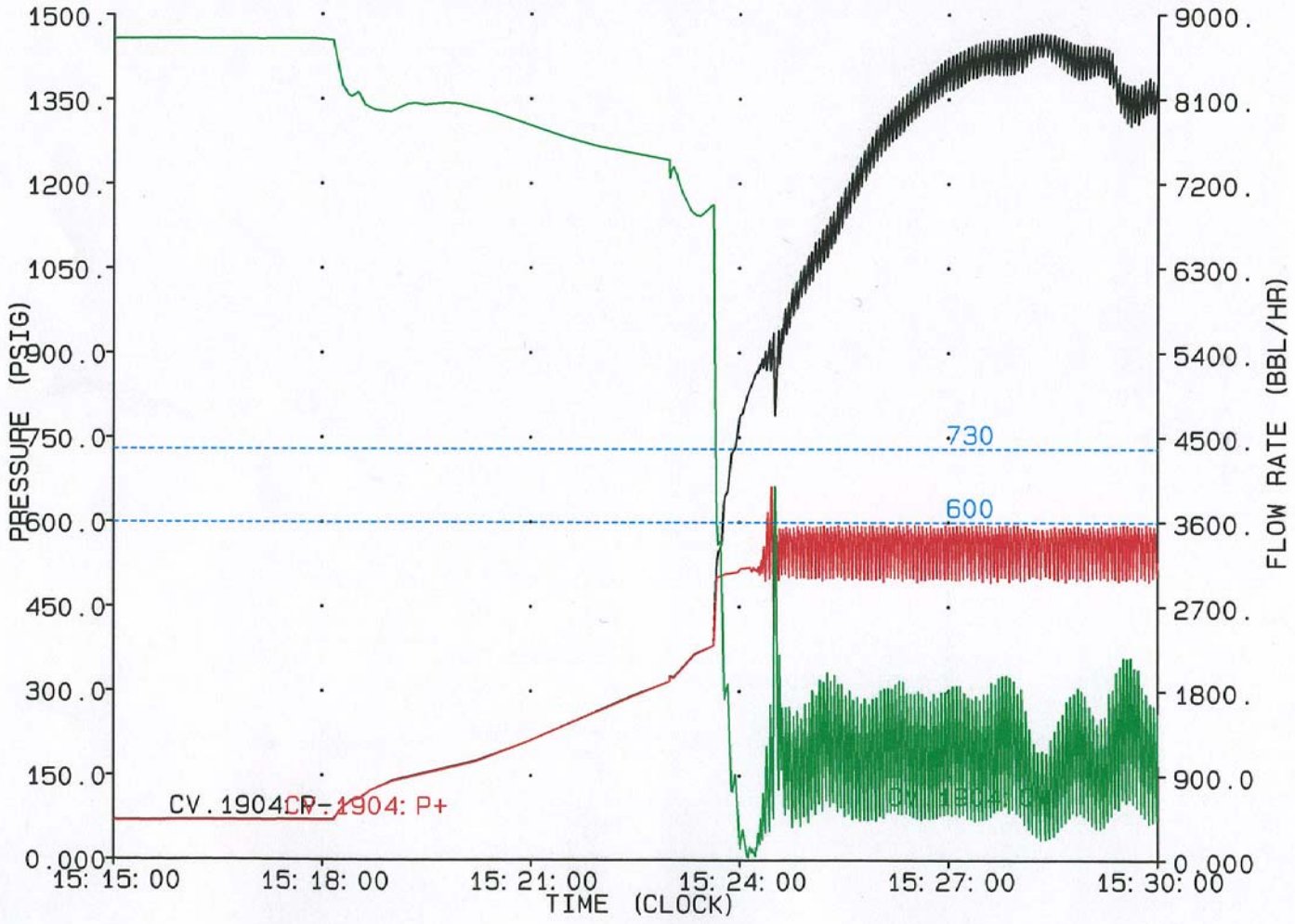
SA 003102

CASE 9, FIGURE 7, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, MV.1902, UPSTREAM PRESSURE & FLOW AT INLET BLOCK VALVE



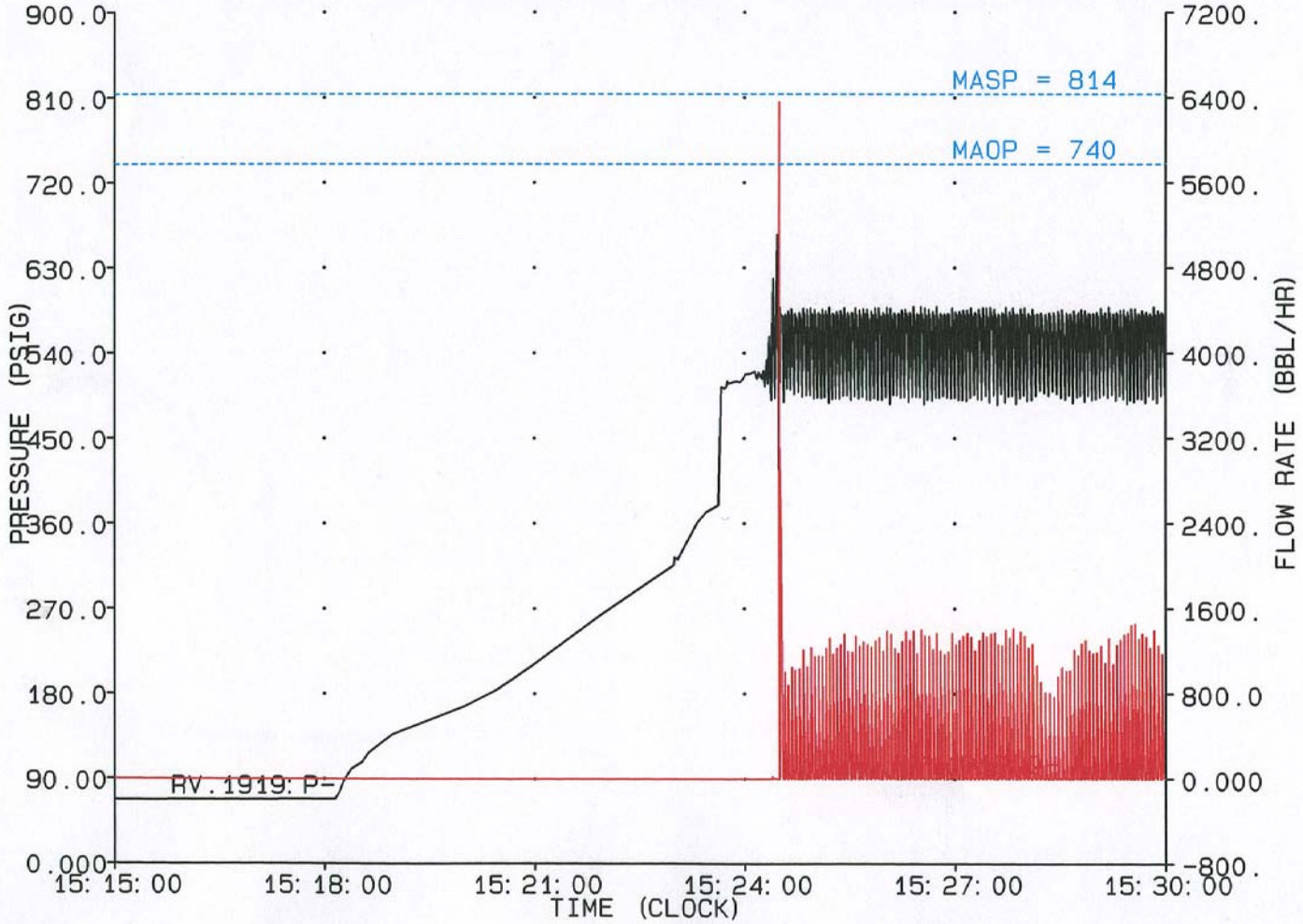
SA 003103

CASE 9, FIGURE 8, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, CV.1904, UPSTREAM PRESSURE & FLOW AT INLET CONTROL VALVE



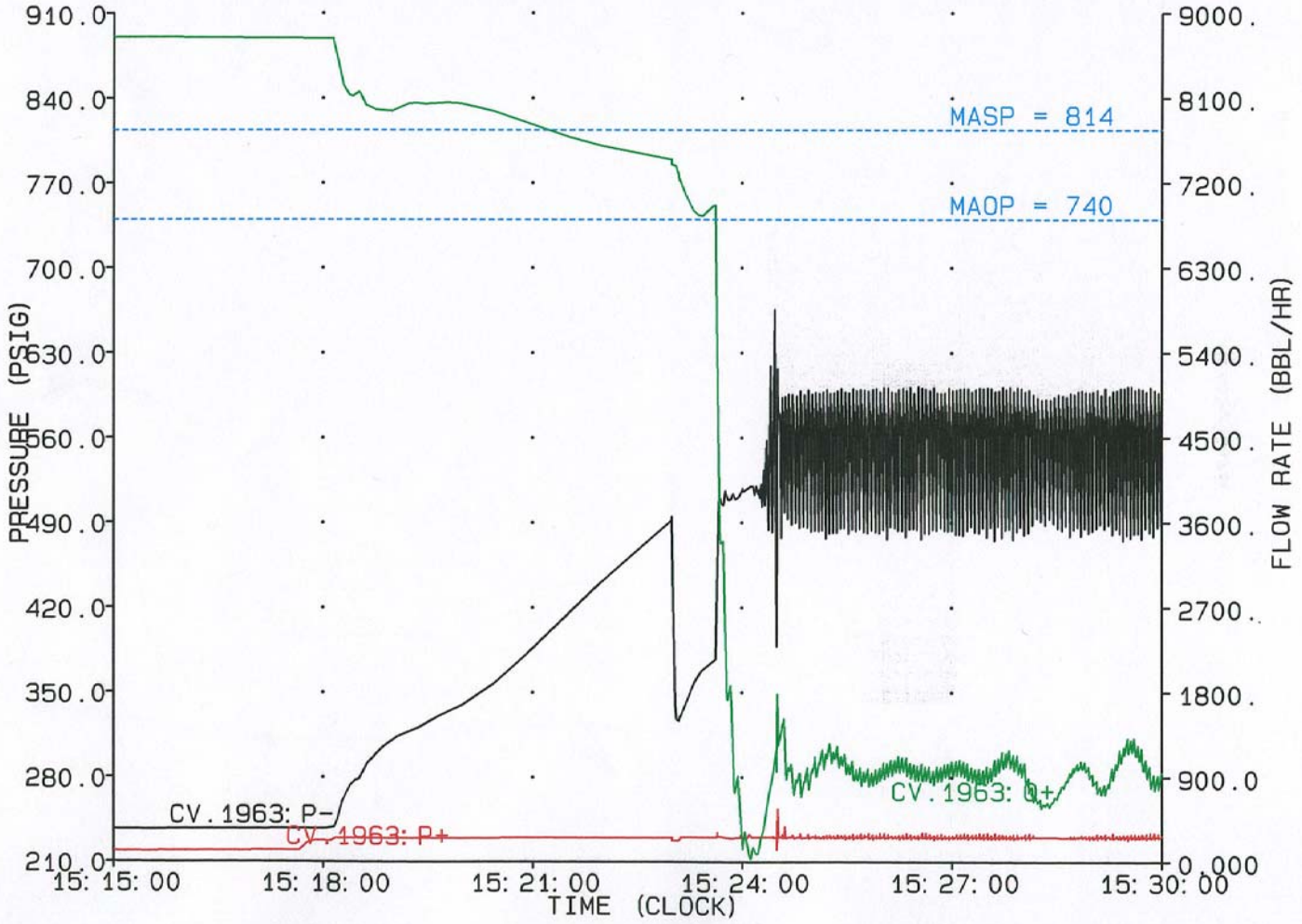
SA 003104

CASE 9, FIGURE 9, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, RV.1919, UPSTREAM PRESSURE & FLOW AT INLET RELIEF VALVE



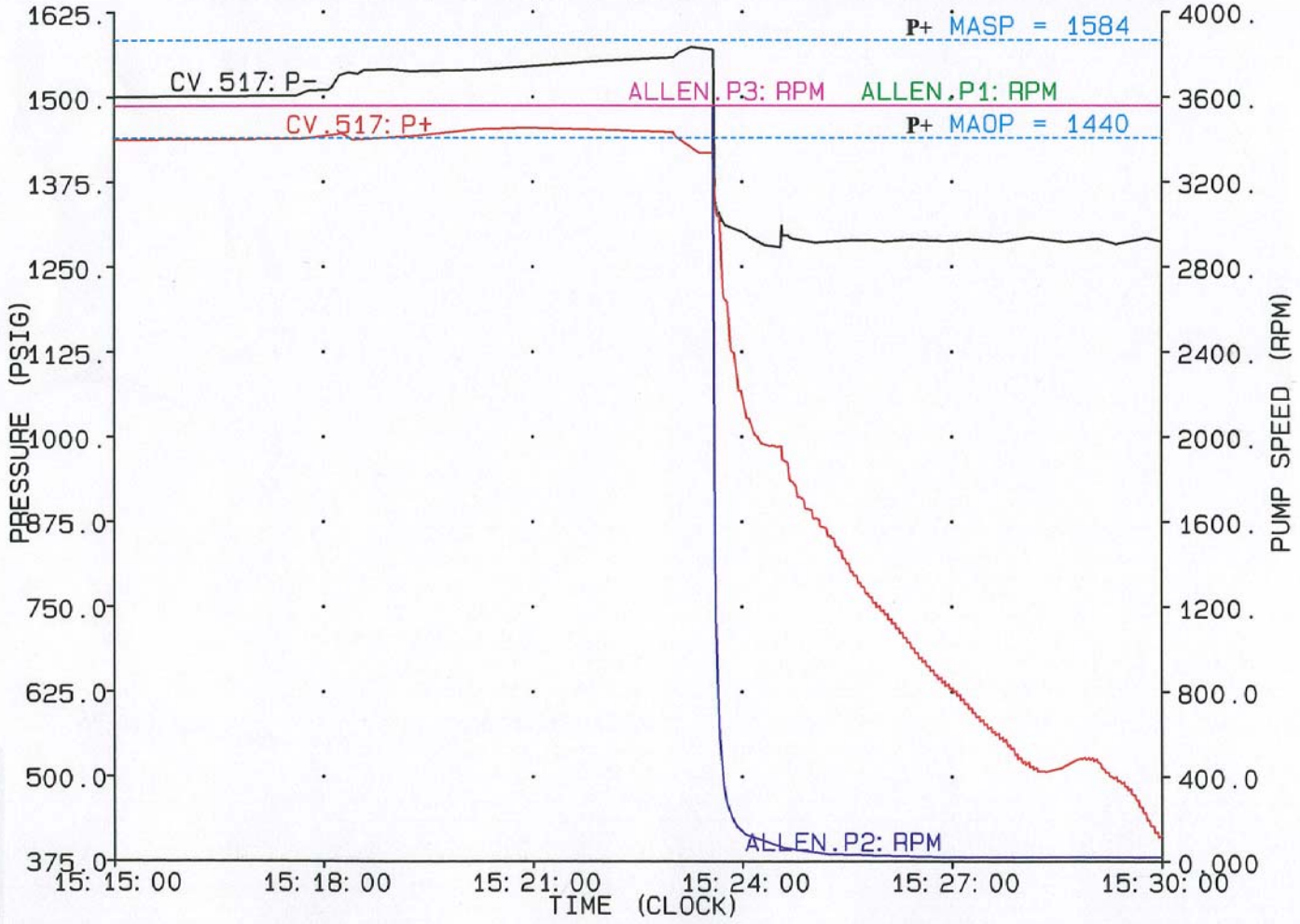
SA 003105

CASE 9, FIGURE 10, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, CV.1963, UPSTREAM PRESSURE & FLOW AT DISCHARGE CONTROL VALVE



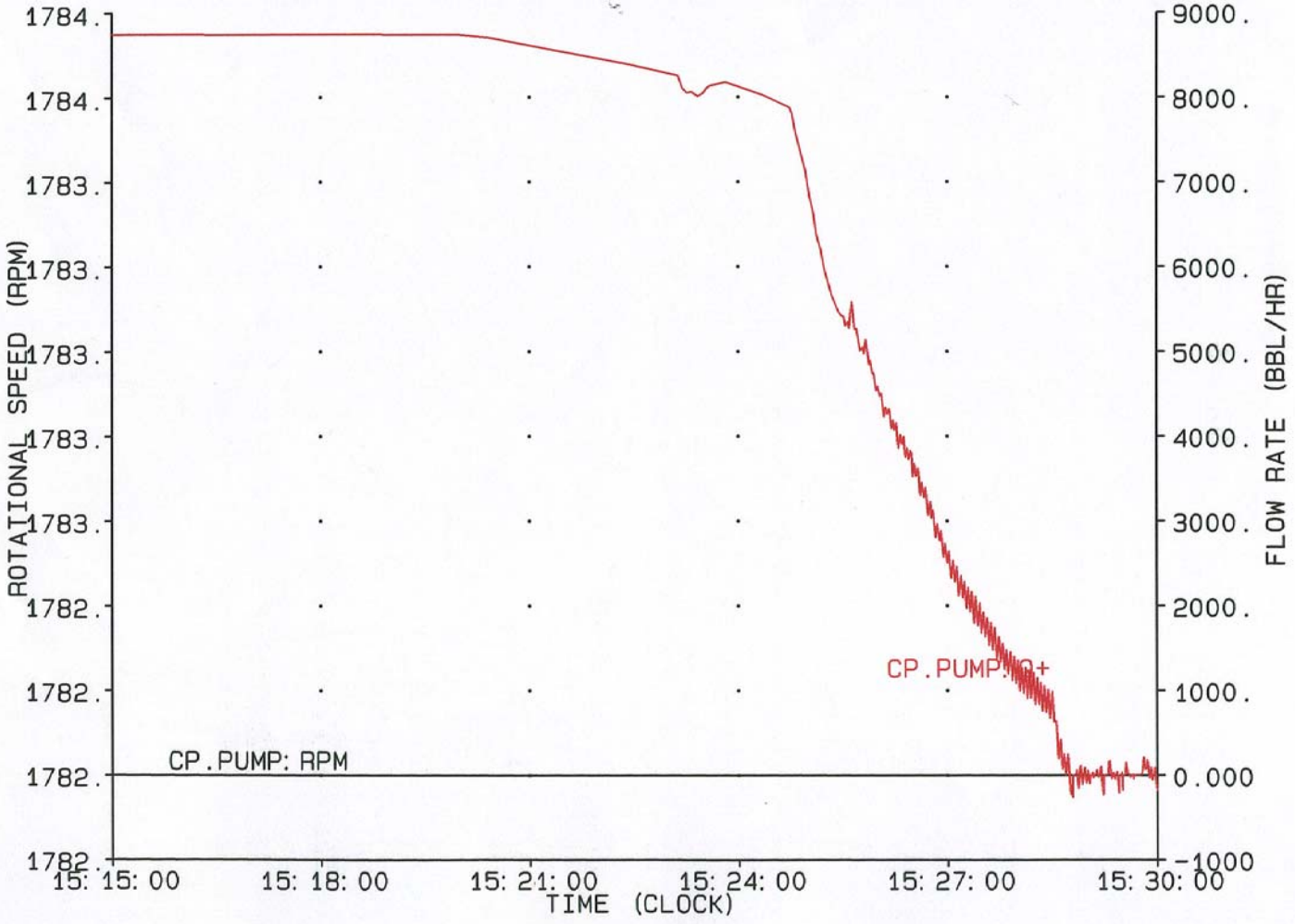
SA 003106

CASE 9, FIGURE 11, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
ALLEN PUMP STA., PUMP SPEEDS & CV.517 DISCHARGE CONTROL VALVE



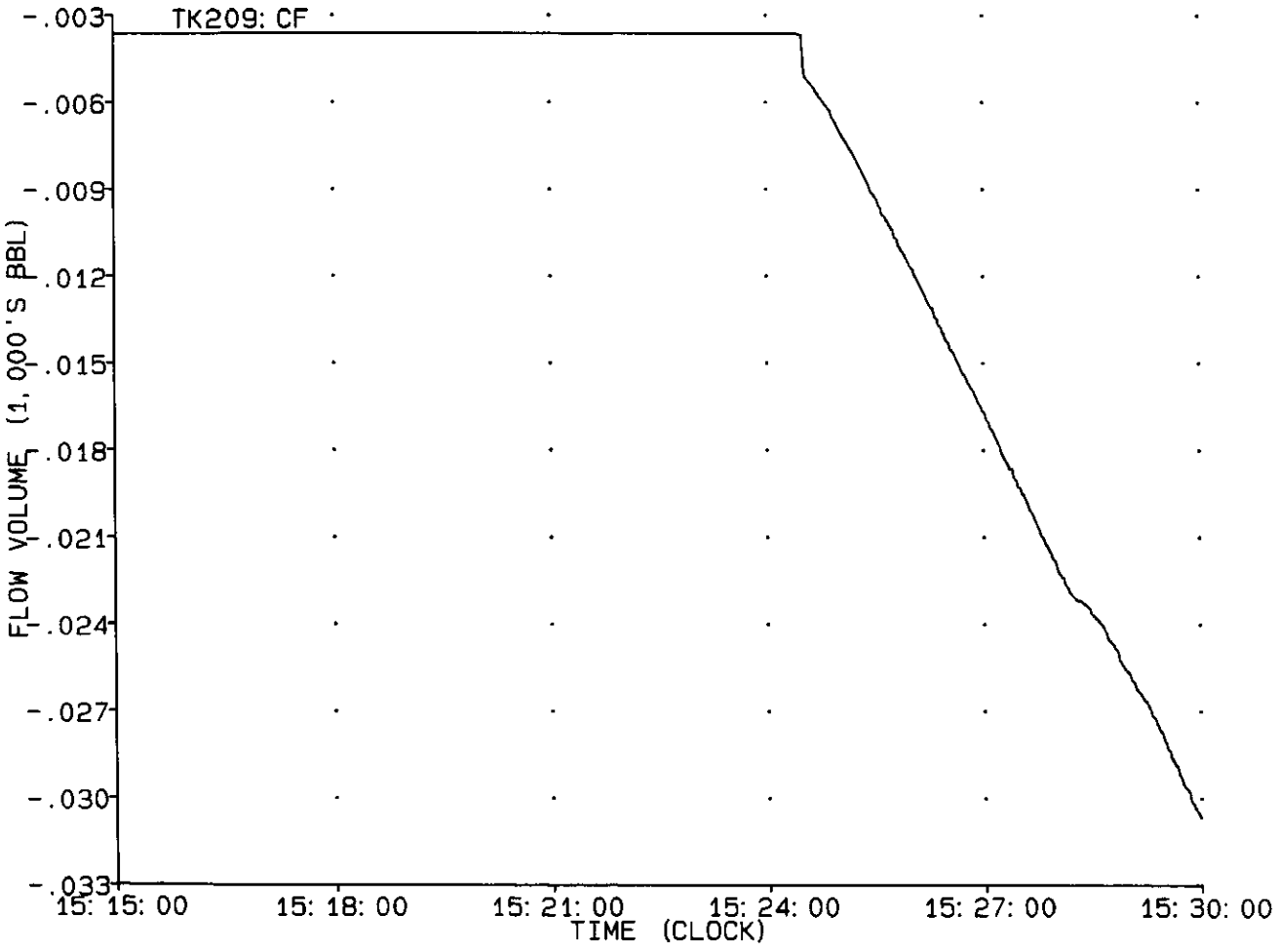
SA 003107

CASE 9, FIGURE 12, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
CHERRY POINT PUMP STATION, PUMP SPEEDS & FLOW RATE



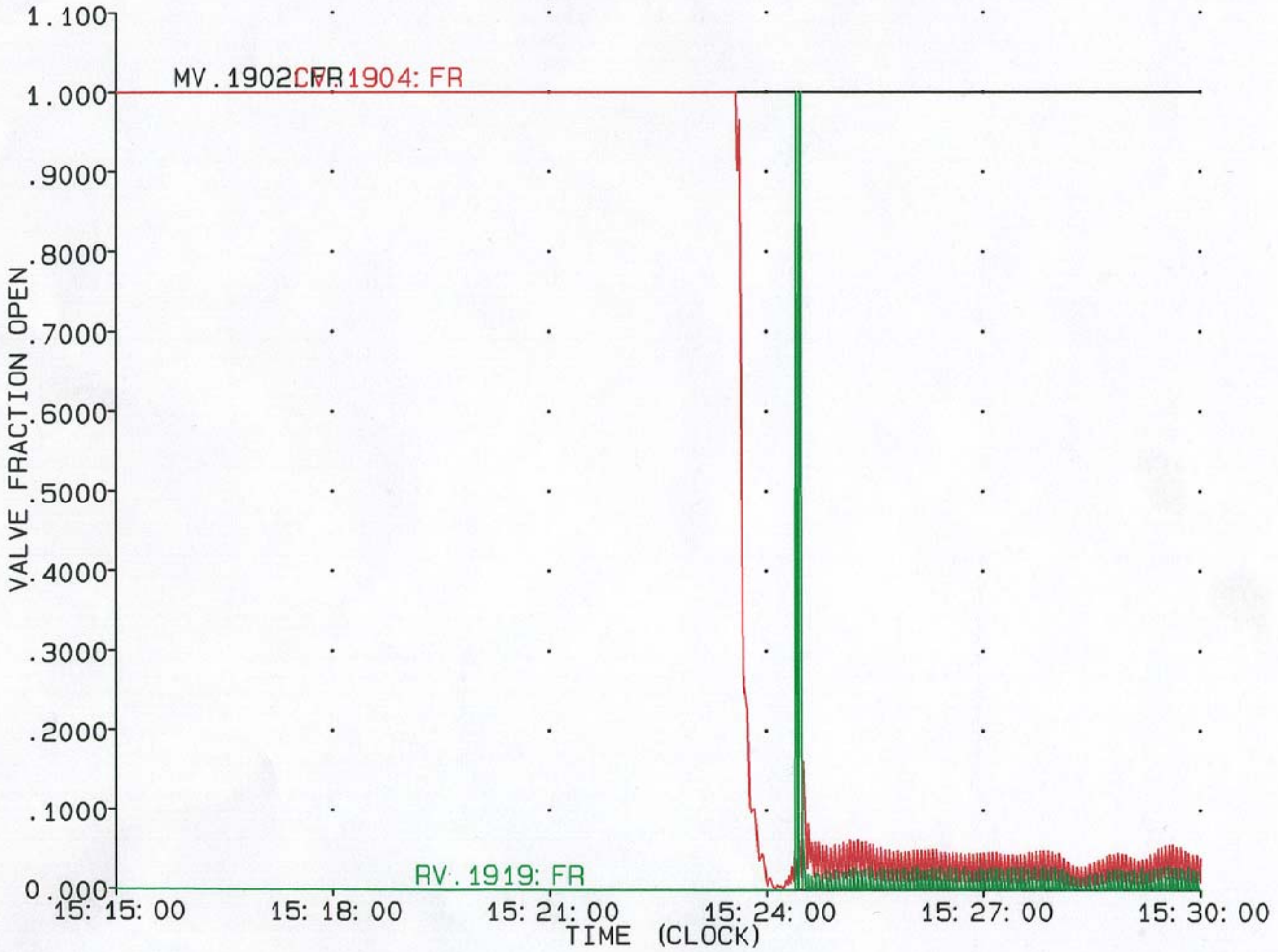
SA 003108

CASE 9, FIGURE 13, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, TK.209, RELIEF VOLUME FROM RV.1919



SA 003109

CASE 9, FIGURE 14, EVENT OF JUNE 10, 1999, FLOW RATE 8748 BBL/HR, 10 SEP 1999
ORIGINAL SEQUENCE, PROPER FUNCTION RV.1919 @ 580 PSIG & MAL-FUNCTION RV.2229
BAYVIEW, MV.1902, CV.1904 AND RV.1919 FRACTION OPEN



SA 003110