GAS NETWORK TRAINING

MODULE : COMPRESSORS

PipelineStudio Training: Module Compressors

The Module

The module contains a series of cases; starting with a case that will be used as starting point to generate additional cases.

The cases will illustrate how to use a generic compressor, driver and centrifugal compressor.

The User

This ***pipelinestudio*** Training Class is intended to the users of the product or someone who wants to become more productive using ***pipelinestudio***.

The goal of the ***pipelinestudio*** training class is to provide a pipeline engineer, technician or professional with all of the skills and familiarity with the product needed to allow them to begin making productive and efficient use of the product.

The Training

pipelinestudio Training is being provided in a laboratory-type environment with the intent to provide the trainee with an interactive and high-ratio of hands on experience. The purpose of this is to keep things interesting and provide better overall retention by the student.

pipelinestudio training is divided into ordered and methodical labs or modules to allow the user to build on skills obtained from the previous module or lab and maximize the retention of knowledge associated with this training. Lecture and discussion will be incorporated into the labs themselves.

Case Study 1 (Simple Network)

Purpose

With this case study we begin looking at more practical network examples in which the interaction of the various pipeline elements is significant.

Important Elements

Transient versus Steady State Behavior

This case model illustrates the concerns between transient and steady state hydraulic behaviour. A pipeline may be capable of considerably more short-term capacity than might be obvious from the steady state results.

Design Concerns

Each of the case studies in this series deals with pipeline capacity and the ability to match supply and delivery requirements under various operating conditions.

Skill Advancements

As each of the case studies progress, less and less model input will be provided. The student is expected to draw from previous case studies, user guides and online help.

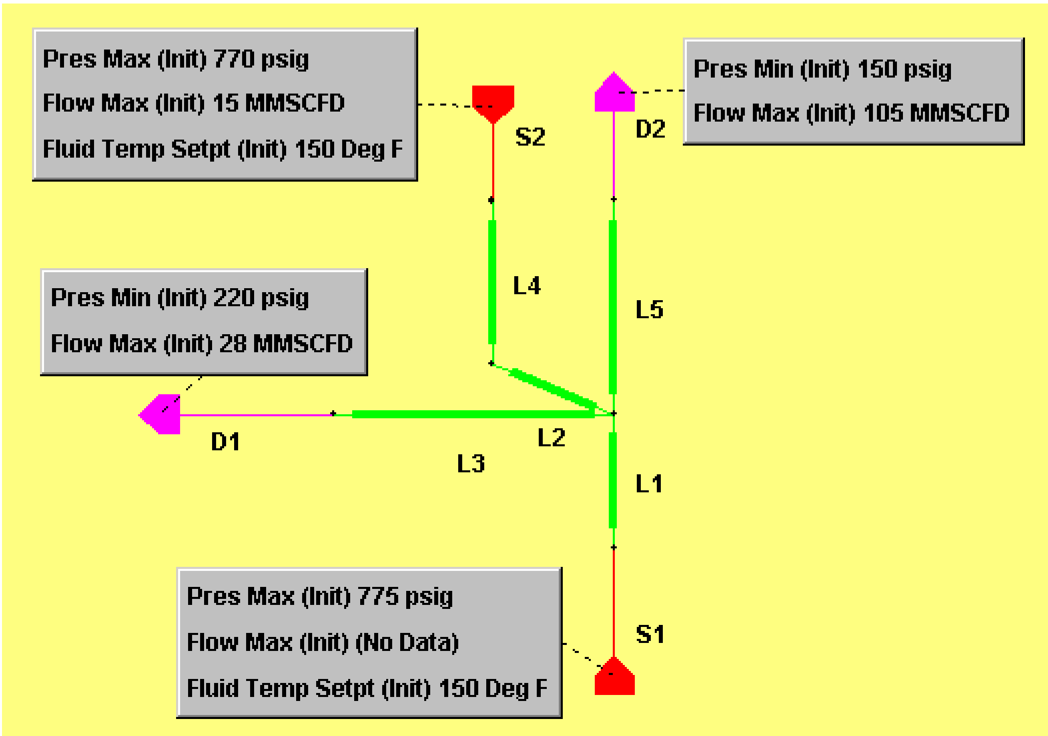
The Scenario

Your main supply, S1, is a gas plant that can deliver an unlimited amount of gas at a constant pressure of 775 PSIG. Another minor supply, S2, can supply up to 15 MMSCFD at a maximum pressure of 770 PSIG.

Case Study 1 (continued)

The system consists of two major gas deliveries, D1 and D2. The power plant (D1) has a constant demand of 28 MMSCFD. The minimum contract delivery pressure for this plant is 220 PSIG. The delivery point (D2) has a constant demand of 105 MMSCFD.

D2 requires an increase in demand to 132 MMSCFD for a 4-hour period. The minimum delivery pressure at D2 is 150 PSIG.



Case1

Supply and Delivery Summary

XREG Name	Flow (MMSCFD	Pressure (PSIG)	Temperature (°F)
S1	?	775	150
S2	15	770	150
D1	28	220	
D2	105	150	

Case Study 1 (continued)

Pipeline Segment Data

Pipe Name	Length (Miles)	ID (Inches)	Roughness (Inches)
L1	37	14.876	0.00250
L2	12	16.876	0.00250
L3	30	10.020	0.00115
L4	17	16.876	0.00050
L5	29	17.350	0.00250

Gas Properties:

Fluid Name	SG	HV (BTU/CF)	CO_2 (%)
Fluid1	0.615	1050	1.4

Use the following data:

Gas Temperature = 150 ^{o}F
Ambient Temperature = 70 ^{o}F
Wall Thickness = 0.25 inches
Knot spacing = 1.0 miles
Overall heat transfer coefficient = 1 BTU/h.ft2.F

TRANSIENT SCENARIO TABLE: CASE 1 (To be used to answer Q2)

Scheduled Time (hours)	Daily Demand D2 (MMSCFD)
1	132
5	132
6	105
24	105

Case Study 1 (continued)

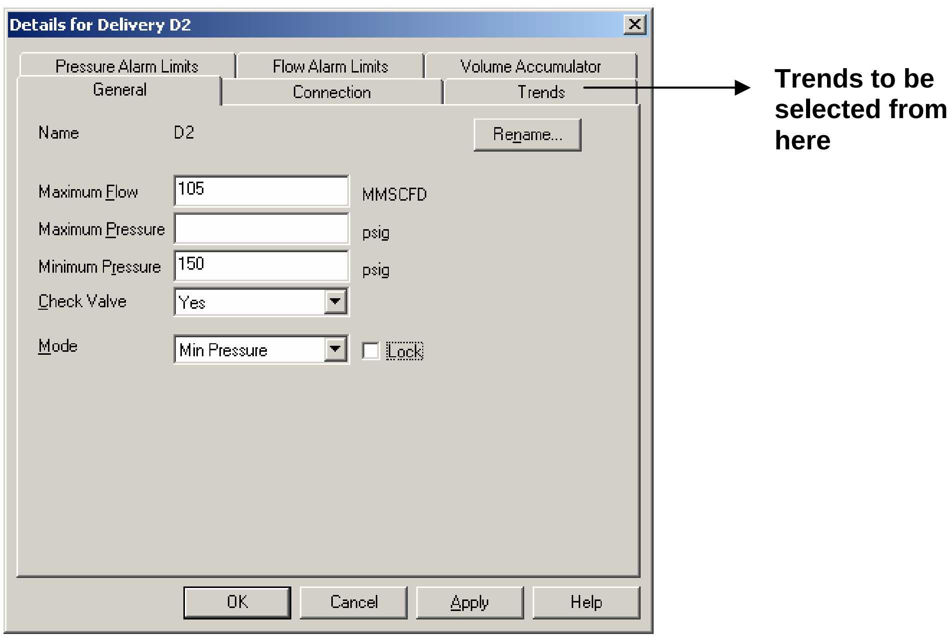
INSTRUCTIONS

1) Configure S1 & S2 with check valves to ensure no gas can return to the supplies. A check valve is a mechanical device, which allows gas flow through it in only one direction. A check valve, as defined by the simulator, is a device that will prevent reverse flow. Reverse flow is defined as flow that passes from the downstream node of the check valve to the upstream node. Upon detecting a negative flow, the check valve closes and remains closed as long as the upstream pressure is less than the downstream pressure. Check valves in the simulator are always either fully open or fully closed.

2) A check valve has two available modes of control: Closed and Open.

3) Use the data provided for the supplies, deliveries and the pipes.

4) Select the appropriate trends at the supplies and deliveries to collect the data needed to answer the questions. The trends have to be selected from the dialogue box by selecting the 'trend' tab for the corresponding external regulator as shown



5) Modify the base model and make any additional runs needed to answer the questions

6) Turn "on" temperature tracking

7) Create a transient scenario table to match the delivery schedule provided for D2

Case Study 1 (continued)

OBSERVATIONS AND QUESTIONS

After entering and executing the model described above, answer the following questions:

1) What are the Steady State pressures in the system with D1 and D2 delivery rates of 28 and 105 mmscfd, respectively?

Pressure at D1= Pressure at D2=

2) What is the impact of the delivery increase at D2? (Hint: see trend plot)?

3) Could contract conditions be maintained at D1 if delivery D2 continued taking gas at 132 mmscfd on this schedule during 72 hours?

Yes/No

4) What is the maximum steady state flow that can be delivered on this pipeline system?

Case Study 1 **(continued)**

INSTRUCTORS' SOLUTION

1) What are the Steady State pressures in the system with D1 and D2 delivery rates of 28 and 105 mmscfd, respectively?

Pressure at D1 = 332.208 psig

Pressure at D2 = 351.153 psig

2) What is the impact of the delivery increase at D2? (Hint: see trend plot)?

Initially, no impact. However, as the line pack is reduced, the pipeline cannot continue to deliver 132 mmscfd and meet the minimum delivery pressure.

3) Could contract conditions be maintained at D1 if delivery D2 continued taking gas at 132 mmscfd on this schedule during 72 hours ?

No, after 48 hours you see the minimum pressure at D1 is starting to impact required flow

4) What is the maximum steady state flow that can be delivered on this pipeline system?

Total= 143.758 mmscfd D1=26.381 mmscfd and D2=117.377 mmscfd;

Case Study 1A (Generic Compressor)

Purpose

The simple network created in Case1 will be augmented in this Case Study to include a Generic compressor.

Important Elements

Generic Devices

pipelinestudio Gas permits the inclusion of several minimally specified devices into the simulation configurations. Generic devices are those which have limited control and which require minimal unit specifications. They are ideal for preliminary network analysis where detailed information or equipment specifications are unknown.

Controlling Generic Compressors

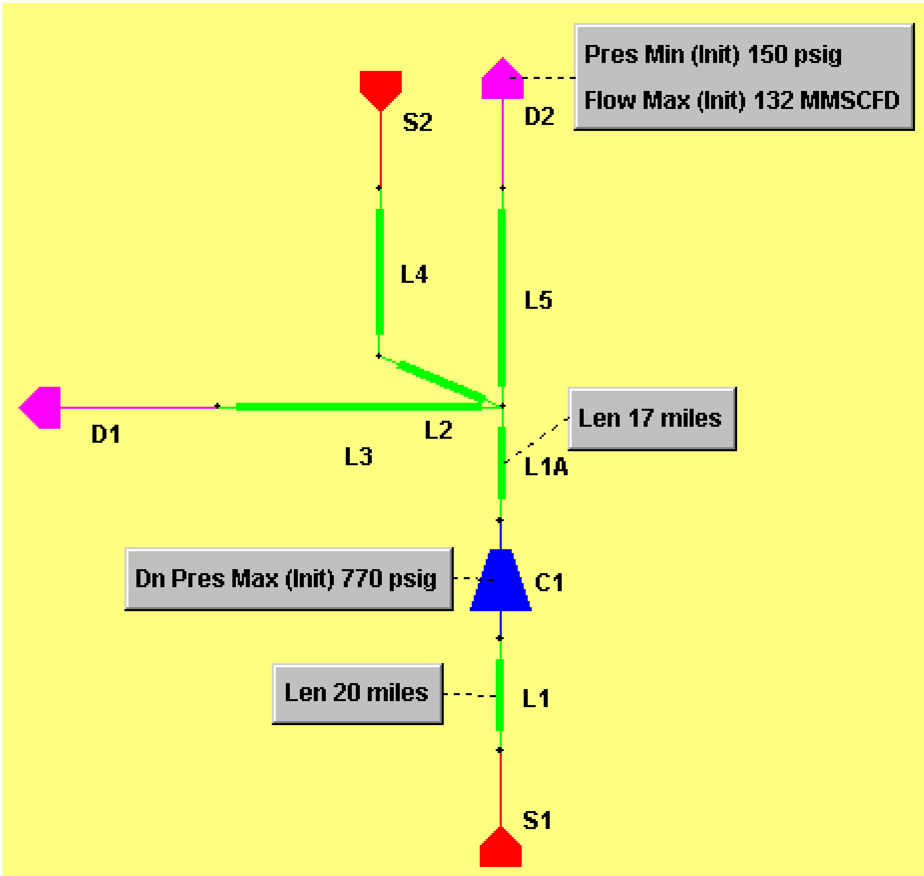
This Case Study will require the use of a generic compressor with controllability for turning the unit on or off. Generic compressors can be controlled, including the ability to "shut down", through their primary pressure or flow controls. In this Case Study we will "ramp" the compressor status to "off". Another method you can try is to ramp the discharge pressure to a small value. This will force the unit into an off condition (since it cannot maintain the required set point).

The Scenario

It has been decided to increase the capacity of the pipeline by adding a compressor station. The only location for this station is 20 miles downstream of the supply S1. The required discharge pressure from this station is 770 PSIG. The delivery point (D2) will have a constant demand of 132 MMSCFD

A problem arises, however, with the compressor station. The compressor has to be shut off everyday for 4 hours.

Case 1A (Generic Compressor)



Case1A

Transient Scenario Table: Case 1A

(PLEASE NOTE: Select "Status" or "Discharge Pressure" not both)

Status for compressor C1: **or Discharge Pressure for compressor C1:**

"Time" (Hours)	"Compressor Status"
1	ON
1.3	OFF
5	OFF
5.3	ON
24	ON

OR

"Maximum Discharge Pressure" (PSIG)
770
10
10
770
770

Case Study 1A (continued)

INSTRUCTIONS

1) Create a new case based on the schematic shown and the information given for CASE1A
2) Create a transient scenario table to match the scheduled operations for the compressor
3) Select the appropriate trend categories to answer the questions
4) Make additional data files and modifications as required

Case Study 1A (continued)

OBSERVATIONS AND QUESTIONS

After entering and executing the model described above, answer the following questions:

1) What are the steady state pressures at D1 and D2?

Pressure at D1

Pressure at D2

2) With the compressor operating, can D2 take gas at the new higher rate without impacting D1?

Yes/No

3) Can minimum gas delivery conditions be maintained at D1 and D2 if the compressor is shut off for four hours?

Yes/No

4) The compressor has gone on annual operational maintenance and it will restore normal operations only after 8 hours. Can the delivery flows be sustained?

5) What is the maximum flow in steady state at D1 & D2 with the addition of the compressor?

Case Study 1A (continued)

INSTRUCTOR'S SOLUTION

After entering and executing the model described above, answer the following questions:

1) What are the steady state pressures at D1 and D2?

Pressure at D1 = 465.773 psig

Pressure at D2 = 412.582 psig

2) With the compressor operating, can D2 take gas at the new higher rate without impacting D1?

Yes

3) Can minimum gas delivery conditions be maintained at D1 and D2 if the compressor is shut off for four hours?

Yes

4) The compressor has gone on annual operational maintenance and it will restore normal operations only after 8 hours. Can the delivery flows be sustained?

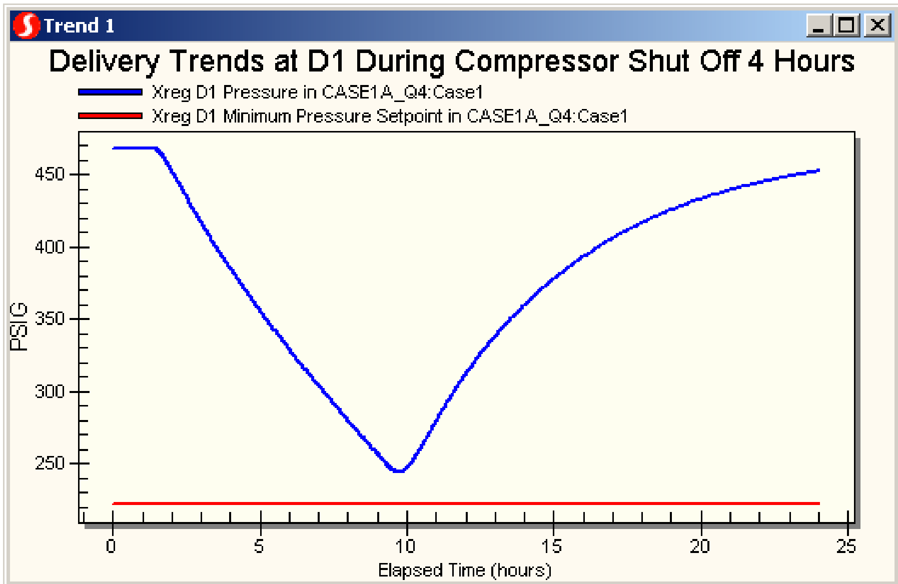
No, the pipeline is able to maintain the flow until time 8.690 hours (8:41:25) before minimum pressure is reached and the delivery flow drops

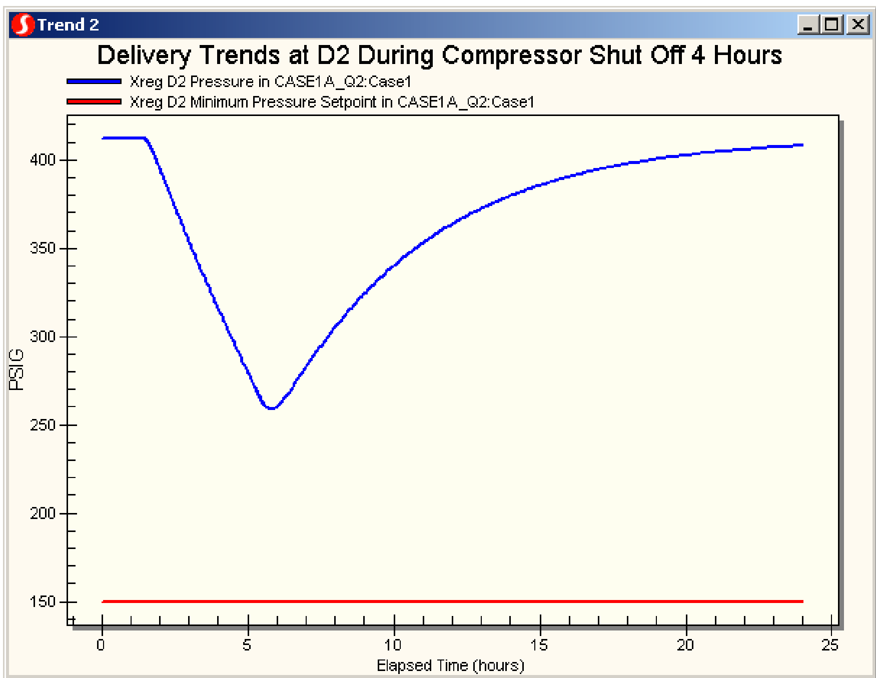
5) What is the maximum flow in steady state at D1 & D2 with the addition of the compressor?

Flow rate at D1 - 34.853 mmscfd Flow rate at D2 - 147.677 mmscfd Total Flow = 182.530 mmscfd

Case Study 1A (continued)

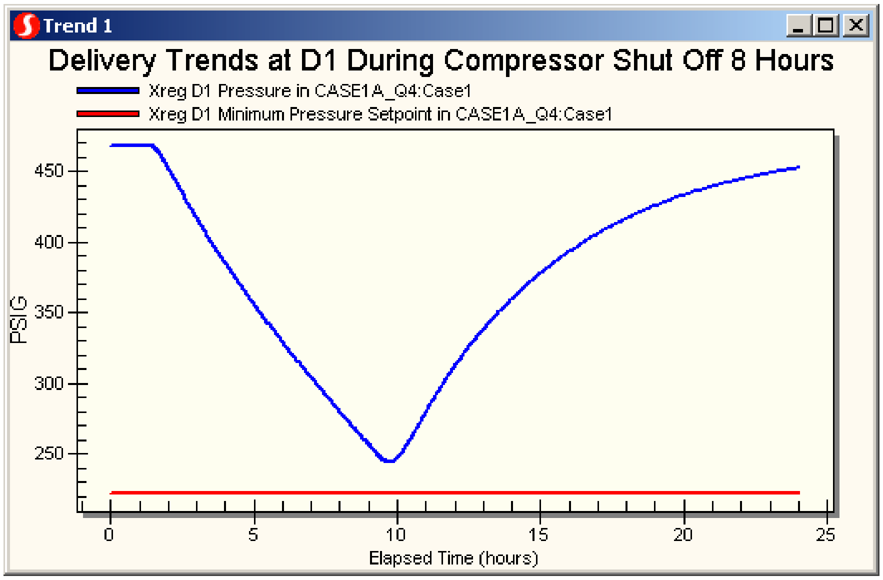
When the compressor is tripped off for 4 hours

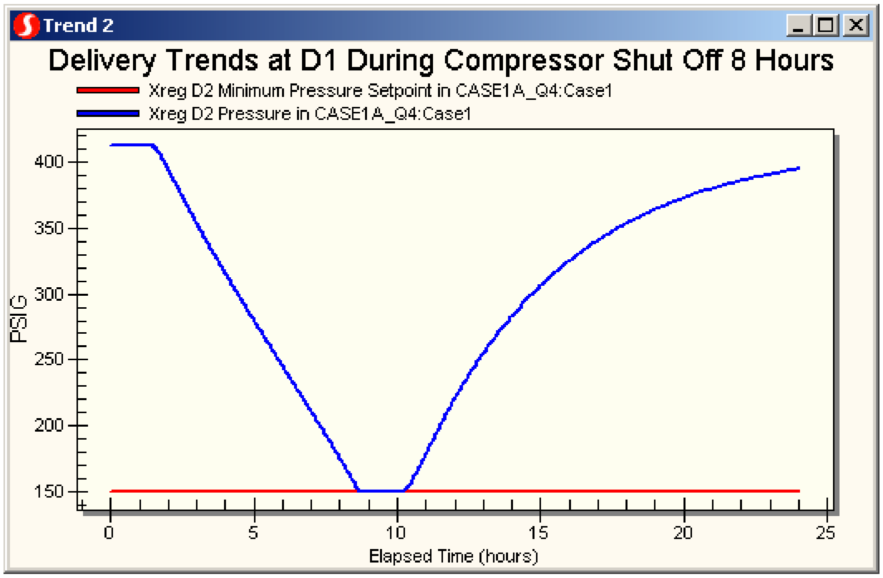




Case Study 1A (continued)

When the compressor is down for 8 hours due to annual operational maintenance





Case Study 1B (Generic Driver)

Purpose

The simple network and compressor created in case1A will be augmented to include a Generic Driver.

Important Elements

Drivers

Drivers are optional devices that provide power to a compressor unit. Studies that require the user to determine compressor fuel gas consumption or for determining the horsepower requirements of a compressor require the use of a driver.

Generic Drivers

A generic driver permits the inclusion of driver limitations and demands on the simulations without the need for detailed particulars of the engines involved.

Fuel Consumption

Specifying a particular driver will allow the user to determine a fuel gas requirement. This volume of gas may be extracted from the pipeline. In this Case Study we will configure a driver and have its fuel gas extracted from the line.

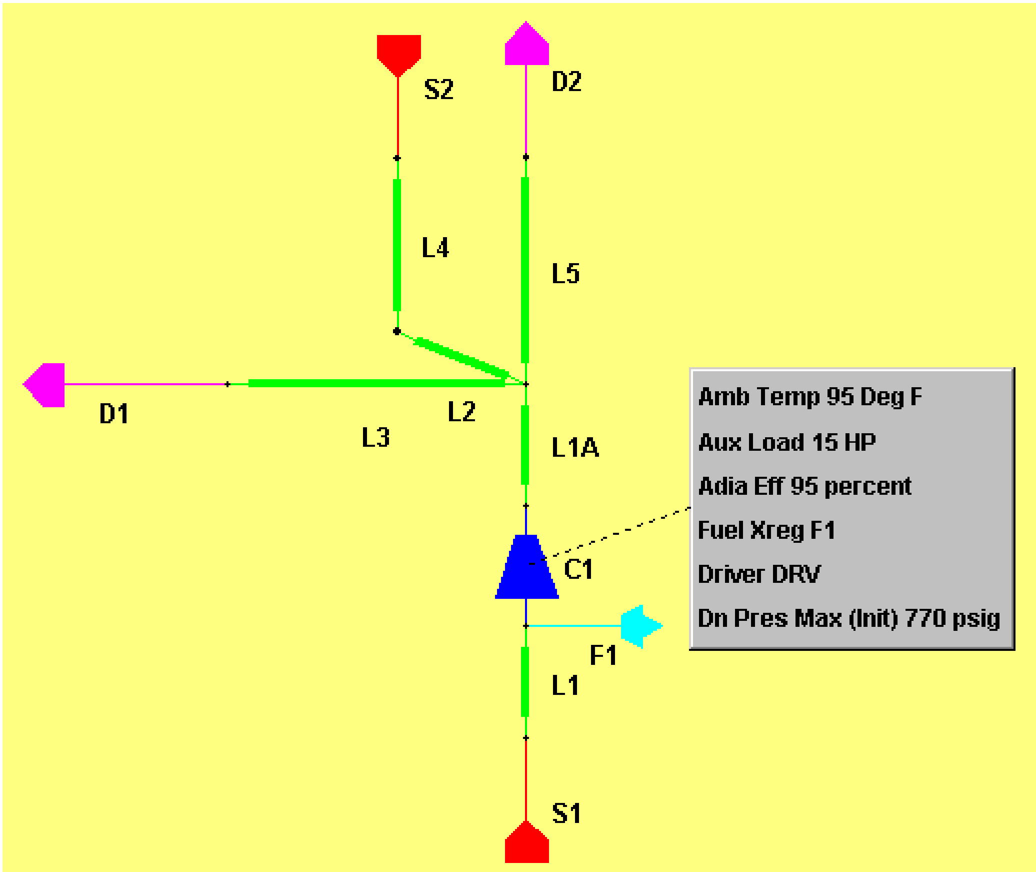
Equipment specifications

Equipment specifications for pipeline facilities such as compressors and drivers (including the associated performance curves) are input into the respective equipment detailed dialogue box.

The Scenario

After considering all the drivers that are available, a unit that is site rated for 1750 HP @ 60^{O}F has been selected. The driver performance coefficients were also provided (see fine print in the manufacturer's specifications - or supplied schematic). Does this unit provide adequate horsepower to allow you to still make your deliveries? Can the compressor be shut off for 4 hours?

Case Study 1B (continued)



Case1B

Driver Performance Data:
A = 1.0, B = 0.0, C = 0.0

Driver:	DRV
Ambient Rating Factor:	0.0005
Rated Temperature:	60 °F
Rated Fuel Efficiency:	30%
Rated Power:	1750 HP

INSTRUCTIONS

1. Create a new case based on the schematic shown and the information given
2. Add the DPID specification
3. Add a fuel external regulator to the configuration
4. Modify the compressor to reflect the DRIVER reference and the other new data
5. Select the appropriate trends to collect the data needed to answer the questions
6. Modify the model and make additional runs as required to answer the questions

Case Study 1B (continued)

OBSERVATIONS AND QUESTIONS

After entering and executing the model described above, answer the following questions:

1) What are the steady state pressures at D1 and D2

Pressure at D1= Pressure at D2=

2) Can we deliver the flow required at D1 and D2 if the compressor is shut off for 4 hours

3) How does this compare to the head for Case1A? Why is there a difference?

4) How much fuel does the compressor consume on an hourly basis during the first 24 hours?

5) What is the maximum flow in steady state at D1 and D2 with the compressor driver addition?

Case Study 1B (continued)

INSTRUCTOR'S SOLUTION

After entering and executing the model described above, answer the following questions:

1) What are the steady state pressures at D1 and D2

Pressure at D1= 322.027 psig Pressure at D2= 237.439 psig

2) Can we deliver the flow required at D1 and D2 if the compressor shut off for 4 hours

No

3) How does this compare to the head for Case1A? Why is there a difference?

It is lower. The compressor in Case 1A has unlimited driver power, whereas the compressor in Case1B has driver limitations

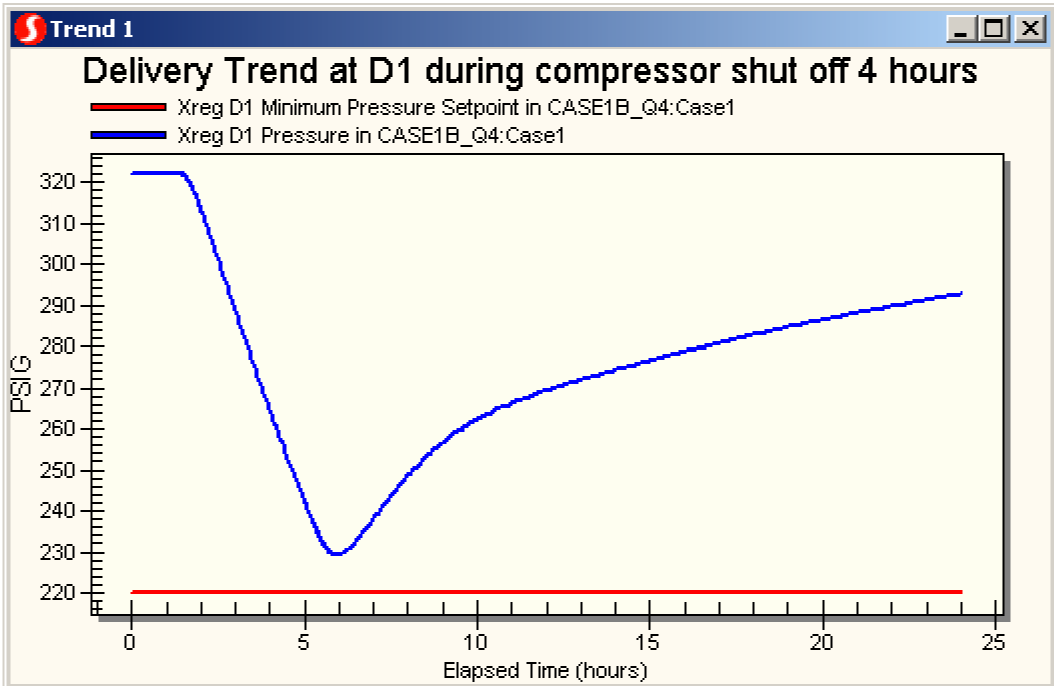
4) How much fuel does the compressor consume in steady state and during the first 24 hours?

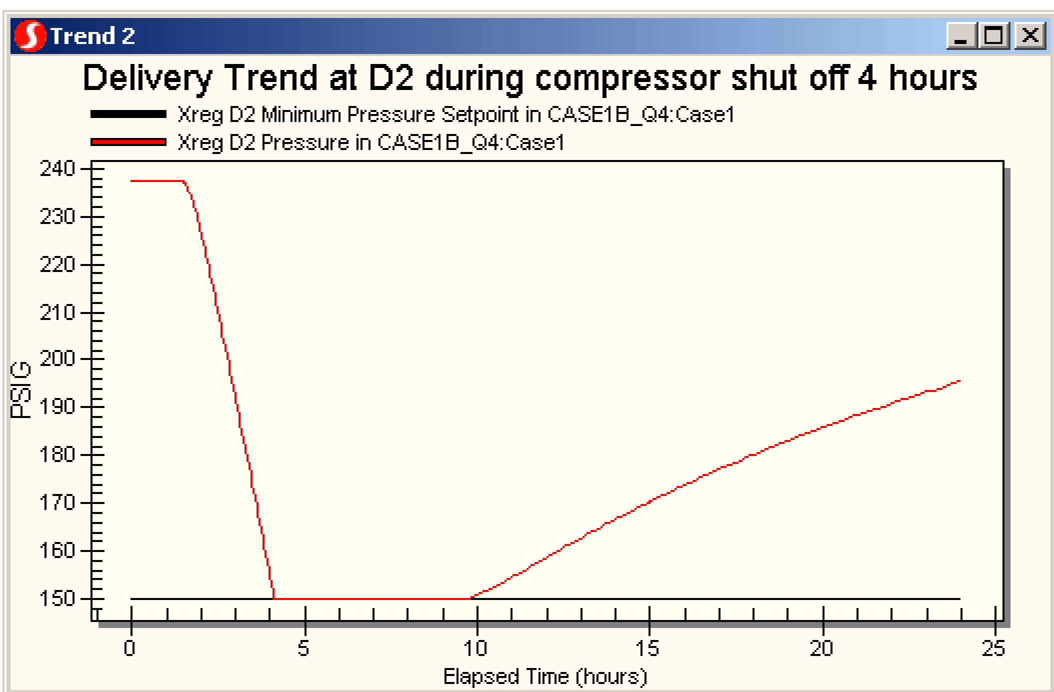
0.333 mmscfd and 0.277 mmscf

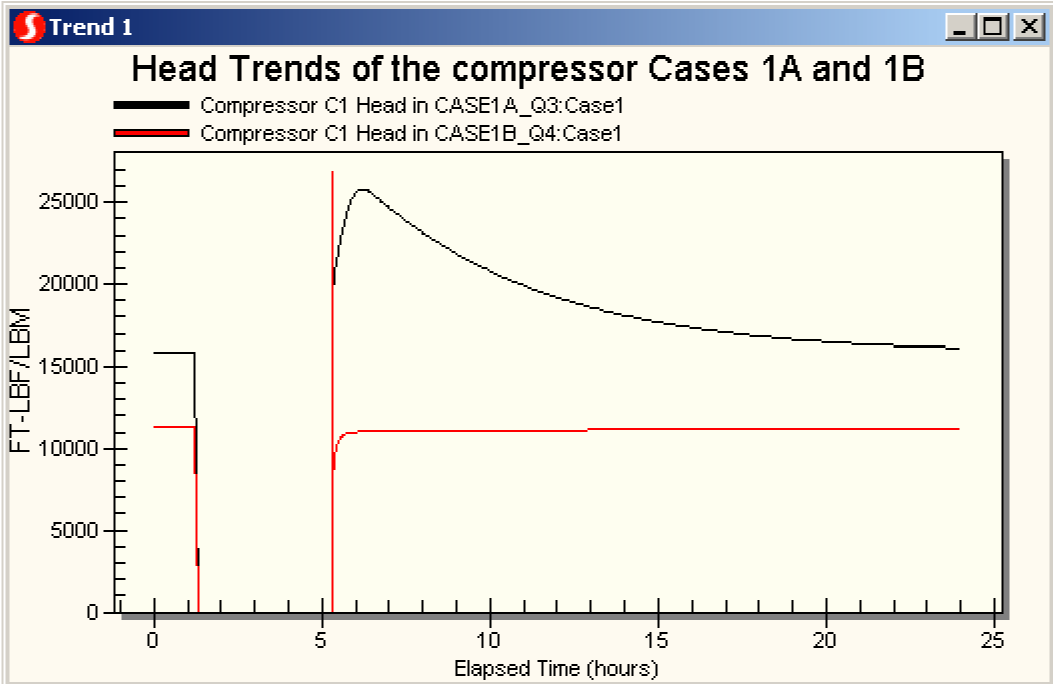
5) What is the maximum flow in steady state at D1 and D2 with the compressor driver addition?

D1 = 30.492 mmscfd, D2 = 131.993 mmscfd Total= 162.819 mmscfd

Case Study 1B (continued)







Case Study 1B (continued)

During peak demand where the demand exceeds the steady state capacity of the line, the ability of the system to respond is governed almost exclusively by the amount of gas stored in the pipeline as resident linepack. The primary difference between this case study and CASE1A is that the power limitation of the modified compressor has produced lower pressures in the downstream portion of the network resulting in less linepack. Consequently, there is inadequate linepack available to cover for the loss of the compressor.

Case Study 1C (Centrifugal Compressor)

Purpose

The compressor used in Case 1B will be replaced by a centrifugal compressor that will include a fully defined centrifugal compressor curve.

Important Elements

Centrifugal Compressors

Centrifugal compressors possess a specified relationship between the flow rate of the gas passing through the unit and the amount of pressure or head that the unit can produce. Additionally, operational boundaries are placed on the unit to prevent the operation of the compressor under unreasonable, inefficient, or hazardous conditions. These limiting boundaries are the surge and stonewall lines.

Head Curve

The head versus flow relationship of the compressor is defined by specifying a collection of performance points. A curve fit is performed on these data points to create a CPID or Compressor Performance ID. At least six data points need to be provided and at least two speeds represented. Values outside of the surge and stonewall limits should be avoided.

Efficiency Curve

The adiabatic efficiency of the compressor is similarly specified. This efficiency term controls how much of the compressor's power is lost as heat into the gas stream. At least six data points need to be provided and at least two speeds represented.

Minimum and Maximum Speeds

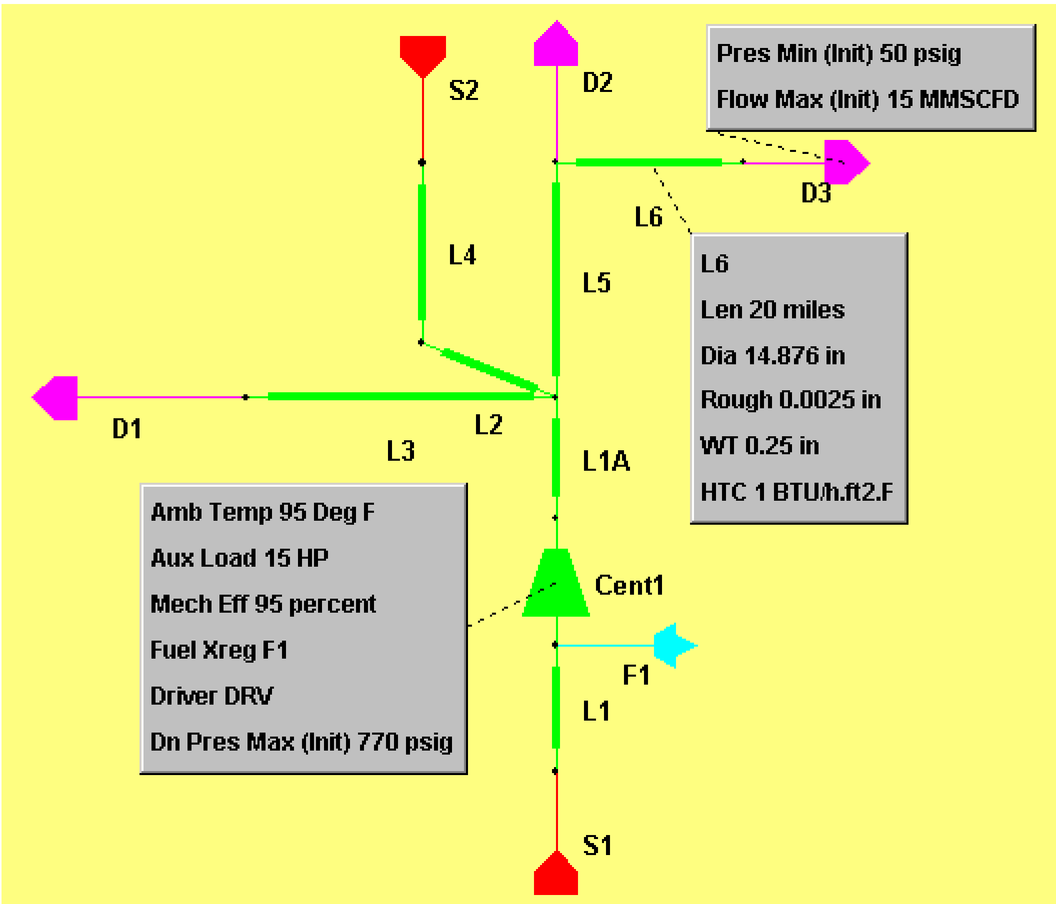
Compressor power is also a function of the unit speed. Each compressor will have a maximum and minimum speed under which the unit should operate (In terms of safety as well as pure mechanical limits).

Case Study 1C (continued)

The Scenario

Having a fairly good idea of power and throughput requirements for a compressor, you start shopping around for a potential vendor. You have finally selected a centrifugal compressor and also got the design data that is required.

A new delivery is likely to come up close to delivery D2.This new delivery will also put a strain on the system. Add the facilities shown and determine the limitations that this centrifugal compressor will impose on the system.



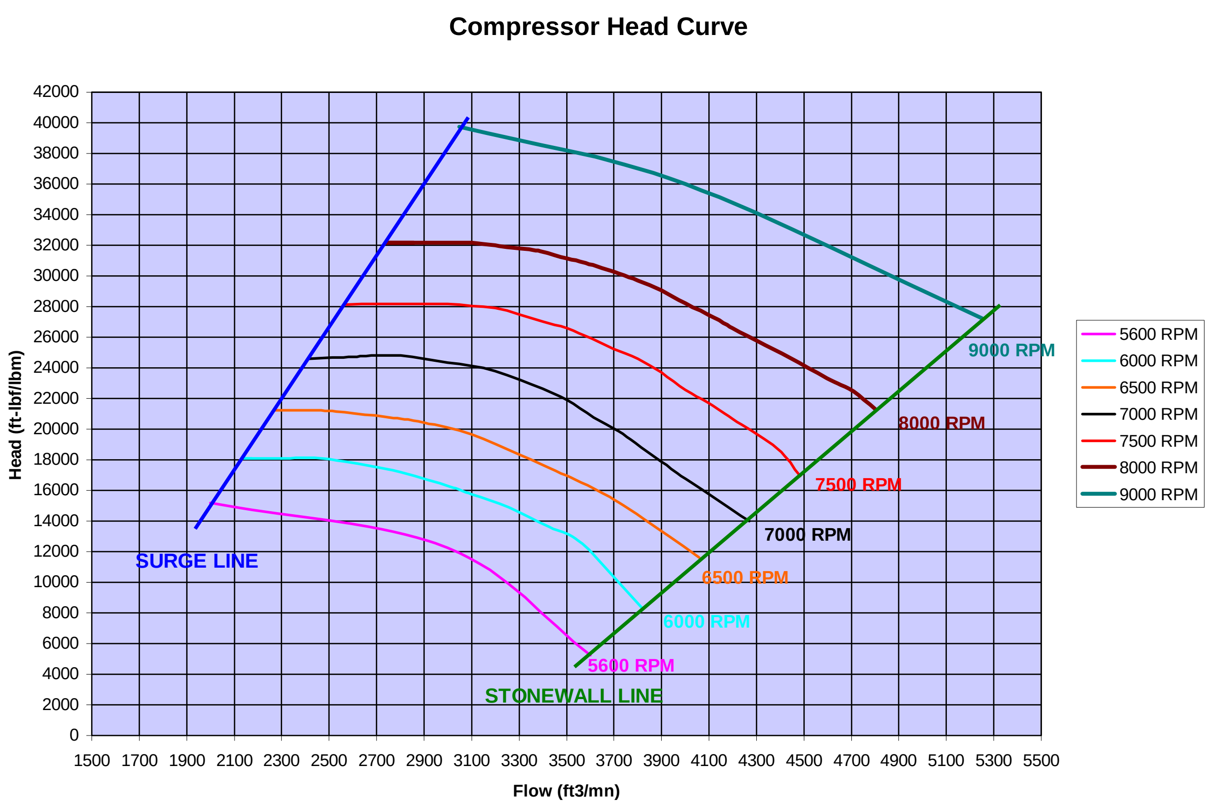
CASE1C

D3 flow= 15 mmscfd, minimum pressure = 50 psig
Driver Performance Data:
Driver: DRV; A = 1.0, B = 0.0, C = 0.0

Ambient Rating Factor: 0.0005
Rated Temperature: 60 ^{o}F
Rated Fuel Efficiency: 30%
Rated Power: 8000 HP

Case Study 1C (continued)
Additional Pipe Data:

Pipeline lateral connection - From D2 to the new delivery D3.
Pipe Name - L06
Length - 20 miles
ID - 14.876 inches
Roughness - 0.00250
WT = 0.25 inches
Heat Transfer Coeffcient = 1.0 BTU/ft·hr·°F
Delivery ("D3") Flow - 15 mmscfd
D3 - Minimum Pressure 50 psig



Case Study 1C (continued)

Extract six (minimum recommended) or eight data points from the curve.

	Head (ft·lbf/lbm)	Flow (ft3/mn)	Speed (rpm)
1			
2			
3			
4			
5			
6			
7			
8			

Efficiency data points are:

	Effic. (%)	Flow (ft3/mn)	Speed (rpm)
1	78.0	2335	6000
2	70.0	3450	6000
3	78.0	2750	7000
4	75.0	3750	7000
5	78.0	3110	8000
6	70.0	4585	8000
7	79.5	4000	9000
8	65.0	5480	9000

Surge and Stonewall data points are:

	SPEED (RPM)	FLOW (FT^3/MN)
SURGE	5600	2000
STONEWALL POINT	9000	5250

Case Study 1C (continued)

INSTRUCTIONS

1) Create a new case based on CASE1B
2) Create a CPID specification
3) Extract HEAD data points from the compressor curve provided and input the head/flow curve data
4) Using the EFFICIENCY data points provided, input the efficiency/flow curve data
5) Modify the compressor to reflect the new data and CPID reference. Specify a minimum and maximum speed of 4000 rpm and 9000 rpm
6) Add new lateral and delivery data
7) Perform a steady state simulation and answer the questions
8) Make sure to review any reported constraint violations to make sure they make sense

Case Study 1C (continued)

OBSERVATIONS AND QUESTIONS

After entering and executing the model described above, answer the following questions:

1) What are the Steady State pressures at D1, D2 and D3?

Pressure at D1

Pressure at D2

Pressure at D3

2) What is the operating speed of the compressor?

3) Plot the compressor operating point on your performance curve. Is this a good point to operate at?

4) How much fuel does the compressor consume in the first day?

5) Try running the simulation with a D3 delivery of 20 mmscfd. What happens?

Case Study 1C (continued)

INSTRUCTOR'S SOLUTION

After entering and executing the model described above, answer the following questions:

1) What are the Steady State pressures at D1, D2 and D3?

Pressure at D1 – 378.718 psig

Pressure at D2 – 236.903 psig

Pressure at D3 – 229.443 psig

2) What is the operating speed of the compressor?

7049 RPM

3) Plot the compressor operating point on your performance curve. Is this a good point to operate at?

Yes

4) How much fuel does the compressor consume in the first day?

0.95 mmscf

5) Try running the simulation with a D3 delivery of 20 mmscfd. What happens?

The delivery flow at D2 reduces to 131.057 mmscfd. So with the present system D3 cannot receive 20 mmscfd.