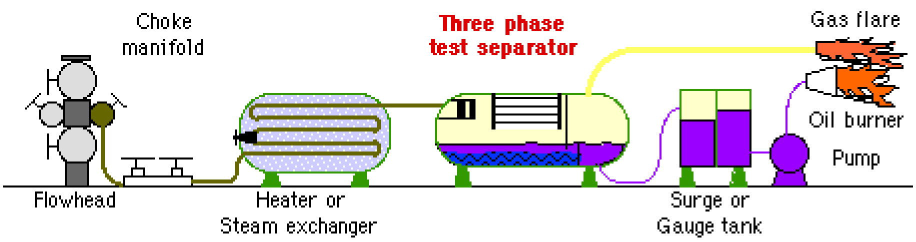
Separators

Introduction

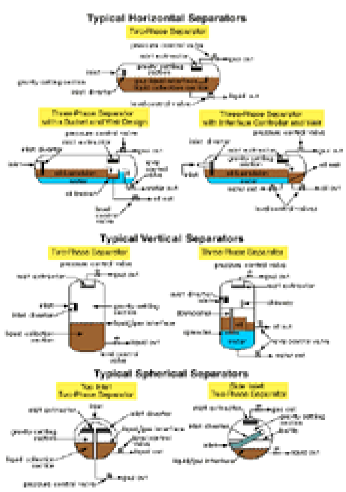
The "Surface Test Equipment" figure shows where the separator is located in relation to other surface testing equipment. The separator is comprised of a pressurized vessel where fluids are separated and a piping system that carries separated fluids out of the vessel. Its principle function is to separate the well effluent leaving the choke manifold (or heat exchanger) into oil, gas, and water components before sending the gas to the gas flare and the oil to either the tank or the oil burner. Other important separator functions include the capability to meter effluent components and take pressurized oil and gas samples.

Surface Test Equipment



Separators are classified by their shape and by the fluids they separate. They are horizontal, vertical, or spherical in shape. Shapes are further classified into two-phase (gas/liquid) and three-phase (oil/water/gas) separators. The "Types of Separators" diagram shows the basic types available. When testing a well, Schlumberger typically uses only three-phase horizontal separators.

Types of Separators



The following list summarizes a few of the advantages and disadvantages of the different separator shapes:

- Horizontal separators are normally more efficient at handling large amounts of gas.

- Horizontal separators are the most economical for normal oil-gas separation, particularly where there may be problems with emulsions, foam, or high gas-oil ratios.
- A vertical separator takes up less space than a horizontal separator with the same capacity.
- On a vertical separator, some of the controls may be difficult to access without ladders or access platforms.
- Spherical separators are the most efficient for containing pressure; however, they are not widely used because of their limited liquid surge capability and because they are difficult to fabricate.

Objectives

Upon completion of this package, you should be able to:

- Explain the purpose of the separator.
- List the components of the separator and describe their functions.
- Explain how to adjust the retention time for the separator.
- Explain why the separator should be run at a constant pressure and how to control this pressure.
- Describe the various types of separators and list their specifications.

Upon completion of the practical exercises for the Separator, you should be able to:

- Perform a FIT and TRIM on a separator.
- Read the gas flow recorder.
- Read the oil flow recorders.
- Direct the flow into the separator.
- Bypass the flow from the separator.
- Adjust the pressure in the separator.
- Adjust the oil level in the separator.
- Perform shrinkage measurements using the shrinkage tester.

Principles of Operation

The operating principles for the separator are covered in the following topics:

- Separation Processes
- Pressure and Level Controllers
- Safety Devices
- Metering Devices
- Piping Systems

Separation Processes

Separators rely on these processes to separate liquid (oil and water) from gas:

- Gravity and the difference in densities between oil, gas, and water.

- Mechanical devices in the separator that are used to improve the separation process.
- Altering the pressure and gas-liquid interface to further optimize separation.

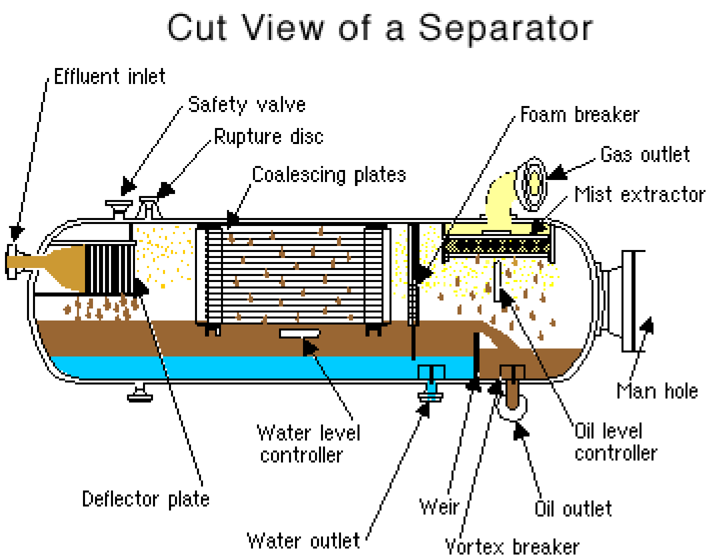
Gravity and Density

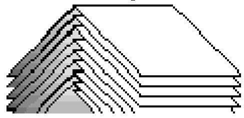
In the separator, oil, gas, and water will naturally separate due to the effects of gravity and the difference in density between effluent components. The denser effluent particles fall to the bottom and the lighter particles rise to the top. Gas rises and liquid falls in the separator. The separator improves this natural separation process by retaining the fluid long enough to slow down its motion, allowing separation to occur.

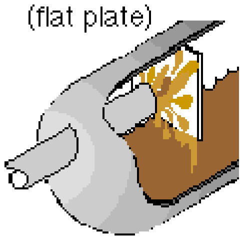
About 95% of the liquid-gas separation inside the separator happens instantly. The relative densities of gas and liquid (oil and water) are typically in the ratio of 1 to 20 so their separation is quick, usually taking only a few seconds. However, some liquid will remain in the gas in the form of a fine mist. This liquid must be separated from the gas with the aid of mechanical devices for separation to be complete. The relative density of oil to water is typically in the ratio of .75 to 1, so separation is a bit longer: one or two minutes.

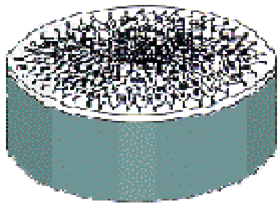
Mechanical Separation Devices

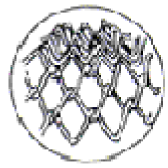
To obtain good separation, speed up the separation process, and minimize retention time, the separator is equipped with mechanical devices. The function of these mechanical devices is explained here so you can understand the role they play in the separation process.











Deflector Plate

This plate is located in front of the inlet. It causes a rapid change in the direction and velocity of the fluids, forcing the liquids to fall to the bottom of the vessel. The deflector plate is responsible for the initial gross separation of liquid and gas.

Coalescing Plates

These plates are arranged longitudinally in an inverted V-shape in the upper part of the separator. The liquid droplets in the gas hit the plates and stick to them. As more gas passes through the plates, more droplets coalesce to form bigger drops that fall to the bottom of the vessel.

Foam Breaker

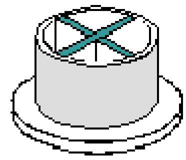
This piece of equipment is made of wire mesh, like the mist extractor. It prevents oil particles in the foam (comprised of oil and gas) from passing through the separator and being carried away with the gas.

Mist Extractor

This piece of equipment is composed of a mass of wire netting. Before leaving the separator, the gas stream passes through the mist extractor, causing the tiny oil droplets remaining in the gas to fall down.

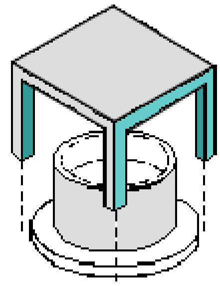
Weir Plate

This plate, located at the bottom of the vessel, divides the separator into two compartments: oil and water. Provided that the water level is controlled, it only permits oil to overflow into the oil compartment.



Vortex Breakers

These breakers are located on the oil and water outlets. Their function is to break the swirling (vortex) effect that can occur when oil and water exit the separator from their respective outlets. The vortex breakers prevent any gas from being sucked away with the liquids.



Pressure and Gas-Liquid Interface

To optimize separation, there are three main parameters that can be controlled:

- the pressure inside the separator
- the level of the gas-liquid interface
- the temperature inside the separator

The goal is to achieve the best separation possible for a given effluent. Because variations in these parameters can affect separation conditions, it's important to keep these parameters as constant and stable as possible. Although the temperature inside the separator is almost equal to the well effluent temperature and cannot be controlled (unless a heat exchanger is connected upstream of the separator), the pressure and gas-liquid interface can be controlled to optimize oil and gas recovery.

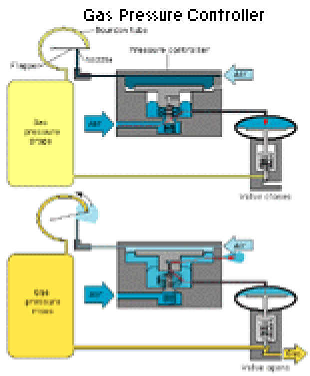
The "**Separation Problems**" table shows two examples of how the pressure, gas-liquid interface, and temperature can be used to control separation problems.

Separation Problems

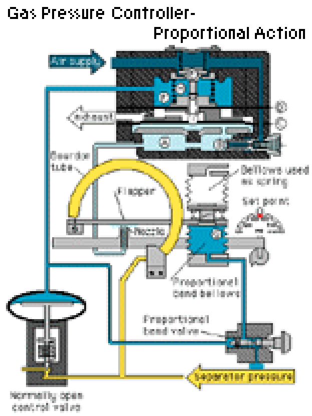
Problem	Causes	Action
Liquid carryover	High flow rate High liquid level Low operating pressure Wave action in separator Foaming	Decrease flow rate Lower oil/gas interface Raise operating pressure or decrease flow rate Reduce sensitivity of oil level controller Increase pressure
Poor oil-gas separation	High viscosity High separator pressure	Heat well effluent Increase retention time Reduce pressure

Separation Processes

Pressure and Level Controllers



This topic covers the controller systems and their associated equipment. The gas pressure controller and the oil and water level controllers maintain constant separation conditions inside the tank. To adjust the separator pressure and the water and oil flow rates, all the controllers use automatic control valves (ACVs). The compressed air used to operate the controllers is filtered through an air scrubber. The air pressure is reduced by using pressure regulators mounted upstream of the controllers. Visual level indicators, called sight glasses, are used to monitor the oil-gas and oil-water interfaces inside the separator.



Gas Pressure Controller

The internal separator pressure is provided by the gas that flows into the separator. The fluid inflow varies depending on the flowing conditions of the well. To maintain a constant pressure in the separator, the fluid outflow must be adjusted so it's as close as possible to the fluid inflow.

Simple Gas Pressure Controller

The most common method of controlling pressure is with a pressure controller that uses a control valve to automatically react to any variation in separator pressure. When the pressure drops, the controller closes the valve and when the pressure rises, the controller opens the valve. Once the separator operating pressure is manually set at the pressure controller, the pressure in the vessel is maintained close to the selected value.

For safety purposes, this control valve is normally open. If for any reason the air pressure supply to the valve is cut, the vessel will not be over pressurized.

The separator pressure is applied directly to the Bourdon tube inside the pressure controller as shown in the "Gas Pressure Controller" figure. A change in the separator pressure deforms the Bourdon tube. This deformation moves the flapper covering the nozzle away from or closer to the nozzle, causing it to leak air. The air leak is used by the pressure controller to open or close the control valve that regulates the pressure in the separator.

Complex Gas Pressure Controller

The "Gas Pressure Controller" figure above shows a simple model of a gas pressure controller. In this simple system, the valve is either wide open or closed, causing the separator pressure to oscillate between a minimum and maximum pressure value.

The actual gas pressure controller mounted on the separator is more complex. In contrast to the simple model, the actual gas pressure controller allows the desired working pressure to be set and utilizes proportional band control to adjust the valve stroke, ensuring smooth regulation of the separator pressure.

For the complex system shown in the "Gas Pressure Controller - Proportional Action" diagram, the desired pressure is set by adjusting the set point lever. Adjusting this lever moves the nozzle either closer or farther away from the flapper to establish the set point pressure. Pressure from the separator is applied directly to the Bourdon tube. The "Gas Pressure Controller - Proportional Action" diagram shows the gas pressure control system in a state of equilibrium with the separator pressure stable.

The following lists describe what happens to the system shown in the "Gas Pressure Controller - Proportional Action" diagram when the separator pressure rises and falls.

When the separator pressure decreases, the set pressure is maintained by

- The Bourdon tube moves the flapper toward the nozzle, closing the gap between the nozzle and the flapper.
- Because chamber A is continuously supplied with air through orifice B, the reduction in the size of the air passage between the nozzle and the flapper causes the air pressure in chamber A of the relay to build up.
- The pressure build up in chamber A pushes diaphragms C and D upward, causing supply valve E to open.
- Air supply pressure enters chamber F and flows to the automatic control valve (ACV), causing it to throttle closer to its seat and reducing the flow of gas from separator thereby increasing its pressure.
- Pressure in chamber F increases until diaphragms C and D are pushed back to their original positions, causing valve E to close and returning the system to a state of equilibrium.
- At the same time that air flows to the ACV, it also flows through the proportional band valve to the bellows G. This air pressure causes the flapper to move away from the nozzle which stops the build up of pressure in chamber A and restores the system to a state of equilibrium.

  As a result, the pressure on the ACV valve is increased (causing it to throttle closer to its seat) and the separator pressure is restored to its set pressure.

When the separator pressure increases, the set pressure is maintained by

- The Bourdon tube moves the flapper away from the nozzle, widening the gap between the nozzle and the flapper.
- This causes the air pressure in chamber A of the relay to decrease.

- The pressure drop in chamber A and the action of the spring H causes diaphragms C and D to move down.
- Air from the ACV starts to bleed off to the atmosphere through chamber I. This reduction in pressure causes the ACV valve to open under the action of its spring.
- At the same time that air flows from the ACV to the atmosphere, the air pressure in bellows G decreases, causing the flapper to move closer to the nozzle. This action will cause the pressure in chamber A to increase enough to close the passage between chambers F and I.

  As a result, the pressure on the ACV is decreased (causing it to throttle away from its seat) and the separator pressure is restored to its set pressure.

Proportional Band Valve

As shown in the "Gas Pressure Controller - Proportional Action" diagram, the pressure going from relay chamber F to the ACV also goes to the proportional band three-way valve. The orifice inlet for this valve is adjustable. This allows the amount of air pressure sent to bellows G (the proportional band bellows) to vary. This variation changes the clearance between the flapper and nozzle.

The proportional band is independent of the set point pressure, but dependent on the Bourdon tube pressure rating. The proportional band setting is expressed as a percentage, based on the Bourdon tube pressure rating, as described in the following examples. This percentage can vary between 0 and 100%. For example, when the proportional band for the Fisher 4150 pressure controller (shown in the "Gas Pressure Controller - Proportional Action" diagram) is fully closed, it corresponds to a proportional band setting of approximately 3%.

The following examples show how a narrow (5%) and a wide setting (50%) of the proportional band changes how the system reacts to a variation in pressure.

- The pressure controller is equipped with a Bourdon tube with a pressure rating of 1000 psi.
- The set point for the separator pressure is 400 psi.

If the proportional band is set at 50% of the Bourdon tube rating of 1000 psi, this means that the ACV will be fully closed when the separator pressure reaches 150 psi and fully open when the separator pressure reaches 650 psi. At this wide setting, the system is not very sensitive to small pressure variations. It will take a large pressure variation of 250 psi on either side of the separator set point of 400 psi to either close or open the valve.

50% of 1000 psi=500 psi
500 psi / 2=250 psi
400 + 250=650 psi
400 - 250=150 psi

In contrast, if the proportional band is set at 5% of the Bourdon tube rating of 1000 psi, the ACV will be fully closed when the separator pressure reaches 375 psi and fully open when the separator pressure reaches 425 psi. At this narrow setting, the system is sensitive to small pressure variations. The system will either close or open the valve for a relatively small pressure variation of 25 psi on either side of the separator set point of 400 psi.

5% of 1000 psi=50 psi
50 psi / 2=25 psi
400 + 25=425 psi
400 - 25=375 psi

The following animation of a gas pressure controller demonstrates the operation of the gas ACV and its controller. The effect of the proportional band valve on the ACV will also be shown.

Gas Pressure Controller Multimedia

Objective: To describe the operation of the valve and controller

To demonstrate the effect of the proportional band valve

Comment: The gas pressure controller and the oil and water level controllers maintain constant separation conditions inside the tank. To adjust the separator pressure and the water and oil flow rates, all the controllers use automatic control valves (ACV), the gas automatic control valve (GACV) maintains the constant gas pressure.

The animation demonstrates how GACV components react to pressure setting changes and how the proportional band valve adjusts the hysteresis.

Steady state GACV interaction will be covered in the next version of this animation.

For related topics, see the Liquid Level Controller and the Gas Flow Recorder animations.

Hints for Setting the Separator Pressure

When setting the separator pressure at the gas pressure controller, consider the following points:

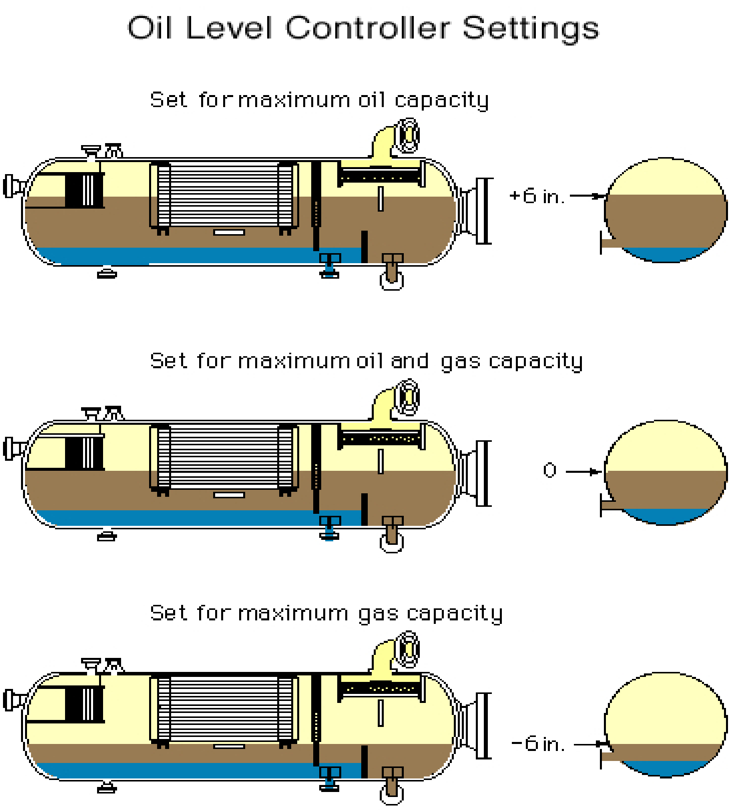
- The pressure rating of the safety relief valve in relation to the separator's maximum working pressure.
- The critical flow conditions at the choke manifold.
- The minimum pressure needed to run the oil out of the separator to either a tank or a burner or to run the oil and water meters.

Oil Level Controller

The level of the liquid-gas interface inside the separator should be kept constant to maintain steady separation conditions. A variation in this level changes the volume of gas and liquid in the separator, which in turn affects the speed and the retention time of the two fluids. The initial set point for the liquid-gas level depends on the gas-oil ratio (GOR)of the well effluent.

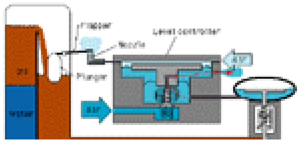
- If the GOR is high, more volume in the separator needs to be reserved for gas so a low oil level is required.
- If the GOR is low, more volume in the separator needs to be reserved for the oil, so a high oil level is required.

To cover different GORs, from the oil level controller, the oil level can be adjusted between two values: plus or minus 6 in. of the center line of the separator. As a guideline, the level is initially fixed at the center line and further level adjustments are made based on the GOR.

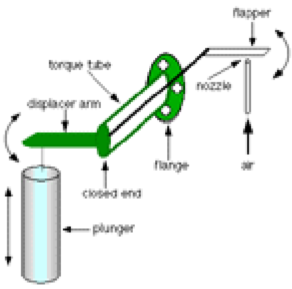


Simple Oil Level Controller

Oil Level Controller



Torque Tube



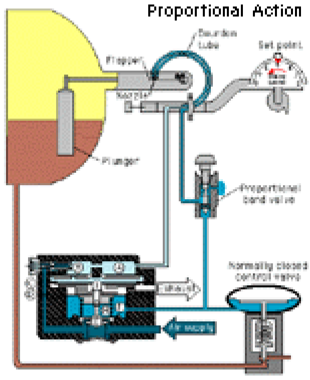
Oil level controllers commonly employ a plunger attached to a controller to open or close a control valve that regulates the oil level. This controller actuates one of the two regulation valves on the oil outlet: a large and a small diameter valve fitted in parallel. This system permits regulation of very low to very high oil flow rates, limited only by the maximum capacity of the separator.

When the oil level changes, according to the principle of Archimedes, the plunger is buoyed up by a force equal to the weight of the displaced fluid as shown in the "Oil Level Controller" and "Torque Tube" figures. The movement of the plunger is converted, through a torque tube assembly, causing the flapper to move away from or closer to the nozzle. In turn, the air leak from the nozzle opens or closes the control valve on the separator oil outlet.

For safety purposes, the control valves on the oil outlet are normally closed. If for any reason the air pressure supply to these valves is cut, this problem should be detected fast enough to prevent oil from backing up into the separator. Oil buildup in the separator can cause oil to outflow into the gas line where it eventually reaches the flare and pollutes the environment. Conversely, if the control valves on the oil outlet were open, oil could build up in the tank, causing similar problems.

Complex Oil Level Controller

Oil Level Controller - Proportional Action



The "Oil Level Controller" figure above shows a simple model of an oil level controller. In this simple system, the valve is either wide open or closed, causing the separator oil level to constantly fluctuate between a minimum and a maximum level.

The actual oil level controller mounted on the separator is more complex. In contrast to the simple model, the actual oil level controller allows the desired oil level to be set and utilizes a proportional band control to adjust the valve stroke, ensuring smooth regulation of the separator oil level.

For the complex system shown in the "Oil Level Controller - Proportional Action" diagram, the desired liquid level is set by adjusting the set point lever. Adjusting this lever moves the nozzle, mounted on the Bourdon tube, closer or farther away from the flapper. This set point lever allows the desired level of liquid to be set (providing that the oil level is between the top and the bottom of the plunger). The diagram shows the oil level controller in a state of equilibrium: the oil level is set in the middle of the plunger and the inlet flow is equal to the outlet flow.

The following lists describe what happens to the system shown in the "Oil Level Controller - Proportional Action" diagram when the inlet flow is greater than and less than the outlet flow.

When the inlet flow is greater than the outlet flow, the level of oil in the separator increases:

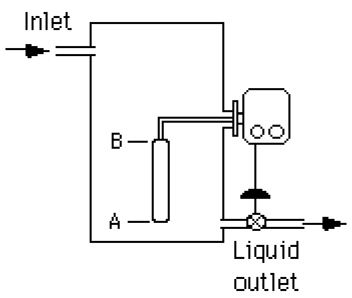
- The buoyant force of the liquid increases, lifting the plunger up. The flapper, connected to the plunger by the torque tube, moves toward the nozzle.
- This displacement of the plunger moves the flapper up, closing the gap between the flapper and the nozzle and reducing the air passage. Because chamber A is constantly supplied with air through orifice B, the reduction in this air passage increases the pressure in chamber A.
- The pressure build up in chamber A pushes diaphragms C and D down, opening the supply valve E.
- Air supply pressure enters chamber F and flows to the automatic control valve (ACV) causing it to throttle away from its seat (opening the ACV). This action increases the oil outflow and causes the oil level to fall.
- At the same time that the air flows to the ACV, it also flows through the proportional band valve to the Bourdon tube. This air pressure causes the nozzle on the Bourdon tube to move away from the flapper. This action stops the pressure buildup in chamber A and restores the system to a state of equilibrium.

  As a result, the pressure on the ACV is increased (causing it to throttle away from its seat) and the separator oil level is restored to its set level.

When the inlet flow is less than the outlet flow, the level of oil in the separator decreases:

- The flapper moves away from the nozzle, widening the gap between the nozzle and the flapper.
- This causes the air pressure in chamber A of the relay to decrease.
- The pressure drop in chamber A and the action of the spring G move diaphragms C and D up.
- Air from the automatic control valve starts to bleed off to the atmosphere through chamber I. This reduction in pressure causes the ACV to close under the action of its spring.
- At the same time that air flows from the ACV to the atmosphere, the air pressure passing through proportional band valve to the Bourdon tube decreases, causing the nozzle on the Bourdon tube to move closer to the flapper. This action causes the pressure in chamber A to increase enough to close the passage between chambers F and I.

Displacement Type Controller



As a result, the pressure on the ACV is decreased (causing it to throttle closer to its seat) and the oil level is restored to its set level.

Proportional Band Valve

As shown in the "Displacement-Type Controller" figure, the pressure from relay chamber F flows to the automatic control valve and also flows to the proportional band three-way valve. The orifice of this valve is adjustable so the amount of air pressure or "feedback" to the Bourdon tube can be set as desired.

This figure represents a displacement type controller, one that does not float on top of the liquid, but floats in the liquid and is displaced (moves up and down) as the liquid level changes. As shown in the diagram, to control the liquid level the liquid must be between points A and B. If the liquid level is below A or above B, the controller will not be able to control the liquid level.

The proportional band setting is expressed as a percentage, based on the length of the plunger, as described in the following examples. This percentage can vary from 0 to 100%. For example, if the proportional band is set at 100%, the liquid level would have to move from A to B or B to A to fully stroke the valve. In contrast, if the proportional band is set at 25%, the level of liquid would have to move 25% of the distance between A and B to fully stroke the valve.

Another way this relationship is expressed is based on the length of the level change that will cause the valve to fully stroke. For example, if the level change that causes a full stroke of the ACV is 8 in. and the float is 16 in. long, the proportional band is set at 50% (50% proportional band).

The following animation of an oil level controller demonstrates the operation of the oil ACV and its controller. The effect of the proportional band valve on the ACV will also be shown.

Liquid Level Controller Multimedia

Objective: To demonstrate the operation of the valve and controller

To demonstrate the effect of the proportional band valve

Comment: The level of the liquid-gas interface inside the separator should be kept constant to maintain steady separation conditions. A variation in this level changes the volume of gas and liquid in the separator, which in turn affects the speed and the retention time of the two fluids. The liquid control valve (LCV) is the equipment responsible for keeping this steady separation condition.

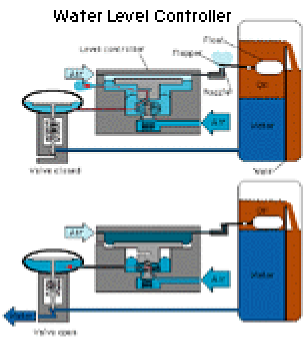
This animation will demonstrate how the LCV components (LCV, Bourdon tube, plunger, level setting, proportional band controller, and the liquid valve) interact with each other.

The steady state condition will be covered in the next version of this animation.

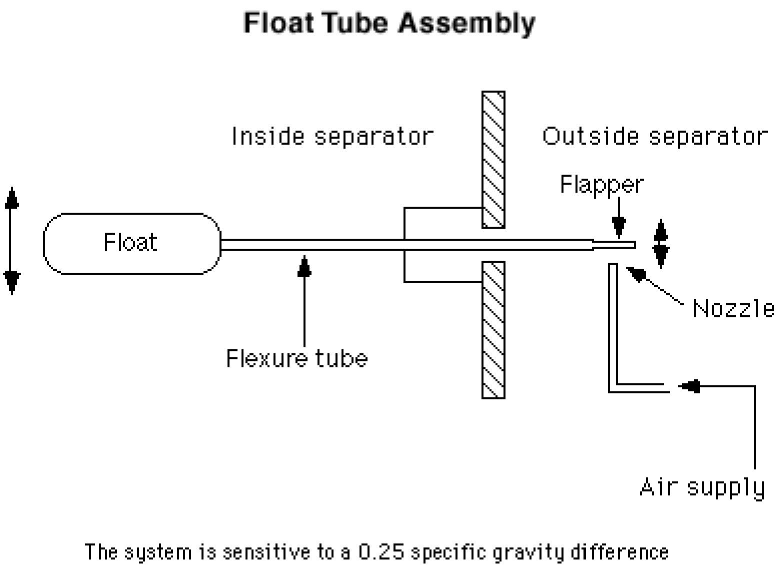
For related topics, see the Gas Pressure Controller and the Gas Flow Recorder animations.

Water Level Controller

The interface level between water and oil in the separator should be kept constant to prevent the water from passing over the weir plate and flowing into the oil compartment. This is accomplished with a float connected to a water level controller that acts on a valve fitted to the water outlet.



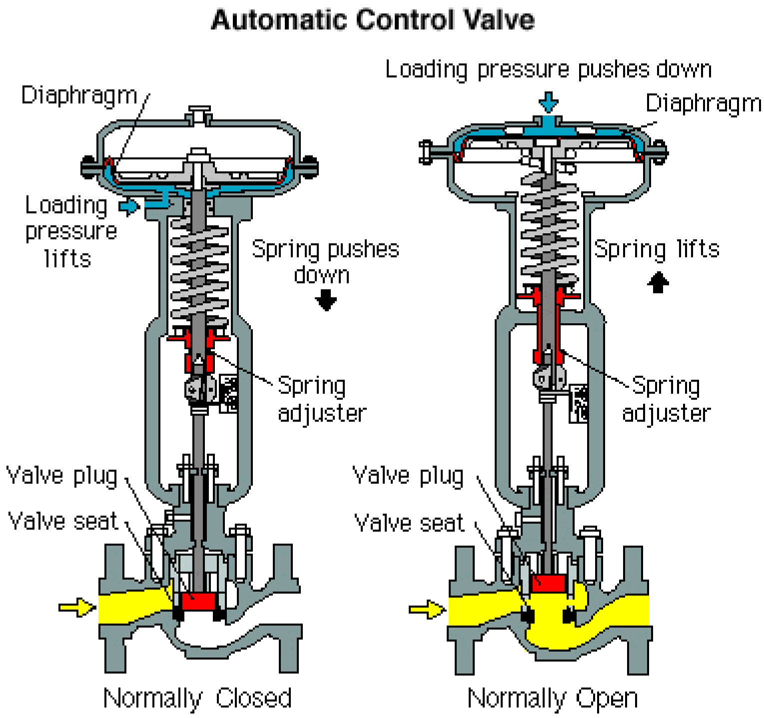
The level of water is controlled with a float that floats in water but sinks in oil. The movement of the float is transmitted through a tube to a flapper that moves away from or closer to the nozzle, causing it to leak air. The air leak from the nozzle is used to open or close a control valve on the separator water outlet.



Automatic Control Valves

The automatic control valves (ACV) for the oil, gas, and water controllers are designed to regulate the rate of flow in a pipe by varying its cross-sectional area in response to an air leak signal received from a controller.

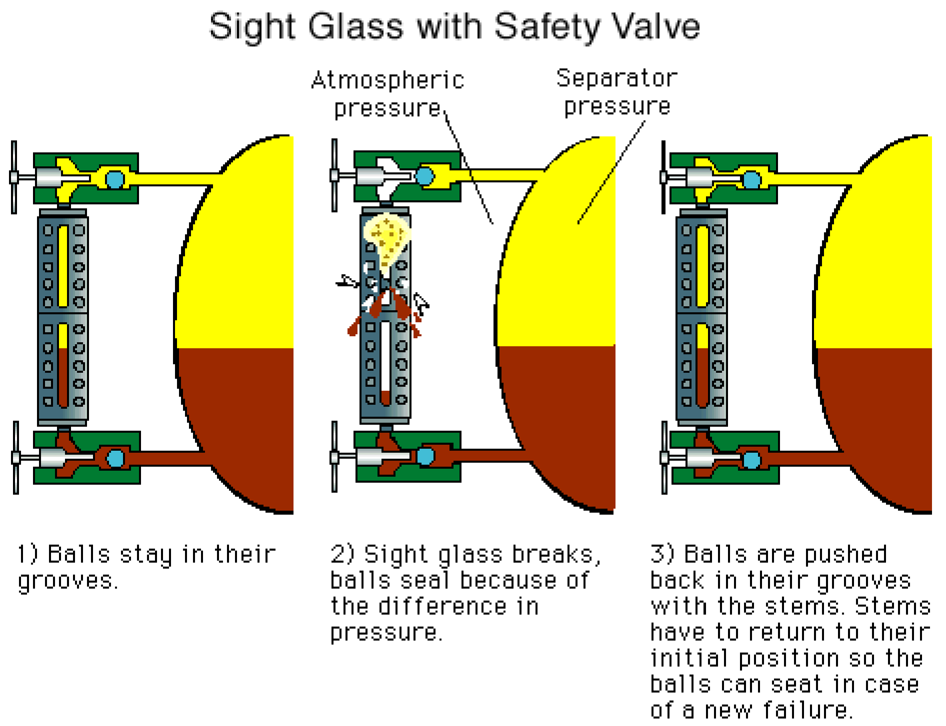
The "Automatic Flow Control Valves" figure shows the two different types (normally open and normally closed) of control valves used in a separator.



Sight Glass

The sight glass is a visual level indicator. On the separator there's an oil sight glass to monitor the oil-gas interface and a water sight glass to monitor the oil-water interface. The levels inside the separator can be seen through the glass.

This device is made of transparent glass housed in a steel chamber to withstand the pressure inside the separator. In the event the glass breaks, the safety glass is equipped with safety valves that prevent fluids inside the separator from escaping. The safety valve works using a ball that automatically seals off the tank from the sight glass using the pressure differential between the tank and the atmosphere. After a broken glass is changed, the ball needs to be pushed back in its groove so it can seal off the separator from the sight glass, in case another failure occurs. Use the stem tip to push the ball back by moving the handle about one quarter turn. Once the ball is in position, turn the handle back to return the stem to its original position.



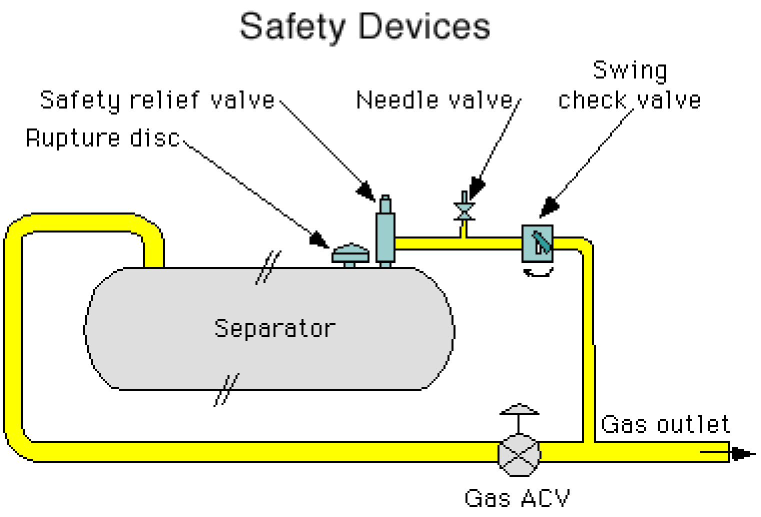
Air Scrubber

The air used to operate the oil, gas, and water controllers is provided by an air compressor. This air from the compressor is first filtered using an air scrubber. The air scrubber is simply a vertical pot where the impurities and water settle. After the air is filtered, it is sent to pressure regulators where the air pressure is reduced to a level that's acceptable for the instruments.

Pressure and Level Controllers
Principles of Operation

Safety Devices

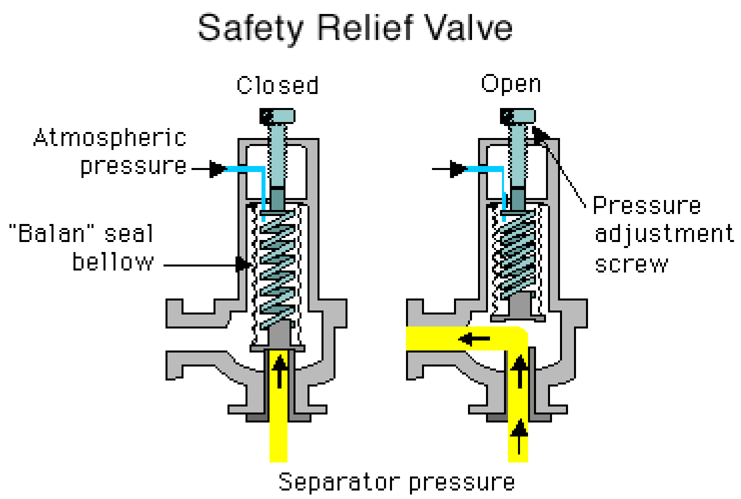
In case a malfunction causes the separator pressure to rise to a dangerous level, these devices provide an emergency vent to the atmosphere. To prevent this type of failure, the separator is designed with two weak points--a safety relief valve and a rupture disk--that are activated in case of overpressure. For the safety valve to operate properly, it needs a needle valve and a check valve.



Safety Relief Valve

The safety relief valve is located on top of the separator. Its outlet is connected to the gas outlet line, downstream of the automatic control valve (ACV). When the safety relief valve is opened, gas is bled off to the flare. Depending on client requirements and local regulations, the outlet for the safety relief valve is sometimes connected to a separate vent line.

The safety valve incorporates a bellows seal that prevents separator fluid discharge from entering the upper part of the valve that's exposed to the atmospheric pressure. The bellows has an effective area equal to the area of the valve seat so the effect of any back pressure from the valve outlet on set pressure is eliminated.



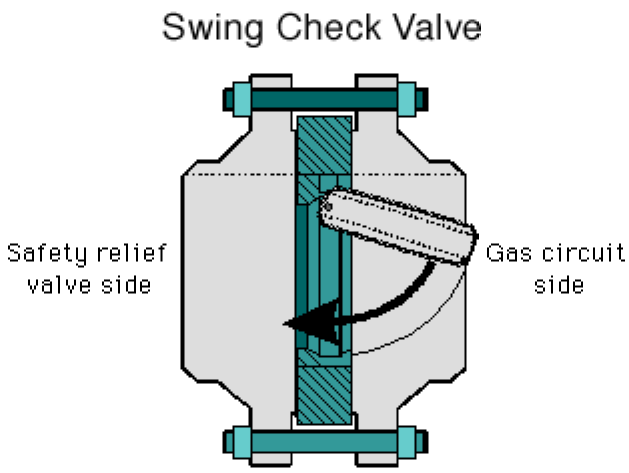
The set pressure is the pressure at which you want the safety relief valve to open. The set pressure is adjusted by the force of a spring on a sealing disk that is exposed to separator pressure.

The set pressure is normally set at 90% of the nominal (600 psi, 720 psi, or 1440 psi) separator working pressure (WP). Due to temperature influence and calibration tolerances, it cannot be guaranteed that the safety relief valve will open at exactly 90% of WP. When setting the operating pressure, it's safe to assume that the valve could open within a range of 85% to 95% of the WP. Consequently, the operating pressure in the separator should be kept at or below 80% of WP to prevent accidental opening of the safety valve.

For example, for a 1440 psi WP separator, the set point is 90% of WP (1296 psi), and the operating range for the valve is between 85% of WP (1224 psi) and 95% of WP (1368 psi). For this separator, the operating pressure should be set at or below 80% of WP (1152 psi).

Check Valve

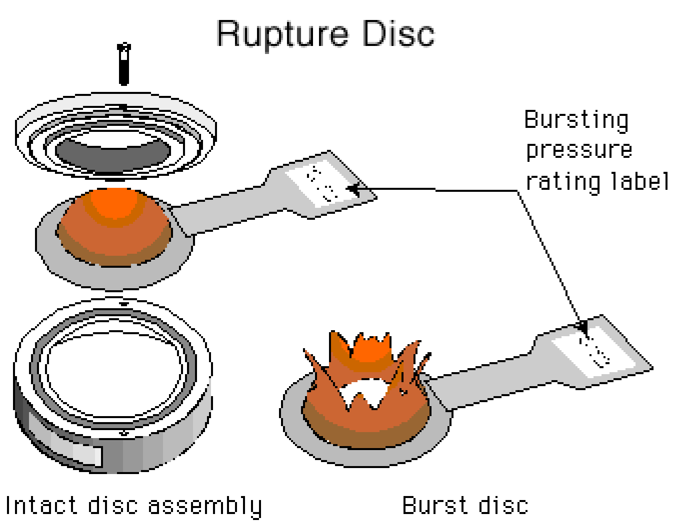
The check valve is located downstream of the safety relief valve. It is a free-swinging flapper valve that prevents back pressure in the gas outlet line from reaching the safety relief valve outlet, where it could possibly affect the opening of the safety relief valve.



Needle Valve

The needle valve, connected between the safety relief valve and the check valve, ensures that any back pressure on the safety relief valve outlet is discharged to the atmosphere. It should be small in size and must be checked often to make sure it's clear. The needle valve is kept open during operations to detect leaks in the check valve and prevent leaks from exerting back pressure on the safety relief valve. In the event the safety relief valve opens, the needle valve limits the size of the leak, making it easy to control. If H_2S is present, a line must be connected to the needle valve to vent the gas away from personnel.

Rupture Disk



The main disadvantage of the configuration shown in the "Safety Devices" diagram is if for any reason the gas line to the flare is blocked, the safety relief valve will not be able to discharge the overpressure. For this reason, and to prevent any other malfunction of the safety relief valve, the separator is equipped with an additional safety device called the rupture disk. The rupture disk operates on a different principle than the safety relief valve. It's made of a fine, convex metal diaphragm designed to rupture at a very specific pressure. The diaphragm is completely torn apart when ruptured, leaving a large hole through which gas and liquid can escape. The disk must be replaced when ruptured, but the safety relief valve can be opened and closed repeatedly.

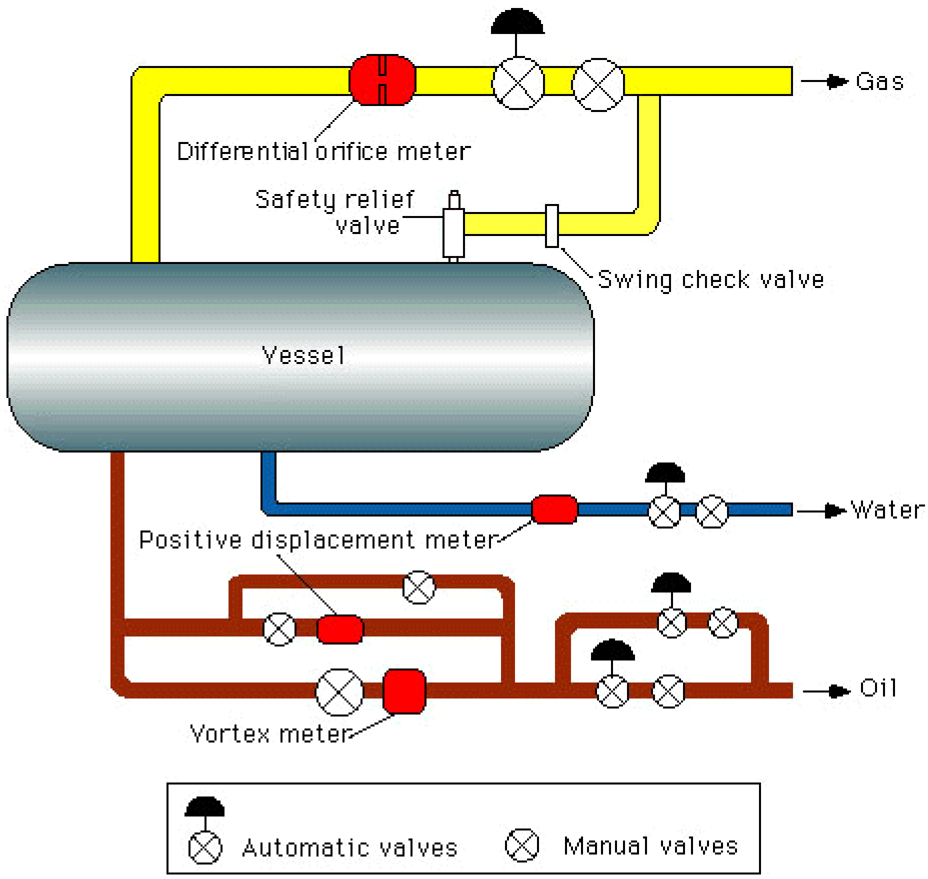
The disk is normally set to break at 110% of the nominal (600 psi, 720 psi or 1440 psi) separator working pressure (WP). Due to temperature influence and calibration tolerances, it cannot be guaranteed that the rupture disk will burst at exactly 110% of WP. It is safe to assume that the disk could burst within a range of 105% to 115% of the WP. Using this range of values helps ensure, in case of an emergency, that the safety valve will always operate before the disk ruptures.

Safety Devices
Principles of Operation

Metering Devices

This topic looks at the meters used to measure flow rates for oil, gas, and water as they leave the separator. To measure low to high oil flow rates, a positive displacement meter and a vortex meter attached to the oil outlet line are used. The gas flow rate is measured using an orifice meter, a type of differential pressure meter, attached to the gas outlet. Water flow rates are measured using a positive displacement meter, identical to the positive displacement meter used to measure oil, that's attached to the water outlet. The shrinkage factor, measured using a shrinkage tester, represents a correction factor used in oil volume computations. Gas scrubbers filter the gas that's used to operate the differential pressure recorder.

Metering Devices

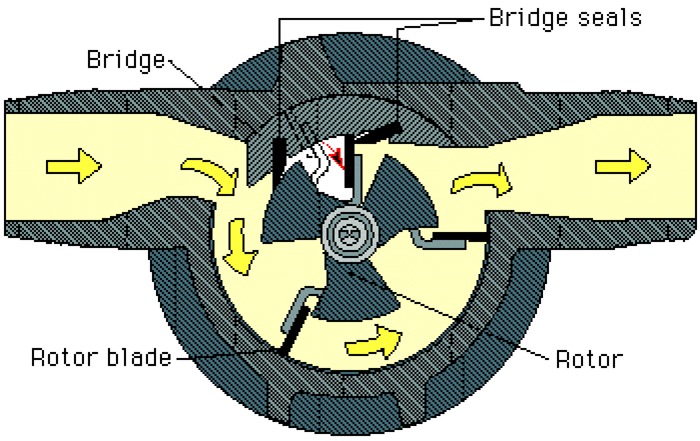


Oil Meters

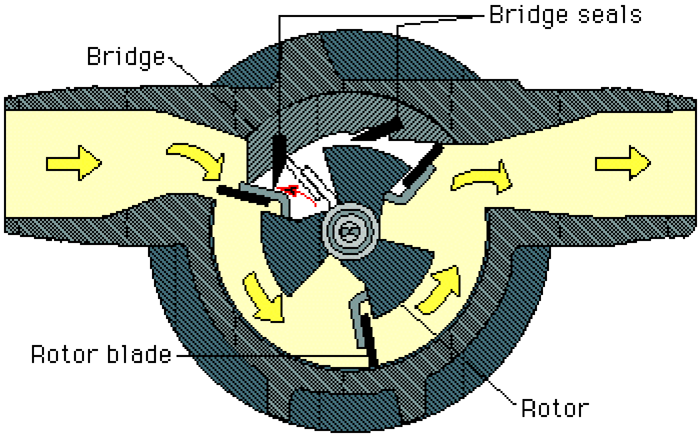
The oil outlet is fitted with two parallel meters, making it possible to cover a broad range of flow rates. A single meter cannot accurately cover the entire range (low to high) of flow rates. Oil meters are used one at a time and the choice depends on the flow rate. Low and medium flow rates are measured with a positive displacement meter, and high flow rates are measured with a vortex meter.

The positive displacement meter measures the liquid passing through it by separating the liquid into segments and counting the segments. Liquid entering the meter strikes the bridge and is deflected downward, hitting the blades and turning the rotor in the right direction. The seals on the bridge prevent the liquid from returning to the inlet side. The rotor movement is transferred to a register (readout device) with magnetic coupling.

Positive Displacement Flowmeter



The rotor blades pivot down when they encounter the bridge. The rotor blades brush against the bridge seals.

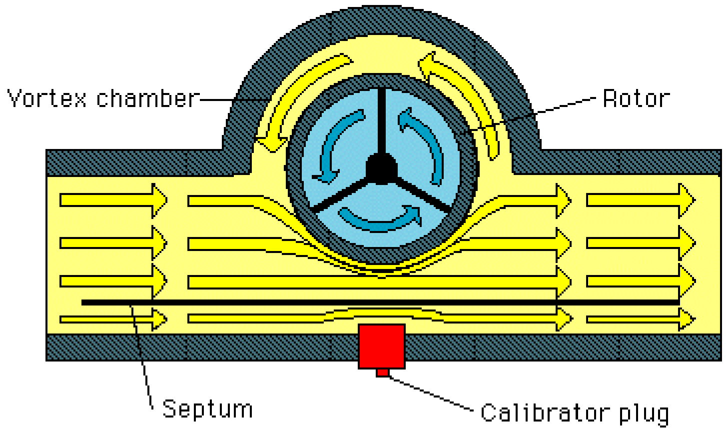


The rotor blades return to an upright position when they pass the bridge and seals.

Separators used for testing are usually equipped with a 2-in. diameter positive displacement meter that can measure a flow rate from 100 to 2200 barrels per day.

The ball vortex meter consists of a body with an offset chamber and a rotor that are mounted transversely to the flow stream. When liquid flows through the meter, a vortex is created in the offset chamber. The rotational velocity of the liquid vortex is proportional to the rate of flow. The rotor movement is transferred to a register (readout device) with magnetic coupling.

Ball Vortex Meter



The meter body is divided by a septum or thin plate. Moving the calibration plug within the section beneath the septum changes the cross sectional area and causes more or less liquid to flow through the measuring section. The calibration plug therefore causes a proportional increase or decrease in rotor speed. Since meter registration is directly related to rotor speed, adjustment of the plug position readily changes the meter registration. The proper calibration is done at the factory and then the calibration plug is sealed.

Separators used for testing can be equipped with a 2- or 3-in. diameter vortex meter. For this type of meter, the flow rate depends not only on the size but also on the type of bearings used as shown in the "Vortex Meters and Flow Rates" table.

Vortex Meters and Flow Rates

Meter Type	Rating with ball bearings in barrels per/day	Rating with sleeve bearings in barrels/day
2-in. vortex meter	850 to 6800 barrels/day	1700 to 8500 barrels/day
3-in. vortex meter	2000 to 17,000 barrels/day	3400 to 22,000 barrels/day

The oil meters located upstream from the automatic control valves operate under pressure, so the volume of oil measured is greater than if compared to standard conditions (atmospheric pressure and 60º F). Oil passing the counter may be hot, which also increases the volume measured. After cooling, the real volume of oil will be less. This is because the oil leaving the separator still contains dissolved gas that will escape when the pressure drops. A first correction for this loss of volume must be applied and a second correction is applied for temperature changes.

Water Meter

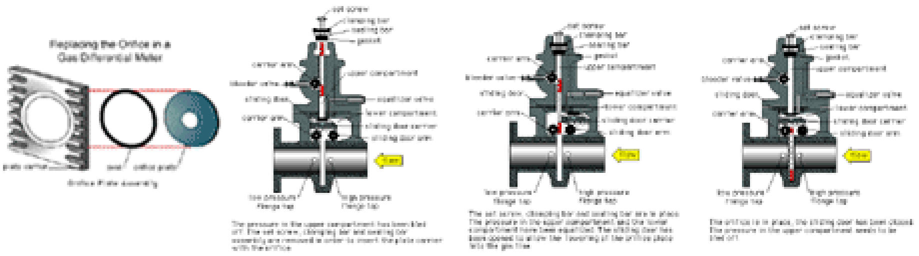
The water outlet is fitted with a 2-in. diameter positive displacement meter that is identical to the positive displacement meter used to measure the oil flow rate.

Gas Meter

Before leaving the separator, the gas flow rate is measured using a type of differential pressure meter called an orifice meter. A calibrated orifice inserted in the gas stream creates a small pressure drop across the orifice plate. The pressure upstream and downstream of the orifice plate is used along with the gas temperature and density to calculate the gas flow rate.

At the beginning of a test, the gas flow rate is unknown. During the test, the gas flow rate may change; therefore, different sizes of orifice plates are used. The correct diameter of orifice plate is selected by trial and error, so it's important to have an apparatus that allows the orifice plate to be changed without interrupting the gas flow. The orifice gas meter is designed for this purpose.

Operation of an Orifice Gas Meter



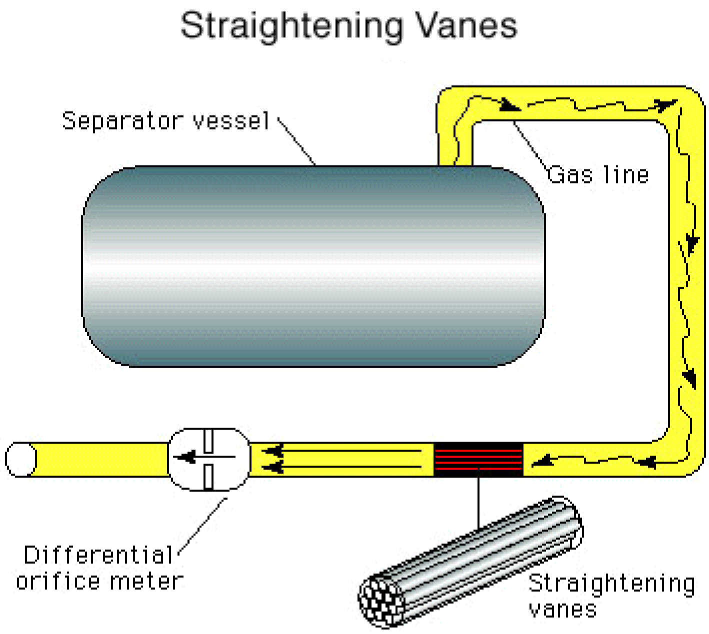
The following animation describes the safe change of the orifice plate in the Daniel orifice meter.

Gas Orifice Plate Meter Multimedia

Objective: To learn how to safely change the orifice plate in the gas orifice plate meter while it is under pressure

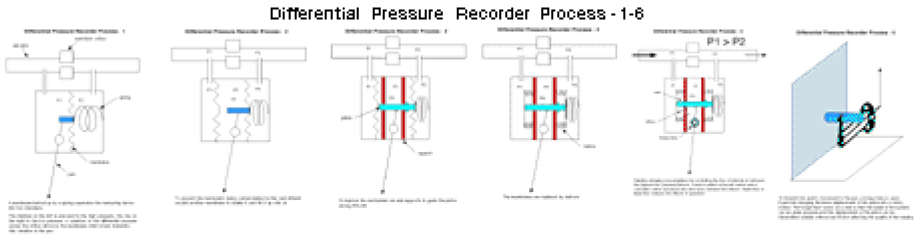
Comment: The Daniel orifice meter measures the gas flow at the separator using the differential pressure across an orifice. This animation describes the step-by-step process of how to remove, change and install the orifice plate.

To obtain accurate measurements, the flow of gas must be streamlined before it reaches the meter. An adequate length of straight pipe and straightening vanes (bundle of straight tubes fitted inside the pipe) are positioned before the meter to reduce the disturbances created by the elbows in the gas line.



To record the differential pressure, a measuring instrument called a differential pressure recorder is used. The high pressure side of the recorder is connected on the upstream side of the orifice and the low pressure side is connected on the downstream side. In this way, the differential pressure can be measured. The movement of the recorder is transferred to a pen that records the differential pressure on a chart. The same chart is used to record the static pressure, measured downstream of the orifice plate. In addition, another pen is used to record the gas temperature.

The "Differential Pressure Recorder Process" diagram includes steps that show how the differential pressure recorder works.

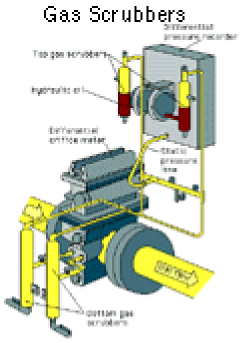


The following animation of a gas pressure recorder depicts how separator pressure changes and selection of orifices affect the pressure readings.

Gas Flow Recorder Multimedia

Objective: To understand the response of the recorder with separator pressure changes and the selection of orifices

Comment: The gas flow recorder (GFR) is one of the instruments attached to the separator. It will record the temperature and pressure in the output line and differential gas pressure across the Daniel meter.



With the help of this recorder, we can select the correct orifice for the Daniel meter to cope with the current flow.

For related topics, see the Liquid Level Controller and the Gas Pressure Controller animations.

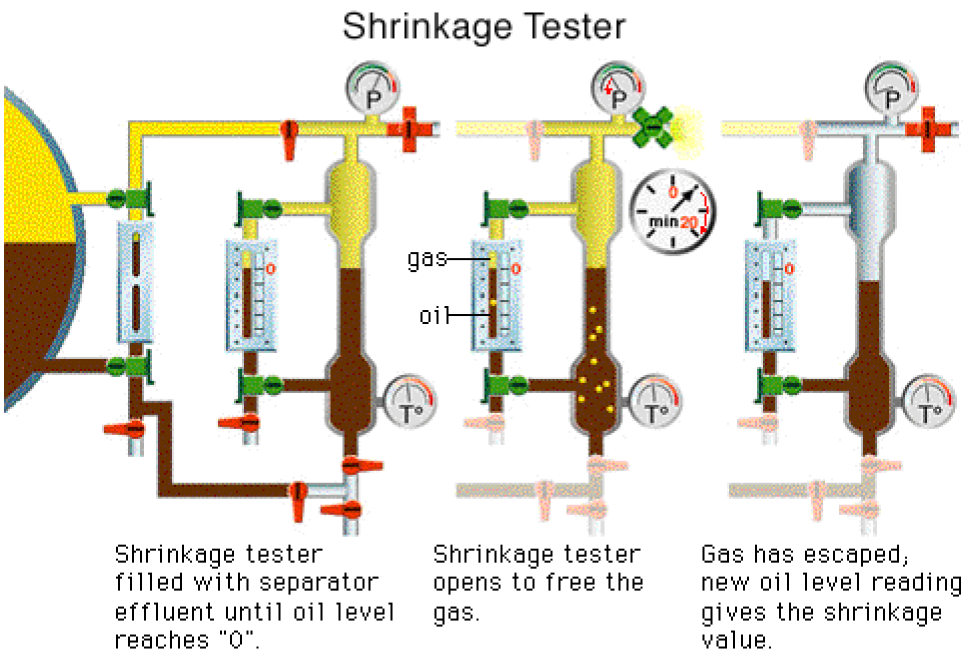
Gas Scrubbers

The gas used to operate the differential pressure recorder is provided by the separator gas line. This gas is first filtered, on both the high and low pressure lines, using bottom gas scrubbers. These gas scrubbers are vertical pots where impurities, oil, and emulsion settle. Before the gas reaches the recorder, it is filtered again by the top gas scrubber. The top scrubbers act as a buffer between the gas and the recorder. In case the gas contains H_2S or CO_2(sour gas), the top scrubbers can be filled with hydraulic oil or diesel to prevent direct contact between the gas and the recorder.

Shrinkage Tester

The shrinkage tester, usually attached to the oil sight glass of the separator, is used to estimate the shrinkage factor in the field. The shrinkage factor is a correction factor used in the oil volume computations. It represents the amount of dissolved gas in the oil that will be freed when the pressure drops from the separator pressure to the atmospheric pressure.

The shrinkage tester consists of a bottle equipped with a graduated sight glass. Oil and gas will flow to the tester until the oil level reaches "0" on the vernier, corresponding to a set volume (Vo). The tester is then isolated from the separator and the bottle pressure is bled off to the atmosphere slowly to prevent oil from being released with the gas. This allows gas to be freed from the oil, so usually after 20 minutes, a new level can be read on the vernier. This new level corresponds to a new volume (V) of oil. The shrinkage factor read on the vernier is simply the V:Vo ratio, expressed as a percentage.



The following animation of a shrinkage tester illustrates the function of the valves and proper operating sequence and measurement procedures. It includes an interactive simulator to reinforce your understanding of this system.

Shrinkage Tester Multimedia

Objective: To understand the function of the valves of a shrinkage tester and learn the correct operating sequence and measurement procedures

Comment: Well fluid in the separator is normally under pressure and its volume will change as soon as the dissolved gas disappears under atmospheric conditions. This multimedia will demonstrate how to operate the shrinkage tester that is normally attached to the separator. Valves need to be operated in a certain sequence to obtain the correct reading. The animation will be followed by a shrinkage tester simulator in which the students will be asked to click the valve open/close in the correct sequence.

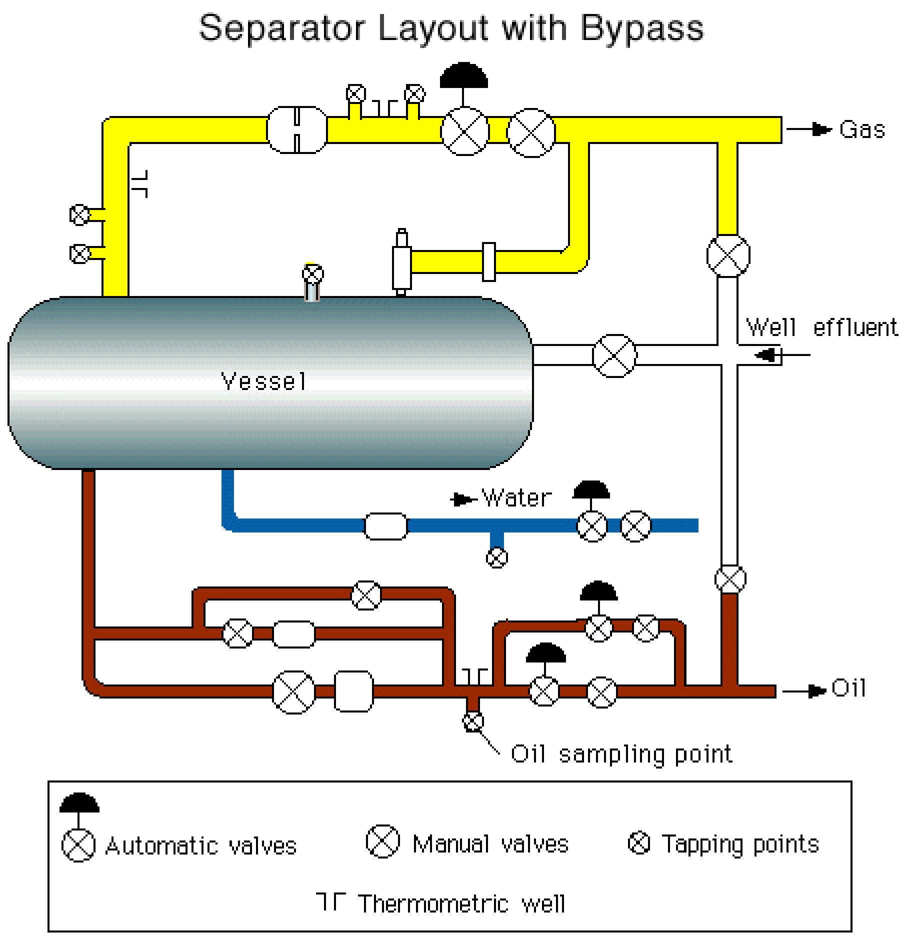
Metering Devices
Principles of Operation

Piping Systems

This topic describes the functions of the other equipment that's attached to the separator piping system: valves, a bypass manifold, and tapping points.

Valves

The "Separator Layout with Bypass" drawing shows a typical separator piping layout plus the manual ball valves used to isolate the parts of the piping not in use.



Bypass Manifold

The bypass manifold between the separator inlet and the oil and gas outlets permits effluent to be diverted to the burners or gas flare without passing through the separator. The bypass manifold is used when the effluent doesn't need to be separated; for example, at the beginning of a test when the well is first opened.

There's also a bypass line for the separator oil meter that's used when the oil flow rate does not need to be measured.

Tapping Points

The oil and gas lines are equipped with tapping points and isolating valves, allowing fluid samples to be taken. Tapping points on oil, water, and gas lines can be used to connect pressure and temperature recorders. The separator is equipped with hammer wing unions for quick connection and disconnection of pipe work.

Piping Systems
Principles of Operation

Equipment

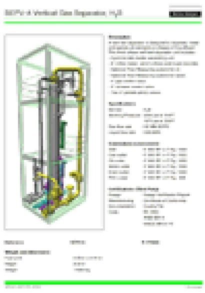
Schlumberger has developed a wide range of separators that differ in size, modularity, portability, and temperature rating which are available in working pressure ratings of 600, 720 and 1440 psi. All are H_2S resistant and each has special features:

The **600 psi** is designed to be light, easily lifted, even by a small crane or an helicopter. Because of its lower working pressure, the metal is thinner so the overall vessel remains light.

The **720 psi** is designed to handle high flow rates of oil, because its extended length provides a long retention time.

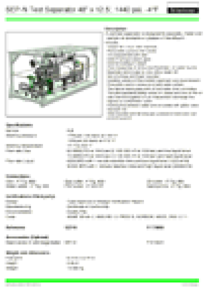
The **1440 psi** version is by far the most commonly used separator. Due to its high working pressure, it can handle higher flow rates of gas. The drawback is the higher overall weight for this separator.

These drawings show examples of several types of separators and their characteristics. For each drawing, specifications are provided If you would like a printed version of these tool specifications, please use the PDF version provided in the original graphics.

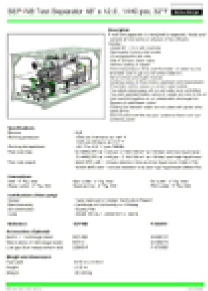


Vertical Gas Separator (SEPV-A)

Test Separator 720 psi, 32°F (SEP-G)



Test Separator 1440 psi, -4°F (SEP-N)



Test Separator 1440 psi, 32°F (SEP-NB)

Test Separator 1440 psi, 32°F 42" x 10' (SEP-T)

Test Separator 1440 psi, -4°F 42" x 10' (SEP-U)

Test Separator 1440 psi, 32°F HT (SEP-W)

Separator Selection Guidelines

The principal criteria for selecting a separator are:

- Project requirements related to working pressure, emulsion, foam, and cost considerations.
- The recommended retention time for fluid inside the vessel is greater than one minute. If the flow rate is high, a larger separator is needed to achieve the recommended retention time. Some jobs may require more than one separator to meet the recommended retention time.
- Weight restrictions can be dictated by crane lift capacity at the well site or access to the well site; for example, only heli-portable separators can be used on some offshore rigs.

Additional selection considerations are:

- A differential pressure cell is needed for gas rate calculation.
- A shrinkage tester is needed if one is not already fitted on the separator.
- Check connection (cross-over) requirements. Connections need to be compatible with manifolds and piping on rig lines.
- A compressed air supply is needed for the level controllers.

Separator Identification

The separator can be identified by its working pressure (WP) rating, temperature rating, and its size. This information is stamped on a metal plate. It is also common to use colored bands (painted or taped) on the separator for quick visual identification.

Safety

The following is a list of key safety considerations for separators:

- After every job, the separator must be thoroughly cleaned to prevent corrosion from well effluents.
- To prevent accidental closure of rig air supply valves during a test, lock open and label air supply valves to separator instruments.
- To ensure proper operation of the pressure safety valve, make sure the swing valve is sealed tight before starting a test.
- To detect any leak that could adversely affect the operation of the safety relief valve, keep the needle valve open. The needle valve is located between the safety relief valve and the swing valve.
- In all operating conditions, it's recommended that compressed air be supplied to separator instruments. In the event that compressed air is not available, sweet separator gas may be used, but never H_2S gas. This is because some of the gas is vented to the atmosphere through the controllers.
- Make sure the lifting eyes on the separator frame are in perfect shape and don't show sign of corrosion, especially at the weldings.
- During transportation, remove the floats used to control liquid levels to prevent them from falling into the vessel.

- Check the expiration date of the official certification test of the separator. Like all pressure vessels, the separator requires periodic recertification.

Maintenance

For information about separator preparation and functional checks, see the recommended steps in the *Field Operating Handbook (FOH) for Surface Well Testing*. For information about equipment maintenance, see the maintenance manuals for the separator and the *Field Operating Handbook (FOH) for Surface Well Testing*.

For this type of equipment, it is quite common to implement some modifications which originate from the engineering center. The changes to be made are listed on modification recaps (MR) and can be mandatory.

Summary

In this training page, we have discussed:

- The main functions of a separator.
- The different processes for achieving the separation between oil, gas and water.
- The main parameters that can be controlled and adjusted to optimize the separation.
- Using the shrinkage tester to get an accurate shrinkage factor.

Main Separator Functions

The separator has three main functions:

- It separates the well effluent leaving the choke manifold (or heat exchanger) into oil, gas, and water components before sending the gas to the gas flare and the oil to either the tank or the oil burner.
- It allows effluent components (oil, gas, and water) to be metered so flow rates for these components can be determined.
- It allows pressurized samples of oil and gas to be taken.

Separation Processes

Separators rely on these processes to separate liquid (oil and water) from gas:

- gravity and the difference in densities between oil, gas, and water.
- mechanical devices in the separator that are used to improve the separation process.
- altering the pressure and gas-liquid interface to further optimize separation.

The goal is to achieve the best separation possible for a given effluent. Because variations in these parameters can affect separation conditions, it's important to keep these parameters as constant and stable as possible. Although the temperature inside the separator is almost equal to the well effluent temperature and cannot be controlled (unless a heat exchanger is connected upstream of the separator), the pressure and gas-liquid interface can be controlled to optimize oil and gas recovery.

The "Separation Problems" table shows two examples of how the pressure, gas-liquid interface and temperature can be used to control separation problems.

Separation Problems

Problem	Causes	Action
Liquid carryover	High flow rate High liquid level Low operating pressure Wave action in separator Foaming	Decrease flow rate Lower oil/gas interface Raise operating pressure or decrease flow rate Reduce sensitivity of oil level controller Increase pressure
Poor oil-gas separation	High viscosity High separator pressure	Heat well effluent Increase retention time Reduce pressure

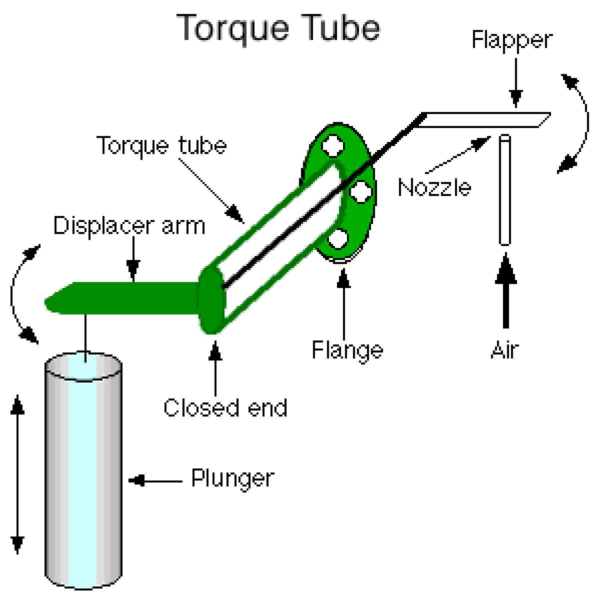
Controlling the Separation Process

To optimize separation, there are three parameters that can be controlled:

- the pressure inside the separator
- the level of the gas-liquid interface
- the temperature inside the separator

Shrinkage Tester

The shrinkage tester consists of a bottle equipped with a graduated sight glass. Oil and gas will flow to the tester until the oil level reaches "0" on the vernier, corresponding to a set volume (Vo). The tester is then isolated from the separator and the bottle pressure is slowly bled off to the atmosphere. This allows gas to be freed from the oil; so usually after 20 minutes, a new level can be read on the vernier. This new level corresponds to a new volume (V) of oil. The shrinkage factor read on the vernier is simply the V:Vo ratio, expressed as a percentage.



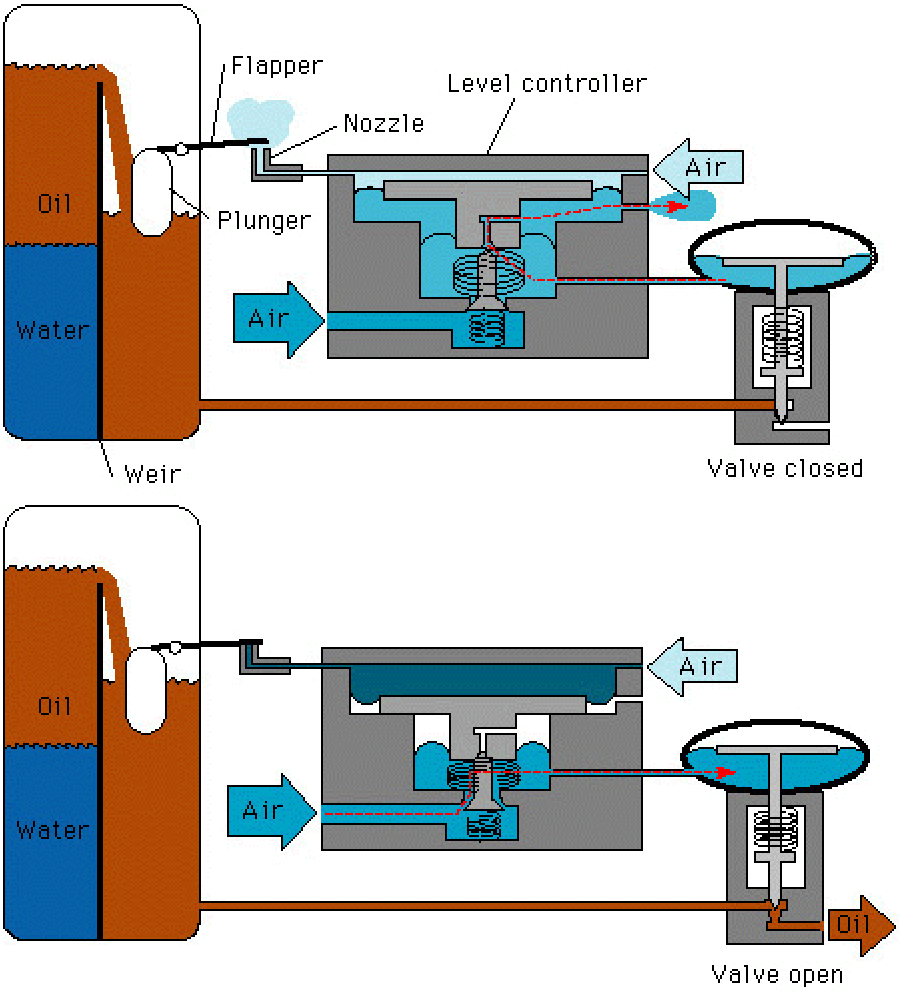
When liquid in the separator rises, the plunger moves up causing the torque tube to twist slightly to the right. a rod welded inside the torque tube transmits the rotation of the torque tube to the flapper, causing it to move closer to the nozzle that opens the automatic control valve (ACV). Similarly, when the liquid in the separator falls, the plunger moves down. The weight of the plunger causes the torque tube to twist slightly to the left. The rod transmits the torque tube rotation to the flapper, causing it to move away from the nozzle, closing the ACV.

Another way to understand how the torque tube system works is to compare it to a spring. The force on the spring is replaced by the torque on the tube and the linear displacement of the spring is replaced by the angular displacement of the tube.

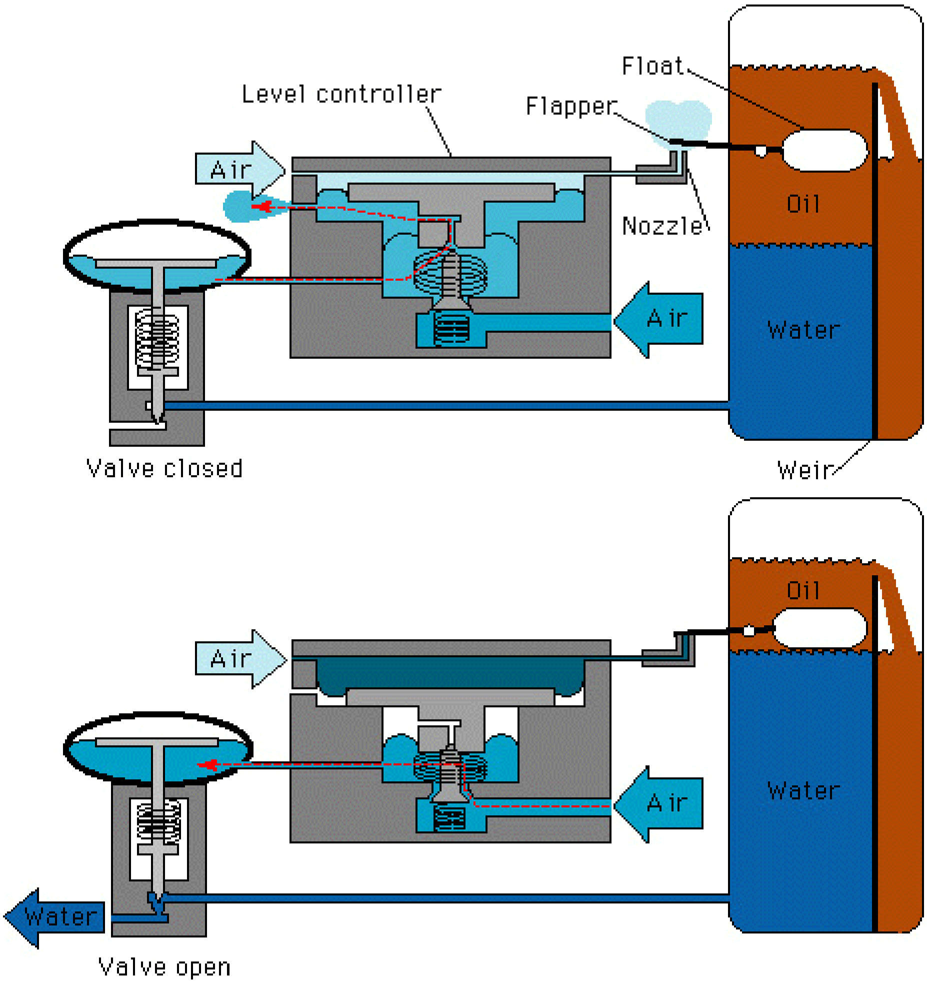
Self Test

1. What are the main functions of a separator?
2. What processes does the separator use to separate oil, gas, and water?
3. Why should a separator be run at a constant pressure?
4. How is the separator pressure controlled?
5. What type of ACV is mounted on the separator gas line? Why?
6. What is the shrinkage measurement used for?
7. How is the separator protected against overpressure?

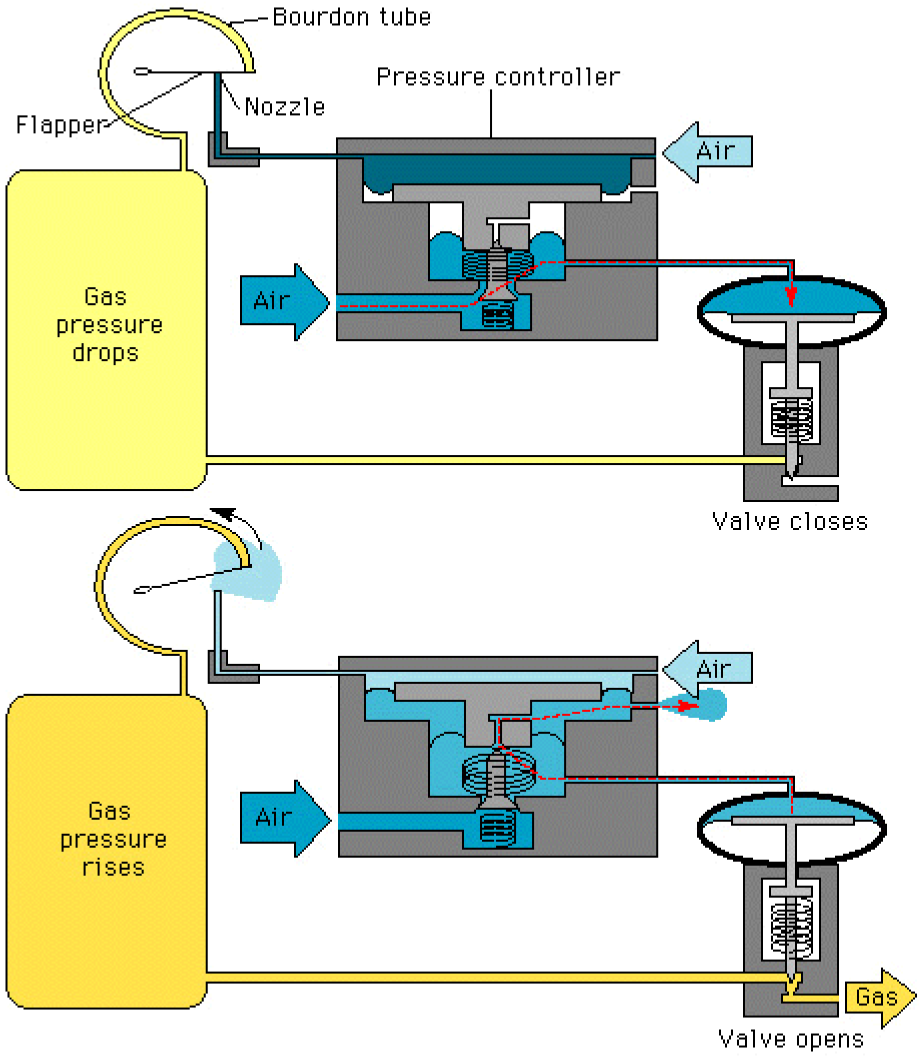
Oil Level Controller



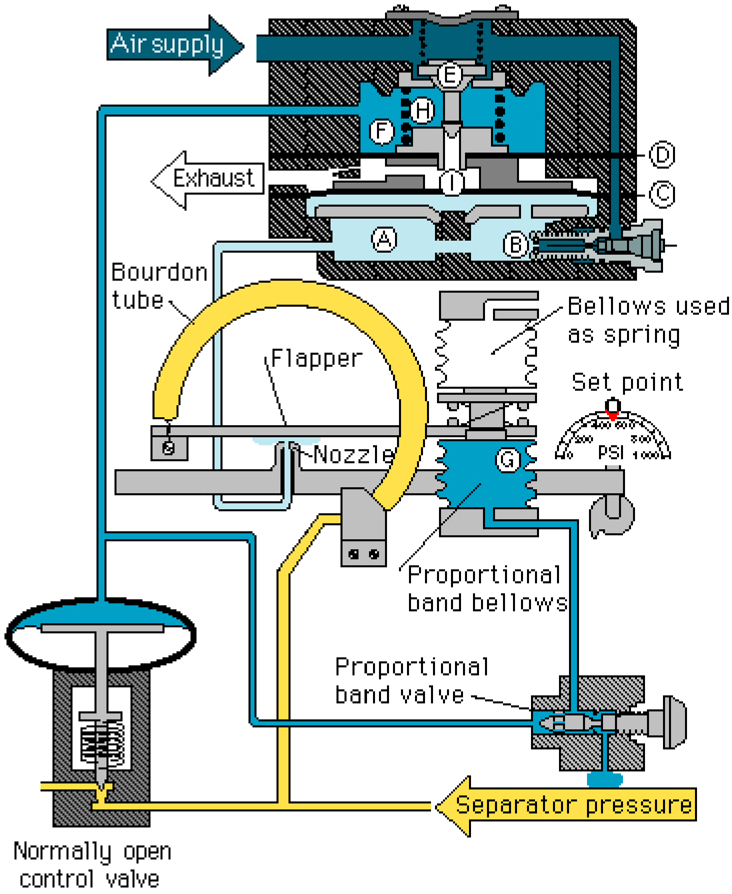
Water Level Controller



Gas Pressure Controller



Gas Pressure Controller - Proportional Action



Introduction

The three-phase test separator is a versatile piece of equipment that allows separation, metering, and sampling of well effluent components. Designed for multiple tasks, the test separator does not separate fluids as perfectly as a production-station separator, but separation is effective enough for fluids to be reliably metered.

Features and Benefits

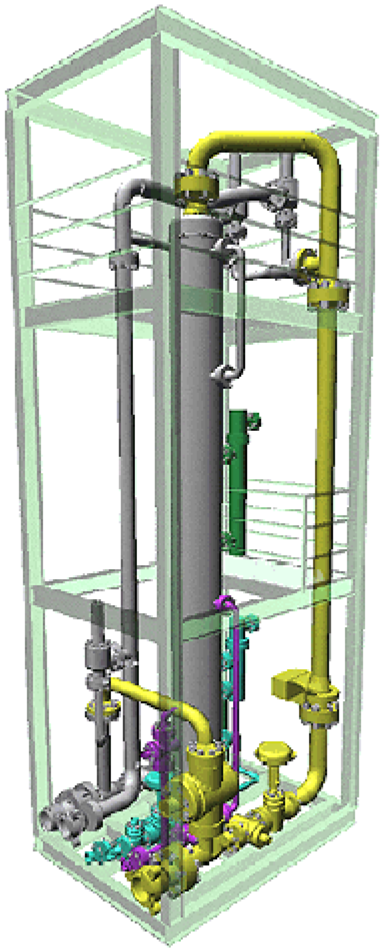
The separator has the following features and benefits:

- mechanical components inside the vessel improve the gravity separation process and reduce retention time.
- an orifice meter to measure the gas flow rate.
- two oil meters: a positive displacement meter for low flow rates and a vortex meter for high flow rates.
- a positive displacement meter to measure the water flow rate.
- a built-in shrinkage tester to calculate the shrinkage factor.
- an adjustable oil-gas interface level to handle various flow rates and gas-oil ratios (GOR).
- a pressure controller to adjust the separation pressure and improve separation efficiency.
- the vessel is protected against overpressure by two different devices: a safety relief valve and a rupture disc.
- several tapping points for taking oil, gas, and water samples.
- multiple dimensions and pressure ratings.

The test separator is capable of treating most types of fluid presently found in exploration wells including gas, gas condensate, light oil, heavy oil, foaming oil, oil containing water and impurities and H_2S bearing fluids.

Applications

In many ways, the separator is the central piece of equipment in the well testing setup. Most well tests require a separator. It is used in all exploration tests and sometimes for production tests, when the permanent separator is unavailable or not installed.



Vertical Gas Separator

Description

A well test separator is designed to separate, meter and sample all elements or phases of the effluent. This three phase well test separator unit includes:

- cyclone inlet cluster separating unit.
- 8 in. orifice meter, set of orifices and 3-pen recorder.
- optional flow measuring system for oil.
- optional flow measuring system for water.
- 4 in. gas control valve.
- 2 in. oil/water control valve.
- two 3 in. piloted safety valves.

Specifications

Service	H_2S
Working pressure	2220 psi at 100ºF 1970 psi at 300ºF
Gas flow rate	100 MM/ft^3/d
Liquid flow rate	1500 b/d

Connections (crossovers)

Inlet	6 in. 900 RF x 4 in. Figure 1002
Gas outlet	6 in. 900 RF x 4 in. Figure 1002
Oil outlet	2 in. 900 RF x 2 in. Figure 1002
Water outlet	2 in. 900 RF x 2 in. Figure 1002
Drain outlet	2 in. 900 RF x 2 in. Figure 1002
PSV outlet	6 in. 300 RF x 6 in. Figure 206

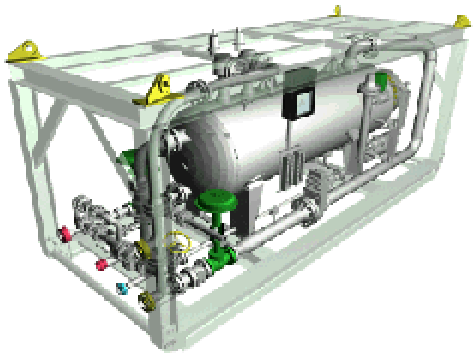
Certifications (third party)

Design	Design verification report
Documentation	Quality file
Manufacturing	Certificate of conformity
Code	BS 5500; ANSI B31-3; NACE MR-01-75

Reference

SEPV-A	P-775669

Weight and dimensions



3.23 m x 2.44 m
8.32 m
14,000 kg

Horizontal Separator

Description

A well test separator is designed to separate, meter and sample all elements or phases of the effluent. This well test separator unit includes:

- vessel 42 in. x 10 ft with 18 in. manhole.
- removable stainless steel modular internals.
- oil compartment with weir.
- inlet 3 in. fullbore check valve.
- flow measuring system for oil by dual flowmeter, on water by one flowmeter and on gas by one orifice meter.
- set of orifices and 3-pen recorder.
- isolating valves on flowmeters (upstream and downstream).
- pneumatic control valves on gas and oil outlets.
- manual control valve on water outlet.
- lateral stand pipe with oil level controller.
- two 3 in. pilot operated, modulating action, pressure relief safety valves manifolded together.
- water/oil bypass
- safety discharge line can be connected to gas outlet or to an independent gas flare.
- sand jet line

Specifications

Service	H_2S
Working pressure	1440 psi at 100°F 1345 psi at 212°F
Working temperature	32°F to 212°F
Gas flow rate	60 MM/ft^3/d at 1440 psi (1,700,000 m^3 at 100 bars) and low liquid level 25 MM/ft^3/d at 1440 psi (700,000 m^3 at 100 bars) and high liquid level
Liquid flow rate	6650 b/d with 1 min retention time and low liquid level (1060 m^3/d) 14,400 b/d with 1 min retention time and high liquid level (2290 m^3/d)

Connections

Inlet	3 in. Figure 602
Gas outlet	3 in. Figure 602
Water outlet	2 in. Figure 602
Oil outlet	2 in. Figure 602
PSV outlet	3 in. Figure 602
Sand jet line	2 in. Figure 602

Certifications (third party)

Design	Type approval or design verification report
Documentation	Quality file and load test
Manufacturing	Certificate of conformity

Reference

SEP-T	P-585700
SEV-T (skid mounted separator)	P-585701
LFS-T (lifting frame for separator)	P-585702

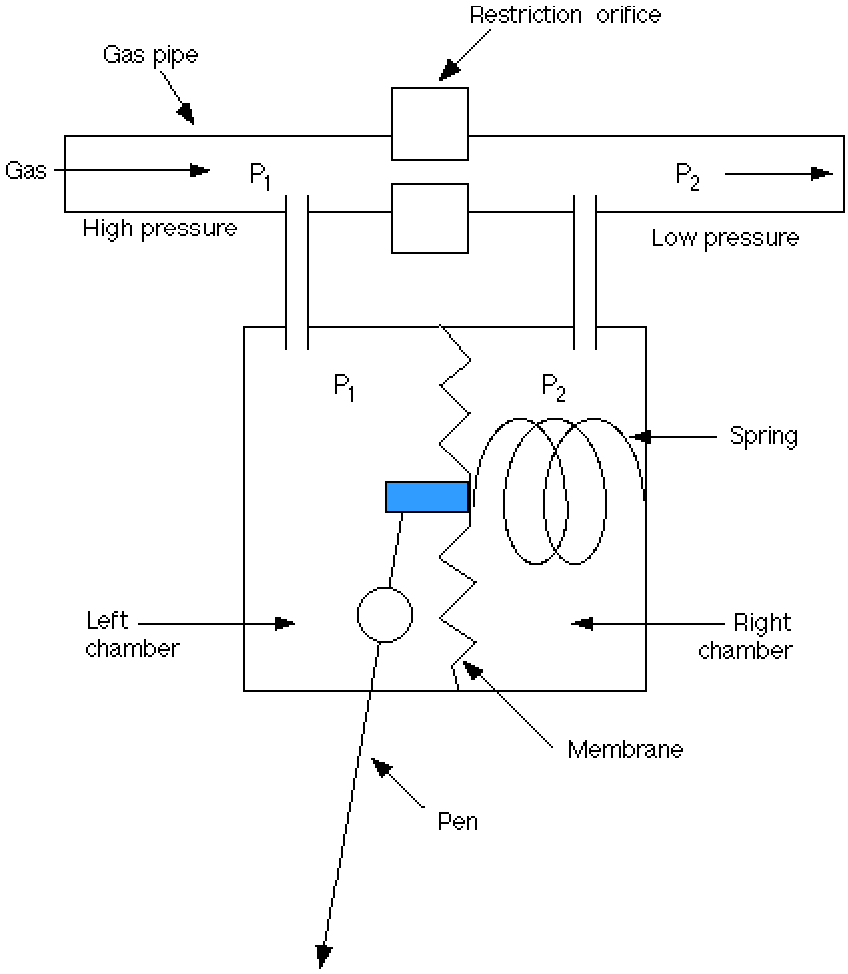
Weight and dimensions

Foot print	5.68 m x 2.24 m
Height	2.42 m (2.73 m with PSV protector)
Weight	14,000 kg

Accessories (optional)

Built in 1 | shrinkage tester (SKT-AB)	M-808721
Stand alone 4 | shrinkage tester (SKT-C)	M-806275
Low gas flow measurement skid (LGMS-A)	P-579083

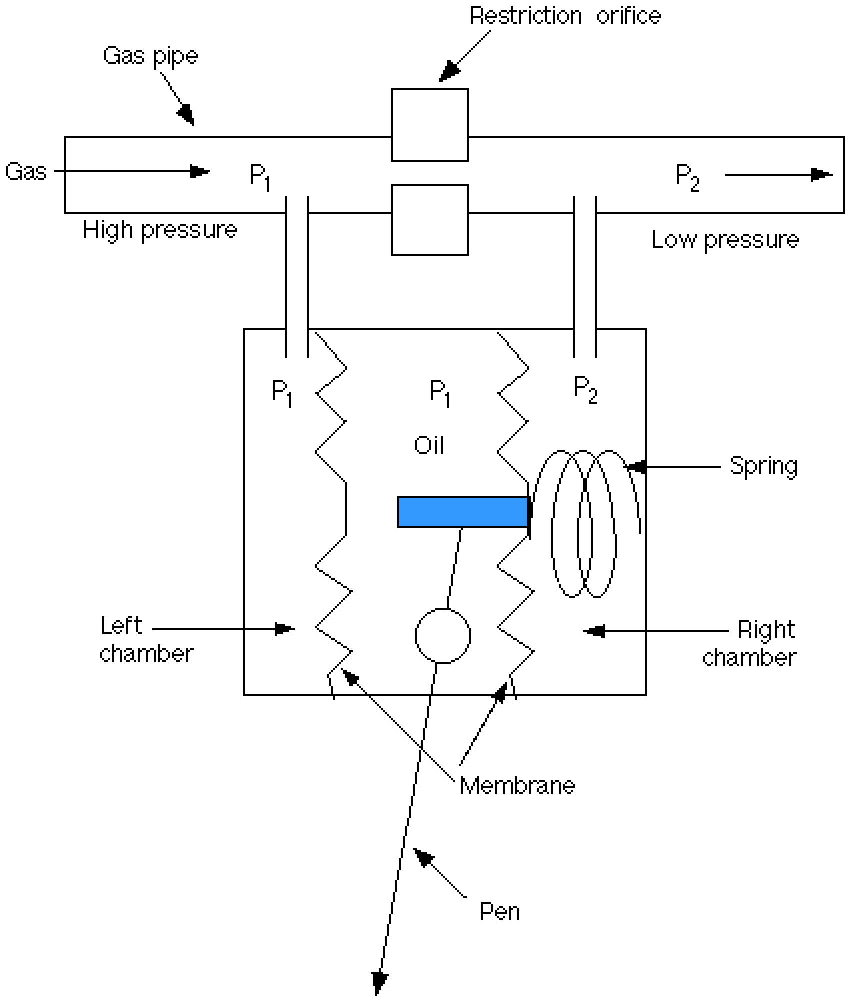
Differential Pressure Recorder Process - 1



A membrane, backed up by a spring, separates the measuring device into two chambers.

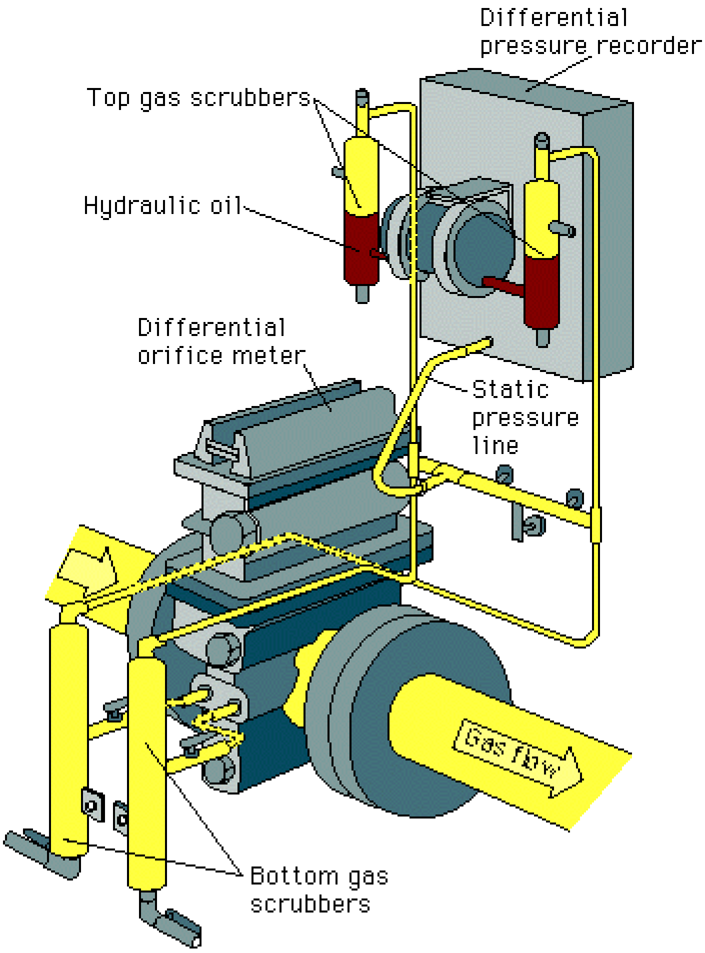
The chamber on the left (P_1) is exposed to the high pressure, the one on the right (P_2) to the low pressure. A variation of the differential pressure across the orifice moves the membrane which in turn transmits this variation to the pen.

Differential Pressure Recorder Process - 2

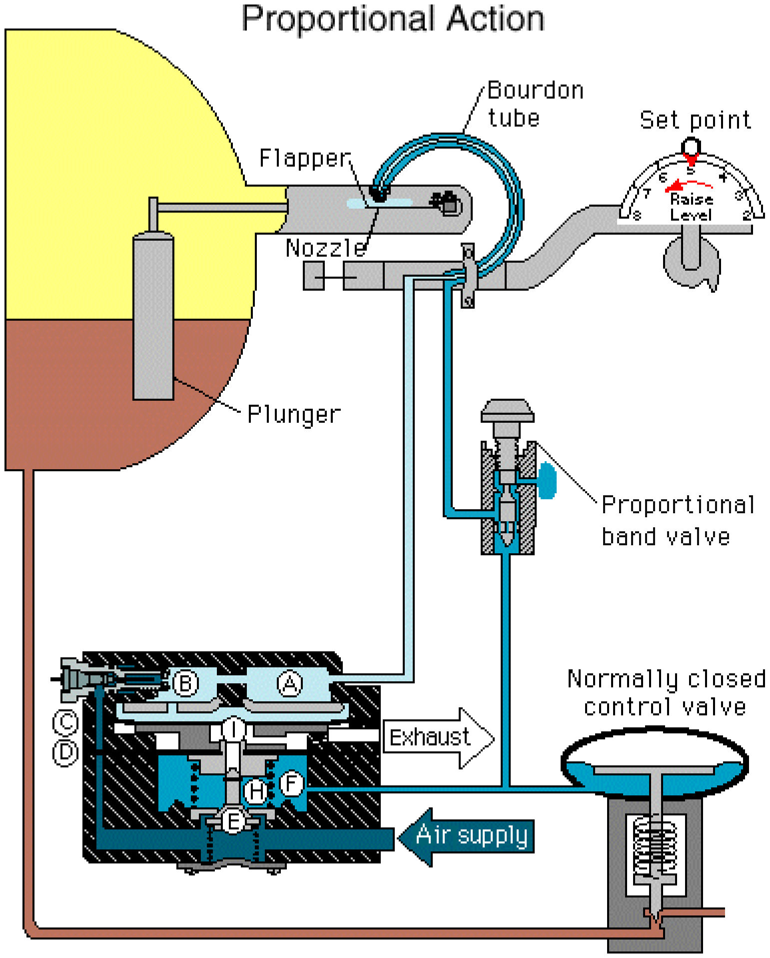


To prevent the pen mechanism from being contaminated by the well effluent another membrane is added to isolate it and the center chamber is filled with oil.

Gas Scrubbers



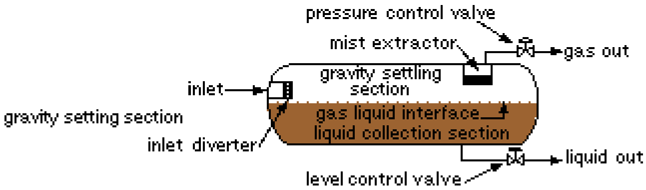
Oil Level Controller - Proportional Action



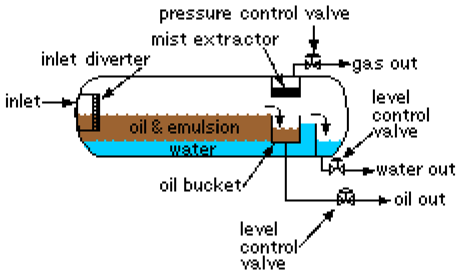
Types of Separators

Typical Horizontal Separators

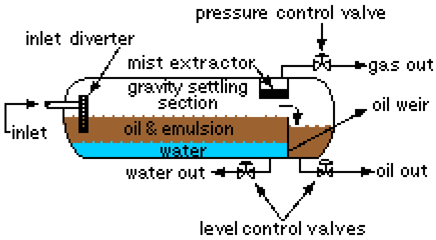
Two-Phase Separator



Three-Phase Separator
with a Bucket and Weir Design

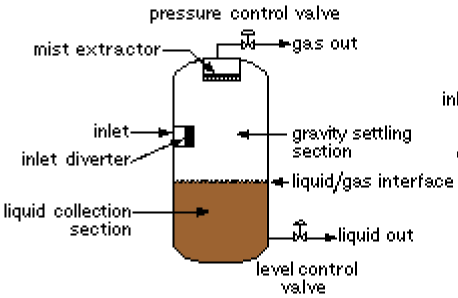


Three-Phase Separator
with Interface Controller and Weir

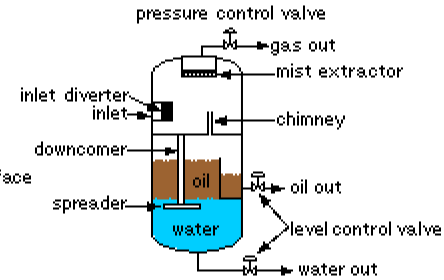


Typical Vertical Separators

Two-Phase Separator

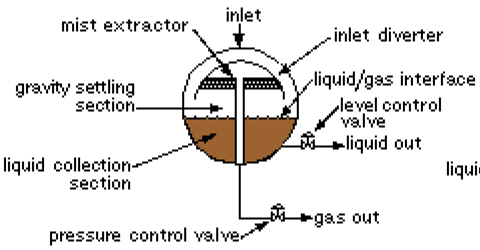


Three-Phase Separator



Typical Spherical Separators

Top Inlet
Two-Phase Separator



Side Inlet
Two-Phase Separator