TURBOCOMPRESSORS

Lube and Seal Oil Systems

Notebook

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About the Authors

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In his past professional experience from 1975 to 2001, Mr. Arias taught engineering courses in Universidad Nacional del Sur. Before resigning from this position, he was Adjunct Professor of Machine Elements course.

In 1990 he founded SEMTEC. Since then he has conducted numerous seminars and workshops on technical and maintenance organization matters in Argentina and around the world including "Compressor Performance Seminar".

Mr. Arias has a Mechanical Engineering Degree from Universidad Nacional del Sur and has extensive hands-on technical training in the USA with Davy-Mc Kee Corporation and Elliott Company. He is a member of ASME, The Vibration Institute and the Society of Tribologist and Lubrication Engineers. You can contact Mr. Arias at: semtec@speedy.com.ar

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While at Elliott Co., Jeannette, PA, USA, he was Sr. Design Engineer in charge of the design of centrifugal compressors. During this period he was involved in the design of new centrifugal compressor staging, oil seal redesign as well as the resolution of various shop problems. As Sr. Compressor Service Engineer at Elliott Co. he was involved with the field-testing of compressors and steam turbines and troubleshooting various field problems like performance issues, bearing and seal problems and vibration problems including instability problems.

Gresh received a B.S. degree (Aerospace Engineering, 1971) from the University of Pittsburgh. In addition to numerous papers and magazine articles, he has published a book on the subject of compressor performance, and has several patents related to turbomachinery. He is a registered Professional Engineer in the State of Pennsylvania. You can contact Mr. Gresh at his e-mail address: mtgresh@flexwareinc.com

Lube and Seal Oils Systems

Oil Systems - Purpose

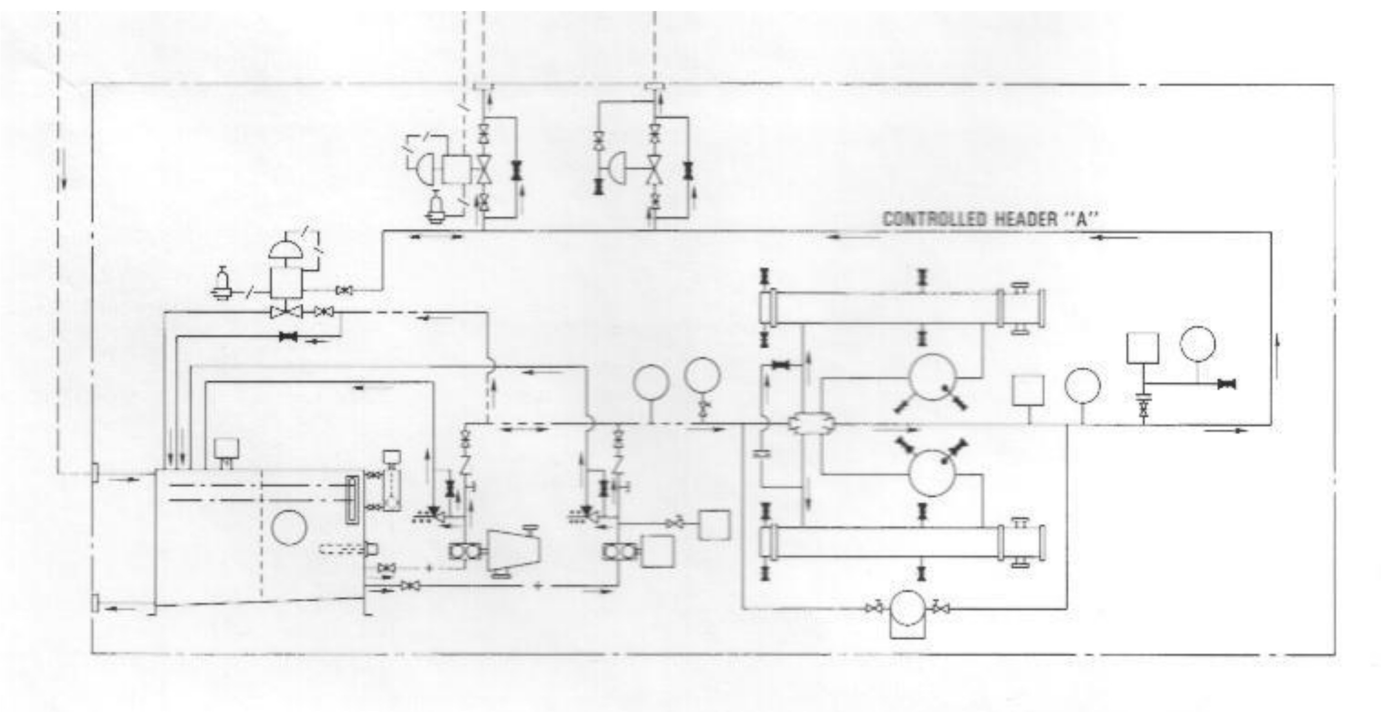
- To provide the required quantities of cooled and filtered oil at properly controlled pressures for lubrication, shaft sealing, and/or control.
- They must be designed to operate over a range of conditions created by variations in ambient conditions, utilities, process, sealing pressure, control demands, start-up, shut-downs, etc.

Basic Components

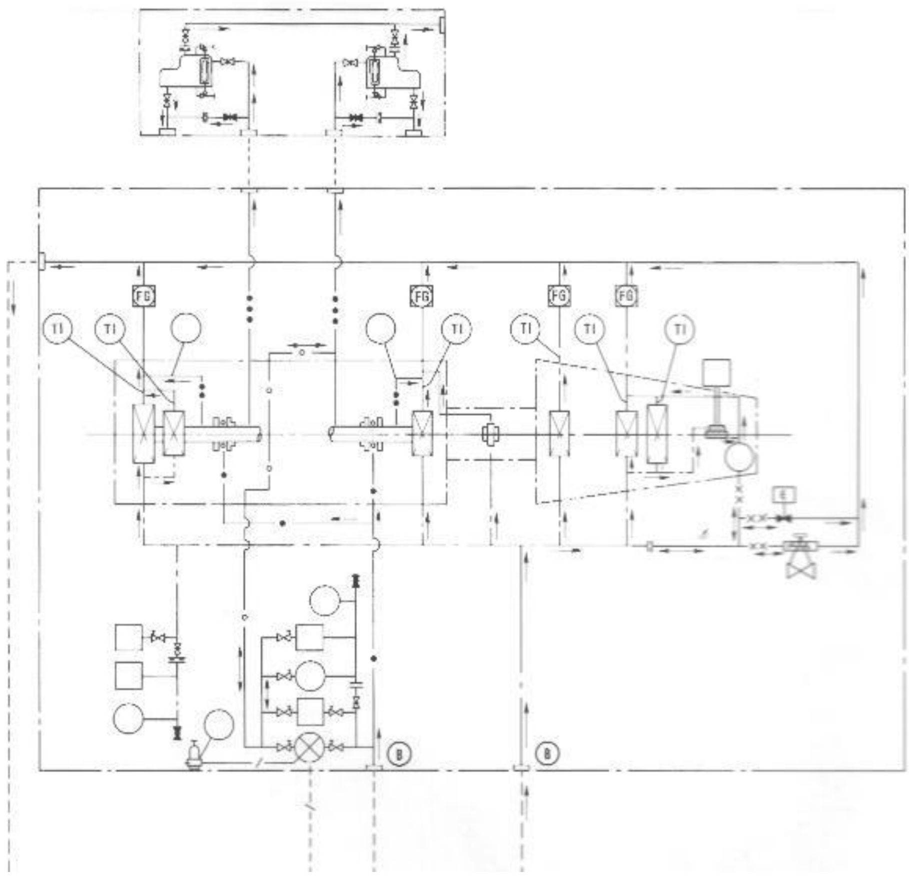
- Reservoir
- Pumps
- Relief valves
- Back-pressure regulator
- Transfer valve
- Coolers
- Filters
- Instrumentation
- Temperature control valve
- Pressure reducing valves
- Differential pressure reducing valves
- Contaminated oil drainers

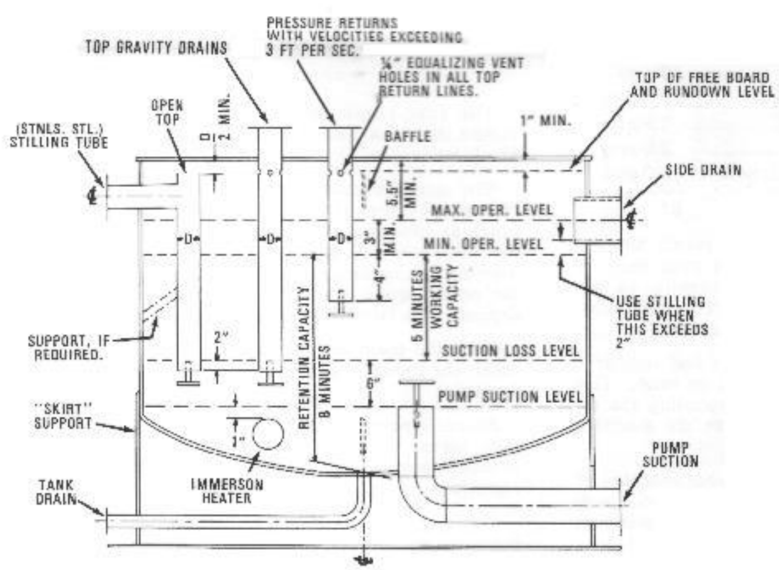
Optional accessory equipment

- Lube rundown tanks
- Seal rundown tanks
- Accumulators
- Degassing tanks
- Overhead seal tanks
- Purifiers



Oil System Schematic





Oil Reservoir

Oil Reservoir

To provide oil storage, to serve as a collection point for oil returns, and to permit the separation of solids and water and the release of entrained gases.

Oil Reservoir Capacity

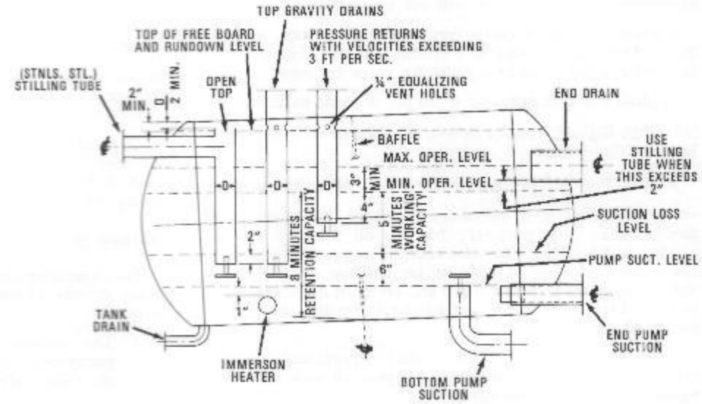
- The reservoir capacity, based on normal flow, is determined strictly as defined by API 614. That is:
- 5 minutes working capacity between minimum operating level and suction-loss level.
- 8 minutes total retention below the minimum operating level

Oil Reservoir Levels

- Above the minimum operating level, the maximum operating level is located to provide a volume sufficient for three days of operation, based on expected oil usage rate, for those systems in which seal oil leakage is discharged from the unit.
- When seal leakage is returned to the reservoir, or on separate lube systems, the distance between maximum and minimum levels is established as 3 inches.
- Above the maximum operating level, rundown capacity is provided to receive the oil from any components, housings, piping, etc. that can drain back to the reservoir.
- Free board is provided above rundown level.
- Below minimum working level the suction-loss level is located to provide not less than the required 5 minutes working capacity.
- Suction-loss level is physically located at a distance of 6 inches above the top of the pumps suction nozzle.

Oil Reservoir Return Nozzles

- Return lines carrying oil at velocities in excess of 3 feet per second, typically relief valves and backpressure regulator discharges, are carried through vented nozzles to a level 4 inches below the minimum working level.
- These lines are baffled to distribute the flow horizontally to avoid air entrainment.



Oil Reservoir

- The API requirement of providing a free surface of oil of not less than 0.25 square foot per GPM of normal flow frequently defines the shape and proportions of the oil reservoir.

Optional equipment - characteristics

- Steam heaters
- Thermostatically controlled electric heaters.
- Additional alarms.
- Material:
  Stainless steel or coated carbon steel

Pumps

- The most common type of pump in use today in oil systems with one pumping level is the screw-type positive displacement pump.

Pumps

- For high flow low head service, and for primary lift in booster systems, centrifugal pumps frequently employed.
- Their use is generally limited to pump discharge pressure under 200 psig with the majority of applications being in the range of 125 psig.
- Pump capacity is based on the maximum flow of oil required by each of the items served by the system.
  Lube oil.
  Seal oil at maximum demand.
  Control oil, including transient conditions.

- Actual pump capacity must not be less than 115 % of the highest total flow required under any operation condition.
- The calculation procedure of the required pressure at the pump discharge flange starts with the highest oil pressure that will ever be required by the machine.
- This may be seal oil at normal or shutdown conditions, control oil or simply bearing supply pressure in the case of a separate lube system.
- To this maximum oil pressure at the machine it is necessary to add various losses:
  - Static head
  - Piping losses
  - Pressure reducing control valve losses
  - Console pipe losses
  - Transfer valve losses.
  - Filter losses.
  - Cooler losses

Relief Valves

- In systems with the required pump discharge pressure of 100 psig or less, relief valves are set at 10 psi above pump pressure.
- For pressures over 100 psig, 10 % is added to establish set pressure.
- Each relief valve is sized to pass the actual full pump capacity at a pressure not less that 10 % over set pressure and not more than 25 % over set pressure.

Pumps

- The pump must be able to develop the maximum pressure while delivering the full flow at a viscosity of 65 SSU.
- Pump drivers are sized based on two operating conditions:

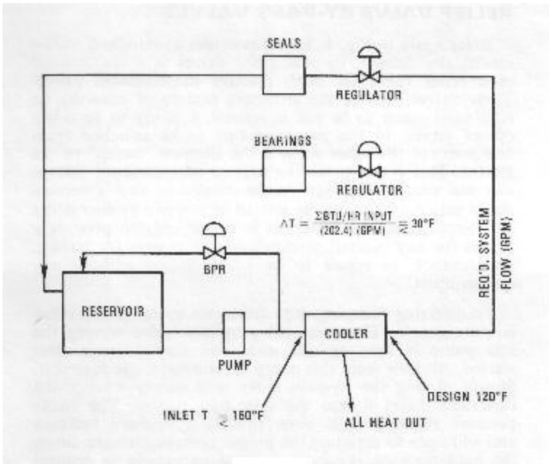
a) The horsepower required during a cold start pumping the full pump capacity at the pressure at which the relief valve passes this flow.
b) 125% of the horsepower required to pump full pump capacity at 65 SSU at maximum operating pump discharge pressure.

Relief Valve By-Pass Valves

- These valves provide the attractive feature of allowing an additional pump to be put in service, a pump to be taken out of service, or the pump duty to be switched from one pump to the other without the slightest “bump” to the system.
- This feature provides manual manipulation of pumps for testing, maintenance or repair to be accomplished without any system upset.

Transfer Valve

- The transfer valve is sized to pass the maximum flow to the equipment being served.
- Good size criteria indicates that the pressure drop through the transfer valve should not be larger than 10 psi.
- Highest pressure drop values occur when the valve is at mid-stroke.
- This requires that the mid-stroke increase in pressure drop for the selected valve be determined.



Heat Schematic

Oil Coolers

- Oil coolers are designed to remove the total heat added to the oil from every source.
- This must include all heat contributed by bearings, seals, and gears and the total heat contributed by the pump or pumps in service during normal operation.
- Normal design is based on the following criteria:
- Oil outlet temperature 120 ºF
- Maximum water outlet temperature 120 ºF
- Maximum oil pressure drop 10 psi
- Maximum water pressure drop 10 psi
- Total fouling factor 0.002
- In order to maintain proper pumping viscosity and not to exceed temperature limitations for positive displacement pumps, the reservoir temperature should be limited to approximately 150 ºF.

Detecting Heat Problems

- A simple calculation is made to determine the existence of a heat problem.
- The oil temperature change may be calculated by the following formula:

$$\Delta T = BTU/hr / 202.4 * GPM$$

If ΔT is less than 30 ºF, no problem exists.

Filters

- Twin filters should be provided downstream of the coolers.
- Unless required by specification or by special design consideration, the filters would be piped in series with the twin coolers, utilizing one transfer valve.
- Conditions to consider in the selection and sizing of filters:
- Clean oil pressure drop should not exceed 3 psi under maximum flow conditions at 100 SSU (120 ºF).
- Pass the maximum flow in cold start conditions without reaching collapsing pressure (80 psi for standard cartridges).
- Filter housings must withstand a pressure of not less than relief valve setting or centrifugal shut-off head.
- Depth-type filter cartridges, rated at 10 microns nominal are standard.
- Cartridges with smaller micron rating are available and should be specified for special services.
- Pleated paper cartridges are not recommended due to their lack to water absorption.

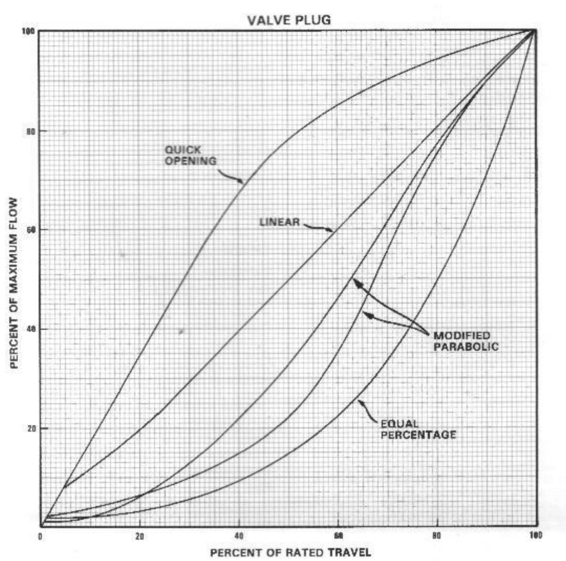
Control Valves

- All control valves must be carefully sized and selected to provide proper control under every possible operating condition.

- The sizing involves the determination of the required Cv under all conditions of flow and pressure drop.
- For oil systems Cv is determined as follows:

  $Cv = 0.975 * [GPM / \Delta P^{1/2}]$

- Cv values are published by the control valve manufacturers for each of their various types and sizes and are generally given for various percentages of stroke from fully closed to fully open.
- The control valves have different flow characteristics for various types of valve plugs.



CHARACTERISTIC FLOW CURVES

- This gives rise to the different valve types:

a) Quick Opening b) Linear
c) Modified Parabolic d) Equal Percentage

Controller

Back Pressure Regulator

- The purpose of this valve is to maintain constant the pressure of the header.
- This valve must be sized to properly control a wide range of flow:
  a) Minimum flow = 1 Pump capacity less Maximum System Requirement.
  b) Normal flow = 1 Pump capacity less Normal System Requirement.
  c) Maximum flow = 2 Pump capacities less Minimum System Requirement.

Pressure Reducing Valves

- These control valves must provide oil for different services as:
  - Lube oil
  - Seal oil
  - Control oil

  Each service has its own pressure reducing valves.
- Reducing from the controlled header pressure to a fixed downstream pressure and passing a constant flow, only a very narrow control range is necessary.

Piping Materials:

- A complete range of materials, flanges and fittings is used to meet the requirements of any system, environment or specification.
- Systems may be built entirely of carbon steel, stainless steel or any desired combination of these materials.

Pumps Piping

- Separate suction lines connect each of the pumps with the oil reservoir.
- The piping is sized to limit suction velocity to a value of 3 to 5 feet per second.
- Eliminate air pockets and minimize bends and elbows.
- Optional suction strainers.

Piping - Hydraulic Design

- Pressure line throughout the system are sized on the basis of pressure drop, using a design value of 9 psi drop per 100 equivalent feet of pipe.

- In all cases, pipe size selection is based on maximum flow, including transients, for the particular circuit or portion of the system under consideration.
- Oil drain lines are sized to flow no more than half full at a slope of ¼” per foot.

EQUIVALENT LENGTHS OF PIPE FOR STANDARD FITTINGS
(Feet)

Fitting	NOMINAL PIPE DIAMETER					
	¾″	1″	1½″	2″	3″	4″
Lung Radius El	1.3	1.7	2.8	3.5	5.2	7.0
Standard El	2.2	2.7	4.5	5.2	8.0	11.0
Tee — straight	1.3	1.7	2.8	3.5	5.2	7.0
Tee — thru branch	4.5	5.7	9.0	12.0	16.0	22.0
Gate Valve (open)	0.5	0.6	1.0	1.2	1.7	2.3
Globe Valve (open)	22.0	27.0	44.0	53.0	80.0	120.0

Instrumentation

- Complete local instrumentation should be provided to control the oil system, to alarm at predetermined variations from normal conditions and to trip the machinery when abnormal conditions approach damaging values.
- Pressure and temperature indicators, liquid level and sight flow indicators provide operators with visual operating information necessary to manual correct for abnormalities in oil temperatures, filter fouling, low oil levels, etc.

Oil Level Switch

- Each reservoir must have an externally mounted level switch to alarm at minimum operating level.
- Normally this indicates the need to refill the reservoir to maximum operating level.

Pressure switch

- Located in the controlled header downstream of the filters, a switch is provided to start the auxiliary positive displacement oil pump on decay of header pressure.
- This switch is normally set to actuate on a falling pressure 15 psi below design header pressure.
- Between the auxiliary pump discharge flange and the check valve in the discharge piping, a pressure switch provides the necessary contacts to indicate Auxiliary Pump Running.
- Each bearing header, or lube oil pressure level, is monitored by separate alarm and trip switches.
- In 15-18 psig lube systems, the alarm switch will actuate at 13 psig falling pressure. The trip switch is normally set at 11 psig falling pressure.

Differential Pressure Switches

- A differential-pressure indicating switch is provided to indicate filter pressure drop and to actuate at a predetermined fouled filter pressure drop.
- As a general rule, the rising differential-pressure set to actuate this switch is 20 psid.
- When a single transfer valve is used for coolers and filters the instrument spans the entire assembly.
- In this case the instrument shows the over all pressure drop.
- As a general rule, the rising differential-pressure set to actuate this switch is 35 psid.

Temperature switch

- A temperature switch is located in the piping downstream of the coolers. The purpose of this switch is to indicate cooler malfunction, insufficient cooling water, high cooling water temperature, etc. resulting in inadequate oil cooling.
- This switch is set normally to actuate on rising temperature at 140 ºF.
- Differential pressure switches are located in the supply piping at the compressor for each contact seal pressure level.
- With contact seals normally operating at 35 psid, the alarm setting is at 30 psid falling pressure with the trip at 20 psid falling pressure.

Pressure Gages

- A pressure indicator is located in the common pump discharge line before the coolers.
- A gage downstream of the filters, reading controlled header pressure is usually arranged.

- In each bearing header and lube oil pressure level a gage is located.
- In each individually controlled seal oil level both a differential pressure indicator and a pressure indicator are installed.

Thermometers

- A thermometer is located in each reservoir that is equipped with either a steam or electric heater.
- Thermometers are located before and after the oil cooler. The downstream instrument is used to monitor and maintain design oil feed temperature, usually 120 ºF.
- The two thermometers together provide the data necessary to verify the cooler performance.
- A temperature indicator in the atmospheric drain from each bearing and seal provides a means of locating abnormal throwoff temperature.

Sight Flow Indicators

- A sight flow indicator is located in each atmospheric drain.

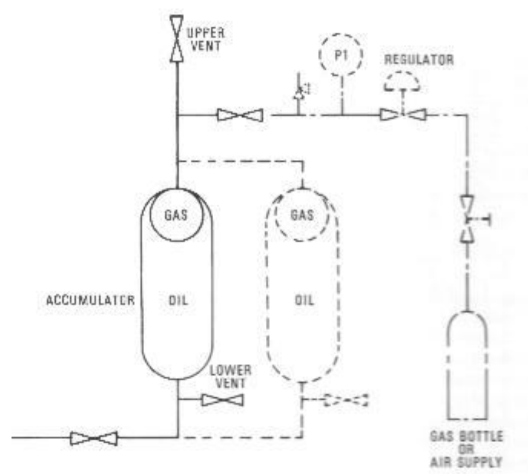
- The depth of flow in the partially full pipe can be observed and any change or abnormality noted.

Liquid Level Gages

- Liquid level gages are provided on a number of both atmospheric and pressure vessels associated with an oil system.
- On rectangular reservoirs a reflex-type weld-pad gage is located to span the range from maximum to minimum operating range as defined in API 614.
- Valved, externally mounted reflex-type glasses are used on cylindrical reservoirs in the proper length and sections to span the required range.
- Reflex glasses are standard on overhead seal tanks, drainers, degassing tanks, and other specially designed vessels.

Acce

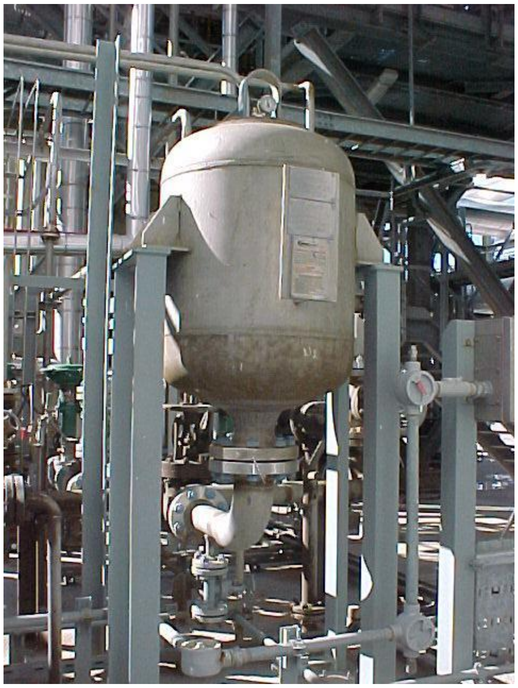
- The need for many other items, additionally to the ones already seen, is created by variations in system design or by specific requirements of the particular installation.



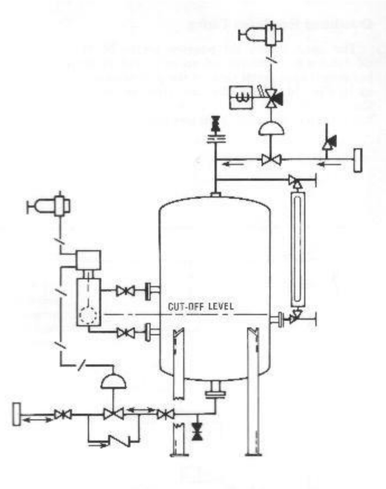
BLADDER-TYPE ACCUMULATOR INSTALLATION

Accumulators

- The most common application is that of transfer barrier accumulators, located in the control pressure header, to maintain adequate oil pressure in the system while pumps swap happens.
- Sufficient accumulator capacity has to be provided to maintain the entire system at normal flow for a period of twenty seconds.
- This time has been established to cover adequately the most difficult and undesirable turbine start-up conditions.



- In high flow systems and particularly those requiring the use of stainless steel downstream of the filters, bladder-type accumulators become impractical and prohibitively expensive.
- In these systems a direct contact accumulator is used.



Direct Contact Accumulation

Pressurized Rundown Tanks

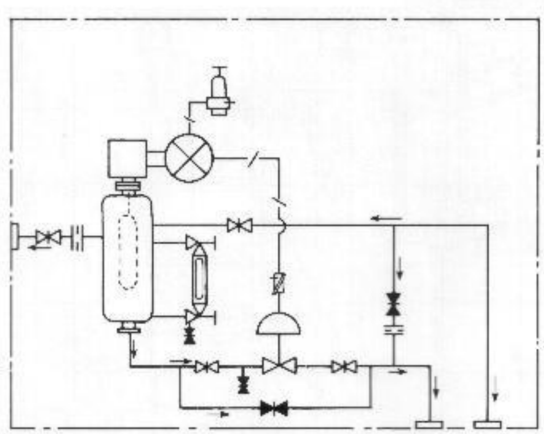
- The purpose of pressurized rundown tanks is to supply emergency oil to seals and/or bearings after a low oil pressure or low differential trip-out.
- The design is just like the Direct Contact Accumulators.
- Since the function is to provide rundown oil, the solenoid at the pneumatic valve is actuated only on a signal from the trip circuit.
- The rundown oil may be piped into the system to provide seal oil only, lube oil only, or all oil.

Overhead Rundown Tanks

- The most simple yet positive means of providing lube oil rundown is the use of an overhead rundown tank.
- A horizontal cylindrical tank of the proper capacity is located above the centerline of the machine such that the top of the tank is at an elevation to provide a static head of approximately 2 psi less than the trip switch setting.
- Upon loss of pressure, the stored oil returns to the system providing oil to the bearings during coast-down.

Overhead Seal-Oil Tank

- An overhead seal-oil tank is required when the compressor is fitted with sleeve seals.
- The overhead seal tank performs two functions:
- Provides the means of controlling the seal oil differential pressure
- Provides seal oil storage for emergency operation and rundown.



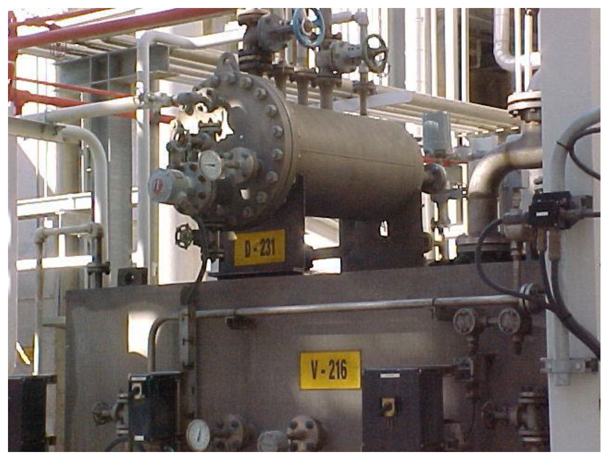
Automatic Snap-action Drainer Schematic

Seal Oil Drainers

- A separate contaminated seal oil drainer is provided for each seal.
- The drainers may be manual, continuous automatic of the mechanical float-type single-lever design, or automatic design with an internal snap-acting level controller and a separate pneumatic off-on control valve.
- The drains from any of the drainers may be returned directly to the oil reservoir, may be returned to a degassing tank and then to the reservoir, or may be discharged outside the oil system.
- The disposition of the drains is defined in each project.

Mist Eliminators

- The purpose of oil mist eliminators is to remove most of the oil mist from the drainer vents.
- The removal of sufficient oil mist to permit recycling or reclaiming the drainer vent gas can only be accomplished by properly considering gas volume, pressure and molecular weight in the design of the mist eliminator.



Degassing Tank

- The purpose of a degassing tank is to reduce the quantity of process gas in the contaminated oil drains before they are returned to the oil reservoir.
- Degassing tanks are capable of removing a large percentage of the mechanically entrained gas but cannot be expected to reduce the quantity of dissolved process gas by any predictable degree.
- Degassing tanks consist of a flat sloping solid plate tray, where oil is discharged.
- This tray spreads the oil in a thin sheet and delivers the flow to the portion of tray made of perforated plate.

- Falling through the small perforated holes, the oil is broken into small drops and streams, allowing the gas to escape.
- To help the degassing process, oil is heated either electrically or with steam, to a temperature of 180 to 200 ºF.

Oil Purifiers

- There is a wide variation of design, function and cost of oil purifiers.
- This variety comes from an equally wide variation of oil contamination.
- The most simple is the installation of a coalescing filter in a by-pass line from the common pump discharge piping back to the reservoir.
- More sophisticated designs go from centrifuges to high vacuum oil conditioners removing gases, solids and water to a high degree of purification.