Title

THE AUTOMATION OF THE COMPRESSOR AND REFRIGERATOR SYSTEMS

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Publication Date

1981-03-01

UC-38
LBID-376 c.1

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Engineering & Technical Services Division

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA ENGINEERING NOTE	CODE TFO 200	SERIAL M5700	PAGE 1 of 8
AUTHOR R. Curtis / EDIT. R. BYRNS — DEPARTMENT Mechanical	LOCATION Bldg.6	DATE March 6, 1981	

PROGRAM — PROJECT — JOB
NBSTF-TFTR Helium cryosystem

CRYOGENICS SUPPLY SYSTEM

TITLE
The automation of the compressor and refrigerator systems.

The refrigerator system at building 6 has been modified recently with an automatic controller. The automatic system balances the heat load ~~from the~~ cryosystem and refrigeration ~~efficiency~~ capacity. It also balances gas/liquid storage within the system along with the kickback regulator.

The automatic controller is the Barber-Coleman analog setpoint controller, model #122H-12892-402-0-10. It is now wired to both the low and high pressure side of the compressor. It senses compressor suction and controls compressor discharge. It does this with a Gulton (#605-01-3s) pressure transducer and a boot-loaded Grove Flexflow regulator used as the discharge or back-pressure regulator (model #80).

The transducer is a 0-5 psig unit. It needs a 10vdc input and will put out a very linear 1 vdc/psig. The Barber-Coleman controller adds this voltage to an internally generated negative voltage. The internal voltage is proportional to set point dial on the front of the unit. If the sum is zero no control action is taken. If it is positive or negative then either output #1 or #2 will be activated. These two outputs are wired to a pair of Asco high pressure solenoids (#8262A214). The solenoids are plumbed into the Grove Flexflow. One solenoid admits compressor discharge pressure to the "boot" and the other releases boot pressure to suction. This has the effect of raising or lowering compressor discharge pressure.

It is this raising and lowering of the discharge pressure that is the key to the automation. By raising discharge pressure we either draw gas from suction or from storage (make-up) and compress it. From experience we know that suction pressure* is a "barometer" of conditions within a cryosystem. If the heat load on a cryogenic liquid exceeds the refrigeration ~~abilities~~ capacity then the boil off gas will

* NORMALLY, GAS IN SYSTEM IS FIXED - (GHe / LHe) - SUCTION MAKE-UP VALVE IS CLOSED FROM TUBE TRAILER OR MED. PRESSURE (PROPANE) TANKS

raise the pressure in the low side of the refrigerator. The Barber-Coleman unit will "sense" this excess pressure and will "load" the boot in the discharge regulator. This causes the compressor to transfer gas from the suction to the discharge side, raising the discharge pressure; and lowering the suction pressure. It ~~and~~ will do this nearly instantly. The expander portion of the refrigerator then expands a higher pressure to the low side, increasing refer yield ~~efficiency~~ a bit. If this is still not ~~efficient~~ enough then boil off will again raise suction pressure and the system will raise discharge pressure a little more, etc. At some point the refer capacity ~~efficiency~~ will equal heat load and suction pressure will stabilize at our set point of 1.1 psi ~~pounds.~~ The converse of this process is true also.

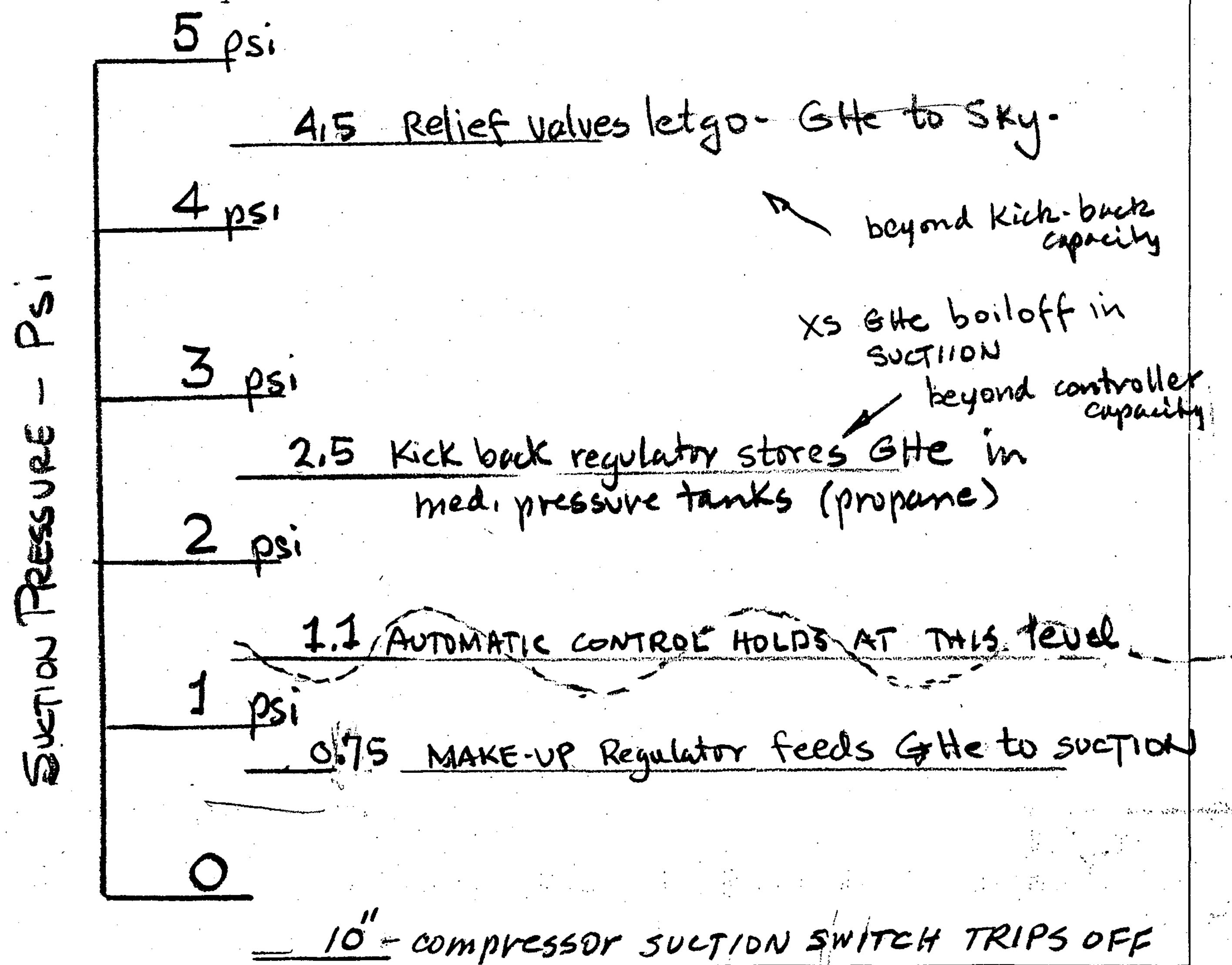
We have four places to store helium in a dynamic system: the large storage tanks; the suction system; the discharge system; and/or the liquid helium system. The Barber-Coleman controller balances suction, discharge and liquid/heat load. The kickback regulator "senses" a suction pressure signal also and will transfer gas from the discharge system to the storage tanks if suction exceeds 2½ psi ~~lbs.~~ If the heat load/boil off rate exceeds the automatic controllers range ~~abilities~~ then the kickback regulator will act as a back-up protection or next control level ~~The final protection~~. The final protection against suction over-pressurization is the relief valve~~s~~ set for 4½ psi ~~lbs~~.

The make-up system is set at 3/4 of ~~a pound~~ 0.75 psi and does not come into use above this point. If the controller is set at ½ lb. then the compressor will load up to 265 lbs. where it will stop. It is stopped by a pressure switch ~~mounted~~ in the boot circuit ~~and is~~ set for 230 lbs. This pressure corresponds to a discharge pressure of 265 psi ~~lbs~~. and maximum compressor capacity. The refrigerator will liquify all available gas. When storage gas runs out the controller will decrease capacity ~~efficiency~~ (lower discharge pressure) until boil off equals capacity ~~efficiency~~. In this way, the cool-down cycle (as well as steady-state) can be left for many hours unattended.

In practice we have not altered the 1.1 ~~lb.~~ psi set point. ~~and~~ All cooldown has been manual and closely monitored.

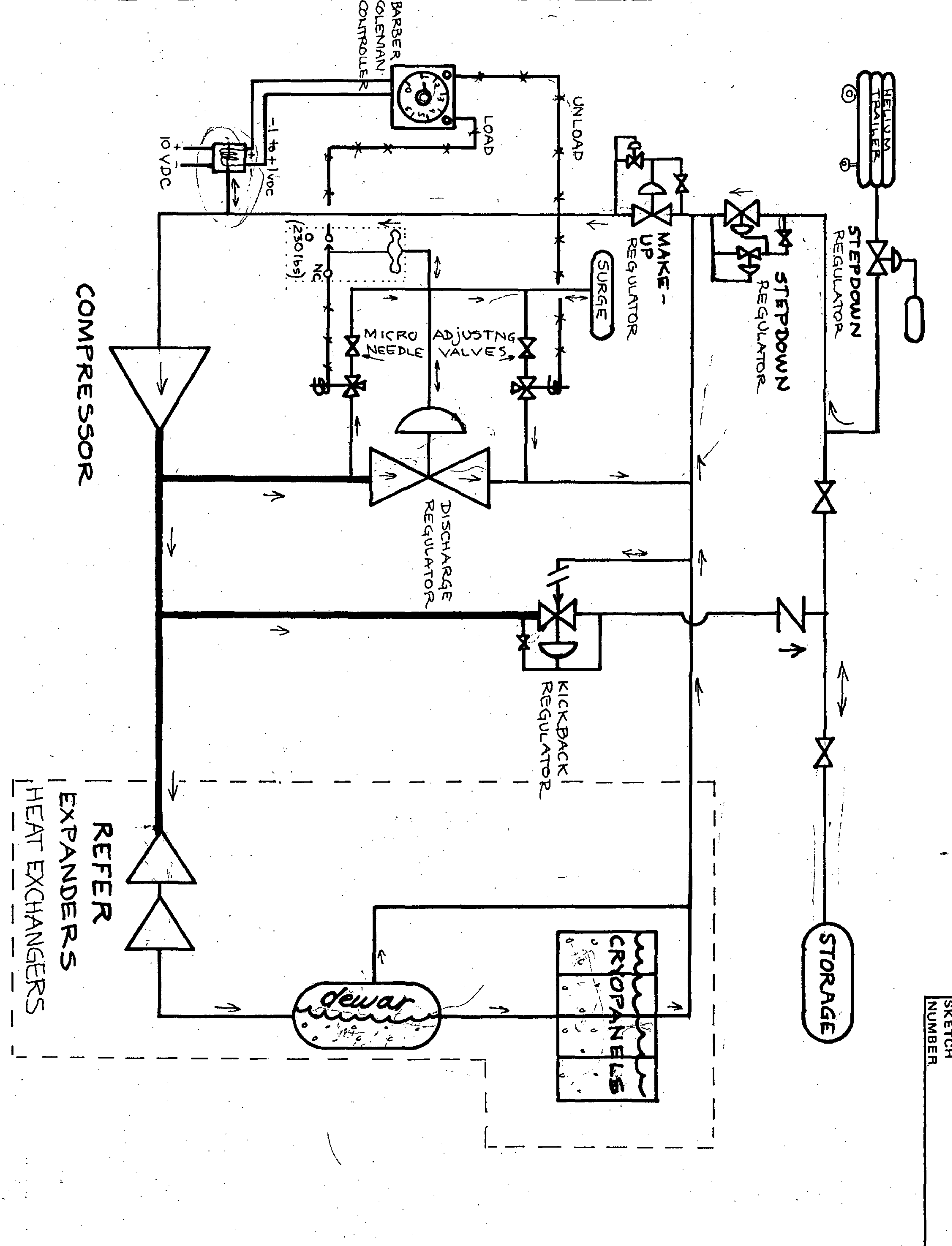
An aside here: Yesterday our LN_2 precool system for the coldbox failed and the automatic controller was forced to increase expander ~~efficiency~~ capacity to make up for the increased heat load in the heat-exchangers. The discharge pressure was raised from 150 to 200 lbs. over a period of 24 hours with a resulting drop from 20% to 10% level in our liquid helium dewar. No other changes in the liquid system were observed.

Following is a pressure ~~schematic~~ level graph showing pressure control points and corresponding functions for each pressure. Page 4 is a schematic for the automatic controller and kick back system.



TFO 200 M5700

SUBJECT NBSTF - TFTR HELIUM COMPRESSOR AUTOMATIC CONTROLLER			SKETCH LAWRENCE BERKELEY LABORATORY UNIVERSITY OF CALIFORNIA		JOB ORDER INFORMATION: Job No. page 4 of 8; Serial No. Reqd.; Date Issued; Date Reqd.
DRAWN BY Robin Curtis					
DATE 2-23-81	BLDG. NO. 6	ROOM NO. A	APPROVED BY	DATE	Deliver To

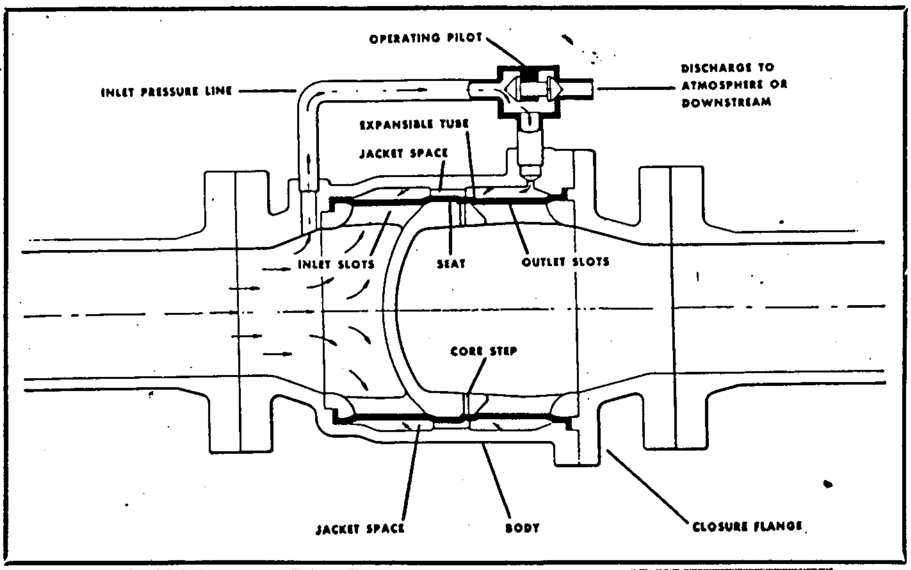


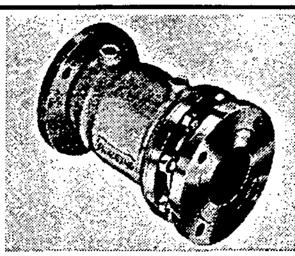
SKETCH NUMBER

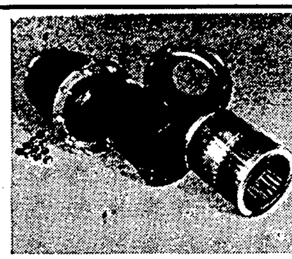
RL-112 (Rev. 8/75) 7600-55589

GROVE "FLEXFLO" REMOTE CONTROL VALVES

Designed to handle Air – Gas – Oil – Water – Salt Water – at temperatures up to 150° F.







SIMPLIFIED PARTS ARRANGEMENT

The Grove Flexflo Remote Control Valve is comprised of just four simple parts: The valve body; a flanged head; a cylindrical core; and the flexible synthetic rubber tube, which expands to open and contracts to close. There are no metallic moving parts, neither are there any complicated mechanisms to wear or cause trouble.

The Flexflo will handle air, gas, oil, water and salt water at temperatures from 0° F. to 150° F. It is ideally suited for liquid and hydraulic services, flow control, pressure control, throttling, etc.

JUST ONE NON-METALLIC MOVING PART

The one and only moving part in the operation of Grove Flexflo valves is the flexible synthetic rubber tube, which is stretched over a rigid cylindrical metal core, and firmly locked in position within the valve body by a bolted or screwed flange closure. This expansible tube is installed with sufficient initial tension to fully compensate for any degree of set the rubber may take. It is this factor of pre-determined elasticity that accounts for the positive opening and closing action of the valve. Operation is accomplished by varying jacket pressure by means of an operating pilot.

The opening and closing movements of the Flexflo are entirely free from mechanical friction and hydraulic or mechanical shock.

The possibility of the valve being held open by any solid particle wedged between seat and disc is completely eliminated in the Flexflo, positive bubble-tight shut-off being thereby assured. The Flexflo is entirely self-operating by fluid pressure; no manual force whatever is required. Moreover, where many valves are located at widely separated points, they can be centrally controlled from a single panel.

TECHNICAL DATA

The following data is provided to facilitate determination of specific Flexflo adaptations, based on technical operating characteristics and principles. The formulas contain the related functions of pressure to valve operation.

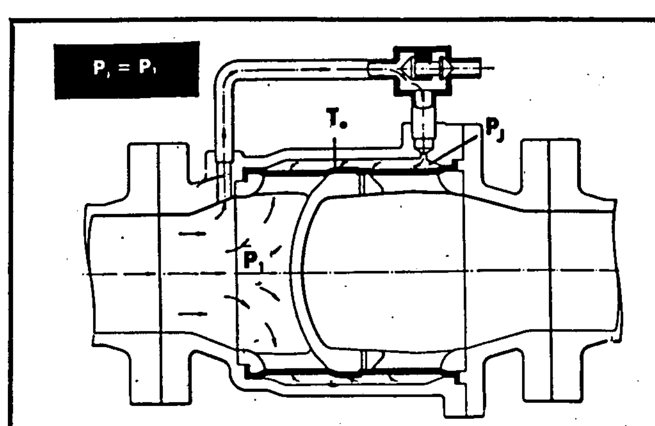
P_1—Inlet Pressure
T—Full Tube Expansion Pressure
P_2—Outlet Pressure
T_o—Initial Expanding Pressure
P_j—Actuating Jacket Pressure
P_x—Pressure under Expanded Portion of Tube
P_t—Pressure on Tube at Transition Curve

CLOSED POSITION

To close the Flexflo the jacket pressure is normally made equal to the inlet pressure. (If operated from an external source of pressure the jacket pressure may be made greater than the inlet pressure.)

When the Flexflo is in the closed position the net pressure holding the tube down over the inlet slots is $P_j + T_o — P_1$, which becomes T_o if P_j equals P_1 (the normal condition for closing).

In order to prevent the inlet pressure from penetrating the space between the core barrier and the tube, the tube must lay against the barrier with a pressure at least



GROVE REGULATOR CO. **Oakland 8, CALIFORNIA**

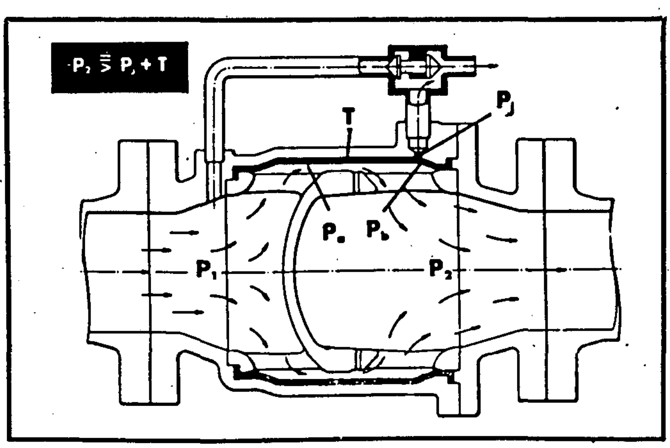
equal to the inlet pressure, P_1. Where the tube lays against a straight cylindrical section, the supporting pressure (from the core) on any small portion of the tube must balance the external pressures and tube tension applied to that section. This gives a net pressure against the core of $P_j + T_0$, which is T_0 in excess of the inlet pressure, P_1, if $P_j = P_1$.

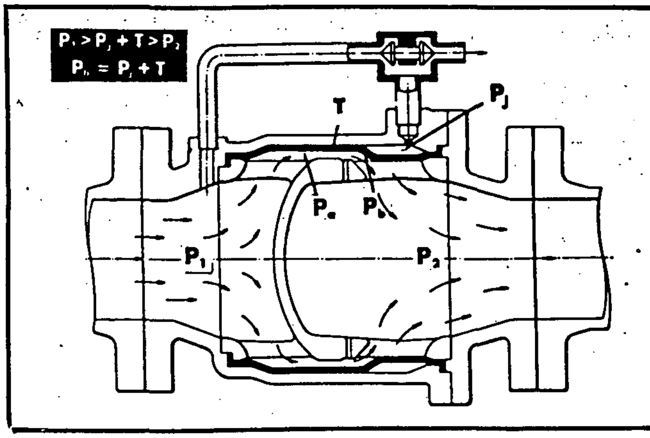
However, where a discontinuity exists, such as over the outlet ports, the resultant unsupported areas of the tube are supported from the adjoining portions of the tube, thus increasing the pressure at these points and increasing the sealing force. The presence of the step on the core barrier greatly increases this effect. The unsupported section of the tube immediately downstream from the step on the core is urged toward the core with a net pressure of $P_j + T_0 - P_2$. When $P_j = P_1$ this is $P_1 - P_2 + T_0$, which is $P_1 - P_2$ (the differential pressure across the Flexflo) greater than the closing pressure over the barrier. This unsupported load must be carried by the edge of the barrier step, greatly increasing the pressure of the tube against the metal at this point and helping to insure a tight seal. In this way the Flexflo can maintain a dead tight seal, under pressure, even without depending on the initial tube tension.

THROTTLING POSITION

When the Flexflo is throttling, the tube is completely expanded on the inlet end and completely against the core on the outlet end. The transition curve of the tube between the expanded and contracted portions occurs over the outlet slots, leaving sufficient slot length uncovered to permit the proper flow.

If there is flow through the Flexflo the pressure, Pb, acting on the transition curve position of the tube is less than P_1 due to two factors. The first is the pressure drop thru the inlet slots. The second is the reduction in pressure due to the high velocity between the core barrier and the tube (Bernoulli's Theorem). The pressure acting on the expanded portion of the tube, Pa, will vary with position in the Flexflo but will, at all points, be greater than Pb due to friction drop, velocity effect, etc.





The outlet pressure, P_2, (under flow) is less than the inlet pressure, P_1, by the pressure drop thru the inlet slots (wide open) and the pressure drop thru the outlet slots (open to throttling position).

At the transition curve of the tube the pressures must be just balanced for throttling and so:

$$\left.\begin{array}{r} P_b = T + P_j \\ \text{or } P_j = P_b - T \end{array}\right\} \text{ For throttling conditions}$$

On the expanded portion of the tube the outward pressure is Pa and the inward pressure is $T + Pj$.

$$\begin{array}{ll} P_a > P_b & \\ \text{and } P_b = T + P_j & \\ \therefore P_a > T + P_j & \text{For throttling conditions} \end{array}$$

Thus the tube is held out against the body wall in the expanded portion under throttling conditions.

The pressure under the contracted portion of the tube is the downstream pressure, P_2, which is less than Pb under throttling conditions.

$$\begin{array}{ll} P_2 < P_b & \\ \text{and } P_b = T + P_j & \\ \therefore P_2 < T + P_j & \text{For throttling conditions} \end{array}$$

Thus the outlet end of the tube is held hard against the outlet core ribs under throttling conditions.

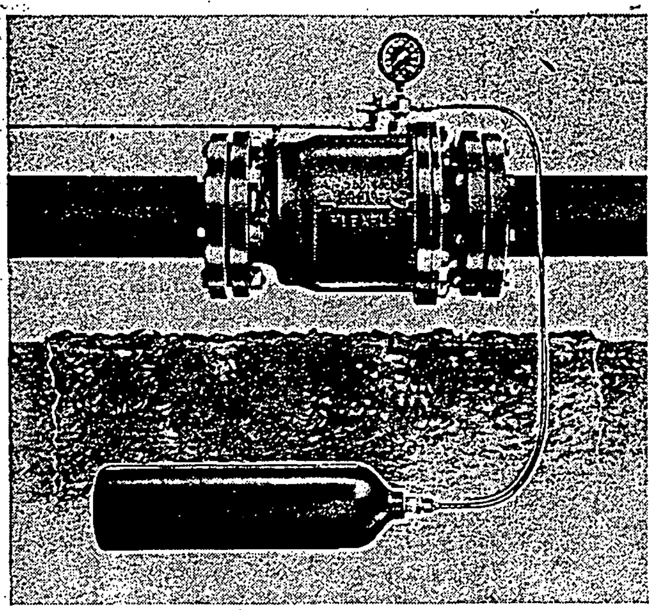
If under throttling conditions either Pb or Pj changes so that Pb is greater than $Pj + T$, the unbalanced pressure will roll the transition curve of the tube ahead, uncovering more length of the outlet slots, until the increased flow reduces Pb to the balancing pressure. If Pb or Pj changes so that Pb is less than $Pj + T$, the action will be reversed so that the Flexflo will throttle down until equilibrium is reached.

WIDE OPEN

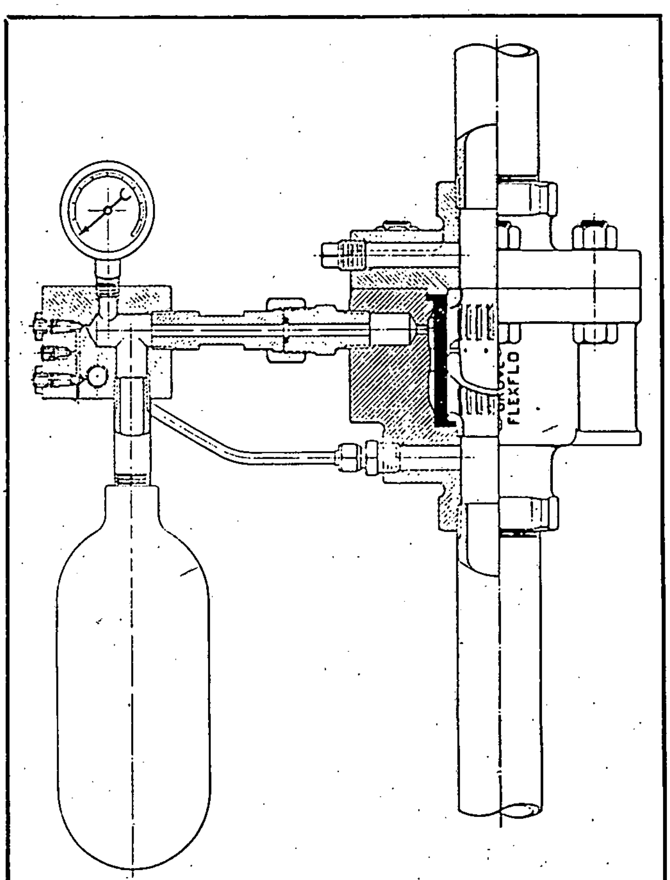
If P_2 is equal to or greater than $T + Pj$ the valve will be wide open as any throttling action would cause Pb to be greater than P_2 and hence greater than $T + Pj$.

Actually the velocity effect on Pb very nearly offsets the pressure drop thru the outlet slots when the valve is wide open, so that under this condition Pb very nearly equals P_2.

GROVE FLEXFLO Dome Pressure Loaded Reliever . . . Model 888



Reliever installed in horizontal line with cylinder buried.



Flexflo Reliever installed in vertical gas line with cylinder attached directly to Flexflo.

The Grove Flexflo Reliever is a combination of the Flexflo valve with a gas cylinder and a manifold, permitting the loading of the Flexflo jacket and the cylinder from an external source to any desired pressure. The combination forms a relief valve with an unusual operating principle, smooth and positive in action, giving dependable service that cannot be obtained from any other form of relief valve.

So sure is the action of the Flexflo Reliever that one of its greatest applications is for use in parallel with a spring loaded relief valve, pop valve or bursting disc where these are required by law or underwriters regulations. Set to relieve at a pressure slightly under the conventional valve, the Flexflo Reliever is an unfailing answer to common relief valve problems such as leakage and failure to operate.

Because of its smooth non-chattering operation the Flexflo Reliever may also be used as a back pressure regulator for continuous or intermittent operation.

In applying the Flexflo principle to pressure relief service, we find that the confined gas will be compressed, with a consequent increase in pressure before the Flexflo tube has moved enough to start to open the valve. Further compression of the confined gas with its attendant pressure increase must take place before the Flexflo can open to its rated capacity.

Because pressure increases caused by the compression of the volume contained in the Flexflo jacket would be of considerable magnitude, it is desirable to attach a relatively large volume gas cylinder to the Flexflo jacket. This decreases the ratio of change to total volume, minimizing the pressure increases.

Since ambient temperature changes affect the pressure of gases in closed vessels, the Flexflo Reliever is provided with a flexible copper tubing connection between the Flexflo and the cylinder, so that the cylinder can be buried to protect its contents from atmospheric temperature changes.

When slight variations in relief pressure due to temperature changes are not of importance, the cylinder may be attached directly to the Flexflo as illustrated in the drawing on the left. As this drawing also shows, it is possible, on gas services, to load the Flexflo jacket and cylinder directly from the Flexflo inlet. This is practical when it is desired to have the Reliever open at a pressure slightly above the normal line pressure.

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AUTHOR Curtis Byrns	DEPARTMENT Mech	LOCATION Berk	DATE 3/24/81	

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