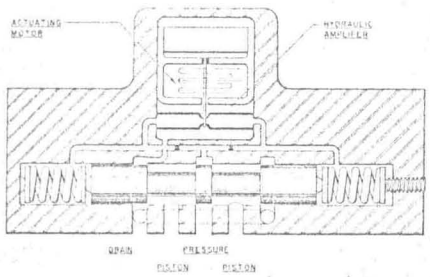

Figure 4. Electrohydraulic servo valve

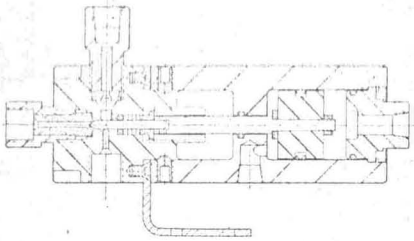

Figure 5. Hydraulically actuated process valve

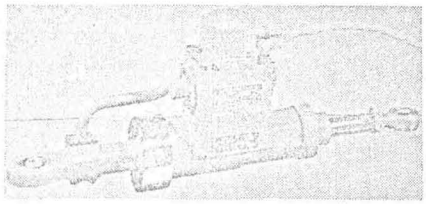

Figure 6. Electrohydraulic valve positioner

transformer was added to inject a small amount of "stick off" voltage, sometimes called "dither" voltage. The third component was an electrohydraulic servo valve of smaller and more customary size than the one shown above. The one used for letdown control (Figure 4) was rated at 6 gallons per minute.

The high temperature, high pressure, and high speed letdown valve (Figure 5) was the most successful of any tested (10-minute life). It was used in the fourth approach, where limited operating life ceased to be a problem.

4. The simple servo system was modified to produce a higher degree of oscillation than was inherent in this integral controller. The amount of dither injected was 5 to 10 times the direct current signal which produced full output.

In the first tests with this controller, the letdown problems vanished. Operating life of the valve was essentially indefinite and pressure deviations were too small to be indicated by the gages. Whenever a pellet condensed, the valve snapped open, passed the pellet, and closed before the reaction pressure showed appreciable deviation.

The chemical uses for a control of this type are obvious. One useful component has not, however, been mentioned. Figure 6 shows an electrohydraulic positioner, which incorporates the same servo valve in a package with an integral hydraulic ram. The latter corresponds to the hydraulic actuator which is otherwise part of the process valve. This package also includes a sealed slide-wire to indicate position of the ram which would be directly connected to the process valve stem. This position feedback signal offers many more circuit possibilities than the simple servo system particularly to achieve true proportional control action in which the valve position is proportional to pressure error.

Linearization of Controls by High Dither Techniques

The usefulness of high amplitude dither was recognized by Oldenburger (*1*) to provide satisfactory stabilization in hydraulic control systems of the high dither type. Successful application for several other control problems has shown, further, that Hither is a powerful tool with more than one use in the control field.

Pertinent design criteria include the following:

The use of Hither may be indicated when controllers oscillate wildly and when the maximum gain for stable operation fails to hold the deviation within tolerable limits.

The magnitude of alternating current ampere-turns in the servo valve coil should be 5 to 10 times greater than the direct current ampere-turns required to saturate the servo valve.

The frequency of Hither should be much higher than the frequency of self-oscillation in its absence.

The frequency of Hither must not be so high that any element of the hydraulic amplifier ceases to move.

Vibration of the stem of the process valve should be invisible, but discernible by touch.

Satisfactory operation in closed loops can be obtained at higher signal frequencies when Hither is used.

Summary of Response and Needs for Speed

The responses achieved with the controls described are somewhat higher than their nominal ratings, as maximum outputs are seldom required at the small strokes of high pressure valves. Estimated and small signal responses for the components illustrated have been tabulated to serve as a guide for the initial selection of control techniques for new applications.

The names applied to the controls and examples indicate where high speed controls have been used by the rocket industry. Requirements for speed of control are similar in both fields. Table I tabulates the reaction properties that influence relative requirements for high speed controls.

Table I. Relative Importance of Speed of Control for Various Reactions

Tolerance for Reaction Fluctuations	Sensitivity (Explosion Hazard)	System Compressibility	Relative Need for Speed
Any	High	Any	Required for safety
Narrow	Moderate	Hard	Required for operation
Wide	Moderate	Hard	Convenient or economic
Narrow	Moderate	Soft	Convenient
Wide	Low	Soft	Not recommended

Ultimate Response Capabilities of Selected Components

Title	Pertinent Ratings, Lb./Sq. Inch	Response, Cycles/Sec.
Instant-action shutoff valve	130,000	7 μs.
High frequency pressure transducer	25,000 (adapter)	250,000
Precision pressure isolator	30,000	250 (est.)
Servo valve for large plants	60 gal./min.	82
Magnetostriction valve operator	(1000-lb. thrust) (0.001-inch stroke)	10,000 (est.)
Magnetostriction motor	300-lb. thrust	50 (est.)
Simple servo system	6-60 gal./min.	190
Electrohydraulic servo valve	6 gal./min.	190
Hydraulically actuated valve	30,000	200 (est.)
Electrohydraulic positioner	300-lb. thrust	65

Literature Cited

(1) Oldenburger, Rufus, "Signal Stabilization of a Control System," ASME Paper 56-A-92, ASME Annual Meeting, New York, Nov. 25 to 30, 1956.

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