valve, 100 hp. for low back-pressure loads, is capable of shifting even massive pipeline-sized valves. Responses to 50 cycles per second are not too difficult, as the hydraulic servo valve is itself responsive to frequencies approaching 100 cycles per second.

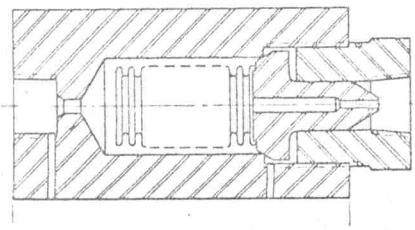
The resemblance between a power plant of this type and a large processing reactor suggests that high speed controls may be used to improve mixture ratios in reactors, to increase the margin of safety with reactions that tend to run away, and to reduce pressure and flow fluctuations in the processing plant. In the example cited, use of high speed controls permitted a striking reduction in the size of supply tanks, for the valves were fast enough to correct for the rapid decay in supply pressures which occurs at peak flow demand.

A similar controller for a smaller power plant eliminated pump and compressor surges that had previously required high pressure surge tanks.

Letdown Controller with Essentially Zero Dead Band

A third application for high speed, high pressure control is in the letdown of reaction products produced in some highly energetic reactions. Speed may be important in such chemical processes for several reasons, such as very low tolerance for either pressure or flow fluctuations. In processes involving a high potential for explosive side reaction, control speed is dictated by safety. The example here involves both narrow tolerances and explosive tendencies and concerns a research train for the study of optimum parameters for the production of better propellants. The desire for more powerful rocket propellants implies directly that a better propellant contains an extreme of chemical energy, and as a rule, these advanced propellants are increasingly hazardous to handle even in small quantity.

Approach to Problem. Letdown specifications for this research plant were almost prohibitive, and four completely divergent approaches were required to find a solution. The specification called for a minimum response of 50 cycles per second, a leakage tightness equivalent to 0.0001-inch orifice, and a maximum flow area equivalent to 0.001-inch orifice. Even more critical was the requirement to throttle the flow smoothly



Precision isolator for pressure instruments

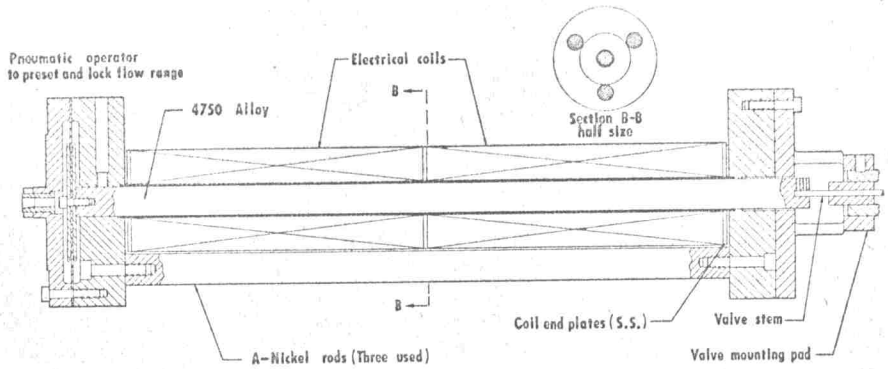


Figure 1. Magnetostriction valve operator

and repeatably anywhere in this range to a resolution of 1 part in 1000.

1. Commercial controllers with this resolution (but considerably larger ranges) were the obvious choice for initial work. All products tested were initially capable of meeting the leakage requirement; none held any promise as to response. Simple tests were made on-line: As the pressure built up to the set point, very little flow occurred; upon passing the set point of 10,000 pounds per square inch, the valve not only opened but completely vented the system, before it closed. In spite of the hazard of increasing the amount of potentially explosive intermediates, small surge tanks were installed, but were found useless.

2. A magnetostriction valve was designed. Although devices of this type were granted letters patent in the early 1800's, search for design data revealed little information. The valve shown in Figure 1 was evolved and tested in the laboratory. Just as the laboratory data looked promising, it became known that reaction products were condensing directly into solids as they left the catalyst region of the reactor. It was obvious that a successful valve would have to clear pellets 0.01-inch diameter rapidly, if upset were to be avoided. The magnetostriction valve held no hope of movements approaching 0.01 inch.

Although long-stroke magnetostriction devices were unknown at the time of those tests, a high speed, magnetostriction stepping motor was recently put on the market. Figure 2 shows that hydraulic clamps are sequenced to add the movements of separate magnetic pulses. (The device is currently incorporated in several milling machines where strokes of many inches may be required.) Study of its use in machinery for cybermation indicates that this device could be used to position valves requiring less than 300-pound thrust.

3. The pellet problem spurred interest in a third approach. The simple servo system (Figure 3) was put together in spite of theory which said it would oscillate. Stock aircraft components were used in this necessarily unstable circuit. In its first test on line, it held pressure so constant that variations could not be seen.

This control was considered successful, for it permitted collection of a minute sample before the letdown valve fell apart. In ensuing months, the life of letdown valves was a problem, being 5 to 10 minutes. Every trick was tried to reduce the destructive hammering of the letdown valve, to obtain longer life. Fourteen methods of stabilization were attempted, but in each case the valve stayed closed until pressure exceeded the set point and then completely vented the system. Alternative designs served no better.

The components of this system effected integral action, and the change in system pressure produced by a measured error was proportional to the time integral of the measured pressure error. The components included, first, a standard aircraft pressure transducer of the slide-wire type; its range was selected to be twice the desired operating pressure. A low voltage "filament"

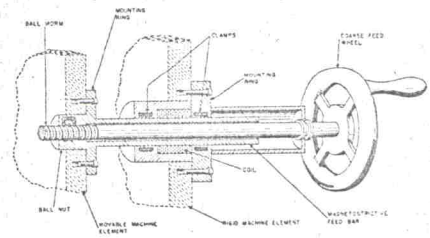


Figure 2. Magnetostriction operator for long strokes

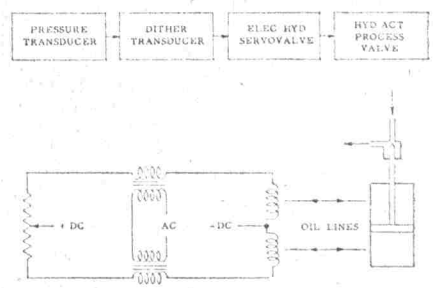


Figure 3. Simple servo system integral action