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Very Fast Flow Control Techniques

High speed controls for high pressure systems, resulting from work on rockets and jet engines, can be applied in the chemical industry

THE ROCKET INDUSTRY's activity in the field of high pressure is so little known that its interest in high speed controls for pressures above 10,000 pounds per square inch may be surprising. The extent is suggested, however, by the diversity of controls developed for application to rockets. Within the framework of response of 50 to 10,000 cycles per second, four examples of unusual controls indicate their use in the rocket industry and suggest their usefulness and performance in chemical applications: instant-action vent valve to generate pressure steps, proportional operator for complex arrays of large valves, letdown controller with essentially zero dead band, and "linearization" of controls by high dither techniques.

Instant-Action Vent Valve

A valve of this type was needed in an ordnance research program. It appears to have use for analysis in the design o chemical plant.

In ordnance research, the instantaneous pressures within the gun barrel are significant, but are difficult to interpret from the data. In-place calibration of the pressure transducers is necessary to determine the frequency response of the measurement system. Perhaps the only feasible method for measuring the response of gun gages under pressures to 75,000 pounds per square inch involves the instantaneous release of breech pressures of accurately known value. If such a step pressure is completed ten times faster than the gage responds, the theory of pulses indicates that the record is a true picture of gage response. The problem then is essentially to devise a step pressure generator standard to release a series of precisely known breech pressures in essentially zero time.

Attempts to build an ideal step pressure generator never perfected signals that decayed in one tenth of the transducer period, for gun transducers are frequently capable of response to 160,000 cycles per second. Ideally, the standard would complete the release of pressure in less than 0.000001 second. A useful degree of success, however, was attained with a standard that incorporated an instant-action valve. Large air ports were provided above and below the diaphragm to maximize operating speed. Conventional use of a large four-way air valve direct-connected to an adequate air supply (50 to 100 pounds per square inch) resulted in time rates of pressure release as high as 100,000,000 pounds per square inch per second. On the basis of corrections for the effects of finite decay time, it is believed that the step pressure standard has generated steps with decay time of about 0.000007 second.

Many applications of such a response may not exist in the chemical industry, but in larger setups the response falls rapidly to values that might be useful. One suggested use is to block the propagation of detonative reactions which can be sensed upstream of the very high speed valve used here. The combination of valve and sensor appears to be feasible, as at least one transducer offers adequate response for frequencies as high as 250,000 cycles per second. The precision pressure isolator may be useful in some corrosive situations, but the response is highly dependent on careful filling.

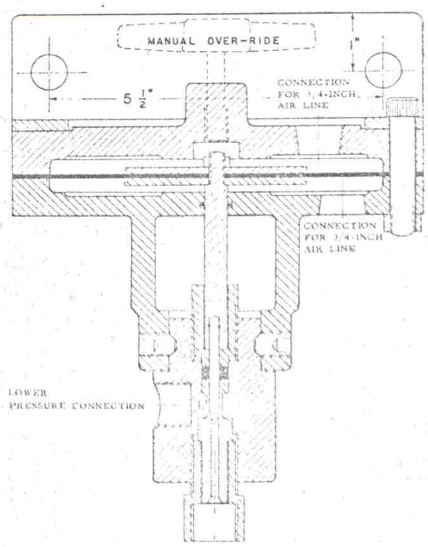
The instant-action valve has obvious use as a relief valve when connected to a suitable pressure-actuated pneumatic relay, and it offers the advantages of narrow differential and tight reseating. Its high speed ability would be wasted unless the reaction tends to run away and requires high speed venting to control that tendency.

Proportional Operator for Complex Arrays of Large Valves

A second example of a high speed control occurred in the development of a chemically fueled power plant. An output rating just under 100,000 hp. required large valves (8-inch pipe size) to control the flow of propellants during start-up and in response to combustion pressure. The application cited was not intended to operate at 10,000 pounds per square inch, but the valve controllers developed for this application are equally usable for any processing pressure for which linear motion valves can be obtained.

Control specifications based on computer solutions required three main valves of different sizes, mutually synchronized to deliver propellants in burnable mixture ratios at all times and ultimately capable of 50 cycles per second response. The difficult specification was, however, that inaccuracies in relative flows of the three propellants must be controlled so that transient errors in relative flows integrate to zero in 1 second—to prevent accumulation of unburned propellants. The set of valves was further required to hold pressure within a few per cent of nominal in the presence of far larger magnitudes of disturbance—and again the error must integrate to zero within a few seconds. An 8-inch valve was the largest in the set.

The important component of this controller, which used hydraulic oil at 3000 pounds per square inch to drive the main process valves, was an electro-hydraulic servo valve. Input signals of only 64 mw. deliver a full output of 60 gallons per minute. Complex signal networks are readily assembled to meet specifications, as the signal level is so low. The high output rating of the



Critical component of the step pressure standard is the instant action valve