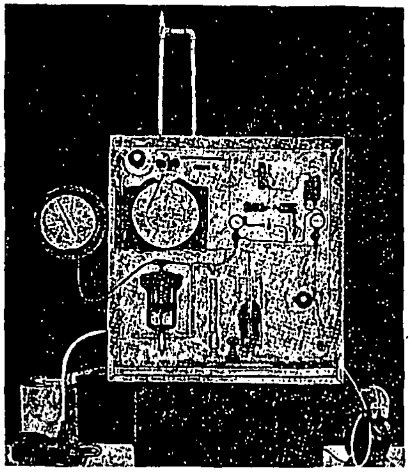
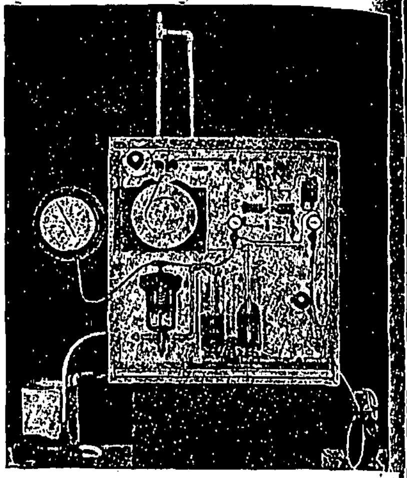
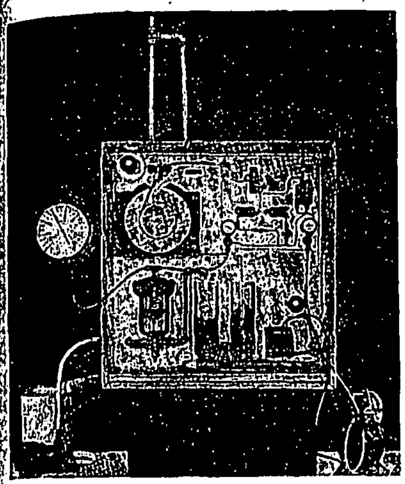


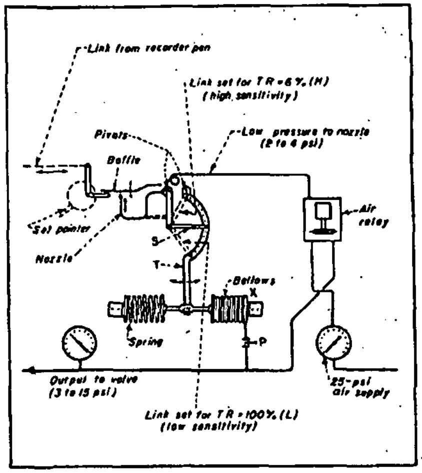
1 Using a bellows to position nozzle gives controller linear and proportional action for every position of baffle



2 Employing 2-tank system and restricting valve illustrates effect of introducing time lag between inflow and float



3 Opposing pressure-loaded bellows replaces loading spring of Fig. 1 and 2 to give a reset action to a controller



4 Bellows loaded by output air pressure moves the nozzle proportionately to keep it a proper distance from baffle

Working Model Simplifies the Theory of Automatic Control

With a demonstration panel it's easy to instruct plant men in operating and caring for control instruments. Conclusion of a 2-part *lecture* by G F Akins, instrument engineer, Eastman Kodak Co

▶RECALLING THE STATEMENT in Part One (POWER, Sept 1948, p 82)—that one major requirement in a controller is to allow a baffle travel of 0.25 in.—let's find out how we can permit such movement and still hold nozzle-baffle clearance within 0.002 in.

If the nozzle can be made to move through a given distance, and its travel be proportional to the instrument's output pressure, the baffle can be moved a total distance of 0.25 by using a suitable mechanical arrangement. Yet the nozzle will always maintain a slight clearance with the baffle.

Minute clearance changes noted in the low-pressure nozzle become useful in the new scheme, since by utilizing an air relay, the slightest change in baffle clearance causes an immediate change in output from the relay. The problem now becomes one of converting output pressure change into proportional mo*tion of the nozzle to cause it to seek out* the baffle's position.

Bellows Pressure. A ready means of transforming pressure changes into motion is a spring-opposed bellows. By increasing or decreasing pressure within the bellows, motion of its free end is proportional to the pressure change. Incorporating the bellows motion to position the nozzle. Fig. 1, we have a controller that produces linear and proportional action for every position of the baffle.

In Fig. 4, *pen motion through a* connecting link (upper left) and a pivoted lever raises or lowers the baffle 0.25 in. as the pen travels full chart width. Below the baffle, a nozzle rotates about a pivot to hold continuous alignment with the baffle.

Backpressure created by the nozzle is carried to the air relay (at right) which *gives an instant change of output pres*sure at the slightest change in low-pressure impulse from the nozzle. Air output line from the relay divides into two branches—one line going to the main control valve and the other to bellows X. A spring opposite the bellows provides a movement proportional to the *change in output pressure*. Bellows and spring are designed for a total travel of ½ in. when output from the instrument changes from 3 to 15 psi.

Lever T, pivoted at its upper end is so arranged that any change in bellows position is transmitted to the nozzle by adjustable link S. With link in its extreme lower position (point L), bellows motion of ½ in. causes the nozzle to move 0.25 in. For every value of output pressure, there is a definite and corresponding nozzle position.

Nozzle Follows Baffle. As we place the baffle in midposition of its 0.25-in. travel and turn on the air, the extreme clearance between nozzle and baffle causes the output pressure to climb rapidly to 9 psi, and thus force bellows X to expand to its midposition. This motion, through link S, causes the nozzle to move to its midposition and *establish a clearance of 0.004 in. with* the baffle. Slightest deviation from the 0.004-in. clearance causes an immediate change in output, thereby producing corrective action through the bellows and linkages to reset the nozzle. For any other baffle position, a corresponding output pressure positions the nozzle at prescribed distance from the baffle.

Placing link S in its lowest position to produce a throttling range of 100%, let's investigate proportional response of the *new device*.

Setting the pen at O on the chart, output from the controller becomes 3 psi and the control valve is fully closed. Moving the pen to 50 gives 9-psi output, and finally as the pen is moved to 100, output increases to 15 psi and control valve is wide open. For any other pen position, Fig 7, output pressure has a *corresponding* and proportional value, Table 1, p 92.

Setting the loading petcocks at 50% load, the controller creates 9-psi output pressure, Fig. 1, to open the control valve to its 50% flow rate. The process becomes stable and remains so as long as load does not change. If we increase the load to 75%, tank level drops and pen moves to 75; baffle assumes a new position and output pressure registers 12 psi, causing valve to reach its 75%-flow position.

Process is again in balance, *but not at desired control point of 50 on chart*. This demonstrates that any proportional-type controller, whether the design is simple or complicated, *follows* the same pattern; that is, to correct for a process-load change, measured level must rise or fall to send corrective impulse to the control valve.

Results Gained. At first glance this controller appears little better than a simple float valve but remember we wanted to operate large valves from small impulses generated by a bourdon spring or similar device. Our controller not only fulfills these requirements but allows far greater adjustability than does the *mechanical leverage of* the float valve. A new control point can be readily established by merely moving the set pointer, Fig. 4, to change baffle-link pivot position. The throttling (proportioning) range of the instrument can easily be altered by moving link S to a new position on arm T.

Suppose we move S to its midposition. Pen now traverses only 50% of chart to produce full output change of 3 to 15 psi. To reduce amount of offset with load change we may wish to reduce the throttling range to the minimum, as, for instance, placing link S in its uppermost position to produce 6% throttling.

If the process has favorable control characteristics, *this setting may over*come the difficulties of offset because a very slight motion of the pen is enough to reposition the valve to a new flow rate. If the process is of a more difficult nature such narrow throttling is undesirable. As an example, let's investigate the influence upon controller settings as established by the process.

*P*utting in operation a controller with 6% throttling range, we find it very unstable. Chart curve is similar to that of an on-off instrument. As an ex*periment*, let's transfer this controller to a process having a greater tank capacity, Fig. 2. We can do this by installing a second tank in the line. Following a number of overshots, the control finally becomes stable. This shows process characteristics, such as capacity, affect proper adjustment of a controller.

The double-tank *system represents*