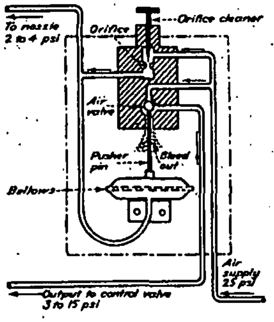
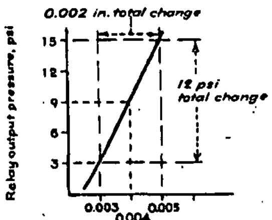


14 Amplifier or relay valve transforms nozzle impulse into high pressure



15 Combination nozzle and relay, Fig. 14, gives an almost linear response

to 0.0015 in., causes backpressure to drop from 15 to 9 psi and move the controlling valve from full-open to 50%-open position. The valve has thus been moved through half its stroke by a slight baffle motion, one-thousandth of an inch.

Mechanism Backlash. Linkages between the recording pen and baffle must be entirely free of backlash or lost motion if the baffle is to be accurately positioned to match the pen arm's position. In building such a linkage we would undoubtedly introduce friction because of tightly fitted pivots. As we sought to reduce friction, the problem of lost motion would again appear.

After rebuilding the linkage system, *we would conclude that the scheme was* impracticable for a commercial-type controller and would turn to some means of obtaining greater baffle travel to lessen the effects of lost motion. By increasing baffle movement to 0.25 in., we could permit an accumulated lost motion of 0.001 in. with little effect upon instrument accuracy. This would permit manufacturing linkages within practical tolerances.

Another fault in the *on-off* design is evident in the table. A change in nozzle-baffle clearance of 0.0005 in. causes an output change of 3 psi at one point while at another a change of 0.0085 in. is required to produce an equal change in output. This represents a 17 to 1 ratio in the rate of response. In other words, if output pressures were plotted against nozzle-baffle clearance, the resulting plot would be a nonlinear curve, Fig. 12.

Such nonlinearity cannot be permitted if the controller is to be truly proportional in its response.

Further experimentation with the baffle mechanism reveals that whenever backpressure at the nozzle reaches the upper limit, jet effect from the nozzle lifts the baffle slightly, causing an erroneous response in controller action. To overcome such a condition it appears logical to limit backpressure to a relatively low value, such as 4 or 5 psi.

Orifice Restriction. As a final step in our analysis, consider the capacity of the *on-off* device to supply air to a large diaphragm valve. We find the orifice employed to restrict air flow to the nozzle also limits the quantity of air delivered to the diaphragm. Flow rate to the valve being slow, its response will be sluggish. To get rapid valve action, we have to use some form of booster air valve. The design of a truly-proportional controller should, therefore, include the following features:

1. The baffle should have a total movement of at least 0.25 in. to compensate for lost motion in the linkages.

2. Output pressure should change proportionally with baffle movement because its position corresponds directly with that of the pen.

3. Nozzle backpressure should be low (maximum of 4 or 5 psi) to improve the linearity of response and to minimize baffle deflection.

4. Controller should have ample output capacity to rapidly inflate large valve diaphragms.

As a starting point in designing an improved controller, let's see how a small-diameter nozzle acts when operated under low backpressures. Experimenting with a nozzle diameter in the *range from 0.020 to 0.030 in. and a* restricting orifice of about 0.011 in. we can plot backpressure versus nozzle-baffle clearance, Fig. 13.

It is evident that the response curve is far more linear than that obtained with the previous design where the full range of 3 to 15 psi was impressed on the nozzle. We get the greater linearity by using an extremely small pressure change; that is, the smaller the increment of change, the nearer the response will approach straight-line performance. It appears, however, that we are now dealing with extremely small changes in nozzle-baffle clearance because total change represented on the graph is only 0.002 in. Naturally, such minute movement cannot be tolerated if controller action depends solely on a clearance change. But as our design continues we will discover that such small deviations can be used advantageously.

Air-Relay Valve. To make use of the improved linearity of the low-pressure nozzle, yet provide the desired air pressure range to the control valve, we conclude that an amplifier or air relay, Fig. 14, is required to transform the nozzle impulse of 2 to 4 psi into an output range of 3 to 15 psi.

Supply air is admitted on the right side and feeds two branches, one to the orifice, another to the air valve. The orifice restricts flow of air to the nozzle as in the previous designs, but here the air line leaving the restricting block branches out to feed both the nozzle and a small bellows below the air valve.

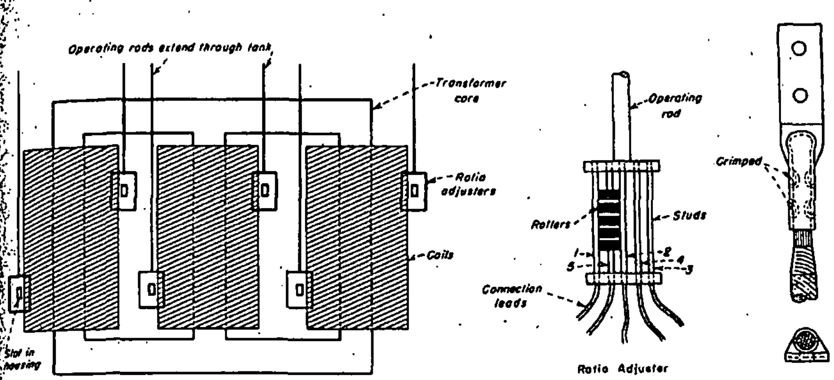
In this design any change in nozzle pressure causes a pusher pin, attached to top of bellows, to position a small ball between two seats, the upper seat being the supply port, the lower seat acting as an exhaust port. As the ball assumes a position between the two seats, a given amount of air flows in the supply port and a corresponding amount flows out the exhaust port.

The resulting pressure created in the valve chamber varies with the ball's position, hence this pressure can be utilized as the output from the relay. An air tube connects the air-valve chamber with the final control valve and is labeled output. Capacity of the supply and exhaust ports can be made large enough to meet the demand for rapidly filling a large-diaphragm chamber.

Such a relay converts the small impulse received from the nozzle to an output pressure of the desired magnitude. Graph in Fig. 15 combines the characteristics of a low-pressure nozzle and relay.

The improved linearity of response as obtained with the low-pressure nozzle and relay, will assist greatly in the final performance of our proportional controller.

Second part of this article will design a system of mechanical linkages that uses bellows motion to position the nozzle and apply this mechanism and other refinements to a proportional controller.



RATIO ADJUSTERS are located adjacent to transformer windings and connect by wood operating rods to external handles. After adjuster froze in position, quick repair was made by cutting it free and installing tap jumpers with solderless crimp lugs

Crimp Lugs Speed Transformer Repair

By K B HOFFMAN
Engineer, Burns and Roe, Inc.

▶ WE RECENTLY FOUND ourselves in a tough spot because of trouble which developed in the ratio adjusters of our power transformers. We have three 5000-kva, 27,000/13,600-v, single phase, oil-insulated outdoor transformers in our plant, which are grouped for bank operation. Ratio adjusters, in each coil group for changing taps while transformer is deenergized, are the bird-cage type, consisting of studs and rollers as shown above.

Ratio Adjuster Detail. Cables connect from taps in transformer winding to individual studs of tap changer. Note cable connections extending through bottom support of ratio adjuster. Springs located inside the rollers exert necessary pressure on studs. Rollers complete transformer circuit by ridging two adjacent studs in tap changer. Micarta enclosure which surrounds ratio adjuster is not shown in above sketch.

Wood operating rods connecting ratio adjusters to external handles extend through cover so taps may be changed without dropping transformer oil level. The only possible way adjusters can be inspected is to drop oil level, sit on top of core laminations and use an adjustable periscope with its own miniature inspection lamp.

Transformer load changed recently and it became necessary to change taps on low-voltage side. When ratio adjusters were operated, two on one transformer required considerable force to turn while another was frozen and could not be moved.

Problem. After taking an oil sample from both top and bottom of transformer in which ratio adjuster could not be moved, we found it dark in color with carbon particles floating in sample. Oil level was then dropped exposing ratio adjusters. Inspection showed a solid mass of carbon covering rollers and studs. In fact, contact surface between both was filled with a quarter inch of carbon residue.

There was a mad scramble to locate replacement ratio adjusters and as luck would have it, none were in stock. Since the contact condition of the ratio adjusters was a potential hazard under load it would be dangerous to put the transformers back in service as they were. High contact temperature or a spark could ignite the oil. The transformer bank had to go back in service as soon as possible since load conditions would not permit an extended outage.

Solution. After some discussion it was decided to connect the proper winding taps for the new voltage and disconnect the ratio adjusters. Tap leads were accessible so they could be cut without removing core and coil assembly from tank. Since the work had to be done inside the transformer and in congested quarters, it was decided that soldering the tap leads together would be a hazard to the men.

Compression Lugs Used. It was decided to make the *connecting jumper* using solderless compression lugs. To satisfy ourselves that this type connection would be satisfactory with the many-stranded flexible cable, a lug was pressed on a sample section. A hand-operated hydraulic press was used to exert approximately 8000 psi to press a ⅝ in. slot along both sides of lug.

A similar section of cable was prepared with a soldered lug. The two samples were given a tension test, pressure being applied between lug and cable. Sample prepared with the hydraulic press withstood more tension than soldered lug and showed distortion at bolt holes in lug before cable strands pulled free.

As a result we used compression lugs to make tap connections on all transformers and the bank was returned to service in record time. No trouble has been experienced with the installation to date and the transformers have been carrying overloads at frequent intervals. Periodic oil tests showed no color change and no further contamination as evidenced by free carbon particles.