TABLE I—OPERATION WITH LINK SET FOR THROTTLING RANGE OF 100%

Pen position on chart	*Baffle, bellows position, Fig. 7*	*Output and bellows pressure, psig*	*Valve opening, %*
0	A	3	0
25	B	6	25
50	C	9	50
75	D	12	75
100	E	15	100

Note: For every pen position, there is a corresponding position for the nozzle and baffle, a corresponding output pressure and control-valve opening.

TABLE II—STEP-WISE ACTION OF RESET BELLOWS

	Load, %	*Pressure at Y, psig*	*Position lever T*	*Pressure at X, psig*
PROPORTIONAL ACTION ONLY ($TR = 100\%$):				
1. Bellows *Y* charged with air at 9 psi; valve *R* closed	50	9	C	9
2. Load increased to 75%	75	9 plus	D	12
ADDITION OF RESET ACTION:				
3. Valve *R* opened to admit output air (12 psi) to bellows *Y*	75	12	C	12 plus
4. Process reaches new balance and original control point is restored	75	12	C	12

Note: In actual practice, valve *R* is partly opened in order to provide reset action at a rate that is consistent with the stability of the controlled process.

controller output to lead response rate of the process.

That is, if the pen were to move at a fixed rate away from the desired control point and air flow to bellows *X*, Fig. 4, were restricted by needle valve *P*, rate of follow-up motion would be retarded and the nozzle displaced from its normal relationship with the baffle. Consequently, output pressure would be accelerated in relation to pen motion. Accelerated output thus obtained *has great value in offsetting the ill effects* caused by time lag in the process and measuring element.

To produce the greatest effect, the process would be arranged to incorporate time lag, such as is imposed by the restricting valve between the tanks in Fig. 3. Then using a motor-driven loading valve to change the system load gradually, improvement in control due to rate response could be vividly demonstrated by alternately opening and throttling valve *P*.

When valve *P* throttles air to bellows *X*, controller output changes rapidly and causes control valve to supply excess water to left-hand tank, which increases its level, and thereby assists in overcoming resistance to flow offered by the *time-lag* restriction valve in the process. *Without rate response, controller* output appears sluggish and the process reaches an unstable condition because the instrument cannot send an advance impulse to control valve to offset time lag.

Finished Design. Our controller is now fully equipped with the three adjustable responses and the instrument is essentially the same as a conventional pneumatic controller. It contains the same elements and operates on identical basic principles but each manufacturer uses a slightly different mechanical design *for adjustments*.

Mechanism to adjust throttling range may be a simple arrangement of pivots and levers or a complicated assembly. Reset action may be accomplished by two opposing bellows or by applying the opposing pressures inside and outside a single bellows. Flow to bellows may be throttled by special needle valves, restricting tubes, or a unit containing variable passageways.

Next step is to design a mechanism that detects and corrects improper position of the control-valve stem. But we must avoid complicated mechanisms because the device may be installed on a valve in a corrosive atmosphere or where space is limited.

Valve Positioner. Suppose the valve stem travels one-half inch as diaphragm *pressure is increased from 3 to 15 psi.* If an accuracy of 1% is required, the stem must stay within 0.005 in. of desired setting. Such close adjustment requires a sensitive "feeler" device to detect variations of this magnitude. Let's try a nozzle-baffle system as the "*feeler*," Fig. 6.

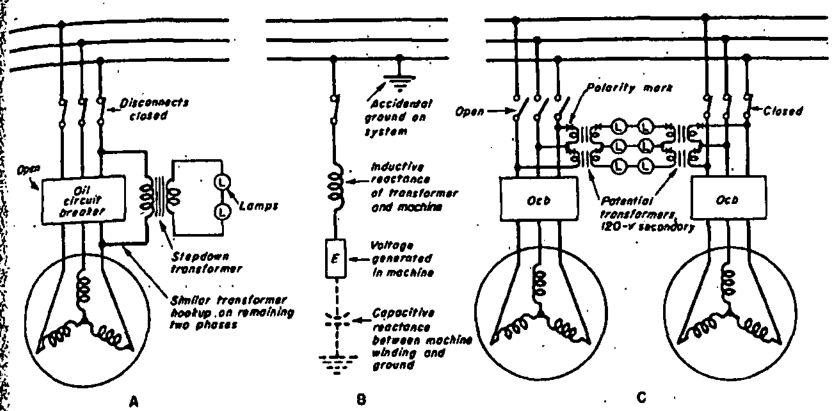
Mounted on right of valve frame is a bellows *A* opposed by a range spring *B*. This assembly, a duplicate of the follow-up unit in the proportional controller, is designed so air-pressure change from 3 to 15 psi causes the bellows to expand one-half inch. A nozzle, *C*, is attached to a plate mounted between bellows and spring. As bellows expands or contracts, plate and nozzle move to a position proportional to the air pressure within bellows. An air-supply connection, upper right in sketch, feeds air to a restriction *R* and thence to nozzle through a length of flexible tubing. A branch from the nozzle line is connected to diaphragm.

Remember that this same scheme, used in the on-off controller, can detect *a baffle movement of thousandths of an* inch. So that valve-stem position may become a function of nozzle position, a baffle *D* is mounted on a collar attached to the valve stem. Once the baffle is adjusted to a definite clearance with the nozzle, any motion of the nozzle causes a change in backpressure and thereby increases or decreases the air pressure transmitted to the diaphragm top.

Suppose the controller supplies an impulse of 9 psi to bellows *A*, and correct valve-stem position for this pressure is midstroke. As the nozzle assumes the new position dictated by the bellows, baffle is manually adjusted by sliding the collar on the stem until the baffle restricts nozzle outflow enough to create a 9-psi backpressure. As the diaphragm receives this impulse it *moves valve stem downward to midpoint* of travel. Baffle support collar should now be locked to the valve stem since the mechanism is in proper alignment.

If valve friction prevents free stem movement, baffle movement would be temporarily retarded, nozzle would continue to approach baffle, and resulting back pressure on diaphragm top would increase to full output pressure, or until the force was enough to overcome friction. Accuracy of valve response has now been improved to equal that of the controller.

Considerable credit is due John H Kowalski for ingenuity and expert workmanship in building the panel. The author also expresses his thanks to R L Clarke, F C Kiesling, N F Koenig, E W Jensen, R C Mack and Miss D E Warren for suggestions in preparing the demonstration.



HOOKING TRANSFORMERS across each phase of open oil circuit breaker is usually OK for phase-out test. Because of ground on one feeder phase, resonant condition was approached with resulting large current flow. Finished job with hookup C.

Ground Halts Generator Phase Test

One of several methods may be used in phasing-out a new ac generator. E J Kelley, of Kansas City, Mo., picked the one shown in A and ran into a resonant circuit condition

▶ PHASING OUT a new ac generator in a small plant is ordinarily a routine job. Although it requires care it does not as a rule present any particular problem. One method that is often used is shown in sketch *A*.

Phasing-Out Procedure. Using the hookup in *A*, with oil circuit breaker open, machine is brought up to speed and proper voltage. Disconnect switches are then closed. Phase rotation of new machine is OK if lamps, connected in transformer secondary, all grow bright and dim together. When lamps in each phase light and go dark alternately, phase rotation of new machine is incorrect. In this case it's necessary to interchange two of the machine leads. This is usually done at the ocb.

Some years ago we had an experience that was distinctly out of the ordinary. Using this same hookup, with machine up to speed and voltage about normal, we found one of the disconnects had not closed properly. With machine still running, the disconnect was opened. We received quite a surprise when a heavy arc broke, which indicated a large current flow. On opening each of remaining phases we noted the same condition. Our first thought was low insulation resistance in machine winding or leads. After megohmmeter tests showed everything clear, we went ahead and took another crack at phasing out.

On the third attempt lamps, connected across transformer secondary, followed no regular pattern in going bright and dark. We noted that lamps, when lit, were abnormally bright. With one set exceptionally bright, the others would only glow.

Ground On System. None of this disturbance seemed to follow the book of rules, so we looked for trouble outside the machine proper. Our first clew came when we noticed the ground detector on the operator's board indicated a ground on one of the feeders. Since the system was ordinarily ungrounded we drew a few mental connections and decided this ground was the seat of our trouble.

Referring to sketch *B*, it was evident that the grounded phase, primary of transformer and capacitance between machine winding and ground, was forming a series resonant, or partially resonant, circuit. Capacitance of machine's winding to ground may be represented as a wye-connected set of capacitors. Under normal conditions the voltage across each capacitor would be the phase or line-to-neutral voltage. But with a ground on one phase external to machine, voltage across that capacitor would be zero. Voltage across each of remaining condensers would then be the line-to-line voltage.

By applying this theory to the condition at hand, the large current flow can be explained. If circuit were in pure resonance, the only opposition to current flow would be the resistance; in most installations of any size this opposition is of negligible value. The pure resonant condition would occur if the machine's *capacitive reactance* and the inductive reactance of transformer and machine were equal. If such a condition exists it is possible to have the voltage across transformer and that between machine and ground exceed the applied voltage. Under that condition the only opposition to current flow would be pure resistance of the series circuit.

Since the fault was not cleared promptly we went ahead with our work using a hookup shown in sketch *C*. This method is used widely in many plants for phasing out as well as synchronizing.