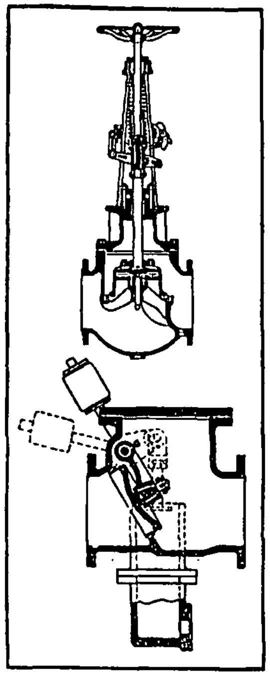
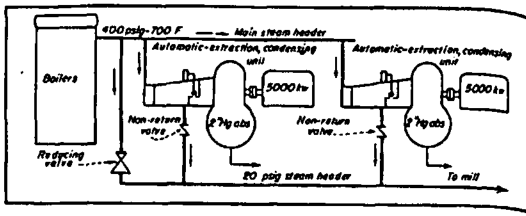


**TRIP-THROTTLE VALVE**, above, replaces the oil-tripped nonreturn valve, shown below, in the turbine-extraction line to allow the units to operate on mixed pressure




**ORIGINAL PLANT LAYOUT** featured two 5000-kw automatic-extraction condensing turbines which took 400-psig 700-F steam and supplied 20-psig steam to mill

120,000 lb per hr continuously at 400 psig and 700 F, burning pulverized coal.

The obvious addition seemed to be a new 7500-kw condensing automatic-extraction turbine alongside the existing units. But a study of steam and electrical loads showed that while the mill runs the steam demand is never less than 100,000 lb per hr. This suggested a backpressure turbine. Further study showed that a heat balance could not be achieved at all times without generating some condensing kw. Since the condensing power is always small, consideration was given to rebuilding the existing turbines to mixed-pressure operation. This could be done by simply replacing the positive-closing nonreturn valve with a trip throttle valve in the extraction line of each unit, sketch above. This allows either admission or extraction of low-pressure steam as demands require, top of next page.

Over the years, steam pressure in the driers had been raised from 20 to 40 psig; it may be raised to 50 psig later. The left-hand performance curve, at bottom of p 73, shows maximum flow to exhaust of 40,000 lb per hr with an extraction pressure of 20 psig (35 psia). Flow through a turbine section varies directly with the absolute steam pressure ahead of that section. Hence, with 40 psig (55 psia) at the extraction opening, flow through the turbine exhaust section would be 63,000 lb per hr.

**Adapting Condensers.** Each condenser has 6000 sq ft of surface and handles 40,000 lb per hr of steam. With increased steam flow through turbine exhaust, condenser capacity had to be increased. An idea to replace the existing units with new, larger ones was discarded in favor of the following scheme. It was found that by raising circulating-pump speed from 690 to 870 rpm enough water could be furnished to each condenser to handle 60,000 lb per hr of steam. With 80-F cooling water an absolute pressure of 2 in. Hg could be maintained. This requires a 50-hp motor to replace the old 30-hp one. The higher cooling-water velocity not only increases heat transfer but helps keep condenser tubes free of silt.

**Speed Governing.** To benefit most from the high efficiency of the 7500-kw back-pressure turbine, as much steam as possible should be passed through it. To do this, frequency will be held by the new unit. The old 5000-kw turbine, running parallel with the 7500-kw unit, will hold the mill steam pressure (40 psig). Speed governor of the 5000-kw unit will be set to keep its high-pressure valves closed at frequencies above 59 cycles. Thus, these valves will ordinarily be closed.

First high-pressure valve to open end the grid-extraction valve will be drilled to pass a steam leakage of 5000 lb per hr, to ventilate or cool the turbine. The backpressure turbine will furnish steam to the mill up to either its capacity or the demand. If steam demand is greater than will pass through this turbine at the prevailing kw load, the reducing valve will furnish the balance and the condensing turbine will merely float, passing 5000 lb per hr clear through to the condenser. This cooling steam will not quite carry the no-load losses so there is no danger of runaway.

If, as will normally prevail, the kw load exceeds the power generated by mill steam, the control on the grid valve will open it to allow enough steam to pass through the backpressure turbine into the mixed-pressure turbine to the condenser to generate the needed kw. This arrangement will produce any kw demand from 0 to 12,300 kw and any mill demand from 0 to 210,000 lb per hr within the limits of the right-hand chart, bottom of page 73.

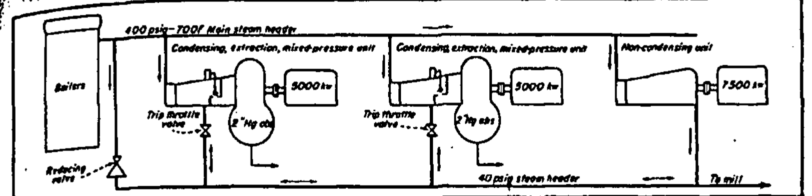
Speed governor on the backpressure turbine must govern over a kw range of 0 to 12,300 kw. This is 12,300/7500, or 164% of its rating. An ordinary

## COST COMPARISON

7500-Kw Condensing Extraction and Noncondensing Turbines

| Equipment | Condensing-extraction turbine | Non-condensing turbine |
|---|---|---|
| Turbine-generator | $237,000 | $220,000 |
| Condenser and auxiliaries | 50,000 | 0 |
| Rebuilding old turbines | 0 | 14,000 |
| New cooling-water line | 5,000 | 0 |
| Total | $292,000 | $234,000 |
| Saving in investment | — | $58,000* |
| Annual fuel saving | — | $35,000 |

* Does not include (1) lower foundation cost for noncondensing turbine (2) lower cost piping layout (3) lower turbine installation cost.




**MODERNIZED PLANT LAYOUT USES** new 7500-kw backpressure turbine, old units as combined mixed-pressure and automatic-extraction turbines. Preferred operation passes all steam through new unit first, old unit's low-pressure end as needed

4% governor would give about 6% speed change for this load range. Therefore, this turbine is being equipped with a hydraulic speed corrector to keep speed changes within satisfactory limits (±0.1% for gradual load or flow change).

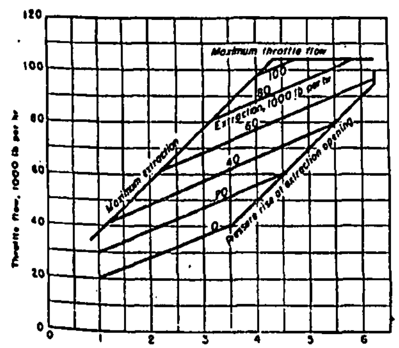
Pressure governor on the 5000-kw mixed-pressure turbine must govern for flow ranges far beyond its original capabilities. This control (1928 design) is being replaced by a modern design that will hold pressure within ±½ psi when flow changes are gradual. With these alterations it is expected that both speed and pressure governing will be successful.

**Performance Comparison.** Having determined that the turbines and condensers could be adapted easily, a study was undertaken of the economics of the alternate schemes. The turbine manufacturer furnished data on (1) the old turbines after rebuilding (2) a new 7500-kw backpressure turbine (3) a new 7500-kw condensing automatic-extraction turbine. Combined performance of a new 7500-kw backpressure turbine, operating in conjunction with one rebuilt 5000-kw condensing mixed-pressure turbine, was plotted in solid lines as shown in lower right-hand graph. Performance of a 7500-kw condensing extraction turbine, operating alone under the same conditions, is shown by the triangular points; 5000-kw unit performance is shown by the circular points.

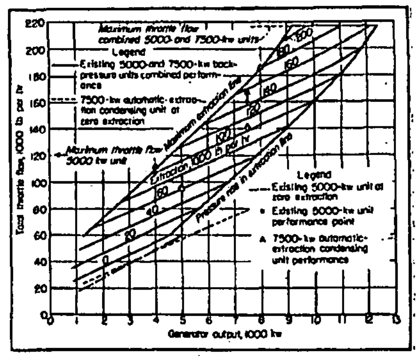
At all flows to throttle above 94,000 lb per hr the combination is best. If flows less than this prevailed, the kw load would be low enough so one 5000-kw turbine would be run alone anyway.

At 5000-kw 60,000-lb-per-hr extraction, performances of all these arrangements are identical. At high flows the combination arrangement shows as much as 20,000 lb per hr less flow for a given kw and steam demand. This is because the efficiency of a straight noncondensing turbine is so much greater than the head end of an extraction turbine. Fuel saving with this operation has been estimated at $35,000 per year.

Cost comparison of a 7500-kw condensing extraction turbine and the plan chosen is shown in the table at the bottom of p 72. The backpressure turbine is less expensive; also, no new condenser and piping are needed. A new condenser would have meant installing a new 200-ft 24-in. water line from the canal. The investment saving as listed is only partial. This figure of $58,000 does not take into account the lower foundation cost for a noncondensing turbine, lower-cost piping layout and lower turbine-installation cost. In addition to these advantages there is sufficient capacity to supply a new large paper machine when conditions warrant its installation.




**PERFORMANCE CURVES** of the original 5000-kw turbines when operating with 400-psig 700-F steam and extracting 20 psig




**COMPARISON OF PERFORMANCE CURVES** shows superior efficiency for the combined operation at high steam-electric loads