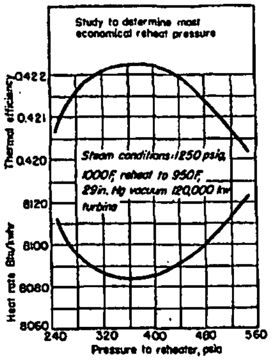
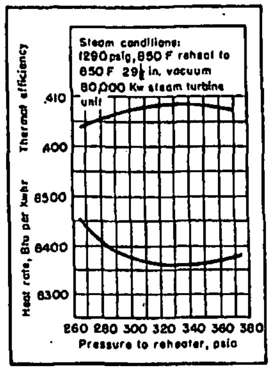
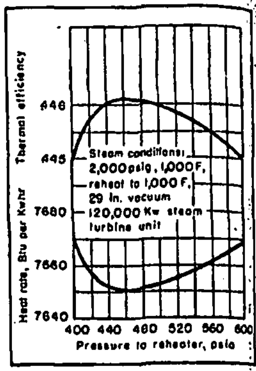


4 Optimum efficiency and heat rate for cycle in Fig. 3 occurs at 365 psia



5 All pressure and temperature levels have one best steam-reheat pressure



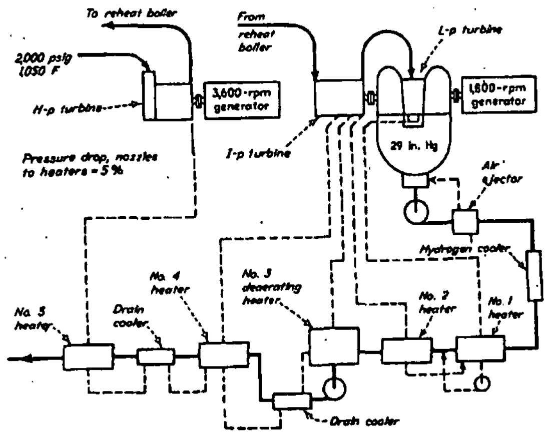
6 Optimum efficiency and heat rate for cycle in Fig. 6 occurs at 460 psia

in a moisture content less than 12 to 13%, there was a feeling among many users that the added complication and cost of reheat installations were not justified.

Also, many engineers were not ready to adopt the unit arrangement of one boiler per turbine, so well suited to reheat. Until the pressure of rising fuel costs was felt recently, less attention was given to reheat and more to increasing thermal efficiency through (1) improving regenerative cycle (2) topping turbines (3) maximum practical throttle pressures and temperatures.

Topping. Topping turbines filled a special need so a considerable number were installed in the late 1930s. Because of limited opportunities, few have been installed in recent years.

Regenerative Cycle. Also in the late 1930s, much progress was made in using the regenerative feedwater-heating cycle. Four and five stages of feed heating became commonplace in central stations; sometimes even six and seven stages were used.



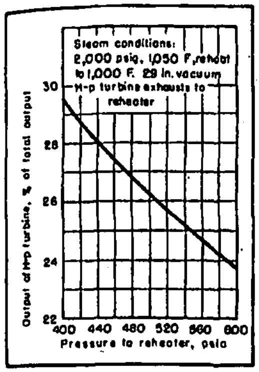
7 Cycle studied for 120,000-kw cross-compound unit with throttle steam at 2000 psig, 1050 F to determine optimum pressure for reheating to 1000-F temperature

Throttle Conditions. For 15 years metallurgical developments have permitted steady increase in allowable steam temperatures. With the gain in thermal economy through higher initial temperatures, additional cost and complication of reheat were not considered justified. The present high fuel prices, however, led to considering the combination of reheat with high initial steam conditions, even though the point fell below the Fig. 1 curve.

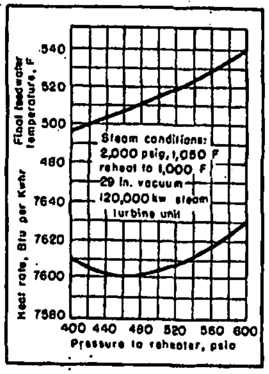
Reheat Operation. There is a definite trend toward wider use of the single-boiler single-turbine arrangement because of proved high availability of modern boilers and the necessity for keeping initial costs as low as possible. Adoption of this setup overcomes some objections to the reheat cycle, which for minimum complication needs a single boiler per turbine.

Power plants that have used the reheat cycle many years report no serious difficulties. Reheat turbines have been put on and off the line as needed with no greater difficulty than with nonreheat machines.

In earlier years, one objection was the large steam volume entrained in reheat lines that might cause overspeeding with load loss. Today, reheat turbines have intercepting valves in the line going to and from turbine to reheat boiler. These valves, under control of the main speed governor, close if turbine speed increases by about 4% above normal. This has proved a satisfactory solution to the overspeed problem without undue complication of the turbine governor gear.



8 Output of h-p turbine decreases with increase in steam reheating pressure



9 With h-p heater above reheat pressure there is an optimum value for latter

Reheat Economy. Estimates indicate that gain in economy by reheat varies from 4 to 6%. Fig. 2 compares heat rates for a typical 100,000-kw nonreheat unit and a similar-size reheat unit. For each, throttle steam conditions are 1250 psig, 950 F; exhaust vacuum is 28½ in. Hg. Feed-heating cycle is the same in both, and reheat is carried to 950 F in the reheat cycle.

Economic analysis, not given, considers initial cost, fuel cost, load factor, reliability, operating convenience, many other variables. Typical analyses show thermal gain may more than offset additional cost and complicating factors.

Reheat Pressure. To find the most desirable pressure to reheat steam for the turbine and its feed-heating cycle, calculations were based on 120,000-kw rating with conditions of 1250 psig, 1000 F at throttle, reheat to 950 F, exhaust at 29 in. vacuum. Calculations were based on the cycle in Fig. 3. This diagram is not necessarily a recommended arrangement, but merely indicates the cycle used for convenience to obtain relative results for comparison. Steam for the h-p heater in each case was extracted from the turbine at reheat belt, before going to reheat boiler. Check figures showed an extraction opening above the reheat point was not practical for this throttle-steam pressure, especially with an economizer.

Fig. 4 shows study results to find the most efficient reheat pressure for this rating. Variation in heat rate over entire range of reheat pressure is only a fraction of 1%. For the conditions set up, optimum reheat pressure is about 365 psia. Since reheat pressure can vary considerably without appreciable change in turbine heat rate, other factors like piping and valve sizes or boiler performance may indicate a different pressure to be more economical from the over-all plant view. These data check with pressures and with throttle to reheat pressure ratios on existing machines.

Fig. 5 shows a similar study for an 80,000-kw turbine for throttle conditions of 1290 psig, 850 F, and 850-F reheat temperature. This machine was actually built to give reheat pressure of 329 psia at the load point for which the analysis was made.

Consideration is being given to large reheat turbines designed for throttle steam conditions in the 2000-psig 1050-F range, reheating to 1000 F. Fig. 7 shows the cycle for making a reheat pressure analysis of a 120,000-kw turbine with these conditions. Unit is the cross-compound type with the h-p 3600-rpm turbine exhausting steam to the reheat boiler and h-p feedwater heater. Steam from the reheater expands in the intermediate-pressure turbine down to 25 psia, then exhausts to the double-flow l-p turbine in tandem with the i-p turbine at 1800 rpm.

Fig. 6 shows again that efficiency variation with pressure is only a fraction of 1%. Curves indicate a most efficient pressure of about 460 psia for turbine and its feed heating cycle.

In addition to over-all consideration of valve and pipe sizes and boiler performance, with the cross-compound turbine, generator size also depends on reheat pressure, which is the h-p turbine exhaust pressure. Fig. 8 shows output of the h-p 3600-rpm element as a percentage of total output at different exhaust pressures for this element. While this curve was plotted from calculations for the 120,000-kw rating, it can be used for close approximations for larger ratings with the same steam conditions. Since reheat pressure can vary considerably without affecting efficiency, reheat pressure may be selected to give standard ratings for the two generators.

For the results of Fig. 6, steam for the highest-pressure heater was taken from the h-p turbine's exhaust. With the cross-compound arrangement, space is available for an extraction nozzle on the h-p turbine at a point giving a pressure higher than reheat pressure, and another heater can be added to the heating cycle. This can reduce turbine heat rate about 0.6%. Whether over-all plant economics justifies this expense, higher-pressure extraction must be analyzed in each case. With an economizer before the boiler, this heater probably cannot be justified, but some power-plant designers are giving serious consideration to these extremely high-extraction pressures.

Fig. 9 shows results of determining optimum reheat pressure when a final heater at a higher pressure produces final feed-temperature. Feed temperature was not held constant in this study, but was varied so an approximately equal rise occurred in the highest-pressure heater in each case.

In this as in all calculations for data on reheat performance, a 10% pressure drop was taken in the reheat lines and reheat boiler.

Today, problems of the steam-plant designer are more complex than ever, since not only have fuel costs increased, but construction and equipment costs have also jumped in varying proportions. Further increases in pressure and temperature with the straight regenerative cycle have reached the point of diminishing returns. In this new light, designs making use of the reheat cycle are being reconsidered. Naturally, reheat is not the answer to all problems of reduction in power-generation cost but a number of cases can easily justify the additional cost of reheating.

Bibliography. "The Reheat Cycle," by W Wadkin, *Mechanical World*, March 30, 1945. "Is Reheat Coming Back?" *Combustion*, September 1947.