Discussion

Samuel H. Arnow

The method of adding or subtracting bits of energy to reflect changes in basic or auxiliary components of a thermal cycle is not entirely new. Thus, if, say, a drain cooler were added to a heater, it would decrease the steam bled to that heater and increase the flow to the next one. The designer would multiply the decrease in quantity by the enthalpy difference and add this energy to the turbine, which would give him the new heat rate. The authors of this paper, nevertheless, deserve considerable commendation for generalizing this approach and citing examples. This will enable the designers of thermal power stations to visualize the effect and assess the desirability of making various changes in basic cycles.

However, this writer wishes to add a note of caution to the concept of "optimizing" a regenerative steam cycle. To get the "best" cycle is all well and good. The trouble is, what is "best"? Is it the cycle with the least thermal rate, the least costly, or the least troublesome? One can, for example, figure out theoretically the minimum size of blowdown lines, as the writer did in his early days, only to find out that such pipes will not pass the "muck" that invariably comes with the blowdown, or that the steam fitters failed to properly ream out the lines. Similarly, an optimized solution might indicate an extraction at a certain pressure point in the turbine, but it would be well to investigate the prosaic fact that this best approach might place this extraction opening smack in the center of a blade. Surely there must be some "practical" conferences with the turbine manufacturers who generally are hard-headed businessmen who have some rather old-fashioned ideas that it might cost, say, $200,000 to develop a new blade path to accommodate such an extraction point. One would have to save a goodly number of Btu's to justify that.

Further, it seems to this writer that, in general, a general solution suffers from the fact that it is just that—a "general solution"—and must of necessity include many factors not relevant to specific problems at hand. Any user of such methods must force spend much time deciphering the various ramifications before he can eliminate all the factors which do not apply to his case. He might perhaps find it better to just use a "local" solution and obtain an answer which, while somewhat less accurate, is nevertheless adequate.

David Aronson

Even in these days of the ready availability of computer facilities there is considerable advantage to the method of small changes proposed by the authors. The man carrying out calculations at his desk is likely to get a feeling for possible cycle improvements or to consider modifications, which is not the case when preparing the program for computer handling. The computer can only follow the program fed into it. An argument can be made for each method of carrying out cycle studies, but the opportunities for creative thinking while running desk calculations should be kept in mind.

John Cruise

Sample Study of Surface Change Effects Upon Cycle Efficiency

Symbols

\[ R = \text{over-all heat transfer rate} \]
\[ W = \text{weight of feed, lb/hr} = 1.0 \]
\[ w = \text{weight of drain, lb/hr} = 1.0 \]
\[ c/p = \text{mean specific heat} \]
\[ S = \text{surface, sq ft} \]
\[ T = \text{mean temperature difference (basic feed - drain)} \]
\[ \log_a(T) = \text{log}_{10} T \]

DRAIN THERMAL EFFICIENCY

\[ \text{Drain thermal efficiency} = \frac{\Delta E - E''}{\Delta E} \]

\[ \Delta E = \text{basic heat balance} = W_c - \frac{\Delta E}{\Delta T} \]

\[ \Delta E'' = \text{basic surface} - \text{reduced surface} \]

\[ E'' = \text{surface} \]

\[ \text{Basic Feed} \]

\[ \text{Reduced Surface} \]
NOTE: Within the limit of change, the transfer rate, pressure drop, and $\log_{10} \Delta T$ are considered constant. The transfer rate and pressure drop are assumed compensated for in a final heater design by a change in diameter or length or both. The $\log_{10} \Delta T$ is of small degree.

Heat balance based on the drain system

\[
\frac{w_c/p_m \Delta T_{ai}}{w_c/p_m \Delta T_{at}} = \frac{RS(\log_{10} \Delta T)}{R(S \pm \Delta S) \log_{10} \Delta T} \]

\[
\frac{w_c/p_m \Delta T_{ai}}{w_c/p_m \Delta T_{at}} = \frac{RS \log_{10} \Delta T}{R(S \pm \Delta S) \log_{10} \Delta T} \]

\[
\frac{c/p_m \Delta T_{ai}}{c/p_m \Delta T_{at}} = \frac{S}{(S \pm \Delta S)} \approx \Delta H_1 \]

\[
\frac{c/p_m \Delta T_{ai}}{c/p_m \Delta T_{at}} = \frac{S}{(S \pm \Delta S)} \approx \Delta H_2 \]

It is thus established that a change in surface is approximately proportional to a change in enthalpy.

Premise Above Plotted Out. Scheme showing relationship of two concepts to achieve basic cycle conditions—(1) change in surface, (2) change in bleed flow.

\[\Delta i_a = \text{enthalpy difference in the heater between entering steam and leaving drains} \]

\[Q = \text{main variation, Btu/hr} \]

**Case G, Table 3**

BLEED STEAM DESUPERHEATED BY EXTRACTED FEED IN A SEPARATE DESUPERHEATER

**Case H, Table 3**

FEEDWATER EXTRACTION FOR DESUPERHEATING BLEED STEAM

Plot Comparison: Surface Versus Flow Change

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Anthony Fiala, Jr.

This paper was quite interesting. It seems quite complex, but I suspect that after use it will not seem as long or complex. In our organization, we do not make as many comparative balances as formerly for the following reason. We feel that, based on experience, we can optimize the turbine cycle with very few balances.

However, when we are looking for cycle differences, we use either of the two following methods to approximate the differential heat rate or capability of the turbine.

1. (a) It is assumed that one balance has been computed and put on paper.
   (b) It is assumed that stage pressures, enthalpy, etc., are constant when the cycle change contemplated is made. In other words, only the item being changed is allowed to vary. Once in a while, if a big change in exhaust flow occurs, a correction for exhaust loss may be made.
   (c) The changes in steam extraction flow to the various feedwater heaters are estimated, and the changes in turbine flow calculated from these changes. The differential kw load is then easily calculated as follows. The changes in turbine flow are multiplied by enthalpy drop between the stages. These products are then algebraically added and the sum divided by 3460 or 3470, depending on size of turbine. This then represents the differential kw load between the two cycles. This differential kw load is then divided by kw load shown on the first balance and multiplied by the heat rate shown on the first balance. This then represents the approximate differential heat rate desired.

2. Another method, sometimes called the replacement factor method, is employed as follows:
   (a) and (b) same as in 1.
   (c) The change in extraction flow is estimated for the various bleed points. The replacement factor is then computed as follows for each point. This is equal to the enthalpy drop from the stage in question, to the exhaust enthalpy including exhaust loss, divided by the total enthalpy drop through the turbine.

   The increase or decrease of the turbine flow in the turbine to the next stage or exhaust is computed from the change in extraction flows. This differential is then multiplied by the replacement factor and all such products are then added together algebraically. This sum is then the equivalent change in throttle flow required to maintain constant kw load. This quantity is then divided by the original throttle flow and multiplied by the existing heat rate to give the differential heat rate.

C. C. Franck, Sr.

The authors are to be commended on the excellent material presented on a very timely subject. They are very gracious to make the information available to steam turbine and power plant designers in the United States.

The paper represents considerable deliberation and a tremendous amount of calculations since it is a subject which depends on the utmost in care and accuracy for its value. Several individual calculations made by our own thermal group indicate that the material is of a highly reliable nature.

This presentation by the Thermal Electric Department of Edisonvolta in Milan, Italy, is representative of the considerations given to all phases of steam electric power generation on the Edisonvolta system. Today this system leads Europe in the efficiency and reliability of its steam electric power generating stations.

The writer has been privileged to participate actively in the growth of the Edisonvolta system during the postwar era. Selection of operating steam conditions and cycle considerations have been based on the same sound reasoning as exemplified by the subject paper. We are appreciative that the work of these fine engineers is shared with those who must give considerations to similar problems.

Authors' Closure

Mr. Arnow expresses concern over the possibility of putting the theoretical results of the study in practice. In particular, he fears that said results call for such impossible, or at least impractical, things as modification of the turbine blade design. We wish to point out that the proposed method has different applications and therefore gives different results according to the phase of the over-all plant design in which it is applied. If the turbine is not yet designed, the cycle study made with the proposed method can suggest optimum extraction pressures: The actual pressures will be a compromise between these theoretical values and the practical mechanical design of the turbine. If, however, the turbine design is complete, then the method can be used to optimize the cycle with the available extraction points.

In other words, the method is not a generalized method, as it is based upon actual data and a specific turbine. However, it is a generalized method in that it presents an orderly routine for preparing an optimization study, co-ordinating all the various

Fig. 6
calculations—essentially similar in nature—in order to shorten the study without sacrificing the precision and reliability of the results.

Referring to Mr. Fiala’s discussion, we are concerned with the possibility of making wrong choices which over-simplified methods may encourage. In the complex cycles of modern units so many variations are possible that the over-all economic loss due to an accumulation of single small inaccurate choices can be considered.

To give an idea of the order of magnitude involved, the outlet terminal differences of the heaters in the cycle of Fig. 2 were optimized using Mr. Fiala’s method and also our own. For some heaters the results are only slightly different, while for others the difference is greater. As an example, the optimization of No. 6 heater is shown on Fig. 6. In this case the simplified method involves an increase in the heater surface, and therefore an additional cost, not actually justified. The over-all loss due to this single inaccurate choice is about $22,000, indicating the value of the more thorough study.

We wish to confirm Mr. Fiala’s feeling that the method, although apparently complicated, actually is fairly simple in nature and not difficult to apply.

Lastly for us, who developed the method, as well as for all the people of Edisonvolta Thermo Electric Department, Mr. Franck’s discussion is cause for deep satisfaction, especially since the support and appraisal comes from such an eminent authority in the field.