XI-1 COO-EY77S024196-2

ENERGY CONSERVATION IN COAL CONVERSION

Energy Conservation Potential in Shaft Power Generation and Distribution

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June, 1978

Prepared for

THE U.S. DEPARTMENT OF ENERGY
Pittsburgh Energy Technology Center
UNDER CONTRACT NO. EY77S024196

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ABSTRACT

A criteria for determining the most energy efficient horsepower break-point for using electric motors or steam turbines is developed and applied to the prime movers in the Ralph M. Parsons Co. Oil/Gas Complex. No significant amount of energy can be saved, since the electric motor turbine break-point established by Ralph M. Parsons Co. coincides with the criteria developed in this study.

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INTRODUCTION

In accordance with the commercial concept design of the Oil/Gas complex as described in Reference 1,524,000 HP of shaft work is provided by prime movers. These prime movers are either turbines or motors. The turbines utilize steam directly. The motors are supplied with electricity from a turbine-dirven generator. Reference 2 indicates that the drivers correspond to the following HP ranges:

Range	Driver
0 - 10,000 HP	Motor
10,000 - 15,000	Variable
> 15,000	Turbine

This report will determine whether energy can be saved by replacing a motor with a turbine or vice-versa.

METHOD OF APPROACH

The first task was to determine the efficiency of the two 110.0 MW turbine drivers used in the power generation unit of Reference 1. The efficiency of either of these multi-stage extraction turbines is 86% (Appendix A).

Reference 3 indicates a 110.0 MW generator efficiency of 97%.

The motor efficiencies (References 4 and 5) range from 80% @ 1 HP to 96.4% @ 10,000 HP.

The overall system efficiency is desribed by the following equation:

$$\eta \text{ system} = \eta \text{ turbine} \times \eta \text{ generator} \times \eta \text{ motor}$$

where the turbine and generator efficiencies are fixed for the 110 mw turbine-generator sets, and the motor efficiency varies with HP (see Appendix B for sample calculation). The curve constructed from this equation is seen in Figure 1. Also present are the efficiency curves of multi-stage condensing turbines and single stage turbines.

Figure 2 allows for accurate resolution of the "Average Efficiency of Multi-Stage Condensing Turbine" curves of Figure 1. It is imperative to note the high sensitivity of the turbine efficiency curves to the superheat and vacuum correction factors.

To demonstrate the sensitivity of the turbine efficiency to these correction factors, consider a 10,000 HP turbine utilizing 900 psi steam. From Figure 1, the average efficiency is 76%. If the incoming steam is superheated by 300°F, however, and exits to a 26 in. Hg. vacuum, the "corrected" efficiency is 79.4%. (1.035 x 1.01 x 76% = 79.4%).

Although the turbine-generator-motor curve of Figure 1 is slightly above the average multi-stage condensing turbines, it is by an insignificant amount when the effect of correction factors and the precision of information concerning the various efficiencies is properly evaluated.

CONCLUSION

Figure 1 indicates that below 10,000 Hp, an electric motor driver is the more efficient choice, between 10,000 Hp and 15,000 Hp depending on superheat temperature and condenser vacuum, either motor or turbine driver could be used, and for drivers above 15,000 Hp, turbines would be more efficient. With respect to Reference 2, no significant amount of energy can be saved by replacing a motor with a turbine, or a turbine with a motor.

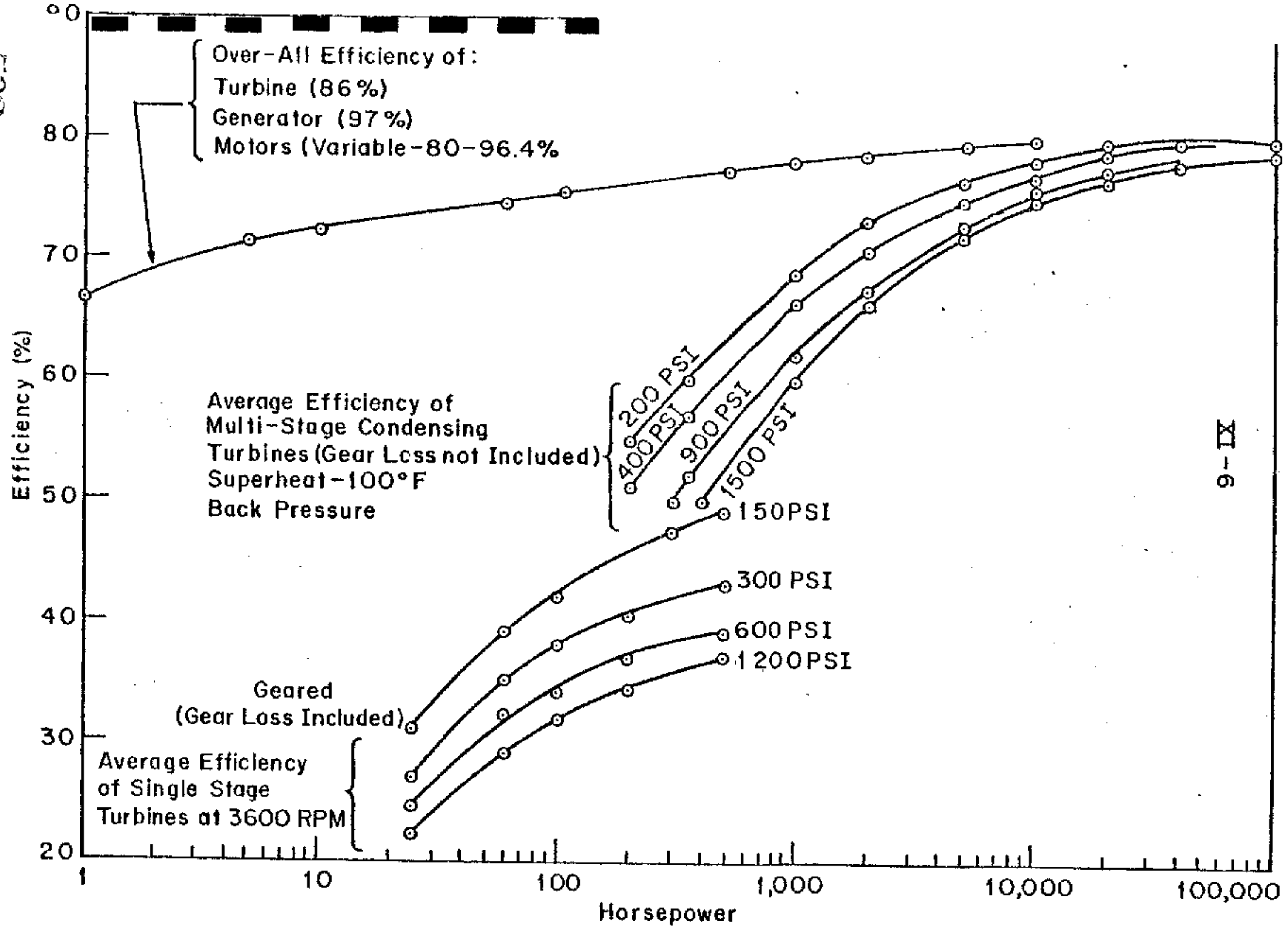

Over-All Efficiency of:
Turbine (86%)
Generator (97%)
Motors (Variable-80-96.4%
Average Efficiency of
Multi-Stage Condensing
Turbines (Gear Loss not Included)
Superheat-100°F
Back Pressure
200 PSI
400 PSI
900 PSI
1500 PSI
150 PSI
300 PSI
600 PSI
1200 PSI
Geared
(Gear Loss Included)
Average Efficiency
of Single Stage
Turbines at 3600 RPM
Efficiency (%)
90
80
70
60
50
40
30
20
1
10
100
1,000
10,000
100,000
Horsepower

FIG. 1

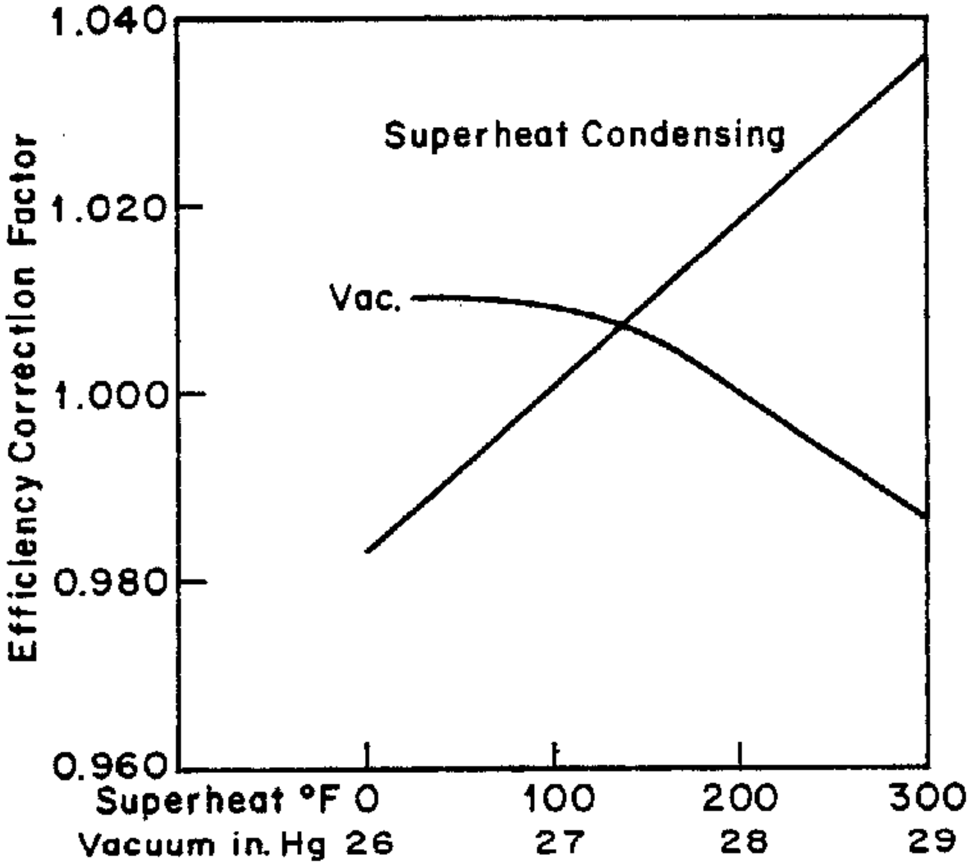

Efficiency Correction Factor
1.040
1.020
1.000
0.980
0.960
Superheat Condensing
Vac.
Superheat °F 0
100
200
300
Vacuum in. Hg 26
27
28
29

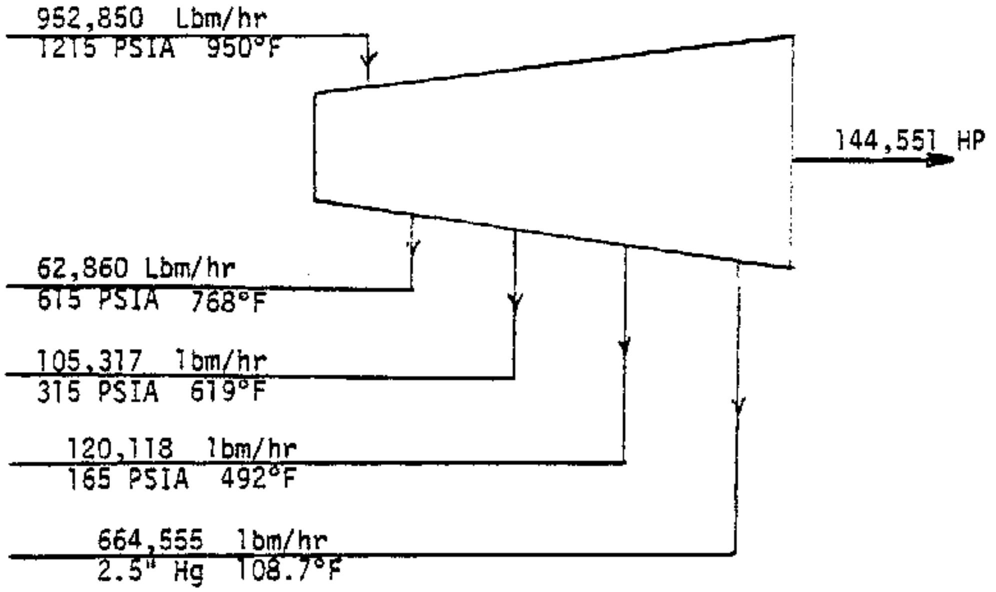
FIG. 2

REFERENCES

1. Oil/Gas Complex, Conceptual Design/Economic Analysis R&D Report No. 114, Contract No. E (49-18)-1775 March 1977.
2. Conversation with Andrew BeLa Ralph M. Parsons Company, Pasadena, California.
3. Conversation with W. G. Steltz, Westinghouse, Lester, Pennsylvania.
4. Converstion with Frank Konechi, U. S. Electric Motors, Milford, Conneticut.
5. Conversation with Bill Joseph, General Electric, Schenectady, New York.
6. Conversation with Dave Laser, Elliott Company, Jeanette, Pennsylvania.
7. Conversation with Professor W. T. Rouleau, Carnegie-Mellon University, Pittsburgh, Pennsylvania.

APPENDIX A

It is of interest to find the external turbine efficiency of the induction turbine operating under the constraints shown:



To do so, the inlet and exit states are examined:

S1 @ 1215 PSIA 950°F; S1 = State at point 1; $h_1 = 1469.7 \frac{Btu}{lbm}$

S2 @ 615 PSIA 768°F; $_1h_{2s} = 1377 \frac{Btu}{lbm}$; $\Delta_1 h_{2s} = 92.7 \frac{Btu}{lbm}$

S3 @ 315 PSIA 619°F; $_1h_{3s} = 1297 \frac{Btu}{lbm}$; $\Delta_1 h_{3s} = 172.7 \frac{Btu}{lbm}$

S4 @ 165 PSIA 492°F; $_1h_{4s} = 1234 \frac{Btu}{lbm}$; $\Delta_1 h_{4s} = 235.7 \frac{Btu}{lbm}$

S5 @ 2.5" Hg 108.7°F; $_1h_{5s} = 907 \frac{Btu}{lbm}$; $\Delta_1 h_{5s} = 562.7 \frac{Btu}{lbm}$

where h refers to the enthalpy at the specified inlet state and $_1h_{nS}$ refers to the isentropic enthalpy drop from that state to the outlet conditions found from Mollier diagrams.

A standard method for calculating the efficiency was employed.[6,7] First, the Rankine cycle steam rate (RCSR), described by:

$$\text{RCSR}\ \left(\frac{\text{lbm}}{\text{HP-hr}}\right) = \frac{2544\ \text{Btu/HP-hr}}{(h_1 - {}_1h_2)\ \text{Btu/lbm}}$$

was found by using a "weighted average" of the available energy described by the isentropic enthalpy drop. This result in:

$$\text{RCSR} = \frac{2544\ \text{Btu/HP-hr}}{0.066\ (92.7) + 0.111\ (172.7) + 0.126\ (235.7) + 0.697\ (562.7)} = 5.689\ \frac{\text{lbm}}{\text{HP-h}}$$

This is compared to the actual steam rate (ASR) of:

$$\text{ASR} = \frac{1{,}905{,}700 \text{ lbm/hr}}{\left(\frac{209.2 \text{ MW}}{.97}\right)\left(\frac{\text{HP}}{0.000746 \text{ MW}}\right)} = 6.592 \ \frac{\text{lbm}}{\text{HP-hr}}$$

This means the external efficiency is:

$$\frac{\text{RCSR}}{\text{ASR}} = \frac{5.689}{6.592} \times 100\% = 86.3\%$$

APPENDIX B

The overall system efficiency is described by the following equation:

$$\eta_{\text{system}} = \eta_{\text{turbine}} \times \eta_{\text{generator}} \times \eta_{\text{motor}}$$

Thus, the system efficiency at 10,000 HP, for example, was found to be:

$$\eta_{\text{system}} = 0.863 \times 0.97 \times 0.964 = 0.807$$