percent of the exhaust enthalpy from the energy exchanger (above ambient) into electrical energy. The overall efficiency of the topping unit and the steam power plant is 52 percent. This cycle is of particular interest because it can also be applied to existing power plants. It would result in an increased output, higher utilization of fuel, and a minimal capital investment.

Concluding Remarks

In the preceding sections of this paper, an examination has been made of the direct fluid-to-fluid energy exchanger and its application to relatively large-scale gas turbine power plant cycles. This study has shown that thermal to electric efficiencies in the range of 50–55 percent are presently feasible for gas turbine power cycles.

The energy exchanger is interposed in the cycle between the combustion chamber and the turbine. The structural requirements of this device do not represent any significant extension of technology. Indeed, the requirements are significantly below those demonstrated by Cornell Aeronautical Laboratory's wave superheater, which is currently in operation.

The energy exchanger described in this paper differs in two significant aspects from the concept first put forth by Seippel of the Brown Boveri Company. First, it is shown that the shock losses associated with compression can be either eliminated or substantially reduced by use of a system of compression waves to replace the shock wave. In addition, by judiciously choosing the molecular weights of the driven and the driver gases, maximum energy exchange efficiency can be achieved. By using combustion air as a driver gas at 2760 deg F and steam as a collected driven gas at 1500 deg F, a very simple cycle has been developed which exhibits a theoretical gas dynamic energy-exchange efficiency of 95 percent. For a 3240 deg F driver gas, which represents a slight impedance mismatch, the theoretical exchanger efficiency is reduced to 93 percent. A conservative estimate of losses due to mixing, leakage, and viscous effects indicates that an energy-exchange efficiency of 85 percent is feasible for the combustion driver temperature of 3240 deg F.

If technological advances in turbine design permit higher turbine inlet temperatures, the energy-exchanger power cycle would benefit more than a conventional gas turbine cycle. For the impedance-matched case with a steam-driven gas, the peak temperature in the power-cycle driver gas may be increased by 160 deg F for a 100 deg F increase in the allowable turbine temperature. For example, an allowable turbine inlet temperature of 1800 deg F would make possible a perfectly impedance-matched driver at 3300 deg F. If the same degree of impedance mismatch is employed as before, the driver gas temperature will be 3800 deg F. The resulting thermal to electric conversion efficiency of the power cycle would be about 60 percent.

In addition, the use of steam in the power takeoff loop isolates the turbine from much of the contamination in the combustion gases. Such a scheme might be suitable for using powdered coal directly as fuel in the power-cycle loop of a large-scale unit. While only relatively large-scale power generating cycles have been considered, it is apparent that this unit might find successful application in many other uses.

Only a limited survey of the modes of cycle operation has as yet been carried out, and variations of these types of cycles leading to further simplifications are possible. The successful introduction of this type of machinery should spur further improvements to gas turbine technology so that, in the future, efficiencies of 60 percent are conceivable.

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DISCUSSION

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With their observation that interface tailoring is essential to the attainment of high energy transfer efficiencies in pressure exchangers, the authors have once more contributed to a field that already owes much to their previous work. Despite its fascinating simplicity, the concept presented in this paper is not at all obvious, except in retrospect. Its implications will probably be found to go well beyond the ingenious applications which are discussed here, just as interface tailoring is now proving its usefulness well beyond Hertzberg's initial objective when he invented it, several years ago.

While on the subject of history, I note that the operation

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described by the "ideal cycle" in Fig. 4 is similar to that which would be performed by a Lebre pressure exchanger with fluids of equal acoustic impedances at either end. One can even recognize, in the recirculating "pressure exchange fluid" of the ancient Lebre scheme, the counterpart of the inevitable "residual gas" of the ideal cycle. The essential difference between the two schemes is one of flow capacity.

I have a question concerning the design in which the drum is stationary. In this design there is a rotating member—the nozzle feeding the hot gas driver—which is subjected to severe bending moments (because of its shape) while being continuously exposed to the high-temperature gas. I wonder if the permissible peak gas temperatures in this situation are the same as those cited for the rotating drum design.