tions and applications, only the first mechanism to be invented had been investigated up to the stage where modern prototype designs and test data were available. This means that much research remains to be done before a sound assessment of regenerative machines becomes possible. A substantial portion of such research is basic and amounts to feasibility studies for new and untried systems, and the research must start from first principles, since no previous experience or data are available.

Many new prototypes will have to be constructed and tested before their full capabilities and limitations can be evaluated.

Up to now the greatest obstacle in the development and application of the regenerative principle has been a lack of understanding of the interrelations between the basic physical parameters which influence the operation. Although the individual phenomena of heat transfer, aerodynamic friction, and regenerator losses are well understood, they interact in so complicated a way that individual contributions of any changes made are hard to assess or to interpret.

Recently, this has been overcome by the application of modern digital and analog computers to the problem. It is now possible to conduct analytical studies of the thermodynamic processes of heat transfer and energy conversion. The procedure used is to formulate an extensive system of simultaneous differential and algebraic equations which are adequate for describing the physical situation in a realistic manner and which can be solved numerically to yield integrated results for the energy conversions and the performance. By such methods, it is now possible to predict the cyclic variations under specified conditions in such significant parameters as pressure and temperature. Since it is possible to compute a complete heat balance, one can, therefore, test the operation of various devices without actually constructing a prototype. It is hoped that such studies will soon lead to the development of improved as well as new types of regenerative machines and hasten their practical application to a number of purposes.

Solar, Nuclear, and Other Applications

Although at present most power is still generated by burning fossil fuel, an intensive search for suitable power converters using solar and nuclear heat sources is in progress. In these new technological areas, regenerative cycles have considerable potential. Referring first to small-scale power production, the main difficulty with regenerative machines is the necessity to transfer heat from the outside of an enclosure, such as a cylinder wall, to the inside. The creep strength of engineering materials at elevated temperature thus limits the temperature and pressure which can be used. Output is also restricted by the area available for heat transfer and by the unavoidable temperature differential between the outside and the inside. All these drawbacks are summed up in the term "external-combustion engine" which is sometimes used.

With nuclear- and solar-energy inputs, it is possible to avoid these disadvantages and to apply the source of heat directly inside the engine. One system, which uses the heat produced from the decay of isotopes, incorporates these materials inside the engine structure. They may, for example, be installed in the form of a grid or matrix which heats internally and through which the working fluid passes. Similarly with solar machines, it is possible to concentrate the solar energy not on the outside of the envelope, but beam it through a quartz window and generate heat right inside the working-fluid system. There are no heat losses apart from the transmission loss at the window, and the radiant energy is absorbed by a matrix or a grid for transmission to the gas. Both methods give a compact unit with practically no direct heat losses from the hot end, which operates with an effective upper temperature limit appreciably higher than that permitted by the creep strength of the engine enclosure. One obvious application is for space probes and satellite auxiliary power plants where such units have all the desired qualities of compactness, efficiency, and reliability.

A more down-to-earth application of solar engines, which may have considerable economic importance in such countries as Pakistan, India and others, is a simple and reliable prime mover which could be operated by unskilled and uneducated farmers. If such machines were produced cheaply and made available in large numbers for irrigation, they might considerably increase the living standard of rural communities in nonindustrialized power-starved countries. Where natural fuels are more readily available than solar energy, as in some regions of Africa and South America, a simple, low-efficiency, but fool-proof power producer could also be built to run on peat, vegetive waste, or other combustible material. This would make available a simple small source of power for lighting, corn grinding, etc., for primitive communities.

Since there are so many different possible designs and so little is known at present about their capabilities and limitations, it is difficult to forecast future commercial developments. Many possible uses of regenerative machines can be foreseen, but apart from considerations of technical feasibility, economic conditions