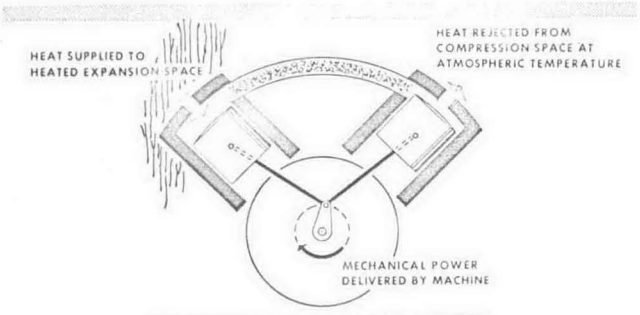
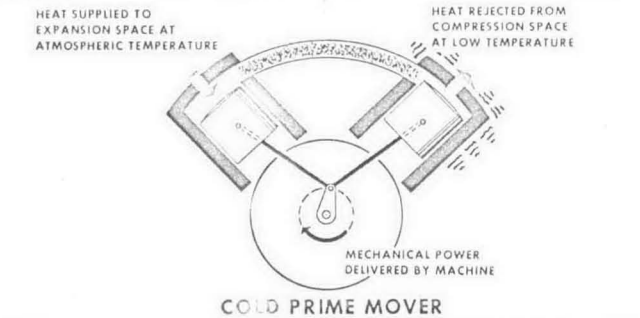
## THE FOUR BASIC OPERATING CONDITIONS OF THERMAL REGENERATIVE MACHINES

*As prime movers producing mechanical energy by degrading heat energy to a lower temperature level.*

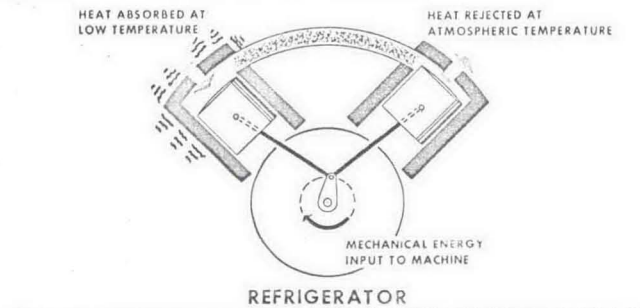



CONVENTIONAL PRIME MOVER

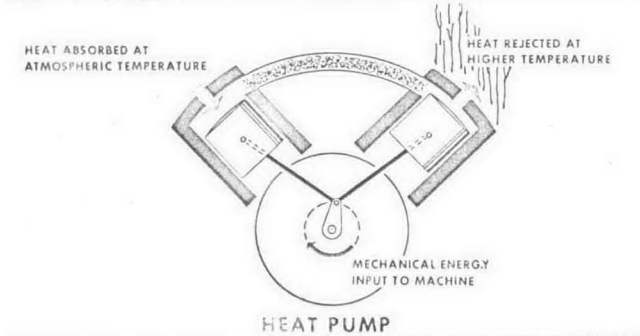



COLD PRIME MOVER

*As heat pumps or refrigerators using mechanical energy to elevate heat to a higher temperature level.*




REFRIGERATOR




HEAT PUMP

*The Four Operating Modes*

*Prime Mover.* When the heat supply is at a relatively high temperature, while rejection is approximately atmospheric, power is delivered by the machine at the crankshaft. The over-all effect, therefore, is that heat energy is degraded from a high to a low temperature level and consequently produces mechanical energy.

*Cold Engine.* A regenerative thermal machine can also function in a novel way as a "cold" prime mover. In this instance, heat energy is supplied to the machine at atmospheric temperature and rejected at a much lower temperature. This is a case where heat energy is dropped from atmospheric temperature to a low level, so that mechanical energy is produced. Although such machines have not yet been developed, they could be used when liquid gases are evaporated to recover some of the mechanical energy which was expended during their liquefaction.

*Refrigerator.* When operation corresponds to a conventional refrigerator, heat is absorbed by the machine at a temperature below that of heat rejection which is approximately atmospheric. Here heat energy is being pumped up from a low to a high temperature level, and mechanical energy must be supplied to the machine at the crankshaft to maintain the process.

*Heat Pump.* This is a machine which takes in heat near atmospheric temperature and rejects it at a high level. By analogy with a hydraulic system, it is called a "heat pump", since mechanical energy must be supplied to the machine at the crankshaft to "pump up" heat to a higher temperature level. Machines of a similar type, but with vapor-compression cycles, are in use for space heating.

*A Demonstration of Versatility*

This unique versatility, of not only a theoretical thermodynamic cycle but also of an actual mechanism, has already been shown in practice. In a demonstration, a standard machine substantially of the same design as originally conceived by Stirling was used. The cylinder head was exposed so it could either be heated or cooled, and a water jacket kept the compression space near atmospheric temperatures. The crankshaft was coupled to an electric armature which could function either as generator or motor.

When the cylinder head was made red-hot by heating it with a burner, it would drive the generator and produce electricity. When the burner was removed and the armature was supplied with electric current to continue driving the machine in the same direction, the