Improved Cryogenic Refrigeration System

The problem:
To simplify the valving arrangement (and crankshaft configuration) in gas-balancing and Stirling-cycle refrigeration systems which are used to produce temperatures below 173°K (−100°C).

The solution:
The multiport sequencing valve employed in the conventional systems is replaced by a simple two-position shuttle valve which connects the displacer and regenerator alternately to the high-pressure supply line or the low-pressure return line of the compressor. This improvement is based upon (1) the establishment of a constant pressure on one end of the drive piston which moves the displacer and (2) the inherent time delay caused by fluid friction in the regenerator.

How it's done:
The first figure is a schematic of the overall system showing the constant pressure $P_1$ in auxiliary volume

(continued overleaf)
V₁. The net force on the drive piston is either upward or downward; the relief valves are required only to maintain P₁ against small leaks that might be present. The inherent friction of the generator provides a time delay in developing pressure P₂ relative to pressure P₃ in volumes V₂ and V₃, respectively. The two-position valve, which is actuated by a linkage from the drive piston, allows the refrigeration cycle to be self-starting.

The second figure shows the displacer in the lowest position, at which time the two-way valve connects the high-pressure line of the compressor to volume V₂ and the top of the regenerator. The displacer remains in this position for a short time, because P₂ is greater than P₃ as a consequence of the time delay introduced by the regenerator. Subsequently P₂ and P₃ become equal at a value larger than P₁, and the resultant force urges the displacer upward.

The third figure shows the displacer in the uppermost position, with the gas volume V₂ displaced into V₃, as would be required in the gas-balancing cycle. At this time, the two-way valve connects the top of the regenerator and V₂ to the low-pressure port of the compressor. The displacer momentarily remains stationary (again as the result of the time delay in the regenerator) because P₃ is larger than P₂. When P₃ becomes equal to P₂, at which time both pressures are less than P₁, the resultant force urges the displacer downward to drive the cold gas out through the regenerator as required. The thermodynamic cycle then repeats.

Notes:

1. A prototype of a single-stage refrigeration unit incorporating the new valve arrangement required only 1 hour to liquefy nitrogen (78°K).

2. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Jet Propulsion Laboratory
   4800 Oak Grove Drive
   Pasadena, California 91103

   Reference: B67-10128

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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