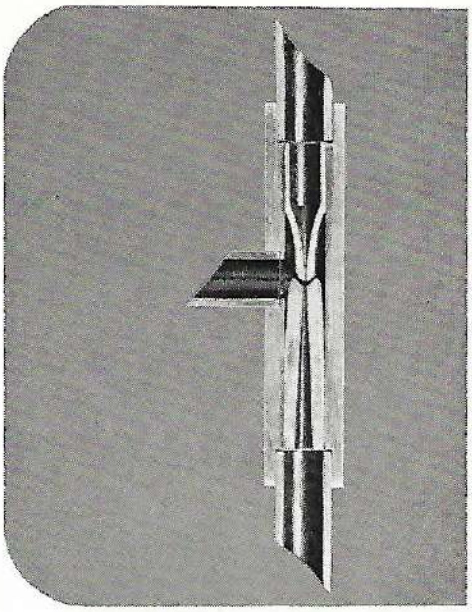
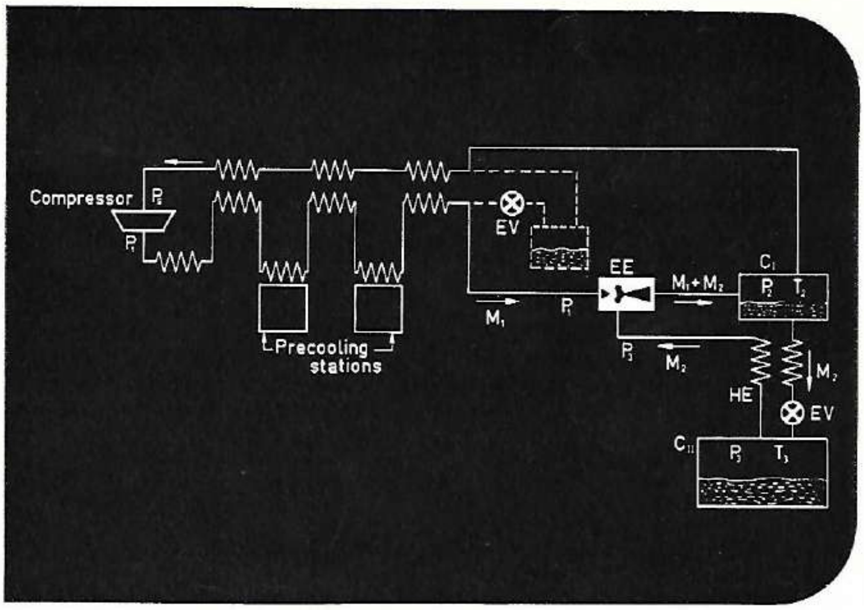




How To Use Your Losses Efficiently

If that statement reads like an offer of 'something for nothing', we apologize! Yet one of our recent cryogenic developments will allow users of super-cooled equipment to put the pressure potential normally wasted in the Joule-Thomson refrigeration cycle to very good use.

Dr. Rietdijk, a worker on cryogenic problems in the Philips Research Laboratories at Eindhoven (Netherlands), found a simple way to obtain a significant increase in cooling system efficiency, by using part of the kinetic energy which is wasted in the conventional Joule-Thomson valve. His findings promise a reduction in the compressor size required to reach a given temperature with practical liquid-helium super-cooling systems; alternatively, users will be able to produce lower temperatures without increasing compressor size.

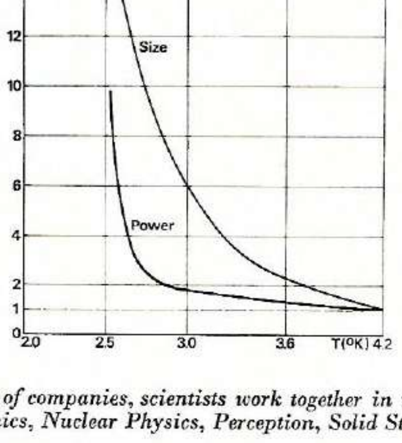
In the conventional Joule-Thomson cycle, an expansion valve (see the diagram above) is used to expand compressed gas, which has already been cooled to below its 'inversion temperature' and passed through a heat exchanger. (Inversion temperature is the temperature below which isenthalpic gas expansion, produced by aperture 'throttling', causes a further temperature decrement). This classic system is 'irreversible': a great deal of pressure potential is wasted.

Since suction pressure P_S in the diagram must always be equal to, or lower than, vapour pressure P_V of the liquid in the evaporator, it is clear from the graph that, with a pressure loss P_V—P_S of, say, 0.1 kg./cm², the required compressor size and power will increase very rapidly with successive temperature decrements below 3.5 degrees Kelvin.

Rietdijk replaced the classic Joule-Thomson expansion valve with a new device, which he called an 'expansion-ejector' (see photograph). In operation, the nozzle of the ejector converts most of the high pressure P_1 of the main flow M_1 into kinetic energy of a high velocity jet. The kinetic energy obtained is then used to compress a second mass flow M_2 from a low pressure level P_3 up to a higher level P_2, which is about the same as compressor suction pressure. This takes place in the ejector mixing zone and diffuser.

Referring to the diagram, the flow is then split again between M_1 and M_2 in C_I. Flow M_2 passes from C_I through the heat exchanger HE to be expanded in the valve EV. The resulting liquid is collected in the evaporator C_{II} where it can be evaporated (refrigeration) or removed from the cycle (liquefaction). Low temperature vapour P_3, T_3 then flows via HE to the ejector's suction side, where it is again compressed to P_2. So, the expansion-ejector behaves as a J-T valve between P_1 and P_2, and as a compressor between P_3 and P_2. Cold is therefore delivered at a temperature T_3 which is much lower than the temperature corresponding to compressor suction pressure (i.e. T_2).

Using the expansion-ejector, P_S can be considerably increased for a given temperature value T_3, and therefore compressor size can be reduced. Naturally, the compressor power consumption goes down as well. For example, experimental results with a helium liquefaction system, using Stirling machines for pre-cooling, show that, given an expansion-ejector efficiency of 30%, refrigeration can be carried out at 3.5 °K. with an efficiency significantly greater than that of the conventional system.



This story is unusual, in that it shows the successful combination of two well-known principles - the Joule-Thomson effect, known since 1852, and the gas ejector - to produce valuable results with a relatively simple device. Rietdijk, although working in cryogenics, happens to be an aerodynamicist; he brought his knowledge of flow and pressure problems to bear on the apparently unrelated problems of the Joule-Thomson cycle. The results of this unconventional approach may be applied, not only with helium, but also with other gases in cryogenics.

In the Research Laboratories of the Philips group of companies, scientists work together in many fields of science. Among these are: Acoustics, Cryogenics, Information Processing, Mechanics, Nuclear Physics, Perception, Solid State, Telecommunications, and Television.

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