ULTRA LOW TEMPERATURE PRODUCTION AND CONTROL IN ENVIRONMENTAL TESTING AND APPLICATION FACILITIES

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Introduction

Papers presented at previous cryogenic engineering conferences by this company\(^1\), \(^2\), \(^3\) described the principles and many of the applications of the Norelco gas refrigeration machine in the range of \(70^\circ\text{C}\) to \(190^\circ\text{K}\). The objectives of this paper are twofold:

1) To describe extensions to the design of the present machine which will allow the production and accurate control of temperatures in the range of \(90^\circ\text{O}\) to \(250^\circ\text{K}\) by means of a circulating cold gas.

2) To illustrate applications in test facilities and in industry where the modified Norelco refrigerator can be utilized efficiently and economically.


Fundamentals of the Norelco Gas Refrigerator

The fundamental operating cycle was described and illustrated adequately by Kohler$^1$ as a special case of the Stirling cold gas cycle and will not be covered here.

Figure 1 illustrates a simplified cross-section of this gas refrigerator used for producing liquid air. Parallel connecting rods drive the main piston while a separate connecting rod to the displacer drives the crosshead which passes through the center of the piston. Crank angles provide a phase shift between the harmonic motion of the piston and displacer which varies the volumes in chambers 4 and 5 periodically. Compressed gas gives up heat in lower chamber 4; it expands and absorbs heat in upper chamber 5, cooling condenser surface 9. Air enters the bottom of the header, rises, and then passes down through the center baffles where water vapor and carbon dioxide condense. Pure, dry air in contact with the condenser is liquefied and drained off into dewar 10.

Figure 2 is a photograph of the Norelco air liquefier. An analysis of the gas cycle shows that its refrigeration effect is reduced only slightly with reduction in temperature. This is contrary to conventional evaporation type refrigeration and is therefore suitable for large temperature ratios. Since the refrigeration is approximately proportional to the head pressure of the gas, small machines can be designed for a proportionately large amount of refrigeration.

Figure 3 illustrates graphically the effect of temperature level on the capacity of this refrigerator. In the instance of liquid air production at atmospheric pressure, the machine has a capacity of about 650 watts refrigeration operating at 1750 RPM with a 10 Hp motor. In the case of condensing oxygen boiling at $-183^\circ$C, the refrigeration capacity is about 800 watts. Thus the higher the temperature level, the greater the refrigeration capacity of the machine.

Figure 4 correlates the effect of certain operating and atmospheric conditions on the capacity of the machine to produce liquid air. These include quantity and temperature of the cooling water, the psychrometric condition of the air and height above sea level.