A One-Dimensional Model of a Closed-Loop Refrigeration Test Block for Centrifugal Compressors

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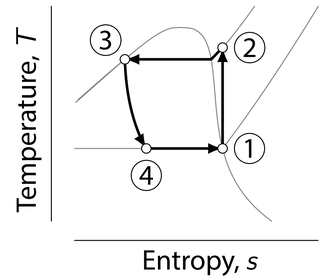
Background

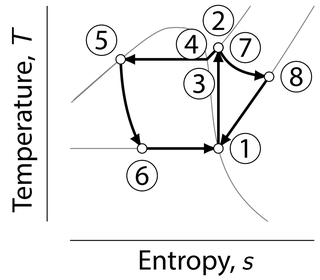
A "Closed-Loop Refrigeration Test Block" is a piece of testing equipment which:

- Maintains compressor suction conditions without requiring a complete refrigeration cycle
- Allows for isolated testing of compressors
- Eliminates the need for an evaporator and associated cooling load

Temperature-entropy (*T-s*) diagrams show the differences between the traditional vapor-compression refrigeration cycle and the hot gas bypass test block cycle:



Traditional refrigeration cycle.



Hot gas bypass test block cycle.

Motivation

A simplified, one-dimensional model of the test block will:

- Reduce time to market for new compressor designs
- Reduce compressor testing costs
- Allow engineers to focus on new design work rather than test calculations

Objectives

To be considered a success, the model should:

- Compute the prime mover power requirements
- Report the best orifice for flow measurement
- Predict the feasibility of a test at specified outdoor air conditions, because capacity is limited by cooling towers

Modeling Approach

Engineering assumptions were used to simplify the test block for modeling purposes.

These assumptions include:

- Steady flow conditions
- Negligible kinetic and potential energy effects
- Negligible pressure drops and heat transfer in pipes
- Uniform fluid properties at each cross section (one-dim.)
- Compressor behavior characterized by compressor maps

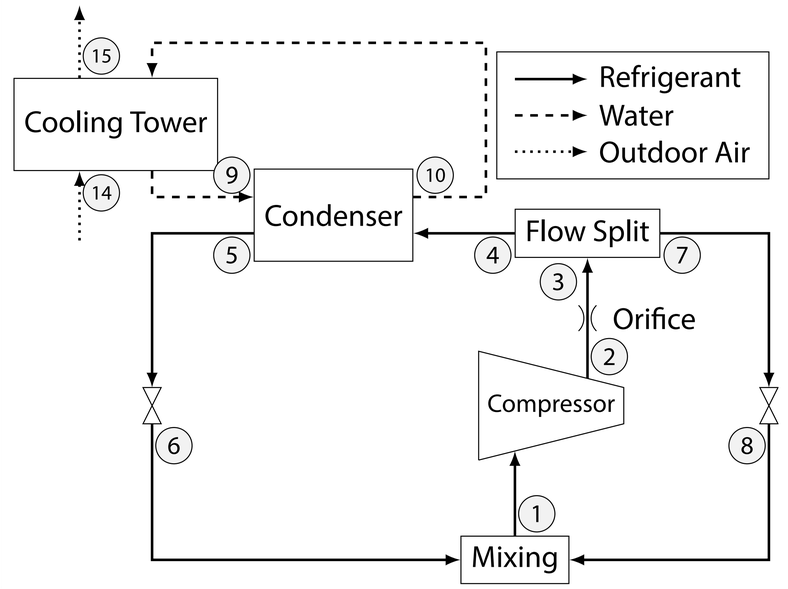
The model was implemented in Engineering Equation Solver (EES) and consists of two separate programs:

Complete Cycle Program: This program is used to predict the feasibility of a test at specified outdoor air conditions.

Orifice Selection Program: This program is used to determine the orifice diameter best suited for a wide range of test conditions.

Test Block Overview

Applying the engineering assumptions resulted in the following simplified schematic of the compressor test block:



Summary of Validation Results

The model predictions were compared to experimental data for validation purposes.

The results demonstrate agreement to within 5% of experimental data for all major output variables, as shown below. Typical results for orifice selection are also shown. For this case, orifices 3, 7, and 12 are acceptable over the range of flow coefficients.