Project Report 3

REFRIGERATION ENERGY USE IN THE FOOD CHAIN

PROJECT REFERENCE (TBA)

CONTRACT REFERENCE (TBA)

by

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Summary

This report summarises the research so far carried out by the LSBU team into the 'Food Chain Refrigeration Energy Use '. The report describes the results of a literature investigation so far into modelling refrigeration systems

13 March 2007

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1. Introduction

A project objective for LSBU is to develop steady state refrigeration system models to test (and optimise) various refrigeration systems used in the industrial production chain for food.

This report describes the results of LSBU's progess upto 13 March 2007.

2. Research Task Definition

The working title for the refrigeration system software is 'VCRmodel'.

At a meeting at FRPERC, Bristol on the 4th December 2006, it was agreed that LSBU would initially concentrate on the development of refrigerator simulation software to model a type of system most commonly applied to batch chilling processes. From a review of technologies and a survey of leading practitioners, LSBU found that air-air systems with a single stage compressor, single compressor, evaporator and dry-air cooled condenser, are the most common types. A schematic of the system LSBU is presently modelling is shown in Figure 1. This schematic was past to FRPERC for comment. Electric defrost, oil cooling, evaporative condensers, individual suction liquid heat exchangers, fully flooded evaporator ammonia systems and screw compressors, were identified by FRPERC as additional requirements. These additional complexities, apart from electric defrost, are thought to be beyond the scope of this part of the study, though, if time permits, some may be included before July 2007.

The target date for the completion of this initial form of VCRmodel is July 2007.

Figure 2 shows the demarcation boundaries of modelling tasks agreed between LSBU and FRPERC.

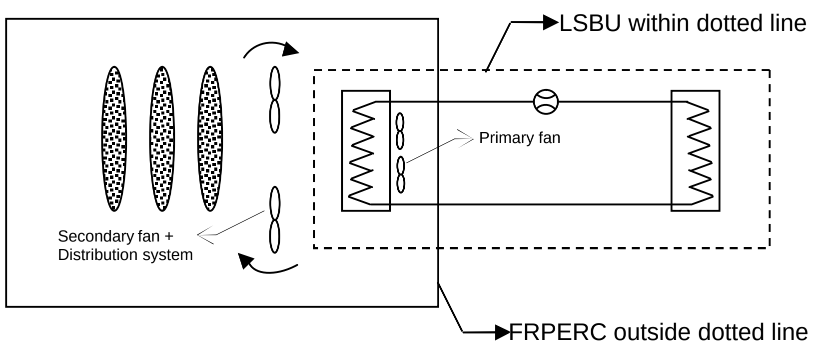

Figure 2. Demarcation of models

It has also been agreed that the VCRmodel, produced by LSBU, would include a fan to overcome the resistance of the heat exchanger whilst the FRPERC model would included any additional secondary flow fans needed to distribute air within the enclosure.

In order that enclosure model (COLDROOM) and refrigeration system model (VCRmodel) will be able to communicate, it has been agreed that FRPERC's ColdRoom software would supply as INPUT to the refrigeration system model (VCRmodel), (via a .dat, .txt or DDL files), air mass flow and its properties to the cooling coil, including dry-bulb temperature and moisture content. In return, VCRmodel will supply, as INPUT to COLDROOM, the air mass flow and properties leaving the cooling coil, including dry-bulb temperature and moisture content. Also, COLDROOM will define the air velocity onto the coil and the thermostat switch on/off (upper and lower set-point) conditions, a defrost schedule, fan power input and RUNTIME time/date of year, as INPUT to VCRmodel.

In order that the VCRmodel's OUTPUT data matches partners' requirements, it has been agreed that FRPERC's would produce a list of operational parameters and LSBU would produce a list of system parameters, for circulation.

3. Model integration

FRPERC have provided LSBU with a development copy of COLDROOM' VB files in order to assist in determining what problems there may be to integrate VCRmodel with COLDROOM. FRPERC's software was found to be very extensive and to assist LSBU parners understanding of its structure a further visit to FRPERC at Bristol was made to meet the programs developer. From this meeting it was found that the refrigerator model currently within COLDROOM is embedded in a way that will make it difficult to modify. Also, because of the size of the programme it is felt that solution convergence times may be excessive. This matter requires further investigation.

4. Progress to Date

Table 1 shows a Gantt chart for the tasks needed to produce the initial version of VCRmodel by July 2007. At the time of writing, most of the user interface has been produced and a number of subroutines for air, primary and secondary refrigerant property data and weather-model data have been written. The RUNTIME module for the Air-Air system model (Figure 1) has also been produced. A demonstration of the software will be given at the meeting and a copy of the software will be provided at the meeting for comment by partner members.

On the other hand, Faults Detection & Diagnosis (FDD) systems for Vapour compression cooling equipment have been investigated due to the potential benefits for FDD of equipment downtime reduction and energy wastage avoidance. A wide range of literature have been reviewed for classifying the faults through different methods of FDD, based upon fuzzy logic, neural network, statistical rules or dynamic models.

Refrigeration system fault is defined as undesired change that tends to degrade the overall performance of a system, which requires detection through a decision process regarding the system status. The determination of the fault location is known as fault isolation. The fault diagnosis consists of fault detection and isolation.

Different surveys for FDD have been investigated, where most of the comprehensive studies and surveys about FDD techniques were done on air-conditioning equipment and direct expansion rooftop air-conditioning units due to their wide markets. According to Stouppe and Lau (1989) who have summarised the cause of 15,716 failures, 76% of the hermetic air-conditioning units were related to electrical components while 19% to mechanical and 5% to refrigeration circuit components as shown in Figure 3.

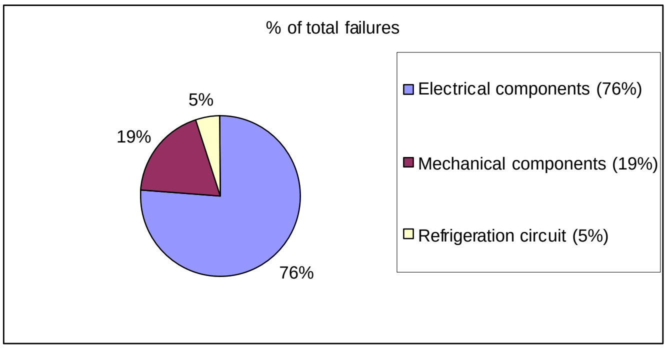

Figure 3: Stouppe survey results for FDD

Almost 87% of the electrical faults were in motor windings due to insulation deterioration, unbalanced operation, short cycling and refrigerant contamination. Although motor windings failure is categorized as electrical faults, yet they results of a mechanical problem which is overloading. On the other hand, the mechanical failures were almost in the compressor valves and bearings due to liquid slugging and loss of lubrication.

According to Breuker and Braun (1989) who have summarised the cause of 6,000 failures for direct expansion rooftop air-conditioning units, Breuker showed that in terms of cost, compressor faults cost represented about 25% of the total costs, while they represented 5% of the total faults. This figure indicates the importance and feasibility of using a diagnosis system that would avoid such faults, which can also increase the efficiency of the system operation.

FDD types and categories

The different techniques FDD relies on the different used tools. Most research has concentrated on artificial intelligence which is based on a set of algorithm produced by experts. The process of FDD is divided into fault detection and fault diagnosis. The first step of FDD, which is faults detection, depends on a baseline reference to compare the measured data with to determine if a fault occurred or not.

The first method for establishing a baseline reference is having knowledge based upon set of rules, facts and procedures produced by experts, which is called qualitative model. These set of rules are combined together to produce the information required to solve a variety of problems. The process of fault isolation follows the previous step, where relevant information (categorical data) is collected and fed into the computer and is tested with the knowledge available.

The second method is to have a dynamic thermodynamic model, where sensor signals inputs to the model, while the remaining sensor signal are compared with the predictions of the model, which is called quantitative model. The significant differences indicate fault existence. An implementation for Quantitative model for a heating coil is shown in the Figure 4.

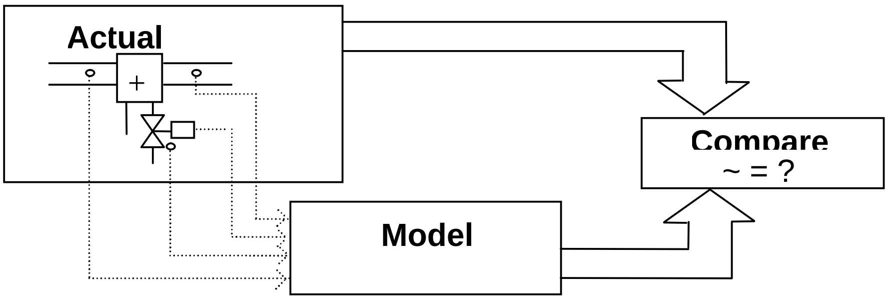

Figure 4: Fault detection model concept for heating coil

The quantitative model can be based upon the physical principles (e.g. effectiveness – NTU for coil), empirical data such as polynomial curve fits (compressor performance maps) or artificial neural networks (NN). Each technique has its advantage. Although the current research for refrigeration systems FDD uses NN technique, but still the accuracy of NN depends on the training data, which decreases rapidly in regions of no training data.

The second step of FDD is the fault diagnosis, which starts with classifying the fault through a rule which maybe be fuzzy or Boolean obtained by experts and corrected by testing using simulation or maybe generated using simulation model. Figure 5 shows the complete FDD system steps, where each step operates within a preset limit (threshold), if exceeded by the residual value (difference between measured and predicted variables), it declares the presence of fault.

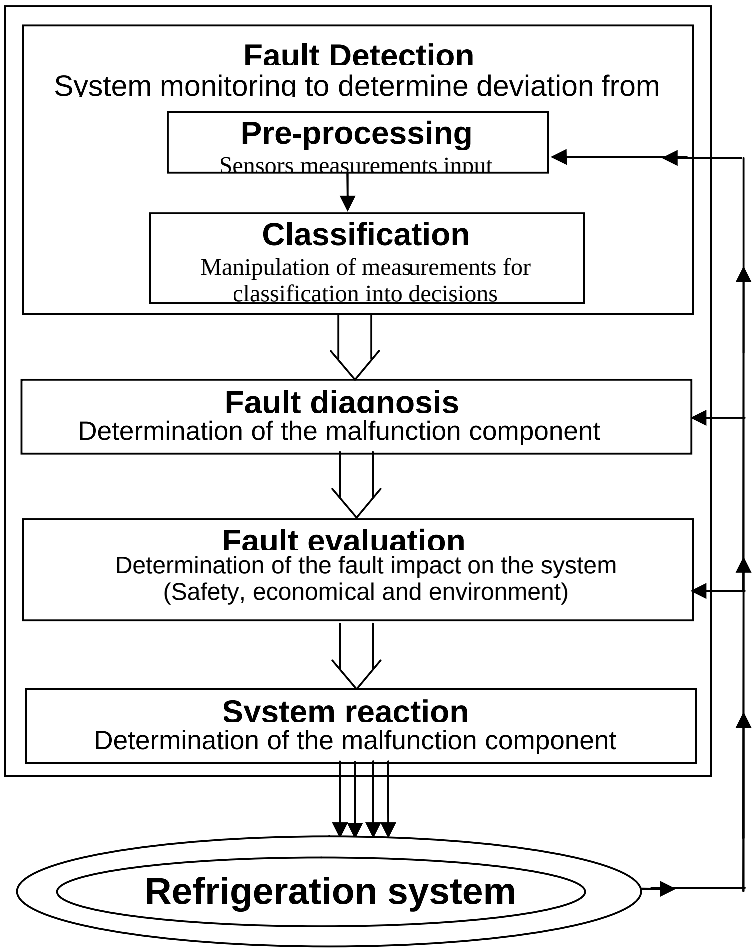

Figure 5 FDD system steps

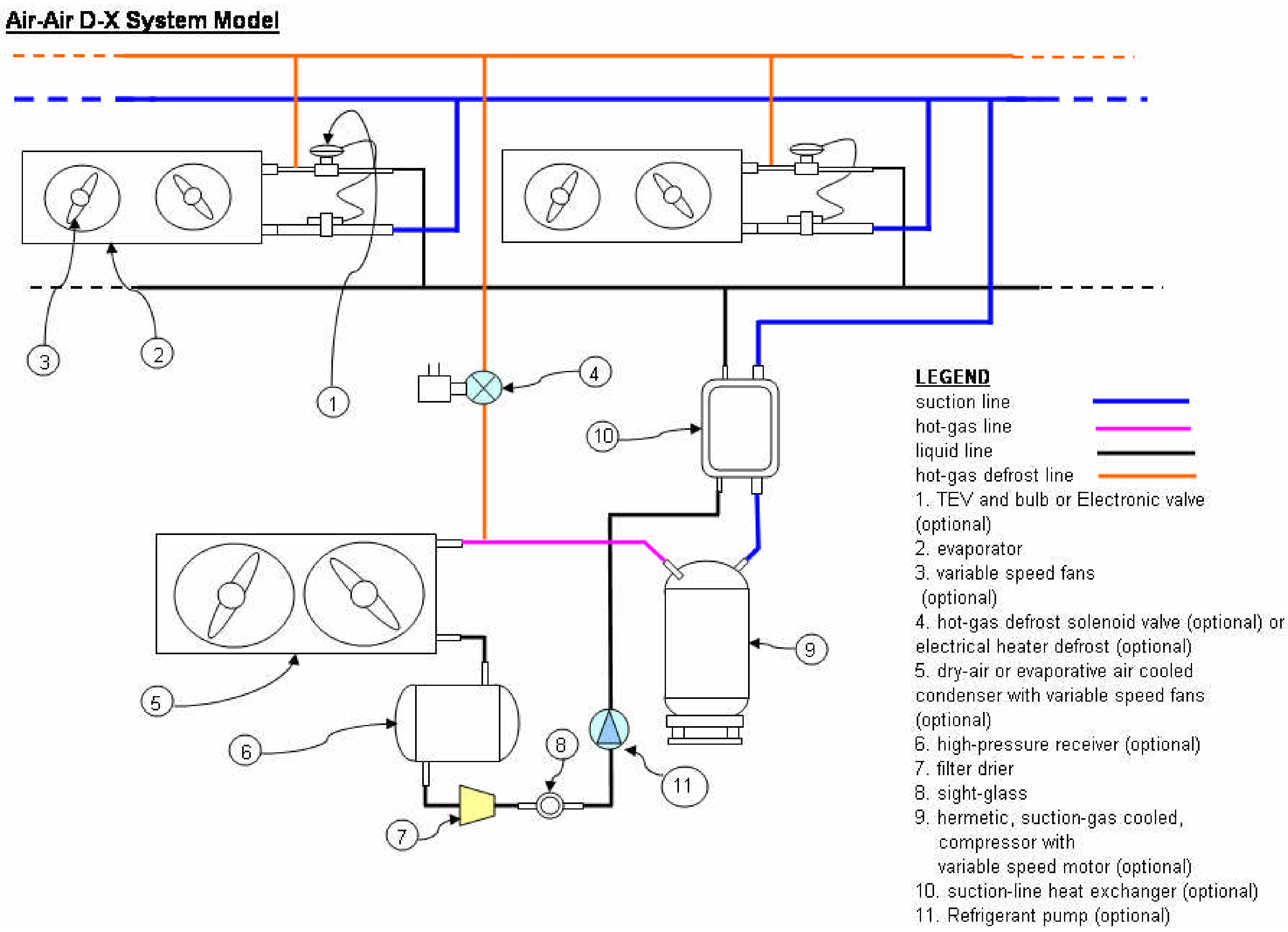

Figure 1: Agreed schematic of refrigeration system for batch cooler model

Table 1: LSBU Research Programme at 13[th] March 2007