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An Alternate Refrigeration Control System

Meat & Livestock Australia Technology Transfer Resource Package # 2

This Do-It-Yourself (DIY) Kit is one in a series of Technology Transfer resources prepared for the Australian meat industry to encourage the development of project engineering skills at meat processing sites while implementing simple but useful items of technology. The Technology Transfer Resource Package #2 was designed to provide the essential information to allow processors to carry out suitable modifications and installations at their own sites to improve some aspects of their processing performance. Each DIY kit in this package is available as a printed brochure with an instructional VHS video or as a CD Rom. As each processing site has unique design and construction features the information in this kit should be used as a guide only. Some modifications from this kit, to ensure the successful application at individual sites, are likely.

DIY Kit # 19 – An Alternate Refrigeration Control System

Reciprocating refrigeration compressors have traditionally been controlled by mechanical pressure switches and back-pressure regulators that react to variations in suction pressure. The control obtained is coarse with a minimum of some 30 kpa required between the high and low pressure signals. Accurate adjustments are difficult to make. As load is increased additional compressors are bought directly on-line in response to activation of the pressure switches. This results in the capacity increasing in steps of whole compressor capacities. The only variability between whole numbers of compressors is the ability to load and unload a two-stage compressor unit to give steps of approximately half a compressor.

While this method is still the normal approach in the meat industry, systems have been developed for the fruit and vegetable industry that give much greater flexibility and almost infinite incremental increases in capacity as load increases. Refrigeration in the fruit industry requires very fine controls of temperature over a reasonably steady and invariable load. Loads in the meat industry are generally much greater and extremely variable as hot carcases at about 40∞C are loaded into chillers for cooling to 0-7 ∞C and warm cartons are loaded into blast freezers for freezing from 0-12 ∞C to minus 8-12∞C. These large and variable loads are hard to control effectively and place heavy demands on refrigeration equipment.

An alternate refrigeration control system developed for the fruit and vegetable industry has been trialed in an Australian domestic abattoir and has proven to be an effective means of improving refrigeration control. Operation of the control system over several months has demonstrated significant savings particularly in reduced carcase weight loss and in energy savings. The system is currently is in operation and as the control program is fine tuned further improvements in performance and resultant savings are expected.

Description

The trial system consists of a programmable logic controller (PLC) managing a bank of nine 22 kilowatt (Kw) compressors, using R22 refrigerant, and six condensers in response to pressure signals from transducers fitted to the suction and discharge lines in the plant room. The individual compressors can be ramped up from 20% to approximately 110% capacity as they come on-line (soft start) and then be controlled through an approximately 590% capacity range using a single vari-speed controller. The trial system uses a Hitachi PLC and Hitachi vari-speed controller. Photographs 1 & 2 show the vari-speed controller in the new control panel. Choice of PLC and vari-speed will vary at other plants and will be dependent on the number and size of compressors used and the complexity of control required.

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Photograph 1: Refrigeration control panel

Photograph 2: Vari-speed controller

The trial system includes control of the available condensers to maximise performance through control of condensing temperature. A reduction in condensing temperature is obtained through the selection of suitable condensing capacity from the two large and four small condensers available to meet load requirements and ambient temperature. By reducing the condensing temperature a lower discharge pressure can be maintained. This reduction in discharge pressure results in an increased co-efficiency of performance (COP) ie the ratio of refrigeration produced per unit of energy input.

Management of compressors and condensers, in the trial system, is programmed into the Hitachi PLC using ActWin software. The choice of software will be dependent on the controllers used and the level of control required.

Operation

When the refrigeration system is turned on the nominated first compressor is brought up to maximum speed in an unloaded condition using the vari-speed drive. The vari-speed operates by increasing the cycle rate of the alternating current from zero cycles per second or hertz (Hz) to 55 Hz. As the standard alternating current electricity supply in Australia operates at 50 Hz the vari-speed is able to obtain a 10% increase in performance from the compressor as its maximum speed is increased by the increase from 50 to 55 Hz. After a short time at peak performance the compressor is loaded and allowed to stabilise for a short time after which the vari-speed controller adjusts the compressor's performance by reducing the speed to meet the demands of the pressure transducer set points. Adjustment range is from 55 Hz to a minimum of 42 Hz, just above the compressors stall point when loaded. By controlling the loading and unloading of the compressor it can operate in the range of 42 Hz unloaded to 55Hz loaded.

When additional load is detected by an increase in suction pressure over a preset time the PLC switches this compressor to a Direct-on-Line (DOL) condition freeing up the vari-speed controller to manage the start of the next compressor. Additional compressors are brought on-line as required with the previous compressors going DOL when held at maximum capacity with additional load detected for a predetermined time. Under current operating conditions (in the pilot plant) a maximum of only four compressors are used although nine are available. The system has been developed to provide sufficient capacity and control for the additional chillers currently under construction.

Meanwhile the PLC is also managing the six available condensers to control the condensing temperature and hence maintain the discharge temperature within a preset range.

The arrangement is shown in the schematic diagram Figure 1 and components can be seen in the video footage associated with the printed version of this kit.

Optimum performance depends on the establishment of the correct reaction speeds, set points and time delays within the system. These are programmed into the PLC by interacting with the software through a remote computer. In the trial system changes to the variable parameters are made by cable interface directly at the refrigeration room switchboard using a laptop computer. Changes could however be made by modem access from a remote location if required. The requirement for

computer access ensures that no unauthorised changes can be made to the control parameters. However digital and pictorial displays are available to show the current status of the control system. Manual switches are available to over-ride the compressors and condensers if necessary. These switches do not affect the control system parameters but merely turn on and off individual compressor or condenser units in emergency or maintenance situations.

Experience with the trial system has shown that optimum performance to date is achieved with the following parameters:

- discharge pressure - 1,250 kpa (prior to installation of the trial system discharge pressure was approximately 1,600 kpa);
- suction pressure low signal - 340 kpa;
- suction pressure high signal - 350 kpa;
- time delay before confirmation of requirement for additional compressor - two minutes; and
- time delays between actions associated with changes in DOL, compressor loading/unloading and ramping new compressors - one minute.

These conditions are expected to be fine-tuned with the on-going operation of the system. These conditions are specific to the trial system and are likely to require modification for control programs for other plants.

Flexibility in the PLC program allows for variations in the nominated order in which compressors are brought on-line. This allows the option to change the nominated number one compressor on a daily basis to spread wear over all compressors. The decision has been taken with the trial system to maintain a constant nominated number one compressor. This decision has been made to ensure that not all compressors receive equal load. The intention is that maintenance requirements will be staggered on the compressors according to load and use and that a situation where all will require maintenance, or ultimately replacement, at the same time will not occur.

Should the control system fail at any time the plant has the capability to operate four compressors and two condensers directly on-line to maintain refrigeration.

Benefits

The trial alternate refrigeration control system has been shown, over six months operation, to effectively manage the compressors and condensers at a medium sized domestic abattoir.

Use of this control system has been demonstrated to:

- reduce weight loss during carcase chilling and holding.

  For Beef carcases, historical evidence shows a weight loss from hot wet weight to cold delivered weight of 2.7% prior to installation of the trial system. Delivery time and location is variable but data has been taken from four separate months in 1999 and 2000. Data from the trial system over a two-week period in March 2001 shows an average weight loss under similar conditions of 2.3%. A 0.4% average weight loss savings relates to an annual savings, on a 160 body per day kill of average 190kg carcases, at an average price of $3 per kg, of about $91,200.

  For Sheep carcases *(80% lamb),* historical and recent evidence indicates a reduction in weight loss of approximately 0.5% from 3.08%. A 0.5% average weight loss savings relates to an annual savings, on a 2000 body per day kill of average 19kg carcases, at an average price of $2.30 per kg, of about $109,250.

  Weight loss reduction on sheep is significantly greater than on beef as no other weight loss reduction measures have previously been taken. With beef, the chillers already have back-pressure regulators and variable speed fans fitted.

- reduce energy usage.

  No hard data is available to accurately determine the energy usage of the refrigeration system in isolation. However anecdotal evidence on operating conditions before and after the installation of the trial system is available from several sources. This evidence strongly indicates a reduction from the use of five compressors to four compressors, under similar seasonal conditions and production capacities, over a six-month period on the old and new control systems.

  The savings on the use of one 22 Kw compressor, operating 12 hours per day, at a current cost of 11.65 cents per Kwhr is around $7,700 pa. This does not take into account any savings from reduction in maximum demand.

- reduce maintenance.

  While it is too early to quantify savings, an effect is expected in two areas. The first is the scheduling of maintenance and replacement of compressors by programming workload on individual compressors as indicated earlier. The second is in the reduced load on contactors and other electrical components in the control panel and compressors. As each compressor is started using the vari-speed, contactors are only operated when the compressors go DOL. In this situation the compressor is already at maximum speed reducing the impact compared to a start from dead stop.

Suitability of Application

The trial system operates on R22 refrigerant. Logically this control system should be suitable for use on any system based on multi-cylinder reciprocating compressors, using any available refrigerant including ammonia. It would not be suitable for use with package refrigeration systems or for large ammonia systems using screw compressors. The cost to control a single compressor in a package system, using this technology, would be cost prohibitive. Screw compressors, by their design, have many of the attributes of this system in-built.

Cost/Benefit Analysis

The cost to install the system, including some costs associated with the increased capacity required, is approximately $126,000 comprising:

Switchboard (including PLC & vari-speed)	$57,000
Plant room upgrade (including supply of transducers and installation of switchboard, all pipework & equipment)	$45,000
Electrical installation	$20,000
Programming of PLC	$4,000

Data available at the time of publication indicates potential savings of:

Weight loss	$200,450 pa
Energy	$7,700 pa

Estimated payback period is 32 weeks.

Support Information

An electrical wiring diagram for the control panel and a logic ladder tree for the PLC program are available on request from Meat & Livestock Australia.

Video presentation (available with printed version of this kit)

Approximately 2.7 minutes of the alternate refrigeration control system installation showing the important features of design and construction are provided Technology Transfer Resource Package Instructional Video. This video shows the conventional and alternate systems in the refrigeration plant room and the condenser units. Footage relevant to the Alternate Refrigeration Control System DIY Kit is approximately located between VCR counter units 63:10 to 65:50.

Acknowledgments

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