Predictive Maintenance Programs (PMP's) In Small HVAC Applications: Analysis of Available Products and Technology

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INTRODUCTION

Maintenance of HVAC&R systems and scheduled replacement of components to avoid costly down time, degraded comfort conditions, or health hazards is not new. In fact, designs have not changed dramatically in many years. However, new regulations placed on CFC emissions and other environmental and energy conservation concerns are causing changes.

On the traditional side of things, cost for down time for any HVAC&R system whether it be for an industrial process or commercial function can add up very quickly and often results in thousands of dollars worth of spoiled goods or uncomfortable customers, tenants or employees. Even the slightest deviation from the operational norm of the refrigeration system can result in spoiled goods. It is also worth mentioning lost revenue in sales or productivity and even the possibility of coming under a civil suit in situations where HVAC systems go down in occupied buildings. Obviously, avoiding such situations would be desirable to say the very least.

In the past, this has been accomplished by what is known as *preventative* maintenance. In the past preventative maintenance programs have been the only means by which a company could avoid the costly alternatives listed above. The thing is, these scheduled maintenance programs can also be very expensive. They too, often require a certain amount of downtime and unfortunately don't always prevent untimely failures. Many man hours of maintenance time, down time, and inefficient system operation could be avoided with the help of a relatively new method of maintenance called *predictive* maintenance. With computers getting smaller and more efficient and the electronics involved in monitoring systems becoming generally less expensive, predictive maintenance is coming within reach to industry as well as the private sector. Someone said, "An ounce of planning is worth a pound of work." If HVAC&R systems could be economically monitored and their operation predicted in a literal sense, then many dollars worth of unnecessary maintenance cost as well as down time could be prevented.

This paper offers an overview of predictive maintenance technologies available. With the exception of the considerably more complex and expensive control type systems (e.g. the AKCESS 25 from Danfoss), all of the predictive maintanence systems presented here basically rely on comparative temperature measurements. The list of PMP's presented here is not to be considered exhaustive.

EXISTING PRODUCTS

Since service and replacement of components of HVAC&Requipment based on a predictive strategy is a relatively new field, there are many types of PMP's evolving. In this report, a predictive maintenance program will include fully automated as well as semi-automated systems. A fully automated system is one which requires very little or no knowledge of the operation of HVAC&R systems to operate. A semi-automated system is one which requires at least some knowledge of the monitored system to operate effectively. Table 1 lists the products and services uncovered during the research for this report. All information contained in the table and in the remainder of the report was extracted primarily from product data sheets and telephone interviews.

FLUKE 52

The first item on the list is the FLUKE 52 made by the Fluke Manufacturing Company. This device is not really a PMP in itself. It is presented here simply because its functions allow it to provide much the same type of data utilized by bona fide PMP's to arrive at predictive maintenance decisions. Fluke makes many different hand held metering devices but this particular unit offers a couple of features which make it a handy tool for not only spot checking

Table 1: PMP products and services available.

COMPANY	PRODUCT	COST	FULLY AUTO-MATED	COMMENTS
Fluke Manufacturing Company	FLUKE 52	$199.00*		Used primarily for spot checking and temporary monitoring. Requires trained technician.
Western Engineers	software based predictive maintenance program	$100.00 installed + monitoring fee		Combines power of computer with hand held metering to predict which component will fail and when.
Paragon Electric Company	Paraguard EC9000	$599.95**	X*	Provides continuous monitoring of system efficiency and performance.
DENCOR Energy Control Systems	Cool-Guard Model ACM-88	$680.00**	X*	Provides continuous monitoring of system efficiency and performance.
Danfoss Automatic Controls	AKCESS 25	$2121.00 ***	X*	Doubles as a HVAC&R process controller and monitor. Requires programming.
Woolery Technology Corporation	MMS-1 (maintenance management system)	****	X*	Utilizes an expert system to monitor HVAC&R equipment for clues that efficiencies are changing or components are failing.

* Service technician is still required to verify and resolve suggested problems.
** List prices. Substantially lower costs are available.
*** Does not include cost of database for programming or sensors and cabling.
**** Not Available

performance of an hvac system but also provides the means for some very limited short term monitoring.

The FLUKE 52 is basically a thermocouple reader with K or J type capability. Some of its special functions are dual sensing capability (T1 & T2), difference mode (T1-T2), hold mode which displays only the highest temperature detected while connected, and finally record mode which allows a limited amount of temperature data to be recorded and recalled for a particular process, for instance start up. This device does not diagnose possible problems by itself. Rather, it requires operation by a trained service technician to utilize the data obtained using the device to detect system operating irregularities and thereby diagnose possible impending system or component failure.[1]

Software based predictive maintenance

A predictive maintenance software program developed by computer programmer Jim White and service technician Jeff Jones both of Portland, Oregon combines the speed of computers with digital multimeters and temperature probes to predict air conditioning or refrigeration component failure. A complete description of the system appears in the Aug. 16, 1993 edition of Air Conditioning, Heating & Refrigeration News.[2]

The PMP requires installation of temperature sensors located at strategic locations throughout the hvac system as shown in Figure 1. The sensor connections are routed to an easily accessible box where the service technician can periodically connect a temperature reader and obtain data quickly. The data is then entered into the computer software. The program compares the new data to old data and with known operating parameters for particular types of equipment and performs a system analysis of specific conditions or components to inspect (i.e. "check condenser coil"). The software also can provide informational charts and graphs of the diagnosis as well as ordering information for parts.

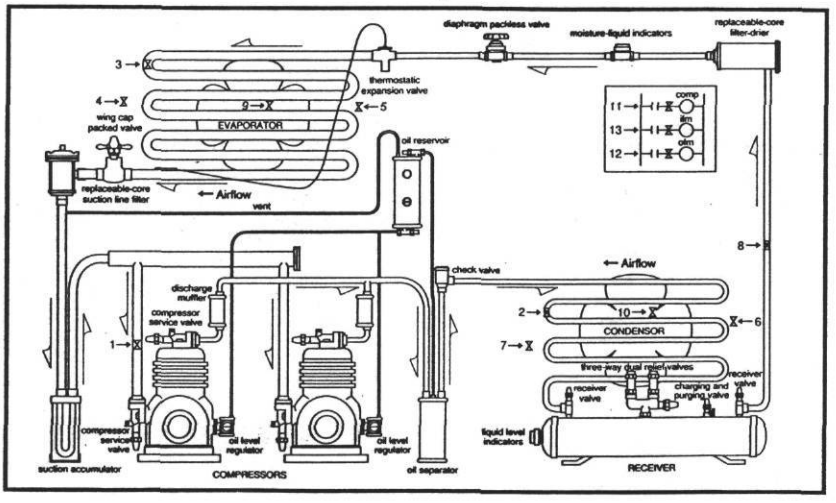

FIGURE 1 - Taken from *Air Conditioning , Heating & Refrigeration News,* August 16, 1993 issue.

Jones currently services 31 customers with his system with 90 more pending.[3] A telephone interview with Mike Anderson of Boise Cascade, one of Jones' primary customers, revealed that installation of this system had indeed reduced downtime and problems with their hvac systems.[4]

Jones offers some other advantages to implementing this system which would apply to any of the other systems mentioned in this report including reduced need for pressure gauge connections which result in refrigerant losses. Also, maintaining the equipment operation within its designed state will result in longer equipment life.

Paraguard EC9000

This system, manufactured by Paragon Electric Company Inc. of Two Rivers, Wisconsin, provides early detection of adverse operating conditions within a commercial refrigerant system by monitoring electrical current and the first five seconds of equipment start-up. The system requires no programming, and alarm conditions are displayed via LED status indicators.[5]

Other features include continuous monitoring of efficiency and performance, irregular cycling, and comparison to previous cycles to detect changing conditions. The system can be applied to conventional and parallel refrigeration systems and is compatible with existing security alarm monitors, building control systems and refrigeration control systems.

Installation requires only a 2 step setup for the defrost duration and compressor selection, and requires no special tools or programming.

Alarm indicators and fault codes used in conjunction with a troubleshooting guide help identify what type and where alarm conditions occurred in the system.

Cool Guard Model ACM-88

Manufactured by Dencor, Inc. in Denver, Colorado. The ACM-88 utilizes four temperature sensors installed on the air side only (no penetration of refrigerant system required) and a water level sensor in the drain pan to monitor compressors, condensers, evaporators, heating units, fans, and condensate drainage. It will identify such problems as refrigerant leaks, dirty filters, fan and blower failure, excessively high or low temperatures, low efficiency, and high water in condensate pan.[6]

The display station shows outdoor temperature, return air temperature, coil output temperature, cooling factor, heat pump factor, auxiliary heat factor, impending alarm conditions and has seven fault indicator lamps: 1. high temperature limit. 2. low temperature limit. 3. cooling output low. 4. heat pump output low. 5. auxiliary heat output low. 6. low air flow. 7. high water level.

The ACM-88 also has and electronic memory module which keeps the data during power outages without the use of batteries.

AKCESS 25

A lot of HVAC&R control systems are available on the market some of which may or may not have the same capabilities as this example.

The AKCESS 25 manufactured by Danfoss Automatic Controls in Baltimore, MD actually controls the operation of commercial refrigeration systems such as cut-in/cut-out control, temperature-modified rate of change control, screw compressor control, condenser control, and defrost control. It can operate as a stand alone device or be interfaced with a local PC or modem for remote access. The system can be programmed to have diagnostic capabilities to identify potential problems such as compressor failure, coil frosting, dirty filters, ahead of time with the proper sensors installed.[7]

MMS-1 (Maintenance Management System)

This system takes a slightly different approach to the predictive maintenance problem. It utilizes advanced computer technology combined with experience from over a dozen HVAC&R experts to watch the unit for changes or patterns which may indicate a problem. When a potential problem is observed via temperature probes the monitor decides what the most likely cause of the problem is and the information stored in its on-board memory. By pushing a button on the monitor, a serviceman can view what problems the unit has observed and the suggested causes.

The unit has the capability to learn how the particular system runs when it tuned to peak performance and detects subtle changes in operation over time. From this data, the unit calculates the relative drop in performance of the system and displays the need for service to the system.

Installation of the MMS-1 is relatively simple and requires no intruding into the refrigerant or control systems themselves. The unit will then program itself by learning the key factors for the system.

The state of the system is evident on the display panel which uses a colored light information scheme. The display provides constant information on relative system performance, on/off status

of the system, and early trouble warnings.

The on-board provides a history of problems such as airflow related, refrigerant related, mechanical, and electrical. It will also identify the likely causes of hvac problems and record the order in which they occurred.[8]

The MMS-1 is no longer in production due to the fact that the manufacturer, Woolery Technology previously based in Dallas, Texas, is no longer in business. The unit was apparently over priced or there was not enough of a demand to support the company. However, the nature of the MMS-1 and its relation to future diagnostic and preventative maintenance systems warrants its inclusion in this report.

SUMMARY

It is evident from the analysis of the systems presented here that PMP's can take a number of different shapes but all have these things in common:

1) They utilize electronic monitoring equipment (primarily temperature sensors) to obtain conditional data for the HVAC&R system.

2) They diagnose problems base on the collected data and in some cases recommend solutions.

3) They provide timely information which can predict or be used to predict component failures which means replacements and repairs can be made in an expedient and timely manner.

4) When properly used, they insure the proper operation and therefore the service life and efficiency of the hvac or refrigeration equipment being monitored.

FUTURE DIRECTIONS

With computers constantly becoming smaller and faster and electronic monitoring equipment becoming more and more economically feasible for industry and the private sector, systems such as those mentioned in this report will no doubt become more common place.

It can also be said with confidence that these types of systems will become more accurate in their diagnosis of hvac system problems as expert systems and artificial intelligence work their way into the framework of PMP's.[9,10,11]

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