Advanced Cold Room Control Unit with Microcontroller

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---ABSTRACT---
Modern refrigeration systems use different automation systems to reduce the temperature in medical applications such as storage of drugs and blood, storage and transport of perishable foods. Industrial cold rooms which are used to cool the products are the devices that can control compressor and defrost thanks to the developed control panels. With the electronic control panel developed, it includes many features such as remote access, voltage - current control, intelligent error management, intelligent defrost control system, error recording, status recording. In this study, the electronic card and the automation system software for the cooling cycle of the cold room systems have been developed. In this system, intelligent fault detection is performed in order to provide optimum control of energy in a high performance way and thus, it is aimed to reduce operating costs
KEYWORDS;-*Cold Room, Defrost, Microcontroller*

I. INTRODUCTION

In the global market place, getting the right goods at the right time and place is as important as reducing costs. Visibility is especially important in a supply chain where temperature control in transportation or storage is needed to keep the quality and quantity of products at the end of the supply chain at the required level [1]. The supply chain can be quite complex when dealing with food products. The limited lifetime and the deteriorating quality of perishable foods over time contribute substantially to the complexity of their management [2, 3]. Perishable foods need proper temperature-controlled environments during the production, storage, transportation and sales processes to ensure food quality and reduce food losses. This is generally referred to as "cold chain logistics" [4].

Refrigerator transportation is an important part of cold chain. Aiming at monitoring the temperature and humidity inside the refrigerator trucks, and managing information of the refrigerator trucks internal [5].

Today, Cold Rooms have been developed for use in commercial storage. The cold room is a place where the foodstuffs are cooled and insulated from the external atmosphere under suitable conditions (heat and humidity) for longer storage. The purpose of the cold store should be to provide as constant temperature and relative humidity as possible. Even the short-term temperature rise causes an acceleration in the growth of microorganisms. However, storage time is limited and varies from product to product. A simple refrigerator can be made by reducing the temperature of the storage space. However, the accuracy of the refrigeration process depends on the design technique, refrigeration technology and storage parameters. The most important is that these parameters are accurately measured and controlled. If the control of these parameters is insufficient for the needs of the system, the refrigeration cycle will cause deterioration of the stored foods. [6-8].

The cooling parameters in the cold storage systems should be checked properly with electronic control cards. If parameter control is lacking, refrigeration cannot be performed according to the properties of the food and this leads to food waste. Cold storage devices are systems that consume a lot of energy. If electronic control cards do not perform cooling properly, electrical waste is increased. At the beginning of this electrical waste, defrosting is done at the wrong times. Cold room design requires instant control of storage parameters. Additional devices and additional control units are needed to control the parameters of the cooling cycle. This not only complicates the design, but also increases the maintenance and initial installation costs of the system. It is necessary to change the temperature, humidity, pressure parameters occurring in the storage area in existing cold storage rooms or to save these parameters in the system. Otherwise, failures cannot be detected in time and the quality of the stored food decreases. [9].

Major components of a typical supermarket refrigeration system include compressors, condensers, display cases, cold rooms and thermostatic expansion valves. The following operation data is available from the monitoring center: 1) continuous variables are sampled every 5 min, including the cold room temperature and 2) binary variables are sampled every 2 min, including the room door open/close status, defrosting status, fan status, cooling status and alarms. Temperature related alarms would be triggered whenever the monitored

temperature is out of a preset acceptable range. Monitoring center operators must find the root cause of the alarm – detect and diagnose possible faults in the refrigeration system. Currently, this analysis is a manual and time-intensive process [10,11].

Significant energy losses occur in electrical energy due to defrosting and continuous operation of fans in cold rooms. In this study, an electronic control card has been developed, which ensures that the automation of the cooling system is optimally maintained and energy saving is achieved while preserving foods. In addition, with the help of intelligent fault detection, optimum control of energy has been performed in a high performance manner and thus, it is aimed to reduce operating costs.

II. MATERIAL AND METHODS

Cold rooms slow down chemical enzyme reactions. In this way, it delays the development of microorganisms and stores them very close to the initial state of nutrients. However, cooling delays the proliferation of the population of microorganisms, but causes a limited number of degrading microorganisms to die. Therefore, it is important to protect the products from microorganism infection. In cold storage, the equilibrium in temperature and relative humidity varies depending on different factors [12].

Research has shown that vegetables, fruits, meat, milk, eggs, etc. will be placed in the rooms for protection. most foodstuffs, such as natural resources immediately after being subjected to a pre-cooling and rapid cooling is required. This prolongs the storage time in the cold room [10-13].

There is a compressor room as a central system in conventional cold storage applications. Refrigerant pressurized in compressor and rising temperature goes to condenser. Here, the fluid is cooled and liquidized. The refrigerant goes to the evaporators in cold volumes with the help of insulated pipes drawn to the volumes to be cooled and evaporated. As the refrigerant evaporates, it takes heat from the environment and cooling takes place. During the system start-up, detailed settings must be performed. Otherwise, an error in the system can cause serious damage to the operator.

This type of cold storage devices have some advantages over conventional cooling systems. These can be summarized as:
• All cooling elements (compressor, condenser, evaporator, expansion valve table, etc.) of each type of cold room device are on their own.
• A single appliance cools only one room.
• Since the device is packaged, it is easier to find the cause of the malfunction and intervene in the malfunction.
• Since the device is placed in a space left in the room wall or ceiling, the compressor systems, etc., which are present in the central systems. the requirement to use the volumes has been eliminated.
• Devices can be used both as air-cooled condenser and as water-cooled condenser.
• If the devices are equipped with air-cooled condensers, the connection to be made during installation is only electrical wiring, which saves a great deal of time.
• As there is no need for service volumes, refrigeration gas return / return lines are no longer required in each room.
• It saves electricity by cooling a certain volume.

Each cold compartment has a thermostatic expansion valve, which acts as the regulator through which the correct amount of refrigerant is passed. On large systems a master solenoid may be fitted. If the compressor stops due to a fault, the master solenoid will close to prevent flooding by liquid refrigerant and possible compressor damage. The sketch is for a three compartment system but shows only the detail of one. Each room has a solenoid, regulator and evaporator. Air blown through the evaporator coils acts as the secondary refrigerant. Regular defrosting by means of electric heating elements keeps the evaporator free from ice. The automatic defrost time switch de-energizes the solenoids to shut down the system and diverts electrical current to the heaters, for a set period [14-16].

Different types (standard, cabin type, ceiling type) evaporators are available according to cold storage characteristics, loading type or product specifications. The outdoor unit is built to withstand atmospheric conditions. There are easy-to-open control covers during installation and failure. The device is manufactured depending on the weather conditions. Automatic fan pressure can be changed according to summer and winter temperatures. In cooling devices, the outdoor unit (condenser unit) operates at very low noise level.

The refrigerant passes through the drainer and moisture sight glass to the externally compensated expansion valves. Valves on both sides of the desiccant filter control excess refrigerant leakage. Thermostats control solenoid valves. The solenoid valve opens or closes depending on the temperature in the thermostat sensor. There is a valve at the evaporator outlet. This valve prevents reverse ingress of gas from the other evaporator if the compressor does not start. An evaporation pressure regulator is installed at the evaporator outlet. This regulator provides a constant evaporation pressure of 8˚C - 10˚C below the desired temperature. The crankcase pressure regulator prevents the compressor from overloading at the start of operation [9-12].
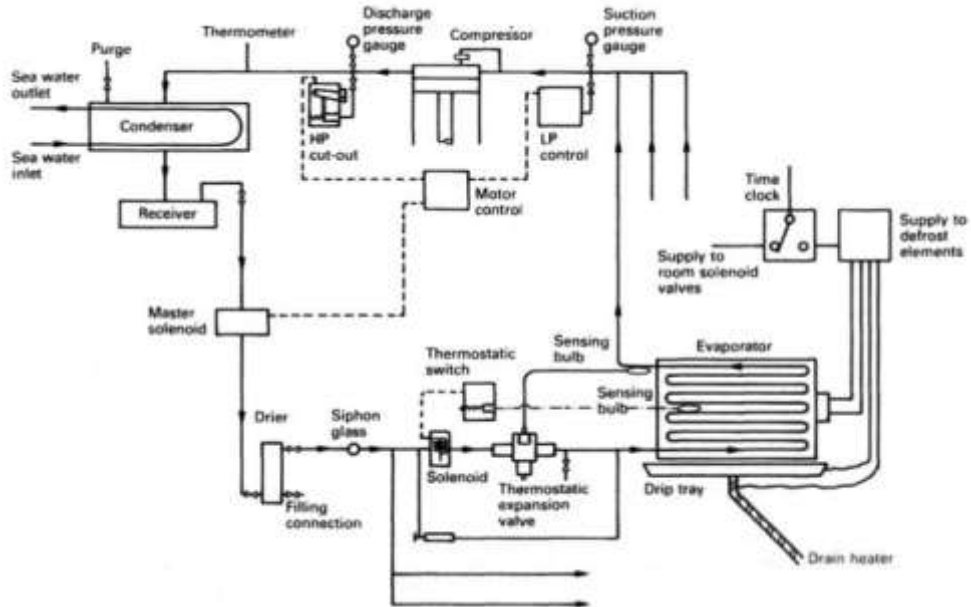
Figure 1. General purpose cold room system structure

The differential oil pressure switch stops the compressor when the compressor oil pressure is too low. High and low pressure controls work together. Prevents the compressor from being subjected to very low or very high pressures. When provided with the necessary condition, sufficient pressure is supplied to the expansion valves in the liquid (liquid) line to provide refrigerant. The cooling system also has a condensation pressure regulator and a differential pressure valve (regulator).

Figure 2. Electrical connection diagram of general purpose cold room system

In portable cold rooms, there is a door heater and lamp in the control circuit. In addition, thermal relay and winding thermic, pressure switches, oil pressure switches are used in the control circuit for safety. Thermostat is used as temperature control. The compressor is operated with the condenser. The liquid line closes when the compressor stops. The crankcase heater and the evaporator fan operate continuously. The circuit diagram in Figure 2 shows a low and high pressure switch, solenoid valve and timer. Low and high pressure switches are connected in series. The solenoid valve is connected in parallel to the circuit. The timer (time relay) controls the thermostat, evaporator fan and evaporator resistance and defrost thermostat.

III. DEVELOPED ELECTRONIC CARD

The system consists of two separate units. The first part is the control unit of the cold room. In this section, it is aimed to read the sensor information about the cold room and control the system with relays. The other part is the keypad and display unit. In this part, it is aimed to control the system via keypad and to read the information on GLCD screen.
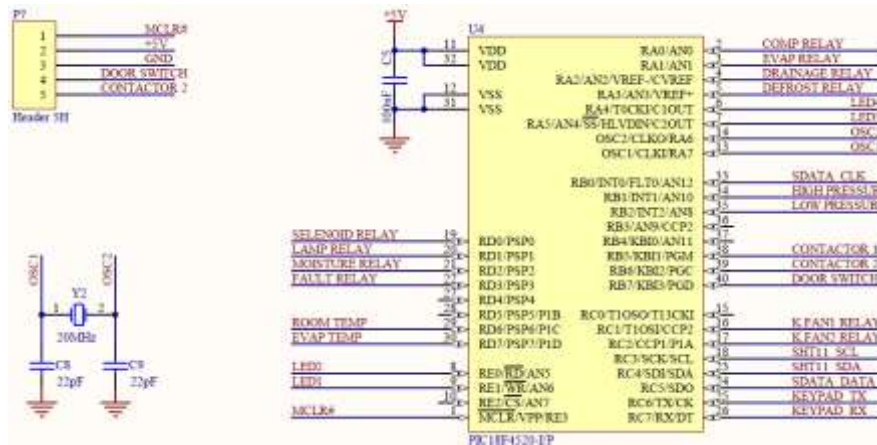

Figure 3 Pin states of the PIC18F4520-I / P microcontroller

Figure 3 shows the processors and pins of the control unit of the system. Two separate processors are used here. The first processor is used for the evaluation of sensors and inputs and for the control operation with relays. The purpose of using an additional processor is that the pins are insufficient and the serial communication process is performed only with this integrated (Figure 4)..
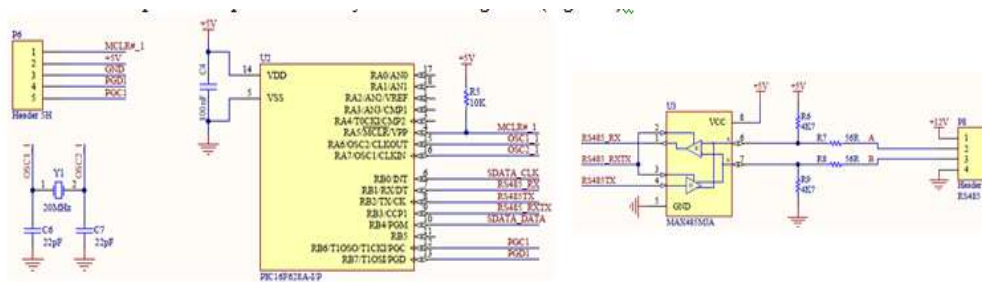

Figure 4 PIC16F628A processor and MAX485 integrated for the communication infrastructure

Main system components; evaporator, condenser, compressor, expansion valve and cooling tower. In this study, it is necessary to properly digitize the data obtained. A 12-bit A / D converter is used. Some sensor information was transferred directly to the microcontroller via serial communication protocol. The data obtained was transferred to the other keypad / GLCD unit using RS485 data transmission standard and, if necessary, to the computer environment {17-19].

Figure 5. The relay is the control unit. With the help of this circuit, the cooling equipment of the cold room circuit is controlled. The refrigerant compressed in the compressor is condensed in the air-cooled condenser. The condensed fluid in the condenser is sent to the liquid reservoir. After being filtered in the liquid line, it is sent to the expansion valve.
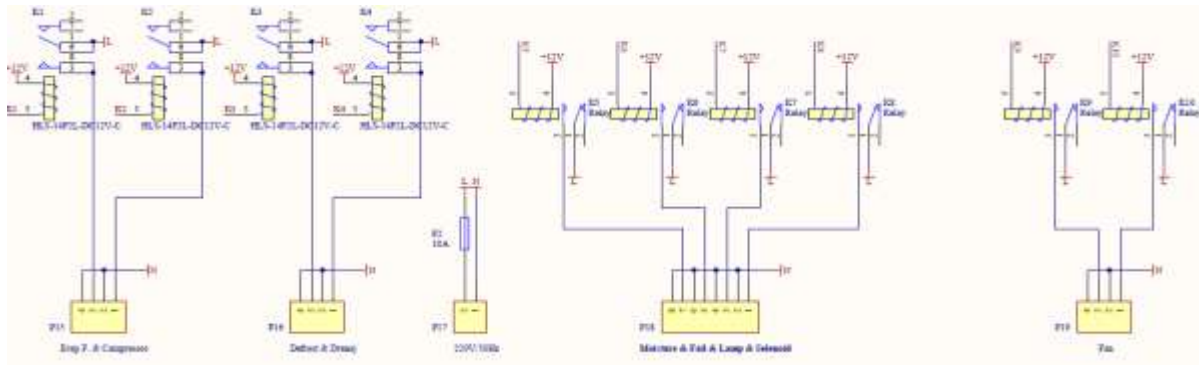
Figure 5. Relay Control Unit

The pressure drop in the expansion valve is sent to the evaporator to boil. The evaporating fluid is reabsorbed by the compressor. The coldest surface in the cooling system is the evaporator surface. Therefore, icing and / or snow occurs on the surface of the evaporator from the moisture of the air. Defrosting is the process of melting to prevent snow or ice on the surface of the evaporator. In room coolers, snow defrosting system must be present at evaporation temperatures below zero degrees. Otherwise, the water freezing between the fins prevents the cooling process to continue by reducing the air movement (even stopping it completely) in a short time. The fans help to remove the vapor from the environment. In addition, control relays are installed for fault conditions in the system (humidity, open door, solenoid error, etc.).
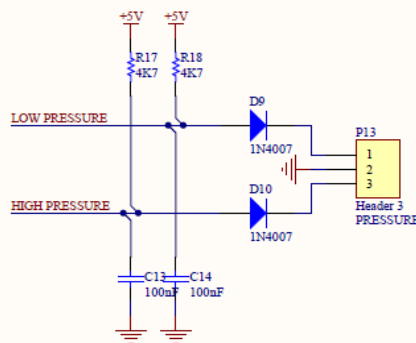

Figure 6 Low and High pressure Pressostat connection

There are two types of pressure processes used in cold rooms: High Pressure process, Low Pressure process. Figure 6 shows the Pressostat connection to the cold room controller.
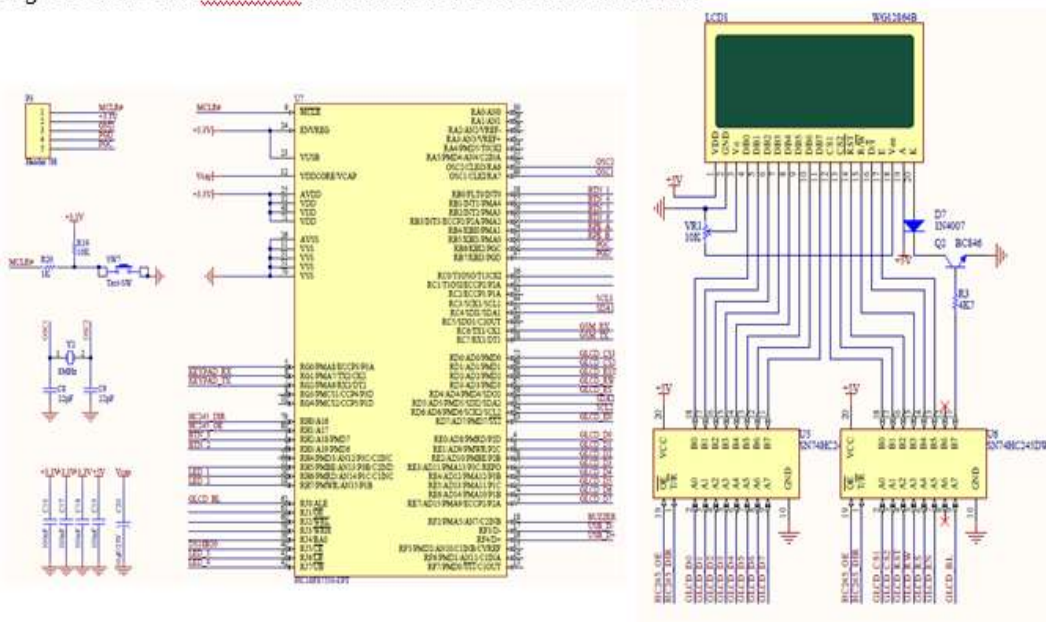

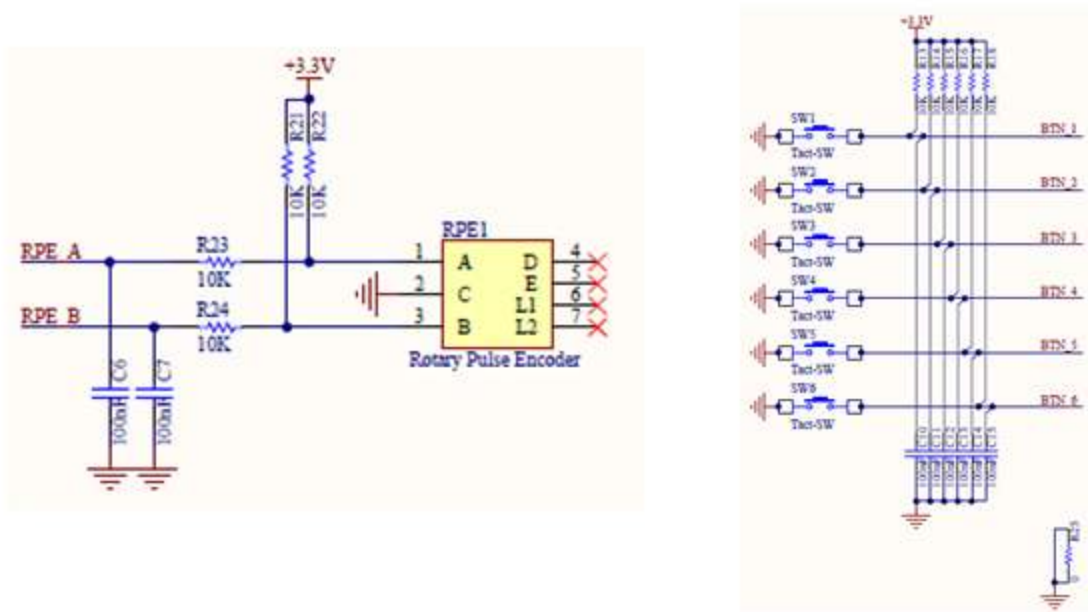**Figure 7 Graphic LCD and PIC18F87J50 Microcontroller connection**

Figure 8 Rotary pulse encoder and keypad

High Pressure Pressostat: This device is a pressure switch and connected to the compressor outlet pipe. When the pressure exceeds the set value, the magnetic switch that turns the compressor into electric motor cuts the current through the windings of the coil and causes the compressor to stop.

Low Pressure Pressostat: Unlike high pressure pressostat, it opens the electrical circuit when it is dropped below a certain pressure, that is, the compressor stops.

Figure 7 shows the keypad and graphic LCD unit. Since the values are easier to enter and occupy less space, a rotary pulse encoder is used in addition to the keypad (Figure 8). It is very easy to use
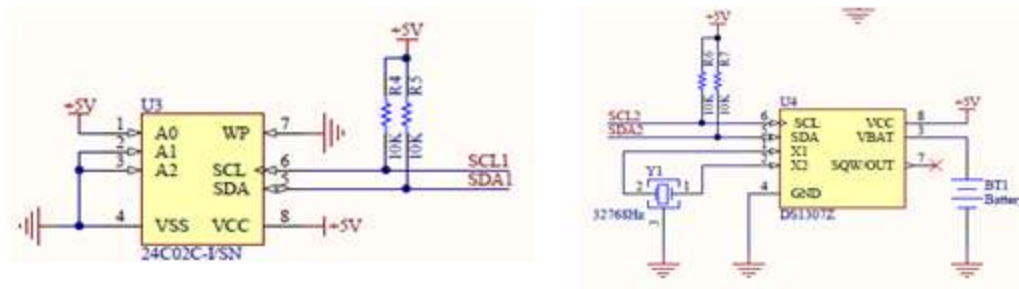

Figure 9 External EEPROM and RTC circuit

This electronic card is also in communication with the data coming from the system. As can be seen in FIG. 9, there is also an RTC circuit and an EEPROM on which the information can be recorded if necessary. RTC system clock, status register time, sensor fall time, defrost repeat time, defrost continuous time, drainage wait time, such as the information contains.

Figure 10 computer cold room control software

Two different software were used. Embedded and PC software

Embedded software: It is the software on the embedded electronic card used to control the cold room device. The software developed with C Compiler combines all automation features. The device uses RS485 as the communication protocol [20,21].

PC software: Developed for controlling the automation systems of the cold room equipment. Instant parameter and error monitoring will be performed on the computer and the system will be intervened when necessary (Figure 10).

Temperature

Room temperature determines the product properties to be stored. Usually the products are stored at temperatures very close to the freezing temperature. However, as with some tropical fruits, product storage may need to be carried out to a high degree. For example, Bananas cannot be stored below 9ºC, oranges below 5ºC. Storage temperatures should be investigated by product type.

In addition, it should be noted that the storage temperature of frozen food products should be -18ºC and below. For example, frozen chicken and red meat are stored at -18ºC, while frozen fish and ice cream should not be stored above -22ºC. Due to this diversity of products, cold room systems must have a wide cooling cycle automation.

Defrost

Defrost is the process of melting the ice formed on the surface of the evaporator at intervals. During defrost period, the melting process of the evaporator surface is commonly done with electrical resistance, hot gas and water shower.

The heating power to be generated on the evaporator should not be too much. Sufficient heating power is determined by the amount of heat prescribed in the evaporator design.

In this study, intelligent defrost systems will be found. In this way, it will be possible to protect the food in a healthy way while saving energy.

Moisture in cold rooms causes icing on the evaporator. When frost begins in the evaporator, the air passing through the blades to the fans will decrease. As the load on the fan decreases, the current drawn will decrease and this current change will be detected and defrost will be activated [22].

Defrost time

One of the most energy consuming applications in the cold room cycle is defrosting. In order to save energy, it would be more convenient to perform the Defrost operation within the specified hours. With the software on the screen, the timing of defrost can be done.

Humidification

In storage of fresh fruits and vegetables, it is inevitable to provide high relative humidity in the room. Correctly designed evaporators can provide high relative humidity in the room, but absolute moisture transfer to the evaporator is inevitable, even if it is minimized by a good design. Given the absolute moisture absorption of

possible hygroscopic materials to be used, humidification in the room becomes inevitable. The transfer of moisture to room air should be in the form of steam transfer, not as the transfer of water mass.

Errors that may occur on the system will be displayed on the screen as alarm. These errors can be:

Door open time recording and alarm, Low and high voltage alarm that may occur in mains voltage, instantaneous voltage swing alarm, phase voltage difference and no phase alarm, phase sequence control and fault alarm, analog and digital monitoring of high and low pressure values and fault alarm etc

Other situations related to automation system are summarized briefly;

• In electric motors; overcurrent, high temperature control and alarm, possibility of manual reset of the system after high current, Run time recording and memory

• Retrospective alarm memory for fault and alarm stop control

• Recording of voltage, current, humidity, temperature values during operation, monitoring from the screen and computer

• Intelligent error management algorithm

• Error recording system

• Gradual control of condenser fans according to gas pressure

In the automation of cold room systems, energy saving was provided by defrosting and operating the fans correctly. With the developed cold room system, a control card has been developed that saves energy and eliminates the need for additional devices.

IV. CONCLUSION

In this study, Thanks to the electronic card developed the cooling system will be cheaper and provide longer life. Products will be stored in a healthier and safer way with the cooling system. It will also contribute to the budget of end users with energy saving.

The desired humidity values on the electronic board can be adjusted digitally. Voltage control structures on the electrical system will be prevented from compressor errors. Energy efficiency solutions with smart defrosting are offered. All parameters related to cooling will be monitored. Power failure etc. In case of emergency, it will alarm through the warning system.

With the help of intelligent fault management, there will be no loss of critical time interval. In this period, the system will be able to make the necessary corrections possible with intelligent fault correction. Since the system will intervene automatically, the device will have longer life. Deterioration of the products stored in the cold room will be prevented as the downtime will be shortened

In addition, in case of a high pressure error, the device fault management system will be operated and other features of the device will be stopped until the high gas pressure is reached. In this way, the condenser fans will be operated in maximum step and the device will return to normal operation after the error is cleared.

By measuring the current drawn by evaporator fans, if defrost is needed, the operation will be performed. This will provide a more efficient method than sequential defrost systems, which expend unnecessary energy and cause room heating. With the real-time clock-date mechanism in the device, it will perform defrosting at times when electricity is cheaper and provide less energy.

The device also has an error recording system. Some errors such as power failure, door open error, high pressure error, contactor sticking etc. during the operation of the device will be recorded and warnings can be read upon request.

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