# THE DIAGNOSTICS OF HEAT PUMPS IN THE CASE OF A DISCRETE-COMPONENT MONITOR SYSTEM

***Prof. Dr. Jozsef M. Nyers D. Sc. , Arpad J. Nyers***
*Polytechnic Engineering College of Subotica*
*24000 Subotica, Vojvodina, Yugoslavia*
*Tel: +381 24 552 501, Fax: +381 24 555 087*
*E-mail: jnyers@vts.su.ac.yu*

***Abstract***

*This article discusses the possible failures of a heat-pump in detail, and deals with the determination of the location and reason of the failure.*

*The paper describes the types of sensors that can be applied, their mode of function, and how they can be categorised.*

*The entire diagnostics of the heat-pump is presented in the form of a table.*

*The controlling and monitoring are dealt with briefly in the introduction.*

## 1. INTRODUCTION

A heat-pump cannot operate without a control system [1], [2]. Operating a heat-pump without a monitor system would involve the danger of a breakdown or explosion in the case of a failure [3]. It is possible to operate the system without a diagnostic system, as it has been until the present, yet it may be of vital importance for the maintenance staff and the owner. In the case of any form of fault the diagnostic system will point out the location and as a reminder, list all possible reasons for it. Besides this the diagnostic system may contain the measured and screen display of the necessary measured sistem parameteres.

Until now heat-pumps and cooling machines were not equipped with diagnostic systems because of the lack of technological background. Microelectronics, and the immense development of semi-conductors have opened great possibilities in the realisation of diagnostic systems. With the appearance of microprocessors, now there is a piece of equipment at our disposal with huge speed and capacity for the storing of incoming data. Visualising the data poses no longer a difficulty considering the various types and price categories of screens that are available.

## 2. CONTROL SYSTEM

There are two methods of controlling the heat-pump [2]. One is the traditional discrete, discontinual controlling system. (This system is made up of traditional, well-known components). The other method is a newly devised, continual control strategy based on semi-conducting technology.

### 2.1. Discontinual Controlling

The discontinual controlling system is made up of discrete components. These are independent units into which there are microswitches installed run by sensors. Besides this the components are equipped with a set point input mechanism. The installed sensor monitors the changes in the system parameters and depending on the set point, re-sets the microswitch into one or the other position. Through this the electric control circuit is either closed, or the system is shut down. The changes of the microswitch can be used as signals in diagnostics.

Discontinual controlling of the heat-pumps can be direct or indirect. In both cases the controlling is done by a room thermostat, based on the measured room temperature and the given set point.

In **direct controlling** there is one controllor, which is the room thermostat. The thermostat disconnects the current in the electric control circuit, thus the contactores stop the electric energy supply in the electromotors, and the system stops.

In **indirect controlling** there are two control circuits, positioned in cascade form. In the primary control circuit the room thermostat switches the solenoid valve (installed in the cooling circuit) on and off. In the secondary control circuit a low-pressure pressostat monitors the pressure in the suction pipe of the compressor. In the case of decreasing pressure the pressostat will shut down the system once the set point is reached.

## 3. MONITOR SYSTEM

The same monitoring system can be attached to both control systems [3]. The monitor checks the parameters of the system, and if they differ from the set point, the monitor reacts and brings the system to a standstill. The operation of heat-pumps without a minimal monitor is not permitted, since the failure of some parts of the system can lead to breakage in the compressor or condensator.

**The minimal monitor system** is made up of a high-pressure pressostat, a thermostat equipped with a sensor for surface temperature, and a thriphase thermal overload relay.

-The high-pressure pressostat monitors the pressure in the condensator and the suction pipe of the compressor. If the pressure rises to the set point, the pressostat will stop the system, keeping the compressor from breaking, and the condensator from exploding.

-The thermostat monitors the surface temperature of the evaporator, and brings the system to a halt if the temperature drops to set point.

-The thermal overload relay monitors the electric current input of the electromotor. If the amount of electric current exceeds the set point, the relay will shut down the system.

**The extended monitor system**,

as described above, can be extended in the following ways:

- by differential pressostat, which monitors the pressure difference in the lubricating oil in the compressor.

- by differential thermostat, which monitors the temperature in the inlet and outlet of the filter. If there is a difference in temperature, and it is outside the set point, there is no need to close down the system, but the operator must be alerted that the filter is clogged and has to be replaced.

- by low-pressure pressostat, which monitors the pressure of the refrigerant in the suction pipe. If the pressure difference sinks below the set point, the operator has to be warned that there is not enough refrigerant flowing through the evaporator.

- with the installation of another low-pressure pressostat into the suction pipe, it is also possible to monitor the condition of the compressor. If the pressure in the suction pipe rises above the set point, that definitely points towards a fault in the compressor. The pressostat will indicate this rise in pressure.

## 4. DIAGNOSTIC SYSTEM

### 4.1. The Purpose

The control system and monitor system are vital to the operation of the heat-pump. A supplement to these two necessary systems is the diagnostic system. It provides both the user and maintainer with useful information. The diagnostic system monitors the operationing condition of the heat-pump and displays the location and reason of the fault.

### 4.2. The Structure

Structurally, diagnostics is based on the monitoring system, they share the sensors monitoring the operating condition of the heat-pump, like the pressostats, thermostats, thermal overload relay.

According to present-day technology, these microswitch-equipped sensors can be replaced by semi-conducting sensors. In this case signalling takes the form of microcurrent, and a microprocessor can be used for signal procession.

The sensor equipped with traditional microswitches operates on network voltage, therefore the display panel of the diagnostic system may also be composed of LED diodes. Naturally, with the appropriate voltage adjustment, these signals can also be fed into the microprocessor for evaluation and establishing of the diagnosis.

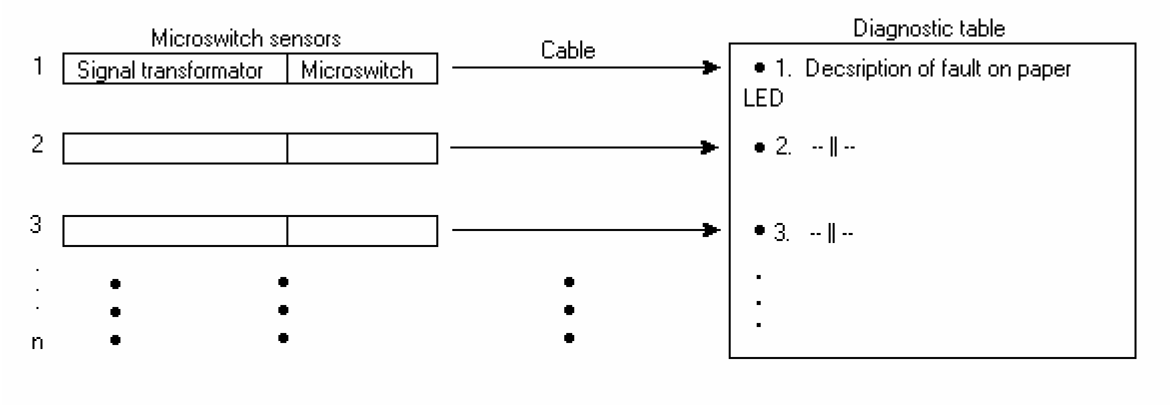


**Fig. 1:** Diagnostic system with LED diodes, with microswitch sensors

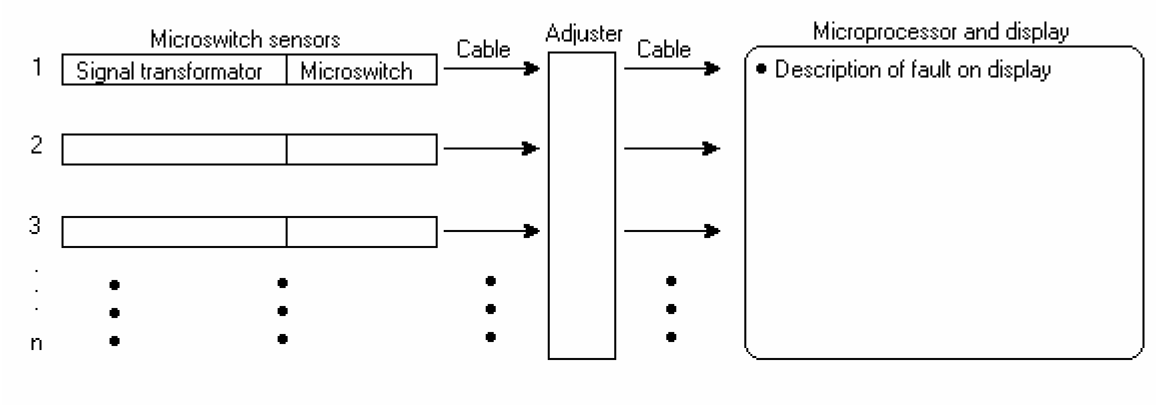


**Fig. 2:** Diagnostic system with microprocessor, with microswitch sensors

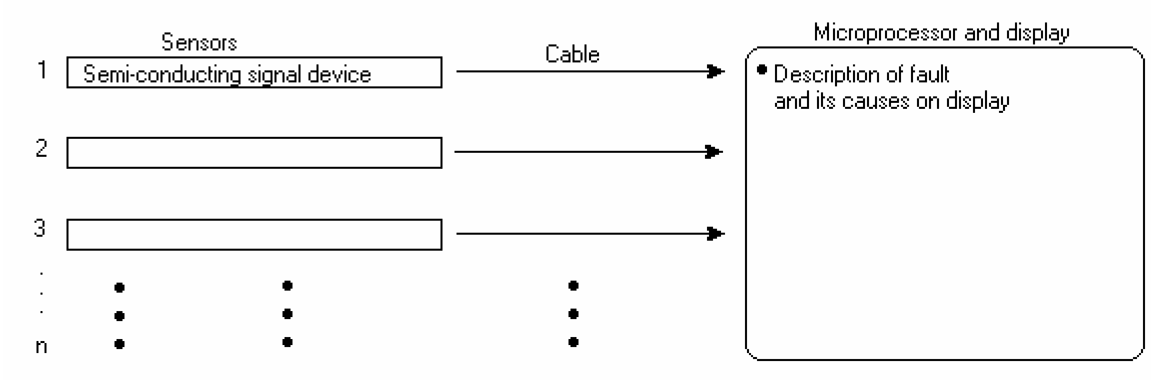


**Fig. 3:** Diagnostic system with microprocessor, with semi-conducting sensors

## 5. OPERATING PRINCIPLE OF THE SENSORS

Theoretically the operating principle of the microswitch sensor is collective, in every case some sort of mechanical switch disconnects the control circuit. With semi-conducting sensors, the sensor changes its electric characteristics based on other mechanical influences, which are changes in pressure, light intensity or temperature. The logic of the diagnostic system will sense these electric signal changes, and indicate a fault.

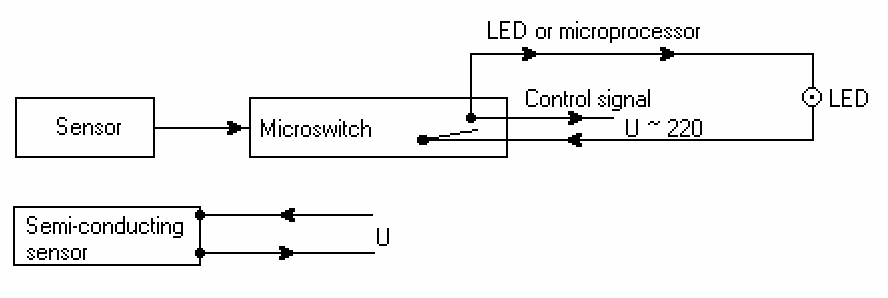


**Fig. 4:** Outline of sensor connection

## 6. OPERATING PRINCIPLE OF THE DIAGNOSTIC SYSTEM

Every monitoring sensor is also a part of the diagnostic system, and besides these the diagnostic system has individual sensors, as well.

The underlying principle of operation in the diagnostic system of signals is that the sensors allow free passage to electric signals if the heat-pump operates within normal functioning parameters.

In the case of any irregularities, the given sensor disrupts the electric circuit, so a change in voltage occurs. Due to this change in voltage the LED diode connected to this sensor indicates, and refers to the content of the fault described below it.

The fault indication can be displayed on paper or on screen.

If the sensors are connected in series, and two irregularities arise simultaneously in the same loop of sensors, then first the fault is indicated by the one sensor sensing the change in voltage, then the next one will indicate it. Each sensor is separately connected with a LED diode or a microprocessor inlet.

With a thorough knowledge of the system, one can describe the system of irregularities, their causes, and the mode of correction. This is the essence of the diagnostic system.

## 7. THE ALGORITHM OF DIAGNOSTICS

The algorithm of diagnostics contains the sum of all detectable faults and irregularities arising during operation. Unfortunately, diagnostics is not always obvious, as different malfunctions or faults are indicated by the same parameter changes, and sensed by the same sensors. This explains why in the algorithm of diagnostics there will be several causes displayed alongside an indicated fault.

| **Sensor indicating fault** | **Change in condition** | **Reason for fault** | **Cause** |
|---|---|---|---|
| **High-pressure pressostat** | 1. Too high pressure in the condensator | 1.1. Not enough heat extraction | 1.1.1. Centrifugal pump fails<br>1.1.2. Centrifugal pump rotates slower<br>1.1.3. Clogging in the pipe system<br>1.1.4. Air-plug in the pipe system |
| | | 1.2. Too much refrigerant in the condensator | 1.2. Heat-pump overfilled with refrigerant |
| | | 1.3. Air got into the refrigerant | 1.3.1. Heat-pump was not vacuumed properly<br>1.3.2. Air got into the system when it was being filled up |
| | | 1.4. After compression the steam of the refrigerant was overheated | 1.4. Thermo-expansion valve was not properly set |
| | 2. Too high pressure in the out let pipe of the compressor | 2.1. Too small surface of condensator.<br>2.2. Steam cannot leave the compressor | 2.1. Mistake of design<br>2.2. Manual valve on compressor that someone forgot to open |

| | | | |
|---|---|---|---|
| **Thermostat with surface sensor** | Surface temperature of evaporator is too low | 1. Not enough heat input | 1.1. Centrifugal pump fails<br>1.2. Flow rate of centrifugal pump decreases<br>1.3. Clogging in the pipe system<br>1.4. Clogging in the evaporator<br>1.5. Capacity of well decreases<br>1.6. Bottom valve allows water to flow back |
| | | 2. Too small surface of evaporator | 2. Mistake of design |

| | | | |
|---|---|---|---|
| **thermal overload relay** | There is overflow in one or more phases of the electromotor | 1. A phase is out<br>--------------------------------------<br>2. Voltage of a phase drops<br>--------------------------------------<br>3. Short circuit in the winding<br>--------------------------------------<br>4. Mechanical jamming in the compressor, electromotor and the pumps | 1.1. A fuse blew<br>1.2. Distributor's fault<br>------------------------------------<br>2.1. Distributor's fault<br>------------------------------------<br>3.1. Poor quality electric insulated winding<br>3.2. Lubricating oil in compressor is acidated, the insulation has been corroded<br>3.3. Electromotor of compressor is not cooled properly. Insulation is worn out<br>------------------------------------<br>4.1. Breakage in the compressor<br>4.2. No oiling in the compressor<br>4.3. Dirt in the centrifugal pump |

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|---|---|---|---|
| **Differential thermostat** | Difference in temperature between the two ends of the filter | Resistance of filter has increased, so pressure has dropped, leading to a decrease in temperature | Filter is clogged by dirt in the filter. Filter needs to be changed |

| | | | |
|---|---|---|---|
| **Differential pressostat** | Pressure in the out let pipe of the compressor's oil pump rises too high | Lubricating oil does not have enough flow | Oil pipes and bearings are clogged |

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|---|---|---|---|
| **Low-pressure pressostat** | Pressure of refrigerant in the suction pipe decreases | 1.Resistance of filter has increased<br>--------------------------------------<br>2. Not enough refrigerant in the system | 1. Filter is clogged<br>------------------------------------<br>2. Refrigerant has leaked from the heat-pump |

| | | | |
|---|---|---|---|
| **Low-pressure pressostat** | Pressure in suction pipe rises too high | 1. Flow rate of refrigerant from the evaporator has decreased<br>--------------------------------------<br>2. Amount of refrigerant fed into the evaporator is too high<br>--------------------------------------<br>3. Temperature or amount of water flowing into the evaporator has risen | 1.Malfunction of compressor<br>------------------------------------<br>2.Thermo-expansion valve too open<br>------------------------------------<br>3. Delivery and water temperature of well has increased |

## 8. CONCLUSION

This article has provided a description of the heat pump's control, monitor and diagnostic systems. The determination of the location and causes of the fault, as well as forms of their elimination have been dealt with in great detail.

The technical realization of the diagnostic system is also presented.

Therefore, according to this paper the design, creation of the entire diagnostic system of the heat pump is made possible.

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