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ABSTRACT

This paper discribes an automatic control and measurement system which is utilized as a testing apparutus for refrigeration compressor performance. The refrigeration capacity is measured by two kinds of methods, the secondary refrigerant calorimeter method as the main measurement and the calorimetry for the water cooling condensor as the accesory measurement. They both meets the precision and other requirements from ISO 917-1982. The regulation of test working condition and the measurement of parameters are carried out automatically by the control of a microcomputer. The test results, a data report table and a series of performance curves, are also given out automatically.

INTRODUCTION

The performance test devices of refrigeration compressors are the key equipment in laboratories of production and investigation. But the performance test by man-control is rather complex and difficult. So, we investigated and manufactured a computer automatic control and testing system CACTS-1 from 1984 to 1987. By now, it has been used in several compressor manufacturers and refrigeration equipment factories effectively.

COMPOSITION OF CACTS-1

Figure 1 shows the principle sketch of this system. The refrigeration system is mainly composed with a hermatic refrigeration compressor, a caloimeter, a condensor, an oil seperator, a dry-filter and a throttle valve. The main measurement is through the secondary refrigerant calorimeter method, and the accesory measurement through the calorimetry for the water cooling condensor.

In this system, each measuring point of parameters is in accordance with the requirements of the International Standard Organization. To decrease the loss of heat, an air-conditioner is installed in the testing cell, and controls the temperature in it. Besides, the calorimeter, thecondensor and the pipe under low temperature are covered with heat insulator. Through measuring, the average heat loss is less than 5% of the full refrigeration capacity under various working conditions.

A sampling equipment attached to this system has been applied to check the oil amount in refrigerant. The tested amount less than 1% meets the ISO measurement rules.

In the CACTS-1 system shown in Fig. 1, the control and measurement instruments with Apple-II microcomputer as the key part are equipped to realize the automatic control of working conditions and the data collection. Through various kinds of transducers and transformers, such testing parameters can be converted into standard D.C. signals as the suction temperature, suction pressure, discharge temperature and pressure in refrigeration compressors, the temperatures and pre-

* This project was also participated by the following: Huayu Xuan, Changlin Zhang, Xiayuan Wu, Dewen Hu, Li Li, Guozhu Zhang, Tintin Zhang, Jinhua Yin, etc.

ssures at the in-port and out-port of the condensor, the cooling-water temperatures in and out the condensor, the cooling-water flow, the pressure of the secondary refrigerant, the heater power in calorimeter, the input power of motor, the rotational speed of compressors, and the frequency of power net-work, etc.. Through A/D converter, the D.C. signals are conducted to the microcomputer, or to the timing/counting circuit in the microcomputer in the form of pulse signals.

Three pieces of mechanism are controlled by the microcomputer to realize the automatic regulation to the required working condition. The throttle valve driven by stepping motor is utilized to regulate the suction pressure in compressors; the cooling-water regulation valve driven by two-phase A.C. motor is applied to control the discharge pressure in compressors; and A.C. voltage regulator is used to adjust the heating power in calorimeter to control the suction temperature in compressors.

Figure 2 shows the software procedure-sketch of 'CACTS-1 automatic control and measurement system. As long as the operator presses through the key board the working condition to be measured, Apple-II microcomputer can operate in accordance to the program to realize the automatic control for the working condition, automatically transcendental limitation alarming, automatic judgement to the stability, automatic data collection and processing, and at last to print the results table or full performance curves automatically according to your demand.

The so-called automatic judgement to the stability means that, according to the measurement rules, the microcomputer automatically decides if the refrigeration system is in stable operation. In more detail, the microcomputer monitors continuously the variation of parameters, and verifies that the system is in stable operation if, within 15 minutes, for suction and discharge prssures the maximum difference between the rule and measurement values is less than ±1%, and the maximum differemce between the average value and each measurement quantity is less than ±0.5%; for suction temperature, the maximum difference between the rule and measurement values is less than ±3°C, and between the average value and each tested point is less than ±1°C (in fact, less than ±0.5°C in this system). Under these conditions, a group of data is collected to the given momeory units. And then, if the refrigeration system is stable, each group of data is collected every other 15 minutes until four groups have been obtained. The average values for the four groups are utilized to compute refrigeration capacity and K_e for the main and accesory measurement methods.

During the processing of tested data, both the refrigeration capacities for main and auxiliary measurements are obtained from the formulae suggested in the relevant internatinal measurement rules, and the specific volume and enthalpy are computed according to Martin-Hou State Equations. If the relative difference between main and auxiliary measurements is less than ±4%, the test results are valid, and conducted to be printed in table form.

To understand the characteristics of refrigeration compressors to the wideliest extent, this measurement system has the function to test their total performance. The function of Apple-II microcomputer with high resolving power, along with a printer, is used to print the total performance curves.

THE AUTOMATIC CONTROL TO WORKING CONDITION

The automatic control to working condition is the basis of the automatic measurement to the total performance of refrigeration compressors. Obviously, if the working condition is not stable to a certain extent, the measurement data are not correct for many kinds of dynamic errors will be included.

To constitute a reasonable control system, we have analysed in detail the mechanism of mathematical model and made experimental identification for refrigeration system. It is confirmed experimentally that the mathematical model for refrigeration system can be expressed as a multi-variable relative system with three fans-in and three fans-out, as shown in Fig. 3, where $G_{11}(s)$, $G_{22}(s)$ and $G_{33}(s)$ are the transmission functions of suction temperature T_1, suction pressure P_1 and discharge pressure P_k with electric heater power N, the throttle valve opening F and cooling-water flow Q respectively, and the transmission functions $G_{21}(s)$, $G_{23}(s)$ and $G_{32}(s)$ are the inter-coupling between two relative variables which results in the regulation complexity. For example, if the throttle valve opening is utilized to regulate the suction pressure, meanwhile the suction temperature and discharge pressure are also changed. In summary, every control circuit is not absolutely independent of others, i.e., when one circuit starts to operate , meantime it will affect others. The endless cycling of this interaction will make difficult the system to operate stably. Therefore, a kind of control algorithm called multi-variable decoupling control is introduced in CACTS-1 system. This control method makes each control circuit basically independent of others.

If the solo control circuit PID is adopted to all the control circuits, it is difficult to meet the requirement of regulation quality becouse of great heat inertia and long pure sluggish time. Therefore, in addition to the decoupling method, other measures must be also used in the CACTS-1 system. For instance, for the control to suction temperature, we found that the solo control circuit PID was not so effective. Considering that the pressure P_s of secondary refrigerant in calorimeter reacts quickly to the electric heater power and has small inertia, we took it as an intermediate variable to form a cascade control system shown in Fig. 4. The secondary refrigerant pressure is taken as a subsidiary loop control variable, and the suction temperature T_1 the main loop control variable. It is verified experimentally that, with the subsidiary loop control existing, the characteristics of control object are improved, the working frequency of control system is highly increased with quicker transition process, and the suction temperature is swifter to become stable.

CONCLUSION

Having operated with steady characteristics for more than a year, the CACTS-1 system brings much convenience to the investigations on the performance of refrigeration systems and refrigeration compressors in China. Here, the authors are wishing to cooperate with foreign scholars or manufacturers to develop this achievement further.

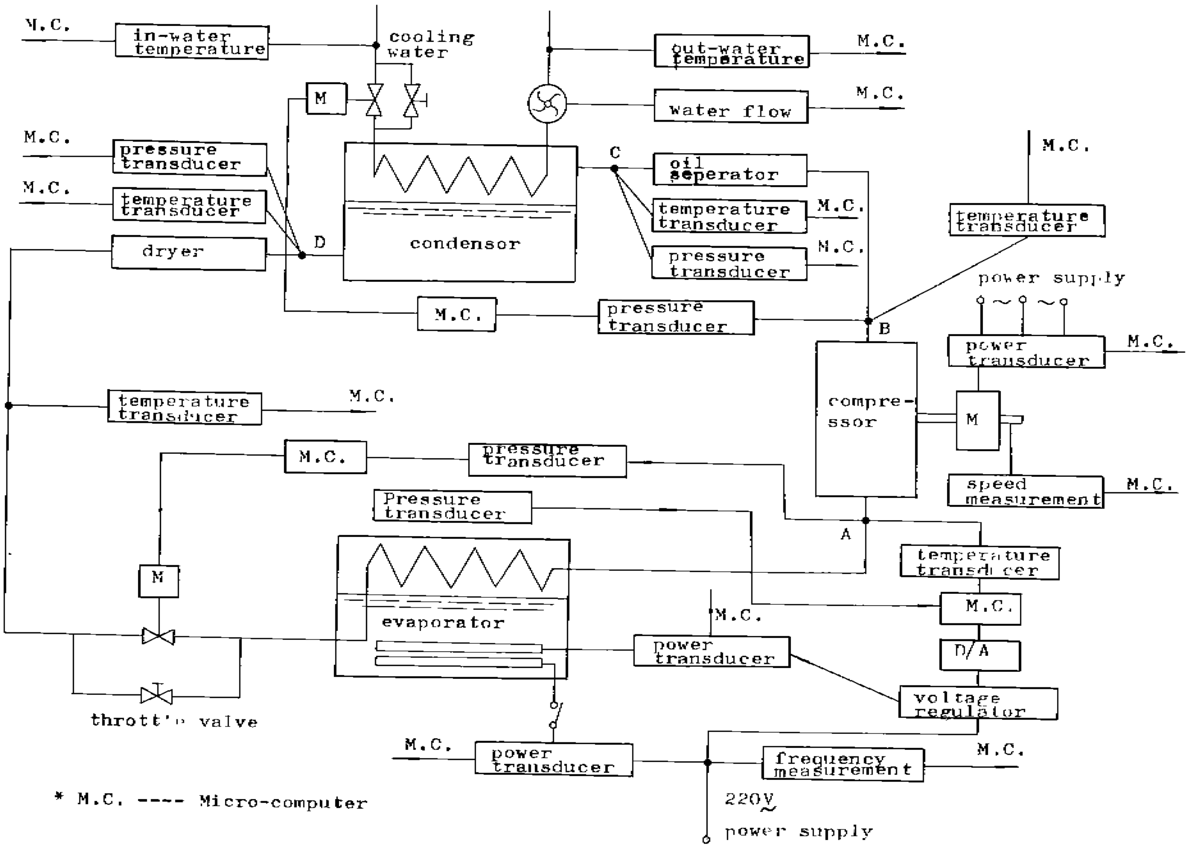

Fig.1 Microcomputer Measurement System for Compressor Performance

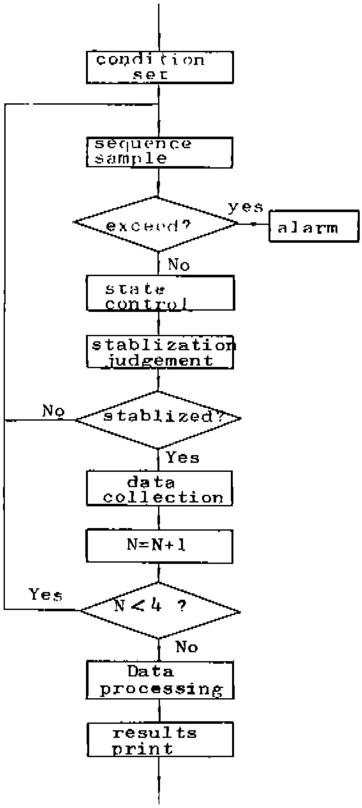

Fig.2 Procedure-sketch of CACTS-1

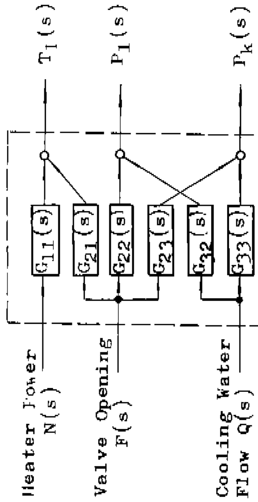

Fig.3 The Sketch of Control Objects

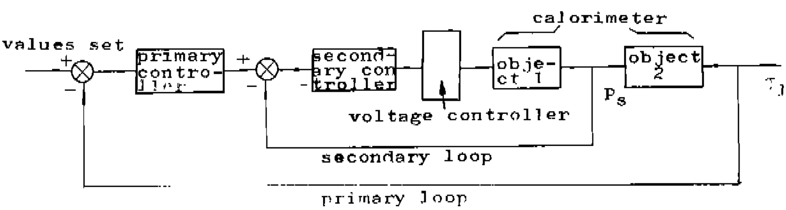

Fig.4 The Sketch of Cascade Control for Suction Temperature