EQUIPMENT MONITORING SYSTEM

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We have developed an equipment monitoring system to observe the condition of production equipment. Through network wiring, sensors such as cameras, microphones, and vibration sensors are easily connected to this system so that you can diagnose the condition of the equipment. When constructing this system, Microsoft Windows*4 is used as the operating system to easily tailor this system to each application.

INTRODUCTION

In petrochemical, pulp and paper, and other plants, control has been highly automated, so that huge plants can now be operated by fewer operators. However, as to the maintenance of the equipment and facilities that support production in those plants, manpower is still depended upon. Presently, plants are maintained by carrying out an equipment inspection daily during each of three shifts. Increased automation in this field means that maintenance can be carried out by fewer operators. Traditionally, the detection of abnormal phenomena in equipment relied on the intuition and experience of inspectors, and was, therefore, a very difficult area to automate. However, we believe this obstacle can be overcome by installing a number of different sensors throughout the field and by building a system that gathers data from these sensors for comprehensive analysis. Sensors incorporated into the system include cameras, vibration sensors, and microphones, which function as the eyes, ears and physical contact senses of the inspectors. To realize such a system, intelligent stations that can handle signals from each sensor in the field and carry out primary processing must be installed at important points in a plant. Data processed in these intelligent stations are sent to the central control room via LAN, where the data are processed further by the host computer for diagnosis.

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*4 Microsoft Windows is a registered trademark of Microsoft Inc., USA.

With such a system configuration in mind, we have developed an equipment monitoring system. Figure 1 presents an external view of an intelligent station.

FEATURES

The equipment monitoring system developed has the following features:
(1) The system adopted Ethernet as LAN. This only requires a single cable, simplifying installation. As a result, the system is easily adapted to existing equipment.
(2) Because image data and sound signals are captured in

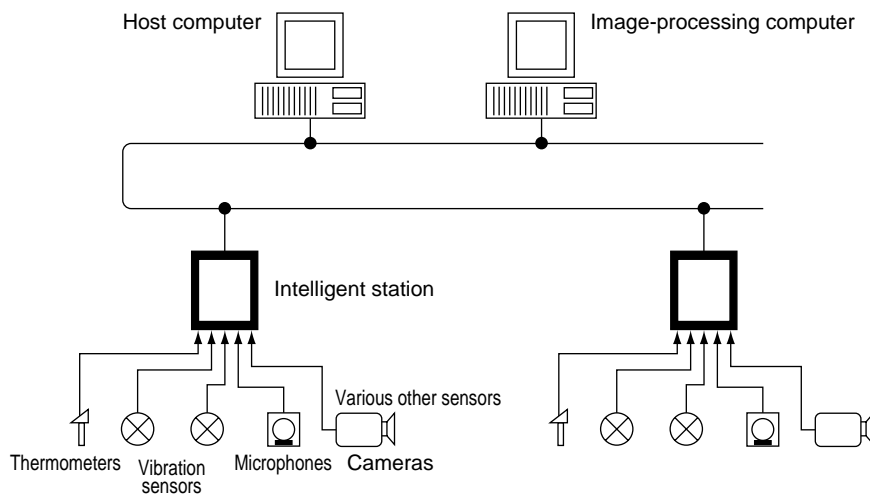**Figure 1** External View of Intelligent Station

Figure 2 Entire System Configuration

addition to conventional vibration analysis, the status of production equipment can be recognized in a more thorough and advanced way.

(3) Intelligent stations have similar features to those of DOS/V PCs and run on Windows. This allows applications to be developed in open environments.

(4) Intelligent stations are of Class 4 water-proof construction based on Japanese Industrial Standards (JIS), and can be installed outdoors.

SYSTEM CONFIGURATION

Figure 2 shows the configuration of the entire system. Various sensors, such as cameras, microphones, and vibration sensors, are connected to the intelligent stations installed throughout the field. A single intelligent station allows the connection of up to eight cameras or up to 32 other sensors. The host computer installed in the central control room and each intelligent station are connected using 10BASE5 Ethernet. A computer dedicated to image processing is also connected to the system via LAN. Intelligent stations can be installed near sensors, thus, wiring is only required over minimal distances. Not only is the addition of sensors very easy, but intelligent stations can also be added simply as they only require the addition of a LAN transceiver. Table 1 shows the specifications of an intelligent station.

Table 1 Specifications of an Intelligent Station

Items	Specifications
Number of channels	32 maximum
Sampling	Signals are captured from each sensor sequentially.
A/D input range	-10 to +10 V DC
Resolution	12 bits
Sampling ratio	100 kiro samples/sec maximum
Number of cameras	8 maximum
Camera input signal	NTSC system

SENSORS

Intelligent stations allow the following sensors to be connected.

(1) Cameras
General-purpose ITVs with NTSC output signals can be used. The equipment monitoring system uses PLANTEYEs, Yokogawa's compact explosionproof cameras.

(2) Microphones
We have developed two types of microphones for the system—audible band and ultrasonic band microphones. Both microphones have intrinsically safe construction, are made of Class 4 waterproof construction based on JIS, and produce outputs at 4 to 20 mA. The safety devices required when installing these microphones in hazardous areas can be installed inside the intelligent stations.

(3) Vibration Sensors
The vibration sensors on a general-purpose amplifier can be used.

(4) Other sensors
Signal converters can be used on intelligent stations to allow a number of different sensors such as thermometers to be connected to that station. The intelligent sensors have contact input and output features.

SIGNAL PROCESSING

Figure 3 shows the flow of signal processing. Signal processing is divided into three parts: preliminary diagnosis by the intelligent stations, detailed diagnosis by the host computer, and image processing by the image-processing computer.

1. Preliminary diagnosis

Signals from the sensors are A-D selected for conversion under respective conditions in accordance with the measuring sequence set in the intelligent station. The data acquired are
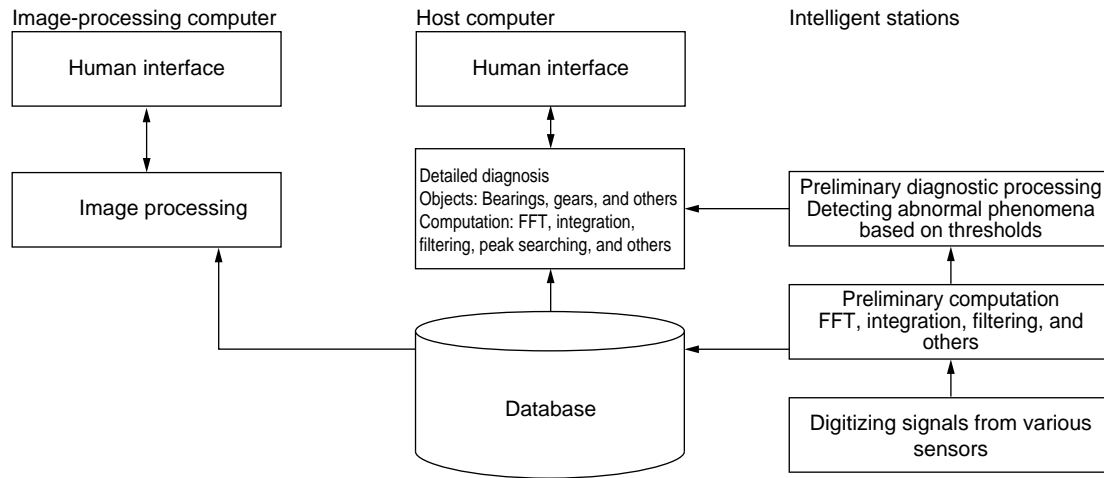
Figure 3 Signal Processing

Table 2 Preliminary Diagnosis Parameters

Sensor monitored	Parameter(s)
Vibration sensor	Overall values of acceleration signals
	Overall values of acceleration signals after passing through a band-pass filter
	Peak values of acceleration signals
	Overall values of speed signals
	Overall values of displacement signals
	Overall and peak values of acceleration signals
Microphone	Overall values of sound-pressure signals

Table 3 Detailed Diagnosis Items

Part monitored	Signal(s) in use	Item(s) judged
Mechanical sections	Velocity	Imbalance
		Misalignment
		Bent shaft
		Insufficient rigidity of frame stands
		Wear on shafts
		Improper installation
Bearings	Envelope of acceleration	Flaw in inner ring
		Flaw in outer race
		Flaw on balls
Gears	Acceleration	Localized loading
	Envelope of acceleration	Deviated shaft
		Worn-out gears
		Abnormal tooth profile
		Localized abnormality
Motors	Acceleration	High-frequency vibration
	Velocity	Imbalanced power supply
Pumps	Velocity	Pulsation in pressure
		Constant wear
		Localized wear
		Localized abnormality

processed by various filtering and fast Fourier transform (FFT) functions, based on the preset processing procedures. Then, the various parameters calculated are compared with the threshold table set for each sensor to see if it has been exceeded or not. If a threshold has been exceeded, it is assumed that an abnormal phenomenon has occurred and is reported to the host computer via the LAN. Raw data concerning that phenomenon are also transferred to the host. Thresholds can be set at two levels: a caution and a warning. Table 2 shows the parameters used in this preliminary diagnosis.

2. Detailed Diagnosis

If an abnormal phenomenon is reported by an intelligent station during a preliminary diagnosis, the host computer starts a more detailed diagnosis. The items to be judged in this detailed diagnosis are listed in Table 3. The contents of a detailed diagnosis differ depending on the part being monitored. For example, in the case of bearings, if a flaw occurs in the inner ring, outer ring, or one of the balls under a certain revolution speed, a signal is output at a specific frequency for each component. As a result, checking the envelope of an acceleration signal allows you to calculate the frequency at which abnormal signals appear and identify the location of the flaw.

3. Image Processing

In order to alleviate the load of intelligent stations, image processing is performed in a processing flow slightly different from that for other sensors. Image data are digitized and then sent to the image-processing computer, which handles all of the processing. If motion images need to be processed, analog signals are sent to the central control room. Wiring is minimized even when there are multiple cameras because a video signal switching function is provided in the intelligent stations. A universal image processing tool is used as the processes required for individual cases.
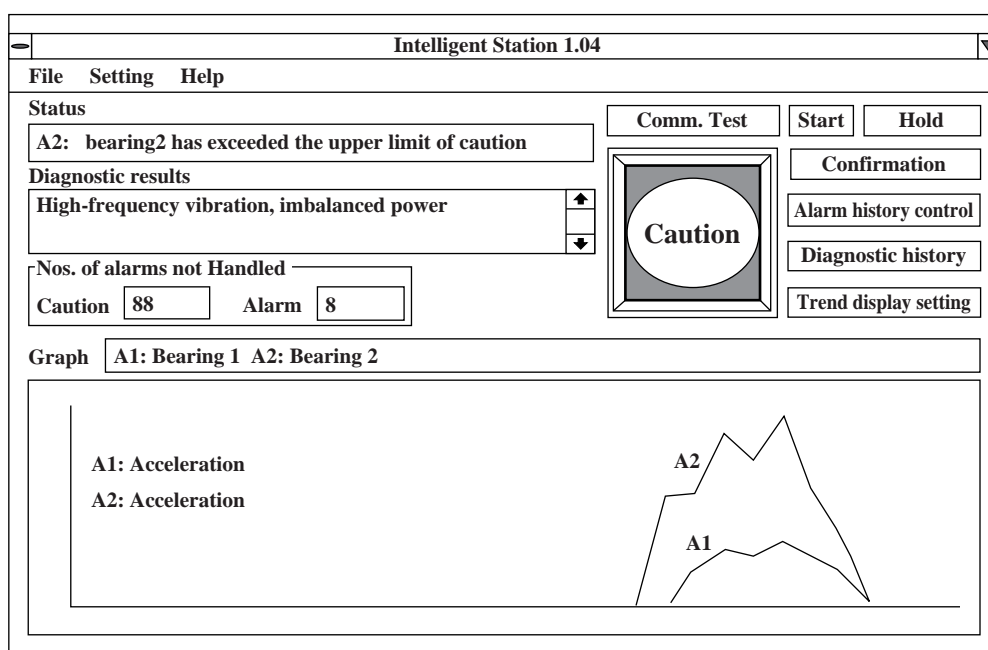
Figure 4 Example of an Operation Screen

OPERATION SCREENS

Figure 4 shows an example of the main screen on the host computer. You can choose four parameters used in the preliminary diagnosis to display its trend. If an error is detected in the preliminary diagnosis, an alarm sign appears on the main screen to notify the operator. At the same time, detailed diagnosis is automatically started, the results of which are displayed as a short message on the screen. The details of the diagnosis or the history of the abnormal phenomena can be retrieved by clicking on the Diagnostic History item that refers to the specific data. A list of abnormal phenomena that have occurred so far can also be retrieved on another screen.

CONCLUSION

This system has been developed to receive signals from various sensors installed on production equipment and diagnose the operating condition of that equipment. Up to now diagnoses have been performed on the basis of individual sensors. In the future, we believe that it is more effective and required to collect many kinds of data from various sensors synthetically and diagnose them. ◆