1. Contents of Empirical Research

1.1 R&D Objective

In view of the very severe business environment surrounding the oil refinery industry at present, strengthening of international competitiveness through labor conservation has become an urgent necessity. This necessity, however, is in direct conflict with stability and safety in plant operations, a concern that we must give the very highest priority. In order to resolve these conflicting objectives, a surveillance system to replace humans has become imperative. Progress is already being made in labor conservation and in fortifying surveillance through the introduction of furnace internal surveillance cameras and emergency stop systems, but an adequate surveillance environment has not yet been established. The main mode of communications at present is wire transmission, and although the wire mode is exceptionally outstanding in terms of communication capacity (speed), signal reproduction and fidelity, it presents a number of noteworthy problems, including the cost of installing cables to remote facilities and breakdowns in communication arising from damaged wire due to earthquakes or fires. It must be admitted, however, that as advances are made in locating facilities in more remote areas, thanks to coordinated distribution of instrument rooms, the priority given to surveillance, which incurs huge costs and does not contribute directly to productivity, must be lowered.

Accordingly, the purpose of the present research is to develop a wide-angle surveillance system employing a wireless mode of communications, with attention focused on the following advantages of wireless communications.

1) No cable damages due to earthquakes or fires (communications guaranteed in a disaster)

2) No cable installations required even if new surveillance equipment is employed (lower costs)

3) Can be easily applied to remote areas or mobile units.

The aim is to contribute to improved surveillance technology in the oil refining industry by developing an auto scanning, unattended surveillance system that can be applied to mobile units, the foremost advantage of a wireless communications system.
2 Results of Empirical Research and Analysis Thereof

2.1 Investigation of Wireless Transmission

The wireless transmission system used in the present research is shown in Figure 1-1.

Image signals (NTSC video signals) obtained via ITV are transformed and compressed into the motion-JPEG format at WEB image server. In addition, signals obtained from flammable gas detectors, oil leakage detectors and other detectors undergo data processing at a programmable logic controller (PLC) and are collected as data at the WEB server.

These elements are installed in an air-purged box, which has a built-in signal converter and wireless transmission system, and wireless signals are transmitted and received in the field.

In consideration of cost and performance, a 1.9GHz-band, digital communications system (PHS: personal handy phone system) is used as the wireless transmission system.

In this system, wireless signals pass through new PHS equipment and a PHS controller; video and detector data are monitored on a WEB server, and instruction signals can be transmitted in emergencies.

Moreover, because PHS data are linked to local area networks (LAN), images can be checked locally. In the current system, because the WEB server for monitoring, all the detectors and the surveillance camera network are each routed in an exclusive fashion, when ITV images are monitored communication with each detector is cut off. Conversely, when routing is established with each detector, communication with the ITV side is cut off.

Using this system, an investigation was made of matching between each surveillance unit installed in the field and the wireless transmission system.

Figure 1-1 Wireless Transmission System
(1) Tests of Wireless Signal Reproducibility

When a wireless transmission format is used, the reproducibility of signals can be damaged substantially, depending on the condition of the radio waves. Accordingly, an investigation was made of the reproducibility of signals from detectors installed in the field when wireless transmission has been used for monitoring. Figure 2-2 presents data obtained when wireless transmission has been used. Solid lines denote output signals obtained in the instrument room; dashed lines are input signals transmitted from instruments in the field. In addition, status signals (ON for anomalies; OFF for normal status) were used for input signals. The figure shows that the signals have a time lag and a response lag of about 1 second, but this is probably due to monitor sampling cycle and signal filtering; no abnormal signal reproductions by wireless could be noted. Moreover, from the standpoint of practical monitoring, this time lag and response lag are not at levels that present any problems.

![Figure 2-2 Tests of Wireless Transmission Signal Reproducibility](image)

(2) Investigation of Potential Transmission Areas and Each Transmissions Obstacle

In applying a wireless transmission system at oil refining facilities, it is imperative that the potential transmission area be determined. In actual transmission, however, is extremely difficult to theoretically calculate the potential transmission area because of attenuation due to distance and the impacts of reflection or absorption by obstacles. Consequently, the potential transmission area must be determined by collecting statistical data based on actual field measurements. Accordingly, an investigation was made of the relationships between obstacles encountered in oil refining (e.g., towers and tanks, heat exchangers, rotors, tank piping) and potential communication distances.
The site shown in Figure 2-3 is comprised of an oil refining plant, and finished or semi-finished product tank clusters. The green circles in the figure denote instrument rooms where new PHS receiving stations are installed; the lateral yellow circles show the areas outside the communication range, and areas within the range of communications are indicated by blue circles. The circles shown by red dashed lines have a radius of 100 m, 200 m or 300 m. By this means, it was confirmed that communications are possible even behind tanks and at congested on-site areas with production facilities. In areas totally free of obstacles, communications up to about 300 m are possible.

The site shown in Figure 2-4 is a yard comprised of crude oil tank yards. In the case of a crude oil tank, the area behind the tank is outside the range of communications. This is because the tanks are large and separated from each other at a distance so that reflected waves are greatly attenuated.

The site in Figure 2-5 is comprised of fuel oil refining facilities and finished or semi-finished product tanks. Here also the areas behind medium-sized or larger tank clusters can easily become outside the range of communications. On the other hand, production areas and small tank clusters tend to become relatively broad communication areas.

Figure 2-3 Potential Communication Range (Yokkaichi site)

Figure 2-4 Potential Communication Range (Umaokoshi site A)
In order to quantify these results, an index of space occupancy rate was defined as shown in Figure 2-6, and the correlation between distance and space occupancy rate was determined. These are presented in Figure 2-7.

In the figure, the dashed lines represent the upper limit within the communication range and the lower limit outside the communication range. The solid lines show the averages. It can be seen that in areas of high space occupancy rate, the potential communication distance decreases whereas in areas of low space occupancy, this distance increases.

At an on-site plant, the occupancy rate is about 30 to 40% and one plant compound has a radius of about 100 m. In view of this fact, it appears that there is an extremely high degree of freedom in base station layout. At a distance of 300 m or more, the area was almost completely visible. In other words, the obstacle occupancy rate was 10% or less. But even here, communication was difficult.
A conception of the base station layout in the future, based on these results, is presented in Figure 2-8.

In the figure, the solid lines outline the potential communication area at a radius of 100 m, and the dotted lines show areas 300 m in radius that can be reached by radio waves. Moreover, by linking up each base station for effective, large-volume communications, all the facilities in an oil refinery can be within the potential communications range of a wireless transmission system. Nevertheless, practical radio wave resources are limited, and the same frequency cannot be used in adjacent areas. In view of these facts, the number of equipment units enabling simultaneous communications is limited.
(3) Investigation of Wireless Image Quality and Transmission Speed

Image signals (NTSC video signals) obtained via ITV are transformed and compressed into the motion-JPEG format at WEB image server. At this time, image quality and transmission speed can be adjusted by modifying the image compression level and the image size. Accordingly, the impact of compression level on image quality was investigated.

Figure 2-9 gives a sample image of a wastewater treatment facility. The surveillance target was vinyl sheet measuring 50 cm along each side. In the high-quality image mode, a clear image can be obtained, but in the low-quality image mode, we find that detailed image data are lost. Figure 2-10 shows an image that is being renewed. In the motion-JPEG format, renewal takes place by taking an image obtained at a certain timing and writing over it an image obtained with the next time stamp.

Here, the image renewal time is the time from the start of the next image renewal until the image is completely shown; the time from completion of image renewal up to the start of the next renewal is the image retention time.
Table 2-1 gives the image renewal time and image retention time for each mode.

<table>
<thead>
<tr>
<th>Image mode</th>
<th>Image size</th>
<th>Compression rate</th>
<th>Image renewal speed</th>
<th>Image retention time</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-quality image</td>
<td>920 KB</td>
<td>6-8%</td>
<td>about 15 seconds</td>
<td>about 2 seconds</td>
</tr>
<tr>
<td>Low-quality image</td>
<td>230 KB</td>
<td>3-4%</td>
<td>about 2 seconds</td>
<td>about 1 second</td>
</tr>
</tbody>
</table>

### 2.2 Development of Auto Scan Surveillance System

An investigation was made of an auto scan surveillance system as an application of wireless transmission technology, and such a system was developed. The system is comprised of a surveillance camera, a drive control, a WEB image server and a PHS system, all mounted on a carriage on the running track. The carriage stop position is controlled by detecting stop position signal with a stop position sensor. The stop position signal is triggered; the camera control signal is transmitted and confirmed, and the camera tilts and zooms to a preset location.

Figure 5. 2-11 shows the installed auto scan surveillance system. At present, the power supply, drive control signals and camera image signals are supplied through each cable in the cable bay.
2.3 Development of Image Processing System

In order to detect anomalies earlier from images obtained by ITV, it is essential to have an anomaly detection system that operates by image processing. A flare surveillance image was taken up as a target of anomaly detection by image processing, and a preliminary investigation was made of image processing system.

In Figure 2-12, the flare image obtained by ITV and its hue are shown as an RGB graph.

At normal times, the percentages of RGB with background are roughly the same, but in areas where there is fire, yellow is detected, indicating that the B element has declined sharply. In this way, it was confirmed that anomalies can be detected by means of RGB percentages.
3. Results of R&D

3.1 Investigation of Wireless Transmission

An investigation was made of the potential communication area of a wireless transmission system and the following results were obtained.

1) Test of wireless signal reproducibility

Tests were conducted on the reproducibility of signals by wireless transmission, and no anomalies in the reproduction of such signals were noted. It was also confirmed that the time lag and response lag of the system as a whole are not at levels that would pose any problems in practical surveillance.

2) Investigation of potential transmission area and each transmission obstacle

Communications are possible even if there are obstacles directly between parent and child equipment. However, it was confirmed that the distances of potential communication are shortened by the presence of such obstacles. It was found that the potential range of communications extends over a broader area than initially anticipated, and even if obstacles are present to some extent, communications are possible if the distances are short. From the standpoint of application to on-site system, there is a high degree of freedom in base station layout. Nevertheless, because there are limits in radio wave resources and in the number of circuits (40 public frequencies/37 private frequencies; 1 frequency 3 circuits) and management for circuit reuse is indispensable. In the case of off-site application, relay stations are required because the surveillance target spans a broad area. Large-volume communications such as SS radio are considered appropriate for communications between base stations because the quantities of data involved are huge.

3) Investigation of wireless image quality and transmission speed

With respect to ITV image evaluation, from a comparison with wire transmissions it was confirmed that in the low-quality image mode, although the image as a whole is not damaged, there are large losses of data on image details; and in the high-quality image mode, the image quality is adequate for surveillance, although the image renewal speed is somewhat inferior. Nevertheless, future progress in dynamic image compression technology is expected to enable image transmissions at greater speeds and at higher image quality.

3.2 Development of Auto Scan Surveillance System

An investigation was made of an auto scan surveillance system and a surveillance system was fabricated. The system has undergone test runs by wire format, and vehicle drive control and camera control by wire transmission were realized.
3.3 Development of Image Processing System

Preliminary investigations were conducted on image processing by flare surveillance image, and the possibility of detecting anomalies by means of hue analysis was confirmed. An investigation was made of an anomaly detection scheme in which burner leakage oil and on-site instruments such as pressure gage or voltmeter are the surveillance targets. Respecting burner leakage oil, white lines are drawn around suspected leakage areas, using tape for instance, and if there are oil leaks in these areas, the anomalies can be detected through changes in hue. As for on-site instruments, differences in instrument panel background and needles of different hue are used. Anomalies can be detected by designating the background areas that must be indicated by the needle and the areas that should not be indicated.

4. Synopsis

4.1 Development of Auto Scan Surveillance System

In the present fiscal year, surveillance equipment installed off site was the subject of evaluation and investigation. The schedule for the next fiscal year calls for wireless transmission and reception of control signals and video signals primarily from on-site surveillance equipment. An investigation will also be made of power supply from independent power sources where auto scan systems can be applied in emergencies, etc.

In addition, for camera drive control combined with image processing system, an investigation will be made of compound control in which anomaly signals are received from each detector in the field and the camera is transferred to the sites of anomaly detection.

4.2 Development of Image Processing System

Among the technological problems associated with an image processing system are adaptation to the surveillance environment (impacts of daytime and nighttime, clear weather and rainy weather, cloudy skies and temporal changes), prevention of erroneous operations, and reproducibility of images when the camera returns to its original position after moving to a different preset location. These problems are scheduled to be covered under R&D in the next fiscal year. In addition, R&D will focus on anomaly detection schemes for cases involving wide-area surveillance such as fire and steam leakage.

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