CHAPTER 2

EXPERIMENTAL APPARATUS

On the whole, the experimental set-up in the present study is based on the test protocol of machinery space [18], where the fire sources are the unshielded/shielded pool fires generated from 1 m^2 square-shaped diesel pan. The test facility consists of a test compartment, different fire extinguishment agents and measurement instrumentations. The schematic configuration is shown in Fig. 2.1. The above-mentioned elements are described in detail as follows.

2.1 Test Compartment

The test room is a rectangular room with dimensions of 6.10 m x 3.5 m x 2.9 m in height. The room has a door of 1.35 m x 0.5 m in size and a 0.75 m x 0.5 m viewing window. The room also equips with two 0.8 m x 0.6 m pressure relief vents; one is on the south wall near the ceiling and another is mounted on the ceiling near the south wall.

2.1.1 Fire Source

According to the draft plan of the extinguishing performance of water mist in machinery spaces, with a horizontal galvanized steel plate and two galvanized sheet metal partitions to simulate the effect of shield (see Fig 2.2). The horizontal galvanized steel plate was an irregular-shaped with dimensions of $1.0\ m \times 2.0\ m \times 3.0\ mm$ thickness to substitute for the outside material of real machines. The horizontal plate was placed at a 1.0 m elevation and the center of the plate mounted a stainless steel with dimensions of $10\ cm \times 5\ cm \times 5\ cm$ thickness for measuring the temperature different on the metal when the conventional sprinklers or water mist fire suppression systems were working. The perimeter of plate was fitted around, with 2mm thick galvanized sheet metal to simulate the lower portion of the real machine. To simulate the curvature of the machine bottom, the sheet metal is installed at a 45^0 angle with respect to the horizontal to a 2 meter width, which was a typical dimension corresponding to the test volume. The space below the plate used two vertical 0.5 m^2 sheet metal baffles. Note that the dimension of galvanized steel plate is not the same as the mentioned in the FMRC protocol [18] because it is too heavy to manufacture.

2.2 Fire Extinguishment Agents

The full-scale tests include three fire protection scenarios, which are non-protection, conventional sprinklers system, and high-pressure water mist fire suppression system.

2.2.1 Conventional Sprinkler System

The sprinkler protection system used in the experiments consists of six pendent sprinklers according to the requirement of Taiwan Fire Code (see Fig. 2.3 for demonstration). The discharge pressure for each sprinkler is given in Table 2.1, which was through a calculation of pressure loss from the equivalent pipe length. Then, according to the pressure-charge rate relationship configuration shown in Fig. 2.4, the discharge water rate for each sprinkler can be known, and they are listed in the bottom of Table 2.1. The six sprinklers are installed under the 3m-height ceiling in a $2.0\ m \times 1.5\ m$ grid as shown in Fig. 2.5.

2.2.2 Water Mist Systems

The high-pressure water mist system is made up of two major components, which are the high-pressure nozzles and the pump, respectively (see Fig. 2.6 and 2.7). In the tests, two protection systems were used. System A consisted of six high-pressure nozzles with 4 pendent and 2 side ones, whose locations are shown in Fig. 2.8, and System B consisted of four 4 pendent nozzles. The K-factors of nozzle was $0.64\ l/\min/bar^{1/2}$ and the flow rate was $6.4\ l/\min$ at 100 bars. The nozzle layouts for both systems were based on the guidelines provided by the manufactures. For System A, shown in Fig. 2.9, four pendent nozzles were installed on the ceiling on the 3.0 m x 1.5 m grid and two side nozzles were posited at the perimeter of plate on the 1.0 m elevation and 1.5 m from the center of pool fire. The electric pump unit used in the tests was of type AEEF with a working voltage 220 v~380 v. Its maximum working pressure was $140\ kgf/cm^2$, and the maximum flow rate was $59\ {}^{l}\!/_{\min}$.

2.3 Measurement Instrumentations

2.3.1 Gas Analyzer

The gas analyzer, shown in Fig. 2.9, is controlled and accessed by the Testo plug-in card (PCMCIA card) with COMFORT3 software. The combustion gas is drawn via the gas probe as the pump is started manually or automatically. The measuring gas is suddenly cooled to 4-8°C. This precipitates the condensation with the lowest absorption of NO_2 and SO_2. The condenser is pumped at regular intervals by the hose pump at the bottom of the unit into the condensation tank. The dry gas is conducted through a particle filter, which holds back the particles. This filter also operates as a water trap. If water breaks through, the filter closes its pores permanently, thereby protecting the pump and the sensor against water. The gas then passes through the pump to the gas sensors. Here, a very small proportion diffuses through the diaphragms into the sensors, which then generates signal. The surplus measuring gas exits the instrument through the exhaust pipe.

2.3.2 Temperature Measurement

Four thermocouple trees, as shown in Fig 2.10, were set up in the room to measure the temperatures. They are marked as #1, #2, #3 and #4, respectively, and their locations can be referred in Fig. 2.5. Each tree contains six K-type thermocouples at approximately at an interval of 0.5 m in between vertically. However, for the first two just underneath the ceiling for #1, #2 and #4 and the thermocouple tree #3, the interval is 0.3

m. A specific thermocouple S-F is set at 0.5 m elevation above the fire source. It is served as an indicator to identify whether the fire is extinguished when the water suppression system is activated. The signals are sent to DA-100 (see Fig. 2.11) to covert the measured data into excel files.

2.3.3 Opacity Monitor

The CODEL Model 200t monitor comprises a signal processor unit and two identical transceivers (Fig. 2.12 and Fig. 2.13). The transceivers are mounted at 1.8 m elevation on the opposite side of the wall. The signal processor houses the power supplies for the system and also the microprocessor for the control.

The signal processor/power supply unit is remotely mounted and provides power for the transceivers, and produces an output of opacity from the transceiver output signal. The cable of production signal is also connected to the DA-100 to convert a current signal into a voltage and the data from the Model 200t is converted to excel files.

The transceivers contain a sensing head comprising a light source, a detector and the associated optical assembly; a calibration mirror and rotary valve; and the electronics associated with control and measurement. The light source consists of a high-powered LED transmitting light at a wavelength of 637 nm (visible to the human eye) modulated electronically at 600 HZ. The optical arrangement of each sensing head is designed so that the detector receives light back from the internal LED and the transmitted light to be measured at each transceiver. Fig 2.14 illustrates this arrangement when a transceiver is transmitting, receiving and during a window compensation cycle.

The detailed principle of opacity measurement is described as follows. Consider the two identical transceiver units positioned at either side of the wall, unit 1 and unit 2. The transmissivity of the light from unit 1 to unit 2 can be represented by the equation:

$$\pi_{21} \quad = \quad K_1(D_{12}/D_{22}),$$

where: K_1 = gain constant to product

π = 1 (100 % transmissivity, clean air condition)

D_{12} = the detector output at unit 1 (internal reference level)

D_{22} = the detector output at unit 2

The transmissivity of light from unit 2 to unit 1 (unit 2 transmitting) can also be represented by the equation:

$$\pi_{12} \quad = \quad K_2(D_{21}/D_{11}),$$

where: K_2 = gain constant to product

π =1 (100 % transmissivity, clean air condition)

D_{21} = the detector output at unit 1

D_{11} = the detector output at unit 2 (internal reference level)

This is demonstrated schematically in Fig. 2.8. Overall transmissivity of the system (π) can, therefore, be represented as:

$$\pi \quad = \quad \pi_{12} \times \pi_{21}$$

$$= \quad K_1(D_{21}/D_{11}) \times K_2(D_{21}/D_{11})$$

As the two bracketed terms above are measured from only one of the transceiver units, the output of the instrument is independent of drift of either detector.

2.3.4 Digital Video

The visualization of the tests are assisted by a digital video (Type DCR-TRV40, SONY), which is fixed at an appropriate position to monitor fire variations. The images from the video are transmitted to a PC by IEEE 1394 card, and the images are processed by an Ulead Video Studio software to show a series of flame structures.

2.4 Procedure of the Experimental Operation

(1) Regulate the time of notebook to be the same with the time of personal computer

(2) Install the thermocouple, smoke opacity measurement and gas analyzer apparatuses. Then, conduct the checking procedure to make sure that their signal outputs are connected to the corresponding channels of data acquisition system (DA-100) correctly.

(3) Pour the diesel oil into the pan and stir the fuel to have a uniform distribution.

(4) Per-record the temperature, smoke opacity and the gas concentration and start the digital video before the pool fire is ignited.

(5) Pour the 95 gasoline into the pan and ignite the pool fire after 30 seconds.

(6) Leave the test space and close the door.

(7) Carry out the fire test and record the observation.

(8) Turn off the measurement apparatuses as the test is ended. Then, start the exhaust systems to exhaust the combustion productions out of the test room until the test environment returns to the normal state, ready for next test.