CHAPTER 2

EXPERIMENTAL APPARATUS AND PROCEDURES

The experimental apparatus and procedures used in the present study to unravel some special characteristics of the mixed convective vortex flow resulting from a gas jet impinging onto a horizontal heated disk confined in a vertical cylindrical chamber are modified slightly from those established in our previous study [10]. They are described in the following.

2.1 Experimental Apparatus

A schematic of the experimental system is shown in Fig. 2.1. The test section includes a circular disk held horizontally in a vertical cylindrical chamber with the gas injected vertically downward through a long straight vertical pipe into the chamber. Note that for clear illustration the plots in Fig. 2.1 are not directly proportional to the actual dimensions of the apparatus. In the present experimental study, we adopted air as the working fluid intending to save cost of the experiment. The present experimental system consists of four major parts: (1) heating unit, (2) gas injection unit, (3) processing chamber, and (4) flow visualization unit. They are described briefly in the following.

(1) Heating unit: The heating unit is designed to maintain the circular disk at the preset uniform temperature during the experiment. It is composed of a 1.0 cm thick copper plate of eight-inch in diameter, acting as the disk, placed above another 2.0 cm thick copper plate of the same diameter, which is heated by D.C. power supplies. The lower copper plate is then placed on a bakelite plate. A gap height of 0.1 cm is kept between the two copper plates allowing the thermal radiation to transfer from the lower to upper plates instead of the conduction heat transfer. The heater attached onto the back side of the lower copper plate is divided into 4 concentric zones (Fig. 2.2). Each zone is independently heated by passing a D.C. current through the nickel coil placed on a stainless steel base. Additionally, to reduce heat loss from the sidewall of the upper copper plate, the lateral surface of the entire heating unit is wrapped with a 2.0 cm thick thermal insulation layer of superlon. A proper control of the currents transferred from the power supplies to the heating coils leads to a nearly uniform disk temperature with a maximum deviation of 0.1℃ across the disk. The temperature of the upper copper plate at selected detection points is measured by three T-type thermocouples inserted into the plate by the small holes drilled on the backside of the plate. The locations of the detection points are indicated in Fig. 2.3.

(2) Gas injection unit: The gas injection unit consists of a 2 HP air compressor, a flow meter, a smoke generator, filters, pressure regulator, and connection and injection pipes. In the experiments, the air is drawn from the ambient by the compressor and sent into a 300 liter and 100 psi high-pressure air tank and is filtered to remove moisture and tiny particles. The installation of the high-pressure air tank intends to suppress the fluctuation of the air flow and to extend the life of the compressor. Then, the air is mixed with smoke tracers in the smoke generator and is regulated by the pressure regulator. It is later injected into the processing chamber through the injection pipe which is coaxial with the processing chamber. The downward vertical air jet issuing from the injection pipe exit impinges directly onto the copper disk. In the present study, the injection pipe diameter is fixed at 10.0 mm and the straight portion of the pipe is 60.0 cm long. This length of the constant cross-section portion of the injection pipe is selected to ensure that it is long enough to have a fully developed air flow at the exit of the injection pipe. The injection pipe is thermally well insulated to prevent heat loss from the compressed air. The distance between the exit of the injection pipe and the upper surface of the heated disk is varied at from 10.0 to 30.0 mm. The air temperature at the cross section 60 cm upstream of the injection pipe exit is measured by a T-type thermocouple. The measured value is considered as the temperature of the air injected into the processing chamber in view of the good thermal insulation over the pipe.

(3) Processing chamber: The processing chamber, which is made of 0.6 cm thick quartz glass to allow for the observation of the flow pattern in the chamber, is cylindrical and has a diameter of 29.1 cm. The distance between the chamber top and bottom is 20.0 cm. To facilitate the flow visualization, the chamber top is made of an acrylic plate. Air is injected vertically downward from the injection pipe into the cylindrical chamber and impinges directly onto the heated disk. The air flows fist over the heated disk, then moves through the annular section of the chamber, and finally leaves the chamber via twenty circular outlets of 1.27 cm in diameter opened at the bottom of chamber. The walls of the chamber are thermally well insulated to minimize the heat loss from the processing chamber during the experiment.

(4) Visualization unit: A smoke-tracer flow visualization technique is employed to observe the flow patterns induced by the jet impinging onto a heated disk in the cylindrical chamber. The smoke is produced from burning incense prepared from sandalwood. The smoke is mixed uniformly in the smoke generator and is carried out by the inlet air and is sent into the cylindrical chamber. The gas flow pattern in the chamber is illuminated by the vertical and horizontal plane light sheets produced by passing parallel lights from an overhead projector through adjustable knife edges. The experimental system is located in a darkroom to improve the contrast of the flow visualization. The time variations of the flow pattern from the top and side views are recorded by the Sony digital video camera DCR-PC100.

(5) Temperature measurement: The air temperature in the processing chamber is measured by inserting a calibrated and corrected thermocouple probe into the chamber through a number of small holes of 1.0 mm in diameter opened at the top of the chamber. The probe is an OMEGA (model HYPO) mini hypodermic extremely small T-type thermocouple implanted in a 1.0 inch long stainless steel hypodermic needle.

2.2 Experimental Procedures

The experimental parameters included in the present study are the jet-to-disk separation distance, jet-to-disk temperature difference, and jet flow rate. The injection pipe diameter is fixed at 10.0 mm. The jet-to-disk temperature difference and jet flow rate are respectively varied from 0 to 25.0℃ and 0 to 12.0 slpm (standard liter per minute). The experiment starts with the air at the ambient temperature T_a compressed first into a smoke generator through the connection pipes, and then injected into the cylindrical chamber. The air then moves over the heated disk and finally leaves the processing chamber. Meanwhile the temperature of the disk is controlled at the preset level. The temporal changes of the flow patterns in the chamber are photographed from the side and top views successively by the Sony digital video camera DCR-PC100 for various jet-to-disk separation distances, gas flow rates, and temperature differences between the disk and inlet air.

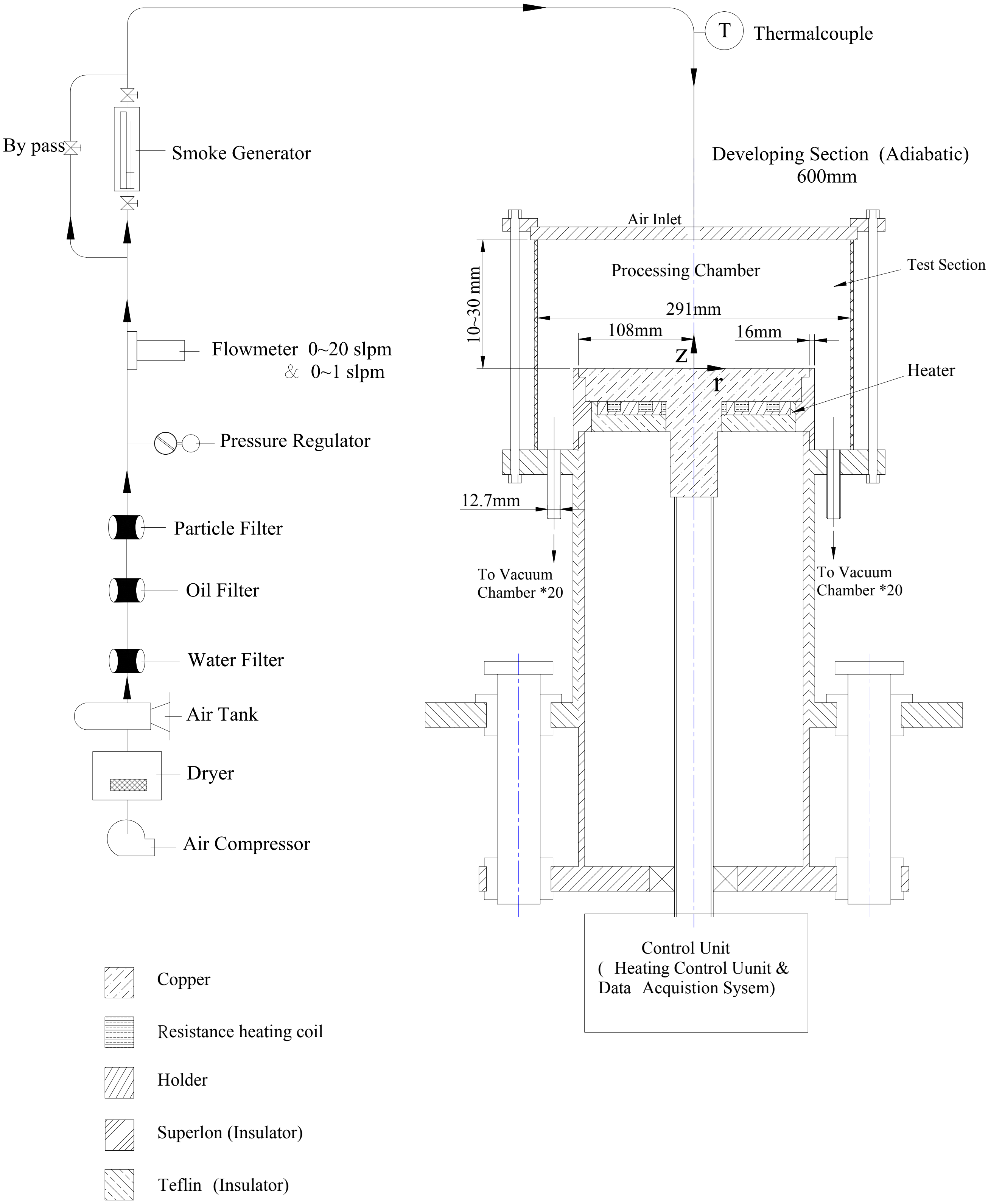

Fig. 2.1 Schematic diagram of the experimental apparatus.

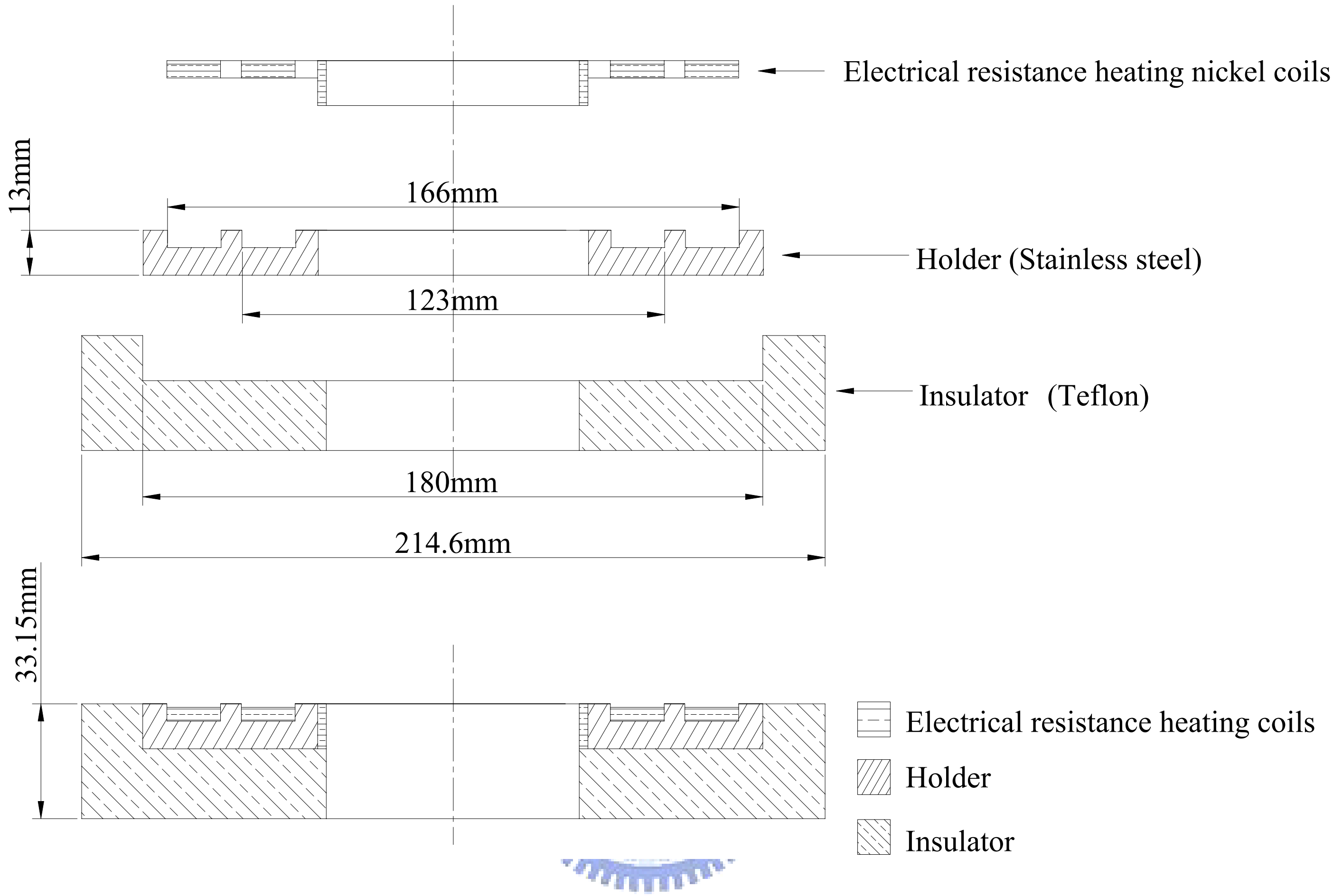

Fig. 2.2 The heater consists of three parts: resistance heating element, holder and insulator.

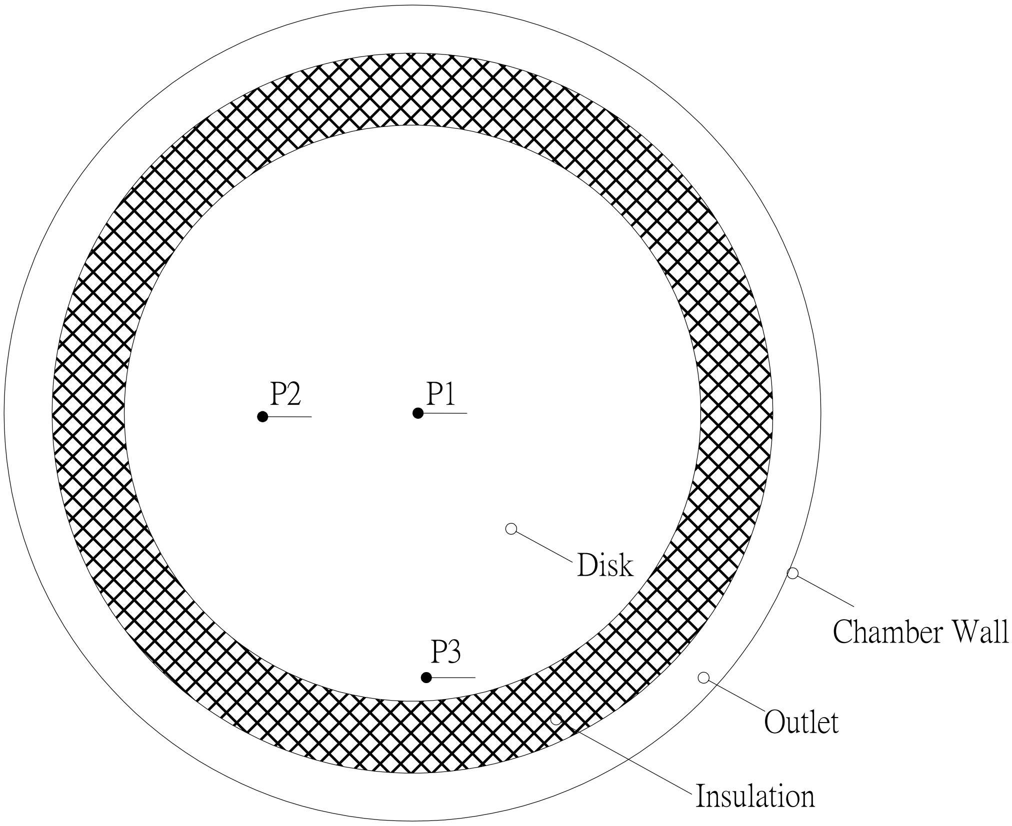

Fig. 2.3 The locations of the detection points on the upper copper plate.