ICESP X – Australia 2006
Paper 6C3

APPLICATION OF FABRIC FILTER TO COKE OVEN

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ABSTRACT

To prevent atmospheric diffusion of smoke and dust contained in flue gases, a fabric filter is generally installed in coke ovens in Japan. However, since such dust has a very small particle diameter and consequently is difficult to remove, the pressure loss of the fabric filter increases. This study examined how to decrease the pressure loss of a fabric filter using actual flue gases from a coke oven. The relation between the pressure within the filter cloth and the acceleration during pulse was also reviewed along with the effect of an agent on the pressure loss to find an optimum pulse method. As a result, the specifications of the optimum pulse system at the pulse pressure of 0.6 MPa were clarified together with the effect of an agent. The optimum system was then introduced to an actual system, which is currently operated with the pressure loss kept within the permissible range.

1. INTRODUCTION

Figure 1 shows the outline of a coke oven. A coke oven is made of fireproof bricks laid on top of each other. Carbonization chambers and combustion chambers are alternately placed in the coke oven. Coal placed in the carbonization chambers is carbonized into coke by the heat from the combustion chambers. The heating materials used in the combustion chambers are gases such as CO. Unburned carbon, if generated in the combustion chambers, is released to the atmosphere as black smoke through a smokestack. The unburned carbon is of vapor deposition type having extremely small dust particle diameter, and so the pressure loss of the fabric filter increases. To find a pulse system that has a low pressure loss and to assess the effect of an agent, we installed a pilot fabric filter in an actual coke oven and conducted experiments using actual exhaust gases.

2. EXPERIMENTAL EQUIPMENT AND METHOD

2.1 Review of Pressure and Acceleration

To clarify the mechanism of pulse, the pressure applied within the filter cloth and the acceleration were examined. Figure 2 shows the outline of the experimental plant. The pressure applied to the filter cloth was measured at specified positions with a pressure sensor adopting the dynamic distortion method hung within the filter cloth. The acceleration was measured with an iron plate attached to the surface of the filter cloth beforehand and with magnetic piezoelectric acceleration pickup fastened to the iron plate.

2.2 Pilot Test

A pilot fabric filter was installed within a coke oven, and the pressure loss was examined using actual exhaust gas. On the assumption that the exhaust gas dust discharged from a coke oven cannot be removed effectively because of its small particle diameter, the dust was removed in the actual system by the off-line method with the airflow of the chamber that was to undergo pulse stopped. The fabric filter was divided into six chambers, and the airflow of each chamber was stopped one by one for dust cleaning. Consequently, the filtration velocity was kept at 1.3 m/min. while all the chambers were operated, and at 1.6 m/min. while dust cleaning was performed. Experiments were conducted at the filtration velocity of 1.6 m/min. in principle.

3. RESULTS AND CONSIDERATION

Dust cleaning of a pulse-jet fabric filter was performed by blasting high-pressure air within the filter cloth. As the pressure applied within the filter cloth increases, the filter cloth expands and acceleration is generated in it; the efficiency of dust removal is affected by the pressure and the acceleration. To clarify the relation between the efficiency of dust cleaning and those factors, the pressure and the acceleration within the filter cloth during pulse were examined. Figure 3 shows an example of simultaneous measurements that were performed. The pressure surged even after the initial rise, remained substantially constant for a certain period of time, and then decreased. The filter cloth was in the shrunk state at the start of pulse, and expanded while pulse was in progress. The initial pressure rise occurred in a transient state in which the filter cloth fully expanded. The surge of pressure is considered to have occurred after the expansion.

3.1 Pressure within Filter Cloth

Figure 4 shows the pressure distribution in the longitudinal direction of the filter cloth when feeding of gas was suspended during pulse. We confirmed that if a sufficient amount of dust was attached to the filter cloth, the pressure distribution became almost uniform. Therefore, the results of the following experiments were evaluated using the intermediate pressure value of the filter cloth. Figure 5 shows the relation between the diameter of a nozzle and the intermediate pressure value of the filter cloth. The pulse rate is the atmospheric pressure equivalent. We confirmed that the pressure was the highest with ϕ14 nozzle at the pulse rate of 15 to 40 L/lot. The pressure within the filter cloth affects the pulse rate of the air blasted in a very short time; the larger the nozzle diameter and higher the pressure within the pulse piping, the higher the pulse rate. As shown by Fig. 6, the smaller the nozzle diameter, the higher the pressure within the pulse piping. Those factors caused the pressure within the ϕ14 filter cloth to reach the highest value in the pilot fabric filter studied this time.

3.2 Pressure Increase Model

The pressure increase within the filter cloth was then examined. In general, the pressure within a nonporous enclosure increases with the increase of air flow that enters the enclosure. On the other hand, with a breathable enclosure such as a filter cloth, since the air that enters the filter cloth is discharged to outside, the pressure increase within the filter cloth is determined by the difference between the quantity coming into the filter cloth and that of the filtrate going out of the filter cloth. Consequently, the variation of pressure with time, dP/dt, can be expressed by the difference between the quantity coming in, Q_{in}, the quantity going out, Q_{out}, and the internal volume of the filter cloth, V, as follows:

$$dP/dt = P_0\,(Q_{in} - Q_{out})\,/V$$

where,

P: Pressure within filter cloth [kPa]

t: Time [s]

P_0: Atmospheric pressure [kPa]

Q_{in}: Quantity coming into filter cloth [m^3/s]

Q_{out}: Quantity going out of filter cloth [m^3/s]

V: Volume of filter cloth [m^3]

Figure 7 shows the result of comparison between the internal pressure of the filter cloth obtained by calculation and the actual value obtained through the experiment. The pressure within pulse piping (experimental value) was used as the pulse pressure in the calculation. Figure 7 demonstrates that the calculated value and the experimental value coincide with each other. The pressure within the filter cloth is affected greatly by the quantity coming in per time unit, Q_{in}. Consequently, to increase the pressure, the quantity coming in, Q_{in}, should be increased. One of the methods for increasing Q_n is to increase the nozzle diameter or the internal pressure of the pulse piping.

3.3 Acceleration on Surface of Filter Cloth

Figure 8 shows the relation between nozzle diameter and acceleration. The pulse rate was 25 L/lot with each nozzle of diameters ϕ10, ϕ12, ϕ14, and ϕ17. The acceleration was the highest with ϕ14 nozzle, which coincides with the trend of the internal pressure of the filter cloth. As a result, it was found that the higher the internal pressure of the filter cloth, the higher the acceleration.

3.4 Pressure Loss of Fabric Filter

Figure 9 shows a part of the chart obtained through the experiment. The periodic increase/decrease of the temperature at the inlet of the fabric filter was caused by taking out coke sequentially from each carbonization chamber placed in multiple rows. Dust cleaning of the fabric filter was performed once every hour. The reduction in pressure loss due to dust cleaning gradually increased, and thus the bottom and peak were repeated.

It was found in our basic research that the highest performance was obtained with ϕ14 nozzle. The pressure loss of the fabric filter was then studied with regard to nozzles having diameters of ϕ10 and ϕ14. Figure 10 shows the result of the study. The peak value reached 1.94 kPa at the pulse rate of 20 L/lot with ϕ10 nozzle, far surpassing the 1.7 kPa target value of this experiment. In the case of ϕ14 nozzle, the peak value reached 1.6 kPa with the pulse rate of 25 L/lot, and 1.4 kPa with the rate of 40 L/lot, thus achieving the target value.

To assess the effect of agents, the optimum quantity of the agent was examined based on the pressure loss with the ratio of agents changed. Figure 11 shows the result. By adding an agent, the pressure loss decreased, and at the agent ratio of 5.5 or higher, the pressure loss remained constant, suggesting that the agent should be added at the agent ratio of 5.5 or higher.

4. APPLICATION TO ACTUAL SYSTEM

Based on the results of the pilot test conducted this time, the optimum system was applied to an actual system. Figure 12 shows the flow of the actual system. The exhaust gas was branched before it entered the flue from the existing smokestack, and introduced to the fabric filter. The agent was supplied in the previous stage of the fabric filter.

Figure 13 shows the transition of pressure loss during the period of approximately 3 months from the start of operation. The pressure loss has remained below the planned value. Dust cleaning is performed using the differential pressure control method, with the pressure loss kept at the specified level. Since the chamber is kept in the closed state while dust cleaning is performed, the pressure loss of the filter cloth increases during that time.

5. CONCLUSION

To develop a high-pressure pulse-jet type fabric filter for the exhaust gas from a coke oven, actual gas was fed to a pilot fabric filter and pulse conditions including nozzle diameter and pulse rate were examined along with the effect of agents to achieve low pressure loss. The following results were obtained:

i) The degree of dust cleaning affects the internal pressure and the acceleration of a filter cloth during pulse. The internal pressure and the acceleration are determined by the internal pressure of the pulse piping and diameter of nozzle.

ii) The internal pressure of the filter cloth during pulse can be calculated.

iii) The acceleration generated during pulse reaches the maximum value the instant the filter cloth has expanded fully.

iv) The fabric filter developed in this research is currently being used in an actual coke oven, and the pressure loss has remained below the planned value for approximately 3 months after the start of operation.

6. REFERENCES

i) K.Morris,C.L.Cursley & R.W.Allen: The Role of Venturis in Pulse-jet Filters, Filtration & Separation, 28, 1, pp. 24-31 (1991)

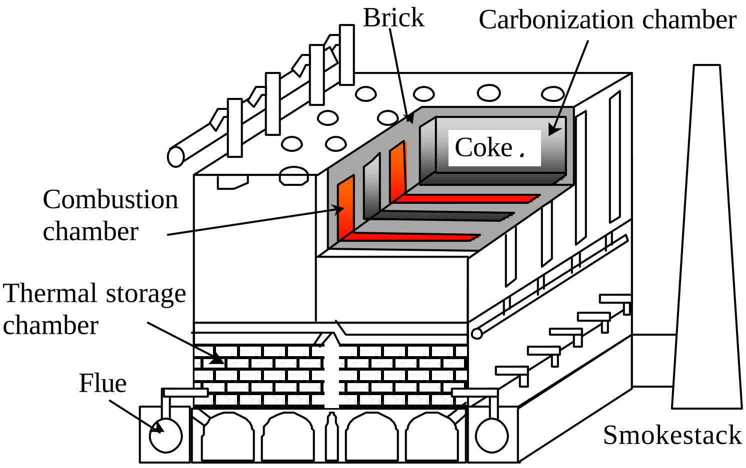
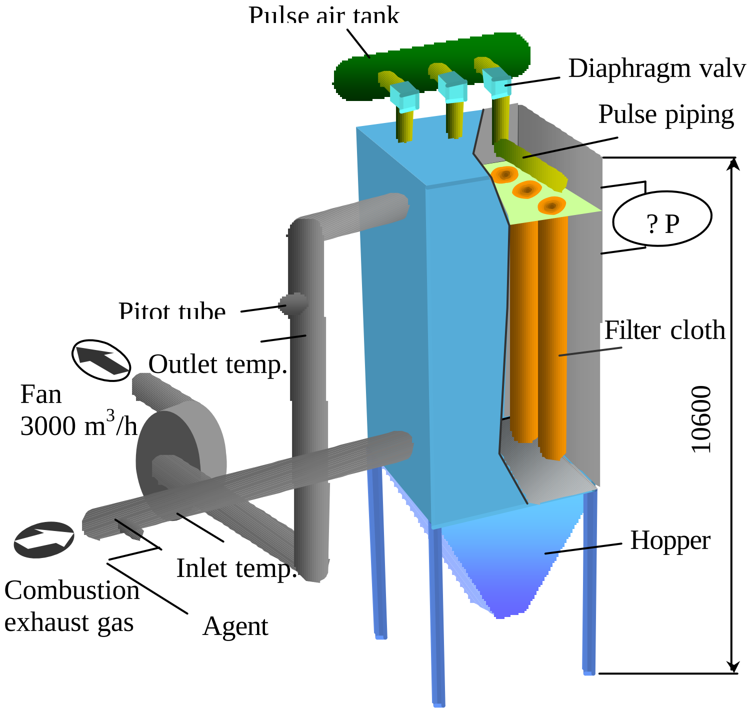


Figure 1: Outline of a coke oven



Item	Specifications
Filter cloth size [mm]	ϕ155 × 6900
Filtration area [m^2]	30.2 (9 pcs.)
Pulse pressure [MPa]	0.6
Diaphragm valve	25A, 40A
Capacity of pulse air tank [L]	85
Nozzle diameter [mm]	ϕ10 to ϕ17
Pulse time [s]	0.2
Pulse period [min]	60

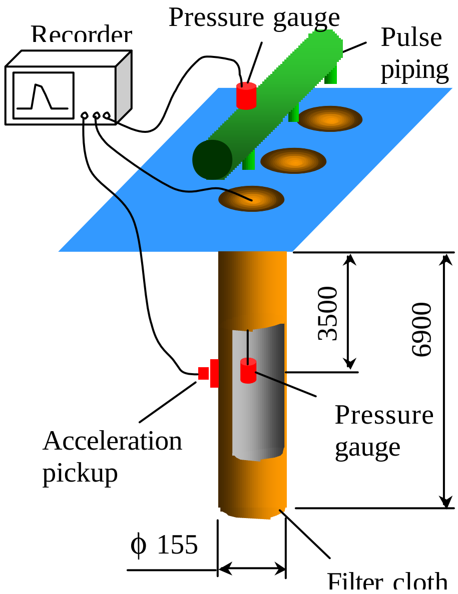


Figure 2: Outline of an experimental plant

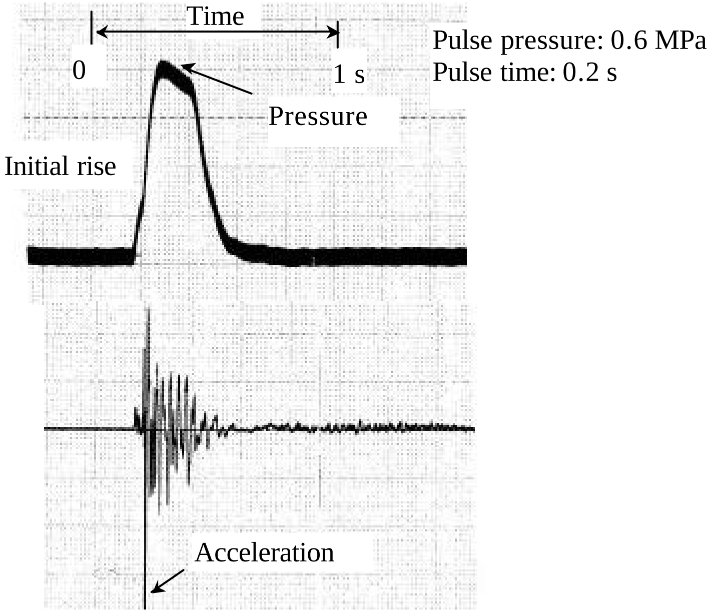


Figure 3: An example of pressure and acceleration

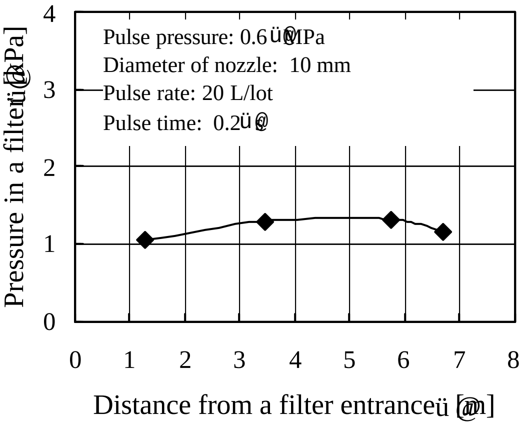


Figure 4: Relation of pressure distribution in a filter cloth

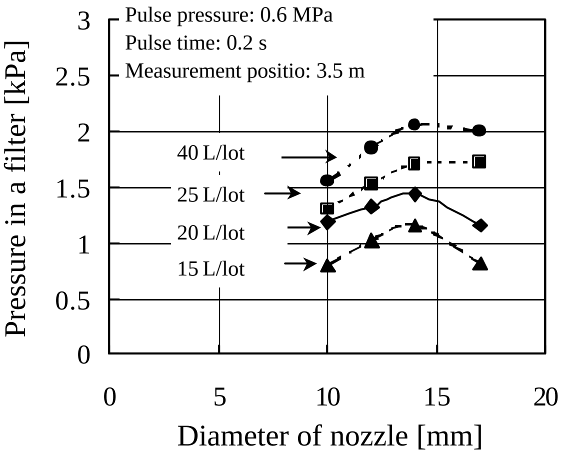


Figure 5: Relation between diameter of nozzle and pressure in filter cloth

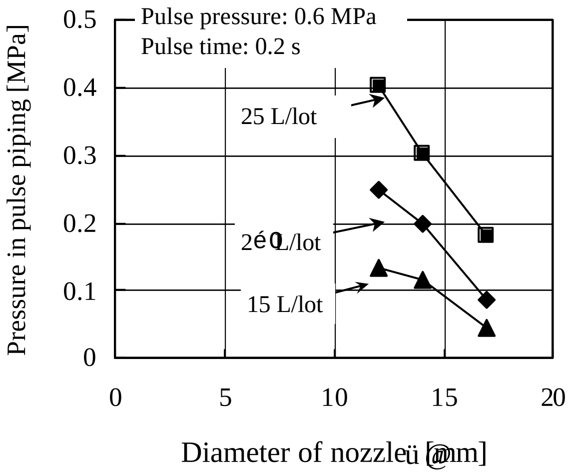


Figure 6: Relation between diameter of nozzle and pulse piping pressure

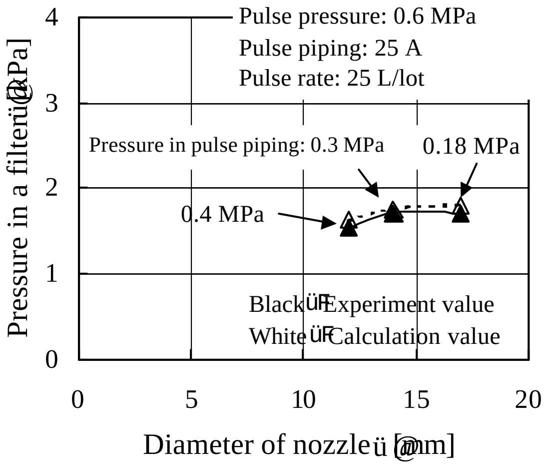


Figure 7: Comparison of calculated value and experiment value

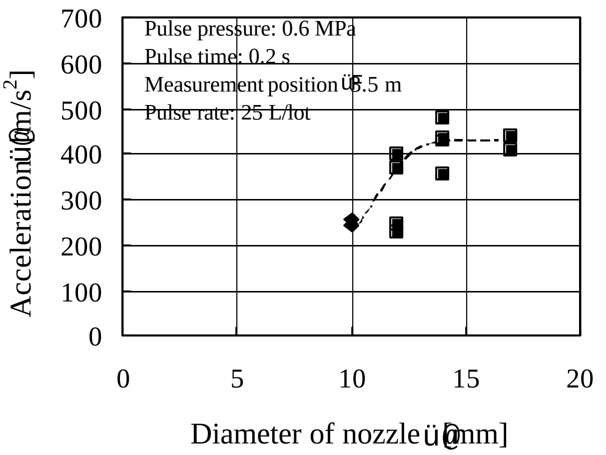


Figure 8: Relation between diameter of nozzle and acceleration

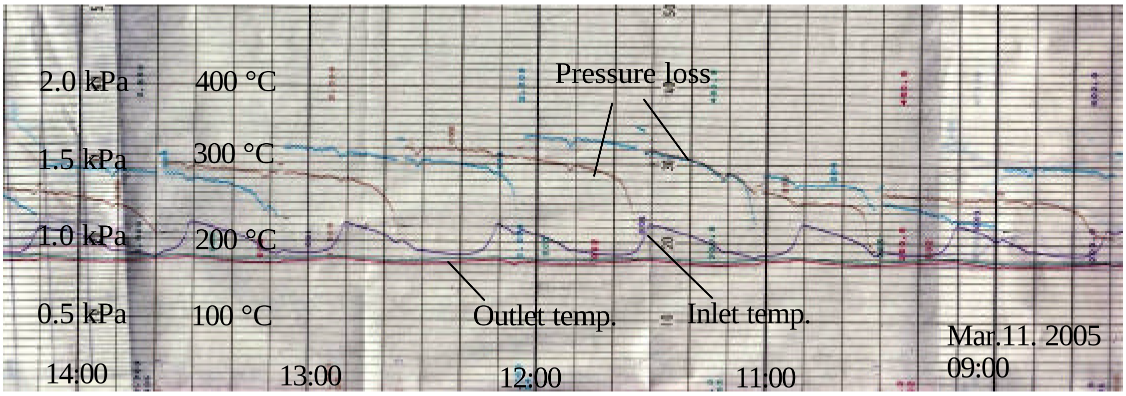


Figure 9: Example of experiment chart

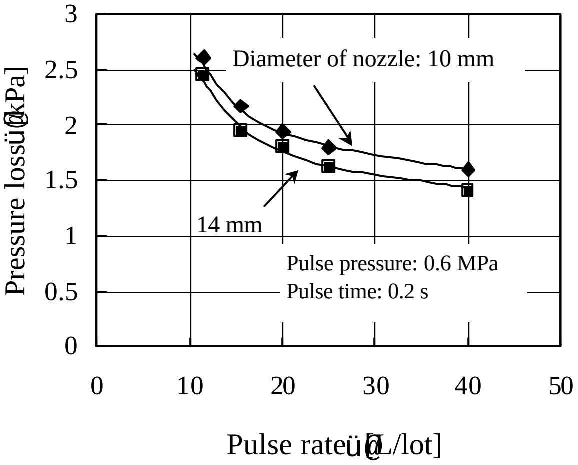


Figure 10: Relation between pulse air volume and pressure loss

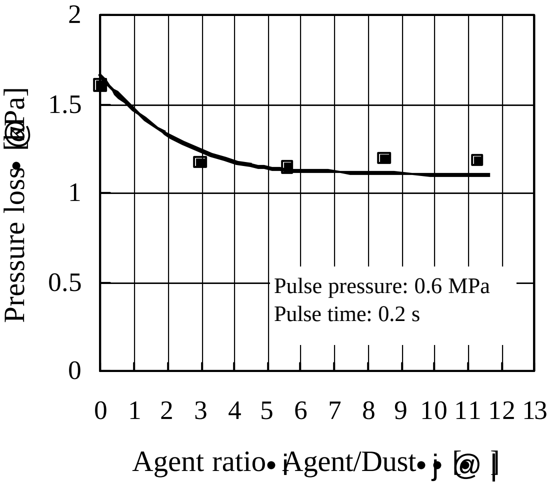
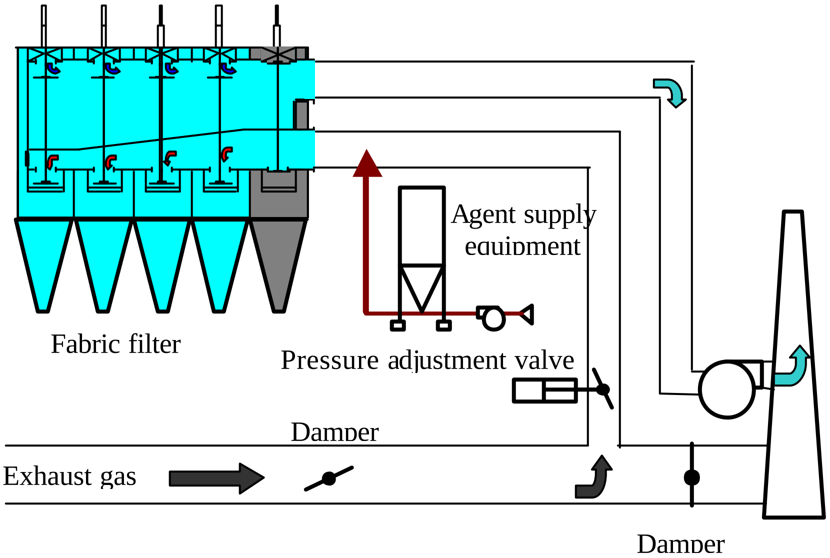


Figure 11: Relation between pulse agent ratio and pressure loss



Gas volume [m_N^3/h]	212416
Filtration area [m^2]	5241
Gas temperature [°C]	190
Dimensions of filter cloth [mm]	ϕ155 × 6900
Number of filter cloths [lots]	1560
Pulse pressure [MPa]	0.6
Nozzle diameter [mm]	ϕ14
Pulse rate [L/lot]	25

Figure 12: Flow of the system

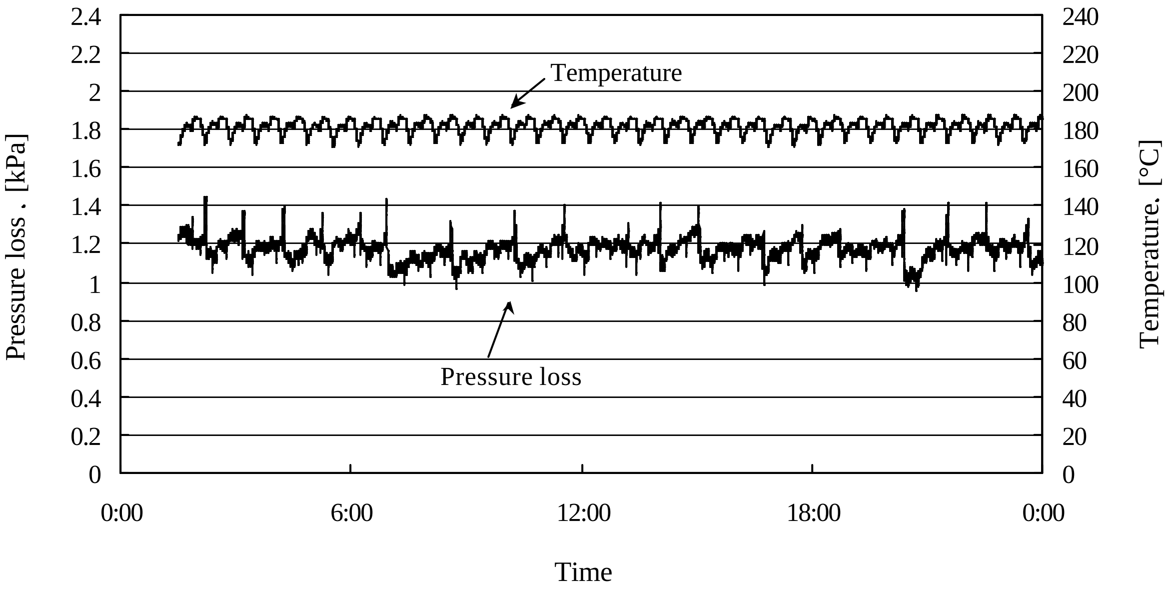


Figure 13: Operation of the system