Development of automatic chimney cleaning and brick dismantling equipment

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Abstract: We have developed automatic chimney cleaning and brick dismantling equipment that allows even and efficient removal of dioxin and other toxic compounds adhered to the inner surfaces of chimneys. The equipment keeps spray distance constant by enabling spray nozzles to move in accordance with the varying diameter of the chimney. The automatic cleaning operation of the equipment is done by controlling the descending speed and rotation speed of the nozzles according to the structure of the chimney and the degree of contamination in the chimney. By adding dismantling attachments, the equipment can also be used for dismantling the brickwork of the chimney, while remotely monitoring the operation with video cameras installed on the equipment. This paper outlines the equipment and presents the results of practically applying the equipment to chimney dismantling at two sites in Japan.

Keywords: dioxin, chimney cleaning, brick dismantling

1. INTRODUCTION

Dismantling of incinerators involves dioxin and other toxic compounds. The Labor Standards Bureau of the Ministry of Health, Labor and Welfare of Japan promulgated the "Guidelines for Preventing the Exposure to Dioxin or Other Toxic Compounds During Work in Waste Incinerators" in April 2001, which made it mandatory to clear incinerating facilities of adherents containing dioxin and other compounds before starting dismantling. Among the facilities requiring cleaning, chimneys in particular contain high concentration of dioxin and involve cleaning work at elevated places; special care for safe and efficient work is thus required.

Chimneys that need to be dismantled are generally brick masonry structures with bricks piled inside a concrete cylinder. Before dismantling the concrete structure, the inner surface of the brickwork is cleaned, the brickwork is dismantled, and the inner surface of the concrete is cleaned again to remove dioxin and other compounds completely. The work used to be carried out manually in most cases using a personnel lift suspended from the chimney top. Recently, mechanical cleaning, in which rotating spray nozzles move vertically in the chimney (see the rotating spray nozzle system shown in **Figure 1**), is becoming more generally used. However, this approach faces a problem of lower cleaning efficiency at the lower part of the chimney, because diameter increases and thus the distance between the nozzle tip and the interior wall (spray distance) increases with depth in the chimney.

We have developed automatic chimney cleaning and brick dismantling equipment (**Figure 2**), which keeps spray distance constant by enabling spray nozzles to move in accordance with the varying diameter of the chimney. The automatic cleaning operation of the equipment is done by controlling the descending speed and rotation speed of the nozzles according to the structure of the chimney and the

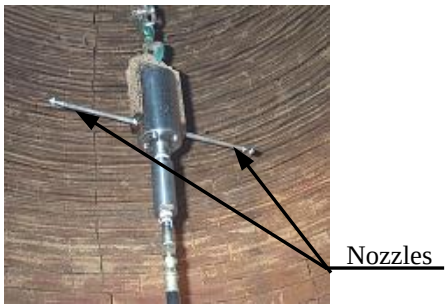

Figure 1: Rotating spray nozzle system

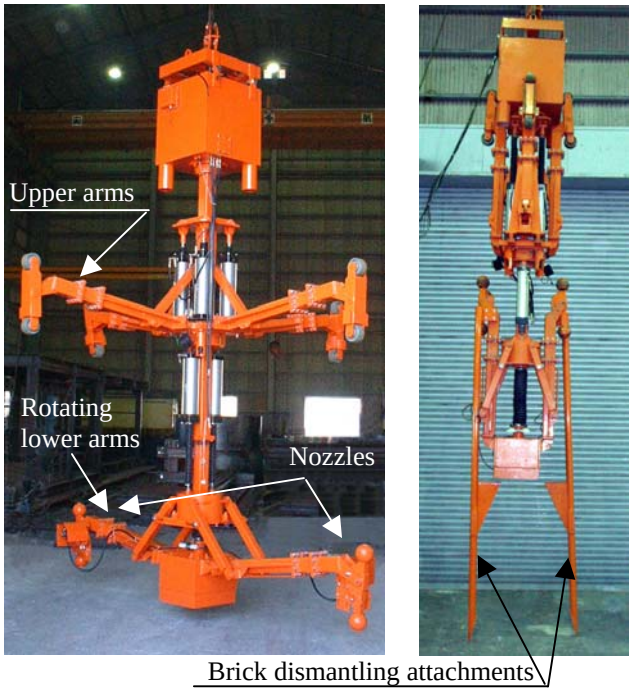

Figure 2: Automatic chimney cleaning and brick dismantling equipment

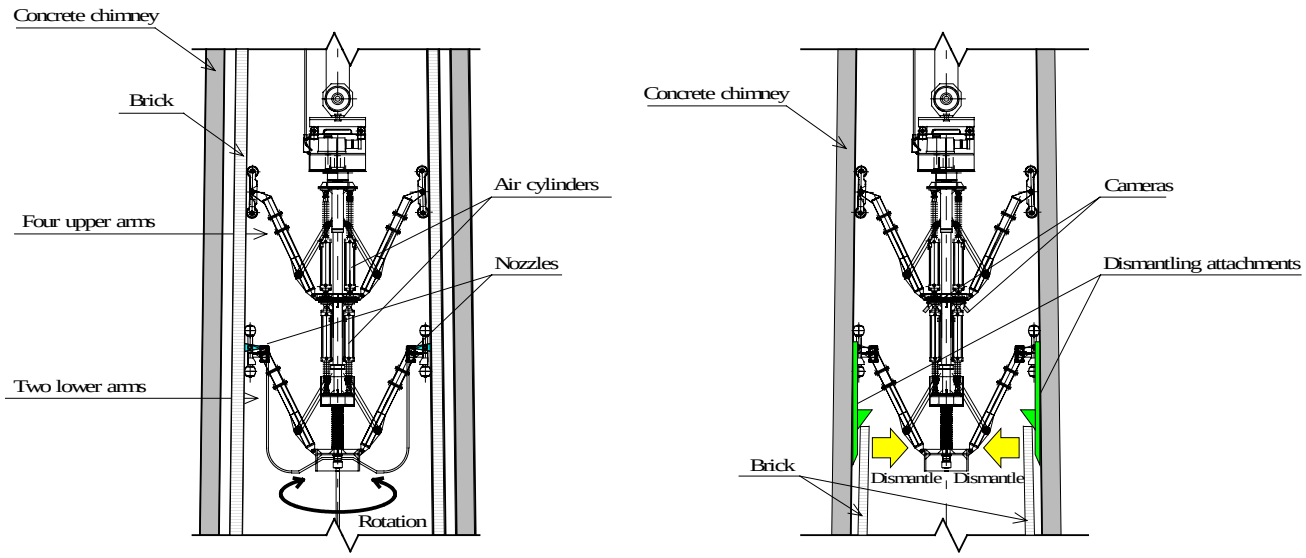

Figure 3: Construction guidelines

degree of contamination in the chimney. By changing attachments, the equipment can also be used for dismantling the brickwork of the chimney in addition to chimney cleaning.

2. OUTLINE OF EQUIPMENT

2.1 Structure

The equipment has four upper and two lower arms that can be opened or closed (**Figure 3**). The upper arms are extended within the chimney to maintain the stability of the equipment, and the lower arms, equipped with attachments, rotate to perform cleaning and dismantling operation.
The main structural specifications of the equipment are as follows:

(1) Equipment height: 3.78m
(2) Equipment weight: 1.0t
(3) Applicable inner diameter of chimney: 0.88 to 3.2m
(4) Spray pressure: 20 to 60MPa
(5) Rotation speed: 0.2 to 2.0rpm
(6) Descending speed: 4.0 to 20.0m/min

2.2 Total system

The equipment is suspended from the top of the chimney with a winch. No cranes are required except when removing the equipment. The nozzles rotate by 180 degrees in one direction to clean a zone of a certain width (about 100mm), and the equipment descends. Then, the nozzles rotate by 180 degrees in the opposite direction, and the equipment descends again. These steps are repeated so that the chimney is cleaned from its top to bottom.

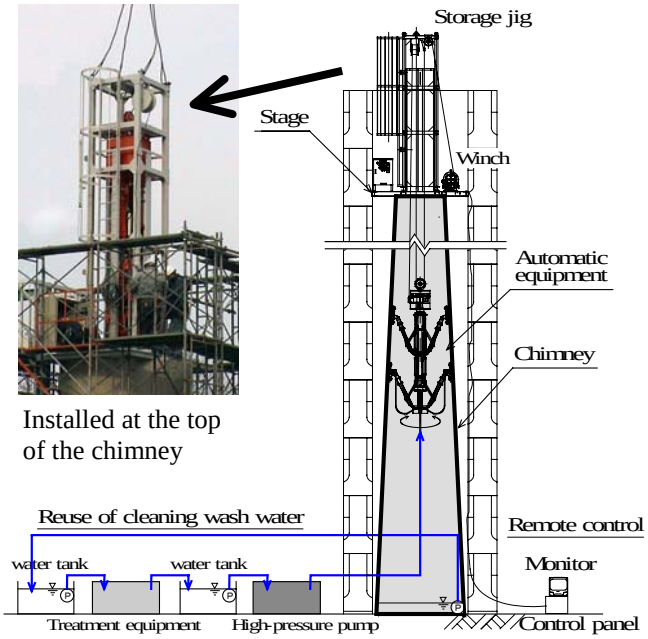

Figure 4: General view of the system

The automatic cleaning is controlled by inputting such data as descending speed, descending time, rotation speed, and rotation time to a control program. The operation of the equipment can be controlled remotely from an operation board on the ground level, while monitoring images taken by two video cameras installed on the equipment. The total system is schematically shown in **Figure 4**. Cleaning effluent is sent to a tank with a pump installed at the lower part of the chimney, treated for reuse, and then recirculated as wash water.

2.3 Equipment setup

The equipment, contained in a storage jig, is placed at the top of the chimney. The jig protects the equipment during its storage and transport and allows reduction of the time required for installing and removing the equipment. Cleaning the chimney downward from the top is made possible by using the jig as a guide for the upper arms during the initial descent of the equipment. The equipment setup at the top of the chimney is schematically shown in **Figure 5**.
The total weight of the equipment, including attachments such as high-pressure hose, is about 1.0t. The lifting load is halved by using a fall block, and the winch installed on the stage has a pull capacity of 1.0t.

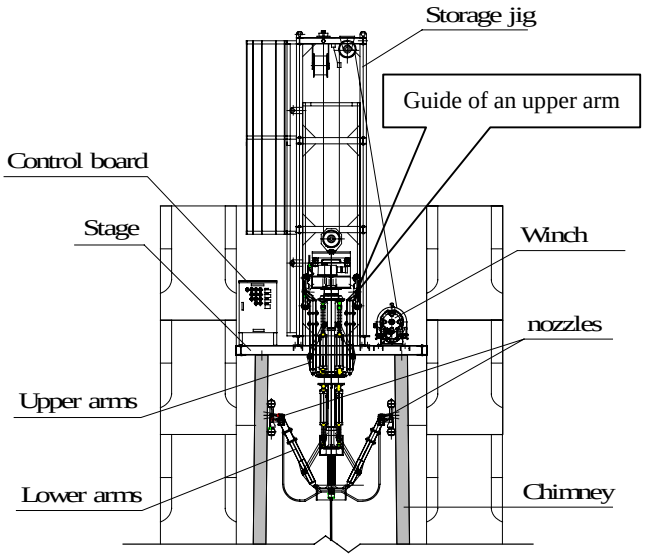

Figure 5: Setup of the equipment at the chimney top

3. USE OF EQUIPMENT

3.1 Development and application of equipment

The development of the equipment was started in 2003. It underwent a performance confirmation test using a dummy chimney in March 2005 at Toda Technical Research Institute. The equipment was first applied to a 21m-high incinerator chimney in Chiba Prefecture in September 2005 and then to a 45m-high chimney of an incineration facility in Fukuoka Prefecture. The work using the equipment is described in the following sections.

3.2 Procedure of work

The procedure of cleaning and dismantling using the equipment is shown in **Figure 6**. Because the video images taken from the equipment are recorded, not only the cleaning and dismantling work but also confirmatory activities before and after the work can be done without workers and supervisors entering the chimney.

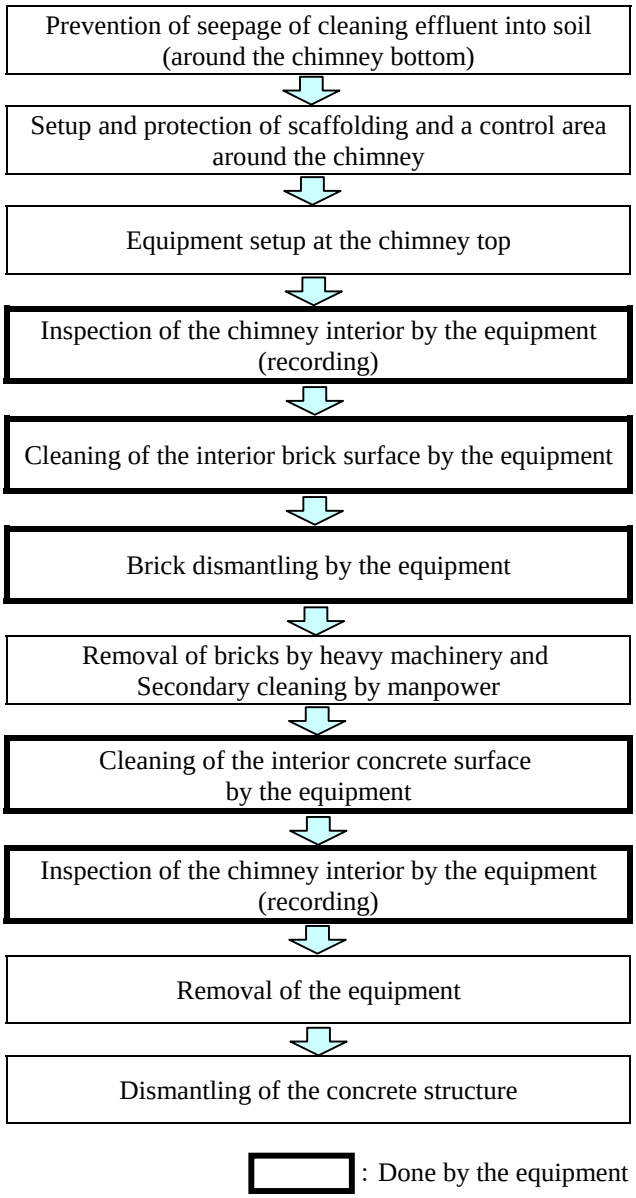

Figure 6: Procedure of chimney dismantling

3.3 Transport and setup of equipment

The equipment, as contained in the storage jig, can be transported by a 4t-truck (**Figure 7**). To place the equipment at the top of the chimney, a stage is first hoisted and secured to the top with anchors, and then the equipment contained in the jig is secured to the stage with bolts. After setting the winch, wires are secured to the jig through the equipment and cables are connected. Then, the equipment is ready for use. In the present case, a rough terrain crane with a lift capacity of 60t was used in consideration of the total weight (equipment plus storage jig) of 2.0t, the required lift of 52m, and the operating radius of 15m. Although it usually takes about four days to assemble and disassemble a derrick at the upper part of a chimney, only two days (one

for assembly and another for disassembly) were required in the present case using the storage jig. A view of setting up the equipment is shown in **Figure 8**.

Figure 7: Transport of the equipment

Figure 8: Setup of the equipment

3.4 Interior brick surface cleaning

Automatic cleaning was done by inputting preset values, listed below, to the control program.

(1) Rotation speed: 1.0rpm
(2) Rotation time: 32sec
(3) Descending speed: 4.0m/min
(4) Descending time: 2.4sec
(5) Nozzle oscillation frequency: 200/min

As the distance between the nozzle tip and the interior wall (spray distance) increases, the energy of high-pressure water decreases substantially so that successful cleaning cannot be assured. In contrast, adherents can be removed efficiently by bringing the nozzles as close as possible to the interior wall.

The equipment allows efficient cleaning by keeping spray distance constantly at 100mm. When spray distance is small, however, it is expected that the zone of wall surface hit by high-pressure water becomes narrow and that the area cleaned per unit time becomes small. To ensure an acceptable level of cleaning area per unit time even when the nozzles are brought close to the wall, the nozzles are oscillated vertically by using an air motor. The nozzle oscillation angle is ±10 degrees, oscillation frequency is 200/min, and spray pressure is 20MPa. A view of spraying high-pressure water is shown in **Figure 9**.

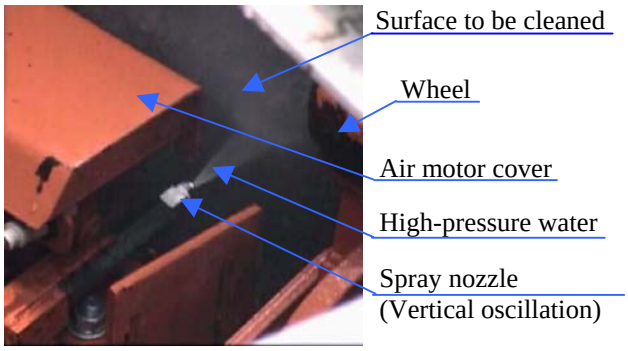

Figure 9: High-pressure water spraying

Because of the automated rotation and descent of the equipment, only two workers were required after the start of cleaning; one person at the chimney top for operational monitoring, and another at the chimney base for pump control and water circulation. The cleaning of the brick surface within the 45m-high chimney was completed in a day, achieving a cleaning speed of 210m^2/day.

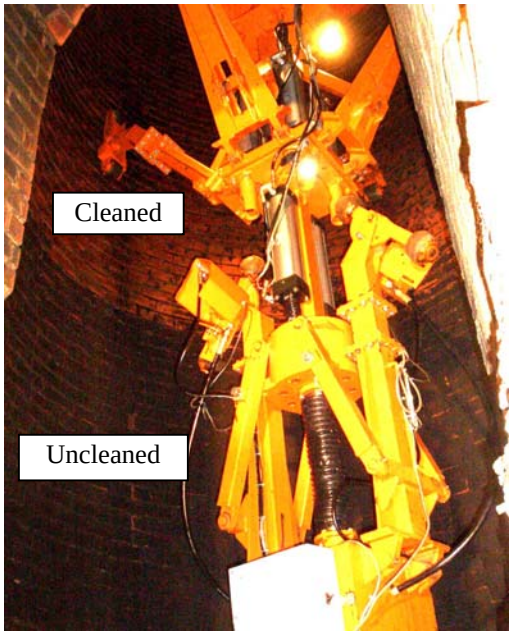

Figure 10: Cleaned and uncleaned wall areas near the lower chimney opening

A view of the lower part of the chimney is presented in **Figure 10**, which shows an apparent distinction between the cleaned and uncleaned wall areas. A view of brick cleaning is shown in **Figure 11**.

Figure 11: Cleaned brick surface viewed upward from the chimney bottom

3.5 Brick dismantling

In a brick-lined concrete chimney, there is usually a gap of about 10 cm between the brickwork and the concrete. The brickwork is dismantled by inserting dismantling attachments into the gap to apply leverage and pulling down the bricks inside the chimney. The following steps are taken in the dismantling work, while the upper arms are always open:

(1) Rotation and positioning of the lower arms,
(2) Opening of the lower arms,
(3) Descent of the equipment, and
(4) Closing of the lower arms.

The bricks are dismantled and pulled down inside the chimney in the above steps 3 and 4.

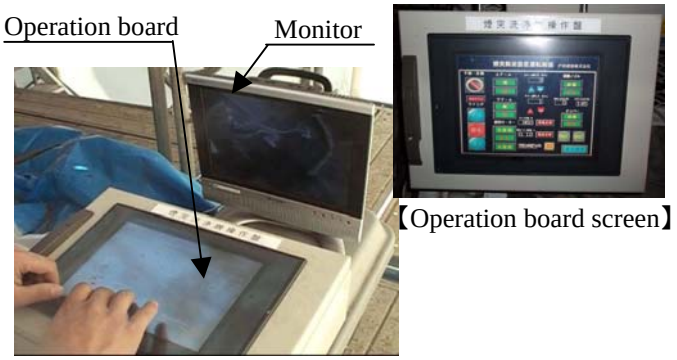

Figure 12: Operation of the equipment

The operator controls the work while monitoring the operation of the equipment and the state of dismantling. Views of operational control and dismantling are shown in **Figure 12** and **Figure 13**, respectively.
A dismantling speed of 15m in height per day (70m^2/day) was achieved.

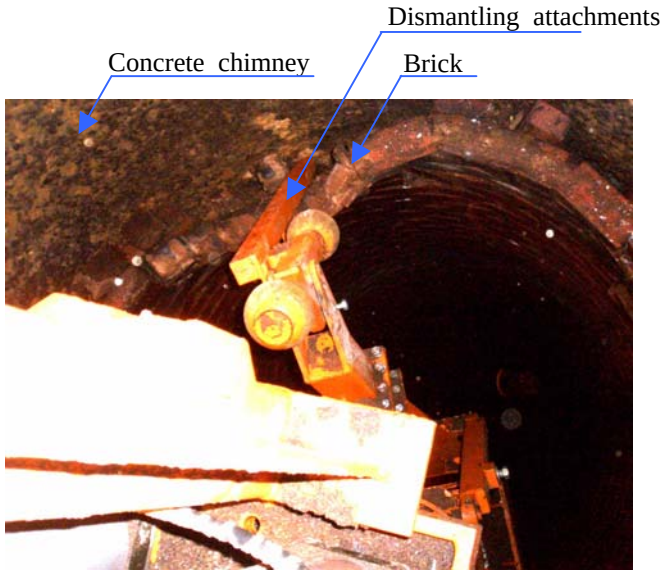

Figure 13: Brick dismantling

The dismantled bricks are raked out from the chimney through a lower opening by using a backhoe (**Figure 14**) and are washed again manually using a jet gun. Due care should be taken so as to avoid simultaneous work at the upper and lower parts of the chimney.

Figure 14: Removal of bricks by a backhoe

3.6 Concrete cleaning

After dismantling the brickwork, nozzles are attached to the equipment again to clean the concrete surface. This ensures complete removal of adherents containing dioxin and other compounds. If the content of dioxin and other compounds after concrete cleaning is less than 3000pg-TEQ/g (analyzed by the official method), the control area of dioxin and other compounds can be removed so that the efficiency of the subsequent operation of concrete dismantling will be improved.

A view of the concrete surface after cleaning is given in **Figure 15**, which shows complete removal of adherents from the surface. The effect of concrete cleaning was also confirmed quantitatively; the content of dioxin and other compounds after concrete cleaning was reduced to 7.9pg-TEQ/g from 140000pg-TEQ/g.

Figure 15: Cleaned concrete surface

4. SUMMARY

In the element experiment[1)] and the performance confirmation experiment at first, the cleaning efficiency was 210m^2/day. This is because spray distance was washed as 200mm. Then, the spray distance was assumed to be 100mm by producing long nozzle, and oscillating it, and the cleaning efficiency was able to be improved greatly.

The automatic chimney cleaning and brick dismantling equipment was applied to chimneys at two sites, and a cleaning speed of 210m^2/day and a brick dismantling speed of 70m^2/day were attained on a practical basis. It was demonstrated for the 45m-high chimney that brick cleaning could be done in one day, brick dismantling three days, and concrete cleaning one day. Compared with the conventional method based on the use of rotational nozzles for cleaning and manual labor on a gondola for brick dismantling, the speed of work was improved by about 40% and the cost of work was reduced by about 20%.

There are about 600 incineration facilities in Japan that are not in use and waiting for dismantling, even when only the general waste incinerators of municipalities are counted. The application of the multipurpose equipment to chimney cleaning and brick dismantling, and in particular to the dismantling of incineration facilities, will be further pursued in the future.

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