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MOCK-UP TEST OF REMOTE CONTROLLED DISMANTLING APPARATUS FOR LARGE-SIZED VESSELS

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ABSTRACT

The remote dismantling apparatus, which is equipped with multi-units for functioning of washing, cutting, collection of cut pieces and so on, has been constructed to dismantle the large-sized vessels in the JAERI's Reprocessing Test Facility (JRTF). The apparatus has five-axis movement capability and its operation is performed remotely.

The mock-up tests were performed to evaluate the applicability of the apparatus to actual dismantling activities by using the mock-ups of LV-3 and LV-5 in the facility. It was confirmed that each unit was satisfactory functioned by remote operation. Efficient procedure for dismantling the large-sized vessel was studied and various data were obtained from the mock-up tests. This apparatus was found to be applicable for the actual dismantling activity in JRTF.

INTRODUCTION

JRTF is the first reprocessing facility constructed in Japan and it was operated during 1967 to 1968 to study basic technology for reprocessing by using spent fuels from JRR-3, and about 200 g of plutonium was recovered. In this test, about 70 m^3 of liquid waste was generated and a part of this waste was stored in four large-sized vessels (LV-3~LV-6) installed in narrow cell of JRTF. After closing the facility in 1970, the decommissioning program started in 1990 to obtain experiments and various data on dismantling of non-reactor nuclear facilities. Liquid waste of the vessels was treated in 1996.(1) In future, the vessels will be dismantled.

The vessels are installed in narrow cell and are connected with piping and other equipments complexly. The inside of the vessels are contaminated with TRU liquid waste. Dose rate in the cell is expected to be relatively high value.

In JRTF, the remote controlled dismantling apparatus was developed for dismantling the vessels. It has many functional units for washing internal vessel, cutting piping and vessel, recovering cut piece, etc. The mock-up test for this apparatus was performed to evaluate the applicability of the apparatus to actual dismantling activities.

This paper reported the outline of remote controlled dismantling apparatus and the result of the mock-up test for the apparatus.

OUTLINE OF LARGE-SIZED VESSELS

Large-sized vessels consist of hand hole part, body part and head-plate part. LV-3 and LV-4 vessels are made of stainless steel and are 1,800 mmϕ x 4,500 mm L x 6 mm t. LV-5 and LV-6 vessels are made of stainless steel and the internal part of them is glass lined. They are 2,400 mmϕ x 4,500 mm L x 12 mm t.

These vessels were used to store TRU liquid waste generated from reprocessing test in JRTF. The liquid wastes were already treated, but sludge is still remaining in the internal part of vessels.

The vessels are in narrow cell (11.6 m L x 6.25 m W x 4.17 m H). In the cell, many stainless steel piping is complex connected with large-vessels. In the floor and the breast wall surface of LV-3, -4 vessels and LV-5, -6 vessels, stainless steel lining and epoxy lining is installed. LV-3,-4 and LV-5,-6 vessels are separated by a lasher.

REMOTE CONTROLLED DISMANTLING APPARATUS FOR LARGE-SIZED VESSELS

Fig. 1 shows construction of remote controlled dismantling apparatus for large-sized vessels. This apparatus consists of washing device, cutting system (grabbing and shearing device, grinder device and plasma torch device), vacuum pad device (collection of cut piece), cut piece transfer system, five-axis movement system, remote control system, etc. This apparatus is operated by remote control system.

Washing Device

Sludge on the inside of vessels is remaining. Before dismantling the vessels, the inside of the vessels is needed to be washed uniformly with a jet of water for removing the sludge as much as possible.

The washing device consists of the washing head with 3D-nozzle, the arm device for moving the washing head to any location of the vessels, industrial television (ITV) camera, etc. In the washing vessels, insert the washing device into the vessels from hand hole, extend the arm device and wash the inside of the vessel with high-pressurized water (Maximum pressure: 180 kg/cm^2, Maximum flow rate: 29 L/min).

Cutting System

1) Grabbing and shearing device

Many piping (process piping, instrumentation piping) are connected with the vessels. The piping is removed before dismantling the vessels. The grabbing and shearing device consists of cutter parts for the shearing of piping, grabbing parts for the holding of piping during cutting operation, ITV camera. The grabbing device can be equipped the adapter for collecting cut piping.

For cutting piping, move the grabbing and shearing device to the piping, hold the piping by grabbing the parts, cut by the grabbed parts and transfer the cut pieces to the cut piece transfer system.

2) Grinder device and Plasma torch device

Grinder is selected as one of cutting tools for dismantling vessels, because the cutting speed is relatively fast. The grinder device consists of the grinder head (grindstone: 305 mmϕ), the cover part, ITV camera.

The plasma torch device is used to cut thicker parts of the vessels that can't be cut easily with the grinder device. This device consists of plasma torch head (maximum power: 300 A), ITV camera. Before the cutting operation starts, the cutting parameters have to be taught (cutting time, cutting speed, etc).

Vacuum pad device

A lot of debris is generated from the dismantling work. The debris is collected to aspirate with a pad using vacuum ejector.

The vacuum pad device consists of vacuum head with rubber pad (50 mmϕ, 8 units), vacuum ejector and ITV camera. The pieces are transferred to cut pieces transfer system.

Cut pieces transfer system

Cut piping and pieces are transferred to the outside of the cell by remote control operation without worker entering the cell. The cut pieces transfer system consists of transfer tray and rails. Transfer tray and rails are installed along the wall in the cell. The tray is 850 mm L x 450 mm W x 50 mm H and has a maximum capacity weight of 90 kg. 10 cut pieces (300 mm L x 300 mm W x 12 mm t) can be transferred at once.

Contamination expansion preventive system

The cutting of the vessels is performed by using grinder device and plasma torch device. During this operation, radioactive waste like dust and fume will be generated. So, it is necessary to remove them and prevent from contamination expansion.

The contaminate expansion preventive system consists of the local exhaust equipment (exhaust flow rate: 6 m^3/min), boots for X-, Y- and Z-axis. Dust and fume generated by the cutting work of vessels are absorbed by the exhaust duct and are collected with a filter of by means of the local exhaust equipment. The local exhaust equipment has a back wash reverse equipment of a filter with pulse jet style. When a filter difference pressure of 100 mm H_2O (= 0.98 kPa) occurred during the operation, a back wash reverse of the filter is automatically carried out.

Boots for the X- and Y-axis are preventing the outside of the cell from dust and fume contamination from flying outside the cell. The boot for Z-axis is preventing Z-axis movement system from contamination.

Five-axis movement system

The five-axis movement system is used for movement of the washing device, the cutting system and the vacuum pad device to the dismantling position in the vessels. This system has five axis (X, Y, Z,θ, ϕ-axis). The movement speed of X- axis and Y- axis is variable (maximum speed: 4000 mm /min).

Remote control system

The remote control system is used to operate the remote controlled dismantling apparatus for large-sized vessels and consists of control panel, operation panel and ITV camera. By the operation panel, every axis of five-axis movement system can be operated independently. Manual operation or automatic operation by teaching is carried out. Working situation (location of the five-axis movement system and cutting point) is checked by ITV camera.

MOCK-UP TEST

Mock-up test was conducted to confirm the application of this apparatus to the actual dismantling work and the dismantling procedure of vessels. The mock-up tests washing inside of the vessels, cutting piping, cutting vessels, collection of cut pieces and ventilation system are done with mock-ups of LV-3 and LV-5.

The mock-up of LV-5 was equipped with a stainless steel plate (850 mm square), which had glass lining (thickness: 1.5 mm) on the upper and lower part of body.

Washing vessels

Sludge and organic solvent were adhered to the inside of the vessels. It is necessary to remove them as much as possible before the dismantling of the vessels starts. So, test pieces (120 mm L x 120 mm W x 5 mm t) coated with sham sludge and organic solvent were installed in the inside of the vessels. The removal effect of the sludge was confirmed by a washing device operated with pressurized water.

For the test pieces were used stainless steel board for LV-3 and glass board for LV-5. Sham sludge (hematite) was fixed on these pieces by heating and organic solvent (TBP-dodecane) was adhered to them. These pieces (total: 17 pieces) were installed in the body part and head-plate part in the inside vessel of LV-3 and LV-5. After washing the inside of the vessels for one cycle (washing time: 6 minute), the removal rate of sludge was measured.

Cutting piping

The grabbing and shearing device is moved to a cutting position by the remote operation, piping is cut with the shearing part. For internal and external piping of LV-3 and internal piping of LV-5, access time (moving time from transfer tray to a cutting position), cutting time of piping and transfer time (after cutting piping, transferring to transfer tray) were measured. The shearing pressure of grabbing and shearing device was 200 kg/cm^2 and the length of cut piping was about 500 mm.

Cutting vessels

The grinder device and plasma torch device are moved to a cutting position by the remote operation. To calculate cutting speed for each part, a hand hole and vessels with internal glass lining are cut with grinder device and plasma torch device.

The access time and teaching time (plasma torch device only), cutting time and exchange time of a grindstone and a nozzle were measured to confirm dismantling efficiency by the cutting method. The size of cut pieces is 300 mm square.

Collection of cut pieces

Vacuum pad device is moved to a collecting position by remote operation and the cut piece is collected, except for platy pieces, which were collected with the grabbing and shearing device.

The access time (moving time from transfer tray to a collection position), collection time and transfer time (after collection of cut pieces, transferring to transfer tray) was measured.

Exhaust with local exhaust system

Dust and fume generated during cutting work are collected with this system. The difference pressure during cutting was measured with a manometer. When the filter difference pressure became 100 mmH$_2$O, the filter was automatically back wash reversed. The change of the filter difference pressure was measured between before and after back wash reversing.

RESULTS

Washing vessels

According to average of sludge removal rate of each test piece, sludge removal rate of whole vessel was 62 % for LV-3 and 65 % for LV-5.

Cutting piping

Fig. 2 shows time required for cutting pipes with grabbing and shearing device. Because piping connected LV-3 was crowded, the cutting work of outside piping lower part was required total 34 minutes. For the cutting of inside piping of LV-5, cutting working efficiency was an average 4.8 times / h at any position.

Cutting vessels

Table I and II shows cutting speed of LV-3 and LV-5 with grinder device and plasma torch device. Concerning the hand hole section in case of the LV-3, because hand hole thickness is 26 mm, the grindstone was clogged frequently, cutting was so difficult. Therefore, an average cutting speed is very low with 0.4 mm / min. The average cutting speed was 10 mm / min with a plasma cutting; good cutting situation was achieved. About LV-5, a similar cutting situation was also obtained.

Table I. Cutting Speed with Grinder Device and Plasma Torch Device (LV-3)

Device Type	Cutting Place	Thickness (mm)	Average cutting speed (mm/min)
Grinder	body	6	30.2
	hand hole	26	0.4
Plasma Torch	body	6	100
	hand hole	26	10

Table II. Cutting Speed with Grinder Device and Plasma Torch Device (LV-5)

Device Type	Cutting Place	Thickness (mm)	Average cutting speed (mm/min)
Grinder	body	12	21.7
	hand hole	26	6.4
Plasma Torch	Body	12	60
	hand hole	14	70

An average cutting speed of the body by grinder cutting was an approximately 30 mm / min on LV-3 and 22 mm / min on LV-5. A cutting speed of a glass lining had no difference compared with other parts of vessel. During cutting of the glass lining, even though several-mm range exfoliates from cutting position, glass materials did not fly off. With a plasma cutting, cutting speed of an average was 100 mm / min on LV-3 and 60 mm / min on LV-5, even though the narrow portion, which is inaccessible with a grinder device. However, dross that generated with plasma cutting was piled up at body lower part of the vessel.

Fig. 3 shows time required for cutting vessels with grinder device and plasma torch device. Access time to a cutting position of grinder device was average 5 minutes. It occupied 10 ~ 15 % of all operation time. A cutting time of grinder device included an exchange of a grindstone was average 30 minutes and dismantling efficiency was 1.8 pieces per hour on LV-3, 1.4 pieces per hour on LV-5. On the other hand, the cutting time of plasma torch device included an exchange of a nozzle was average 15 minutes, as needing a more than half in all operation time with a teachings work, dismantling efficiency fell down 1.3 pieces per hour on LV-3 and 0.9 pieces per hour on LV-5.

Collection of cut pieces

Table III shows the result of collection of various cut pieces with the collection unit. The platy cut piece was collected by a vacuum pad device. And various cut pieces except for platy piece were collected with grabbing and shearing device (The working time of collection was maximum 12 minutes).

It is confirmed to collect completely by combined use of grabbing and shearing device with vacuum pad device.

Table III. Collection Result of Various Cut Pieces with Collection Unit

Collection Unit	Collection place	Access Time (min)	Collection Time (min)	Transfering Time (min)	Total (min)	Presence of Adapter
Grabbing and Shearing	hand hole	5.7	1.7	4.8	12.2	Yes
	head-plate	9.9	1.5	5.1	16.5	No
Vaccum pad	hand hole	4.0	-	-	-	-
	head-plate	3.7	0.8	2.3	6.8	-

Exhaust with local exhaust equipment

Fig. 4 shows a relation between differential pressure and cutting length on LV-5. And Table IV shows rising rate of differential pressure for cutting length on LV-5.

Table IV. Rising Rate of Differential Pressure for Cutting Length on LV-5

Device type	Cutting Place	Average Difference Pressure Rising Rate of Filter (mmAq/m)
Grinder	body and head-plate	1.8
	Glass lining part (opposite side of lining)	2.3
	Glass lining part (surface of lining)	2.7
Plasma torch	body and head-plate	1.1
	Glass lining part (opposite side of lining)	1.5
	Glass lining part (surface of lining)	2.7

An average difference pressure rising rate of a filter is the lowest at a body and a head plate of vessels and is the highest with 2.7 mm H_2O / m by a cutting of a glass lining surface. The differential pressure rose gradually by the collection of duct and fume generated with cutting. When the differential pressure reached 100 mm H_2O, the back wash reverse was started automatically. The filter differential pressure fell down to 20 - 40 mm H_2O.

DISCUSSION

Washing effect

Sludge removal rate of LV-5 was larger than that of LV-3. From the results gathered so far, adherence of sludge on glass lining was smaller than that of stainless steel lining. So, adhesion of sludge was easily come off from glass lining.

As a result of washing the sludge adhered by intensely heat as a whole vessel of LV-3 and LV-5, the every removal rate were approximately 60 %. That means that the sludge, which comes in contact with the inside of the vessel loosely, was removed sufficiently.

The residual sludge has come in contact with firm, it is expected that the cutting of vessel and the collection of pieces can do without hindrance.

Cutting work

- Cutting piping

Cutting work efficiency had large difference between outside piping and inside piping. In case of piping crowds like outside piping, it takes much time because cutting head access to piping by ITV camera with a remote operation. A cutting work advanced, piping gets a few, and cutting work efficiency got high.

On the other hand, as for cutting of inside piping, in addition to the fact that number of piping are few, and dismantling of the body part has ended, could be advanced efficiently. From these results, it is necessary to remove the piping whose contamination level is low in advance for effective vessel dismantling.

- Cutting vessels

With plasma torch device, a thick part of vessels could be cut and cutting speed of plasma cutting is faster than that of grinder cutting. But it needed many hours for teaching time a little dross were generated. Therefore, dismantling efficiency was superior grinder cutting to plasma torch cutting. As a result, it will be valid that grinder cutting must be used under the usual conditions and plasma touch cutting is used in case of thick part of vessels and the narrow portion that is inaccessible with a grinder device.

On the other hand, average differential pressure rise rate of a filter per a cutting length 1 m for glass lining part is higher than that of body part of a vessel, because it was collected by a filter a particle of the glass which generated from cutting of glass lining. In order to decrease a rise of a difference pressure and be in the intervals useful long term for a filter, it is valid that cut from opposite side of lining for a cutting of a glass lining part of LV-5.

Collection capability

It was confirmed that all cutting pieces generated from the dismantling of the vessels were completely collected by combined use of the vacuum pad device, the grabbing and shearing device. Vacuum pad with flexible rubber is applicable for platy cut piece and grabbing and shearing head is valid cutting piece of a hand-hole part.

Exhaust capability

During cutting work, the differential pressure of the filter gradually ascended. It was confirmed that dust and fume generated by cutting work is collected sufficiently.

On the other hand, reverse washing approximately for a change of a filter difference pressure with 50 - 65 mmH_2O again. It was confirmed the repetition re-available enough back wash reverse effect for a filter by repeating a back wash reverse of a filter.

Calculation of required dismantling days

Required dismantling days for large-sized vessels was calculated by conclusion of this research. As a result, it calculated 108 days for dismantling (washing inner vessel, cutting of piping and vessel, collecting and packing of cutting pieces) LV-3 and 125 days for dismantling LV-5.

CONCLUSION

In order to dismantle large-sized vessels installed in JRTF, JRTF developed the remote controlled dismantling apparatus for large-sized vessels and mock-up test was performed by using mock-ups of LV-3 and LV-5. As a result, following conclusion was obtained.

- Sludge loosely adheres to the vessel inside part could be removed with high-pressure water by means of 3-D nozzle.
- In order to be efficient with the cutting of piping and advance the work, it was necessary to withdraw low contaminated piping in advance.
- The vessels main part was cut with a grinder device mainly and it was confirmed that it was valid to apply a plasma cutting for the thick wall part, and the cutting procedure for large vessel was established by result of dismantling efficiency and differential pressure data of ventilation system.
- It was confirmed that cutting pieces generated from dismantling of a vessel were completely collected by vacuum pad device and grabbing and shearing device.
- Collecting of dust and fume and back wash reverse of filter were performed sufficiently.
- To consider a dismantling plan of a large sized vessel, dismantle number of days of a large sized vessel was evaluated with the working efficiency.

With the above-mentioned result, dismantling of large-sized vessels, washing of vessel, a cutting of vessels and piping, and a collection of a cutting piece were performed successfully. This apparatus was found to be applicable for the actual dismantling activity in JRTF.

REFERENCES

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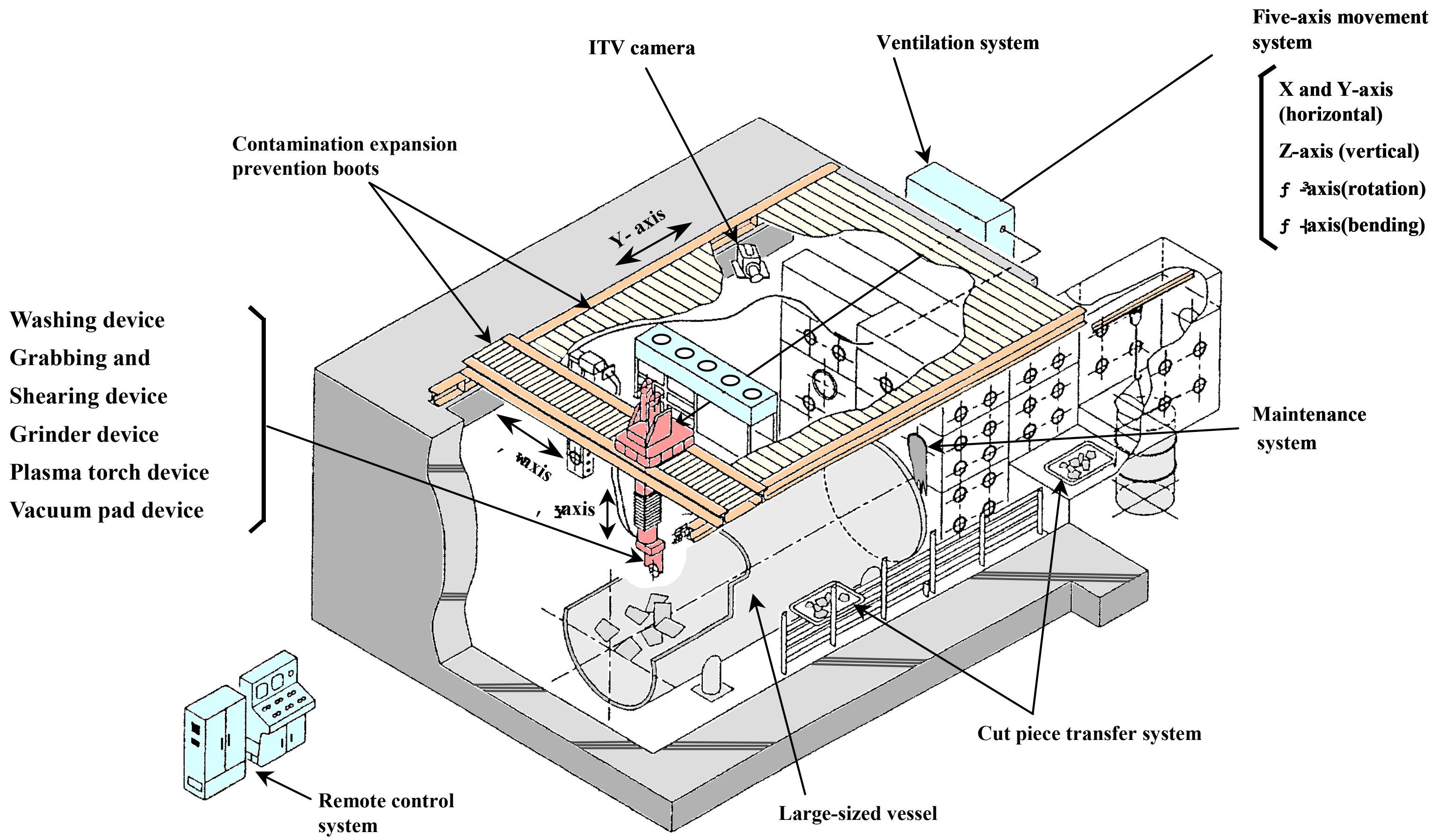


Fig. 1. Construction of Remote Controlled Dismantling Apparatus for Large-sized Vessels

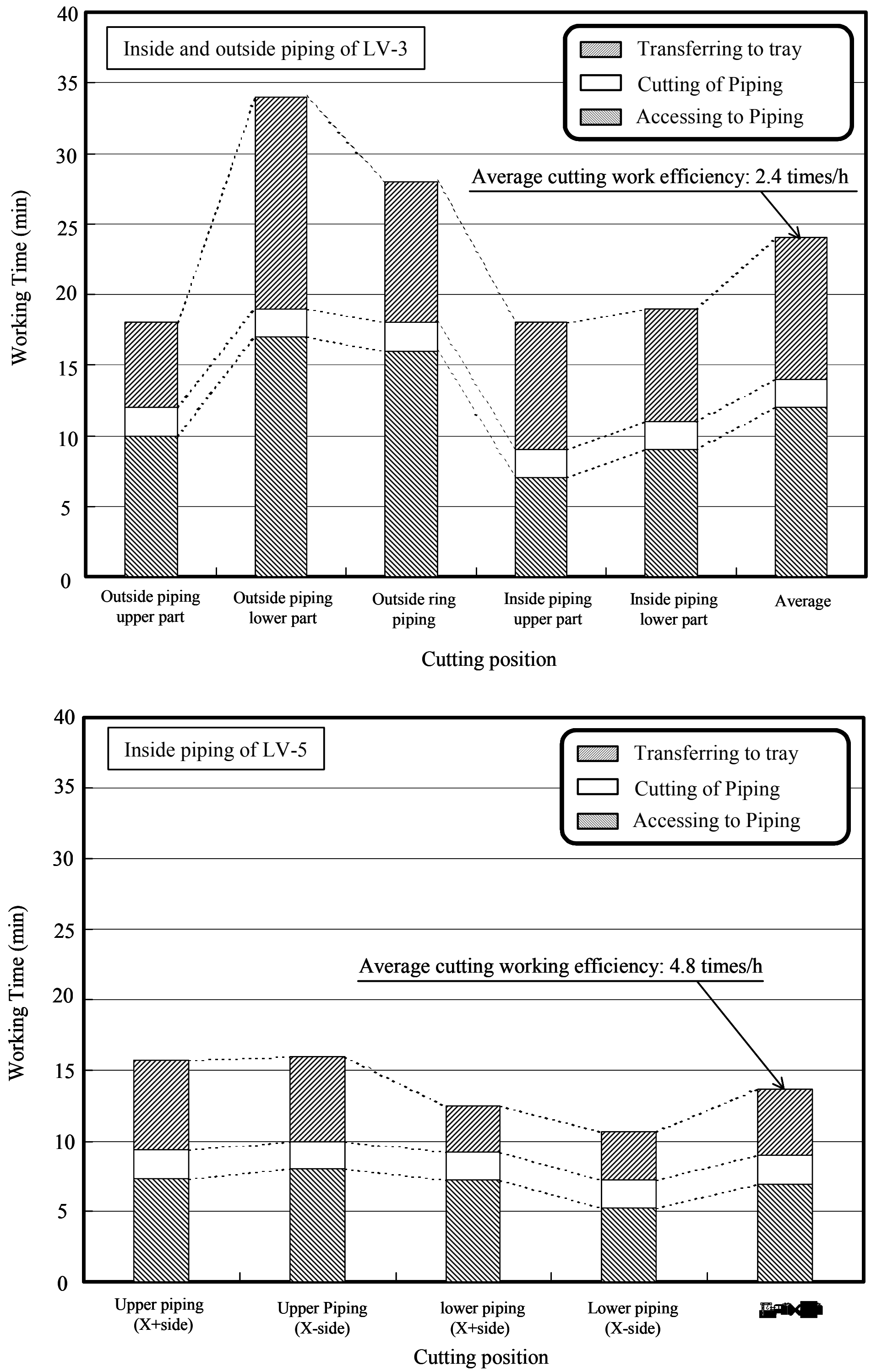
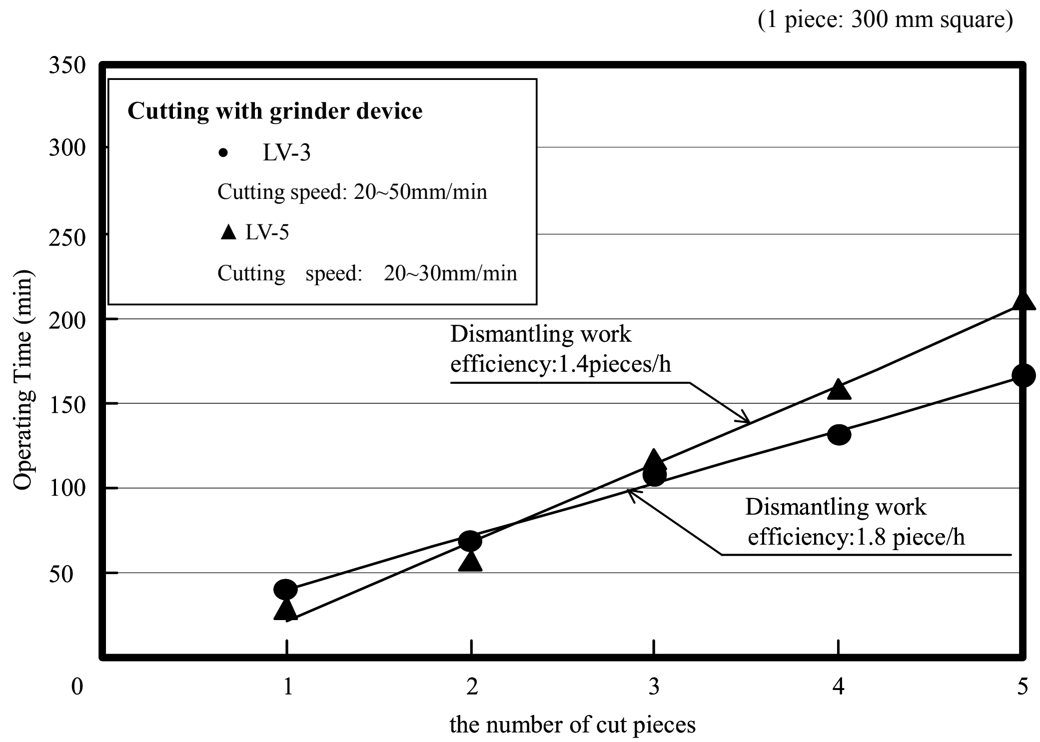


Fig. 2. Time Required for Cutting pipes with Grabbing and Shearing Device



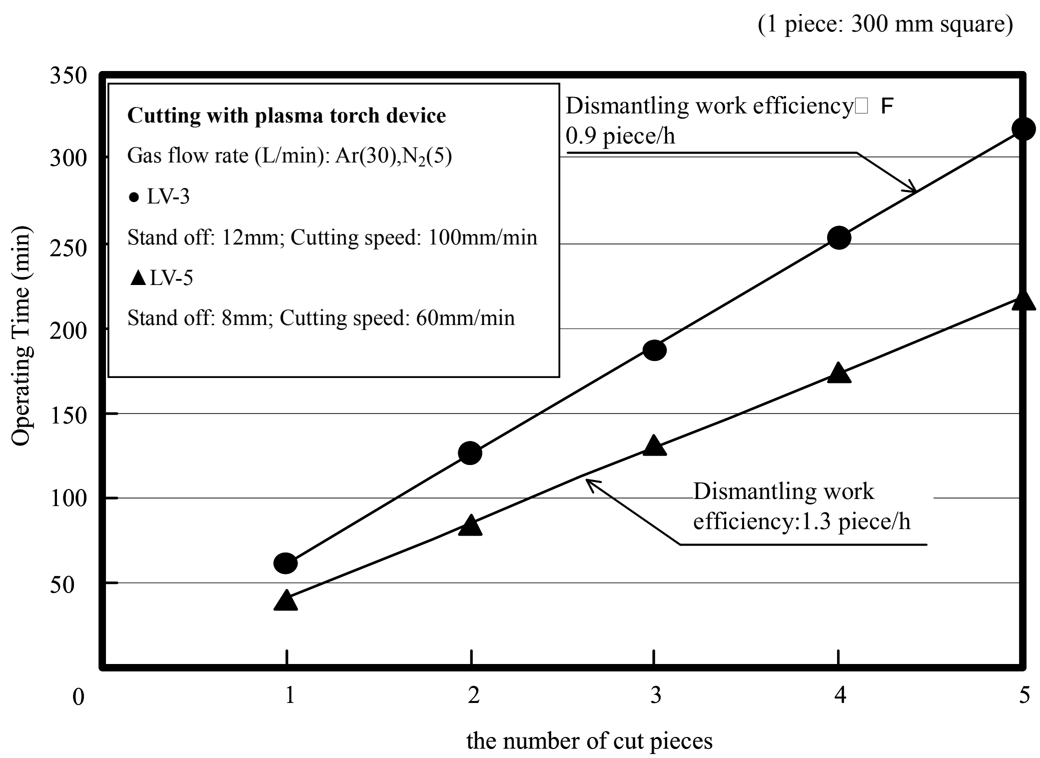


Fig. 3. Time Required for Cutting Vessels with Grinder Device and Plasma Torch Device

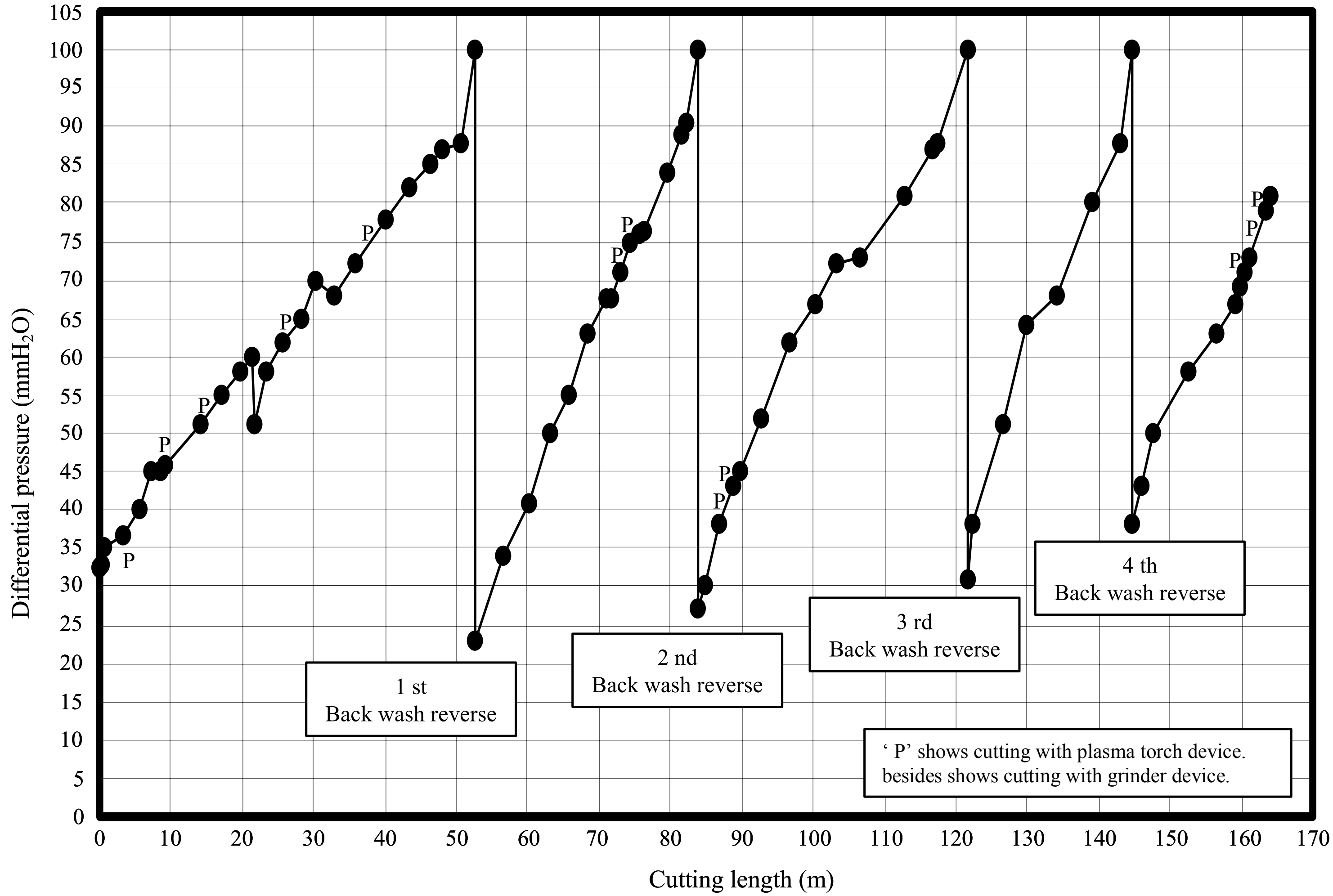


Fig. 4. Relation Between Differential Pressure and Cutting Length on LV-5