NitroJet®'s Verification Test of Contaminated Water Storage Tank Decontamination in Fukushima Daiichi Nuclear Power Plant - 16489

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ABSTRACT

After the Fukushima Daiichi nuclear disaster, much radioactively contaminated water has generated and has been stored into tanks in the site. Therefore, these contaminated water storage tanks (flange-type) are severely required to be decontaminated in order to be dismantled or to be reused to store cleaner water with less radioactive liquid waste and exposure of workers.
Then, IHI Corporation (hereinafter, IHI) have verified that NitroJet® had capability to decontaminate these tanks under governmental grant (the Validation of technologies for contaminated water management project in the FY2013 Supplementary Budget). For this verification, IHI achieved acquiring DF (decontamination factor) by fabricating radioactive partial mock-ups with Rb-86. Moreover, IHI have demonstrated remote operation of decontamination work by using tank's partially full-scale mock up.

INTRODUCTION OF NITROJET®

NitroJet® is an "Ultra-High Pressure Cryogenic Decontaminating System" by using liquid nitrogen, which was developed in INL of the US DOE, and improved and put into commercial service by NitroCision, LLC.
IHI group acquired NitroCision, LLC. in 2013, and have promoted NitroJet®'s decontaminating method especially in Japanese nuclear business.

NitroJet® is technology that makes it possible to scabble concrete, remove coatings and cut metal by spraying a target object with highly pressurized liquid nitrogen (410 MPa at maximum in US spec) at a very low temperature without secondary waste. (See Fig. 1.) The force that is utilized are the mechanical effect resulting from mechanical impact of liquid Nitrogen jet and the burst effect produced by nearly instantaneous feeding up of liquid nitrogen into nitrogen gas. The burst effect is generated when the liquid nitrogen at a very low-temperature (-150°C approximately), vaporizes and expands approximately 700 times.
NitroJet® system includes a liquid nitrogen storage tank, a main skid, a cooling chiller, a jet nozzle that sprays the liquid nitrogen, a shroud cover that recovers the contaminated matter, and a vacuumed collector. (See Fig. 2.) When the level of contamination is low, NitroJet® can be operated directly by workers wearing protective clothing and a full mask, and when the level of contamination is high, the jet nozzle can be held by a robot with work being performed remotely.
In order to prevent scattering contaminated material to the surrounding areas, the jet nozzle is covered by a shroud cover and it is connected into a vacuumed collector. (See Fig. 3.) The recovered material is handled as solid waste, so handling is also simple. It is also possible to mount NitroJet® together with the liquid nitrogen storage

tank on to a trailer.

NitroJet® was supposed to be capable to decontaminate contaminated water storage tanks in Fukushima Daiichi NPP, so that verification was achieved as described below.

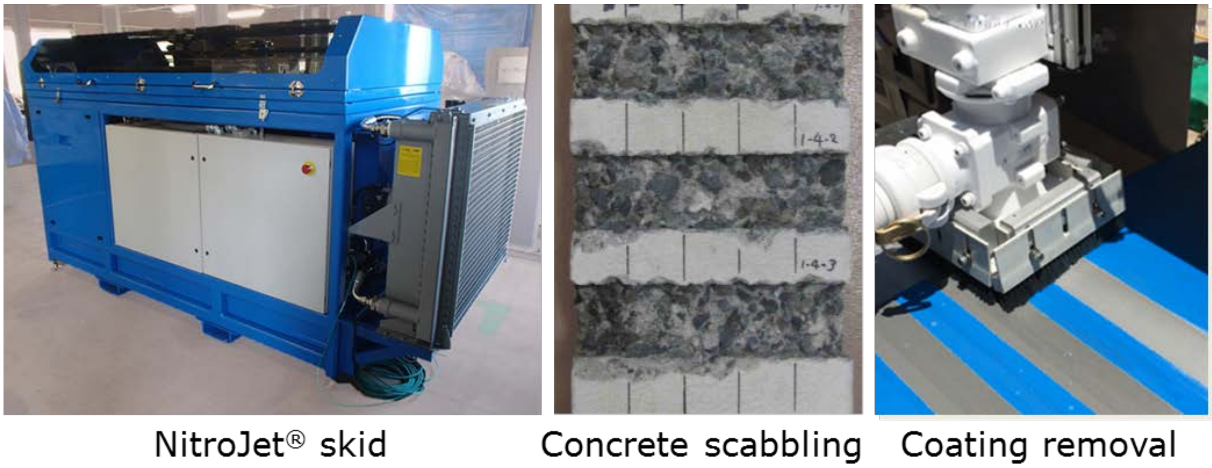


Fig. 1. NitroJet®

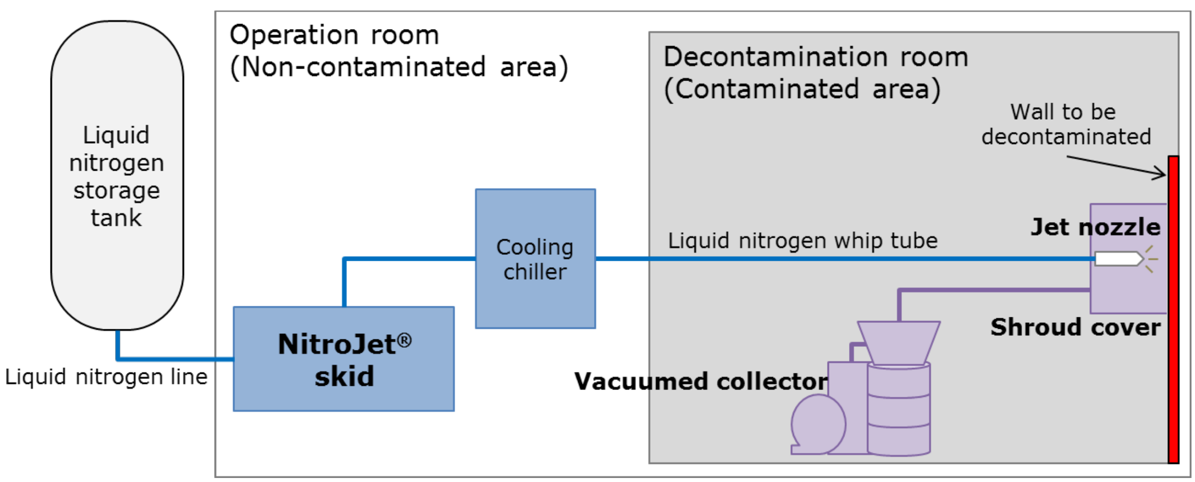


Fig. 2. NitroJet® process

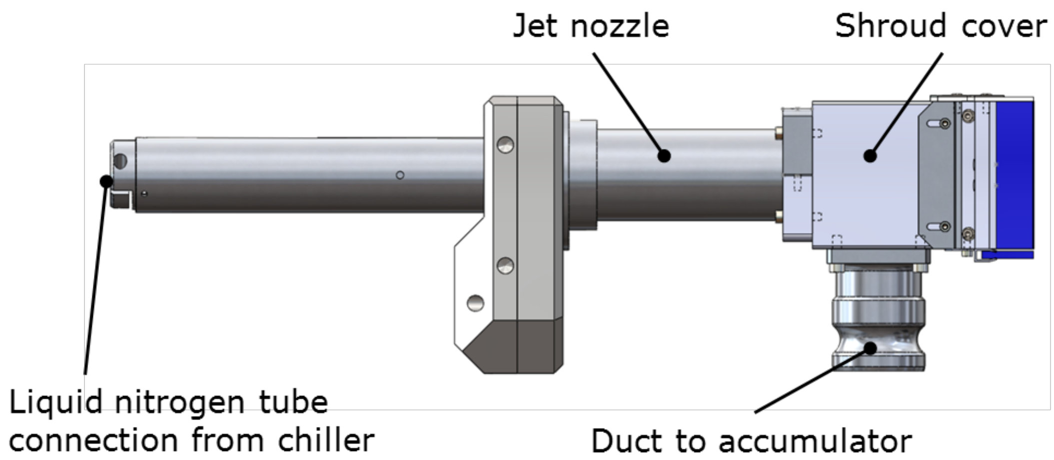


Fig. 3. NitroJet® end tool

OBJECTIVES

Our objectives to verify NitroJet®'s decontamination performance for tank were as below.

1. To acquire DF data of NitroJet® by decontaminating test pieces on which radioactive tracer was adhered
2. To demonstrate remote operation of decontamination work by using tank's partially full-scale mock up

When NitroJet® is operated, it has some parameters, for example, intensifier pressure, scan speed, stand-off (distance from jet to target), orifice size, and so on. These parameters were already optimized before.

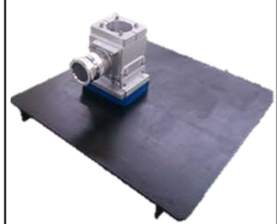
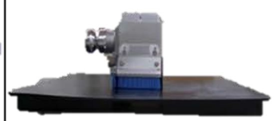
TEST PIECES

To acquire NitroJet®'s DF, we at first categorized complex structures of tank into flat, curved, corner, and flange-joint (silicon sealant removing), and fabricated hand-carried test pieces with the same specifications of actual tank. (See TABLE I.) Besides, we adhered Rb-86 on them as a radioactive tracer. The reason why we adopted Rb-86 is that it is beta nuclide as well as Sr-90 which exists in the contaminated water storage tanks in Fukushima Daiichi NPP, that its half life time is quite short as 18.8 days, and that it is easy to use in the point of availability.

[Rb-86]

Atomic number:	37
Half life time:	18.66 days
Radiation:	Beta ray 1.77Mev (91.24%), 0.69Mev (8.76%)
	Gamma ray 1.077Mev (8.76%)

TABLE I. Category of tank's complex structures

Tank Structure	Flat surface	Curved surface	Corner	Flange-joint (Silicon sealant)
Test Piece				

To preclude effect of radiation coming from out of NitroJet®'s scanning area, we adhered Rb-86 only in the reach of one path of NitroJet®. For example, the width of one path of NitroJet® is about 52mm, so tracer adhering area was narrower than it (32mm). (See Fig.4.)

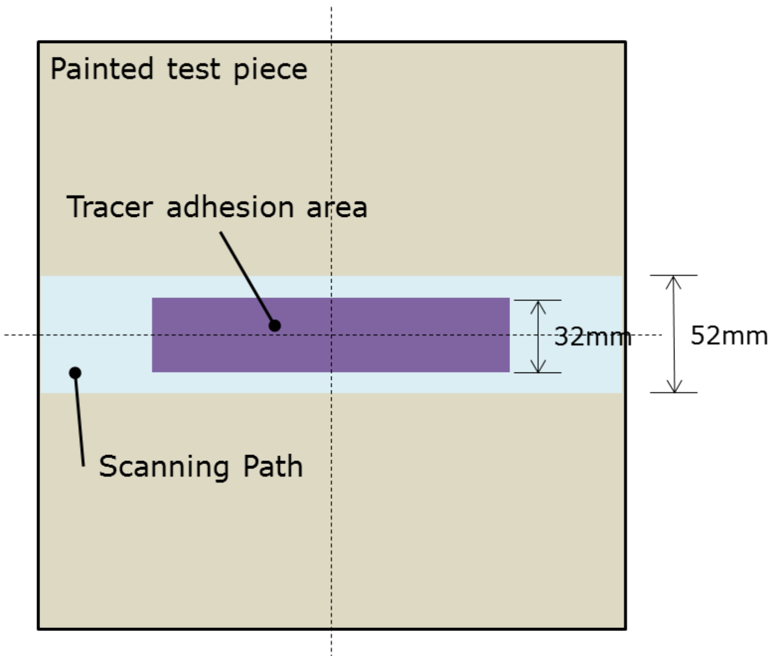


Fig. 4. Tracer adhesion area (flat surface test piece)

DECONTAMINATION VERIFICATION TEST

To calculate DF, we measured dose rate of beta ray from each test piece both before and after decontamination. (See Eq. 1)

$$\mathbf{DF_1} = \frac{\mathbf{D_0}}{\mathbf{D_1}} \qquad \text{(Eq. 1)}$$

Here, DF_1 stands for decontamination factor of once scanning, D_0 stands for dose rate

before decontamination, and D_1 means dose rate after decontamination. D_0 and D_1 already charged off back ground dose rates.
Moreover, we verified NitroJet®'s DF after scanning twice (DF_2). (See Eq. 2)

$$\mathbf{DF_2} = \frac{\mathbf{D_0}}{\mathbf{D_2}} \qquad \text{(Eq. 2)}$$

NitroJet®'s operation parameters were set as TABLE II.

TABLE II. NitroJet®'s operation parameters

Intensifier pressure		280MPa
Scanning speed	Flat	80cm/min (2.5m^2/h)
	Curved	50cm/min (1.6m^2/h)
	Corner	50cm/min (0.5m^2/h)
	Flange-joint (silicon sealant)	150cm/min (4.8m^2/h)

We achieved decontamination for each test piece in the radiation controlled area. (See Fig. 5.)
The collected DF data are listed in TABLE III. The DF data of flat and curved were more than 200. The test pieces were enough decontaminated and silicon sealant on flange-joint was completely removed. However, corner test piece was not decontaminated as well as other structures. This is supposed to be caused by that corner structure was too narrow for NitroJet®'s jet nozzle to approach and keep appropriate stand-off.
Furthermore, dose rates after scanning twice on flat and curved test pieces were reduced to back-ground level. It means these were decontaminated almost completely.

Fig. 5. Test equipment layout

TABLE III. Acquired DF data

Test piece	DF_1	DF_2
Flat	>200	>9000 (Back-ground level)
Curved	>200	>9000 (Back-ground level)
Corner	>9	>13
Flange-joint (silicon sealant)	>200 (Totally removed)	-

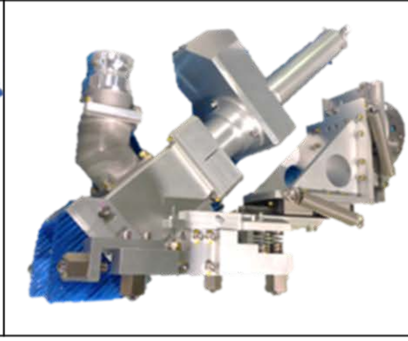
DEVELOPMENT OF END TOOLS

When we considered remote operation of NitroJet® to decontaminate contaminated water storage tanks with less exposure of workers, advanced end tools to fit tanks' complex structures came to be necessary. It will be able to help us to keep appropriate stand-off and good accumulation efficiency.

These end tools are consisting of NitroJet®'s jet nozzle, shroud cover and passive alignment system. Passive alignment system is consisting of rotation and slide structures. We developed end tools to fit each structure which was categorized above. (TABLE IV.)

In the demonstration described below, we verified remote-operability of them.

TABLE IV. Developed end tools

Flat / Curved Surface	Corner	Flange-joint
		

DEMONSTRATION

We also tried demonstration of NitroJet®'s remote decontamination. Test piece was fabricated as partial mock-up of actual contaminated water storage tank, which contains all the categorized complex structures. (See Fig. 6.)

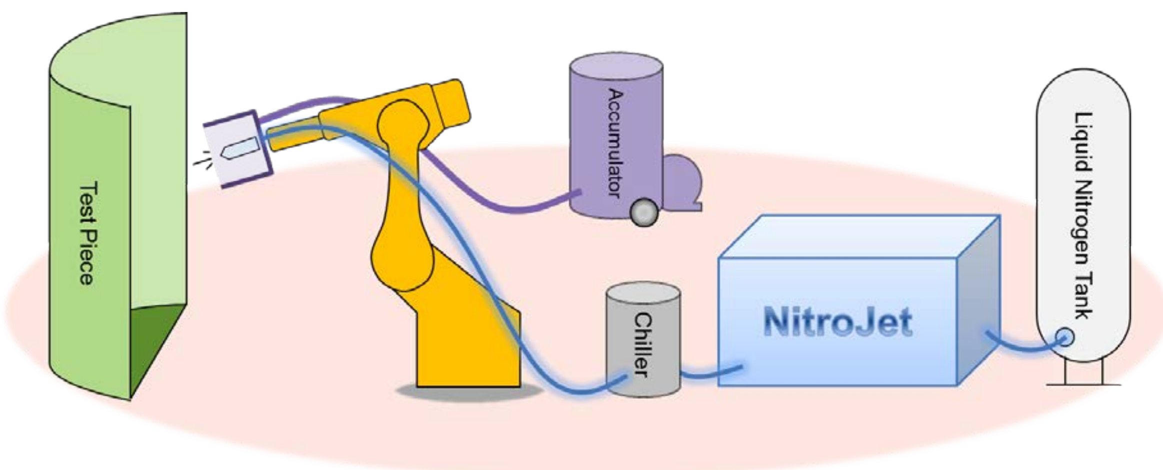


Fig. 6. Demonstration layout image

As the result, end tools with passive alignment system which we developed were successfully verified. However, we got some technical items to be solved. (Fig. 7., 8.) At first, it is very important to plan the cable management (liquid nitrogen tube, accumulation duct hose, air tube for jet nozzle rotation) along with robot-arm to be suitable for actual work. Secondly, whip tube has high stiffness and low flexibility so that it may be managed not to prevent alignment. Finally, it might be difficult to decontaminate in very narrow space like acute angle corner nearby side wall, because the robot arm holding NitroJet® end tool cannot access there.

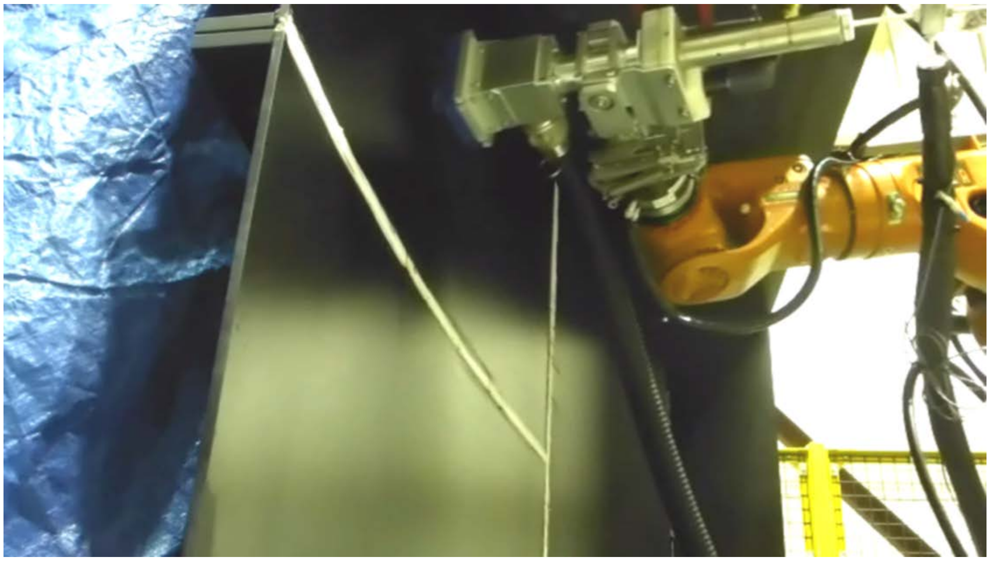


Fig. 7. Demonstration (curved wall)

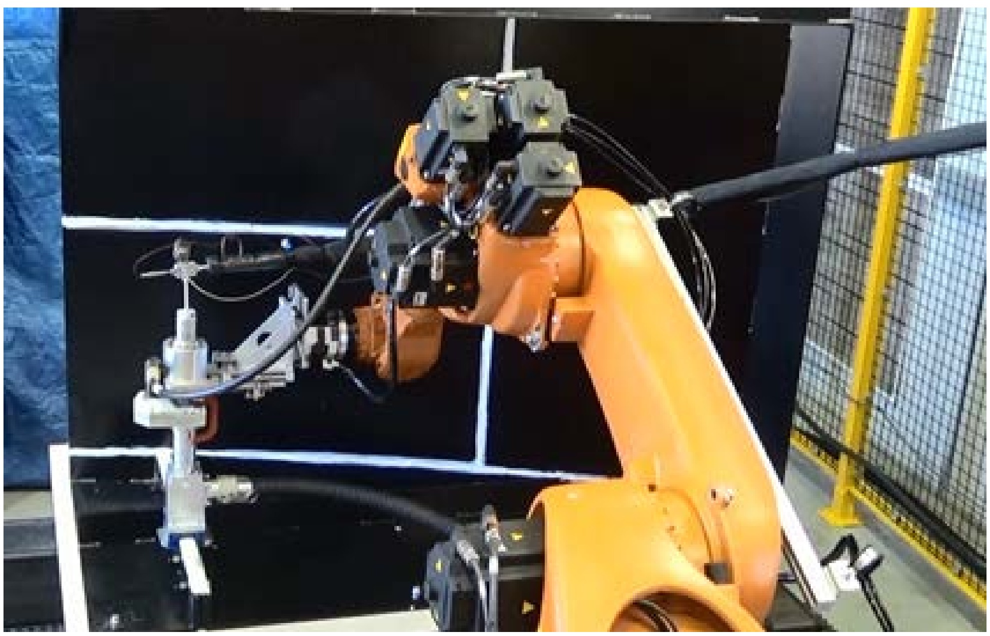


Fig. 8. Demonstration (flange-joint)

CONCLUSION

For the objective to verify whether NitroJet® can work to decontaminate contaminated water storage tanks in Fukushima Daiichi NPP, IHI tried acquiring DFs by decontaminating radioactive tracer on categorized structures. Furthermore, IHI developed end tools to fit each structure automatically and keep stand-off and accumulation efficiency. Finally IHI demonstrated remote operation of decontamination work.

DFs of flat, curved and flange-joint structures were more than 200 and quite high. And

tracer was removed almost completely with scanning twice. (>DF 9000)
Advanced end tools were developed and remote-operability of them were well verified in the demonstration.

From these results, IHI verified that NitroJet® could work for the decontamination of contaminated water storage tanks in Fukushima Daiichi NPP after overcoming some items. And we got to know that NitroJet® was much capable to down-grade contaminated materials.
IHI will continue to improve the technologies of NitroJet® and contribute D&D in Fukushima.

REFERENCES

1. Lettie Chilson (2011) "Decontamination Using Remote-Deployed Nitrocision® Technology," Proceedings of the Waste Management 2011 Symposia.