# A feasibility study on worksite visualization system using augmented reality for Fugen NPP


**IZUMI Masanori**[1], **SHIMODA Hiroshi**[2] and **ISHII Hirotake**[3]

*1. Fugen Decommissioning Engineering Center, Japan Atomic Energy Agency, 3 Myojin-cho,Tsuruga-shi,Fukui, 914-8510, JAPAN (izumi.masanori@jaea.go.jp)*
*2. Graduate School of Energy Science, Kyoto University, Yoshidahonmachi, Sakyo-ku, Kyoto 606-8501, JAPAN (shimoda@energy.kyoto-u.ac.jp)*
*3. Graduate School of Energy Science, Kyoto University, Yoshidahonmachi, Sakyo-ku, Kyoto 606-8501, JAPAN (hirotake@energy.kyoto-u.ac.jp)*



**Abstract:** Fugen Nuclear Power Plant, Advanced Thermal Reactor, was permanently shut down in March 2003 and it is at the decommissioning stage. Decommissioning Engineering Support System, DEXUS, has been developed to help planning of the optimal dismantling process and for carrying out the dismantling work safely and efficiently. Worksite Visualization System (WVS), as part of Dismantling Work Support System of DEXUS, has been developed to support the field workers to deal with the information on the dismantling facilities comprehensibly and intuitively. In this article, outline of the dismantling process of Fugen is first introduced, then a feasibility study on WVS is described.


**Keyword:** Fugen, Decommissioning, DEXUS, Augmented Reality


## 1 Introduction

The decommissioning program of Fugen, prototype Advanced Thermal Reactor (ATR), started in 2008 as the first decommissioning of the commercial-scale water reactor. It consists of four periods including the transportation of spent fuel assemblies and waiting period for radioactive decay of highly activated material. It is expected that the overall program of decommissioning will be completed in 2028.

The decommissioning is now in the first period; the spent fuel assemblies and heavy water have been removed from Fugen, and a part of the turbine system with relatively low radioactive contamination has been dismantled. Until now, the Nos. 3 and 4 feed water heaters and the main steam piping have been dismantled and tritium in the heavy water system, moderator, has been removed since 2008.

Because the nuclear facilities have a large number of components and structures, planning for economical and rational dismantling method and making guidelines before the dismantling are important issues. A system engineering approach is necessary in order for us to evaluate the process effectively and precisely to reduce the workload, exposure dose, waste mass and cost by selecting appropriate dismantling plan. .

## 2 Decommissioning of Fugen

### 2.1 Outline of Fugen

Fugen Nuclear Power Plant (NPP) is a heavy water-moderated, boiling light water-cooled, pressure tube-type reactor. The thermal output is 557 MW, which can produce electrical power of 165 MW. As the heavy water moderate neutrons, the reactor core structure is different from those of light water reactors. The moderator, heavy water, is kept in the calandria tank equipped with 224 fuel channels (assemblies) arranged vertically. One fuel assembly is set in each pressure tube, where light water flows as coolant. Each pressure tube is surrounded by a calandria tube, making a double-tube structure, so that the heavy water and light water are completely separated. $CO_2$ gas flows in the annular space between the pressure tube and the calandria tube to minimize the heat transfer from the fuel side to heavy water side, and they act as a detector of the coolant leakage. Facilities other than reactor parts, such as turbine system, are similar to those of boiling water reactors. Figure 1 shows the reactor core cooling system of Fugen.


**Received :January 28, 2010**
(Revised: February 2, 2010)

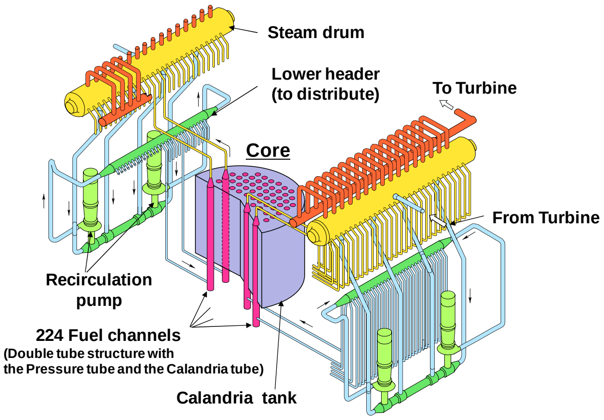


Fig.1 Reactor core cooling system of Fugen.

Fugen was operated steadily for 25 years; first criticality in March 1978, commercial operation from March 1979 through March 2003, and permanently shutdown in March 2003. Concerning the number of MOX (U-Pu mixed oxide) fuel assemblies loaded on one commercial reactor, Fugen is on the top position in the world. The total number of MOX assemblies loaded hitherto is one-fifth of the totally loaded on all the thermal reactors in the world. Fugen never experienced fuel failures.

### 2.1 Decommissioning Program of Fugen

Fugen was constructed and operated according to the reactor license under the Laws for Regulation of Nuclear Fertile Materials, Nuclear Fuel Materials and Reactors. In the decommissioning program, the target components and structures other than non-contaminated underground structures and basements are confined in the facilities under the reactor license. After the termination of operation, all the fuel assemblies were removed from the core, and have been stored in the spent fuel storage pool. The heavy water was taken out from the heavy water system. The coolant was also drained from the reactor cooling system. At present, almost all of the facilities are already closed and maintained to keep the radioactivity safely. The function of the spent fuel storage pool is to be maintained for the next several years until the transportation of the spent fuel assemblies is completed.

Decommissioning program of Fugen consists of four periods[1] as shown in Figure 2. Dismantling works have been proceeded step-by-step getting practical experience. Figure 3 shows the procedure of the decommissioning in each period.

In the spent fuel transfer period, both the spent fuel assemblies and the heavy water are transported outside of Fugen: The spent fuel assemblies are transported to Tokai Reprocessing Facility of JAEA for reprocessing and heavy water is transported to Canada to be reused in CANDU reactors. Some related systems for spent fuel storage such as the pool water cooling system are operated until the transportation of spent fuel assemblies is finished. The dismantling of less contaminated facilities started; they include the turbine device which was already closed.

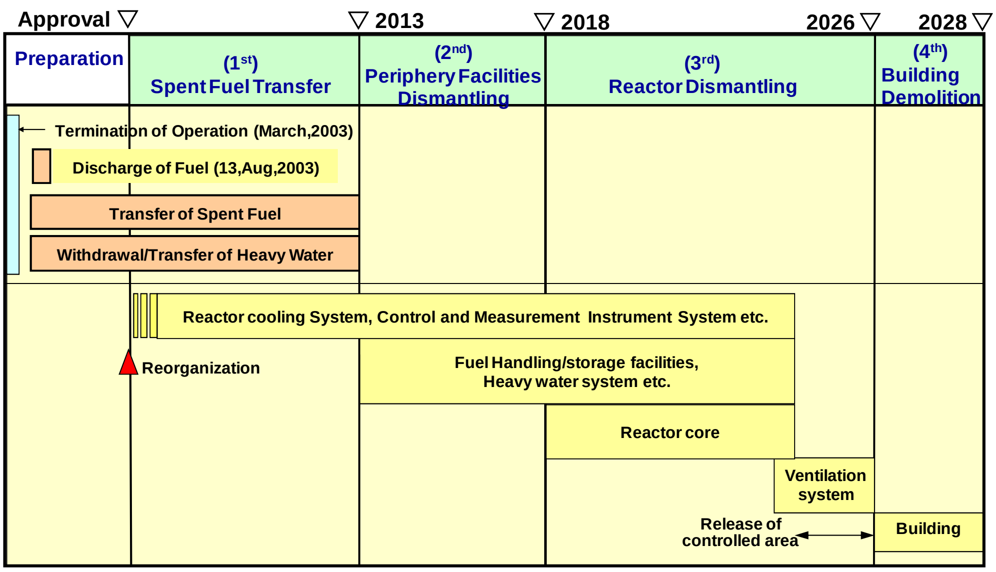


Fig.2 Decommissioning program of Fugen.

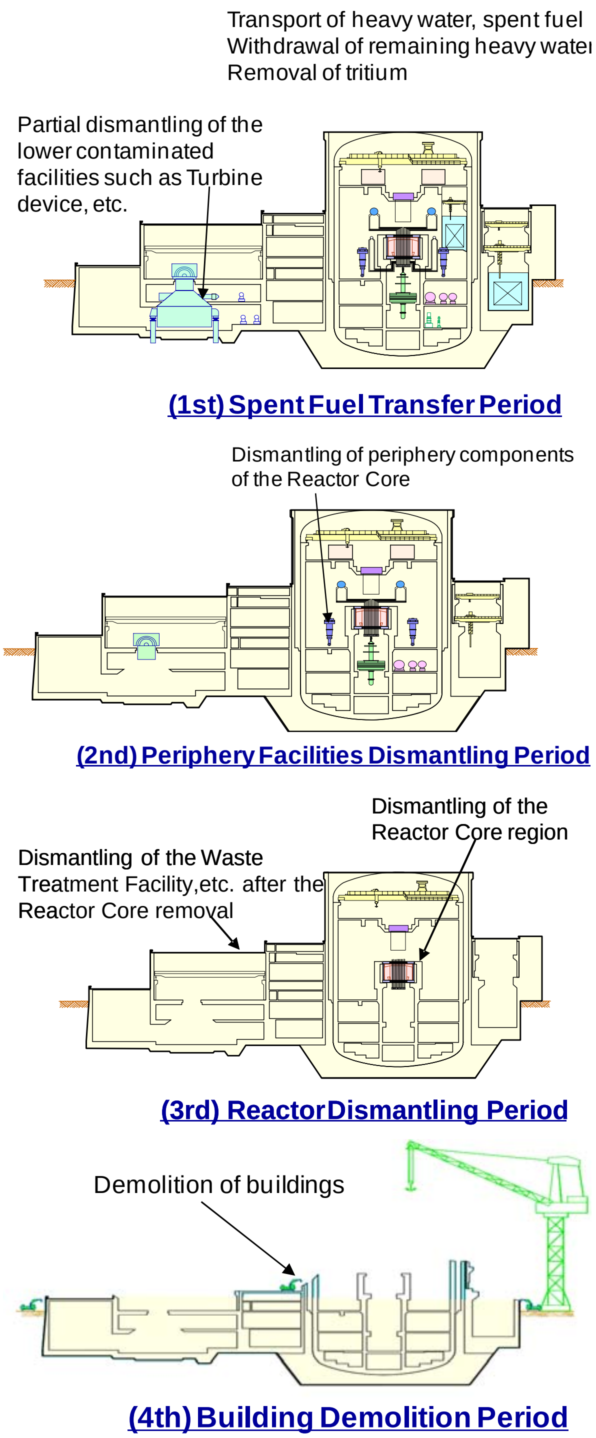


Fig. 3 Procedures of Decommissioning.

In the peripheral facilities dismantling period, the facilities such as the reactor cooling system and the heavy water system will be dismantled to enable workers to access to the core in the next period. Because the core part is planned to be dismantled under water in order to shield the radiation from around the core and prevent airborne dust when cutting, a temporary pool structure and remote-operated dismantling machines need to be installed above the core.

In the reactor dismantling period, the core will be dismantled under water by remote-operated machines. The core structures are highly activated mainly with Co-60 and Fe-55 due to long term operation. The half-life of these nuclides is a few years. The reactor dismantling period is set on the timing when it is expected that the exposure dose in the worksite is minimized to equivalent to annual dose during the plant operation phase. All the contaminated facilities will be removed, and the buildings will be decontaminated. The radiation-controlled area will be released before the demolition of the buildings.

Finally, in the building demolition period, the buildings will be demolished by similar methods and processes as applied to ordinary buildings.

It is important to assess the public exposure dose and the radioactive waste amount. The planning of appropriate method and procedure for dismantlement is based on accurate radioactive inventory assessment in advance.

### 2.3 Current Status of Decommissioning

The government approved the decommissioning program in Feb. 2008, and the decommissioning process started. In the first period, spent fuel assemblies are transported to Tokai reprocessing facility and heavy water is transported to Canada. Dismantling of turbine facility started in parallel. Cutting technologies and relevant data acquisition such as total manpower data have been accumulated during the dismantlement of two of five feed water heaters and main steam lines. In this period, Decommissioning Engineering Support System (DEXUS) was developed and evaluated. This is introduced in the following chapter. Figure 4 shows the work area of the feed water heaters. Figure 5 shows scenes of cutting work of feed water heaters.

Before dismantling work After dismantling work

Fig.4 Dismantling work area of feed water heaters.

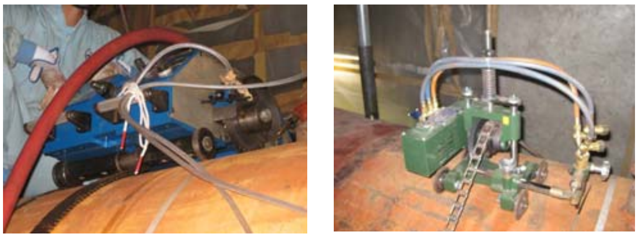

Fig.5 Cutting work of feed water heaters.

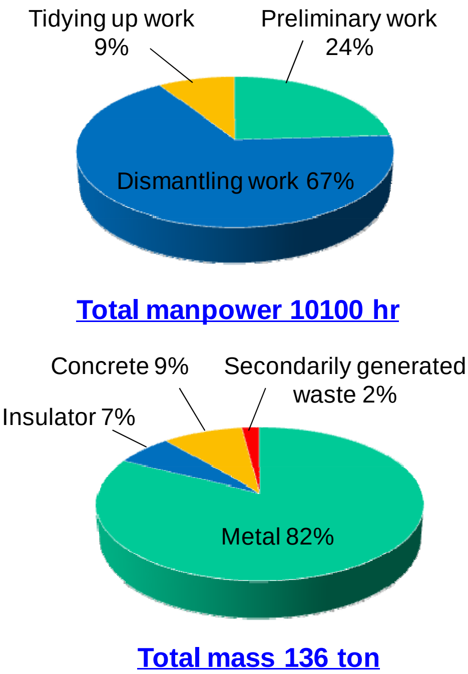


Fig.6 Dismantling results of the feed water heaters.

Compositions of manpower and waste related to the feed water heaters dismantling work are shown in Figure 6. About 30% of total manpower was preliminary and tidying up works. The mass of secondarily produced waste was about 2% of dismantled objects.

## 3 Decommissioning Engineering Support System (DEXUS)

The Decommissioning Engineering Support System (DEXUS) has been developed to help planning the optimal dismantlement process and for carrying out the work safely [2]. DEXUS consists of two subsystems, Decommissioning Planning Support System and Dismantling Work Support System. Figure 7 shows the structure of DEXUS. The Worksite Visualization System (WVS) as a part of the Dismantling Work Support System has also been developed [3].

It is important to provide the workers with necessary information regarding the dismantling method, facility status and radiation dose in order to keep the safety of the workers and the efficiency of the work without fault. Because the facility status changes while decommissioning process proceeds, it is required to manage the changes accurately from moment to moment. The WVS needs functions such as providing the necessary information and recording work progress as 3D CAD (hereinafter CAD) data to be satisfied with the requirements.

A prototype system of WVS and its feasibility study is introduced in the following chapters by using the system at the worksite as a trial.

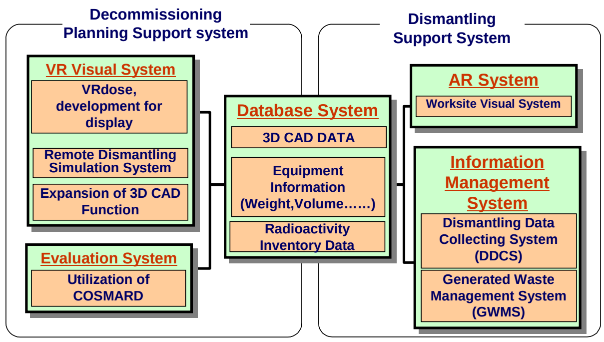


Fig.7 Structure of DEXUS.

## 4 Worksite Visualization System (WVS)

When a NPP is dismantled, it is required to keep the safety of workers. It is also important for successful project management to understand both the working progress and the change of facility configuration. The objective of WVS is to visualize the necessary information comprehensibly and to record the work progress intuitively at the decommissioning worksite by using Augmented Reality (AR) technology. Conventional applications of AR for industrial field are automobile navigation system [4], support for maintenance of aircrafts [5], support for water system isolation tasks for NPPs [6], etc.. However, there is no trial application to decommissioning work for NPPs [7].

WVS provides two functions to support the fieldwork at the worksite; (1) reference support for cutting lines and restraints, and (2) support for the progress recording of dismantling work. The target users to be supported are field directors. Since they are not always accustomed to operating computers, the WVS should be comprehensible and intuitive for them.

### 4.1 Reference support for cutting lines and restraint parts

The field director carries a small tablet PC (hereinafter PC) with a video camera to the worksite as shown in Figure 8. Taking videos of the dismantling target equipment with the video camera, the image will appear on the display of the PC superimposing transparent CAD data of the equipment in the same position, orientation and size by AR. The CAD data are colored by the parts to be cut off. Especially, the restraint parts (hereinafter restraints) which should not be cut in the process are colored emphatically not to be misunderstood. The user can therefore confirm the cutting lines and restraints intuitively prior to the dismantling work by referring the colored CAD data. When referring to the CAD data, the user can change his position and view angle freely by moving around the target facility to be dismantled.

If the function mentioned above is realized, it is expected for the field director to understand the cutting lines and restraints more intuitively, comparing with the conventional work method that he should refer to both paper instruction sheet and real target facility to be dismantled.

### 4.2 Record support for progress of dismantling

The user also utilizes the PC as shown in Figure 9 for recording the dismantling progress of the day. When all the work of the day finish, the captured image will appear on the display superimposing transparent CAD data in the state. The user can record the work progress by tracing the border between the parts remained and the parts already cut off with an electronic pen (a stylus pen). At that time, the user first suspends the video image, then records the progress on the paused image with the electronic pen, because the posture of the user taking video image is different from that of the user using the electronic pen. Since the tools of this function are metaphors of an actual pen and a paper record sheet, it is expected that he can use this function intuitively.

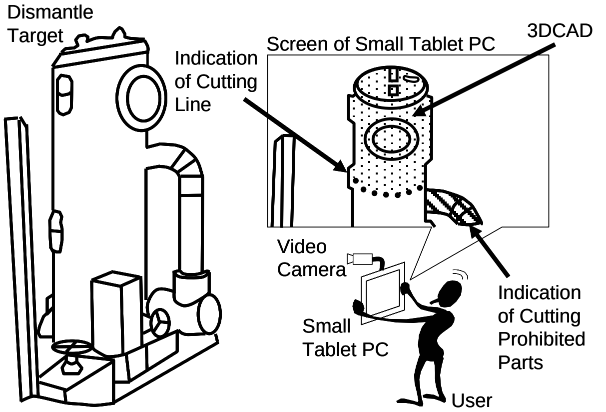


Fig.8 Reference of cutting lines by AR.

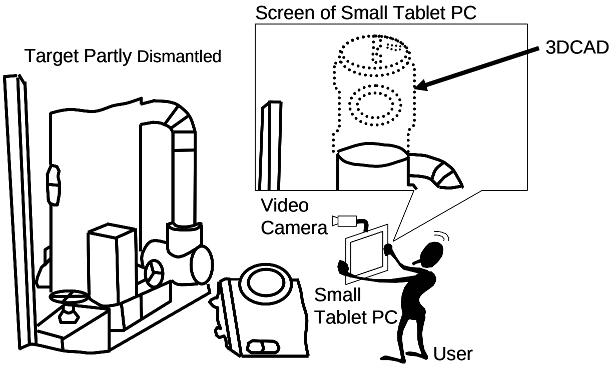


Fig.9 Record of dismantling progress by AR.

If the function mentioned above is developed, the user can record the progress of dismantling intuitively by only finding the difference between real dismantled equipment and displayed CAD data. In addition, since the record is made in the worksite without delay, the database for managing the decommissioning progress can be updated immediately.

### 4.3 Prototype System Development

Since WVS is a novel system which offers work support at the worksite, it is necessary to study its feasibility beforehand. The authors have developed a prototype system of the WVS and checked the feasibility of the concept by using it.

In order to realize the functions mentioned above as a prototype system, both of the following functions should be developed; a function in which CAD data is superimposed on the captured image with the same position, orientation and size of the real target equipment and a user-friendly interface for comprehensible and intuitive operation.

4.3.1 Realization of superimposing 3D CAD data

In order to realize a function in which CAD data is superimposed on the image of real equipment, it is necessary to develop real-time tracking method which measures relative position and orientation between a video camera mounted on a PC and the target equipment in real time. The prototype system employs the tracking method with linecode marker developed by the authors[8]. In this method, line-shaped markers are pasted in the work environment and the relative position and orientation between the camera and the markers can be measured in real time by image processing of the captured images of the markers. Figure 10 shows an example of the linecode marker.

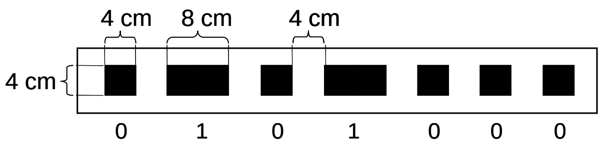

Fig.10 An example of linecode marker.

4.3.2 Cutting function of 3D CAD data

In the proposed function, when the user records the progress of the dismantling work, he inputs the cut parts by tracing the cut line on the CAD data with a stylus pen. Then, it is easy to understand if the CAD data are also cut off. In order to develop this function, the CAD data can be cut off freely along with the input trace line by the user. It is, however, difficult to realize the function because CAD data are managed as groups of certain shape data. In this prototype system, the users are expected to use it along with the designated scenario, because the function is limited only to cut off the CAD data designed, in advance.

4.3.3 User interface and hardware

The software of the prototype system was developed with Microsoft VisualStudio2005 on Microsoft Windows XP Operation System. Figure 11 shows an example of the user interface of the system. A small tablet PC, SONY VGN-UX90PS, shown in Figure 12 was employed as hardware of the system. This PC has a small video camera on the backside and its LCD has touch-panel function. By using a stylus pen, the user can indicate a position on the display. Table 1 shows the outline of the specification of the PC. The computing speed of the PC is 7 frames per second on average where the markers are recognized by image processing and CAD data are superimposed with the captured video images.

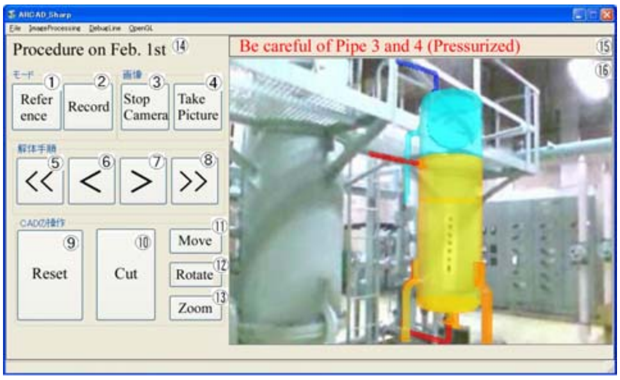

Fig. 11 An example of user interface.

Fig.12 Hardware of prototype system.

**Table 1 Specification of tablet PC**

| | |
|---|---|
| CPU | Intel CoreDuo U1400 (1.20GHz) |
| Display | 4.5 inch TFT Color LCD |
| Size | 150.2mm(W),38.2mm(D),95.0mm(H) |
| Weight | 492g (including battery) |
| Camera Resolution | VGA |
| Focal Length | 3.8mm |

## 5 Feasibility Evaluation of WVS

### 5.1 Purpose and outline of evaluation

The prototype system mentioned above employs a small tablet PC for portability at worksite and realizes intuitive operation method for non-expert users. It is, however, unknown whether each function is effective or not, how acceptable it is for the field directors, and what kind of problem arises in practical use. An evaluation experiment was conducted with heuristic evaluation method to find the questions above and to confirm the feasibility of the WVS functions. The heuristic method was proposed by J. Nielsen and the staffs of the target work examine the problems by using a prototype system or referring to specification sheet based on a guideline[9]. In this evaluation experiment, a dismantling scenario was prepared in advance, then three staffs evaluated the prototype system assuming that one of the plant equipment was dismantled along with the scenario. They answered the questionnaire prepared referring to Nielsen's guideline.

### 5.2 Evaluation Method

The evaluation methods and questionnaire are described below.

#### 5.2.1 Evaluation environment

The target equipment to be dismantled in this evaluation scenario is "an ion tower" in water purification facility shown in Figure 13. The tower is like a cylinder with the diameter 1.0m and the height 3.7m. Figure 14 shows the layout of the evaluation environment. The evaluator can view the ion tower from three areas which are indicated as "Evaluator Working Area" in shown with shaded area in Figure 14.

#### 5.2.2 Evaluators

Evaluators are three staffs of Fugen NPP, described as "evaluator A, B and C" below. The evaluator A is a leader of operator group of Fugen, B belongs to decommissioning team, and C is an engineer who develops decommissioning technologies.

#### 5.2.3 Dismantling scenario

The dismantling scenario was designed based on opinions of evaluators. All the functions mentioned in chapter 4 are utilized at least once. In the scenario, the ion tower is expected to be dismantled in three days and the plan before dismantling is assumed as follows;

(1)The first day

Pipe 1, pipe 2, a view window and upper quarter of the ion tower are dismantled in this order.

(2)The second day

Pipe 3, upper half and lower quarter of the ion tower are dismantled in this order.

(3)The third day

Pipe 4 and the remaining parts are dismantled.

In the scenario, it is assumed that the dismantling work of the second day is delayed and the lower quarter of the ion tower can not be dismantled within the second day. The plan of the third day is modified as follows;

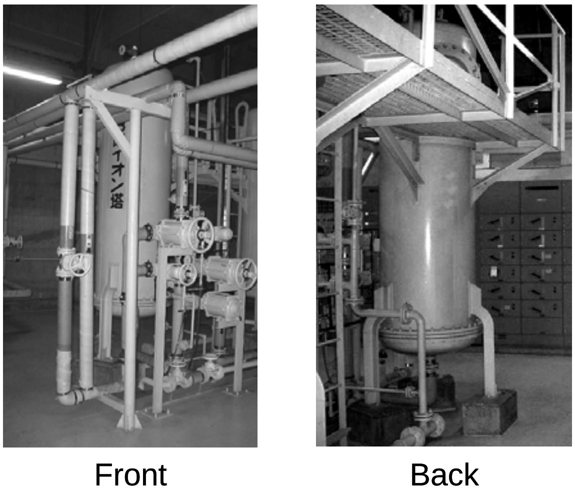


Fig.13 Target to be dismantled.

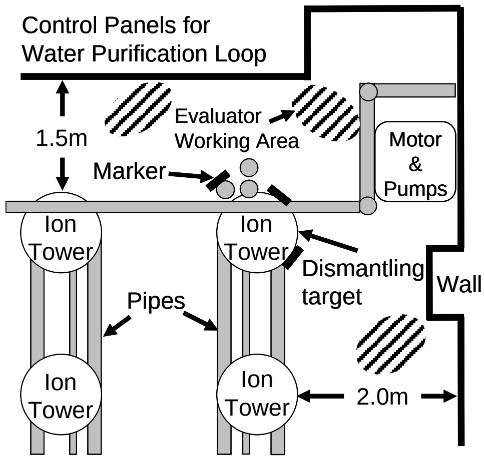


Fig.14 Layout of water purification facility (top view).

(3)The third day (modified)

Pipe 4, the lower quarter of the ion tower and the remaining parts are dismantled.

Figure 15 shows examples of 3D CAD data (3D model) presented as dismantling order of the ion tower on the display of the tablet PC.

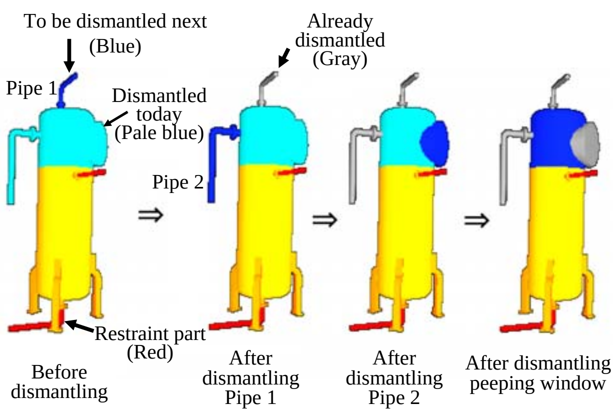


Fig.15 Examples of 3D model presented to user.

**Table 2 Result of questionnaire for system function**

| Questions | Answers | | |
|---|---|---|---|
| | Evaluator | | |
| | A | B | C |
| Q1. Superimposing 3D CAD data is more understandable than by paper instruction sheet. | 3 | 3 | 3 |
| Q2. It is comprehensible that dismantling order is presented by color (blue, pale blue). | 2 | 4 | 4 |
| Q3. It is comprehensible that restraint parts are displayed by color (red). | 5 | 4 | 2 |
| Q4. Warning display of restraint part in text is comprehensible. | 3 | 4 | 1 |
| Q5. It is easy to confirm cutting lines because 3D CAD data is displayed transparently. | 4 | 4 | 4 |
| Q6. It is easy to input dismantled part by a stylus pen. | 5 | 5 | 4 |
| Q7. Dismantled parts can be recorded exactly by superimposing 3D CAD data on real equipment. | 5 | 5 | 5 |
| Q8. It is effective to realize the function to move CAD data. | 5 | 5 | 4 |
| Q9. It is effective to realize the function to rotate CAD data. | 5 | 5 | 2 |
| Q10. It is effective to realize the function to magnify / shrink CAD data. | 5 | 5 | 4 |
| Q11. It is effective to realize the function to reset CAD position/orientation by pressing reset button. | 5 | 5 | 4 |
| Q12. It is effective to stop the image capture and operate it. | 5 | 5 | 5 |
| Q13. Recording function of dismantling progress is effective. | 5 | 5 | 4 |
| Q14. Recording function provides high work efficiency because they don't have to input the work record into database again. | 4 | 4 | 4 |

**Table 3 Result of questionnaire for usability**

| Questions | Answer | | |
|---|---|---|---|
| | Evaluator | | |
| | A | B | C |
| Q1. Size of PC is suitable for user's hands. | 1 | 3 | 3 |
| Q2. Weight of PC is appropriate. | 5 | 3 | 2 |
| Q3. Key size is adequate (easy to operate). | 4 | 4 | 4 |
| Q4. Battery life is long enough (4 hours). | 3 | 4 | 3 |
| Q5. PC is easy to carry. | 5 | 5 | 4 |
| Q6. Operation to move CAD data is easy. | 5 | 5 | 5 |
| Q7. Operation to rotate CAD data is easy. | 5 | 5 | 5 |
| Q8. Operation to scale up/down CAD data is easy. | 5 | 5 | 5 |
| Q9. Operation to cut off CAD data is easy. | 5 | 5 | 5 |
| Q10. Response is quick. | 4 | 5 | 5 |
| Q11. Display size is large enough. | 1 | 2 | 2 |
| Q12. It is easy to notice the change of display. | 1 | 4 | 1 |
| Q13. Text size is large enough. | 2 | 4 | 3 |

5.2.4 Procedure of evaluation

After brief explanation of the system and the evaluation procedure to the evaluators, they used the prototype system for approximately twenty minutes along with the scenario one by one, and answered the questionnaire. Then they moved to another room and were interviewed and had a group discussion. In the interview and the group discussion, they were asked to give their reasons of their answers and their opinions if the proposed functions could be applied to the actual decommissioning work.

5.2.5 Questionnaire

The questionnaire consists of 14 questions for system function and 13 questions for usability based on the guideline of the heuristic evaluation method. The evaluators answered each question in 1 to 5 scale (5:completely agree, 4:agree, 3:fair, 2:disagree, 1:completely disagree). In addition, free description was added at the last of the questionnaire and they made comments on other problems and points to be improved.

### 5.3 Evaluation Result

Table 2 shows the result of the questionnaire for the system function, while Table 3 shows those for usability. Table 4 shows their comments to the free description, the interview and the group discussion.

### 5.4 Discussion

As shown in Table 2, all the evaluators answered "3:fair" for Q1. It is supposed that they could not answer it clearly because the comprehensibility was different depending on the work condition and environment.

From Q2 to Q4, the evaluator A marked low to Q2, while the evaluator C marked low to Q3 and Q4, and other answers were high. The evaluator A made a comment in the interview, "colored display of dismantling order is incomprehensible(A5)", and "restraint parts in red is comprehensible(A2)", "more comprehensible than paper instruction sheet(A3)" and "more comprehensible if it displays the dismantling numerical order(A4)". The evaluator C pointed out that "warning display in the upper part of the display is difficult to see (C1)", and "more comprehensible if the information is displayed near the CAD data as text (C5)". These results show that the information presentation needs to be more comprehensible, and it can be also confirmed from the interview with the evaluator B (B7).

-System function-

All the evaluators gave high marks for Q6 and Q7 for the system function. The answers in the interview also supported it (A1), (B1). This result leads us to think the recording functions of the work progress can be applied to the actual decommissioning work.

All the evaluators gave high marks for Q5 and Q8 to Q12. This shows that the functions which are transparent display, move/ rotation/ magnification display of CAD data and pause function of image display are effective in recording the work progress.

The evaluators also gave high marks for Q13 and Q14. This result shows the design of the recording function is appropriate.

**Table 4 Comments of free description and interview**

| Evaluator | Comments |
|---|---|
| A | (A1) Easy to record the work progress.<br>(A2) Comprehensible to display restraint parts in red.<br>(A3) 3D CAD data are more comprehensible than paper instruction sheet.<br>(A4) It becomes more comprehensible if dismantling order is displayed in numbers.<br>(A5) Difficult to notice the change of color.<br>(A6) Display is small.<br>(A7) Whether battery life is enough or not is depending on the usage.<br>(A8) It is better if the memorandum can be input into the work progress record.<br>(A9) This method can be applied to training for beginners. |
| B | (B1) Easy and effective to record the work progress by a stylus pen.<br>(B2) It might be incomprehensible if the work environment is complex.<br>(B3) This scenario was conducted in simple area, but there are more complicated areas in NPP.<br>(B4) In case that there are lots of pipes around target equipment, AR display may be incomprehensible.<br>(B5) When work area is narrow and target equipment is large, camera can not capture all the images of the target.<br>(B6) Because peripheral equipment is not displayed, it is difficult to compare real equipment with 3D CAD. Larger display is required.<br>(B7) Correspondence between text information and 3D CAD is incomprehensible. The text information should appear on 3D CAD.<br>(B8) Record of dismantling progress can be used for explanation of decommissioning process to the public. |
| C | (C1) Difficult to see warning information on upper part of display.<br>(C2) Feel tired when capturing image by camera. The camera should be positioned at the viewing position.<br>(C3) Feel PC heavy when using it for a long time.<br>(C4) Display size of PC is too small.<br>(C5) More comprehensible if the information is displayed near the CAD data as text. |

-Usability-

All the evaluators gave high marks from Q6 to Q9 for the usability questionnaire as shown in Table 3. This result shows the CAD data operation is easy enough.

The answers to Q11, Q13, and comments (A6), (B6) and (C4) show that the LCD of the tablet PC is too small to see the details. If the system employs a PC with a larger display, it may be bigger and heavier than the prototype system. From the answers to Q2 and (C3) of the interview, they feel the PC heavy even if the small tablet PC is employed as the prototype system. This shows that a lighter PC with a larger display is required.

As for the processing speed of the PC, it is high enough because the answers to Q10 were high mark. This result shows the PC employed in the prototype system has enough processing ability.

Interviewees proposed that memorandum should also be put into the work record (A8) and it is effective for training of beginners (A9) and for explanation method of the decommissioning progress to the public(B8) as new applications of the WVS.

It was pointed out in (B2) through (B6) that the correspondence between real equipment and CAD data may be difficult to be understood if the work environment is complicated or the work area is narrow.

## 6 Summary

In this article, the outline plan of the decommissioning of Fugen Nuclear Power Plant and its current status were first described, then the trial of developing Decommissioning Engineering Support System (DEXUS) was introduced. As support functions at dismantling worksite, the authors have developed a prototype system of Worksite Visualization System (WVS) by employing Augmented Reality (AR) which is a novel information technology. The prototype system of WVS offers two support functions; (1) reference support for cutting lines and restraints and (2) record support for progress of dismantling. By using the prototype system, the concept of WVS was evaluated along with a designated scenario by three staffs of Fugen NPP. The result of the evaluation leads to;

1. The information presentation of cutting lines by using AR and CAD data is more comprehensible than that by paper instruction sheet. It is, however, more comprehensible if not only the colored display but also text information is displayed.
2. The record function of work progress is easily used and acceptable to the actual decommissioning work.
3. The PC of the prototype system has high ability, however, the display should be larger and the weight of the PC should be lighter.
4. The functions of WVS can be also applied to training of beginners or advertisement to the public.

On the other hand, it was pointed out that the display of CAD data might be difficult to be understood if the work environment is complicated. It is necessary to evaluate whether or not the support functions of WVS can be applied even in the complicated environment for practical use.

## References

[1] YANAGISAWA, T.: Preparatory activities of the Fugen Decommissioning Project, J. RANDEC, 2000, 21, 2-11.

[2] IGUCHI, Y., KANEHIRA, Y., TACHIBANA, M., JOHNSEN, T.: Development of decommissioning engineering support system (DEXUS) of the Fugen Nuclear Power Station, J. Nucl. Sci. & Tec., 2004, 41(3): 367-375.

[3] SHIMODA, H., NAKAI, T., ISHII, H., IZUMI, H., BIAN, Z., KANEHIRA, Y., MORISHITA, Y.: A Feasibility Study of Decommissioning Support Method by Augmented Reality, Proc. ISSNP, Fukui, Japan, 2007, 244-249.

[4] TONNIS M., SANDOR, C., KLINKER, G., LANGE, C., BUBB, H.: Experimental Evaluation of an Augmented Reality Visualization for Directing a Car Driver's Attention, Proc. ISMAR2005, Wien, Austria, 2005, 56-59.

[5] FRIEDRICH W.: ARVIKA: Augmented Reality for Development, Production and Service, Proc. ISMAR2002, Darmstadt, Germany, 2002, 3-6.

[6] SHIMODA, H., ISHII, H., YAMAZAKI, Y., WU, W., YOSHIKAWA, H.: A Support System for Water System Isolation Task in NPP by Using Augmented Reality and RFID, Proc. NUTHOS-6, Nara, Japan, 2004, N6P205.

[7] NAVAB, N.: Developing Killer Apps for Industrial Augmented Reality, IEEE Comp. Graph. & Appl., 2004, 24(3): 16-20.

[8] SHIMODA, H., MAESHIMA, M., NAKAI, T., BIAN, Z., ISHII, H., YOSHIKAWA H.: Development of a Tracking Method for Augmented Reality Applied to Nuclear Plant Maintenance Work, Proc. ISOFIC2005, 2005, 203-208.

[9] NIELSEN J, MOLICH, R.: Heuristic Evaluation of User Interface, Proc. ACM CHI'90, Seattle, U.S.A., 1990, 249-256.