Report on the 14th Meeting of the Joint Working Group of the U.S.-Japan Coordinating Committee of Fusion Energy on Safety in Inter-Institutional Collaborations

(U.S.-Japan Safety Monitoring Program)

Meeting in Japan, July 29-August 2, 2013

Submitted: October 16, 2013

Respectfully submitted to:

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A. PURPOSE

The Office of Fusion Energy Sciences (FES) is committed to conducting research that ensures protection of the workers in all of its facilities. This commitment extends to foreign researchers visiting our laboratories and U.S. personnel traveling abroad to participate in experiments and meetings. Protecting our workers is a direct and individual responsibility of all FES managers and FES supported research staff. We also want to provide assurances to our collaborators that we are taking the necessary steps to provide for their safety.

In order to help meet this responsibility we initiated an exchange program involving a Joint Working Group (JWG) on Safety with our Japanese colleagues in the mid 1990’s. The JWG conducts alternating visits every 1-2 years to major fusion research laboratories in Japan and the U.S. The JWG on Safety will be comprised of a small group (3-4) of safety experts from each country representing their major fusion laboratories. These alternating visits will include general facility orientations and specific discussion of safety systems and policies implemented at each location. After each visit the JWG will prepare a report providing observations that may be used by both parties to improve the safety of all of our researchers. It is important to emphasize that this is not an inspection and is not meant to have any regulatory function. It is meant merely to educate, observe, and exchange information involving successful safety system implementation.

The 14th meeting of the U.S.-Japan Safety Monitor Joint Working Group was to informally evaluate the programmatic aspects of environmental, safety and health (ESH) programs in Japanese fusion research facilities by touring laboratory areas and meeting with researchers and safety professionals. Based on these interactions, the U.S.-Japan delegation was able to share information and provide suggestions in an effort to reduce the likelihood of bodily injury and/or property damage in fusion research. In addition, good approaches and practices developed at different institutions should be utilized to improve ESH programs at other institutions.

B. EXECUTIVE SUMMARY

The U.S. participants in the 14th meeting of the U.S.-Japan Safety Monitor Joint Working Group conducted from July 29-August 2, 2013 were:

Keith Rule, Senior Project Engineer, Princeton Plasma Physics Laboratory
Lee Cadwallader, Fusion Safety Analyst/Advisor, Idaho National Laboratory
Martin King, Fusion Safety Engineer, General Atomics

The main Japanese Participants were:
Dr. Yuichi Takase, Professor (University of Tokyo)
Dr. Akio Komori (NIFS)
Dr. Kiyohiko Nishimura (NIFS)
Dr. Katsumi Nakajima (JAEA)
Dr. Atsuhiko Sukegawa (JAEA)

The Safety Monitor Tour is an exchange of information between U.S. and Japanese fusion researchers to review personnel safety at fusion experiments operated in each country. This work is part of U.S. Department of Energy exchanges; the tour is listed in the DOE Coordinating Committee of Fusion Energy (CCFE) version 27-10, the safety monitoring tour for the U.S.-Japan Cooperation. The schedule suggests that every two years a tour is conducted where safety professionals walk through fusion facilities and review the safety precautions at the selected facilities. In 2010, the Japanese contingent came to the US and the US contingent visited Japan in 2013.

Overall impressions of the labs and universities were very good. The Large Helical Device was in an upgrade outage, and we were allowed a look inside the vessel. The work was being performed in a professional manner,
with good use of personal protective equipment (PPE). There were many good safety ideas in use (walkways, plexiglass shields to prevent dropping of any tools or items to lower areas), and use of international pictogram safety signs. The Naka site was also in a major outage for construction of the new JT-60SA, the superconducting tokamak to replace JT-60U. The JT-60U vessel has been disassembled to make space for the new machine. The work is being done with a high level of professionalism.

The U.S. safety personnel making this trip were Keith Rule, a Senior Program Engineer from the Princeton Plasma Physics Laboratory in New Jersey; Lee Cadwallader, a safety and risk analyst from the Fusion Safety Program at the Idaho National Laboratory; and Martin King, a fusion safety engineer at the DIII-D fusion experiment operated by General Atomics in San Diego, California. The U.S. trip itinerary is listed in section E.
C. Sites Visited

July 29-30, 2013 – National Institute for Fusion Science

Contacts:
Dr. Akio Komori, NIFS
Dr. Osamu Kaneko, NIFS
Dr. Masashi Iima, NIFS
Dr. Kiyohiko Nishimura, NIFS
Dr. Yasuhiko Takeiri, NIFS
Dr. Akio Sagara, NIFS
US Participants:
Keith Rule (PPPL)
Lee Cadwallader (INL)
Martin King (GA)

We met with Dr. Komori (Director General) and Dr. Kaneko (Deputy Director General) and others in the office area. The Large Helical Device (LHD) is in an outage for upgrades. They are installing a divertor to form a closed divertor system. The schedule is to complete the work, then seal the vacuum chamber and begin pump down by the end of August 2013. After baking and achieving good vacuum, there will be 4 weeks of magnet cooldown. Dr. Komori had stated that safety comes first, the public must see fusion as a safe technology and “green” research. NIFS researchers want people to recognize the different between fusion and fission. Dr. Komori talked about how they have been in negotiations on using deuterium fuel at LHD for the last 16 years (that is, the entire time LHD has been operating), he had to excuse himself in the afternoon to prepare for a public hearing that would take place that evening where he would explain deuterium usage at LHD. They received approval from the neighboring local governments in March 2013 and have started the licensing procedure with the ministry, so they believe that they have achieved success and can use deuterium beginning in 2016. They will keep ~13 m³ STP of deuterium gas (about 2.2 kg) on hand.

The LHD staff of 100 typically has over 500 collaborators each year, most from Japanese institutes. About 70 collaborators are from abroad. They have a safety manual in English for those visiting collaborators. The Japan strategy is that JAEA operates tokamaks, and NIFS operates helical devices.

Dr. Yasuhiko Takeiri led a tour of the machine hall. Many good examples of personnel safety engineering controls were in evidence during our visit. Good use of walkways with railings, toe boards, and plexiglass barriers to prevent items from being dropped to levels below. Bump covers over hazards in spiral staircases, and use of international pictogram safety signs - as well as safety signs with English translations. The Japanese have a chemical hazard label system that is similar to the US National Fire Protection Association hazard diamond placard with flammability (red), health (blue), chemical reactivity (yellow), and special notice (white).
(see NFPA Standard 704). The LHD is very clean and well organized; it is difficult to believe the machine is 16 years old.

**Issues called to the attention to the lab staff:**

- Facility was very clean and organized.
- Protection of wiring and hoses on floors was very good.
- The plexiglass covers on railings in elevated areas was very good.

Then we visited the smaller experiments for research and development. These experiments have recently been moved to a temporary position in a high bay area and they will move again to a permanent location soon. Each experiment area is cordoned off. There was good use of safety signs with pictograms and English translations. Since it was a temporary area, there is not much to point out. There was personal protective equipment and fire extinguishers, etc., around the experiments. Then we saw the machine shop used for small tasks and a metal sample polishing laboratory. Some issues were raised since the polishing lab is labeled as a chemistry lab but it was not outfitted with typical safety equipment found in chemistry labs – fire extinguisher, first aid kit, safety shower and eyewash station, and a good ventilation system. There was a fume hood with chemical storage but the hood was not operating. Dr. Sagara explained that while the room is labeled as a chemical lab it does not handle many chemicals (only liter quantities of acetone, alcohol) and water-based polishing agents.

Research and Development Areas
- Please visit the metal polishing lab and re-assess if any chemistry lab protective equipment is needed in that lab. Several areas need to be reviewed for proper chemical storage.

**July 31, 2013 – University of Tokyo**

Contacts:
- Dr. Yuichi Takase, University of Tokyo – TST-2
- Dr. Zensho Yoshida, University of Tokyo – RT-1
- Dr. Yasushi Ono, University of Tokyo – UTST

US Participants:
- Keith Rule (PPPL)
- Lee Cadwallader (INL)
- Martin King (GA)

All three machines that were visited at the University of Tokyo are housed in the Transdisciplinary Sciences Laboratory Building of the Graduate School of Frontier Sciences. The building has a personnel status board at the main door, where persons indicate their presence in the building. The board has two columns, one to indicate being present in the building and the other to indicate that the person is away from the building. The status is indicated by moving a magnet assigned to each person. Dr. Takase stated that sometimes people forget to switch their tag, so the personnel status board is a guideline rather than an absolute indicator of personnel present. There is a public address microphone near the main door to give emergency instructions as well.

**RT-1**

The first machine visited was the Ring Trap-1 (RT-1) machine, which is a levitated dipole experiment. RT-1 confines a high beta plasma by using a dipole field and fast rotation. The magnet is mechanically lifted into place within the machine and levitates by magnetic field, then it rotates to better confine the plasma. Plasma pulses are 1-second duration. Dr. Zensho Yoshida is the principal investigator. A post-doctoral researcher, Dr. Yohei Kawazura, briefed us on the machine. The RT-1 has a cylindrical vacuum chamber that is 1 m radius and 0.56 m tall. The ring magnet inside the machine draws 250 kA and weighs 110 kg. The peak magnetic field is 0.3 Tesla.
Visitors to RT-1 are always escorted in the experiment hall. There is a sign to denote the RT-1 area, but doors to the experiment are not well marked and anyone with a key could open the door and enter – there is no good indication in the experiment room that the machine is operating. One door to the experiment hall opens to the main building foyer. There is no calling list or instruction for the Japan emergency number (119) near the control room telephone. There was janitorial and other equipment storage in front of the electrical panels. They had a first aid kit but it was on a lower shelf of one of the bookshelves in the control room, so it was not easily accessed and it was not well marked. There was good gas cylinder safety in this experiment room, and good discipline regarding electrical cords on the floor – which is an improvement from our 2008 visit.

The doors in the experiment room that lead to the control room and to the storage room were blocked open with wedges or unused equipment. These doors have door closer arm units at the top of each door and this suggests that perhaps they are fire doors. The staff did not have an answer to the question of fire doors, apparently the doors are not true fire doors and they are propped open to allow better ventilation. Doors propped open are also more convenient for the staff - and propped doors are not always opening and slamming shut so they do not require maintenance.

**Issues called to the attention to the lab staff:**
- Please post appropriate signs, international pictograms for exits and for hazards.
- Please post appropriate signs on exterior doors to inform persons of the experiment within.
- Please move the storage items from the front of the electrical panels.
- Please post a call list and emergency phone number 119 sign in the control room.
• Please determine if the aforementioned doors are in fact fire doors. If so, avoid blocking doors in open position, good ventilation also means good smoke movement.

UTST
The second machine visited is the University of Tokyo Spherical Tokamak (UTST). The UTST machine has a major radius of 0.39 m, a minor radius of 0.24 m, and a toroidal field on axis of 0.3 Tesla. Dr. Yasushi Ono gave us a brief description and tour of this machine. Dr. Ono told us that the doors to the experiment hall are not interlocked but they are locked (with a bicycle lock) when the machine is in operation, and the main entryway to the machine hall is through the control room (like the TST-2). No one is allowed inside the machine hall during experiment operations since there are several charged capacitor banks that provide magnet power and other live electrical equipment. Emergency stop buttons for the experiment and the laser are mounted on the wall next to the main door to the experiment and have English labels as well as Japanese. The UTST is using only a few international pictogram symbols for safety, most of the warning signs are written in Japanese. Some efforts transcend language; for example, the yellow and black cord used to rope off the aisle to the capacitor bank was obvious to all. The capacitor grounding stick was not easily found. A graduate student produced it from underneath various cords and cables on the floor. Dr. Ono stated that the university hires an electrical contractor company to perform maintenance, inspection and upgrade work on the capacitor bank and high voltage electrical equipment rather than staff or students performing such work. There are warning lights (stack lights) in the experiment room to alert staff that a plasma pulse is pending. The engineer in charge of the UTST will sweep the room before starting pulse operations.
Issues called to the attention to the lab staff:
- Please post appropriate signs, international pictograms for exits and for hazards.
- Please post appropriate signs on exterior doors to inform persons of the experiment within.
- Please inspect the grounding stick and make a mount for it so that it is easily found.

TST-2
Dr. Takase briefed us on recent events at the University of Tokyo Kashiwa campus. Professor Yoshito Oshima is the Associate Dean of this campus and he is also the campus safety officer. The Tokyo Spherical Tokamak-2 (TST-2) machine investigates plasma initiation and plasma current ramp-up using the lower hybrid wave. Parameters of TST-2 are $R = 0.38$ m, $a = 0.25$ m, and $B_t = 0.3$ Tesla.

There are not many visiting researchers or foreign students at the three fusion machines at Kashiwa campus. Visits can be a few weeks to several months. Short term visitors (weeks) and long term visitors take a safety training lecture class rather than computer based training. Brief visitors (~a day) are continuously escorted. Dr. Takase stated that each machine has several safety inspections per year performed by university safety personnel at Kashiwa campus. The TST-2 safety manual was translated into English in 2004 and it has been updated since then to reflect the new campus and experiment changes.
The TST-2 control room has pertinent safety equipment, hard hats, flashlights, fire extinguishers, and first aid kit. There is an emergency stop button for the experiment mounted on the wall next to the main door to the experiment. The machine is mounted in a pit, and there is an oxygen monitor at the entryway for personnel to use when entering the pit to access the lowermost parts of the tokamak or when accessing the interior of the vacuum vessel. Each researcher and student has an assigned magnetic token. These tokens are placed on a cabinet close to the door that leads from the control room to the machine hall. The staff members move their token from the cabinet to the door itself when they enter the experiment room, this is a form of personnel status board that is used as opposed to the board in the building foyer. There is a telephone call list mounted on the wall near the land line telephone. The call list is in Japanese. There is a sign for the emergency phone number 119 as well. Dr. Takase pointed out that everyone uses cell phones now; he doubts his staff would use the land line unless there was some interference or other loss of cellular service. Cell phones are in widespread use in Japan.

In our 2008 visit, there were suggestions to enhance safety of TST-2. In this visit we noted that these suggestions had been implemented. Door interlocks have been installed so that the control room is alerted if anyone tries to open a door to the room. More red, rotating strobe lights were installed to notify persons that the
The machine is in operation. The emergency stop button in the control room is marked in English. The room doors are locked but not marked. There is a camera to monitor part of the experiment room from the control room. There was use of international safety pictogram signs. The large exterior doors that allow deliveries are locked. They are not marked, neither inside nor outside, but these are not designated as emergency exits. One double door to the experiment room from the machine shop room was locked but could be pushed open since the fixed door was not fastened. Dr. Takase opened the doors and he engaged the upper and lower flush bolts to lock the fixed door, solving the problem. It was a simple oversight, someone likely needed the double door opened and when they closed the doors they forgot to re-engage the upper and lower flush bolts. The double door locks should be turned to unlock the doors from inside the experiment room rather than from the machine shop.

The space around the experiment is free of clutter. During the walkthrough, the team found one gas cylinder that was not properly secured. Dr. Takase was upset by this finding because he believes in securing gas cylinders in this highly seismic region; he secured the cylinder immediately.

**Issues called to the attention to the lab staff:**

- Please translate the emergency calling plan near the telephone or provide directions for non-Japanese visitors to call for emergency assistance (e.g., dial 119).
- Please post appropriate signs on exterior doors to inform persons of the experiment within.

Dr. Oshima gave a talk about safety and an organization he formed in 2007. The organization is called REHSE, Research for EHS Education. The idea of this organization is to teach students the reasons for EHS rules because enlightenment allows students to become part of the process instead of reacting to numerous prescriptive rules. He showed a safety teaching lab room where students can perform real chemistry experiments but with an emphasis placed on safety in chemical handling and laboratory technique. By using harmless smoke, the students learn why they should not lean into a fume hood, but rather work outside the hood with the sash partly closed. They learn about chemistry lab personal protective equipment and the reasons for the equipment. Dr. Oshima developed a “Radar Chart” software program for chemical risk, using a visual system plotting instant toxicity, long term toxicity, irritation, environmental toxicity, chemical volatility, and chemical reactivity. Nested dialog boxes are used to display examples of accidents that have occurred with the chemical of interest, minimum risk information on the chemical, potential hazards of the chemical, safety guidelines, legal regulations, and other data. The REHSE is a creative way to get students to understand reasons for safety rules and to follow good safety practices in the chemistry lab. Perhaps this organization can be expanded to include other types of laboratories. This type of training, to demonstrate reasons why the safety rules exist and should be followed for one’s own personal protection, is an excellent idea and this group should be fostered as much as possible. We are not aware of any analogous effort or program in the U.S. and will introduce these concepts to our lab safety leaders for possible collaboration with Dr. Oshima.

We should point out that this initial research was conducted using safety surveys based on analysis of students’ risk perceptions at 7 universities in Japan and then at MIT in the U.S.. The results of this research proved to be very different between the U.S. and identify the different approaches. Japan being more system based while U.S. being more compliance based. This is a over-simplification of the extensive research and to learn more we can collaborate with Dr. Oshima.

August 1-2, 2013 – Japan Atomic Energy Agency (JAEA)
L to R: Dr. Atsuhiko Sukegawa, Lee Cadwallader, Dr. Yoshitaka Ikeda, Keith Rule, Marty King, Dr. Masahiro Fukumoto, Dr. Kouhei Kushita, Dr. Kiyoshi Shibanuma

Contacts:
- Dr. Katsumi Nakajima, JAEA
- Dr. Atsuhiko Sukegawa-Morioka, JAEA
- Dr. Masahiro Fukumoto, JAEA
- Dr. Kazuhiro Kobayashi, JAEA
- Dr. Kiyoshi Shibanuma, JAEA
- Dr. Kouhei Kushita, JAEA
- Dr. Yoshitaka Ikeda, JAEA

US Participants:
- Keith Rule (PPPL)
- Lee Cadwallader (INL)
- Martin King (GA)

**Naka Fusion Institute**

Dr. Sukegawa drove us to the Naka site. Dr. Nakajima, the deputy director of administration for the Naka site, greeted us. He stated it is always important to check each other’s sites. JT-60SA is under assembly and they always pay attention to safety, especially in construction activities. There were several presentations, including Dr. Ikeda with an overview of the Japan fusion research steps – JT-60SA, the International Fusion Materials Irradiation Facility (IFMIF), ITER, and a demonstration power plant (DEMO) based on the tokamak concept. Dr. Kushita discussed safety management of the ~400 persons at the Naka site and the Plan Do Check Act (PDCA) safety approach that was made popular by Dr. W. E. Deming. Their safety manuals are translated into English. Dr. Shibanuma presented an outline of the JT-60SA project. The plan is for first plasma in March 2019. Before that time, they will have a number of European workers on site who have been contracted for
They have concern for the safety of these non-Japanese speaking technicians and workers, so there have been efforts in English translation and with safety pictogram signs. Dr. Ikeda stated they had 10 hiyari-hatto – meaning a small but fearful and startling event (in other words – a near miss) during JT-60U vessel disassembly, so they discussed these to learn from them and prevent recurrence. These are all signs of a very healthy, forward thinking, and mature safety program. They have good use of international signs, safety manuals have been translated into English. It was noted during the tour that they have retained the low occupational exposure values for magnetic fields while the US has increased exposure limits as given by the ACGIH. Conservatism is fine in safety matters. Figure 4 shows the torus hall during this construction activity.

Figure 4. The JT-60U torus hall, machine is removed. Note the JT-60SA vacuum vessel segments at the right.

We visited the magnet conductor spool winding facility, where conductor is coiled for shipping. Dr. Sugimoto gave a tour of the Radio Frequency R&D lab. We also toured the Central Solenoid Model Coil test facility. The facility had fencing for magnetic field exclusion areas. Greater than 100 mT is restricted, between 10 and 100 mT is a warning zone, and over 0.5 mT carries a restriction for cardiac pacemakers. The limit is 200 mT for an entire workday. We also saw the remote handling facility, Dr. Takeda presented the facility to us.

JT-60U Torus Hall
- Comprehensive industrial safety and radiation safety programs are in place.
- Housekeeping and cleanliness of this facility is very good especially for a construction activity.
- There was good use of international pictogram safety signs.

Magnet Conductor Winding Facility
- Housekeeping and cleanliness of this facility is very good.

Radio Frequency Heating Test Facility
- Housekeeping and cleanliness of this facility has improved since our last
visit. More use of international safety signs and marking of hazards.

Superconducting Magnet Test Facility
- Controlled areas for magnetic fields are well defined and posted.
- Facility specific training is conducted for visiting workers for 1-2 hours.

Remote Handling Facility
- Good use of warning lights when the facility is in operation.

Tokai Establishment
Dr. Sukegawa drove us to the Tokai site to see the Tritium Process Laboratory and the Fusion Neutronics Source (FNS). At the TPL we met with Dr. Takumi Hayashi, the facility head, and his deputy, Dr. Hirofumi Nakamura. They have 10 petabecquerels of tritium on site now (~27 grams). Their license allows 63 grams. They have a group level (facility staff) safety patrol once a month, and 4 unit level (Tokai site safety personnel) safety patrols every year. The total number of persons working in the building is 17. This count includes researchers, radiation control staff, and maintainers. They have collaborated with the US in the past, but not recently. Figure 5 shows the glovebox line at TPL.

We next visited the FNS facility. Dr. Chikara Konno is the safety officer for this facility. He gave a presentation about the facility. Deuterium ions are accelerated into a titanium tritide target at 2 mA current, producing reactions that generate $3 \times 10^{11}$ neutrons/second. The facility started operation in 1981. The staff is small, similar to TPL. The shielding for the facility is impressive, as it must be to protect the staff against neutrons. The facility runs in the day shift only, 7 hours/day and 4 days/week. When using the rotating target, they can operate up to 4 months with one target. For the stationary target, they can operate up to one month with one target. There has not been any recent collaboration with the US. In the March 2011 earthquake in Japan, there was damage to the FNS – many high voltage insulators were cracked or broken, a motor case was
cracked through. They needed a year to make repairs and return to service. There is a management safety patrol every 3 months, and Dr. Konno makes a safety patrol each month.

Tritium Process Laboratory
- Facility is clean and organized.
- Radiation protection program is properly implemented.

Fusion Neutrons Source
- Facility is clean and organized.
- Radiation protection program is properly implemented.

D. ACKNOWLEDGEMENTS

The U.S.-Japan Safety Monitor JWG members would like to thank all the individuals who participated in the facility tours. The U.S. JWG members especially thank the hosting institutions for their very gracious support, local transportation and hospitality. In addition, the U.S. members were very appreciative of Yuichi Takase, Kiyohiko Nishimura (the Japanese team leader), Atsuhiko Sukegawa, and others for their efforts in organizing the trip and providing transportation and guides as needed. Their attention to detail, prior to and during the trip, made the entire event both advantageous and enjoyable to all.

E. AGENDA

Saturday, July 27, 2013 - All three JWG members depart the U.S.

Sunday, July 28, 2013 - All members arrive in Tokyo, Japan.

Monday, July 29, 2013 – Travel by train to Tajimi and visit NIFS.

Tuesday, July 30, 2013 – Complete NIFS visit. Travel by train to Tokyo.

Wednesday, July 31, 2013 – Visit Kashiwa campus of the University of Tokyo. Then travel by train to Mito.

Thursday, August 1, 2013 – Visit JAEA Naka.

Friday, August 2, 2013 - Visit JAEA Tokai. Travel by train to Tokyo.

Saturday, August 3, 2013 – free day in Tokyo.

Sunday, August 4, 2013 – All three JWG members depart from Narita airport.
APPENDIX A – EXAMPLES OF SAFETY BEST PRACTICES
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Staging & Storage

Elevated Areas

Gas Cylinders