Summary

Safety Management of Nuclear Power Plants

✧ Objectives: To check the nuclear security of nuclear power plants to make sure that they are well-prepared for earthquakes, floods, and other disasters
✧ Duration: 30 days (from December 4, 2017 to February 2, 2018)

I. Overview

The accident of Fukushima Daichi Nuclear Power Plant that occurred on March 11, 2011, demonstrated how disastrous a nuclear power plant accident that entails a leakage of radiation can be, resulting in massive damage to a countless number of people's lives and properties.

On September 12, 2016, an earthquake struck off Gyeong Ju City with a magnitude of 5.8, the largest earthquake in the recorded history of Korea. This raised a concern over the earthquake resistance of the nuclear power plants adjacent to the point of the earthquake. Also, in March 2015, steel debris and 89 other materials that may damage the steam generator pipes[1] were discovered in the steam generator of Hanbit Nuclear Power Plant. In June 2016, it was found that some parts of the Containment Liner Plate[2] of Hanbit Nuclear Power Plant were corroded. This raised concern and criticism over the safety management of nuclear power plants.

Against this background, the Board of Audit and Inspection (BAI) audited six relevant organizations[3], including the Nuclear Safety and Security Commission (NSSC), from December 4, 2017 to February 2, 2018 to find things that require structural and systemic improvement for securing the safety of nuclear power plants and eliminate the hazard elements by scrutinizing the overall safety of all nuclear power plants in Korea.

[1] It is a pipe through which the steam generated from the nuclear reactor is moved to the steam generator.

[2] It is 6mm-thick carbon steel plate installed in a hangar of a nuclear power plant. It prevents leakage of radiation.

[3] Nuclear Safety and Security Commission, Ministry of Trade, Industry and Energy, Korea Hydro and Nuclear Power Co., Ltd, Korea Institute of Nuclear Safety, Korea Foundation of Nuclear Safety, Korea Radioactive Waste Agency

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II. Status of Nuclear Power Plants and Safety Management System

(1) Status of Nuclear Power Plants

The Korea Hydro and Nuclear Power Co., Ltd. (KHNP) operates 24 commercial nuclear power plants as of the end of December 2017. Out of the 24 plants, 20 of them are pressurized light water reactors (including Kori Nuclear Power Plant units 2-4), and the rest of the four are pressurized heavy water reactors (Wolseong Nuclear Power Plant units 1-4).

Table 1. Domestic Nuclear Power Plants

(Unit: MWe)

Category	**Kori (Busan Gijang-gun)**	**Shin-Kori (Busan Gijang-gun)**	**Wolseong (Gyeongsa-ngbuk-do, Gyeongju City)**	**Shin Wolseong (Gyeongsa-ngbuk-do, Gyeongju City)**	**Hanbit (Jeollanam-do, Yeonggwang-gun)**	**Hanwool (Gyeongsa-ngbuk-do, Uljin-gun)**
Power plant Unit No.	Units 2-4	Units 1-3	Units 1-4	Units 1-2	Units 1-6	Units 1-6
Capacity (MWe)	2,550	3,400	2,779	2,000	5,900	5,900
Operated in	Jul.1983 – Apr. 1986	Feb. 2011– Dec. 2016	Apr. 1983 – Oct. 1999	Jul. 2012 – Jul. 2015	May 1986 – Dec. 2002	Sep. 1988 – Apr. 2005

As of the end of December 2016, the total capacity of all domestic nuclear power plants amounted to 22,529 MWe, taking up 20.59% of the entire capacity of power facilities in Korea (109,789 MWe). In terms of the amount of electricity generation, nuclear power plants generate 161,995 GWh per year, accounting for 29.9% of the entire amount of electricity generation (540,441 GWh).

Table 2. Energy Generation of Each Source as of 2016

(Unit: GWh, %)

Category	**Nuclear**	**Hydro**	**Coal**	**Oil**	**Gas**	**Alternative**	**Total**
Capacity of power generation facilities (% of power generation)	161,995 (30)	6,634 (1.2)	213,803 (39.6)	14,221 (2.6))	120,852 (22.4)	22,936 (4.2)	540,441 (100)

As of the end of December 2017, since the first operation of the commercial nuclear power plant, six out of 24 nuclear power plants are more than 30 years old now. Five of them are between 20 and 30 years, and eight of them are older than 10 years and less than 20 years. The

rest of the five are less than ten years old.

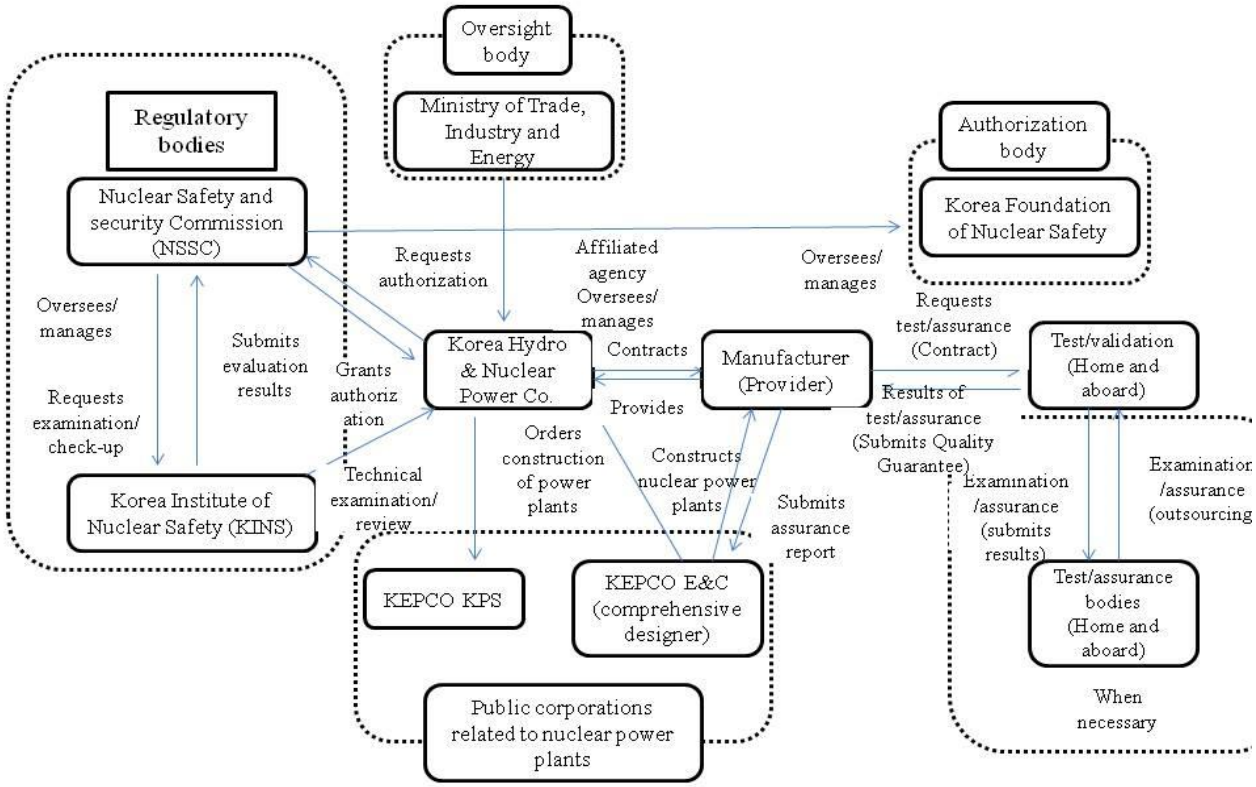
Table 3. Status of the operation of commercial nuclear power plants

Years of operation	More than 30 years	Between 25 and 29 years	Between 20 and 24 years	Between 15 and 19 years	Between 10 and 14 years	Less than 10 years
No. of plants (out of 24)	6 (25%)	2 (8.3%)	3 (12.5%)	6 (25%)	2 (8.3%)	5 (20.8%)

(2) Mechanism of safety management for nuclear power plants

To explain how the safety of commercial nuclear power plants are managed in Korea, the NSSC and the Korea Institute of Nuclear Safety (KINS) function as regulatory bodies by granting the KHNP authorization for operation of nuclear power plant and conducting technical examination or inspection. As a supervision authority, the Ministry of Trade, Industry and Energy (MTIE) oversees the overall works of the KHNP.

Figure 1. Mechanism of safety management for nuclear power plants



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III. Audit Results

This audit examined the facilities of nuclear power plants, the safety management mechanism, and maintenance/operation. It was found that the KHNP measured the thickness of the container liner plates of nuclear reactors in an improper way, and the NSSC applied the rules on the eligibility of Commissioners incorrectly in managing their Commissioners. On June 14, 2018, BAI requested these agencies, including the NSSC, to take proper actions to reverse its errors. Details are as follows:

(1) Safety management for Nuclear Power Plants

① Improper measurement of the thickness of containment liner plate of nuclear power plants

During the in-service preventive inspection of Hanbit Nuclear Power Plant unit 2 in June 2016, it was discovered that the inner surface of the Container Liner Plate (CLP) had been corroded. Concerned about the safety of the nuclear plant, the in-service preventive inspection was expanded to inspect all CLPs of nuclear power reactors in operation through visual examination and to measure the thickness of the lowermost parts of the CLPs.

According to MIE-3500 of the Korea Electric Power Industry Code, when 10% of standard thickness (6 mm) of a CLP is damaged, the safety of it should be either examined by technical evaluation, or secured by repairing the damaged plate or replacing it with a new one.

Surfaces of CLPs are to be coated to prevent corrosion. And, the thicknesses of coated parts are all different from one another, because: (a) it may be coated differently than originally designed by an error at initial try, (b) some parts may be coated multiple times if there were any damages on previous coatings, and (c) the thickness of coatings may vary depending on the locations of the coatings.

Therefore, when assessing the thickness of the inner surface of CLPs for the purpose of securing the safety of nuclear power plants, it is necessary for the KHNP to take into consideration that there is a possibility of inaccuracy[4] in the measured values of the inner surface of CLPs. Thus, it should adopt a measurement that can show correct values of thickness.

[4] When the thickness is measured with ultrasonic wave-based equipment, the thickness of metal is measured correctly. However, the equipment cannot examine the thickness of coated parts correctly because the velocity of wavelengths of coated parts is different from the one of metal.

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However, the KHNP did not have an understanding about which measurement type should be employed to measure the thickness of the inner surface of CLPs. It just uniformly applied the standard measurement to all CLPs—that is to subtract an estimated value of the coated part (0.2 mm) from the measured value of thickness, leading to a big difference in the measured values of thicknesses than the actual ones.

In order to examine whether the KHNP had measured correctly, BAI auditors re-assessed the thickness of the coated parts at 365 points of the KHNP's measurement. It was found that the thickness values of the coated parts of 59 points had exceeded 0.5 mm, signaling that subtracting a uniform value of 0.2 mm (for coated parts) from all measured values was inappropriate to get the actual value of thickness.

Also, BAI re-assessed the thicknesses of surfaces of the CLPs of Kori Nuclear Power Plant units 3 and 4, at those points that the provider of measurement devices had already measured, through the same measurement method. The result showed that at 143 points of Kori unit 4 (which had satisfied the safety standard already), the CLP thicknesses of 65 points turned out to be lower (5.17 mm at the lowest) than the required standard (more than 5.4 mm).
This meant that if the standard measurement is continually used, those points whose thickness is actually lower than the required due to the coated parts can still be evaluated as appropriate. This raised a concern over the possibility that the safety of nuclear power plants is not managed well.

As a result of this audit, BAI notified the KHNP to:

- establish proper ways to strengthen the safety of the 65 points of Kori Nuclear Power Plant unit 4, whose inner surface is found to be less thick than required; and
- establish the ways to improve the accuracy of the measurement method by adopting the Thru-coat method[5] or Eco method[6] when assessing the thickness of the surface of CLPs.

[5] It is one of the ways to measure the thickness of the surfaces of CLPs by penetrating ultrasonic wave through an assessment point. While the ultrasonic wave penetrates through steel materials, it cannot penetrate through any non-steal materials (coated parts). It results in measuring the thickness of the steel materials only (coated parts not measured at all).

[6] It is another way of measuring the thickness of the surfaces of CLPs by penetrating ultrasonic wave through an assessment point. This thickness is assessed by the time difference between the first peak value of waveform and the second peak value of waveform.

② Insufficient measures for designing earthquake-resistant facilities of nuclear power plants

In March 2010, the KHNP set up the "Plan for Securing Earthquake-resistance of Nuclear Power Plants and Their Annexed Buildings" (hereinafter referred to as Plan for Earthquake-resistance). The KHNP examined the current status of existing buildings of nuclear power plants for retrofitting.

According to subparagraph 3 of Article 3 of the *Act on the Preparation for Earthquakes and Volcanic Eruptions*, the head of the agency in charge of emergency management (KHNP) should conduct an evaluation of the seismic performance of all nuclear reactors and related facilities, and formulate measures for improvement when necessary. In other words, (s)he should establish a plan for securing seismic performance of all facilities under his/her jurisdiction.

However, the plan dealt only with those parts related to the reactor's safe shutdown, leading the KHNP to reinforce only the parts to sustain 0.3g of peak ground acceleration, stronger than its intended design (0.2g of peak ground acceleration).

In connection to this, BAI found that: (a) Hanul Nuclear Power Plant units 1 and 2, which are non-reactor safe shutdown facilities, and other 22 buildings, including liquid radioactive waste containers, had not been designed for seismic performance at all; (b) as for five buildings, including the turbine building of Kori Nuclear Power Plant unit 2, it was not even possible to check whether they are safe or not because there was no drawing and specification at all for all of the five; and (c) 59 buildings, including those circulating water intake facilities like Hanbit Nuclear Power Plant unit 3, had been left without further plans for reflecting the strengthened standards for seismic performance established in 2005 and 2016.

As a result of this audit, BAI notified the KHNP to:

- conduct evaluations of seismic performance of those buildings, for which earthquake-resistance was not designed; and
- establish responsive measures for reinforcing them in accordance with the evaluation.

(2) Safety Management of Nuclear Power Plants

① Improper management of the eligibilities of Nuclear Safety and Security Commission members

The Nuclear Safety and Security Commission (NSSC) is a collegiate administrative agency composed of nine Commissioners including the Chairperson. In order to secure the independence and fairness of the agency, the eligibility of its Commissioners is defined by the *Act on the Establishment and Operation of the Nuclear Safety and Security Commission* (hereinafter referred to as the *Act on the Establishment and Operation of the NSSC*).

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Insufficient rules on treating Non-standing Commissioners of the NSSC: On November 4, 2013, the Anti-Corruption and Civil Rights Commission (ACRC) advised the NSSC to establish rules on treating Non-standing Commissioners. The NSSC responded that they will do so by June 2015.

As stipulated in Articles 11 and 12 of the Act on the Establishment and Operation of the NSSC, the NSSC deals with the safety and authorization of nuclear power plants by deliberating and making decisions on granting authorizations over the use of nuclear power. Article 13 of the same act directs that the NSSC makes decisions with the consent of the majority of the Commissioners present. In other words, the Standing Commissioners and the Non-standing Commissioners are to make equal amounts of contributions to making decisions on safety-related issues.

Therefore, it is adequate for the NSSC to establish proper ways to hold the Non-standing Commissioner accountable when (s)he makes any action that undermines the fairness of the works of the NSSC, as it pledged to do so to the ACRC.

This audit found that from June 2015, when the NSSC submitted its pledge to establish a rule on treating their civilian Non-standing Commissioners as public officials, to the date of this audit, the NSSC had not done anything related to the establishment of relevant rules.

This signaled that the fairness of the safety management of nuclear power plants may be threatened because there is no statutory measure for punishing Non-standing Commissioners, even if (s)he commits wrongdoings related to the works of the NSSC.

Inappropriate management of the eligibility of Commissioners (grounds for disqualification): Article 10, paragraph 1, subparagraph 5 of the *Act on the Establishment and Operation of the NSSC* stipulates that a person who is currently conducting, or has conducted a research and development task or any other project entrusted by an institution specified in the items of subparagraph 4 during the preceding three years should not be qualified as a Commissioner of the NSSC. Paragraph 2 of the same Article also stipulates that if a Commission member falls under any subparagraph of paragraph (1), he/she should be dismissed from office automatically.

Nonetheless, the NSSC maintained that subparagraph 4 of the *Act on the Establishment and Operation of the NSSC* ~~does~~ did not specify ~~who~~ which ~~the~~ institutions had entrusted research and development tasks or other projects~~in subparagraph 4 are (those institutions that have obtained either a permit or license/designation as per the *Nuclear Safety Act)*~~. It also added that it is vague to interpret exactly what kinds of tasks it indicates. Based on these reasons, the NSSC screens eligible Commissioners just by receiving the records of their participation in research and development tasks entrusted by the KHNP, not even checking the records from other agencies since 2016.

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BAI reviewed the records of research and development projects entrusted by the institutions specified in paragraph 4 of Article 10. It found that three incumbent Commissioners including Commissioner A, who was appointed on November 18, 2016, and Commissioner B, who was appointed on June 9, 2016, were being engaged in research and development projects as executive officers at the Korea Atomic Energy Research Institute. However, the NSSC did not acknowledge it.

For these findings, BAI notified the NSSC to:

- establish rules on treating Non-standing Commissioners as public officials;
- establish proper ways to systematically manage the eligibility of Commissioners by, for example, requesting prospect/incumbent Commissioners to submit records of participating in any tasks of all institutions using atomic energy; and
- review thoroughly whether the three Non-standing Commissioners who were engaged in research projects of other institutions as an Executive Officer falls under the category of automatic removal, and enforce the most appropriate measure against them.

② Inappropriate management for regulations on reviewing and reflecting international standards for nuclear safety

Inappropriate review and reflection of international standards for nuclear safety: In accordance with Article 21 of the *Nuclear Safety Act*, the NSSC plays a role in regulating nuclear safety through granting authorizations to the operators of nuclear power plants. Paragraph 1, subparagraph 3 of Article 111 of the Act stipulates that the standards for nuclear safety that is to be applied in regulating the safety of nuclear power plants should be developed by the Korea Institute of Nuclear Safety (KINS). The NSSC then oversees the works of the KINS.

According to Requirement 33 of *Governmental, Legal and Regulatory Framework for Safety*, which are the safety standards established by the IAEA (International Atomic Energy Agency), regulations and guides shall be reviewed and revised by regulatory authorities as necessary to keep them up to date, with due consideration of relevant international safety standards and technical standards and of relevant experience gained.

Meanwhile, the NSSC has been aware of the necessity to review international standards for safety technology. It set up a plan for establishing a system for consistent review and revision of international standards for nuclear safety.

In other words, when the NSSC entrusted the KINS to conduct research and development projects for safety standards for atomic energy, the NSSC should have let the KINS know about what international standards to collect and review, how to review and reflect the collected information, and how to assimilate them into domestic ones.

However, other than hearing from the KINS about the status of monitoring international standards, the NSSC did not do anything about managing the research and development projects of the KINS, without even a specific plan to do it. This raised a concern over the possibility that the most up-to-date information on international standards are not reviewed or even acknowledged, making it difficult to reflect them onto the domestic standards in a timely manner.

Lack of establishment of periodic assessment of nuclear safety and operation of vague regulations on safety: According to Article 23 of the *Nuclear Safety Act*, operators of nuclear power plants should conduct a comprehensive safety review periodically on their reactors and relevant facilities, which are operated for a ten-year period to prevent radioactive accident and secure public safety. The NSSC manages the periodic safety review system by having the operators conduct it and report the result of it to the NSSC.

The purposes of this periodic safety review are to: (a) compare the technology applied at the time of authorization to the new technologies developed at the time of the review to ensure if there is anything to improve; (b) examine the changes in function/performance of facilities happened over the period of operation; (c) re-examine the safety of nuclear power reactors for the present and beyond (the next decade) based on the experiences/know-hows accumulated over the period of operation since authorization; and (d) make improvements based on the results of the review. This review was commenced with Wolseong Nuclear Power Plant unit 2 in 2018, followed by subsequent reviews of Wolseong Nuclear Power Plant units 3 and 4, and of Hanul Nuclear Power Plant units 1-4 in 2019.

To examine the safety of nuclear power plants objectively through the review, and make the review meaningful, it is necessary for the NSSC to make clear what kinds of technical standards should be employed for conducting the periodic reviews.

However, the NSSC has yet to produce its own clear-cut definition of the technical standards to be used for the review. Instead, the organization is letting it suffice to use "effective technical standards," as stipulated in Paragraph 1 of Article 23 of the *Nuclear Safety Act* and the Enforcement Decree of the said act, which reads, "To conduct a safety review utilizing the effective technical standards for the relevant reactor facilities at the time of such safety review." It remains vague to understand which technical standards fall under the category of "effective." This raised a concern over the appropriateness of the technical standards used for the safety reviews.

To resolve the concern, BAI notified the NSSC to:

- determine the appropriate scope of collecting data on international standards for nuclear safety and document what is reviewed through the collected data; and
- develop a clear definition of the term "effective technical standards" clearly, as it is the standard for the periodic safety review.

(3) Maintenance and operation of nuclear power plants

① Omission of what to do for preventive maintenance of nuclear power reactors

In every 18 months, the KHNP conducts preventive maintenance on nuclear power reactors. It is to enhance the nuclear security by preventing functional failures that may occur during operation, and heighten the economic efficiency of operating the reactors.

In order to secure the reliability of the preventive maintenance, it is quintessential for the KHNP to have full knowledge about what to fix and prepare checklists at the planning stage, so that nothing is omitted from the checklist. Moreover, during the maintenance operation, they still need to check if anything is left out, and update the checklist if there is anything omitted from the list.

In this audit, BAI scrutinized the two most recent rounds of preventive maintenance conducted by the KHNP for 23 units of four nuclear power reactors. In cases of all of the four nuclear power reactors, it was found that the KHNP had skipped the preventive maintenance for 1,744 items (0.29%) out of 595,251 due to system errors and/or unavailability of replacement components. Out of the 1,744 items, 380 items were of urgency levels A and B,[7] which may threaten the safe operation of nuclear power reactors.

Since the power facilities of urgency levels A and B did not get checked at proper times, a concern was raised over the unavailability of achieving the very objectives of the preventive maintenance, which are to prevent functional failures of nuclear facilities through periodic preventive maintenance and to enhance nuclear security.

Therefore, BAI warned the KHNP to make sure no item is omitted from the checklist for periodic preventive maintenance by paying keen attention to repairing facilities and establishing plans for the maintenance.

[7] They are machines that are highly critical in running nuclear power plants as its failure can cause cutback and/or shutdown of nuclear reactors.

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② Inadequate oversight of safety management by the employees of nuclear power plants

As per the *Nuclear Safety Act*, the KHNP are responsible for overseeing the works of nuclear power reactor operators, mechanics of on-site maintenance groups, among others.

Nuclear power reactor operators perform safety control of important equipment and facilities, such as those that may cause shutdown or overload, radioactive leakage, and control the powers of nuclear reactor equipment and systems. Meanwhile, mechanics of on-site maintenance groups perform preventive maintenance operations as well as regular maintenance for all systems, structures, and equipment of nuclear power reactors.

Considering that these staff are of critical importance in terms of nuclear security, it is surely essential to monitor their works at all times. For example, it is a must to prevent a case where the operators and/or mechanics perform their duties while intoxicated. The KHNP is obliged to monitor the condition of those staff, and if any unusual condition is detected, the staff should be replaced by other available employee(s).

Nevertheless, the KHNP is managing this issue only through having the nuclear power reactor operators themselves check one another on whether anyone is under the influence, and replace the intoxicated person, if any, with one of themselves. As for the mechanics of on-site maintenance groups, a sobriety test is conducted only during preventive maintenance operations. A more objective and thorough monitoring system is necessary.

BAI checked whether the nuclear power reactor operators and the mechanics of on-site maintenance groups have ever been put on duty while intoxicated for the period of January 2011 – December 2016 by looking into the records of clocking in and out of the employees of nuclear power plants. As a result, it was found that a total of three employees had come to work after getting caught by the police for driving while intoxicated (blood alcohol concentration of greater than 0.05%), and just performed their duties of controlling the powers of nuclear equipment and other important facilities, without being replaced by others or getting a sobriety test at all. In addition, another three mechanics of on-site maintenance groups had also come to work under the influence (blood alcohol concentration of greater than 0.05%), and performed their regular duties of repairing critical equipment, systems, and structures, without getting any sobriety test from the KHNP.

For these, BAI requested the KHNP to:

- have a third party conduct the sobriety test, instead of co-workers;
- have all mechanics of on-site maintenance groups get a sobriety test when coming to work; and
- impose proper punishment on the employees who performed their work while intoxicated with a blood alcohol concentration of greater than 0.05% in accordance with the internal rules of the KHNP.