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# A SUMMARY OF THE REPORT OF THE CRITICALITY ACCIDENT INVESTIGATION COMMITTEE THE NUCLEAR SAFETY COMMISSION

December 24, 1999

Barbara - Is this one of our references? Do we have a "final" translation?

Tom

re: #30

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## I. Introduction

On September 30, 1999, a criticality accident occurred at a uranium processing plant operated by JCO Co., Ltd. (hereinafter referred to as JCO) in Tokai village, Ibaraki Prefecture. Three JCO plant workers were exposed to high levels of radiation in the accident. This has resulted in the death of one of the workers making this an unprecedented nuclear accident in Japan which has developed nuclear energy for peaceful purposes.

Recognizing the magnitude of the accident, this Criticality Accident Investigation Committee was established within the Nuclear Safety Commission in order to fully investigate the causes of the accident and to work out complete measures to prevent similar nuclear accidents in the future.

On November 11, 1999, the Committee submitted "Urgent Recommendations – Interim Report" to the Japanese Government, in response to which the Government implemented several measures, including a revision of the Law on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors and the adoption of the Special Law of Emergency Preparedness for Nuclear Disaster. In addition, a fund for nuclear safety and disaster prevention was appropriated in the second supplementary budget.

At a later date, the Committee engaged in further discussions and produced a final report.

This paper which was prepared at the responsibility of the Secretariat of the Committee outlines the final report of the Criticality Accident Investigation Committee.

# II. An Overview of the Criticality Accident

## 1. The Sequence of Events

The criticality accident took place in the conversion building of the JCO uranium processing plant in Tokai village in Ibaraki Prefecture. (See Figure 1.) JCO had obtained a license to use nuclear fuel material in this building in November 1980. Four years later, in 1984, the company was granted permission to alter this facility to the processing facility, which enabled it to produce uranyl liquid with an enrichment below 20%.

On the day of the accident, operations were being undertaken at the conversion building to produce uranyl nitrate solution with an enrichment of 18.8% and concentration below 380 gU/l, which was supposed to be used in "JOYO".

The operation to produce uranyl nitrate solution, which was performed by three JCO workers, started on October 29. The government-approved procedure required the workers to dissolve uranium powder with added nitric acid in a dissolution tank. Instead of this procedure, they dissolved uranium powder in a 10-liter stainless steel bucket. In violation of the operation manual as well as of an approved procedure, they seem to have fed seven batches of uranyl nitrate solution (work unit: about 16.6 kgU) into the precipitation tank which was designed to limit the mass to 1 batch (2.4kgU), using a 5-liter stainless steel bucket and a funnel. (See Figure 2.)

As a consequence of these actions, the uranyl nitrate solution in the precipitation tank reached a criticality and alarms sounded at around 10:35 a.m. on September 30. This criticality consists of a very short period in the initial stage in which a large number of nuclear fission reactions took place and the later stage in which the fission reaction continued slowly for approximately twenty hours. At around 2:30 a.m. on October 1, the operation of draining cooling water running through the jacket pipes installed around the precipitation tank was initiated. At 6:15 a.m. on the same day, the criticality terminated. Later, a boric acid solution was injected. At 8:30 a.m. the end of criticality was eventually confirmed.

Based on the results of the analysis of the residual solution in the precipitation tank, the total nuclear fission number caused by this criticality is estimated at $2.5 \times 10^{18}$.

2. Measures taken in response to the Accident: Communications and Evacuation

JCO made its first report of the accident to the Science and Technology Agency at 11:19 a.m. on September 30. In response to the report, the Agency notified the official residence of the Prime Minister of the accident at 12:30 p.m.. At around 1:00 p.m., officials from the Agency were dispatched to the accident site. A formal report about the accident was made to the Nuclear Safety Commission at 2:00 p.m.

At 2:30 p.m., the Science and Technology Agency set up its Countermeasure Headquarters. Subsequently, at 3:00 p.m., the decision was made to establish the Government Accident Countermeasure Headquarters headed by the Minister for Science and Technology in accordance with the Disaster Prevention Basic Plan. At around 3:30 p.m., Local Countermeasure Headquarters was established, and at 9:00 p.m., the Government Task Force for the Accident, headed by Prime Minister Keizo Obuchi, held a meeting.

Meanwhile, at 3:30 p.m. on September 30, the decision was made to convene the Emergency Technical Advisory Body of the Nuclear Safety Commission, which met at 6:00 p.m. Local authorities took necessary measures including the recommendation by Tokai-mura of evacuation to residents living within a 350-meter radius of the JCO plant at 3:00 p.m. and the recommendation by Ibaraki prefecture of sheltering indoors to residents within a 10-km radius of the plant at 10:30 p.m..

## 3. The Impact of Radiation and Radioactive Substances

### (1) Environmental Monitoring

Gaseous substances (noble gas and iodine), which were produced in the criticality, were released into the environment and radiation dose rate (gamma rays) rose at several monitoring stations in the area. Furthermore, decay products of iodine and noble gas with short half-lives, which were generated in the criticality, and activation products, which were generated by neutron activation, were detected in some environmental samples. However, it was concluded that the radiation and radioactive substances which were released from the site did not have any significant impact on the health of local residents nor the environment for the following reasons. ; (i) the radiation dose rate (gamma rays) was measured at a few micrograys per hour at the highest point, but in a short period, (ii) the levels of radioactive substances released from the facility and detected in the samples were quite low and these substances decay out rapidly, (iii) the levels of integral dose.

### (2) The Evaluation of Radiation Doses

Radiation doses of concern were direct radiation of neutron and gamma rays from the precipitation tank and the radiation from the radioactive substances discharged from the facility.

The doses of neutron radiation and gamma rays, which were discharged from the precipitation tank and which reached the surrounding area while the criticality continued, were directly evaluated from the values of neutron radiation and gamma rays measured at monitoring posts in and around the accident site. Based on this evaluation, basic data on the radiation dose levels were compiled by time and location in the surrounding environment.

An evaluation was also made of the doses from gamma rays, which came from the precipitation tank and reached the surrounding environment after the criticality, and radioactive substances which were released into the environment. It is concluded that the doses of these gamma rays and radioactive substances were found to be quite limited.

(Residents)

Surface contamination survey were conducted on the residents who evacuated to the Community Center from September 30, the day of the accident. If surface contamination were detected, whole body counting were done. Furthermore, those who were requested from the Tokai-mura and those who personally wish radiation measurement were also measured by whole body counting. Measurements were made at three separate institutions - the Japan Nuclear Cycle Development Institute (JNC), the Japan Atomic Energy Research Institute (JAERI), and the National Institute of Radiological Sciences (NIRS). These measurements revealed that significant amount of radioactivity were detected for seven persons who stayed near JCO fence for several hours after the accident. These levels (provisional values) ranged from 6.4 millisieverts (mSv) to 15 mSv.

Meanwhile, the Science and Technology Agency is conducting a behavioral survey on local residents living in the vicinity of the site. Based on the results of this survey and the basic data which has been compiled, the Agency is planning to produce personal radiation dose estimates.

(JCO Employees)

The three JCO workers, who were performing operations at the site, received a high level of radiation dose as a result of the accident. One of them died on December 21. The radiation doses estimated for these three JCO employees were over 16-20 gray equivalent (GyEq), 6.0-10 GyEq, and approximately 1-4.5 GyEq, respectively. In addition, 56 other employees were exposed to radiation. Thirty-six of them were measured with a whole body counter and the measured values (provisional) ranged from 0.6 to 64 mSv. Exposure dose measurements on the film badges revealed that 22 workers had been exposed to radiation. The doses of radiation they received ranged from 0.1 to 6.2 mSv (1-cm depth dose equivalent; gamma rays). Radiation was also detected using the whole body counter for two of these 22 workers who were significantly detected by film badge radiation dose measurements.

Twenty-four JCO employees, who performed the operations to stop the criticality, were found to have received a significant dose of radiation while engaging in these operations. The dose levels (provisional) detected for those employees for whom measurements were taken with the whole body counter ranged from 9.1 to 44 mSv. For other employees, radiation doses were measured with dosimeters (pocket dosimeters). The results (provisional values) ranged from 0.03 to about 120 mSv (1-cm dose equivalent).

Many of the JCO employees and workers from affiliated companies who had been in the JCO uranium processing plant when the accident occurred includes those who did not wear film badges which was prescribed by regulation, and those who left their film badges in the facility when the accident occurred. In addition, some of these persons were not radiation workers. Exposure dose estimates should be made for these JCO employees and others by JCO in co-operation of relevant organizations based both on the survey of their behavior and further available information.

(Persons Engaged in Disaster Prevention Activities)

Some of the persons engaged in disaster prevention activities from the Tokai-mura fire station, JNC and JAERI were found to have been exposed to radiation after the accident. However, the radiation doses for these persons were well below 50 mSv, the upper exposure dose limit established for those persons responsible for disaster prevention.

Exposure dose measurements taken with personal dosimeters found that 49 JNC personnel and eight JAERI employees exceeded the detection limits. Moreover, the three Tokai-mura firefighters who had carried the three JCO workers to hospital were found to have received 6.2 to 13 mSv (provisional values) of radiation.

Some of the persons involved did not wear film badges or pocket dosimeters while they were performing disaster prevention activities. From the conditions under which they worked during the accident, the radiation dose they received must be determined. Therefore, plans have been made to estimate the exposure doses for these persons by checking basic data on dose levels measured in the area, as well as by surveying their actions during the accident.

## III. The Cause of the Accident and Related Circumstances

### 1. The Cause of the Accident and Measures to Prevent Similar Nuclear Disasters

#### (1) The Direct Cause and the Remedy

The direct cause of the accident was workers putting uranyl nitrate solution containing about 16.6 kg of uranium, which exceeded the critical mass, into the precipitation tank, which was not designed to dissolve this type of solution and was not configured to prevent eventual criticality.

A suggested remedy is that when workers are to handle a solution type equipment which is not configured to prevent an occurrence of criticality and is controlled by human management, both the critical mass and concentration limits should be observed with due consideration of the human factors involved.

#### (2) The Problem in the Operation Procedure and the Remedy

A problem in the operation procedure was that the process of re-dissolving refined triuranium octoxide ($U_3O_8$) and homogenizing one lot (about 40 liters or 14.5 kgU) each of the resultant uranyl nitrate solution was not appropriate. The remedy is to make a prior assessment of the relationship between the workability and the safety of the equipment requiring criticality control.

#### (3) The Problem in Operational Management and the Remedy

A problem in operational management was that workers had performed operations exceeding the critical mass limit of 2.4 kgU per batch. Observing this limit is an essential requirement for safe operations. In order to eliminate such a gross error in operational control, it is necessary to ensure physical safety for solution type equipments by imposing a double limit of volume and critical mass as a criticality safety requirement. In addition, it is imperative to form an operational control framework which will insure compliance with the critical mass limit by providing workers with education and training as well as by rigidly enforcing the approval rule on the transportation of nuclear fuel material.

(4) The Problem in Technical Management and the Remedy

A problem with technical management was that the company failed to establish proper technical management procedures for the preparation and revision of manuals and instructions. These include the failure to require the approval of a safety management group chief or a chief technician of nuclear fuel. In order to prevent this type of problem in the future, it is important that operators provide employees with proper education and training, reinforce the administration of field workers, and improve safety and quality control. It is also essential that business operators adopt a self-active safety concept based on self-responsibility by encouraging them to obtain certification of the ISO standards.

(5) The Problem in Business Management and the Remedy

A problem found in business management was that the company did not pay full attention to the specific nature of the operation being performed at the nuclear fuel conversion building. This operation was smaller in scale and not frequently undertaken compared with the company's main operations in the nuclear fuel processing building. In order to prevent similar nuclear disasters, business operators should be required to take special safety control measures in the process of manufacturing special products in small quantities on an irregular basis. The fact that these processes have special characteristics must also be recognized.

(6) The Problem in Licensing Procedure and the Remedy

A problem in the licensing procedure was that as the safety review, design and construction method review had focused on checking the appropriateness of a safety design for facilities and equipment and not on the detail of the operational procedure, adequate description on the re-dissolution process was not necessarily made in the safety review and the design and construction method review. When evaluating the appropriateness for a criticality safety related to the basic design of facilities, equipments or components during a safety review, the following must be considered as preventive measures. First, identify conditions under which facilities, equipments or components are put to use. Second, consider the possibilities, if any, of deviating from these conditions when the facilities, equipments or components are put to use. Third, require the implementation of specific safety designs against wrongful operation while taking into consideration of potential dangers. Lastly, if necessary, the concerned impact must be studied as one of the maximum credible accident.

(7) The Problem in Safety Regulations and the Remedy

A problem in the safety regulations was that the regulatory authorities failed to provide valid checkups to ensure compliance with the safety rules. In order to reinforce the inspection ability of the regulatory authorities, the following measures should be implemented. The Government should ① add additional regulatory items concerning the nuclear fuel processing business, and order the regulatory authorities to conduct periodic inspections, ② introduce a system of effectively checking compliance with the safety rules, and ③ make the regulatory authorities to carry out inspections without prior notice in an efficient manner.

## 2. Technical Measures Taken During the Accident

### (1) Measures Taken during the Accident

The accident occurred at around 10:35 a.m. on September 30. In the early stages, the proper officials were not fully aware that the criticality accident had taken place. Furthermore, the concerned officials reported the accident to the Science and Technology Agency at 11:19 a.m., about 40 minutes after it had occurred. The operators, using such a solution of enriched uranium at level of about 20%, are expected to take necessary measures against the possible danger of criticality accidents.

### (2) The Response to the Continuation of Criticality

The effects of the accident were increased because the responsible officials took so much time to check whether the criticality had been continuing or not. The information which they initially received was fragmentary and limited. It is the fact that following the cumulating of the concerned information, the continuation of the criticality had been gradually recognized .

From the above observations, the following measures can be proposed. Concerned corporations should:

① set up a device capable of directly detecting a continuing criticality;

② provide safety measures against criticality accidents in facilities in which uranium with an enrichment of around 20% is handled in a liquid form;

③ introduce a mechanism which provides accurate information regarding whether a criticality is continuing and collect and examine information in an appropriate expertise;

④ disclose and provide information in a timely fashion and unify the source of information, and;

⑤ transmit accurate information promptly to foreign countries.

(3) Actions Taken to Stop the Criticality Accident

Because a criticality accident was not believed to occur, a great deal of time was taken to initiate special emergency measures to stop the criticality. In order to prevent this error from being repeated, it is important to:

① consider establishing a support task force of experts to take quick action in the event of an accident, and

② clarify, among the concerned parties, where responsibility lies and what legal justifications exist in cases where special operations subject to radiation exposure will be needed to put an end to an accident.

(4) Actions Taken to Prevent the Spread of the Effects of Radiation

Based on a study of actions which were taken to prevent the spread of radiation to theoutside , the following can be pointed out.

① Because it took a considerable amount of time to stop the criticality, radiation levels at the boundary of the site remained higher than the normal level for long time.

② Doses of radiation, which local residents had received during the accident, must be assessed as closely as possible after this report is published. Even if some residents are found not to have received a significant dose of radiation, sufficient follow-up mental and health care services for these residents must be provided.

③ Radioactive substances released from the site did not have an adverse effect on the health of local residents nor on the outside environment.

④ A study of the relationship between the released radiation dose rate and the distance from the site showed that the radiation dose rate at a point 350 meters away from the accident site was about one-eightieth of the value observed at the site boundary, while the dose rate one kilometer from the site was about 1/14,000.

## 3. Recommendations

### (1) The Reassessment, Systematization of the Safety Review System and Safety Regulations

① Considering the particularity of the concerned operation, this facility, even though it was designed as a nuclear fuel processing plant, could have been subjected to a review as a special using facility. Thus, the Committee recommends that a study be conducted on a safety review process which will allow regulatory ministries and the Nuclear Safety Commission to conduct double checkups in a multiple, complementary fashion.

② This type of facility is considered as a category of facilities in which a state of complete safety must be established and great importance must be attached to operational control. Therefore, the Committee points out the urgent necessity to make a technical examination for the safety review and safety regulation, as well as control system, operational procedures and inspection and confirmation methods.

③ The Nuclear Safety Commission is required to exercise supervision and direction over safety administration independently from the regulatory ministries in order to meet the needs of the ever-changing times and present day society while taking a broad view of nuclear power plants and the nuclear fuel cycle. In order to fulfill its mission, we suggest that the Nuclear Safety Commission reinforce its secretariat in drastic way and secure a group of technical advisers.

(2) Specific Measures to Eliminate the Causes of the Accident

① Operators handling nuclear fuel material must recognize the importance of designing and building safe facilities with due consideration to workability.

② A system which ensures safety through process and operational control through process and operational control should be established.

③ A system for safety improvement and succession of expertise in each establishment should be established. Business and production managers must gain a better understanding of the safety concept. They must be given education to gain this understanding.

(3) Proper Information Management under a Risk Management Structure

① Information sources must be unified in order to minimize information disruption. Persons who are designated as direct contacts with information sources should be responsible for providing information to the mass media.

② In order to make a quick and accurate decision to prevent disaster or put an end to an accident, the provided information must be analyzed technically. This work should be performed by those who are especially in charge at an appropriate place.

(4) The Unification and Systematization of Safety Management Information

① Operators having facilities which are dependent on human control, such as the concerned facility, should be required to establish a system to control information about nuclear material.

② Operators having facilities where more sensitive nuclear fuel materials are handled, should be required to unify and systematize the nuclear material control information with the nuclear material physical protection information.

(5) The Creation of a Social System to Ensure Safety through Self-Responsibility

① The present circumstances now call for a shift in consciousness from the "safety myth" in nuclear power and the "absolute safety" idea to a "risk-based safety assessment". The risk assessment concept is being established in the United States and European countries; however, efforts must be made to promote an understanding of this concept in Japan.

② The self-responsibility safety principle will become effective only if there is a sound relationship with tension existing between the regulator and those being regulated.

③ In a project-oriented technology development scheme, the project which consists of the individual subprojects, must be managed and operated, so that those individual subprojects be directed to evolve through the autonomy of each subproject. In addition, a risk management system, which will forecast and minimize a possible accident under unavoidable circumstances should be developed. At the same time, it is suggested that as a new topic of research and development, scientific attention be given to what a project-oriented technology development scheme should be like.

④ A group of technicians and engineers who have expertise, are adaptable to society, and have a strong sense of safety is now needed to participate in the process of creating a social system to ensure safety by the rule of self-responsibility. It is essential to train an individual who can lead this group. An additional important task is to cultivate good field workers in various fields.

## IV. Actions taken after the Accident

### 1. Nuclear Disaster Preparedness in Japan

The nuclear disaster preparedness in Japan is arranged in consideration of the possibility of the release of large amounts of radioactive materials from nuclear power plants, spent fuel reprocessing facilities and others. Nuclear disaster like the criticality accident at the JCO uranium processing plant was left out of consideration. This fact imposed tremendous constraints on decision-makers in gathering quick and accurate information on the situation at the site of the accident and in examining and deciding appropriate preventive measures to be taken in the initialstages.

Considering the seriousness of this criticality accident, the Japanese nuclear disaster prevention policy must be reassessed to include uranium processing facilities in the list of facilities to which possible nuclear disaster preparedness should be taken. At the same time, some guidelines must be established to improve preparedness for a possible criticality accident at uranium processing facilities.

### 2. Initial Response

Looking at an aspect of preparedness for initial response to nuclear disaster, actions taken by the concerned parties were inappropriate. JCO was late in reporting the accident to the Science and Technology Agency and other related agencies. JCO did not tell the fire station that the accident was a nuclear accident. In addition, the Science and Technology Agency's initial response was not satisfactory in terms of the collection of information on the accident and the notification to the concerned parties.

From now on Nuclear operators should be required to improve their arrangements for disaster prevention. At the same time, efforts should be made to improve the communication system for quickly and accurately transmitting notification of the accident from nuclear operators to the Government and local authorities as including municipalities in the vicinity of the accident site. In order to collect and analyze information promptly, the Government should arrange an on-site system in an ordinary times, establish teleconferencing and other systems which allows two-way communication, and set up a system for quickly mobilizing experts and technical organizations in the emergency situation.

3. Disaster Management Headquarters

In a nuclear disaster prevention system, relevant government agencies must cooperate among themselves and coordinate their efforts closely with one another from the early stages of disaster. In this sense, it is effective that the Cabinet should take the leadership in organizing actions from the initial stages. On the other hand, a powerful risk management system securing prompt initial action and close co-operation in the case of the event of certain scale must be considered on the need of the quick action at the initial stage. As to headquarters for the accident, a prototype of "an idea on the Off-site Center" come to be materialized to take necessary actions. Learning lessons from the accident, further studies must be made on various aspects of the idea, including information sharing, the coordination of activities, and the clarification of responsibility for decisions and implementation, in order to embody theidea in more effective way . . Furthermore, a study should be conducted on the regime to continually provide local authorities with advice and to coordinate activities at an initial stage. Consideration should also be devoted to the creation of a system under which the Emergency Technical Advisory Body of the Nuclear Safety Commission and the government task force for the accident can share information and work in close cooperation with each other.

4. Guidance and Advice on Evacuation and Sheltering Indoors

During the accident, the Government's initial action was not necessarily appropriate so that the mayor of Tokai-mura recommended local residents to evacuate their homes without guidance and advice from the central and prefectural governments, the action which was proven to be appropriate.

As problems to be rectified, the Government should consider arranging a system, such asgathering information and providing advice in an initial action, and establishing a structure , to systematically judge and secure protective measures for local inhabitants.

In this accident the recommendations of evacuation and sheltering indoors were issued as protective measures for local residents, which is the first time in Japan. It will become necessary through surveys to verify facts of inhabitants' reaction and public notification, including treatment for weak victims, and to study furthermore what protective measures for inhabitants should be.

5. Technical Support

Fortunately many experts and equipment were mobilized during the accident because there were numerous institutions with nuclear expertise in the area. Based on this experience, an arrangement must be established to allow a quick dispatch of personnel from Emergency Technical Advisory Body and other emergency technical experts. In addition, efforts must be made to provide information necessary for support, secure emergency materials and equipment, and improve back-up support systems. Moreover, it is important to provide adequate education and training during ordinary times in order to make use of the capabilities of experts in an emergency situation.

## 6. Response to the News Media

During the accident, relevant government agencies provided information to the news media on a timely manner. However, some problems came out in publicity service. Communication among the central and local governments and municipalities was not adequate enough to provide public information. For instance, there was no distinct contact point always available to answer inquiries from the public.

In a crisis, local inhabitants and general public must be provided with correct and intelligible information in a timely fashion. In order to do so, information sources should be unified to every possible extent. Consideration should be given to some systems to establish an officer specifically in charge of a media response, who could be always available to respond to the inquiry in order to promote the unification of the information and to take more appropriate action to the media. Among such arrangements is the establishment of a press secretary who will always be made available to make official announcements.

## 7. Medical Service in Nuclear Disaster

As the emergency radiation exposure medical treatment network worked properly, the National Institute of Radiological Sciences (NIRS) cooperated smoothly with related medical institutions to treat the three JCO workers who were exposed to heavy doses of radiation in the accident.

Based on the personal dose estimates derived from the results of a behavioral survey as well as from an evaluation of radiation dose levels measured in the area and the conclusions of the Health Care Study Committee, plans are to provide long-term health care to those local inhabitants who were exposed to radiation in the accident.

Measures to be taken in this field include the following.

① Treatment of Persons exposed to Significant Amounts of Radiation

(a) Recognizing that rescuing human lives have the highest priority in the event of accident or disaster, it is of vital importance to prepare an emergency medical service manual and, based on this manual, provide training in emergency medical treatment periodically.

(b) It is necessary to set up a forum for studying a nation-wide emergency radiation exposure medical care system. An emergency medical care system for persons exposed to radiation should be supported by advanced medical technology and the state-of-the-art medicine. A network connecting major medical institutions must be established.

(c) It is necessary to publicize Japan's experience of this nuclear disaster to the world by publishing reports on medical services provided in the accident, making presentations at academic societies and organizing international symposiums.

② Treatment of Persons exposed to Small Amounts of Radiation

(a) It is necessary to examine a system and a scenario for comprehensively providing medical treatment, health and mental care services on the site immediately after a nuclear disaster. A study must be conducted to prepare manuals for health care for workers and residents who have received certain levels of radiation and the manuals for assessing the radiation doses of local inhabitants. It is also of considerable importance to make arrangements which allow relevant government bodies and local authorities to work together and take measures in a coordinated manner in the event of accident.

(b) It is essential to establish a system in which scientific knowledge regarding health hazards is disseminated understandably in the early stages of accident. It is also necessary to publicize the correct knowledge of radiation and radioactivity, particularly a radiation dose, biological effects and radiation protection at ordinary times.

(c) It is necessary in implementing measures to note that even if an accident comes to an end, victims must receive health and mental care for a long period of time. For this purpose, professional advice on health and mental care for victims should be taken from specialists in psychiatry, psychology, social psychology, and sociology.

## V. The Health Checkup for Residents and the Safety Measures taken at the Accident Site

### 1. Health Care for Residents

The Health Care Study Committee, which was established within the Nuclear Safety Commission, is examining plans for long-term health care for local residents. The Committee is estimating radiation exposure doses, based on the results of a behavioral survey on those who live or work in evacuation recommendation area, which is within approximately 350-meter radius of the conversion building of the JCO plant. It is important that the Science and Technology Agency should cooperate with local authorities in implementing a long-term health care program in line with a health care policy suggested by the Health Care Study Committee, based on estimated exposure doses.

### 2. Safety at the Accident Site

After the criticality accident, a set of measures were duly taken for ensuring safety at the accident site, such as the containment of radioactive materials and the establishment of a radiation shielding. In addition, uranium solution, the cause of the accident, was put in a container and temporarily stored in the conversion building. This container will be transported to the Japan Nuclear Cycle Development Institute (JNC) for reprocessing.

In order to dispose of uranium solution safely and quickly, it is important that the Government should make continued efforts to provide guidance to JCO and request cooperation from relevant agencies.

# VI. A Study of the Background of the Accident

## 1. Enterprises and Industry

### (1) Nuclear Power Industry

The nuclear power industry represents a wide-range of industry including the nuclear fuel cycle sector, the manufacturing sector, the design and construction sector, and the service sector. JCO is an enterprise carrying on the re-conversion business in the nuclear fuel cycle sector.

### (2) Effect of Management Efficiency Enhancement in International Competition on the Accident

Before the accident, JCO's business was poor due to international price competition, and JCO took a set of measures for management efficiency enhancement, including personnel reduction. Although the small-quantity manufacture of special products requires particularly careful quality and safety control, JCO did not operate within an adequate quality and safety control scheme. It is difficult to see how the company's efforts toward betterment of business management in the international competition lead to the criticality accident. However, it is easy to presume that a dominant factor behind the accident was a decline of the ethical awareness in employees as the result of the company's pursuit of efficiency in management.

### (3) Efficiency and Safety in the Nuclear Power Industry

Due to the tremendous social impact of nuclear accident, the nuclear power industry should naturally give the highest priority to safety. The industry must attain efficiency and safety at the same time. The advancement of a science to analyze a form and impact of moral hazards, together with risk assessment and risk management, is needed.

JCO appears to have attached importance to efficiency in order to reduce costs and earn profits in the production of a non-marketable special product, which is manufactured in small quantities and not traded in the market.. When placing orders, not only employees in charge of closing the contract but engineers must take part in the negotiations and check whether the acceptance company is operating safely. Companies which place orders must use care to check whether the acceptance company is maintaining safe operations.

In order to ensure complete safety, related organizations and systems must be improved and corporations should be encouraged to create safety culture in their environment.

(4) Social Responsibility and Ethical Awareness of Business Operators and Engineers in the Nuclear Power Industry

The primary responsibility of ensuring safety rests with business operators. The government plays a complementary role in helping business operators to ensuresafety. Based on this responsibility sharing, it is important to clarify what responsibility each party should assume. Business operators are required to set up employee education and training systems to raise the safety consciousness of all the personnel, create a risk management structure based on action guidelines, and establish corporate governance. For this purpose, it is important for business operators to establish a highly transparent corporate management through information disclosure. In the nuclear power industry, which faces a lot of risks in its operations, companies should refrain from passing risks on to their subsidiaries. Sumitomo Metal Mining Co., Ltd. must sincerely reflect on its conduct and check whether it has been taking a full social responsibility as a parent company of JCO.

It is important that the nuclear power industry should make efforts to improve its ethics in order for its players to maintain high morality and discharge their social responsibility. For this purpose, the nuclear power industry should become an attractive industry. In order to be attractive, it is important that the nuclear power industry should make vigorous efforts toward technological innovation, promote exchange of researchers and engineers and conduct joint researches with universities and other institutions. Furthermore, the nuclear power industry should make effort through the school education and public education in order to promote a public understanding of the necessity and importance of nuclear energy.

Meanwhile, the nuclear power industry must devote its efforts to raising the safety consciousness and the ethical awareness of engineers to provide them with the spiritual support. The nuclear power industry should consider taking measures to enforce the codes of morality effectively. In the field of nuclear power, providing engineers, as expert officials, with ethical education at places including universities is urgently needed.

(5) Safety Management in the Nuclear Power Industry

It is important that safety is ensured in the entire nuclear fuel cycle. If there is a lack of safety in any segment of the nuclear fuel cycle, the nuclear power industry will be unable to gain public trust in nuclear energy. In the maintenance sector, business operators using the services of subcontractors and affiliates must consider a responsible way of safety management. In operating the Nuclear Safety Network, the nuclear power industry must cooperate closely with the government and provide well-balanced safety measures through mutual education. The nuclear power industry is expected to increase the number of business operators participating in the Nuclear Safety Network.

## 2. Society and Safety

### (1) The Basic Issue Concerning Society and Safety

Safety consciousness, which is one of the values specific to the upcoming 21st century, should be made known generally to the public. Members of the nuclear power industry must reaffirm that the principle of "safety comes first".

### (2) The Creation of a Safety-First Social System

Safety culture is a fundamental idea that supports all efforts to ensure safety in the nuclear power industry. With the criticality accident as a turning point, there is a greater call to bring the fundamental idea of safety culture home to the heart and mind of the Japanese people. Based on this idea, efforts must be made to create a social system in which safety receives the highest priority.

Lessons learned from the criticality accident point to the significance of a comprehensive design for a safety-first social system that will fully take account of the following four elements in proportion to their relative importance.

① Risk Recognition

Risk recognition means that one has a correct understanding of an event in which he or she or a third person is involved, foresees the effects of his or her actions, and recognizes the potential risks behind those actions. Unless the recognition of risk is correct, there will be no possibility of taking proper measures or providing support which will ensure safety before and after an incident. As such, risk recognition lies at the heart of the safety issue.

A lack of risk recognition was the underlying cause of the criticality accident that occurred at the JCO plant. In order to ensure safety, necessary preventive measures must be taken based on a full understanding of potential risks that may be in the background. An important measure which should be taken to attain risk recognition is to properly deploy key persons responsible for safety management and encourage employees to be always conscious of the risks involved in the tasks they undertake.

② Safety Precautions

Safety precautions are a package of actions which are formulated in advance in order to prevent a previously perceived potential accident. Safety precautions can be classified into hardware precautions and software precautions. Sufficient hardware safety precautions in the form of safety engineering design are already available, but it is impossible to make all safety precautions in hardware form. Thus, software safety precautions, such as safety design-based engineering, management and administrative procedures, are indispensable.

Specifically, it is important that the fail-safe, multiple safeguard design concept is deeply understood by all employees, operational and manufacturing manuals are carefully prepared and operational management is improved.

③ Safety measures taken after the accident

The measures mean a whole range of responses taken to deal with an accident after it has occurred. These include predetermined equipment designs, laws and regulations, institutions, procedures, practices, ethics and orders. Like safety precautions, there are hardware and software measures. Among these are measures designed to detect an accident immediately after it occurs, bring it to an end promptly, suppress the release of radioactive substances into the environment, control the impact of radiation on residents living near the accident site, and provide medical services for persons affected by radiation. An important factor that makes these measures effective is the dissemination of information. In order to take adequate measures, efforts must be made to improve systems which detect accident, provide accident response manuals, work out programs which prevent disaster, and conduct drills.

④ Support for Public Safety

Support for public safety refers to a set of supporting measures which have been previously formulated and which are designed to ensure safety through safety precautions and the measures taken after the accident. When hardware safety engineering designs are put at one pole of the safety-first social system, support measures designed to assure the effectiveness of safety precautions and the measures after the accident can be placed at the opposite pole. These support measures are very closely connected with society. The support measures include complete training and education, the introduction of a social psychological mechanism, improvements in internal and external assessment systems, information disclosure and the assurance of its transparency, the dissemination of accurate knowledge about nuclear power among the public, and participation of local citizens and communities. The support measures for public safety can be classified into those measures taken by business operators to directly assure that safety measures are promptly taken and that those measures ensure the safety of all members of society, including the business operators themselves.

Even in the fields with matured technologies, accidents exceeding the limits of safety engineering designs have occurred frequently recently. Lessons learned from these accidents have not necessarily resulted in the development and improvement of safety engineering designs. The criticality accident suggests that as the development and improvement of hardware types of safety precautions have reached a saturation point, the creation and materialization of software types of safety securing measures and safety support measures are gaining in importance.

However, it is essential to recognize that partial changes may spoil the optimization of an entire system. The realization of the above four elements must ultimately depend on the knowledge and skills of individuals, their motivation, and awareness of the need to ensure safety. It should be noted that excessive government intervention may reverse this process.

In developing a comprehensive design for a safety-oriented social system, all conceivable factors affecting the safety issue must be taken into consideration, including the public's sense of security and the sharing of responsibilities among business operators, the government, local authorities, local residents and third-party organizations. The government must assume the primary responsibility for developing a comprehensive design for a safety-oriented social system.

At the same time, all members of society must shoulder the costs of paying for the establishment of safety. It is important that the government, local authorities, corporations and other players should bear the proper cost of safety and play their respective responsibilities and roles within the context of a comprehensive design for a safety-oriented social system.

(3) The Role of Japan in the Future

The criticality accident resulted in a loss of Japan's credibility in the international community. With this accident as a turning point, if a social infrastructure which will help alleviate the risks involved in advanced technologies can be created and the international community's recognition of Japan as a safe nation can be regained, then Japan will be able to forge a bright future for mankind and play a major role in solving the important problems facing the international community.

# VII. Recommendations

An overview of the abovementioned measures and tasks clarifies the actions which should be taken to prevent another similar nuclear accident. This chapter summarizes the abovementioned measures, highlights the essential points of the suggested actions, and presents a set of recommendations for ensuring future accident preparedness.

## 1. Risk Awareness and the Creation of a Risk Assessment in Society

A lack of awareness of the risk of criticality was the underlying cause of the criticality accident. Correct risk awareness must be regarded as the starting point of all efforts to ensure safety. All organizations and individuals concerned with nuclear power must maintain risk awareness while playing their respective roles. In order to have risk awareness become deeply embedded in society, we must change our attitude from the belief in the "safety myth" and the notion of "absolute safety" to, the notion of "risk-based assessment of safety."

## 2. Ensuring Complete Safety By Nuclear Operators

It should be emphasized that the primary responsibility of ensuring nuclear safety rests with operators. Operators are encouraged to establish systems which will ensure safety through process and operation control, make risk forecasting and proper management a part of routine operations, and introduce internal and external assessment systems. It is important to establish a greater degree of safety consciousness and enhance the ethical standards of engineers, and measures should be taken to effectively enforce ethical codes. It is also important that safety is ensured in the entire nuclear power industry.

## 3. Actions by the Government

The role of the government is to support nuclear operators to secure safety and do their utmost to protect the general public. With the criticality accident providing momentum, the Law for the Regulations for Nuclear Source Material, Nuclear Fuel Material and Reactors was revised to include numerous improvements, such as requiring nuclear fuel processing operators to conduct periodic inspections and introducing a system to check operators' compliance with safety regulations. The Committee thinks highly of this revision because the Law was amended in response to the Urgent Recommendations - Interim Report made by the Committee. The government should also ensure that the revised Law will be effectively implemented by conducting inspections without prior notification to check compliance. The government should also pay greater attention to human factors and encourage operators to introduce the multiple protection, fail-safe concept in various aspects of nuclear operations. Furthermore, an emphasis should be made on the integration and systematization for control and the protection of nuclear material in order to prevent another similar nuclear disaster.

The government is strongly urged to improve preparedness for nuclear disaster by nominating key persons with the technical ability of risk management, properly controlling information in the risk management structure, and taking the specific measures necessary to ensure that the recently adopted Special Law of Emergency Preparedness for Nuclear Disaster is effectively enforced.

Moreover, the government is encouraged to make further efforts to take the following basic measures in order to reconstruct the safety regulation framework:

① reinforce staff of the safety regulatory authorities and clarify their role;

② strengthen the independence of the Nuclear Safety Commission, reinforce its Secretariat, and secure a group of experts to assist it in various fields;

③ formulate a complete set of examination guidelines and set up an efficient system of redundant complementary safety regulations, and;

④ make the regulatory ministries and the Nuclear Safety Commission meet the needs of the times and society and reappraise the effectiveness of their organizations.

## 4. The Cultivation of Nuclear Safety Culture and the Establishment of A Safety First Social System in the 21st Century

With the criticality accident as a turning point, safety culture must become deeply embedded in society. Efforts must be made to establish a safety first social system built on safety culture. In addition, an attempt must be made to make all relevant parties understand the principle of self- responsibility in ensuring safety and keep the ground rule of doing common things in a common way.

Business operators, the governments, local authorities, local inhabitants and third-party organizations should bear their own shares of responsibility and work together to develop a comprehensive design for a safety first social system. The government is required to assume the full responsibility for developing a comprehensive design of the entire system, with the Nuclear Safety Commission taking a leading role. Furthermore, the government, local authorities, and corporations should shoulder a proper share of the costs involved in materializing a safety first social system.

Meanwhile, efforts should be made to promote safety research projects to construct a safety infrastructure and push ahead with international education programs for training engineering leaders with a strong sense of safety. In order to secure safety personnel, a constant effort to ensure safety must be seen as a goal which is as valuable as technological development.

Considering the fact that nuclear accident has a tremendous social impact, a project to develop nuclear technologies must be carried out so that subprojects making up the project will be independently operated and administered and the whole project will evolve through this process. This research and development project must be promoted jointly with the development of a risk management system.

The criticality accident should be taken not merely as a warning to the maturing Japanese nuclear energy utilization, but also as an indication that prosperity supported by the advancement of science and technology is built on shaky ground. Out of this recognition, the government must build a consensus of public opinion on the value of safety. In order to create a safety first social system, the government should make every possible effort to ensure safety in every aspect of social life. By so doing, the government must revive Japan's reputation as a safe nation and take the safety-based road into the 21st century.

## 5. The Future of the Japanese Nuclear Power Industry

The Japanese nuclear power industry will be able to create a bright future only if all relevant parties respond seriously to what the Committee has pointed out and overcome the problems which they face. The Committee expects that the set of recommendations which have been made in this report will be put into practice without fail. At the same time, the Committee fully expects that a safety first social system, which will be constructed as the product of those recommendations, will be properly evaluated within the Nuclear Safety Commission after a reasonable period of time.

## VIII. Conclusions of the Chairman

As the direct cause of the criticality accident was the violation of procedural regulations, it is in itself a simple accident. However, it is by no means simple from the standpoint of prevention of similar accidents. This Committee has conducted its investigation from as many standpoints as possible. The Committee has investigated the cause of the accident and made recommendations in order to avoid similar accidents in the future. The recommendations encompass a wide range of fields and place heavy responsibilities upon those who are expected to carry them out. A sincere and extraordinary effort is expected of these individuals and institutions.

The following problems, which are inherent and structural, have arisen through consideration of the recommendations.

### (1) Characteristics of Nuclear Energy Technology and its Current Situation—Co-existence of Different Levels of Maturity.

In many of other technologies, technological elements which constitute constraint conditions could be identified through trial and error during their actual utilization. However, nuclear technology cannot assume such a trial-and-error approach, and therefore, is unique. In the nuclear industry, technologies are developed on the premise that the constraint condition, which is safety, shall absolutely be maintained.

In the process of moving toward maturity, all types of safety technology were fiercely pursued so that they could be fully understood regardless of their degree of complexity. Capital investments for technology development were always made for that purpose. In such processes of technological development, it was always understood that different types of difficulties were inherent in the field. A problem in nuclear technology lies in the situation where both mature technology and immature technology, which is in the stage of development, such as the technology related to new types of reactors, coexist with one another. Because the criticality accident occurred in the gap of technologies at different degrees of maturity, it is necessary to deeply consider this problem of coexistence of mature and immature technologies. Some may say that they might have to be separated from each other.

However, this report does not include this recommendation to separate these technologies. Although the above discussion concerns the primary nature of the technologies, it is necessary to consider the problem more deeply in order to reach a definite conclusion. We must recognize the fact that a great number of unknowns always remain in the technologies even if we are the ones who invented them. We must also recognize the need to analyze the technologies more deeply.

(2) Methodological Immaturedness--Antinomy

In the investigation of the criticality accident, we encountered following antinomies when considering methods to eliminate the causes of the accident. For example:

A. if safety increases, efficiency decreases;

B. if regulations are reinforced, creativity is lost;

C. if surveillance is reinforced, spirit declines;

D. if manuals are introduced, self-management is lost;

E. if fool-proof measures are implemented, the level of skills decreases;

F. if responsibilities are centered on a key person, the group loses concentricity;

G. if responsibilities are too strict, cover-ups result;

H. if information disclosure is promoted, situation becomes too conservative;

This report takes as a premise that efforts should be made by those concerned to prevent such antinomies from materializing. and concentrates on the issues which are necessary for the improvement of safety at the present.

However, when considering the future of the policy on nuclear energy in the long run, the resolution of these antinomies is important. Specifically, there is no future for nuclear energy unless the safety vs. efficiency antinomy noted above is resolved. It is our understanding that this antinomy will be resolved if we succeed in identifying specific aspects of nuclear technologies and developing quality control which applies specifically to nuclear technology.

The same is true for the other antinomies. Therefore, those antinomies listed above should be viewed as clarifying the objectives which must be achieved for the development of nuclear technology, and simultaneously as identifying a set of conditions for future development of nuclear technologies.

(3) The Separation of Authority and Responsibility

In a mature democratic society, various functions of the society are specialized and allocated throughout the society. In such specialization and allocation, it is necessary that the authority both of decision-making and of its administration and the corresponding responsibility be explicitly stated, so that the society will function smoothly. Especially in the case of nuclear technology, where safety must come first, it is critical that this necessary condition is not be violated.

This Committee discovered that the allocation of authority and the responsibilities among several entities in the field of nuclear energy were not necessarily clear. The underlying relations are between the Nuclear

Safety Commission, regulatory administrative bodies and operators, as well as the relation between these three and the general public.

The criticality accident should be viewed as the result of the failure to foresee the danger of a potential serious nuclear accident in the current structure where above four groups co-relate. That is, when we devise preventive measures, it is important to recognize that there was a peculiar point within the structure comprising these four groups in the sense that the potential danger in the situation could not be anticipated. Moreover, the fact that we cannot easily point out what part of the structure should have been revised so that we might have prevented the criticality accident should be seriously accepted.

This Committee put its entire efforts into identifying such necessary revisions. The outcome is the analytical investigation which includes a number of recommendations. The lack of clear allocation of authority and responsibility among four groups, which has been above-mentioned, is the principal reason for the diverse and complex nature of the analysis included in this report. In particular, the ambiguity of the allocation of authority and responsibility is considered to be one reason for the fact that no one was able to point out that there was something which could not be foreseen.

Another reason for the inability to point out this fact is an incomplete knowledge of the technology involved. That is, we do not have a complete understanding of nuclear technologies which are continuously changing as they move toward their maturity.

We must emerge from the present situation in which the gaps of views of groups involved and the lack of understanding of the technologies themselves overlap with one another. In order to do so, we would like to point out that the authority and responsibility among the four groups must be clarified and that a specialized research to cover the whole aspects of nuclear technology should be undertaken. The complete disclosure of information concerning the event which might occur at the site also seems essential.

These are the subjects which we should pursue continuously. However,, the recommendations proposed in this report, where it is clearly stated which entities are responsible for implementing these recommendations, must be put into practice as soon as possible. This Investigation Committee believes that the recommendations made in this report will prove to be effective because they are immediately necessary for the assurance of safety at the present time and they address the structural problems pointed out in this report; thus, their implementation will facilitate the resolution of these critical structural problems.

## Figure 1. Boundary of the Processing Facilities and Peripheral Monitoring Area