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Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

2010 ANNUAL REPORT

Published in June, 2011

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1 Preface

Technology Development and Applications of Nuclear Energy

Future Prospects - Sustaining Development for INER

Institute of Nuclear Energy Research (INER) is the leading nuclear energy research and development organization in Taiwan, and our mission is to develop advanced nuclear technologies, providing clean, abundant, affordable and reliable energy to Taiwan. In striving to earn international recognition as a world-class research institute, we here at INER adhere to the following three core values: Professionalism, Innovation and Safety.

In addition to cutting-edge technology, INER also specializes in system integration and is capable of developing applicable systems.

INER strives to develop (1) energy strategy for future reference, (2) energy technology to provide solid platform, (3) innovative technology and proven solutions to assist regulatory authorities maintaining nuclear-safe home and (4) civil usages of nuclear isotopes and high-end nuclear-imaging medical devices.

In 2010, INER has carried out 12 R&D programs, totaled 1,088,471 thousands NT dollars, and 371 research staff. To comply with national policy and public needs, the 12 R&D programs cover areas of nuclear energy, renewable energy and nuclear medicine. Nuclear energy topics comprises of nuclear safety, spent nuclear fuel, advanced nuclear technology, technology industrialization, etc. Renewable energy topics includes HCPV, wind turbine, cellulosic alcohol, SOFC, smart grid, IGCC & CCS, etc. Nuclear medicine topics comprises of medical device, diagnostic medicine, treatment medicines, etc.

As an effort to be in accordance with the call for global carbon dioxide reduction, INER follows the Carbon Reduction Action Plan of Sustainable Energy Policy adopted by the Executive Yuan. To actively promote the photovoltaic industry, INER established the Authentication and Development Center of High-Concentration PV in Kaohsiung Science Park to facilitate technology transfer and promotion. In addition, INER established the Authentication Laboratory of international standards to help enhance the competitiveness of the industry internationally.

INER has accumulated considerable technical skills and concrete achievements in the areas of promoting clean energy technologies, supporting energy conservation and carbon reduction, strengthening radiation safety and the quality of nuclear medical care to improve quality of public health and improving expertise in nuclear energy and management of intellectual property. This annual report will highlight the various achievements in each area.

INER has transformed from a research unit, that passively implements national missions, into a national research institute, that proactively resolves national issues and social demands in science and technology. As a way to continuous growth and development, INER made a third-time request to the National Science Council for an organizational evaluation. Combined with the strategic guidance and the team-works from the staff INER the only institute that was ranked excellent for three consecutive years in its institutional evaluation.

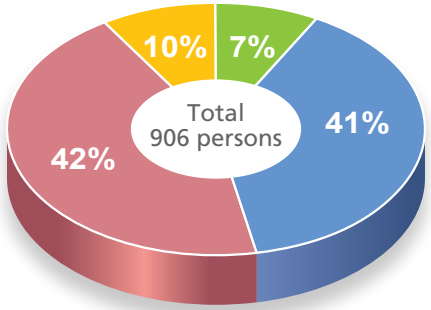
Looking forward, INER will improve R & D achievements, innovate management so as to manage innovation, and will accumulate R & D and application abilities of atomic energy science. Future strategic goals of INER will aim at academic researches and industrial developments.

Director-General

2 Human Resources and Budgets

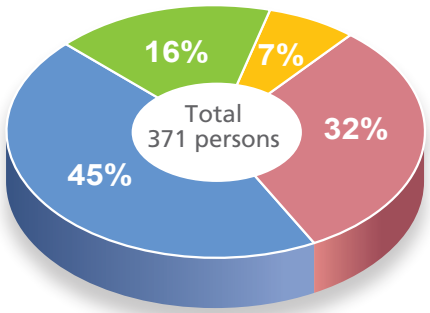
(Time of data: December, 2010)

Manpower Distribution of INER



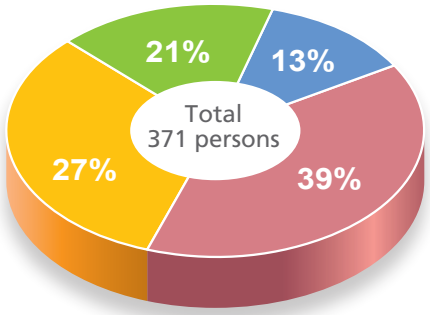
Research Staffs	371 persons	(41%)
Technicians	380 persons	(42%)
Administrative Staffs	88 persons	(10%)
Other Staffs	67 persons	(7%)
Official Staffs	906 persons	

Statistics of Educational Background for Research Staffs



Ph.D.	118 persons	(32%)
Master	165 persons	(45%)
Bachelor	61 persons	(16%)
Vocational School	27 persons	(7%)
Research Staffs	371 persons	

Statistics of Job Category for Research Staffs



Researcher	47 persons	(13%)
Associate Researcher	146 persons	(39%)
Assistant Researcher	100 persons	(27%)
Research Assistant	78 persons	(21%)
Research Staffs	371 persons	

2010 Annual Budget

Unit：Thousand NTD

Administration and Safety	**1,342,392**	51%
Management, Operation and Maintenance	**86,713**	3%
R&D Programs	**1,088,471**	41%
Technology Promotion and Service	**127,950**	5%
Total	**2,645,527**	100%

3 Events of the Year

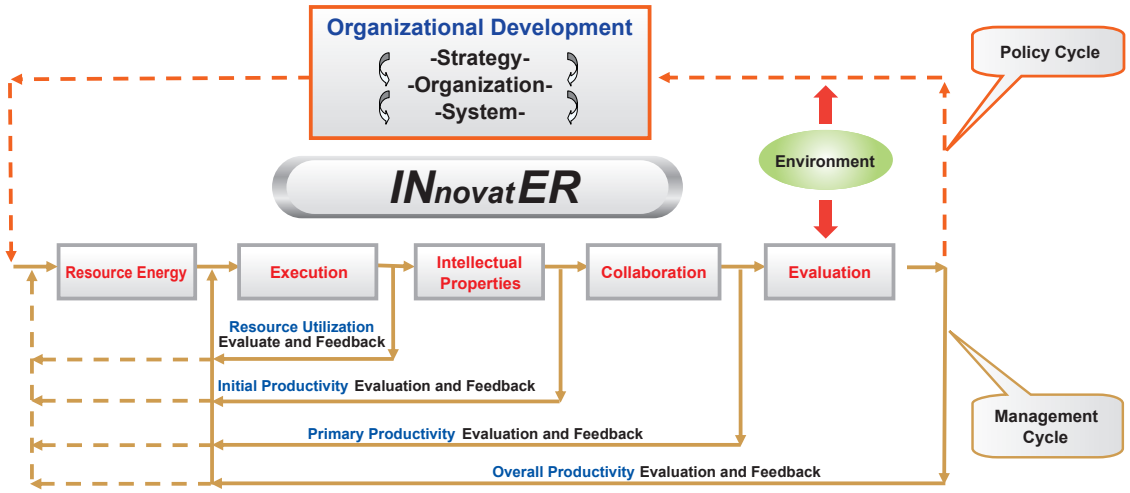
3-1 Organizational Evaluation of Scientific and Technological Research Institutions in ROC - INER was Ranked Excellent for Three Consecutive Years

Yung-Fu Hsu

Implementing the provisions of the Basic Law of Science and Technology, public authorities undertaking research are evaluated by National Science Council (NSC), and such evaluation also facilitates the establishment of the performance approval practices. The evaluation not only stresses authenticity and improvement, but also demands technology research institution to practice self-regulation and self assessment to enhance its quality and efficiency.

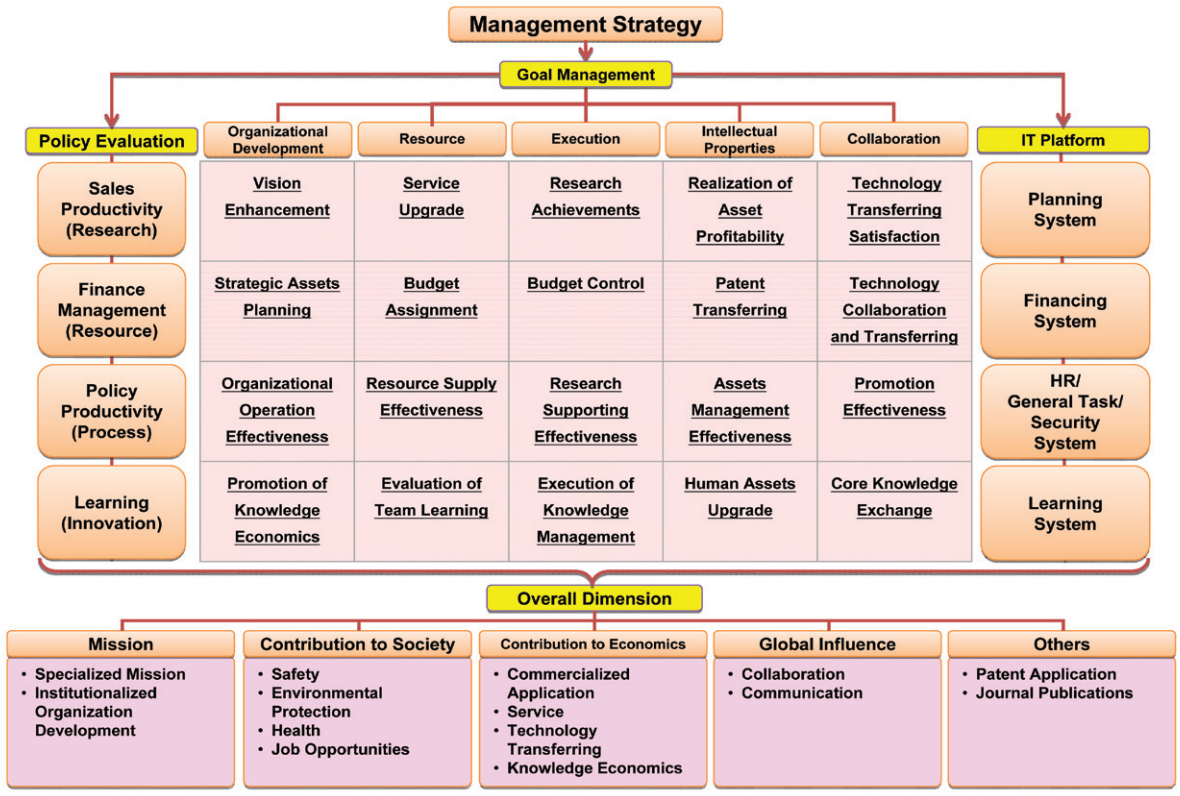
In addition to annual check, Institute of Nuclear Energy Research (INER) has actively participated in the organizational performance evaluation conducted by NSC, to maintain its competitiveness. Evaluation is conducted in six aspects, that is, organizational development, resource, management, intellectual properties, collaborative work and organizational characteristics, each with independent qualitative and quantitative sub-indicators. In 2011, INER participates for the third time, and is the only institute to take part for three consecutive years (2003~2005). Nominated as one of the excellent institutes in the first round in the categories of Nuclear Energy, Energy and Environmental protection, field assessment proceeded on Dec. 23 & 28, 2010 and Jan. 6, 2011, and the proposed research and management performance earned positive results. On Jan. 25, 2011, INER was granted excellent institute during the 14th meeting and the result was announced on the Public Construction Commission (PCC) website. With the given status, INER has exclusive advantage while bidding for state-assigned projects, effective until Jan 26, 2014.

INER has participated in NSC's organizational evaluation since 2003, and based on its results, INER expects for further improvement. By analyzing the evaluation results, INER has developed its own learning organizational system as the infrastructure for sustainable improvements.

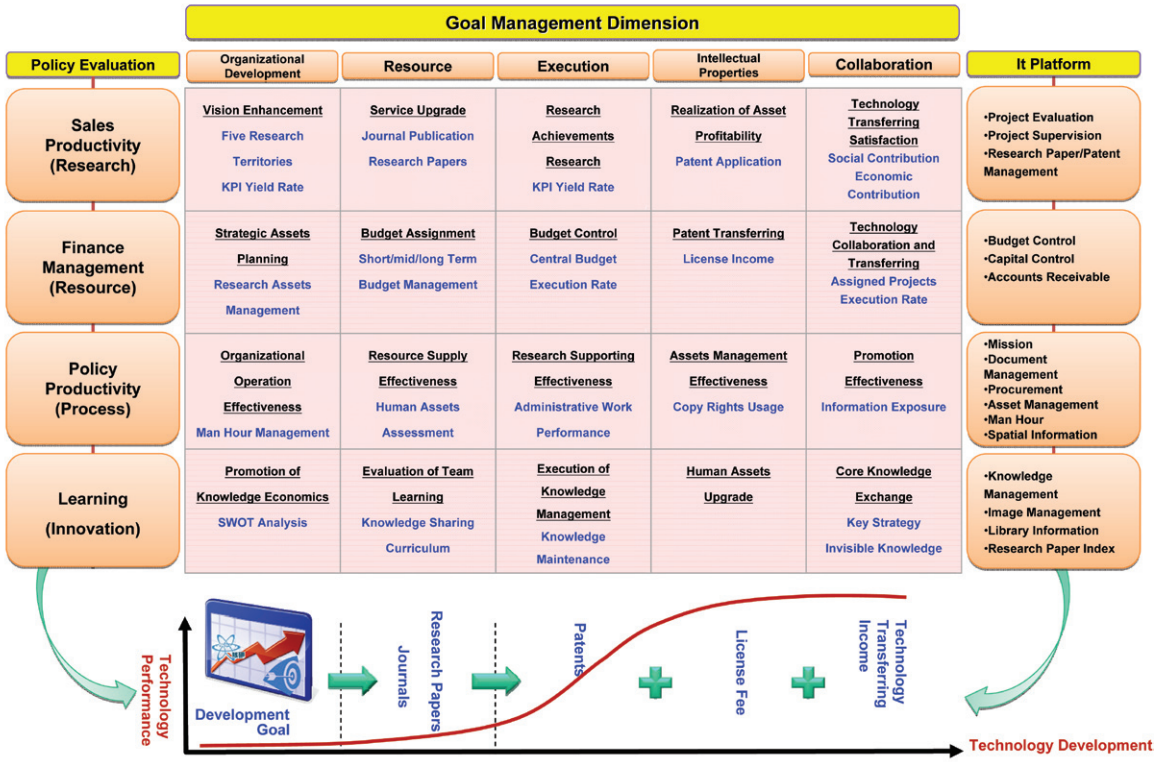


▲ Diagram 1. INER's Learning Organization Model Integrated with the Six Dimensions of Organizational Performance

For the implementation of the e-platform, INER adopted balanced scorecard as its core, and integrated with NSC's six major organizational dimensions and four major governmental evaluation dimensions, which identifies the connection of each dimension and analyzes data in real time. Diagram 2 shows the key performance indicator infrastructure of the policy that combines management goal, policy achievement and information platform. Diagram 3 goes one step further, representing each indicator in numerical value. Technology life cycles of five major indicators were indicated as the x-axis, to evaluate the outcomes of INER's on-going projects, and continues to breakthrough.



▲ Diagram 2. Computerization of Organization and Management of Key Performance



▲ Diagram 3. Management Dimension of Key Performance Indicators

3-2 The Process Development and ANDA Licensing of INER Sodium Fluoride [F-18] Injection

Jenn-Tzong Chen

INER has taken the opportunity of the shortage of Mo-99/Tc-99m generator due to the maintenance of the major nuclear reactor worldwide by developing new radiopharmaceuticals. The shortage of Mo-99/Tc-99m has caused the interests damage of patient for domestic bone tumor, myocardial imaging and thyroid disease. Developing new substitute radiopharmaceutical is instructed by Atomic Energy Council. The production process and licensing of alternative medicine, "INER Sodium Fluoride [F-18] injection", is needed for health care of domestic bone cancer patients.

The shortage of technetium-99m is a very important topic of discussion recent years, both in the International Symposium of Nuclear Medicine (ISNM) and in the International Isotope Symposium (IIS). Foreign governments have already done a lot of effort for this subject. In U.S, Sodium Fluoride [F-18] had been approved as an IND new drug by U.S. Food and Drug Administration (FDA) for bone imaging in 1972 (NDA 17-042). Now Sodium Fluoride [F-18] positron emission tomography imaging has been included in the insurance benefits coverage.

INER has completed Sodium Fluoride [F-18] production process development within three months, based on domestic targetry and the highest proton energy cyclotron in Taiwan. INER has prepared all the CMC documents for Sodium Fluoride [F-18] injection in accordance with the relevant provisions of the domestic drug inspection and registration in 2010. In 2011, the ANDA license of INER Sodium Fluoride has been granted by TFDA and it is the second new drug license for PET radiopharmaceuticals in Taiwan.

Positron emission tomography radiopharmaceutical is currently a fast growing R&D subject worldwide because of its high sensitivity, quantitative characteristic and functional imaging ability. These properties of PET are especially useful in tumor diagnosis, brain studies and cardiac imaging, which owns a unique position other techniques cannot replace. The new discovery of Sodium Fluoride [F-18] injection in Germany reveals it's great imaging potential for detecting coronary artery atherosclerosis in cardiac patients. The achievement of INER Sodium Fluoride [F-18] Injection is one of the major gifts for bone cancer and heart disease patients in the coming centennial of the Republic of China.

▲ INER Sodium Fluoride [F-18] Injection

▲ TFDA License (R000032)

3-3 Institute of Nuclear Energy Research Plan in Advanced Research Park at Chung-Hsin New Village

Chun-Lung Chang

Based on the "Planning Proposal of An Advanced Research Park in Chung-Hsin New Village" as approved per Executive Yuan 2009, the Institute of Nuclear Energy Research (INER) proposed to set up a "Low Carbon Energy R&D Center" in the park. The above proposal is to cope with the preliminary planning of Advanced Research Park/ Chung-Hsin New Village of the Council for Economic Planning and Development (CEPD), I-Taiwan 12 Projects, New High-Tech Industry Clusters Project in Central Taiwan, Six Emerging Green Energy Industry and Biotechnology Fields so as to build up basic R&D environment of green energy, bio-technology and low carbon industry.

The prospect is to drive up the development of the green energy and biological technology via forward-looking green energy and bio-technology research, taking the 3E issues of energy security, economic development and environmental protection into account.

"Low Carbon Energy R&D Center" shall take advantage of INER's expertise and R&D capability in integrating the forward-looking low carbon energy research which includes: wind power generation system, high-temperature solid oxide fuel cell hybrid system, photo-voltaic/thermal co-generation system, micro-grid technology, biomass power generation system, nuclear-grade component verification/certification technology, bio-refining technology and combined cooling heat and power system, etc., where the target is aimed at integrating researches of forward-looking low carbon energy and bio-technology so as to consolidate the regional sources of production, academy and research fields. Also, it will be able to promote the industrial innovation, upgrade the industry and create emerging industries via the platform of realizing technology into production.

The green buildings as planned by "Low Carbon Energy R&D Center" shall meet "EEWH" Taiwan golden grade standard in evaluation of green building. In the mean time, in order to lead the demand of upgrading industrial technology for Taiwan in future, INER developed and provided laboratories with high accuracy equipments and experimental environment for Taiwan industries in research collaboration.

The construction base of "Low Carbon Energy R&D Center" is located at the land No.17 of Chung-Hsin New Village, with capacity of 186 people (including 40 people from industry/academic). The project shall take 4 years in green building construction and equipment installation; the primary working tasks include:

1. Accomplish the design, commission, construction of the green building, personnel stationing, and the start of operation.
2. Accomplish the setup of high-speed broad band internet communication platform, provide remote video conference and professional services to the external, and provide fine digital learning environment to the internal personnel.
3. Accomplish the setup of core laboratory and provide high accuracy apparatus and equipments; proceed new energy research in collaboration;

INER has completed and sent the business plan to the Central Taiwan Science Park for approval, as well as sent construction proposal to Executive Yuan for approval. As INER will be merged into "Ministry of Economy & Energy Affairs" in near future, review inspection and discussion are in progress about the consistency between the orientation of the current planning and the strategic direction of "Ministry of Economy & Energy Affairs". INER will coordinate the prospect, and further seek the impelling direction in the future.

Geographical Location of Low Carbon Energy R&D Center

3-4 INER in the 2010 Taiwan Nano Exhibition

Shu-Pei Chiu

"Taiwan Nano Exhibition" was held in Taipei World Trade Center, Hall 1 from October 7 to 9, 2010. This exhibition supported by National Nanoscience and Nanotechnology Program was the only nanotechnology event in Taiwan this year. The main purpose of the exhibition was to offer the public a more profound understanding about the infinite potentials in the nano-world application which in turn stimulates more resources and dimensions of originality into the economy. There were six areas, 52 exhibitors and 245 booths in this exhibition, included energy and optoelectronics pavilion, government zone, nano life house, instruments zone, domestic exhibition zone and international exhibition zone. During the three exhibition days, 13,094 visitors gathered at Taipei World Trade Center to get information on latest developments in the field.

In this EXPO, the latest research results pertinent to the development and application of nanotechnology at INER were also presented. There were three topics in INER pavilion including nano-diagnostic radiopharmaceutical, nano-therapeutic drug and biological assay kit. Our exhibition included animation, light boxes, models, interactive games and posters. We used on-site explanation to let people easily and clearly understand how nanotechnology be applied diagnostic and therapeutic cancer drug. INER pavilion was one of the most popular areas of biomedical fields in this EXPO. Especially the animation and interactive games attracted the most attention. To further encourage participants, improving the exhibition with creative, aesthetic and interactive designs to attract more people and potential buyers to the festival, the organizer initiated the "Best Choice Award" contest this year. The visitors voted most advanced technologies or most outstanding exhibitor. INER pavilion won the "Best Choice Award" out of the exhibitions of all government entities.

It has been the eighth anniversary for Taiwan Nano Exhibition. And the annual event has evolved to be the best exhibition and networking platform for nanotechnology. Besides demonstrating routinely the substantial achievement of nanotechnology in Taiwan, it will also act as an international networking platform to provide the engaging opportunities among domestic and overseas R&D, and promote the cooperation opportunities. We deeply hope that nanotechnology applications will contribute more and more in health care and daily life.

▲ INER Pavilion

▲ Taiwan Nano Exhibition

▶ Best Choice Award

3-5 External Communication and Information Disclosure

Yung-Fu Hsu

Information transparency is one of INER's core value. INER concerns about its neighbors and strives to clarify any doubts regarding safety issue and at the same time publicizing the development of nuclear technology and its contribution to our daily life. Related tasks are categorized as following:

1. Communicating with its neighborhood

(1) Listening to neighbors: actually visit and understand the concern of its neighborhood regarding safety issue.

(2) Contributing to its neighborhood: sponsor local activities and low-income families.

(3) Sponsoring medical examinations.

(4) Technical tour for general public.

(5) Inviting the neighbors to participate in the sampling operation of the surroundings, calculating the impact of radiation to its neighborhood by radioactivity analysis and establishing accurate database based on the results of this operation.

2. Press Conference

To improve the effectiveness of communication, INER has held press conference under four guidelines:

(1) Reaching out to the people

(2) Sharing manifestable knowledge

(3) Publicizing vision

(4) Placating the anxiety

The following is the summary of the press conferences held in 2010:

Date	Title
02/08/2010	Three kinds of advanced plasma coating technology: high power pulse plasma coating, thick aluminum plasma coating, and roll-to-roll flexible transparent conductive film plasma coating.
05/18/2010	Identification and Analysis of Nuclear Medicine Laboratories of INER have become the first institute of nuclear medicine approved by the Department of Health as Good Laboratory Practice (GLP) for none-clinical trial medicine".
07/19/2010	INER has successfully manufactured a diagnosis drug (INER ECD KIT) for imaging blood flow in the brain.
10/05/2010	Under the cooperation with industry, INER has completed the first high-radiation zone nuclear pipeline welding to expedite domestic nuclear power plant maintenance and repair industries.
11/22/2010	INER's new cancer drugs of radiation treatment won the best choice award. Issued a press release that INER has successfully developed liver receptor contrast agent which can be applied to the diagnosis of residual liver function.

3. The Visiting of Distinguished Guests

To strengthen the cooperation with the governmental ministries and to increase the management capacity, INER continued expanding the cooperation network.

The followings are the seven visits by the distinguished guests in 2010:

Date	Title
01/05/2010	Director Chang-Jen Fee, Taiwan Power Company.
04/19/2010	Mr. San-Zhong Lin, vice minister of Economic Affairs, Mr. Chao-Yi Chen, Deputy chairman of State-owned Enterprise Commission, Mr. Hui-Ching Yeh, Chief of Energy Bureau, Ministry of Economic Affairs.
06/09/2010	Arnaud LALO (Scientific Attaché), Frederic Moser (Deputy Scientific Attaché), Odile HUANG (Section Chief).
08/11/2010	Mr. Joseph J. Krol, Assistant Commissioner, Nuclear Security Bureau, United States Department of Energy.
08/20/2010	Lt. General Lee and staff, Military Police Command, Department of Defense.
09/10/2010	Mr. Yi-Shi Lin, CEO of Incumbent Party Policy Committee, VIPs of Bank Management Committee and Think Tank.
11/23/2010	Mr. Yun-Ming Wang, vice chief of Energy Bureau, Ministry of Economic Affairs.

4. Seminars & Exhibitions

INER held 10 large-scale seminars and meetings in 2010 in the fields of nuclear safty, nuclear medicine and energy, etc. INER also participated in 7 exhibitions in the fields of nanotechnology, energy and environmental protection to promote technology exchange and knowledge sharing.

The followings are the seminar & exhibition held in 2010:

a. Seminar & Meeting

(1) Seminar on Cross-Strait Nuclear Power Plant Technology
(2) Seminar on Geological Carbon Dioxide Sequestration Technology
(3) Seminar on Radioactive Waste Disposal Technology
(4) Seminar on the Authentication of Key Components and Suppliers of Nuclear Energy
(5) Molecular Imaging of Brain Central Nervous System
(6) Drug Quality and Analysis Seminar
(7) 2010 Seminar on Ionizing Radiation Measurements Proficiency Test
(8) 2010 International Conference on Radiation Dose and Safty
(9) 2010 Joint Symposium of the AEC Contracted-out Research Program and the AEC-NSC Mutual-Fund Sponsored Research Program
(10) 2010 Cross-Strait Seminar on Digital Instrumentation and Control System

b. Exhibition

(1) 2010 Taiwan's Health Month- International Medical Cosmetics and Travel Exposition of Organic LOHAS
(2) 2010 Taipei Int'l Show of Environmental Protection and Energy
(3) 2010 Taipei International Invention Show and Technomart
(4) 2010 Taiwan Nano Exhibition
(5) 2010 Taiwan International Green Industry Show
(6) 2010 The Carnival for the New Ideas of Safe consumption and Consumer Protection
(7) 2010 Taiwan International Solar Photovoltaic Forum & Exhibition

5. Reception for General Public

In 2010, there were 60 receptions for general public to promote governmental technology policy and INER's achievements in R&D so that the general public has the opportunity to understand the application of atomic science and technology and the status of low-carbon energy development.

4 Current Major R&D Activities

1. Nuclear Safety Regulatory Technologies

Shiun-Jyh Chang

In parallel with technical advancements, NPP (Nuclear Power Plant) reliability and performance in recent years have been significantly improved. It follows that regulatory technologies and tools for nuclear and radiation safety bound to be advanced in correspondence with the accumulation of related experiences. As such, this Program aims to meet AEC (Atomic Energy Council) regulatory requirements, seeks reference on the current status and trends of international nuclear regulation developments, as well as takes full consideration of domestic situations, in developing regulatory technologies and tools in need. The Program composes three Sub-programs and their main achievement in year 2010 is summarized as follows:

1. Nuclear Safety Regulatory Technology Development:

In order to perform the reevaluation of the seismic safety of existing nuclear power plant (NPP), the seismic PRA Standard (draft) is completed. In addition, the prototype of risk significance determination tool for seismic and typhoon evaluation based on the Kuosheng NPP model has been established. For the instrumentation and control (I&C) related regulatory study, an analysis system is developed to observe and to analyze the operators' behavior under digitalized human system interfaces. For the safety evaluation of NPP system, the TRACE Model for Manahan NPP is established. It can be used to perform the transient analysis, and the results can be provided to the NPP and to the regulatory body for reference.

In the area of technical support to the AEC, we work with AEC to complete the composition of the Safety Evaluation Report (SER) after all the reviewing works of the Lungmen Final Safety Analysis Report (FSAR). For the study of stress corrosion cracking (SCC) behavior on the dissimilar metal (DM) weldments, Alloy52-A 508 effects of post weld heat treatments and specimen sizes on the SCC growth rates of DM welds were evaluated under a simulated BWR coolant condition. The crack growth rate for the DM weld with heat treatment at the temperature 621°C for 8h then at 400°C for 200h was observed to be slower than those of the as-welded depending.

2. Development of Technical Tools in Support of Emergency Preparedness and Radiation Dosage Evaluation:

With respect to the Emergency Response Support System (ERSS), the connection program between Chinshan NPP ERSS and MAAP data bank is established. It can provide the whole plant system diagram and display the accident status.

In dose evaluation and investigation for proton therapy facility, the FLUKA has been used to establish the neutron shielding database. The database can be used for estimating neutron doses outside the concrete shielding accurately. For radiation Protection Quality assurance and detectors verification technology establishment, a discarded Co-60 source together with INER's patented technique to accomplish a radiation system that meets ISO-4037 criteria. Also INER-developed measuring equipment was used to establish the computed tomography (CT) X-ray dose calibration system that fits the IEC-61267(2005) criteria and to reduce the unnecessary radiation exposure of patient.

3. Development of Radioactive Waste Management Technology:

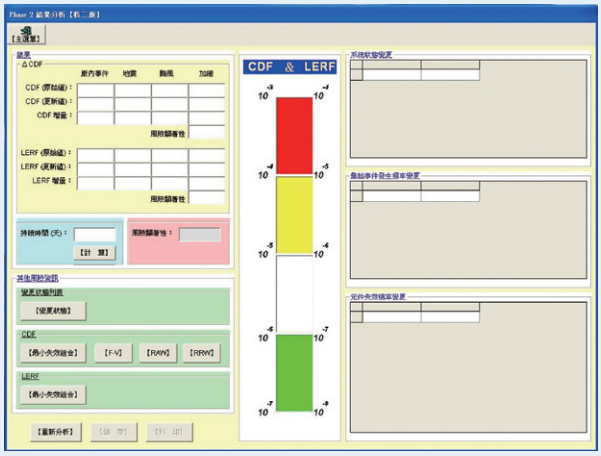
There are about 10,000 drums of very low activity waste insulators stored in nuclear facility. Most of them can reach clearance level through surface decontamination process or be treated by the combined thermal and compressive processes to achieve the goal of amount reduction. For the performance assessment of low-level radioactive waste repository, the differences between the Andrews Repository in USA and the DGR Repository in Canada have been evaluated. It would be very helpful for the establishment of domestic guidelines. For the low-level waste repository data base guideline, by way of the cloud computing concept and the Service-oriented Architecture (SOA), an overall radioactive waste package record management system, has been proposed.

1–1 Development of Risk-Informed Inspection Tools and Study on the Seismic Regulation

Jyh-Der Lin

The operational performance of nuclear power plant can be significantly enhanced through various risk-informed applications. The success of a risk-informed application is dependent on the correct use of the associated probabilistic risk assessment models. The development of PRA standard is one of the major regulatory approaches of the USNRC to ensure the technical adequacy of PRA models in various risk-informed applications. Based on the PRA standard, the associated peer review is performed to validate that the PRA is of necessary quality. This project introduces the associated standards for seismic PRA and seismic margin assessment. The standard, comprising seismic margin assessment, probabilistic seismic hazard analysis, plant response assessment and seismic fragility evaluation, characterizes the evaluation process of PRA application to verify whether the capabilities of PRA elements are sufficient to support the decision making. The capabilities of PRA elements are expressed in terms of capability categories which represent their levels of compliance with different quality requirements. This project is focused on the seismic events PRA model which is of highly importance for the vulnerable geological environment of Taiwan. This effort is one of the attempts to systematically introduce the PRA standards for different hazard groups for domestic applications.

The project also develops a prototype of risk significance determination tool for external events. This tool will be used by the inspectors in their assessment of risk implication of seismic and typhoon related inspection findings. The project has completed the prototype for seismic and typhoon based on Kuosheng nuclear power plant model. It can be provided for regulatory use after the verification and validation process was completed. It also helps to extend the inspection scope for the inspectors.



▲ Results from the Inspection Findings Evaluation

1-2 A Study on Software/Hardware Design of Instrumentation and Control (I&C) Modernization Related Regulatory Issues

Tsung-Chieh Cheng

A Human/Machine interface observation/analysis of the digital I&C system has been established in this year. The major objectives are to: (1) observe the operators' behavior on manipulating the digital I&C system, (2) enhance the research capability on detecting the digital I&C system vulnerability by data collection and analysis.

For example, the influences of computer-based procedures on team communication and performance, and a strategy for long-term monitoring of operator ability to reliably perform the manual operator actions credited in a D3 analysis have been studied by the digital I&C system Human/Machine interface observation/analysis system in this year. Furthermore, the relationship between human-systems interfaces automation and operating workload is evaluated by principles of human factors engineering and the established system to strengthen the delectability for digital I&C system vulnerability.

The future works will focus on (1) the construction and /or replacement of NPP digital I&C system, (2) interim staff guidance (ISG) related regulatory issues, and (3) other important human/machine interface issues, which include:

(1) Influences of computerized procedures on team performance;
(2) Visual influences of the Video Display Unit (VDU) design in the main control room;
(3) Staffing and job design of the construction and/or replacement of modern main control room;
(4) Tradeoff analysis of operators' vigilance and workload;
(5) Communication behaviors and team mental models.

These issues are also concerned by the Halden Reactor Project (HRP) of OECD Nuclear Energy Agency. Thus, this study will cooperate with international organizations to work together and make every endeavor in the future.

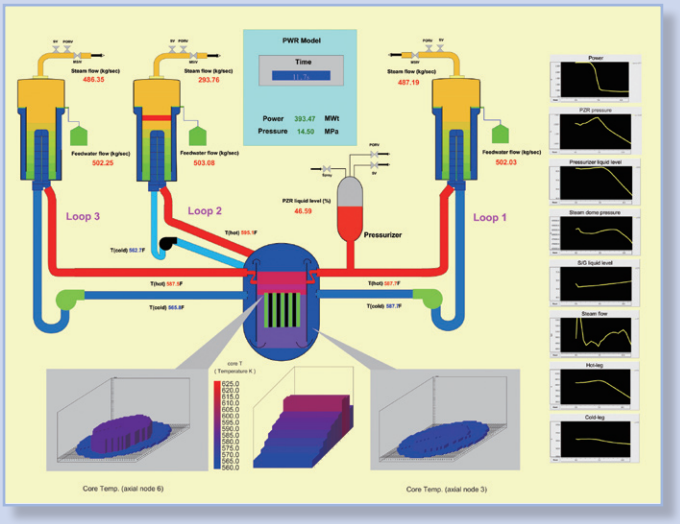
▲ Experimenters' Platform

▲ Simulator and Data Recorder

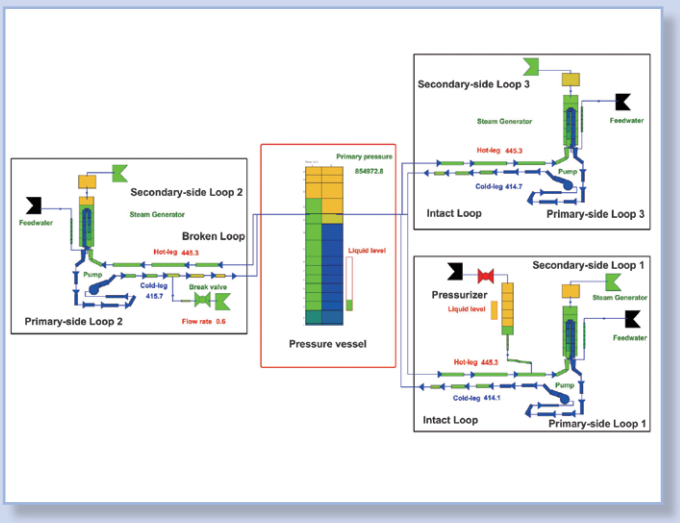
1-3 Research and Applications of NPP Safety Analysis Code - TRACE

Jong-Rong Wang

Taiwan has joined an international collaborative project of the Code Applications and Maintenance Program (CAMP) since 2004. The project focuses on developing a new-generation thermal-hydraulic system analysis program, TRACE, and Taiwan's responsibility is to apply TRACE code and to provide users' experiences and code assessment reports. INER is the organization responsible for TRACE research in Taiwan. To fulfill the above responsibility, INER exploits TRACE to establish and assess models. One object of this sub-project, a part of the whole TRACE project, is to establish the TRACE model of Maanshan nuclear power plant using startup tests and FSAR data for model assessment and verification. Figure shows the animation layout of TRACE model of Maanshan nuclear power plant containing a RPV, a pressurizer and three steam generators. Another object is to establish the TRACE model of IIST (Institute of Nuclear Energy Research Integral System Test) which was a reduced-scale experimental facility formerly located in INER. It has performed many different kinds of experiments with complete experimental data. After the IIST TRACE model was established, the experimental data was used for model assessment and verification. Figure shows the animation layout of TRACE model of IIST facility. The results of Maanshan TRACE model and IIST TRACE model show that the TRACE predictions are comparable to startup test data, FSAR data and experimental data. The results of this study were presented in USNRC NUREG-IA reports, SCI papers, and international conference papers. Besides, the following benefits could be obtained: (1) Maanshan TRACE model can be used to perform the transient analysis, and the results can be provided to the plant and to the regulatory body for reference, (2) the experiences of this model development could be a basis on which the TRACE models of Chinshan, Kuosheng, and Lungmen nuclear power plants are developed, and (3) during TRACE model development, the people with the use capability of TRACE could be trained. When TRACE is well-developed in the future, there would be related people available to catch up with the global trend of using TRACE.



▲ Animation layout of Maanshan TRACE model.



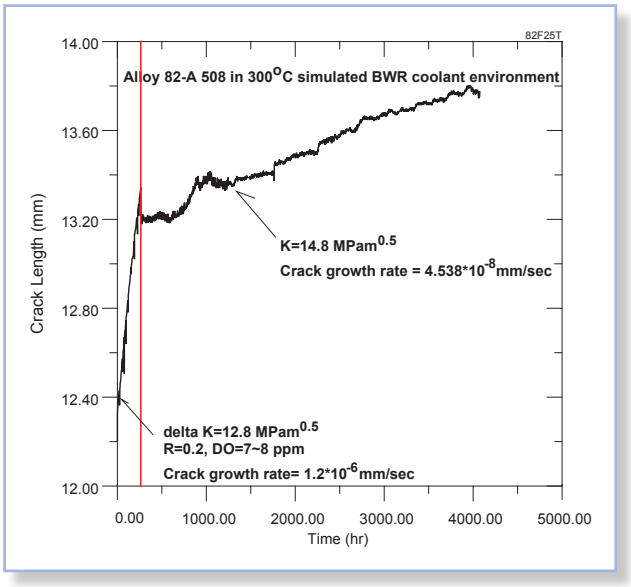
▲ Animation layout of IIST TRACE model.

1-4 Stress Corrosion Cracking Behavior of Dissimilar Metal Weldments in High Temperature Water Environment

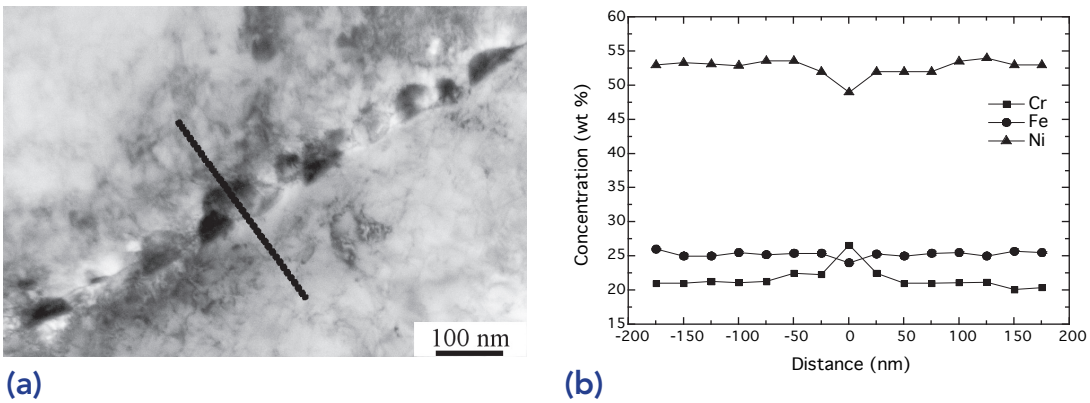
Jiunn-Yuan Huang

Alloy 82/182 has been used as a filler metal to join the low alloy steel reactor vessel nozzle and the austenitic stainless steel coolant piping and other dissimilar metal (DM) weldments of the reactor coolant pressure boundary. Incidences of stress corrosion cracking (SCC) of Alloy 182 weld in both Boiling Water Reactors (BWRs) and Pressurized Water Reactors (PWRs) have been reported since the 1970s. Recently, Alloy 52/152, which has a higher chromium content than Alloy 82/182, has been used to repair the defected Control Rod Drive Mechanism (CRDM)/thermocouple penetration nozzles, Pressurizer (PZR) nozzles and hot leg nozzles, etc. because of its superior SCC resistance. The DM weldments of recirculation nozzle and hot-leg nozzle, etc. are the immediate periphery of the pressure vessel. Therefore, the degradation of the DM weldments is considered to be a great concern to the integrity of the reactor pressure vessel. SCC and corrosion fatigue (CF) are the main mechanisms responsible for the degradation of the DM weldments exposed to reactor coolant environments. The initiation of stress corrosion cracking and corrosion fatigue behaviors of Alloy 52/152/82 welds in high-temperature water environments were investigated in last annual report. The stress corrosion cracking behavior of dissimilar metal welds, including Alloy 52-A 508 and Alloy 82-A508, under a simulated BWR coolant condition was studied in this report. Effects of postweld heat treatments and specimen sizes on the SCC growth rates of DM welds were evaluated.

The crack growth rate for the DM weld heat treated at 621°C for 24 hrs was observed to be faster than those of the as-welded. But the DM weld heat treated at 621°C for 8 hrs and 400°C for 200 hrs shows the better SCC resistance than those of the as-welded. The longer the heat treatment at 621°C, the higher the chromium carbides density along the grain boundary was observed. The SCC growth rate of the 1/2 TCT specimen is faster than those of 1TCT specimen. It could be accounted for by the fact that the thinner specimen has the shorter distance for oxygen ions to diffuse to the crack tip.



Environmentally-assisted Cracking Growth Rates for the As-welded Dissimilar Metal Weld, Alloy 82-A508, in 300°C Oxygenated Water Environment.



▲ (a) TEM Microstructure and (b) Composition Profile Across the Grain Boundary of the As-welded DM, Alloy 52-A508, Sampled from the Bottom of the Weld Near the Fusion Line.

1-5 Technical Support to Outage and Construction Inspection of Nuclear Power Plants and Evaluation of Nuclear Safety Reports

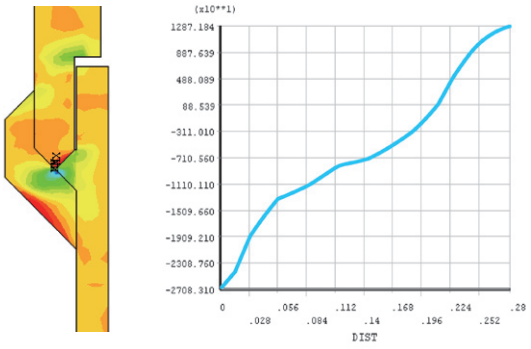
Ren-Jai Liao

One of the important achievements of this project is to provide a fully support to Atomic Energy Council (AEC) for performing technical review of the Lungmen Final Safety Analysis Report (FSAR) which includes 15 chapters and 4 appendixes. During the four stages of reviewing, we raised 298 questions, reviewed the related responses from Taiwan Power Company (TPC) and conducted on-site verifications with AEC staffs. In order to provide a rigorous regulation on the safety of plant construction and enhance the stability of future operation, we work with AEC to complete the composition of the Safety Evaluation Report (SER) after all the reviewing works.

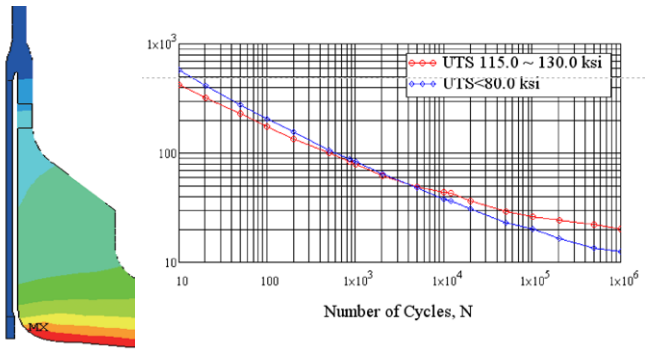
In addition, we assist AEC in the outage inspections of the three operating nuclear power plants and have found out problems such as shortcomings of maintenance activities, mistakes in maintenance procedures, qualification concerns of the workers, as well as the lack of calibration of the measuring tools, etc. These findings will also provide a more rigorous and efficient regulation on the later outage activities of the operating plants. The finished inspection reports can serve the purpose of experience feedback to enhance the knowledge basis of our new inspectors to come.

The other important works include Lungmen routine inspection, evaluation of nuclear safety information reports, update of nuclear safety information data base and review of nuclear safety reports for license renew, etc. They are summarized as follows:

Supporting items	Supporting achievements
Outage inspection	Support 3 times of outage inspection
Evaluation of nuclear safety information reports	Complete 10 safety information reports
Update of nuclear safety information data base	Update of 4 quarters of nuclear safety information data base
Routine inspection of Lungmen nuclear power plant	Support 38th, 39th, 40th routine inspection
Review of safety analysis report of Chinsan nuclear power plant for license renew	Complete the review of 6 auxiliary systems, 5 aging management plans, time-limited aging analysis
Establishment of the capability of evaluating the aging of mechanical and structural components of nuclear power plant	Complete the residual stress analysis of socket weld for nuclear piping system (fig. 1) and develop the fatigue analysis tools for metal component (fig. 2)



▲ Fig1. Residual Stress Analysis of Socket Weld for Nuclear Piping System



▲ Fig2. Fatigue Analysis of Metal Component

1-6 Radiation Safety Inspection for Radioactive Materials

Yung-Muh Yang

Radioactive materials and radiation facilities capable of producing ionizing radiation have been widely used by government-owned entities, private organizations and academic institutes in fields of agriculture, industry, medical diagnosis and treatment. With the enactment of "Ionizing Radiation Protection Act," the management of related affairs has been added with penalty besides advice-giving. The Competent Authority (Atomic Energy Council, AEC) which has been devoted into management, protection, control and inspections of various radiation safety for protection of radiation facilities, radiation workers and the general public becomes more prudent and careful to avoid any unnecessary exposure from radiation.

The amounts of radiation safety inspections in 2010 are as follows.

Items	Facility No.	Completed
1. Non Medical Radiation Source Inspections	28	28
2. Medical Ionizing Equipment Inspections	409	409
3. Medical Exposure Quality Inspections	62	62
4. Radiation Contamination Building Inspections	2	2
5. Radiation Contamination Building Improvements	2	2

The abnormalities that have been reported included 47 cases of abnormal radiation materials, two cases of rejected delivery, 6 cases of pending receiving and 58 cases of completed analysis. For the failures, analyses and advice for reference for future inspections had been provided in order to meet the requirement of regulations for radiation safety of operation facilities, workers and the members of the public.

Besides, in response to domestic issues of nuclear power plant units expansion in the future, the following researches have been completed in 2010 including establishment of the standard assessment procedures of radioactive source term and atmospheric transport and dispersion models of gaseous effluent for Light-Water-Cooled Reactors as well as development of the applicable standards compliant with ICRP-60 criteria.

▲ Radiation Safety Inspection for Radioactive Materials

▲ Radiation Safety Inspection for Radioactive Materials

1-7 Establishment and Applications of the Radiation Safety Analysis Techniques for Advanced Boiling Water Reactor of the Lungmen Nuclear Power Plant

Shu-Jun,Lin Chang, Chun-Cheng, Ju-Chuan Huang

In response to the review comments of Atomic Energy Council (AEC) for the projects "The Evaluation Report of the Exclusion Area Boundary and Low Population Zone of Lungmen Nuclear Power Plant" and "The Final Safety Analysis Report (FSAR)", Taiwan Power Company (TPC) has entrusted the Health Physics Division at Institute of Nuclear Energy Research (HPD, INER) to provide an objective assistance in clarifying the AEC's review comments as well as in verifying the rationality for the radiation shielding design and dose analysis of the Lungmen Nuclear Power Plant (NPP).

Through the service, the HPD not only has reviewed the vendor's reports associated with the shielding design of the Lungmen NPP and its dose analysis results, but has independently developed the technique for evaluating radiation shielding design for a NPP and its consequent radiological impacts, for strengthening the native technology in this field.

This implementation of this project has two aspects: one is about the radiation shielding evaluation, and the other one is about the environmental impacts analysis. In the aspect of radiation shielding, the HPD has established the radiation safety analysis technology of the Turbine Building (TB) and Radwaste Building (RB). In order to ensure the radiation safety of the staff and public, the HPD also associates TPC to improve NPP's shielding design and design changes proposed. In the aspect of environment, there are two sides that we have to concern. One is accident analysis, the HPD consider that the topographical characteristics of the Lungmen NPP to evaluate the radiation dose of the Exclusion Area Boundary (EAB) and Low Population Zone (LPZ) which are caused by the exposure to the released radioactive materials from the potential design basis accidents. Thus further, the project associates TPC to get approval of the AEC's review comments. The other one is the routine analysis that HPD evaluates the impact of environmental dose about releases of radioactive gaseous/liquid form routine operation of nuclear facilities by update meteorological data and usage factor. This analysis not only establishes the native parallel verification for environmental dose of the NPP, but associates TPC to clarify the misgivings about the vender's analysis report that AEC concerned.

▲ The Aero View of the Turbine Building of the Lungmen Nuclear Power Plant

▲ The Aero View of the Lungmen Nuclear Power Plant

1-8 Seed Instructors Training for Radiological Emergency Response

Chao-Hui Huang

Since more and more radiation applications have been practiced, the government included the solution of radiological disaster prevention and protection in the basic plan for disaster prevention and protection in 2007 to accomplish the goal of building national all-hazard prevention and protection systems. According to the Disaster Prevention and Protection Act enacted in August 2010, the important tasks and operations to be conducted before, during, and after disaster by each responsible department are clearly stated based on the government's three-level hierarchy (central administration, municipal, county(city) governments) vertical job assignment as well as the prevention and protection systems of each organization. However, local governments' first responders of emergency response are not familiar with radiological emergency awareness and related judgment. They usually lack of the experience of using radiation detectors and the skills of fundamental detection. With the specialty of radiation techniques, the Institute of Nuclear Energy Research (INER) aggressively involved in the trainings and exercises of seed instructors for radiological emergency response to promote the ability and awareness of emergency response of Taiwan's first responders.

In 2010, the Atomic Energy Council (AEC) specially invited the specialists of the National Nuclear Security Administration (NNSA) of Department of Energy (DOE) of the U.S.A. to Taiwan to lecture on related topics through civil nuclear cooperation of both sides. With the abundant practical experiences of the USA trainers and the complementary interpretation of INER's Health Physics personnel, the trainees learned essentials of radiation and built up the skills of detection and identification. This training aimed to help local governments cultivate seed instructors for first line responders to promote their ability of handling emergency and fulfill the goal of radiological disaster prevention and protection as well as maintain the radiation protection and safety of the personnel. The training contents included lectures on basic radiation concepts, radiation protection measures, introductions to radionuclides and radioactive materials, personal protection and equipment, job planning, applications of detectors, hands-on exercises of detection and surveillance, practice of identification demonstration. Thirty trainees from various organizations attended in this training course.

Organization	Attendant(s)	Organization	Attendant(s)	Organization	Attendant(s)
National Police Agency	1	Taipei City	3	Chiayi County	1
National Fire Agency	1	Taipei County	3	Chiayi City	1
Army Command Headquarters	2	Taoyuan County	2	Tainan City	1
Institute of Nuclear Energy Research	1	Hsinchu County	1	Tainan County	1
Fuel Cycle and Materials Administration	1	Hsinchu City	1	Kaohsiung City	2
Radiation Monitoring Center	1	Taichung City	2	Kaohsiung County	1
Department of Nuclear Technology	1	Taichung County	1	Pingtung County	2

▲ Admiral Joseph J. Krol (NNSA) and Dr. Bor-Jing Chang (INER) Both Chaired the Ending Ceremony

▲ Introducing Detectors, Hands-on Detection Exercises for Surveillance Scenarios

▲ Group Picture of all the Trainers and Trainees

1-9 Establishment of Emergency Response Supporting System (ERSS) – A Useful and Effective Tool for Managing Severe Accidents

Wen-Shing Wang, Yu-Wen Wang

Considering if a severe accident occurs in a nuclear power plant that the core may melt and thus the fission products may be released, even the well-trained personnel of an accident management team would be under great pressure. Therefore, during an accident, it will be definitely very helpful for the quality and the reliability of emergency response if there is an additional supporting system. The

supporting system can help the personnel of the accident management team in a limited time to judge the cause, attribution, core status, radioactivity releases, and integrity of the containment, besides the existing emergency response system.

The current work demonstrates the Lungmen emergency response support system (ERSS) developed by INER which will be provided for the use of nuclear regulatory agency. The current ERSS can simulate the progress of various severe accidents occurring in the Lungmen nuclear power plant, including the phenomena of core meltdown and radioactivity release. Applying computational technologies, the monotonic textual information, as well as the decision process of accident management, has been shown in a dynamic graphing way. The Lungmen ERSS contains the subsystems of plant status display system, accident diagnosis system, accident predication system, accident management monitoring system, and accident assessment database. Through the Lungmen ERSS, various primary operational information can be monitored in a real-time mode. The ERSS will automatically display alarm signals when the abnormal operational information is shown. Additionally, the accident evaluators can identify accident attributes, rebuild accident conditions, measure core damages, monitor the progress of accident management, predict the accident evolutions and time needed, as well as estimate more accurate radioactive source terms. By the use of the ERSS, the accident evaluators can provide more accurate information for decision-making. Actually, this ERSS has been successfully applied in the nuclear emergency exercise implemented in 2010 with satisfactory performance.

Main Frame and Structures of Emergency Response Support System (ERSS)

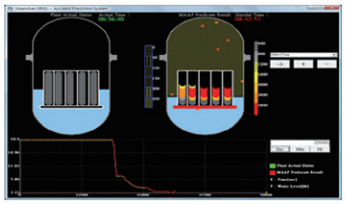
Parameter File From MAAP5

Exercise

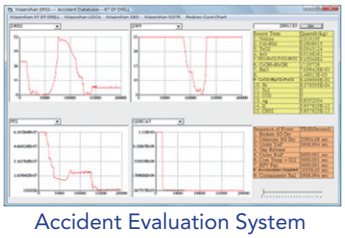
Actural Plant Parameter

Emergency Response Support System

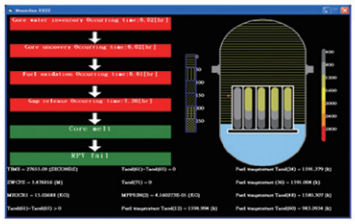
Accident Status Display System



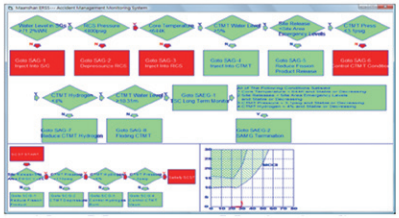
Accident Prediction System



Accident Evaluation System



Accident Diagnostic System



Accident Management Monitoring System

1-10 Radiation Protection Quality Assurance and Detectors Verification Technology Establishment

Jeng-Hung Lee, Shi-Hwa Su, Tzeng-Te Huang and Chin-Hsien Yeh

To fulfill the competent authority's needs for medical exposures quality assurance, radiation protection and control, INER developed related radiation dose calibration systems and evaluation technologies. INER also established the radiation detectors testing techniques and the verification platform which meet the international standards. The tasks concretely accomplished in 2010 are:

(1) Used a Co-60 source that had been discarded, together with INER's patented technique (Irradiating apparatus with attenuating medium, R.O.C. Patent No.I-302325) to turn this discarded source to a mandatory calibration and irradiation system that meets ISO-4037 criteria. It brought the effects of multi-strength sources by just using one single-source and it saved the time and costs required by oversea purchasing of sources and irradiation equipment. This irradiation instrument was to be installed at INER's Radiation Instrument Calibration Laboratory to be practically used in operations of instrument calibration and performance testing to effectively enlarge the capacity of the secondary instrument calibration laboratory and uplift calibration accuracy.

(2) Used the INER-developed measuring equipment to establish the computed tomography (CT) X-ray dose calibration system that fits the IEC 61267 (2005) criteria and the calibration technique for CT radiation dose measuring instrument to enable domestic hospitals having both quality images and reasonable diagnostic doses. That was to fulfill the policy of the Atomic Energy Council (AEC) of gradually moving the CT medical exposure quality assurance program to reduce the unnecessary radiation exposures of patient and to effectively secure the quality of CT Diagnosis received by 1.3 million person/year in Taiwan.

(3) Based on the requirements of ANSI/IEEE N42.17A (2003) and N42.20 (2003) for radiation response and mechanical performance testing of portable radiation instruments and active personnel radiation monitors, INER established the verification equipments and verification techniques for instrument performance tests that meet with the international criteria. INER also carried out on-site performance tests for contamination monitors, dose-rate survey meters, and electronic personal dosimeters. With these accomplishments, INER is to promote the performance and measurement accuracy of nuclear instrument manufactured in Taiwan, assist the competent authority with radiation control and secure the safety of the public and all the radiation workers.

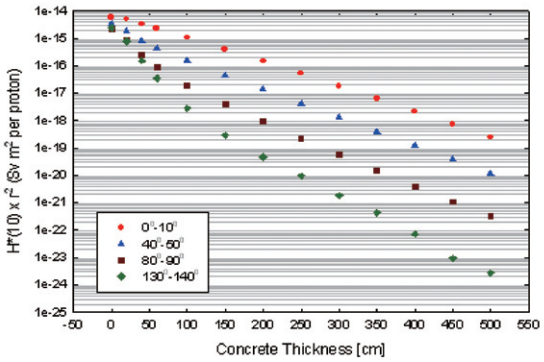
▲ Irradiating Apparatus with Attenuating Medium Using a Discarded Co-60 Source

▲ On-site Performance Tests for Radiation Detectors

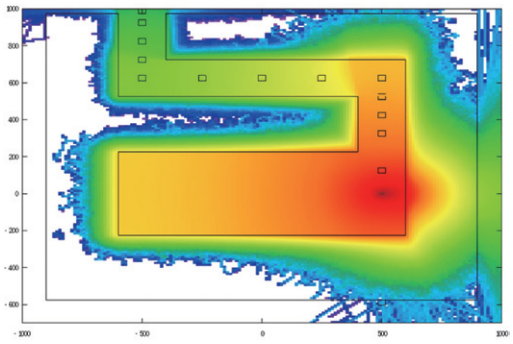
1-11 Dose Evaluation and Investigation for Proton Therapy Facility

Chih-Ming Chou

Proton therapy is one of the most effective tools treating cancers. Proton therapy can kill cancer cells precisely and in the meanwhile reduce radiation damage to normal tissues. Therefore, it is expected that proton therapy facilities will be introduced into some domestic hospitals in the near future. The proton energy used in clinical treatment is much higher than the electron energy produced by conventional medical accelerators, so the effects of secondary particles such as neutrons, photons and electrons, etc., resulting from collision of protons with accelerator components should be considered for shielding design. Among them, neutrons are considered the most important radiation source in shielding design of a proton accelerator since they contribute the most doses. So far, there is still no domestic experience on radiation shielding analysis of a proton therapy facility, the INER has introduced two Monte Carlo codes, the FLUKA and the PHITS, into our country by referring to the international literatures. The two codes are used to simulate different kinds of cases in the shielding design of proton facilities. The consequences are compared with those calculated by the quasi-empirical formula and with the analytical method, in order to establish the ability of our own for the Monte Carlo technology associated with the shielding design of proton facilities. In this project, the FLUKA has also been used to establish the neutron shielding database. In the establishment, a large amount of neutrons are originated by simulating the collision of protons of 250 MeV (commonly used in clinical treatment) with different materials of the accelerator components, and bombarded on three target materials, i.e. Fe, Cu and human tissue equivalent. The database can be used for estimating neutron doses outside the concrete shielding accurately, combining with the quasi-empirical formula recommended by the NCRP-144. It is expected that the development of this project can be applied to assist the competent authority in reviewing shielding design analysis related to proton therapy facilities, for the purpose of protecting radiation safety of the hospital staff members and patients.



▲ Attenuation Curve of Total Dose Equivalent in Concrete for 250 MeV Protons Impinging on an Iron Target

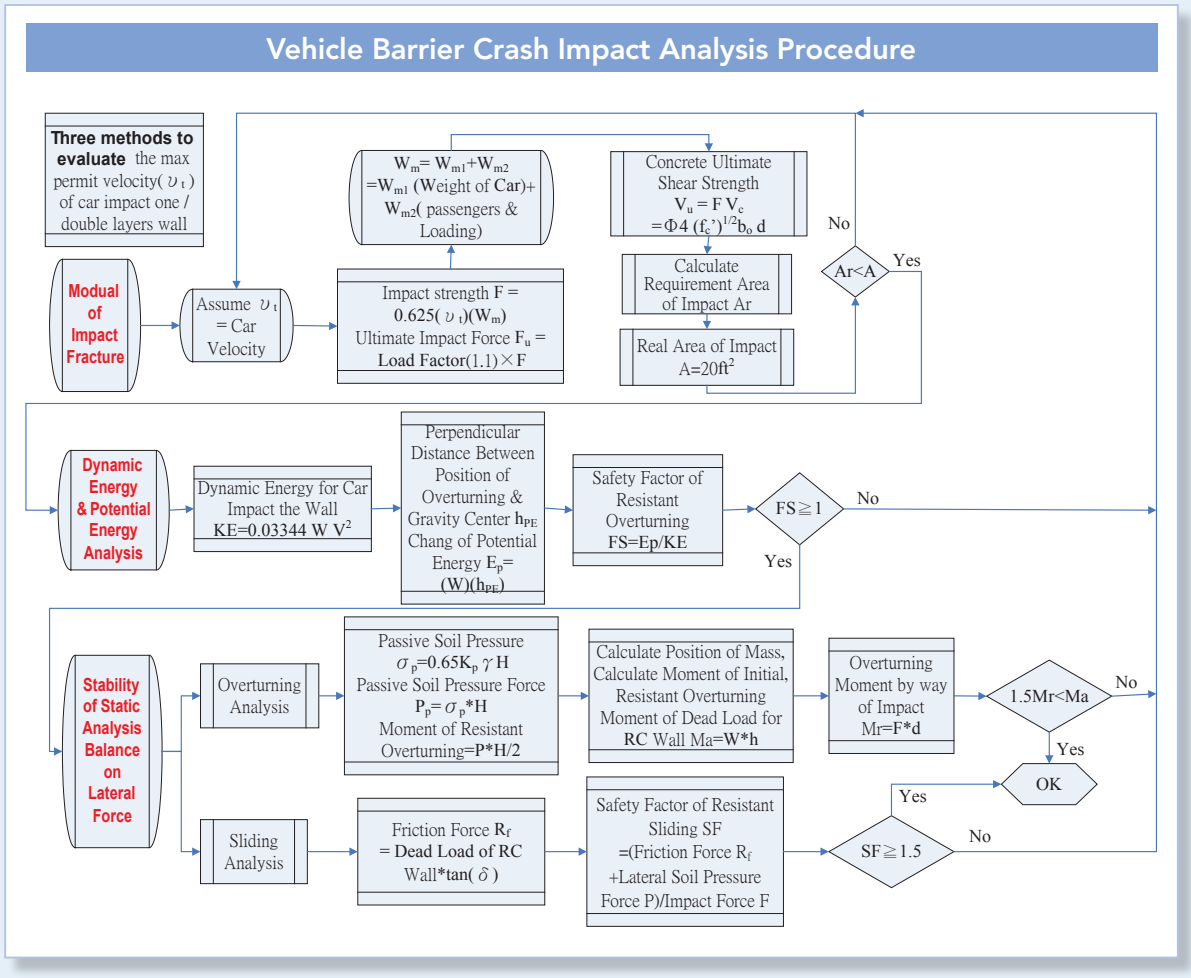


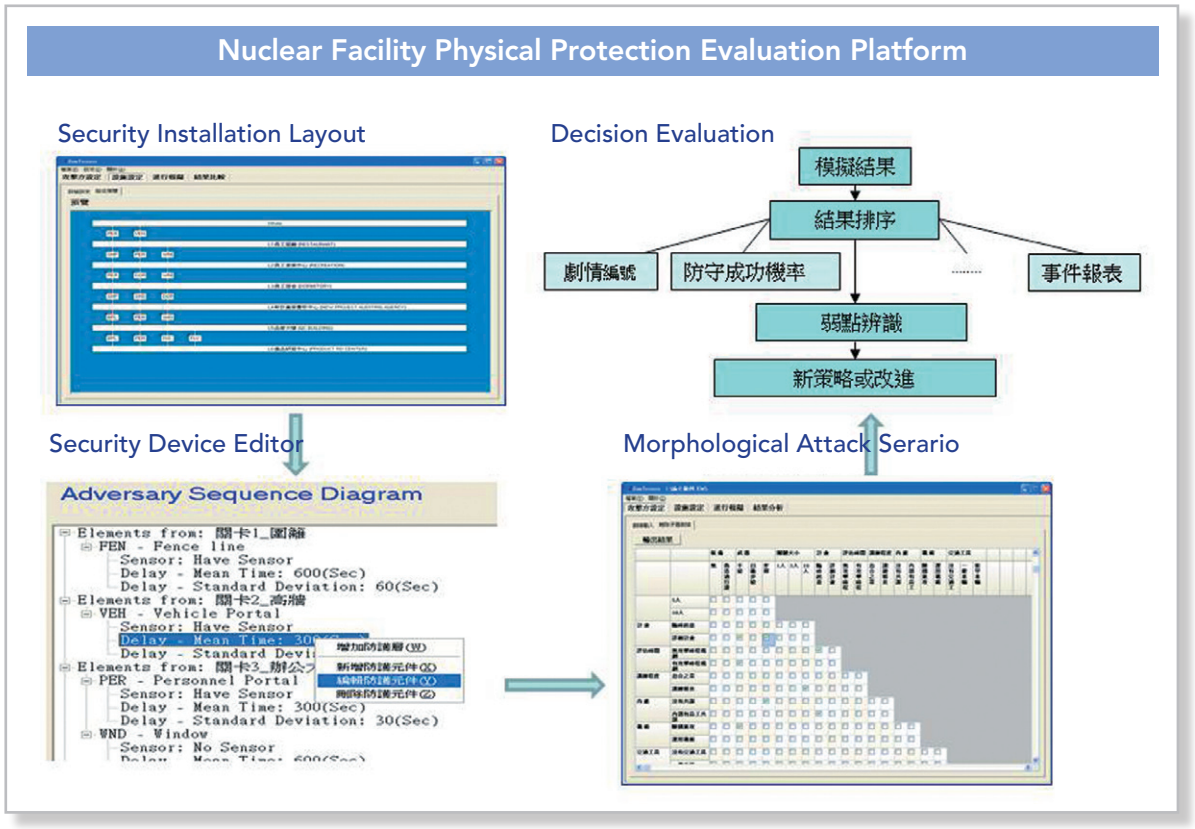
▲ The Neutron Dose Distribution for a Typical Concrete Shielding

1-12 Nuclear Facility Physical Protection and Vehicle Barrier Evaluation Methods

Wu-Yueh Cheng, Tung-Liang Chu

A nuclear facility physical protection evaluation platform consisting of the following 4 main functions was established: security system layout, security equipment attribute editor, morphological attack scenario generation, and security decision management. Besides the above, the vehicle barrier crash impact analysis was created and included (1) Impact Fracture, (2) Dynamic Energy & Potential Energy Analysis, (3) Stability of Static Analysis Balance on Lateral Force. These quantitative evaluation methodologies also can be applied in other domestic critical infrastructure.





1-13 Treatment Technology Assessment of NPP Waste Perlite

Yu Chao, Kin-Seng Sun, Hsien-Ming Hsiao, Yen-Hua Chang

This project has developed a surface decontamination process and has improved the conventional compression process for the treatment of waste perlite.

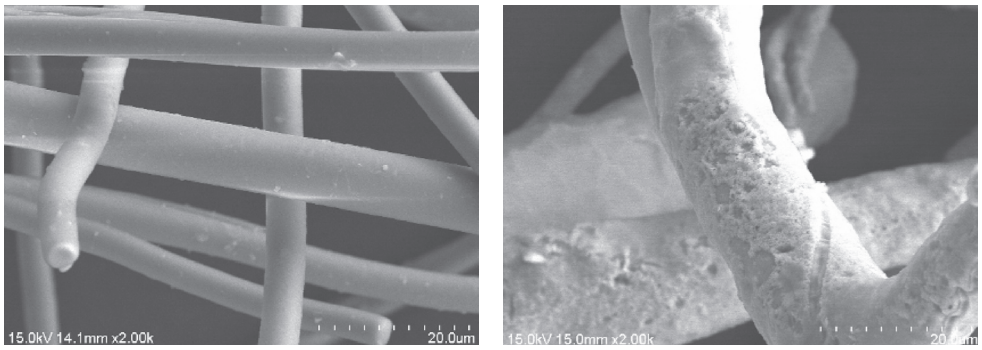
Waste perlite was immersed in several kinds of acidic or basic solution, followed by ultrasonic vibration to remove surface contamination. Preliminary experiments showed that HCl solution had excellent decontamination effect. The decontamination efficiency for some nuclides was as high as 80%.

The combination of thermal and compressive processes was investigated. Regardless of which process was carried out first, the performance of the combined process was better than the single process. Nevertheless high-temperature treatment followed by compression has demonstrated the best result. A volume-reduction efficiency of 80% being with 22% in weight loss and 71.9 in hardness was achieved experimentally.

There are about 10,000 drums of waste insulators stored in nuclear facilities. The activities of most waste insulators are very low. Most of them can easily reach the clearance level through the use of appropriate surface decontamination process. Others with higher activity can be treated by the combined thermal and compressive processes to achieve the goal of amount reduction. Additional experiments will be conducted in the near future to confirm the results. It is expected that the amount of waste insulators and the cost for final disposal can be dramatically reduced by implementing the developed technology.

Table 1. The Effects of Surface Decontamination Process

Nuclide	Activity(Bq/g) Before Decontamination	Activity(Bq/g) After Decontamination	Decontamination Efficiency
K-40	7.96E-01	6.25E-01	21.48%
Tl-208	7.10E-02	1.36E-02	80.85%
Pb-212	6.14E-02	4.77E-02	22.31%
Bi-214	5.18E-02	4.10E-02	20.85%
Pb-214	2.85E+00	3.90E-02	98.63%
Ra-226	1.51E-01	1.44E-01	4.64%
Ac-228	5.71E-02	4.80E-02	15.94%
K-40	7.96E-01	6.25E-01	21.48%



(a) (b)

▲ The Structure of Rockwool: (a) Original, (b) 850°C Treated.

1-14 Study on Guidelines for Performance Assessment of Low-Level Radioactive Waste Repository

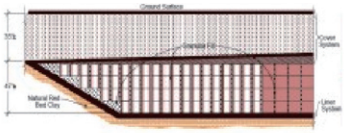
Li-Hao Wu

Two potential candidate sites of low-level radioactive waste (LLW) repository in Taiwan have been announced in 2010 and follow-up works are in progress. One important work is the licensing review for the safety analysis report. This program was conducted based on the regulations promulgated by the competent authority (FCMA) to study the safety assessment technology and audit key points. The results were used to develop the technical guideline for safety assessment, which will benefit the competent authority to perform safety review.

For the safety review of LLW site and disposal facility, the IAEA and the USA regulations as well as other technical reports will be used as international standards and references. This program studied the LLW safety assessment report of the IAEA and the USA. The safety assessment methods and process were discussed. We also integrated related references to be science background information for the competent authority to obtain the disposal facility application cases in the future. Moreover, we compared the difference between the Andrews Repository in the USA and the DGR Repository in Canada (see figure 1) for the case study.

In the study, we discussed the model suitability, data reliability, assumption reasonability of safety assessment. It also had a practice test by a reference case (see figure 2). Through testing, we conformed the necessary analysis tool and parameter, performance requirements, reliability and reasonable of examine points.

Fig1. Case Study of LLW Repository Safety Assessment



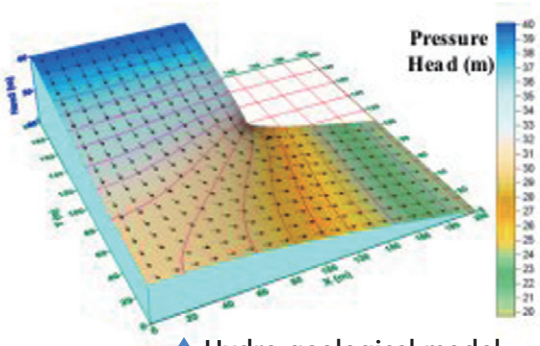
▲ US Andrews

▲ Canada Andrews

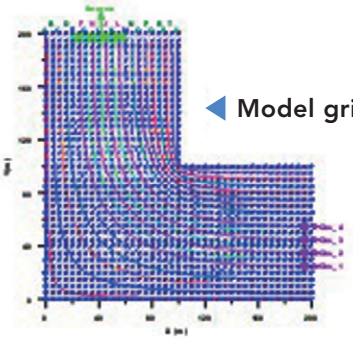
Items \ Case	Canada Bruce 2003	Canada Bruce 2009	US Andrews 2007
Year	2003	2009	2007
Authors	4	21	?
Duration	7 months	1 year	2003?-2007
Waste	LLW, ILW	LLW, ILW	Class A,B,C
Facility numbers	4	1	3
Propose	Concept	Design	License application
Stage	closure	Before closure, closure	operation, closure
Scenarios	2	2	4
Nuclids	37	34	77
Time scale	1,000,000	10,000,000	100,000

Fig 2. Safety Assessment Model Developing Case

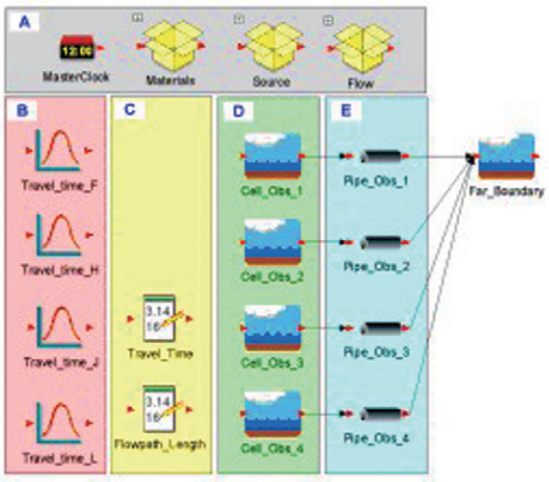
Safety assessment model developing case



▲ Hydro-geological model



◀ Model grid

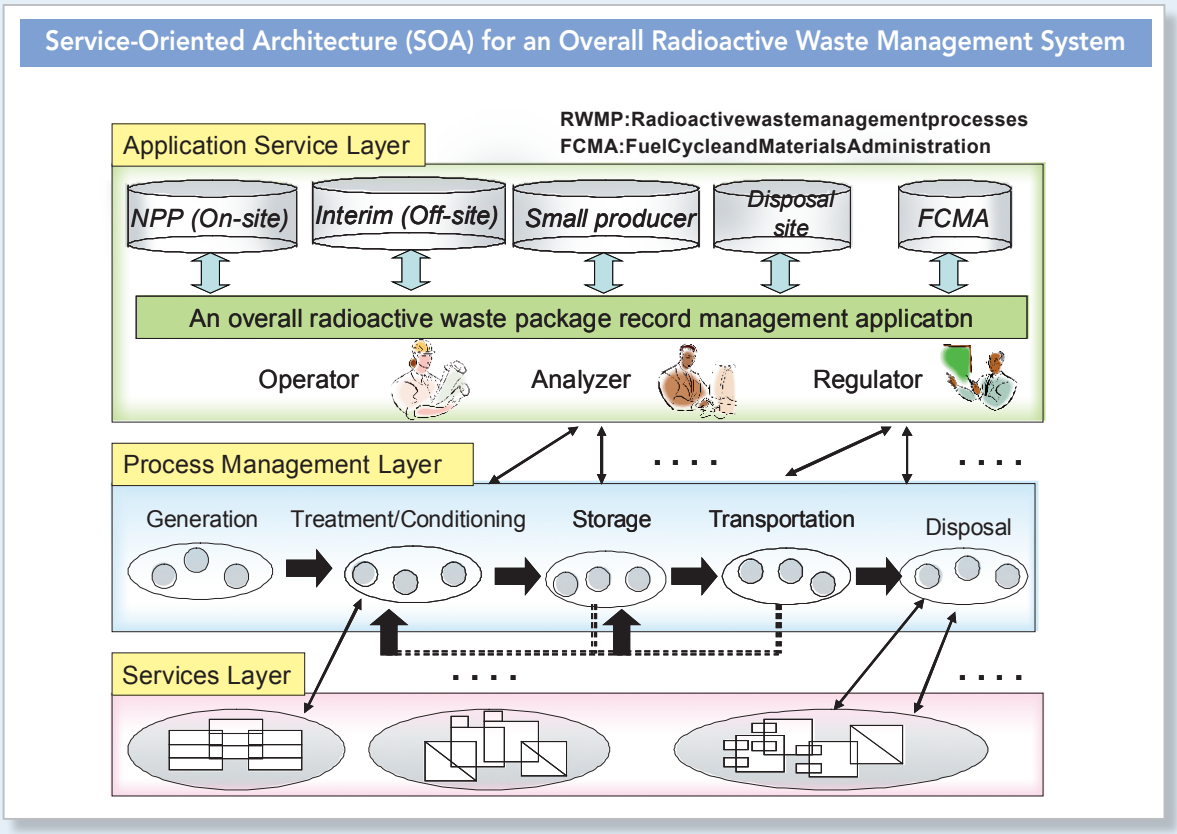


▲ Safety assessment model by 1-D pipe module

1-15 Cloud Computing Application in Radioactive Waste Management: Service-oriented Architecture Design for an Overall Radioactive Waste Package Record Management System

I-Hsin Chou

In Taiwan, there are a few radioactive waste package record management systems independently implemented by radioactive waste generators, operators of waste management facilities, transport organizations and storage facilities. To claim compliance of a radioactive waste package record meets the waste acceptance criteria for disposal, an overall radioactive waste package record management system which records and tracks all relevant information, from raw waste characteristics, through changes related to waste processing, final checking and verification of waste package parameters should be constructed in accordance with IAEA recommendation. Service-oriented is a one of main technology of cloud computing. Service-oriented architecture (SOA) is also widely accepted as a new paradigm for integrating heterogeneous systems in an effective way. It has formed a new trend being adopted by organizations in mitigating legacy system problems as in to maximizing interoperability, reusability and flexibility. Based on the current radioactive waste management processes, this project proposes a three-tier SOA for the further management system design of overall radioactive waste package record.



2. Nuclear Facility Decommissioning and Radioactive Wastes Management

Horng-Bin Chen

Considering sustainable energy for safety, economic development, and environmental protection, nuclear application is a must for low carbon energy. In order to safely apply nuclear energy, both the nuclear facility decommissioning and radioactive wastes management are the major concerns.

The objectives of the project are focused on enhancing the capability for planning and implementation of nuclear facility decommissioning, carefully dismantling and restoring nuclear facility of INER, and developing the technologies of radwaste inspection, reduction, stabilization, and safety storage. Those are based on the principles of (1) reducing radioactive waste for further disposal during the nuclear facilities decommissioning; (2) enhancing the efficiency of radioactive waste management so that the domestic LLW can be properly treated and safely stored; (3) improving the nuclear safety, maintaining the quality of environment, and ensuring the public health, so as to eliminate the public concerns on the safety of radioactive waste management.

The developed technology verifies and demonstrates with the practical decommissioning execution, and laid the foundation for the future domestic decommissioning on large nuclear facilities.

After four years of effort, INER had achieved a great progress on the highly contaminated facilities decommissioning, such as TRR spent fuel pool clean up and dismantling of transuranic contaminated experimental facilities in building 016. The stabilizing treatment technology and process development on TRR spent fuel rods has been completed, and 6 sets of TRR stabilized fuel can had been sealed and safely delivered to storage cask. A total of 18 out of 39 sets of fuel rod had been stabilized (45% completed). Building 016 transuranic contaminated facilities including Unit 21, Unit 20 contaminated glove box, 5 large tanks, and lead cell had been dismantled to accomplish the goal of zero alpha pollution.

The development of radioactive waste clearance reaches the technology application and promotion stage. INER had established the professional clearance measurement laboratory. By complying with the international ISO / IEC 17025 laboratory quality standards, INER achieved the first local certified radioactive waste measurement laboratory. INER developed the measurement verification procedures and equipments which meet regulations, and cooperates with authorities to establish the national radwaste measurement specifications. Also, for the first time in domestic history, INER has released 1,200 tonnes of concrete and 140 tonnes of scrap metal.

This year, the development of treatment technologies on complex composition of radioactive liquid wastes, which include strong acids produced by Mo-99 process, organic and inorganic liquid wastes were executed. Several inorganic adsorbents were synthesized to treat the wastewater which contains radioactive materials such as lanthanides, actinides, strontium, cobalt, cesium, and so on. The adsorption efficiency is reaching 99% in experiments and the costs of adsorbents are dramatically decreased.

2-1 Evaluation of the Radioactive Inventory of TRR Vessel

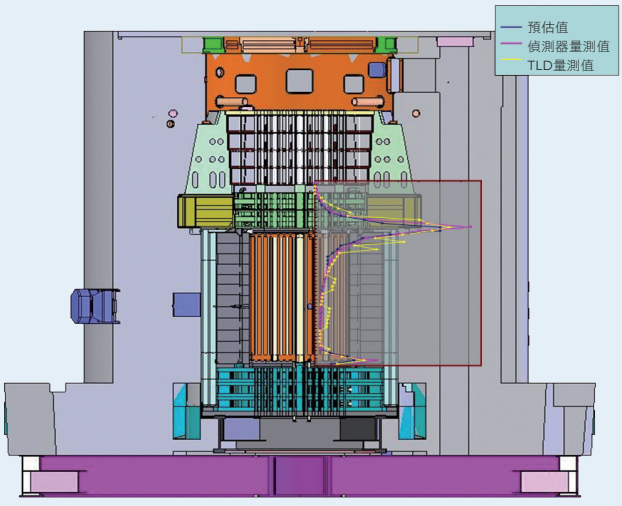
Yi-Chang Chen

The decommissioning of TRR reactor assembly was continued in 2010 for developing dismantling plans and associate technologies. The reactor assembly is composed of activated components with high radiation. The detailed investigation and evaluation of radioactive inventory are necessary during the planning period, which includes analysis of the main radionuclide, measurement of the radioactivity, and evaluation of the activities and specific activities within the assembly. Thus, the survey of radiation inventory are not only used for planning dismantling methods, radiation protections, transportation route, and equipments arrangement, but also as an important reference for waste evaluation and analysis.

In order to precisely reveal the distribution of radiation dose rate and verify the main radionuclide, we performed a radiation dose rate measurement through the central experiment tube down to 6.6m deep. The detector and TLD were both used to gather the distribution of radiation dose rate along the central experiment tube. The data were further analyzed and compared with the data measured in 1997, and then established a distribution curve of radiation dose rate. By examining the decay curve of dose rate form 1997 to 2010, we can verify that the main radionuclide is Co-60.

The sampling and analysis of the components were taken in 2010 by accessing through the central experimental tube. Four layers of upper biological shield (A, B, C, and D) and also two layers of upper thermal shield (A and B) were each drilled to collect scraps for analyzing the activity and nuclide. The analysis results proved that the principal nuclide is Co-60 and the highest specific activity occurred at layer B of the upper thermal shields. The analysis results conformed to the measuring results. Base on the sampling results and the specific activities evaluate with the theoretical value, a simplified 3D models for each component were setup. A dedicated program was used to calculate and analyze the distribution of radiation dose rate for each individual component. The results will be used as a basis for planning the dismantling, conveying, radiation protection, and cutting methods.

In accordance with this radiation inventory evaluation of TRR reactor assembly, the estimation on radiation dose rate can be more accurately for planning the decommissioning and also have a reference basis for classifying specific activities of wastes, so as to make the whole project safer and catious.



▲ Dose Rate Distribution Measured in 2010

▲ Sampling of TRR Components

2-2 Dismantle of TRR Emergency Water Tower

Wen-Lain Lo

▲ Top Cover Cutting Operation

▲ Concrete Block Lifting Operation

The emergency cooling water tower of Taiwan research reactor (TRR) is located on the south side of reactor disassembly building. It can be divided into three main parts: cistern, supporting body, and base. The height is 28.98 meters and the capacity is 250,000 gallons. TRR was shut down in 1988, immediately the emergency cooling water tower ceased operation. Upon approval, emergency cooling water tower has listed as a part of the required removed item in "TRR Facility Decommissioning Plan".

The dismantling of emergency cooling water tower began in 2010, INER also introduced private companies to involve in site work. The dismantle team first surveyed and cleaned inside of emergency cooling water tower. After meeting the standard, based on the technologies of diamond wire saw and circular saw which established by INER, the tower was cut layer by layer from top to bottom. Then with rigorous high-altitude lifting technology, the concrete blocks were transported piece by piece to nearby temporary storage area. It is estimated to generate approximately 1,078 tons of concrete waste from this work. The concrete waste will be released under the restriction of regulations systems for long-term disposal, recycling or reuse through strict radiation measurement and quality assurance procedures. We believe that 99% of concrete waste could be released through clearance procedure, which significantly reduce the storage space for radioactive waste and management fees for future disposal. After the site been recovered and meet the clean area standard, estimate of 100 square meters space could be released for further usage.

The dismantling of emergency cooling water tower began on October 4th, 2010. The original schedule was to remove the top cover (8% of the total weight) by the end of 2010. However, it actually reached to the bottom of the tower, removed a total of 37 blocks, weighing 768.1 tons (over 70% of the total weight), which exceed the annual target. Under rigorous safety protection, control of industrial safety, project management, and real-time video surveillance systems, INER has the full control to ensure operation safety. The dismantling of TRR emergency cooling water tower verified the contamination survey, radiation protection, high-altitude cutting and lifting, and clearance technologies which INER has established. It is a successful case of nuclear facility decommission which fully implemented by the domestic.

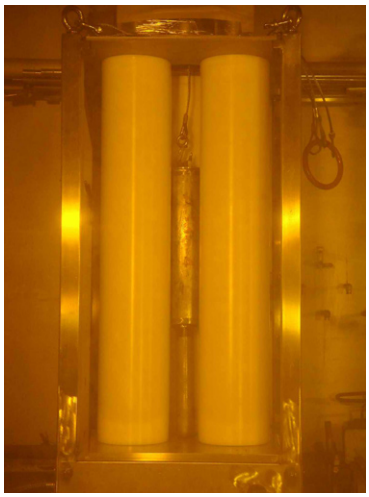
2-3 Establishment of Hotcell Nuclear Materials Measuring and Evalution Technique using the Stabilized TRR Spent Fuel Powder

Chun-Liang Lin

The aim of this work was to establish the Neutron Coincidence Counter (NCC) system in the hotcell. INER cooperated with National Tsing Hua Unversity (NTHU), using the neutron measurement method to determine the plutonium content of the stabilized Taiwan Research Reactor (TRR) spent fuel powders. The obtained results were then compared with the Los Alamos National Lab.(LANL) results.

The NCC system measured the single rates and double rates of neutron from the canisters which filled with TRR spent fuel powder. Three major neutron sources were the spontaneous fission from U-238 and Pu-240, and the (α,n) reaction from the oxide powder. By subtracting the contribution of U-238 spontaneous fission from the single rates and double rates of neutron, the Pu-240 content of the TRR spent fuels were solved and then converted into the total plutonium content according to the calculated mass ratio of 240Pu-to-Pu. The detection efficiencies of the NCC system were determined by measuring an U3O8 powder of known weight in couple with MCNPX calculations.

Neutrons of the oxide powder from three TRR spent fuel rods (A336, A28X, A152X) were measured, and plutonium contents were calculated. The obtained plutonium content of the oxide powder from A336 spent fuel rod coincided with the declared value, only 3% in difference. The plutonium contents of the oxide powder from the other two spent fuel rods deviate significantly from the declared values. This discrepancy between measured result and declared value may be attributed to an incorrect declaration for the severe broken fuel rods since declared values were based on normal operation. Results showed that the NCC system can accurately determine the plutonium content of TRR spent fuel and be used for revising the declared values of plutonium content of a broken spent fuel rod.



▲ NCC System and Inner Powder Can

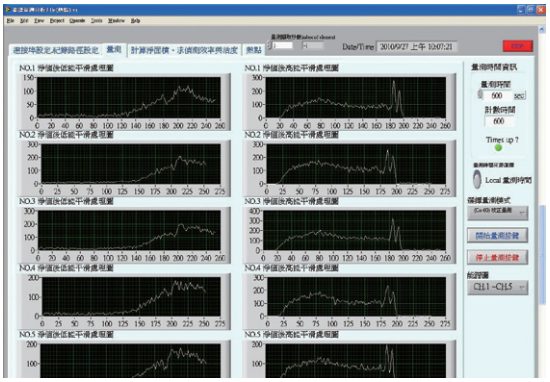
2-4 Fundamental Energy Spectrum Analysis for NaI (Tl) Detector and FNS99 Assembly

Kuo-Jen Lin

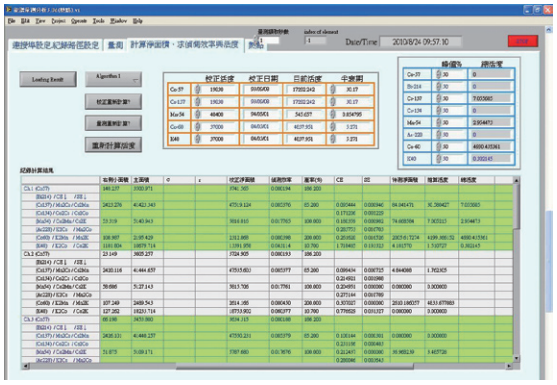
NaI (Tl) detector is the most popular scintillation material for gamma-ray spectroscopy. FNS99, an electronic assembly developed by INER, can change NaI (Tl) detector's output pulses into spectrum and also counts the number of the incoming pulses. The radioactivity of nuclides can be measured according to the counting number. However, the resolution of NaI (Tl) detector is not good enough, such that an overlapped spectrum appears if there are several nuclides exist inside the measured object . This spectrum-overlap phenomenon causes some difficulties to distinguish nuclides and to calculate the corresponding radioactivity.

In order to solve this problem, analyzing the fundamental characters of spectrum formed by NaI (Tl) detector and FNS99 assembly is a must. Mono-energetic calibration source spectrum consists two parts, one is an energy peak whose distribution is similar to Normal Distribution in mathematics, and the other is a scattered low-energetic spectrum due to Compton Effect. These two spectrums have particular correlation. Extracting characteristics of these two spectrums can be done by means of doing some mathematical operations. The spectrum of measured object with multi-nuclide inside is formed by superposing each nuclide's spectrum linearly, each nuclide's spectrum can be separated from the overlaid spectrum after doing some mathematical operations. Then the radioactivity intensity can be determined.

The analysis result is very helpful for constructing a system which can be used for distinguishing radioactive nuclides and calculating radioactive intensity. This system can be applied in waste release. So far the measurement of nuclides inside scrap is done. Target nuclides include ^{137}Cs, ^{54}Mn, ^{60}Co, and ^{40}K. The measurement of nuclides inside soil waste is going to be done in the future. Extra target nuclides include ^{57}Co, ^{214}Bi, ^{134}Cs, and ^{228}Ac.



▲ HMI: Measured Spectrum of Waste



▲ HMI: Measured Result of Activities

2-5 Executive Status of releasing Scrap Metal at INER

Huang-Sheng Chiu

The Regulations on Clearance Level for Radioactive Waste Management was promulgated by the Atomic Energy Council, Executive Yuan on Dec 29th, 2004. In aims to relieve the pressure of radioactive waste repository and to reuse the waste material, INER has affirmatively studied the equipments and the procedures for clearance regarding the release of scrap metal. The results of R & D were then applied to the scrap metal which is under clearance level and stored in the temporary storage location in Building No. 031. The release of four batches of scrap metal weighing 110.4 tonnes was accomplished by the Low-Level Radioactive Waste Repository (LLRWR) of the Chemical Engineering Division (CED) and the Clearance Measurement Laboratory (CML) of the Health Physics Division (HPD) with the Release Plan for Scrap Metal in the Temporary Location Storing Radioactive Waste Under Clearance Level at INER. In order to establish the release for scrap metal in common use, the Release Plan for Scrap Metal at INER was prescribed according to Letter Wu-Yi-Tzu No. 0980000439 approved by the Fuel Cycle and Materials Administration on Mar 2nd, 2009. Then the Release Protocols for Scrap Metal were prescribed by HPD, approved and put on records by Occupational Safety and Health Committee according to An-Hui-Tzu No. 0980000136 on Sep 29th, 2009 to be followed by INER's divisions that would need to execute release operations for scrap metal.

In 2010, LLRWR at INER along with the Engineering Technology & Facility Operation Division (ETFOD) and CML of HPD chose the decontaminated scrap metal which was stored in the Decontamination Center in Building No. 012 or decommissioned by ETFOD for release. The operation was divided into three phases of measurements and analyses. First, the composition of radionuclides in the scrap metal was determined based on the historical data, source classification and sampling. Second, the scrap metal was classified preliminarily in accordance with the net count rate on the surface to exclude that containing radioactivity. Third, the scrap metal package was performed the measurements on gross specific activity and the sampling for verification to ensure the scrap metal intended for release can comply with the regulation limit. The aforementioned procedures for the release of scrap metal were implemented under the vigorous criterions of quality assurance. The scrap metal of total 29,802 kilograms was sieved, measured, and analyzed. The results showed that the specific activity of the concerned scrap metal were under the limit for release. Hence, the release was completed successfully, and the pressure of radioactive waste repository can be effectively relieved. As a result, the benefit of environmental sustainability can be achieved by means of reducing the waste material and reusing the resources.

▲ Measurement on Gross Specific Activity of Scrap Metal for Release

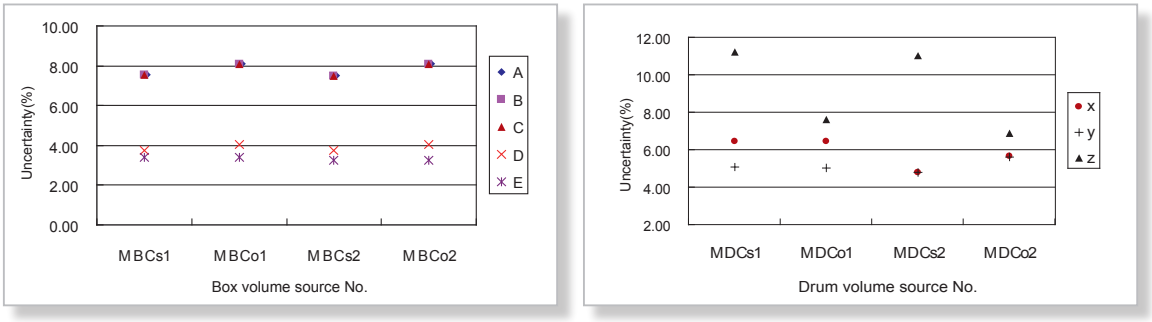
▲ Sampling of Releasing Scrap Metal for Verification of Specific Activity

2-6 Performance Test for Measurement and Analysis of Clearance Mixed-Nuclide Samples

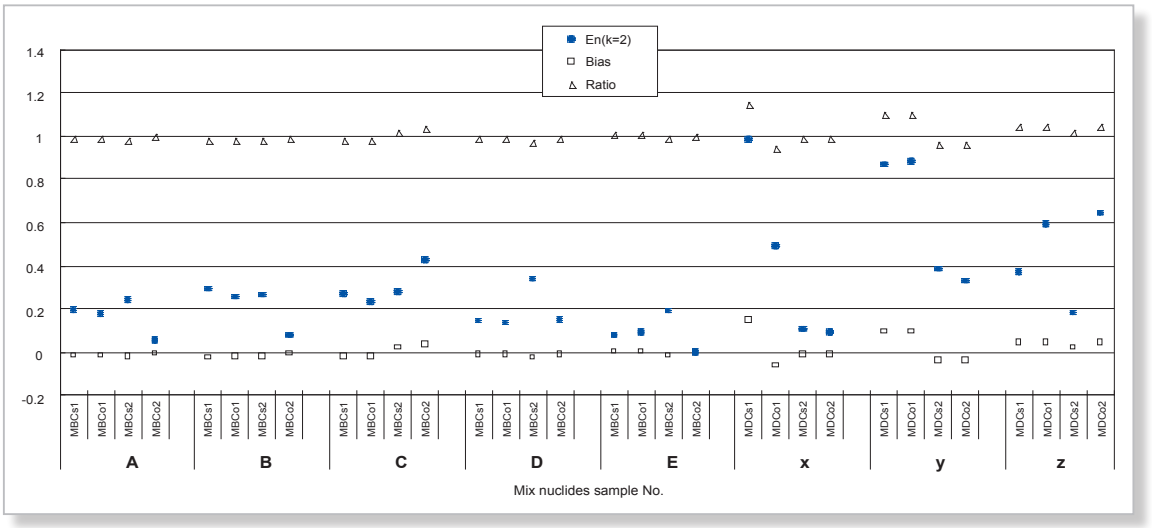
Chin-Hsien Yeh

The National Radiation Standard Laboratory (NRSL) of the INER organized the performance test for measurement of clearance samples in 2010. This performance test was done by INER, preparing a set of samples which were added with known radionuclides and radioactivities. The participating laboratories measured and analyzed the samples, and their results were compared with the known radioactivities. Five laboratories took part in the performance test workshop by offering 8 measuring instruments. They measured drum volume sources and box volume sources of the same density. Those samples were of single-nuclide solutions and mixed-nuclide solutions. The evaluation results showed that all the participants passed the requirements of Taiwan Accreditation Foundation's (TAF) "Technical Criteria for Radioactive Waste Clearance Measurement": (Bi)≦-0.25~0.5, En≦1, weight deviation≦10%, combined uncertainty.≦20%. Also, the minimum detectable activity (MDA) value less than 0.02Bq/g for those detectors was compliant with TAF-CNLA's technical criteria.

Measurement Uncertainties of Box-type(MB)and Drum-type(MD) Mixed-nuclide Samples



Measurements Results of Drum-type and Box-type Mixed-nuclide Samples for Performance Test



2-7 Establishment of Sorting and Re-packing Technology for High-Active Wastes

Feng-Jung Chang

The high-active wastes underground storage vault 015D (hereinafter referred to as "015D vault") was built in the 1970s to store the high-active wastes produced from Taiwan Research Reactor (TRR) and other laboratories of INER, and it also began to accept spent radioactive sources produced from domestic radioisotope application organizations since 1980s under AEC's order. Now the wastes stored in the 015D vault still lacked the basic related information because the imperfect of the early management regulation for hight-active waste's storage and the acceptation of the high-active wastes being mostly guided by duty. However, based on the current waste management policy, these wastes must be taken out to sort and re-pack for safe storage. Therefore, we established a 4-year plan from 2010 to develop a heavy-type underground removal equipment and procedures for high-active waste realignment by remote control (robot) and shielding technologies. Based on the developed technologies, another small-type remote control technology for the treatment of the spent radioactive sources in 015D vault will be further developed. In addition, the foregoing technologies can also be applied to the remote handling of the high-active wastes produced from life-cycle operation, equipment replacement caused by life extension, or decommissioning of nuclear power plant.

The first-year work is mainly to complete the planning of sorting and packaging technologies, an effective and safe management of high-active wastes will be adopted. Main contents include,

▲ Present Storages Status of High-active Wastes

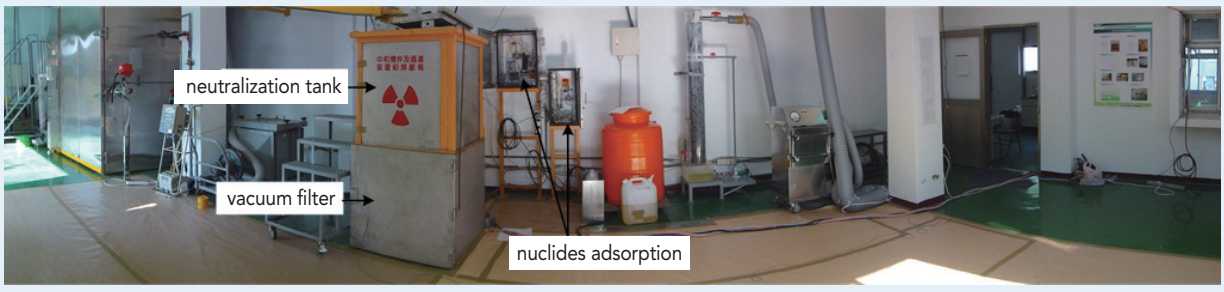
1. Establishment of unpacking and transfer technologies (by remote control operation) to properly take out high-active wastes from underground storage vault and sealed container.
2. Design and construction/fabrication of standard storage container.
3. Identification of nuclide and activity of high-active wastes and dispensing of high-active wastes into standard containers.
4. Establishment of a series of standard procedures for high-active wastes treatment including unpacking, transfer, identification/analysis of nuclide and activity, sorting, repacking, and storage.

After completion of the tasks, a professional and systematic management for high-active wastes can be established to fulfill the requirements in radiation/industrial safety control.

2-8 The Treatment Study of Radioactive High-acidity Solution from Mo-99 Process

Ben-Li Pen

Mo-99 liquid waste, including high acidic inorganic solution and organic extractants, are classified as GTCC wastes. By self-developed treatment process and equipments, the treatment costs are less expensive if compared to those of Australia. The treatment equipments include neutralization tank, vacuum filter, and nuclides adsorption, also a set of control instrument and the lead radiation shield for those equipment. The liquid waste pumped from each stored tank of WC-103, WA-503 and WA-2 was treated and its volume was about 70 liters. The remaining β、γ nuclide of treated waste comply with the limitation of discharge. However, the treated waste still exists impurities such as nitrate, mercury, as well as α nuclide that could be removed by chemical reaction and membrane filtration. At the impurities removing treatment, radiation shielding is no longer required due to the removal of γ nuclides previously. The used adsorbents with high dose rate were stored in the heavy duty shielded tank which is recovered from stored tank. When the treatment of highly acidic waste solution is executed, the leakage risk of radioactive solution is reduced. This small scale liquid waste treatment facility shows the capability of INER's enhanced waste management. Besides, the Mo-99 acidic liquid waste treatment experience can be applied international.



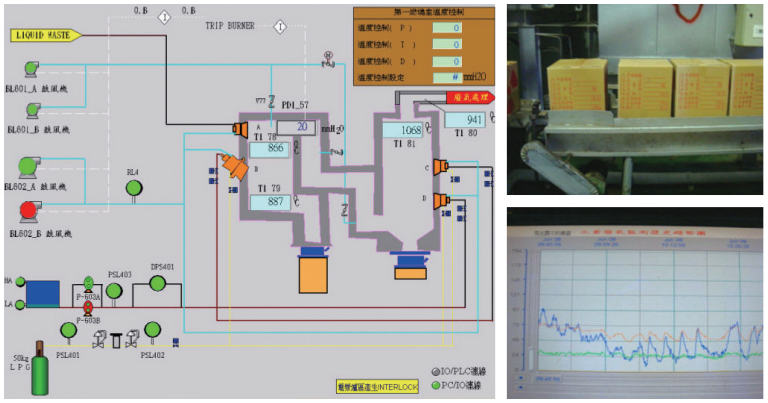
▲ View of Treatment Equipments

2-9 Study on Treatment for Organic Radioactive Liquid Waste from Domestic Hospitals and Research Institutes

Yih-Ping Chen

INER has been receiving low-level radioactive liquid waste generated from domestic hospitals and research Institutes since 1979. A lot of 20-liter plastic containers filled with the liquid waste are stored in the *low level radioactive waste treatment plant*. Some of the waste was blended in several tanks with each capacity greater than 10 m^3 due to short of storing space. On account of signature nature of the waste, it fails to be treated to date. If the liquid radwaste is left untreated, it tends to deteriorate and is likely to pose a potential threat to the ambient environment.

This study has successfully developed a strategy of treatment for the waste after gleaning information of the waste, conducting experiments with surrogates, and genuinely treating the waste in T-61. Preliminary heating the waste to 40°C is first employed to divide the waste into two parts. The organic part which accounts for 22.8% of the waste and contains no chloride can be safely burned off by the incinerator in INER. The other part which accounts for 75.7% of the waste is treated by Fenton oxidation under the process of 2 mL/min of hydrogen peroxide feed rate, [Fe^{2+}] equivalent to 0.1M, and over 40 minutes of reaction to decompose greater than 99% of TOC within to meet environmental protection regulation's requirements. The TOC-deprived liquid waste proceeds to remove Cs-137 via specific processes such as evaporation or ultrafiltration. The processed liquid waste, still including tritium though, can be scheduled to discharge while the sludge produced in the process of Fenton oxidation can easily be filtrated out and further solidified by cementation. The test results show that it is a very promising process.



▶ Photos of Organic Liquid Waste Feeding, Treatment, and Off-gas Monitoring in the Process of Incineration

No.	Fe^{2+}Conc. (M)	H_2O_2 50% soln.(ml)	TOC for 20min (ppm)	TOC for 30min (ppm)	TOC for 40min (ppm)	TOC for 60min (ppm)
1	0.03	20	6,686		6,822	6,676
2	0.03	30	6,942		6,639	6,346
3	0.06	20	3,846		2,396	2,414
4	0.06	50		2,210	2,010	1,560
5	0.10	50		230	147	155
6	0.10	60		253	174	176
7	0.12	60		135	115	127

TOC initial conc. 19,720 ppm ; H_2O_2 adding rate 2 mL/min

▲ Effect on TOC Removal of the Waste Water in T-61 by Fenton Reaction

2-10 Development and Application of High-Efficiency Inorganic Adsorbent

Kou-Min Lin

The radioactive liquid wastes produced by domestic research institutions or nuclear facilities in the past have contained trace amount of problematic nuclides that are difficult to remove by conventional separation methods such as precipitation, filtration and solvent extraction. The use of ion-exchange material is one of the simplest and effective ways to treat such wastes. Traditional ion-exchange materials are often made of organic substances that are chemically unstable and may pose another problem when disposing of these materials after usage. Therefore, the use of inorganic ion-exchanger to replace its counterpart has been adopted by many advanced countries in the world for the treatment of problematic liquid waste. In order to treat a wide variety of metals or nuclides found in radioactive liquid waste, several inorganic ion-exchangers or adsorbents with good efficiency have been developed. However, such inorganic adsorbents are costly and their purchase usually requires the order of a huge quantity. To solve these problems, the Institute of Nuclear Energy Research (INER) has developed several high-efficiency inorganic adsorbents that are low-cost and can be self-produced. The inorganic adsorbents developed have been tested with real radioactive liquid wastes to demonstrate their effectiveness. With further improvement, the technology can be applied for the treatment of liquid waste found in domestic nuclear facilities and industries.

▲ Inorganic Adsorbent Developed by INER

The Performance of Several Inorganic Adsorbents Developed by INER
(100 ml of Liquid Waste)

Adsorbent (1g)	TRR Fuel Pool Liquid Waste			Tritium-contaminated Liquid Waste with High Conductivity	
	Co-60	Sr-90	Cs-137	Cs-137	Sr-90
IA-AC-01	91%	100%	87%	52%	99%
IA-AC-02	82%	100%	78%	66%	97%
IA-AC-03	100%	96%	92%	100%	100%
IA-AC-Cs	30%	97%	89%	99%	51%
IA-AC-5	100%	94%	90%	73%	100%
Activity before adsorption (Bq/ml)	2.32	247	1200	4.68	0.31

3. Isotope Researches and Applications in the Medical Field

Tsai-Yueh Luo

Isotope Application Center at Institute of Nuclear Energy Research has integrated the capabilities of isotope production, radiopharmaceutical manufacturing, precursor synthesis, chemical analytic technique and medical radiation protection for the research and applications of molecular diagnostic agents and therapeutic radiopharmaceuticals in CNS, cancer, and cardiovascular diseases. The definite purpose is to fulfill the application of Investigation new Drug and New Drug Application to Department of Health (DOH) at Taiwan, so the final products can be applied in the healthcare services for the people worldwide.

In the fiscal year of 2010, we got the drug license of INER ECD KIT from DOH which can be used in the brain perfusion imaging agent. We also established the manufacturing process of F-18 NaF Injection in this year and the necessary documents for drug registration. This drug is an important alternate for bone scanning to face the global challenge of Mo-99/Tc-99m shortage. INER won the best popular award in 2010 nanotechnology exhibition held by National Science Committee at Taiwan. Since the only certificated GLP for radiopharmaceutical analytical laboratory was approved by DOH in November of 2000, INER earnestly created the cooperation opportunity with the other investigation units for research and service. Besides, we cooperated with National Taiwan University for I-123 MIBG clinical trial and the result won the second honor place at 2010 Annual Meeting of Society of Nuclear Medicine (2010SNM) in USA. In the same meeting, the report of radioimmunoagents, Re-188-Herceptin, won one of ten best reports in basic oncology section of 2010SNM. WE also found three biomarkers from the gastric cancer tissues and hope to investigate the new agent for the early diagnosis of gastric cancer. As the research of Re-188 liposome, the therapeutic effect was compared with 5-FU, the most available anticancer drug in clinic, in colorectal carcinoma animal model. The experimental result showed that Re-188 liposome has better treatment effect than 5-FU. In order to lessen the interference of different volume for the dose measurement method of Y-90, a pure beta isotope, INER has engaged and established the calibration standard method. In order to satify the demand of nuclear medicine for the diagnostic and therapic applications in clinic, INER has involved the evaluation technique for the release standard of patient used radiophamaceutical. In this year, INER has proposed a new system, "Self-Management of Radiation Safety at Home", in response to the potential risks in nuclear medicine radiation safety. It is expected that this system would potentially benefit the patients of nuclear medicine and the public members. It would truly uplift the living environment of citizens for their health and maintain the quality of patient's household life.

3-1 INER Has Successfully Developed a Radiopharmaceuticals for Cerebral Perfusion Imaging - INER ECD KIT

Shih-Woei Yeh, Mei-Hsiu Liao

Nuclear medicine, a non-invasive diagnostic technology, uses radiopharmaceuticals with appropriate detector to provide clinicians more accurate and safe diagnostic information as the basis of diagnosis, treatment and prognosis of the disease.

Technetium-99m-ECD is the drug of choice for the cerebral perfusion scan with SPECT (Single Photon Emission Computed Tomography) in Taiwan. However, the limited source of the imported drug keeps the price high that forced INER to develop it locally. After a five-year development since 2004, INER ECD KIT has been approved by the Department of Health in February 2010 which could be used to evaluate the regional blood perfusion for the brain of the adult patients with pathological change of the central nervous system. INER has provided samples to the medical centers such as NTUH and TSGH for probation, and the imaging results fulfilled the requirement of the clinical use. It is expected that more patients will benefit from the examination per year after the launch of the kit in February 2011.

It is common for advanced countries to perform the cerebral perfusion scan with SPECT using Technetium-99m-ECD. INER ECD KIT can fulfill the requirement of the local-made imaging agent for the hospitals in Taiwan to cost down the imaging procedure and promote the examination rate, so the patients will receive better medical care.

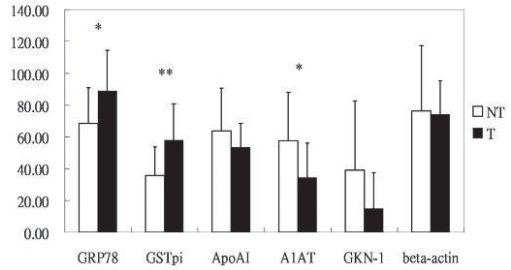
▲ INER ECD KIT

▲ License of INER ECD KIT

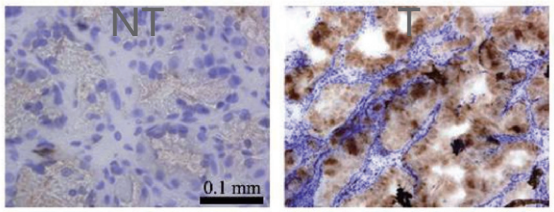
3-2 Discovery and Validation of Tissue Biomarkers by 2D-DIGE Cooperating with Western Blotting and Immunohistochemistry in Gastric Cancer Patients

Shui-Cheng Lee , Chun-Chia Cheng

Gastric cancer (GC) has high rate of morbidity and mortality among various cancers worldwide. The development of noninvasive diagnostic methods or technologies for tracking the occurrence of GC is urgent, and searching reliable biomarkers is considered. In this study, we intended to directly discover differential biomarkers from GC tissues based on two dimension-differential gel electrophoresis. Twelve pairs of GC tissues were analyzed by western blotting and immunohistochemistry for protein expressional validation. Five of the interested proteins were confirmed by WB and IHC, including glucose regulated protein 78 (GRP78), glutathione s-transferase pi (GSTpi), apolipoprotein AI (ApoAI), alpha-1 antitrypsin (A1AT) and gastrokine-1 (GKN-1). Among the results, only GRP78, GSTpi and A1AT were significant difference, which were up- and down- regulated respectively in gastric cancer patients. Moreover, GRP78, ApoAI and A1AT are correlated among each other for protein expression. In this study, we not only use 2D-DIGE for GC biomarkers discovery, but also validate the protein expression in clinical GC patients. We suggest that GRP78, GSTpi and A1AT are associated with GC and could be the reliable biomarkers of GC.



▲ Protein Expression of Differential Biomarkers Analyzed by Western Blotting



▲ GRP78 was Overexpressed in the Tissues of Gastric Cancer Analyzed by Immunohistochemistry

3-3 INER ^{123}I-MIBG Tracer Development and Clinical Application

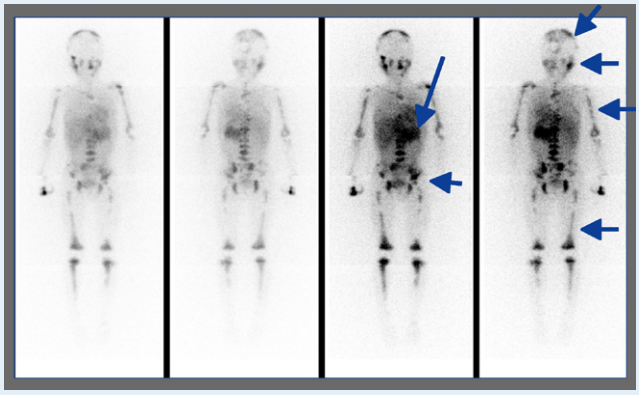
Tsai-Yuel Luo, Ying-Hsia Shin

Neuroblastoma is a common pediatric extracranial malignant solid cancer. which derived from neural crest cell of the sympathetic nervous system. Related diagnosis tracer development becomes quite important. Radioiodine labeled MIBG (metaiodobenzylguanidine) has been found to be very useful for the diagnosis and localization of neurogenic tumors. However, only imported ^{131}I-labeled MIBG has been used in Taiwan. Now, INER has successfully synthesized ^{123}I-MIBG with high radiochemical purity (>95%).

Since August of 2009, INER cooperated with the pediatric and nuclear medicine departments of National Taiwan University Hospital (NTUH) to execute the clinical trial "The evaluation of the 6-[^{18}F] fluoro-levo-dopa and ^{123}I-MIBG uptake in the patients with neuroblastoma" which protocol was approved by the IRB at NTUH and DOH at Taiwan respectively. Until the end of 2010, we had offered forty doses of ^{123}I-MIBG for the clinical trial and forty seven patients accepted ^{123}I-MIBG. The nuclear images obtained after injection with ^{123}I-MIBG clearly demonstrated the tumor site which is notable for diagnosis and prognosis. In 2010 Society of Nuclear Medicine Annual Meeting, we reported the clinical trial result and received the second place honor in general clinical field.

In future, we will continue cooperate with NTUH for clinical trials. After collecting the necessary manufacture-related information and the clinical trial data, we shall apply the new drug application of ^{123}I-MIBG to DOH at Taiwan. Let ^{123}I-MIBG be beneficial to the diagnosis and prognosis of the neuroblastoma patients in the future.

▲ INER ^{123}I-MIBG Product.



▲ The physican in National Taiwan University Hospital used INER I-123 MIBG Injection to diagnose the neuroblastoma disease for a seven-year old boy in 2009 Oct. From these images, we can find the diease distribued in left adrenal gland, para-aortic lymadenopathy, bone marrow and right Skull bone.

3-4 Development of Nuclear Medicine for Diagnosis of Central Nervous System

Chia-Chieh Chen

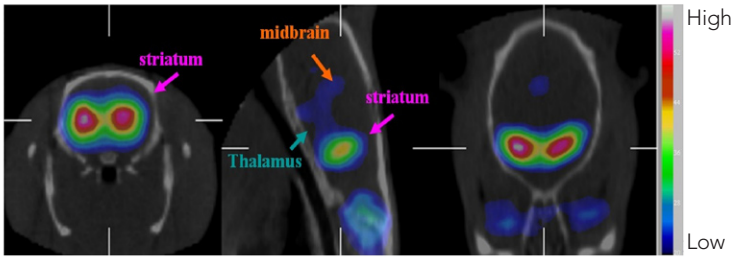
Global diseases of central nervous system like Depression, Schizophrenia, Parkinson's syndrome and Alzheimer's disease result in loss of physical function in patients. And most serious of them, Alzheimer's disease caused most lengthy the progression. In treatment of central nervous system diseases, huge medical resources, manpower for family influence heavily, the social pressure and the costs are considerable.

In order to resolve the seriousness of the current CNS (Central Nervous System) diseases problem, INER engaged in discovering brain diagnostic nuclear medicine agents and developing non-invasive imaging technology platform for small animal experiment.

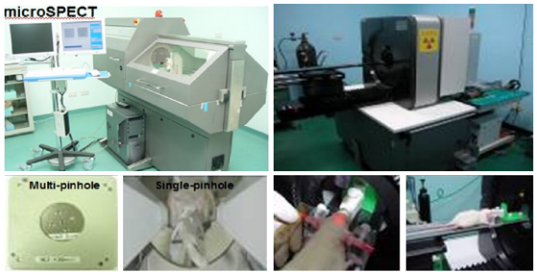
In 2010 the technical objectives include:

1. To establish iodine-123-Epidepride (dopamine D2 receptor agent) in brain distribution and the drug occupancy analysis instrument by microSPECT (micro single photon emission computed tomography).
2. To establish the animal model for Parkinson's disease.
3. To establish the iodine-123-Epidepride microSPECT analysis techniques with Parkinson's disease animal model.

In INER, the established brain diagnostic nuclear medicine agents and non-invasive imaging technology could be used as a platform for evaluating the drug treatment efficacy. It also could provide the integrated services of drug screening by in-vivo imaging. It could effectively shorten the duration of the specific CNS therapeutic drug development process and reduce the time and cost for research and development. In clinic, the brain diagnostic nuclear medicine agents could benefit the patients with CNS disease, also reduce the probability for the false positives and improve the overall quality of healthcare.



▲ Dopamine D2 Receptor Imaging of Iodine-123-Epidepride in Rat microSPECT Imaging.



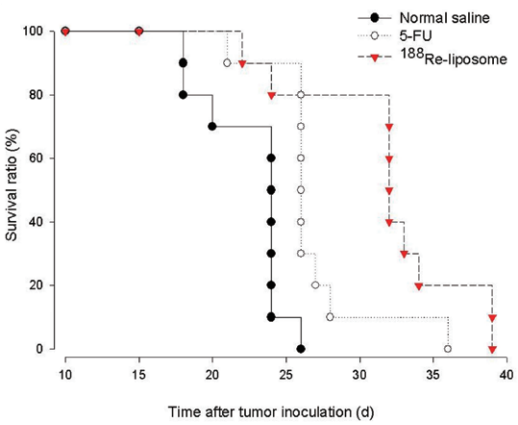
▲ In Vivo Molecular Nuclear Imaging Platform for Small Animal.

3-5 Comparative Therapeutic Efficacy Evaluation of ^{188}Re-liposome and Fluorouracil in C26 Colon Carcinoma Peritoneal Metastasis Mice Model

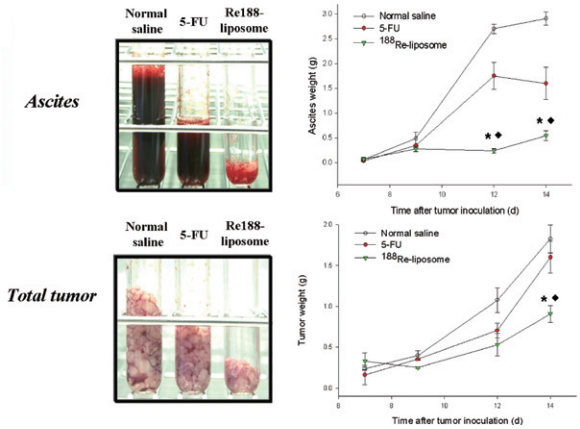
Chia-Che Tsai

Nanoliposomes are designed as carriers capable of packaging drugs through passive targeting tumor sites by enhanced permeability and retention effects. This study was purposed to evaluate the therapeutic efficacy, biodistribution, pharmacokinetics, micro-SPECT/CT image, and dosimetry of ^{188}Re-labeled nanoliposomes (^{188}Re-liposomes) in the C26 Colon Carcinoma Peritoneal Metastasis Mice Model. Colon carcinoma peritoneal metastatic BALB/c mice were intravenously (i.v) administrated with ^{188}Re-liposomes. For therapeutic efficacy, the survival, tumor and ascites inhibition of mice after treating with ^{188}Re-liposomes and fluorouracil (5-FU) respectively were evaluated and compared. ^{188}Re-liposomes attained a longer life span (increased by 34.6%) and better tumor inhibition activity in tumor-bearing mice than chemotherapeutics of 5-FU did. In the biodistribution study, the highest uptake of ^{188}Re-liposomes was 7.91% ± 2.02% at 24h after i.v. administration and the high tumor/muscle ratio was observed. Micro-SPECT/CT image of ^{188}Re-liposomes showed a high uptake and targeting in ascites, liver, spleen, feces, and tumor. The results were correlated with the images by autoradiography and

biodistribution data. Pharmacokinetics of ^{188}Re-liposomes was showed the properties of high circulation time and high bioavailability (MRT=19.22h, AUC=820.39 %ID /g·h). Dosimetry study revealed that the ^{188}Re-liposomes did not cause high absorbed doses in normal tissue, but did in small tumor. These results demonstrated that the use of ^{188}Re-liposomes for passively targeted tumor therapy exhibited greater therapeutic effects than the currently clinical applied chemotherapeutics drug 5-FU. The ideal pharmacological properties of ^{188}Re-liposomes showed in this study were suggested the potential benefit and safety in treating peritoneal carcinomatasis of colon cancer.



▲ ^{188}Re-liposomes Attained a Longer Life Span in Tumor-bearing Mice than Chemotherapeutics of 5-FU Did



▲ ^{188}Re-liposomes Attained Better Tumor and Ascites Inhibition Activities than Chemotherapeutics of 5-FU Did

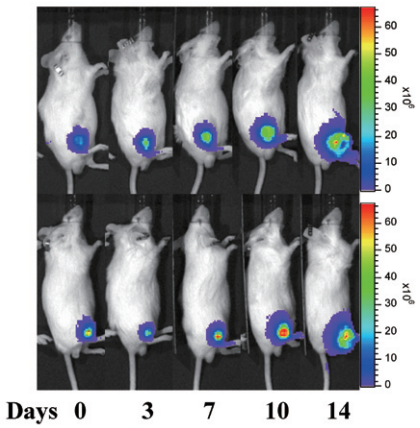
3-6 Multimodality Image of ^{177}Lu-AMBA for Human Prostate Tumor-bearing Mice

I-Hsiang Liu

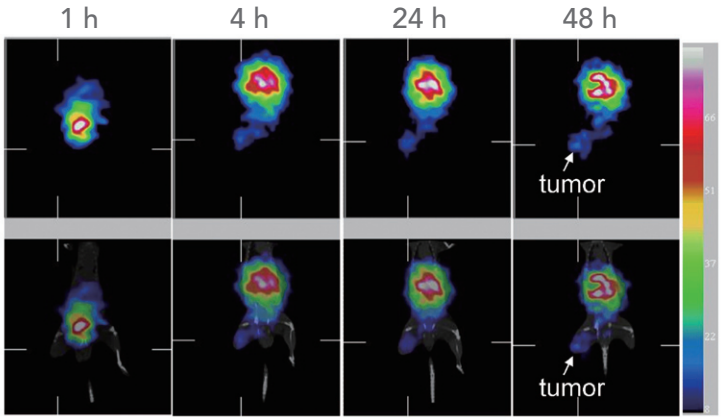
AMBA (DO3A-CH_2CO-G-(4-aminobenzoyl)-QWAVGHLM-NH_2) is a bombesin (BN)-like peptide having high affinity with gastrin-releasing peptide receptors (GRPr). ^{177}Lu-AMBA is currently undergoing clinical trial as a systemic radiotherapy for hormone refractory prostate cancer (HRPC) patients in USA. This study evaluated the biodistribution, pharmacokinetics, bioluminescent imaging (BLI) and microSPECT/CT imaging of ^{177}Lu-AMBA in PC-3M-luc-C6 luciferase expressing human prostate tumor bearing mice.

Plasma stability of ^{177}Lu-AMBA could be maintained up to 55.67±6.07% at 24 h in a protection buffer. High positive correlations of PC-3M luc-C6 tumor growth in SCID mice between caliper measurement and BLI were observed (R^2=0.999). Both the biodistribution and microSPECT/CT imaging in PC-3M-luc-C6 bearing-tumor mice showed that ^{177}Lu-AMBA in tumor uptake could be retained for 24 h. The distribution half-life ($t_{1/2\,\alpha}$) and the elimination half-life ($t_{1/2\,\beta}$) of ^{177}Lu-AMBA were 0.52 h and 26.6 h, respectively, in mice.

These results indicated that BLI could be used to monitor the growth of tumor. High uptake of ^{177}Lu-AMBA in PC-3M-luc-C6 tumour bearing mice by microSPECT/CT imaging can further evaluate the potential of ^{177}Lu-AMBA therapy for PC-3M-luc-C6 tumors.



▲ Bioluminescent Images of Two SCID Mice are Displayed on Day 0, 3, 7, 10 and 14.



▲ Micro-SPECT/CT Imaging of ^{177}Lu-AMBA was Performed in PC-3M-luc-C6 Tumour-bearing Mice. Mice were Intravenously Injected with 14.8 MBq/0.95 μg ^{177}Lu-AMBA. The Energy Windows and the Image Size were Set at 113 keV ± 10%, 209 keV ± 10% and 80×80 Pixels, Respectively.

3-7 The Development of INER ASGP-R Imaging Agent- A Tool for Diagnosis of Residue Liver Function

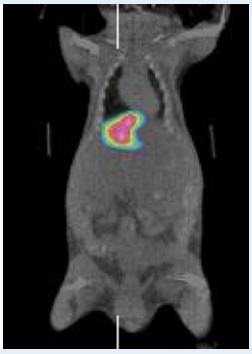
Mei-Hui Wang

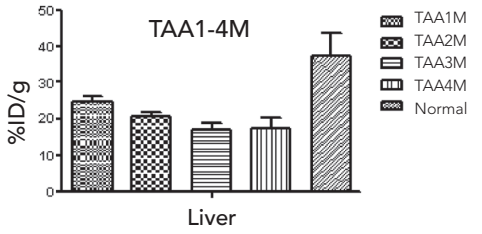
INER ASGP-R imaging agent is a highly liver targeting molecule. The major component is Indium-111 hexa-lactoside which could specifically bind to heapatic asialoglycoprotein receptor. It has been proved that the more severe liver diseases resulted in the lower uptake of ASGP-R imaging agents. We suggest that INER ASGP-R imaging agent could be used to evaluate the severity of liver disease and the remnant liver function. INER has applied the patents for pharmaceutical formulation, clinical application, radiolabeling technology and synthetic methods. We also developed a one-step formulation method for ASGP-R imaging agent with lyophilized kit preparation. Preclinical studies indicated it could be used effectively for diagnosis of liver function. Serum tests indicated that INER ASGP-R imaging agent is more sensitive than GOT and GPT to early detect drug-induced hepatitis and cirrhosis of the liver.

For most of the drugs, only about 2% of drugs will distribute to liver by intravenous administration, however, our animal data showed that more than 90% of INER ASGP-R imaging biomarker reached the liver due to its liver targeting characteristics. Its biological half-life of blood is only 0.15min, completely goes into the liver in 6.4min, and the biological half-life is less than 6 hours. The cytotoxicity tests showed INER ASGP-R imaging biomarker is a quite safe drug.

INER has established the data base of its pre-clinical pharmacokinetic study. The trial production will be run in our radiopharmaceutical factory which meets cGMP requirements. The data of chemistry, manufacturing and control (CMC) will be established according to the regulation of Department of Health at Taiwan. The lyophilized kits were formulated to design for diagnosis of residual liver function via iv injection. We plan to submit investigational New Drug application in 2011.

▶ INER Hepatic Receptor Imaging Marker has Liver Targeting Characteristics





▲ INER Hepatic Receptor Imaging Uptake has Negative Correlation with the Severity of Liver Disease

3-8 Standardization of ^{90}Y Radiopharmaceutical Radioactivity Measurement

Chien-Yung Yeh

High radioactivity ^{90}Y radiopharmaceuticals can be used for cancer therapy, but accurate measurement is requested before applying treatment on patient. For dose calibrators used for ^{90}Y, the pure beta radionuclide, the measurement results could be quite different with variety of containers and solution volumes. Therefore, it is necessary to establish the ^{90}Y radioactivity standardization capacity to sustain the measurement accuracy and consistence of dose calibrators.

The research accomplishments were : (1) Use the direct measurement method to perform radioactivity standardization of ^{90}Y; (2) Calibrated the 4 $\pi\gamma$ pressurized transfer standard chamber.

The direct measurement method used was the triple to double coincidence Ratio (TDCR) method. The cocktail samples with known mass of ^{90}Y radionuclide were prepared for TDCR counter with efficiency variations by use of the chemical quenching method. The ratios of TDCR's double sum and triple sum were used to derive the counting efficiencies. The major uncertainties were the sample stability and the efficiency variations, and an accuracy of ±0.6% standard uncertainty was evaluated. The standardized massic radioactivity was then used to calibrate the 4 $\pi\gamma$ pressurized transfer standard chamber; the calibration figures and their volume correction factors for different containers and solution volumes were established.

In practical applications, the established ^{90}Y radioactivity standardization capacity can be used to calibrate the radioactivity of ^{90}Y radiopharmaceuticals and then to calibrate dose calibrators by using different containers and solution volumes.

▲ TDCR Counting System

▲ 4$\pi\gamma$ Pressurized Transfer Standard Chamber

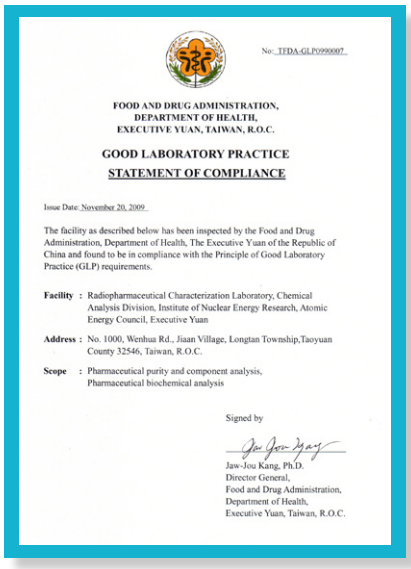
3-9 Pass the 'Good laboratory Practice [GLP] for Drugs Nonclinical Laboratory Studies' Inspection

Kung-Tien Liu

Radiopharmaceutical Characterization Laboratory (RPCL) at Institute of Nuclear Energy Research (INER) has successfully passed the 'Good laboratory practice [GLP] for nonclinical laboratory studies' authentication by the Department of Health (DOH), the Executive Yuan on Nov., 2009. RPCL is the unique qualified GLP Testing Facility in Taiwan focusing on radiopharmaceuticals.

It is a required work to accomplish drug metabolism studies for new drug products marketing. The purpose of drug metabolism studies is to find out the possible induced toxicity or correlation from drug in body. We hope to ensure patients the medicine safety and present the detriment of pharmaceuticals. In order to fortify the marketing competitive potential of new drugs worldwide, INER developed the drug metabolites analytical technique platform for cells, organs, mice, rats and human bodies (cooperate with hospitals), included in- vivo, in-vitro and ex-vivo methods. RPCL provides new drug research projects of pharmaceutical industry the key point analytical technique to assure the effective ingredients, avoid from side effects, shorten the development schedule, and decrease fraction defective of products by means of GLP quality assurance system. After building up both 'GLP' norm and 'radioisotope pharmaceutical metabolism study' techniques, it has shown that INER has approached the international level for the ability of new radiopharmaceutical development independently. Instead of spending much capital for outsourcing international firms to study tedious drug metabolism, pharmaceutical industries in Taiwan could also discover new drugs by compatriots. Moreover, we could endeavor after 'Contract Research Organization' (CRO) projects from worldwide medicine markets, which total fund approach US$28G per year. Nuclear Medicine Team of INER welcomes and prepares for collaboration with domestic/ international universities, hospitals and pharmaceutical companies following CRO mechanisms to proceed strategic alliance and share resources.

▲ Tandem Mass Spectrometry Room



No: TFDA-GLP0990007

FOOD AND DRUG ADMINISTRATION,
DEPARTMENT OF HEALTH,
EXECUTIVE YUAN, TAIWAN, R.O.C.

GOOD LABORATORY PRACTICE
STATEMENT OF COMPLIANCE

Issue Date: November 20, 2009

The facility as described below has been inspected by the Food and Drug Administration, Department of Health, The Executive Yuan of the Republic of China and found to be in compliance with the Principle of Good Laboratory Practice (GLP) requirements.

Facility : Radiopharmaceutical Characterization Laboratory, Chemical Analysis Division, Institute of Nuclear Energy Research, Atomic Energy Council, Executive Yuan

Address : No. 1000, Wenhua Rd., Jiaan Village, Longtan Township,Taoyuan County 32546, Taiwan, R.O.C.

Scope : Pharmaceutical purity and component analysis, Pharmaceutical biochemical analysis

Signed by

Jaw-Jou Kang, Ph.D.
Director General,
Food and Drug Administration,
Department of Health,
Executive Yuan, Taiwan, R.O.C.

▲ TFDA-GLP0990007

3-10 The 2010 Annual Operation Report of Cobalt-60 Facility in INER

Chia-Chieh Chen

The Cobalt 60 facility of INER had accomplished its annual operation program this year. In addition to complete the R&D and service operation, this facility also focused and updated several security systems, like source rack system, conveyor system and the motion security system. This IR monitoring system can help the source rack down to the water pool once it detects some unknown people intrude into the radiation area.

The total operation time was 4,758 hours this year. During this long operation period, there was not any violation to the safety regulation. The exposure dose for all the operators were under the dose level of annual dose limitation.

To operate ergonomically this year, the operation time was 12 hours per day at least. To maintain the radiation quality, every batch had its own dosimetry measurement. There were several research contracts this year. The total income from the research contract service closed to 1 millions. Some other contracts were under discussion yet. These will become the most important service and income in the near future.

This year the radiation service items included deinsectization, eliminating the mildew, disposable medical supplies, medicine and related materials, industrial material, mutation radiation and food irradiation. The total number companies asking for the service was over 89. The boxes number finished radiation service was over 28,389 and the total income was over 10 millions dollars.

The cobalt 60 facility keeps its interesting with the international and civic demand to update their R&D program. Customer satisfy and service always are important to all the staffs. However, the safety will be the most important concern. Keeping no violation and accidence to the radiation safety will be the first priority to all the people working in this facility.

▲ Body Temperature Sensor System in Cobalt 60 Facility

▲ Security Lock System in Cobalt 60 Facility

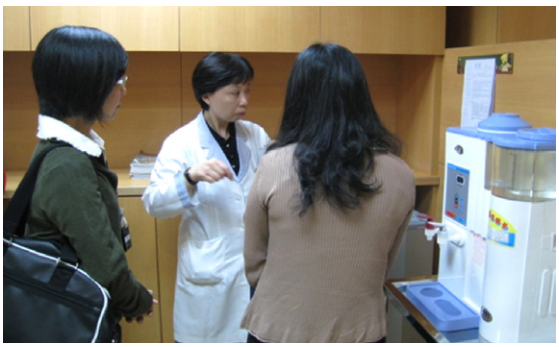
3-11 Development of Dose Assessment System for Nuclear Medicine Patient Release - to Protect Radiation Safety of the Public

Shu-Jun Chang, Kuo-Wei Lee, Ju-Chuan

In recent years, the probability and the number of persons suffering from cancer diseases as a result of delicate lives and aging of population are continuously climbing. Radiopharmaceuticals that enable direct detection of cellular activities and effective treatment toward cancer cells thus have become an important medical alternative for patients. According to the statistical database of the Department of Health, it was found that the patients administered radiopharmaceuticals were as many as 500 thousand in 2009. The implication behind the great amount of usage of nuclear medicine treatment is the increasing risks of radiation exposure of the public from nuclear medicine patients, since radioactivity retaining in the bodies would take a few hours or days to decay.

In this year, the INER has proposed a new system, "Self-Management of Radiation Safety at Home", in response to the potential risks in nuclear medicine radiation safety. Based on the long-term dose assessment technology and by referring to the new recommendations of several international radiation protection institutes, the INER has developed a dose assessment method for released nuclear medicine patients, for being the technical basis of the Self-Management system. With understanding the medical prescriptions and patient's living styles, the dose assessment method could result in a potential time-impact table for critical members exposed to an individual patient. Depending on the time impact table, several necessary, simple and feasible guides would be introduced in an individualized guidance to patients and family members, in order to guide them with correct concepts and procedures of radiation protection after being released from a hospital. On one hand, with an individualized guidance, a carer would clearly know how to compromise their hours in a day for taking care of a patient without having more exposure than the level of our Safety Standards. On the other hand, a patient could follow the given guide for better protecting their families with lower anxiety and uncertain feeling. Besides, such Self-Management system does not need extra societal and economical burdens to implement. All we have to do is to instruct well everyone how to manage him- or her-self at home and at societal activities.

It is expected that this system would potentially benefit the patients of 500 thousand treatment per year of nuclear medicine and the public members of about 2 million per year. Taking precautions against a possible calamity could be an effective way for reducing background radiations that might induce cancers from medical behaviors as much as 50%. Thus, it would really uplift the living environment of citizens for their health and maintain the quality of patient's household life.



Visiting the I-131 Ward in Department of Nuclear Medicine, for Investigating Radiation Safety Management Program

The Maximum Effective Dose after 10mCi I-131 Nuclear Medicine Administration (mSv)

Time after Administration (day)	Family Takes Care With Patient in Day-Time	Family Sleeping With Patient at Night	Total Does to Patient's Sleeping Partner	Working Partner	Helding Children	Total Does to Patient's Helding Children
1	0.876	11.754	12.630	1.156	7.124	8.000
2	0.757	10.152	10.909	0.999	6.153	6.909
3	0.661	8.870	9.531	0.872	5.376	6.037
4	0.578	7.762	8.340	0.763	4.704	5.282
5	0.506	6.793	7.299	0.668	4.117	4.623
6	0.443	5.945	6.388	0.585	3.603	4.046
7	0.388	5.204	5.591	0.512	3.154	3.541
8	0.339	4.554	4.894	0.448	2.760	3.100
9	0.297	3.986	4.283	0.392	2.416	2.713
10	0.260	3.489	3.749	0.343	2.114	2.374

▲ Illustration of a Time Impact Table for Critical Members Exposed to an Individual Patient Administered Radiopharmaceutical

4. Renewable and New Energy Technologies

Ying-Sheng Lee

The program of renewable and new energy technology in the Institute of Nuclear Energy Research (INER) has been conducted in concert with the energy policy of the Taiwan government. The research topics in the program are: high concentration photovoltaic (HCPV) systems, epitaxial silicon solar cells, quantum dot/polymer solar cells, small/medium wind turbine systems, cellulosic ethanol pilot plant and the core processing technology, solid oxide fuel cells, hydrogen storage materials, micro grid, clean coal, and energy models.

Substantial progress has been made in 2010. Solar Module Qualification Lab at Kaohsiung Scientific Park had completed 17 items of solar module testing platform conforming to IEC62108 standard, and passed UL lab certification in Nov, 2010 which will provide domestic testing and qualification services for concentrating solar module. The fabrication processes of the epitaxial silicon thin film were established and an epi-Si/UMG-Si solar cell device was also developed. For quantum dot/polymer solar cells, P3HT/PCBM(C_{60}) system with large area (> 4cm^2) were found to have a power conversion efficiency of 31.2%. With regard to the development of small/medium wind turbine system, a design certification project for the loads and load cases of INER-P150, a home-made 150 kW wind turbine system, was also conducted in cooperation with Det Norske Veritas (DNV) and was approved to be in compliance with IEC 61400-1 standard. In accordance with a ton-scale pilot plant with a capacity of one ton dry biomass (rice straw) per day, a mass production applicability tests and technology validations have been conducted. A 1,000-L fermentation system for the development of in-house cellulase production has been constructed. The cellulase produced by this system has reached an activity of 2.5 FPU/ml. A "Micro Grid Test Field" with total capacity of hundred-kW scale including wind power (175kW), micro-turbine (60kW), high concentration photo voltaic (HCPV 100kW) generations and energy storage system has been established. The fabrication processes for 100 grams Pt/AC sample were established, and the gravimetric hydrogen storage capacity of the hydrogen storage material was up to 9 wt%. For SOFC development, an 18-cell stack was assembled using the home-made metal supported cells (MSC), and its total power delivered was 596W (with the average power density at 408 mW/cm^2). A novel 3D multi-stage moving granular cold test bed is established for the clean coal technology, and the design rules can be applied for the commercialized moving granular bed filter development. In Addition, the energy-economic models, MARKAL and MARKAL-MACRO, have been established and validated for the energy model studies. The expert review of relevant analysis for BAU (Business As Usual) and the verification of power generation sector, industrial sector and transportation sector have all been accomplished.

4-1 Development of High Concentration Photovoltaic Technologies

Cherng-Tsong Kuo, Ying-Ling Wang

The advantages of High Concentration Photovoltaic (HCPV) are high power generating efficiency, less land required, low temperature coefficient, short recovery time of return on capital, and the potential of lowering the power generating cost, etc. INER has developed the technologies pertaining to HCPV system since 2003, including the III-V solar cell epitaxial and manufacturing process, concentrating solar module manufacturing process, solar tracker manufacturing, establishment of system monitoring and integration, on-grid techs, and solar module qualification, etc. The accomplishments included 45 patents acquired, 8 items of technology transferred, and 16 items of technical services provided till the end of 2010. INER has effectively integrated the upstream, middle-stream, and down-stream of local HCPV industry to reduce the system cost, and to promote the commercialization of HCPV. The R&D achievements of HCPV technologies are listed as follows:

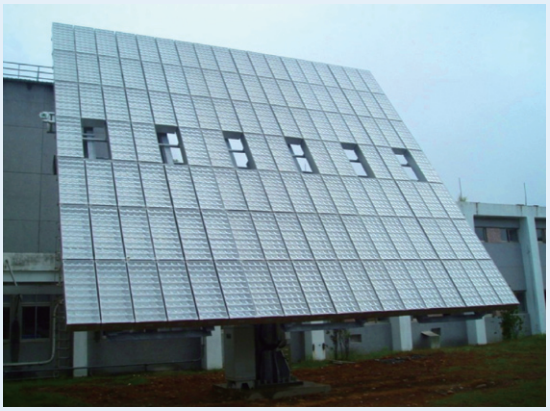
(1) Based on the manufacturing process of stacked mono-type multi-junction solar cell, the conversion efficiency of InGaP/GaAs/Ge triple junction solar cell reach up to 38.3% under 167 suns.

(2) Concentration PV lens was designed and manufactured by injection molding, which adopts PMMA certified by UL as its material, the highest outdoor conversion efficiency of the module is 29.31% under 476 suns, and 27.39% under 1,000 suns. Cost of the solar module will reduce by 20% while the geometric concentration ratio increases from 476 suns to 950 suns. Besides, the outdoor conversion efficiency is 28.08% while taking silicone-on-glass (SOG) as the material of the concentration PV lens.

(3) Cost of the solar tracker decreased by 10% by developing the large scale solar tracker for increasing the power capacity of modules from 5 kW to 15 kW, and decreasing the required parts and subsystems so to speak.

(4) INER has built up the multi-tasking and multi-threading HCPV central control and monitor platform, which is designed by the object orientated programming, and enables the programming to be flexible, traceable, testable, and easy for maintenance.

(5) Solar Module Qualification Lab at Kaohsiung Scientific Park (INER) completed 17 items of solar module testing platform conforming to IEC62108 standard, and passed UL lab certification in Nov, 2010 which will provide domestic testing and qualification services for the concentrating solar module.



▲ 15 kW Grade HCPV System

▲ UL Certificate for Solar Module Qualification Lab at Kaohsiung Scientific Park

4-2 R&D on the Upgraded Metallurgical-grade Silicon Solar Cell

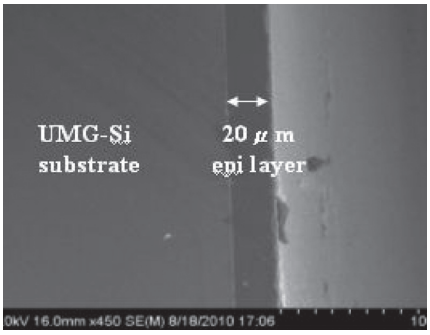
Tsun-Neng Yang

The objective of the project is to develop a laboratory-type epitaxial silicon thin-film solar cell with energy conversion efficiency greater than 10%. The main working items are (1) to develop the fabrication process of a high-quality epitaxial silicon thin film, and (2) to develop an epi-Si/UMG-Si solar cell device.

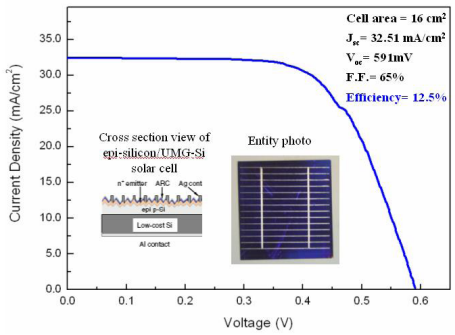
A home-made APCVD system is used in the following application. The thickness of ~ 20 μm p-type epitaxial silicon layer is successfully grown on the upgraded metallurgical silicon substrate with a purity of 4-5N at the temperature of 1,140°C. The etch pit density of the epitaxial silicon thin film is 1.8×104 / cm^2.

We have established the technologies of fabricating the laboratory-type epi-Si/UMG-Si solar cells, such as substrate surface polishing, high temperature epitaxial growth, plasma surface texturing, hydrogen passivation, etc. Under AM1.5 illumination, the best efficiency of the epi-Si/UMG-Si solar cell is 12.5% with the cell area about 16 cm^2.

The purpose of this project is to develop a low-cost, high-efficiency epi-Si/UMG-Si solar cell device, which combines the advantages of the thin film solar cell and the high efficiency of silicon solar cell. It is compatible with the traditional silicon solar cell technology, and is a potential alternative to the high cost multi-crystalline silicon in the future.



▲ SEM Cross-section View of the P-type Epitaxial Si Layer



▲ I-V Curve of the Epi-Si/UMG-Si Solar Cell

4-3 Development of Large Area Organic Solar Cells by Spray Coating Process

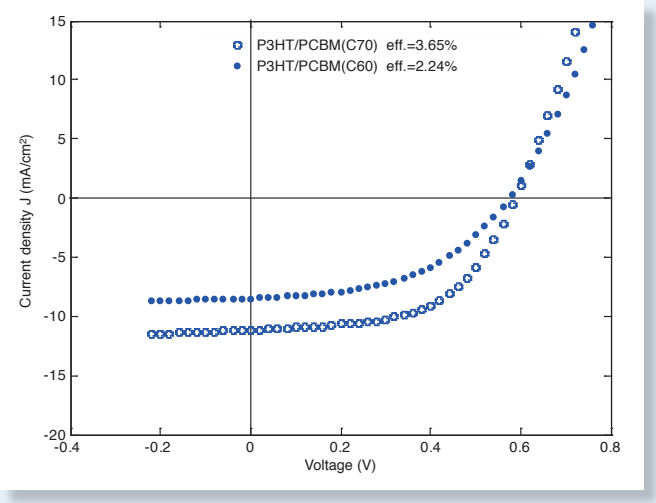
Chih-Min Chuang

The quantum dot/polymer solar cells have become the most promising third generation solar cells due to their advantages of low weight, mechanically flexible, environmentally friendly process, and low cost. The manufacturing process can use the fast roll-to-roll technique which has the large area and low cost advantages. It can be able to combine with portable consumer electronics products to enhance the practicality and breadth of market applications. With the improvement of solar cells efficiency and the large area manufacturing process, the quantum dot/polymer solar cell will become the mainstream technology of low cost, off-grid portable energy.

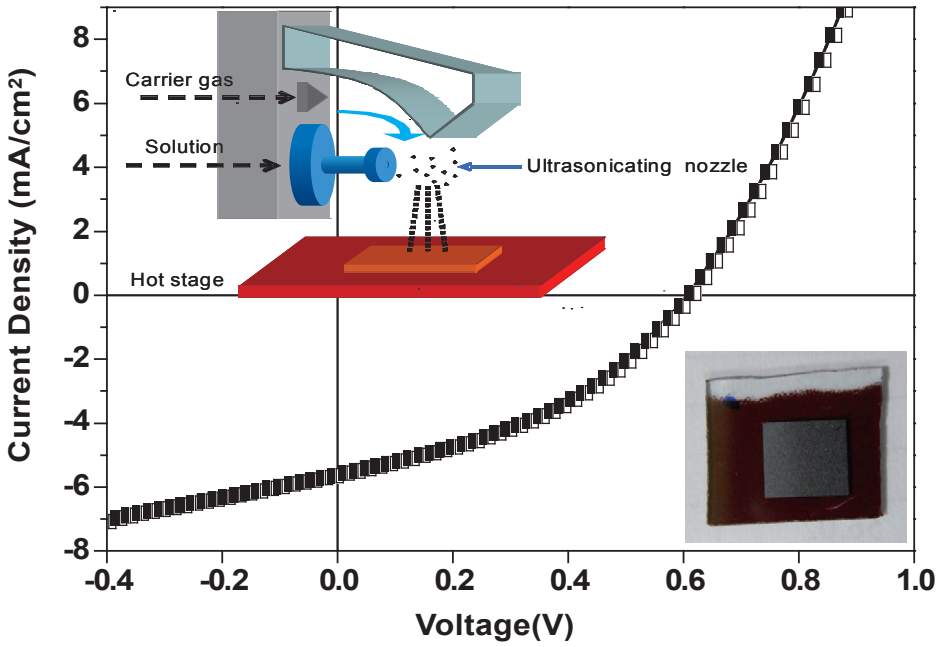
Our study was focused on the technology of organic solar cells fabricated in small area (<1cm^2) and large area (> 1 cm^2). The small area organic solar cells were fabricated by using spin coating process. In the hybrid of poly(3-hexyl thiophene) (P3HT) and (6,6)-phenyl-C_{71}-butyric acid methyl ester (PCBM(C_{70})) system, the highest power conversion efficiency of 3.65% can be achieved by tuning the process parameters, such as the mixing time and concentration of the hybrid solution, devices annealing temperature and annealing time, the molar ratio of P3HT and PCBM and the deposited cathode thickness. Furthermore, in the hybrid of P3HT and phenyl-C_{61}-buryric acid methyl ester (PCBM(C_{60})) system, the power conversion efficiency can be improved from 2.36% to 3.50% by using Ca/Al cathode instead of Al cathode. Figure showed the current-voltage curves of the two different hybrid systems with Al electrode deposition.

Moreover, we developed the spray coating process of large area solar cells successfully. This process first dispersed the hybrid solution into 20-30μm drops by ultrasonic and then deposited on the substrate uniformly. From our initial results, the power conversion efficiency of P3HT/PCBM(C_{60}) system with large area (> 4cm^2) can be achieved to 1.2%.

The performance of our quantum dots/polymer solar cells has been met the international standard. Nowadays, the international researches are still focused on improving the performance of small area solar cells; the technology of large area solar cell leave room for development. This project builds up the technology of large area solar cells with fast, low cost and low energy-consuming process; it will have a lot of opportunities to set up its unique patents.



I-V Curves of the Two Different Hybrid Systems with Al Electrode Deposition



▲ I-V Curve of Large Area (> 4cm^2) P3HT/PCBM(C60) Solar Cell System with Conversion Efficiency of 1.2%

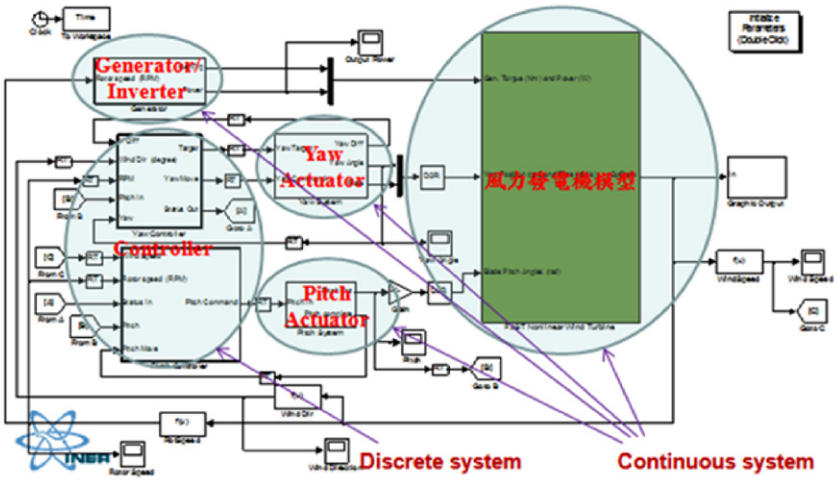
4-4 Development of Design Assessment Technique in Compliance with IEC 61400 Standard

Wei-Nian Su

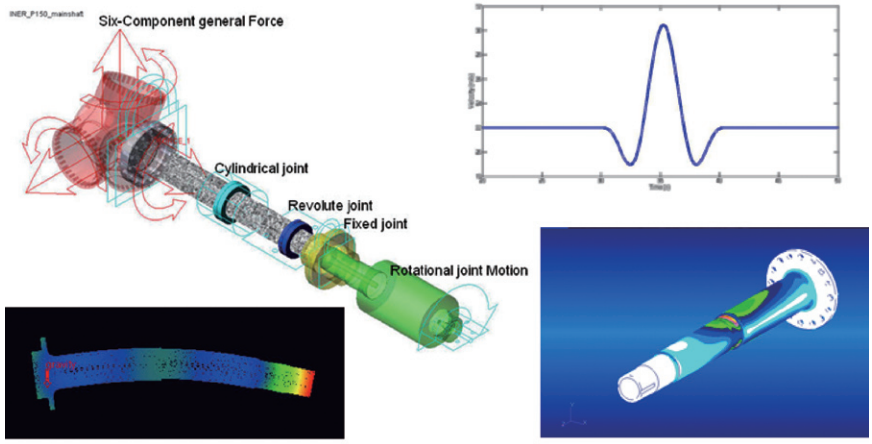
The small-and-medium-sized enterprises have been actively involved in the development of small-and-medium-sized wind turbine systems these years. The European countries and America also noticed the uniqueness of this market and started their own regulation for small wind turbine system. Inevitably, the type certification of small-and-medium-sized wind turbine will become mandatory in the near future. The Institute of Nuclear Energy Research (INER) has developed the technique of design assessment in compliance with IEC 61400 standard in 2010.

The certification process involves the fault analysis of control and protection system, dynamic simulation of wind turbine system, and transient analysis of component strength. In cooperation with Det Norske Veritas (DNV) in 2010, the loads and load cases of INER-P150, a 150 kW wind turbine designed by INER, is approved to be in compliance with IEC 61400-1 standard.

In overall, INER will continuously work on the development of analysis technique for small-and-medium-sized wind turbine system. Furthermore, cooperating with wind turbine test sites, the type certification platform for mall-and-medium-sized wind turbine system will be established in the near future.



▲ Dynamic Simulation of INER-P150 Wind Turbine



▲ Transient Analysis of Drive Train System

4-5 Development of Cellulosic Ethanol Technology at INER

Chwei-Huann Chiou

In comply with the national energy policy, INER has dedicated to the development of the second generation biofuel technology - cellulosic ethanol technology. A ton-scale pilot plant with a capacity of one ton biomass feed per day was built up in 2009, while a mass production applicability tests and technology validations have been conducted in 2010. Progress achieved will be served as the basis for the cost assessment as well as technology commercialization of cellulosic ethanol. In addition to the demonstration and promotion of the cellulosic ethanol, the pilot plant will also be served as a testing platform for validating the scalability of novel technologies developed for cellulosic ethanol. In 2010, the main achievements are the development of continuous acid hydrolysis explosion pretreatment and solid-liquid separation system, which effectively improved the efficiency of the pretreatment process. Separate hydrolysis and fermentation (SHF) process was studied in the pilot plant. Standard operation procedures, equipment control tests, and system software/hardware improvements were performed to improve the system operation stability. To enhance the process performance, simultaneous saccharification and

fermentation (SSF) process will be examined, which is expected to improve the yield of cellulosic ethanol per ton of rice straw from 150 L to 180 L. Another achievement during this year was the construction of a 1000-L fermentation system for the development of in-house production of cellulase. Currently, the cellulase produced by this system has reached an activity of 2.5 FPU/ml. In the microorganism for co-fermentation of glucose and xylose development, through collaborations with academic institutions, a co-fermentation yeast strain, designated *Saccharomyces cerevisiae* YY5A, was developed via gene recombination technology. The total sugar-to-ethanol conversion efficiency of *Saccharomyces cerevisiae* YY5A can reach as high as 80%, while the xylose utilization rate and ethanol conversion are 1.6 g/L/h and 65%, respectively. Such performance is comparable with results reported worldwide. The *Saccharomyces cerevisiae* YY5A will be applied to develop the simultaneous saccharification and co-fermentation (SSCF) process.

▲ Ton-scale Continuous Acid Hydrolysis Pretreatment System

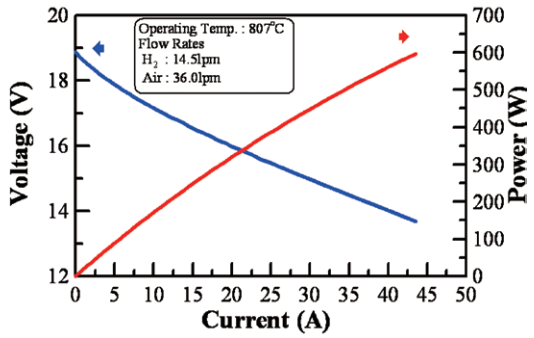
▲ Enzyme Production Facility at INER

4-6 Development of SOFC and Hydrogen Storage Materials Technology

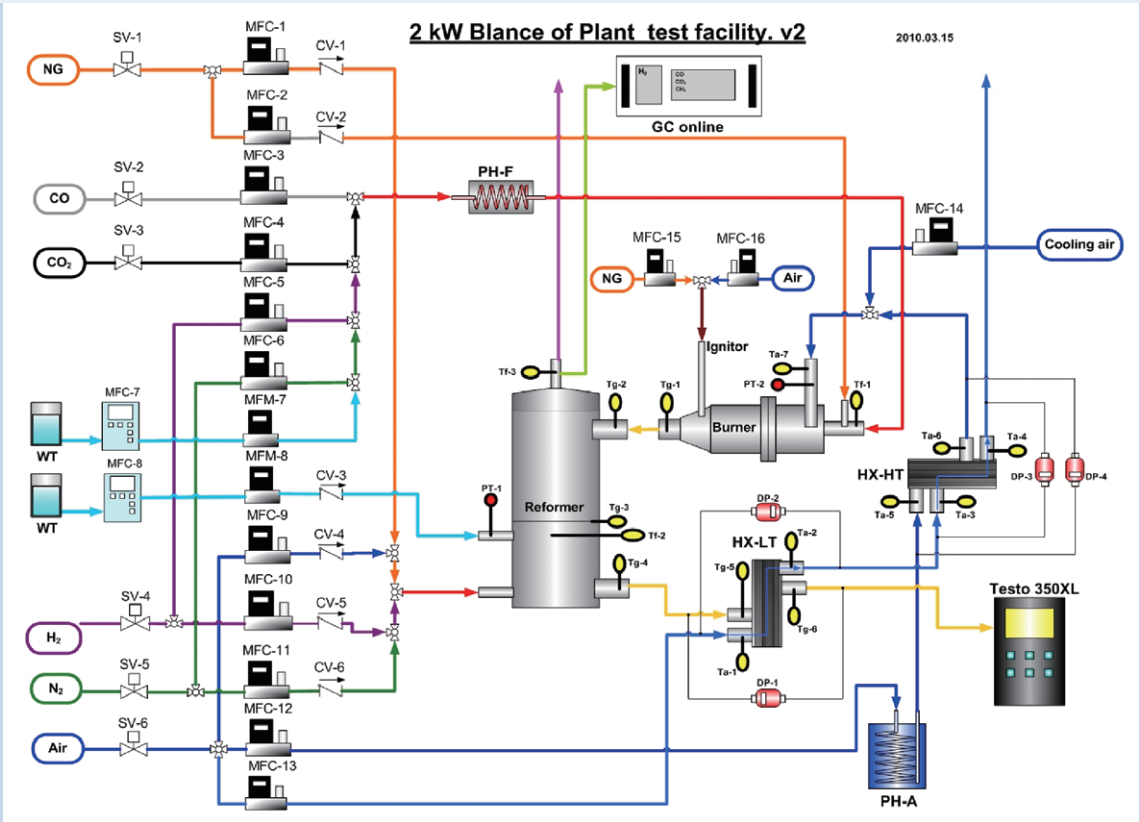
Kin-Fu Lin

In concert with the governmental energy policy, this project was aimed to develop technologies associated with 1~5 kW SOFC power generating system and hydrogen storage materials. The progresses achieved in 2010 include: (1) Assembling an 18-cell stack by using the metal supported cells (MSC) fabricated by INER, and the total power delivered was 596W (with the average power density at 408 mW/cm^2). (2) Through the using of MEA purchased from InDEC, over 150 hrs'durability test was conducted for an 18-cell stack (543W), and a 5-cell short stack was tested for over 1,300 hrs. The average degradation rate of performance was about 1.1%/kh. (3) Validation tests on the key components, e.g. reformer, heat exchanger, after burner etc. for system integration were proceeded, and satisfied results were achieved. (4) The MSC-MEA was tested over 4,000 hrs, followed by the thermal cycling test and redox test. After abovementioned tests, the degradation rate of cell performance was less then 0.4 %. (5) A series of composite cathode was tested for the ASC-MEA, maximum power density of 411 mW/cm^2 was measured at 800°C. (6) The standard process for fabricating 100 grams Pt/AC sample was established, and the hydrogen storage materials were loaded into the cartridge for testing the performance.

For SOFC technology development, the quality of stacking has been continuously improved. Incorporated with the established techniques of sealant and interconnect, also the key components for system integration, the overall R&D achievements in year 2010 has facilitated the fulfillment of program target in a faster speed. The fabrication processes for 100 grams Pt/AC sample were established, and the gravimetric hydrogen storage capacity of the hydrogen storage material was up to 9 wt%. With such high hydrogen storage capability, the materials will be ready for commercial applications provided that the uptake and release rates of hydrogen gas from the cartridge meet the practical requirements.



▲ Performance of the 18-cell Stack



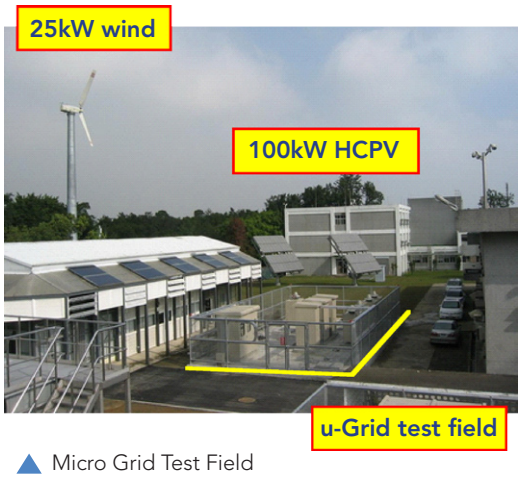
▲ Schematic Diagram of Balance of Plant for SOFC System

4-7 Development of Micro Grid Technology

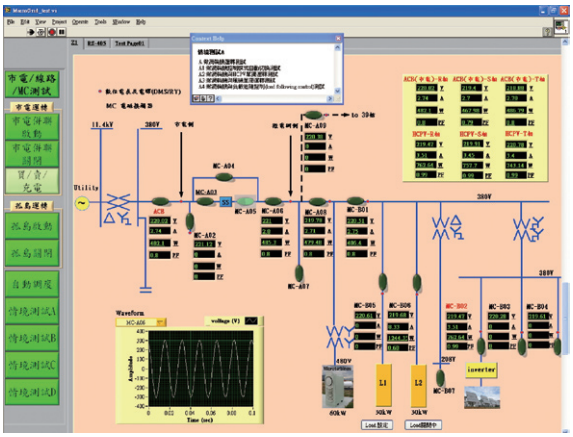
Yung-Ruei Chang

The renewable energy systems in modern world, ether in individual house or in small communities, belong to small-scale dispersed generation system. However, the high-potential renewable energy sources, particularly wind and direct solar energy, are intermittent. Due to the intermittent and uncertain characteristics, the high penetration of renewable power generation will causes power fluctuation and dramatic impact on the operation of regional power system. Dispersed Generation (DG) and Micro Grid (MG) technology provide alternative solutions, especially for national energy security and national carbon emission reduction.

INER is currently developing the low voltage micro grid technology. A "Micro Grid Test Field" with total capacity of hundred-kW scale including wind power and high concentration photo voltaic (HCPV) generations has been constructed at INER. The Micro Grid Test Field can provide an integrated platform that can be applied not only for academic research purpose, but also for industrial testing and implementation. Based on these facilities, INER is developing an autonomous micro grid technology including reactive power control, LVRT, frequency droop control, protection coordination, and energy management for micro grid. INER will play a middle-stream role on the integration of smart grid technology, which is between the upper-stream academic research and down-stream industrial society. We believe that it will contribute to energy saving, carbon emission reduction, and industry demonstration in the future.



▲ Micro Grid Test Field



▲ The Control System for Micro Grid

4-8 Development of Multi-Stage Dust Removal System

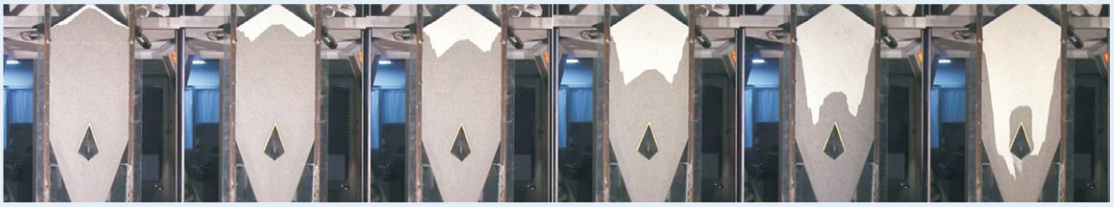
Yau-Pin Chyou, Yi-Shun Chen

The gasification system for power generation and the advanced coal-fired power plants have been developed in United States, Europe and Japan in recent years. The high temperature gases contain many dust particulates and fly ashes which should be filtrated before entering gas turbine.

In order to save more filter media and filtration cycles, the project designs a two-dimensional (2D) system of angle of wall degree 20 and 40. The best analyses results which compares to previous year will apply to the manufacture of three-dimensional (3D) cold model.

With the result of this study, a novel 3D multi-stage moving granular bed for the cold test is established. The plan in the future will manufacture a 3D multi-stage compacted granular bed filter (GBF) cold model system. And the measurement of air velocity distribution on inlet of compacted of GBF and measurement of pressure drops across the moving bed of GBF will be processed. The final goal of the project, we wish the design rules for the commercialized moving granular bed filter can be developed.

Flow Patterns of Filter Granules in the Moving Bed with the Angle of Wall Degree 20



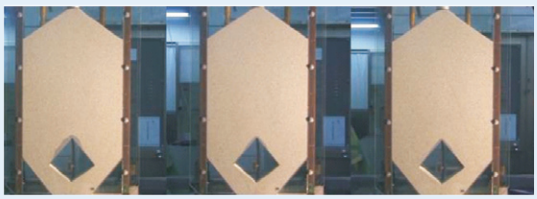
0 min 5 min 10 min 20 min 30 min 40 min

50 min 60 min 90 min 120 min 240 min 360 min

Flow Patterns of Filter Granules in the Moving Bed with the Angle of Wall Degree 40

0 min 5 min 10 min 20 min 30 min 40 min

50 min 60 min 90 min 120 min 240 min 360 min



480 min 600 min 720 min

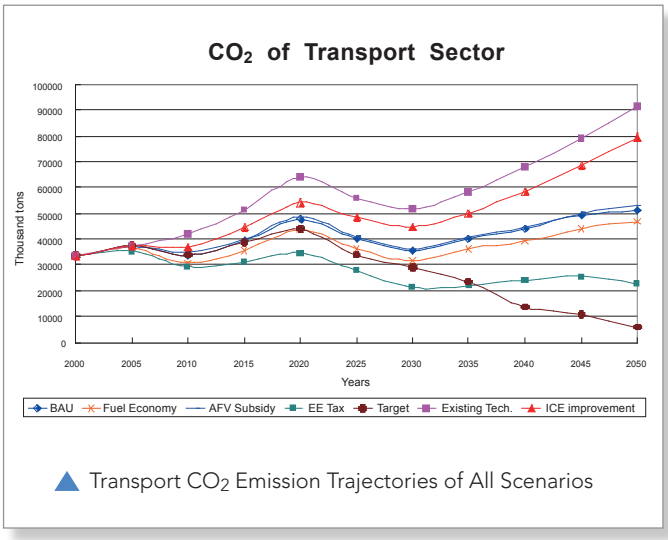
4-9 MARKAL-MACRO Energy Model Development-Validation and Analysis for Transport Sector

Fu-Kuang Ko, Chung-Han Lin

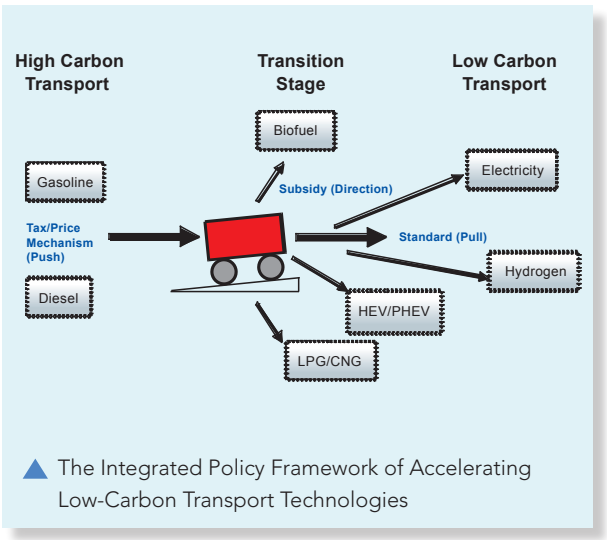
INER established and improved continuously the energy model, INER MARKAL and MARKAL-MACRO (integrated with macro-economy). The expert review of relevant analysis for BAU (Business As Usual) and the verification of power generation sector, industrial sector, and transportation sector are completed. In 2010, INER expanded the modeling parameters of transportation sector from the original 30 to 108 technologies. Relevant settings about ICE Upgrading, Alternative Fuel, and AFV technologies of passenger/freight transportation are added and the competition and cost-effectiveness of vehicle technologies are evaluated from overall and systematic viewpoints.

From the results, it should improve energy efficiency in the short/mid-term and decrease the carbon intensity of transportation energy in the long-term to achieve the mitigation target of transportation sector. Therefore, to reduce carbon emissions, the following technologies should be adopted, such as HEVs, PHEVs and BEVs for passenger transportation and HEVs, biofuel and FCVs for freight transportation.

Notable conclusions are as follows: Firstly, Energy and Environmental Tax are effective and comprehensive policy to reduce CO_2 emissions from transportation significantly. Secondly, raising fuel economy standard can contribute a certain amount of CO_2 reduction but its effect diminishes with natural technological progress. Thirdly, existing subsidies policy on AFV has few effects on CO_2 reduction. Finally, an integrated policy framework about three main strategies for accelerating development of low carbon vehicle technology is suggested.



▲ Transport CO_2 Emission Trajectories of All Scenarios



▲ The Integrated Policy Framework of Accelerating Low-Carbon Transport Technologies

5. Environmental Plasma Technologies

Chin-Ching Tzeng

Thermal and non-thermal plasmas technologies are developed at INER for environmental and industrial applications. Based on the pertinent properties of the DC thermal plasma torch (i.e. high temperature and high energy density) and non-thermal plasma (i.e. high chemical reactivity), several technologies such as plasma vitrification for waste treatment and resources recovery, plasma gasification for power generation and bio-fuel production, plasma coating for thin-film solar cell fabrication and plasma surface modification for many industrial applications, etc. are developed. The main research activities of this year include: (1) Advanced studies on high temperature thermal plasma, (2) Reclamation of aluminum dross and applications of the derived products, (3) Plasma-assisted gasification technology for power generation and bio-fuel productions, (4) Development of flexible thin film solar cell processes, (5) Design and installation of R2R demonstration system for thin-film solar-cell depositions, and (6) The promotion of plasma coating technique of high power impulse magnetron sputtering. Achievements and details of the research activities are described as follows.

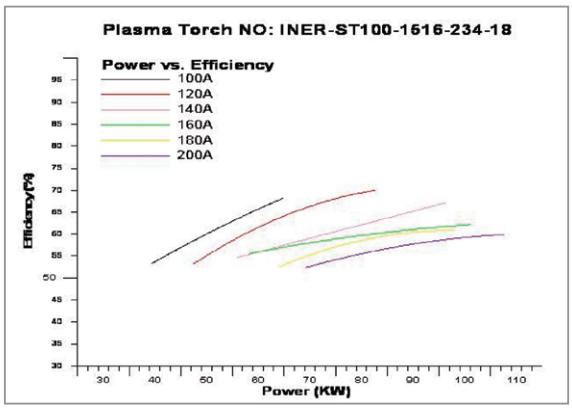
5-1 Advanced Studies on High Temperature Thermal Plasma

Shiaw-Huei Chen

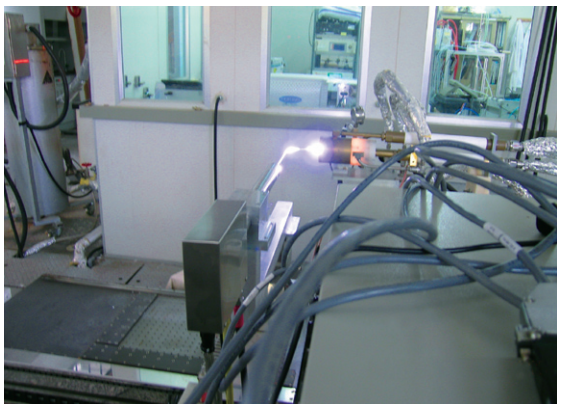
The project "Advanced Studies on High Temperature Thermal Plasma" focuses goals on the integration of high temperature plasma diagnostic techniques and the verification of plasma simulation, with an aim on plasma torch performance improvement. In the first year of this project, a test platform of integrated torch operation and data acquisition system were constructed. It included all the subsystems such as gas supply, cooling water, and a 3-axis precision position control used as a graphic control interface. This platform was used to calibrate and map out the characteristic of the 100kW grade steam plasma torch, and subsequently improved the thermal efficiency of the well-type steam plasma from 30% of the previous year to 65% at the 95kW. An enthalpy probe was added as a high temperature plasma diagnostic tool during this year. This probe can directly measure physical properties such as temperature, enthalpy, velocity, pressure etc., at the exit flame of the plasma torch. All these installed equipments provided a platform for the verification of the plasma simulation code developed at INER. This shall result in code enhancements and subsequently benefit us better in the understanding of physical mechanism involved in high temperature thermal plasma and the design improvement of the plasma torch with confidence. Since computer simulations of thermal plasma involves complicated physics and requires significant computing power, a novel 12 CPU core workstation with a state-of-the-art Nvidia GPU C2050 was installed to speed up the calculation. The original plasma code will be transformed into a parallel-computing code expecting that the computing time will be reduced from days to hours.

Follow-up tasks include performing additional plasma measuring and diagnostic tests on the systematic torch platform to double-check the plasma simulation code. Aiming at enhancing industrial applications and technology transfer, the establishment of a standard torch testing protocol for quality

assurance purpose is scheduled. To meet the need for speed verification of simulation results with experimental data, a high-efficient parallel-computing plasma code will be developed as a high priority. The experience gained will be beneficial to the research on higher temperature plasma regimes like MHD and thermal fusion.



▲ The Thermal Efficiency vs. Torch Power of the Well-type Steam Plasma



▲ Photo of Enthalpy Probe Measuring the Flame at Plasma Torch Exit

5-2 Reclamation of Aluminum Dross and Application of Derived Product

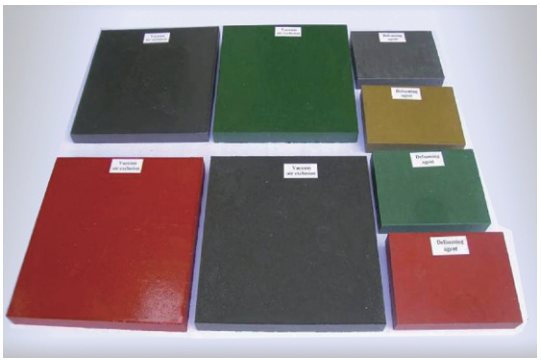
Sheng-Fu Yang

The Institute of Nuclear Energy Research (INER) has been devoting to the research of plasma-melting technologies for years to treat municipal solid waste incinerator (MSWI) ashes and reutilize end products as green materials. Accumulated experience are fruitful that have been promoted for treating industrial wastes. In this project, INER is commissioned by a domestic company to develop composite material (Fig. 5.2a) and refractory (Fig. 5.2b) from aluminum dross.

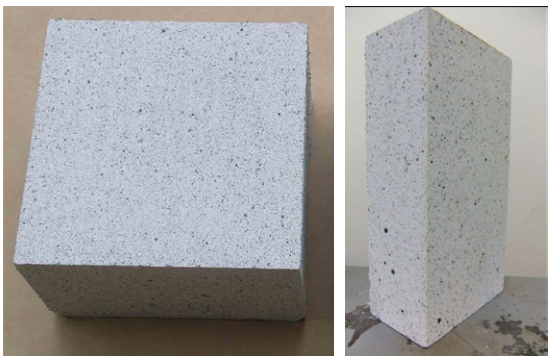
According to test results of produced composite material, the amount of aluminum dross to be added is 53.3 wt% to produce composite material with density, water absorption and Barcol hardness at 1.68 g/cm^3, 0.89% and 37, respectively. The corresponding mechanical properties of compressive strength (Fig. 5.2c) and flexural strength are at 1010 kgf/cm^2 and 500 kgf/cm^2. After corrosive etching tests, there are no apparent defects presented on the surface of the composite material that is suspectable for immediate stress-related cracking, swelling or peeling. According to experimental results and the Chinese National Standards (CNS), the produced composite material can be categorized as: 1. Decorative laminated sheet based on thermosetting resins (CNS 11366); 2. Casting sheet (CNS 9715); 3. Movable partition (CNS 8072). For refractory, we suggested the added amount of carboxyl methyl cellulose (CMC) solution to be at 8 % (V/W) and calcination temperature at 1,200°C. At this condition, a product with the bulk density, porosity, compressive strength (Fig. 5.2d) and flexural strength at 1.78 g/cm^3, 11 %, 390.6 kgf/cm^2 and 36.8 kgf/cm^2 respectively can be formed. Al_2O_3 is the main chemical composition of the refractory product at a proportion of 75.35 %. Both of composite material and refractory met the Toxicity Characteristic Leaching Procedure (TCLP) tests are environmentally benign. According to experimental results and the Chinese National Standards (CNS), the produced refractory can be classified as: 1. High alumina brick (CNS 2352); 2. Fire clay brick for metallurgical refining (CNS 2394);

3. Fire brick for steel-refining electric furnace, such as electric furnace roof brick, high alumina stopper, nozzle brick, sleeve brick and runner brick (CNS 3588).

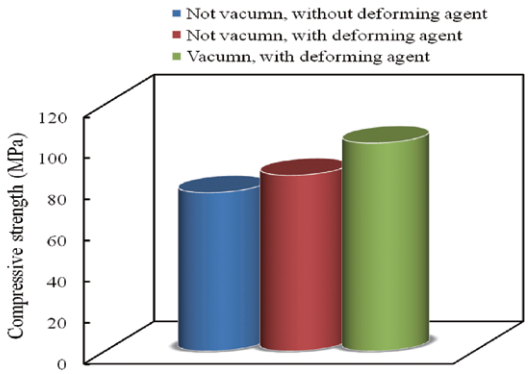
In 2011, we will continue to develop products such as commercial-sized fiber cemented composites which are made of man-made vitreous fiber (MMVF) with an energy consumption rate lower than 2.0 kWh/kg. Cooperation with the industry to solve waste-disposal problems and to avoid inappropriate treatments of wastes that impact on our environment remains our main objectives.



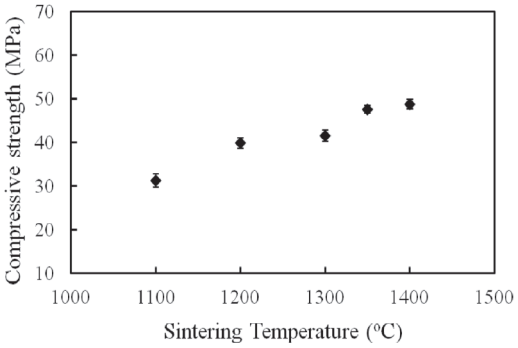
▲ Fig.5.2a. Composite Materials
(Size: 300×300×30 mm)



▲ Fig.5.2b. Refractory Brick
(Size: 230×114×65 mm)



▲ Fig.5.2c. The Comparison of Compressive Strength For Various Composite Materials



▲ Fig.5.2d. The Relationship Between Calcination Temperatures and Refractory Compressive Strength

5-3 Plasma-assisted Gasification for Power Generation and Biofuel Production

How-Ming Lee

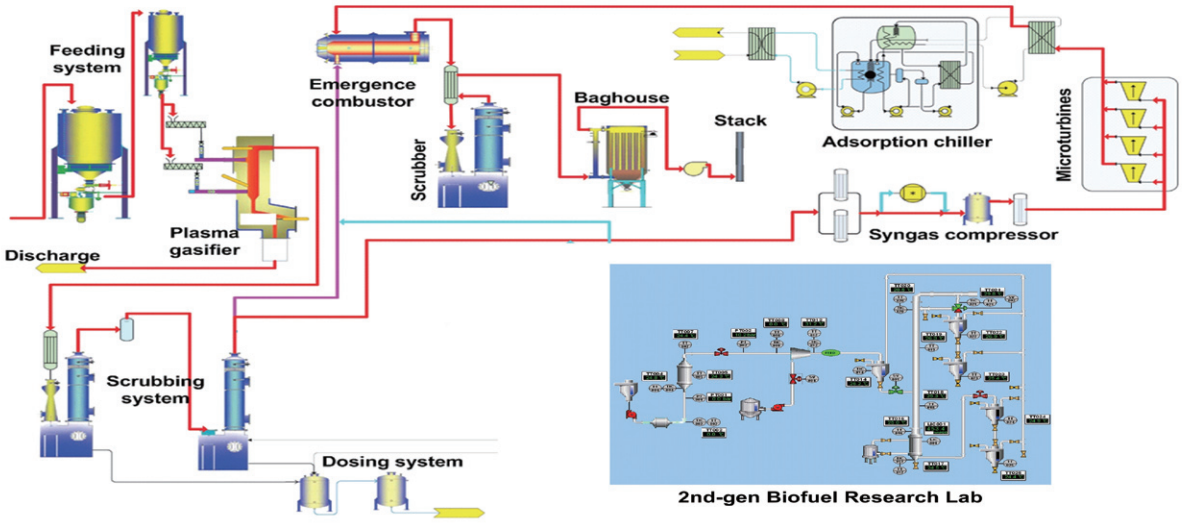
The Physics Division of INER devotes to development of bioenergy power generation technologies as well as biofuel production techniques. An innovative plasma-assisted gasifier, a high-efficiency CHP (combined heat and power) system, and a syngas liquefaction technique have been developed in INER. An advanced plasma-assisted biomass gasification plant has been constructed in INER. The designed biomass feeding rate is of 100 kg/hr, the max operating temperature of 1600°C, the max gasification pressure of 10 kg/cm^2, and the power capacity of 120 kVA. An academic biofuel production lab has also been established. Current objective at INER is to focuses on synthesis of clean biofuels like methanol (MeOH), dimethyl ether (DME), and gasoline that is of higher economical value.

The research outcomes in 2010 are listed as follows:

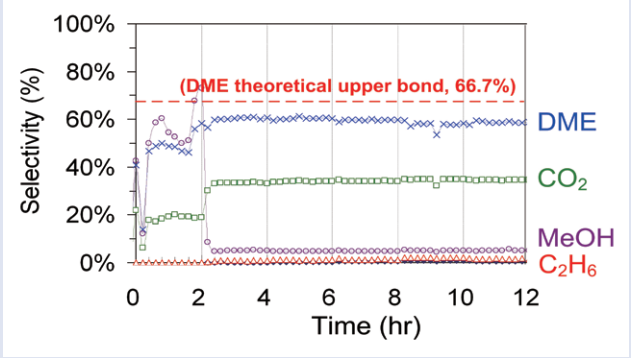
(1) In terms of plasma gasification, with the aid of air plasma torch (10~100 kW), wood chips are gasified to form high quality syngas containing 30% CO and 10% H_2 with CO/CO_2 >3, which is better than traditional gasifiers. The arching problem has been overcome with a new feeding system due to its special mechanical design and unique control sequence. The feeding rate is greatly enhanced from 40 kg/hr to above 120 kg/hr.

(2) CHP: The CHP system integrates a set of micro-turbines with an adsorption chiller. The micro-turbine can operate properly with fuels containing at hydrogen concentration as high as 10%, and with thermal to electricity efficiency at 25%. The thermal energy of micro-turbine exhaust is efficiently recovered by an adsorption chiller. An overall thermal efficiency of 60% can therefore be achieved.

(3) Biofuels: A series of highly active catalysts have been successfully developed. The syngas can be converted into 2nd-gen clean biofuels like methanol and DME. A DME selectivity of above 60%, close to the theoretical upper bond of DME synthesis, is achieved. A DME yield above 2.0g-DME/g-cat.-hr is also achieved. In addition to the development of catalyst, a lab-scale 5 kg/day DME production system is also successfully established. It can produce DME with a purity greater than 99.9%, which meets the international DME standard. The lab-scale DME production system can serve as a R&D and/or demo platform for industrial, academic, and institutional organizations. The success of this project is beneficial to the national goals of carbon reduction, alternative energy supply, indigenous fuels, and developing a new industry.



▲ Plasma-Assisted Gasification Power Plant & the Syngas Liquefaction



High Selectivity Achieved for Clean 2nd-Gen Biofuel, Dimethyl Ether (DME) ▶

5-4 Developments Of Flexible Thin Film Solar Cell Processes

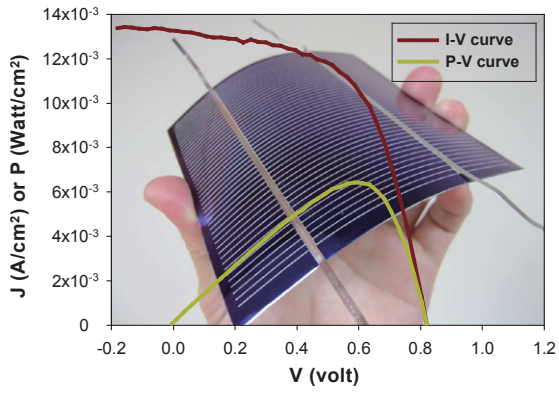
Der-Jun Jan

As compared with conventional crystalline silicon solar cells, which are bulky and rigid, flexible silicon thin film solar cells are lightweight and could easily be integrated into roofs and building facades. These flexible modules could also be incorporated much easily with the design of consumer electronics and become more attractive than conventional solar modules. Technology and equipments for mass production of flexible solar cells are not available in Taiwan. The object of this program is to develop thin film solar cell based on stainless steel (S.S.) substrate adapted to the roll to roll plasma-coating platform at INER. In doing so, we enhance the competitiveness of our local photovoltaic industry in the world market.

In this program, we have developed processes using showerhead plasma source under RF 27.12 MHz compatible with nontransparent stainless steel substrates in the n-i-p configuration. Followings are items that have been achieved during this year:

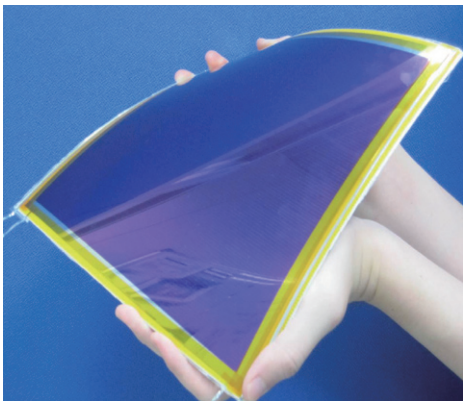
1. Deposition conditions on S.S. substrate have been identified for which device quality i-layer with uniformity of ±5% and photosensitivity above 10^5 can be obtained over 25 cm×25 cm substrate area. These characteristics meet the requirements of thin film silicon solar cell on S.S. substrate.
2. The flexible solar cells on 10 cmx10 cm S.S. substrate with conversion efficiency of 6.4% has been achieved for a a-Si:H single-junction solar cell device.
3. The preliminary production of large-area 530 cm^2 flexible solar cells and their module encapsulation have been evaluated. These modules demonstrated a good potential for industrial applications and had been presented in the 2010 Taiwan International Green Industry Show.

Furthermore, the conversion efficiency of flexible silicon film solar cells can be enhanced by means of optimizing the p-layer and back contact layers. The solar-cell production technology scaled up to 30 cm×30 cm unit will be developed.



Voc (volt)
0.824
Isc (mA/cm²)
13.1
Eff.(%)
6.35
F.F.(%)
58.4

▲ The 100 cm^2 Flexible Thin Film Solar Cell Developed in INER with Output Characteristics as Indicated



▲ The 530 cm^2 Large-Area Flexible Thin Film Solar Cell Developed in INER

5-5 Establishment of Roll-to-Roll Plasma Coating Platform

Cheng-Chang Hsieh

Roll to roll plasma coating platform provides a continuous muti-layer plasma-enhanced coating process for flexible materials. Not only the flexible productive function is demonstrated, the goal in reducing production cost and product weight has also been realized significantly. These advantages provide a much competitive edge in the world market in the fabrication of flexible thin-film solar cell comparing to the rigid (glass) thin-film solar cell using conventional in-line plasma coating systems. To make more contribution in next generation thin film solar cell fabrication, the roll to roll plasma coating platform for producing flexible solar cell on the stainless steel (S.S.) sheet substrate is under construction in this program.

Major progresses made during the year are as follows:

(1) The roll to roll ultra-clean pretreatment system, including functions of metal sheet unwinding and rewinding, tension and position controls, ultrasonic washing and drying, and plate-cutting, has been installed. It provides a dry and particle-free S.S. substrate suitable for thin film silicon deposition. The surface contact angle is lower than 40 degree at substrate speed up to 1 meter per minute. An atmospheric plasma cleaning process will be added to this system in the next step. We expect this will further reduce the surface contact angle to less than 30 degree to meet the design requirement.

(2) A lab-scale roll to roll PECVD system is under development. The subsystems for vacuum pumping and tension control have been completed with vacuum quality meeting process requirement. The tension control functions include the precision tension balance for moving S.S. substrate and the substrate speed operating range is between 0.02 and 10 m/min. In addition, the optimized design of the gas gate for isolating the neighboring process chamber to prevent inter-contamination during deposition has been simulated and will be incorporated into the system accordingly.

▲ Roll to Roll Ultra-Clean Pretreatment System

▲ Roll to Roll PECVD System

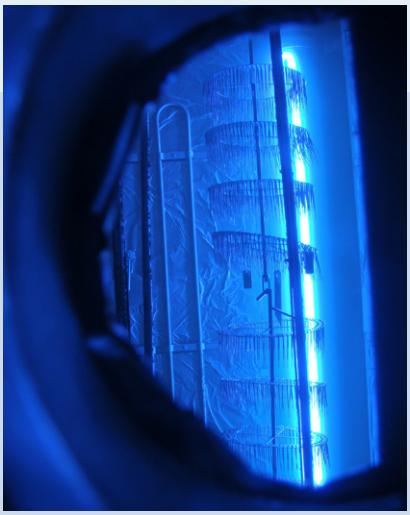
5-6 The Promotion for Plasma Coating Technique of High Power Impulse Magnetron Sputtering

Gin-yu Wu

In recent years, the high-power impulse-magnetron sputtering (HIPIMS) technique has become most promising in term of functionality in the physical vapor deposition (PVD) field. HIPIMS can produce very high plasma density during the pulse period of hundreds of micro-seconds with plasma power at the range of mega-watts. In HIPIMS coating, the substrates are subjected to plasma of nearly 100% ionization for concurrent bombardment and deposition, which resulted in a film surface with excellent quality in ion adhesion, anti-corrosion and a dense substructure. The technique has been recognized as a definite solution to overcome problems in traditional PVD coating and a promising tool for greater economical opportunities.

The HIPIMS technique developed in INER has been successfully qualified for the surface coating of a few selected commercial products and obtained durability improvement of two to three times comparing with uncoated ones. Tested products include gears, bearings, needles used in the textile industry and lathe tool for metal machining, which all coated with nearly 1 μm thickness of TiN films. In addition, HIPIMS is capable of using the temperature controllable process to perform low temperature coating. This year we have reached a technical transfer contract for HIPIMS with a domestic fabrication company to develop an exclusive mass-production coating system with a coating chamber sized at 1.8 meter in diameter, 2.1 meter in height and equipped with a rotating cylindrical target 1.5 meter in height, connecting to a world-class plasma source at 40kW average power. The company accepting such technology transfer is reknowned of plasma coating on bathroom sets and aims, through this transfer, to improve film adhesion by coating their existing products with TiN and ZrN films. More importantly, HIPIMS have demonstrated to add value to products of large molding or machine tools by improving film qualities of anti-corrosion, abrasion resistance and smoothness. In the future, research on HIPIMS will emphasize on applications to various products in the electrical, optical and energy industries by offering greater economical value to the society.

▲ The Mass-production HIPIMS System



▲ The Plasma Coating Condition of HIPIMS System for Depositing the Needles by Cylindrical Target

5 Appendices

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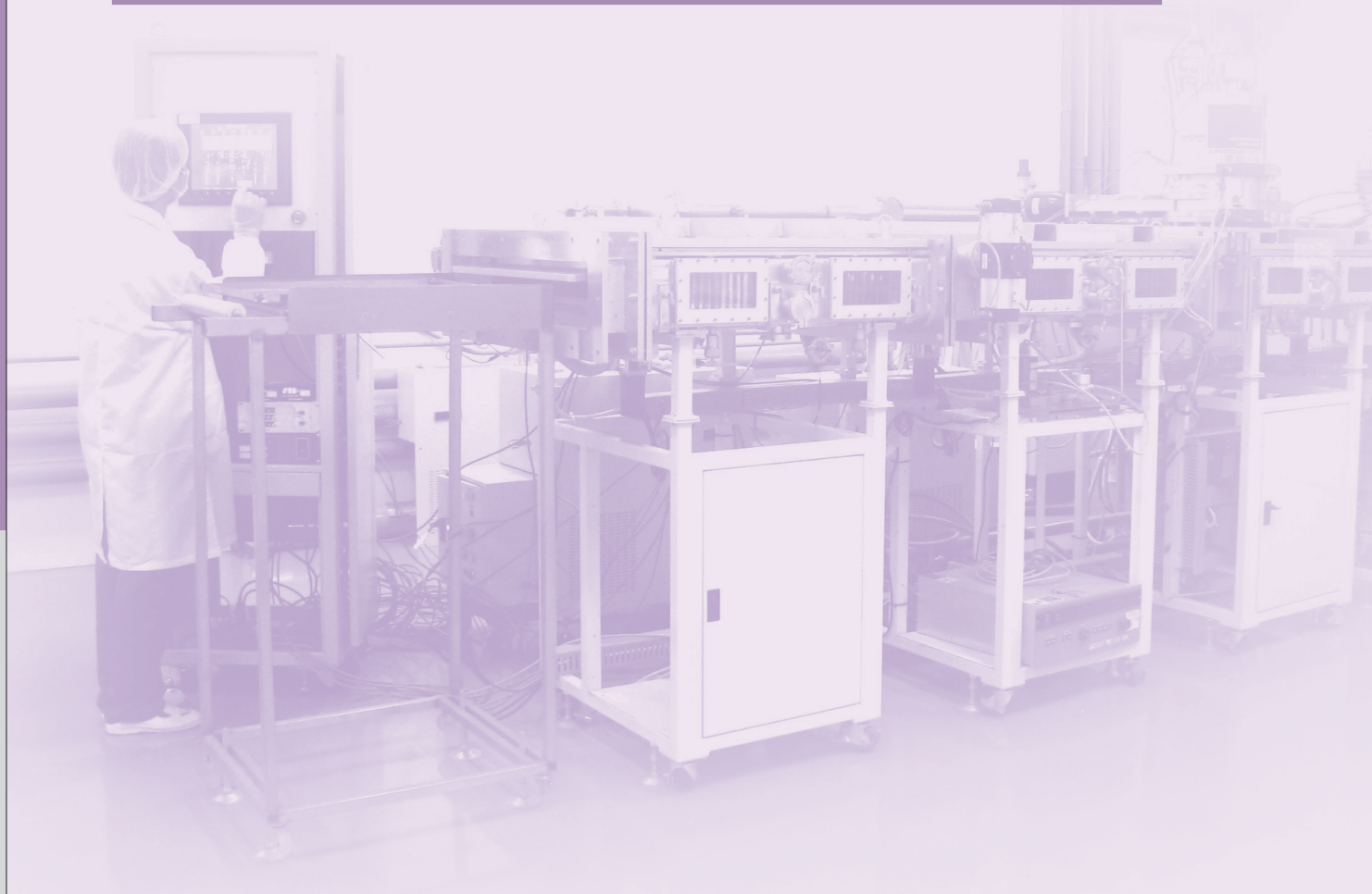

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Institute of Nuclear Energy Research
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No.1000, Wenhua Rd., Jiaan Village, Longtan Township,
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