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INER 2008 Annual Report

Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

Published in June, 2009

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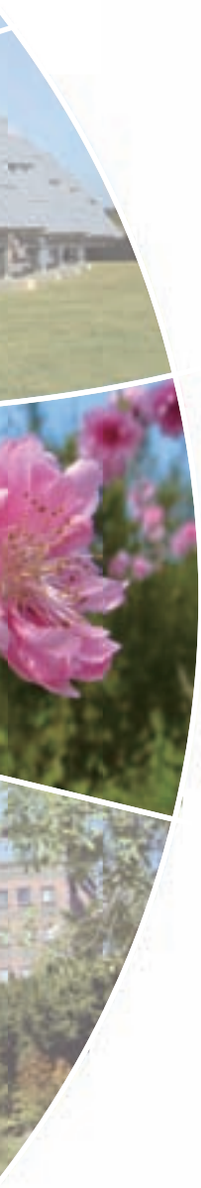
Contents



1. Preface

Constructing Low-Carbon Homeland & Heading toward sustainable Development

Director-General

The Institute of Nuclear Energy Research (INER) is a national laboratory whose goal is to gain an international reputation as a major research organization for the development of nuclear energy, new and renewable energy, radiopharmaceuticals, and related technologies. In addition to the development of science and technology, INER also develops relevant systems with systems integration as a specialty.

Specific areas under nuclear energy development are nuclear safety technologies, radioactive waste processing and treatment, advanced nuclear energy science and technologies, and nuclear technology industrialization. In the area of new and renewable energy, our studies focus on High Concentration Photovoltaics (HCPV) technology, wind power, cellulosic ethanol, solid oxide fuel cell (SOFC), intelligent electric power network (Smart Grid), integrated gasification combined cycle and carbon capture storage (IGCC&CCS), energy policy assessment on the MARKAL-Macro energy models. For preserving the environment, INER works to improve current environmental plasma technology. Finally, in the area of radiopharmaceuticals, INER works on research and design in nuclear medical instrumentation and irradiation therapy technologies for both diagnosis and treatment.

Presently, much interest, both domestically and internationally, is focused on the reduction of atmospheric carbon dioxide as a way of reducing greenhouse gasses. The "Sustainable Energy Policy Summary" passed at the 5th June, 2008, meeting of the Executive Yuan promotes the diversification of energy resources. The summary states that nuclear power plants should be considered as an alternative method to reducing carbon dioxide emissions

from coal-fired power plants. Subsequently, in the "Energy Security Strategy Report" published on 28th August,2008, by the Ministry of Economic Affairs, strategies were proposed for ensuring the safe operation of Taiwan's Nuclear Power Plant No. 4, for increasing the efficiency of existing nuclear power plants, and for the safe treatment of nuclear waste.

In order to comply with new national energy policies, INER promotes R&D in nuclear energy and assists in the uprating of existing nuclear power plants. Meanwhile, in 2008, INER underwent a structural reorganization within the matrix management system, establishing eleven functional divisions for pursuing research. INER has accumulated sufficient technologies in nuclear power generation safety and has established generic safety analyses and evaluation technologies. In addition to gaining essential technologies for enhancing nuclear safety analysis, the construction review of Nuclear Power Plant No.4, emergency preparedness for radiological dispersal devices, quality control of radiation protection technologies, etc., we have extended the commercial value of these technologies and incubated domestic nuclear power related industries. Furthermore, in an effort to prevent the monopoly of foreign businesses and to prepare for technology commercialization, we commercially certify the technologies with value.

Regarding the management of radioactive materials, we have completed the review for the Zero Power Reactor (ZPRL) fuel return transportation proposal and the preparation for transport. We also finished the design for the relocation of the Taiwan Research Reactor (TRR) fuel pool waste resin and its safety evaluation report. INER has also applied plasma vitrifaction technology to handle domestic low-level radioactive waste and to reduce the cost of the final repository of solid nuclear wastes.

In the area of promoting nuclear technologies for civilian applications, research activities focus on nuclear medicines and their applications. In order to stabilize the supply of radiopharmaceuticals and increase their availability, INER endeavors to improve the operational reliability of the medium scale cyclotron and establishes the radiopharmacy. Also, INER has established prototype devices for positron emission tomography for diagnosing breast cancer.

To meet domestic demand and international trends, INER devotes itself to R&D work on new energy and environmental plasma. INER has already established many new facilities, such as the III-V group HCPV system, cellulosic ethanol plant, wind power system, direct methanol fuel cell (DMFC), roll-to-roll plasma surface activation system, etc. We have also transferred some technologies to related domestic industries. Furthermore, in the Taiwan Science Park at Fuchu, INER is currently establishing a HCPV verification laboratory and a technology transfer center to drive the HCPV industry as well as to assist in the development of local colony.

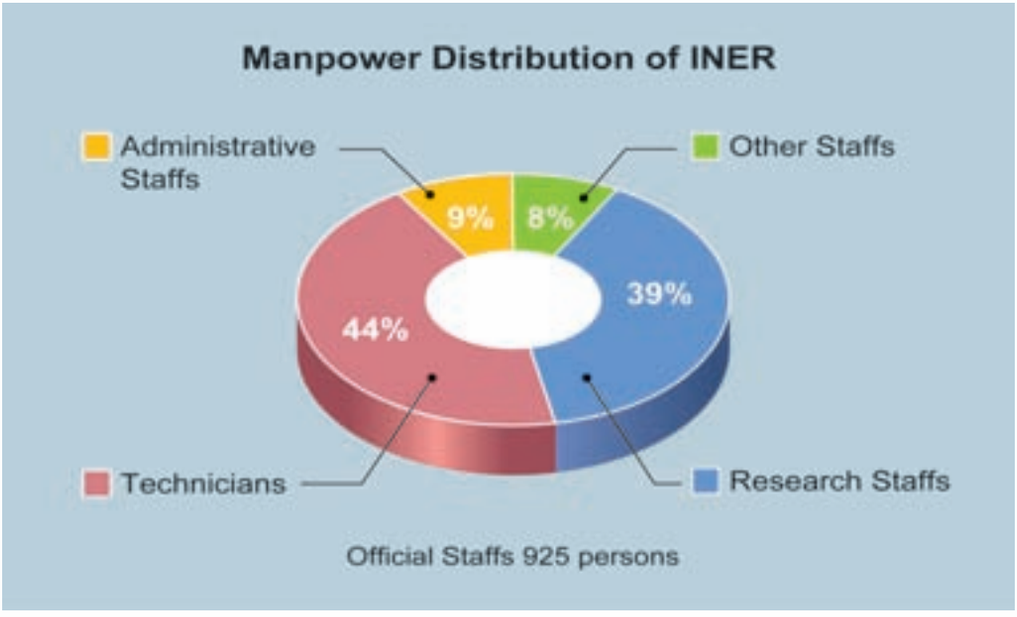
The above mentioned R&D achievements are evaluated by five quantitative performance indices: technical reports, journal papers, patents, technology licensing, and technology services. In recent years, these indices have increased from 15% to 60%. INER particularly emphasizes foreign patent applications (including the U.S.A.) with the intent of maximizing the value of these patents, and extending their benefits.

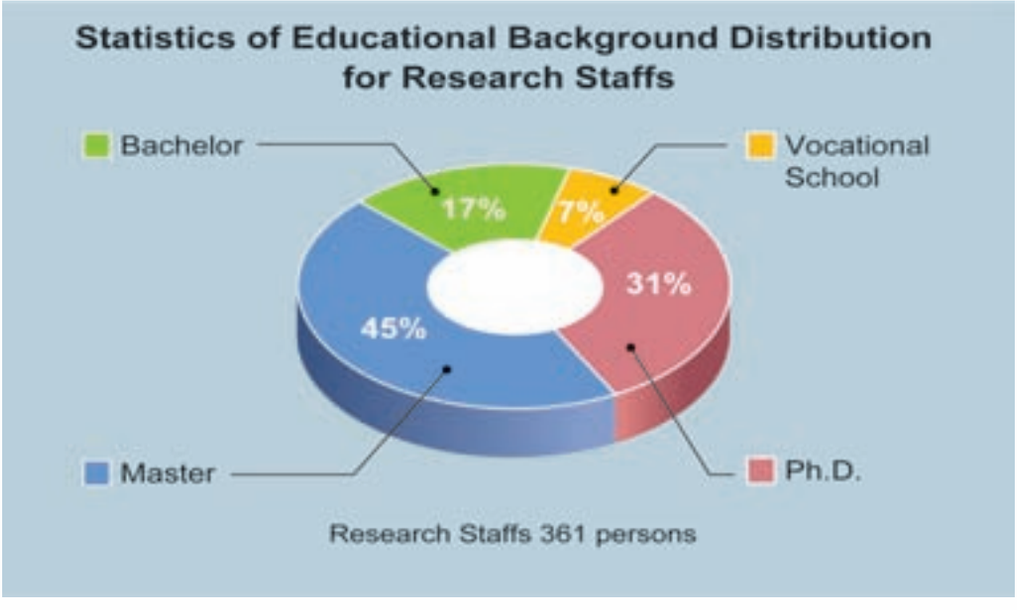
INER, participating in the 2009 National Energy Conference, successfully included nuclear energy into the "Low-Carbon Homeland" long-term energy development program and brought up the topics of nuclear technology industrialization and nuclear professional human

resources incubation.

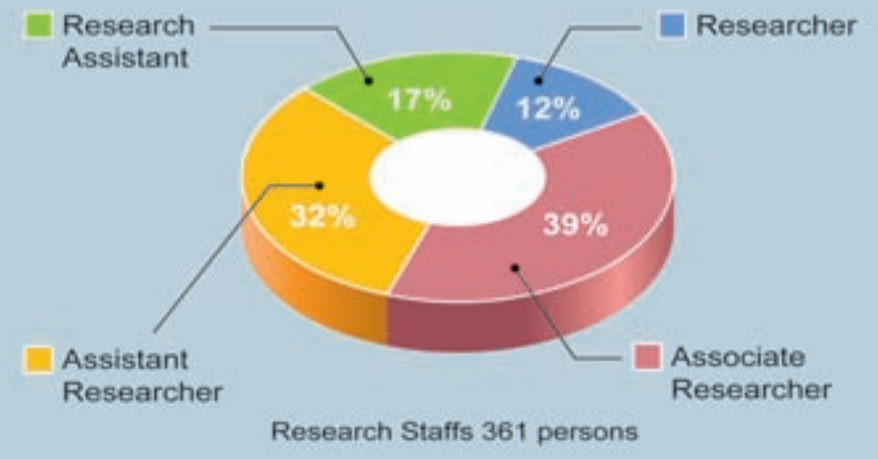
Energy security is also national security, and so, national energy policy plays an important role in a country's development. Sustainable energy development should take into consideration energy safety, economic development, and environmental protection. Due to Taiwan's lack of natural resources and limited environmental capacity, the development of low-carbon energy resources, such as nuclear energy and renewable energy, are an urgent mission for the Institute of Nuclear Energy Research (INER). With all these efforts, INER strives to become a trustworthy, competitive, public-affirmed, employee-honored and internationally synchronized world-class institute, and to build up a beautiful homeland.

(Time of data: December, 2008)





Statistics of Educational Background Distribution for Research Staffs



Research Staffs 361 persons

2008 Annual Budget (2,661,804)

Unit：Thousand NTD

Administration and Salary	**1,330,382**	50%
Management, Operation and Maintenance	**91,879**	3.5%
R&D Projects	**1,119,988**	42%
Radiation Application Technology	*138,726*	*5%*
Environmental and Energy Technology	*741,586*	*28%*
Nuclear Safety Technology	*239,676*	*9%*
Technology Promotion and Service	**119,554**	4.5%

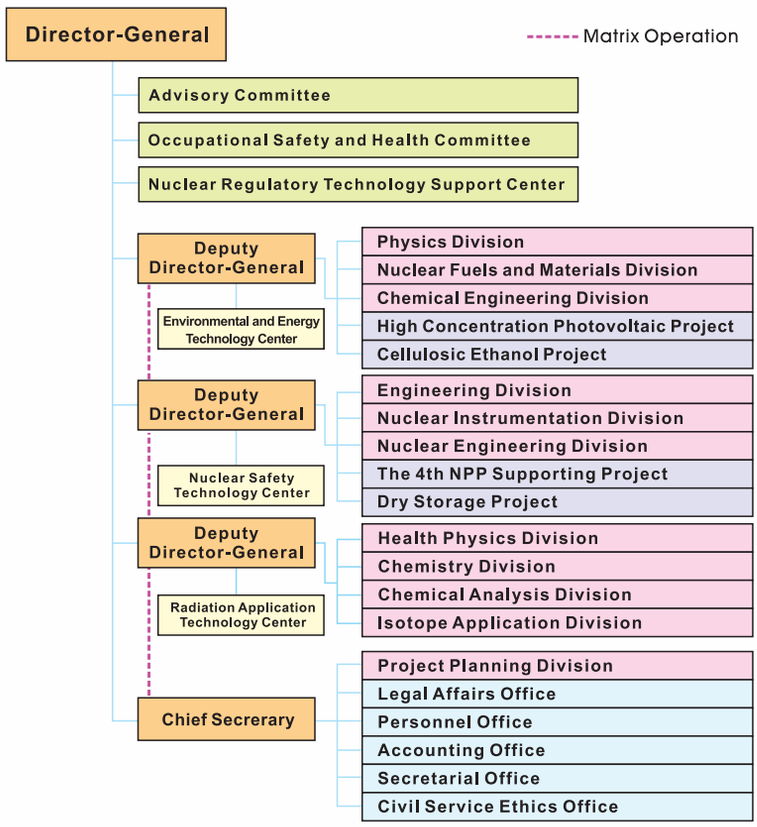
3. Events of the Year

Innovative Management

◎Yung-Fu Hsu

With the essence of striving toward perfection, INER keeps its spirit of continuous improvement in management both qualitatively and quantitatively. According to the ever-changing demands of markets and industries, INER promotes its intellectual properties (including patents, know-how, etc.) via technology transfer, technology authorization and technical service. In 2008, the revenue from royalty and technology service reached 120%. It is absolutely an outstanding achievement. The background reasons for the improvement are due to innovative management and listed as follows:

Organization Chart of INER



(1)Organization Alignment: In compliance with new government policy and to meet the environmental challenges, INER focuses its research activities in power up-rating and construction of new units of nuclear power plant, performing national energy projects as well as pursuing continuous growth in project performance. INER's major research areas shall include nuclear energy, new/renewable energy, radiopharmaceuticals and plasma technology. All these R&D projects operate in close matrix with eleven functional divisions. The new aligned organization's structure was approved by Atomic Energy Council in June 2008. INER is ready to march toward to the goals of "Sustainable Operation" and "Continuous Open to Public Access".

(2)Innovative Management: A computerized procurement management system was established and put on line for test in May 2008. Through its computerized purchasing mechanism and information technology, specialist advices are provided for purchase in the early stage. As a result, procurement process is hastened. For those important projects' purchases, the quality and efficiency, therefore, are improved. It is proved very efficient for budget management.

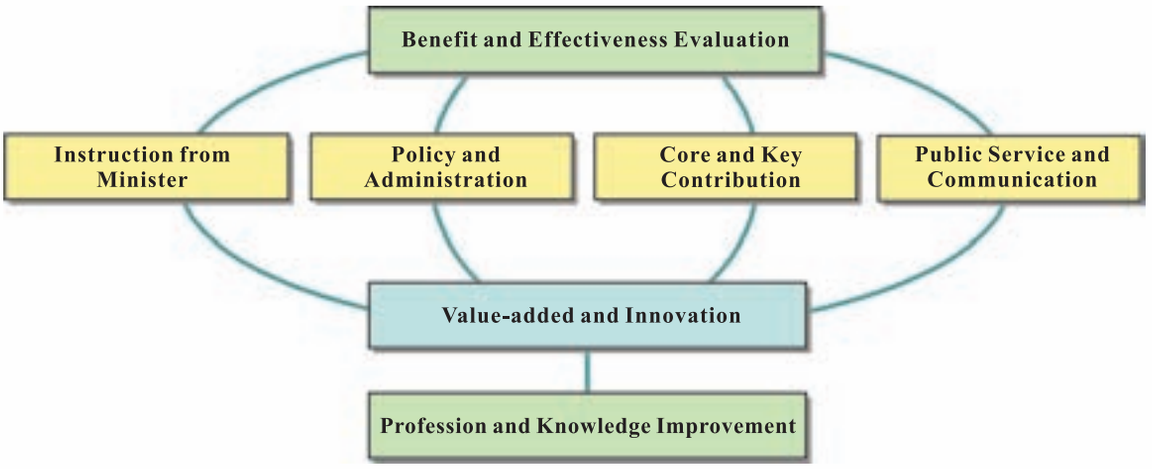
(3)Human Resource Management: Recruitment of research staff will be focused on those with Master's or Doctoral degree. Mentor and apprentice system is established to cut down the learning curve. It is shown very efficient in the research laboratory. Those new research staffs' R&D performance are hastened and promoted in a short period. INER has started up a new practice to cultivate new bloods to be world-class researchers by sending young talents to world-famous organizations for training. For example, we dispatched young talents to join the program - "Meet the Best Minds" held in USA to raise their international view and build up international corporation network.

(4)Innovative Business Model: Techniques in nuclear safety field had already reached its maturity. The innovative business model "primary contractor" is adopted. INER will play the role as the primary contractor and provide complete and systematic total solution to the industries so as to promote the technology service market growth. Nowadays, the domestic nuclear industry market is still small, but we can create a new research field, and increase technology service to build the second technology S curve.

(5)Innovative Research Domain: New energy is a new research field in INER. Owing to increasing energy demand by domestic industries and world energy resource shortage, INER devotes its R&D into new energy field. In resent years, patents obtained and revenue received from technology transfer and service are highly increased.

(6)Innovative Technology/Market: In the field of solar energy, INER's high concentration photovoltaic system technology meet the trend and quality of the emerging industrial market. Its royalty and income from technology transfer are highly increased. In radiation application field, the research in radiopharmaceutical development also has fruitful result. Its return of investment is rather high. Due to the aging society, increasing medical requirements are essential. The fair price and excellent quality of INER's radiopharmaceuticals not only reduce the burden of National Health Insurance but also create stable growth on revenue of radiopharmaceutical service.

The top-down strategy and bottom-up team collaboration generate high and efficient performance. However, the annual performance is just a short-term results. Looking into the future, we expect to deep cultivate our research works and bring welfare to the people as well as feedback to the society and the country.



▲ INER's Performance-based Management Model

A Report Concerning the 40th Anniversary of the Institute of Nuclear Energy Research and Parent-Child Acitvities

◎Chun-Tang Hsiao

Every year, in August and September, there is a lot of excitement, and everybody is full of expectations. This year (2008) is different from other years because it is the INER's 40th Anniversary. In order to celebrate this, there were activities available to the employees of the institute and their families.

These activities included visiting the offices and labs of the Institute of Nuclear Energy Research, which was also open to the visitors. They could also watch movies and presentations concerning the research results. People could attend the time corridor exhibition, the Wii game system and chorus performance provided at the recreation center. Employees and their families enthusiastically attended this celebration. Overall, 682 employees of INER and 1,223 of their family members attended the event.

The organizer specifically chose two heartwarming movies which were thoroughly enjoyed by the people who attended. That was part of the reason why there were many employees who brought their families to participate in these activities, especially during Summer vacation period. Additionally, the Wii game system was especially popular during the event, and it helped improve the relationship between parent and child. In order to celebrate the 40th anniversary, which was September 4, 2008, INER invited representatives in the Taoyuan area. This included university's presidents and the directors of the research centers from Taoyuan area. Furthermore, former directors of INER came to the activity as special guest speakers. This included also the major of Longtan township.

To the activity are also invited retired employees of the Institute of Nuclear Energy Research, and eighty-five retirees came to participate in all the festivities. There were many VIPs and high ranking officers who attended the activities. Previous directors and retired employees especially made the celebration even more festive. The theme for this year's celebration was about love for the Institute of Nuclear Energy Research. This was expressed by showing historical events of the last forty years to all the previous directors and retired employees, so they could remember previous years of development and progress made through their efforts. The lunch buffet was thoroughly enjoyed and made this celebration even more joyous.

Special thanks to all the high ranking officers, employees, and attendees of this celebration. Without their support this celebration could not have been a satisfatory success and last, but not least, happy 40th Anniversary of the Institute of Nuclear Energy Research!

INER took on Chairmanship of the Technical Committee on Ionizing Radiation (TCRI) of the Asia Pacific Metrology Programme (APMP)

◎Ming-Chen Yuan

Mr. Ming-Chen Yuan of Health Physics (HP) Division of the Institute of Nuclear Energy Research (INER) was assigned a business trip to Indonesia during November 2-8, 2008, for the Asia Pacific Metrology Programme General Assembly (APMP GA) as well as the Technical Committee on Ionizing Radiation (TCRI) Meeting. In the TCRI meeting, the Australian delegate, Dr. David Webb, nominated Mr. Yuan the TCRI Chairman and all the delegates from member institutes unanimously agreed on Mr. Yuan's taking on the position from 2009 to 2010. With this opportunity, the international community recognized INER's contributions to this professional field; with this opportunity, INER would step forward and give nothing but best.

The APMP, founded in 1977, is primarily responsible for facilitating exchanges and cooperation of metrology technologies and mutual recognition of the measurement standards among the region's member economies. Till now, the Full member consists of

thirty-two (32) organizations from twenty-one (21) economies, and the five (5) organizations from five (5) economies are the Associate members. With the active participation of members and the growing needs of technical collaboration and exchanges, the APMP started to establish Technical Committees (TCs) in different fields to deal with measurement comparisons and technical exchanges and moreover, to play the bridge among the APMP, international metrology bodies and technical committees of other regions' metrology institutes. Now the APMP has established 11 technical committees (including TCRI).

With the entrustment of the Bureau of Standards, Metrology and Inspection (MOEA), INER is responsible for the establishment and maintenance for national standards of ionizing radiation. Starting from 1998, INER has been participating in APMP activities. In the same year, the TCRI was established and Mr. Wen-Song Hwang of INER was elected as the first Chairman with an office term during 1998-2000 giving efforts for internationalizing the standards of INER and the region. Through various measurement comparisons, the TCRI links the ionizing radiation standards of its members with those of the Bureau International des Poids et Mesures (BIPM) in the hope of working with the world's national metrology institutes (NMIs) toward homogeneity and mutual recognition of global measurement standards.

The TCRI has been operating for ten years. The other precedent Chairmen came in order: Dr. Tae-Soon Park (Korea, 2000-2002), Dr. David Webb (Australia, 2002-2005) and Dr. Yoshio Hino (Japan, 2005-2008). Now, the Chairman torch is again passed onto INER. Once more, the international community recognizes INER's professional compeINER. Once more, the international community recognizes INER's professional competence. In 2008-2009, TCRI helped NMIJ/Japan and OAP/Thailand with ISO17205 accreditation programs and moved comparisons on low-energy X-ray, the absorbed dose to water for Co-60 and radioactivity of I-131. Focusing on what it is meant to be, the TCRI is always at the community's service for ionizing radiation metrology standards and brings everyone together to achieve global standards mutual recognition.

▲ Picture of delegates to 2008 TCRI meeting

The 9th International Conference on PSAM (PSAM 9) in 2008

◎Tsu-Mu Kao

The International Conference on Probabilistic Safety Assessment and Management (PSAM) had long become a fine tradition as the foremost forum for the presentation and discussion of probabilistic safety assessment and management methods applied to complex systems. It becomes the largest PSA and management associated conference in the world. The 9th International Conference on PSAM (PSAM 9) held in Hong Kong on May 18 through 23, 2008 had succeeded in bringing together risk analysts and safety managers from 42 different countries to present and to discuss 355 papers in over 90 sessions at a very wide spectrum of technical disciplines.

An INER's staff, Dr. Tsu-Mu Kao was elected as the Technical Program Chair of the PSAM9 and edited the PSAM 9 Proceedings. The PSAM 9 Proceedings contains the abstracts of the papers and full papers with PSAM 9 CDROM presented at the Conference. As such, it provides a collection of the summaries of advanced technical works on methods and applications of safety assessment and management in different disciplines. For ease of reference, the collection is structured to closely follow the technical sessions

of the PSAM 9 Technical Program. It is obvious that the success of a conference depends on the cooperative efforts of many individuals and organizations; PSAM 9 was no exception in this regard.

▲ Poster of the PSAM 9 Pre-Conference Workshop

In corporation with the PSAM9 held in Hong Kong, a pre-conference workshop was organized at Taiwan to bring together the international and domestic representatives from various public and private industrial sectors, to share their reliability and risk assessment expertise's and professional knowledge with selected PSAM 9 experts. The workshop took place on May 15 and 16, 2008, at the Howard Plaza Hotel, Taipei, Taiwan. This pre-conference workshop provides a good overview covering from fundamental reliability, availability, maintainability and safety theories, human reliability and data analyses, to the applications of the risk assessment to homeland security and LNG (Liquefied Natural Gas) storage systems. The INER's staff, organizers of this workshop helped the participants extended their professions into a new realm where the safety decision-making meets with risk assessment techniques from the two-day Workshop courses.

▲ PSAM 9 International Conference

▲ PSAM 9 Pre-Conference Workshop

The 23rd Sino-Japanese Seminar

◎Wei-Whua Lo

The 23rd Sino-Japanese Seminar on Nuclear Safety was held on December 2-3, 2008 with 150 participants attended from all areas of nuclear energy related field. As the host, INER planned and prepared the seminar from invitation of local experts and scholars, collection of papers, to the arrangement and management of the seminar sessions with enthusiasm. Thanks to the collaboration of all the sponsors, inclusive of Atomic Energy Council, Taipower Company, Fuel Cycle and Materials Administration, and Radiation Monitoring Center etc., the seminar was going smoothly with a satisfactory ending.

The objectives of the Sino-Japanese Seminar is to provide a forum to gather as many eminent experts in nuclear energy field both from Taiwan and Japan for the sharing of technology information and valuable experiences. Mr. Haruhiko, the chairman of the Japanese delegation, led 23 experts from nuclear industries of Japan to participate in the seminar. The following topics were presented and discussed in the seminar: (1) Radiological safety management and environmental radiation protection for high-energy particle accelerator facility; (2) ABWR construction experiences exchange; (3) Life extension of Nuclear Power Plant; (4) Related issues after Niigata earthquakes in Japan 2007; (5) Radioactive waste management; (6) radiation application; and (7)Relate dissues

on nuclear renaissance. The seminar has built a firm foundation and provided an excellent opportunity for Taiwanese experts to discuss with and learn from their Japanese counterparts face to face. The participants had an intense discussion about each topic throughout the seminar. The purpose of this annual meeting to improve bilateral interaction and cooperation in nuclear safety and technical experiences between Taiwan and Japan has been well achieved.

In the prospect of nuclear renaissance, this seminar has a profound significance. It facilitates not only information exchange about the works of each participant, but also strengthens nuclear safety and promotes well-beings of the people both in Taiwan and Japan.

Five-Years Consecutively Winning the Award for "Excellent Employer of Reserved Duty Officers for Defense Industry Reserved Duty Program"

◎Yin-Yi Tsai

In order to comply with the government policy of training talented people, improving industry competence. INER, since 2001, has actively participated in the Reserve Duty Officers for Defense Industry Reserve Duty program. Through the efforts of senior researchers and those young talents, new innovation and technology achievements have

confirmed the fruitfulness of our efforts. The Ministry of National Defense awarded INER with the "Excellent Employer of Reserve Duty Officers for Defense Industry Reserve Duty Program" for the 5th consecutive year.

In order to win this award each year, INER appreciatively complied with the standard operation procedures. In addition, we demonstrated the ability to develop technologies and became well renowned as a first-rated institute internationally. Cultivating young blood and keeping them are important issues in INER. New people joined INER with the interest and abilities are most welcomed. Our objectives are to inspire young talents and improve their quality and competitiveness. Also, the management style was improved to become more people oriented. Some selected talents shall be sent abroad to visit well known research organizations to do research and interning, so that they can become well rounded in an international sense. In research and development domain, INER provides opportunities to develop multiple research interests, such as nuclear safety, new/renewable energy and radiation applications. In order to improve the ability in research, INER aggressively encouraged people to publish their dissertations and explore new technologies, products, patents, and etc., and use those technologies and results to apply to Taiwan's local industry so as to improve livelihood.

In order to welcome an era of knowledge economy, INER will aggressively use nuclear knowledge to broaden the fields of radiopharmaceutical, biology, energy resources, the environment, and nano-technologies. Also, INER will participate in research and development in improving Taiwan's technology capabilities in order to keep up the competitive advantage of this nation.

4. Current Major R&D Activities

1. Nuclear Safety Technologies

◎Tsu-Mu Kao

Over 40 years of devotions, the INER has established its fame as the top research institution equipped with the advanced nuclear technology in Taiwan. The major tasks include supporting governmental safety reviews and regulations in nuclear power plants (NPPs), as well as enhancing operational safety and efficiency for the plants. Currently as the energy prices and CO_2 emissions have become the main issues of the domestic energy supplies, the nuclear power has proved itself as one of the efficient alternatives. The INER will continue its efforts to the researches and development of nuclear safety, the feasibility planning of national energy, and the operational safety of NPPs.

In order to echo with the renaissance of nuclear power worldwide, The nuclear safety technology field of the INER sets goals at continuously supporting the safety for operating NPPs, maintaining the quality for the constructing Lungmen NPP, and assisting the Taiwan Atomic Energy Council (AEC) in their regulatory requirements to review and to audit the NPPs of Taipower.

Major achievements of the nuclear safety technology field during 2008 will be described in details item by item as follows: (1) Assisting Taipower to lead an engineering evaluation on MUR (Measurement Uncertainty Recapture) power uprate for Chinshan NPP and Maanshan NPP. After project completion, the total electric generation from three units were increased by 24 MWe and the operation performance for Taiwan NPPs had been improved; (2) Continuing to broaden opportunities of business development for the Probabilistic/Quantitative Risk Assessment (PRA/QRA) Techniques; (3) Development of emergency response support system of Taiwan NPPs; (4) Commercial-grade item dedication for nuclear safety-related applications; (5) The research on safety evaluation for digital I&C systems of Taiwan NPPs; (6) Spent fuel rods examinations and root causes analysis of failure rods; (7) Study on environmentally assisted cracking of Nickel base

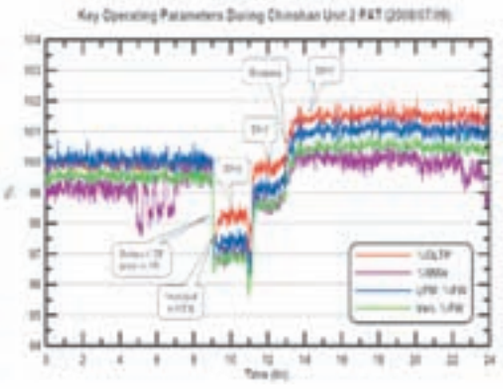
alloy weldments; (8) Meeting new domestic criteria of year 2009 for testing personnel dosimetry performance; (9) Avertable dose intervention in emergency response dose evaluation system applied for nuclear emergency preparedness and response; (10) Establishing a released gas sampling and analysis method for short half-life radioactive isotopes; (11) Technical service support, safety evaluation during construction period of the Lungmen NPP; (12) Supporting Taiwan AEC for the site inspection and technical review of safety-related reports of NPPs in operation and under construction.

1.1 Performance Improvement of the Operating Nuclear Power Stations

◎Gung-Huei Chou

Facing the global warming and Carbon Dioxide (CO_2) reduction issues, the improvement of the operation efficiency for the existing nuclear power stations is the urgent work. Many nuclear power stations around the world have been implemented power uprate operation for improving their efficiency and economic performance. Measurement Uncertainty Recapture (MUR) power uprates are achieved by installation of the ultrasonic feedwater flow meter to reduce the uncertainty for calculating core thermal power. There are a lot of successful MUR uprate cases implemented at international nuclear power stations, which not only increase the generator output obviously, but also achieving the efficient investment. Based on the reasons as stated above, Taipower decided to implement MUR power uprate first, then assess the feasibility to the larger power uprates, i.e., Stretch Power Uprate (SPU) and Extended Power Uprate (EPU). INER has been granted to assist three nuclear power stations in Taiwan for the MUR power uprate engineering service since 2005.

▲ The UFM system installed at Maanshan



▲ The power ascension test and switchover at Chinshan Unit 2

With engagement in the implementation of MUR power uprates on domestic nuclear power stations, INER obtains the professional experiences for the engineering service and would like to challenge the further services.

The duration for each nuclear station to implement the MUR project is about 3 years. Kuosheng Nuclear Power Station (KSNPS) was chosen the first one to lead the project, then followed Chinshan and Maanshan Nuclear Power Stations. KSNPS has conducted the Power Ascension Test (PAT) and switchover for Unit 2 and Unit 1 on 7/7/2007 and 11/30/2007, respectively. Totally the increases of generator outputs for both units have been amounted as 20 MWe. Also, both units on Chinshan and Maanshan Unit 2 have achieved the MUR power uprate operations to date. The total increases of generator outputs due to MUR power uprates for 5 nuclear units are about 44 MWe. Moreover, it is expected that the MUR power uprate implemented for Maanshan Unit 1 will be achieved in July 2009. The revenue gained from the power increases will save Taipower alternative fuel cost about 900 million New Taiwan dollars as well as the reduction in emission of carbon dioxide (CO_2) about 180 thousand metric tons per year. The MUR power uprates implemented at three nuclear power stations have made significant contribution in improving their operation performance.

1.2 Opportunities of Business Development for the Quantitative Risk Assessment Technique

◎Jyh-Der Lin

The contemporary uses of the word 'risk' often have much to do with making decisions. The financial tsunami, which arose from subprime mortgage crisis since late 2008 and eventually seized the world, could be attributed to the sequential compound failures in risk management. It is self-evident that proper recognition of risk may play an important role in the robustness of decision-making of various applications.

The nuclear industry has long addressed the risk in a prudent and scientific manner. They use quantified figures-of-merit of risk and the insights herein to complement the traditional approaches in nuclear safety regulation. This is related to a technique called 'Probabilistic Risk Assessment' (PRA). INER passed on the domestic PRA technique and has developed the tools of risk assessment in the last ten years. These tools had been used in the applications of 'risk monitor' and the risk evaluation of inspection findings. The latter has been adopted for use in the nuclear safety traffic lights program which posts the results quarterly on the website for public access (as depicted in figure). In 2008, INER supports the AEC in its baseline inspection of the Maintenance Rule implementation at the three operating NPPs. INER also promotes the product reliability evaluation in industry by developing a user-friendly software for fault tree analysis named INERFT. Till 2008, The trial inquiries of INERFT

▲ Application of the risk monitor technique to the nuclear safety "traffic lights" program

often come to tens of cases each year. More recently INER aggressively promote the application of PRA to other non-nuclear industry including the accomplishment of the PRA of a LNG storage site for the Taiwan Chinese Petroleum Company. In 2008, this PRA has now extended to the assessment of natural hazards such as typhoon, seismic and lightning events to meet the requirements by the industrial safety regulatory body. INER also helped the formulation of the regulatory guide for the risk assessment of special petrochemical storage tanks.

1.3 Development of Emergency Response Support System of Nuclear Power Plant

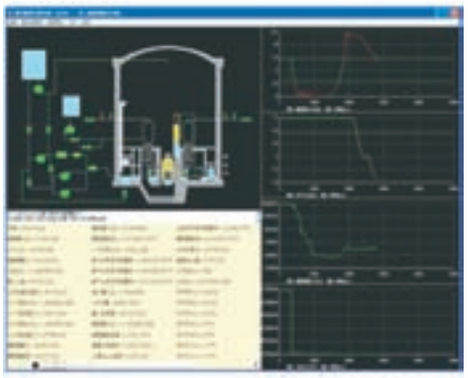
◎I-Ming Huang

After the TMI accident in 1979, the emergency response planning of the nuclear power plant became an important issue. Nuclear power plants are designed based on the design basis accident. Once the plant is in abnormal condition, the operator applies the emergency operation procedure to prevent the reactor core from damage. If the operator is not able to recover the plant, the reactor core will be damaged and approaches to severe accident. For severe accident condition, severe accident management guideline is used to mitigate the event. The emergency planning can be used to minimize the effect on the public health if the core melts to challenge the containment integrity.

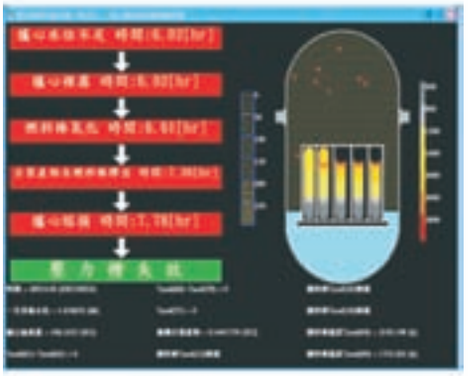
There are two main teams in the central nuclear hazard response center. The main work of the accident evaluation team includes understanding its cause, watching the accident response, predicting its progression, evaluating the integrity of the fission product barriers, estimating the timing of fission product release and the source term. The main work of the dose evaluation team is to estimate the dose on the population and suggests the proper protection actions.

Emergency Response Support System (ERSS) is developed to assist accident evaluation team during emergency condition of nuclear power plants. The ERSS is composed of five subsystems.

They are accident status display system, accident diagnostic system, accident prediction system, accident management monitoring system, and accident database. The new modular accident analysis program (MAAP5) is selected as a tool to predict sequence of events, source term, and related doses. In addition, graphical display technique is applied to provide the progression of accidents.



▲ Accident Status Display System of ERSS



▲ Accident Diagnostic System of ERSS

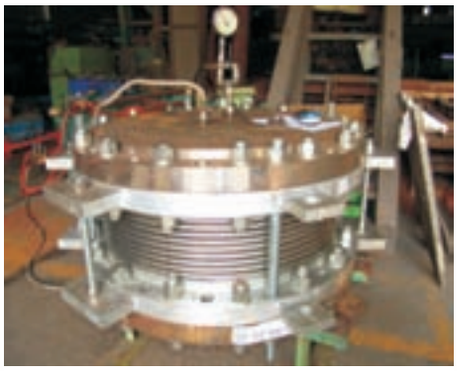
ERSS has been developed to support the accident evaluation activities during the nuclear emergency event. The ERSS of Maanshan NPP was developed and applied in the emergency response exercise of 2008. In future, this system will be connected with plant data to achieve the supporting capability during accident. Furthermore it can be applied for preparing the emergency response drill and routine training of related persons. It can enhance the response capability of accident evaluation team during emergency condition.

1.4 Commercial-Grade Item Dedication for Nuclear Safety-Related Application

◎Yao-Tung Hsu

In order to fulfill the localization of nuclear technologies in Taiwan and carry out the components dedication projects, the dedication group of INER has actively performed the commercial-grade item dedication service to support the maintenance requirements of the existing nuclear power plant and the 4th nuclear power plant construction, in combination with local company and organizations. In 2008, the following tasks have been successfully accomplished:

(1)The dedicated components have been executed, including the fluid level gauges, metal expansion joints, current transformers, resistors, and electric control boards, etc. Especially, the domestically manufactured expansion joint, is the important case. The highly complicated formation of the expansion joints is the most challenge technology. We have successfully designed and developed the expansion joints, and carried out the dedication project on our own. Now the expansion joints are used in the safety system of Maanshan power plants and working well.



▲ Metal Expansion Joints Hydraulic Tests

(2)The Motor Control Center (MCC) was qualified, after taking off its seismic damping equipment, for use in the 4th nuclear power plant. The MCC seismic qualifications have been conducted by monitoring component's safety function during the tests. We have successfully resolved the conflicts that may occur during the site installation. The qualification capability was further improved at the same time.

▲ Motor Control Center Seismic Qualification

(3)The cable trays dedication includes the mechanical loading tests. The main goal of this work is to help the 4th nuclear power plant constructions effectively. In addition, this project also assisted the local company and factory to establish the necessary operation process to comply with nuclear standards.

(4)The aging evaluation of safety-related components supports the Chinshan nuclear power station license renewal application. These evaluations and experiences can benefit to promote the nuclear critical components localization.

By means of the dedication, not only the operation and maintenance requirements of safety-related components for nuclear power plants can be fulfilled, but the improper components can also be avoided. In the long run, the dedication may support the nuclear critical components localization policy.

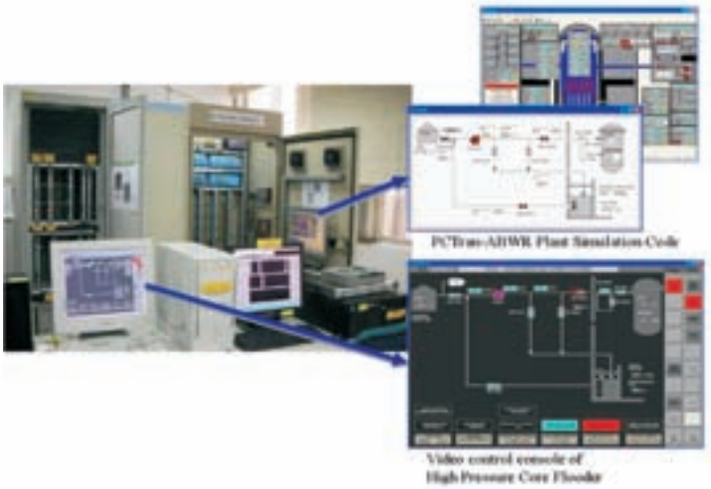
1.5 The Research on Safety Evaluation for Digital I&C Systems

◎Tsung-Chieh Cheng

In 2008, the Nuclear Instrumentation Division of INER has completed the tasks as follow,

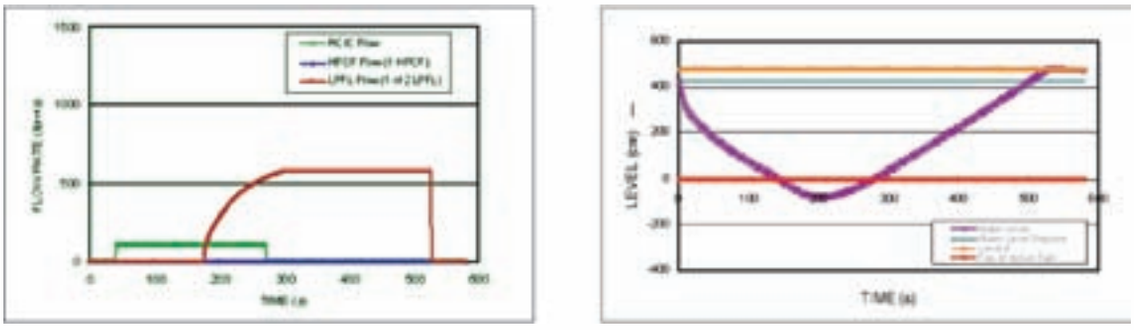
(1)Establish the Software Fault Injection Facility that consists of PCTran power plant simulator and High Pressure Core Flooder System. The simulation results after intentionally injecting software faults to digital control system was analyzed. Fig shows the reactions of nuclear power plant while software fault was injected to the valve controller of the system. Factors are related to accuracy, functionality, reliability, robustness, safety and security that effect software quality. It could also provide guidance to observe new fault mode and to assist software safety analysis.

(2)Human errors have been found to be one of the key factors behind many catastrophic accidents in complex automated systems. This study investigated the difference in human information processing (HIP) and workload of the operators, with an



▲ Architecture of Software Fault Injection Facility

attempt to find the correlation between HIP and workload. To developed both quantitative (subjective questionnaire) and qualitative (interview) method were developed to evaluate the four stages in HIP, including “perception” “cognition”, “vocal response”, and “manual response”. Further analysis was carried out with the multiple regression analysis to predict the participant's workload as a function of the incidence of HIP. The results indicated those processing stages with higher cognition had significantly higher participant's workload. This HIP analysis provides a useful way to further understand why their workload might be different with respect to their staffing roles and responsibilities in a hope to evaluate the staffing in the environment of automated human machine interaction.



▲ Reactions of power plan after software faults injecting to a valve controller of HPCF

(3)To prevent digital networks from being attacked, the U.S. Nuclear Regulatory Commission provides guidelines regarding achieving high reliability and design quality requirements. However, quality assurance in hardware/software components is not sufficient to ensure the security of the overall network system. Security policies and sound system administration are also indispensable factors to rigid security. To take advantages of the guidelines of RG 1.152, we follow follows the network security standard of NUREG-0800 Appendix 7.1-D and attempt to plan and design an Information Security Management System (ISMS) based on the methodology of BS7799. The Modbus protocol has not considered security issues since its invention. Applying the concept of hash chains, the proposed design bases its security on the one-way property of cryptographic hash functions.

1.6 Spent Fuel Rod Examinations and Failure Root Cause Analysis

◎Shih-Chung Cheng, Wan-June Chiu

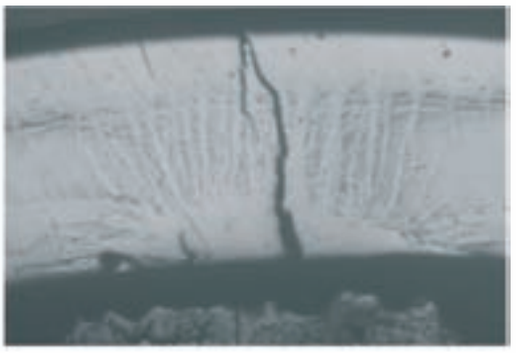
Spent nuclear fuel examination technologies have been developed at INER for more than 30 years. INER has built its own equipments for the spent fuel poolside inspections and hot laboratory examinations. Many fuel surveillance examinations have completed at the nuclear power plants of Taiwan power company. Besides, the failure fuel hot baboratory examinations and root cause analysis have completed with appropriate improvement recommendations in several times.

1. Hot laboratory examination

The non-destructive examinations are included as folloeing: fuel rod visual examination,Gamma scanning, profilometry measurement, eddy current inspection and cladding oxide thickness measurement. With those NDE results, the suspected defect could beidentified for further destructive examination.

A new developed micro-visual inspection system can effectively enhance the identification of visual inspection. It could be used to ascertain the defect form, observe the cross-section of the cladding long crack, confirm the initial position and growth direction of crack. A debris wear in the size of 0.6 mm on the cladding surface has been distinguished .

▲ Micro-visual inspection system in hotcell



▲ Metallographic microstructure picture of the fuel defect

The destructive examination are included as following: metallographic examinations and cladding hydrogen analysis on the suspected defects. With the optical microscope, the material microstructure, fuel pellet, cladding characteristics and crack direction could be observed. With those examination results, the root cause of failure fuel could be clarified.

2. Poolside fuel inspection

The BWR power plants of Taiwan power company have started the HWC operation from October 2006. A fuel surveillance program at Chinshan 1 & Kuosheng 1 has executed to monitor the fuel performance and assure the fuel reliability under the HWC environment.

A new underwater camera system was taken instead of the underwater periscope system for the spent fuel pool-side visual inspection. Furthemore, the oxide layer thickness was measured for cladding corrosion monitoring.

1.7 Environmentally Assisted Cracking of Nickel Base Alloy Weldments

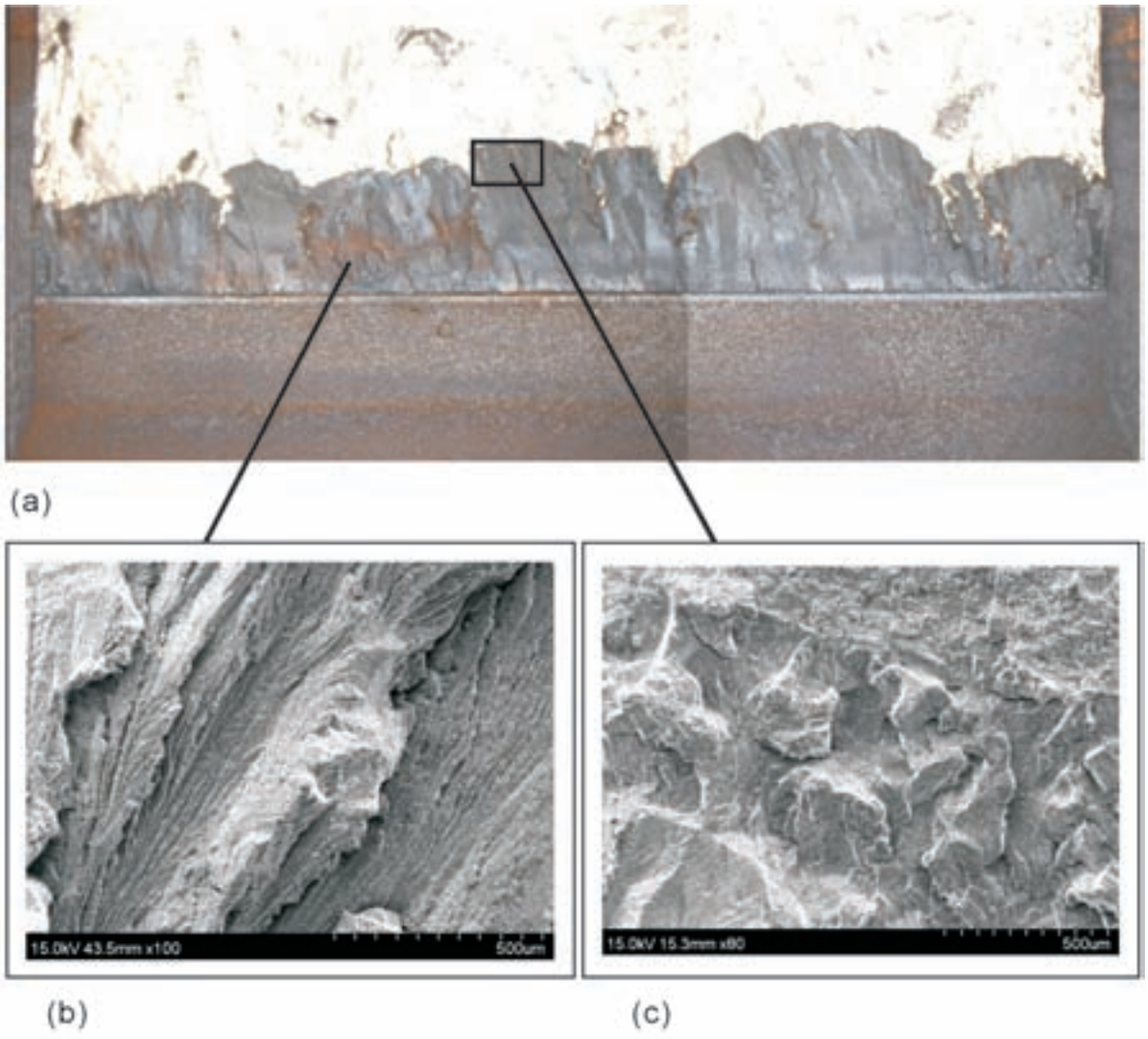
◎Jiunn-Yuan Huang

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 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. 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 boundary. SCC and corrosion fatigue (CF)

are responsible for the main degradation mechanisms of the DM weldments exposed to reactor coolant environments. This work was intended to study the effects of water chemistry, temperature, crevice corrosion, postweld heat treatment (PWHT), residual stress, dendritic orientation and loading mode on the SCC and CF of the weldments, based on which a mitigation and prevention strategy for SCC and CF of nickel base alloy welds in service is to be formulated and the quality assurance standards are to be developed.

SCC tests under the static loading and loading-partial unloading are under way and will be compared to illustrate the effect of loading mode on the cracking susceptibility and crack growth behavior. The SCC resistance of the Alloy 52/152 weldments is to be evaluated and compared with that of Alloy 82/182 weldments to gain a better understanding of the degradation mechanism of the defected component welds. CF crack growth tests were also conducted on the weldments of A508-Alloy 52 and Alloy 600-Alloy 182 under the nominally constant △K loading mode. Effects of PWHT on the SCC growth rates of the DM welds of A508-Alloy 52 were explored.

The crack growth test results showed that CF crack growth rates of the DM welds of A508-Alloy 52 increased with crack extension under the nominally constant △K loading mode. It could be a result of an increase in the tensile residual stress and a decrease in the crack closure effect with the weld depth. After PWHT at the temperature 621℃ for 24 hours, the tensile residual stress did not decrease and no martensite was present. The results for the specimens with double-sided grooves on the crack path agreed well with those of specimens with no groove. The CF crack growth rate for the Alloy 600-Alloy 182 weldment was significantly higher than its SCC growth rate. On the fracture surface of the tested Alloy 600-Alloy 182 weldment, the secondary cracks were observed to propagate along the interdendritic boundary in the Alloy 182 weld and intergranular SCC (IGSCC) was prevalent in Alloy 600. As for the effects of PWHT on the SCC growth rates of the DM welds of A508-Alloy 52, the results showed that the heat treatment at 621^{0}C for 24 hours induced Cr-carbide precipitation along grain boundary, which may lead to grain boundary sensitization and, as a consequence, an increase in stress corrosion crack growth rate.



▲ Fractographs of the weld of Alloy 52-A508 weldment tested under a loading-partial unloading mode in an aerated pure water environment at 300°C, (a) general fracture features, (b) dendritic features of the fatigue precracked region, (c) IGSCC features of the stress corrosion cracking region.

1.8 Personnel Dosimetry Performance - Criteria for Testing

◎Chun-Liang Chen

In accordance with Ionizing Radiation Protection Act of AEC, any personnel external dose evaluation laboratory in Taiwan must be accredited by TAF before providing related services. The existing criterion of "Technical criterion for Personnel External Dose Evaluation Laboratory Accreditation - TAF-CNLA-T08(1)" is based on ANSI/HPS N13.11-1993 standard. Nevertheless, the new version of ANSI/HPS N13.11 was issued in 2001.

TAF announce new version "Technical criterion for Personnel External Dose Evaluation Laboratory Accreditation - TAF-CNLA-T08 (2)" that base on ANSI N13.11-2001, For the reason, AEC and TAF decide to use this new standard to accredit and to assess performance of laboratories at 2010. According to the definition of dosimeter, it can be TLD, film, OSL and other item announced by AEC.

This standard applies to dosimetry systems used to determine personal dose equivalent for occupational conditions and absorbed dose for accident conditions. Tests are conducted under controlled conditions and include irradiation with photons, electrons (beta particles), neutrons and selected mixtures of these radiations. The range of delivered absorbed doses or personal dose equivalents and tolerance levels are based on considerations of radiation protection expressed in current publications of the NCRP, ICRU and ICRP. Organizations should be tested in those categories which best represent the dosimetry services they provide or use. The tests outlined in this standard may be used to test both the suppliers of dosimetry services (processors) or the users of these services (users).

▲ Personnel dosimetry

The new version standard defines more complex photons testing items than pre-version. The providers of proficiency testing (now is National Radiation Standard Laboratory) shall establish the ISO beam code radiation systems and promote the evaluation techniques of new version standard in advance.

▲ Irradiation system of dosimetry

Benefit of this standard:

(1)to provide performance testing for external personnel dosimetry laboratory.

(2)to conform with the requirement of Ionizing Radiation Protection Act, AEC.

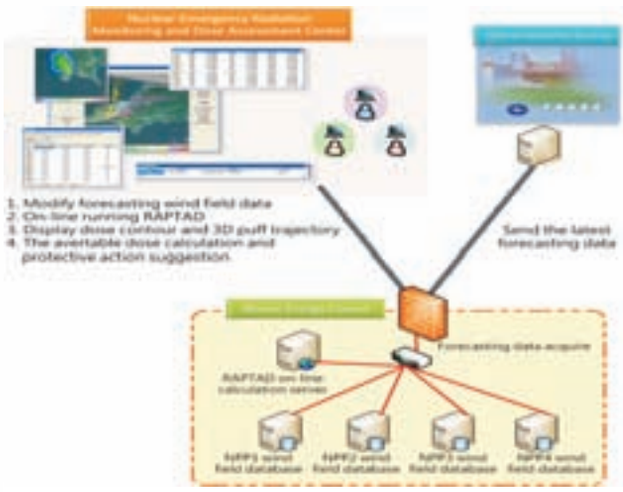
(3)to protect the safety of radiation works and environment.

1.9 Avertable Dose Intervention Applied in Emergency Response Dose Evaluation System for Nuclear Emergency Preparedness

◎Chung-Hsin Lu

Dose evaluation system is an important reference basis to the public protective actions. To meet the requirement of the Nuclear Emergency Public Protective Action Guides laid down on 2005, this project has completed both technologies of the avertable dose calculating models and the extended weather forecasting output had been implanted and added in the dose evaluation system. The graphical user interface also had been improved and added the functionalities for exporting avertable dose results and providing the recommendations of protective actions as well.

The dose evaluation system simulates the atmospheric dispersion to get concentration distribution via network. With the result, the system provides the ability to adjust the reduction factors of all exposure pathways for avertable dose calculation. The avertable dose and recommended public protective actions will be exported both in tabulating and in graphical format. The visualized displays of the dose evaluation are provided by GUI program for dose contour with wind field and 3D puffs' trajectory respectively.



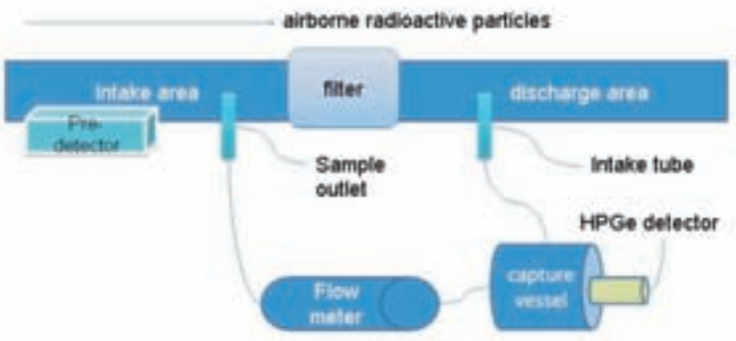
▲ The diagram of the dose evaluation system framework

This system was put to use in the annual nuclear emergency exercise of 2008 in the Maanshan nuclear power plant. It has been a major assistance for decision making during routine exercise and nuclear accident.

1.10 Establishing a Released Gas Sampling and Analysis Method for Short Half-Life Radioactive Isotopes

◎Hsin-Fa Fang

Radioisotopes have been used in the application and research for medicine, agriculture, industry and environmental protection. Radioisotopes have more and more contribution to the life quality and civilization of modern humankind. Sixth international conference on isotopes was held in Seoul, Korea in 2008. The keynote announced that radiation is an efficient tool to improve the welfare of humankind. In recent year, the researchers of nuclear medicine are developing the positron emission tomography (PET) scanning technology. The half lives of the radioisotopes used for PET are usually very short such as ^{11}C (20.3 min), ^{13}N (9.96 min), ^{15}O (2.03 min), and ^{18}F (109.3 min). The positron radioisotopes are produced by using a cyclotron and radiochemistry laboratory in close proximity to the PET scanning and imaging facility. These radioisotopes are incorporated either into compounds normally used by the body or into molecules that bind to receptors or other sites of drug action. Such labeled compounds are known as radiotracers. We can observe the working function of organ after injecting the radiotracer into body. The applications of PET are very useful to oncology, neurology, cardiology and neuropsychology et al. They are used widely in the world. It is hard to monitor the radioactive gas released from the PET facilities by traditional method because of the short half lives of radioisotopes typically used in PET scanning and the uncertain timing of the release. So INER established a novel method shown in the figure below for monitoring the released gas in the duct from the PET facilities.



▲ The infrastructure of the sampling and analysis instruments used in the method

The sampling and analysis method established by INER for the short-lived radioisotope released in the duct is depicted by the figure below. There is a high sensitive pre-detector installed in front of the filter. It is used to determine the timing of sampling. The air sampler will be started when the counting rate of pre-detector is higher than a setting value. Therefore we can catch the sample with the highest concentration. Positron isotopes decay very quickly. The gas samples should be directly stored in a stainless counting container and analyzed by high purity germanium detector (HPGe) in the field. The limits of the concentration of released gases are listed in the Safety Standards for Protection against Ionizing Radiation. The limit of ^{11}C is3.0×10^{4} Bq/m^{3} and ^{18}F is 4×10^{3} Bq/m^{3}. The minimum detection activity of the method are only about one tenth of the limits. The method showed a very good performance in practice for many hospital cases in Taiwan. We will do our best to provide the service for the radiation protection works of nuclear medicine.

1.11 Technical Service Support for Construction of Lungmen Nuclear Power Plant

◎Shih-Kuei Chen

In 2008 Institute of Nuclear Energy Research (INER) has spent 158 man years under 18 technical service projects to support construction of Lungmen Nuclear Power Plant (LNPP). These jobs can be classified into three categories,

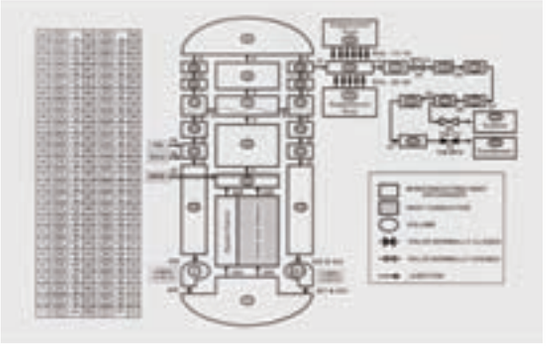
1. On Site Technical Support

The function of safety related Motor Operated Valves (MOV) of LNPP are tested and validated by INER. In 2008, phase 1 of the work, including MOV system information collection, request thrust/torque calculation, and weak link analyses, has been completed. It is expected that the test and validation of all the unit 1 (220) MOVs can be completed in 2009. As a third-party authorized inspection agency approved by AEC, INER is performing two Authorized Nuclear Inspection (ANI) jobs at LNPP. One job is the Owner ANI, and the major works

for 2008 were Unit 1 RPV hydro test, Unit 2 RPV internal installation, chimney piping construction, and instrument piping construction. The other job is the ANI for the BOP ASME piping construction, and 75% of the Unit 1 BOP piping work was completed at the end of 2008.

2. Safety Analyses and Assessment

Thermal hydraulic safety analysis (RETRAN) model for Lungmen Nuclear Power Plant has been established in 2008. Turbine trip start up test transient and load rejection start up test transient were studied. In the mean time, the probabilistic risk assessment model and severe accident analysis model have been developed.



▲ RETRAN model for LNPP start up test

▲ DCIS man machine interface validation and test for LNPP

3. Digital Control and Instrumentation System (DCIS) Site Test and Safety Evaluation

INER has established the technologies of software safety analysis (SSA) for DCIS including the method of software fault tree, software sequence tree and dynamic computer simulation. The SSA technologies were applied to the Reactor Trip Isolation Function (RTIF) and High Pressure Core Flooder (HPCF) systems for analyzing all stages of software development life cycle. The safety evaluations and validation procedures are prepared for the software installation of site testing phase for DCIS. Software Configuration Management System (SCMS) was developed to manage the DCIS as built information, change control record as well as software configuration items such as design document, software configuration file, source code, and software (firmware) component. Also, the Lungmen I&C Knowledge Management System (LIC-KMS) was developed to integrate valuable technical information during the DCIS system development.

The technologies developed in this program, e.g., MOV test and validation, ANI, Safety analysis/assessment model, DCIS safety evaluation, will effectively support the startup test and construction of LNPP. The technology can also be applied to the existing plants. For new unit constructed in the future, these developed technology can support the construction and reduce the reliance on foreign vendor.

1.12 Safety Regulatory Technology Support or the Lungmen nuclear power plant

◎Lih-Yih Liao

In support of the AEC over the safety regulatory related issues for the nuclear power plants, INER's activity can be divided into two parts. One aimed at the support for safety report review, including safety analysis and evaluation of technical report; the other is focused on the support for safety inspection, close monitoring the status of the operation and construction of nuclear power plants, to assure that all the actions meet the nuclear safety regulatory requirements.

With respect to the support of safety report review for the Lungmen nuclear power plant, the major task during the 2008 is the review of the Final Safety Analysis Report (FSAR) of Lungmen Nuclear Power Plant. The FSAR is roughly 16,800 pages with 5 million words. The INER's review team is composed of 57 staffs with diversified expertise. The total manpower devoted to this work is 7 man-year. The total review comments are about 256 items, e.g. “the description is not detailed or clear enoug h”, “the requirements of Standard Review Plan may be violated”, “data error” ...etc.

In support of the AEC over the safety inspection of Lungmen NPP construction, 6 man-year manpower have been devoted during 2008, and 12 reports have been written, some of the major findings are illustrated below:

(1) Feb. 2008, the stainless steel sleeve plate welding width of the suppression pool was found to be 50 mm, which can't meet the requirement of 12 mm;

(2) Apr. 2008, arc striking was found on the flange surface near the bolt of the 1B31-P-0001P motor casting;

(3) Nov. 2008, the assembling angle at whip restrain was found to be incorrect.

The contribution of this project: With of the review of technical reports and the on-site inspection, the regulatory technology can be enhanced and the deficiencies during construction can be discovered in time. As a result, quick corrective measures can be made and the quality of the nuclear power plant construction can be assured.

▲ Root opening of weld joints are not accepted when assembling the liner of the suppression pool

▲ Arc strike found on the surface of motor casing of reactor internal pump

▲ Assembly of pipe whip restraint is not compliant with installation specification

2. Nuclear Facility Decommissioning and Radioactive Wastes Management

◎Horng-Bin Chen

The development of nuclear facility decommissioning technology is an issue nowadays that is concerned by all nuclear-advanced countries. Tremendous efforts were made worldwide to develop final disposal technology for radioactive waste generated from nuclear power plant operation and other nuclear-related applications. To fulfill the mission of recycling INER's retired nuclear facilities as well as establishing domestic radioactive waste management technologies, INER devoted to dismantling and retrofitting retired nuclear facilities cautiously and further emphasize on complying with the requirements of clearance release. Also, we put effort on developing technologies of radioactive waste restoration, decontamination, volume-reduction, stabilization, and storage. Especially, the well-developed technologies of radioactive waste solidification have demonstrated excellent volume-reduction efficiency, operation flexibility, and high quality for solidified waste, offering a total solution to radioactive waste volume reduction and stabilization. Furthermore, for issues on the disposal of both low level waste and spent fuel, INER not only makes effort in developing assessment tools, but also provides solutions for spent fuel dry storage of Chinshan Nuclear Power Plant.

2.1 The Verification of Stabilization Process of TRR Metal Uranium Spent Fuels

◎Te-Wen Chu

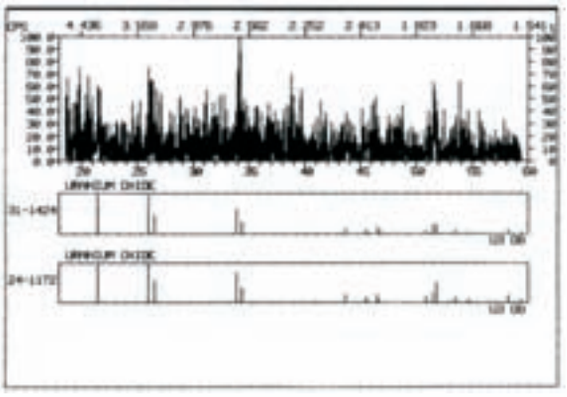
The stabilization process is to transform the TRR spent fuels from metal uranium into the most stable uranium oxide phase (U_3O_8), so that the product can be loaded into the stainless steel cans followed by sealing and welding procedure for interim storage.

Since metal uranium is very easy to react with water to produce hydrogen, the potential risk for long-term storage of the stabilized product is closely related to whether the metal uranium fuel is completely transformed into the stable phase of U_3O_8 or not. In the

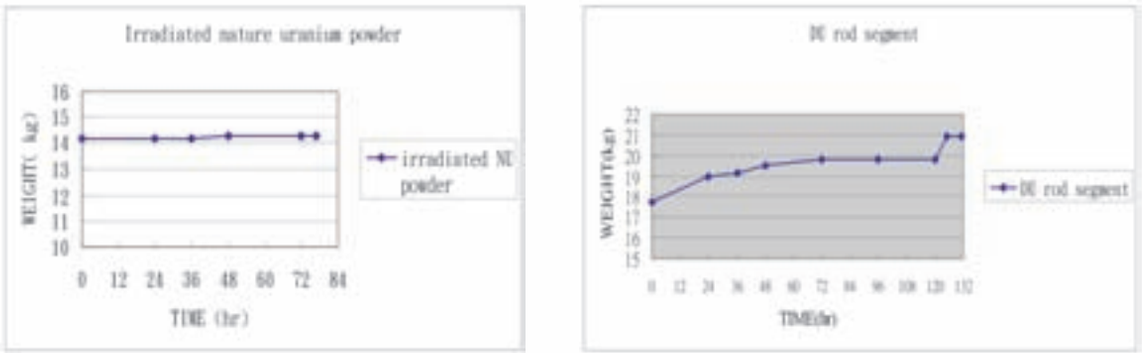
early stage of the process development, un-irradiated metal uranium was used to simulate the stabilization process outside the hot cell. The basic oxidization conditions of heating in oxygen atmosphere at 400°C for 48 hours were established based on the simulation results. In order to cope with all the variations, it is necessary that the stabilization process in the hot cell be investigated in detail to verify or to modify the previous process parameters.

In order to enhance the quality for the stabilization process, the variation of the weight of fuel with the stabilization time at different temperature of different types of spent fuel rods was studied to verify the stabilization process. The results are the basis of the quality assurance and verification of the stabilization process. An additional examination procedure was established in the stabilization process as a double check. In the examination process, the stabilized uranium oxide product at high temperature was reheated to observe if the weight of the stabilized uranium product varies before and after reheating. If there are no change observed, it means the stabilized product have been fully transformed into the stable oxide phase.

▲ Weighing of the stabilized (irradiated) nature uranium in hot cell.



▲ X-ray diffraction result (cold test) shows the uranium is completely oxidized to a stable U_3O_8.



▲ Verification of stabilization process—weight change of depleted U rod segment with time. Showing that the stabilizing temperature greatly influence the stabilization of DU.

2.2 The Welding Process and Leak Test of the Storage Canisters Containing Stabilized Powder Product of TRR Spent Fuel

◎Chun-Liang Lin

The stabilized powder product of TRR spent fuel is designed to be safely sealed in a multi-layer storage mechanism. This storage mechanism consists of three different containers. The inner-canister confines powder product by a screw-tight cap with rubber O-ring. The outer-canister accommodates up to seven (7) inner-canisters and is welded to meet the airtight requirement. The leak rate of outer-canister should be less than 1×10^{-6} cm^3/sec (STP). The clean-canister surrounds outer-canister and keeps contamination on the surface of outer-canister from dispersing during transportation and storage.

The gas tungsten arc welding (GTAW) technique is applied in welding the lid of outer-canister. The GTAW method can be easily performed on almost all kinds of metal. It results in clean welds and requires little finishing because of the coverage of inert gas. These advantageous characteristics make the GTAW suitable for welding tasks inside hot cell. Special tools are designed for compatible handling with manipulators for operators to perform welding task which is inside hot cell.

Helium leak testing method is used to measure the leakage rate of outer-canisters. The vacuum pump loop and helium mass spectrometer system outside the hot cell is connected with the outer-canister in the hot cell with a special adaptor. The leak rates of the outer-canister cylinder and weld path are both measured and should be lower than 1×10^{-6} cm^3/sec (STP). Helium is sequentially filled into the outer-canister cavity and the vent port on the lid is sealed in the end.

▲ The Welding Equipment in Hot Cell

▲ The Helium Leak Test Instrument

2.3 The Bottle Plutonium Canister Counter (BPCC) system

◎Ming-Chen Yuan

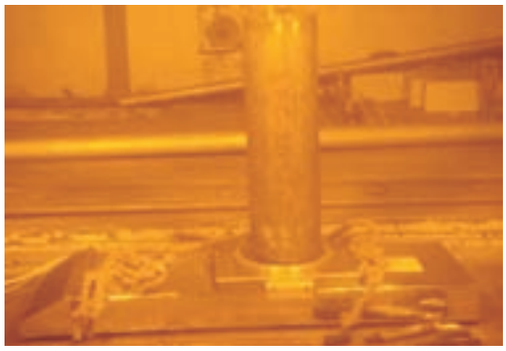
The bottle plutonium canister counter (abbreviated as BPCC) system was majorly used for measuring the Pu content in uranium oxide powder which is produced from stabilization of the spent fuel rods of the Taiwan Research Reactor (TRR). This system and the analysis code for measurement results were provided by the Los Alamos National Laboratory (LANL), USA; the instruments calibrations and the practical sample measurement techniques were conducted by the Institute of Nuclear Energy Research (INER).

The BPCC was mainly comprised of three He-3 proportional tubes. It was used to detect neutrons from the spontaneous fission or (α,n) reaction of the products from stabilization of spent fuel. The stabilized products not only emitted neutrons but also

emitted high dose gamma rays. To avoid gamma ray disturbance, LANL coated the He-3 proportional tubes with lead and tungsten sheet, both about 1 cm thick. However, during real practices, we found that the gamma ray disturbance was larger than expected for the original system design. We performed a high voltage plateau curve test for the system in the hot cell using two inner-canisters. We made a comparison between the above curve and the curve obtained from the Cf-252 radioactive source (without gamma ray disturbance). It showed that when the working voltage of the detector was over 1620 V, the gamma ray disturbance was highly increased. To avoid gamma ray disturbance for the measurement operations to come, we tuned down the BPCC high voltage from the originally recommended 1700 V to 1580 V. Though the BPCC neutron detection efficiency would be reduced by about 15% due to the voltage drop, more steady and reliable measurement results are expected in return.

INER, in co-operation with LANL, completed the system calibrations and sample measurements of stabilized powder from 3 spent fuels. The measurement results agreed with the results from the spent fuel plutonium coincidence counter developed in 2007. The BPCC system will keep servicing the stabilization of spent fuel to meet the IAEA's nuclear safeguards requirement.

▲ BPCC Detector



▲ BPCC Measurement in Hot Cell

2.4 TRR Spent Resin Transfer and Storage System

◎Kuo-Yuan Chang

The cleanup of the spent fuel pool is a major working item of the TRR decommissioning project. All kinds of radioactive waste in the spent fuel pool must be removed. For the highly contaminated spent resin stored in the pool, the strategy is to remove them from the pool and store temporarily before a proper stabilization technology is developed. The transfer and storage system is designed to move the resin from the canisters in the fuel pool to the storage tank in room 023 of TRR basement.

Main equipment of the transfer and storage system are transfer pump, dewater pump, transfer pipeline system, resin storage tank, underwater operation tank, programmable logic control system and monitoring system. The working principle is that transfer pump absorbs water from the spent fuel pool and pressurizes the submerge resin tank. Dewater pump discharges water filtered through Johnson Screen from the resin storage tank back to the spent fuel pool.

The construction, unit test and system test of the TRR spent resin transfer and storage system have been completed. In order to verify the design function, clean resin is used for function simulation. In addition to the function test, operational simulation and training workshop including working sequence, operation procedure and safety monitoring are practiced to ensure the successful performance of in situ tasks.

▲ Spent Resin Storage Tank

▲ Pump and Pipeline System

▲ Programmable logic control system and monitoring system

▲ Simulation Test

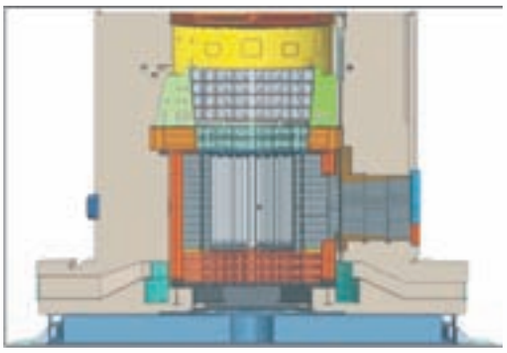
2.5 Application of 3D Virtual Simulation on the Development of TRR Dismantling Methods

◎Yi-Chang Chen

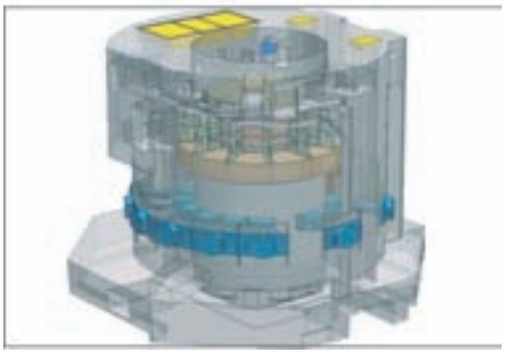
The TRR reactor block is in safe storage and will be dismantled in accordance with the Nuclear Materials and Radioactive Waste Management Act. The techniques for dismantling the reactor block and internals will influence the outcome of TRR decommissioning project. The reactor internals are highly activated. Therefore, 3D engineering simulation can be applied to help evaluate the dismantling technique.

To commence the 3D engineering simulation, 3D models of the TRR reactor block with its internals and the confining building, 074, would be built up with CAD software. The virtual models could provide the perspective check of element positions, dimensions and disassembling cutting paths. Furthermore, the virtual simulation could provide a dynamic display for dismantling techniques, which is helpful to integral planning and detailed technical discussions. The efficiency and accuracy of evaluating the dismantling techniques are increased with the aids of 3D models. Additionally, the original design details of reactor block and internals are digitalized and easily kept. 3D engineering simulation can also be applied to information management.

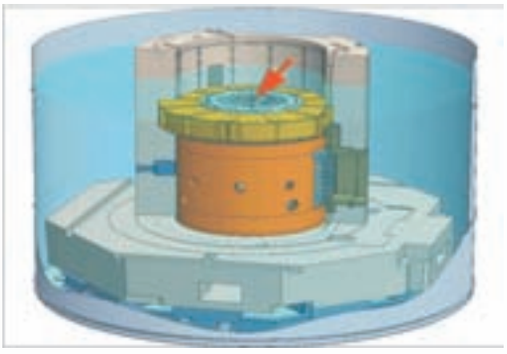
3D virtual simulation application in the development of TRR dismantling techniques would no doubt upgrade the efficiency and accuracy of the decommissioning project.



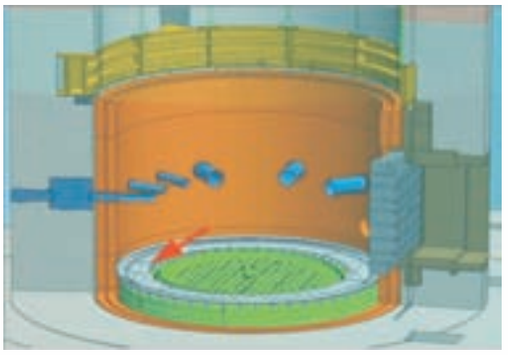
▲ Section View of TRR Reactor Block



▲ Transparency of TRR Reactor Block



▲ Dismantling Technique-3D Ssimulation (1)



▲ Dismantling Technique-3D Simulation (2)

2.6 Dismantling of the Trans-Uranium Contaminated Facilities

◎Chung-Shin Lee

The final goal of the decommissioning of trans-uranium contaminated facilities at building 016 of INER is to make this laboratory free from α-contamination.

Two large-scale α-contaminated glove boxes, Unit 20 and Unit 21, have been successfully dismantled and the final report has been approved by AEC.

For year 2008, a working plan for dismantling the analytical lead-cell line in building 016 is prepared. Based on the approved working plan, three isolating working areas are categorized within building 016, including dismantling area in room G32, cutting area in room A55 and packaging area in room G43. The equipments for radiation safety monitoring and recording are set up. Some other preparation tasks including standard operation procedure reviewing and personnel training are also finalized.

According to the well-organized plan, the lead shielding blocks around the analytical lead-cell line is dismantled within twenty days. Annual goal is achieved with both industry and radiation safety requirement met.

▲ Dismantling of Analytical Lead-cell Line

▲ Dismantling of Lead Shielding Blocks

2.7 The Implementation of SWAM2 Clearance Monitor

◎Mao-Chen Liu

The SWAM2 Clearance Monitor is set up for the purpose of waste classification from the specific radioactivity of waste drums. With a 4 design, the framework is shielded with 6cm-thick lead blocks and a 4cm-thick lead shielding door. The outer dimension of the cabinet is 1,820 mm high, 1,520 mm long and 1,430 mm wide with an inner effective measurement space enough to accommodate a 55-gallon waste drum. There are 10 plastic detectors mounted inside the lead-shielded rectangular cabinet. The detectors are arranged on four sides, top and bottom of the cabinet. The SWAM2 Clearance Monitor can detect up to 454 kg or 55 gallons of waste for each batch. The throughput is approximately 1200 kg/hr. MDA of the SWAM2 Clearance Monitor is less than 70Bq for Co-60 within 120sec and 210Bq for Cs137 within 120sec under a radiation background of 0.1Sv/h.

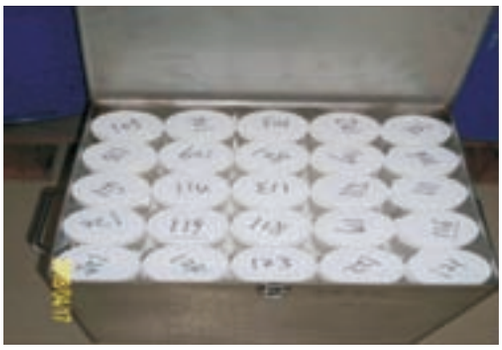
▲ SWAM2 Clearance Monitor

▲ Integrated System Software

2.8 The Test Run for the Verification of Clearance Samples Measurement and Analysis Capability

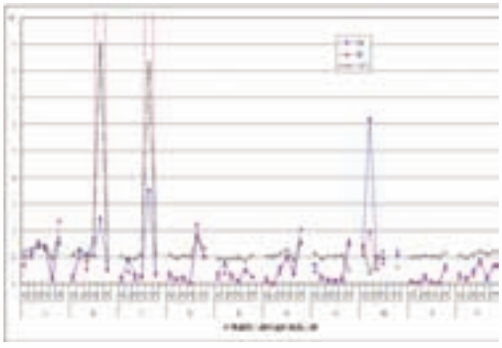
◎Chin-Hsien Yeh

Domestic nuclear facilities perform the classification, measurement, release and storage of radioactive waste produced from decommissioning or operation of the facilities by following the "Regulations on Clearance Level for Radioactive Waste Management" enacted by the Atomic Energy Council (AEC). Acknowledging the technical needs from laboratories dealing related measurements, and referring to the TAF accreditation criteria for ionizing radiation, the National Radiation Standard Laboratory (NRSL) ran this trial performance test for measuring instruments used in release practices. There are fourteen (14) measuring instruments from seven (7) laboratories, including nuclear power plants of Taiwan Power Company, were verified in the performance test workshop. About 3/4 of measurement results derived from 7 box-type and 7 drum-type testing samples appeared to meet "$En \leqq 1$" or "difference $\leqq 30\%$ compared with reference values" The minimum detectable activity (MDA) values of ^{60}Co and ^{137}Cs are less than the release limit of 0.1Bq/g defined by IAEA, and the minimum detectable threshold value of 0.02Bq/g required by the competent authority. Furthermore, the results are anticipated as a reference for technical regulation for clearance measurement of radioactive waste.

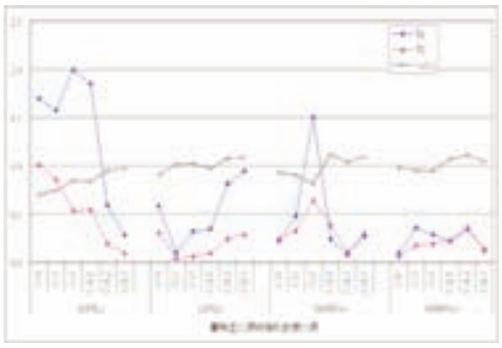


▲ Box-type testing sample

▲ Drum-type testing sample



▲ Proficiency testing results of box-type instruments



▲ Proficiency testing results of drum-type instruments

2.9 The Metal Waste Clearance Release

◎Feng-Jung Chang

A release plan directed against the metal waste stored in the Extra-low Level Radwaste Temporary Storage Area (Building 031) of INER, including dismantled steel frame construction of the Warehouse 015K, peeled cable of TRR, wave-type roof iron sheet of the Garage 015L, decommissioning metal waste of Building 023 and 036, had been executed in 2007 and 2008 with a quantity of 110.4 tons. The release operation of this plan were done by three stage implementations, firstly analyzing waste sample according to their working history to judge nuclide composition, secondly initial piece-screening by surface net counting rate to eliminate rejected waste, finally taking gross specific activity measuring and specific activity verification analysis for whole waste drum to make sure detected waste meet clearance level.

The plan had released about 20.5tons waste in 2007, 80.9 tons in 2008 and the rest waste of about 9 tons will be released in early 2009.

▲ Surface Net Counting Screen

▲ Q2 Specific Activity Verification Analysis

▲ SWAM2 G ross Specific Activity Measuring

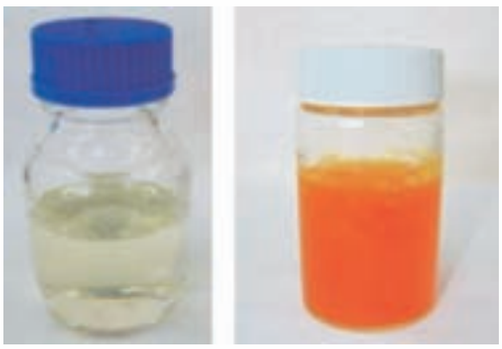
2.10 An intelligent Colorimetric Gel for Surface Radioactive Decontamination

◎Jen-Chren Chung

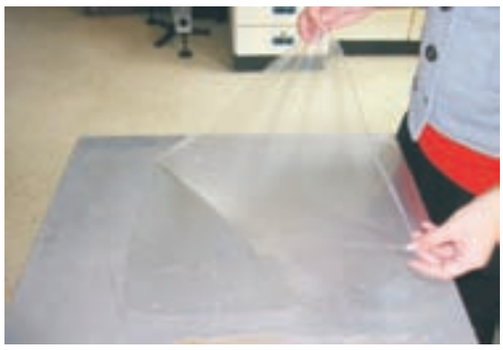
In this research, an intelligent colorimetric gel has been developed for decontamination of a large surface area with radioactive contaminants or a difficultly dismantled device that need to treat in situ such as wall of a building. It can be effectively used to remove radioactive element and grease stain from contaminated surface. Additionally, the strippable gel also has the colorimetric function that accurately indicates contaminated location with radioactive contaminants such as Co, Cs, and Sr, and further treatment can be executed to promote the decontamination efficiency.

During the treating process, removing the coated gel, only few amounts of used films are produced, therefore, the target of waste reduction can be easily achieved. Furthermore, the pasted gel forms a protection film on a contaminated surface that can prevent contaminant diffusion and protect operators away from the radioactive source.

According to experimental results, we can conclude that larger than 98% surface contaminants are removed after a strippable gel coating treatment. The decontamination factor is about 10^2 that close to the results of electrochemical treatment in the range of 10^2-10^3. Currently, spraying and heating equipments have begun to be constructed and will be used to test the decontamination efficiency by treating a large area of contaminated floor in the fiscal year of 2009. However, the problems of surface contamination also commonly occurs in various industrial processes and lead to generate large amount of secondary wastewaters due to treating contaminated surface by solvent washing. Therefore, the above-developed gel coating technology can also be effectively provided as the purpose of surface cleaning for industrial devices.



▲ Gel Decontamination Agent



▲ Formed Protection Film by Using a Strippable Gel Coating

2.11 Technical authorization of the Low Level Wet Radioactive Wastes High Efficient Treatment Technology

◎Yih-Ping Chen

To deal with the wet low-level radwaste generated by nuclear power plants, INER has successfully developed several key technologies, including (1) High-Efficiency Solidification Technology for sodium borate waste (PWRHEST), (2) High-Efficiency Solidification Technology for sodium sulfate waste mixed with powder-type spent ion-exchange resin (BWRHEST), and (3) Wet-Oxidation High-Efficiency Solidification Technology for bead-type spent ion-exchange resin (WOHEST). All the well-developed technologies have demonstrated excellent volume-reduction efficiency, operation flexibility, and high quality for solidified waste, offering a total solution to radwaste volume reduction and stabilization. Among these technologies, PWRHEST and BWRHEST have been implemented in Maanshan and Kuosheng Nuclear Power Plant of Taipower respectively showing outstanding volume-reduction efficiency. Furthermore, the pilot system of WOHEST built in INER has met all the requirements for volume reduction and stabilization of spent resin.

Since the high-efficiency solidification technologies have potential benefit in commercial application, to promote domestic technologies and realize the R&D achievements for better social welfare, INER decided to spin off the technologies. After going through the public and equitable process of technology announcement, cost evaluation, qualification review, and price examination, INER had a non-gratuitous and non-exclusive contract with Asia Giant Engineering Co. on Sept. 1, 2008. A team responsible for handling the technology transfer-related affairs has been organized at INER to assist Asia Giant Engineering Co. for their recent demonstration in the 2009 Nuclear Power Industry Exhibition held in Beijing, China. In addition, the team will continue to provide Asia Giant Engineering Co. with the necessary training and technical consultation (a total of 300 hours) within two years. Transfer of the technologies can provide prospect profit of NTD$1.5 billion for transferees. What's more, each of nuclear power plants may save NTD$90 million when employing the technologies instead of conventional process of cement solidification in consideration of the final disposal cost.

▲ Asia Giant Engineering Co. participating in the 2009 Nuclear Power Industry Exhibition held in Beijing, China

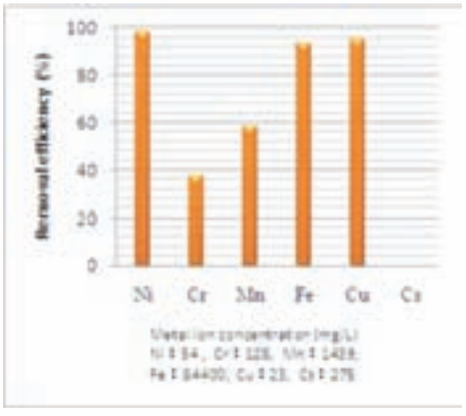
▲ Providing training and technical consultation to Asia Giant Engineering company

2.12 Regeneration Technology for Spent Phosphoric Acid-Based Decontamination Agent

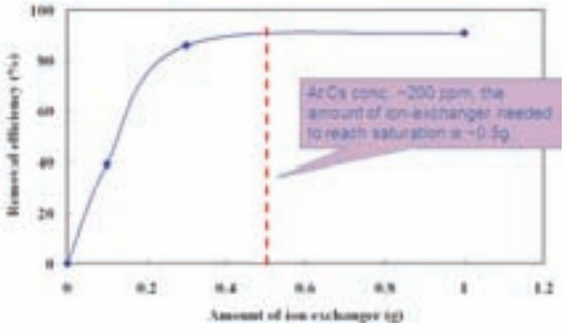
◎Kou-Min Lin

Most of the metal wastes from nuclear facility decommissioning at INER are composed of cast iron. Owing to their complicated geometry, chemical treatment based on phosphoric acid was selected as the favorable method for decontamination. As the efficiency of the decontamination agent, phosphoric acid, declines, regeneration is often carried out to extend its performance. The occasion to perform regeneration will depend on (1) the concentration of iron (when Fe concentration is over 100g/L), and (2) the concentration of radionuclide (when radioactivity is over the acceptable limit). Oxalic acid-based precipitation was adopted as the main technique for the regeneration of spent phosphoric acid at INER. The precipitation reaction Fe^{+2}+HOOCCOOH $\cdot$ $2H_2O \rightarrow Fe(OOC)_2 \cdot 2H_2O + 2H^+$ which was carried out at 60°C, was capable of removing over 90% of the dissolved Fe ion. The produced precipitate, ferrous oxalate, can subsequently be volume-reduced via incineration. The only drawback of the precipitation technique is the poor removal efficiency for Cs ion (< 5%) that may also exist in the decontamination of metal wastes from nuclear facility decommissioning. To solve this problem, Cs ion-exchanger was added simultaneously during oxalic acid precipitation. The Cs ion-

exchanger was added simultaneously during oxalic acid precipitation. The Cs ion-exchanger prepared according to the reaction $Na_4Fe(CN)_6 + Cu(NO_3)_2 \rightarrow Na_2[CuFe(CN)_6] + 2NaNO_3$ has demonstrated an outstanding Cs removal efficiency as well as selectivity of over 90%. The reduction of radioactive Cs not only lowers the dose exposed to the operating personnel, but also avoids the generation of secondary waste and prevents facility contamination by radioactive Cs.



▲ Removal efficiency of various metal ions by oxalic acid precipitation



▲ The dependency of Cs removal efficiency on the amount of ion exchanger

2.13 The Abnormal Scenario Assessment Technology for the Low-Level Radioactive Wastes Disposal Site

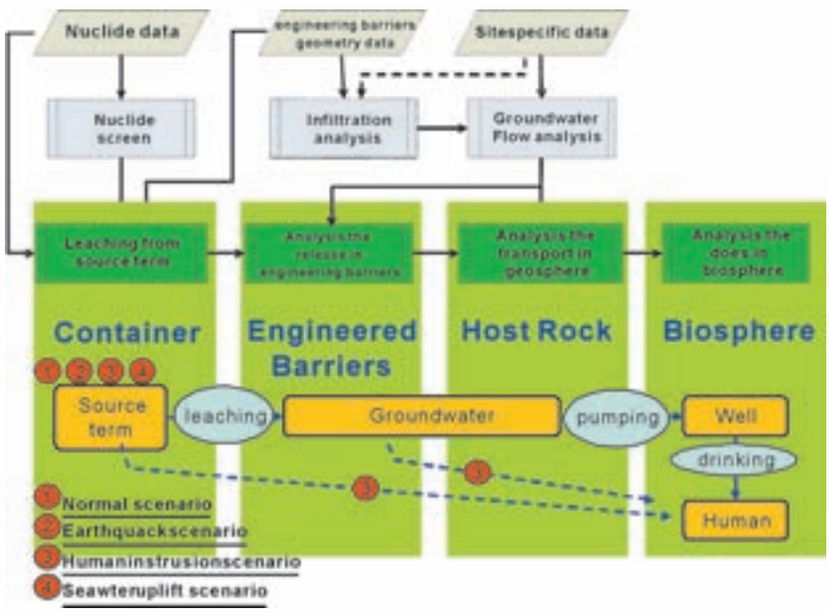
◎Fu-Lin Chang

MOEA (Ministry of Economic Affairs, R.O.C.) based on " Act on Sites for Establishment of Low Level Radioactive Waste Final Disposal Facility" had been published three low-level radioactive waste disposal candidate sites at August, 2008. It will hold on a public opinion polls for selecting a final disposal site. For the schedule, the low level radioactive waste disposal safety assessment technology is one of important issue for us. During 2004-2007, we focused on final disposal concept and applied GoldSim to be a platform integrated the technology of nuclides release from

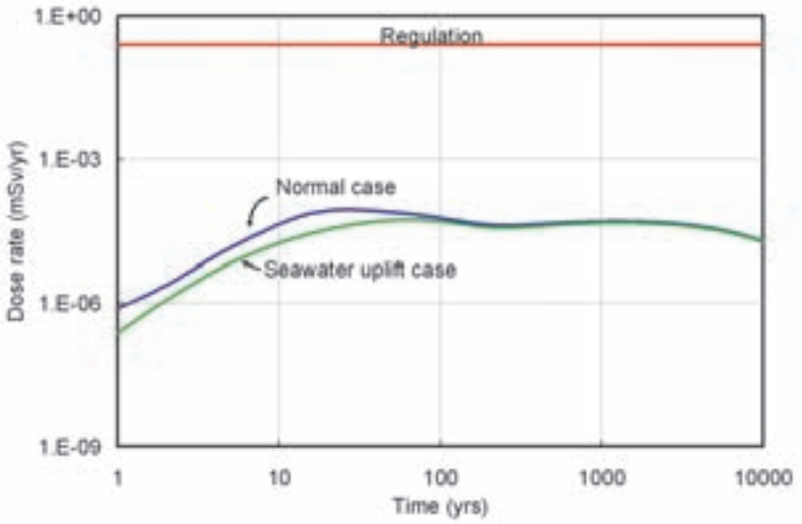
source term and far-field migration assessment technology. Finally, we finished the deterministic and probability analysis long-term safety assessment model of normal scenario.

The major development at 2008 is unusual scenario safety assessment technology. Through analysis the affected factor by FEPs of unusual scenario, and listed the assessment parameters table, we constructed a possible unusual scenario. It could assess the working staff and public irradiated dose at operating period of unusual scenario (includes fire, scatter of free falling, aerodynamic particle, and uplift of seawater). The results show the irradiated dose of working staff and public at unusual scenario operating period is lower than the limits.

We had developed the low level radioactive waste disposal safety assessment technology. It could be refined from research data and supplied safety assessment technology of vary stages for conductor. Since 2009, we will advance the nuclides migration experiment for verification of safety assessment. This will benefit to increase the confidence of research and promote the public faith of low level radioactive waste disposal safety assessment.



▲ Scenario of nuclide release safety assessment



▲ The public irradiated doses of seawater uplift scenario and normal scenario

2.14 Executive Status of Chinshan Dry Storage Project at 2008

◎Bor-Tsang Lee

TPC is unable to obtain the approvals of Environmental Impact Assessment (EIA) report and the Soil and Water Conservation (SWC) plan on schedule. Thus the whole project is re-scheduled to be accomplished at end of 2014, which is a two years delay. The overall progress is about 35.8% and the executive status of this year (2008) is briefly described as follows:

1. The manufacture examination and QA audit of TSC

A trial TSC (Transportable Storage Canister) was finished at this February and INER team verified that CTCIM, the TSC vendor, meets the requests of codes and contract. As the notice of manufacture issued from TPC (Tai-Power Company), first two TSCs were put into fabrication at September of 2008. These two casks will be delivered to site at February of 2009. INER's survey group executed a series of examinations on 43 hold points and 137 witness points. Furthermore, INER, TPC and regulatory administration audited CTCIM at May and at December of this year.

2. The follow-up of Safety Analysis Report (SAR) review proesses

Under INER's assist, the SAR passed the review by regulatory administration at this January. The EIA report of CSNPS ISFSI system was also approved conditionally by Environmental Protection Administration at this August and then the construction permit of system was issued by the Atomic Energy Council (AEC) at December of 2008.

3. Planning and execution of major procurements

After the notice of manufacture issued, the transfer service, transfer equipments, TFR and Vacuum Dry System (VDS) of TSC has been contracted with local vendor at this September and this December, respectively. However, the procurements of VCC, AOS and Pad are still pending for TPC's commitment on the date of handing over the site of Pad to INER.

4. Operation mock-up and planning

The mock-up equipments have been purchased and several operation trainings have been executed, such as TSC upending, air-pad operation and closure welding. Totally five developed techniques have been patented this year. One project team member passed training course and obtained a certificate of senior mechanical inspector, issued by INER, and 7 members obtained mechanical inspector certificate. One member of the team obtained a certificate of senior civil inspector, issued by INER, and 10 obtained junior civil inspector certificate.

The project also organized an action learning team on design, analysis and operation of spent fuel dry storage system. We promoted performance of the team members by a series of learning activities. Moreover, the project was commended by the AEC on our tribute about radiation material storage technique development.

▲ Fabrication of test TSC---basket assembly

▲ Fabrication of test TSC---shell go gauge test

▲ Operation mock-up--- Closure welding

▲ Project was commended for radiation material storage technique development

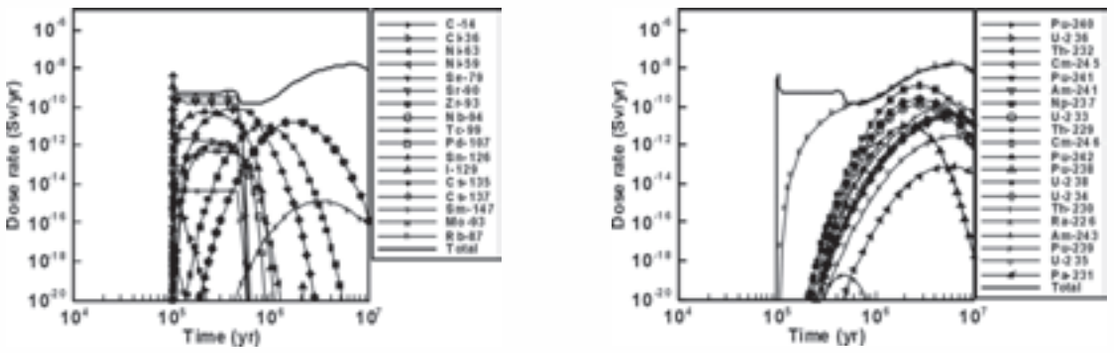
2.15 Performance and Safety Assessment of Spent Nuclear Fuel Final Disposal

◎Ching-Fang Shih

The purpose of spent nuclear fuel final disposal (SNFD) is to assess characterization of potential site by site investigation and the development of assessment technology. This research implements the analysis of source term characteristics of high-level wastes generated from reprocessing of spent nuclear fuel and the international HLW disposal information, and looking forward to complete the waste form types, the final disposal concepts, the configuration of disposal site and the disposal operation procedures of HLW. Then the integrated cases of the total system performance assessment will be analyzed to achieve stage objective of the fiscal year 2009 for domestic spent nuclear fuel.

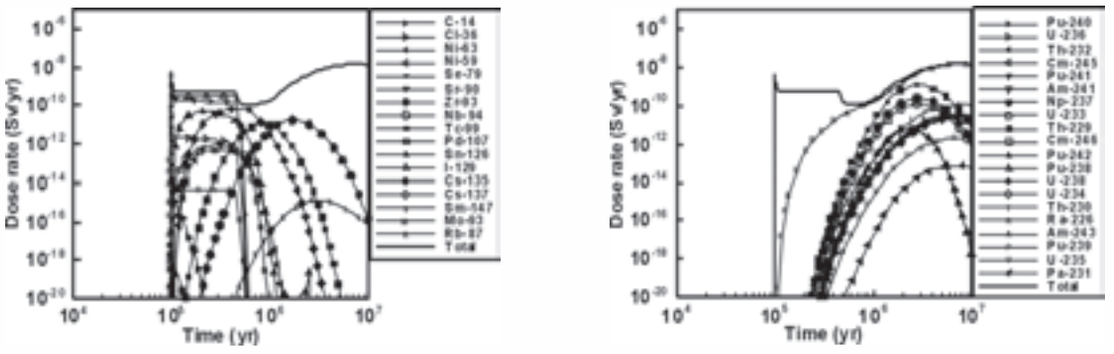
The Yucca Mountain Disposal Project of USA presents the comparison for these reprocessing methods. The results show that PUREX has advantages for commercial experience and economical benefit, but it produces large liquid wastes and proliferate nuclear weapons. UREX+ and Pyrochemical reprocessing have economical benefit, but it can't separate the heat-load radionuclides (Cs and Sr) if just only using pyrochemical reprocessing. Besides, the research for characteristics of high-level waste forms focus on understanding the physical and chemical properties of high-level wastes generated from reprocessing of spent nuclear fuel. It analyzes physical properties of high-level wastes generated from reprocessing of spent nuclear fuel, and these results could provide detail informations for earlier stage assessment. It collects the international HLW disposal information, includes disposal status in each country is analyzed and demonstrated by (1) country name；(2) regulated organization；(3) type of nuclear power plant；(4) operation duration；(5) waste management organization；(6) retreatment and storage status；(7) disposal procedure and host rock；(8) technology developing procedure.

The base cases are performed by total system for performance assessment (TSPA) integrating the near-field, far-field and biosphere codes. The assessment models include RT-NV (Radial Transport Model for Radionuclide Near-Field Release with Canister Vertical Emplacement), ART-NV (Axial and Radial Transport Model for Radionuclide Near-Field Release with Canister Vertical Emplacement) and ART-NH (Axial and Radial Transport Model for Radionuclide Near-Field Release with Canister Horizontal Emplacement) models. The assessment results show that the total dose rates of all these three models are below the regulation limit, 0.25 mSv/yr.



(a) Fission products (b) Actinides

▲ Case of ART-NV



(a) Fission products (b) Actinides

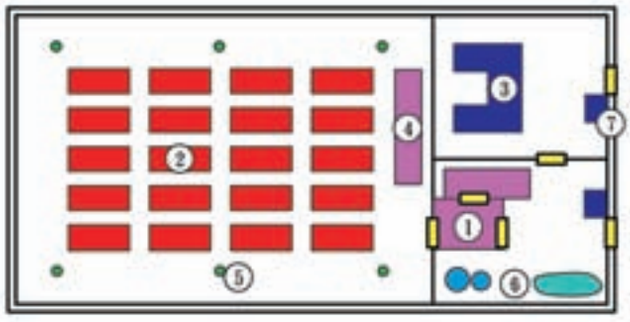
▲ Case of ART-NH

2.16 Feasibility Study on Spent Nuclear Fuels Long-Term Storage

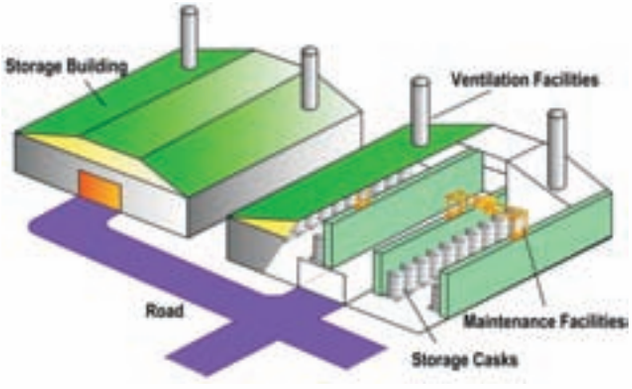
◎Li-Min Chi

For spent nuclear fuel, the best international consensus option is deep geological disposal. Difficulties have been encountered in most countries, however, in proceeding with the development and construction of disposal facilities for spent nuclear fuel and as yet no such disposal facilities are in operation. In recent years, a long-term storage option has been given consideration seriously in some countries. The INER was requested by AEC to investigate the role of long-term storage in a sustainable program of spent nuclear management, and especially the implications for safety. The schedule of study is from 2007 to 2009. The purpose of the study is to reflect the worldwide status. It is intended for use as reference documents for policy discussions.

In 2008, this study focuses on facilities requirement and operation concept for the long-term storage of spent nuclear fuel. Alternative concepts for long-term storage facilities are developed and discussed, include of reactor-site storage, centralized storage, casks in storage buildings, and casks in rock caverns. These storage facilities must to meet the design requirements of nuclear safety, that is, sub-criticality, containment, and shielding. Also, retrievability should be concerned in a storage facility. The option concept of casks in storage buildings is illustrated. The main facilities include waste treatment, storage, administration, maintenance, monitoring, utility, safeguard, and ventilation. The study provides the INER with basis for further feasibility study. The technical reports also provide reference document for regulatory agency to further develop the long-term storage option for spent nuclear fuel management in Taiwan.



▲ Layout concept for casks in storage buildings option.



▲ Concept of casks storage buildings

3. Biomedical Application of Radiation Technologies

◎Kuan-Yin Chen, Chia-Chieh Chen

The research and development of Radiation Application Technology Center (RATC) was the third of the total 4 year program. This program included 5 subsections as (1) Radiation isotopes research development and promotion, (2) Radiopharmaceuticals research development and promotion, (3) Drug efficacy evaluation and the application of radiation therapy research (4) The analysis, identification and the standards chemicals research and development (5) The research and development of radiopharmaceuticals radiotherapy and radioimmunotherapy.

This program focused on the research of radiopharmaceuticals and their application. It's purpose on developing nuclear medicine was to develop diagnosis, therapy and the molecular image technique for the local health care. The final aim would be establishing a local radiopharmaceutical industry in Taiwan. RATC is improving the existing nuclear medicine technique continuously to meet the update speed of the world standard, and the current trend and the market tendency. Proceeding into the international market will be another step for its nuclear medicine research. Moreover, RATC accented on radiation applied research such as ligands synthesis and radiation biology and some other correlated technology, and also expected to step into the global area of this specialized radiation biomedical application field.

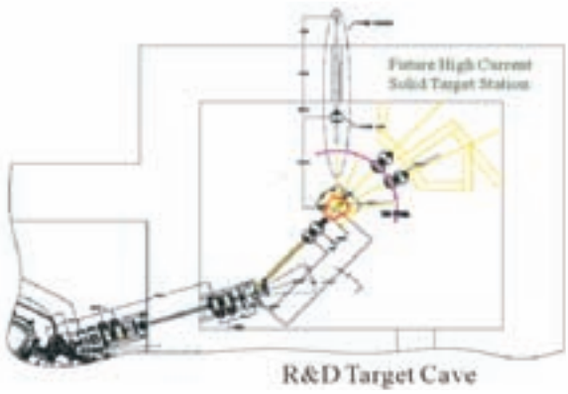
The achievements of this year including 23 pattern application, 18 international journal papers, 6 local journal papers, 18 international conference papers, 27 local conference papers, and 43 INER reports, There were at least 15 important programs accomplished this year. They were: (1) Beamline extension program for the INER TR30/15 Cyclotron, (2) The development and improvement of solid target preparation technology for cyclotron produced radioisotope production, (3) Study on fabrication of [18-F] Acetate Synthesizer Module, (4) The performances of I-123-IBZM multi-center registration trial, (5) Comparing the therapeutic effect of ^{188}Re-ECD/Lipiodol and Lipiodol in rat hepatoma model, (6) Evaluating the potential of ^{188}Re-SOCTA-Trastuzumab as a new radioimmunoagent for breast cancer treatment, (7) Biodistribution and pharmacokinetics

of transgenic pig-produced recombinant human factor IX (rhFIX) in rats, (8) Receptor-binding, biodistribution, dosimetry and micro-SPECT/CT imaging of ^{111}In-DTPA-[Lys3, Tyr4]-BN in human prostate tumor-bearing mice, (9) Discovery of serum biomarkers for liver fibrosis detection by two-dimension difference gel electrophoresis (2D-DIGE), (10) Preparation and preliminary study of In-111-galactopeptide, (11) Nowadays and vision of radiopharmaceutical characterization laboratory in 2008, (12) Establishment of computed tomography (CT) Dosimetry standard for radiation diagnosis, (13) Establishment of calibration standard and measurement comparison technology for brachytherapy sources, (14) Measurement standard establishment for ^{123}I Radiopharmaceuticals at INER, (15) Establishment of high dose measurement system, (16) Development of molecular imaging technology.

3.1 Beamline Extension Program for the INER TR30/15 Cyclotron

◎Ting-Shien Duh

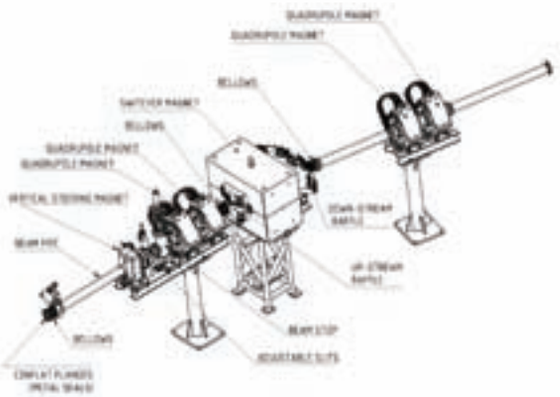
The original beamline specification of the INER TR-30/15 cyclotron had four beamlines with nine beam exit ports. Up to now, eight of the beam ports have been connected with target stations, including two solid target stations, a gas target station, four liquid target stations and an external beam station. All the beam exit ports have been occupied except one left for beamline extension. Therefore there is a need to build more beam exit ports for the future target stations.



▲ Fig. 1 The layout of beamline extension.

Beamline extension is a part of the upgrading project of third phase for the INER cyclotron, the other part of the project is to set up a high power solid target station after the beamline extension. The beamline extension is scheduled to be done by the end of 2010, with design and manufacture in 2009 and installation and test in 2010. The beamline will be extended from

the beam-port 2B4 in R&D cave(Fig. 1), with the beamline components consisting of a gate valve, a vertical steering magnet, an adjustable collimator, a beam stop, a quadruple doublet, a switching magnet with five beam ports and a pumping system (Fig. 2). One of the new-built ports is planned to connect with a high power solid target station in 2011-2012, for that reason a downstream beamline with a quadruple doublet will be built in advance. The remaining ports will be used for the new research projects in the future.



▲ Fig. 2 A schematic diagram of extended

In summary, there will be five more beam exit ports available for our cyclotron after the beamline extension. With these beam ports more target stations can be set up for new research projects. In addition, after setting up the high power solid target station for our cyclotron, the production yields of our radioisotopes will increase, and this will be good for the medical diagnostics in domestic hospitals.

3.2 The Development and Improvement of Solid Target Preparation Technology for Cyclotron Produced Radioisotope Production

◎Jenn-Tzong Chen

Solid target technology is one of the most critical technologies for cyclotron produced SPECT radioisotopes such as thallium-201, gallium-67 and indium-111. These three artificial radioisotopes are most commonly applied in clinical and preclinical studies among all the short and medium type half life radioisotopes produced from an adjustable proton energy of 30 MeV cyclotron. The aim of cyclotron produced radioisotope's project this year is to develop the solid target technology for high proton flux in the increase of the production capacity of thallium-201 and gallium-67. After one year study and development in this project, the production capacity and actual output of

thallium-201 and gallium-67 are increased from 2 Ci to 4 Ci. Maximum output of thallium-201 is 4.6 Ci, and 4.4 Ci of gallium-67.

The development of the new process of solid target material is to improve target material preparation process by developing a new technigue and related process. The combination mass of the solid target material can be increased by 50% after the preparation method and skill developed. The activity of radioisotope produced from the target technology can be highly increased by appropriate proton irradiation, and reach the quality of radiopharmaceutical labeling grade. The process has been applied in practical process, achieve the object of increasing the production capacity and quality of radioisotopes.

High quantity target material preparation technology, two units mixed separation technology and fast process volume reducing technology are developed to reduce the processing time and to increase the processing loading activity of radioisotope operation in order to attain highly advanced radioisotope production purpose. Besides, the first phase hardware fabrication of the extended external high energy proton beam has been accomplished. Future work is to construct an extended external high energy proton beam orienting, deflection and focusing system for developing new high energy proton irradiated target to produce some potential medical purpose radioisotopes.

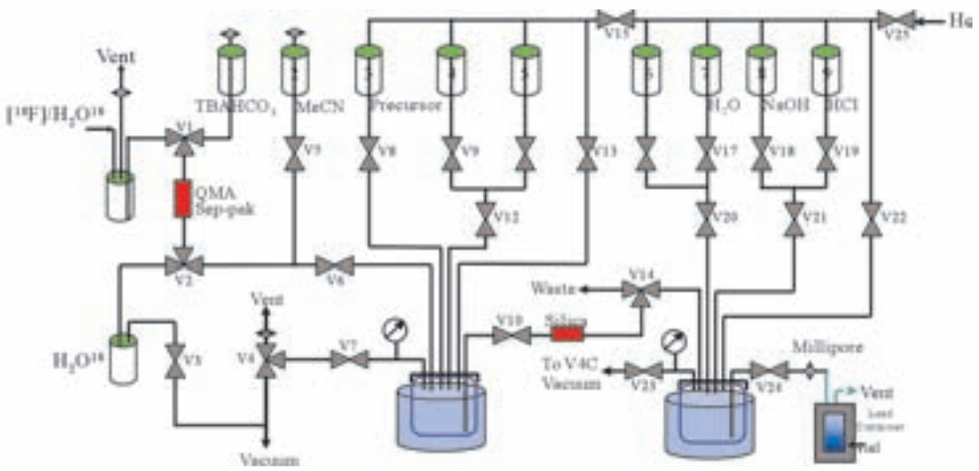
3.3 Study on Fabrication of [^{18}F] Acetate Synthesizer Module

◎Ming-Hsin Li, Ther-Jen Ting

The purpose of this study is to develop a fully automated controlled system for the synthesis of sodium [^{18}F]acetate with a compact synthesizer module. Main procedures of the process include (Fig. 1): (1) injection of [^{18}F] nuclide; (2) processing with reagents; (3) hydrolysis and evaporation; (4) neutralization; (5) separation; and (6) collection.

The advantages of this fabricated synthesizer module are illustrated as follows. Firstly, the whole processes are operated in a closed system with a liquid nitrogen trapper

used to condense the release gases of leaked radioactive material and organic solvent that can reduce the environmental radiation. Secondly, the assembly of the module is made as small as possible. Thirdly, this module is functioned with a fully automated control for synthesis of [^{18}F] acetate making the process time reduced to 20 mins.The products obtained with yield of 70% and purity of greater than 99.9% is sufficient to meet the requirements of the specifications for PET in nuclear medicine applications. Furthermore, the production can be carried out continuously for six batches. Other than the previous statements, the software designed can be used to execute the process step by step precisely under the command to be called. During the process performance, the temperature, pressure and variation of radiation dose can be monitored and recorded simultaneously to reflect the reaction situation at that time. Eventually, every recorded data are filed and reserved automatically to compliant with the regulation of GLP/GMP.



▲ Control process for [18-F] Acetate synthesis

3.4 The Performances of I-123-IBZM Multi-center Registration Trial

◎Mei-Hsiu Liao

Parkinsonism is a clinical feature characterized by a heterogeneous group of movement disorder. This type of motor disturbance is seen in several conditions that have in common neuronal degeneration to the nigrostriatal dopaminergic system. The most frequent neurodegenerative causes of parkinsonism are Parkinson's disease(PD),followed

by progressive supranuclear palsy (PSP) and multiple system atrophy (MSA). Discrimination between idiopathic Parkinson's disease (IPD) and other neurodegenerative parkinsonian syndromes (non-IPS) is important owing to the marked difference in prognosis and therapy.

I-123-IBZM, a benzamide derivative with high affinity to dopamine D2/D3 receptor, has been developed for the visualization of dopamine D2 receptors in vivo with single-photon emission computed tomography (SPECT). In order to market I-123-IBZM, Institute of Nuclear Energy Research (INER) is conducting a multi-center, phase III trial for registration purpose. The clinical trial is contracted with Virginia Contract Research Organization (VCRO). The study aims to evaluate the D2 receptor activities and safety of I-123-IBZM SPECT in the differential diagnosis of Parkinsonian syndromes. A total of 100 subjects will be included in this study, including 40 IPD, 40 non-IPD patients (25 MSA patients and 15 PSP patients) and 20 normal healthy volunteers.

The study protocol was approved by Department of Health (DOH) and Joint Institutional Review Board (JIRB) respectively. The first subject was enrolled in October. Till the end of 2008, clinical evaluation and SPECT scan were carried out in 45 subjects, including 19 patients with IPD, 8 patients with MSA, 10 patients with PSP, and 8 age-matched control subjects. Individual study sites are monitored at appropriate intervals to assure satisfactory enrollment, data recording, and adherence to the protocol. The trial is expected to be completed by the end of 2009. We anticipate this study could provide a more accurate method in differential diagnose of Parkinsonism.

3.5 Comparing the Therapeutic Effect of ^{188}Re-ECD/Lipiodol and Lipiodol in Rat Hepatoma Model

◎Tsai-Yueh Luo

Radiolabeled lipiodol has been routinely used in hepatoma therapy. Intratumor injection of therapeutic radiopharmaceutical is a potential therapeutic modality for the treatment of primary liver tumor. In this study, we compare the therapeutic effect between

the new radiopharmacutical ^{188}Re-ECD/Lipiodol and the clinical available embolization agent Lipiodol by intratumor injection in an orthotopic xenotransplantation animal model.

Male SD rats implanted with N1S1 hepatoma cell line were divided into two groups randomly. The rats in Group I (n=19) were injected with ^{188}Re-ECD/Lipiodol (0.62-1.88 mCi/0.1ml) individually to evaluate the response rate in two month follow-up. Group II (n=13) received intra-tumor injection of 0.1 ml lipiodol and served as the control group. The response rate was evaluated by the change in tumor size and survival rate.

The microSPECT/CT images showed that most of the ^{188}Re activity was retained in hepatoma at 4-hour postinjection. In the rats treated with ^{188}Re-ECD/Lipiodol showed a good response. Their survival rate achieved 78.9% and only one of the fifteen survival rats still had the hepatoma in the liver tissue at the end of 2-month observation. In lipiodol group, there were 7 rats died with ascites after treatment and its survival rate for 60 days was 46.1%.

The results of ^{188}Re-ECD/Lipiodol through direct intra-tumor injection show the synergistic therapeutic potential than lipiodol as an attractive therapeutic alternative in clinical application for hepatoma treatment.

3.6 Evaluating the Potential of ^{188}Re-SOCTA-Trastuzumab as a New Radioimmunoagent for Breast Cancer Treatment

◎Tsai-Yueh Luo

Radioimmunotherapy, which utilizes monoclonal antibody and therapeutic radioisotopes against antigen-expressing tumor tissues, is an attractive therapeutic approach for cancer therapy. Trastuzumab (Herceptin^{R}) is a humanized anti-HER-2/neu monoclonal antibody for breast cancer treatment. In this paper, we introduce a new radioimmunoagent ^{188}Re-Trastuzumab via a bifunctional ligand SOCTA, (succinimidyl 3, 6-diaza-5-oxo-3-[2-((triphenylmethyl)thio)ethyl]-8-[(triphenylmethyl)thio]octanoate), and evaluate the potential to be a therapeutic radiopharmaceutical for breast cancer treatment.

Equal mole of SOCTA and Trastuzumab was selected to react and the conjugation ratio of SOCTA-Trastuzumab was evaluated by MALDI-TOF method. The immunoreactivity of SOCTA- Trastuzumab was compared with non-conjugated Trastuzumab in HER-2/neu over-expressing human breast cancer cell BT-474. Biodistribution experiment and microSPECT/CT images of ^{188}Re-SOCTA-Trastuzumab administered intravenously in SCID mice bearing xenografted BT-474 breast cancer were investigated to evaluate the tumor targeting capability.

The covalent attachment of SOCTA to Trastuzumab (at 1:1 molar ratio) could result in the averaged conjugation ratio 0.27 0.06 (n=3). The complex could be easily labeled with ^{188}Re and achieve 95% of radiochemical purity (RCP) after one hour reaction at room temperature. The in-vitro stability study also revealed that the RCP of ^{188}Re-SOCTA-Trastuzumab could keep more than 80% after 24 hours incubation with human serum. The immunoreactivity evaluation showed that SOCTA-Trastuzumab and non-conjugated Trastuzumab had the similar binding capacity (B_{max}) to HER-2/neu receptor in BT-474 cells. The animal experiments showed that ^{188}Re-SOCTA- Trastuzumab accumulated intensively in the tumor site than in normal tissue.

We suggest that ^{188}Re-SOCTA-Trastuzumab might be a potential candidate for radioimmunotherapy.

3.7 Biodistribution and Pharmacokinetics of Transgenic Pig-produced Recombinant Human Factor IX (rhFIX) in Rats

◎Te-Wei Lee

Recombinant human factor IX (rhFIX) provided by Animal Technology Institute, is a 56 kD glycoprotein with full biological activity providing a guarantee of freedom from blood-borne viral contamination in the therapy of hemophilia B, but no data are available on the distribution of the transgenic pig-produced rhFIX post injection (p.i.) Therefore, an ^{131}I radiolabeled rhFIX was developed to evaluate the distribution of rhFIX in rats.

Materials and Methods: rhFIX was labeled with the Iodogen method. ^{131}I-rhFIX (25 μCi/25 μg/200 μl/rat) was intravenously injected through the tail vein in normal Sprague-Dawley (SD) rats and the biodistribution was examined from 5 min to 72 h p.i.. The pharmacokinetics were also evaluated from 5 min to 96 h p.i.. Results: The radiolabeled efficiency and radiochemical purity of ^{131}I-rhFIX was over 96% and 98%, respectively. The biodistribution study showed that the rhFIX chiefly accumulated in the liver. The distribution and elimination half-life ($t_{1/2\alpha}$ and $t_{1/2\beta}$) of ^{131}I-rhFIX were 0.82 and 9.34 h, respectively. The maximum concentration in the plasma (Cmax) and the area under the concentration versus time curve (AUC_{INF}) of ^{131}I-rhFIX in rats were 3.09 % injected dose (ID)/g and 15.3 hx%ID/g. Conclusion: The transgenic pig-produced rhFIX is mostly retained in the liver and the preclinical biodistribution and pharmacokinetic studies of ^{131}I radiolabeled rhFIX are helpful for researching its biological effect in vivo.

Parameter	Unit	Value
A	(%ID/ml)	2.10±0.26
B	(%ID/ml)	0.99±0.09
α	(h^{-1})	0.96±0.18
β	(h^{-1})	0.08±0.01
$t_{1/2\alpha}$	(h)	0.82±0.13
$t_{1/2\beta}$	(h)	9.34±0.96
MRT	(h)	9.08±1.16
K_{10}	(h^{-1})	0.20±0.02
K_{12}	(h^{-1})	0.47±0.11
K_{21}	(h^{-1})	0.36±0.06
V_1	(ml)	33.85±3.42
C_{max}	(%ID/g)	3.09±0.33
AUC_{INF}	(hx%ID/g)	15.30±1.17

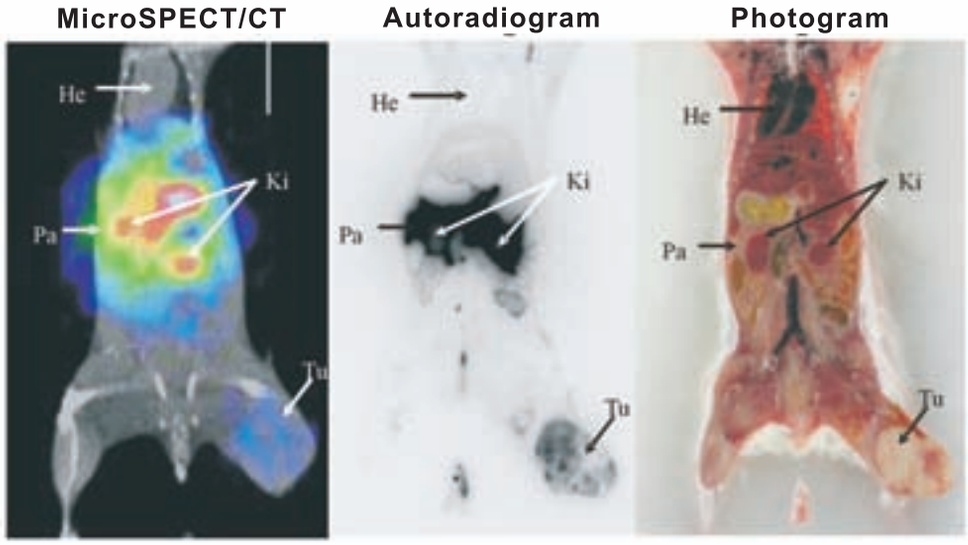
A, B, α, β : macro rate constants; $t_{1/2\alpha}$, $t_{1/2\beta}$: distribution and elimination half-life, respectively; MRT: mean residence time; K_{10}, K_{12}, K_{21}: micro rate constants; V_1: apparent volume of the central compartment; C_{max}: maximum concentration in plasma; AUC_{INF}: area under concentration of ^{131}I-rhFIX versus time curve.

▲ Pharmacokinetic parameter estimates from radioactivity in plasma after intravenous injection of ^{131}I-rhFIX (25 g/rat) in rats (Each value represents meanSEM of 5 rats).

3.8 Receptor-binding, Biodistribution, Dosimetry and micro-SPECT/CT Imaging of ^{111}In-DTPA-[Lys^3, Tyr^4]-BN in Human Prostate Tumor-bearing Mice

◎Chih-Hsien Chang

Gastrin-releasing peptide receptors (GRPR) are overexpressed on a variety of human tumors like prostate, breast, and lung cancer. Bombesin (BN) is a 14 amino acid peptide with high affinity for these GRPRs. We synthesized DTPA-Q-K-Y-G-N-Q-W-A-V-G-H-L-M, a 13 amino acid peptide chelated with diethylenetriaminepentaacetic acid (DTPA), and radiolabeled this BN analogue with $^{111}InCl_3$. The purity of synthesized DTPA-[Lys^3, Tyr^4]-BN was greater than 95%. The radiochemical purity of ^{111}In-DTPA-[Lys^3, Tyr^4]-BN was 98.0±0.43%. The IC_{50} and Ki of DTPA-[Lys^3, Tyr^4]-BN were 1.05± 0.46 nM and 0.83±0.36 nM, respectively. The Kd and Bmax of ^{111}In-DTPA-BN were 22.9±6.81 nM and 880±420 fmole/10^6 cells, respectively in GRPR-expressing PC-3 tumor cells. Both biodistribution and micro-SPECT/CT imaging studies with ^{111}In-DTPA-[Lys^3, Tyr^4]-BN demonstrated the highest uptake at 8 h postinjection. The Pearson correlation analysis showed a positive correlation of tumor uptake between biodistribution and micro-SPECT/CT semi-quantification imaging analysis (r=0.832). Our result revealed ^{111}In-DTPA-[Lys^3, Tyr^4]-BN has high affinity with BN type 2 receptor (Fig.).



▲ Fig. Coronal micro-SPECT/CT image correlated with whole-body autoradiography (WBAR) in mice. Micro-SPECT/CT imaging was performed at 48 h after i.v. injection of 10 MBq/0.1 μg ^{111}In- DTPA-[Lys^3, Tyr^4]-BN and scanned for 120 min. The mouse was anesthetized with 1.5% isoflurance and positioned prone in the scanner. The mouse was i.v. inoculated PC-3 prostate cancer cells after one month. The autoradiogram and anatomic photogram of the section were performed immediately after micro-SPECT/CT imaging. Tumor nodules are indicated by red arrow (He: heart; Ki: Kidney; Pa: pancreas; Tu: tumor).

The results demonstrated a good uptake in the GRPR-over expression PC-3 tumor-bearing SCID mice. ^{111}In-DTPA-[Lys^{3}, Tyr^{4}]-BN is a potential agent for imaging GRPR-positive tumors in humans.

3.9 Discovery of Serum Biomarkers for Liver Fibrosis Detection by Two-Dimension Difference Gel Electrophoresis (2D-DIGE)

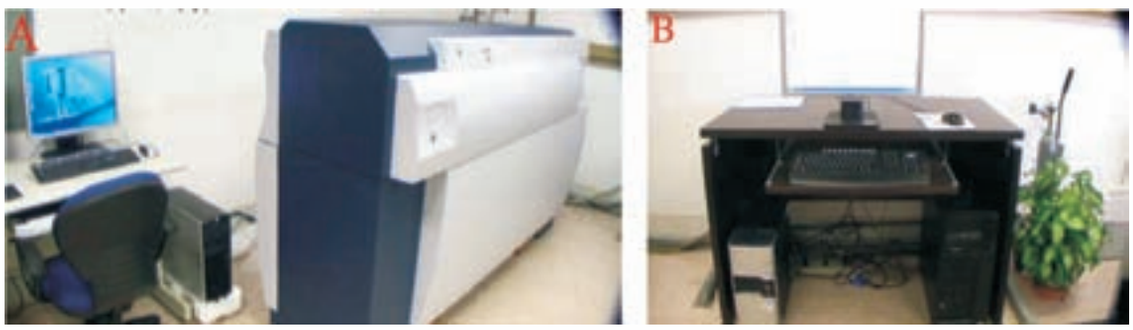
◎Shui-Cheng Lee

Liver biopsy is still the gold standard for assessing the hepatic fibrosis in hospital, but it is not accepted by many people because of the invasive character and sampling error. Therefore the serological biomarkers would be the better solution to detect liver fibrosis exclusively.

In the past year, we totally collected 25 healthy serum controls and 12 liver fibrosis samples from HCV infected patients, and the samples were discriminated into five stages according to the METAVIR classification. The proteomics method based on 2D-DIGE was used to find potential liver fibrosis biomarkers. The triple samples of 5 fibrosis stages were labeled with 3 fluorescent cy-dyes (Cy2, Cy3 and Cy5) and separated in 8 gels totally. The gels were scanned with Typhoon Trio scanner (GE Healthcare) and the images were analyzed to find out the potential candidates. The putative biomarkers were picked up by hand on UV transilluminator under SYPRO Ruby staining. After tryptic digestion the Matrix Assisted Laser Desorption ionization-Time of Flight Tandom Mass Spectrometer (MALDI-TOF/TOF) was used to do the peptide mass fingerprinting and protein identification by comparing the peptide mass data with MASCOT software.

Technical platform

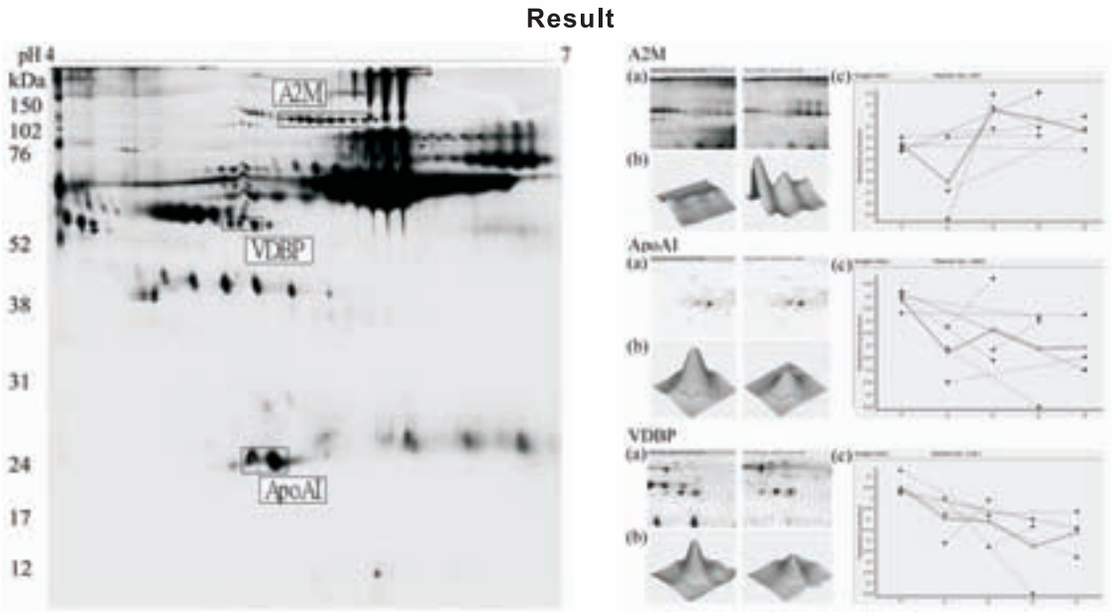
▲ (A) Sample freezer; (B) The instruments of Two-Dimension Difference Gel Electrophoresis (2D-DIGE), including 1D-IEF, 2D-SDS-PAGE and Typhoon Trio scanner.



▲ (A) MALDI-TOF/TOF instrument; (B) MASCOT station for protein identification.

Three prominent putative biomarkers were identified and their differential expressions were measured as below: Alpha 2 macroglobulin (P=0.021) was up regulated in hepatic fibrosis serum whereas Vitamin D binding protein (P=0.020) and apolipoprotein AI (P=0.027) were down regulated.

In the findings, the hepatic fibrosis biomarkers were available after being evaluated in larger patient population with ELISA or Western Blotting. Thus the combination of these novel biomarkers could assess hepatic scarring and decrease the need of liver biopsy.



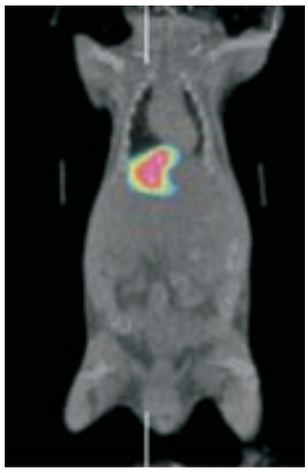
▲ (Left) One of the 2D-PAGE images. (Right) The protein expression trend of 3 putative biomarkers. Four panel of each data presented gel spots, 3D view, expression trend. (1) Alpha 2 macroglobulin (P=0.021), (2) Vitamin D binding protein (P=0.020) and (3) apolipoprotein AI (P=0.027).

3.10 Preparation and Preliminary Study of In-111-galactopeptide

◎Mei-Hui Wang

Currently, quantitative measurement of residual liver function is not a routine clinical test. ICG (Indocyanine green) clearance was used to estimate liver functions, but may increase the burden of the liver which already suffered from a certain degree of damage. Furthermore, it can not be used to distinguish between intrahepatic and extrahepatic cholestasis. The primary liver function is to remove toxins from the body through metabolism and excretion, and to synthesize biologically active substances such as clotting factors and albumin. Impairement of liver function as a result of hepatitis, infections, jaundice, cirrhosis, or cancer can lead to a variety of gastrointestinal disorders. The evaluation of hepatic function is an important parameter in the determination of the physiological state of the liver, particularly for patients who have been diagnosed with liver disease and are waiting for the treatment of a hepatectomy or liver transplantation or supporting therapy. Therefore, determination of the hepatic function is now considered important before and after a hepatectomy or liver transplantation to predict patient outcome. The asialoglycoprotein receptors (ASGPR)

exist specifically on hepatic cell membrane and are believed to be necessary for intracellular trafficking and endocytic activity in the liver. The number of ASGPR on the hepatocytes of individuals with liver disease is altered and is thus considered a good indicator for the evaluation of liver function. Multivalent galactose or lactose containing compounds are frequently used for targeted delivery of drugs and genetic materials to liver, which is an ASGPR ligand that accumulates specifically in the liver and suitable to determine hepatocyte function.



▲ SPECT imaging of Hepatic receptor Agent in INER

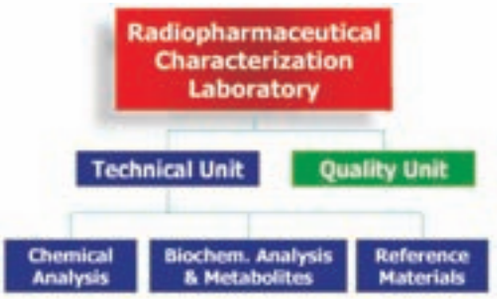
In this year, we develop an universal peptide scafford (Z-DCM-Lys, ε -benzyloxycarbobyl-α-dicarboxylmethyl-L-lysine) for G-ah-GalNAc [Glycyl-aminohexyl-β -GalNAc] and its DTPA derivative. The molecular weight recharacterized by Ultraflex III is 1340.967 and 1715.868, respectively. It almost equals to the calculated molecular weight. 30uCi In-111 was reacted with 2ug/mL DTPA-Z-DCM-Lys(G-ah-GalNAc)$_3$ in 0.1M citric acid (pH2.1) for 30min. The labeling efficiency is almost 100% lasting for 72hr. We use the Micro-SPECT/CT image to check and confirm the target sites. The SPECT/CT image shows radioactivity is almost concentrated in liver only.

3.11 Nowadays and Vision of RadiopharmaceuticalCharacterization Laboratory in 2008

◎Kung-Tien Liu

In 2008, Radiopharmaceutical Characterization Laboratory (RPCL) was reorganized as two independent parts (Fig. 1) based on the regulations and spirit of drug analysis of international regulatory authorities, such as US Food and Drug Administration (FDA), US Pharmacopeia (USP), and International Conference on Harmonization (ICH). The first part, technical unit, is charged to provide methods R&D and documentation for chemical analysis of API, process-related impurities (PRIs) and

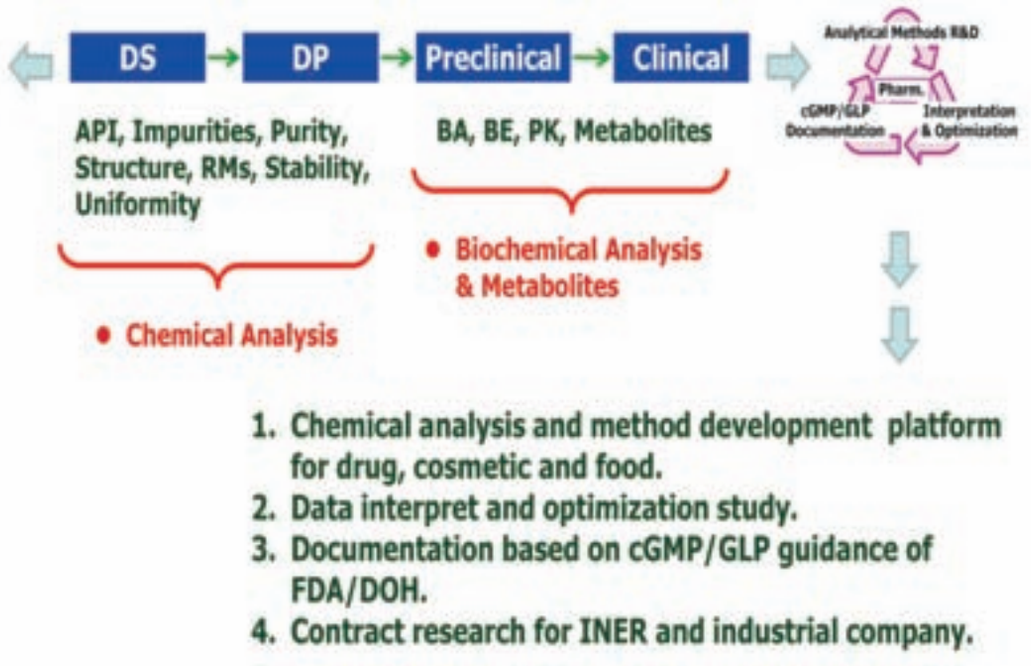
degradation-related impurities (DRIs), biochemical analysis of metabolites as well as certificates of analysis (COA) of reference materials (RMs) (Fig. 2). The second part, quality assurance unit (QAU), is responsible to the traceability and integrity of analytical processes and results.



▲ Fig. 1. Organization of RPCL.

Four analytical core techniques (Fig. 2) for drug discovery and development (DD&D) were kept engaging in RPCL, i.e.

1. Active pharmaceutical ingredient (API) & imputies assay of BZM and Sn-ADAM
2. Metabolite identification of I-123-ADAM
3. Au-Nanoparticle for high through-put screening
4. Computer simulation for pharmacophore modeling and drug design



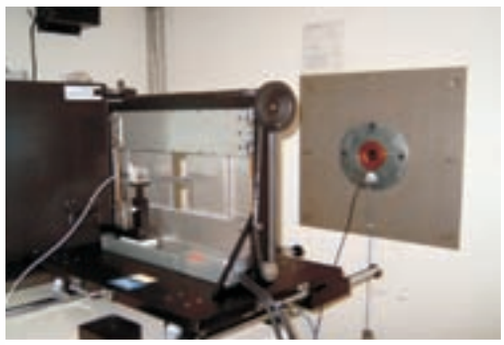
▲ Fig. 2. Development vision of RPCL

In the past year, we accomplished the purity and structure determination methods of Sn-ADAM, BZM, ECD, and SMPY. We also accomplished the RM COA reports of BZM, I-127-IBZM, Sn-ADAM, and I-127-ADAM. At present, primary studies are concentrated on the topics of uniformity and degradation analysis of ethyl cysteinate dimer (ECD) cold kit, bioanalysis of metabolites of I-123-ADAM, structure determination of polysaccharide, functional group modification and analysis of Au-nano particle, and binding models analysis between the Aβ imaging agents and Aβ protofibrils.

3.12 Establishment of Computed Tomography (CT) Dosimetry Standard for Radiation Diagnosis

◎Chien-Hau Chu

Computed tomography (CT) scans are widely used in medical diagnosis but the patient could possibly receive higher radiation doses; the potential radiation dose risks are high. For example, the effective dose of a chest CT (eq. 5 mSv) is nearly 100 times the effective dose from a frontal and lateral chest radiographic series (0.06 mSv) for an adult. Hence, dose assessment and risk evaluation are vital for CT scans of patients.



▲ Computed tomography dosimetry calibration standard

Pencil ionization chambers are employed for the direct determination of CT dose index, which is used for patient dosimetry in CT examinations. The chambers are calibrated in air kerma length in a reference X-ray field. In 2007, the Institute of Nuclear Energy Research (INER) established the national level CT dosimetry calibration standard in Taiwan. The techniques used in the establishment of the standard were in the same pace with the world-class laboratories of Europe and the USA adopting the length calibration technique recommended by the IEC 64674. The standard was verified through the comparison with the National Institute of Standards and Technology, NIST/USA. It was put to service starting 2009 providing domestic hospitals with calibrations of CT

dosimetry standards. Through the traceability of this measurement standard, the CT scanner's adjustment would be improved and people's radiation safety would be secured during radiation diagnosis.

According to statistics, there were 406 CT scanners in Taiwan areas in 2007, meaning 17.4 scanners for every million population. It showed that the CT scanners have been commonly used here as diagnostic instruments. Since the Atomic Energy Council (AEC) enacting the Standards for Medical Exposure Quality Assurance in 2005 till 2008, radiation treatment instruments and materials have been all included in the QA programs. And the CT scanners were planned to be covered under the whole QA program aiming to promote radiation medical quality, reduce unnecessary medical exposure of patient in the hope to have doses as low as reasonable when creating good diagnostic images.

3.13 Establishment of Calibration Standard and Measurement Comparison Technology for Brachytherapy Sources

◎Jeng-Hung Lee

Brachytherapy is a means of radiation therapy which is performed by placing radioactive sources in the body as nearest to the tumor. For cervical cancer and nasopharyngeal cancer, we usually perform external large-area irradiation using linear accelerators or Co-60 sources to reduce the tumor size. Notice worthy is that doses at the tumor would be increased with in-vivo brachytherapy after the external irradiation; these two steps together could avoid radiation damages for normal tissues and enhance treatment effects.

The remote afterloaders for Ir-192 brachytherapy are widely used in domestic hospitals. Since the half-life of Ir-192 source is only about 73.8 days, hospitals have to replace the Ir-192 sources every 3-4 months to meet the high dose rate (HDR) requirement. Though the HDR Ir-192 source could shorten the treatment time and minimize the discomfort of patient, it should be precisely measured for strength to avoid clinical unrecoverable incidents. According to the "Standards for Medical Exposure

Quality Assurance" enacted on July 1 2005 by the Atomic Energy Council (AEC), the measurements of brachytherapy sources strength are one of the important quality assurance items, the hospital should perform calibration and traceability for the source when replacing the brachytherapy source.

Usually, the Ir-192 source would produce more than 100 different photon radiations in the process of decay and electron capture. The photon spectra are so complicated that the strength measurement of the source would be hard. To fulfill the requirements of radiation protection and control of the competent authority, the Institute of Nuclear Energy Research (INER) fabricated the double spherical ionization chambers as the Ir-192 brachytherapy source calibration standard (Fig. 1) to provide hospitals with calibration services for their well type chambers which are to measure the Ir-192 sources strength. INER's Ir-192 brachytherpay source calibration standard was compared with that of the PTB/Germany and the measurement difference between the two laboratories was less than the measurement uncertainty. It showed that the comparison results and measurement capabilities of INER and PTB were in good agreement. Also, INER designed a set of portable brachytherapy source measuring device (Fig. 2) and worked with 20 domestic hospitals organizing Ir-192 brachytherapy source measurement activities exploring the impact from brachytherapy equipments, source types and measuring instruments towards source measurements. With the activities, we can recognize the delivery of measurement standards and truly carry out the regulations.

▲ Fig. 1. Brachytherapy source calibration standard system

▲ Fig. 2. Portable brachytherapy source measuring device

According to 2006 statistics of the Department of Health (DOH), about 6700 brachytherapy treatments were made annually and that meant the National Health Insurance program paid 27 million NT dollars annually for related treatments. Regarding the results of this research, we would establish the domestic brachytherapy dosimetry calibration and traceability system to carry out brachytherapy quality assurance programs, satisfy regulations, effectively promote medical quality and make the premium that has been spent by government concretely worth of it.

3.14 Measurement Standard Establishment for ^{123}I Radiopharmaceuticals at INER

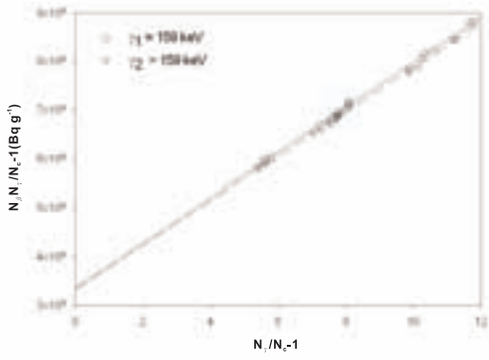
◎Ming-Chen Yuan

^{123}I radionuclides are commonly used in nuclear medical diagnosis. Radiopharmaceuticals such as ^{123}I-Nal, ^{123}I-IBZM, ^{123}I-MIBG and ^{123}I-ADAM have been used in diagnosis for thyroid and nervous system functions. In Taiwan, the Institute of Nuclear Energy Research (INER) has been able to produce and sell ^{123}I-Nal. As to ^{123}I-IBZM and ^{123}I-MIBG, INER has accomplished the preliminary research work or clinical tests. This research aimed to establish the ^{123}I radioactivity measurement standard and moreover, to provide related calibration services.

This research established the 4β-γ coincidence counting system to perform primary standard measurements for ^{123}I radioactivity (Fig. 1). This system was comprised of 4β detectors, gamma detectors and coincidence circuits. Assuming N_β for the detector, N_γ for the gamma detector, N_c for the counting rate of coincidence circuits, then the relations among them would be as the following equation according to the ^{123}I decay structure:

$$\frac{N_\beta N_\gamma}{N_c} = N_0[1+(1-K)(\frac{N_\gamma}{N_c}-1)]$$

This equation is called efficiency equation where N_c/N_γ is the detection efficiency of the detector. K is a constant under ideal experimental conditions. If we could get the efficiency equation through an experimental method, the absolute radioactivity of the radioactive source would be determined when N_c/N_γ is extrapolated to 100% (Fig.1). In this research work, the measurement uncertainty was assessed as 1.3%(K=1) which was about the same values of other standard laboratories(Fig.2). This measurement standard would be transmitted to the 4γ ionization chamber of the National Radiation Standard Laboratory (NRSL) and thus be the basis for radioactivity calibration services which are provided to domestic hospitals to improve the accuracy of the radiopharmaceuticals which are injected into the patients.



▲ Fig. 1 Efficiency curve of ^{123}I in 4$\pi\beta$-γ system

Laboratory	Standard Uncertainty(%)
IRMM/European Union	0.61
PTB/Germany	1.1
IRA/Switzerland	0.48
BNM-LNHB/France	0.4
SCK-CEN/Belgium	0.39
NIRH/Denmark	1.5
NPL/UK	0.37
INER/Taiwan	1.3

▲ Fig. 2 Standard measurement uncertainties of variousNMIs (national metrology institute) for I-123 radioactivity

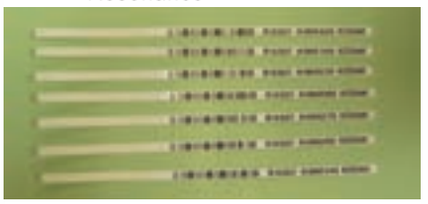
3.15 Establishment of High Dose Measurement System

◎Chun-Liang Chen

Dosimetry is the important part of the radiation processing industry, where high dose and dose-rate have to be measured with reasonable accuracy and can be traceable to the national standard. In 1985, IAEA has established Alanine/EPR (Electron Paramagnetic Resonance) dosimetry to evaluate the accuracy of high dose evaluation laboratories of IAEA members. The alanine had been used as a transfer standard by the USA, Japan, Australia and so on.

▲ Fig 1: Electron Paramagnetic Resonance

The national laboratory of INER used a benchtop EPR spectrometer (Fig. 1) dedicated to the evaluation of absorbed dose in alanine dosimeters (Fig. 2). With appropriate accessories, the e-scan measures high level absorbed dose. The e-scan alanine system is equally suited for use in electron beam, X-ray, or gamma irradiation facilities.



▲ Fig 2: Alanine dosimeters

This system can provide calibration program to high dose irradiations and research of radiation dosimetry. Irradiation factories use alanine dosimeters and radiochromic films to conform with the requirement of ISO, FDA, GMP and CEN standards.

Benefits of this standard :

(1)To provide standard of high dose of radiation, validation the irradiation factories can conform with international standard criteria, to avoid international trade barrier.

(2)To disseminate technical service of blood irradiation dose evaluation, and to setup quality criteria at hospital, secure the patient's safety against Graft Versus Host Disease(GVHD).

(3)To development of irradiator program and dose evaluation of biomaterial, polymer and electronic material, is able to promote industry and economy value of productions.

3.16 Development of Molecular Imaging Technology

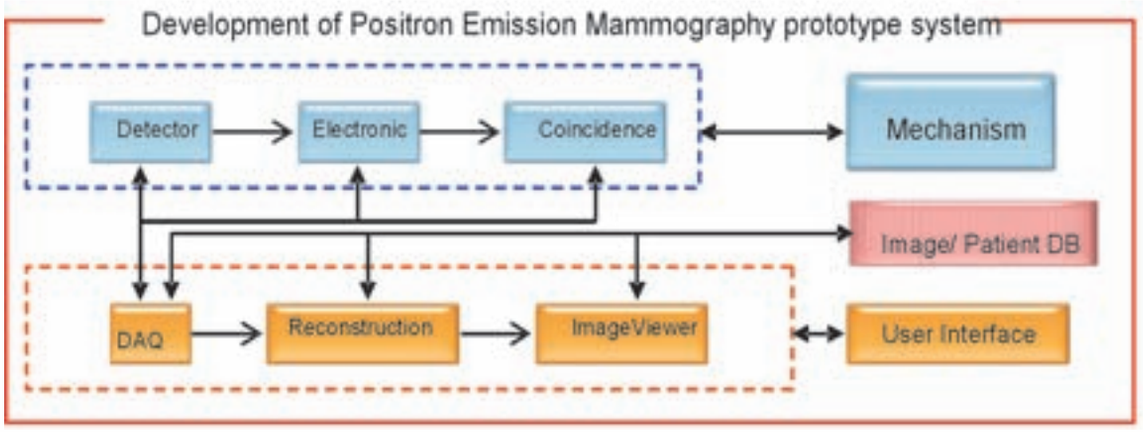
◎Meei-Ling Jan

According to the data from the Department of Health in Taiwan, breast cancer has the highest incidence and fourth highest mortality of cancer among women in Taiwan. Compared to women in the west, the age of incidence is ten years earlier and the rate is increasing at about 17.8% for eastern women. The current standard detection method is through X-ray mammography, but its PPV (positive predictive value) is only about 15-30% for eastern women, who have denser breasts compared to their western counterpart. However, molecular imaging technologies such as Positron Emission Tomography do not have such limitation. Its sensitivity and specificity are about 84-96% and 85-100%, respectively, making it suitable for early detection of breast cancer and evaluation of therapeutic result.

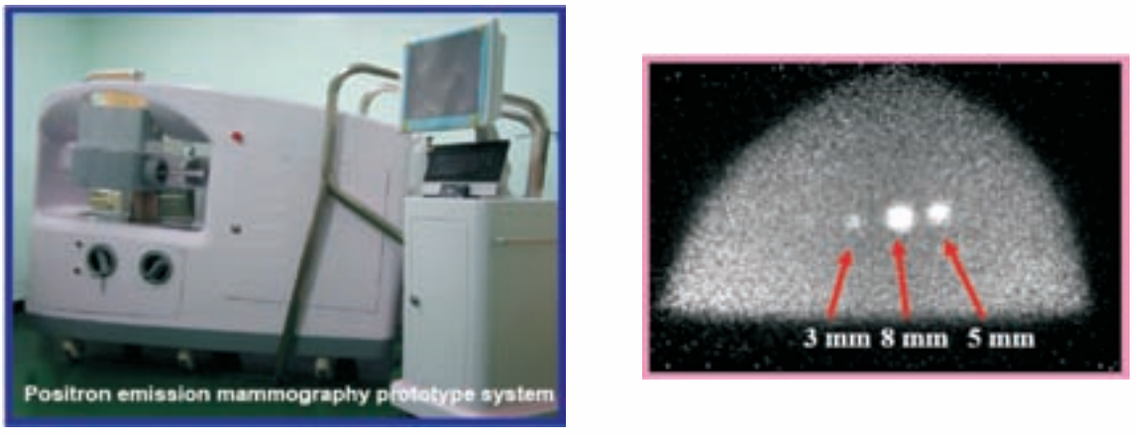
With the financial support from the Department of Industrial Technology under the Ministry of Economic Affairs (MOEA) in Taiwan, the INER medical equipment R&D team had finished the development of imaging hardware/software technologies along with the development of Positron Emission Mammography system within two years. Some of the key technologies include (a) the algorithms for the reconstruction and optimization of images taken from planar tomography, which is ten times faster than existing methods and is pending patent; (b) using material with adjustable tension to move the detector head closer to patients' breasts in order to increase effective detection area, also pending patent; (c) building large area detector head (19.7x9.8 cm^2) by using the low cost PMT-quadrant-sharing method through collaboration with M.D. Anderson Cancer Center in University of Texas; (d) the integration of image reconstruction, display, and analysis software with control and acquisition hardware, thereby increasing usability.

The finished Positron Emission Mammography prototype provides several benefits: two modes of operation (standard breast detection mode and axillary detection

mode), low manufacturing cost, large detection area (up to at least E cup), short imaging time, etc. It has high sensitivity, therefore able to provide information on whether the cancer had metastasized. The prototype is not affected by dense breasts (eastern women), offering better breast cancer detection rate and product competitiveness. Developed solely by Taiwanese, the accomplishment of the medical imaging system represents the opportunity for domestic industries to become highly skilled and highly profitable. Combined with nuclear medicine, this could pave the way for Taiwan to enter into high-end biological and medical industries.



▲ Hardware/Software developed for Molecular breast image system.



▲ Positron emission mammography prototype system and its breast phantom image (F-18-FDG, without any correction).

4. Renewable and New Energy Technology

◎Ying-Sheng Lee

To comply with the energy policy of the government, the Institute of Nuclear Energy Research (INER) in Taiwan has initiated an integrated program, consisting of several projects, to develop renewable and new energy technology. The goal of the program is to develop, deliver, or promote clean and energy efficient technology, as well as to fulfill the national requirements on improvement of energy security and reduction of carbon dioxide emission. The projects in the program are: development of high concentration photovoltaic (HCPV) systems, R&D of the epitaxial silicon solar cell, development of small/medium size wind turbine systems and wind energy assessment and forecasting technology, establishment of a pilot plant for cellulosic ethanol production, development of SOFC and DMFC technology, storage of hydrogen in nano carbon materials, development of renewable energy power control and management technology, and energy model studies. Much effort and substantial progress have been made for each project in 2008. High efficiency multi-junction solar cells, with a conversion efficiency of 35.8%, have been fabricated in cooperation with the domestic manufacturers. The maximum module efficiency for the HCPV systems is about 27%. For epitaxial silicon solar cell, the energy conversion efficiency of the epi-Si/UMG-Si solar cell with 10x10 mm^2 in area is 7.5% under the AM1.5 illumination. In the development of small/medium size wind turbine systems, a 25 kW WT design certification program through an eminent international certification body is currently being conducted. Technologies such as WT blade manufacturing processes and WT system integration design are ready for transfer to the industry. INER is also the first organization in East Asia area with staff passing the WAsP certification examination held in Risoe National Laboratory of Denmark. A pilot plant for cellulosic ethanol production with a feedstock capacity of one ton dry biomass per day is under construction which is designed based on the process of Separate Hydrolysis and Fermentation (SHF). In the study of hydrogen in nano carbon materials, a hydrogen storage capacity of 11.8 wt% at room temperature and 6.9 MPa hydrogen pressure has been observed for microporous activated carbon (AC) impregnated with platinum nanoparticles inside the nanopore channels. For SOFC development, the manufacturing technology through the tape casting-spin coating-screen printing process for ASC type MEA was established for mass production and technology transfer. A 1 kW SOFC power generating

system was also constructed and validated through long-term test. A direct methanol fuel cell (DMFC) system is integrated for use as a power source for E-Bike. A prototype of 50 W DMFC was successfully demonstrated in 2008 Taiwan Nano Symposium. To make efficient use of renewable and new energy, INER has also built a demonstrative DC house and a high-efficiency 5-kW SOFC power conditioning system in 2008. In addition, MARKAL-MACRO, an integrated model of energy technology and macro-economy, was established since 2007. The expert review of relevant analysis in BAU (Business As Usual) and electricity sector were finished and the results have been published in international conferences, such as IAEE.

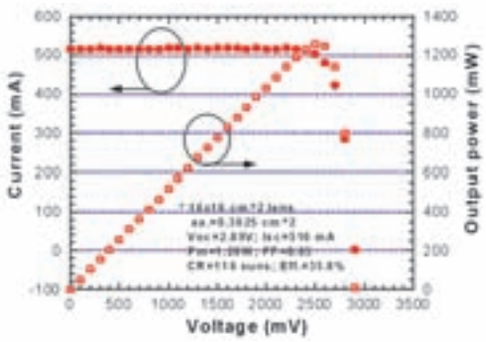
4.1 Development of High Concentration Photovoltaic (HCPV) Systems

◎I-Tao Lung, Cherng-Tsong Kuo

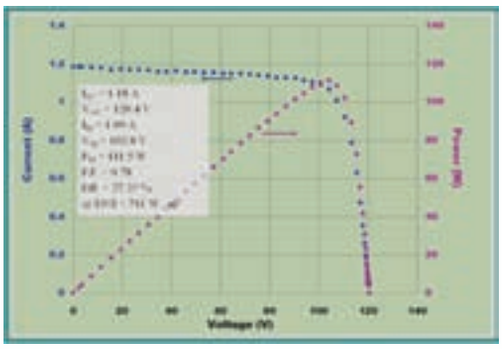
The R&D achievements of HCPV systems in 2008 covered high-efficiency III-V solar cells, Fresnel lens, concentrating solar module, solar tracker, electric power control system, and central control system. They are: (1) The high-efficiency multi-junction solar cells, with a conversion efficiency of 35.8%, have been fabricated in cooperation with the domestic manufacturers (2) Under 850 W/m^2 DNI and passive cooling condition, the maximum module efficiency is about 27% with a geometrical concentration ratio of 476x by using Spectrolab's cells with an average conversion efficiency of 37%. (3) Advanced sun positioning sensor and controller with innovative control algorithms and mechanism are developed for better tracking (≦ 0.3 degree). (4) A 7.5 kW HCPV array was successfully demonstrated. (5) The establishment of the High Concentration Photovoltaic Qualification and Development Center at Kaohsiung Science Park was set off for promoting HCPV technology in the southern part of Taiwan. As of the end of 2008, 94 HCPV related patents are applied worldwide, and 21 granted. Nine technical transfers and three technical services are completed. Besides, INER has signed non-disclosure agreements (NDA) with 29 domestic companies so as to build up the foundation for the local PV industry.

According to the assessment of Sharp Corporation of Japan, more than half of the future PV market may be occupied by emerging techniques including HCPV, in owing to that the market for traditional single and multi-crystalline Si solar cells in close to saturation. It is hopeful that a domestic HCPV industry can be created in Taiwan through our R&D efforts in INER.

▲ Improved Sun Positioning Sensor



▲ Conversion Efficiency of Solar Cell Cooperated with Domestic Manufacturer is Upgraded to 35.8%(116 suns)



▲ I-V&P-V Curves of a HCPV Module

4.2 R&D of the Epitaxial Silicon Solar Cell

◎Tsun-Neng Yang

The objective of this project is to develop epi-Si/UMG-Si solar cells with energy conversion efficiency >10%. The main working items include: (1) developing a process for growth of the epitaxial silicon thin film, and (2) establishing the processes for an epi-Si/UMG-Si solar cell device.

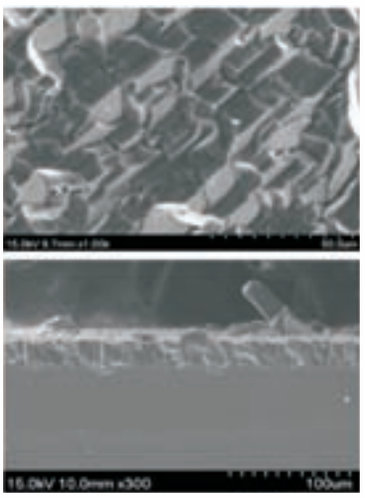
In the epitaxial silicon growth experiments, a thickness of ~ 20 - 30 μ m p-type epitaxial silicon layer is successfully grown on the upgraded metallurgical silicon substrate, which is 40x40 mm^2 in area and 210 m in thickness, in a home-made APCVD system with SiH_2Cl_2 as reaction source. The boron doping concentration and silicon deposition rate of the epitaxial silicon layer are ~1.5 - 6x10^{17} cm^{-3} and ~ 0.67 - 1 μ m/min, respectively.

In the solar cell processes, we have established the technical abilities for making n-type diffusion layers, SiNx anti-reflection coating, metal contacts, etc. The solar cell processes are certificated by using the single-crystal, multi-crystal, and upgraded metallurgical silicon wafer based solar cells, the energy conversion efficiencies of which are 15.91%, 14.87%, and 12.01%, respectively. Furthermore, the best energy conversion efficiency of the epi-Si/c-Si solar cell is 12.26%. At present the energy conversion efficiency of the epi-Si/UMG-Si solar cell with 10x10 mm^2 in area is 7.5% under the AM1.5 illumination. The characteristic parameters such as V_{oc}, I_{sc}, and FF are 0.53 V, 21.2 mA/cm^2, and 0.67, respectively.

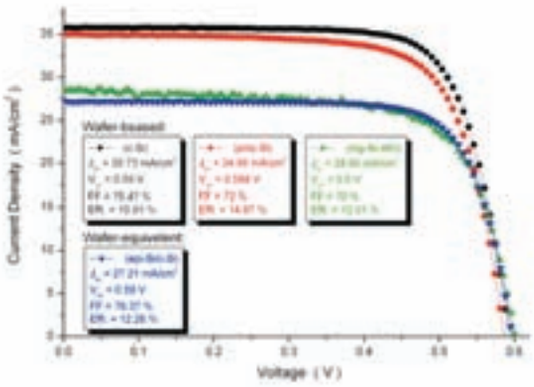
The motivation and purpose of the project is to develop a low-cost, high-efficiency, and high-stability epi-Si/UMG-Si solar cell. Utilizing the advantages of the low cost of the thin film solar cell process as well as the upgraded metallurgical silicon material, the cost of module is estimated to have the potential to lie in the range of 0.9 - 1 USD/W_p. Upgraded metallurgical silicon materials have no feedstock supply shortage problem and have the similarity to the traditional silicon technology. Therefore, it is an attractive alternative for the bulk silicon solar cell in the future.

Technology transfer would be expected after this project is completed, so as to promote the next generation solar cell industry.

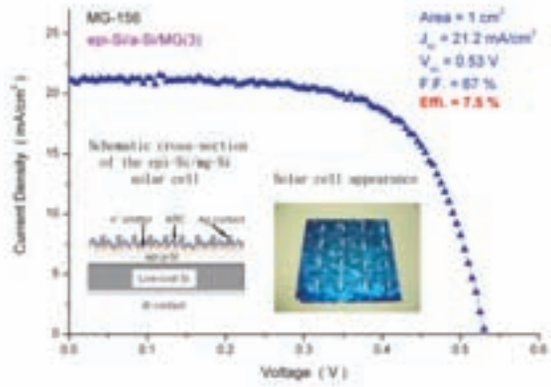
▲ Fig.1 APCVD system



▲ Fig.2 SEM top and cross-section views of the epitaxial Si layer



▲ Fig.3 I-V curves of different types of wafer-based solar cells and epi-Si/c-Si solar cell.



▲ Fig.4 I-V curve of the epi-Si/MG-Si solar cell.

4.3 Development of Small/Medium Size Wind Turbine System at INER

◎Chin-Jen Chang

This technology development is under the funding support from Science Foundation of Executive Yuan. INER has achieved four major accomplishments during 2008. They included (1) the technology establishment of wind turbine (WT) design compliance with IEC-61400-1 and IEC-61400-2 international standards, (2) system load analyses and mechanical designs of INER 150 kW WT, (3) the design and fabrication of 25 kW and 150kW PM generators and grid-tie inverters, and (4) the design of 25 kW and 150 kW WT control and monitoring systems and their control logics.

The target of this development is to establish a solid technology basis through step by step and from small to medium size WT R&D processes. The goal is to develop a hundred kilo-watt class WT and, moreover, is expected to help establish a firm domestic system design technology and to promote an early market for homemade small/medium size WTs. In 2008, we were the first in our country to perform a 25 kW WT design certification program through an eminent international certification body. Items of certification covered aerodynamic / blade design and analyses, system design safety, system load

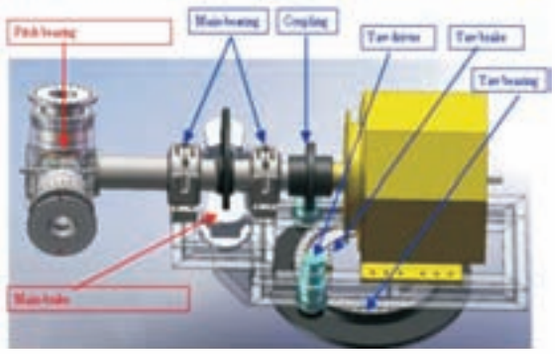
envelop analyses, system mechanical design and analyses, the electric system design, and the tower design and analyses. To suffice the target of more than 90% of local contents in our WT, we have been integrating with local industrials to develop 25 kW and 150 kW WT key components such as blades, PM generators, grid-tie inverters, and WT main frame castings. In addition, we had announced technologies such as WT blade manufacturing processes and WT system integration design technologies for technical transferring. A total of three technical transfer cases to local industrials were occurred in 2008. The development of control systems and comprehensive control logics to simulate the like of a large size WT was another important achievement during the year. The control and operation logic were integrated with the system load envelop considerations to fulfill the effectiveness of WT operations.

The WT R&D at INER has evolved into a team with expertise of aerodynamic design, blade design and fabrication, mechanical design and assembly, and electric system design. Tools used by the team comprise several three-dimensional high-level CAD and CAE software and the associated fluid dynamic computing programs. The team has also developed an automatic WT blade design computer package, power electronic design tools, and WT control and monitoring drivers' software development tools. In the long run, the WTs established at INER is expected to integrate with HCPV and various renewable sources to form an energy park with smart grid technologies to facilitate the best application of renewable energies.

▲ INER 25 kW active control WT and its control interface

▲ The 150 kW PM generator and the grid-tie inverter

▲ The manufacturing process and the extreme load test of 150 kW WT blade



▲ The inside view of INER 150 kW direct-drive WT design

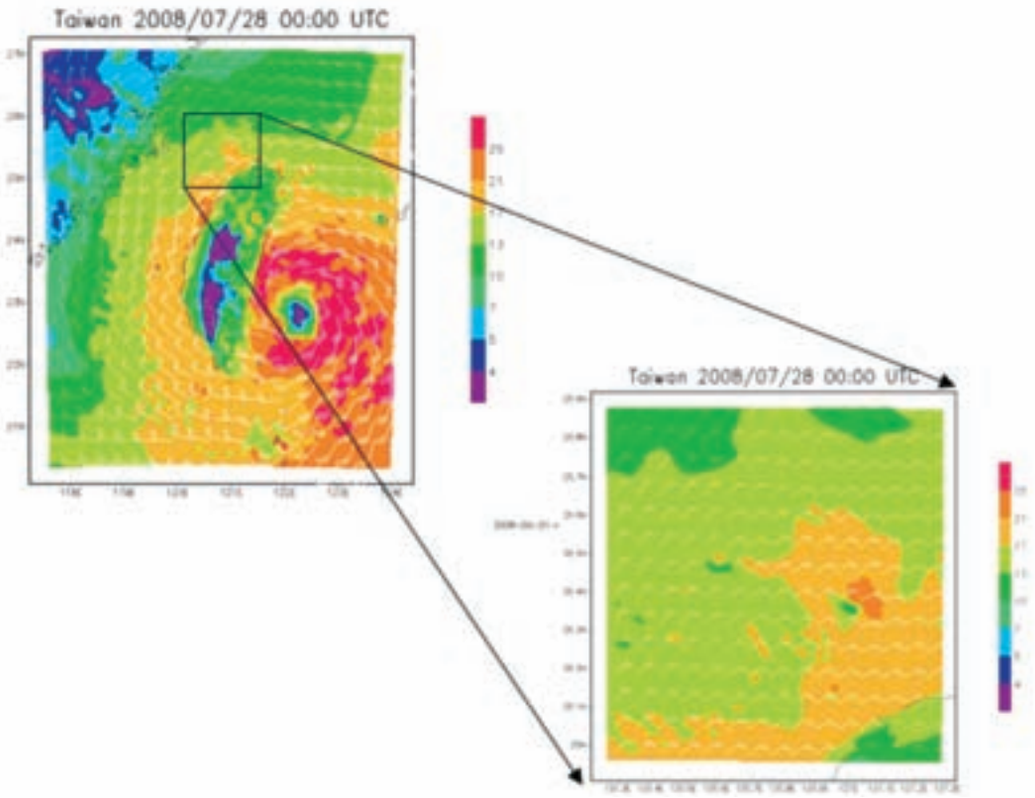
4.4 The Development of Wind Energy Assessment and Forecasting Technology

◎Hsin-Fa Fang

To be in face of the challenges of promoting energy supply security and reducing greenhouse gas emission, increasing the use of renewable energy and accelerating the development of renewable energy industries are already the important energy policies of every countries in the world. Of all the energy consumed in Taiwan, 98% is dependent on importing. It should be the essential energy policy of Taiwan to make the best use of the renewable energy. The average wind speed of Taiwan area is about 7m/s at the height of 10m above ground according to world wind atlas from the analysis of NCEP/NCAR data. The wind energy potentials seem even higher than that of Germany and Denmark. This makes wind energy one of the most important items for developing renewable energy in Taiwan. For large scale use of wind energy, we must have the capability for wind energy assessment and wind energy short-term forecasting.

INER began to study wind energy assessment and wind energy short-term forecasting technologies in 2007 based on the experiences learned from wind field studies for nuclear power plant emergency response. INER is the pioneer in Taiwan which uses the topographic data generated from Shuttle Radar Terrain Mission (SRTM) that can solve the problem of lacking topographic data for remote islands of Taiwan. INER is also the first

organization in eastern Asia with staff passing the WAsP certification examination held in Risoe National Laboratory of Denmark. WAsP is an industry standard for wind energy assessment in the world. INER has established the method of using the numerical weather prediction (NWP), WRF, with a 1 km resolution to solve the problem of the complex terrain in Taiwan. Much effort has been done to NWP because it is a major source of error for wind energy short-term forecasting. There have been a number of incidents that extreme winds caused by Typhoons have destroyed the wind turbines in Japan, China and Taiwan. This is the bottleneck of wind energy development in these areas. SafeWind project was launched by the 7th Framework Program of European commission in 2008. The purpose of SafeWind is to establish advanced wind energy forecasting model for extreme weather. A wind turbine design project for the development of a guideline for extreme wind condition is currently being conducted in Japan. INER will also spend efforts in this regard based on the wind energy assessment and wind energy forecasting technology.



▲ The simulation result of WRF with a 1 km resolution

4.5 Renewable Energy Power Control and Management Technology

◎Yung-Ruei Chang

The Renewable Energy Power Control and Management Technology Project is a subproject under the New and Renewable Energy Technology Development and Application Project. The major goal of this project is to develop a new technology which can efficiently control and manage power electricity generated from renewable energy. During 2008, INER has achieved two major accomplishments including (1) building up a demonstrative DC house and (2) developing a high-efficiency 5-kW SOFC power conditioning system.

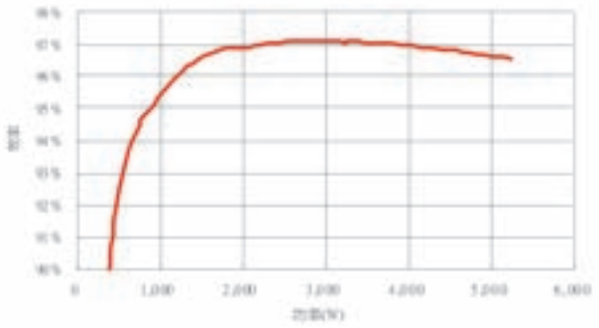
Due to the diversity and instability of power characteristics for renewable energy, including voltage vibration, current alternation, frequency droop, and reactive power issues, it is crucial to establish power control and management technology for effective extraction and manipulation of renewable energy. Under this project, a demonstration site of renewable energy DC house with 360V DC power supply system has been constructed, where a 1-kW bidirectional inverter with the functionality of selling or buying electricity between DC bus and utility grid has been developed and applied. In addition, a high-efficiency 5-kW SOFC dc/dc converter has been developed. The input and output voltage are 48 and 400 Vdc, respectively. The peak efficiency reaches 97.17% and the nominal efficiency is above 96% under 20~100% load condition, which means the technique level achieves international class. Moreover, two technique transferring cases were conducted in 2008 and more cases can be expected in upcoming years.

This power system of DC house constructed under this project can be regarded as a prototype of renewable energy micro-grid which is scheduled to be developed in the next 5-year project. Based on this infrastructure, developing power control and management technology for a micro-grid will be feasible for increasing penetration ratio of renewable energy into utility grid and will be beneficial for CO_2 emission reduction and national energy security. In addition, developing high-efficiency special-purpose power conversion system for various types of INER's energy systems, including SOFC, HCPV

and wind power, will be the key to improve up the overall system performance, reduce the cost of energy source materials, achieve the goal of technique transferring and hopefully create a new industry.

▲ A demonstration site of renewable energy DC house.

▲ The human interface of power control system for DC house.



▲ A high-efficiency 5-kW SOFC Power Conditioning System with 97.1% peak efficiency

4.6 Development of a Pilot Plant for Cellulosic Ethanol Production

◎Wen-Song Hwang

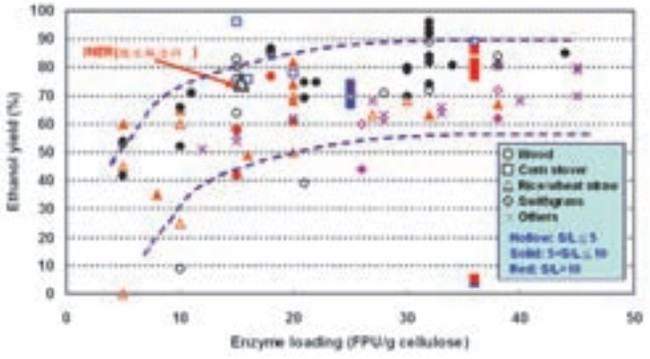
Starting from 2007, the Institute of Nuclear Energy Research has launched a new project, which was aimed to establish a pilot plant for cellulosic ethanol production with a feedstock capacity of one ton dry biomass per day. The conversion process is based on the route of biochemical conversions; the feedstock is first subjected to dilute-acid pretreatment and enzymatic hydrolysis which release sugars from saccharification of

fiber, followed by converting sugars to ethanol through fermentation processes, and finally about 99.3% ethanol is recovered from the fermentation broth by purification and dehydration system. The pilot plant under construction was designed based on the process of Separate Hydrolysis and Fermentation (SHF); it is estimated that 200 liters of ethanol can be produced with one ton of rice straw feedstock. This plant will also comply with the needs for R&D of SSF, SHCF, SSCF processes. Major accomplishments of this project in 2008 included (1) the basic integration process design and the detail engineering design for the pilot plant; (2) construction of plant utilities such as boiler, compress air system, DI water supply system, cooling water system and electricity substation; (3) manufacturing of process equipments, e.g. solid-liquid separation for biomass, fermentation tanks, enzymatic hydrolysis tanks, facility pipelines, and storage tanks. The ethanol distillation and dehydration system was also completed. This ethanol purification facility has been tested using surrogate solution of 1.6% ethanol at a feeding capacity of 1000 L/h. Ethanol of 93% can be obtained through the distillation system and 99.5% ethanol is received with a moisture content of less than 0.5% after further dehydration with molecular sieves or pervaporation membranes. The quality of purified ethanol was demonstrated to meet the CNS15109 fuel alcohol specification.

In development of the core technology for cellulosic ethanol production, this project has completed construction of biomass pretreatment facilities including high-pressure steam explosion system and continuous screw conveyer pretreatment system, as well as establishment of bench-scale hydrothermal pretreatment technology without acid addition. In order to reduce the cost of cellulase production, we have collaborated with universities for screening local microorganisms that can generate cellulase with high hydrolysis efficiency, and also investigated the potential for in-house production of cellulase. Moreover, xylose fermentation and Simultaneous Saccharification and Fermentation(SSF) technologies developed by us are also competitive with that of the leading international research institute; the ethanol yield from xylose fermentation and SSF process were 85 and 75%, respectively.

Cellulosic ethanol, produced from lignocellulosic material such as agriculture and forest residue, has the advantage of abundant and diverse raw material compared to sources like corn and cane sugars which are also food for humans. There is 150 million tons of rice straw produced annually in Taiwan. If the residue could be fully utilized for cellulosic ethanol production, it will not just solve the pollution problem caused by burning the straw, but is also helpful for creating a new energy industry and reducing carbon dioxide emission. Taiwan government is planning to implement E3 low ethanol-blended fuel nationwide by the year 2011. It is estimated that 100,000 kiloliters ethanol-gasoline fuel will be required annually. Since the construction of our pilot plant is to be completed in 2009, the plant will serve as a platform for the development of mass production technology of cellulosic ethanol. This technology can be further transferred to local industries for establishment of commercial cellulosic ethanol production plant.

▲ Ethanol Distillation and Dehydration System



▲ Global Comparison for the Conversion Ratio in SSF Process Research

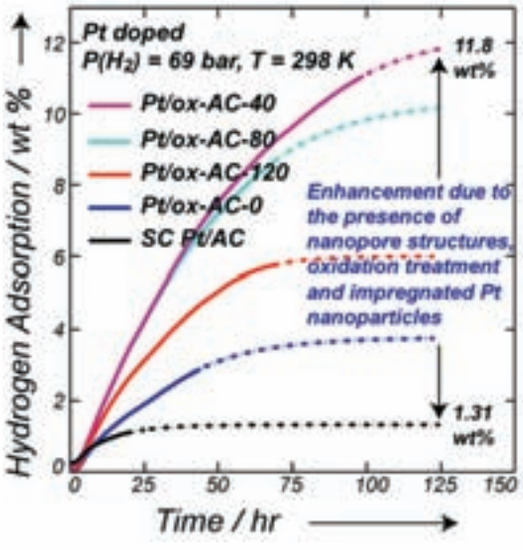
4.7 Reversible Hydrogen Storage of Pt-impregnated Activated Carbon

◎Ming-Sheng Yu

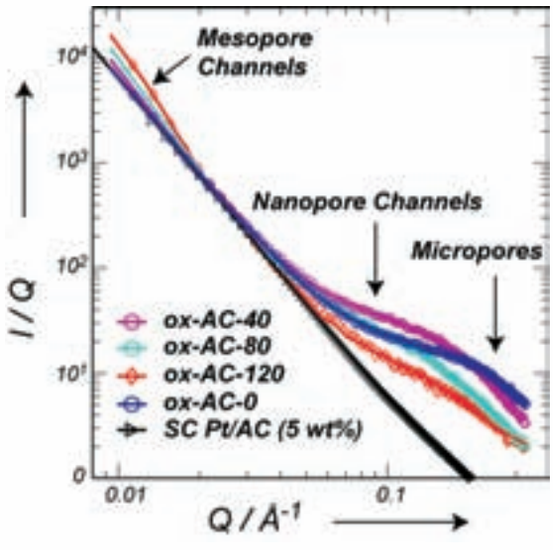
In this study we use the impregnation method to put platinum nanoparticles inside the nanopore channels of microporous activated carbon (AC), giving rise to a hydrogen storage capacity of 11.8 wt% for AC at room temperature and 6.9 MPa hydrogen pressure. This material is stable under repeated storage-and-discharge cycles, which process is fully reversible at room temperature. The pore structure of activated carbon had been treated to consist of micropores, nanopores and mesopore channels. By correlating this

pore structure with the hydrogen storage property, we found the storage capacity reduces as the amount of the micropores and nanopore channels reduces. The TGA measurement shows the weight of the sample increases as the pressure is raised to and kept at 6.9 Mpa over a long period of time. As the pressure is reduced to the atmosphere, the stored hydrogen is released giving rise to the gradual loss of weigh and eventually returning the sample weight close to the original value. For fuel cell demonstrating purposes, we have extended our sample preparation procedures to make 10 gram of such Pt-AC materials in one batch. A setup of a 75 W surveillance system driven by a PEM fuel cell connected to a home-made 550 cc cartridge filled with 76 g of our Pt-AC has been demonstration. This should be the first one in the world to use a room temperature Pt/AC storage cartridge as a hydrogen source to generate an output of 75 W.

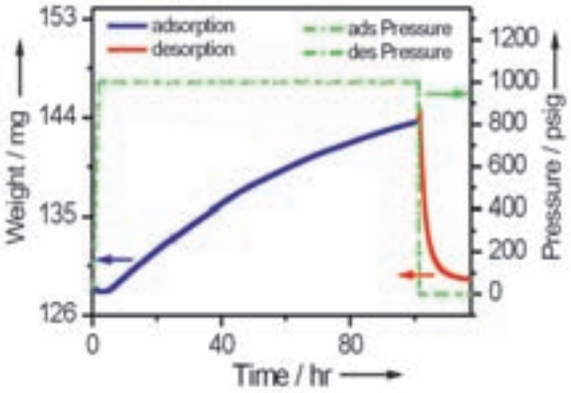
So far, our Pt-AC is the only material satisfying the DOE's requirement in terms of storage capacity under ambient conditions. By being economically viable the Pt-AC hydrogen storage system will accelerate the realization of hydrogen economy in the near future.



▲ The hydrogen adsorption kinetics for the Pt/AC samples with different treatments. The maximum hydrogen uptake at room temperature and 6.9 MPa can reach 11.8 wt%.



▲ SAXS profiles indicating pore structures for Pt-AC after different treatments, i.e. mesopore channels , fractal nanochannel network and micropores.



▲The variation of weight gain and loss of the optimized Pt/ox-AC sample with time under the prescribed pressures of the adsorption and desorption processes, showing the fully reversible hydrogen storage behavior and fast desorption kinetics.

▲ The 75 W surveillant system was driven by hydrogen storage tank filled with Pt/AC.

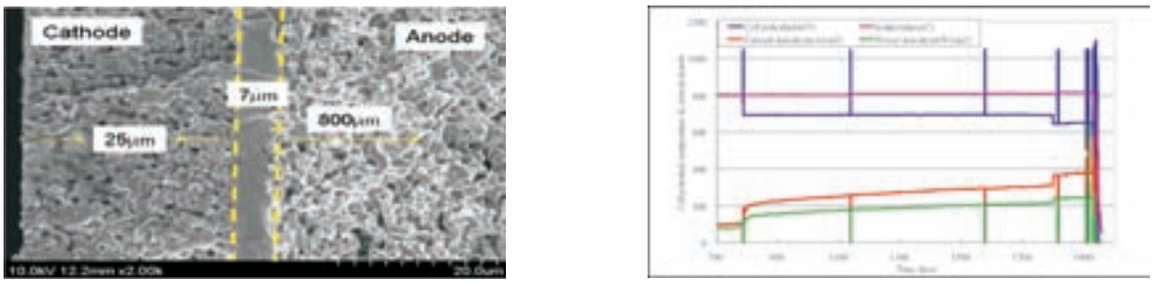
4.8 Development of SOFC Technology

◎Chien-Hsiung Lee

INER's SOFC project was initiated in 2003. The goal is to develop technologies associated with 1~5 kW SOFC power generating systems in 2010. The progresses achieved in 2008 included: (1) manufacture of planar anode supported cells (ASC) of size 10 x 10 cm^2 with anode: NiO＋8YSZ, electrolyte: 8YSZ, and cathode: LSM; The anode, electrolyte and cathode layers were produced by tape casting, spin coating, and screen printing method, respectively. In addition, metal supported cells (MSC) employing porous nickel substrates were manufactured via the atmospheric plasma spraying (APS) process. The cell consists of anode: LDC/Ni, anode buffer: LDC, electrolyte: LSGM, cathode buffer: LSGM/LSCF, and cathode: LSCF. Both types of ASC and MSC exhibited maximum power density higher than 500mW/cm^2. (2) Borosilicate glass-ceramics type sealant has passed the 800°C, 1000-hour testing and 50 thermal cyclic tests (RT↔800°C) with leakage rate below the allowable limit of $5.2x10^{-4}$ mbarl/s/cm. (3) A LSM protective layer was sputtered on the metallic interconnect to prevent chromium evaporation and stack degradation. A single-cell stack performance test at 750°C showed output power

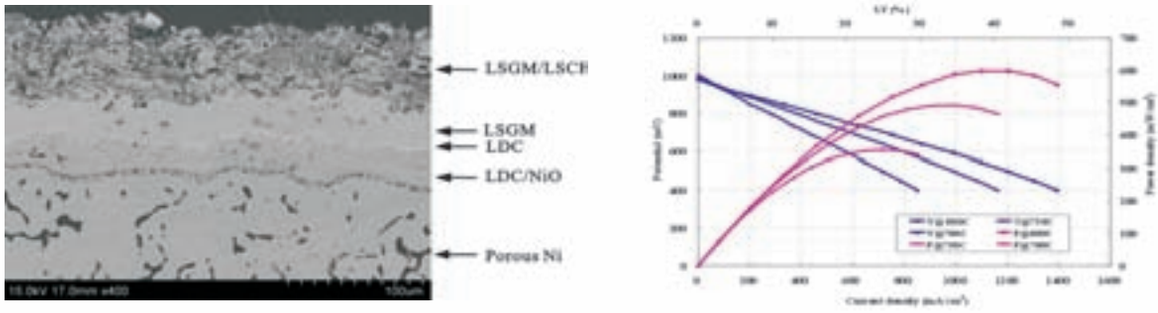
density reaching the target of 300 mW/cm^2 at 0.7 V. (4) A 1 kW SOFC stack from HTceramix SA, Switzerland, was successfully integrated into the 1 kW power generating system. The system has displayed an average power degradation rate of 2.0%/1000 hr after a long-term test of 1080 hours. Besides, a compact 2 kW system was also designed and built . The system testing with dummy stacks is still on-going.

In summary, the manufacturing technology through the tape casting-spin coating-screen printing process for the second-generation ASC was established. The technology can be easily adapted to the process of mass production and cost reduction after commercialization. A novel sealant has been successfully employed in sealing of SOFC stacks. The coating applied on interconnect has significantly reduced the stack degradation rate, showing the effectiveness on preventing stack deterioration. The performance of the 1 kW power generating system was validated through long-term test. All the technologies established so far will serve as a base for developing the 2 kW residential power generating system.



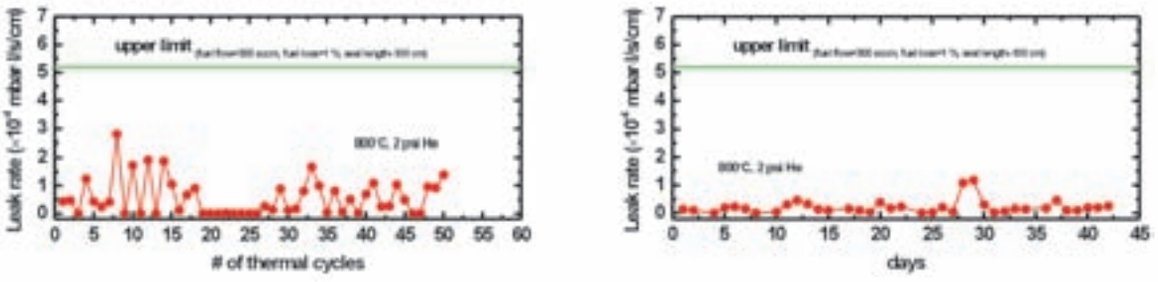
(a) (b)

▲ The anode supported cell made via the tape casting-spin coating-screen printing method (a) cross-sectional structure; (b) long-term performance testing curves.



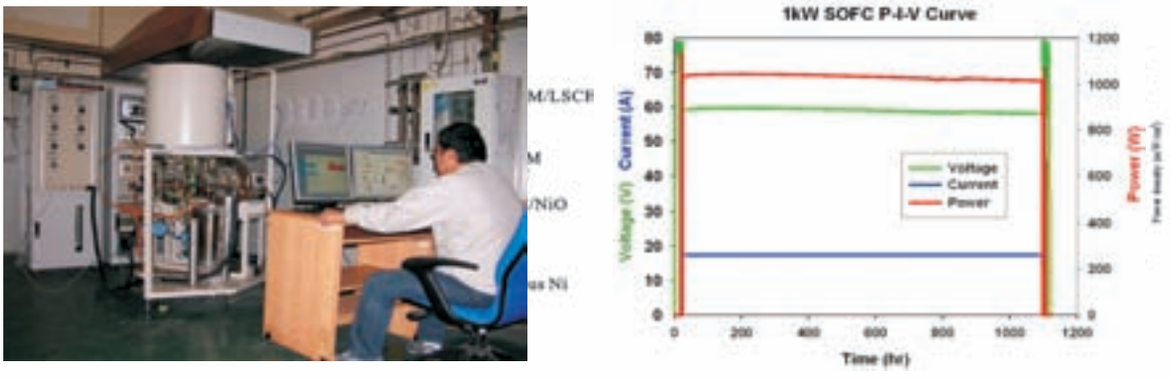
(a) (b)

▲ The metal supported cell made via the atmospheric plasma spraying method (a) cross-sectional structure; (b) performance curves showing power density over 500mW/cm^2



(a) (b)

▲ Interconnect/sealant/interconnect adhesion (a) thermal cyclic and (b) long-term isothermal leakage tests showing leakage rate below the upper limit.



(a) (b)

▲ (a)The 1 kW SOFC power generating system; (b)System long-term performance testing curves showing a degradation rate of 2%/1000 hours under the constant current (17.5A) mode operation.

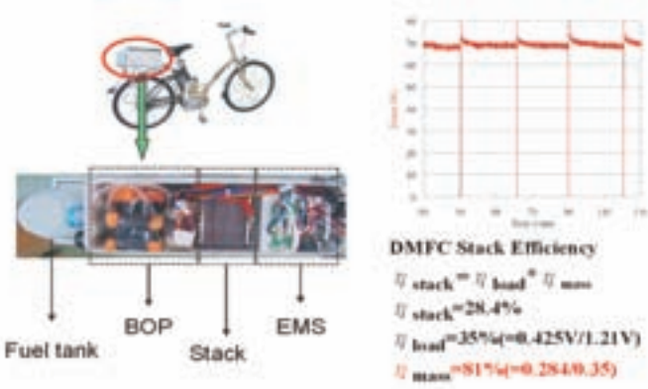
4.9 Direct Methanol Fuel Cell Power Pack

◎Charn-Ying Chen

In this project a direct methanol fuel cell (DMFC) system is integrated for use as a power source for E-Bike. A prototype of 50 W DMFC was successfully demonstrated in 2008 Taiwan Nano Symposium. The system is integrated with key techniques developed by INER including stack and energy and fuel management system. A methanol sensor-less control technique is applied in this system which can increase fuel utilization(up to >80%) ,system energy density/reliability and decrease the system weight/volume/cost. INER has profitably transferred methanol sensor-less control technology to the collaborated industry partner. INER has also developed innovative MEAs based on using CNT as supporter to produce Pt series and non-Pt catalysts such as Pt/CNT, PtRu/CNT, PtRuIr/CNT, and RuSe/CNT etc. To accelerate the commercialization of portable DMFCs,

INER has worked together with international leading companies such as DuPont, Johnson Matthey, PolyFuel, and DMFCC in addition to cooperation with DMFC research groups of the domestic universities.

▲ DMFC Development at INER



▲ 50W DMFC for E-Bike

Fuel cells offer the potential for clean and reliable energy generation. Among various kinds of fuel cells, the Direct Methanol Fuel Cell (DMFC) operates at low operation temperature (< 80°C), and uses methanol as the fuel which is a liquid and is thus easier for fuel storage and transport than hydrogen. Therefore, DMFC is regarded as a promising candidate in portable power applications, such as notebook, PDA, cellular phone and E-bike. Optimistically, significant new business opportunity in fuel cells could be available from around 2010.

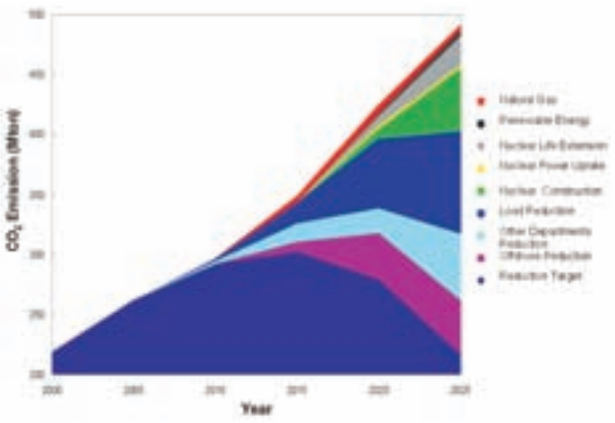
4.10 Energy Model-Establishment and Analysis

◎Fu-Kuang Ko, Jong-Shun Chen, Chung-Han Lin

The Institute of Nuclear Energy Research (INER) began to establish the energy model, INER MARKAL, from September 2005. MARKAL-MACRO, an integrated model of energy technology and macro-economy, was established in 2007. At present, we have finished the expert review of relevant analysis in BAU (Business As Usual) and the

results have been published in international conferences, such as IAEE. From 2008, we have focused on the establishment and validation of industrial sector settings in MARKAL-MACRO. The concerned major industrial investment was also included in the model and the effects on overall economy and environment were evaluated through energy usage, CO_2 emission and GDP growth.

▲ 2008 Cross-Strait Workshop on the Theory and Practice of Integrated Modeling in Energy, Environment and the Economy.



▲ Contributions of CO_2 abatement from all kinds of alternatives in reduction scenario.

The setting of abatement goal, the life extension or newly construction of nuclear power plants, the induction of energy tax and carbon trade, and some other issues are debated in "energy-saving and CO_2 abatement" planning. From the results of INER MARKAL, we gain the following insights. First, the CO_2 abatement target to 2000 level by 2025 cannot be satisfied only by the expansion LNG and renewable energy usage. Second, the imposition of energy tax and the induction of carbon trade market can help to decrease the energy service demand in all sectors and to promote the outland abatement strategy. Third, the nuclear power generation can help to reduce about 30% CO_2 emissions and also help to ensure energy security and electricity supply. Therefore, the government should draw up the relevant nuclear power development strategy as soon as possible, however, the safety of nuclear power plant and the treatment of nuclear waste disposal must also be guaranteed.

5. The Environmental Plasma Technologies

◎Chin-Ching Tzeng

The environmental plasma technologies developed at INER can be divided into two categories, thermal and non-thermal plasmas. The DC thermal plasma torch is used as a heat source to treat various wastes for detoxification, volume reduction, vitrification and resources recovery. Non-thermal plasmas operated in vacuum and atmospheric conditions are implemented for clean production such as surface coating and modification, sterilization and reforming.

Novel DC steam plasma torches are designed and tested this year to improve the stability of gasification process and its conversion efficiency of biomass. The construction of INER's pilot plasma gasification system is successfully completed in this year. Full system testing is conducted by using wood chips as feedstock. High quality syngas is produced and could be used for power generation and liquid fuels synthesis. Echo products like fiber blanket, non-woven paper, brake pads and lightweight composites are developed and characterized to meet the requirements for industrial applications. The recycling products from vitreous slag with the high added value could effectively reduce the treatment cost of ash residues generated from municipal solid waste incinerator (MSWI) using plasma melting technology. Research achievements and future benefits of environmental plasma technologies developed at INER are elucidated as follows.

5.1 Development of Novel DC Steam Plasma Torch

◎Heng-Yi Li

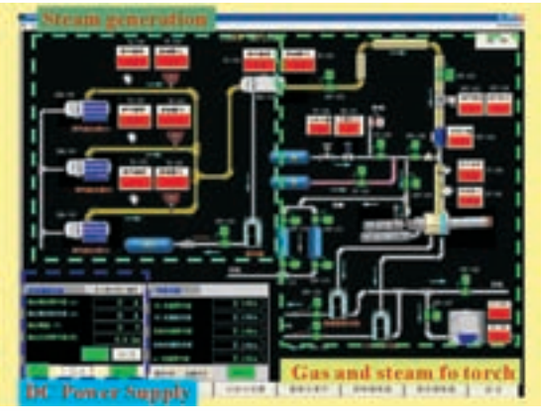
To develop plasma assisted gasification technology for better bio-energy utilization, two types of novel dc steam plasma torch are developed this year. The first type torch is upgraded from the original air plasma torch, which is ignited with hot air and cooled with warmed circulated water as shown in Fig.1. The steam flow is controlled by electric servomotor driven needle valve and variable area flow meter. The maximum conversion efficiency is up to 78%. The second type was developed by improving the structure of a 100kW plasma torch. The modification includes adding fixed magnet and window in rear electrodes, heating gas in front of gas ring. So far, the second type torch could be operated

with 100% steam and the arc root could be controlled effectively. By using the spectroscope to measure the erosion rate, the electrode lifetime is estimated to be over 150 hours.

In addition, INER establishes several measuring tools and technologies for the purpose of handling the characteristics of torch and reducing the developing time as follows. A) The endoscope technology, with which the erosion patterns of the well electrode could be inspected at any time of torch testing period; B) The high speed image capturing and processing technology, with which the connection between the flame images and operation conditions of the plasma torch is built, and the torch design and operation condition could be optimized; C) Laser Doppler Velocimeter, with which the exit velocity of the torch is measured and the theoretical simulation results are verified; D) Electrode erosion rate estimation, which uses the collimator of spectroscope to measure the variation of copper line intensity, and build the connection of erosion rate and torch operating condition so that the lifetime of electrode can be estimated and test time be reduced; E) Setup of the digitized long time test platform which assists the operator to remotely control dc power, cooling water, air, argon, and steam via human interface (HMI) of PC monitor as shown in Fig.2, and the Intouch software could record 200 hours of voltage, current, flow, pressure and temperature; F) Setup of the digitized remote monitoring system, with which operator could monitor site condition from digital CCTV.

Steam plasma contains reactive radicals like H, O, OH, which have two major applications. The biomass like wood chips, sunflower oil cakes, straws are gasified to produce syngas consisting of H_2 and CO, with minimum amount of char and tar, and high gasification efficiency. The toxic substances such as PCB, CCl_4, and CFC are destructed and transformed into nontoxic matter for the safety of environment.

▲ Fig. 1. Photo of novel steam plasma torch in operation



▲ Fig. 2. Platform of DC plasma torch

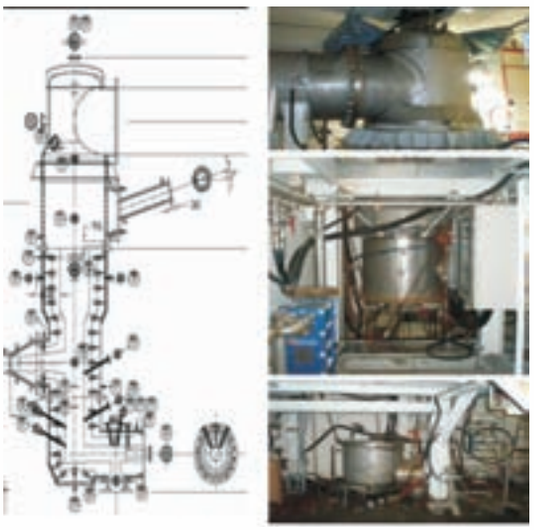
5.2 Development and Test of Pilot-scale Plasma Gasification System

◎Heng-Yi Li

INER has successfully constructed a 500 kW_{th} plasma gasification plant, which can convert organic matters like biomass, waste plastics, or coals into syngas (CO and H_2 mixtures), which can be further used to generate electricity as well as synthesize liquid fuels like methanol, ethanol, and dimethyl ether (DME). Tests for individual units and full-scale operation have been accomplished. The designed maximum pressure and temperature are 5 kg/cm^2 and 1,650°C, respectively. The plasma gasification plant mainly consists of pilot-scale plasma gasifier (Fig.1), syngas cleaning system, advanced energy system, DC plasma torch system, storage tanks, daily tank ($2m^3$), pusher feed, screw feeder, central monitoring system, and continuous syngas analysis and monitoring system. The syngas cleaning system, consists of a set of acidic scrubber, caustic scrubber, and activated carbon adsorption tower, can remove SOx, NOx, HCl, H_2S, and particulate matters. The advanced energy system (Fig.2) consists of a set of syngas compressor, four microturbines (30 kWe), and an adsorption chiller. The latter two can generate electricity of approximately 100 kW with an efficiency of 26% and provide cooling gas (14°C, 22 RT) for the on-site use. The overall thermal efficiency of the plant can achieve up to 60%. With gasification of crushed wood pieces, at given gasification temperatures and carbon-to-oxygen ratios, a syngas with the heating value ranging between 5.43 and 6.69 MJ/ Nmis

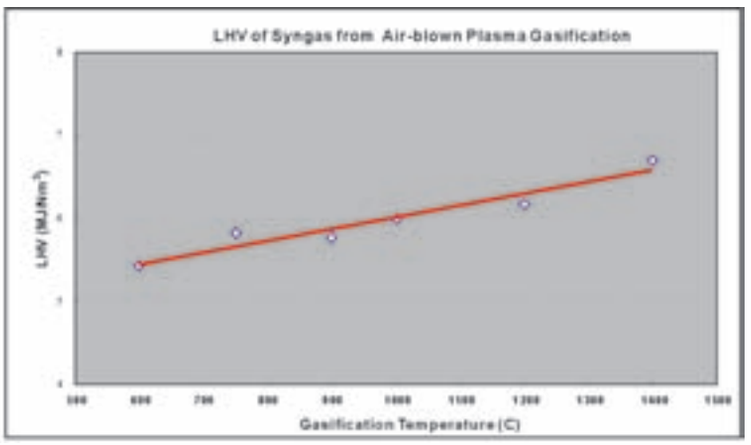
achieved (Fig.3).

Plasma gasification technology can effectively treat the municipal solid waste (MSW) with reduction of dioxin emission by more than 90%, and with improvement of electricity generation by 80%, when compares with the traditional MSW incinerator. Electricity generation from biomass for better utilization of the sustainable energy and production of liquid fuels (e.g. methanol, ethanol, dimethyl ether etc.) can increase the self-sufficiency ratio of indigenous energy.



▲ Fig.1. Illustration of pilot-scale plasma gasifier.

▲ Fig. 2. Advanced energy system.



▲ Fig.3. Influence of the gasification temperature on the lower heating value (LHV) of syngas from air-blown plasma gasification

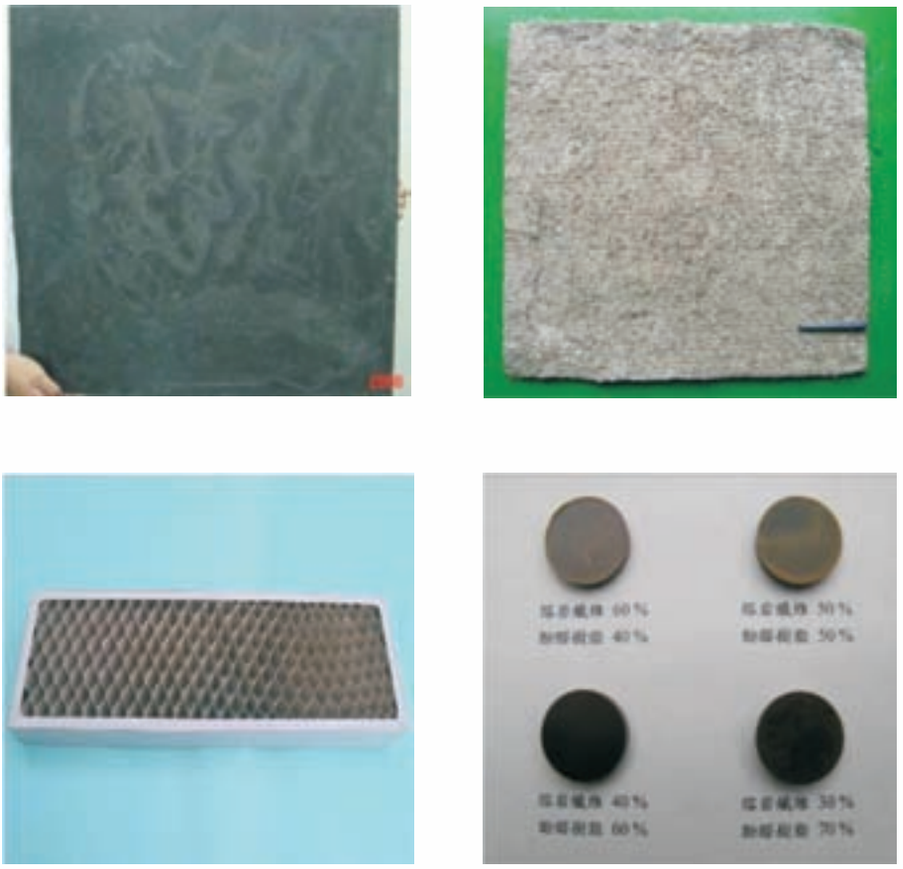
5.3 Development and Applications of Plasma Melting Reclamation Technique

◎Wen-Cheng Lee

Plasma melting technology developed at INER has been recently used to treat MSWI ash residues. To broaden its applications, different recycling products have also been studied with its vitrified water-quenched slag as a raw material. In 2008, we continued to develop products, such as lightweight composites, fiber blanket, honeycomb structure non-woven paper as well as brake pads.

The lightweight composite board with specimen size, 600(L) x 600(W) x 5(T) mm, bulk density 1.3 g/cm^3, flexural strength 250 kgf/cm^2, water content 0.06 wt% had been made, in which their properties were comparable to calcium silicate boards, and could be applied for architectural and decorative purposes. In addition, the slag fiber was also produced. Its shot content (3 wt%) was lower than that of commercial mineral fiber (16 wt%); therefore, it is competitive with the market-available mineral fiber. The production of fiber blanket, honeycomb-structure non-woven paper and brake pads were further realized by using slag fiber as the basic additive. The fiber blanket can be used as fire-resistance and heat-insulation material below 700°C. Similarly, the honeycomb-structure non-woven papers can also be used as fire-resistance material in automobiles such as the Mass Rapid Transit (MRT) cabin. Slag fiber and phenolic resin were mixed together to manufacture brake pads with properties of coefficient of friction 0.5-0.6 and abrasion loss 2-5 mg, which is equivalent to that of commercial brake pads. Furthermore, thermal plasma technologies are also applied to destroy and remove non-metal materials from PCBs and to recover valuable metal such as Au, Ag, and Cu. The purities of these metals can reach as high as 95%.

The results shown that the efforts to treat hazardous MSWI ash residues by plasma melting technology and then convert to recycling products have been made successfully. These achievements apparently have the potential not only to resolve the shortage of landfill sites for incinerator ashes but also to promote the commercialization of recycling products.



▲ Products form plasma molten slag
(Top left：Lightweight composite board；Top right：Fiber blanket；
Bottom left：Honeycomb-structure non-woven paper；Bottom right：Brake pad)

5.4 Development of Motorcycle Powered by the Mixed Fuel of Syngas and Gasoline

◎Yu Chao

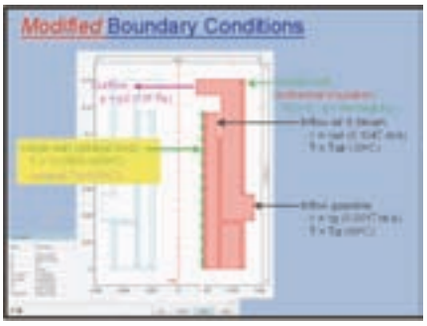
As a supplementary fuel for vehicle engines, hydrogen can improve engine performance and reduce pollutant emission. However, the application of hydrogen fuel still has a bottleneck in terms of the readiness of hydrogen supply. One of the promising and realizable solutions is an onboard hydrogen reformer.

This year, a new compact hydrogen reformer with thermal recovery feature was developed via a computer aided CFD design. This reformer can recover the heat liberated from the exothermal reforming reaction and utilize it to evaporate the liquid gasoline and

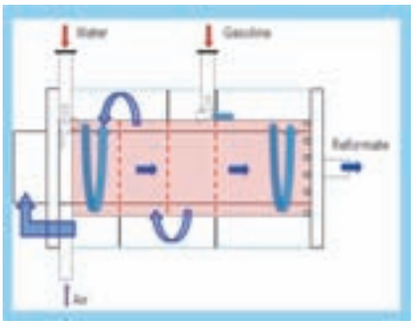
water as well as to preheat the reactants. An atomizer for gasoline or water was also developed through the cooperative research with domestic university. This reformer uses a new metal oxide catalyst optimized for auto-thermal reforming. Comparing to partial oxidation reaction, the new reformer system has the advantages of lower reaction temperature and higher Hydrogen yield. With the assistance of plasma and suitable O/C ratio, the whole startup process can be completed less than 30 s. Then the plasma is shut off and a self-sustained catalytic reaction takes place in this system without extra electric power. The experiment results indicate that the reformed gasoline is reduced from 4 cc/min to 3 cc/min, while the hydrogen concentration increased from 17.5% to 26.1% and the yield from 3.2 slpm to 4.1 slpm, respectively.

Results of integrated tests of reformer and motorcycle for dual fuel operation have shown better engine performance, pollutants emission and gasoline consumption than gasoline fuel. In idle test, the concentrations of major pollutants like CO, HC are improved by 42.1% and 20.6%, respectively. The gasoline consumption and the brake power are improved by 33.3% and 14.3%, respectively. NOx emission increased by 26.5% but with low NOx concentration of only 43 ppm. For cruising test, the gasoline consumption and NOx emission are improved by 9.5% and 8.1%, respectively. A control logic system, which smartly controls fuel, air supplies and reformer operation, based on the conditions of engine speed and reformer temperature, have also been developed. This system enables motorcycle drivers to ride it easily without learning difficulty.

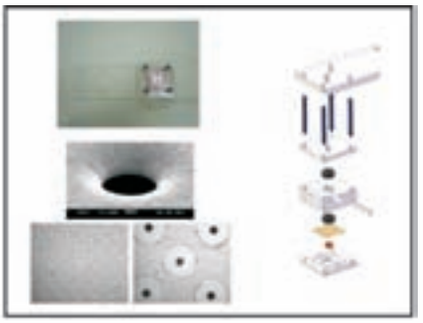
Currently there are more than 10 million motorcycles in Taiwan, which have contributed over 10% of the total CO and HC emissions nationwide and are considered as one of the major pollution sources, especially in the metropolitan area. The goal of this project is to enhance energy saving and air quality improvement. More effort is needed to promote cooperation with vehicle manufacturers for commercialization.



(a) CFD modeling of reformer



(b) Heat recovery reformer



(c) Atomizer for gasoline/water

▲ Fig. Compact plasma reformer

Table 1. Engine performance and the pollutant emission in idle mode

PAC reformer	Engine condition			Major pollutants in exhaust			Engine performance	
	Operating mode	Throttle opening (%)	Engine speed (rpm)	CO (%)	HC (ppmv)	NOx (ppmv)	Brake power (kW)	Gasoline comsumptio (ml/min)
OFF	Idle	5	2000	8.53	165	34	1.4	9
ON	Idle	5	2000	4.94	131	43	1.6	6

5.5 Non-Thermal Plasma for High Efficient Inactivation of Airborne Bacteria

◎Shiaw-Huei Chen

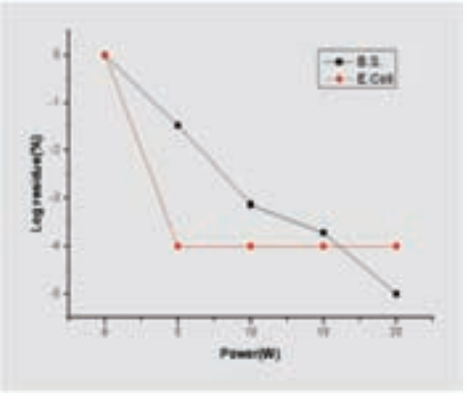
Recently, atmospheric-pressure non-thermal plasma technique has been successfully applied in area such as medical disinfection and sterilization. Many international symposium and journals were held and published with these topics. This technology can

generate and provide at the same time the synergic mechanisms for micro-organism inactivation like ultraviolet, high energy impact, ozone and highly active radicals etc., and has the merits of short processing time, easy operate, low temperature and energy saving.

In 2006, we had established a P2-class microbe laboratory and a plasma test platform. In this year (2007), a specialized plasma sterilization laboratory had been certified to operate by INER (Fig.1). Development of a high efficient non-thermal plasma device for inactivation of airborne bacteria had been constructed and tested, Gramm positive and negative microorganism like Escherichia coli and Bacillus subtilis, are used as the representative object. The bacterial samples are cultured and the number tested can reach 10^5CFU/m^3, where CFU stands for colony forming unit. In the one-pass non-thermal plasma treatment, with treatment time at 0.03 second, a high inactivation efficacy of reaching a 5-log reduction (99.999%) is achieved for Bacillus subtilis for less than 20W, ~4-log reduction (99.99%) is achieved for Escherichia coli for less than 5W of input electric power (Fig.2). Also under development are the pulse electrostatic participation, TiO_2 photo catalyst, and ozone decomposition catalyst etc. The plasma assisted photo catalyst was proven to further enhance the inactivation efficacy to 99.6% at 5W of input electric power.

The high efficient non-thermal plasma device for inactivation of airborne bacteria can be applied to the heat, ventilation, air condition (HVAC) system at most office buildings, local and center hospitals, especially for the air contagious diseases like SARS, Flu, and Bird flu etc. Environmental Protection Agency (EPA) of Taiwan had issued a set of recommended values of safe indoor air quality (IAQ) in 2005. This technique is also helpful to improve IAQ. The non-thermal techniques developed here can also be applied to the area of disinfection and sterilization of medical device with high efficiency, where the inter-contagion in hospital is a critical issue.

▲ Fig.1. Photo of plasma sterilization laboratory



▲ Fig. 2. Inactivation efficacy under different electric input power

5.6 Development of Large Area Helicon Plasma Source

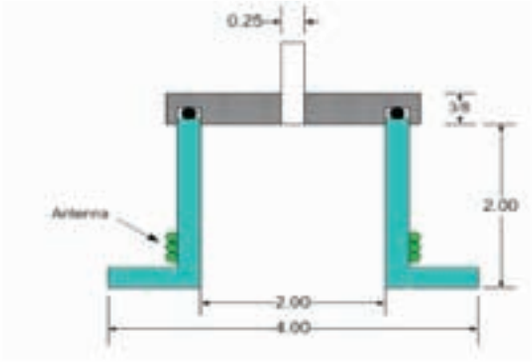
◎Cheng-Chang Hsieh

Plasma enhanced chemical vapor deposition (PECVD) is the most widely used fabrication process for thin film solar cell and plasma source plays a key role in the research and development of this process. In order to establish the key technologies, to attain required patents and to reduce production costs, we have developed an innovative and efficient plasma source with characteristics of large-area, high plasma density, high plasma uniformity, low ion energy, high stability, simple configuration, and friendly operation.

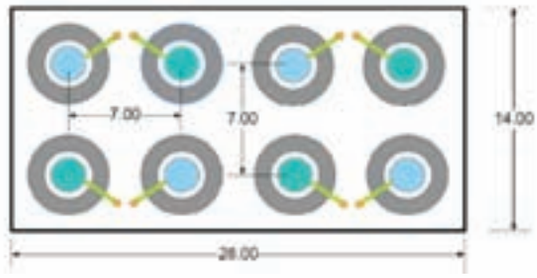
Through our international collaboration with UCLA, we have constructed a multi-tube large-area helicon plasma source. The single discharge tube is shown as Fig.1, in which its inner diameter and its height are 2 inch and its discharge current loop of antenna m=0 near the plasma tube exit and connected to RF power supply. Fig.2 shows the developed 4 x 2 discharge tube array, in which the optimal distance between tubes is 7 inch for both x and y-axis, based on the calculation of the density profile of each tube. Furthermore, there are distributed process gas outlets below the discharge electrodes. The plasma system of helicon is illustrated in Fig.3 and its hardware was shown in Fig.4.

Fig.5 shows the distribution of plasma density in the pressure of $5x10^{-2}$ torr at 3 kW and 4.8 kW, respectively. The homogeneity of the plasma density is 11.8% along x-axes for 3 kW, and 13.7% for 4.8 kW. The ionization rate of reactive gas for helicon plasma source is very high, which has great advantage to prepare amorphous and microcrystalline silicon thin films. The microcrystalline silicon thin film has been deposited successfully in low H_2 dilution ratio of silanes (H_2/SiH_4 =1) as compared to 20 for conventional CCP process. The deposition rate is up to 5.4 A/s.

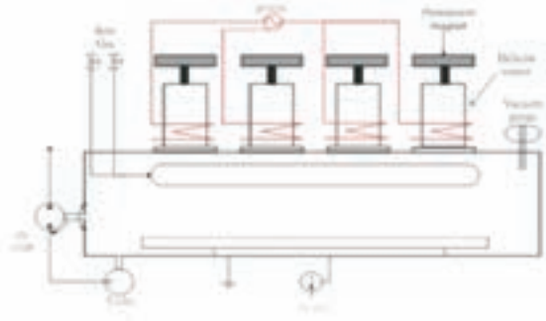
Some improvements are still needed in the uniformity and stability of the plasma source. Continuous research efforts will focus on the optimum conditions of the thin film depositions to obtain the related patents and technologies, to reduce production costs and to enhance competitiveness for the future roll-to-roll thin film solar cell fabrication.



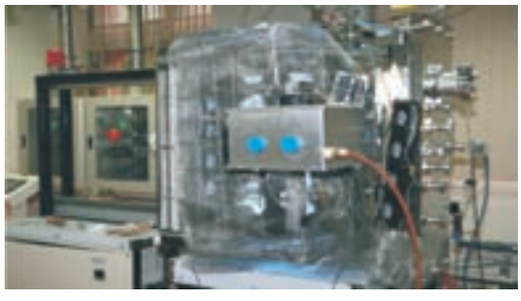
▲ Fig.1. Schematic of the dischargetube



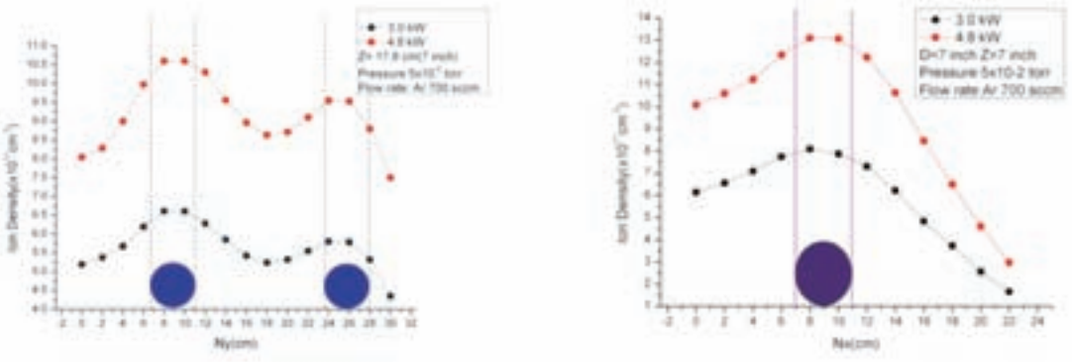
▲ Fig.2. Schematic of the 4x2discharge tube array



▲ Fig.3. Schematic of the plasma system



▲ Fig.4. Photo of the helicon plasma system



▲ Fig. 5. Plasma density profile of helicon system at 3kW and 4.8 kW, respectively.

5.7 Development of Novel Large-scale Coating Systems

◎Gin-yu Wu

In recent years, due to the improvement on plasma power supply, much progress for plasma technology has been made in various plasma surface treatment including cleaning, implantation and coating. By employing the energetic species of plasma for the deposition of various high functional metal or composite films, much better protection and decoration functions of the products can be achieved than the conventional electroplating process. The deposition of plasma is an environmental-friendly process and its products do not contain any toxic element. Thus, it has gradually become the main stream of the surface treatment industry. For the purposes of cost reduction and market expansion, the major goals are the developments of a large-scale plasma deposition system to meet the requirements of domestic industry and the best demonstration of INER's capability in the relevant technology of plasma deposition system.

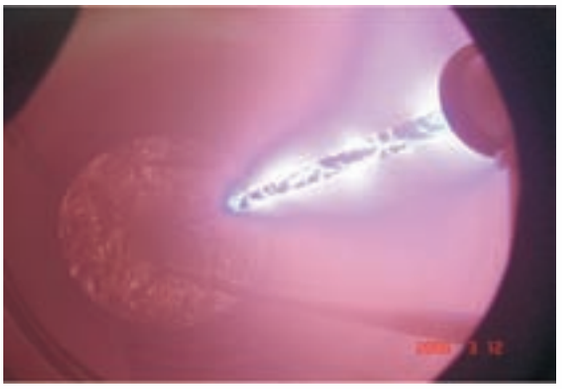
Two large-scale and novel plasma deposition systems have been developed in this year. One of them is the huge plasma deposition chamber of screws as shown in Fig.1. The apparatus has been used for the life extension and anti-corrosion of plastic screws rod by the deposition of protective films such as TiN. The length of screw rod is over 3m, much

longer than the ordinary workpieces. Thus, a vertical plasma deposition chamber of 1.3 m in diameter and 5 m in height has been specially designed to accommodate the long screw rod. As shown in Fig.2, the system contains 21 sets of arc plasma sources and its weight of the loading machine with planetary revolutions for the workpieces is over 2 tons. The functions of the deposited films have met the commercial requirements. With integration of the advantages of the previously developed deposition systems for building metal plates, the new design of hybrid type plasma source employs over 30 sets of planar arc plasma sources installed together with one set of 5-m cylindrical plasma source shown as Fig.3. This configuration is unique around the world. It is a horizontal chamber of 5.5 m in length and 2.4 m in diameter as shown in Fig.4, with the weight of over 2 tons in one batch.

▲ Fig. 2. Photo of large plastic screws coated with TiN film

The two large-scale and novel plasma deposition systems have been tested in domestic factories, which not only help the domestic industry to promote the quality of their products but also to speed up their manufacturing processes to meet the requirements of high technology and environment protection. These two huge deposition systems developed by INER have attracted over 2 billions NT of investments and provided the employments of about fifty workers. At the same time, the plasma deposition technology has been developed domestically and its niche will be magnified continuously to form a chain of production with INER developing technology.

▲ Fig. 1. Photos of plasma coating system with a huge vertical chamber (1300 H 3900 mm), located at Gong-Sung Industry Park



▲ Fig.3. Photo of arc-spots moving on the surface of cylindrical target during coating process

▲ Fig. 4. Photo of the plasma coating system installed in factory of Far - Eastern Corporation

5. Appendix

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No.1000, Wenhua Rd., Jiaan Village, Longtan Township,
Taoyuan County, 32546, Taiwan (R.O.C.)
Tel: 886-2-8231-7717 886-3-471-1400 0800-001-766
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