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2007 Annual Report

Institute of Nuclear Energy Research

Atomic Energy Council, Executive Yuan

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Contents

Preface

Director-General

To Develop Innovation-oriented and Nature-friendly Advanced Technologies

In order to pursue the long-term development and make diversified contributions, over the past few years the Institute of Nuclear Energy Research (INER) has taken measures to continuously improve management efficiency and make structural transformation, as well as to respond to the needs of the society changes and promote the growths of industry and economy by taking advantages of our unique R&D strengths. In the process of transformation and remodeling, we were able to maintain the power for progresses and demonstrate concrete research results even facing with some severe challenges. In fact, these growths and changes come from the distinctive characters of our colleagues for not being afraid of trying and solving problems. This will lay a sound foundation for INER to become an excellent research institute.

Looking back on the year 2007, we faced with the severe impacts of two main issues, i.e., global shortage of resources and deterioration of living environment. Therefore, to develop related technologies so as to solve the problems of resources storage and environmental deterioration has become an urgent need. In particular, in the event that energy storage, climate change and waste-induced environmental pollution have turned into common threats, our country should not be ignorant to such problems, because the impacts can be severer due to the limitations of our geographic location and resources. An even worse situation is that our country will lose competitiveness and be drowned in the currents of the time if no suitable measures

are taken in advance. Serving as a national laboratory, fortunately INER has quickly responded to such demands and challenges. In addition to strengthening the core power in nuclear energy technology, we have extended our integration technology and system development capabilities to explore new energy territories and nuclear medicines, and have progressively made some significant progresses. Meanwhile, from the views of pursuing the spirits of innovation and creating industrial values, we have promoted our solid contributions of the R&D work to meet the needs of our country and the society, especially in the fields of maintaining nuclear energy safety, developing new energy technologies and exploring radiation applications. From this annual report, one will be able to clearly see the tracks of our devoted efforts in these respects.

In the field of nuclear safety technologies, we have several completed power plant-related projects including time limited integrated plant assessment (TLIPA), measurement uncertainty recapture-power uprate (MUR-PU), independent safety analysis methodology for reactor core hot-water flow, development of several power plant operation and maintenance (O&M) technologies, and independent verification mechanism for comparison and review of bid for Pressurized Water Reactor (PWR) fuels and capital costs of fuel cycles. Also, we have conducted inspectional checks on digital instrumentation system, nuclear safety maneuver monitoring system and operational platform, control system for plant construction, and a variety of other inspections for the fourth nuclear power plant of Taipower. In the meantime, we have established the drug dosage calibration system platform for breast cancer Computed Tomography (CT) imaging agent; promoted probabilistic risk assessment (PRA) technology for petrochemical industry applications; finished safety assessment of LNG storage tanks without opening for CPC Corporation, Taiwan.

In the field of nuclear facilities decommission and radioactive wastes deposition, we have completed removal of biological shield for Water Boiler Reactor (WBR) and cleaning up the nuclear fuel manufacturing pilot plant; cleaning up of glove box highly contaminated by transuranium elements for decommission; establishment of test technology and verification mechanism for radio activities of wastes; design of dry-storage facilities and safety analysis; technology development of a complete set of equipment with adsorbent for contaminated dust collection; technology establishment for stabilization processing of spent uranium fuel; development of potential site study and facility safety evaluation technology for storage of low-level wastes in the country.

In the field of radiation application technologies, INER was the first in Taiwan to complete animal tests of our developed nuclear medicines, i.e., Tc-99m-MIBI for use as an imaging agent for heart and breast cancers and ^{188}Re-BMEDA-DXR-Liposome for use as a diagnostic drug for intestinal tumors, and pharmacological studies of nuclear medicines; application of molecular imaging technology to screening of new drugs (including Chinese herbal drugs); technology establishment for imaging optimization of micro Positron Emission Tomography (micro-PET).

In the field of new energy technologies, we have set up a 100 kW high concentration photovoltaic (HCPV) solar power generating system, developed 40W direct methanol fuel cell (DMFC) power devices, completed design, manufacturing and installment of a high-efficiency 25 kW commercial wind power generator as well as finished design and test manufacturing of blades for a 150 kW wind turbine. In addition, we have established a 10 kg/batch cellulosic ethanol test system and completed the design of a 1 ton/day (on feed stock basis) pilot plant. For the solid oxide fuel cell (SOFC) system, we have obtained a maximal single-cell power density of 550mW/cm^2, completed a portable hydrogen production system by ethanol reforming to be used for kW grade SOFC stacks, finished feasibility assessment of a sustainable integrated gasification

combined cycle (SIGCC) power supply system as well as completed assessment and analysis of the MARKAL-MACRO energy model.

In the field of environmental plasma technologies, INER has obtained the operation license for the established low-level radiation plasma burning and melting plant. We also have completed several projects including a demonstration setup of high precision roll-lift type plasma activation system that can be applied to surface modifications of plastic films and a variety of equipment items, a plasma gasification process and a 100 kg/h plasma gasification system for using biomass, a non-thermal plasma sterilization test platform, etc.

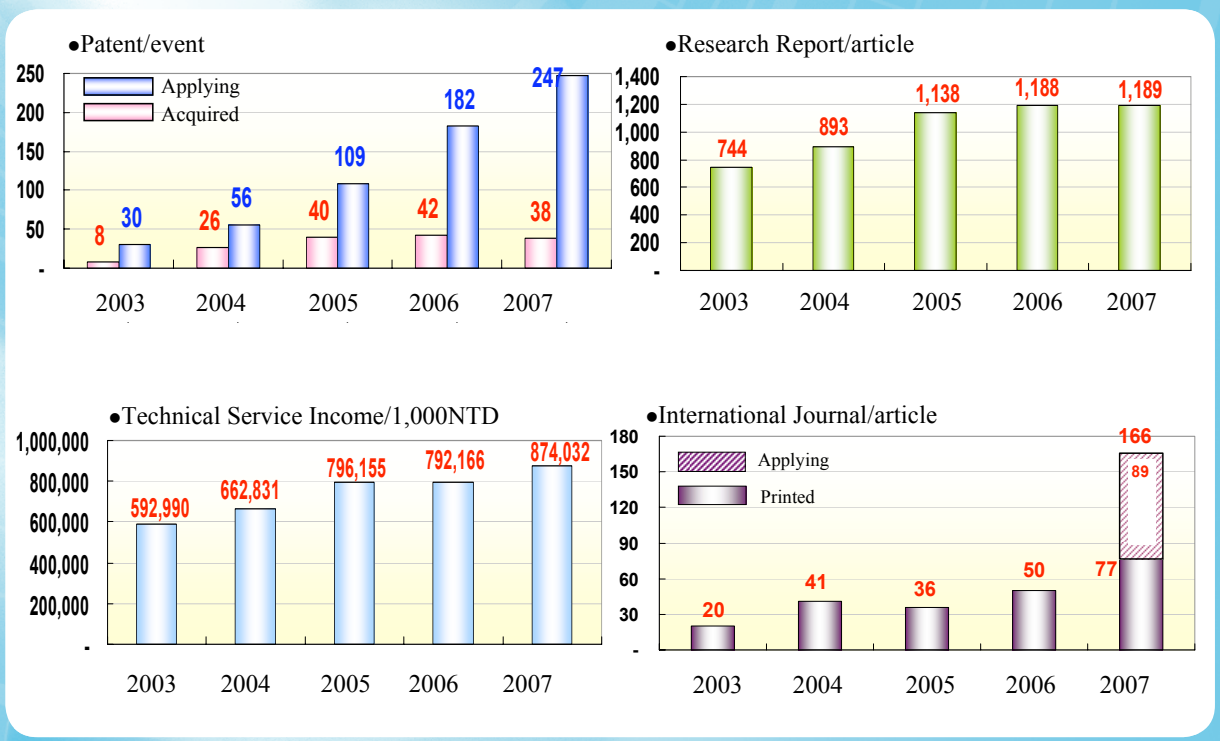
In addition to the performances in technical skills, in fulfillment of the targeted goals our key performance indicators (KPIs) show that the journal paper submissions have grown more than 20%, the invention patents have increased more than 30% and the royalty incomes have increased 2% compared to those of 2006. As results, INER has been evaluated by the National Science Council (NSC) to be one of the top R&D organizations (for both management and R&D performances) in Taiwan and awarded with prizes of excellent grade in two fields.

Looking forward to the year 2008, we pledge to devote more efforts to secure the nuclear energy safety of our country and significantly upgrade our R&D performances, actively participate in national-grade R&D projects, and accelerate the industrialization of our developed technologies. To become an excellent research organization is the vision for each and every member of INER. Therefore, in facing with important issues regarding to human development and environmental sustainability, in the future INER will develop innovation as a core and nature as a dear friend advanced technologies in order to solve the problems as well as to promote the well-beings for our people.

Abstract of Annual Key Performances and Achievements

The Institute of Nuclear Energy Research (INER) was established in 1968 and is under the administration of Atomic Energy Council (AEC), Executive Yuan. INER is the sole national institute in Taiwan commissioned for nuclear science studies. Since 2004, INER has actively integrated her R&D resources and set up three Technology R&D Centers and one R&D Support Center to take charge of the related matters. Among them, the Nuclear Safety Technology Center is responsible for conducting R&D on nuclear energy safety technologies, nuclear facilities decommission and radioactive wastes deposition technologies; the Radiation Application Technology Center is responsible for radiation biology and nuclear medicine applications; the Environment and Energy Technology Center is responsible for new energy technologies and environmental plasma technologies. In total, there are five main R&D fields and the key focus is on the development of practical solutions using system integrations.

Each INER's R&D project was carried out based on the plan made at the beginning of the year. The respective Technology R&D Center would set up a set of measurable key performance indicators (KPI) for each project based on the planned goals in order to maintain a high research standard and pursue the power for growths for ourselves. Then, the office of each Technology R&D Center was responsible for coordination and management so as to present the KPI data of the related R&D fields and push hard to achieve the goals. In 2007, INER has surpassed the targeted KPIs of the year with respect to publications in international journals, filings of invention patents, research reports as well as technical service and royalty incomes.



The 2007 annual key performances and achievements of INER are abstracted as follows:

■ Nuclear Safety Technology

The Nuclear Safety Technology Center (NSTC) visions itself to be a capable and unbiased technical center, a technical arbitrator at national laboratory level of excellency, and a reliable research institution that contributes to enhancing the public confidence on nuclear safety. In order to keep step with global renaissance of nuclear power, NSTC thus sets goals at continuously supporting the safety for operating NPPs and the quality for the constructing Lungmen NPP, establishing appropriate techniques to process nuclear wastes, and assisting the Atomic Energy Council (AEC) in their requirements to review and audit related regulation affairs. In 2007, NSTC submitted 52 patents applications, published 58 international journal papers and 598 internal technical reports, and received business revenue for about NT$ 582,866,000 and technical licensing fee at NT$ 1,997,000. Comparing with previous years, each of these performance indicators reflected substantial progress and attained various technical achievements, with typical examples briefly described as below.

In the area of nuclear safety, Chinshan NPP's 81 license renewal related scoping, aging management, TLAA, fatigue evaluation and application documents were finished, and a peer review conducted in the USA this June. Progressing about one year, Safety Analysis Report (SAR) of the spent fuel dry storage project of Chinshan NPP is nearly approved by AEC. Assisted by NSTC, the subcontractor, CTCI Machinery Corporation, of the canister manufactory is qualified by ASME as a N Certificate Holder. The Measurement Uncertainty Recapture (MUR) work of Kuosheng Unit 2 has been finished. The UFM for Unit 1 has also been installed and is conducting required tests at the end of 2007. Both units can raise about NT$ 100,000,000 electricity yearly. AEC has approved and issued SERs for the reports of RETRAN system thermal-hydraulic analysis model, ATWS safety analysis methodology and SBO safety analysis of Chinshan NPP. These reports will sufficiently support the MUR application. NSTC was contracted "Economic and Safety Evaluation for New Fuel Fabrication Services Bid for Nuclear Power Plant". The fuel vendor awarded the contract will provide new fuel fabrication services for next 10 years. The 126 spent control rods of Chinshan Unit 2 have been cut and pressed to reduce storage space, and the work of Unit 1 is expected to

be finished soon. The MOV verification test contract for Lungmen NPP has been awarded to NSTC. Comparing to the foreign quotation, it saves about 1 billion NT dollars. In 2006, the PRA team conducted a quantitative risk assessment (QRA) on the phase 1 LNG tanks at the Yung-An site of the Taiwan Chinese Petroleum Corp. (TCPC). The results had been reviewed and accepted by the Labor Affairs Council (LAC). The LAC granted the TCPC with 2 additional years of extension in March 2007, depending on the final results of the QRA of the LNG tank systems performed by INER. The TCPC saved more than 2 billion NT dollars of direct costs with the exemption of periodic inspections of LNG tanks. The QRA technique has demonstrated its effectiveness in helping managers to make decision on the base of associated risk information and to optimize the resource taking full consideration between safety and operation requirements. The PRA team prepared the continued project for the QRA on the phase 2 LNG tanks at the Yung-An site in 2007, and it is expected to be granted the QRA associated projects on the Earth-Covered Tanks (ECTs) at the refinery and the OL3 plants of the Formosa Petrochemical Company in 2008.

In radiation safety, NSTC used the ICP-MS technique to develop the measurement and analysis method for transuranium radionuclides with long half-lives. This technique saved us complicated chemical purification processes of the traditional alpha spectrum counting method. Meanwhile, NSTC completed performance evaluation of the radioactivity monitors, which measure the solid wastes that are contained in barrels to be released or delivered. NSTC also continued to work actively on development of radiological dispersal devices (RDD)/dirty bomb emergency preparedness technology and improve mobile detection technology for environmental radiation to meet national needs in anti-terrorism operations. In 2007, NSTC supported the Won-An No. 2 drill with its self-developed web-based GIS information integration management system, emergency preparedness data warehouse system, contamination diffusion dosimetry evaluation system, PC simulation on-line training platform as well as the mobile detection technology for environmental radiation. For the measurement standards establishment in the national standard laboratory, 19 comparison items of dosimetry and radioactivity were entered into the Appendix B of the BIPM (Bureau International des Poids et Measures) KCDB (key comparison database) and another 88 calibration services

items were entered into the Appendix C of the BIPM KCDB. In international comparison activities, NSTC hosted the APMP.RI(I)-K4 comparison and played the chairman of the Technical Committee on Ionizing Radiation (TCRI) of the Asia-Pacific Metrology Programme (APMP); both showed that Taiwan's radiation protection technologies have achieved the world-class level.

Nuclear facilities decommissioning and radioactive waste handling play important rolls in environment safety. Major achievements in 2007 are described briefly as follows. One of the three research reactors in INER, the Water-Boiled-Reactor (WBR) in building 019, was decommissioned. In the on-going TRR spent fuel stabilization operations, seven ruptured spent fuels have been transported into the hot cell and five of them have accomplished the oxidation procedure. The transuranic contaminated Unit 20 glove box and five large-scale process tanks with its subsidiary piping facilities were dismantled in the 016 laboratory. The UO_2 fabrication laboratory in building 021 and the solidification experiment facilities in the 039 laboratory have also been decommissioned and reused as non-radioactive controlled laboratory. For the radioactive waste recycling, 1,200 tons of concrete and 20 tons of metal from the WBR and 015K decommissioning procedure were qualified for clearance release, and 650 tons of concrete from the WBR biological shield were qualified to release as usual material. Furthermore, INER has obtained permission from the authority for the operation of, one of the five in the world, radioactive waste plasma incinerator, which is under test before get into operation. The metallic waste decontamination facilities in the 012 building have fulfilled 600 barrels annual operation target. The major function of the decontamination facilities is to collaborate with the clearance procedure for metallic waste recycling.

■ Radiation Application Technology

Both in the industrial development plan of "Challenge 2008 National Developing Key Plans" and "Two Trillion, Twin Star", bio-technology is listed one of the major intent industries the government focus on. In terms of this policy, the Radiation Application Technology Center (RATC) aims at the domestic clinical applications which provide the protection of the national health and early treatment among the related diseases. RATC developed medical radioisotope, new nuclear medicine, and irradiation therapeutic technology for both diagnosis and therapeutic demands, image fusion technology, technical service, created GMP and ISO-9001 (2,000) with its connected SOP, moreover, to promote the competitive ability of our country industry.

The RATC quantification accomplishments in 2007 contained: there were 187 research reports, 34 papers in international journal (31 papers in SCI), and both external and internal conference dissertations. Of the 34 invention patents, 6 cases had been licensed and franchised income of NTD 5,825,000. Revenue in approving qualified sales of new medicines and radiation service amounted to NTD 167,750,000. Acquired one chartered license for INER MIBI KIT and hold two domestic large-scale seminars. Annual performance was listed as following:

- Promoting technologies of isotopes producing: Beam upgrade for the ion source performance we achieved 8 mA at 2.5 kW arc power, the tellurium-alumina target was set up technologies to produce radioiodine isotopes, we completed an automatic radiopharmaceutical dispenser and developed process of new irradiation therapeutic Cu-64.

- Radiopharmaceuticals: Establishment of proteomic analysis system and technical platform for protein biomarker discovery. It could support us to discover the protein biomarkers of early liver cirrhosis and Alzheimer's disease and furthermore set up the diagnostic technologies and kits. We completed drug resistance of cells and its analysis combine with the Tc-99m-MIBI resistance applications thus it will be a good platform of sifting

new anti-cancer drugs. The results of radioiodinated annexin V induced cell apoptosis were as our anticipation, we set up the biodistribution, pharmacokinetics and imaging of ^{188}Re-BMEDA-Liposomes after intraperitoneal injection in a C26 Colon carcinoma ascites mouse model, the techniques of SOCTA-Herceptin and HYNIC-Herceptin to combine to HER-2/neu breast cancer receptors were successful set up, and we also developed procedures of labeling Re-188 SOCTA-Herceptin, QC analysis and animal experiments, the animal model of liver cancer cell line N1S1 inoculated to SD rats and therapeutic assessment of Rh-188 ECD/ Lipiodol in animals were developed. There was one member made a visit mission to the Drug Studies Unit, Analytical Division of UCSF, and NIDA of NIH to introduce bio-assay and techniques of metabolite of drugs and this will help us to setup a unique laboratory to authenticate both pre-clinical and clinical metabolite of radiopharmaceuticals, and furthermore we cooperated with Prof. Huang of University of North Carolina to clad radioisotope Re-188 into liposomal vaccine to cure lung tumors, and we signed a contract with the University Federal of Sao Paulo (UNIFESP) to extend Tc-99m TRODAT-1 kits as international cooperation.

- Molecule image and medical equipments: We successful developed a bi-functional animal molecule image system, micro PET/CT, for R&D new drugs, and upgraded the SSD to improve the image contrast of INER micro-CT, and a new system interface between operator and INER micro-CT was created, for simplify procedures of the experiments the technique for image quantification was set up. We complete program development and reconstruction of 2D radiography and 3D images. Round photomultiplier tube (PMT) was successfully developed to adjust the front-end electircal processor module before signal amplifying. For improving the reconstruction efficiency and images quality, there was one member made practical training to the PET research laboratory in M.D. Anderson Cancer Center, University of Texas for a month, and the mission included the design idea of the units of PQS PET detectors, conducting scintillation crystal, input/output signal processing, and signal interface. The introduction of new technology from Prof. Gary Wong, University of Texas was a low cost and globular unique PMT Quadrant Sharing technology.

■ Environment and Energy Technology

The major R&D efforts of the Environment and Energy Technology Center are focused on the development of environmental plasma, renewable energy and associated technologies. To implement these technologies, a series of small-scale testing, prototype and pilot plants as well as demonstration facilities, are being set up. This Technology Center will then foster those matured technologies to industry communities.

In the year of 2007, accomplishments made in this center include: publishing 62 international journal papers (57 SCI papers), 70 conference papers (18 international conferences) and 351 technical research papers, application of 155 invention patents, and endorsement of NDA agreements by 7 domestic companies for technology transfer, and income from commissioned projects and royalty of NT 110 million and 20 million respectively. The other achievements of 2007 are outlined below.

■ Environmental Plasma Technologies

On February 16, 2007, permission for commercial operation of "The LLW Plasma Incineration and Melting Plant at INER" was granted by the FMCA, Atomic Energy Council of R.O.C. Taiwan then became the fourth country possessing plasma melting capacity to treat low-level radioactive wastes after Russia, Switzerland and Japan. The novel technique of high-temperature measurement for thermal plasma using Alexandrite spectropyrometer has been well established at INER. The actual temperature of flame jets can be correctly measured in real-time, irrelevant to the distribution of emission spectrum from flame of thermal plasma and whether the plasma is in LTE state. Obviously, it would be a great benefit to monitor and adjust the plasma torch. The fabrication of porous soundproofing plates from plasma molten slag was also completed. The plate has a dimension of 30×30 cm^2, porosity of 55%, and bulk density of approximately 0.85 g/cm^3. In addition, the material has a soundproof level of E class, which would absorb a noise level of 42 dB. In order to study the lifetime of the electrode and gain the optimal condition of operation for plasma torch, the long-time testing platform has been installed as well. The modules of testing platform include gas-supply, cooling, power-supply, and safeguard subsystems.

Furthermore, a series of techniques of plasma diagnostics have been established. The large-scale hollow cathode plasma source driven by 350 kHz DC discharge has been developed. Due to its lower ionic energy compared to the pure DC discharge and the higher plasma density up to 5×10^{10} n/cm^3, enhancing the activation rate on the polymer films, it is very suitable for the industrial application. The MOS device forming high-K dielectric layer by PIII (plasma immersion ion implantation) makes the EOT (equivalent oxidation thickness) reduction as well as leak current reduction. This process thus presents a great potential to further reduce the scale of integrated device. The roll-to-roll plasma activation system has also been developed successfully and applied in the flexible raw materials for domestic touch-panel industry.

- Renewable Energy: In this project, an "Energy Demonstration Park at INER", including a 100 kW HCPV power generation demonstration system, a pilot plant for 10-kg grade Cellulosic Ethanol Production, and a height of 49m lattice type wind tower for wind turbine field testing, was set up. Additionally, hydrogen storage capacity of MOF materials developed by INER is over 4.7 wt% under room temperature and 6.9 MPa. As the pressure increases to 10 MPa, it is possible to have a storage capacity over 5 wt%, a rather high value among most international research organizations.

- R&D work on SOFC: The robust capability of stack design, component manufacture, sealing procedures, operation procedures, as well as cell/ stack performance test, has been well set up. The major accomplishments are briefly outlined. (1) The power density of INER-made MEAs either by traditional tape casting methods or Atmospheric Plasma Spraying techniques reaches 400~600 mW/cm^2 (800 ^{o}C), which is at the same level as the famous international organizations. (2) Screening test of 42 formula of noble metal honeycomb type reforming catalyst with ethanol was performed. The system hydrogen generation efficiency is higher than 60%, and it would suffice the requirement of a 1 kW SOFC system. Furthermore, the 960-hour durability test was executed for a revised ethanol-hydrogen production system with a system size reduction of 50%. (3) The glass-ceramic sealant material gc9, with proper physical and chemical properties and long-

term stability, has been employed for INER's stack. (4) A series of SOFC stack have been assembled and tested. The power output of a 25-cell stack, where InDEC's cells were used, reaches to 1008 W with λ equal to 1 and fuel utilization 48%.

- Wind Power Technology: The following accomplishments were fulfilled: (1) setting up an integrated software package system for wind potential evaluation and wind field forecasting in our High Performance Computer Cluster System, (2) developing 25kW wind turbine systems with both active and passive control designs, (3) designing a FRP wind turbine tail vane for yawing control and for over speed protection, (4) setting up a 50m high lattice type wind tower for wind turbine field testing, (5) developing and completing the test of the first homemade hundred kilowatt class wind turbine blade, (6) setting up the first homemade hundred kilowatt class dynamo test station for wind turbine, and (7) developing a 25kW wind turbine inverter with maximum power tracking and low speed kickoff functions.

- Power Base Load: This project is to establish the integral assessment of sustainable IGCC system, including system design, optimization of advanced process research, life cycle assessment and domestic energy system model. The evaluation time period for the energy model is from 2000 to 2050, which is adequate to reflect possible technologies and scenarios in the future. The energy model is suitable for evaluating mid-term and long-term energy plan. This plan has accomplished the theory framework and preliminary establishment of CGE model for evaluation new energy industry development.

- Photovoltaic System: The goal of this project is to establish domestic High Concentration Photovoltaic (HCPV) system technologies including manufacturing processes, assembling and testing of solar cells, encapsulating and qualification of HCPV module, developing of solar tracker, system integration and testing technologies, etc. The output power of one single module reaches over 100 W as the Direct Normal Irradiance (DNI) is 850 W/m^2. Tracking accuracy of the homemade 5 kW tracker is below 0.5°. Compliance with the testing requirement and standard procedure of IEC 62108, 13 out of 17 items for the qualification technology of HCPV module have been successively established.

■ Cellulosic Ethanol Production

The two-step pretreatment technologies including acid-catalyzed steam explosion and twin-screw extruder were established. The release efficiency of xylose from xylan in lignocellulosic fiber can reach up to 80%. These processes will be the design bases for the first instrument of acid-catalyzed pretreatment process with a feeding capacity of 1 tons/day in Taiwan. High solid reactor of enzymatic hydrolysis was also developed with a the solid content of hydrolysates over 20%. Investigation of simultaneous saccharification and fermentation process would result in a further reduction of capacity cost and reaction time. To enhance the fermentation efficiency of xylose, the adaptive yeast and its fermentation technology for xylose-to-ethanol were also developed. The ethanol yield of xylose fermentation was as high as 85%, which places this center at a leading position among international communities.

■ Conferences/Workshops hosted by INER

(1)The 2007 Taiwan Bioethanol Development Trend Workshop was held on Jan. 24, 2007. Outstanding domestic and international experts on micro-organism development were invited to present 8 papers to around 150 people in the workshop.

(2)The 2007 Taiwan Small Fuel Cells Workshop was held on June 21-22, 2007. In the workshop, internationally renowned companies, such as: Samsung, DuPont, Johnson Matthey, PolyFuel, ACTA, and CMR, participated and exhibited their latest development on the small fuel cell technologies.

(3)A meeting for the "INER MARKAL-MACRO Modeling Capability Establishment-Taiwan's 2000-2025 BAU scenario energy analysis" was held for peer reviews and discussions by review committee outside the INER.

■ International Collaboration

(1)A memorandum with Underwriters Laboratories (UL) was signed to develop a collaborative relationship on HCPV module validation, reliability analysis, safety issues, material degradation, and failure analysis.

(2)A R&D project of the low-voltage input, high-efficiency power conversion system was commissioned to the Virginia Polytechnic Institute and State University (VT), which is

known for its experience on power modulation and conversion design.

(3)A Non-Disclosure Agreement was signed with the American Polyfuel Company on the DMFC technology.

(4)A Non-Disclosure Agreement was signed with a NASA's strategically allied Working Group.

(5)A collaborative work with the University of California at Los Angelus (UCLA) was performed for the "high-density, high-uniformity plasma reactor system".

- Honors and awards: "The development and application of photovoltaic technology using compound semiconductor" was granted a Grade A distinguished research award by Technology Committee of Executive Yuan in 2006.

This year, we also have been evaluated by the National Science Council (NSC) as a research organization of grade "excellent" in two categories (i.e., atomic energy and environmental protection) based on the R&D performances, and INER is the sole research institute to receive such a high honor this year. Looking forward to the 21st Century, to become a leading world-class research institute is our perspective, the specific directions for our R&D efforts in the future are put forth as follows: (1) to accelerate the industrialization of our developed technologies as well as to actively transform into a leading R&D team of system technology in the world; (2) to participate in the national new energy R&D programs, to fully make use of our advantages on system integration, and to combine with the industrial strengths of our country so as to explore our natural resources as an island nation; (3) to take into account the international trends on nuclear renaissance, to accelerate the cleaning-up of our unused nuclear facilities, to develop technologies for reduction of decommissioned radioactive wastes, to develop optimization systems for deposition and storage of nuclear wastes, as well as to strengthen the studies on effects of earthquakes on the safety of nuclear facilities; (4) to integrate global useable resources, to focus on key issues of R&D, to expand international collaboration and cooperation, to lower the risks of R&D, as well as to promote the R&D performances and efficiencies.

R & D Activities

Nuclear Safety Technologies

Upon 40 years of devotion, INER has established as a sole research institution in Taiwan with an unique advanced nuclear technology. The major tasks include supporting governmental safety review and regulation, as well as enhancing operational safety and efficiency for nuclear power plants in Taiwan. As to the major issues of energy price and CO_2 emission currently confronting the domestic energy supply, nuclear power proves to be an efficient solution. INER will continue devoting to nuclear energy safety research in support of national energy planning and operational safety for nuclear power plants.

Major achievements during 2007 include the following : (1) supports AEC for the inspection of nuclear power plants in operation as well as under construction and for technical review of related reports ; (2) implements the "Time Limited Integrated Plant Assessment (TLIPA)" project contracted by Taipower in support of the license renewal process for Chinshan NPP. Upon approval by the regulatory body in the future, Chinshan plant can gain an additional 20 years of operational lives ; (3) assists Taipower to lead an engineering evaluation on NUR power uprate for Kuosheng NPP. After project completion, the generator output of each unit was increased by 20 MWe. This records the first power uprate achievement in Asia ; (4) develops a fundamental tool for the implementation of maintenance rule that will be a critical step towards improving the capacity factors via on-line maintenance ; (5) assists TPC in the evaluation of fuel loading service via a contract "Economic and Safety Evaluation for New Fuel Fabrication Services Bid for Nuclear Power Plant" ; (6) develops an emergency response support system for the Kuosheng NPP to assist TPC in enhancing its accident response capability during emergency condition of nuclear power plants ; (7) supports promoting the verification and audit for radiotherapy dosimeter that is vital to the carryout of quality assurance for medical exposures.

■ In Support of the AEC Over the Inspections and the Technical Report Reviews

》Lih-Yih Liao

In support of the the AEC over the inspection, 4 outage inspections have been executed for the operating nuclear power units and daily on-site inspections as well as periodic inspections were executed for the constructing nuclear power units. The aim is to discover the deficiencies so that quick corrective measures can be made. More importantly, the self regulation mechanism of the TPC will be enhanced to avoid the reoccurrence of the same mistakes. Two specific examples are illustrated below:

- In March 2007, a joined inspection of the AEC and the INER discovered that the 90° standard hook of RCCV wall shear bar was mistakenly cut by the constructor so that the function of the shear bar acting as an anchor was lost. As a result, the overall stress and earthquake retaining capabilities of the containment were impacted. Enforcement actions were imposed accordingly.

- In April 2007, a joined inspection of the AEC and the INER discovered that a plastic water bottle was embedded in the containment wall. Subsequent follow-up audits by the AEC have revealed that several hundred examination tables were not properly filled out. Enforcement actions were imposed accordingly.

In support of the AEC over the review of technical report, a technical team of the INER has been established to review the FSAR of the Lungmen nuclear power plants. The review team is composed of 53 staffs with diversified expertise. With respect to the technical report review of operating plants, more than 10 tasks have been performed. An example of an in depth technical review is illustrated below:

- During the review of the MUR of the Kuosheng nuclear power plant, a vendor provided topical report of the ultra-sonic flow meter was also submitted for review. It was found

that part of the Kuosheng plant specific calculation process was different from what in the submitted topical report. During the review discussion, the vendor indicated that the calculation methods in the submitted topical report are not conservative enough. In addition to that, one parameter used in the Kuosheng plant specific power uncertainty calculation needs to be corrected and the impact of this parameter is not negligible.

◎ Research Team:Lih-Yih Liao, Ren-Jai Liao, Yu-Chung Chen, Yih-Hsui Wu, Fong-Man Yang, Jui-Chin Chang, Chi Liou, Mei-Chia Shih.

■ License Renewal Process

》Shian-Shing Shyu

Based on US 10CFR54 regulation, License Renewal process utilizes methodologies such as Aging Management Review (AMR) and Aging Management Program (AMP) to evaluate the maintenance of the System, Structure and Component (SSC) in a nuclear power plant in order to be granted the extended operation license. To date, there are almost half of the nuclear units that have already been granted the license by USNRC.

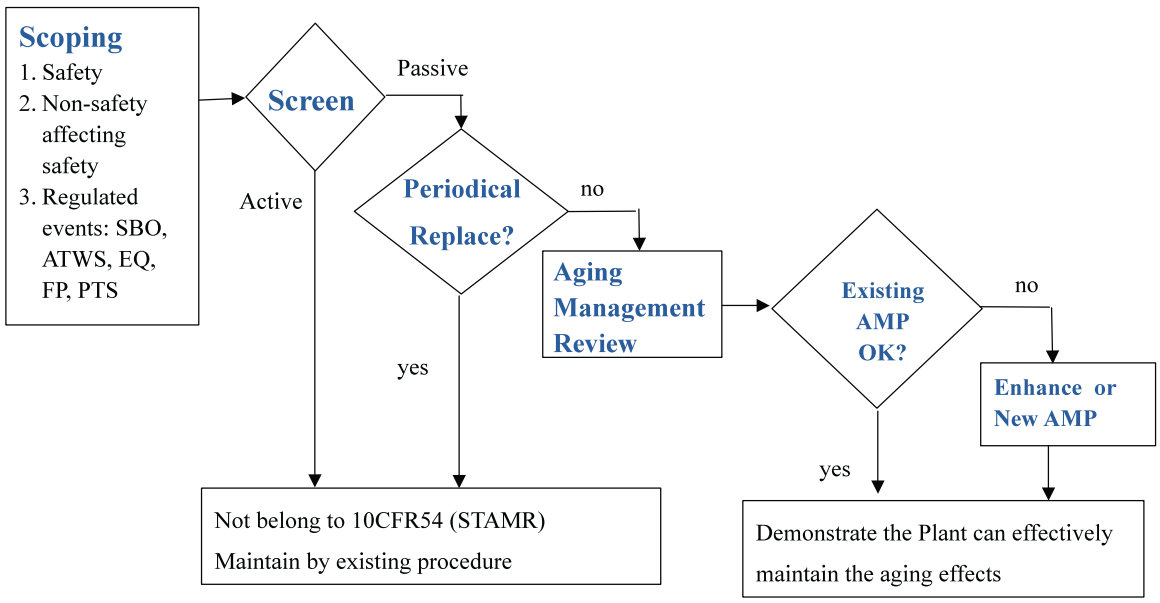
The methodology and process of license renewal is shown as Figure. The first step is the scoping process. Its criteria are 1) if it is safety related system, 2) if the malfunction of the non-safety related system will affect the safety related system, or 3) if it is a regulated event system, such as SBO (Station Blackout)、ATWS (Anticipated Transient Without Scram)、EQ (Environmental Qualification)、FP (Fire Protection)or PTS (Pressurized Thermal Stress). The second step is the screening. It identifies long-lived components. The short-lived components are excluded since they are replaced or maintained periodically. For long-lived components, the AMR is executed in accordance with Material, Environment, Aging Effect, and Program (MEAP) combination.

Another important aspect is the Time Limited Aging Analysis (TLAA). It analyze the life of the SSC. The main topic includes reactor related components, piping fatigue, and EQ

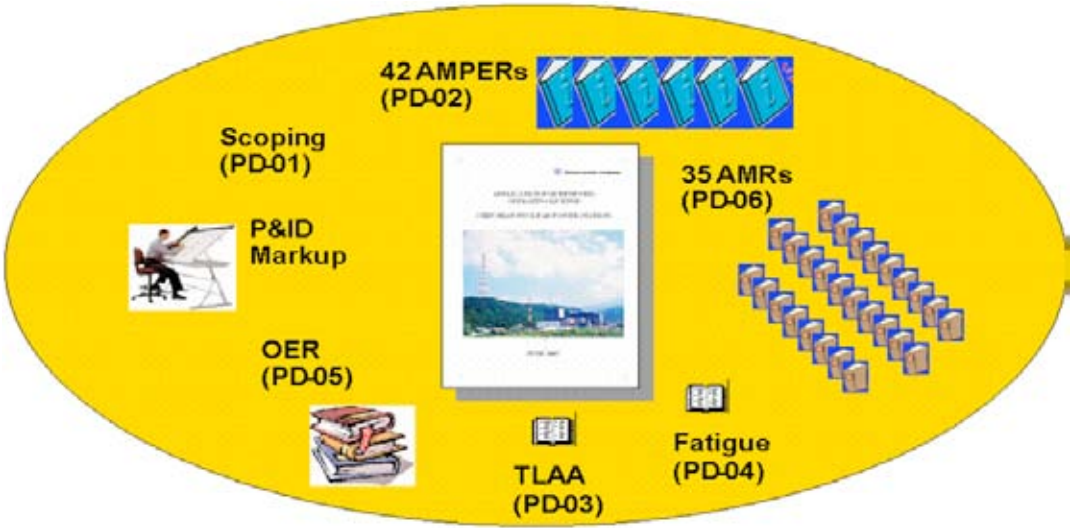
components. The results are summarized as one of the following: 1) CLB is valid for the extended life, 2) re-do the analysis, or 3) use a AMP to maintain the components.

INER was contracted the "Time Limited Integrated Plant Assessment (TLIPA)" project by Taiwan Power Company (TPC) to implement the license renewal process of Chin Shan NPP. The project team includes other domestic and foreign expertise organization, such as ITRI, E&C, and US Entergy Companies. The Chin Shan License Renewal Application (LRA) and other support documents were issued by the end of 2007 and been peer reviewed by other US license renewal experts. In the coming years, the TLIPA team will support TPC to answer the review comments issued by regulatory body to accomplish the first case of license renewal in Taiwan.

◎ Research Team:Yin-Pang Ma, Shian-shing Shyu, Chung-Kung Lo, Jien-Jong Chen, Ting Chow, Chung-Shing Chang, Jen-Hung Chen.



▲License Renewal Methodology and Process



▲Chin Shan License Renewal Application (LRA) and other Support Documents

■ Measurement Uncertainty Recapture Power Uprate at Kuosheng Nuclear Power Station

》Chin-Jang Chang

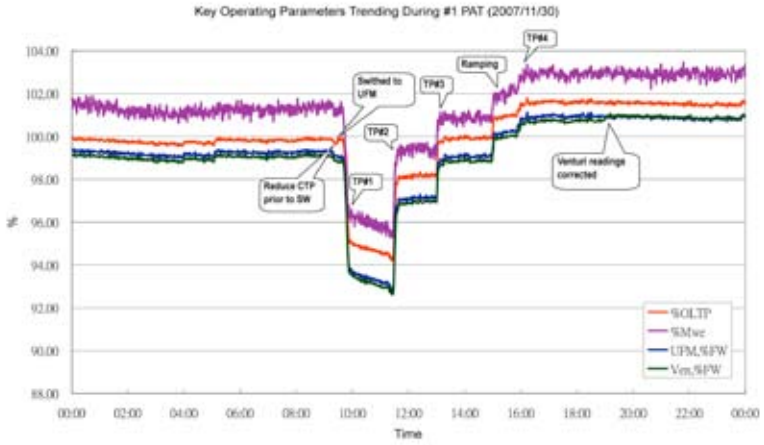
Many nuclear power stations around the world have been implemented power uprate operation for improving their efficiency and economic performance. In the United States, licensees have applied for implementing power uprates since 1977 as a way to increase the power output of their plants. To date, the USNRC has approved 113 power uprates which have added approximately 4900 MWe to the nation's electric generating capacity, the equivalent of about five large nuclear power plants. Also, there are 34 nuclear units (35 cases) have adopted the more delicated feedwater flow measurement for Measurement Uncertainty Recapture (MUR) power uprates since 1999. MUR power uprates are achieved by implementing enhanced techniques for calculating core thermal power. This involves the use of state-of-the-art feedwater flow measurement devices, i.e., using the ultrasonic flow meters (UFMs), that reduce the degree of uncertainty associated with feedwater flow measurement and in

turn provide for a more accurate calculation of core thermal power. The analysis margin, previously fixed at 2%, was required in Emergency Core Cooling System Evaluation Models (ECCS) in accordance with the requirements set forth in the code of 10CFR50 Appendix K. In 2000, the regulator made a change to 10CFR50 Appendix K to allow licensees to use a power uncertainty less than 2 percent in ECCS evaluation. The change provides licensees with the option to apply a reduced margin for ECCS evaluation. Due to a lot of successful MUR uprate cases implemented at international nuclear power stations, INER has assisted Taipower to lead the engineering evaluations, UFM procuments, licensing, implementation and power ascension test (PAT) since 2005.

To implement MUR power uprate, the key elements are the evaluation and selection of UFM and the detail engineering evaluations. Based on the evaluation results, INER completed the design changed documents, DCR-K1-3617/K2-3618, to address the changes of documentation, hardware, I&C setpoints. Also the MUR power uprate safety analysis report, a thermal power uncertainty calculation and the commitments have been attached with the design changed documents to apply for the licensing approval of 1.7% power uprate. After AEC approving the licensing requests, Kuosheng nuclear power station (KSNPS) has conducted the 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 counted as 20 MWe. KSNPS not only is the first nuclear power station in Taiwan to be granted for power uprate operation, but also the first power uprate case in Asia.

◎ Research Team:Lain-Su Kao, Yeong-Jen Su, Ruey-Yng Yuann, Gung-Huei Chou, Yea-Kuang Chan, Chin-Cheng Huang, Hou-Chin Chu, Jan-Ru Tang, Wu-Hsiung Tung, Feng-Jung Chang, Chung-Hsien Liang, Jin-Sen Chung, Jong-Rong Wang, Chung-Yen Lee, Chiao-Hsiang Tsai, Cheng-Yen Wang,Yung-Muh Yang, Jien-Jong Chen, Hui-Chen Lo, Pi-Chun Wei.

▲The UFM System (Caldon LEFM CheckPlus) Installed at Kuosheng NPP



▲The Power Ascension Test and Switchover at Kuosheng NPP Unit 1

■ Development of the Fundamental Tools for Implementation of the Maintenance Rule

》Jyh-Der Lin

It is the responsibility of the nuclear utility to keep their equipment in a reliable condition to ensure the safe operation of the reactor, which is also crucial for good economic performance.

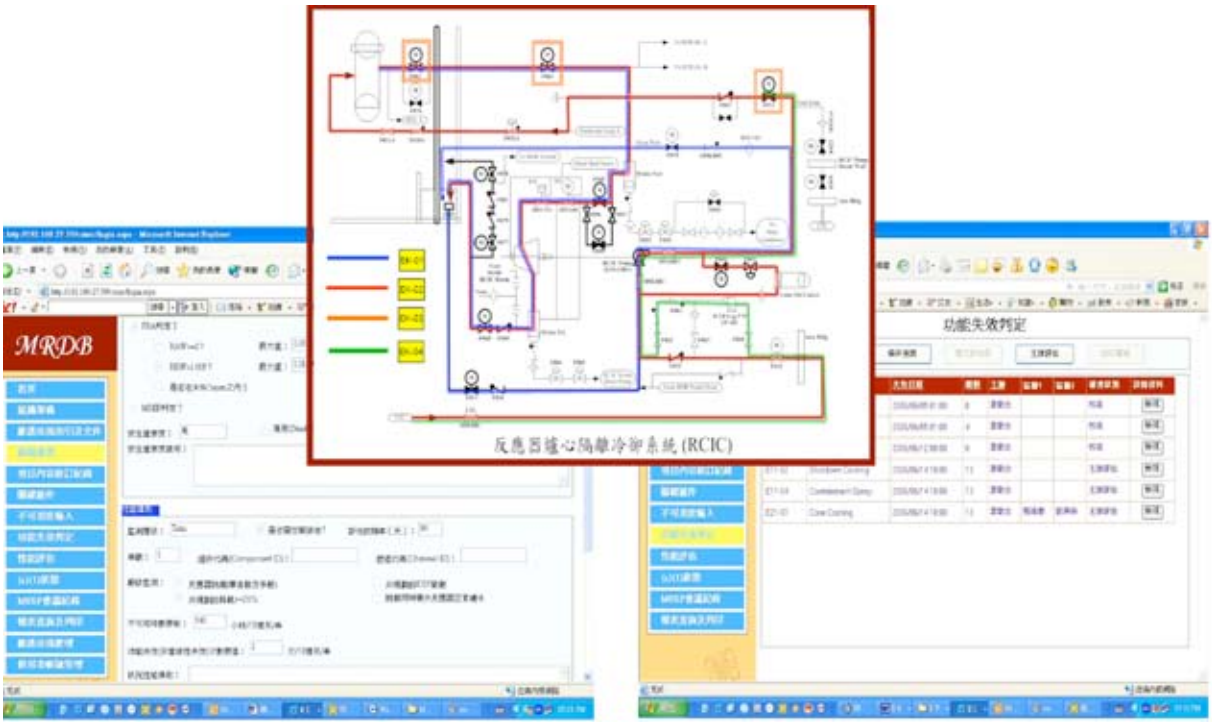
The Maintenance Rule is one of the few regulations that are associated with maintenance of the nuclear power plants. It requires the plants to monitor the effectiveness of the maintenance activities to ensure all the equipment will be able to perform their intended safety functions when needed. The Taiwan Power Company has declared their policy to implement the Maintenance Rule from the beginning of 2008, for the objective to future rolling on-line maintenance.

By the Maintenance Rule, performance criteria shall be established for each of the scoped-in system functions according to their safety significances as quantified indices to measure the effectiveness of the associated maintenance activities. The indices may be the reliability or availability or both, or some indices to show the specific conditions of the equipment. When it happens that the equipment can not meet the performance criteria, the plant shall take appropriate corrective measures to return the equipment back to the reliable status. The rule also requires the plant to evaluate the configuration risk before any safety significant equipment is taken out of service for maintenance. Since the implementation of the Maintenance Rule involves various sections in the plant and there exists the need to consider the current practices during the transition, a web-based database embodied with the required process is urgently necessary. Based on the mature quantitative risk assessment capabilities, INER helps each of the operating plants to decide the importance of their scoped-in equipment in terms of risk significance and develop the maintenance effectiveness monitoring process. INER develops the application database software with name abbreviated as MRDB to streamline the process which has been in test run for almost a year at these plants. It comes out with satisfactory results and the expectations to fulfill the requirement of the Maintenance Rule.

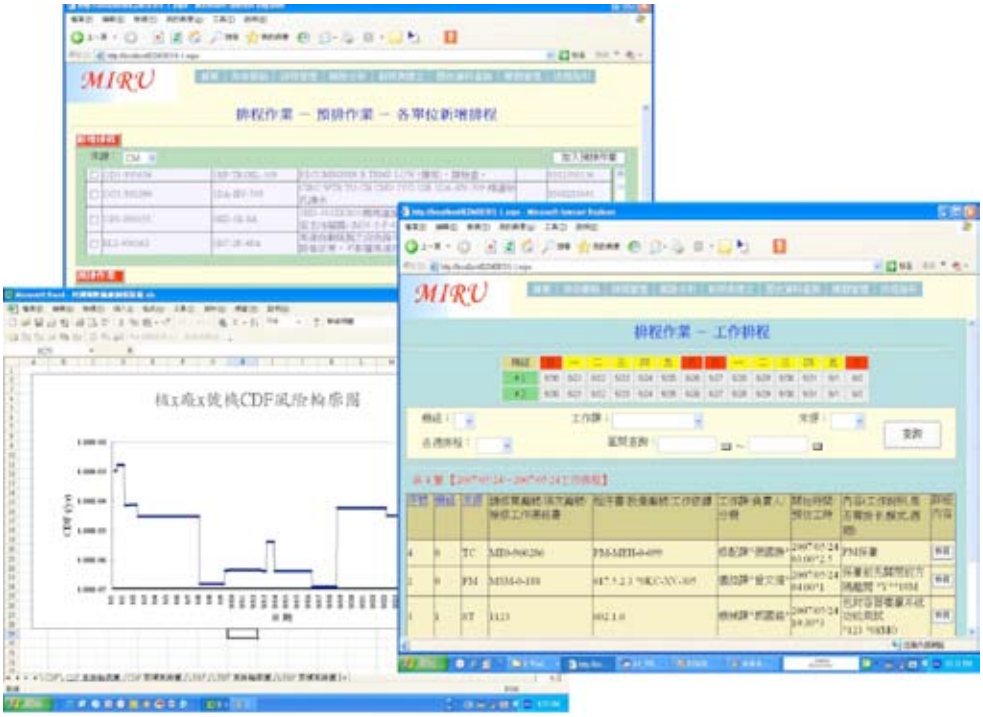
INER also develops a software tool called maintenance integrated risk utilities (MIRU) that can be used in the on-line maintenance scheduling and risk assessment process. The MIRU serves as a platform for the plants to plan their daily maintenance activities and perform the risk assessment in the future rolling on-line maintenance under the so-called (a) (4) requirement of the Maintenance Rule. The implementation of routine on-line maintenance will

be a critical step towards improving the capacity factors and thus further enhancement of the performance of nuclear power in Taiwan.

◎ Research Team:Chung-Kung Lo, Pi-Lin Hsu, Shang-Tzu Ho, Jui-Yang Wu, Ching-Hui Wu, Jui-Cheng Hsu, Pei-Chen Lu, Po-Jung Chiu, Kuan-Fu Chen, Jyh-Der Lin.



▲The Maintenance Rule Database (MRDB) System



▲The Maintenance-Integrated Risk Utilities (MIRU) Software

■ Economic and Safety Evaluation for New Nuclear Fuel Fabrication Services Bid for Nuclear Power Plants

》Shyun-Jung Yaur

Taiwan Power Company (TPC) has invited bids (call BID hereinafter)for a new Nuclear Fuel Fabrication Services Agreements for Chinshan, Kuosheng and Maanshan nuclear power plants from 2006 to 2007. These agreements will cover the new fuel requirement for about next 10 years for Chinshan, Kuosheng and Maanshan nuclear power plants. The total fabrication fee is estimated to be multi-hundred million dollars.

It is very important to choose the best fuel fabrication service which can provide not only

reliable fuel but also the most economic fuels as substantial increase in the price of uranium ore. The process of the BID includes two stages of Bidding Instruction (BI) preparation and proposal review. INER has been consulted and technical support in both stages.

INER has to prepare the supplement of BI with all the information of plant characteristics, fuel design data, and 3 reference cycles design including loading pattern and control rod pattern for all plants. For Chinshan and Kuosheng plants, INER also has to prepare the Design Input Information for LOCA and Transient Safety Analysis.

INER reviews not only the thermal hydraulic and mechanical performances of the fuels proposed but also the safety analysis methodologies and results to justify the important core design criteria. Besides, INER builds the core analysis models for new fuel types to evaluate the cycle energy and thermal margins independently from the transition cycles to the equilibrium cycles to confirm that all the design results meet the BI and to propose the fuel cycle length adjustment.

◎ Research Team: Wu-Hsiung Tung, Chung-Hsing Hu, Weng-Sheng Kuo, Cheng-Hsien Chou, Jau-Tyne Yeh, Chien-Hsiang Chen, Tai-Ting Huang, Tzung-Yi Lin, Hsien-Chuan Lin, Li-Chuan Chang, Tian-Tzuoh Lee, Yao-Nan Huang, Yung-Hung Teng, Hui-Ting Yang, Hsiao-An Shu, Lain-Su Kao, Jan-Ru Tang, Yang-Kai Chiu, Hon-Chin Jien, Chih-Chung Chung, Shih-Chung Cheng, Wan-June Chiu.

■ Development of Kuosheng Emergency Response Support System

》Shih-Jen Wang

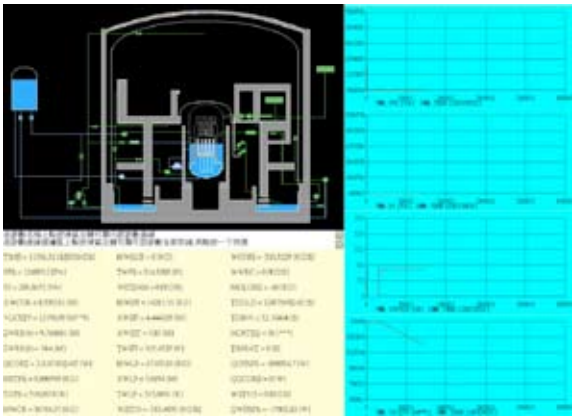
Emergency Response Support System (ERSS) is developed to assist accident evaluator during emergency condition of nuclear power plants. Many advanced countries have developed this kind of system. In Taiwan, Institute of Nuclear Energy Research (INER) is planning to develop an advanced ERSS system for emergency response use. 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 accident including accident status display system, accident diagnostic system, accident management monitoring system, and accident database. This system is developed using Visual Basic for easy understanding and revision. Accident status display system expresses the important plant data in a dynamic fashion for easy understanding the plant status. In addition, it provides trend plots of important plant parameters. Accident diagnostic system converts the plant data during accident into simple core status by applying the knowledge of severe accident phenomena for easy understanding of the core status. Accident management monitoring system couples the plant data with the flowchart of severe accident management guideline, indicating the correct status. With this system, the accident evaluator can monitor the accident management status of the plant. Accident database performs various accident sequences in advance and stores the associated sequence of events, source term, and important trend plots. This database can provide important information at the beginning of similar accident sequence. In addition, a standard format of the plant information and evaluation results including the plant status can be generated automatically for reporting use. The accident diagnostic system and accident management monitoring system are new products of this ERSS.

In order to promote the accident evaluation capability during emergency situation, a proto type emergency response support system of Kuosheng nuclear power station was developed at INER. This system was successfully applied in the emergency response exercise in August 22, 2007. It is composed of five sub-systems, including accident status display system, accident

diagnostic system, accident prediction system (MAAP5), accident management monitoring system, and accident database.

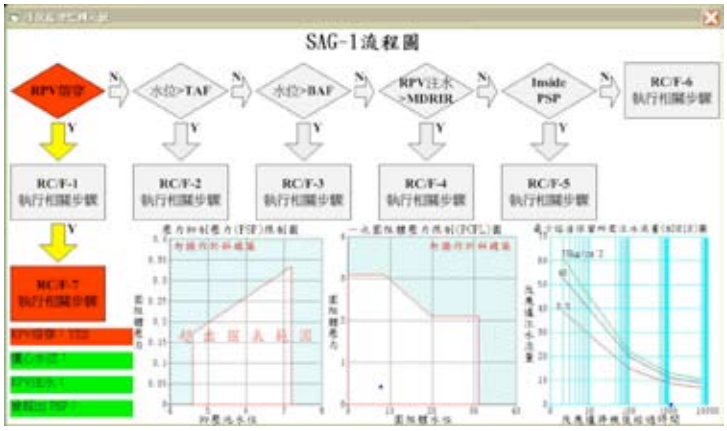
This proto type system will be improved, including more functions, connecting with plant data, to achieve the supporting capability during accident. Meanwhile, this system will be applied to other nuclear power plants in Taiwan, enhancing the emergency response capability.

◎ Research Team:Shih-Jen Wang, Wen-Shing Wang, Chang-Jian Wang, I-Ming Huang, Shen-Yuan Fann, Min-Jie Chang, Jin-Sen Chung.

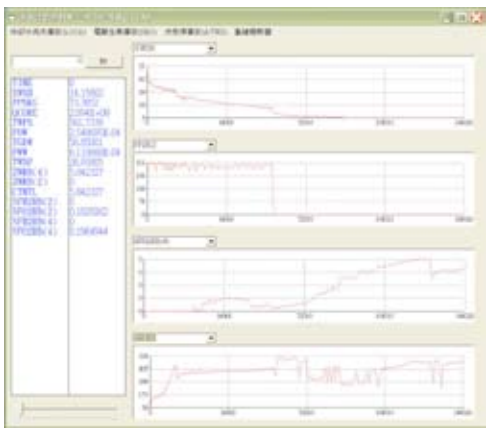


▲Accident Status Display System

▲Accident Diagnostic System



▲Accident Management Monitoring System



▲Accident Database

■ Establishment of Measurement Standards and Verification Technique for Radiotherapy Dosimetry

》Jeng-Hung Lee

To elevate radiological diagnosis and treatment quality and reduce the radiation exposure received by patients, the Atomic Energy Council of Taiwan issued Standards for Medical Exposure Quality Assurance in December 2004, which provided that health care organizations should prepare medical exposure quality assurance plans for their radioactive materials, equipments capable of producing ionizing radiation or related facilities and report to the Competent Authority for approval and implementation. For now, the medical exposure quality assurance program is focusing on radiotherapy instruments and was already enacted on July 1, 2005.

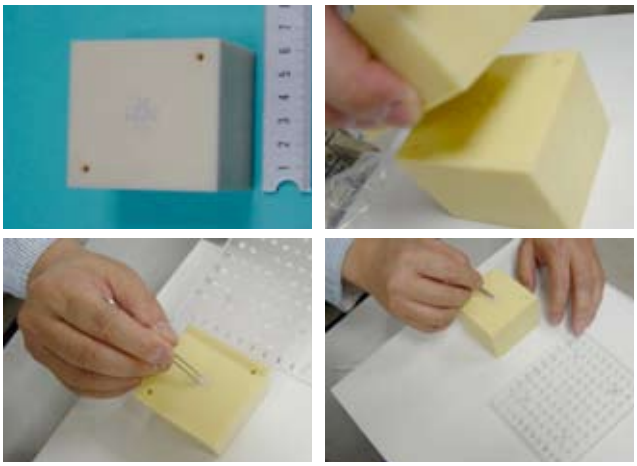
The reference dosimetry in clinical high-energy photon beam lies at a critical point in the overall chain in radiotherapy quality assurance, In Taiwan, the reference dosimetry for medical accelerators photon beams is traditionally performed using ionization chambers that have been calibrated by the air kerma standard for ^{60}Co at INER and the various conversion factors quoted from the American Association of Physicists in Medicine (AAPM) Task Group 21 (TG-21) protocol (1983). The AAPM published a new TG-51 external beam dosimetry protocol in 1999 based on the use of an ionization chamber calibrated in terms of the absorbed dose to water standard for ^{60}Co beam. To meet the domestic demands for ionization chamber calibration recommended by AAPM TG-51, INER fabricated a graphite pancake ionization chamber as the primary standard of the absorbed dose to water for ^{60}Co. With the establishment of the absorbed does to water standard for ^{60}Co, INER got to be the pilot laboratory of the Asia Pacific Metrology Programme (APMP) comparison on the absorbed does to water for ^{60}Co in 2007; there are 10 National Metrology Institutes (NMIs) from the Asia-Pacific, Europe and South Africa areas participating in this comparison.

Besides, INER designed a polystyrene solid phantom and used TLD-100 chips and Monte Carlo code to investigate an accurate and convenient quality assurance programme for the

purpose of dosimetry quality assurance in Taiwanese radiotherapy centers. A total of 21 beams in 10 radiotherapy centers were checked. The dose verification differences under reference conditions for ^{60}Co, high energy X-rays of 6 MV, 10 MV and 15 MV were truly within 4% and that proved the feasibility of applying the method suggested in this work in radiotherapy dose verification. In the future, INER will not only realize the calibration traceability system of radiotherapy dosimetry but also fulfill the Competent Authority's requirements by moving verification and audit of radiotherapy dosimetry in Taiwan to carry out related operations of medical exposure quality assurance and ensure the quality of more than one million of radiotherapy treatments for domestic oncology patients per year.

◎ Research Team:Jeng-Hung Lee, Bor-Jing Chang, Chien-How Chu, Shi-Hwa Su, Ming-Yuan Shih, Yi-Chun Lin, Ming-Tsung Hsieh, Kuang-Sung Chiu, Chun-Liang Chen.

▲Primary Standard of the Absorbed Dose to Water for ^{60}Co and the GraphitePancake Ionization Chamber



▲Radiotherapy Dosimetry Audit Device Designed by INER (including solid phantom and TLDs)

■ The Development of Data Warehouse and Online Exercise System for Radiological Dispersal Devices (RDD) Emergency Response

》Chung-Hsin Lu

In the digital era, efficient database can serve to fast acquire needed data from rapid information circulation and massive data exchange. Radiological Dispersal Devices (RDD) data warehouse was developed to store annual drill experience, documents, video data, and etc. By systematic data management and update, different emergency response departments could get identical information. The integrated data warehouse provides the function of data search and learning to responder in usual. In emergency, this system will sort related reference efficiently to assist with decision making.

For the purpose of developing and integrating online exercise system, this project has re-built the Information Integration and Management System for RDD Emergency Response which completed in 2006. The core technology of AJAX (Asynchronous JavaScript And XML), similar with Google™ Map, was applied to the new system. The advantage of this technology was to promote system efficiency, to lower server loading, and to depart system from expensive commercial GIS kernel server.

Online exercise system was designed based on the standard operation procedure (SOP) of emergency response, and provided an interactive platform for simulation of exercise progress. Beside the regular real exercise for RDD emergency response, this system brings a new way to train responder to practice response procedure and working items. The multi-persons multi-sites virtual real-time exercise could be achieved only via web-browser and network connection. The great benefit of this system is to spend the least resource to accomplish exercise training.

◎ Research Team:Chung-Hsin Lu, Bor-Jing Chang, Chao-Hui Huang, Tsung-Liang Pan.

■ Development and International Cooperation of Digital Instrumentation and Control System Technology for Nuclear Power Plants

》Ming-Huei Chen

The application of digital instrumentation and control (I&C) system in nuclear power plants is an unavoidable trend due to the rapid progress of electronic and computer technology. However, there are still many safety concerned topics related to nuclear regulations including software quality and reliability, common mode failure assessments, human factors engineering, commercial grade item dedication, hardware/software qualification, and cyber security issues, etc. In order to buildup the localized technology infrastructure, INER continues its efforts in research and application of nuclear digital I&C system technology in 2007.

Moreover, INER continues to join the COMPSIS (Exchange of Operating Experience Concerning Computer-based Systems Important to Safety at Nuclear Power Plants) international cooperation program hosted by OECD/NEA, and INER is responsible for completing the pilot analysis of the digital system failure events for the project. INER is also promoting international cooperation with Germany, Korea, and USA regarding digital I&C system topics, and hosted the 2007 Seminar on Qualification of Safety Digital I&C Systems in Nuclear Power Plants.

The major achievements in technology development include: (1) Development of software safety analysis methodology and software fault-injection test platform applied for the ABWR HPCF system (High Pressure Core Flooding System). (2) Development of integrated operator performance measurement technique and human-system interface design change evaluation checklist for advanced main control room. (3) Development of software configuration management system technology. The major achievements in technology application include: (1) Technology support to Taipower Company to complete the factory acceptance validation tests of Unit#1 DCIS system (Distributed Control and Information System) and perform parallel software safety verification of the HPCF system for Lungmen project. (2) As regard to the

digital upgrade of operating nuclear power plants, I&C system upgrade project planning for the Maanshan nuclear power plant which greatly enhance the application of localized digital I&C technology.

◎ Research Team: Cherng-Tsong Kuo, Ming-Huei Chen, Shaw-Cuang Lee, Wu-Yueh Cheng, Tsung-Chieh Cheng, Hong-Yih Yeh, Chung-Lin Lee, Wen-Chung Lu, Yu-Chin Chi, Shu-Yen Li, Chien-Fu Huang, Tzu-Chung Yenn, Chong-Cheng Hsu, Hao-Wu Huang, Huei-Wen Hwang, Li-Hsin Wang, Yuan-Chang Yu, Ben-Ching Liao, I-Hsin Chou, Cheng-Tao Li, Szu-Yin Kuan.

▲Safety I&C System Factory Test

▲Human Factors Engineering Evaluation

Decommissioning of Nuclear Facilities

》Chien-Liang Shih

In 2007, INER's achievements in the area of nuclear facility decommissioning were fruitful. Major achievements include (1) planning for the dismantling of TRR reactor, (2) decommissioning of phased-out nuclear facilities in INER, (3) solid waste clearance and deliverance, and (4) development of an Integrated Information Management System for nuclear facility decommissioning. Furthermore, INER continues its efforts to stabilize TRR metal fuels, and to collect uranium powder in the fuel pool.

■ The Underwater Measurement Technique for Plutonium Content in Spent Fuel

》Ming-Chen Yuan

The spent fuel rods of Taiwan Research Reactor (TRR) had been stored in the pool for more than 20 years. Most of the canisters that contained the spent fuel rods are very fragile because of oxidization. These spent fuel rods should be stabilized in order to be safely stored for a long time. However, the IAEA required that the content of Pu in these rods should be verified by means of practical measurement methods before they are processed with stabilization. For this reason, INER worked with LANL to develop the spent fuel plutonium coincidence counter, which is an underwater technique for measuring the Pu content in the rods before they are removed from the pool.

The spent fuel plutonium coincidence counter is abbreviated as SPCC. In this collaborative project, LANL provided detectors, signal measuring instruments and the software for analyzing the measurement results. INER, on the other hand, designed and fabricated the coincidence counter and performed the on-site measurements.

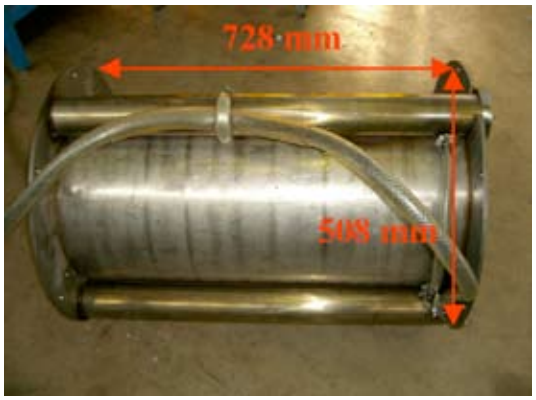
The SPCC system mainly detected the neutrons from spent fuel rods. For the metal rods of INER, neutrons came from U-238 and Pu-240. Before calculating the total Pu content, we had to know the radionuclides composition contained in the rods as well as other parameters such as detector efficiency. The fuel rod was then detected section by section (every 30 cm) to obtain the neutron counting rate of each section.

Firstly, INER calculated the radionuclides composition with the ORIGEN-2 code and burnup rate of each rod. LANL calculated the detection efficiency of the SPCC system for neutrons with the MCNP-X simulations. The calculated results were verified from the rod that has never been irradiated. Finally, the data from the actual measurements were utilized to evaluate the Pu content in the rod.

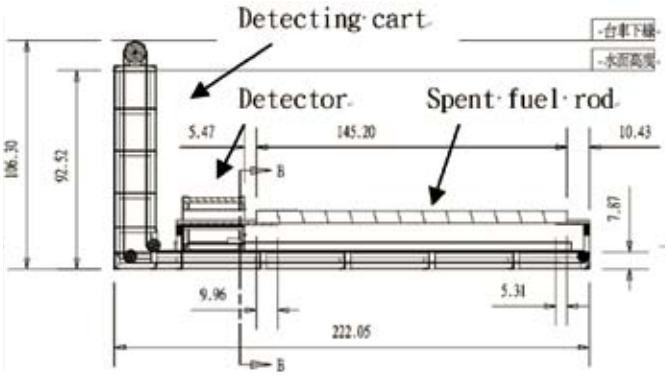
In reality, the measurement result of the rod No. LFC-1017 showed that the SPCC had a

measurement uncertainty of 4 % for Pu-240, a measurement uncertainty of 11 % for the total Pu content. These results only differed from INER's report values to IAEA by about 1 % which meant good agreement and completion of the system. The spent fuel rods which have been measured and verified can then be sent to the hot-cell to be processed with stabilization.

◎ Research Team: Ming-Chen Yuan, Cheng-Si Tsao, Ling-Huan Chiao, Chung-Sheng Chen, Ming-Tsung Hsieh.



▲Appearance of Detector Set



▲Cross-sectional View of the Detecting Instrument (Unit:inch)

■ Planning of TRR Reactor Body Dismantling

》Lun-Hui Lee

TRR reactor and its biological shield were completely moved to building 074 in 2002 for safe storage. The decommissioning plan was approved and a dismantling permit was issued on April 23, 2004 by AEC. The plan stated that the decommissioning work should be completed in 25 years (before 2028), in which the reactor and the biological shield should be dismantled.

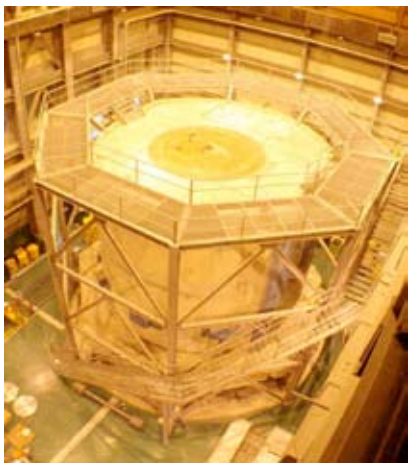
The reactor body is a major part of the reactor. Besides its complicated structure, it is highly contaminated. As the result, a complete and deliberate plan is essential to perform safe dismantling that meets the regulation requirements within the limited time. The execution

of the project was divided into three steps namely planning and technology development, simulation testing and dismantling engineering. Currently, it is in the first step. The main tasks in 2007 include compiling the data of TRR and establishing the 3D digital models of the reactor body.

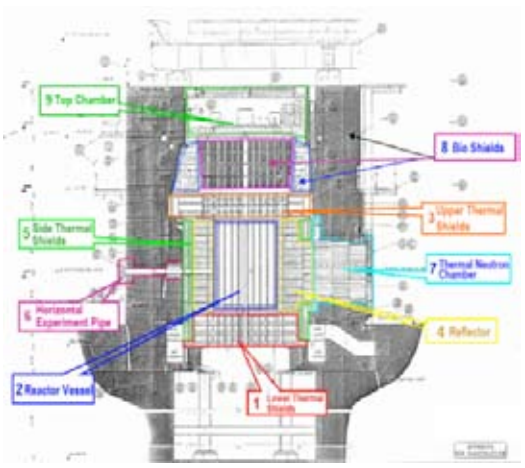
The compiling work basically transformed the historical data and documents of TRR construction, operation, shutdown, and relocation into digital forms systematically. A data searching system was built up which not only serves as a tool to provide reference information for the future decommissioning work, but also a good way to preserve the data. This certainly will be a representative and valuable database for the nuclear development in Taiwan. The construction of 3D digital models is the first step of applying 3D simulation technology to reactor dismantling. The models were constructed entirely based on the engineering blueprint. It will be beneficial for dismantling method development, dynamic simulations, waste evaluation, space route planning and personnel training.

Besides the physical dismantling work, local dismantling techniques such as (1) gross activity evaluation technique, (2) decontamination technique, (3) cutting technique, (4) remote operation and loading system development, (5) waste management, (6) radiation protection and safety evaluation technique, (7) digital 3D simulation technique, etc., will be developed in this project. This will set up an example for nuclear reactor decommissioning domestically.

◎ Research Team:Horng-Bin Chen, Lun-Hui Lee, Tsai-Fei Chu, Yi-Chang Chen, Ru-Jye Shuai.

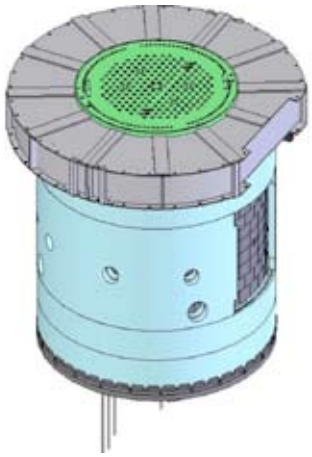


▲Safe Store of TRR Reactor Body



▲Components of TRR Reactor Body

▲TRR Data Searching System



▲Constructed 3D Models of TRR Reactor Body

■ Decommissioning of Phased out Nuclear Facilities in INER

》Chien-Liang Shih

In 2007, INER has continued the dismantling of Unit 20 glove box and five large liquid waste tanks for the radiochemical laboratory in Building 016. Moreover, the decommissioning or cleanup of uranium dioxide fuel manufacturing laboratory in Building 021, biological shield of water boiled reactor(WBR) in Building 019, and decontamination laboratory as well as solidified waste quality testing laboratory in Building 039 have also been carried out in 2007. After the decommissioning or cleanup plans of facilities mentioned above have been approved by AEC, INER begins to implement the dismantling tasks according to procedures in the plan.

The decommissioning of Unit 20 glove box and five large liquid waste tanks in Building 016 was completed in October, while the cleanup of laboratories in other three Buildings was completed on May, September and December, respectively. After decommissioning, free spaces of 200, 560, 400 and 300 m2 in area have been made available for other usages.

In accordance with the "Solid Waste Deliverance Operation Plan" approved by the AEC in May 2007, the dismantled wastes generated from decommissioning of the four Buildings have been classified, segmented, separated and measured. With scrupulous measuring and quality control procedures, most of these wastes could be free released. For Building 016, four boxes with volume of 31.5 m^3 have been saved. The total wastes produced from the dismantling of Building 021 are about 18 tons, and more than 17 tons of the wastes can be free-released. The dismantled concrete blocks of the biological shield in Building 019 weighs 643 tons. A total of 611 tons of the concrete blocks have been delivered as gravel in November and only 11 tons have been identified as low-level radwaste. As for Building 039, the total wastes from decommissioning add up to 10 tons. Only less than 100 kg of the wastes have been identified as low-level radwaste.

◎ Research Team:Horng-Bin Chen, Chung-Shin Lee, Wen-Jang Lee, Chen-To Tsai, Wen-Lain Lo, En-Tian Tenq, Ching-Shih Liu, Te-Wen Chu, Yu-Ying Chen, Kou-Ming Lin, Cheng-Hsien Fang, Chien-Liang Shih.

▲Unit 20 Glove Box in Building 016 Before Dismantling

▲Unit 20 Glove Box in Building 016 After Dismantling

▲Before Dismantling of WBR Biological Shield in Building 019

▲After Dismantling of WBR Biological Shield in Building 019

▲Before Cleanup of Room 110 in Building 021

▲After Cleanup of Room 110 in Building 021

▲Decontamination Laboratory in Building 039 Before Cleanup

▲Decontamination Laboratory in Building 039 After Cleanup

■ Solid Waste Clearance and Deliverance

》Jyi-Lan Wuu

To reduce storage pressure, promote waste recycling and ensure radiation safety in the environment, INER has adopted two measures namely “deliverance” and “clearance” respectively for treating general solid waste and the radioactive solid waste with activity or specific activity that falls into the category of clearance.

“Deliverance” is intended for handling solid waste produced from general constructions, routine maintenance which is expected to be free from contamination. For this purpose, the deliverance limit (80 Bq/kg) in the “Solid Waste Deliverance Operation Plan” set up by INER is 20 % more stringent than the most rigorous stipulation (100 Bq/kg) in the “Regulations on Clearance Level for Radioactive Waste Management.” To protect the public health as well as the environmental quality, solid waste cannot be handled as general waste unless they have gone through rigorous screening/inspection and the measured activity is below the deliverance limit. This “Solid Waste Deliverance Operation Plan” was approved by the regulating authority on May 16, 2007.

“Clearance” was performed based on the “Regulations on Clearance Level for Radioactive Waste Management”. Several multi-stage measuring techniques and processes have been developed in advance by INER. Such techniques include surface dosage scanning, surface contamination analysis, and whole-drum specific activity measurement. Each operation has rigorous quality control and verification processes. The “Release Plan for the Dismantled Concrete Blocks of TRR Wet Storage Tank” and the “Clearance Plan for Temporarily Stored Metal with Very Low Level Activity” proposed by INER had been reviewed and approved by the authority on April 20 and Oct 31, 2006, respectively. After completing the preparation work of project planning and personnel training, INER began the measuring processes for both Deliverance and Clearance. It is expected that the performance of such measure could significantly reduce the cost needed for waste storage and disposal.

◎ Research Team: Chien-Liang Shih, Jeng-Jong Wang, Jyi-Lan Wuu, Wen-Lain Lo, Hsun-Hua Tseng, I-Hsin Chou, Chung-Wu Yang, Chin-Hsien Yeh, Huang-Sheng Chiu, Hui-Mei Peng, Kuo-Yuan Chang, Mao-Chen Liu, Cheng-Tao Li, Feng-Jung Chang, Chung-Zen Lin, En-Tian Tenq, Tzonq-Liang Pan, Ching-Ho Yang, Hsiu-Ya Chang, Yue-Wei Chang, Chun-Fu Mai, Sheng-Hsing Peng, Li-Chih Lo, Tyng-Jun Lai.

▲Release Operations of Concrete Blocks Dismantled from TRR Wet Storage Tank

■ Developing Integrated Information Management System of Nuclear Facility Decommissioning

》I-Hsin Chou

After TRR was shut down in January 1988, INER began the decommissioning project to dismantle its expired nuclear facilities step by step. For this reason, Integrated Decommissioning Information Management System (IDIMS) was developed to ensure dismantling safety and to record all activity data during the decommissioning project. These data recorded involve activities such as, licensing, pre-treatment, radiation measurement,

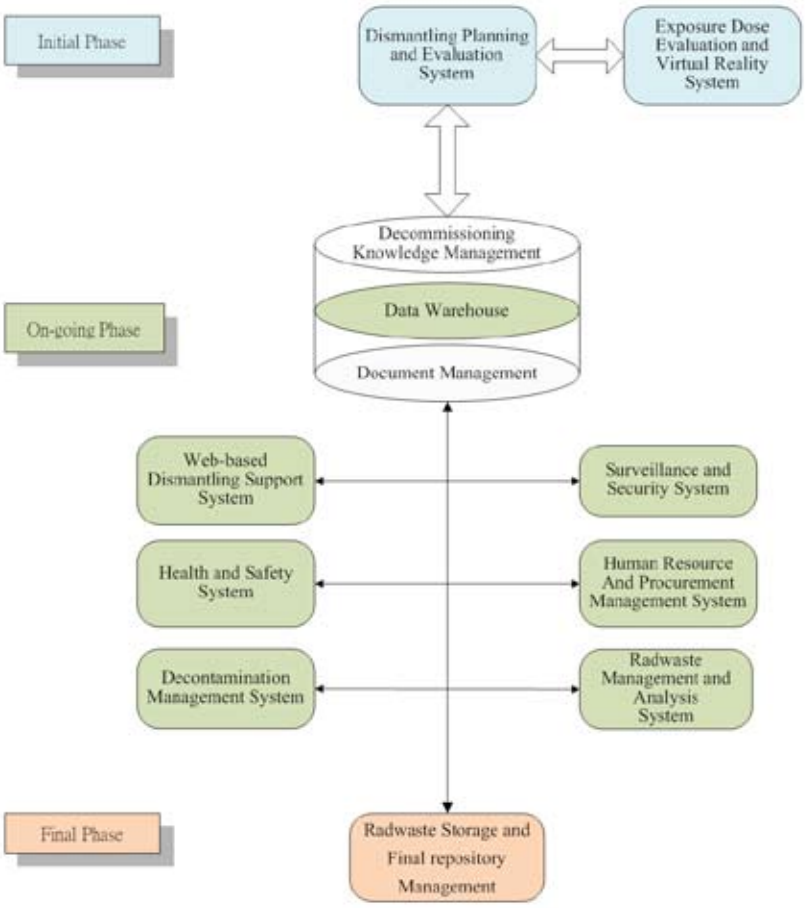
dismantling & decontamination, clearance technology, and radwaste management.

By taking suggestions from the IAEA, the decommissioning project was carried out in three stages namely initial stage, on-going stage, and final stage. In the initial stage, decommissioning planning/evaluation and dose evaluation/virtual reality simulation systems were proposed for the pre-project planning. For the on-going stage, decontamination management, dismantling support, surveillance/security, human resource/procurement, radwaste management, and clearance management systems were suggested. As for the final stage, radwaste storage and final disposal systems will be provided.

We have completed several systems such as web-based dismantling support system, surveillance & security system, health physic & safety system, air & radiation monitoring, radioactive waste analysis system and so on. To meet the requirement of "TRR Wet Storage Tank Concrete Blocks Release Plan", our Clearance and Release Management System (CRMS) was developed in 2007. CRMS provides more detailed records and descriptions for clearance and release activities which include practical data and experiments in planning, measurement, scanning, sampling and release. Its aim is intended to reduce radiation concern of public and nuclear regulating authorities.

In order to build up a knowledge databank for decommissioning, we also developed the Decommissioning Knowledge Concept Map (DKCM) to collect valuable information and technologies during the course of the project. The collected information comprise dismantling technology, cutting technology, decontamination methods, detection equipment, dose assessment, site restoration, waste management, radiation monitoring, clearance and final disposal. It is anticipated that DKCM will be an important reference for the future decommissioning of nuclear power plants in Taiwan.

◎ Research Team:Yi-Chong Chou, Pan-Hsi Chang, Shiu-Ju Yang, Cheng-Tao Li.



▲System Architecture of IDIMS

▲Web-based Dismantling Support System

▲Clearance and Release Management System

▲Decommissioning Knowledge Concept Map

■ Development and Application of Radwaste Management Technology

》Ching-Liang Chen

The INER over the years has been striving towards the goal of improving radwaste management performance, developing core technologies, such as radwaste volume-reduction, treatment, decontamination, storage, disposal, etc., and establishing reliable, state-of-the-art, technologies and local facilities that will meet the requirement of safe radwaste management and can be applied in domestic as well as international industries. To ensure public safety and protect the ecological environment, INER, as demanded by the Atomic Energy Council (AEC), is also responsible for the management of small-source radwastes generated from the usage of radioactive materials by various medical, agricultural industrial and research organizations.

The major works carried out in 2007 include development of strippable gel-coating technology for surface radioactive decontamination, practical applications of radwaste treatment technologies, volume reduction of spent control rod blades for Taipower's nuclear power plant, technology development for the performance and safety assessment of spent nuclear fuel final disposal, establishment of the safety assessment technology for the cavern type disposal of low-level radwastes, development of the integrated low-level radwaste treatment system, etc.

■ Development of Strippable Gel-coating Technology for Surface Radioactive Decontamination

》Jen-Chren Chung

Traditional decontamination agent for treating radioactive waste usually contains strong acid or alkali chemicals, such as phosphoric acid, sulfuric acid, nitric acid, fluorboric acid, potassium permanganate or sodium hydroxide to improve its effectiveness. After prolong operation, the large amount of spent decontamination agent must be further treated. However,

the treatment may not be so easy owing to the complex content of the spent decontamination agent; as the result, more time and higher costs are required for the treatment. To minimize the amount of the waste and reduce the radioactive dosage on the contaminated surface, a strippable gel-coating technology was developed in this study. Conventionally, this gel-coating technology is applied as protective layers to prevent industrial objects from contamination and collision. However, in the present study, the emphasis is on the decontamination of contaminated surface, therefore, different gel preparation formula is needed.

Various chemical components were used to prepare a decontamination gel, which includes mixing a blend of polymers, characteristic additives and decontamination reagents. After preparing the decontamination gel, it was coated on the contaminated surface with a brush or a spraying tool at a temperature between 10 and 40°C and left for 3 to 24 hours to allow the formation of a strippable film. The film can show contaminated areas on the surface and the contaminants are stuck in the film by physical adsorption and chemical chelation. Hence, the contaminants are decontaminated by simply removing the film. In addition, this strippable film also provides a barrier to prevent further surface contamination and avoids contaminant diffusion. These advantageous characters may protect operators in site away from the contaminated spots and allow them to carry out the decontamination more effectively.

A series of tests have been completed to verify the decontamination efficiency. Based on the experimental results, we can conclude that more than 95% of the surface contaminants are removed after treated with the strippable coating film. This method will be applied to remove surface contamination of metal waste generated from nuclear facility in order to fulfill the goal of decontamination and waste reduction in the future.

◎ Research Team:Jen-Chren Chung, Tsong-Yang Wei, Kou-Ming Lin, Che-Nan Chen.

Decontamination Efficiency of the Strippable Film on Contaminated Metal Surface

Co-60			Sr-90		
Before decon.(μg)	After decon.(μg)	Participation factor(%)	Before decon.(μg)	After decon.(μg)	Participation factor(%)
12.6	<0.02	>99	12.4	0.48	96.1
12.8	<0.02	>99	12.4	0.50	96.0
104.8	0.58	99.4	103.0	5.10	95.0
104.8	0.82	99.2	103.0	2.88	97.2

▲Surface Decontamination for Co-contaminated Material using Strippable Gel-coating Technology

■ Application of Radwaste Treatment Technology

》Yih-Ping Chen

The Chemical Engineering Division of the Institute of Nuclear Energy Research (INER) has long been devoted to radwaste treatment research and developed several technologies, such as High Efficiency Solidification Technology (HEST), Total Organic Carbon (TOC) Removal Technology, etc. which have been applied to the Taipower Company demonstrating substantial benefits. This year (2007), the technologies were applied in the *Establishment of Waste Solidification Process Control Program for Maanshan Nuclear Power Plant (NPP)* as described in the following.

The radioactive sludge waste in Maanshan NPP has to be stabilized by solidification for safe storage. To ensure that the quality of solidified waste conforms to regulations, INER was commissioned by Maanshan NPP to conduct the Solidification Process Control Program (PCP). In the project, 48 sets of solidification recipe have been formulated and a total of 1,200 solidified samples were created according to the composition of waste. Subsequently, quality tests (compressive strength, water resistance, weather resistance, radiation resistance) were carried out for these solidified samples and 44 solidification quality evaluations were completed. All the results fit in with the criteria stated in Article 6 of *Regulations on Final*

Disposal of Low Level Waste and Safety Management of the Facilities. Furthermore, an optimal formula was selected to perform solidification on the authentic waste and the quality of solidified waste was well proved.

◎ Research Team: Yih-Ping, Chen, Jiing-Guang Tyen, Wan-Fen Huang.

Quality of Solidified Waste of Sludge in Maanshan NPP

Item number	Compressive strength (kg/cm^2)				
	1	2	3	Average	Std. Dev.
R4B	43	37	40	40	3
Item number	Radiation resistance (kg/cm^2)				
	1	2	3	Average	Std. Dev.
R4B	35	38	33	35	3
Item number	Water resistance (kg/cm^2)				
	1	2	3	Average	Std. Dev.
R4B	48	48	49	48	1

Item number	Leaching index		
	Co-60	Cs-134	Cs-137
R4B-A	12.6	9.06	8.45
R4B-B	12.5	9.13	8.63
R4B-C	12.5	8.99	8.39

■ Volume Reduction of Spent Control Rod Blade for Nuclear Power Plant

》Ching-Wei Yang

In BWR nuclear power plants, the space of spent fuel pool for spent control rod blade (CRB) storage is limited. Therefore, it is necessary to perform spent CRB volume reduction in order to free more storage space for the subsequent CRBs discharged during plant operation.

The Institute of Nuclear Energy Research (INER) has developed specific technique for volume-reducing spent CRBs. Due to the relatively lower radioactivity, the velocity limiters of CRB can be separated first by a specially designed cutting machine and placed into standard waste barrel after removing it out from the pool. The compressing machine was designed

to compress the cruciform blades of CRB, which reduces its volume. Finally, a container is designed to accommodate 6 compressed blades.

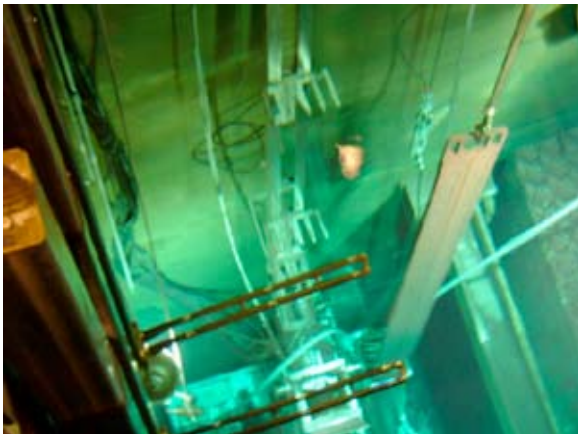
This volume-reduction technique has been successfully applied to Chinshan nuclear power plant (NPP). In addition, a unique technique, incorporating a C-shape cramp around the compressed blades, was developed to overcome the bouncing-back problem encountered for some compressed blades caused by the irradiation hardening effect. On the other hand, a standard procedure was established for the loading of velocity limiter into the waste barrel. A standard waste barrel can accommodate more than one velocity limiters, which also minimizes the radiation exposure to the operating personnel.

Some outstanding performances of INER's spent CRB volume-reduction technique applied in unit 2 of Chinshan NPP are summarized as follows:

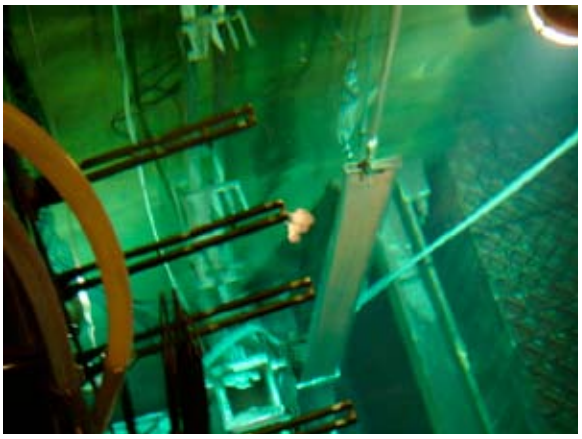
1.The number of waste barrels used was reduced from 130 to 38.
2.The background radiation level from the surface water of spent fuel pool was 5 μSv/h, which is much lower than that reported previously (10 μSv/h).

◎ Research Team:Heng-Shiung Sheu, Chen-Chzu Peng, Den-Ren Chen,Chain-Sing Tom, Tsu-Han Cheng, Chun-Ming Wu,Ming-Liang Hsu, Fu-Jiun Lin, Yuh-Chyi Wen,Chung-Chich Sun, Yung-Kuang Hu, Fu-Chun Chiang,Ching-Hsien Liu, Tsumm-Rong Chu, Shi-Chien Hsu, Chao-Dan Lee, A-Lai Chung, Yeou-Yuan Lee, Su-Kew Chen, Rong-Kae Lain, Cheng-Hsin Ho, Chin-Cheng Huang, Ti-An Hu, Yung-Neng Cheng, Yu-Tang Yang, Shenq-Horng Lee, Hua-Thai Huang, Chi-Fu Liu.

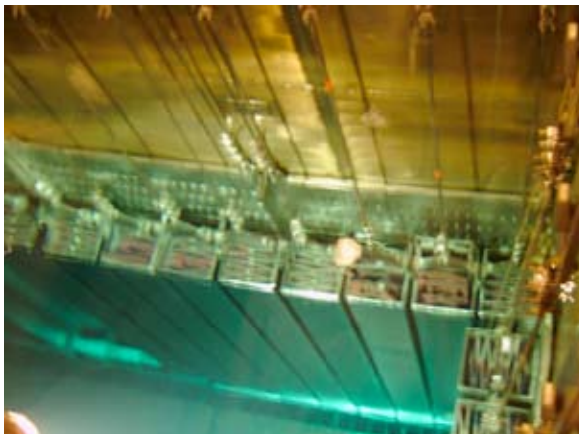
▲The Loading of CRB Velocity Limiter into the Waste Barrel



▲The Loading of Compressed CRB Blade into the Container



▲The Loading of Compressed CRB Blade with C-shape Cramp into the Container



▲The Container Loaded with Compressed CRB Blades Hanged Inside the Spent Fuel Pool

■ Technology Development of Performance and Safety Assessment of Spent Nuclear Fuel Final Disposal

》Ching-Fang Shih

In accordance with the regulation for radioactive waste management, the purpose of spent nuclear fuel final disposal (SNFD) is to assess applicable site geology characterization for site investigation and the development of assessment technology. According to the proposal "Spent Nuclear Fuel Final Disposal (2006)" approved by Atomic Energy Council, Taiwan, that scheduled from 2005 to 2055, the project is divided into five phases in sequence including "Characterization and Evaluation of the Potential Host Rock", "Candidate Site Selection and Approval", "Detailed Site Investigation and Test", "Repository Design and Safety Analysis" and "Repository Construction". In 2009, the major goal for the final disposal project is to complete "SNFD Preliminary Technical Feasibility Assessment Report, SNFD-2009", which is regarded as the foundation for future development. Based on the existing geological data, spent nuclear fuel characteristics, as well as the international experiences, technical development project at the current stage is split into several subprojects of near-field, far-field, biosphere, system integration, and disposal system database which facilitates the development of performance and safety assessment technologies for long-term spent nuclear fuel disposal that meet the required regulations.

- Performance and safety assessment of near-field

  It verifies the vertical and horizontal emplacement assessment models with an analytical solution and international case. Under the conditions of reference scenario, the radionuclide release rates assessed by vertical and horizontal emplacement models were performed. The effects of groundwater velocity, porosity and diffusion coefficient of buffer on the radionuclide release rates from near field to far field are also discussed.

- Performance and safety assessment of far-field

  It develops the method of generating discrete fracture model and conduct the assessment of radionuclide discharge in far-field by the nominal and variant case. Upon the completion of these two parts, it reaches the achievement for addressing the potential

function that handles "Characterization and Evaluation of the Potential Host Rock Stage" to assess the research of performance assessment, especially for the advanced research in the far-field.

- Radiation assessment of biosphere

  According to ERB1A/1B of BIOMASS 6/IAEA, the drinking water well scenario caused by radionuclides released into aquifer, radiation assessments of biosphere were conducted. Using the drinking water well scenario, the construction of conceptual model in the hypothetical site is completed.

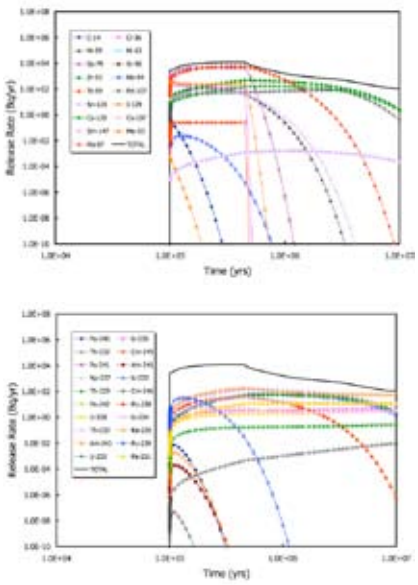
- System integration of performance and safety assessment

  Summarized achievement of the studied area, especially for hydrogeological model, was used to perform the research of near-field, far-field and biosphere. Integrated system is set up for the linkage of far-field and biosphere.

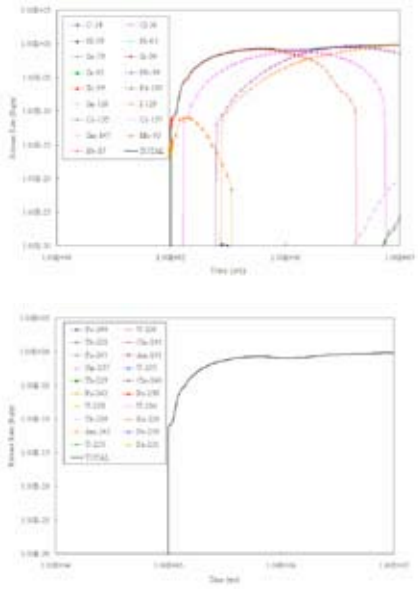
- Information system development of performance and safety assessment

  The software requirement specification of the information system was identified. By adopting Entity-Relationship Model and database normalization, the analysis and design of performance/safety assessment database were accomplished. The information system interface was also analyzed. The results could serve as the references for future development and design of the spent nuclear fuel final disposal performance/safety assessment information system. In the future, through the utilization of internet web browser, this information system, such as text descriptions, graphic/table records, R&D achievements, and data, etc., may come in handy for the project members.

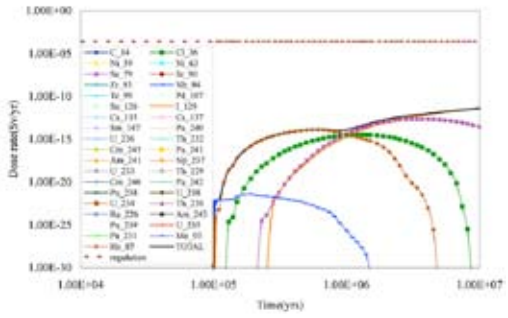
◎ Research Team:Ching-Fang Shih, Wen-Shou Chuang, Fu-Lin Chang,Li-Min Chi, Shin-Jon Ju, Cong-Zhang Tong, Li-Hao Wu, Chin-Lung Chen, Po-Lin Wu, Ching-Chang Chang, Chen-Chang Lee.



▲The Near-field Radionuclide Release Rate of Vertical Emplacement Base Case Analysis

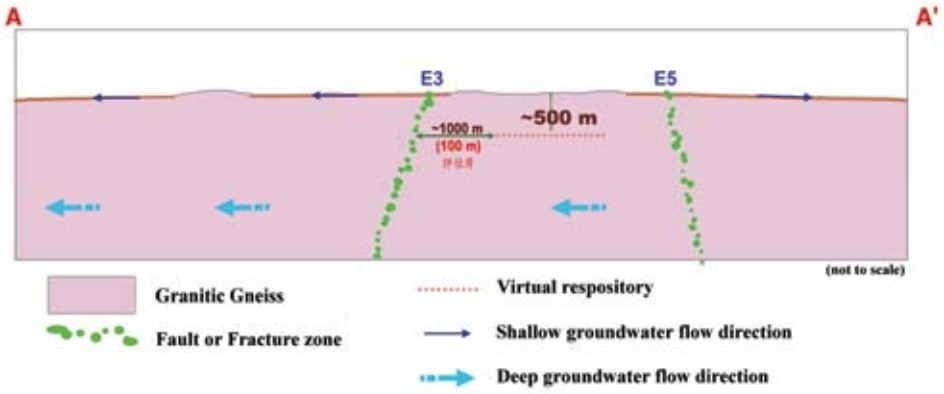


▲The Far-field Radionuclide Release Rate (vertical emplacement in near-field)



▲The Biosphere Radiation Analysis Result (vertical emplacement in near-field)

▲The Information System Development of Performance and Safety Assessment Home Page



▲Hydrogeological Model of Hypothetical Repository

■ Establishment of the Safety Assessment Technology for the Cavern Disposal of Low-level Radioactive Wastes

》Ching-Fang Shih

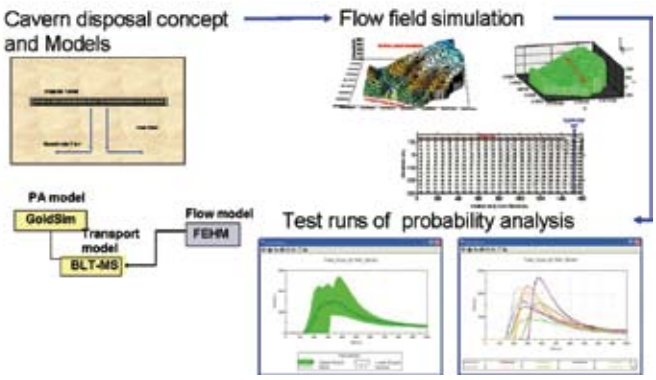
Based on the "Act on Sites for Establishment of Low-Level Radioactive Waste Final Disposal Facility", the authorities in concern should complete the site selection for the low-level radioactive waste (LLRW) repository in 2011 and the repository will begin operation in 2016, To help the AEC in performing the reviewing process, INER continues to carry out the study on LLRW disposal and safety assessment.

In the year of 2007, probabilistic performance assessment models for the concept of cavern disposal were constructed by utilizing software such as FEHM for far-field nuclide transport calculation, BLT-MS for near-field nuclide transport calculation, and GoldSim as a total system assessment platform. Other major R&D tasks of INER including LLRW characteristic assessment, waste acceptance criteria establishment, radionuclide releasing scenario development, and alternative disposal methods, etc. were also performed.

In laboratory experiments, INER continues to carry out the R&D of engineering barrier material and disposal container; for instance, the application of clay materials in the disposal facility, as well as the development of high-performance concrete disposal container for special occasions. Several kinds of strength tests for the High Integrate Container (HIC) have been assessed so far.

The R&D results can benefit further activities in site selection, facility design, and license application review for LLRW disposal in Taiwan.

◎ Research Team:Wen-Shou Chuang, Fu-Lin Chang, Li-Min Chi,Shin-Jon Ju, Ching-Tu Chang, Cong-Zhang Tong, Li-Hao Wu, Chin-Lung Chen, Ching-Fang Shih, Po-Lin Wu, Ching-Chang Chang, Chen-Chang Lee.



▲The Safety Analysis Module of LLW Cavern Disposal

▲Strength Tests of High Integrate Container (HIC)

■ Integrated Low-level Radwaste Treatment System

》Kwang-Fu Tsai

The Institute of Nuclear Energy Research (INER) has developed incineration, casting, and plasma melting technologies for the treatment of dry solid wastes. In 2006, both waste-metal decontamination & activity measurement systems were established to manage the free release of metal radwastes. To effectively utilize the resources and eliminate the undesired store up of dry wastes, facilities, such as incineration, casting, plasma melting, decontamination, and free-release monitoring, at INER were integrated. For combustible solid radwastes, incineration was used, whereas casting or plasma-melting technology was adopted for treating incombustible wastes. As for the incombustible, very low-level radwastes that are decontaminable, grinding, electrolysis, and polishing were first applied followed by classification and dose measurement. These radwastes can only be free-released if the measured dose rate is below the regulatory standard.

In 2007, INER has successfully reduced the volume of combustible radwastes by 34,761 kg, incombustible radwastes by 2,950 kg (60 drums), metal radwastes by 34,960 kg, and low-level metal radwastes by 20,000 kg (600 drums). In the case of decontaminated radwastes,

20,506 kg of very low-level metal radwastes decontaminated by blasting device, chemical and electrochemical equipment and 1,200 tons of concrete measured by Activity Monitor have passed the regulatory limit and, therefore, being free-released.

◎ Research team:Kwang-Fu Tsai, Wen-Jen Lee, Sheng-Yuh Cheng, Kou-Ming Lin, Feng-Jung Chang, Jenn-Tsang Uen.

▲The Overview of Blasting Decontamination Device

▲The Chemical/electrochemical Cleaning Equipment

▲Spent Metal Screening and Detecting

■ Execution Status of Chinshan Spent Nuclear Fuel Dry Storage Project

》Bor-Tsang Lee

The execution status of Spent Nuclear Fuel Dry Storage Project for Chinshan NPP in 2007 is described as follows:

1.Planning and preparation of important procurements

We have completed the planning and preparation of procurements for items such as the storage system (Transfer Cask, Vertical Concrete Cask, Add on Shield and ISFSI Pad), operation labor inside and outside of reactor building (RB). The major planning and preparation items includes: interface clarification, investigations of potential vendors, specification of procurements, design drawing, documents preparation and cost estimation.

2.Clarification for the comments of SAR reviewers

TPC formally submitted Safety Analysis Reports, SAR, to AEC for application of the construction license at March of 2007. According the contract between INER and TPC, we will provide technical support during review process of license application. During the reviewing period, several conferences were held by AEC and TPC. Many important issues, such as cask heat load, corrosion resistance of materials, lifetime of components, seismic analysis and design, ambient temperature monitoring and drilling investigation on the transporting route, had been discussed.

3.Contract execution and quality audition for TSC manufacture

TSC, whose function is to contain and seal the nuclear spent fuel, is an A class component of dry storage system. In order to help the manufacturer acquire the verification successfully, the project team held internal meetings weekly as well as coordination meetings monthly with the vendor. In addition to that, a survey team was organized to perform shop surveys and quality audits. As the result, the quality of manufacture was fully under control. Moreover, a specialist of NAC was invited to pre-survey vendor's preparation for N-certificate application. The vendor has passed the verification of ASME, and will obtain an N-certificate soon.

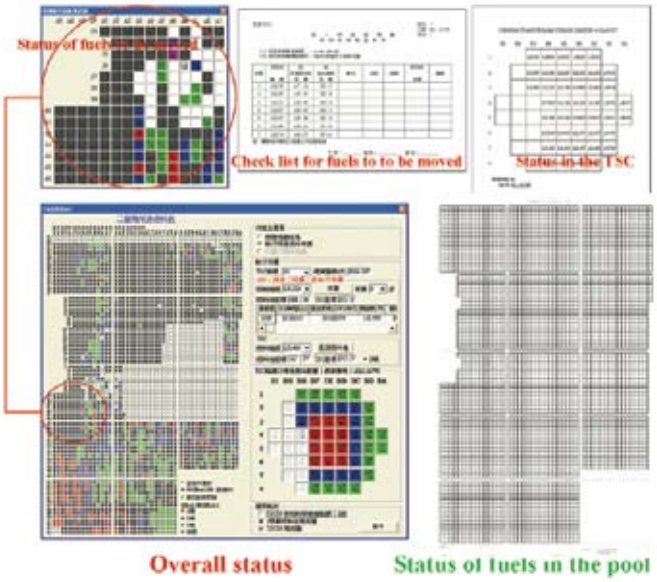
4.Operation planning

In the past year, the project team continued to discuss with CSNPS for interfacial issues. We have obtained CSNPS's approval that they will provide us the hardware needed for operation and enough storage space for components and equipments. Moreover, those existed equipments of CSNPS, which may interfere with dry storage operation, will be removed. The operation planning and procedure had been developed, and the transport route between the pad and RB had also been tested and verified.

◎ Research Team:Ding-I Lee, Chien-Liang Shih, Yu-Hao Huang, Jing-Tong Yang, Jong-Rong Wang, Yu-Tang Yang, Ti-An Hu, Ling-Huan Chiao, Chen-Yang Liu, Chih-Hao Chen, Yung-Hung Teng, Chin-Cheng Huang, Huang-Jau Wu, Ming-Chih Chen, Kuo-Shing Liang, Chung-Yu Yang, Tung-Liang Chu, Ting-Yi

Lin, Kuei-Jen Cheng,Chen-Chzu Peng, Chen-Fa Lan, Uei-Tyng Lin, Jeng-Ning Wang, Wen-Hwa Wang, Bor-Tsang Lee, Meei-Shiow Lin, Chia-Chi Su, Chung-Sheng Chen, Tein-Chan Chang, Shenq-Horng Lee.

▲The Project was Commended as the Winner of "Involvement & Creation" Contest, Sponsored by the Executive Yuan



▲Patents: Optimization of Spent Fuel Loading Sequence for Dry Storage Operation

■ Radiation Protection and Emergency Preparedness

》Ing-Jane Chen

The Institute of Nuclear Energy Research (INER) has been working to secure radiation safety and establish the world-class technologies of radiation protection and emergency preparedness. Facing domestic needs in decommissioning/dismantling of nuclear facilities and solid radioactive waste release, INER is actively developing related technologies. Moreover, INER has been planning advance research topics in radiological dispersal devices (RDD)/dirty bomb and anti-terrorism preparedness, radiological medicine application standards, public health and living quality improvement, etc. In 2007, the major R&D tasks

are listed as below:

1.Established radioactivity measurement technologies and applied them in waste clearance.

2.Developed emergency preparedness information management system, built up emergency response & handling capabilities, and provided preventive drills as well as decision-making think-tank in case of occurrence.

3.According to the domestic needs in radiation diagnosis, radiation protection, laboratory accreditation, and industrial applications, national measurement standards were established and maintained to ensure better life quality and safety for citizens.

■ Achievement of Joining EUROMET X-Ray Measurement Comparison Program

》Chien-How Chu

Starting from 1993, the Institute of Nuclear Energy Research (INER) was commissioned by the Bureau of Standards, Metrology and Inspection (BSMI) Ministry of Economic Affairs (MOEA) to establish the "National Radiation Standard Laboratory (NRSL)". NRSL was meant to establish and maintain the nation's highest ionizing radiation measurement standards, ensure the consistency with international standards, deliver the national measurement standards through the accreditation system of the Taiwan Accreditation Foundation (TAF) and facilitate applications and safety of atomic energy use in domestic radiological medicine, radiation protection, environmental protection, radiation processing and nuclear power.

In 2007, NRSL finished the EUROMET.RI(I)-S3 report for the measurement comparison on X-ray air kerma rate organized by the EUROMET. NRSL's measurement values were consistent and in good agreement with the international reference values. This comparison took two years and was hosted by the PTB/Germany. Ten laboratories, mainly coming from the EUROMET, included PTB/Germany, NPL/UK and NMI/Netherlands; NIST/USA was

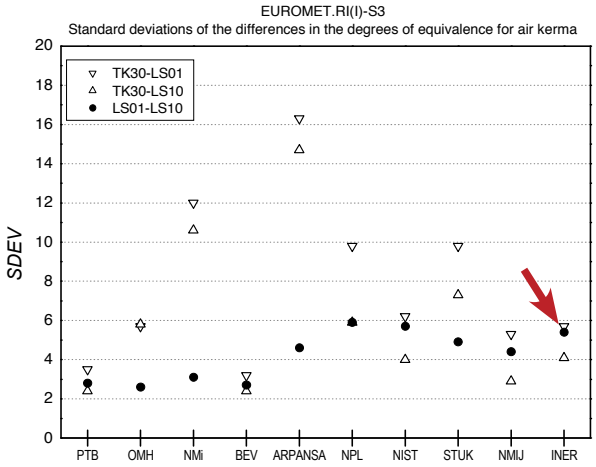
the only laboratory from SIM; in the APMP, only NMIJ/AIST (Japan), ARPANSA/Australia and NRSL/Taiwan were invited. The invitation from PTB showed that INER's measurement competence has been recognized internationally and INER's measurement technology has been synchronizing with those of the international communities. This comparison was made on the X-ray air kerma rate dosimetry standards in ISO narrow spectrum series and was also the first time such a comparison ranging from 30 keV to 300 keV being held in the global metrology system. The comparison results could stand for the evaluation basis for technical competence of the laboratories.

The X-ray air kerma rate standards in ISO narrow spectrum series were of the area of radiation protection. There were difficulties of low air kerma rate and ionization chamber positioning relating to standard establishment and measurement technology. To meet requirements of this comparison, INER developed a medium energy free air ionization chamber which was based on the existing low energy free air ionization chamber and covering the to-be-measured X-ray energy ranges of this comparison. The technologies used in standard establishment included evaluation of correction factors, calculation of radiation field, evaluation of measurement uncertainty and so on; Monte Carlo calculations including EGS4 and MCNP were used to evaluate correction factors of electron loss and photon scatter. On the other hand, INER developed measurement techniques for air attenuation and collection volume for the self-designed standard ionization chamber. These techniques could effectively reduce measurement uncertainty and showed INER's R&D competence. INER's measurement results were outstanding in degree of equivalence as agreeing with PTB/Germany, NIST/USA, BEV/Austria, OMH/Hungary and NMIJ/AIST(Japan). After being reviewed by the global metrology organizations, INER's results would speak for themselves and be entered into the BIPM KCDB (key comparison database) accordingly.

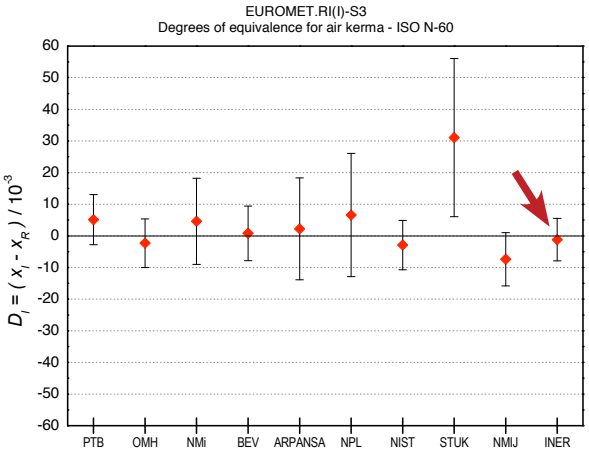
◎ Research Team: Chien-How Chu, Ing-Jane Chen, Shi-Hwa Su, Hong-Long Tzeng, Jeng-Hung Lee, Ming-Chen Yuan, Yi-Chun Lin, Sheng-Ji, Chen.

Participant	Institute	Country
OMH	National Office of Measures	Hungary
NMi	NMi Van Swinden Laboratoriumi	The Netherlands
BEV	Bundesamt für Eich- und Vermessungswesen	Austria
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency	Australia
NPL	National Physical Laboratory	United Kingdom
NIST	National Institute of Standards and Technology	United States
STUK	Radiation and Nuclear Safety Authority	Finland
NMIJ/AIST	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology	Japan
INER	Institute of Nuclear Energy Research	Taiwan
PTB	Physikalisch-Technische Bundesanstalt	Germany

▲Participating Laboratories of the EUROMET.RI(I)-S3 X-ray Measurement Comparison Program



▲INER's Degree of Equivalence in the EUROMET. RI(I)-S3 X-ray Measurement Comparison Program



▲INER's Results in the EUROMET.RI(I)-S3 X-ray Measurement Comparison Program

■ Proficiency Test in the Field of Ionizing Radiation

》Chuen-Tay Liou

TAF commissioned INER to perform the proficiency test in the field of ionizing radiation in order to conform to the international criteria and fulfill the mutual recognition arrangement with ILAC and APLAC. In 2007, INER performed three proficiency testing programs in ionizing radiation including:

- Proficiency test for the seventh external personnel dose evaluation laboratories
- Proficiency test of radionuclides analysis for environmental samples
- Proficiency test of low- and intermediate-level radionuclides analysis for H-3 solution

According to TAF's proficiency testing requirements, the laboratory which applies for its first accreditation or applies for an extensive accreditation should pass a proficiency testing program within 3 years. "The seventh external personnel dose evaluation laboratories proficiency test" conducted by INER in 2007 was for the laboratories that had been recognized by AEC and TAF as capable of dealing dosimeters or the ones which applied for their first accreditation; eight dosimeter evaluation laboratories participated in the program and all of them passed all the eight accreditation categories. "The proficiency test of radionuclides analysis for environmental samples" was arranged by INER with eight kinds of spiked samples covering water, air-filter, milk powder, tea leaf, soil, meat, synthetic urine and synthetic feces. Since every environmental monitoring laboratory has different needs, this proficiency testing program is now held once a year; seven laboratories participated in the program and all of them passed all the accreditation categories. "The proficiency test of low- and intermediate-level radionuclide analysis for H-3 solution" had 5 participating laboratories and they all passed the testing.

◎ Research Team:Chuen-Tay Liou, Chun-Liang Chen, Jeng-Jong Wang, Hui-Mei Peng, Huang-Sheng Chiu.

▲Phantom for Dosimeters

▲Analysis Sample of H-3 Solution

■ Pharmaceutical Primary Standard Establishment for In-111 Radionuclide

》Chien-Yung Yeh

^{111}In is one of the most used radionuclides for nuclear medicines. Its half-life is 2.8 days, which undergoes decay by electron capture to stable ^{111}Cd with two low-energy gamma ray cascading emissions of 171 keV (91%) and 254 keV (94%). This nuclide not only suits for diagnostic purpose of locating and imaging certain tumors, visualizing lymphatic system and labeling, but also provides potentially therapeutic usage as being an electron capture emitter. INER has become a producer of ^{111}In pentetretide injection used for locating neuroendocrine tumor since 2005 , and it is necessary for the National Radiation Standard Laboratory (NRSL) of INER to develop methods for its radioactivity standardization and to distribute this standard.

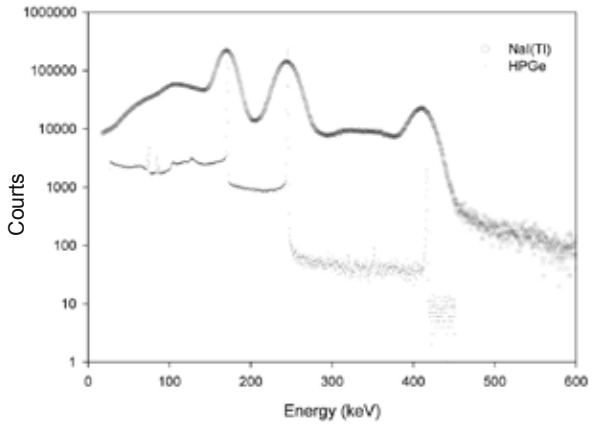
For a long time the coincidence methods are well developed for the radioactivity standardizations of (β,α,X)-γ, γ-γ and X-X emitters. The system that NRSL has established is a 4πβ(PC)-γ coincidence counting system, in which detector of the β channel uses a 4π proportional counter, detector of the γ channel uses two NaI scintillation counters, coincidence channel counts when both β and γ channel counts simultaneously and linear efficiency extrapolation techniques are adopted to deal with nuclides of complex decay scheme.

The observed counting rates for the three channels N_β, N_γ and N_c , can be deduced to have the following relation, $$\frac{N_\beta N_\gamma}{N_c} = N_0[1+(1-K)(\frac{N_\gamma}{N_c}-1)]$$

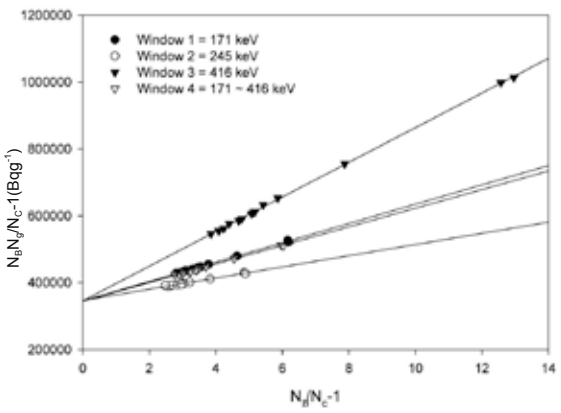
N_0 is the activity we need. The essence of linear efficiency extrapolation technique is to fulfill the β channel counting rate N_β to be a linear relation with (N_γ/N_c -1), i.e. K is a constant, and to vary the N_γ/N_c such that (N_γ/N_c -1) approaches zero experimentally, and these can be accomplished with no special problem for this nuclide by having the γ-windows set at the photopeaks, and by varying the amount of the sources at the samples preparation stage in order to achieve different self-absorption effects in the counting stage.

At sample preparation, an ^{111}In chloride solution was supplied from the Isotope Application Division. After several days of decay and dilution by 0.1N HCl, 30 samples were prepared on the conducting VYNS films (~ 25 mg/film) for the coincidence counting, and several standard ampoules of solution with the same specific activity were also prepared for transferring the standard to the standard ionization chambers of NRSL. The γ-spectra of the coincidence counting and the HPGe's spectrometer are shown in the bottom left figure, and the linear efficiency extrapolation graph for the 30 films with respect to the different γ-window settings are shown in the bottom right figure. The result of this standardization is 0.3458 ± 0.55 % MBq g-1 at 2007/06/25 12:00.

◎ Research Team:Chien-Yung Yeh, Ming-Chen Yuan, Min-Ta Chen.



▲^{111}In γ Spectra



▲Efficiency graph of the 4πβ(PC)-γ Counting

■ Establishment of Laboratory and Technology for Clearance Measurement

》Jeng-Jong Wang

The Fuel Cycle and Materials Administration (FCMA/Taiwan) enacted the "Regulations on Clearance Level for Radioactive Waste Management" (the Regulation) on Dec. 29, 2004. Article 4 of the Regulation states that radioactive waste with activity limit or specific activity limit in accordance with the stipulations of clearance level (referred to IAEA RS-G-1.7) shall be allowed for release. According to the international experience, more than 95% of waste produced from nuclear facility routine operation or decommission can be released or recycled.

To solve the problem of limited space in waste storage, and fulfill the waste-reduction policy, INER has been developing clearance technologies since 2004. Two waste-release plans, "The Release Plan of Dismantled Concrete Blocks of TRR Wet Storage Tank" and "The Release Plan of Scrap Metal stored in INERs' Extra-low-Level Waste Temporary Storage Area", were submitted to FCMA on August 12, 2005 and June 8, 2006, respectively; and were approved by FCMA on April 20, 2006 and October 31, 2006, respectively.

In order to integrate related technologies such as radioactivity measurement, radionuclide analysis, instrument design and equipment calibration for carrying out the waste clearance practices, the "Clearance Measurement Laboratory" was established. To assure the measurements quality, the QA-manual and documents of QA/QC and SOP were also completed according to the ISO 17025, and the laboratory will apply for the TAF accreditation in 2008. The main measuring instruments equipped in the laboratory were:

- 220L Bulk Gamma Specific Activity Counting System (germanium detector, Q2)
- 220L Bulk Gross Gamma Specific Activity Counting System (plastic scintillation detector)
- In Situ Object Counting System (germanium detector, ISOCS)
- Conveyer Type Radioactivity Counting System (plastic scintillation detector)
- Area Radioactivity Detector (plastic scintillation detector)

In 2007, about 1,200 tons of the dismantled concrete blocks and 20 tons of scrap metal were free released successfully by INER for the first time in Taiwan. In the future, for establishing the measurement traceability, Clearance Measurement Laboratory will collaborate with the National Radiation Standard Laboratory to hold a proficiency testing program in waste radioactivity measurement, so that the measurement results can be in line with the international standards. Furthermore, all the technologies established by INER on waste clearance will be transferred to a local manufacturer, which is expected to be beneficial for promoting our international business.

◎ Research Team:Jeng-Jong Wang, Bor-Jing Chang, Huang-Sheng Chiu, Chin-Hsien Yeh, Jyi-Lan Wuu, Hsun-Hua Tseng, Mao-Chen Liu.

▲Gamma Specific Activity Counting System

▲Gross Gamma Specific Activity Counting System

Radiation Biomedical Application

》Kuan-Yin Chen

The research and development of Radiation Application Technology Center (RATC) have focused on radiopharmaceuticals and their application. The main purpose in developing nuclear medicine was to study diagnosis, therapy and the molecular image technique for the local health care. RATC created the technology of radiopharmaceuticals and the final aim would be establishing a local radiopharmaceutical industry in Taiwan. We are 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 to the internationalization area of this specialized radiation biomedical application field.

The projects operated in RATC may broadly be divided into three categories, 13 important achieved programs accomplished this annual: (1) Nuclear medicine and molecular image medical equipment (The clinical trial planning program for diagnostic radiopharmaceuticals, the development of radioimmunotherapeutic agents for breast cancer treatment at INER, synthesis and characterization of SOCTA as a bifunctional ligand program, development and applications of planar tomography reconstruction program.); In project (2) The research and application development of the cyclotron technology in isotope production (The tellurium-alumina target technology for the development of iodine-124 radioisotope process, improvement of ion source in a cyclotron and a radiopharmaceutical auto-dispenser.); Whereas, the main achievements in project (3) Radiation biology research and irradiation service (Biodistribution, pharmacokinetics and microSPECT/CT Imaging of ^{188}Re -BMEDA-Liposome in a C26 murine colon carcinoma solid tumor animal model, Biodistribution, pharmacokinetics and imaging of ^{188}Re-BMEDA-Labeled pegylated liposomes after intraperitoneal injection in a C26 colon carcinoma ascites mouse mode, the establishment of proteomic analysis system and technical platform for protein biomarker discovery, radiation method for TiO_x biomedical material onto polymer sheet, the annual operation report of Cobalt-60 facility in INER).

■ Beam Upgrade Program for the INER TR30/15 Cyclotron

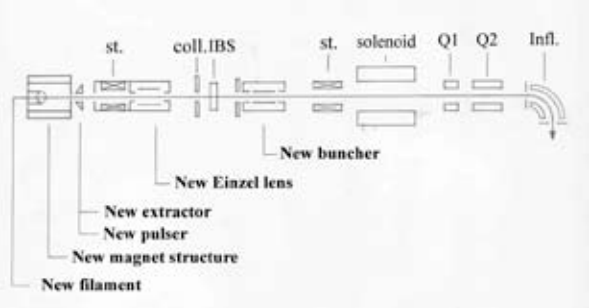
》Ting Shien Duh

The INER TR-30/15 cyclotron can accelerate both H^- and D^- particles. The original specification was 500 μA H^- at 30 MeV and 150 μA D^- at 15 MeV. In anticipating higher future demand on isotopes produced by protons around 30 MeV, our cyclotron needs to be promoted its beam capability and operation reliability. An upgrading project for the proton mode following TRIUMF/Nordion model was proposed. The project consists of three phases: phase 1 is to improve the ion source and injection system, phase 2 to increase the RF power for higher beam current and phase 3 to set up high power solid target stations.

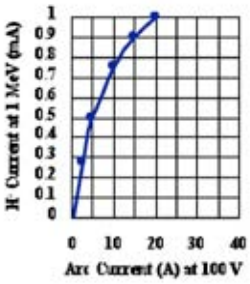
Up to now, the 1st and 2nd phases of the project have been making good progress although not yet 100% completed. The injection line has been modified by adding an Einzel lens, a buncher and a pulser. Test results show that the beam transmission increases from 10% to 25% for 500 μA operation and to 36% around 200 μA. The beam stability was found greatly improved as well. For the ion source performance we achieved 8 mA at 2.5 kW arc power. A 12 mA goal at 4 kW arc power is set to achieve soon. For increasing the RF power, a new 100 kW RF power amplifier has been acquired, installed and tested. The new amplifier has been proven to work with our cyclotron very well. However, the new transmission line has not yet been acquired.

Due to the limitation of the original transmission line and the beam capacity of the existing solid targets, proton beam up to 800 μA was chosen for our preliminary high beam current test at the end of 2006. The test was completed successfully and smoothly. At present, our cyclotron has already the capability to run proton beam to1 mA at 30 MeV using 5 mA injection (trans. eff. ~20%) and 55 kW of RF power.

◎ Research Team:Ting-Shien Duh, Mao-Hsung Chang, Chia-Zong Fann,, Ching-Lin Liaw, Ping-Yen Huang, Kuo-Yuan Chu, Kuei-Yuan Hsu, Dow-Che Chen,, Hogan Hong.



▲System schematics for source-injection upgrade.



▲1 MeV pop-up current as a function of source arc power.

■ The Tellurium-alumina Target Technology for the Development of Iodine-124 Radioisotope Process

》Jenn-Tzong Chen

The tellurium-alumina target is one of the most important technologies to produce radioiodine isotopes. This technology provides the distinguishing feature to transform the tellurium powder into tellurium-alumina crystals, and increase the thermal conductivity of the target material as well. After proper sintering process, the target can be irradiated with the internal targetry instead of the external targetry in order to increase the heat dissipation quantity during the irradiation of the high energy proton.

Radioiodine isotope is a group of the most important radioisotopes in the field of medical applications. The varieties of the iodine radioisotopes include from diagnosis to therapeutic purpose. Such as the iodine-123 for SPECT imaging radioisotope with 13.2 hours short half-life and the iodine-124 for PET imaging radioisotope with 4.2 days half-life. Besides, the iodine-131 for the therapeutic radioisotope with 8 days half-life and the iodine-125 with 60 days half-life for radioimmunoassay are included as well. Therefore, radioiodine isotopes are provided high research and application values in medical and clinical studies.

There are two basic methods to prepare the tellurium-alumina target (table 1). One method includes the oxides and the other one is not. The oxides included method developed in the project provides at least two beneficial properties such as low target material loss and low temperature operation. The special design of the target body and target back plate has solved the problem of no product produced when the proton irradiation is at very low angle such as seven degrees. A pneumatic system to deliver the irradiated high activity target is another important feature of the new designed target. This feature makes the process can be operated in the reproducible proton irradiated target operation. By way of the development of the target technology, the activity and purity of iodine-124 is progressed.

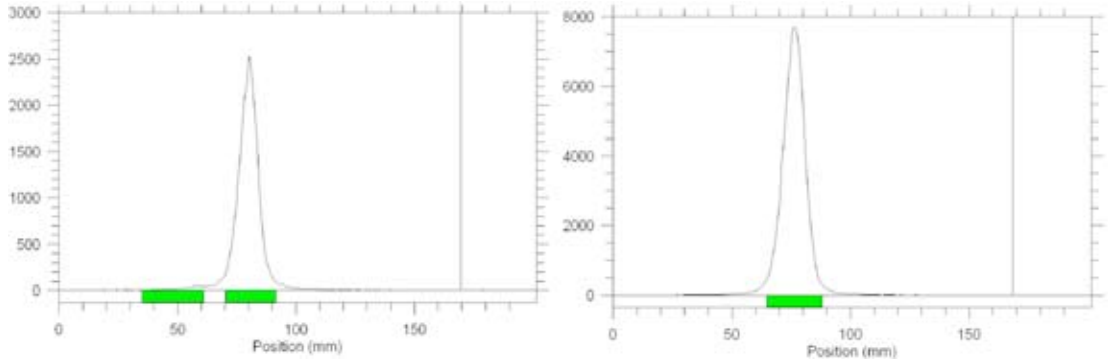
Table 1: The Properties of Tellurium-alumina Target Material

Compound	Appearance	Dry distillation temperature (℃)	Te-124 mass fraction(%)	Te-124 loss(%)
TeO_2	White powder	750	79	<1
TeO_2/Al_2O_3	Semiopaque crystals	700	43	<1
Al_2Te_3	Black crystals	910	87	<2

The tellurium dioxide of the main target material powder is sintered with aluminum oxide to form some semiopaque crystals at medium temperature. With the physical property of the Te-Al oxide, these crystals are tightly adhered to the platinum target plate groove after sintering process. Therefore, internal proton beam irradiation is achieved to prevent target material loss. Platinum target body generates low radionuclide impurities during proton irradiation to form high radionuclide purity product. The variation weight of target material is summarized to explain the mass loss of the new process. The results of the mass loss of the platinum target are less than one percent. In fact, most of the test runs are less than 0.3 percent. These results reveal the sintering and dry distillation processes are suitable for routine production of iodine-124. The improved chemical separation process of iodine-124 can produce high

quantity product to apply in iodine labeling. The separation efficiency of dry distillation process increased 240% and the production activity increased 170% compared to the previous process. The new improved target and separation process of iodine-124 is developed to produce higher activity product. The radiochemical purity of iodine-124 product is higher than iodine-123. This process provides a considerable benefit for iodine labeled compounds for PET imaging studies.

◎ Research Team:Jenn-Tzong Chen, Mao-Hsung Chang, Kuo-Yuan Chu, Chia-Bin Cho, Ting-Shien Duh and Wuu-Jyh Lin.



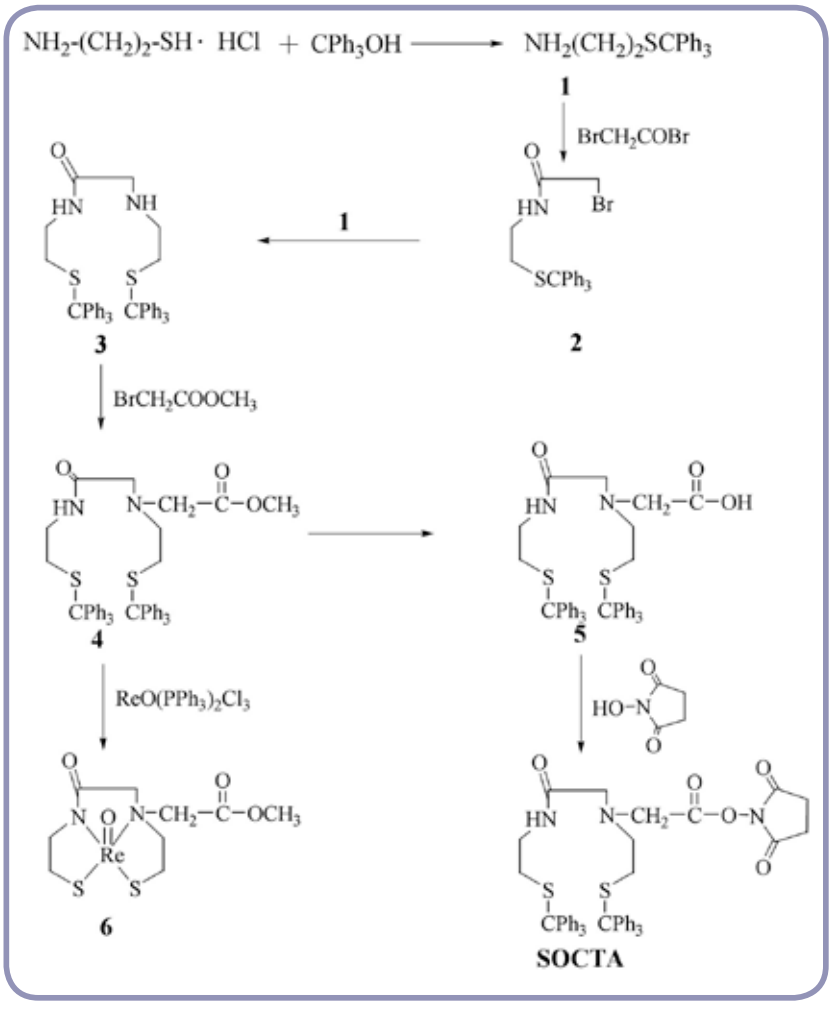
▲The Radiochemical Purity of Iodine-123(97%) and Iodine-124(100%) Produced at INER.

■ Synthesis and Characterization of SOCTA as a Bifunctional Ligand

》Cheng-Hsien Lin

A bifunctional organic compound containing a ligand set for Tc or Re complexing and a functional group for amino-bonding is essential to modify a protein or peptide for imaging or radiotherapeutic purpose. Our study aimed to synthesize such a bifunctional organic compound. Thioprotection reaction of 2-thioethylamine hydro-chloride with triphenylmethanol was catalyzed by boron-trifluoride ethyl ether complex to form 2-[(triphenyl-methyl)thio]ethylamine (1). The amidation of compound 1 with chloroactyl chloride was

performed in chloroform to afford N-[2-((triphenylmethyl)thio)ethyl] chloroacetamide (2). The thioprotected tetradentate ligand N-[2-((triphenylmethyl)thio)ethyl] [2-((triphenylmethyl)thio) ethylamino]ace-tamide (3). was pre-pared from the substitution reaction of compound 1 and 2 in alkaline dichloromethane solution. Substitution reaction of compound 3 with methyl bromo-acetate afforded methyl 3,6-diaza-5-oxo-3-[2-((triphenyl- methyl)thio) ethyl]-8-[(triphenylmethyl) thio]octanoate (4). Hydrolysis reaction of compound 4 in alkaline methanol solution yielded 3,6-diaza-5-oxo-3-[2-((tri- phenylmethyl)thio) ethyl]-8-[(triphnylmethyl)thio] octanoic acid (5). Esterification of compound 5 with N-hydroxy succinimide and 1, 3-dicycl ohexylcarbodiimide gave SOCTA that is composed by an actived carboxylic acid and a N_2S_2 ligand set. Amidation reaction occurred immediately when SOCTA was added into a protein or peptide solution. This modified protein or peptide could be labeled with MO^{3+} (M = Tc or Re) in mild condition.



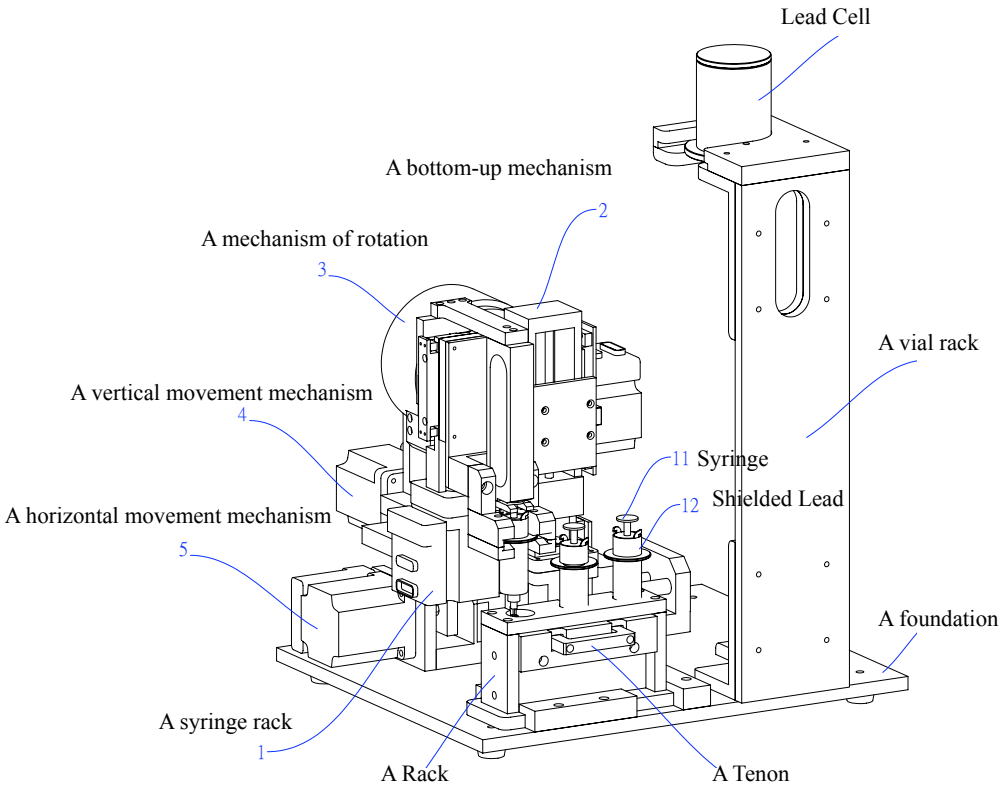
◎ Research Team: Cheng-Hsien Lin, Tsyh-Lang Lin, Shiu-Wen Liu and Cheng-Fang Hsu.

■ An Automatic Radiopharmaceutical Dispenser

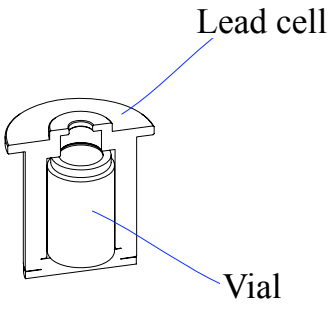
》Ming-Hsin Li

The present invention provides a fully automatic controlled system, employed for distribution radiopharmaceutical to single unit dose, or injection of radioisotope to several reaction bottles to get chemical reaction. It employs a personal computer interfaced to five axis step motors, and a sterile syringe. Only the sterile syringe contacts with the radiopharmaceutical. The sterile syringe is disposable. A novel transport safe is employed to further reduce radiation exposure.

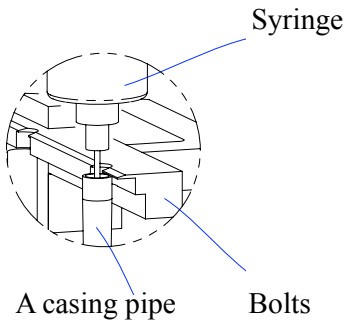
◎ Research Team:Ming-Hsin Li, Ther-Jen Ting, Jin-Jenn Lin, Jun-Chieh Tsai, Ming-Yen Hsieh, Wen-Shen Lan.



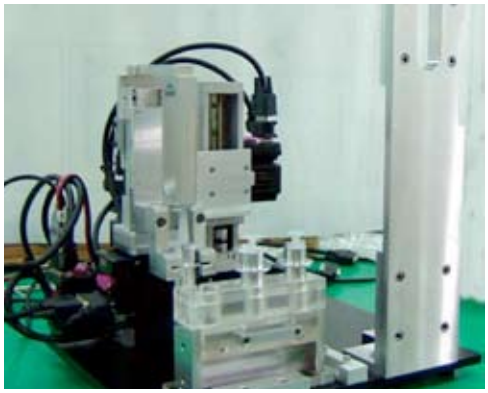
▲Configuration of Radiopharmaceutical Dispenser



▲The design of Lead Cell



▲The Design of Casing Pipe



▲An Automatic Radiopharmaceutical Dispenser

■ Study Toxicity of Meta-Iodobenzylguanidine in Mice

》An-Shoei Yang

Meta-iodobenzylguanidine (MIBG) is a potent neuron blocking agent and analogue of guanethidine and nor-epinephrine. Radioiodinated MIBG has hence been used for imaging euroendocrine tumours. An acute toxicity study was conducted to evaluate the toxicity of meta-iodobenzylguanidine (MIBG) in ICR mice via single intravenous injection. Forty-eight mice were used in this study and randomized into four groups, each consisting of six males and six females. The treated mice were administered via intravenous injection with MIBG at dose levels of 75, 150, and 300 ng/kg, the control mice were administered with 5% ethanol solution diluted with saline for injection as vehicle control. The dose volume was 20 mL/kg. The test article solutions were freshly prepared by ethanol then diluted with saline for injection to 5% (v/v) on dosing day. The mice were observed for 14 days. The mice were observed 4-consecutive hours after dosing, followed by once daily for clinical observation and twice for mortality and moribund observation. Body weight was recorded on dosing day (D1) and then at weekly interval (D8) to the end of the study period (D15). The mice were euthanized by carbon dioxide exposure followed by exsanguinations and necropsied. No animal death was occurred during the study period. No clinical sign was observed. No remarkable difference

in mean body weight in any group at any time and no observable gross lesion was found in all mice. MIBG exerted no adverse toxic effects in ICR mice at dose level of 300 ng/kg. The results of this study will be served as a reference of safety margin for human use.

◎ Research Team:An-Shoei Yang, Lie-Hang Shen, Chia-Chieh Chen, Mei-Hsiu Liao, Tung-Chuan Chiang.

■ Clinical Trial Planning for Diagnostic Radiopharmaceuticals

》Yu-Chin Tseng, Mei-Hsiu Liao

Diagnostic radiopharmaceuticals are generally radioactive drugs or biological products containing a radionuclide that may be linked to a ligand or carrier. These products are used with planar imaging, single photon emission computed tomography (SPECT), positron emission tomography (PET). The purpose of conducting clinical trial for diagnostic radiopharmaceutical is to demonstrate its diagnostic performance and safety. Since diagnostic radiopharmaceutical is administered in a trace amount, serious adverse effect is unlikely to occur. Therefore, the extent of clinical safety monitoring and evaluation can be scaled down. In addition, the special characteristics of a diagnostic radiopharmaceutical should have taken into considerations, including its dose or mass, route of administration, frequency of use, and biological, physical, and effective half-lives. Hence, the protocol design for diagnostic radiopharmaceutical quite differs from general pharmaceuticals. To facilitate the conduct of clinical trials of a diagnostic radiopharmaceutical, Food and Drug Administration, USA, European Association of Nuclear Medicine, and Department of Health, Taiwan have issued some related guidelines in the past few years. The recommended indications for diagnostic radiopharmaceutical can be categorized as: structure delineation, functional, physiological, or biochemical assessment, disease or pathology detection or assessment, diagnostic or therapeutic patient management.

Developing neuroimaging agent is a major goal at INER. In cooperation with domestic medical centers and contract research organizations (CRO), INER had successfully carried

out the registration trail of INER TRODAT-1 kit, the first commercialized Tc-99m labeled dopamine transporter imaging agent in the world. Moreover, radiopharmaceuticals targeting to dopamine, serotonin, norepinephrine system, and beta-amyloid have also been developed at INER. Some of them have been carried out investigational clinical trials for years. An iodinated benzamide, [^{123}I]iodobenzamide (I-123-IBZM) has been developed for SPECT imaging of dopamine D2 receptor. After years of exploring the clinical application of I-123-IBZM, we plan to conduct a multi-center, phase III trail for registration purpose. From animal studies, clinical investigations and post mortem evaluations, it is well known that the dopaminergic neurotransmitter system plays a major role in movement disorders and particularly in parkinsonism. Besides, D2 receptor availability can provide information relevant to the extent of D2 receptor blockade of patients treated with typical and atypical neuroleptics. The aim being chosen for this trail is to compare the dopamine transporter and D2 receptor density among Parkinson's disease, multiple system atrophy (MSA), and uncertain patients using Tc-99m-TRODAT-1 and I-123-IBZM images. This trail is conducted by a CRO now and schedules to be finished up in two and half years.

■ Development and Applications of Planar Tomography Reconstruction

》Yu-Ching Ni, Meei-Ling Jan

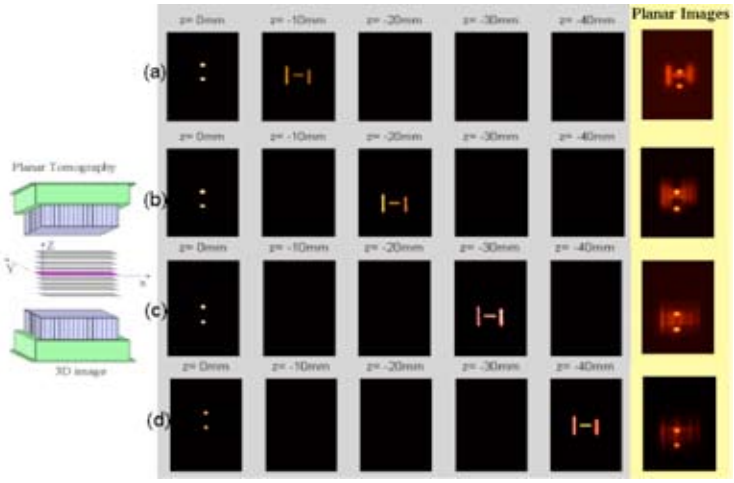
Dual-head coincidence imaging systems have a long history, which were used in the early stage of PET system development. Such kinds of studies have to rotating detectors to get tomography images. Recently due to the planar positron imaging system has an advantages (such as high sensitivity, low cost, high throughput) over ring type positron imaging system, a new investigation of fast screen imaging system using planar detectors were introduced. This kind of application often gets a planar image without rotating detectors to save scan time.

We have developed Planar Tomography –a new image reconstruction method. With stationary planar detectors we can not only get original planar image but also obtain 3D image. The planar tomography is a kind of iterative backprojection method but with weighting

factors. Determination of weighting factors is based on the voxel-value distribution of the previous iteration. In order to verify the identification ability of the source location, two 18F-FDG solution filled phantoms with shapes of ":" and "H" were scanned simultaneously. The phantom "H" was placed at various locations along the Z direction (Z=-10, -20, -30, and -40 mm), while the ":" was always placed at the center (Z=0). In figure 1., left panel are the results of planar tomography, and right are original planar. In figure 2., using Planar Positron Imaging System (made by Hamamatsu Photonics K.K, Japan) to test two-layer couched tumor-bearing mice imaging, two mice placed at Z=20 mm, and Z=-50 mm were scanned simultaneously. The results of planar tomography reveal that scanned mice could be placed on the off focal plane without blurring the images.

The application of Planar Tomography can improve the performance of Planar Positron Imaging System (such as double the scanned mice at a time, scanned mice could be placed on the off focal plane without blurring). Also can implement in the new program-Development of Positron Emission Mammography. In the future we will combine more physics models in this reconstruction method to get better image quality and quantification ability.

◎ Research Team:Meei-Ling Jan, Yu-Ching Ni, Fan-Pin Tseng, Zhi-Kun Lin, Shyang-Yeu Wang, Chuen-Shing Shyu.



▲Two phantoms placed at different z-direction locations. ":" phantom was always at the center and the "H" phantom was moved to various locations (z=-10, -20, -30, -40 mm). Left panel are the results of planar tomography, and right are planar.

▲Results of two-layer couched tumor-bearing mice imaging, two mice placed at Z=20 mm, and Z=-50 mm were scanned simultaneously. The results of planar tomography reveal that scanned mice could be placed on the off focal plane without blurring the images.

■ The Research of Radioimmunoagent ^{188}Re-SOCTA-Herceptin for Breast Cancer Treatment at INER

》Tsai-Yueh Luo

The major goal of study is to evaluate the therapeutic potential of a new radiopharmaceutical ^{188}Re-SOCTA-Herceptin in human breast tumor animal model. Herceptin, an antibody to Her-2/neu receptor in the breast cell membrane, can hinder and destroy the growth of the cancer cell. ^{188}Re is an attractive radioisotope emitting 2.12 MeV β particles to result in the damage of cancer cell. SOCTA, (succinimidy-3,6-diaza-5-xo-3 -[2-((triphenylmethyl)thio)ethyl]-8-[(triphenyl-methyl) thio]octanoate),was used to as a bifunctional chelating agent to conjugate with Herceptin and ^{188}Re. In this report, we established the breast cancer animal method by inoculating with tumor cell BT-474 (human breast cancer cell) on the right thigh of SCID mice. When the tumor volume of SCID mice achieved 120-180mm^3, these animals were chosen to perform the following biodistribution study.

The radiochemical purity of ^{188}Re-SOCTA-Herceptin, cstimated by HPLC and TLC, was more than 95%. Each SCID mouse (n=11) was injected with 004~0.05mCi/0.1ml of ^{188}Re-SOCTA-Herceptin through intravenous injection. Nine mice were equally separated into three groups and sacrificed at 1, 24 and 48 hours post-injection. Two mice were left to take the distribution image using micoSPECT/CT and then sacrificed to do the whole body autoradiography.

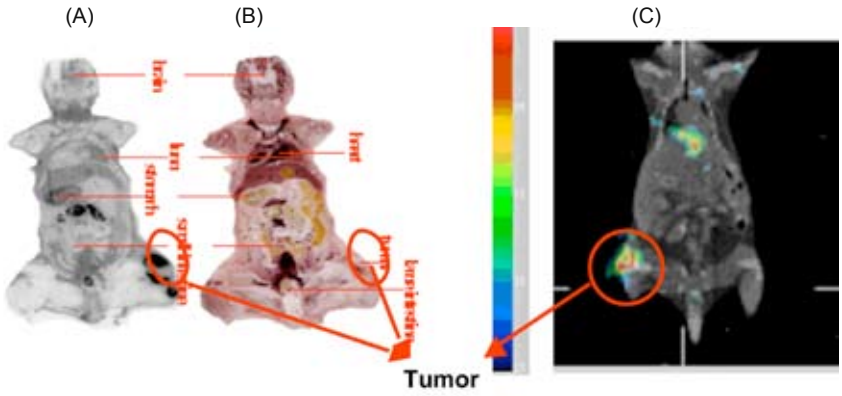
The biodistribution data showed that ^{188}Re-SOCTA-Herceptin has the tendency to accumulate at the tumor site. However, the excretion of ^{188}Re-SOCTA-Herceptin in the normal tissue was progressively decreased. We also found that tumor/blood ratio and tumor/muscle ratio were achieved 11.39±2.25 and 57.01±10.4 at 48 hours individually.

From microSPECT/CT images, ^{188}Re-SOCTA-Herceptin is mainly distributed at abdominal cavity and bladder in 4 hours. It was found that bladder and tumor have the relatively higher absorbance of ^{188}Re-SOCTA-Herceptin at 24 hours postinjection. However, the

autoradiography pictures showed that the absorption at the tumor of ^{188}Re-SOCTA-Herceptin was higher than normal tissue.

The data showed that ^{188}Re-SOCTA-Herceptin has the potential to be a therapeutic radiopharmaceutical for breast cancer treatment. We still need to perform more advanced studies to prove its efficacy.

◎ Research Team:I-Chung Tang, Tsai-Yueh Luo, Yu-Lung Wu, Chang-Mau Shing, Show-Wen Liu, Wuu-Jyh Lin.



▲Posterior whole body autoradiogram (A), photogram (B) and micro-SPECT/CT images (C) of a representative SCID mouse bearing subcutaneous HER-2/neupositive BT-474 human breast cancer xenografts at 24 h post-injection of ^{188}Re-SOCTA -Trastuzumab. Tumor uptake is visualized as indicated by red circles and arrow. The autoradiogram and anatomic photogram of the section were performed immediately after micro-SPECT/CT imaging.

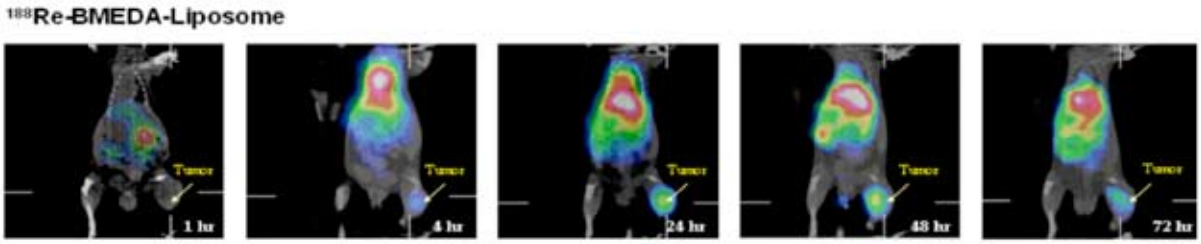
■ Biodistribution, Pharmacokinetics and Micro-SPECT/CT Imaging of ^{188}Re -BMEDA-Liposome in a C26 Murine Colon Carcinoma Solid Tumor mouse Model

》Te-Wei Lee

Nanoliposomes are useful carriers in drug delivery. Radiolabeled nanoliposomes have potential applications in radiotherapy and diagnostic imaging. The biodistribution and

pharmacokinetics of nano-targeted ^{188}Re-BMEDA-Liposomes and unencapsulated ^{188}Re-BMEDA administered by the i.v. route in murine C26-colon tumour-bearing mice were investigated. Micro-SPECT/CT images were performed to evaluate the distribution of drug in mice. For the biodistribution study, the highest uptake of liposome in tumors was 3.62%±0.73% at 24 h after ^{188}Re-BMEDA-Liposomes administration, and the tumor to muscle ratio of ^{188}Re-BMEDA-Liposomes was 7.1-fold higher than that of ^{188}Re-BMEDA. With image analysis, the highest SUV in tumor was 2.81±0.26 at 24 h after injection of ^{188}Re-BMEDA-Liposomes, the imaging analysis result showed a positive correlation of tumor targeting or uptake of ^{188}Re-BMEDA-Liposomes between biodistribution and microSPECT semi-quantification imaging analysis. The results of the pharmacokinetics revealed that the area under the tissue concentration-time curve (AUC) of ^{188}Re-BMEDA-Liposomes was 4.7-fold higher than that of ^{188}Re-BMEDA. These results suggested the potential benefit and advantage of ^{188}Re-labeled nanoliposomes for imaging and treatment of malignant diseases.

◎ Research Team:Te-Wei Lee, Chih-Hsien Chang, Wei-Chuan Hsu, Shu-Pei Chiu, Liang-Cheng Chen, Tsui-Jung Chang, Ya-Jane Chang, Chung-Li Ho, Chia-Yu Yu, Wan-Chi Lee, Yu-Hsien Wu, Su-Jung Chen, Chung-Hsin Yeh, Shyh-Yi Chyi, Tien-Fu Huang.



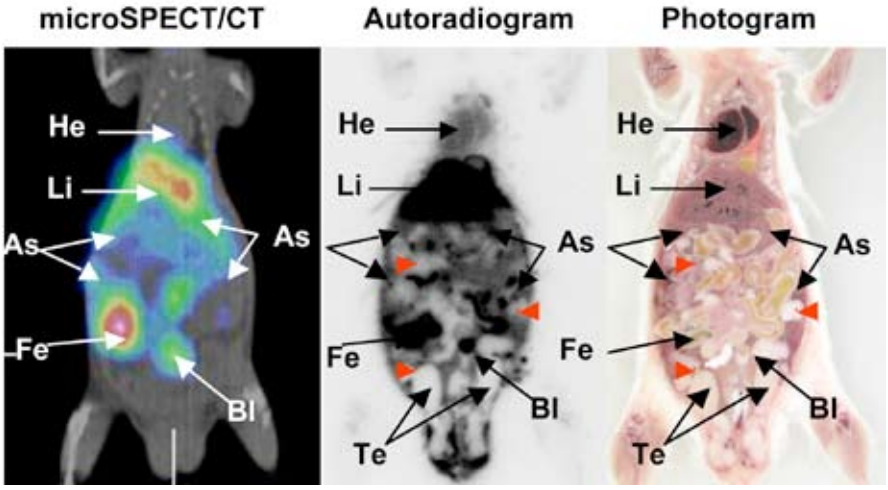
▲Micro-SPECT/CT images of ^{188}Re-BMEDA-Liposomes targeting tumors in C26 tumor bearing BALB/c mice. The ^{188}Re-BMEDA-Liposomes containing 0.5 mCi of ^{188}Re was administered to each mouse by intravenous injection. The images were acquired at 1, 4, 24, 48 and 72 h after injection. Images clearly showed the accumulation of ^{188}Re-BMEDA-Liposomes in tumors at 24, 48 and 72 h after injection.

■ Biodistribution, Pharmacokinetics and Imaging of ^{188}Re-BMEDA-Liposomes after Intraperitoneal Injection in a C26 Colon Carcinoma Ascites Mouse Model

》Chih-Hsien Chang

Nanoliposomes are important carriers capable of packaging drugs for various delivery applications. Radiolabeled liposomes have potential applications in radiotherapy and diagnostic imaging. The purpose of this study was to investigate biodistribution, pharmacokinetics and micro-SPECT/CT imaging of ^{188}Re-BMEDA-Liposomes and unencapsulated ^{188}Re-BMEDA after intraperitoneal (i.p.) injection in a C26 colon carcinoma ascites mouse model. The pegylated liposomes were labeled with ^{188}Re-BMEDA. The radioactivity in ascites was maintained at relatively steady levels before 24 h after i.p. administration of ^{188}Re-BMEDA-Liposomes. The radioactivity in tumor was progressive accumulation to a maximum level at 24 h. Pharmacokinetic studies revealed that the terminal half-life ($T_{1/2\lambda z}$), total body clearance (Cl) and area under the curve (AUC) of ^{188}Re-BMEDA-Liposomes were 5.3-fold, 9.5-fold and 9.4-fold higher than that of ^{188}Re-BMEDA in blood, respectively. MicroSPECT/CT images showed a high uptake and targeting of ^{188}Re-BMEDA-Liposomes in ascites and also in tumor, liver and urine. These results suggested that the long circulation, bioavailability and localization of ^{188}Re-BMEDA-Liposome is a potential multifunctional nano-radiotherapeutics and imaging agents on a C26 colon carcinoma ascites mouse model.

◎ Research Team:Te-Wei Lee, Chih-Hsien Chang, Wei-Chuan Hsu, Shu-Pei Chiu, Liang-Cheng Chen, Tsui-Jung Chang, Ya-Jane Chang, Chung-Li Ho, Chia-Yu Yu, Wan-Chi Lee, Yu-Hsien Wu, Su-Jung Chen, Chung-Hsin Yeh, Shyh-Yi Chyi, Tien-Fu Huang.



▲Coronal microSPECT/CT image correlated with whole-body autoradiography in mice. MicroSPECT/CT imaging was performed at 72 h after i.p. injection of 12.95 MBq/200 μl RBLPL and scanned for 90 min. The mouse was i.p. inoculated C26 colon cancer cells after 13 days. The autoradiogram and anatomic photogram of the section were performed immediately after microSPECT/CT imaging. Tumor nodules are indicated by red arrow (Li: liver, As: ascites, He: heart; Fe: feces, Te: testis, Bl: bladder).

■ The Annual Operation Report of Cobalt-60 Facility in INER

》Chia-Chieh Chen

The Cobalt 60 facility of INER had finished its annual operation program this year. In addition to accomplished the R&D and service operation, this year the facility also updated several systems, like air condition, conveyor system and the safety system. Especially the water purifying system, it can reduce the water conductivity and protect the cobalt source. The computering of monitoring system can let people survey and remote control this facility.

The total operation time was 3,588 hours. During this long operation, there is no any violation to the safety regulation. The total exposure dose for all the operators were under the level of radiation safety regulation requirement.

To operate ergonomically this year, the average operation time was 16 hours per day. In maintaining the radiation quality, every batch had its own dosimetry measurement. There were several research contracts with other source this year. The total income from the research

contract service closed to 7 millions. Some more contracts were under discussion yet. It will become the most important service and income in the near future.

This year the radiation service items included disposable medical supplies, medicine and related materials, industrial material, mutation radiation and food irradiation. The total number companies ask for the service was over 50. The boxes number finishing radiation service was over 6 thousands and the total income was over 10 millions dollars.

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

◎ Research Team: Jiin-Hwang Chou, Kuan-Yin Chen, Shiang-Rong Chang, Hung-Chih Lin, Te-Hsing Wu, Chia-Chieh Chen.

A. Pinky
(No.1 of INER, Taoyuan)

B. Pink Lady
(No.2 of INER, Taoyuan)

▲New Breeds of X'mas Flower Irradiated by Co-60 (cooperation between INER and Taoyuan District Agricultural Research and Extension Station).

▲Irradiation of Fire-resistant Materials Aging Tests by Commend in Cobalt 60 Facility of INER (Dose:1000kGy).

■ The Establishment of Proteomic Analysis System and Technical Platform for Protein Biomarker Discovery

》Shui-Cheng Lee, Chun-Chia Cheng

Recently protein biomarker has become more important because it could be used to diagnose the early stage of disease and trace the progression after therapeutic cure. When the Human Genome Project is completed, scientists can understand and solve more problems of clinical disease from rapid bioinformatics research. On the other hand, proteomics is becoming the major trend now and applied to biomarker discovery by cooperating Electrophoresis and Mass Spectrometer.

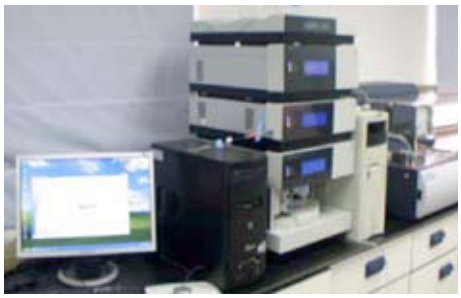
Protein is the major functional role in the cell, therefore protein is thought as the better candidate for clinical diagnosis. In clinic, the sample which includes serum, plasma and cerebrospinal fluid only need a bit quantity, so it has simple, safe, rapid and economic advantages. Moreover protein biomarker labeled with nuclear drugs could help doctor to diagnose patient's disease and evaluate the efficacy.

In order to execute the protein biomarker projects, we had already built up "Proteomic Analysis System" in 2007/7/11. The system contains four major parts as follows: (1) MALDI-TOF MS (Matrix Assisted Laser Desorption Ionization-Time-of-flight Mass Spectrometer), (2) LC/MALDI (Liquid Chromatography/ Matrix Assisted Laser Desorption Ionization), (3) 2D-DIGE (Two Dimension-differential gel electrophoresis), and (4) MASCOT protein identification system. It could support us to discover the protein biomarkers of early liver cirrhosis, Alzheimer's disease and furthermore set up the diagnostic technologies with kits. In this year we complete six technical Platform for biomarker discovery as below: (1) 2D-DIGE technology, (2) SELDI-TOF MS (Surface-Enhanced Laser Desorption Ionization-Time-of-Flight Mass Spectrometry) technology, (3) MB-MALDI-TOF MS technology, (4) MALDI Imaging technology, (5) ICPL technology, and (6) protein identification technology.

◎ Research Team: Shui-Cheng Lee, Mei-Hui Wang, Chun-Chia Cheng, Wen-Yu Hsu.

Outline of Proteomic Analysis System

▲MALDI-TOF/TOF MS



▲LC/MALDI

▲2D-DIGE

▲MASCOT Protein Identification System

New Energy Technologies

》Ying-Sheng Lee

To comply with the energy policy of the government, the Institute of Nuclear Energy Research has initiated an integrated program, consisting of several projects, to develop new, renewable and eco-friendly energy technologies with lower cost and higher efficiency. The goal of the program is to fulfill the national requirement on CO_2 reduction, to reserve the energy resources, and to foster the development and application of new energy technologies in this country. The projects in the program are: Small/Medium Size Wind Turbine System, High Concentration Photovoltaic (HCPV) System, Cellulosic Ethanol Technology, SOFC Technology, DMFC for Applications in the 3C Power System, Hydrogen Storage in Metal-Organic Frameworks, Quantum Dots Light Emitting Device, and Planning on the Performance Enhancement of IGCC System. Through an effective integration and implementation of INER's research resources, remarkable and substantial progresses have been made for each project in 2007.

In the project of Wind Turbine System, INER, cooperating with the domestic companies had completed the design, fabrication, and assembly of a passively controlled 25 kW commercial type WT in October of 2007. It had a unique design of FRP tail vane providing the yawing and over-speed protection functions. For the HCPV project, a 100 kW HCPV system with passive cooling conditions and dual-axis tracking subsystem was set up at INER in October 2007. Its maximum module efficiency reached about 26.1% under 850 W/m^2 DNI. Regarding the development of bioethanol, the domestic agricultural wastes, such as rice straws, bagasse, and silvergrass, containing abundant cellulosic fibers were used as feedstock. In 2007, A unit process testing facility had been set up for bioethanol production with a capacity of 10 kg feedstock per batch.

In the development of SOFC technology, power density of 500mW/cm^2 at intermediate temperatures has been achieved for MEAs made either by tape casting-screen printing or atmospheric plasma spraying (APS) processes. Deliberate efforts have been made on the stacking technology as well as on the demonstrative kW-grade SOFC power system. A 1 kW stack, with commercial MEAs, had been successfully assembled and tested in December of 2007. To take advantage of Taiwan's strength in the 3C industry, a prototype DMFC system of 20/40W utilizing a methanol sensor-less control technique was established up to provide the power source for a notebook. This system has a much higher specific energy density than that

of the Li-ion battery. In addition, the research team has transferred the control technology to domestic industry partners for further commercialization.

In the project of Hydrogen Storage in Metal-Organic Frameworks, a nano-structured IRMOF has been synthesized. This material manifested a hydrogen storage capacity of 4.7 wt% at room temperature under a pressure of 6.9 MPa. In the project of Quantum Dots Light Emitting Device, both low and high temperature thin film deposition processes have been developed with the PECVD and APCVD systems. The outcome of the project will be subsequently employed to develop the low cost epitaxial/textured silicon solar cells.

In the project of Planning on the Performance Enhancement of IGCC System, a preliminary plan and evaluation on the Sustainable Integrated Gasification Combined-Cycle (SIGCC) technology is undergoing. It is aimed to improve the electrical performance of base load for power companies so as to effectively decrease the amount of CO_2 emission. Through the project, the expertise on system optimization for domestic energy technologies will be upgraded and the integrated modeling capability of life-cycle assessment on overall national economy will be established.

Brief descriptions are outlined for each aforementioned project as follows:

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

》Chin-Jen Chang

The Institute of Nuclear Energy Research (INER) started its small and medium size wind turbine (WT) system integration R&D in April of 2005. There are four emphases of our activities: (1) the system design and integration of 25kW class WT, (2) the system design and integration of 150kW class WT, (3) the establishment of dynamo test station for small and medium size WT, and (4) the development of wind field evaluation and the grid-tied power electronic design capabilities.

An actively controlled 25kW experimental WT, was designed and installed in December, 2005. Similar to the control systems used on most large size WT, it is equipped with blade pitch control, active yaw control, anti-lock brake control, and various on-line sensors for monitoring the performance. This WT had undergone one year test and operation, and the power curve measurement had been accomplished. Following the experimental WT, a passively controlled 25 kW commercial type WT was designed, fabricated, and completed its assembly in October of 2007. It has a unique design of FRP tail vane providing yawing and over-speed protection functions. Emergency brake system is the only control of this WT. This 25kW machine is targeted for whole system technology transfer to our local industries and thus low rated power wind speed (9~10m/s), high blade design efficiency (~40%), efficient permanent magnetic generator, and grid-tied inverter with maximum power tacking function are emphases of our system design. The field test and the performance evaluation of INER-C25 are undergoing. INER engineers also work on the project to accomplish the design and installation of a 150 kW typhoon resistant type WT at the end of 2008. The design features are structure strength and the mechanical design with typhoon resistant functions. Its blades with 13 meters in length and a high aerodynamic efficiency are being manufactured now and are projected to have a bending test at the end of 2007.

Regarding the test of WT, a 50m high truss tower for field test and a 200 kW dynamo test station have been installed for ground test. The top section of this truss tower is designed to be easily substituted to offer a flexible hang for both 25 kW and 150 kW WT. The dynamo

test platform uses a 200kW dynamo and the associated servo motor to simulate the wind power source and combines with the gearbox, torque meter and load bank to perform function tests on a WT system at ground. The research team has also established capabilities for performing wind power potential evaluation, and for developing wind field forecasting model. Furthermore, in order to well tune the stability and efficiency of the grid-tied WT, the grid-tied power electronic technology was also exploited.

The research team sets up the goal of INER self-design WT with no less than 90% of its components provided by domestic manufacturers. Therefore, the technology integration with local wind industries is an important subject of the project. It is expected INER WT combined with INER HCPV systems will provide smart grid-tied or DC electricity utilizations at the institute. Furthermore, the technologies developed herein will help establish solid strength for domestic wind energy industry.

◎ Research Team:Chin-Jen Chang, Chin-Cheng Huang, Yung-Yen Kuo, Yung-Ruei Chang, Hung-Yun Wu, Yu-Shun Yeh, Wei-Nian Su.

▲The INER-P25 Experimental WT

▲The INER-C25 Commercial Type WT and the Field Test Truss Tower

▲The Conceptual Designs of INER 150kW WT

▲The 200kW Dynamo Ground Test Station for Small/Medium Size WT

■ Technologies of High-concentration Photovoltaic (HCPV) System

》Cherng-Tsong Kuo and I-Tao Lung

The R&D activities of this project include the researches of the process and measurement of high-efficiency III-V solar cell, design and manufacturing of imaging/non-imaging Fresnel lens, concentrating solar cell module, solar tracker, electric power control system, and central control system. Based on the developed technologies, the research team is integrating the domestic related industrial fields including the upper stream like GaAs epitaxy and cell process, the midstream like cell package and module developments, and the down-stream like solar tracker and HCPV system integration.

The research project of high-concentration photovoltaic HCPV system technologies has been conducted at INER since 2003. The development history of HCPV system at INER can be divided into four phases as follows: Phase I: Technologies of Characteristics Measurement; Phase II: Techniques of Cell Design, Manufacture & Testing; Phase III: Module & System Integrations; Phase IV: System Improvement. A 5 kW HCPV system (1st generation) was established at INER in December, 2006, adopting homemade solar cells and tracking devices. The controller takes the signal coming from the sun position sensor to drive worm gear and actuator of solar tracker.

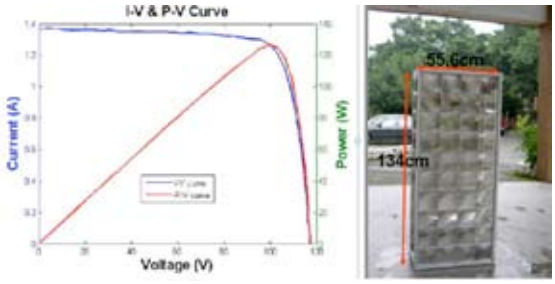
A 100 kW high-concentration photovoltaic HCPV system had been constructed in October, 2007 at INER. The maximum module efficiency with a geometrical concentration ratio of 476x was about 26.1%, under 850 W/m^2 DNI, passive cooling conditions, and dual-axis tracking. The 100 kW HCPV system consists of 14 sets of pillar-stand 5 kW (40 modules) and 21 sets of roof-top 1.5 kW (12 modules). Each module has 40 solar cells, of about 35% conversion efficiency, manufactured by Spectrolab Company, USA.

To ensure the quality of HCPV system, IEC 62108 has been introduced to a test lab since 2005 for the module verification in compliance with the international standard. Through the collaboration with the International Testing Institutes, up-to-date test specifications and regulations have been established. The test lab will be expected to be fully qualified for ISO/

IEC 17025 in 2008, accredited for IEC 62108 in mid 2009.

◎ Research Team:Cherng-Tsong Kuo, Hwa-Yuh Shin, Chih-Hung Wu, Chih-Kang Chao, Keng-Shen Liu, Chi-Joe kao, Hwen-Fen Hong, Zun-Hao Shih, Hung-Zen Kuo, Chun-Yi Chen, Shoy-Yuan Ma, Cheng-Dar Lee, Hong-Yih Yeh, Tzu-Chung Yenn, Ying-Lang Huang, Pan-Chih Liu, Bor-Shiun Huang, I-Tao Lung, Shang-Lee Chyou, Chih-Chieh Ma, Shou-Ju Yang, Wan-Li Hsu.

▲Sun Positioning Sensor and Controller



▲I-V&P-V Curves of One Module Used in 100kW HCPV System

▲Pillar-stand 5 kW and Roof-top 1.5 kW HCPV System

■ Technologies on Bioethanol Production for feedstock of kg/Batch Scale

》Lee-Chung Men

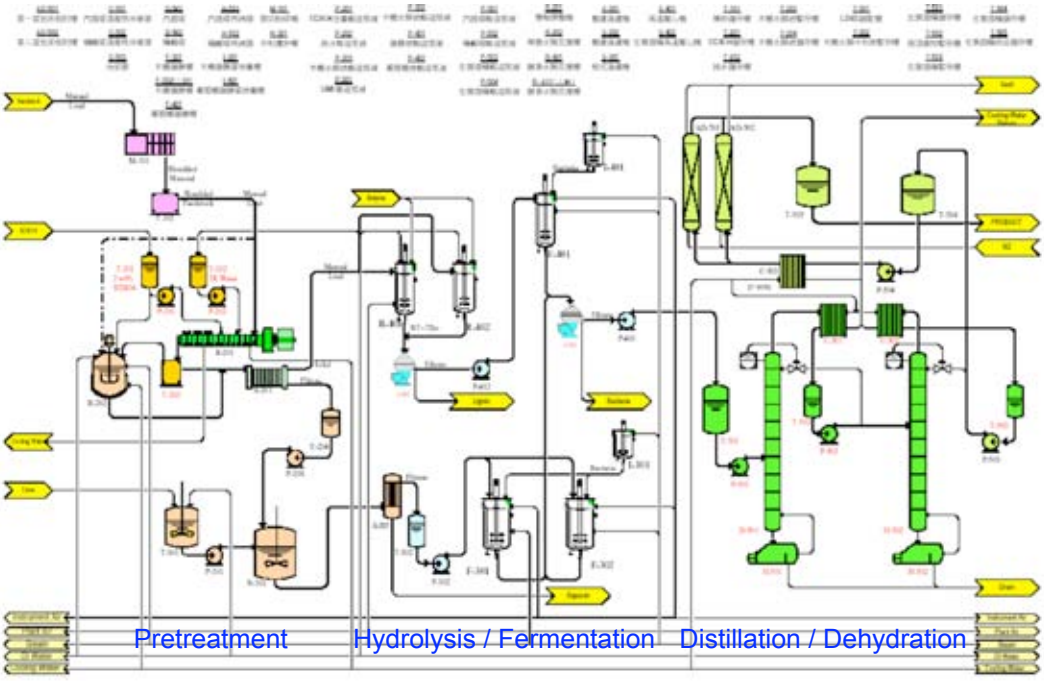
In order to solve the long-term energy as well as environmental problems of the world, the global society begins to consider using bioethanol as an alternative fuel for the traffic sector in energy consumption. INER launched its cellulosic ethanol project since 2005 starting with using local agricultural wastes which contained abundant cellulosic fiber as feedstock, such as rice straw, bagasse, and miscanthus. After the pretreatment and hydrolysis process, polysaccharides in the cellulosic biomass are degraded into fermentable monosaccharides, such as glucose and xylose. These fermentable sugars can be transferred to produce ethanol through a series of microorganism metabolism pathway. Ethanol can be used as an alternative fuel in replacement of gasoline for the automobile. By using biotechnology to transfer the agricultural waste into energy source, the pressure of the steep rise in price of crude oil can be released, and the pollution caused by burning the waste is also reduced. Furthermore, encouraging the plantation of energy crops for production of bioethanol, the following advantages will be attained: to stimulate economic activity in rural area, to keep the young labor staying in the farm, and to balance the income difference between urban and rural area.

Based on the experience of bioethanol production studied in the laboratory scale apparatus of 400 g lingocellulosic material per batch, a unit process testing facility had been set up for bioethanol production with a capacity of 10 kg feedstock per batch in 2007. The facility was designed on the base of SHF (Separated Hydrolysis and Fermentation) process. It consists of three main subsystems: twin-screw extruder pretreatment system, enzyme hydrolysis / fermentation system, and distillation/dehydration system. This was the first domestic testing platform for the bioethanol production that can be applied to evaluate the integrated process. For researches on feedstock properties, improvement on the hydrolysis efficiency of enzymes, and genetic modification of microorganism for fermentation, this test facility can be applied to study and evaluate their performance through integrated experiments to obtain valuable data for pilot plant design.

Using rice straw as the feedstock, a process developed in the 400 g/batch laboratory apparatus was evaluated and confirmed in the 10 kg/batch unit process testing facility. The hydrolysis efficiency of hemicellulose to five-carbon sugar can reach the range of 70% to 80%; the efficiency of cellulose hydrolysis to glucose is around 70%; the ethanol yields of 5C and 6C sugar fermentation are 77% and 95% respectively. The purity of ethanol can reach over 99.5%, which that meets the CNS specification of fuel ethanol for blending in gasoline up to 10%.

In addition, a high temperature and high-pressure reaction system for alkali pretreatment has also been set up. Ammonium aqueous solution was used in this system to digest the rice straw to produce sugar for fermentation. The total sugar yield of 70% has been realized. In this fiscal year, a contract project, "Development of Advanced Mass Production Technologies of Bioethanol from Lignocellulosic Material", has been granted from the Bureau of Energy, Ministry of Economic Affairs. A process development plant with the capacity of 1-ton dry biomass material per day will be constructed by 2009 for the evaluation of commercialization feasibility. The experiences gained in the design, construction, and operation of this system will be applied for scale-up of a demonstration and pre-commercial plant in the future.

◎ Research Team: Jia-Baau Wang, Lee-Chung Men, Wen-Song Hwang, Ming-Yih Liu, Gia-Luen Guo, Wen-Hua Chen, Sheng-Hsin Chou, Wen-Heng Chen, Hwa-Jou Wei, Wei-His Chen, Chiung-Fang Huang, Jong-Sheng Chen, Wei-Fan Huang, Ming-Chia Yiu, Deng-Chieh Hsu, Ting-Shiang Lin, Ching-Liang Chen, Tsong-Yang Wei, Ben-Li Pen, Ruey-Yu Chan, Yong-Yan Xu, Ming-Tseh Tsay, Ching-Huei Wang, Hsiao-Fang Pang.



▲PFD (Process Flow Diagram) of Cellulosic Ethanol Production System with 10 kg / day Capacity

▲Pretreatment System-twin Screw Extruder

▲Hydrolysis / Fermentation System

▲Distillation / Dehydration System

■ Development of SOFC Technology

》Chien-Hsiung Lee

INER's SOFC project was initiated in 2003, and its goal is to develop technologies for 1~5 kW SOFC distributed power generation systems in 2010. With substantial efforts on the project, remarkable progresses have been made in 2007. These include: (1) MEAs of power density ~500 mW/cm^2 at intermediate temperatures are made by both tape casting-screen printing and atmospheric plasma spraying (APS) processes; (2) glass ceramics of appropriate composition and its fabrication processes are developed for sealing of SOFC stacks; (3) proper dispensing, curing and reducing processes have been well defined for SOFC stacks; successive stack tests have been carried out to illustrate the sophisticated skills for stacking technology; (4) a 25-cell stack is designed, assembled and tested with power up to 1008 W under operation at 820^{o}C, exceeding the yearly target 600 W; (5) a 1kW SOFC demonstrative system has been set up with powerful data acquisition and control logics systems and satisfactory test results for a 1 kW stack, provided by HTceramix SA, Switzerland.

Novel processes for fabrication of air-tight/thin film of electrolyte layer for high performance SOFC-MEAs with nano-scale YSZ powders have been established by tape casting-screen printing methods. In addition, innovative APS coating processes for intermediate temperature (600~800°C) solid oxide fuel cell with nano-structured anode electrodes have been developed. Microstructure examinations of the MEAs indicate dense and thin films of electrolyte (<10mm) with nano-scale YSZ powders by conventional methods are achieved. Porous nickel metallic supported SOFC MEA substrates with nano-structured LDC/Ni as anode, LDC as barrier layer, LSGM as electrolyte and LSGM/LSCF+LSCF as cathode by APS processes are obtained. The power densities, were over 500 mW/cm^2 for INER's MEAs.

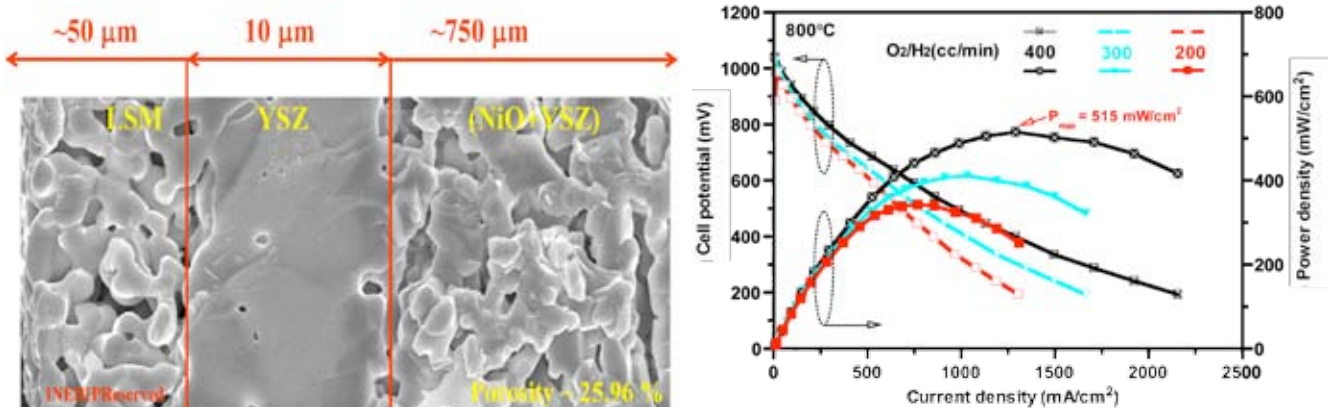
Sealant material plays an essential role for effective sealing of the planar SOFC stacks. In the project, different compositions and fabrication processes for glass ceramics are systematically investigated. It is found that a novel borosilicate glass-ceramics, coded as gc9, for SOFC stacks possesses a compatible CTE (~10 ppm/ºC) with those of both interconnect

and MEA over a wide temperature range. Microstructure analysis indicates that the gc9 glass-ceramic adheres very well to either interconnect (Crofer22) or MEAs. While tested at 800ºC with helium gas, a leakage rate of ~1.2×10^{-3} sccm/cm is obtained, surpassing the hermetic requirements for SOFC stack at intermediate temperatures. Adhesion mechanism as well as long-term stability of sealing materials is still under investigation for further improvements.

The project has also progressively established the capability of stacking technology both in software and hardware. Currently, different configurations with internal manifold and counter flow for planar SOFC stacks have been designated and analyzed. A series of SOFC assemblies including 1-cell, 3-cell, 5-cell and 25-cell were fabricated and tested to accelerate the stacking technology development. Results of the 25-cell stack test revealed that power output was around 1008 W and power density was 490 mW/cm^2 at the conditions of 0.8V/cell and 820ºC.

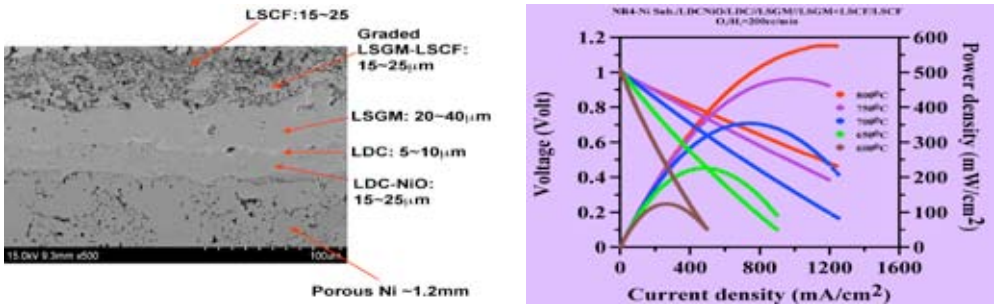
Deliberate efforts have been made to set up a 1 kW demonstrative SOFC power system. A 1 kW SOFC stack associated with data acquisition and control logics systems, and natural gas reformer was successfully integrated into the power generation system and yielded satisfactory functional test results. On the following steps, a compact design will be implemented to integrate the stack and the balance of plant (BOP) into a box to optimize heat management and increase overall efficiency of the SOFC power system.

◎ Research Team:Chien-Hsiung Lee, Maw-Chwain Lee, Chang-Sing Hwang, Ruey-Yi Lee, Kin-Fu Lin, Wei-Ping Huang, Wei-Ja Shong, Li-Fu Lin.



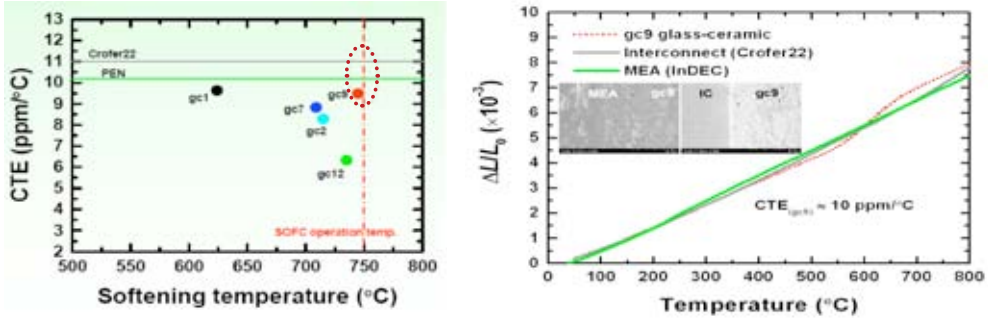
(a) (b)

▲(a) Microstructure and (b) I-V-P Curves of a Cell made by the Tape-casting Method



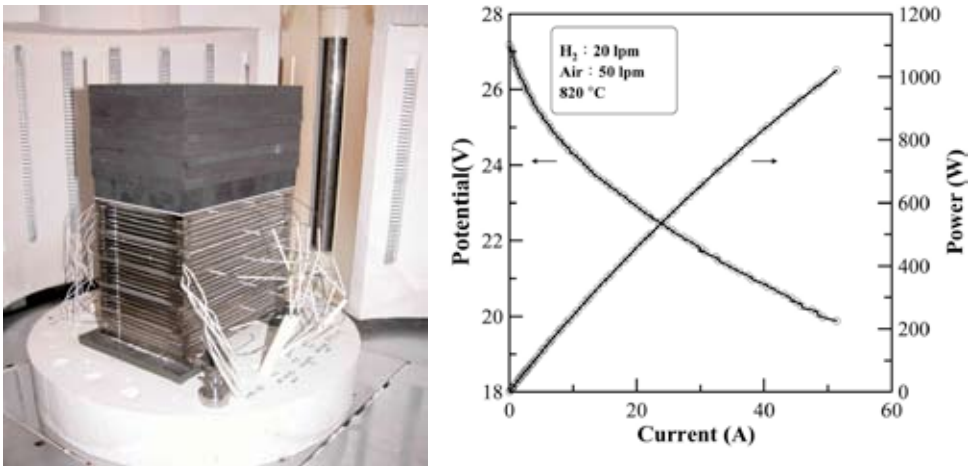
(a) (b)

▲(a) Microstructure and (b) I-V-P Curves of a Cell made by the APS Method



(a) (b)

▲(a) Softening Temperatures and CTEs for Various Self-made Glass-ceramic Sealants; (b) Elongation of gc9, Cell and Interconnect with Respect to Temperatures.



▲(a) The Outlook and (b) I-V-P Curves for a 25-cell Stack

■ DMFC for Applications in the 3C Power System

》Charn-Ying Chen

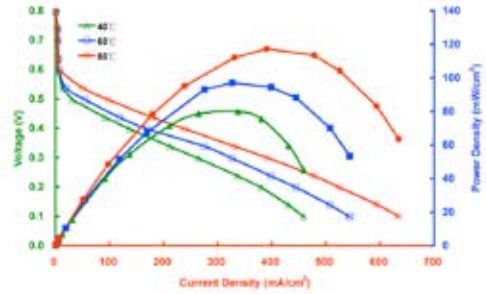
Fuel Cell systems offer the potential for clean and reliable energy generation used for power stations, road transportations and portable power supply units. Among various kinds of fuel cells, the Direct Methanol Fuel Cell (DMFC) operates at low operation temperature (RT-80^{0}C), and uses methanol as the fuel which is a liquid and is thus easier for fuel storage and transport than hydrogen. Compared to Li-ion battery, DMFC exhibits higher energy density and is considered to be a suitable power source for longer operation of personal electronic devices such as notebook, PDA or cellular phone. The aim of INER DMFC project is to develop a DMFC system with improved power density, reduced size and lower cost for portable applications.

The Membrane Electrode Assembly (MEA) is the key component of DMFC. The project has developed innovative MEA based on using CNT as supporter to synthesis Pt series catalysts such as Pt/CNT, PtRu/CNT, PtRuIr/CNT etc. When applying homemade both anode and cathode catalysts to make a DMFC single cell, the maximum power density output is

about 120mW/cm^2. A 20-cell DMFC stack with a single MEA of 50cm^2 active area is also successfully fabricated in-house, the power of this stack can reach up to 83W at 60ºC in the air mode.

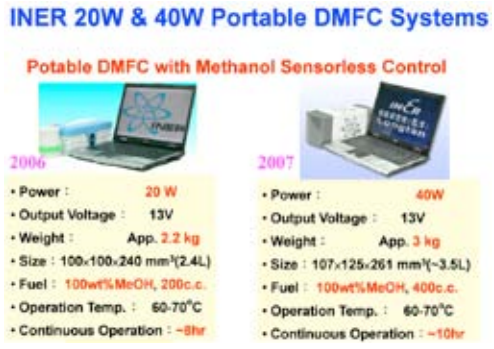
In addition, a prototype DMFC system of 20/40W is developed for use as a power source for notebooks. A methanol sensor-less control technique is applied in this system which can run for 9 hrs with 400cc 100wt% neat methanol. The energy density of 72 hr mission of this system is estimated to be 431 Wh/L (502 Wh/kg), which is greater than that of Li-ion battery of 250Wh/L (150Wh/kg). Furthermore, the volume /weight of the system are only 3.5 L/3 kg and 2.4 L/2.2 kg for 20W and 40W systems, respectively. Currently, the project has demonstrated these portable DMFC systems in 2006 Fuel Cell Seminar and 2006/2007 Taiwan Small Fuel Cells Symposium. Also, the project has successfully transferred methanol sensor-less control technology to the collaborated industry partner.

◎ Research Team: Ying-Sheng Lee, Charn-Ying Chen, Yeong-Der Lin, Chun-Lung Chang, Peng Yang, Chi-Yuan Chang, Chih-Yuan Hsu, Der-Hsing Liou, Chih-Lin Huang, King-Tsai Jeng, Chun-Ching Chien.



▲Performance Curves of Catalysts Supported on Carbon Nanotubes

▲Stack Development of DMFC



▲20/40W DMFC Prototype Systems for Notebook Applications

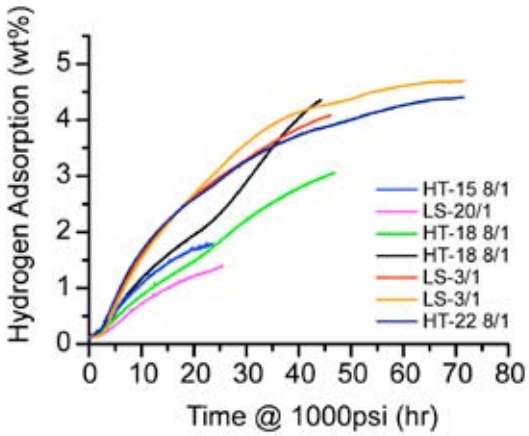
■ Hydrogen Storage in Metal-Organic Frameworks (MOFs)

》Ming-Sheng Yu

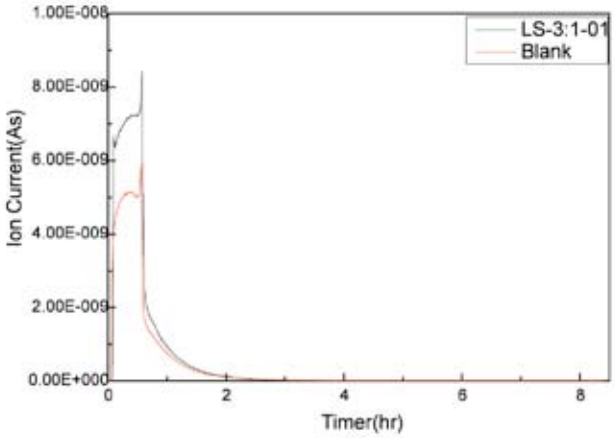
Development of efficient, safe, and cost-effective hydrogen storage system with capacity greater than 6.5 wt% is required if hydrogen is to become a viable energy carrier for vehicular application. Nanostructured materials, such as metal-organic frameworks (MOF), which have uniform nanopores and sufficiently large surface area, are regarded as promising materials for hydrogen storage. However, the storage capabilities of these materials remain unclear and need more effort to understand factors governing their performance.

In this study, the synthesized MOFs are bridged with appropriate catalysts to enhance hydrogen uptake capacity through hydrogen spillover. It was found that a specific bridged sample of IRMOF-8 with specific wetting and carburization treatment manifests a hydrogen storage capacity of 4.7 wt% at room temperature and 6.9 MPa H_2 pressure. The maximum hydrogen uptake is estimated to exceed 5 wt% with an increase in hydrogen pressure or charging time. TPD tests also indicate that hydrogen can be released from bridged-MOFs at room temperature and atmosphere. In order to demonstrate the performance of hydrogen cartridge with bridged-MOFs, a synthesis system had been set up and 5 grams of MOFs per batch were produced successfully. A system containing hydrogen cartridge of MOF, pressure regulator and flow controller was also set up. An iPod Shuffle can be powered to play music with a 3 W PEMFC stack connected to a hydrogen cartridge. The desorption time for the hydrogen storage cartridge with bridged-MOFs sample could last at least about 105 minutes longer than that of empty one through the measurement of OCV utilizing fuel call test station. This demonstration was the first time in the world regarding an MOF's storage cartridge to store and to release hydrogen gas, and also to produce electricity.

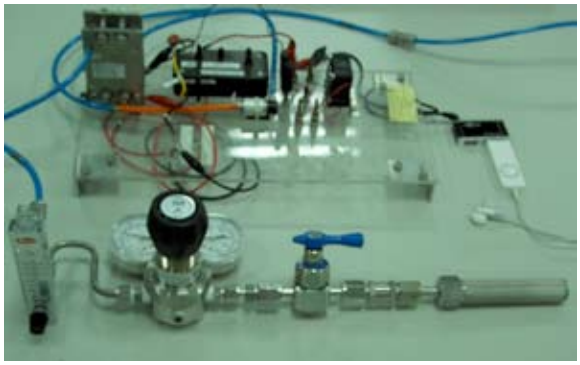
◎ Research Team:Ming-Sheng Yu,Cheng-Si Taso, Pin-Yen Liao, Chen-Yu Wang, Tsui-Yum Chung, Hsiu-Chu Wu, Yan-Hui Wu, Hsiu-Pei Hsu, Che-Chung Lai, Yun-Hwa Hwang, Chen-Chung Liu, Wen-Fan Chang.



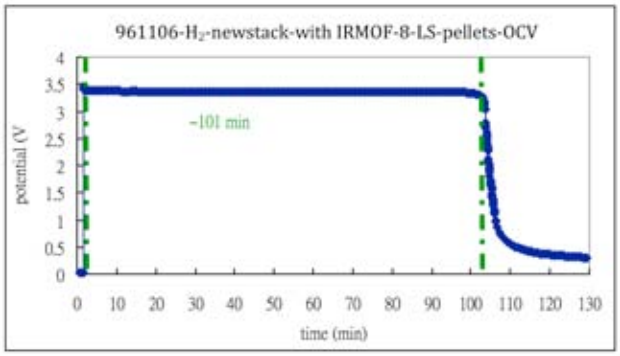
▲The Variation of Hydrogen Storage Capacity with Time for Bridged IRMOF-8.



▲The Hydrogen Release Signal Versus Time.



▲An ipod Shuffle is Powered to Play Music through the Connection of the Hydrogen Storage Cartridge of Bridged-mofs with Regulator, Flow Needle Valve, PEM Fuel Cell and Voltage Control Box.



▲The Duration of Hydrogen Release for a Cartridge with Bridged-MOF Specimens Through the Measurement of OCV.

■ R&D of Quantum Dots Light Emitting Device

》Tsun-Neng Yang

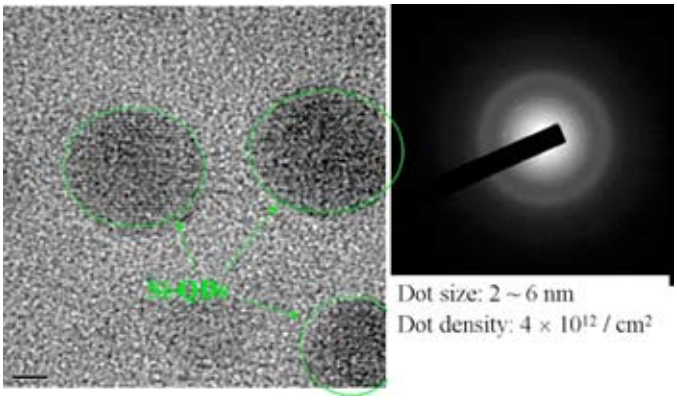
In 2001, Korean researchers, Park et al., successfully synthesized silicon quantum dots (Si-QDs) embedded in silicon nitride matrices (SiN_x) by plasma enhanced chemical vapor

deposition (PECVD) and confirmed the existence of "quantum confinement effect". Their results indicated that the peak position of the photoluminescence (PL) spectrum would be influenced by the Si-QDs' size. As a result, visible fluorescence materials with different emission wavelengths could be obtained by controlling the size of the Si-QDs. The complicated interface structures between the Si-QDs and the matrices, such as the dangling bonds of H, N atoms and their combinations, will form the white-luminescence emission center. By PL or electroluminescence (EL) techniques, a continuous white-luminescence emission band from 400 to 700 nm would be obtained.

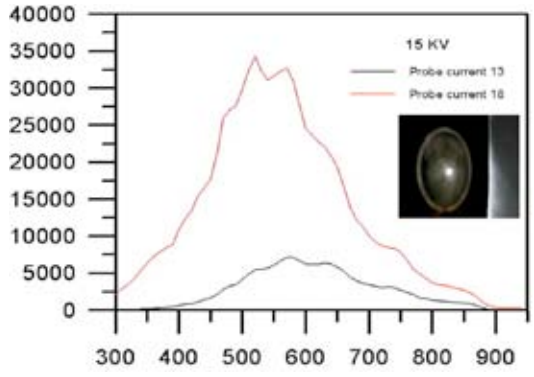
In this study, the PECVD system and the home-made APCVD system were used respectively to undergo the low temperature (< 500 ^{0}C) and high temperature (> 500 ^{0}C) thin film deposition processes. For the visible fluorescence thin film depositions, the optimum temperature for the Si-QDs/SiN_x thin film deposition in the APCVD system was about 850 ^{0}C. The HR-TEM micrograph of the Si-QDs/SiN_x thin films revealed that the Si-QDs with sizes about 1 ~ 10 nm were embedded uniformly in the SiN_x materials. An emission band from 400 to 700 nm could be obtained from the PL spectrum; meanwhile, a bright white-light source excited by He-Cd laser (325 nm) at room temperature could be observed by naked eyes. In contrast to the samples without H_2 annealing treatment, the PL peak showed a "blue-shift" tendency due to the decrease of the Si-QDs' size after H_2 annealing treatment. In addition, the decay of the PL intensity would be improved by H_2 annealing. For the EL experiments, the carbon nanotubes (CNTs) emission device fabricated by APCVD was chosen as the exciting sources for the Si-QDs. The experiment results showed that the CNTs could successfully excite the low-temperature Si-QDs/SiN_x fluorescent thin films.

This study shows that the Si-QDs/SiN_x visible fluorescence thin films can be an innovative visible light emitting source and further developed as a flat field emission luminescence lamp.

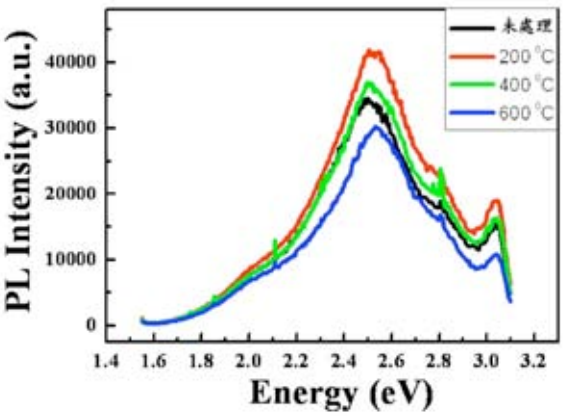
◎ Research Team:Tsun-Neng Yang, Shan-Ming Lan, Chien-Te Ku, Meng-Chu Chen, Yu-Hsiang Huang, Wei-Yang Ma, Yu-Han Su, Chin-Chen Chiang.



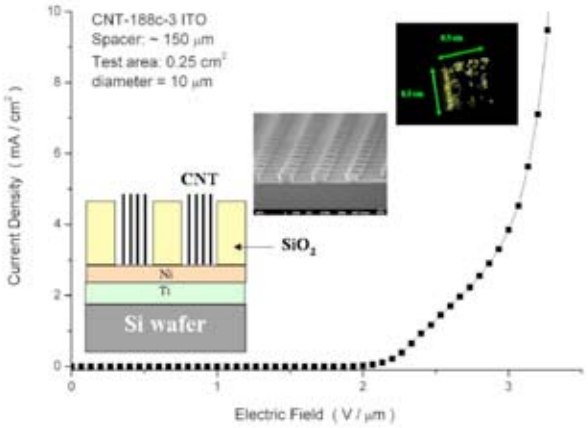
▲The HR-TEM Micrograph of the Si-QDs/SiN_x Thin Films



▲The EL Spectra and PL Picture (excited by 325 nm He-Cd laser) of the Si-QDs/SiN_x Thin Films



▲The PL Spectra of the Si-QDs/SiN_x Thin Films after H_2 Annealing Treatment



▲The Field Emission Test of the Si-QDs/SiN_x Thin Films

■ R&D Planning on the Performance Enhancement of IGCC System

》Yau-Pin Chyou

"Kyoto Protocol," the outcome of the meeting held from December 1 through 11, 1997 in Kyoto, Japan, where more than 160 nations met to negotiate binding limitations on greenhouse gases for the developed nations, has been activated since February 16, 2005. The worldwide efforts of environmental protection for the sustainable development of human society are expected to impose international pressure in the future; hence, pre-caution measures for domestic economical and industrial development should be planned in advance. Due to the "Nuclear-free Homeland" policy, Taiwan has no choice but to heavily rely on the use of carbon-rich energy sources and the dominant share of coal-fired power plants. Hence, it would be necessary to introduce sustainable base-load (BL) options for power utility industry, in order to preserve the continuous development of society and the balance among environment, energy, and economy. Integrated Gasification Combined-Cycle (IGCC) with carbon capture option, namely sustainable IGCC or SIGCC, seems to be an ideal candidate to fulfill the requirement for the aforementioned situation. In addition, domestic economic growth can be enhanced, provided that the promotion of indigenous energy industry can be achieved. This project covers an integrated R&D planning, of which topics include the following: (1) System Design & Optimization, (2) Advanced Processes, and (3) Life-Cycle Assessment (LCA).

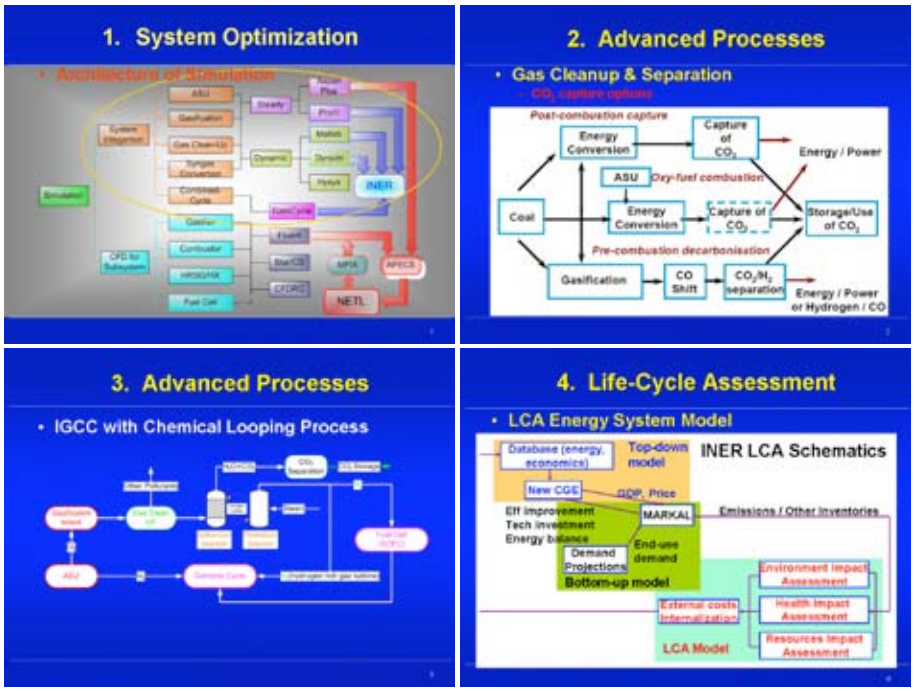
The activities of System Design & Optimization will be focused on system process simulation, CFD of key components, as well as commissioning of benchmark. The ultimate goal will be aiming at enhancing domestic technological capability and upgrading design hierarchy, in order to establish indigenous system integration expertise.

Evolutionary design improvements have been implemented into new IGCC projects, via the accumulation of operation practice in the past years. However, it is hoped that research on advanced processes for future systems can formulate the leading-edge scope of system engineering R&D, which can further enhance the performance and indices of sustainable development. Two topics are included in the present work, namely Gas Cleanup & Separation

processes, and chemical looping processes feasibility study.

In the LCA category, activities include energy system modeling, economical analysis, and LCA for SIGCC. The aim of this sub-project is to establish an indigenous integrated energy-economic analysis model, which incorporates various technological features, such as R&D benefits, technology innovation, efficiency improvement, cost reduction, etc.. It is expected that this model can reasonably evaluate the economical benefit due to the commercialization of new technologies through R&D, and provide a scientific tool to the government for planning energy, technology, and industry policies.

◎ Research Team:Yau-Pin Chyou, Fu-Kuang Ko, Ching-Tsung Yu, Po-Chuang Chen, Wei-Chung Chen, Jong-Shun Chen, Chang-Bin Huang, Pei-Ying Tseng, Chung-Han Lin.



The Environmental Plasma Technologies

》Kuo-Chuan Cheng

The research activity of INER in the area of environmental protection this year keeps focusing on the development and applications of environmental plasma technology. Besides end-of-tube types of pollution control, waste processing, etc., advanced environmental technologies, such as clean production process, resource recovery and waste-to-energy, are also developed for their sustainability goals of zero waste.

The INER plasma melting factory for low-level radwastes, completed its "hot test" last year, was granted operational license early this year as expected and was included in the INER radwaste processing facilities for routine operation. Taiwan becomes the fourth nation to own a plasma plant for LLW, succeeding Russia, Swiss and Japan. Plasma melting is a stabilizing solidification method of toxic ashes from the incineration of metropolitan solid waste (MSW), whose industrialization requires improvement in its cost effectiveness. Recycled products made this year from water-quenched slag, such as sound-proof board, paper and blanket of mineral fiber, etc., are of such high value that they will impact investment decision favorably. In the mean time of plasma-treating the inorganic contents of wastes, the proportion of organic contents is pyrolized and gasified into syn-gas, which can be used for high-efficient power generation. The INER pilot plasma gasification system and the syn-gas microturbine generators are now taking their shapes and will soon be commissioned for the preparation of waste-to-energy experiments. The steam plasma torch uses steam as energy carrier, as well as a source of hydrogen and oxygen needed for specific chemical reforming reactions. Deep investigations were carried out on steam plasma torches using various newly established diagnostic and measuring tools, providing understanding of various facets of torch. Roll-to-roll coater is a modern vacuum plasma machine for mass production of flexible workpieces. A plasma surface activation machine of this type, together with a matching wide plasma source, was successfully transferred to industry this year, marking the advancement of INER plasma surface modification. Other topics, such as the atmospheric plasma sterilization laboratory, new process for semiconductor using PIII, dual functional textiles using atmospheric plasma, plasma protective coating of the connecting plate of SOFC, etc., are efforts extending into new application territories, taking advantage of the INER strength in plasma technology, and will also be described in the following.

■ Development of Steam Plasma Torch

》Peir-Jyh Wang

The DC plasma torch with steam as the working gas is a favorable instrument for organic decomposition due to its high enthalpy and rich content of active species (H, O, and OH). Besides working as the heat source for organic decomposition, it can also be used for plasma spraying and metal cutting. The Plasma Torch Research Laboratory of the Institute of Nuclear Energy Research (INER) has devoted to commercializing steam plasma torch based on its well-established experience in other types of plasma torches. As the result, a lifetime testing and monitoring system for non-transfer DC steam plasma torch were constructed in 2007. In addition, several torch diagnostic technologies, such as temperature, flame image, plasma gas flow-rate, flame optical spectrum, voltage spectrum, etc., have been established to help optimize the design of steam plasma torch as well as its operation.

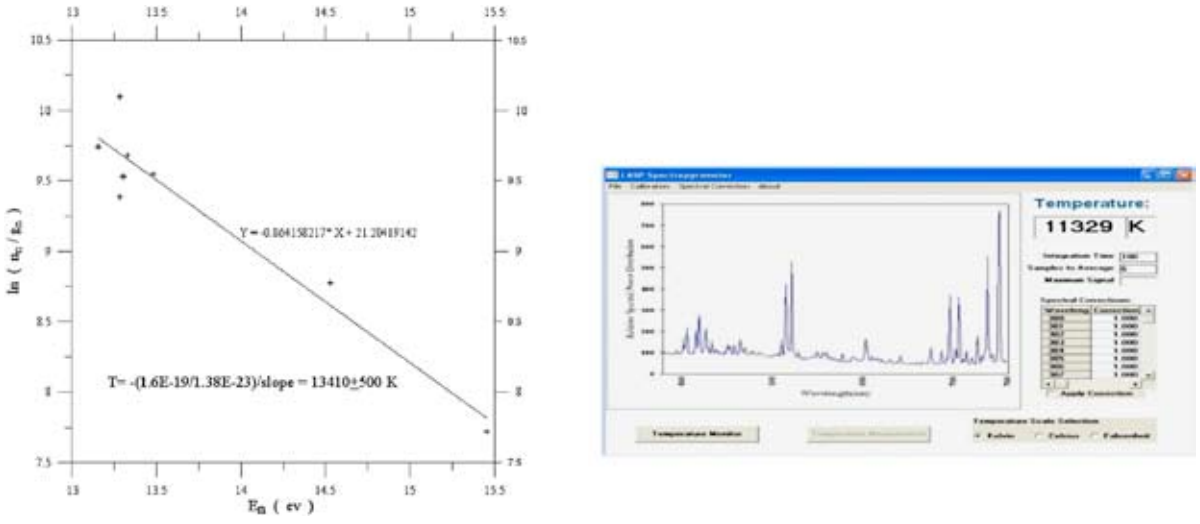
The chemical decomposition efficiency of a plasma torch depends closely on the plasma-jet (flame) temperature at the exit and the conventional way to measure it is by the optical emission spectroscopy (OES), which assumes the plasma is under local thermal equilibrium (LTE) and calculates the temperature from the collected intensities of appropriate spectral lines. This method has the drawback of being unable to monitor the real-time temperature variation during system operation. To overcome this problem, INER has successfully utilized the Alexandrite spectropyrometer to develop a novel plasma-temperature measuring technique, with which the real-time temperature can be detected accurately, beneficial to the monitoring and operation of steam plasma torch. In addition, the working properties and operational conditions of non-transfer steam plasma torch with well-type cathode have been extensively measured.

Generally, the flame image of a plasma torch reflects its physical, chemical, and structural properties, as well as its operational conditions. For this reason, a CMOS (Complementary Metal Oxide Semiconductor) high-speed camera was adopted to analyze the dynamic characteristics of the flame. Furthermore, the acquisition of other physical characteristics, such

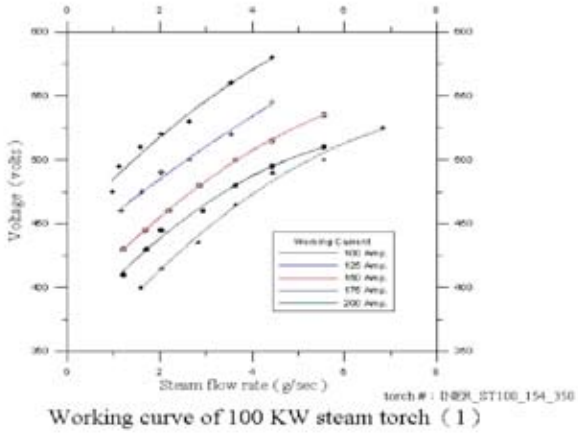
as current, voltage, induced noise or vibration, etc., from steam plasma torch was conducted to investigate the correlation between these parameters in frequency domain and operational conditions.

◎ Research Team:Peir-Jyh Wang, Shih-Wen Huang, Jih-Shan Tang, Deng-Lain Lin, Chen-Yuan Hsu, Chin-Ching Tzeng.

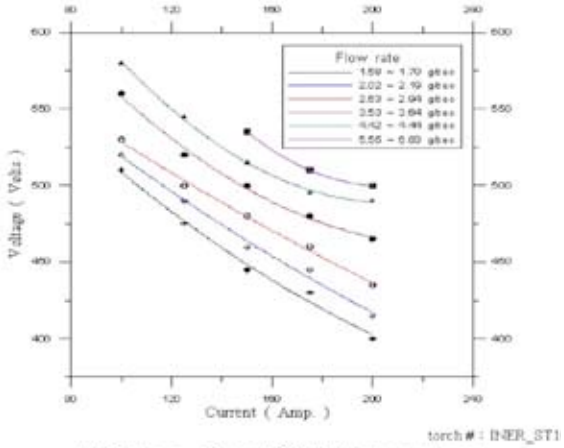
▲Torch Lifetime Testing and Monitoring Systems



▲ Plasma-jet Temperature Measurement by OES and Alexandrite Spectropyrometer



Working curve of 100 KW steam torch （1）



I-V Curve of the 100 KW steam torch

▲The Working Curves of Steam Plasma Torch

(a) (b)

▲Images of Plasma Jet in Different Torch Configurations Captured by CMOS High-speed Camera. The Exposure Time is (a) 2 μsec and (b) 100 μsec.

■ Development of the Recycled Products from Water-quenched Plasma Molten Slag

》Wen-Cheng Lee

In 2006, the Institute of Nuclear Energy Research (INER) began the study of porous materials and fiberous materials made of water-quenched slag resulted from the plasma melting of incineration ashes. Several experimental facilities have been established to investigate the parameters in preparing such materials. In 2007, a comprehensive study on

the processes of making porous materials and fiberous materials has been conducted to further enhance their material qualities. Furthermore, products, such as porous light-weight soundproof plates and non-woven fireproof papers, have been developed to expand the commercial application of these materials.

The essential characteristics of the materials for making soundproof construction plates or walls include high porosity, lightweight, soundproofing, and thermal insulation. Currently, we are able to achieve density and porosity ratio of 0.9-1.2 g/cm^3 and 50-60 %, respectively. Colored porous plate samples having dimensions of 60 cm (L) × 60 cm (W) × 1 cm (T) were successfully fabricated as well. In addition, the soundproof plate developed in collaboration with a contracted company achieved an E-class sound-absorbing level, which means a noise reduction of 42 dB.

The study of slag fibers emphasizes on reducing the shot content and improving the material quality as well as the production yield. In 2007, 75 kg total of slag fibers have been produced experimentally in 40 batches, which gave an average production yield efficiency of 80 wt%. The slag fibers prepared have a shot content of 10-15 wt%. They can function normally under the pH of 3-13 and at a temperature as high as 700 °C. These values all fit in with the requirement of CNS 3657 standard. Due to the excellent fire-resistance of slag fibers, the slag-fiber-containing, non-woven papers developed in collaboration with Taiwan Textile Research Institute have been proven to be first-class fire-resistant materials. They can be marketed commercially as fireproof decoration papers.

In 2008, we will continue to improve the recycling technology associated with plasma-melting. The future study of porous materials will focus mainly on fabrication of light-weight composite materials (60 cm (L) × 60 cm (W)), the construction of soundproof walls (1.2 m (L) × 1.8 m (H)), and their potential market. As for the slag fibers, we will construct a continuous fiber-manufacturing unit with a capacity of 1 kg/h to produce a 20 cm (W) × 0.3 cm (T) slag-fiber blanket, and find more of their applications in the market.

◎ Research Team:Sheng-Fu Yang, To-Mai Wang, Yung-Wuo Lee, Wen-Tung Chiu, Wen-Cheng Lee, Kin-Seng Sun, Ching-Liang Chen.

▲Recycled Products from Plasma Molten Slag(Top left: Colored light-weight slag plate; Top right: Soundproof slag plate; Bottom left: Slag fibers; Bottom right: Slag-fiber-containing non-woven paper)

■ Construction of Plasma Assisted Gasification System for Biomass and Organic Wastes

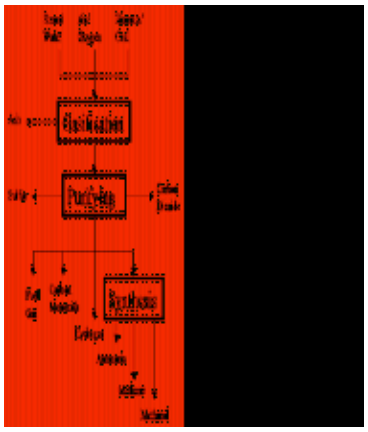
》Heng-Yi Li

Biomass energy as well as waste energy is of great attention worldwide nowadays. Therefore, INER is actively developing plasma gasification for conversion of biomass as well as organic solid wastes into syngas ($CO+H_2$). The syngas can then not only be used as a clean fuel for electricity generation but also be a potential candidate for synthesis of economical chemicals, as illustrated in Fig. 1. A lab-scale plasma gasifier has been constructed and used for gasification experiments since 2006. Currently, a pilot-scale plasma gasification plant is under construction and scheduled to be finished in the end of 2008.

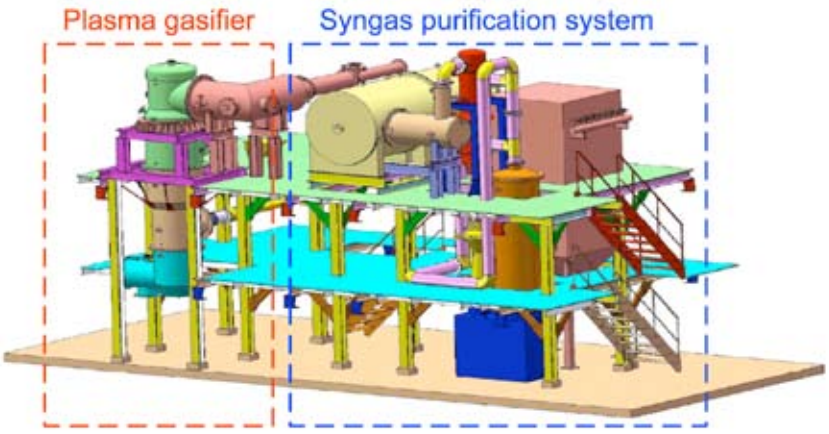
INER now focuses on development of the thermal plasma assisted biomass gasification technology as well as the advanced fixed-bed gasifier. A traditional fixed-bed gasifier generally suffers several problems such as the tar formation and plugging, the system instability due to variation of the moisture content and the heating value of biomass, and the low conversion rate due to low gasification temperature. To overcome the problems, INER proposes a novel concept-Plasma Assisted Gasification. A plasma torch can provide a hot gas with a temperature as high as several thousands degree Kelvin that can thermally decompose the tar formed. Similar idea has been proven effective in literatures published in last decade. Accordingly, a plasma torch is installed at the exit of gasifier. Because plasma torches can provide a high enthalpy gas instantly and flexibly, the influence of water content and heating value of biomass on the gasifier operation can be eased by additional plasma torches. At the mean time, consumed electricity serve partially as an extra energy source to raise not only the temperature of gasifier but also the biomass conversion rate.

Currently, a pilot-scale gasification plant is under construction. The plant is designed with a capacity of 100 kg/hr, at the operation pressure of up to 5 bar, and to handle either agricultural biomasses or refuse derived fuels (RDF) of dimensions smaller than 1.0 inch. Several steam plasma torches will be installed with the gasifier. The gasifier convert biomass into gas products, which mainly contain CO and H_2 as well as a variety of trace gases such as HCl, H_2S, tar, and metals. Downstream of the gasifier, a series of gas cleaning devices (e.g., Venturi scrubber, acid scrubber, alkaline scrubber, and amine scrubber) are installed to handle these impurities. Thereafter, the cleaned syngas is converted into the electricity and the cooling gas by a set of micro-turbine generator and an absorption chiller, respectively.

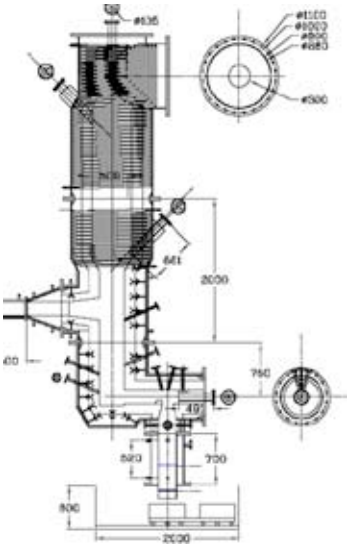
◎ Research Team: Heng-Yi Li, How-Ming Lee, Ching-Hui Kuo, Yuh-Jeng Yu, Lieh-Chih Chang, Kuo-An Wang, Shyh-Chang Hwang, Lin-Chiu Tsai, Der-Heui Shieh, Maw-Suey Kuo, Min-Lin Chu, Hsiao-Shan Yang.



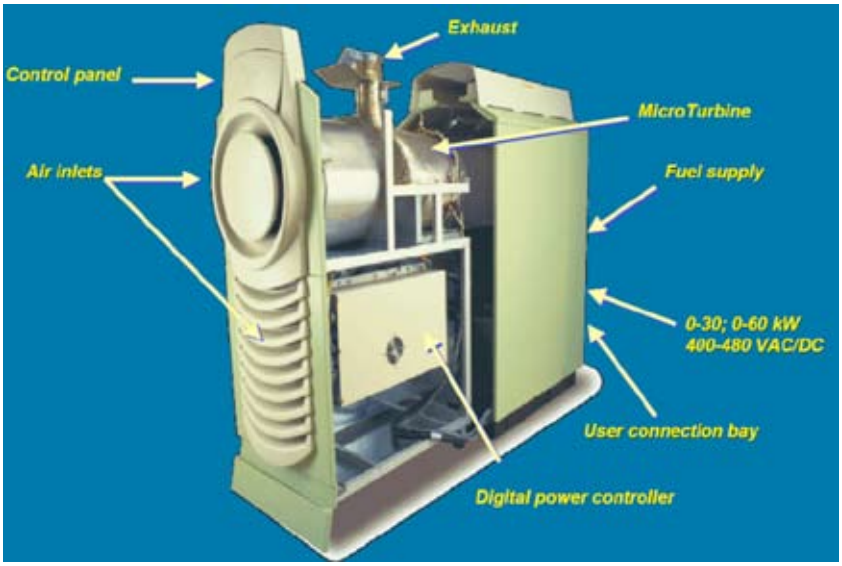
▲Gasification Flow Diagram



▲3D Model of the Pilot-scale Plasma Gasification Plant



▲Advanced Fixed-Bed Gasifier of INER



▲Capstone Micro-turbine Generator

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

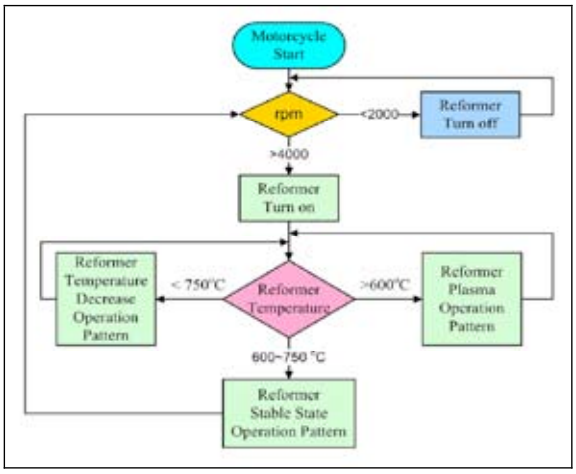
》Yu Chao

There are more than 10 million motorcycles in Taiwan now, which have contributed over 10% of the total CO and HC emissions nationwide and are considered as one of the major mobile pollutant sources. This project's objective is to develop a low-pollution and environment-friendly motorcycle powered by mixed syngas-gasoline fuel, that can improve air quality as well as energy efficiency. The syngas is generated via an on-board plasma reformer before mixing with gasoline and air as the fuel of engine.

A prototype motorcycle utilizing butane as the reformed fuel had been demonstrated last year. In order to improve the usability of the reforming motorcycle, development of gasoline-reforming catalyst, gasoline vaporization device as well as overall system integration is the key work item this year. The catalyst can reform vaporized gasoline to generate reformat containing 30% syngas. The proportion of syngas agrees well with the literature suggested value of syngas/gasoline = 5-10 wt%. A control logic system which smartly controls fuel, air supplies and reformer operation based on the conditions of engine speed and reformer temperature, had also been developed. This system enables motorcycle drivers to ride it easily without added difficulty. Next year an improved reforming system will be developed to further utilize engine waste heat to vaporize gasoline so as to enhance overall energy efficiency.

◎ Research Team: Yu Chao, Hung-Tsai Hu, Chao-Yuh Chen, Ching-Tsuen Huang.

▲Integrating Control Unit of Engine Speed and Reformer Temperature



▲Control Logic Flow Chart of Reformer Motorcycle

■ Development of Atmospheric-pressure Plasma Technology for Air Sterilization

》Shiaw-Huei Chen

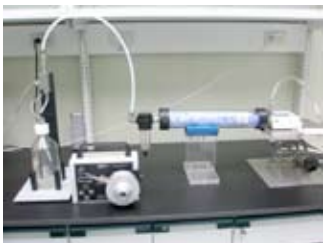
Since 2003, Asia has deeply suffered from the SARS and Bird-Flu air-borne plagues; people begin to be aware of and realize the importance of air sterilization. In the highly populated Taiwan, the heat, ventilation, air condition (HVAC) system of most office buildings and hospitals are not equipped with proper function of bacteria disinfection and sterilization. The Environmental Protection Agency (EPA) of Taiwan recently proposes an "Indoor Air Quality Protocol" for improvement and protection of the health of people. Atmospheric-pressure non-thermal plasma is an emerging technique since 2000, and is regarded as a promising approach for effective bacteria sterilization. This non-thermal physical method has the merits of short processing time, easy operation, wide range of treatment material, and its combined mechanisms including ultraviolet, ozone, charge particle bombardment, and highly reactive radicals etc. In 2007, we have established a P2-class microbe laboratory and a plasma testing platform. A series of experimental tests have been conducted for air sterilization using a set

of dielectric barrier discharge (DBD) reactors. Greater than 99% of bacterial killing efficiency has been achieved at the air resident time less than 0.2 second. Future research will focus on optimizing sterilization efficiency, detailed study on experimental parameters as well as the killing mechanism. Also the pulsed AC filter sterilization device and biomedical disinfection device will be developed as well.

◎ Research Team:Shiaw-Huei Chen, Tsair-Fuh Huang, How-Ming Lee, Yung-Chih Chen, Men-Han Huang, Jyh-Ming Yan, Ming-Song Yang.

▲Isolated Changing Room

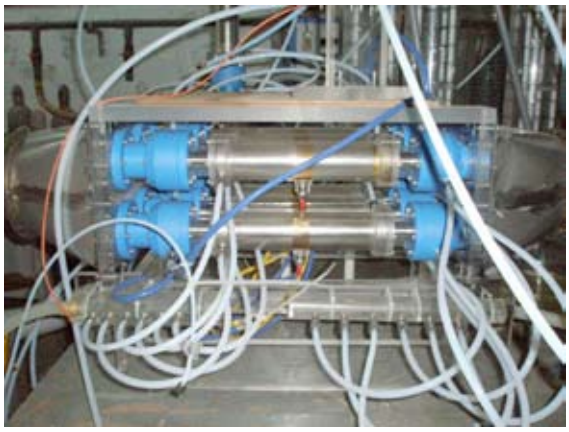
▲Experimental Area



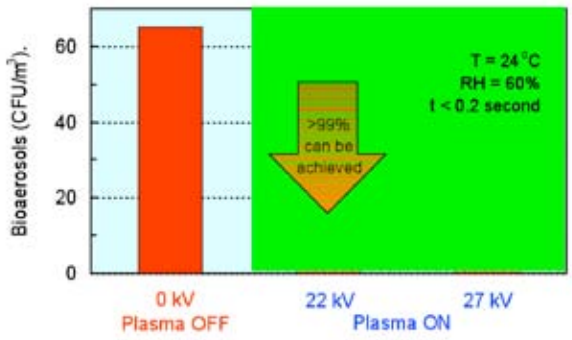
▲Bioaerosol Generator and Sampler

▲Incubators and Sterilizers

▲P2-class Microbe Laboratory



▲DBD Air Sterilization Reactor



▲Sterilization Result for Ambient Air with DBD Plasmas

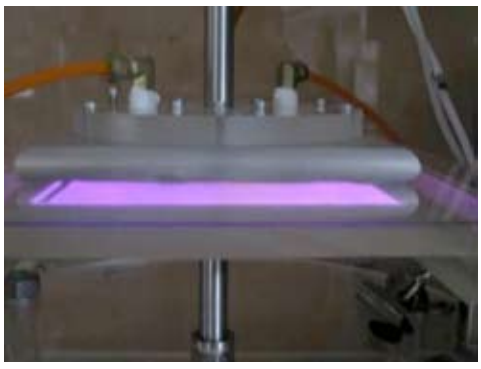
■ A Triple-electrode Atmospheric-pressure Plasma Source

》Cheng-chang Hsieh

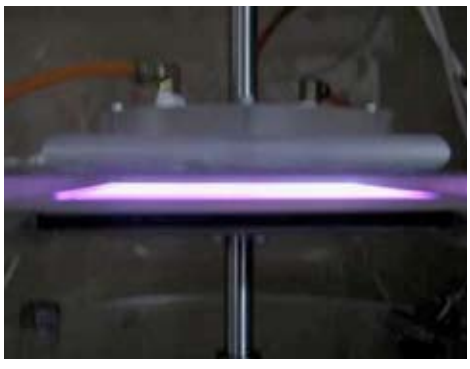
Generally, the atmospheric-pressure glow discharge plasma source employing capacitive dielectric barrier discharge can only be operated homogeneously by using helium as principal working gas. However, helium is very expensive. If attempting to use argon as the alternative working gas, homogeneous discharge can only be generated at an electrode gap of narrower than 1.5 mm, which imposes a stringent limit on its applications.

A new atmospheric-pressure argon plasma source was developed by the combination of a coplanar plasma source equipped with three electrodes. The operating principle of this device is that a uniformly pre-ionized plasma was generated on the electrode surface by the first unipolar pulsed voltage, followed by the subsequent space plasma discharge induced by the charged particles attracted by the second unipolar pulsed voltage on the electrode surface. Due to the presence of the pre-ionized surface plasma, the subsequent space discharge is more easily generated. Thus, the effective reduction of the high voltage required , the increase of electrode gap, and the enhancement of plasma stability can all be obtained. As a matter of fact, a homogeneously ionized argon space plasma has been experimentally produced at the 10-mm electrode gap at atmospheric pressure.

◎ Research Team: Cheng-Chang Hsieh



▲Homogeneous Ar Surface Discharge Plasma



▲Homogeneous Triple-electrode Ar Discharge Plasma

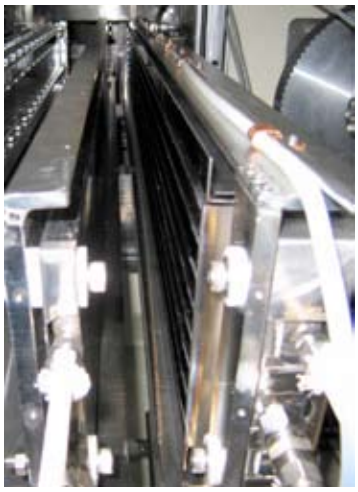
■ Roll to Roll Plasma Surface Activation System

》Ching-Pei Tzeng

To promote the plasma surface treatments of large-area flexible materials, a mass-production type of plasma surface activation apparatus for PET films with width of 1,200 mm was developed to meet the industrial demand. A large vacuum chamber with dimensions of W2,400 × H1,800 × D2,150 mm, vacuum roller sets and their precision tension controller, vacuum pump and modular heating units are all included in this apparatus. In addition, for the key plasma production unit, a set of hollow-cathode-discharge plasma source with 1,500 mm in length and 400 mm in width was also developed. The plasma density is enhanced by hollow-trench configuration, and thus, it reaches higher than 4×10^{10} n/cm^3. The uniformity across plasma region is still within ±10%. The maximum operation power is capable of driving to as high as 10 kW. While employing 6 kW plasma to activate the PET films moving at 6 m/min, the contact angle of treated film is found lower than 30^o. This result shows that this developed system and process meet the requirements for commercial production capacity as well as quality.

◎ Research Team:Ching-Pei Tzeng, Cheng-Chang Hsieh, Deng-Lian Lin, Fu-Chun Lin, Ming-Chung Yang.

▲Roll to Roll Plasma Surface Activation System



▲A Set of Hollow-cathode-discharge Plasma Source

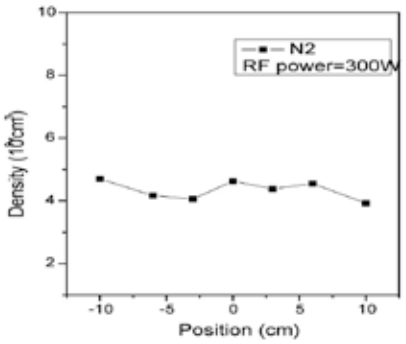
■ Plasma Immersion Ion Implantation Apparatus for the Study of Novel Semiconductor Process

》Shang-Feng Huang

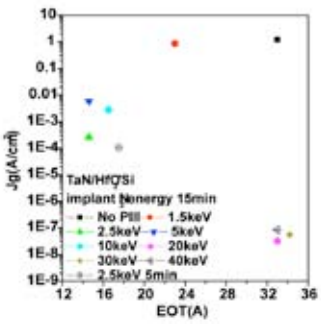
The dense plasma generated by inductively coupled plasma (ICP) is very suitable for the use of plasma immersion ion implantation (PIII). The ICP system generates plasma by transmitting RF power to the reactive gas inside the quartz chamber via the copper coils wound around outside. The plasma density uniformity measured by Langmuir probe at 7 cm above sample holder is within 15%. The ICP-PIII system combining ICP and the high-voltage pulsing system has the advantage of large area processing as well as extended implantation energy range, which can be used to study the instability issue of high-k device. The experiment which was collaborated with NTHU ESS department conducted ion implantation of 1.5~40 kV for 15 minutes to HfO_2 high-k device. The resulting leakage current presented the lowest value at the implantation energy of 20 kV, but the equivalent oxide thickness (EOT) was greatly decreased at the implantation energy of 2.5~10 kV where the leakage current is still lower than that of sample without PIII processing. Preminary results implied that PIII was proven to be good for stabilizing high-k semiconductor devices.

◎ Research Team: Shang-Feng Huang, Wen-Fa Tsei, Chia-Cheng Lee, Shin-Wu Wei.

▲Inductively Coupled Plasma Source



▲The Horizontal Distribution of Nitrogen Plasma Density



▲The Distribution of EOT and Leakage Current Density under Various Implantation Energy

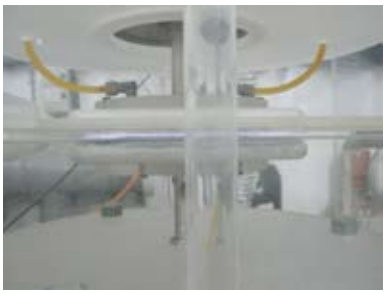
■ Dual-Functional Modification of Antibacterial and Quick Drying Nylon Fabrics with Atmospheric-pressure Plasma

》Min-Win Wu

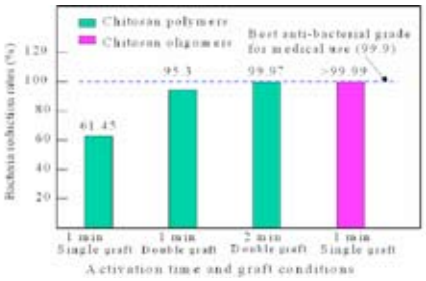
An argon atmospheric-pressure plasma source developed at plasma surface modification laboratory was employed for the present investigation. Low molecular-weight chitosan polymers and oligomers, which are natural antibacterial agents with good biocompatibility, were used respectively. Thus, the whole process meets 100% environment protection requirements. Single and double plasma-induced graft polymerization were adopted according to the activities of the antibacterial agents. Single graft polymerization was applied to the high-activity chitosan oligomers, while double graft polymerization to the low-activity chitosan polymers. Via simultaneous plasma activation, graft polymerization and cross-linking of the grafted bonds on the graft solution and woven fabrics, the graft rates and the bacteria reduction rates can be substantially improved.

The reduction rates of E. coli were tested by SGS company, Taiwan, for the modified nylon woven fabrics at various conditions. Only 61.45 % can be reached for 1-min plasma activation followed by single graft. It can be increased to 95.30 % for double grafts. The reduction rate can be enhanced further to 99.97 % for 2-min activation followed by double grafts. Greater than 99.99 % has also been achieved by 1-min activation and subsequent graft for chitosan oligomers. These are all better than the best grade of antibacterial textiles for medical use (99.9 %). Moreover, the wicking time is less than 0.1s for modified nylon fabrics, indicating its excellent moisture-transferring and quick-drying properties.

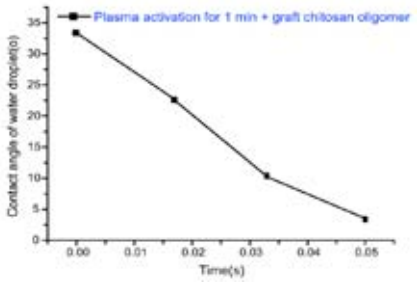
◎ Research Team: Min-Win Wu, Tien-Hsiang Hsueh.



▲Activation of Nylon Fabric by Argon Atmospheric-pressure Plasmas at INER



▲Reduction Rates of E.Coli for Nylon Fabrics Modified at Different Conditions



▲Wicking Time of the Modified Nylon Fabrics

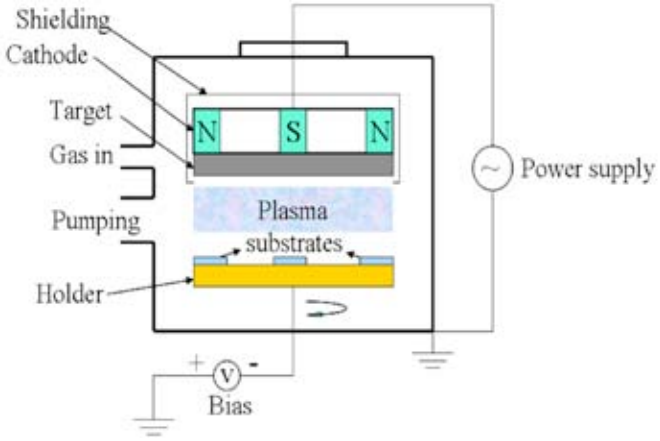
■ Protective coatings for Solid Oxide Fuel Cell Interconnect by Pulsed DC Magnetron Sputtering

》Chi-Ting Lin

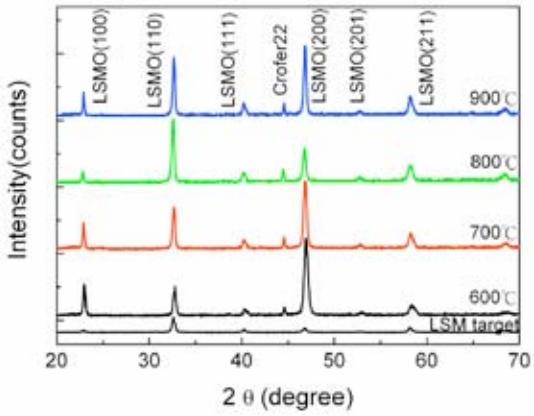
In recent years, studies investigating solid oxide fuel cells (SOFCs) has apparently moved from high operating temperature (>1000°C) to intermediate operating temperature (600–800° C). Thus an interconnect can be made of metallic materials instead of expensive ceramics. However, long-term exposure of metallic interconnects to high temperature under an oxidant atmosphere results in the formation of oxide scales, such as Cr_2O_3, which decrease rapidly fuel cell performance. Consequently, recent trends in the development of metallic interconnects is moving toward depositing a protective coating on the interconnect surfaces to improve interconnect oxidation resistance over the service lifetime. This study presented a process for depositing $La_{0.67}Sr_{0.33}MnO_3$ (LSM) films on stainless steels via pulsed DC magnetron sputtering . After deposition, coated substrates were annealed in air at various temperature from 600 – 900°C for 1 h. The XRD patterns of films after 1 h annealing at various temperatures showed that peaks of LSM perovskite phase appeared at 600°C and stabilized at about 750°C. The area sheet resistance (ASR) of stainless steels with and without LSM coatings varied with time at 760°C in air. After 4,300 h, it is clear that the LSM layer had high conductivity at high temperatures and was sufficiently dense to resist outward diffusion of Cr

from stainless steels. Therefore LSM films deposited by pulsed DC magnetron sputtering are good candidates for a protective coating of stainless steel as an SOFC interconnect.

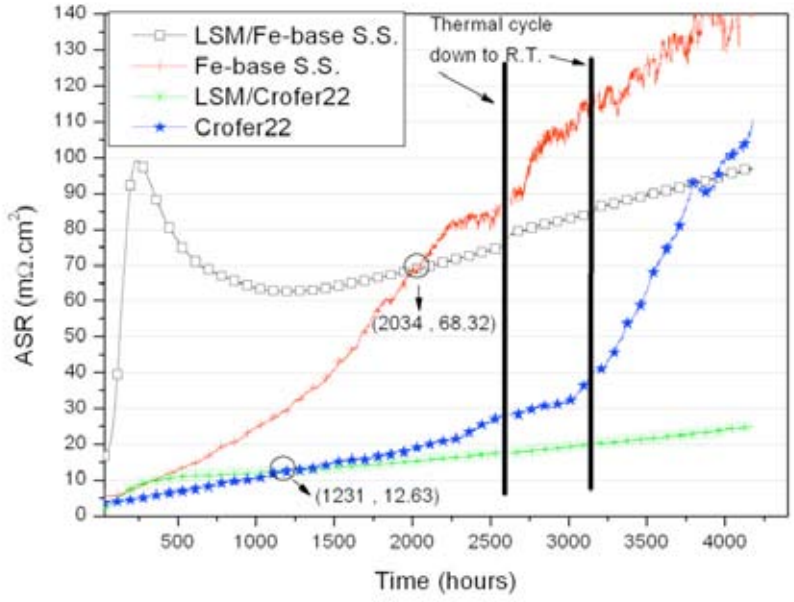
◎ Research Team: Chi-Ting Lin, Der-Jun Jan, Shih-Cheng Tseng.



▲Schematic Diagram of The Pulsed DC Magnetron Sputtering Deposition System



▲XRD Patterns of LSM Films Grown on Crofer22APU after Annealing in Air at Different Temperatures for 1 H



▲Variation of ASR with Time at 760°C in Air in LSM Coated Crofer22APU and Fe-based Stainless Steel

Appendix

Publications and Reports

· International Jurnal Papers

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4	INER-4440, Wang, T.C., Wang, S.J., "Analysis of Severe Accident Management Strategy for a BWR-4 Nuclear Power Plant", Nuclear Technology, 152 (3): 253-265. (Dec. 2005), Impact Factor:0.326.
5	INER-4456, Lin, C.K., Chen, T.T., Chyou, Y.P., Chiang, L.K., "Thermal Stress Analysis of a Planar SOFC Stack", Journal of Power Sources, 164 (1): 238-251. (Jan. 10 2007), Impact Factor:3.521.
6	INER-4462, Li, Y.C., Chen, K.B., Chen, H.L., Hsu, C.S., Tsao, C.S., Chen, J.H., Chen, S.A., "Fractal Aggregates of Conjugated Polymer in Solution State", Langmuir, 22 (26): 11009-11015. (Dec. 19 2006), Impact Factor:3.902.
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12	INER-4510, Chang, C.L., Chen, C.Y., Sung, C. C., Liou, D.H., "Fuel Sensor-less Control of a Liquid Feed Fuel Cell System Under Steady Load for Protable Applications", J. Power Sources, 164 (2): 606-613. (Feb. 2007), Impact Factor:3.521.

13	INER-4511, Lee, S.C., Yang, Y.J., Sheu, B.S., Wu, J.J., "More Economic 25 mg ^{13}C-urea Breath Test Can be Effective in Detecting Primary Helicobacter Pylori infection in Children", Hepato-Gastroenterology, 22 (3): 335-339. (Mar. 2007), Impact Factor:0.756.
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17	INER-4533, Lin, Y.C., Hung, G.U., Luo, T.Y., Lin, W.Y., "Reading Renal Uptake of In-111-DOTATOC: A Comparison Among Various Basic Amino Acids", Annals of Nuclear Medicine, 21 (1): 79-83. (Jan. 2007), Impact Factor:0.779.
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22	INER-4546, Cheng, T. W., Huang, M. Z., Tzeng, C. C., Cheng, K. B., Ueng, T. H, "Production of Coloured Glass-ceramics from Incinerator Ash using Thermal Plasma Technology", Chemosphere, 68 (10): 1937-1945. (Aug. 2007), Impact Factor:2.442.
23	INER-4555, Hwang, H.W., Shih, C. K., Yih, S., Chen, M.H., "Software Failure Events Derivation and Analysis by Frame-based Technique", Annals of Nuclear Energy, 34 (4): 307-318. (Apr. 2007), Impact Factor:0.69.

24	INER-4556, Liang, J. H., Wang, C. S., Tsai, W.F., Ai, C.F., "Parametric Study of the Nitrided AISI 304 Austenite Steel Prepared by Plasma Immersion Implantation", Surface and Coating Technology, 201 (15): 6638-6642. (Apr. 2007), Impact Factor:1.559.
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