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PROCEEDINGS OF THE FNCA WORKSHOP ON APPLICATION OF ELECTRON ACCELERATOR

JANUARY 28 - FEBRUARY 1, 2002, JAERI, TAKASAKI, JAPAN

February 2003

(Eds.) Fumio YOSHII and Tamikazu KUME

日本原子力研究所
Japan Atomic Energy Research Institute

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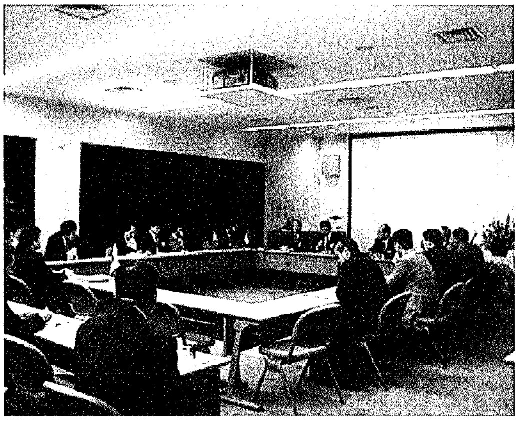
FNCA Workshop on Application of Electron Accelerator

January 28-February 1, 2002, Takasaki, Japan

1. Opening



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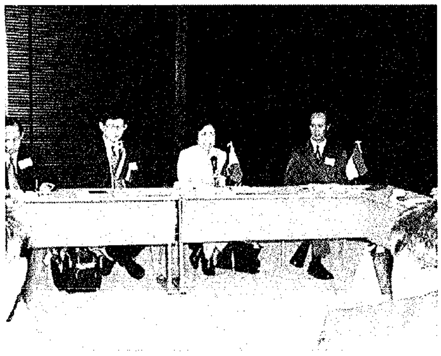
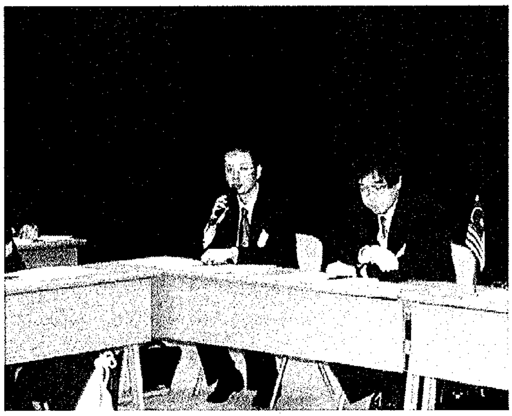
2. Participants





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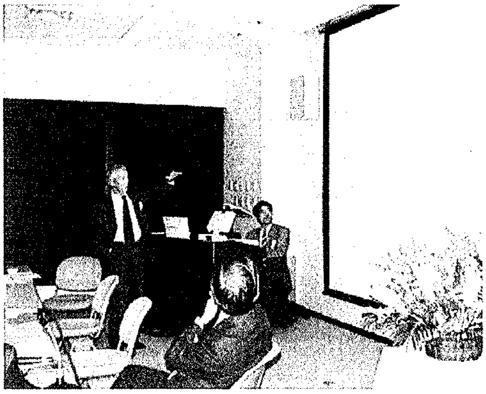
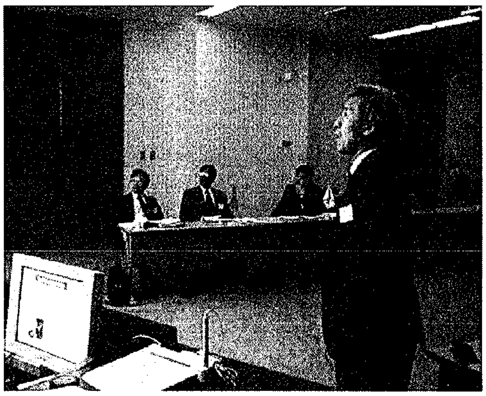
3. Presentation



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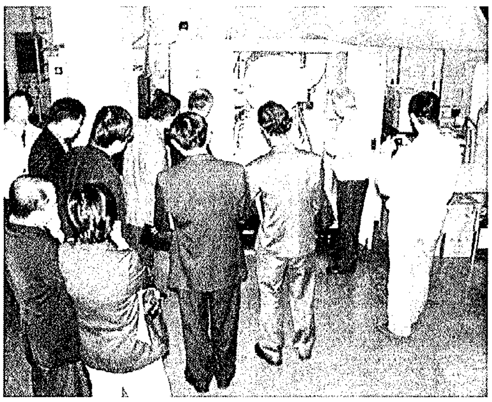


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Proceedings of the FNCA Workshop on Application of Electron Accelerator

January 28-February 1, 2002, JAERI, Takasaki, Japan

(Eds.) Fumio YOSHII and Tamikazu KUME

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(Received November 6, 2002)

"Forum for Nuclear Cooperation in Asia (FNCA) Workshop on Application of Electron Accelerator" was sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and hosted by Japan Atomic Energy Research Institute (JAERI) and Japan Atomic Industry Forum (JAIF). It was held at the Takasaki Radiation Chemistry Research Establishment (TRCRE), JAERI, Takasaki, Japan from 28 January to 1 February, 2002.

The Workshop was attended by experts on application of electron accelerator from each of the participating countries, i.e. China, Indonesia, Korea, Malaysia, The Philippines, Thailand and Vietnam and 16 participants from Japan

A total of 17 papers including invited papers on the current status of application of electron accelerator in the participating countries were presented. The characteristics of various kinds of electron accelerators were introduced. Current research and development on the utilization radiation processing for natural rubber latex, natural polymer solution, polymer films, sterilization of spices and seeds, radiation treatment of flue gases and dioxin in liquid, solid, and gases were reported.

Based on the proposed needs from the participating countries, the work plan was discussed and agreed on application of electron accelerator for liquid and for solid (thin films and granules/powder)

All manuscripts submitted by every speaker were included in the proceedings.

Keywords: Electron Accelerator, Radiation Processing, Natural Polymers

「原子力フォーラム(FNCA)電子加速器利用ワークショップ」論文集
2002年1月28日～2月1日、 高崎研究所、 高崎市

日本原子力研究所高崎研究所材料開発部
（編）吉井 文男·久米 民和

（2002年11月6日受理）

「アジア原子力フォーラム(FNCA)電子加速器利用ワークショップ」が、文部科学省の主催、日本原子力研究所及び日本原子力産業会議の協賛により、2002年1月28日（月）～2月1日(金)に高崎研究所で開催された。

本ワークショップには、中国、インドネシア、韓国、マレーシア、フィリピン、タイ、ベトナムから各1名、日本からは電子加速器利用の専門家など16名が参加した。

本ワークショップでは、放射線利用とくに電子加速器の利用に関する各国の現状報告及び各種電子加速器の形式や特性の紹介が行われた。特に、天然ゴムラテックス、天然高分子溶液や高分子フィルムの加工、香辛料や種子の殺菌、排煙の脱硫・脱硝やダイオキシンの分解処理など、液体、固体、気体への利用に関する研究開発の現状が報告された。各国からのニーズ提案に基づき、プロジェクト実施計画の討議を行い、対象を液体及び固体（フィルム、粉粒体）とすることが合意された。本論文集は、これら各発表者からの投稿原稿を収録したものである。

高崎研究所 ： 〒370-1292 群馬県高崎市綿貫町 1233

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1.1 Opening Address

Hiroshi WATANABE
Director General
Takasaki Radiation Chemistry Research Establishment, JAERI

Good morning, Ladies and gentlemen

It is a great pleasure for me to give a welcome address for the "Workshop on Application of Electron Accelerator" as a FNCA project. First of all, on behalf of JAERI-Takasaki, (Japan Atomic Energy Research Institute, Takasaki Radiation Chemistry Research Establishment), I wish to extend my hearty welcome to you all here today. We are pleased to hold the Workshop in Takasaki, and I would like to express my appreciation to Mr.Shinya Takeuchi, Director of MEXT, and Dr.Sueo Machi, Coordinator of FNCA.

Since 1963, JAERI-Takasaki has carried out R&D of radiation processing as a research center of Japan. Using gamma-rays and electron beams, a lot of radiation technologies have been developed for the upgrading of polymers such as battery separator, vulcanization of natural rubber latex, biodegradable polymer, heat resistant ceramic fiber, rare metal absorbent polymer and so on. The electron beam purification of flue gas is also a valuable technology for environmental conservation. Based on this technique, application of low energy electron accelerator is now studied to removal of toxic volatile organic compounds from ventilation air and removal of dioxin from incinerator. Some of these radiation technologies have been already transferred to the industry in Japan, and also spreading to Asian countries through the cooperation with RCA and IAEA, and the bilateral collaborations. Nowadays the application of radiation technology is highly appreciated in many fields of industry, medicine, agriculture and environment. It is our pleasure to spread radiation applications to the world, because radiation is a valuable tool for the increased quality of our life.

Since1993, we have conducted the advanced radiation technology program, using the characteristics of various ions produced by AVF cyclotron and three electrostatic accelerators. This R&D centers mainly on material science and bioscience in the field of innovative science and technology. However, I think that electron accelerator will be still suitable for the practical use of radiation technology. From the viewpoint, this workshop on application of electron accelerator in FNCA is important. In our institute we are studying on radiation processing of natural rubber latex and removal of dioxin using low energy electron accelerator that will be presented in this workshop.

I expect that this Workshop will give a good occasion to discuss and bring to fruitful conclusion through the stimulating discussion.

Finally I would like to close my speech by expressing my sincere wishes for the success of the workshop, and my sincere welcome for all participants.

Thank you very much for your attention

1.2 Opening Address

FNCA Project on "Electron Accelerator Application"
27 Jan. 2002
Sueo MACHI
FNCA Coordinator of Japan

Distinguished participants from FNCA countries,
Ladies and Gentlemen:

As the FNCA Coordinator of Japan and the counselor of the Atomic Energy Commission, I would like to welcome all participants to the workshop.

Project on "Electron Accelerator Application" was officially adopted by the FNCA Ministerial level Meeting in October last year.

Radiation chemistry and processing have been studied more than 50 years aiming industrial applications. Prof. Charleshy in UK, Prof. Chapiro in France, Prof. Sakurada in Japan are great pioneers in this field. Radiation processing is one of major applications of nuclear technology and still has a great potential for new industrial development. In fact, radiation processing has been efficiently used in industry for upgrading polymeric materials.

Electron accelerator has been proven as an important radiation source which is reliable, powerful and safe after continuous effort for improvement for many years.

I like to emphasize that objectives of their new project is to develop new radiation application system using low energy electron accelerator which should be advantageous in terms of economy, safety, operational simplicity, and versatility. Detail proposal will be introduced by Dr. Kume later.

The FNCA is an excellent mechanism to promote cooperation among Asian countries to develop practical application of nuclear technology which should meet needs of participating countries. The FNCA projects aim to achieve semi-economic benefits as much as possible. I wish you all to contribute to achieve this goal through the regional cooperation.

In conclusion, I hope you have constructive and active discussion reaching appropriate formulation of the project work plan.

Thank you for your attention.

2. Outline of FNCA Project on Application of Electron Accelerator

Tamikazu KUME
Takasaki Radiation Chemistry Research Establishment,
Japan Atomic Energy Research Institute,
1233 Watanuki, Takasaki, Gunma 370-1292, Japan

A new project on "Application of Electron Accelerator" was proposed from Japan and Vietnam at the 2nd FNCA Coordinator Meeting held in March, 2001 in Tokyo. The proposal (Attachment 1) was officially approved at the 2nd Ministerial Meeting (MM) and Senior Official Level Meeting (SOM) on 27 and 28 November, 2001 in Tokyo.

The objective of the project is to develop new technology of low energy electron beam irradiation system which has a variety of applications and good safety features, and to demonstrate its application. A self-shielded low energy accelerator system needs an initial investment much lower than a Co-60 facility. Its operation is simple and safe. The system can be applied in various fields such as radiation processing of natural resources, environmental conservation, etc.

An economic scale of "utilization of nuclear" in Japan, that is, a sum of "radiation" and "nuclear energy" was 132 b$, and the ratio between radiation and nuclear energy was 54%: 46%. Economic scale of utilization of radiation in Japan was 71 b$ (1$=121¥) at a fiscal year of 1997. The value of 71 b$ consisted of 60 b$ for industrial applications, 1 b$ for agricultural uses and 10 b$ for medical/health uses, respectively. Under the FNCA, 7 projects including the radiation application in the field of agriculture and medical/health have been implemented but the project in the field of industry is not included, even though the economic scale is much bigger than the other two fields. Furthermore, the FNCA expects not only the information exchange but also the real active project to be beneficial for the member states. Under these backgrounds, a new project on application of electron accelerator was established.

The penetration of low energy electron beam is limited but it can be applied in various fields with development of irradiation system for products of liquid, solid and gas.

Liquid:
- Radiation vulcanization of natural rubber latex
- Degradation of polysaccharides for plant growth promotion
- Waste water treatment

Solid:
- Surface irradiation for sterilization/pasteurization of spices, seeds, etc.
- Curing and crosslinking of films

Gas:
- Flue gas treatment
- Degradation of dioxins

At the first workshop at Takasaki participating eight countries, China, Indonesia, Korea, Malaysia, The Philippines, Thailand, Vietnam and Japan, it is expected to discuss the present status of radiation processing in each member states according to the reply for the questionnaire (Attachment 2) and to formulate the program of 3-5 years project (Attachment 3).

Attachment 1

New Project Proposal for FNCA from Japan

Development of Technology for (Low Energy) Electron Beam Application

November 26, 2001

1. Objectives of the project:

"To develop new technology of low energy electron beam irradiation system which has a variety of applications and good safety features, and to demonstrate its application for products of liquid, solid and gas."

A self-shielded low energy accelerator system needs an initial investment much lower than a Co-60 facility. Its operation is simple and safe. The system can be applied to radiation processing of natural resources to produce value-added products.

2. Lead Country / Host Country
   a. Lead Country : Japan
   b. Lead Organization : Japan Atomic Energy Research Institute (JAERI)

3. Period and Work Plan:

1) Project Period : From FY 2001 to FY 2005

2) Work Plan :

FY 2001

① Meeting for Project Programming and Information Exchange (Japan).

② Report on Radiation Facilities in the Participating Countries.

③ Survey and Proposal for EB Application in the Participating Countries.

FY 2002

① Test Operation of the EB Irradiation System (Japan and Participating Country).

② Workshop (Project Meeting) on the Technology and Application of the EB System (Japan).

③ Designing and Cost Analysis of the EB Irradiation System.

FY 2003

① Workshop (Project Meeting) and Test Operation of the EB Irradiation System (Malaysia).

② Study on optimum EB Irradiation System (Japan).

Attachment 1 contd.

③ Demonstration Test of the EB System for Application (Malaysia and Participating Country).

FY 2004

① Workshop (Project Meeting) and Test Operation of the EB Irradiation System (Thailand or Vietnam).

② Study on Optimum EB Irradiation System (Japan).

③ Demonstration Test of the EB System for Application (Thailand or Vietnam and Participating Countries).

FY 2005

① Workshop (Project Meeting) and Test Operation of the EB Irradiation System (Vietnam or Thailand)

② Study on Optimum EB Irradiation System (Japan).

③ Demonstration Test of the EB System for Application (Vietnam or Thailand and Participating Countries).

4. Qualifications of Participating Countries: Indonesia, Korea, The Philippines, Malaysia, Thailand, Vietnam and Japan.

① A country that has actual needs of developing new technology of low energy electron accelerator system to process liquid, gas, powder and film products.

② A country that already has a low energy electron accelerator system, or is planning to have it in the near future.

③ A country that is ready to provide its own data for developing processing technology with its low energy electron accelerator system.

5. Fund:

FY 2001: Cost for Holding Workshop

FY 2002～ FY 2005 : Cost for Holding Workshop, and Dispatching Experts

6. Available Resources and Facilities

① Electron Accelerators of JAERI (3MeV × 25mA, 2MeV × 30A, 250 keV × 10mA)

② Electron Accelerators of Participating Countries.

Korea

Malaysia

Indonesia

Attachment 2

QUESTIONNAIRE

Radiation Application / Utilization of Electron Accelerator

Respondent :

Organization :

Tel : Fax :

e-mail :

1. Present Situation

1) γ-ray irradiation facility / electron accelerator for commercial use

What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in your country at present ? Please fill in the following table :

① γ-ray irradiation facility for commercial use

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks

② Electron accelerator

Name of company / organization Installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use

2) Please state about the rules and regulation for the management of the irradiation facility, specifically. (about safety control and the law)

3) Please state about the present situation of radiation processing

4) Electronic accelerator utilization technology

What kind of ①research(es) and/or ②commercial use, has been done utilizing electron accelerator technology in your country up to now ?

Please fill in the following tables:

Attachment 2 contd.

① Electron accelerator utilization technology - for research

Field	Target	From when	Title (contents)	Remarks

② Electron accelerator utilization technology - for commercial use

Field	Target	From when	Title (contents)	Remarks

2. Future plan

1) Electron accelerator utilization technology

In what field /application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table:

Field	Target	From when	Title (contents)	Remarks

2) Electron accelerator

What type of accelerator does your country plan to have for the future ?

Please fill in the following table:

When	Accelerator voltage	Beam current	Purpose of Use

3) What kind of support do you expect from the FNCA workshop ?

4) Education/training of human resources

Please describe your comments and desire on the training/ education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

3. Others

Please describe your comments other than the above, if any.

Attachment 3

5 YEARS PROGRAM FOR FNCA PROJECT ON APPLICATION OF ELECTRON ACCELERATOR
(Tentative)

	FY2001		FY2002		FY2003		FY2004		FY2005		Remarks
Overall Schedule	Nov. 2^{nd} FNCA (Japan)	Mar. 3^{rd} CDM (Japan)	Autumn 3^{rd} FNCA (Korea)	Mar. 4^{th} CDM (Japan)	Autumn 4^{th} FNCA (Japan)	Mar. 5^{th} CDM (undecided)	Autumn 5^{th} FNCA (undecided)	Mar. 6^{th} CDM (Japan)	Autumn 6^{th} FNCA (undecided)	Mar. 7^{th} CDM (undecided)	
Participating Countries	China, Indonesia, Korea, The Philippines, Malaysia, Thailand, Vietnam and Japan (total 8 countries)										
Schedule of WS	January 28 – February 1, 2002 (Japan)		Undecided (Japan)		Undecided (Malaysia)		Undecided (Thailand or Vietnam)		Undecided (Vietnam or Thailand)		
Contents of WS	· Project Programming and Information Exchange · Survey of Radiation Facilities in the Participating Countries. · Proposal for EB Application in the Participating Countries		· Test Operation of EB Irradiation System (Japan) · Review of the irradiation systems · Designing and Cost Analysis of EB Irradiation System		· Demonstration Test of EB System for Application (Malaysia) · Study on Optimum EB Irradiation System · Open Lecture		· Demonstration Test of EB System for Application (Thailand or Vietnam) · Study on Optimum EB Irradiation System · Open Lecture		· Demonstration Test of EB System for Application (Vietnam or Thailand) · Study on Optimum EB Irradiation System · Open Lecture		
Others	December: Sending out the Questionnaire (Present Status and Needs in Each Country)										

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3. Application of Electron Accelerator Worldwide

January 28, 2002
Sueo MACHI,
FNCA Coordinator of Japan, JAIF

1. Introduction

Electron accelerator is an important radiation source for radiation technology application, which covers broad fields such as industry, health care, food and environmental protection. My paper over-viewing these applications published at International Meeting Radiation Processing in 1997 is useful reference for broader information. My presentation today is focusing on commercial electron accelerator applications.

2. Electron accelerator and Co-60 irradiator

There are about 1,000 electron accelerators for radiation processing world-wide[1). Electron accelerator has advantages over Co-60 irradiator in terms of high dose rate and power, assurance of safety, and higher economic performance at larger volume of irradiation in addition to better efficiency of radiation absorption and free of recharge of Co-60. Penetration range of electron, however, is much shorter than photon from Co-60 gamma radiation.

Accelerator generating higher energy in the range of 10 MeV and high power electron beams is now commercially available, which can be used for wide range of applications including sterilization of medical product and foods.

Application of X-ray generated by conversion of electron beams seems not very feasible because of low conversion efficiency and damage of accelerator by backscattered X-ray[2)].

Medical Products Irradiation

Currently about 40% of medical products are sterilized by radiation. Sterilization of medical products has been carried out mainly by Co-60 because of high penetration range of gamma rays. There is a trend to use high energy electron accelerator replacing Co-60 in case of large through-put of products.

One typical irradiation system using 10MeV electron beam designed by Titan Scan Co. was shown in Figure 1. High energy accelerators of 5-10MeV are provided by several companies in Belgium, France, Japan, U.S.A. and Canada.

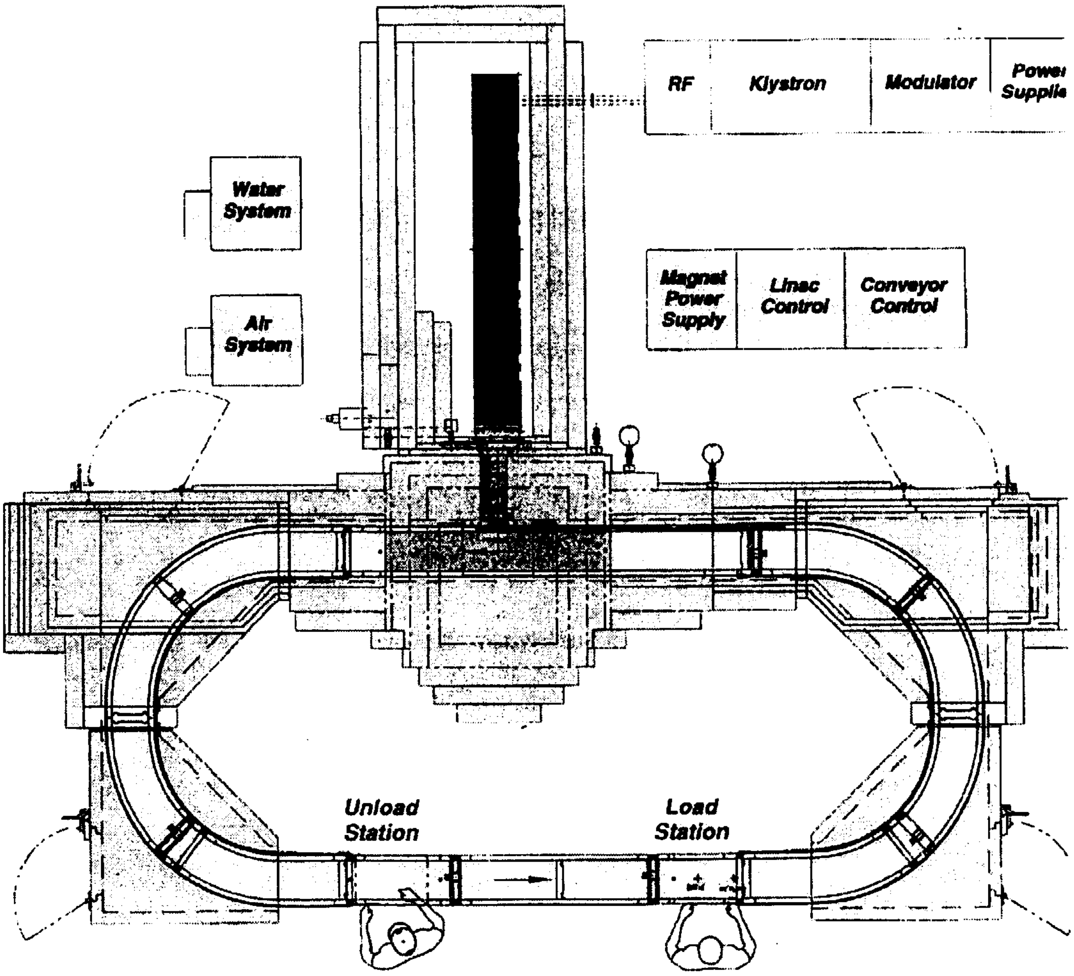


Fig.1 Plan view of the Surebeam On-Site System utilizing single sided processing and conformal steel shielding.

4. Food Irradiation

Irradiation reduces spoilage, improves hygiene and extends shelf life of foods. Food irradiation can also contribute to increase export potential for quarantine purposes without using methyl bromide fumigation which depletes the ozone layer. Irradiation of deboned poultry meat to reduce contamination with Salmonella and Staphylococcus has been commercially used in France since 1990. An electron accelerator (LINAC) of 10 MeV, 10kW has been used for irradiation.

In Odessa in Ukraine, the electron accelerator plant to disinfest grain to avoid loss after harvest eliminating insect pest using electron beams of 1.2~1.5 MeV with the power of 40kW. The grains are irradiated during continuously flowing in a pipe under beams as shown in Figure 2. [3)]

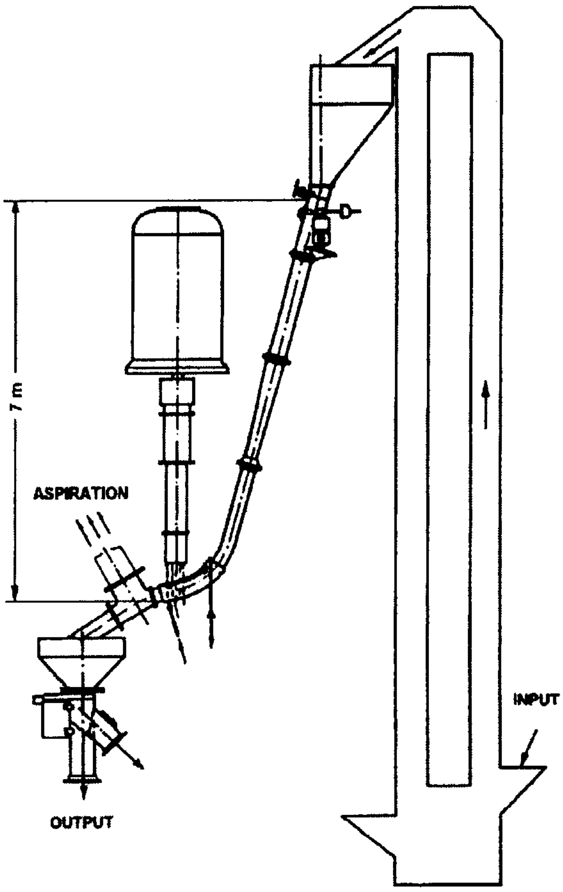


Fig.2 The operational scheme of the technological line

Food borne diseases increasingly affect the health of populations. In the United States for example, food derived pathogenic bacteria such as Salmonella, E. Coli, Listeria, Campylobacter, Vibrios, Trichinella and other parasites claim an estimated 5,000 lives annually and between 24 and 81 million cases of diarrhea of various kinds. Food irradiation has been increasingly recognized by health authorities as a means of countering this health problem. Currently 250 supermarkets in the USA are selling irradiated ground beef for hamburgers.

Irradiated foods, in particular species, are on the commercial market in 35 countries worldwide.

5. Polymer modification

Electron accelerator is used efficiently and economically for production of new or modified polymeric materials through radiation-induced cross-linking, grafting and polymerization reactions.

The advantages of radiation processing over chemical methods are:

- Savings in energy consumption
- Improved product quality or new products
- Reduction in emissions of environmentally harmful substances
- Elimination of harmful chemical residues in products.

Owing to these cross-linking technology properties of plastics such as polyethylene, polyvinylchloride and rubber can greatly be improved in terms of thermal resistance, chemical resistance and mechanical strength. Examples of commercial products manufactured by electron accelerator are listed in Table 1.

Cross-linked insulation shows increased resistance against heat, chemical attack and cuts, and is more compact being used in the automobile industry, telecommunications, the aerospace industry and in home electrical appliances.

In the automobile industry, electron accelerator is used to cross-link rubber molecules in the production of radial tires. For example, Michelin in France, Goodyear and Firestone in the USA, Bridgestone and six other tire manufacturing companies in Japan and a company in Korea have been producing tires using electron accelerators.

Heat shrinkable polymeric materials produced by radiation processing are unique products widely used for food packaging, electrical insulation at junctions and corrosion protection of underground pipeline welds.

Another important application of electron beams is the curing of surface coatings in the manufacture of products, such as wood panels, adhesive tapes, surface coats for printing, floppy discs, and decorative steel plates. A major advantage of electron beam (EB) curing is that no organic solvent is emitted into the environment during the process. This process is more friendly to the environment. Wound dressing, deodorant polymers, membrane for battery separator are more recent products sold in market.

Table 1: Commercial Application of Electron Accelerator

1. Modification of polymeric materials (commercial products)
Heat-resistant wire/cable Hear shrinkable materials for food packaging, insulation, etc. Formed polyethylene Automobile tires Cross linked nylon and polyurethane for automobile parts Cross linked polyethylene tubes for floor heating, drinking water Membrane for battery separator Hydrogel for wound dressing Deodorant polymers Surface coating
2. Sterilization of medical products
Japan, the U.S.A., Canada
3. Treatment of foods
Deboned separated poultry meats, France, 10MeV, 10kW Disinfection of grain, Ukraine Odessa, 1.2~1.5meV, 20kW Meats, frozen patties, USA, Calif., 10MeV, 4kW[4)]
4. Environmental protection (Industrial plants, large pilot plant)
Cleaning flue gas from coal burning power station, Poland, 0.8MeV~1.2MW Cleaning flue gas from coal burning power station, China, 0.8MeV Cleaning flue gas from heavy oil burning power station, Japan, 0.8MeV, 24MW Cleaning waste water from dyeing factory, Korea, MeV, 40kW

6. Cleaning environment

Electron accelerators of large capacity are used for cleaning exhaust gases in industrial scale in China, Japan and Poland and for waste water cleaning in pilot scale in ROK, the U.S.A., Austria and Brazil.

Innovative technology using electron beams to simultaneously remove SO_2 and NO_x by irradiation was first developed in Japan Atomic Energy Research Institute by the research group that I was heading and further followed by research groups in several countries. The mixture of ammonium sulfate and ammonium nitrate, which is a by-product of the process, can be used as agricultural fertilizer. As shown in Figure 3, the flue gas is exposed to electron beams while it passes through an irradiation chamber. A small fraction of gaseous ammonia is injected into the chamber. As a consequence of reactions induced by radiation, SO_2 and NO_x are converted into a mixture of ammonium sulfate and nitrate particulates.

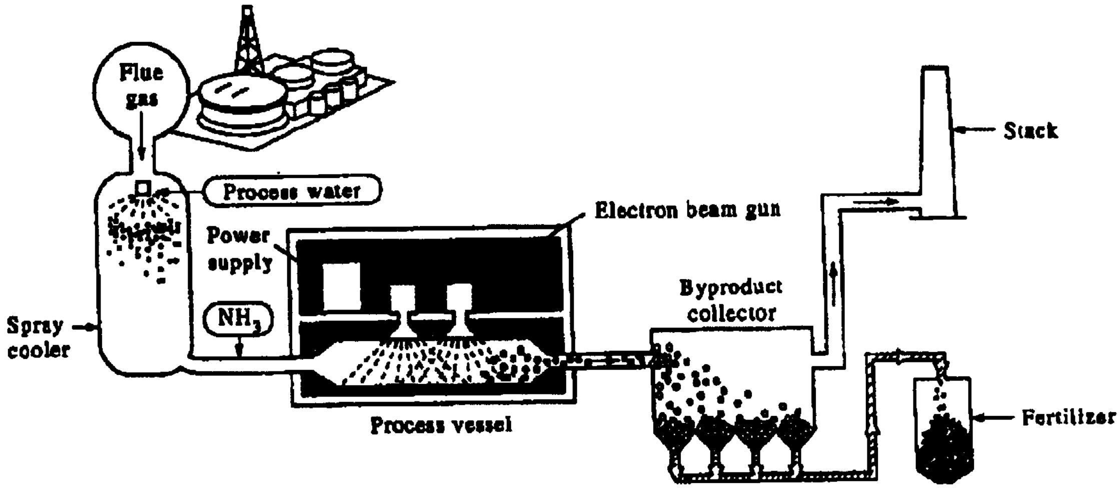


Fig. 3. Flow diagram of electron beam process for flue gas treatment.

The advantages of this technology over conventional processes for treating flue gases are:

- It is the only process to simultaneously remove both SO_2 and NO_x.
- The by-product of the process can be used as agricultural fertilizer.
- The process does not require large amounts of water.
- It can meet the stringent requirements for removal efficiency of SO_2 and NO_x.

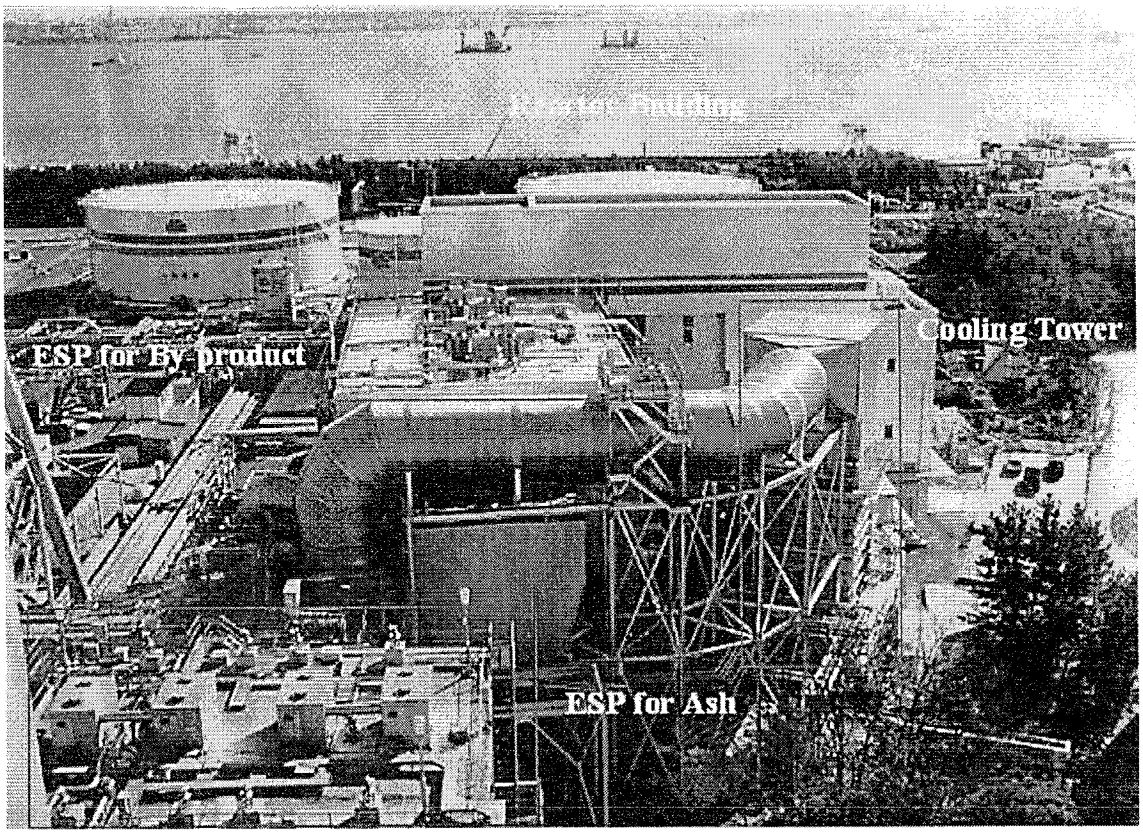
A large demonstration plant with the capacity to clean 270,000 Nm^3/hour of coal burning flue gases has been in operation in Poland using accelerator of 0.8MeV, 12MW under an IAEA/Poland Technical Co-operation project since early 2001.

In China an industrial demonstration plant to remove SO_2 from flue gas of a coal burning power station is in operation. In Japan a demonstration plant in Chubu Power Co. (Figure 4) to clean oil burning flue gases of power station 220MWe is about to start operation in 2002.

Economic feasibility studies of this electron beam process have shown that this technology is more cost effective than the conventional process. It should be noted that the conventional limestone process produces gypsum as a by-product, which cannot be used in some countries. By contrast, the by-product of the electron beam process is a valuable fertilizer.

In Japan Atomic Energy Research Institute (JAERI) will soon start operation of pilot plant to remove dioxin from flue gas of municipal incineration plant.

In Korea a commercial company has been extensively studying treatment of wastewater from dyeing factory using pilot plant of 1,000m^3/day capacity showing promising results.



Plant Capacity: 62,000m^3/h (220MWe), SO_2 Removal > 92%, NOx Removal > 60%
Electron Accelerator: 800keV, 500mA × 6units
Fig.4. EB Plant to Clean Flue Gas of Heavy Oil Burning Power Plant of Chubu Electric Power Co.

1) S. MACHI, Atomic Energy Week of the Philippines, Dec.11, 2001
2) Y. AIKAWA, Radiation Physics and Chemistry, 57(2000) 609
3) R.A. SOLIMOV, et al., Radiation Physics and Chemistry, 57(2000) 625
4) K.G. CARLSON et al., Radiation Physics and Chemistry, 57(2000) 619

4. Country Reports

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JP0350119

4.1 Application of EB in Japan

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1. Introduction

Electron Beam (EB) facilities are applied for radiation processing in much extend than use of gamma-rays facilities in a number of applications in Japan. Table 1 shows the number of electron accelerators for radiation processing installed in Japan during 1970 – 2000. In the table, numbers of the accelerator were classified for electron energy region and field of the application. This data was obtained from the original data[1] (1970-1998) published in 2000 by Japan Atomic Industry Forum (JAIF). During recent 2 years (1999-2000), 28 accelerators were increased in Japan and most of them were low energy machines. As the radiation used in radiation processing, EB has following features compared with gamma ray.

1) EB is easily controllable in turn ON/OFF and beam power (beam energy and current).
2) Maintenance of the radiation source is simple compared with RI sources. Because, in case of EB it is free from treatment of used sources and radioactive contamination.

Table1. Numbers of electron accelerator for processing installed in Japan (1970-2000)

Energy / Application	Low $E \leqq 300keV$	Medium $300keV < E \leqq 3MeV$	High $3MeV < E \leqq 10MeV$	Total
Wire, Cable	1	51	0	52
Foam polymer	4	12	0	16
Heat shrinkable	15	17	1	33
Tire	3	20	0	23
Curing	46	2	0	48
Flue gas, Waste water	1	7	0	8
Sterilization	3	2	6	11
Irradiating service	7	11	4	22
Research	120	2	1	123
Total	200	124	12	336

3) High beam output power system is available and high throughput in the process is obtained.
4) Power of penetration is less than gamma rays, therefore it cannot be applied to thick or heavy materials. But it is useful for the treatment of surface or controlled layer. By using the high-energy electron beam, power of penetration is increased and objects of application are expanded. Furthermore, bremsstrahlung, generated by conversion of electron can be applied to thick and heavy materials.

5) Beam stability and reliability in operation are weak points with comparison to gamma-rays facilities. Efforts to increase the stability and reliability of accelerator should be taken into account by manufacturers.

Anyway, EB from accelerator is a useful tool for the radiation processing. It is expected to progress the use in wide field of application. In this paper, outline of present status of EB application in Japan is described.

2. EB application

2.1 Polymer

Radiation induced chemical reactions such as cross-linking, decomposition, graft polymerization are applied to polymer processing. Objective materials and the applied chemical reactions are listed in Tab. 2. Polymer processes have been carried out for a long time since the beginning of radiation processing. Each product is closely connected to our daily life.

Electron accelerators to be used for polymer process are almost laid in low energy and medium energy region. Performances of these accelerators are well established as high power and high reliable in the operation. EB process of polymer is typical of radiation processing and it bears large economical contribution[2)]. It is expected to develop the new application in this polymer process.

Table 2. Objective materials and applied chemical reactions

Reaction	Objective materials
Cross-linking	Wire, Cable, Radial tire, Heat shrinkable tube, Foam polyethylene
Decomposition	PTFE
Graft polymerization	Battery separator, Adsorbent material

2.2 Environmental preservation

Electron flue gas treatment technology is typical example of application of radiation to environmental preservation. This technology was developed originally in Japan about 30 years ago. Coal and oil fired flue gas, which include SOx and NOx can be treated by EB irradiation. SOx and NOx in the flue gas react with ammonia (NH_3), which is added prior to irradiation and turn into $(NH_4)_2SO_4$ and NH_4NO_3. These products are powdered fertilizers, and can be removed easily by bag filter and electrostatic precipitator.

This technology progressed step by step. As the present status, practical scale test plants are constructing in not only Japan but also in another countries. Table 3 shows the latest large-scale test plant, which coal or oil fired power plant is equipped. In this plant, extremely high power electron accelerators were used. It will be demonstrated the reliable performances of this technology soon.

Decomposition treatments of volatile organic compounds (VOC) and dioxins by EB irradiation are under study. In TRCRE, JAERI, both studies are carrying out using two electron accelerators of 175 keV, 10 mA, and 300 keV, 40 mA respectively.

Wastewater and sludge treatment by EB irradiation has been studied for 30 years in TRCRE and another institutes. The significant data that concerned to this technology was accumulated. Recently, treatment of wastewater from dye factories and other industries has been reported in Korea and Brazil.

Table 3. Latest large test plants for flue gas treatment installed in power plants

Name of plant	Country	Throughput	Output of accelerator
Chengdo p.p.	China	300 km^3/h	800 keV, 400mA x 2 set
Pomorzany P.P.	Poland	270	800 keV, 375mA x 4
Nisinagoya P.P.	Japan	620	800 keV, 500mA x 6

2.3 Sterilization of medical supplies

Radiation sterilization of medical supplies was started by gamma ray irradiation. Even now, share of EB treatment is less than 10 % compare with gamma ray treatment in economical effect.

EB treatment started in 1991 in Japan using a 5 MeV accelerator. Since that time, EB facility increased favorably for sterilization and amounted to 4-in house, 4-irradiation service center today. Accelerators for this purpose are laid in 5 – 10 MeV. Appearance of high energy and high power machine brought application of EB to extensive medical supplies. Sterilization of medical supplies is promising field of EB application hereafter.

2.4 Food irradiation

Potato is only one food which permitted as irradiation treatment in Japan. That treatment is limited by gamma ray irradiation. This permission was passed in 1974. And since this time, no-request for the permission of food irradiation has been continued. In case of the world, about 220 kinds of food are permitted in 52 countries. Especially spices are permitted in 47 countries, and executed in 27 countries. In 2000 Japan spice industry requested for permission of spice irradiation to the government. In case of spice irradiation, it seems that EB is useful. Answer from government to spice industry is noticed.

2.5 Application of low energy EB

The share of low energy accelerator in total number of electron accelerators installed in Japan is high, as shown in Tab.1. Use of EB for treatment of surface region is typical way of utilization of low energy EB machines. Generally, low energy electron accelerators are self shielded type, and they can be set in the spare area in the factory. Price of such installation is relatively low. These are the reason why the number of low energy system is quite large. The purpose of low energy EB is surface treatment of irradiated materials by painting, printing and adhesion. Almost these products are familiar with our life.

On the other hand, many low energy electron accelerators are installed for research of application, and almost of them are laboratory model. Low energy electron accelerator has applicability to wide field.

It is expected that the research work of application using these laboratory model machine will conduct to practical scale production soon. Improvement in economical condition will be effective to progress of it.

3. Activity of JAERI using the EB

In TRCRE, JAERI, many kinds of studies have been initialized using four electron accelerators. Table 4 shows the list of electron accelerators installed in TRCRE, JAERI.

And Table 5 shows the latest dominant experiments using these accelerators. Acc.No.1 and No.2 are used for multi purpose experiments. And they are opened not only for JAERI but also for another researchers. Numbers of experiments that carried out in 2000 by using each accelerator are 250 and 430, respectively. And operation (beam) times were up to 500 and 700 hrs, respectively. Another two accelerators were installed for particular experiments in the laboratory. These accelerators were intended to do experiments of treatment of volatile organic compound and vulcanization of natural rubber.

Table 4. Electron accelerators installed in TRCRE, JAERI

Name	Type	Energy (MeV)	B. Current (mA)
Acc. No.1	Cockcroft-Walton	0.5-2.0	30
Acc. No.2	Dynamitron	1.0-3.0	25
VOC Processor	Electrocurtain	0.15-0.175	10
NRL Processor	Electrocurtain	0.15-0.25	10

Table 5. Dominant experiments in TRCRE, JAERI using the electron accelerator

Accelerator	Application (Experiments)
Acc. No.1	Flue gas treatment, Bio-degradable plastics, Cross linking of PTFE, Composite
Acc. No.2	Graft polymerization (adsorbent), Semi-conductors, Radiation resistant test of the materials
VOC Processor	VOC treatment
NRL Processor	NRL vulcanization

4. Prospects and challenges for the future

It is recognized that EB is a very useful tool for radiation processing, and it can contribute to our comfortable life. Especially, the progress in application study of EB to environmental conservation, food irradiation and functional materials can be expected in the near future. It might appear the quite new yet unknown target.

To utilize fully this useful tool for our life, study for development of EB application should continue hardly.

It seems that the efforts for cost reduction and improvement of reliability in operation of the facilities is very important to popularize the EB application.

References

1) Japan Atomic Industry Forum: NSA/COMENTARIES, No.8, “Recent Progress in Radiation Application” (2000) (in Japanese)
2) Japan Atomic Energy Research Institute: “Report of survey for economical contribution by radiation application” (2000) and (2001), (in Japanese)

4.2 Research and Application of Electron Accelerator in China

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Institute of Modern Physics (IMP), CAS. Lanzhou 730000

Abstract: There are more than 30 product lines of irradiation cross-linking wire & cable and shrinkable tube by EB in Chinese industry. Total of 3,000KW power of EB, in which 40% coming from home made accelerator. Recently, about 450KW electron accelerator is being manufactured used in protection of environment that is removal of SO_2 & NO_X from flue gas.

1, the Applications of EB in China

The radiation process by EB has been developed rapidly in China since 1990's. The first production line of irradiation cross-linking wire &cable was built in Tianshui cable factories in industry scale in 1990.[1)] Before that a pilot of radiated wire has been built in Shanghai cable factories. One or two years after Tianshui production line, another production line of irradiation cross-linking cable has been constructed in Yantai cable companies, whose equipment made in China fully. The high voltage of electron accelerator is about 2MV with beam current of 20mA and the under beam facility made by 4 stainless steel drums driven by a motor synchronously, total of equipment of the line is under controlled by an industry computer (fig.1). The many cable enterprises constructed their own radiation facility in china since then. Part of them imported the electron accelerator from Russia, Some of them imported accelerator and under beam facility with pay-off and take-up machine from RDI or Vivilad. Others, about 40% of total, built by home-made electron accelerator and cable transportation facility (see table 1).

Simultaneously, the varieties of formulation and products of radiation cross-linking wire & cable demand by Chinese market after those production lines of radiation cross-linking wire & cable and shrinkable tube set up. The main properties of those products such as 1KV and 10KV rated radiation cross-linking polyethylene insulated power cable with thermal-endurance 105℃, 1KV and 10KV rated radiation cross-linking polyolefin aerial insulated power cables with thermal-endurance 105℃ have come up to the new advanced standard. Others with excellent properties for instance, high temperature endurance, flame retardant, oil and radiation endurances as well as automatic-controlled temperature, etc. have been finished research of formulation under going to develop products. Moreover, foam plastic, medical sterilization and curing of coatings are under research or preproduction.

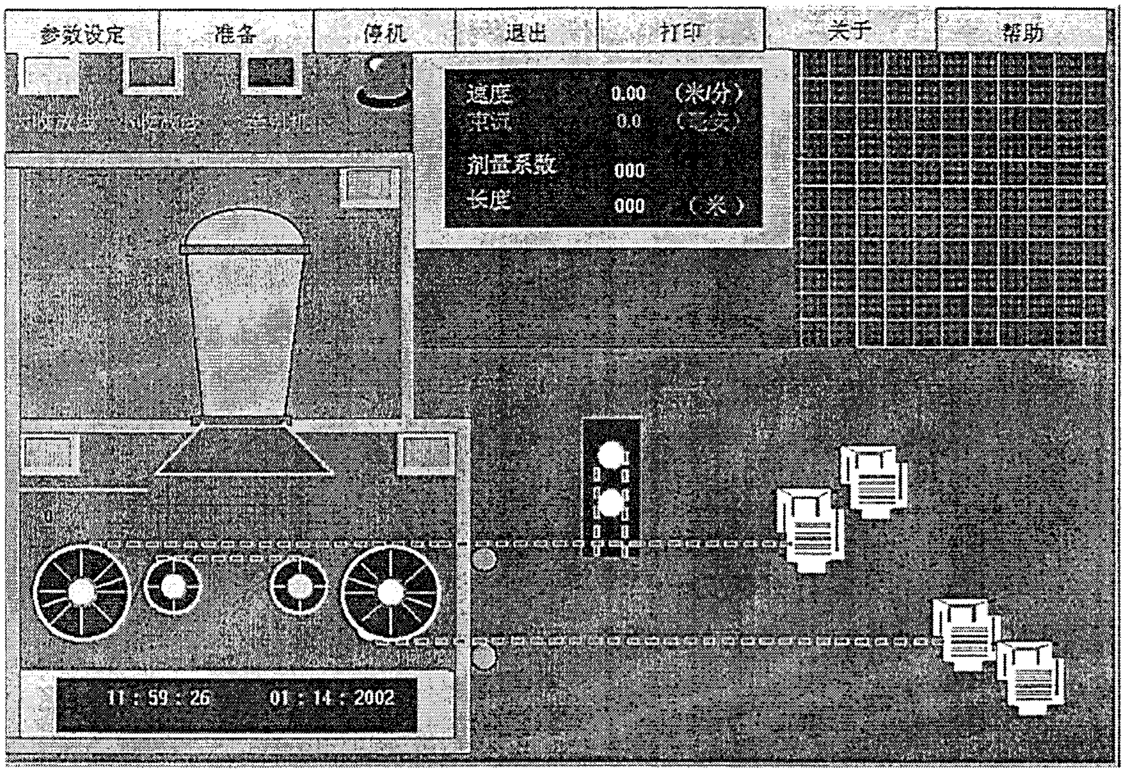

Fig. 1, Overview of electron irradiation controlled by computer

2, Electron Accelerator development at IMP

There is a R&D group for radiation processing in my institute. They did under

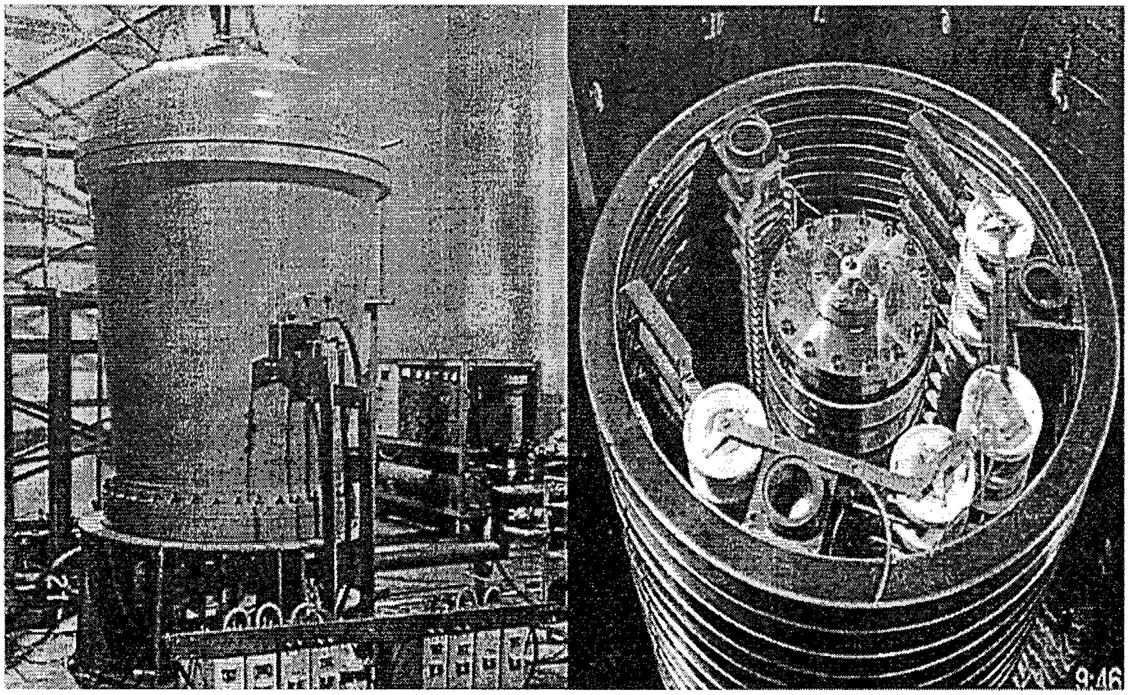

Fig.2, The transformer type electron accelerator at IMP

beam facilities and formulation of modification of polymer products for domestic cable companies. From the end of 1990's, a transformer type pilot machine (fig. 2) was built at the electron radiation laboratory of my institute. It was basis on resonant transformer type of accelerator[2)]. The technology of accelerator tube has been developed in 1980's to construct a 2*2.2 MV tandem electrostatic accelerator. The tube welled ceramic rings with titanium electrodes in vacuum oven. The gradient of tube is reached up to 2.24MV/m for proton; it would be higher for electron.

The status of the pilot machine is of 1.2MV/40mA and using for the irradiation experiment inside IMP. It will be upgraded in multi-purpose within next 3 month. If the secondary rectifying sections are installed double in series, it would be reached 2.5MV/40mA or in parallel reached 1.2MV/80mA. The power supply of the primary winding of the pilot machine is an IGBT frequency converter.

The high power electron accelerator is 3-phases transformer type of accelerator under construction (fig.3). The main characters is following:

1) High voltage: 1.5MV;
2) Beam current: 300mA;
3) Two window extraction device;

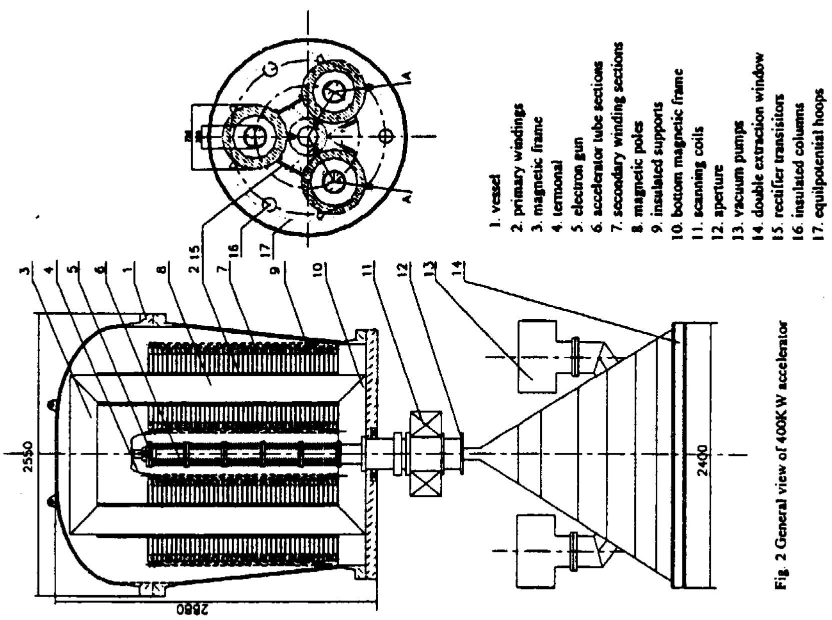

Fig. 3, 1.5MV@300mA, 3-phases transformer type of accelerator

The magnetic transformer has three pillars parallel made 0.15mm Si-steel pieces. The shape of up/bottom magnetic pole is triangle (see fig.4). The primary windings was rounded up magnetic pillars and connected to 3-phases IGBT frequency converter with triplet-connection. The secondary coil sections were installed centrality. 40 sections were connected in series in each three high voltage columns. Each secondary coil connects two transistors to rectifier and three phases with star-connection. There are equi-potential hoops outside the columns. The accelerator tube was located in the center of high voltage columns and has independent divided resistors. The electron gun inside a high voltage terminal is above of accelerator tube. There is a special coil for its power supply. The high voltage generator was installed a tank filled SF_6 of 0.65 MPa. The operational vacuum in the accelerator tube and extraction device is provided by two magnet-pumps and a turbo-pump. The operation value is 10^{-5} Pa because of metal seals in accelerator tube section and extraction window of Ti film.

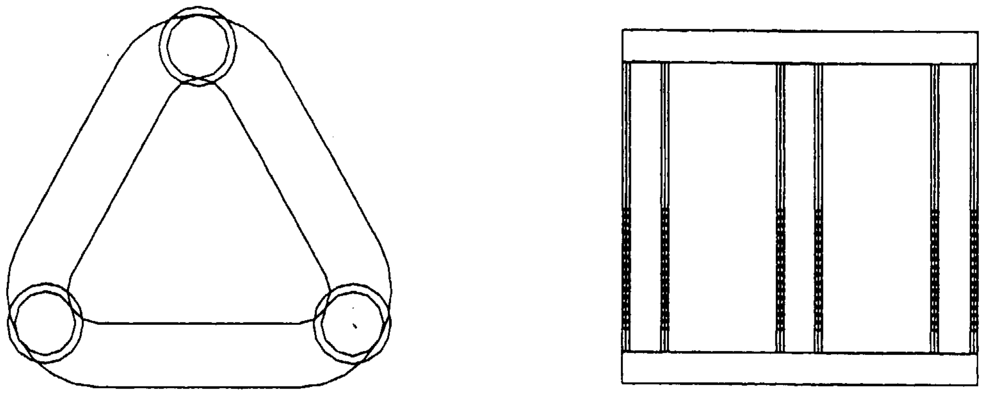

Fig. 4, The 3 phase magnetic transformer

In future, if invert the polarity of output voltage and improving the ripple of high voltage, this kind of high voltage generator will be used in ion implanter with ECR ion source to give heavy ion current or used as neutron generator.

REFERENCE

1) Zhou Zhiming et al, "Radiat. Phys. Chem." Vol. 42, Nos 1-3. pp.113-116, 1993

2) E. E. Charlton "General Electric Review" Vol. 44, No. 12. pp. 655-661, 1939

Table 1. Application of Electron Accelerator in Chinese Industry

Name of company / Organization Installed	Year installed	Facilities Maker	Acceler voltage	Beam current	Application
Jilin radiation chemistry institute	1984	RDI	3MV	40mA	Shrinkable tube
Tianshui Cable Company	1989	BINP(1) &IMP(2)	2.2MV	25mA	Irradiation cross-linkin cable& wir
Yantai Cable Company	1991	IHEP(3), I &SINP(4)	2MV	20mA	Irradiation cable
Institute of Engineering Physics	1987	Nissian HV Ltd.c	3MV	10mA	Shrinkable tube

Xian wire Company	1993	RDI	2MV	30mA	Wire
Institute of radiation protected, Taiyuan	1993	BINP & IMP	2.5MV	30mA	Shrinkable Tube, cable, Form Plasti
Sichuan Cable Company	1993	SPC[5]	2.0MV	10mA	Cable
Chengdu Shuangliu Shrink Company	1993 2000	SPC ViVilad	2.0MV 3.0MV	10mA 30mA	Shrinkable Tube
Changshou Cable Company	1994	SINP	2.5MV	20mA	Cable
Liyang Cable Company	1994	SINP	2.5MV	20mA	Cable
Xinhua Cable Company	1995	BINP & IMP	1.5MV 1.5MV	40mA 30mA	Cable
Guangdong cable Company	1995	RDI	2.5MV	40mA	Cable
Institute of Changcun Chemistry	1994-1997,4set	BINP	2.5/1.5M	30mA/40m	Shrinkable Tube
Institute of Nuclear Technology	1995	BINP & IMP	2MV	20mA	Shrinkable Tube
Kunming cable Company	1995	SINP	2.5MV	30mA	Cable
Shanghai cable Company	1995	RDI	2.5MV	33mA	Cable
Huangshi cable Company	1995	RDI	2.5MV	40mA	Cable
Shenyang Special Cable Company	1995	SPC	2MV	10mA	Cable
Dayu shrink-tube Company	1995/2set	SPC.	2MV	10mA	Shrink tube
Tianjin Tech-Pysics Inst.	1995	SPC	2MV	10mA	Shrink tube
Yangzhong cable Company	1995	SPC	2MV	10mA	Cable
Jiangxi cable Company	1996	SPC	2MV	10mA	Cable
Shanghai-minhang Cable Company	1996	BINP & IMP	2.5MV	30mA	Cable
Tianjin cable Company	1997	IHEP	2.5MV	20mA	Cable
Lanxi cable Company	1997	BINP & IMP	2.5MV	40mA	Cable
Huaian cable Company	1997	SINP,	2.5MV	25mA	Cable
Zhengzhou cable Company	1998	Vivilad	2.5MV	30mA	Cable
Zhunhua cable Company	1999	SINP	2.5MV	25mA	Cable
Shenzhen special Plastic product Company	2000	BINP Russia	2.5MV	30mA	Shrinkable Tube
Sijiazhuang cable Company	2001	IHEP	2.5MV	20mA	Cable

BINP[1]: Burker Institute of Nuclear Physics, Russia
IMP[2]: Institute of Modern Physcis, Chinese Academy of Sciences
IHEP[3]: Institute of High Energy Physics, Chinese Academy of Sciences
SINP[4]: Shanghai Institute of Nuclear Physics, Chinese Academy of Sciences
SPC[5]: Shanghai Xianfeng Company

4.3 The Use and Potential Application of Electron Accelerator in Indonesia

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INTRODUCTION

Electron accelerators have been used in radiation processing such as processing of polymer product, sterilization, food preservation, production of wire and cables, heat shrinkable tube and sheets, pre-vulcanization of tire rubber components and radiation curing. In environment issues, electron accelerator is useful for decomposition pollutants in waste water, disinfection of solid waste as sewage sludge, and purification of flue gas.

In 1984, a pilot plant of radiation curing technology particularly for wood surface coating using low energy electron accelerator has been installed in the Center for Application of Isotopes and Radiation (now : Center for Research and Development of Isotopes and Radiation Technology) , Jakarta. The accelerator has energy of 300 keV and beam current of 50 mA. The pilot plant was designed, for training and demonstration, studying both technical and economical aspects of the technology and also for radiation services [1]. Another electron accelerator (EBM GJ 2: 2 MeV, 10 mA) was installed at the Center in 1993. The accelerator was used mainly for R & D of crosslinking process such as crosslinking of wire and cable, and heat shrinkable tube and sheets, instead of radiation processing subjects. Another low energy electron accelerator has also been installed by a private company, namely PT. Gajah Tunggal at Tangerang (near Jakarta) for crosslinking of rubber tire in 1998.

This paper describes the use of electron accelerator in Indonesia for research and development, radiation services, commercial purposes and potential application in the future.

ELECTRON ACCELERATOR FOR RESEARCH AND DEVELOPMENT

Wood Surface Coating

Research and development using electron radiation has been started since the pilot plant of wood surface coating erected in 1984. The pilot plant was constructed under the cooperation of International Atomic Energy Agency (IAEA), United Nation Development Program (UNDP), and the Government of Indonesia. The pilot plant is equipped with a low energy electron beam machine (300 keV, 50 mA), a number of wood coating and wood handling equipment such as wood sanding machine, roll coater and laminator. A small modification of equipment, plant layout and installation of liquid nitrogen generator was done in 1989. Table 1 shows the specification of equipment that was used for research & development mainly in the field of radiation curing of surface coating of wood products. This is based on the fact that sixty percent of the tropical rain forests in South East Asia that is equal to 10 % of the world's total area found in Indonesia. The main products of the forest are mahogany, teak, ramin (*Gonystylus bancanus* Kurz), rubber wood, meranti (*Shorea* sp.) and other kinds of timber species [2]. Forest based product such as plywood, furniture & component, building materials, rattan, papers and pulp play an important role in economic development of Indonesia. Surface coating process is needed by almost all of those products for improvement of their physical and chemical properties as well as their performances. Due to the availability of the wood as raw materials of wood based products, the R & D were focused in radiation curing of surface coating of wood products. Several leading wood products have been used in the R & D such as plywood, parquet flooring, commercial timbers, particle board etc. [3]. The production test of several wood panels i.e. plywood, particle board, parquet flooring, and sengon wood (*Parasemianthes Falcataria* Roxb.) have been carried out for calculation of production cost [4, 5]. Some experiments of EB curing of surface coating of several substrates such as metal, ceramics, gypsum tile, asbestos, and marble to improve their surface properties have been done. Good results were obtained in a scientific and technical point of view.

The pilot plant had been used four times for training courses & demonstration on radiation curing of surface coatings of wood products. The training course were attended usually by participants from Malaysia, Bangladesh, China, India, Singapore, Sri Lanka, Korea, Thailand, Vietnam and Indonesia under direction of IAEA. The subjects of the courses and training consist of basic knowledge regarding the technology and practical experience on the pilot plant .

Although the equipment of the facility are in commercial size, but it was not designed for commercial production. The technology is not yet transferred to Industry, but a significant development has been achieved. Several companies have used the EB irradiation for coating of plywood and particle board to get special properties of the finished products. These products were used particularly for laboratory furniture, some thousands sq. m irradiated coated parquet flooring have been used for flooring of house, office and mosque.

Wire and Cable

The experiment on determination of the best result of cross linked LDPE and PVC have been conducted using various energy of electron beam. The results showed that the highest value of the gel fractions of XLDPE was 73 %, tensile strength of 277 kg/cm^2 and elongation at break of 368 %. This result was achieved at energy of 2 MeV, current of 1.0 mA and the dose of 300 kGy [6]. Heat- and oxidative- resistance of LDPE for cable insulation increase significantly by addition of anti oxidant after crosslinked using 300 keV electron beam. Addition of 0.2 % of antioxidant gave the optimum result at the dose of 300kGy. Anti oxidant of Irganox 1076 resulted better film properties as compared to the use of Irganox 1010 and Santowhite powder [7]. The influence of flame retardant to the rate of flammability of polyethylene has been observed. The flame retardant (halogen compounds) used i.e. chloroparafin (CP), tetrachloro-bisphenol-A (TCBA), polyvinyl chloride (PVC) and antimon trioxide (Sb_2O_3). Linear burning rate of sample without irradiation is lower than that of irradiated one. It can be concluded that the flame retardant can not retard the burning rate of the irradiated compound [8].

Vulcanization of Natural Rubber Latex

National Nuclear Energy Agency (BATAN) has been working on radiation vulcanization of natural rubber latex (RVNRL) since early 1970. A pilot plant for radiation of natural rubber latex using γ-ray of Co-60 has been installed at P3TIR – BATAN in 1983 under UNDP / IAEA / RCA Project. This facility can be used for irradiation of 1.6 ton/batch. Instead for R & D, the facility has been used for training & demonstration, studying technical & economical aspects and for radiation services. A lot of papers have been published concerning with RVNRL. using γ-ray of Co-60. A few research on RVNRL have been done using electron beam. One of the experiments is the use of sensitizer for radiation of natural rubber latex using 300 keV electron beam. Data obtained showed that without addition of sensitizer CCl_4, optimum irradiation dose is about 250 kGy, whereas by using sensitizer of 4 phr , the optimum dose can be reduced to about 120 kGy. A comparison study with γ-ray showed that without sensitizer, the optimum dose was almost the same. Sensitizing effect of CCl_4 or a combination of CCl_4 / n-BA were not as good as gamma irradiation [9].

There are three importance factors for producing free-protein pre-vulcanized natural rubber latex using low energy electron beam (250 keV, 10 mA) in a pilot scale i.e. the quality of natural rubber latex, standard irradiation method and treatment of irradiated natural rubber latex. The optimum condition was achieved at the irradiation time between 20 – 30 minutes, 5 phr of 1,9-nonediol diacrylate (ND-A) as sensitizing agent, and rotation speed of mixer was 210 rpm. By using this condition tensile strength of film was 26 mPA (Table 2). The water soluble protein with 1 % of ammonia for 15 – 30 minutes was 34 μg/g, and after adding with PVA (polyvinyl alcohol) or CMC become less than 4 μg/g [10].

Type I allergy is a serious problem in the use of medical rubber products such as surgical gloves, condom, and rubber tube for Spygmomanometer. This allergy is causes by problem of the natural rubber product, which contact with human body. Another serious problem is that various N-nitrosamine have been shown to be carcinogen. The new procedure for solving this problem is to produce free nitrosamine and protein of pre-vulcanize natural rubber latex by using γ -ray or electron beam. It was noted that centrifuged pre-vulcanized latex was free from nitrosamine and protein, which can be used directly for producing condom, surgical gloves, rubber tube for Spygmomanometer etc. The protein and nitrosamine content were 10 μg/g and 2 μg/g respectively. The objective of proposal of this work is to develop the production of pre-vulcanization natural rubber latex and its rubber products free from nitrosamine and protein content in the factory scale [11].

Grafting of Fabrics

The grafting of polyethylene terepthalate (PET) in the form of textured fabrics with normal methylol acrylamide (NMA) or acrylamide (AM) monomers was conducted using 300 keV electron accelerator at total dose of 5 Mrad. Grafting yields obtained by radiation was higher as compared with thermal curing at 135° C for 5 minutes. The grafted PET has maintained its good thermal stability, crease resistance, as well as its stress-strain properties, with some improvements for the hydrophylic properties, such as increasing in moisture regain, dyeability to anionic and cationic dyes, along with its normal dyeability to non ionic-dispersed dyes. The functional group analysis by means of FTIR spectrophotometer has shown some additional peaks of amide group, which indicated for the improvement of hydrophylic properties of the PET [12].

Radiation Sterilization

High energy radiation give the incredible power effects to achieve the rapid effective sterilization of medical products. The target is usually the ubiquitous micro – organisms found in various medical disposables, instruments, implants, etc. Electron beam can attack the metabolic and reproductive systems of such organisms by literally tearing them to pieces. The technique is having the dosage properly distributed to all surfaces and cracks of the product. The packaging material also must maintain the right degree of sterilization up to the point of their use. Generally, radiation sterilization has been successful application where steam sterilization, usually the lower – cost method, can not be used. The radiation technique is successful in replacing ethylene oxide(ETO) which is having difficulty in meeting toxic safety requirements. Ethylene oxide is very toxic and flammable material and has displayed carcinogenic activity. Some disadvantage factors of the use of ETO are patient health concerns, product residues, worker safety, environmental emissions of gas, legislation for the use of hazardous chemicals, increasing capital and operating costs [13].

Degradation of Cellulose

Exposure of pulp to high energy electrons or γ-rays can be used to lower the degree of polymerization of cellulose. Electron –treated pulp has been found to possess higher reactivity, resulting in decreased amounts of chemicals required, such as CS_2. The decreased usage of CS_2 does not have adverse effect to the properties of fibers produced from viscose made by irradiated pulp. The benefits of this method are enhancement of reactivity and lowering the chemicals used such as CS_2, NaOH and H_2SO_4 which can reduce the environmental releases (CS_2 and H_2S). The experiment of this field has been started since two years ago.

HANDICAPS ON THE APPLICATION OF ELECTRON ACCELERATOR

Almost all of the technology have advantage and disadvantage factors such as technology, economic, social and environment point of view. For instance, the advantage and disadvantage of radiation curing of surface coating can be stated as below.

Advantages

- Avoidance of pollution
- No catalyst and heat
- High speed curing
- Space saving
- Instantaneous start-up and shut down

Disadvantages

- High cost of equipment
- Inert atmosphere
- High price of radiation curable materials

Economic analysis based on the present situation concluded that radiation curing of surface coating cost was relatively high. The high price of radiation curable materials, machinery and radiation sources are the main constraint to expand their activity. This condition was pushed by the monetary crisis that hit Indonesia since mid-1997. Effect of monetary crisis on declining of foreign exchange can be seen on Table 3. The constraint of the use of electron accelerator for all application such for cross linking of wire and cable, cross linking of natural rubber latex, sterilization, food preservation, flue gas control almost similar, that is economical aspect.

POTENTIAL APPLICATION

Instead in the field of radiation processing and environment as described above, another potential application look like have a promising application in the future particularly in Indonesia. Those are radiation curing for production of composite and solving the problem of environmental problem.

A major break through for the composite industry by successfully developing Electron – Beam (EB) curable epoxies and EB curing cycles that reduce processing time and cost while meeting the demanding requirements of high- performance composite structures. These developments make it possible to use a large class of common epoxies to build composite parts without the need for slow, high temperature, high pressure curing cycles, the associated expensive fabrication tools, or the toxic chemical hardeners. This method is suitable used for production of automotive, marine and sporting good industries [14].

Electron beam curing can be used to manufacture composite material component at higher speeds and greater production flexibility than conventional techniques. As long as curing process is not initiated until radiation, timing limitation associate with lay up and resin infusion can be relaxed, leading to reduced scrap and rework. In general, E B curing systems are " solvent less " with fewer volatile organic compound(VOC) and therefore more environmentally friendly. One of the practical applications of this system is in the boat building industry. Electron beam can successfully penetrate complex boat structures fabricated with off – the – shelf marine resins. The practical use of low – cost tooling with EB curing system is reinforced. The EB technology successfully in the use of off – the shelf vinyl ester for the production marine craft cured with EB radiation [15]. As the maritime country, Indonesia has a potential application for production of boat by this method.

In environmental issues, emissions of toxic gases, such as sulfur oxides (SO_2) and nitric oxides (NO_x) from industrial plants have become serious problem in many countries. The coal-fired flue gas from thermal power plants is one of the main sources of environmental pollution, due to its large amount of S and N component.

The environmental problems caused by air pollution in Indonesia focus on Java island. Industrial development is concentrated on Java which accounts for only 8 % of the Indonesian land area. Due to further economic growth, the energy consumption of industry, traffic and households will increase significantly, and finally increasing the amount of pollutants released into the environment. In particular pollution due to coal utilization. Environmental pollution in many industrialized area of Java. The air pollution affects the tropical ecosystems (soil, crops, plantations, forest and water) and human health. More serious pollution will occur in the future if corrective actions are not taken in the future. The study on environmental impacts of energy strategies for Indonesia has been done by Agency for the Assessment and Application of Technology (BPPT) from Indonesia, and Forschungszentrum Julich GmbH (KFA) from Germany. One of the study covers assessment and evaluation of the potential risks of the energy related air pollutants (SO_2, NO_x, CH and dust) on the ecosystems of Java until the year 2021 and recommendation regarding the schedule for preventive measures (Table 4). Data on air concentration and deposition rates for SO_2, NO_x and dust predicted for the years 1991, 2001, 2011 and 2021 by the MARKAL Computer Model. Two environmental scenarios (cases) are investigated namely, Doing Nothing Case (DNC) and Emission Reduction Case (ERC). In the DNC, it is assumed that hardly any significant measures will be taken to reduce emissions in the future. In the ERC, it is assumed that significant steps are taken within the next 10 years to reduce air pollution. Even for the total amount of SO_2 and NO_2 will at least triple by the year 2021 and reach 43% of the level of DNC (Table 5). The volatile hydrocarbon (VHC) emissions will double and reach 66% of the DNC. Particulate matter (PM) increasing only by 30% and reach 43% of the DNC level in the year 2021. The critical areas for all ecosystem of Java in the year 2021 at least 38,3% and 75% of West Java. The harmful environmental pollution in the vicinity of large plants should be avoided at present by several ways, namely employing high chimneys by appropriate site selection and abatement technology [16]. Electron accelerator can be used for treatment of flue gas as a promising pollution control method by reducing of SO_x and NO_x with dry process simultaneously.

Almost all technical and environmental aspect the use of electron accelerator have a lot of advantages compared with another method for the same purpose. High population, man power, natural resources as several important factor to develop the market and industry which can use electron accelerator. For example, the data of wood resources balance of Indonesia as shown on Table 6 [17]. So many fields can reached by the technology for production and solving the problem in a current issues such as environment. It is predicted that the market of product treated by electron accelerator will increase in Indonesia due to the following reasons:

- Development of more feasible and economical of electron accelerator for a given process.
- Development of more efficient process to reduce the production cost.
- Awareness of an efficient and friendly environmental process.
- The employment of both ISO 14000 and ISO 9000 as the certification of production method and management systems.
- The hope that monetary crisis will be over as soon as possible.

CONCLUSION

Based on the number of population, man power, natural resources and current problem such as environment issues the application of electron accelerator will increase if several condition can be met, such more efficient process, lower cost of equipment and financial crisis will be over. The promising future for industrial application is in the production of composite, cross linking natural rubber latex, pollution and all process which using abandon of cheap raw materials. To realize this purpose the research and development of the use of electron beam play an important role.

REFERENCES

1. DANU, S., Research and development on radiation curing of surface coating at CAIR – BATAN, Proc. RadTech Asia'91, Osaka (1991) 65.

2. ANONYMOUS, "Promising future for Indonesian furniture", Asian Furniture, June (1997) 13.

3. DANU, S., SUNDARDI, F., TRIMULYADI, G., SUNARNI, A., DARSONO, and MITRO, M., "Radiation curing of surface coating of five commercial timbers ", Second Indonesia – JICA Symposium on Polymers, RDCAP – LIPI, Bandung(1990) 103.

4. DANU, S., "Economic analysis of radiation surface coating of woodpanels," Presented at UNDP/IAEA/RCA Regional training Course on Radiation Curing of Wood Products, Jakarta (1990), unpublished.

5. DANU, S., "Economic analysis of radiation surface coating of parquet flooring", J. BATAN, Vol. XXII, No. 3/4 (1989) 37 (in Indonesia).

6. TRIMULYADI, G., SUNARNI, A., MARLIYANTI, I., RAZZAK, M. T., "Comparison of irradiation cross linking of LDPE and PVC at various electron beam energy", Proc. Nat. Symp. of Polym., Indon. Polym. Assoc., Jakarta, (1995) 83. (in Indonesia)

7. SUNARNI, A., TRIMULYADI, G., MARLIJANTI, I., and RAZZAK, M. T., "The Influence of antioxidant to the cross linking of polyethylene", Proc. of Mat'l Sc. II, Serpong (1996) 240. (in Indonesia)

8. MARLIJANTI, I., SUNARNI, A., MIRZAN, T. R., and TRIMULYADI, G., "Effect of flame retardant to the burning rate of polyethylene compound", Proc. Sem. of Appl. of Isotopes and Rad., Jakarta (1996) 41. (in Indonesia)

9. SOFIARTI, W., UTAMA, M., and SUNDARDI, F., "Radiation vulcanization of natural rubber using 300 keV electron beam machine, Proc. of Int. Symp. on Rad. Vulcanization of. Nat. Rubber Latex, JAERI, Takasaki (1990) 350.

10. UTAMA. M., SUMARTI, M., IRAMANI, D., PUSPITASARI, T., HAQUE, E., IKEDA, K., YOSHII, F., KUME, T, MAKUUCHI, K., "Trial production of protein free RVNRL by low energy electron beam", Center for Res. and Dev. of Isotopes and Rad. Tech, Jakarta (2001), (Technical Report).

11. UTAMA, M., SISWANTO., SYAMSYU, Y., SUNDARU, H., SANTOSO, I., VIQAYA, S., MUKLIS, M., RAHAYU, T., MAKUUCHI, M., "R & D, feasibility study, and implementation free from nitrosamine and protein pre-vulcanized natural rubber latex and its rubber product", , Center for Res. and Dev. of Isotopes and Rad. Tech, Jakarta (2000), (Technical Report).

12. ISMININGSIH, G., ZUBAIDI., WIBOWO, N., HADITYATI, S. S., SUNARYATI S., and UTAMA, M., "Resin – finished processing of poly (ethylene tere –phthalate) with normal hydroxy acrylamide and acrylamide by means of electron accelerated irradiation or heat curing process ,"First ASEAN- JAPAN Symp. on Polymers, JICA – LIPI, Bandung (1991) 121.

13. BRINSTON, R. M., "Future growth in the gamma sterilization of disposable medical products, Radiat. Phys. Chem., Vol.35, No. 1-3 (1990) p.390

14. LOPATA, J. L., SAUNDERS, C. B., SINGH, A., JANKE, C. J., WRENN, G. E., and HAVENS, S. J., "Electron-beam-curable epoxy resins for the manufacture of high-performance composites, Rad. Phys. and Chem. 56 (1999) 405 – 415.

15. CHAPPAS, W. J., DEVNEY, B.G., OLDING, R. P., and MCLAUGHLIN, W. L., "EB curing of maritime composite structures " Rad. Phys. and Chem. 56 (1999) 417-427.

16. ANONYMOUS, "Environmental impacts of energy strategies for Indonesia", Draft Summary, BPPT-KFA (1992)

17. RATNASINGAM, J., "Wood resources in Asia: Are They Sustainable?", Furniture Design & Manufacturing – Asia, October (2001) 48.

Table 1. Specification of low energy electron beam machine (Nissin High Voltage) and wood handling systems installed at P3TIR-BATAN.

Equipment	Type
EB machine	Scanning Type, 300 kV, 50 mA
UV source	One lamp, 80 Watts / cm
Belt sanding machine	-
Direct roll coater	-
Reverse roll coater	-
Curtain coater	Flow
Sprayer	High Pressure
Film Laminator	-
Liquid nitrogen generation	-

Table 2. The properties of pre-vulcanized natural rubber latex prepared by low energy electron beam and gamma rays of Co-60 in pilot scale trial production.

Process & Properties	γ-ray of Co-60	Electron beam
Place	P3TIR-BATAN	TRCRE-JAERI
Date of irradiation	Feb. 20, 2000	Nov. 28, 2000
Source	210 kCi (2.96 kW)	250 kV,10 mA (7.5kW)
Sensitizing agent	2 phr nBA	5 phr ND-A
Vulcanization dose	35 kGy	30 minutes (±20kGy)
Capacity of vessel (liter)	1500	18
Speed of stirrer, rpm	25	210
Properties of latex & its film **Source of latex**	Jalupang plantation, Indonesia	Centrifuged NRL, Malaysia
PH	10.3	9.75
Viscosity	94.0	80
Total solid content (TSC),%	64.77	61.7
Dry rubber content (DRC),%	64.47	-
TS-DRC	0.30	-
VFA number	0.003	-
Mg content, % TS	0.00051	-
Extractable protein cont, μg/g	8	4
Modulus-600 %, MPa	2.1	2.2
Tensile strength, MPa	28.0	26
Elongation at break, %	1000	950

Table 3. Foreign exchange earnings of some forestry products from 1994 to 1998

Products	1994	1995	1996	1997	1998	% trend
Plywood & Veneer	3720.25	3465.97	3568.99	3413.32	2079.95	-11.11
Furniture & Component	956.87	943.99	1070.61	972.27	484.06	-12.48
Paper & Pulp	735.97	1452.04	1387.35	1427.78	2115.44	23.30
Printing Mat'l	79.12	118.58	132.96	93.05	65.28	-6.08

Table 4. Comparison of emission for the DNC and ERC in Java.

Pollutant	Case	Emission in Mill t/a			
		1991	2001	2011	2021
SO_2	DNC	0.35	0.56	1.36	2.78
	ERC	0.35	0.45	0.65	1.20
NO_2	DNC	0.56	1.08	2.10	3.95
	ERC	0.56	0.81	1.03	1.73
SPM	DNC	0.85	1.31	1.83	2.56
	ERC	0.85	1.05	1.09	1.09
VHC	DNC	0.28	0.41	0.63	1.02
	ERC	0.28	0.32	0.43	0.67

SPM = suspended particulate matter
VHC = volatile hydrocarbon

Table 5: Sectoral Emission Shares, Java (High Scenario, Doing Nothing Case)

	NO_2		SO_2		PM		VHC	
	1991 %	2021 %	1991 %	2021 %	1991 %	2021 %	1991 %	2021 %
Power Plants	23.4	46.3	62.2	67.9	1.6	11.9	1.6	1.6
Industry	6.7	5.9	30.5	25.2	63.1	70.9	26.3	20.5
Household	4.5	0.8	3.1	0.8	34.3	15.2	18.7	6.3
Traffic	65.4	47.0	4.2	6.1	1.0	3.0	53.5	71.5

Table 6. Wood resources balance in Asia.

Country	Wood resource balance
Japan	Deficit
Philippines	Deficit
Thailand	Deficit
Indonesia	Surplus
Malaysia	Surplus
China	Deficit
India	Deficit
Fiji	Surplus
Myanmar	Surplus

4.4 Utilization of Low-energy Electron Accelerators in Korea

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There are more than 20 electron accelerators in Korea. Most of those are installed in factories for heat-resistant cables, heat-shrinkable cables, radical tires, foams, tube/films, curing, etc.. Four low-energy electron accelerators are in operation for research purposes such as polymer modification, purification of flue gas, waste water treatment, modification of semiconductor characteristics, etc..

1. Status of Low-energy Electron Accelerators in Korea

The first electron accelerator in Korea was installed at the Korea Atomic Energy Research Institute (KAERI) in 1975. The energy and the current of the electron beam of the accelerator are 0.3 MeV and 25 mA, respectively. The accelerator was dedicated for researches on polymer modification. The accelerator, together with the Co-60 irradiation facility at KAERI, has been the key utility in Korea for research on the industrial application of radiation technology.

From the early 1990s, more than 20 electron accelerators have been introduced into the Korean industry for the production of heat-resistant cables (9 installed / 8 operating),, shrinkable cables (1/1), radical tires (5/3), foams (3/3), tube/films (1/1), etc.. The energy range of the accelerators is from 0.5 MeV to 1 MeV. The average current ranges 40~150 mA. The accelerators have contributed very much to the Korean economy. For example, Korean companies supply more than 40 % of e-beam treated heat-resistant cables in the world. EB Tech, a private company, has started its business on electron accelerators since 1994, and has supplied a many accelerators to the Korean companies and foreign companies.

Table 1. List of γ -ray irradiation facilities in Korea

Institution Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
KAERI	1975 (1998)	176 cm	130,000 Ci	Research	
Greenpia Tech	1986	~ 180 cm	1,000,000 Ci	Commercial	

There are four accelerators in operation dedicated to research purposes: one at KAERI, two at EB Tech, and one at YoungNam University. These accelerators are now being used for research activities such as polymer modification, purification of flue gas, waste water treatment, modification of semiconductor characteristics, etc.. One of these accelerators is a RF linac with energy of 2 MeV, and the others are electrostatic accelerators with energy ~ 1 MeV. The 2-MeV linac at KAERI will be upgraded to 10 MeV.

Table 2. List of low-energy electron accelerators in Korea

Name of company / Organization Installed	Year Installed	Maker	Accelerator Voltage	Beam Current	Purpose of Use
LG Cables DongYang Cables Daewon Cables Daeryuk Ind. KDK KyungShin Co.	'84-'00 '96 '91 '97	3 NHV 2 EB Tech. 1 EB Tech. 1 RDI 1 RDI 1 BINP 1 NHV	~ 1 MeV	50~100 mA	Cables and Heat shrinkable tubes
Hankook Tires KumHo Tires		3 NHV 2 RDI	0.5 MeV 0.8 MeV	~ 100 mA ~ 100 mA	Tires
YoungBo Chemicals TongIl Co.		2 NHV 1 NHV	0.5~1 MeV	50~100	Foam Sheet
Korea TetraPack		1 ESI	0.175 MeV	300 mA	Coating
Ceratech Co.		1 EB Tech.			Polymer
Dyeing Complex		1 EB Tech.			Waste water
KAERI	1975 2000	1 HVEC 1 BINP	0.3 MeV 2 MeV	25 mA 45 mA	Research
EB Tech.		2 EB Tech.	~1 MeV		Research
YoungNam Univ.		1 BINP	0.8 MeV		Research

In Korea, the regulation for electron accelerator is very strict. Any electron generator with voltage above 50 kV is under regulation. For "production", "import", "sale", and "use" of radiation generator with voltage above 50 kV, it is necessary to get approval of the Ministry of Science and Technology.

At the present time, as far as the author knows, there is no electron accelerator in operation with energy lower than 250 keV (soft electron beam) in Korea. Even though it is expected that soft electron beam technologies will give a strong impact to the industries in Korea, the technology has not been introduced into the Korean industries. The above-mentioned accelerators dedicated for research could be used, after some modification, for the development of technologies of soft electron beam.

2. Status of Radiation Processing and E-beam Utilization Technologies in Korea

Table 3 shows the status of radiation processing technologies in Korea. Polymer modification technologies using electron beam for production of heat-resistant cables, heat-shrinkable tubes, tire cores, and form sheets have already been commercialized for the last 20 years. Recently, a new high-performance polymer switch has been developed using e-beam in Korea, and the technology has been commercialized. Curing and coating of woods, papers, etc are under development, or commercialized. Curing and coating of woods, papers, etc are under development, or at the beginning of commercialization. Table 4 shows the list of commercialized technologies in Korea.

For food irradiation, 13 food groups are authorized in Korea; Potato, onion, garlic, chestnut, fresh/dried mushrooms, dried meats, powdered fish and shellfish, starch, dried spices and their preparations, dried vegetables, yeast and enzyme foods, powdered aloe, ginseng products including red ginseng, second sterile meals for patients, soybean paste powder, hot pepper powder, and soybean sauce powder.

Each year, 4,000 tons of foods are commercially processed by γ-ray only. There has bee no commercial activities for food irradiation be electron beam. One reason for this is that there has been no electron accelerator with energy 5-10 MeV in Korea.

Table 3. Summary of the present situation of radiation processing technologies in Korea

Applications		Status in Korea (Commercialization)
Polymer modification	Flame resistant cables Thermo-shrinkable tubes, sheet Curing of tire cores Foam sheet Artificial leather Films of coating and packaging	OOO OOO OOO OOO X X
Sterilization/ Disinfection	Sterilization of medical items Preservation of spices, food Disinfection of grains	OO OO OO
Environmental Protection	Flue gas purification Waste/Wastewater treatment Sludge treatment	O OO X
Others	Curing/Coating of wood, paper, etc. Semiconductors, PTC/NTC Ceramic composites Surface treatment of fabrics	OOO OOO X X

OOO: Commercialized, OO: Engineering, O: Research, X: No activity

Table 4. Electron accelerator utilization technology - for commercial use

Field	Target	From when	Remarks
Polymer modification	Flame resistant cables	1984	LG Cables Co.
	Conductive material	1999	Ceratech
	Shrinkable tubes	1997	Hankook KDK
	Tire core	1991	Kumho Tire
	PE form	1991	Tongil Industry
Curing	Curing of print	1989	Hankook Teprapack
Waste water	Purification of dyeing waste water	2002	Daegu Dyeing complex

There have been some research activities for purification of flue gas. It has been successfully demonstrated that SOx and NOx are removed efficiently by irradiating electron beam. But this technology has not been commercialized yet.

One successful demonstration of e-beam technology is purification of dyeing waste water. In 1995, about 20% of waster water discharged in Korea is from textile industry. Taegu city has been famous for textile industry for more than 30 years, and there is a huge dyeing complex near Taegu city. EB Tech demonstrated successful purification of dyeing waste water by combining electron beam irradiation together with biological treatment process. The number of treatment stages has been reduced, and the economy of the process has been verified. After demonstrating pilot scale facility, EB Tech is now constructing a commercial plant from 2001 under the financial support of IAEA (International Atomic Energy Agency), MOST (Korean Ministry of Science and Technology Laboratory), and KAERI.

3. Future Prospects

The Korean government is now promoting energetically the development of Radiation Technology. The promotion plan for utilization of radiation and radioisotopes has been established very recently by MOST. According to the plan, 30 % of nuclear R&D budget shall be devoted to the development of radiation technology. A new "Research Center for Advanced Utilization of Radiation" is now being constructed, and will open at the end of 2004. On of the major research facility is high power electron accelerator with energy 5~10 MeV. The 2-MeV RF linac at KAERI will be upgraded to 10 MeV by the end of 2002. It is expected that the use of electron beam in Korea will increase very much in a few years. Especially, sterilization of medical products by ~10 MeV electron beam and irradiation on foods will be activated. The use of ~1 MeV electron accelerator for polymer modification, waste water treatment, etc.

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4.5 Applications of Electron Accelerator in Malaysia

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INTRODUCTION

Radiation processing is one of the core research programs of the Malaysian Institute for Nuclear Technology Research (MINT). As a government research institute, research activity of MINT is designed to meet the government policies and aspiration of developing knowledge driven economy (k-economy). It is recognized that knowledge is the main driving force for economic growth of a country. In this connection, R & D program in Malaysia is designed to generate knowledge that can meet market demands and needs.

The government supports R & D and technologies that promote growth (increase export & reduce import); enhanced industrial efficiency, productivity and competitiveness; generate home-grown technology with own brands of goods and services; reduce labor with increasing automation, improve quality of life and protect & clean the environment.

Within the manufacturing industry, advanced materials such as composites, either polymer-based, metal-based or ceramic-based are given priority. It is much so, if resource based material can be integrated into the development of advanced materials. In this case, natural rubber and oil palm are the main sources. The by-products of the two resources such as rubber wood, rubber wood fibers, oil palm fronds and empty fruit bunches are the primary materials for further utilization - value added and meeting the zero waste concept

In addition to composite materials, the modification of resource base materials that have commercial value is also given high priority. Epoxidised natural rubber and thermoplastic natural rubber elastomer are amongst the products that have been developed and commercialized in Malaysia. Modified palm oils such as polyol and epoxidised palm oil are developed and used as starting materials for polyurethane and polyester based resins for various applications.

The current industrial application of electron accelerator fits in well into the country's development program. Electron beam processing is one of the industrial processes that can be used for cross-linking, grafting, elimination of microorganisms, modification of organic compounds, etc. The electron beam processing technology can be an integral part of the manufacturing line for the production of flame/fire resistant wire and cable, heat shrink tube, hot water tube, heat shrink film for packaging, sleeve, composite materials, viscose rayon and many other profile and molded products. It has been proven as unique and commercially viable process. On the other hand, the materials used for electron beam processing are specifically compounded and are not easily available. Therefore, the introduction of electron beam processing technology in local industry requires mix strategies as follows;

- Established technology/material/product - development of radiation crosslinkable materials for specific use.
- New technology/material/product – development of advanced and modified materials based on indigenous and locally available raw materials
- Development of affordable electron beam accelerators for research and industrial use.

In addition, electron beam processing has also been proven as a viable process for cleaning up flue gasses from power station and incinerator. It can also be used for cleaning of volatile organic compounds and industrial wastewater Therefore, it has great potential to be used for protection of environment.

CURRENT APPLICATIONS OF ELECTRON BEAM ACCELERATOR

In Malaysia, there are a number of industrial applications of electron accelerators such as given in Table 1. The main applications are for crosslinking of polymer compounds for wire insulation, tubing (flexible and heat shrinkable), plastic films in particular heat shrinkable film. Most of the companies irradiate in-house products. However, Malaysian Institute for Nuclear Technology Research (MINT) is the only establishment that provides electron beam processing services. Currently, a heat-shrinkable tube manufacturer and a flexible tube manufacturer are using MINT's electron beam processing services. For heat shrinkable tube manufacturer, MINT has transferred the technology of compounding the heat shrinkable resins. MINT has also developed a series of heat and fire resistant compounds that electron beam crosslinkable for wire insulation, tubing and other purposes.

Table 1. Electron Beam Irradiation Facilities in Malaysia

No.	Purpose of Irradiation	Machine specification	Manufacturer	Year establ.	Name of company, Address and contact number
1	Electron beam accelerator CURETRON (research and services) – mainly for curing of surface coatings	200 kV, 20 mA	NHV, Japan	1991	Malaysian Institute for Nuclear Technology Research (MINT)
2.	Electron beam accelerator (research and services) for crosslinking of tubes, heat shrinkable tubes, crosslinking of wire insulation	3.0 MV, 30mA	NHV, Japan	1991	Malaysian Institute for Nuclear Technology Research (MINT)
3.	Electron beam accelerator for cross-linking of wires insulation	800 kV, 100 mA	NHV, Japan	1995	Sumitomo Electric Interconnect Products, Johor
4.	Electron beam accelerator for crosslinking of wire insulation	2.0 MeV, 100 mA	NHV, Japan	2001	Sumitomo Electric Interconnect Products, Johor
5.	Electron beam accelerator for cross-linking of heat shrink packaging film	550 kV, 60mA 2 units		1996	W.R.Grace, Kuantan
6.	Electron beam accelerator for cross-linking of plastic packaging film	150 kV, 460 mA	ESI, USA	1997	S.K.Polymer, Klang.

CURRENT AND FUTURE R & D PROJECTS

The following (Table 2) are some of the possible materials, processes and out put of the research projects undertaken by the Malaysian Institute for Nuclear Technology Research (MINT);

Table 2. Indigenous and locally available materials, processes and expected applications

Materials	Process	Output Product/Application
Natural rubber - SMR (Std.Malaysian Rubber) - epoxidized natural rubber - atex - rubber wood fibers *Oil palm* - crude and refined oil - expoxidized palm oil - palm oil fibers *Polysaccharide* - Starch from Sago & Tapioca - Chitosan Thermoplastic - Low Linear Density Polyethylene (LLDPE) - Linear Density Polyethylene (LDPE) - Ethylene Vinyl Acetate (EVA) - Polypropylene - Polyvinyl chloride - Polystyrene	• Blending/Composite • Modification/synthesis • Compounding • Extrusion • Injection molding • Coating/lamination • Casting • Gamma vulcanization, • Electron beam crosslinking, grafting and curing	• Composite profiles such as panels, frame, flooring for construction and furniture industry. • Continues extrusion tube/hoses, sheet/film, pipe, foam, membrane as industrial products • Continues composite sheet, foam for automotive parts such as window trim, rear shaft and front panel etc. • Injection molding of modified and composite materials for automotive parts • Hydrogel for bio-medical application • Biodegradable foams and films for packaging • Pressure sensitive adhesive, printing inks and hard coatings
Environmental preservation - SOx and NOx from power stations and incinerator.	• Cleaning the gases	• Clean air release to the atmosphere. Fertilizers as by product
- Organic & inorganic pollutants from dye conversion industry and food beverage industry	• Cleaning industrial waste water	• Clean water

Table 3. List of Projects Division of Radiation Processing Technology, MINT

Established technology/material/product – using electron beam processing
• Development of heat shrinkable compounds (flame retardant) – completed • Development of electron beam processing for heat shrink tubes – completed • Electron beam sterilization of medical items. – trial run completed. • Utilization of electron beam technology for purification of flue gases in the applications of electricity supply industry - Research cooperation between MINT and TNB Research Sdn. Bhd.- completed by June 2002 • Utilization of electron beam technology for treatment of industrial wastewater from dye conversion industry – beginning 2002 • Development of expertise and capabilities in the design and fabrication of electron beam machine – beginning 2002
New technology/material/product - using electron beam processing
• Thermoplastic natural rubber including epoxidised natural rubber and its compatibilizers. • Sago starch for biomedical applications such as hydrogel for wound dressing • Development of water soluble chitosan for biomedical applications • Modification of sago starch and chitosan such as CMS and CMC • Modification of starch from sago starch for biodegradable foam and films by blending and grafting techniques • Synthesis of radiation curable materials from palm oil for pressure sensitive adhesive (PSA) and printing ink applications • Development of formulation for PSA and printing ink using palm oil based resins • Development of high abrasion and scratch resistant coatings • Agro-fibers reinforced polymer composite compounds for automotive and construction industry

CONCLUSION

In the past several years, there is a significant progress and development on the application of electron beam processing in Malaysia. Government continues to support R & D on this field by providing the necessary infrastructure, facility, trained manpower and research funds. Various mechanisms for commercialization are also in placed to facilitate the transfer of technology from laboratory to industry.

In the private sector, several units of electron bream machines are in operation such as 3 units for heat shrink films, 2 for crosslinking of wire. A few more are in the planning stage for crosslinking tubes and heat shrink sheet. For gamma sterilization facility, four industrial plants are in operation including Sinagama at MINT. It is envisaged that radiation processing will continue to contribute to the progress and development of industry in Malaysia.

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4.6 Utilization of Electron Accelerator in the Philippines[1]

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Introduction

Radiation processing has found many industrial applications. It is recognized that radiation is effective for the sterilization of a wide variety of medical and surgical supplies and can be used to process a wide range of consumer products, including food, pharmaceuticals and cosmetics. Another major application of radiation is in the modification of polymers, such as crosslinking and curing. Though these industrial applications are well established technologies in the more developed countries, this is not the case in developing countries, like the Philippines.

Radiation Facilities

To demonstrate radiation technology to the local industries, the Philippine Nuclear Research Institute (PNRI) with the technical assistance of the International Atomic Energy Agency (IAEA) has set up a pilot scale multipurpose gamma irradiation facility. The irradiator, a Gammabeam 651PT from Nordion International was commissioned in 1989 with an initial loading of 1.1 PBq (30,000 Ci) ^{60}Co. In 1993 and 1996 additional Co-60 were loaded, making the total loading about 5.5 PBq (150,000 Ci) in 1996. Due to radioactive decay, the present loading is 2.6 PBq (70,000 Ci) ^{60}Co.

The source configuration consists of eight source racks, each of which can be operated independently and can be raised to seven different positions. Effectively the source configuration can be considered as a plane source, 112 cm wide by 140 cm high. Maximum loading is about 9.3 PBq (250,000 Ci) ^{60}Co.

PNRI assists and offers technical advice to prospective users of the irradiation facility. In collaboration with these clients, PNRI conducts bioburden determination, dose setting and validation of compatibility of product and packaging with radiation.

Though on a small scale, these investigations led to the commercial application of radiation sterilization of empty aluminum tubes, orthopedic implants, amnion and bone grafts and microbial decontamination of empty gelatin capsules, carrageenan, spices and dehydrated vegetables. Table 1 shows the products irradiated at the facility from 1996-2001.

Terumo (Philippines) Corporation, a subsidiary of Terumo Corporation has established the first industrial electron accelerator in the Philippines. The facility is located in an export processing zone in a technopark, south of Metro Manila. The electron accelerator has beam energy of 10 MeV and beam power of 28 kW, with scan width of 30-80 cm. Conveyor velocity is 1-10 meter per minute. The electron accelerator, manufactured by

[1] Presented at the FNCA Workshop on Application of Electron Accelerator, Takasaki, Japan, 28 January-1 February 2002

Mitsubishi, is used for in-house radiation sterilization of syringes. The company uses state-of-the-art technology, facilities and processes. Production started in April 2000.

Regulations and Regulatory Authority

The Philippine Nuclear Research Institute (formerly the Philippine Atomic Energy Commission) by virtue of Republic Act No.2067, known as the Science Act of 1958, Republic Act No. 5207, known as the Atomic Energy Regulatory and Liability Act of 1968 and Executive Order 128 of 1987, is mandated to promote and regulate the safe and peaceful uses of nuclear technology in the country.

The Philippine Nuclear Research Institute (PNRI) promotes the advancement of the peaceful applications of nuclear science and technology by implementing research and development projects, providing specialized nuclear services and training, operating radiation facilities and laboratories and enhancing public awareness through different modes of information dissemination.

As a regulatory agency, PNRI enforces nuclear regulations to ensure that the use of nuclear and radioactive materials is carried out safely without posing undue risk to the workers and the public. The Institute promulgates and issues Code of PNRI Regulations (CPR) as well as regulatory guides to enhance the effectiveness of its regulatory functions. Examples of Code of PNRI Regulations, which are relevant to gamma irradiators are CPR Part 3, "Standards of Protection Against Radiation", CPR Part 4, "Regulations for Safe Transport of Radioactive Materials" and CPR Part 15, "Licenses for Large Irradiators."

On the other hand, Presidential Decree No. 480 of 1974 created the Radiation Health Service under the Department of Health with responsibilities to regulate the use of non-ionizing and ionizing radiation-emitting machines, such as electron accelerators and x-ray machines. In the year 2000, the Radiation Health Service has been reorganized into the Bureau of Health, Devices and Technology (BHDT) as a consequence of structural changes in the Department of Health.

Research and Development

In the absence of an electron accelerator, all research and development work on radiation processing have been done utilizing the gamma irradiation facility of PNRI.

Experiments have shown the suitability of radiation vulcanization for local natural rubber latex. Radiation vulcanized natural rubber latex (RVNRL) can be used for the production of dipped rubber products, which are non-toxic and less allergenic. The possibility of producing finger cots from RVNRL for use by the semi-conductor industry is being explored. Studies to identify antioxidants from natural sources, which could replace toxic chemicals used to prolong the shelf-life of rubber, are on going.

The Philippines is the number one producer of carrageenan, but most of the local and international demand for carrageenan is for food applications. Studies to explore the potentials of carrageenan for non-food applications are being conducted. Through radiation crosslinking, hydrogel from carrageenan and polyvinyl pyrrolidone (PVP) has been successfully prepared. The hydrogel can be used as dressing for burns and wounds. Clinical tests showed that this hydrogel is comparable with commercial hydrocolloid burn dressing. A patent for PVP-carrageenan as burn dressing has been filed at the Philippine Intellectual Property Office. The use of carrageenan as a plant growth promoter is also being investigated.

To contribute to the minimization and recycling of agricultural wastes, studies to upgrade sugar cane bagasse by radiation and fermentation into useful products is on going. The use of irradiated bagasse as substrate for mushroom production showed encouraging results. The potential of the fermented bagasse as animal feed is being explored, since physico-chemical analysis indicated a reduction in the crude fiber and a slight increase in the protein content.

Studies on radiation treatment of some meat products showed that irradiation can significantly reduce the microbial growth and extend the shelf-life of the meat products by one month under refrigerated temperature. Decontamination of herbal tea and disinfestation of cacao beans are being investigated.

Through an IAEA/UNDP regional project, the Philippine Associated Smelting and Refining Corporation (PASAR) became aware of the potential of electron beam (EB) treatment of flue gases. As a copper smelting company, PASAR has shown strong interest in the technology and may even consider EB treatment as an alternative for controlling their environmental problem.

Regional Cooperation

Experience has shown that regional cooperation can make significant and valuable contribution to the introduction and promotion of the applications of radiation technology in the region. For example, some regional projects have been instrumental in the initiation and strengthening of activities on radiation technology and even resulted in the transfer of developed technologies in some countries.

Regional training events as well as national training courses and seminars supported by regional projects have resulted in introducing and promoting radiation technology to local industries. Participation in such training activities has a multiplying effect, since most participants would usually give echo seminars after attending these training events.

On the other hand collaborative research on common problems can lead to the development of new applications of radiation processing. Since the region is rich in natural polymers and other materials, the potential of using radiation to develop applications for these materials need to be explored further. Surely such undertaking will mutually benefit the countries in the region.

Table 1

PRODUCTS IRRADIATED AT THE
MULTIPURPOSE IRRADIATION FACILITY
1996 – 2001

PRODUCT (purpose)	1996	1997	1998	1999	2000	2001
A. Medical Products						
empty aluminum tubes (sterilization), m^3	18.1	15.9	6.3	10.9	16.8	10.5
orthopedic implants (sterilization), m^3	4.6	4.4	3.4	2.8	0.5	2.3
empty gelatin capsules (decontamination), m^3	103.8	162.4	104.9	60.8	18.9	
cosmetics raw materials (decontamination), m^3	0.7	0.06	3.3			
B. Food Products						
spices (decontamination), tons	38.1	62.2	34.3	77.7	80	45.3
fresh onions (sprout inhibition, market testing), tons	10	81	14			
C. Other Products						
carrageenan (decontamination), tons	55.5	20			9	
fruit fly pupae (SIT), m^3						9.2
feed ingredient (decontamination), tons				1.4	0.4	
mail/printed materials (decontamination), m^3						1

4.7 Current and Future Industrial Application of Electron Accelerators in Thailand

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1. Introduction

It was in 1997 that industrial application of accelerator in Thailand was first introduced. A Swedish own company started to commercialize some radiation sterilized products such as doctor gown, pampas, feminine napkin etc. for export to Europe. This might result from Thai government's policy to welcome foreign investment in the country, also from our relatively cheap labor and of course from our developed infrastructure. Later on in the year 2000, another American company installed a high energy electron accelerator together with a cobalt-60 irradiator aiming at producing new value added products like gem stones, topaz, tourmaline and zircon in particular. The company gave irradiation services also for food irradiation and sterilization of some export items using the company's cobalt source. Research and development in electron accelerator started last year, 2001, starting from assembling used components donated by few local hospitals. One machine is currently operational, the second is being reassembled. Both machines operate in pulse mode with energies of 20 and 4 MV respectively. Gem stone irradiation and radiation grafting of some polymers will be focused among other activities. The need for low and medium energy electron accelerators with moderate power for R&D in radiation technology is becoming more pronounced, hopefully, to be installed at the new national nuclear research center north east of Bangkok.

2. The need to conduct R&D using electron accelerators in Thailand

Current uses of electron accelerator by two private companies in Thailand now (Table1) are considered to be exceptional in view of establishing new technology and technology transfer to the local manufacturing companies. The technical-know how, process control, irradiation techniques, etc. are still proprietary and many of the useful data are kept secret. This is common for a high tech production process in business. It is, however the task of the governmental research institutes as well as universities to disclose some useful information and publicized to local businessmen and investors. A cooperation with JAERI / JAIF or FNCA to share expertise from source personals through seminars, meetings, workshops is a very effective way to reach the goal to achieve such purpose. The first of its kind was in 1993, when JAERI, JAIF and OAEP organized a workshop on the Utilization of Electron Beam in Bangkok. Although most of the participants were from the governmental sectors, a few from private sectors were apparently shown their interest, not yet to establish one in their factories but they follow the possible way to learn more about this radiation technology. It is expected that this kind of seminar will be organized again and again in Thailand.

As an electron accelerator is still new to our local industrial sector, also the machine with biological shielding is very costly, too costly and too doubtful for the investors to have courage to make any decision whether or not the machine can make profit in short or long term. The problems of machine maintenance, know-how of the processes among other things are still obscure for the industrialists and investors. In order to solve these problems, the responsible governmental nuclear research institute like OAEP should make a role to support facilities: low and medium energy electron accelerators, hopefully to be installed at our new ONRC (Onkharak Nuclear Research Center) to serve for - demonstration pilot unit using electron accelerator for - production of value-added products from local raw materials- using electron beam processing (EBP) to manufacture products of high quality with low cost- HRD to support private sectors on EBP- provision of technical assistance for private sector through training course, seminar, workshop, etc.

R&D using EBP should be emphasized on technology transfer rather than develop our own technology at least at the beginning. This is to shorten the time to move forwards to pilot scale and industrial scale respectively.

3. Electron accelerator v.s. gamma irradiation facility

Electron accelerator and gamma irradiation facility are known to be complementary in radiation processing. While an electron accelerator is good for irradiation of thin film, laminated, flat, small rod shape, free falling powder, lamina flow liquid or solution products with very high dose rate and continuous irradiation capability, gamma irradiator is very good for bulky, high density, thick container products. In many cases, certain kind of products can be well adapted to use both electron accelerator or gamma irradiation, the proper choice is to be determined by the user whether machine source or isotopic source will be installed depend upon over all unit cost, process control and through put. In developing country like Thailand, another main factor to be considered is the need to have high caliber personal for electron accelerator maintenance. The readily supply of spare parts, availability of technical advice are also among other factors to be considered. For an electron accelerator in the lab using for R&D, a timely maintenance may be acceptable but in an industrial production process, any failure of the process by all means even in a short time is indeed a serious problem.

In Thailand, gamma irradiation facilities both for R&D and for commercial purpose are available only in Bangkok and near by cities (Table 2). The commercial facilities are operated in under capacity. Campaigns to convince people to become their customers are common. New application like pasteurization of pharmaceuticals, simultaneous radiation vulcanization of natural rubber latex and allergenic protein removal is also welcome if the customers can find the market. In other part of the country, irradiation facilities for R&D are needed in universities and some glove manufacturing factories in the south of the country may need the machine for sterilization of their products and put it for good use in removal of latex allergenic protein.

4. Role of OAEP and Universities to stimulate the utilization of radiation processing

4.1 conduct R&D on radiation processing related to immediate and potential uses for local industry

4.2 provide research result of new development related to radiation processing both from abroad and in house

4.3 encourage related industry to upgrade their product by using radiation technology

4.4 provide demonstration radiation processing plant using low and medium energy EB machine (if available in the future) for industry to make a test production

5. Immediate and potential uses of EBP in local industry

5.1 Cross linking of electrical wire and cable

There is at least one electrical wire and cable local manufacture shows strong interest to invest for an EB machine 1.5 – 2.0 MeV, 25 kW to upgrade the products of thermal resistant, low smoke, non halogen wire and cable. This is in response to the government new policy to add import tax to finished products and cut import tax for raw materials (Table 3). In addition, Asian countries shall have an agreement to reduce import tax of all items to 0 – 5 % by the year 2003. Local supply of polyolefin and EVA may cut unit cost of the products and ensure a steady supply of raw materials.

5.2 Heat shrinkable materials

Heat shrinkable tubes for electrical appliances, auto industry, telecommunication, corrosion prevention of pipeline can be manufactured in parallel with cross linking of wire and cable mentioned above. Irregular shape of heat shrinkable materials can be irradiated in limited air using readily available Co-60 irradiators.

5.3 Low protein concentrated rubber latex

The newly developed process of Dr. K. MAKUUCHI (JAERI) using low energy EB can be well adapted to produce low protein concentrated natural rubber latex without radiation pre-vulcanization. This is to meet requirement of sulfur vulcanized glove producers and meet requirement of US. FDA's new regulation to keep water soluble protein (allergenic protein) in rubber glove to less than 200 $\mu g / dm^2$. However, most of the glove manufacturers now can make a longer leaching time to cope with this problem. Only if the US. FDA lowers the protein amount to less than the mentioned value, the factory may consider radiation process. Table 4 shows our current export of HA latex and pertinent rubber products.

5.4 Rubber wood furniture and parts

One of the top twenty export items from Thailand is furniture and parts. Unlike the top export value of electronics and electrical appliances which led the country's export for several years, it relies on 80 – 90 % import content and generate only 5 – 10 % in added value, furniture has very low import content. Value of about 60 % of export wood furniture, rubber wood furniture has a steady increase in export of about 20% per year. Rubber wood does not involve in rain forest destroy as we cultivate the tree for latex. Supply of rubber wood is also very secure as we have the largest rubber plantation area in the world of about 5 million acres. The export value of rubber furniture and parts account for more than 10,000 million Thai Baht per year. Curing of surface coating by EBP can generate more value added to the mass production of these products with relatively low cost.

5.5 Degradation of silk protein by radiation

Degradation of silk protein by gamma irradiation is under investigation by OAEP staff in collaboration with JAERI. The products may find application in cosmetic industry as well as tonic food industry. Very high radiation dose is required to degrade the protein so silk waste can be flatten and efficiently irradiate by EB machine can be done.

6. Conclusion

Although two of commercial electron accelerator has been installed in the country, electron beam processing is still considered to be new technology. In order to strengthen the use of EBP to improve the finished product quality with an added value, FNCA may help in publicize this new technology to our industrial sectors through seminars, workshop, demonstration, etc. and finally an introduction of joint venture between Japanese side and Thai local company may lead to the success of establishing the technology very soon. This is also to comply with our government's policy to promote manufacturing of finish products with high quality for export.

Table 1 Current uses of commercial and R&D electron accelerators in Thailand

Name of company / organization installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use
Thai Klinipro Co. Ltd.	1997	Minilac USA	1.8-2.4 MeV	10 kW	Sterilization of doctor gown
IBA S&I (Thailand) Ltd.	2000	MEVEX Canada	15 MeV	8.5 kW	Upgrading of gem stone

Field	Target	From when	Title (contents)	Remarks
Particle physics	Research	2002	Production of far infrared coherent radiation	Reassemble From medical unit (20 MeV)
Materials modification	Research	2002	R&D on radiation processing	Reassemble From medical unit (4 MeV)

Table 2 Industrial gamma irradiation facilities in Thailand

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
Kendal Gammatron Co.Ltd.	1984	500 kCi	150 kCi	Sterilization of medical supplies	Nakorn Prathom
Thai Irradiation Centre	1993	3 MCi	450 kCi	R&D on radiation processing	Government own (OAEP) Pratumthani
IBA S&I (Thailand) Ltd.	1999	3 MCi	1 MCi	Sterilization and others	Rayong
GAMMASTER (Thailand) Ltd.	2000	6 MCi	1 MCi	Sterilization and others	Chonburi

Table 3. Four categories of new regime for import tax

Category	%
Raw material	5 (max)
Primary product	6 – 10
Intermediate or semi-finish product	10 – 15
Finish product	15 - 20

Table 4. Export of HA latex and medical use products in 2000 and 2001

Products	2000	2001
HA latex (metric ton)	538,418	276,305 (Jan-Jun)
Rubber gloves (1000 pairs)	6,959,300	5,625,200 (Jan-Sep)
Hygiene medical products (1000 items)	70,600	31,000 (Jan-Sep)

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4.8 Present Status of Radiation Processing and Its Future Development by Using Electron Accelerator in Vietnam

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Abstract

In Vietnam, studies on Radiation Processing have been carried out since 1983. Some results are applicable in the field of agriculture, health and foodstuff, some researches were developed to commercial scale and others have high potential for development by using electron accelerator. The paper offers the present status of radiation processing and also give out the growing tendency of using electron accelerator in the future.

A. Status of Radiation Processing in Vietnam

1. Facilities

Although studies on radiation processing have been early carried out in Vietnam, due to the lacking in finance facilities used for research and development in this field are too modest. At present, the facilities used for radiation processing in Vietnam are listed in the table 1.

Table 1: Statistics of facilities used for radiation processing in Vietnam

No.	Facility	Main Characteristics	Owner
1	Gamma Cell	- Present activity: 3 kCi - Irradiation volume: 4 litters	Nuclear Research Institute - NRI (Dalat)
2	Co^{60} Industrial Irradiator	- 400 kCi in Feb. 1999 - Tote box type - $D_{Max.}/D_{Min.}$ = 1.3 at 0.2 g/cm^3	Research and Development Center for Radiation Technology - VINAGAMMA (Ho Chi Minh City)
3	Co^{60} Semi-industrial Irradiator	- 107 kCi in 1991 - Carrier type	Institute for Nuclear Science and Technique (Hanoi)
4	UV machine	10 kW	NRI (Dalat)

2. Manpower

Vietnam Atomic Energy Commission (VAEC) has 5 institutions named as Nuclear Research Institute - NRI (Dalat), Institute for Nuclear Science and Technique – INST (Hanoi), Institute for Technology of Radioactive and Rare Element (Hanoi), Center for Nuclear Techniques in Ho Chi Minh City and Research and Development Center for Radiation Technology – VINAGAMMA (Ho Chi Minh City).

The Research and Development of Radiation Technology is assigned to Nuclear Research Institute, Institute for Nuclear Science and Technique and Research and Development Center for Radiation Technology. The statistics of manpower is as follows:

Table 2: Statistics of manpower in the field of Radiation Technology

Institution	No. staff	Degree			Profession		
		Ph.D	Master	B.Sc.	Physics	Chemistry	Biology
NRI	12	1	3	8	0	6	6
INST	7	1	3	3	0	3	4
VINAGAMMA	6	1	1	4	2	2	2

Remark: Number of Technicians is not taken into account

B. Present activities of radiation processing

The present activities in the Radiation Processing field in Vietnam can be classified into three categories illustrated in the Table 3.

Table 3: Categories of activities in radiation processing

No.	Category	Scale	Product
1	Sterilization	Commercial	- Medical products - Traditional drugs - Tissue graft (Biology)
2	Pasteurization	Commercial	- Frozen food - Dried food
3	Material production	Research	- Hydrogel for burn treatment - Biodegradable material - Modification of Natural Polysaccharides - Radiation processing of NRL
		Commercial	- Plant growth promoter

Among the irradiation facilities in Vietnam the irradiator SVST-Co60 at VINAGAMMA is the biggest one. The irradiator has been put into operation since March 1999 and economically runs. The total investment for the irradiator was near to 2 millions USD. The investment funds consist of a half million USD of Ministry of Science, Technology and Environment (MOSTE), near to a half million USD supported by IAEA and about one million USD borrowed from the bank. It is the first time researchers in the field of irradiation technology dared to borrow money from the bank to apply their research results to the country economics. The operation of the irradiator and processed products are given in the table 4.

Table 4: Statistics of the irradiator operation at VINAGAMMA for 3 years

Year	Irradiation time (hours)	Processed products		Remark
		Medical product (m^3)	Food (tons)	
1999	2,531	405	307	Since April, 1999
2000	6,934	654	3,756	
2001	7,745	777	4,671	
Total	17,210	1,820	9,125	

At present, the irradiator is running at full rate with the averaged turnover of about 65,000 USD per month. As the market demand is growing and the irradiator is in overload status. The feasibility study for construction of other irradiator is under consideration. Upon our plan, the second irradiator is food irradiation type and hopefully will be operated at the end of 2003.

The operation of the irradiator in Hanoi has low effectiveness due to the lacking in products and low activity at present. It is necessary to modify the present design for sprouting inhibition and food preservation purposes to the purposes of medical product sterilization and food irradiation. The project on modification of the irradiator was submitted to MOSTE for consideration.

The gamma cell at NRI is the first irradiation facility in Vietnam. It is effectively exploited for studies on radiation processing. By using this gamma cell researchers of NRI have got a lot of success in the radiation processing of rubber natural latex, the production of plant growth promoter and in the production of hydrogel, etc.

Beside the effective activities in sterilization of medical products and food pasteurization there are several successful researches and their results became commodities. The technology for production of plant growth promoter has been transferred to one private company. This company well does business with this product. Production technology of hydrogel for burn treatment, natural rubber latex grafted with methyl methacrylate and irradiated chitosan used as fungicide in agriculture were completed and in a course of waiting for technology transfer.

The UV machine is only used for technology demonstration and for processing small volume of clear coating products.

C. Future Development of Radiation Processing by Using Electron Accelerator in Vietnam

Vietnam is a developing country. The country economics develops with rather high rate. The rate of GDP in 2001 is 6.8%. It is expected that the foreign investment will be higher and higher. In turn, the demand of radiation processing certainly will increase. There are the following fields in Vietnam that require using EB for processing:

- Production of heat shrinkable materials, wire and cable for electricity and communication.
- Production of biodegradable materials for packaging purposes in foodstuff.
- Production of degraded Natural Polysaccharides for plant growth promoter and protector.
- Radiation processing of NRL
- Hydrogel for utilization in medical and agricultural fields.

Upon the above-mentioned demands the further research and development requires an electron accelerator. The electron accelerator is intended to use for research and development purposes, technological demonstration, test production and production in pilot scale if possible.

One low energy electron accelerator should be equipped in the period of 2003-2004.

The utilization of the electron accelerator should be aimed at some feasible applications which could lead to invest electron accelerators for commercial purposes upon the requirements of the country industries.

The finance settlement for the accelerator is a burden for Vietnam scientists. We are looking for cooperations in finance, research, education as well as technology transfer.

Conclusion

The success in sterilization of medical products, food irradiation and other applications in healthcare and agriculture by using gamma irradiation is a great encouragement to Vietnamese researchers to step in using the new ionizing radiation source that is electron accelerator.

To reach the higher level of the radiation processing, Vietnam should choose the way for itself. A procurement of a low energy electron accelerator is the first appropriate step on the way of utilization of industrial electron accelerators for the country industries.

References:

1. Proceedings of the workshop on the utilization of electron beams, JAERI – M, 90-194, November 1990.
2. Proceedings of the Takasaki workshop on bilateral cooperations – Radiation processing of natural polymers- JAERI-Conf, 2000-003, November 1 and 2, 1999, JAERI, Takasaki, Japan.
3. Electron beam facilities, W. J. RAMLER, Radiat. Phys. Chem., Vol. 9, pp. 69-89, 1997.
4. Electrocurtain – Process and Applications R+D Facilities in Geneva, Urs V. LAUPPI et al., Radiat. Phys. Chem. Vol. 22, Nos 3-5, pp. 823-830, 1983.
5. Developments in electron beam curing, T. J. MENEZES, Radiat. Phys. Chem. Vol. 35, Nos 1-3, pp. 52-58, 1990.

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5. Invited Reports

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5.1 Low Voltage electron beam Accelerators

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Iwasaki Electric Co., Ltd.

1. Introduction

Widely used electron accelerators in industries are low voltage electron beam (e-beam) processors with acceleration voltage at 300 kV or less. In this paper the basic concept of the low voltage e-beam processor and its applications will be introduced.

2. Type of the beam

Most of the low voltage e-beam processors generate continuous curtain like beam as in Fig. 1. In this curtain-type processor the product receives electrons over its width continuously while traveling under the beam.
In a scanning-type system a beam spot is generated and swing across the product width with relatively high speed so that the product surface can be treated substantially uniform while the product is transported under the swinging beam. The scanning-type system is used mainly in the medium or high voltage accelerators with energy from over 300 keV up to 10,000 keV. The detail of the scanning-type system will also be presented in one of this workshop session.

Curtain-type processors operate at lower voltages than most scanning-type systems, usually at voltages ranging from 120 to 300 kilovolts. When energetic electrons strike the matter, a small percentage of their energy is converted to penetrating (X-ray type) radiation. The lower voltages permit the equipment to be self-shielded against this radiation, with the result that curtain-type processors can be installed and operated safely in unrestricted areas.

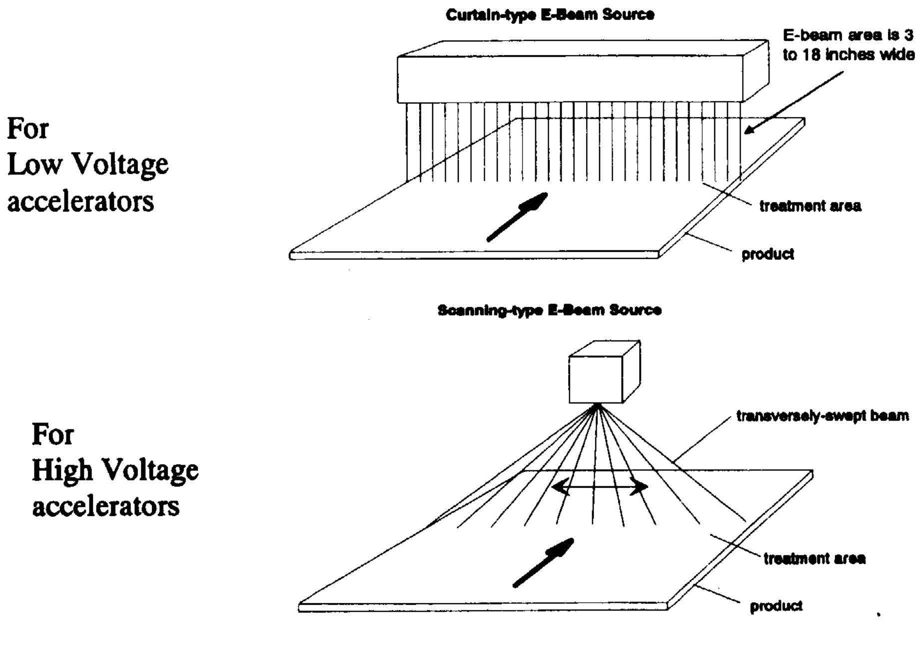


Fig. 1 Type of e-beam, Curtain & Scanning

3. Low voltage e-beam equipment manufacturers in the market

The manufacturers of commercially available low voltage e-beam equipment are listed in Table 1. Each manufacture has its unique technology in its products. However, in this paper, hereafter introduced mainly will be the curtain-type low voltage e-beam processors produced by ESI (Energy Sciences Inc.) ma. USA, a group company of Iwasaki Electric Co., Ltd. of Japan. The low voltage electron processing is widely used in the industries of all over the world.

Table 1

Manufacturers and distributors of low voltage e-beam in Japan

Companiy Name	Naming	HV(kV)(*2)	Power(kW)(*2)	Width(cm)(*2)
Sumitomo Heavy Ind.	WIPL	130-250	10-50	60,70
Nissin-High Voltage CO., LT	Curetron^R	100-300	5-100<	15-100<
Iwasaki Electric Group (ESI)	Electrocure^TM	80-300	1.1-100<	15-100<
Ushio Inc. / Toyo Ink Mfg.	Min-EB	50-70	0.01-0.36	2.5-22
Others				

* Voltage is 300kV or less
*2 Assumption was made for some figures .

4. Curtain-type e-beam processor

4.1 Mechanism of electron acceleration

Typical low voltage e-beam system mainly uses a single gap DC acceleration performed in high vacuum as illustrated in Fig. 2. The hot electrons generated from the filament are extracted by a DC potential applied between the extractor grid and the filament. The electrons gathered at the terminal grid are then accelerated by a high voltage potential applied between the grids and the window. The accelerated electrons increase their speed so that they can penetrate the window foil as electron beam then emerge in the process zone usually at atmospheric pressure.

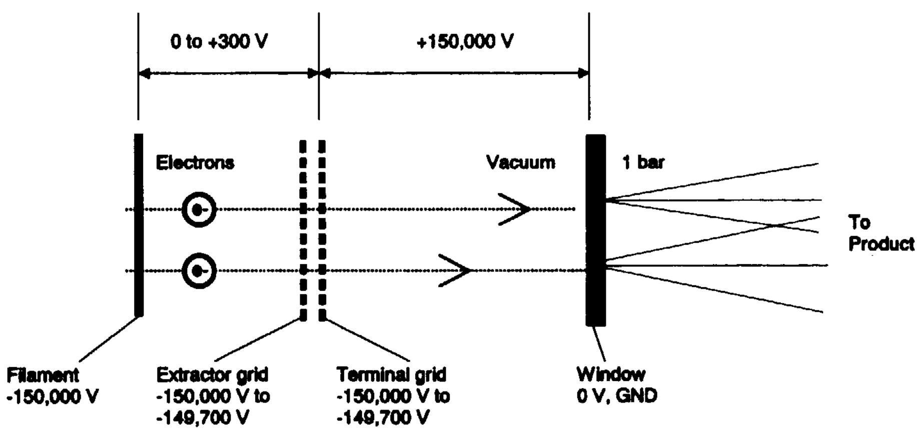


Fig.2 Acceleration mechanism

4.2 Equipment configuration of low voltage e-beam processor

Fig. 3 shows an outlook of a low voltage e-beam processor. The product web enters from right entrance and exit from left exit. Fig. 4 shows a cross-sectional view of the e-beam processor acceleration head and process zone. Fig. 5 is a block diagram of the equipment giving another cross-sectional view at acceleration head. Both figures help understand the operation of e-beam processor. The functions of each major unit of the processor will be described below.

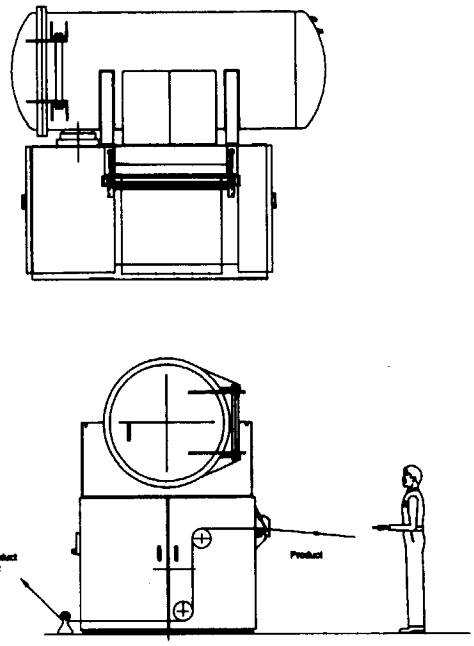


Fig. 3
Typical e-beam Processor

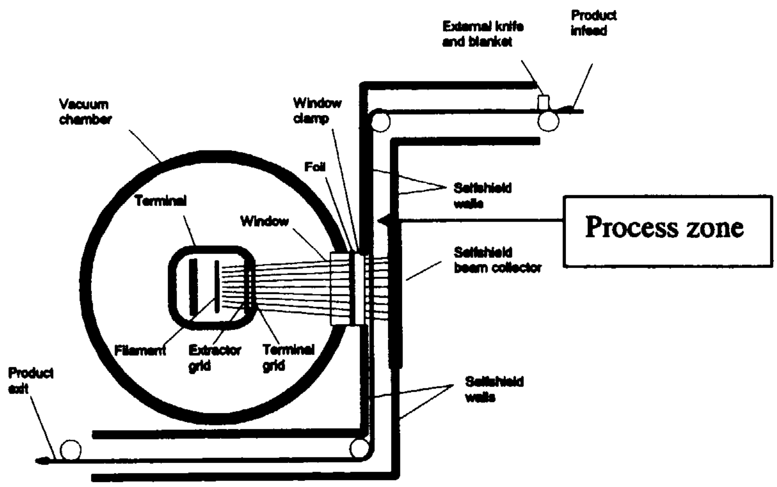


Fig.4
Typical e-beam processor

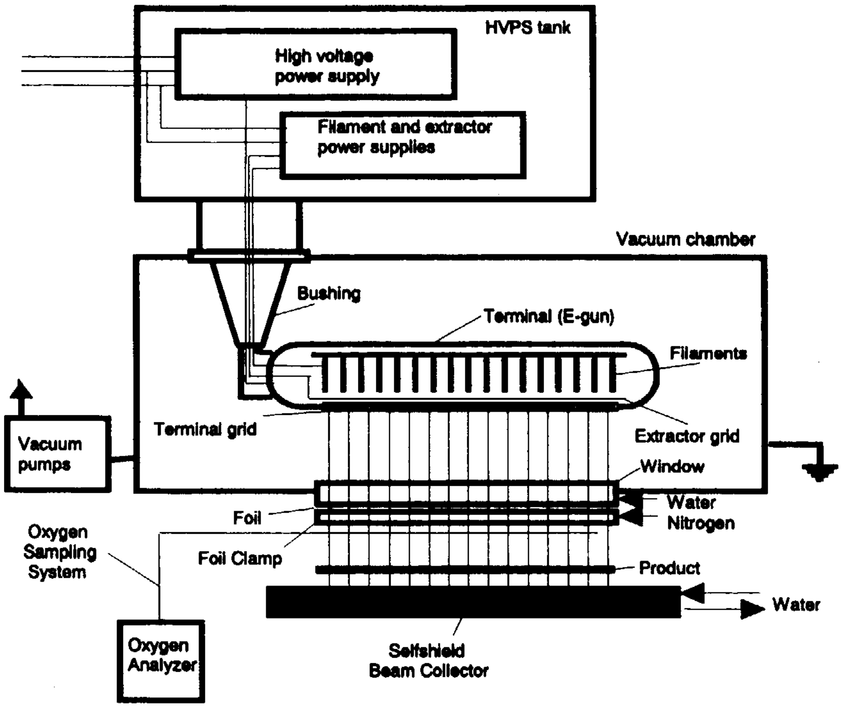


Fig.5 Block diagram of LV e-beam system

Vacuum chamber with electron window

Works as an acceleration head of e-beam. It contains high voltage terminal in the center with filament / extractor grid mechanism inside. An e-beam window is installed to the chamber wall opening to introduce the beam to the process zone. The window is a cooled foil-covered opening in the chamber body that determines the "shape" of the electron beam as it begins to traverse the path to the product being treated. The window is water-cooled to offset the heat induced by the electron beam as it strikes the surfaces of the window and the window foil. The outside of the window frame is covered by a metal, usually titanium foil, which acts as a pressure-to-vacuum seal for the chamber. The foil is partially transparent to the electron beam and permits the chamber to operate at a high vacuum. The high vacuum is required in order to minimize oxidation of the filament and also to minimize collisions of electrons with gas atoms within the chamber during acceleration. An excessive number of electron-gas atom collisions would result in electron beam losses and reduce the effectiveness of product treatment.

High voltage power supply tank

Supplies acceleration voltage as well as filament power and extraction potential to the high voltage terminal through the bushing in the vacuum chamber. The bushing is usually made of ceramics with good insulation to the high voltage.

Vacuum system
Is used to maintain the vacuum chamber at high vacuum typically at pressure lower than 1.33 x 10-3 Pa. Usually two stage evacuating system is adopted employing rotary oil pump for roughing and Turbo molecular pump or cryopump for high vacuum.

Radiation Shield
Is designed to contain X-ray generated by electron collision in the processor that no significant amount of X-rays is detected outside the processor and working area. X-ray radiation is generated whenever electrons are stopped or absorbed in matter. The intensity of X-ray radiation depends upon the characteristics of the absorbing material. X-rays scatter in all directions as they interact with atoms and molecules and have a long range in air. In the e-beam system, X-rays are absorbed by the shielding. The selfshield system is designed so that no openings exist in the shielding except for the entrance and exit of the product. These openings are designed in such a way that radiation and leakage are reduced to safe levels.

5. Operation of e-beam equipment

5.1 Control system
In order to operate the system easier the modern e-beam equipment is provided with process parameter monitor display with keyboard. To control system output, the operator must enter desired parameters (set points) of filament power, beam current, and high voltage. He enters these values through the keypad on the console's control panel. The system computer will then act to maintain the desired values. These performance specifications permit operation with a wide range of product line speeds and quick response to changes in line speed.

5.2 Inerting
Presence of oxygen in the product treatment area is usually undesirable because it may interfere with the curing process and result in the generation of ozone when energized electrons collide with oxygen molecules. Means are provided, therefore, to minimize oxygen concentration in the processing zone. Several different techniques may be found in e-beam systems for reducing oxygen concentration in the product treatment area to a level at which the product can be successfully cured. Window cooling gas is the only inerting process common to most e-beam machines. Its purpose is to prevent overheating of the window foil and it removes heat from the foil by convection. If inerting is not required, air may be used for cooling the window foil, provided precautions are taken to prevent condensation of corrosive products (HNO_3) in the process zone. If, however, inerting is needed, an inert gas such as nitrogen is used.

5.3 Oxygen monitoring system
In combination with the inerting system, most applications of e-beam systems are required constant monitoring of oxygen in the treatment area. If supplied, the oxygen monitor continually samples the gas in the treatment zone and displays the oxygen concentration in PPM (parts per million).

5.4 Ozone exhaust system

When the e-beam processing is done in air ozone is generated in the process zone as described above. In this case the processor would be equipped with ozone exhaust system to prevent ozone concentration to the working area

6. Determination of process parameters

The radiation dose received by the product may be defined as the energy absorbed in a mass of material. It is dependent on the following factors:

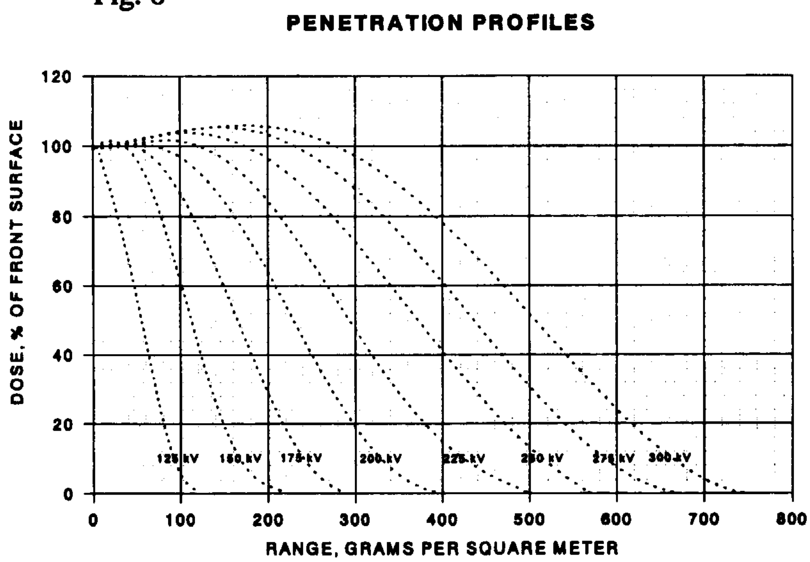
- Beam current (I, in mA)
- Line speed (S, in meters/min)
- Yield factor (K) of the machine at the required high voltage (HV) operating level
- Beam energy or the High Voltage operating level (kV)
- Thickness of the material to be treated
- Density of the material to be treated

The dose is usually measured in kilo Grays (kGy). A 10 kGy dose is equivalent to the absorption of 2.4 calories of energy by one gram of the treated material (4.3 BTU/lb), and 1 MR = 10 kGy. In most cases, determining the proper dose and the proper HV with which to treat a product is a simple matter. To select a proper voltage (kV) a penetration profile data is used. (see Fig. 6) One can determine the energy easily from the profile for the thickness to be treated. Then the following simple formula can be used to determine beam current (I) for the required dose (D) and the speed (S) for the production:

$$I = D \cdot S / K$$

Where, D is the absorbed dose of the material.

Fig. 6



7. Performance of the equipment

There are three items to evaluate the performance of e-beam processors.

1 Yield factor K as described above
2 Beam uniformity
3 Penetration

These three performances can be measured by dosimetric technique using FWT(*) nylon chips commercially available.

(*) FWT: Far West Technology Inc.

8. Basic maintenance requirement

There are some consumable parts that should be replaced periodically. The items are listed in Table 2.

Table 2 Basic Maintenance Requirement

Item	Typical Lifetime
window Foil	1000 - 2000 hrs.
E-gun Filament	10,000 hrs.
O-rings	2000 - 5000 hrs

9. Safety consideration for radiation

As previously mentioned low voltage e-beam processor is equipped with radiation shield called Selfshield[R] that the user will have no need to install the equipment in the restricted area. In addition, environmental radiation monitors mounted at several locations on the Selfshield[R] system ensure that the system is always operating well within the limits specified by local regulations.

10. Electron Beam Processing and applications

In a number of industrial processes, the output products can be physically and/or chemically modified by subjecting them to a controlled beam of high energy electrons. This general technique is described as electron processing, e-beam processing, or as radiation processing. In its basic sense, electron processing may be defined as the technology of using ionizing radiation to cause desired changes in the physical properties of matter. Ionizing radiation has sufficient energy to convert atoms or molecules to ionized or excited states in which free radicals are generated and bond scission occur. These processes lead to several generally useful effects. One effect is the initiation of chemical reactions, primarily polymerization, crosslinking, or grafting reactions; another is the inactivation of microorganisms with consequent sterilization. In Japan various advanced development works are being done using electron beam at JAERI Takasaki and other government research institutions of Japan. These achievements will be presented in one of this work group session.

11. Advantage of low voltage e-beam

In the e-beam processing in the existing application field like curing and cross-linking the advantages below have already been proven. (Table 3)

Table 3 Low voltage e-beam advantages

High speed cure
Hard, scratch resistant finishes
Stain, chemical resistant finishes
Extremely high gloss finishes
Solventless – 100% curing
Energy efficient curing
Low temperature increase(15°C)
Consistent cure
Relatively compact equipment
Simple equipment operation
Very low odor / Low extractable

12. Recent trend of low voltage technology

New e-beam processors with acceleration voltage around 100kV were introduced maintaining the relatively high dose speed capability of around 10,000kGy x mpm at production. The application field like printing and coating for packaging requires treating thickness of 30 micron or less. It does not require high voltage over 110kV. (Fig.7) The reduction of energy made the accelerator compact and economical. (Fig. 8, 9, 10, 11)

Also recently developed is a miniature bulb type e-beam tube with energy less than 60kV. The new application area for this new e-beam tube is being searched.

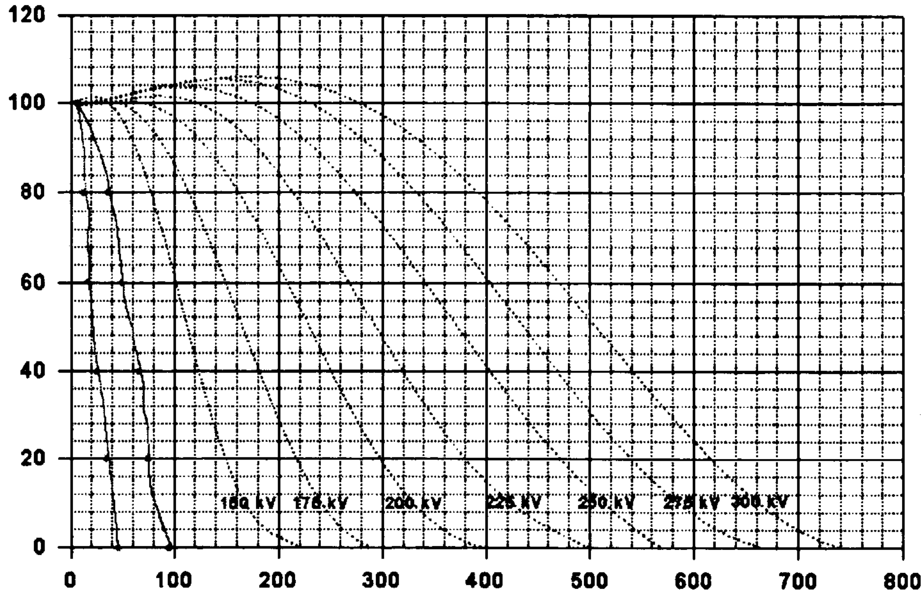


Fig 7. Penetration Profile

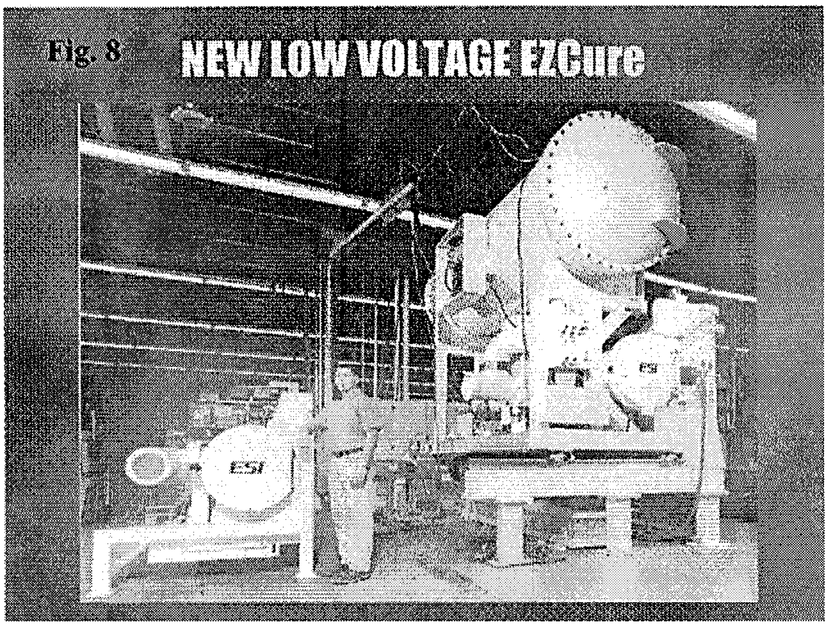


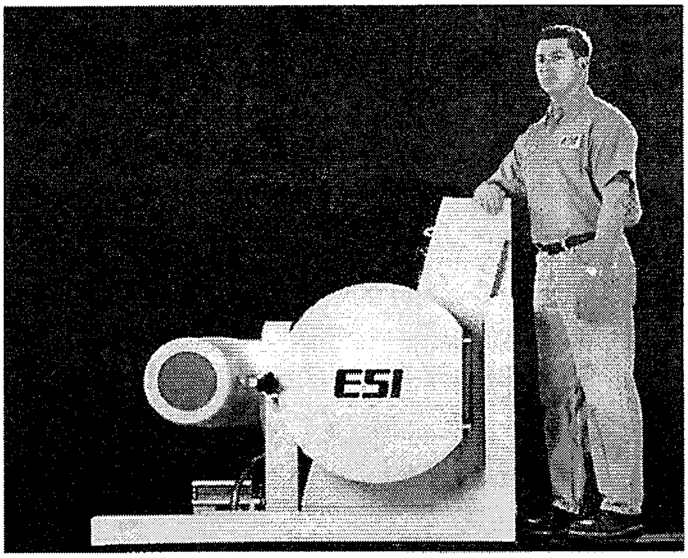
Fig. 9

EZCure[tm] LOW VOLTAGE EB SYSTEM

MAX SPEED
300 mpm @
30 kGy

WEB WIDTHS
50cms to 165cms

DIMENSIONS
1.5m H x 1.5 m L x
WEB WIDTH



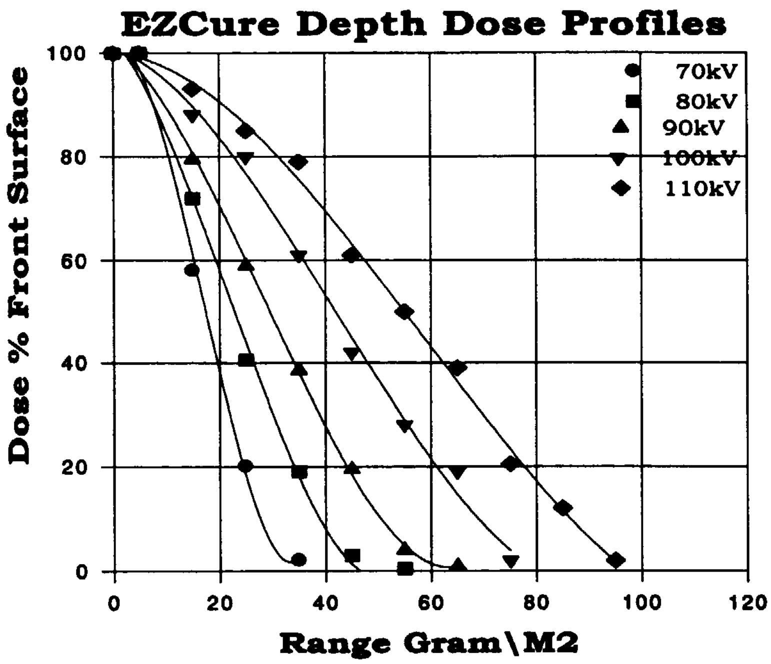

EZCure Depth Dose Profiles
Dose % Front Surface
Range Gram\M2
70kV
80kV
90kV
100kV
110kV
0
20
40
60
80
100
120

Fig. 10

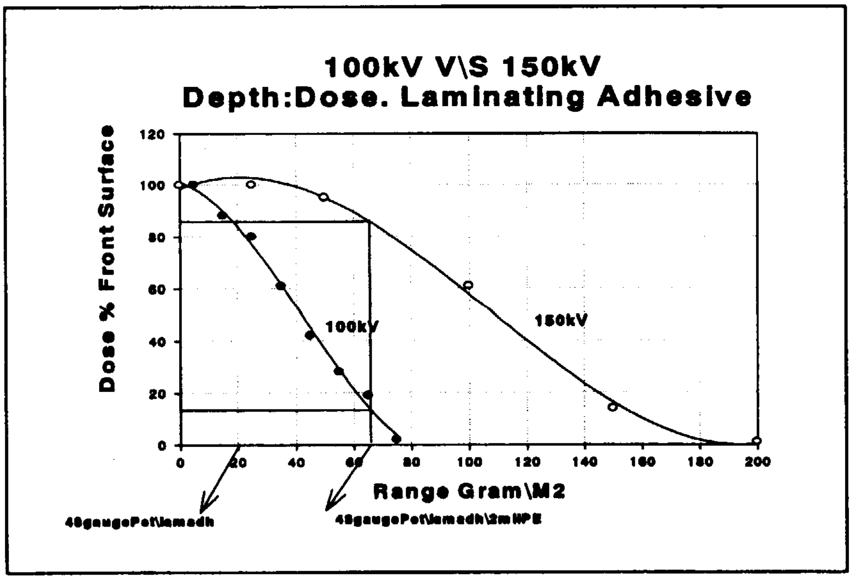

100kV V\S 150kV
Depth:Dose. Laminating Adhesive
Dose % Front Surface
Range Gram\M2
100kV
150kV
0
20
40
60
80
100
120
140
160
180
200

Fig 11

13. Summary

Low energy electron processor has many advantages as described above. In this workshop recent advanced R & D of Japan will be presented from JAERI Takasaki and the government research institutions of Japan. On the other hand the equipment is becoming compact and less expensive. The author thinks that the drive force of this technology to spread in the industries would be further development of new application, process and market as well as the price reduction of the equipment, upon which further acknowledgment and acceptance of the technology to societies and industries would entirely depend.

References

1. Company brochures of EB equipment
   Sumitomo Heavy Ind.
   Nissin-High Voltage
   Ushio Inc.,
   Toyo Ink Mfg.
2. Operating and Maintenance manual, ESI, 2000
3. MAKUUCHI, Keizou "Polymer Digest" p17-33, 1999

JP0350128

JAERI-Conf 2002-013

5.2 Medium and High Energy Electron Beam Processing System

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1. INTRODUCTION

Electron beam Processing System (EPS) is a useful and powerful tool for industrial irradiation process such as the production of cross-linked wire, heat shrinkable film and tubing, sterilization and environmental application. In this paper, the composition and feature of EPS, the selection of machine ratings and safety measures will be introduced.

2. Feature of EPS

2. 1 Electron beam (EB) Irradiation

EB means the flow of electrons with energy which electrons get as kinetic energy by moving in electric field (Acceleration). It is similar that the stone dropped down from high roof gets the energy by gravitation of earth. EB is braked by electrons outside nuclear because of its minus charge and gives a part of its energy to the atom, which generates secondary scattered electron as the result of reaction. The secondary electron interacts with another atom, generates many secondary electrons like a shower and loses their energy in the irradiated material. The lost (absorbed) energy generates active free radicals, which make chemical reaction in the material. Because electron is one of components in atom, electron beam is carrier of energy purely.

2.2 Feature of EPS

EPS has the following feature.

a) EB gives its energy directly to the material, so the energy utilization efficiency is extremely high. In a case of normal thermal chemical reaction, the energy is given to activate the molecular activity and to make chemical reaction between each molecular as the result. Therefore normal thermal chemical reaction is indirect injection of energy.

In EB irradiation, the unit of kilo-gray (kGy) is used generally as energy absorbed in the material (dose) and the energy of 10 kGy is only 2.3 cal. for 1 g of water. Usually, dose for radiation chemical reaction is several ten kGy up to 200 kGy, so the material, which is weak for high temperature such as plastic can be treated. Also the EB chemical reaction can occur in wide range of low and high temperature, so the reaction is not affected for secondary or third reaction.

b) It is not necessary to mix third material such as catalyst for chemical reaction.

c) EPS has very large capacity for irradiation process.

EB is particle beam and has higher energy transmission rate compared with electromagnetic waves such as electric wave, visible ray, UV, X-ray and gamma ray. Now, EPS with the capacity of 100 kW above is manufactured and mass irradiation processing is available.

d) Easy operation

Because EPS is an electric machine, the start and stop of production or reaction can be made only switch on or off.

e) Easy maintenance

Because EPS is not radioisotope such as Cobalt-60, the maintenance work is excellent easy and safety because it can be made on the condition of switch off.

3. Electron beam Processing System (EPS)

3.1 Type and feature of EPS

EPS is simply said as the processing system which generates thermal electrons from cathode, accelerates the generated electrons, gets them into air through thin metal foil, irradiates material and makes chemical reaction in the irradiated material. EPS is classified in various kinds as shown in Table 1 and has each feature.

3.1.1 Type of Acceleration

There is a classification by acceleration method of electron. One is the method using DC high voltage and the other is the method using high frequency voltage.

The acceleration method using DC high voltage is that the DC high voltage as high as acceleration energy is generated and in the electric field of this DC high voltage, the thermal electrons from filament cathode are accelerated. In this method, the continuous beam is available and the energy conversion efficiency, which is the ratio of output and input capacity (DC/AC) is quite high. But it is necessary to generate as same DC high voltage as acceleration energy and this makes the size of DC power supply bigger according with the acceleration energy. The limitation of practical utilized energy range is said 5 MV.

The acceleration method using AC high frequency is that the thermal electrons are repeatedly accelerated in the electric field of high frequency voltage like surfing. There is a single cavity type using repeated acceleration system (Rhodotron from IBA). In any case, this high frequency acceleration method can make machine size small but poor energy conversion efficiency because repeated acceleration using high frequency electric field.

In industrial application field, the DC acceleration type machine has been used generally because the good energy conversion efficiency but Linear accelerator (Linac) and Rhodotron with 10 MeV energy become to use in the sterilization field, which is needed big penetration.

3.1.2 Type of DC Power Supply

DC power supply is one of most important component in DC acceleration type and there is a classification by type of DC power supply. DC power supply is divided in three types roughly. One is Cockcroft-Walton type and another is transformer type. The other is Van-de-Graaff type, which generates the DC high voltage carrying electron charge on insulation belt has poor capacity and is used in research and development purpose only.

Cockcroft-Walton type is a circuit using capacitor in series and because the frequency of several kiloHertz (kHz) is used as input power, the energy conversion efficiency of 60 % to 80 % is relatively high. The modified circuit of Cockcroft-Walton is Shuenkel type in which the capacitors in parallel are adopted. In this circuit, the capacitor at high voltage side is charged the maximum voltage and the actual capacitor can be not adopted, therefore the stray capacitance between high voltage terminal and ground electrode is used as capacitor. As the result, it is necessary to adopt very high frequency as input power and this limits energy conversion efficiency low. Both Cockcroft-Walton and Shuenkel circuits are shown in Fig. 1 and 2.

Transformer type is divided in two types. One is grounded core type which is insulated DC high voltage between primary and secondary coils and the other is insulated core type which is insulated DC high voltage divided among secondary step up coils. In both type, the rectifier circuits are provided to plural secondary coils and connected in series at DC sides to generate high voltage.

In a grounded core type, the magnetic flux connection is good, so DC power supply with large beam current capacitance up-to 1000 mA can be manufactured now. But the maximum rated voltage is limited 1000 kV because of difficulty of insulation. The largest merit of this type DC power supply is that the magnetic flux connection is very good, the commercial frequency can be used basically, high frequency power supply as input is not used, and so the high energy conversion efficiency more than 90 % can be achieved.

In an insulated core type, cores are divided and insulated in each step up stages and are not necessary to insulate DC voltage generated in each step up stages, so the high voltage machine with 2000 kV can be manufactured. But because of rough magnetic connection between primary and secondary coils, the energy conversion efficiency is lower than it of ground core type and beam current capacity is also small. Both grounded and insulated core types circuits are shown in Fig. 3 and 4.

3.1.3 Type of Scanning

EPS is also divided in scanning type and non-scanning type by the method of electron beam extraction. In a scanning type, the spot electron beam accelerated in an acceleration tube is scanned to the necessary irradiation width by electro-magnetic field. It is similar to a cathode ray tube of TV. On the other hand, in non-scanning type, electrons from big cathode (multi filaments) are generated as wide as irradiation width and accelerated in one step. It is similar to triode. In non-scanning type, because of the structure without acceleration electrodes and scanning chamber, machine can be made simple and small, but the acceleration voltage is limited up-to 300 kV. In scanning type, the acceleration voltage is divided and applied to the multi acceleration electrodes, so the high voltage machine up-to 5 MV can be made but machine size becomes big. Scanning and non-scanning photos are shown in Fig 5 and 6.

3.2 Constitution of EPS

For example of scanning type machine, EPS consists of a power supply, an acceleration tube assembly, a scanning chamber, window, a vacuum system and control system. A Block diagram of the system is shown in Fig. 7.

A Cockcroft-Walton type DC power supply and acceleration tube system are enclosed in a pressure vessel. The pressure vessels are filled with SF6 gas to insulate the high voltage. The D.C. power supply generates high voltage via the Cockcroft-Walton circuit, which is driven by a high frequency system. The DC high voltage is applied to the top of an acceleration tube assembly, where a filament assembly provides as a source of electrons. The filament is heated using a motor generator set. The electrons are emitted from the filament at a negative potential and are accelerated through the high vacuum acceleration tube, scanned electro-magnetically in the scanning chamber, and then passed through a thin window foil to irradiate the product.

4. Selection of EPS ratings

The selection of EPS is decided by consideration to irradiate what material with how thick and wide, how much dose, how to handle, in what atmosphere. The parameter to decide the ratings of EPS is acceleration voltage, beam current and irradiation width. The actual selecting work will be done as follows but it is better to consult with manufacturer of EPS because of limitation of manufacturing.

4.1 Acceleration Voltage

Acceleration voltage is decided to irradiate what material with how much penetration. Actual selection work of acceleration voltage is used penetration curve shown in Fig. 8. Generally the depth of 60 % relative dose is said the effective thickness. The thickness is normalized by specific gravity of 1.0; therefore in irradiation of material with different specific gravity, the thickness should be calculated specific gravity 1. Also the discharge by charged up electrons inside material in case of irradiation to high insulation material such as polyethylene should be considered that maximum penetration is thicker than the irradiated material. (Lichtenberg discharge)

4.2 Beam Current

Beam current is expressed the number of electrons and is the parameter related to dose and handling speed. The relation formula is shown as follows.

$$D = \frac{\Delta E}{\Delta R} \cdot \frac{\eta \cdot I}{W \cdot V} \times 1000$$

Here is, D : dose (kGy)
I : beam current (mA)
W : irradiation width (cm)
V : handling speed (cm/sec)
η : irradiation efficiency (normally 0.9)
$\Delta E/\Delta R$: energy absorption ratio (MeV/g/cm2)

The energy absorption ratio($\Delta E/\Delta R$) is decided by acceleration voltage, widow foil thickness, distance between window foil and irradiated material. Typical data is shown in Table 2. Beam current is limited by irradiation width because of cooling efficiency of window foil for energy loss of electron beam.

5. Safety Measures

In designing an EPS, it is necessary to consider sufficient safety measures such as x-ray shielding, ozone control and interlock system described below.

5.1 X-ray Shielding

X-rays are generated in the irradiation area by the interaction of fast electrons and materials such as the window foil, the water-cooled beam catcher and/or the customer's product. X-ray shielding for the EPS must be provided to reduce the radiation to acceptable levels.

The radiation enclosure or shielding can be constructed using a number of materials such as concrete, lead, steel and sometimes in combinations to reduce the X-ray output to acceptable levels. The safety standard for x-ray should be prescribed by the government rule or authority recommendation such as the ICRP (International Committee of Radiation Protection). Typical levels outside the enclosure or shielding area are 1 mSv/2000 hr. (0.5 mSv/hr) for uncontrolled areas

In general, there are 2 (two) main areas to be considered, these are classified below:

a) The Irradiation Area

This is a highly controlled area. NO PERSONNEL are permitted in this area when the high voltage power supply of EPS is energized. In addition, only trained personnel are permitted in this area during maintenance operations. All maintenance operations are only permitted with the approval and supervision of the plant safety office.

b) Areas Outside the Irradiation Area

All areas except a) are classified as uncontrolled areas.

5.2 Ozone Control

When electron beam passes through air, a large amount of ozone is generated, which causes violent irritation in case of higher ozone concentration than 1 ppm. The presence of ozone is perceptible of its pungent odor. An experienced person can sense its presence even if low concentration of 0.01 ppm.

The regulatory maximum permissible concentration of ozone for daily exposure of 8 hours/day was set to 0.1 ppm in 1954 in USA. In Japan, the working group for air pollution of the central council on anti-pollution measures recommend in 1972 in its "technical committee report on environmental criteria for nitrogen oxides, etc." that the hourly mean concentration of photo chemical oxidant, most of part of which is ozone, is 0.06 ppm or less. Therefore, suitable measures to avoid ozone hazard must be considered according to the local regulations.

5.2.1 Ozone Generation

The amount of ozone generated is determined by the energy loss of electron beam in its air path and beam current. The ozone generation rate is given 0.11 kg/kWh and calculated in the following form.

$Q = 0.11\ W$

Here is W: energy loss in a unit time in air (kW)

Q: amount of ozone generated (kg/h)

5.2.2 Disposal of exhausted ozone

The generated ozone must be exhausted and disposed by suitable method such as followings.

a) Combustion method

Ozone can be decomposed at temperature of 450 degrees centigrade.

b) Catalyst treatment method

Ozone can be decomposed by manganese dioxide.

c) Activated charcoal method

Ozone can he decomposed by activated charcoal, which is made as the mixture of charcoal and silica alumina gel.

d) Diffusion method

Ozone is exhausted and diffused in the air from a high chimney.

In these cases, activated charcoal method and diffusion method are ordinarily selected.

5.3 Interlock System

It is also necessary to consider an interlock system, consisting of redundant switches and a safety key system. These are typical requirements for entrance/exit doors, all of which are usually under a set of government regulations.

The basic interlock system is designed to prevent unauthorized personnel from entering the radiation area while the EPS is in operation. The system is designed to shut the EPS down if the entrance door or other interlocks are activated. A summary of the interlock system is provided in Table 3.

5.3.1 One Key System

The one key system is highly recommended for all EPS equipment. Only one key is used at the following locations:

a) EPS operational terminal
b) Main shield door key lock
c) Selector switch in the shield room

The EPS is designed to operate when the one key is inserted into the operation terminal and turned to the ON position. To open the shielding door the single key must be removed from the operation terminal, this will shut down the EPS, similar to an emergency stop.

5.3.2 Door Interlocks

Redundant door interlocks should be provided to ensure that the system will shutdown should personnel try to enter the shield room when the system is in operation. Two or more separate limit switches connected in series are recommended to provide on the door. These switches will be a part of the EPS operational sequence conditions. When either one or all of these switches are activated, the EPS cannot be operated. An indication will be lit on the operation terminal of the EPS so the operator can determine the cause of the interlock. If one of the door interlock switches is activated during EPS operation, the system is designed to shut off, similar to an emergency STOP.

5.3.3 Safety Box and/or Selector Switch in the Shield Room

A safety box or selector switch (OPERATION/MAINTENANCE) is recommended to install in the irradiation area. The selector switch should be wired to EPS control panel to interlock the EPS when MAINTENANCE will be performed. Any personnel, who enter the shield room, must take the single key after opening the shield door. Using the one key to turn the key switch to the MAINTENANCE position.

These procedures render the EPS inoperative when personnel are in the shield room.

5.4 Operation Indicator

The following three operation indicators are recommended to install on the top of the shielding and/or near the entrance door.

a) RED (OPERATION) indicates EPS is in operation.
"DO NOT OPEN THE SHIELD ROOM DOOR."

b) YELLOW (STOPPING) indicates EPS is in the process of shutting down. "Stopping" means after STOP button is pushed, the Electron Beam Current and the Acceleration voltage decreases in a controlled shutdown, and the main power switch will be turned off automatically. The YELLOW indication remains for a few minutes to exhaust the remaining ozone.

c) GREEN (Safe to Enter) indicates that EPS has shutdown and the shield room door can be opened.

5.5 Warning Buzzer

The two audible warning buzzers are recommended to install on the top of shielding beside the warning lights.

a) Starting Alarm: beeping sound, the EPS will start in TEN seconds.
b) Warning Alarm: beeping sound when the main shield door is open and selector switch is at the OPERATION position.

This alarm will be shut off when the selector switch is turned to MAINTENANCE position. The sound of both the starting and warning alarms should be different.

5.6 Monitoring and measuring

5.6.1 Personal Monitoring

Operators and workers may be required to wear a personal radiation monitor such as film badges, or other device. Government regulations should be reviewed to determine specific requirements.

5.6.2 Area Monitoring

An X-ray monitor of a suitable design should be installed outside the shield room to monitor X-ray level in the working area. Typically, a Halogen G.M. tube is used as a detector that has an alarm contact signal output. The system is used for monitoring continuously X-ray level, and it also can provide emergency shut down of the EPS if the X-ray level exceeds a set value.

5.6.3 Area Check

The X-ray level around the shielding should be surveyed or checked once every six (6) months, and recorded in the EPS Log.

6. Cost Estimation

The cost estimation to install EPS is very difficult to do generally because the cost such as labor charge, construction and material handling system is different in each country. The initial cost to install typical EPS is shown Table 4. In this table, material handling system is considered only rolls provided in the shielding room.

Table 1 Type and Feature of EPS

Classification	Type	Rating Range	Feature
Acceleration	Electrostatic Type (DC Acceleration)	5 MV below	a) high energy conversion efficiency b) large machine size
	High Frequency Type (AC Acceleration)	5 MV above	a) relatively small size because of repeated acceleration b) low energy conversion efficiency
DC Power Supply (electrostatic acceleration)	Cockcroft-Walton	5 MV below	high energy conversion efficiency of 60 to 80 % because of lower input frequency of several kHz
	Shuenkel	Ditto	low energy conversion efficiency because of radio frequency using as input power
	Grounded Core	1 MV below	high energy conversion efficiency using commercial frequency as input power limited energy range because of insulation problem
	Insulated Core	Ditto	a) low energy conversion efficiency because of leakage magnetic flux problem simple insulation structure but element damage problem by surge voltage
	Van-de-Graaff	10 MV	simple structure poor beam current
Scanning	Scanning	300 kV above	no limitation of acceleration voltage b) large machine size
	Non-scanning	300 kV below	simple structure high beam current no limitation of acceleration voltage

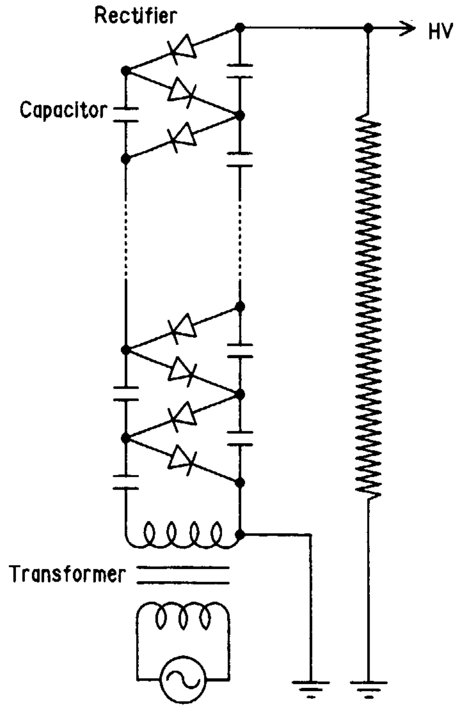


Fig. 1 Cockcroft-Walton Circuit

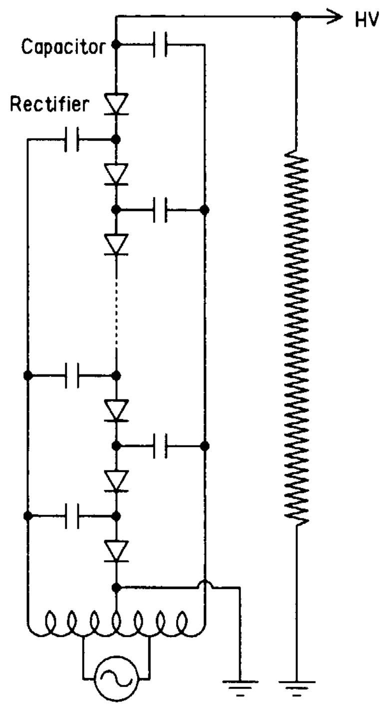


Fig. 2 Shuenkel Circuit

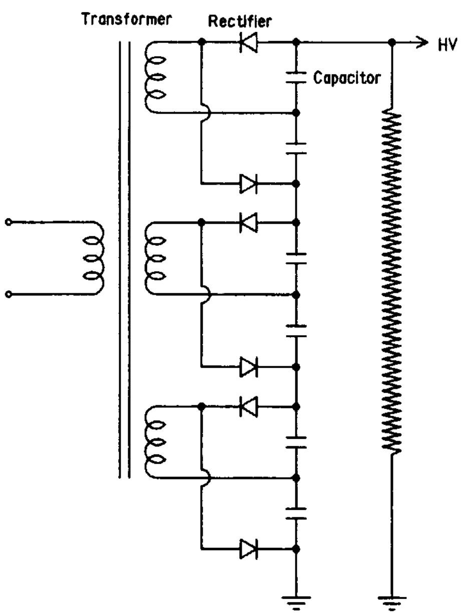


Fig. 3 Grounded Core Type

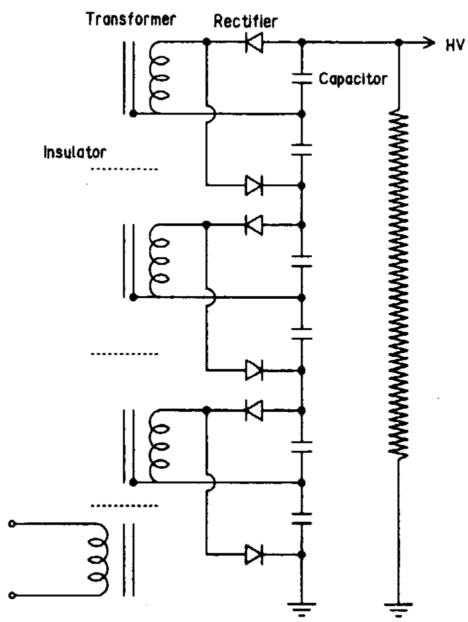


Fig. 4 Insulated Core Type

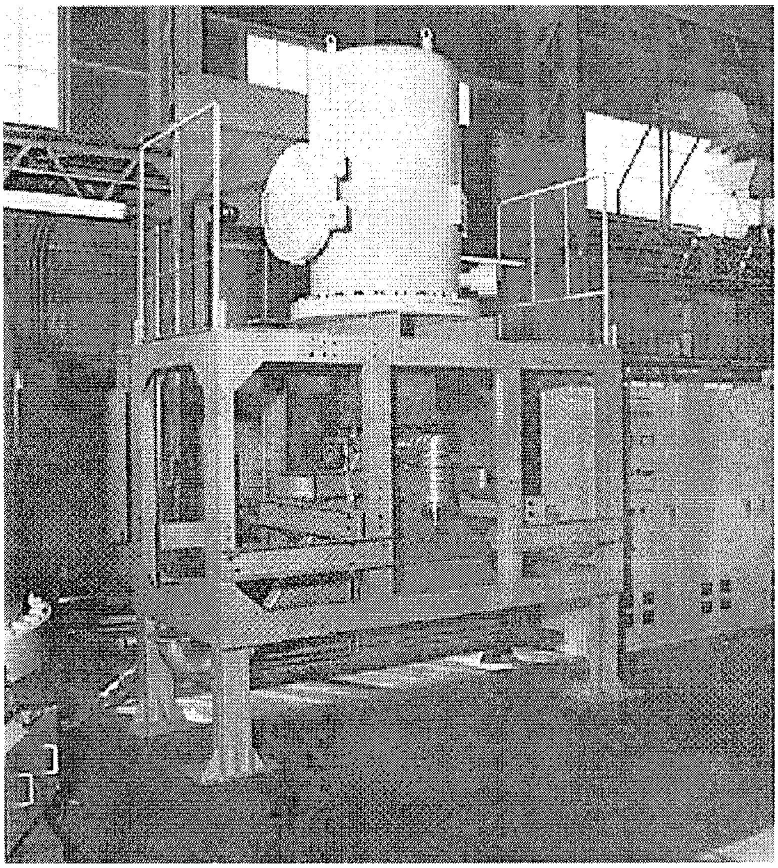


Fig. 5 Scanning Type EPS

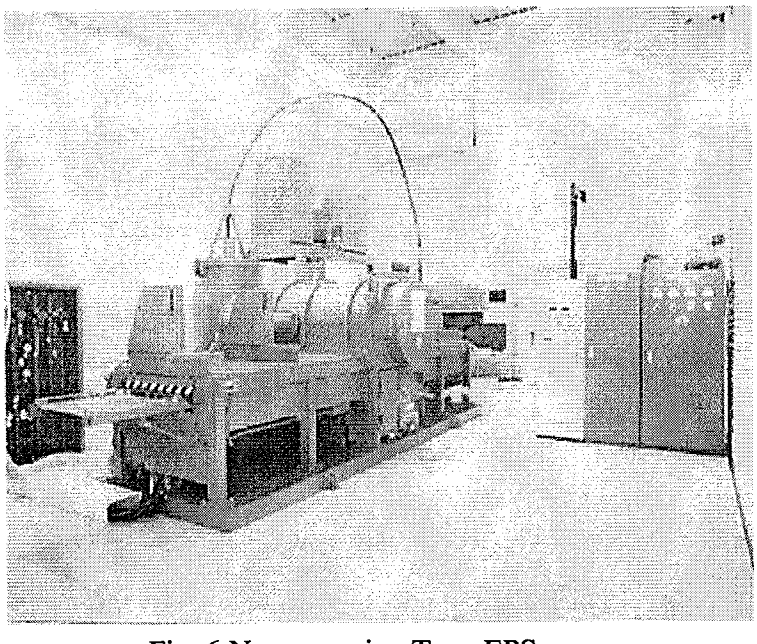
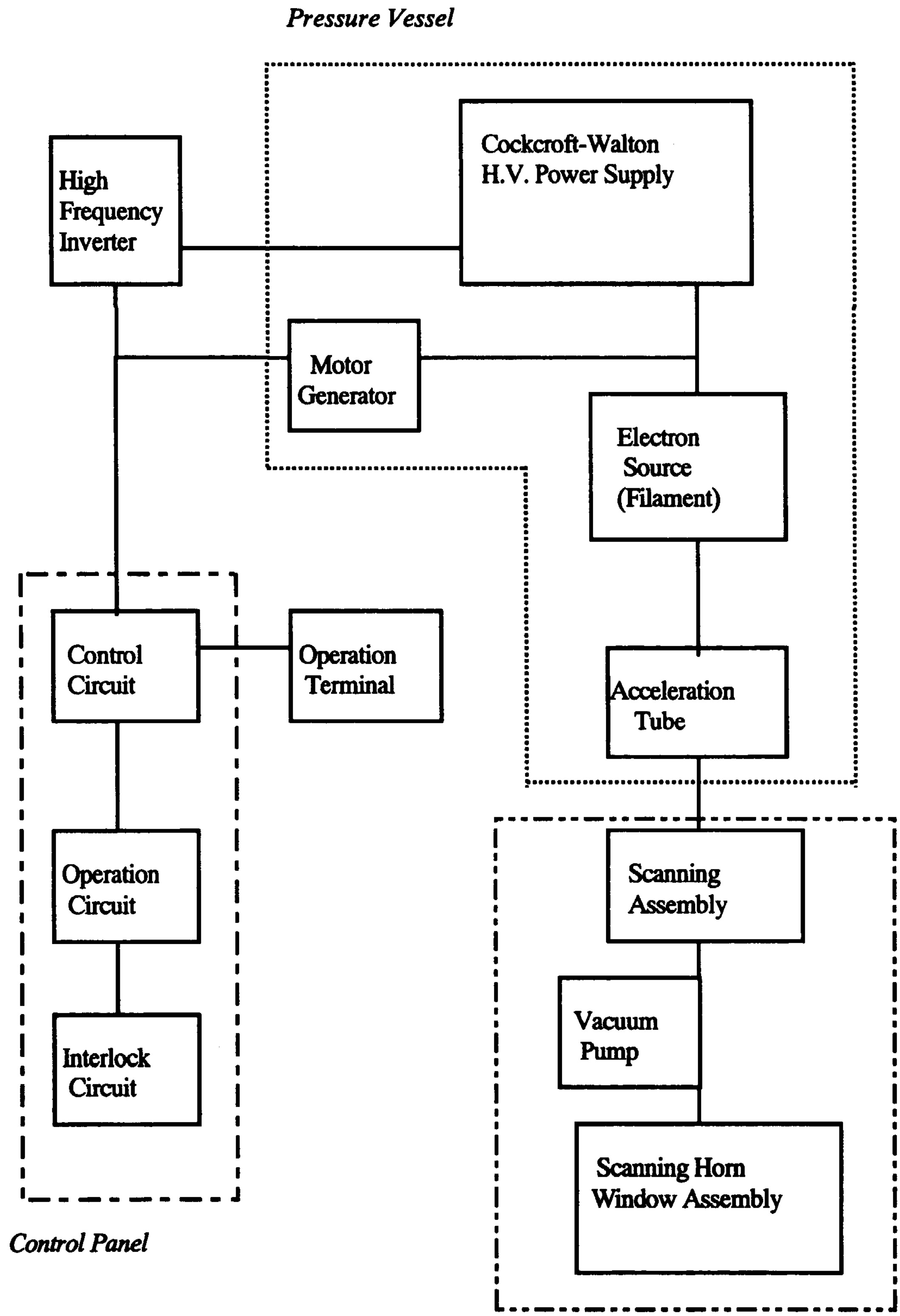
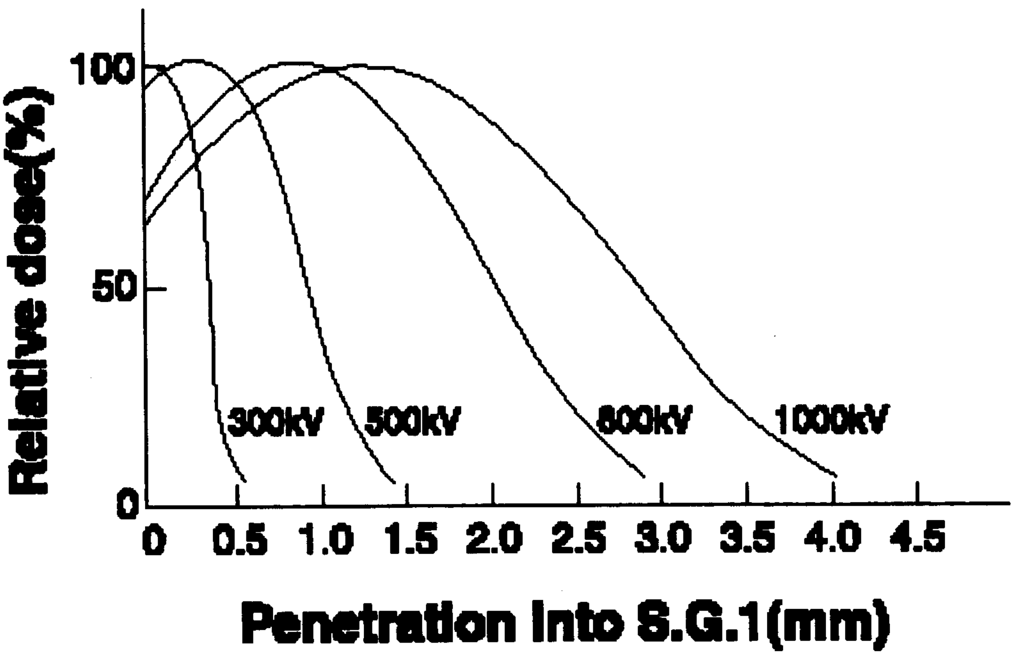


Fig. 6 Non-scanning Type EPS



Radiation Shielding

Fig. 7 Block Diagram of EPS



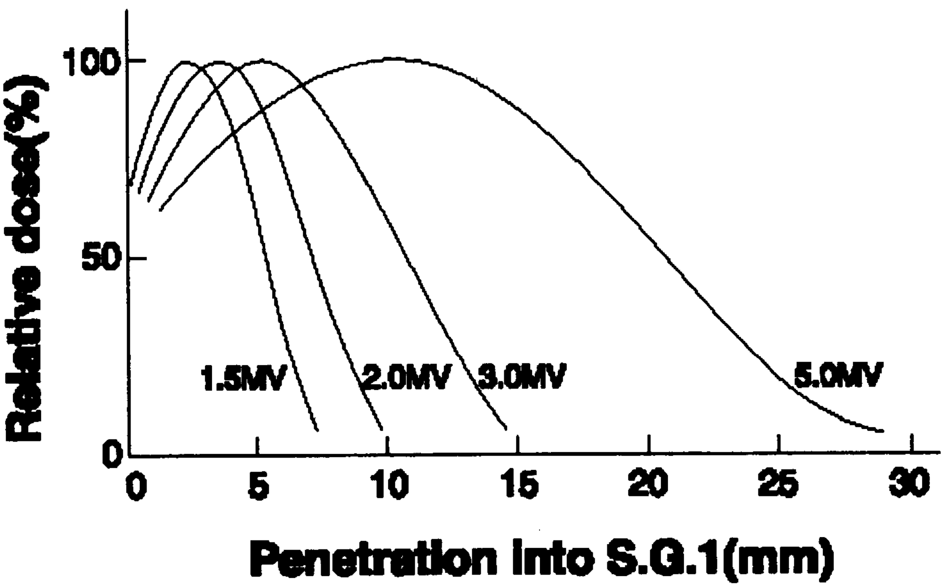


Fig. 8 Penetration Curve

Table 2 Typical Energy Absorption Ratios

Acceleration Voltage (MV)	Energy absorption Ratio (MeV/g/cm2)
0.3	3.6
0.5	2.9
0.8	2.45
1.0 above	2.0

Table 3 Interlock Systems of EPS

No.	Item	Location	Activity
1	One Key System is recommended. (All key switches and locks can be one key)	a. operation key switch of operation terminal b. main shielding door lock c. safety key switch in the irradiation part	a. If the key switch is not turned on, EPS is not in operation. The key can not removed at ON position. b. The main shielding door key has a mechanical lock. If the door is not locked, EPS is inoperative. The key can be removed at both ON and OFF positions. c. If the key switch is not turned on to the position of OPERATION, EPS is not in operation. The key can not removed at the position of MAINTENANCE.
2	Door Interlock is recommended. (Limit switches are provided for	a. main shielding door	If any limit switch is not operated (OFF), EPS is inoperative.
3	Safety Switch is recommended.	Safety switch in the irradiation part	same as above "One Key System"-(C)

Table 4 Budgetary Price List for EPS
(reference only)

(Unit : M¥)

Type	EPS 500	EPS 800	EPS1000	EPS2000	EPS3000	EPS5000
Acceleration Voltage	500 kV	800 kV	1 MV	2 MV	3 MV	5 MV
Beam Current	100 mA	100 mA	100 mA	75 mA	50 mA	30 mA
Irradiation Width	180 cm	180 cm	180 cm	180 cm	180 cm	180 cm
X-ray Shielding	Lead	Lead	Concrete	Concrete	Concrete	Concrete
Price Item						
EB Machine	90	120	150	250	300	450
X-ray Shielding	80	100	70	100	120	150
Auxiliary Equipment	25	25	25	35	35	35
Material Handling	50	50	50	50	50	50
SV for Installation	10	10	10	10	10	10
Ozone Exhaust Duct	10	10	10	10	10	10
Cooling Water System	10	10	10	10	10	10
Wiring & Piping	10	10	10	10	10	10
Total Price	285	335	335	475	545	725

Remarks: These prices are reference only because the price should be changed for each case.
The price of x-ray shielding should be changed by construction cost.
Auxiliary equipment includes window cooling blower, ozone exhaust blower and SF6 gas handling equipment.
In installation work at site, actual workers of 3 to 4 persons for 2 moths are necessary.

5.3 Radiation Processing of Liquid with Low Energy Electron Accelerator

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ABSTRACT

Radiation induced emulsion polymerization, radiation vulcanization of NR latex (RVNRL) and radiation degradation of natural polymers was selected and reviewed as the radiation processing of liquid. The characteristic of high dose rate emulsion polymerization is the occurrence of cationic polymerization. Thus, it can be used for the production of new materials that cannot be obtained by radical polymerization. A potential application will be production of polymer emulsion that can be used as water-borne UV/EB curing resins. The technology of RVNRL by γ-ray has been commercialized. RVNRL with low energy electron accelerator is under development for further vulcanization cost reduction. Vessel type irradiator will be favorable for industrial application. Radiation degradation of polysaccharides is an emerging and promising area of radiation processing. However, strict cost comparison between liquid irradiation with low energy EB and state irradiation with γ-ray should be carried out.

1. INTRODUCTION

In this paper, liquid includes solution, emulsion and latex. The radiation processing of liquid developed so far are as follows;

① Organic synthesis

② Waste water treatment

③ Emulsion polymerization

④ Vulcanization of NR latex

⑤ Graft polymerization in NR latex

⑥ Degradation of Natural Polymers

Several processes of organic synthesis by radiation were developed in USSR and USA in '60[1, 2]. However, they have no industrial value at present because the same substances are produced by other nonradiation processes. The waste water treatment by radiation is recognized as an important area of radiation processing[3]. It will be discussed in other part of this Workshop. The graft polymerization in NR Latex is also not dealt with in this paper because nonradiation method is commonly utilized. Thus the emulsion polymerization, vulcanization of NR latex and degradation of natural polymers will be reviewed in this paper.

2. EMULSION POLYMERIZATION

Radiation induced emulsion polymerization was studied for long time[4]. The advantages of radiation emulsion polymerization are as follows;

① Higher molecular weight

② Complete conversion

③ No purification of monomer

④ Reproducibility

⑤ No heat source

⑥ Easy control

⑦ Clean products without impurity

Only acrylic emulsions for textile printing and dyeing are produced commercially in China by radiation[5]. This process was developed by University of Science and Technology of China. Industrial production was started in 1986. This process is now widely used in China. Annual production shipment value was $ 1 Million in 1998. Figure 1 illustrates the outline of the plant of radiation emulsion polymerization.

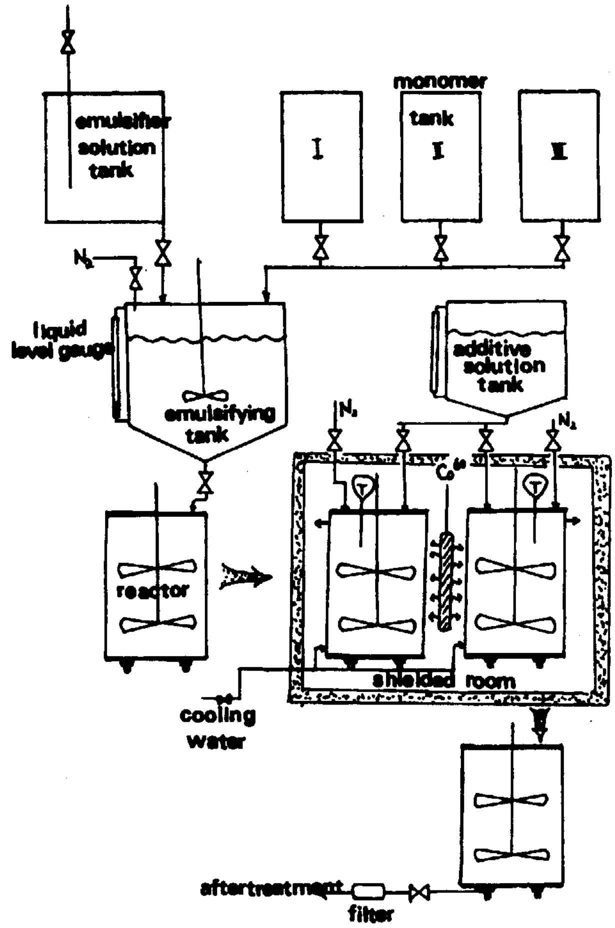


Fig. 1 Outline of the plant of radiation emulsion polymerization

A batch process was adopted in the industrial-scale production. The primary intensity of radiation source was 80 kCi and the producing capability of latex was 6 ton/day (2000 ton/y). The prepared emulsion is fed into four 600 litters movable reactors that are arranged on the two sides of the plate-form Co-60 source to receive the γ rays and carry out the emulsion polymerization independently. Each reactor is equipped with stirring and cooling systems, temperature detectors and automatic feeding entrance. The whole emulsion system is stirred at low speed during the irradiation. The preferable dose rate is 10-30 Gy/min. The temperature detector and the cooling system is set to take the reaction heat away and to keep the reaction temperature. A lower temperature is favorable to raise the molecular weight of resulted polymer, so that to raise the latex quality. Two types of latexes are produced: (1) water based latexes produced from oil-in-water emulsion and (2) oil based latexes from water-in-oil emulsion. The former are used as the binders for textile pigment print and dying and the later as thickeners for print paste

Emulsion polymerization with electron accelerator was attempted. One of the most important characteristics of irradiation with electron accelerator is the high dose rate irradiation. The advantages of the high dose rate polymerization are as follows:

① High rate of polymerization
② Predominance of cationic mechanism
③ Liability to form Oligomer

Study on the emulsion polymerization of styrene (St) in a flow system by using electron beam of 1.5 MeV was carried out by JAERI-Osaka[6, 7]. The reaction system is schematically illustrated in Figure 2. Sodium lauryl sulfate (SLS) was used as an emulsifier.

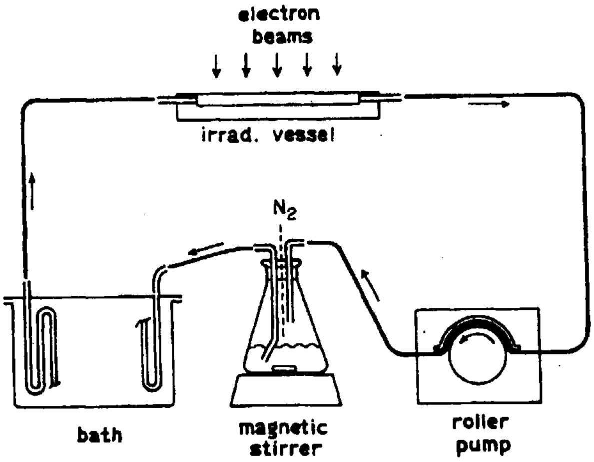


Fig. 2 System of emulsion polymerization with electron accelerator

Deaerated emulsion was circulated through an irradiation vessel after passing a heat exchanger to keep the sample temperature at 40℃. The flow rate of the emulsion was 4.7 ~ 5.0 ml/sec. The inner size of the irradiation vessel was 440×10×5 mm. The electron beam of 1.5 MeV penetrates 3 mm in the direction of the depth. The average dose rate in the vessel was 3 kGy/sec for a space of 300×10×3 mm.

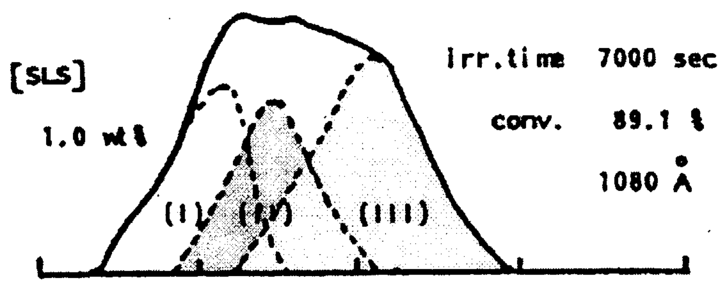


Fig. 3 GPC curves of polystyrene prepared by emulsion polymerization with EB

Figure 3 shows the typical GPC curves of polymer latex prepared by the high dose rate emulsion polymerization. The GPC curve is composed of three components. Peak I indicates the curve of oligomers with molecular weight of about 1000, Peak II polymers obtained by radical polymerization, and Peak III polymers obtained by cationic polymerization. The higher the [SLS]/[St], the more the amount of polymer produced by cationic process. The amounts of oligomer and radical polymer decrease at higher [SLS]/[St].

Figure 4 shows the GPC curves of polymers prepared under various dose rates. It is clear that radical polymer predominate at a low dose rate, while at a higher dose rate cationic polymers predominate.

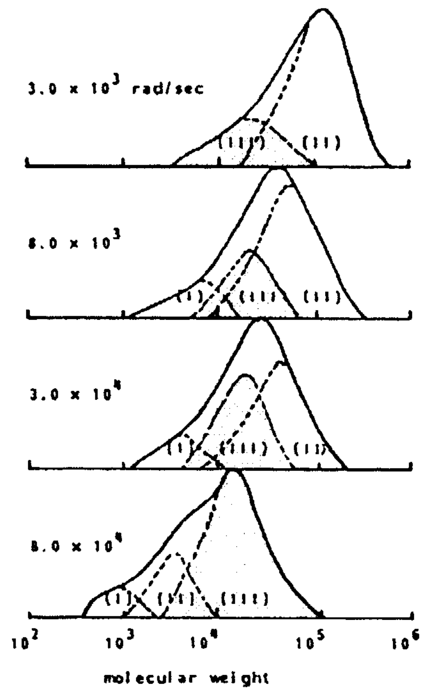


Fig. 4 GPC curves of polystyrene prepared under various dose rates

The molecular weight distributions of cationic polymers are rather narrow. Figure 5 shows the number average molecular weight (Mn) of cationic and radical polymers as a function of the dose rate, respectively. Mn of radical polymers decreases with increasing dose rate, while Mn of cationic polymer keeps. Emulsion polymerization with electron accelerator is a high dose rate polymerization.

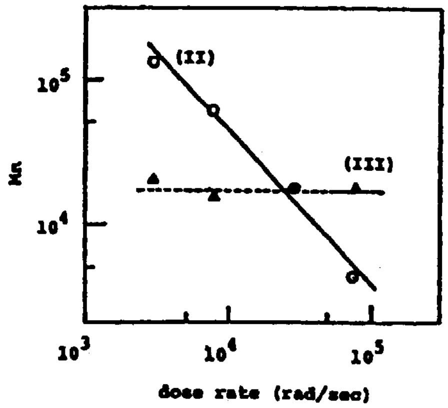


Figure 5 Number average molecular weight of cationic and radical polymers

The significant characteristic of electron beam induced high dose rate emulsion polymerization is the emergence of cationic polymer mechanism. This suggests that electron beam induced emulsion polymerization is suitable for the production of polymer emulsion that can be used as water-borne UV/EB curing resins.

3. RADIATION VULCANIZATION OF NR LATEX

Radiation vulcanization of natural rubber latex (RVNRL) means the radiation-induced crosslinking of natural rubber (cis-1,4-polyisoprene) dispersed as microscopic particles in an aqueous medium. Following excellent qualities of RVNRL have been specified[8).

① Absence of N-nitrosamines
② Very low cytotoxicity
③ Less protein content
④ Easy degradation in the environment
⑤ Transparency and softness
⑥ Less formation of SO_2 when during incineration

These arise from the facts that RV NR latex does not contain dithiocarbamates, sulfur and zinc oxide that are essential for the conventional vulcanization. Pilot plants of RVNRL have been set up in Indonesia, India, Malaysia and Thailand. Radioactive isotope Co-60 is used as a radiation source of pilot plant of RVNRL. Irradiation facility with Co-60 sources needs heavy bioshielding, resulting in high initial investment and high irradiation cost. Replenishment of decayed Co-60 sources is another factor to be considered. Thus, RVNRL by Co-60 has not come into wide. The RVNRL with electron accelerator also studied in a few countries. Generally, medium or high energy electron accelerator was used. A pilot plant with electron accelerator was installed in France[9)]. Figure 6 illustrates the plant. A linear electron accelerator having a mean power of 10 kW and energy of 6 MeV was used as the radiation source. The irradiation vessel is equipped with a latex circulating pump to permit continuous vulcanization. The critical problems of RV NR latex preparation with EB are as follows;

① Avoiding local overdosing
② Limiting heating of the latex.

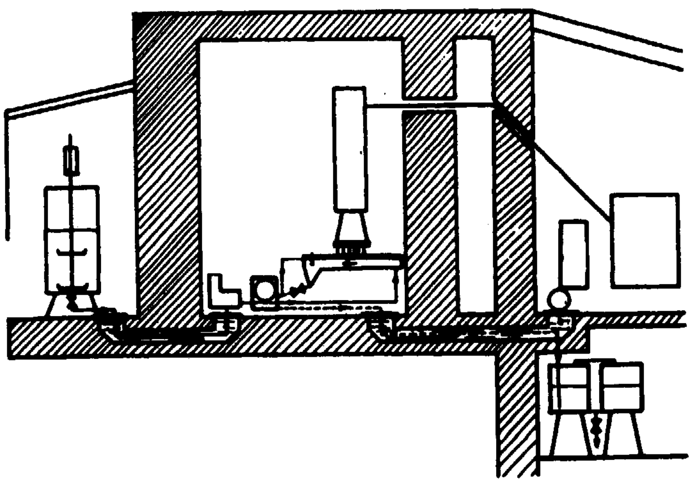


Fig. 6 Pilot plant of RVNRL with linear electron accelerator

Special care was taken in the designing of the irradiation vessel to prevent the coagulation of the latex that can occur because of over dosing and heating. It has been reported that EB irradiated NR latex and the resulting latex films exhibit good properties that make them suitable for any conventional use of rubber latex.

In China, a van de Graaff electron accelerator (2 MeV, 0.15 mA) was a radiation source[10]. The NR latex (TSC 50 %) was irradiated to 300 kGy with a dose rate of 1.2 kGy/sec. The latex was stirred during the process at 300 rpm to ensure homogeneous irradiation. The physical properties of RV NR latex films thus prepared were compared with those of a sulfur vulcanized NR latex film. The vulcanization dose was 300 kGy. The maximum tensile strength and elongation at break were 19.2 MPa and 918 %, respectively. While the tensile strength of sulfur vulcanizate was 29.0 MPa. After aging at 100 C for 24 hr the tensile strength of radiation vulcanizate increased to 22.5 MPa, while that of sulfur vulcanizate decreased to 5.9 MPa. High transparency of radiation vulcanizate was observed. The RV NR latex irradiated with EB is absolutely free from contaminants and suitable for medical use.

In Germany a 1.5 MeV, 25 mA (Dynamitron) was used for RVNRL source[11, 12]. Initially, NR latex was placed on metal plates (with thickness of about 4 mm) having elevated edges. The plates were mounted on a table that can move automatically under the electron beam scanner during radiation. Finally, flow type irradiator with metal slope was installed to irradiate NR latex continuously (300 kg for each trial). Polyfunctional monomers were used as accelerator.

German latex using industry was interested in RVNRL. The electron beam crosslinked natural rubber latex was tested for a number of different applications. Best results were obtained in the dipping industry. Trial manufactures of teats, toys, balloons, condoms, household-gloves, surgical gloves, examination gloves, catheters and medical tubes were carried out. Advantages were also seen in the productions of cork soles because of a better appearance. However, the development of radiation process by electron beam was stopped due too high investment cost.

RVNRL with a self-shielding low energy electron accelerator is supposed to be more feasible and economic than those with Co-60 source, medium and high energy electron accelerator because special building with thick bioshielding is not required for low energy electron beams (EB). However, the low energy EB has the following disadvantages:

① High absorption by air

② Low penetration in latex

③ Wide scattering in air

Figure 7 shows the percentages of absorbed electron beams in latex that was put in a vessel covered with 6 μm aluminum foil as shown in Figure 8.

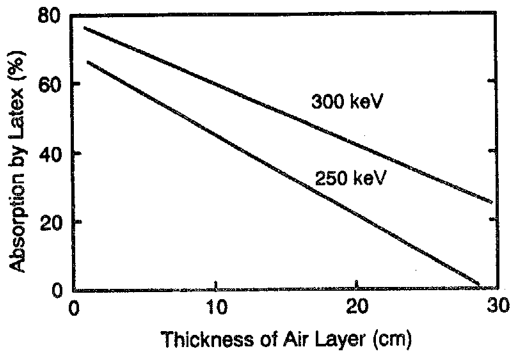


Fig. 7 Absorbed EB in latex

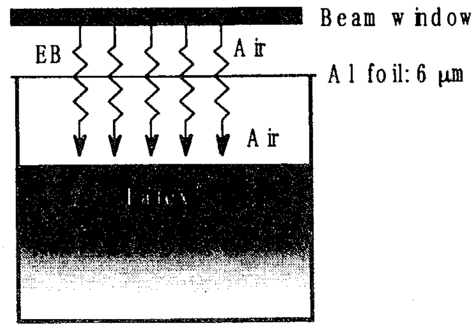


Fig. 8 Absorption of EB in vessel

With increasing the thickness of air layer between the surface of latex and the beam window absorption percentages of electron beams in latex decreases. Low penetration of low energy EB in latex causes serious technical problems.

Figure 9 illustrates a typical relationship between dose and tensile strength of NR film prepared from RV NR latex. The tensile strength increases with increasing dose, after achieving maximum value it decreases. For practical usage 70% of maximum tensile value should be kept. This means the lowest dose should be about 50% of the dose at that maximum tensile strength is achieved.

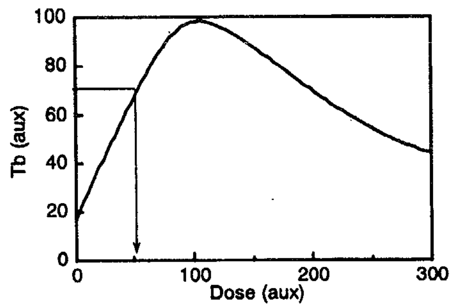


Fig.9 Dose and tensile strength Relationship of RVNRL

Figure 10 shows the depth dose curve of 250 keV EB in NR latex in the irradiation vessel covered with 20 μm titanium foil. The thickness of air layer is 10 cm. The thickness of NR latex that absorbs enough energy to vulcanize is less than 40 μm. It is hard to control the thickness of NR latex layer less than 40 μm in industry.

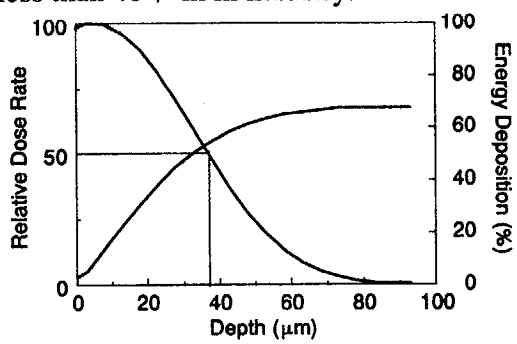
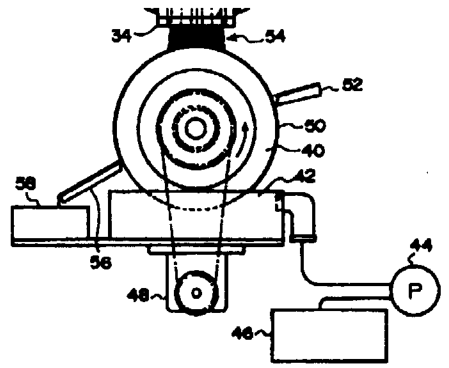


Fig. 10 Depth dose curve of 250keV EB in NR latex

Several irradiation systems were tried to vulcanize NR latex[13]. Figure 11 illustrates a rotating drum type irradiator. Surface of the rotating drum adsorbs NR latex at the bottom of drum and the latex is irradiated at the top of the drum.



34: Beam window
40: rotating drum
42: NR latex
44: latex pump
46: latex tank
48: motor
50: thin latex layer
52: thickness adjustor
56: latex collector
58: latex reservoir

Fig. 11 Rotating drum type irradiator

Figure 12 shows tensile strength and weight swelling ratio of NR film prepared from NR latex irradiated with the rotating drum type irradiator at various beam current at the fixed accelerating voltage (250 kV) and the rotating speed. With increasing beam current the tensile strength increases and the swelling ratio decreases.

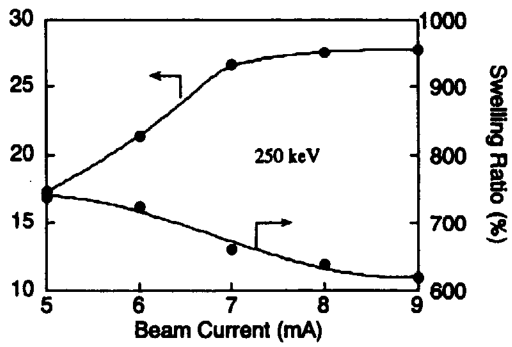
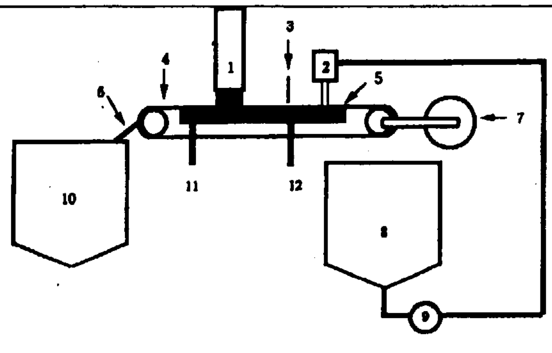


Fig. 12 Results obtained by using rotating drum type irradiator

Belt conveyer type irradiator shown in Figure 13 is a modification of rotating drum type irradiator.



1: electron accelerator
2: latex coater
3: thickness controller
4: conveyer belt
5: cooling head
6: latex collector
7: motor
8: latex tank
9: pump
10: latex reservoir

Fig. 13 Belt conveyer type irradiator

Figure 14 demonstrates a natural flow type irradiator. The NR latex flows under EB naturally due to gravitational force and circulates by using diaphragm pump.

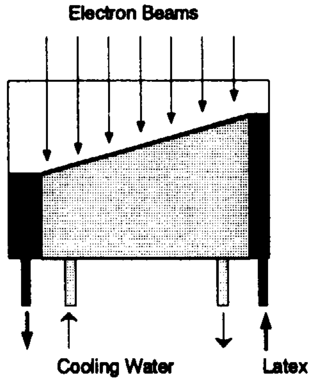


Fig. 14 Natural flow type irradiator

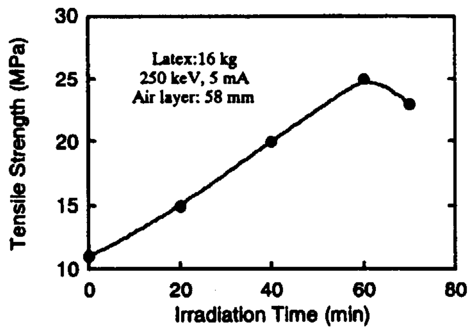


Fig. 15 Results obtained by using natural flow type irradiator

Figure 15 shows some data obtained by this irradiator.

Vessel type irradiator will be favorable for industrial application. Figure 16 shows two vessel type irradiators, prototype and its modified one. Mixing efficiency was improved in the modified irradiator by installing the stirrer at the bottom of the irradiator.

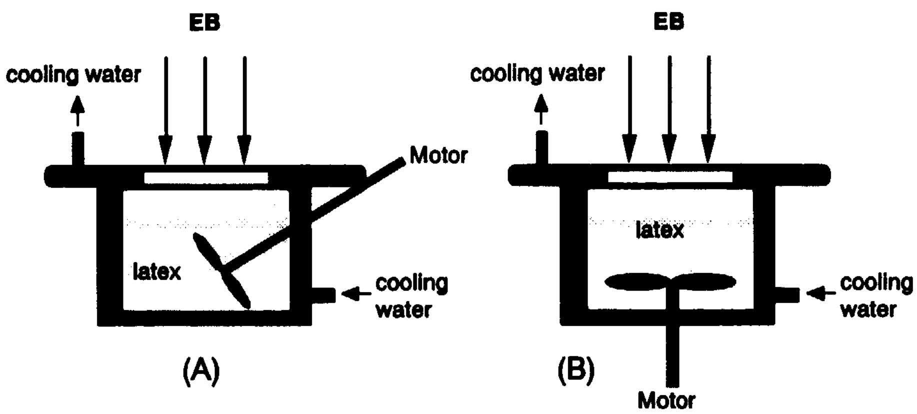


Fig. 16 Vessel type irradiators, (A) prototype, (B) modified

Problem of vessel type irradiator was the formation of small rubber blocks on the surface of latex during irradiation. Number and size of the block increase with increasing irradiation time. The rubber blocks originated from drying of latex at the wall of irradiator where the scattered electron beams hit. It is essential to design the irradiator to be larger than beam window. The irradiator should apart 15 cm from the edge of beam window.

Figure 17 shows the effect of mixing speed on RVNRL with vessel type irradiator. The capacity of the vessel is 1,450 ml latex. NR latex was irradiated in the absence of sensitizer with an accelerating voltage of 300 kV. Clearly the optimum radiation time is 25 minutes at 100 rpm (Reynolds number Re: ca 800), 15 minutes at 150 rpm (Re: ca 1,200) and around 20 minutes at 200 rpm (Re: ca 1,600). The maximum tensile strength is also achieved at 150 rpm. This indicates that suitable flow of latex is attained at the Reynolds number around 1,600. High speed stirring produces foams that cause coagulated surface layers with partially carbonized NR because almost all of energy of the electron beams is adsorbed by the foam. Formation of foams was prevented by addition of defoamer. Figure 18 shows effect of beam current (equivalent to dose rate) on the tensile strength with a 300 kV of EB energy at 150 rpm of stirring speed. It can be seen that for higher beam current reduces vulcanizing time. However, there is slight dose rate dependency of rate on vulcanization. Probably this is due to the insufficient mixing during irradiation.

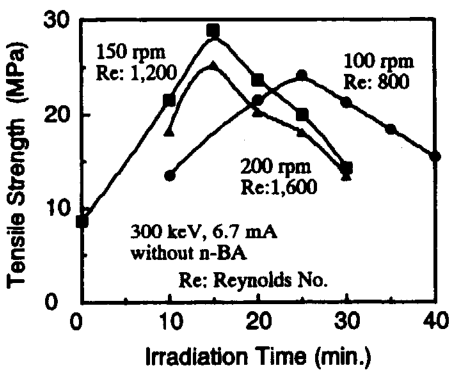


Fig. 17 Effect of mixing speed on RVNRL

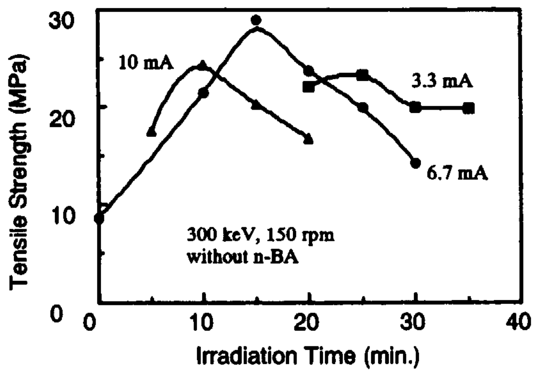


Fig. 18 Effect of beam current on RVNRL

A pilot plant of RVNRL with low energy electron accelerator was installed at TRCRE[14]. The appearance of the plant is shown in Figure 19. It consists of 250 keV-10 mA electron accelerator and vessel type irradiator having capacity of 18 litters.

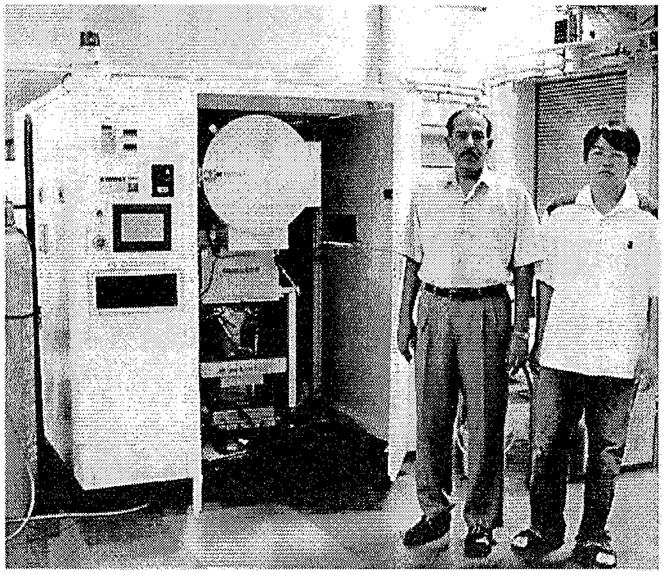


Fig. 19 Pilot plant of RVNRL with low energy electron accelerator

Figure 20 shows some results obtained by this plant. Remarkable reduction of the initial investment and vulcanization cost of RVNRL can be expected by utilization of low energy electron accelerator.

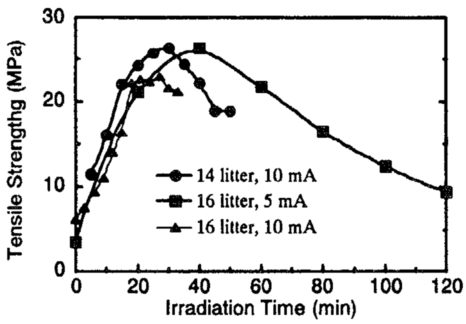


Fig. 20 Results obtained by using the pilot plant

4. RADIATION DEGRADATION OF NATURAL POLYMERS

It is well known that the polysaccharides (carbohydrates) such as sodium alginate, chitosan and carageenan are easily degraded by irradiation. Recently it was found that the degraded polysaccharide has various kinds of biological activities such as promotion of plant growth[15], anti-bacterial activity[16], suppression of heavy metal stress[17]. Radiation degradation of polysaccharides is an emerging and promising area of radiation processing.

Low energy electron accelerator is useful tool to degrade polysaccharides. Figure 21 and Figure 22 show molecular weight change of sodium alginate in 1 wt % aqueous solution with γ-rays and EB, respectively. The EB irradiation was carried out by the RVNRL pilot plant described above. It is clear that there is no remarkable difference between EB and γ-rays in the degradation of sodium alginate. However, solid state degradation with γ-rays will be more easily, even though the high dose is needed. Strict cost comparison between liquid irradiation with low energy EB and state irradiation with γ-rays should be carried out.

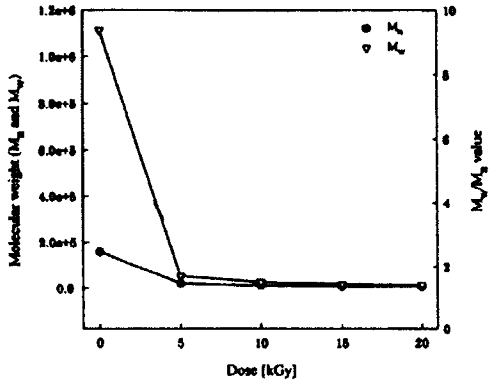


Fig. 21 Molecular weight change of sodium alginate by γ -ray irradiation

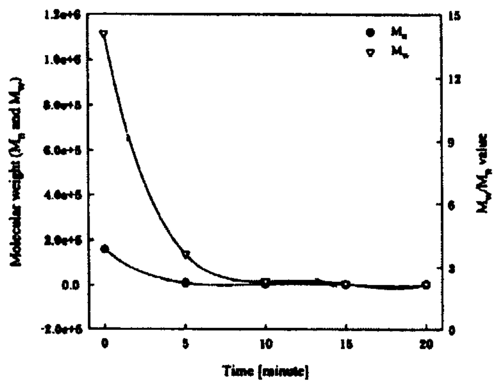


Fig. 22 Molecular weight change of sodium alginate by 250 keV EB irradiation

5. CONCLUSION

Low energy electron accelerator is a practical radiation source for processing of liquid. Emulsion polymerization, RVNRL and degradation of natural polymers are the potential application field of low energy electron accelerator. However, the reduction of price and maintenance cost of the EB machine is needed for the promotion of radiation processing of liquid with low energy electron accelerator.

REFERENCES

1) C. D. WAGNER, Chemical synthesis by ionizing radiation, Adv. Radiat. Chem., 1, 199 (1969)
2) V. VERESHCHINSKII, Some topics in radiation chemical synthesis of organic compounds, Adv. Radiat. Chem., 3, 75 (1972)
3) A. K. PIKAEV, Current status of the application of ionizing radiation to environmental protection: I. Ionizing radiation sources, natural and drinking water purification (a review), High Energy Chem., 34, 1 (2000)
4) K. MAKUUCHI, H. NAKAYAMA, Radiation processing of polymer latex, Progr. Org. Coat. 11, 241 (1983)
5) Zhang Zhichcng, Zhang Manwei, Industrialization of radiation-induced emulsion polymerization - Technological process and its advantages, Radiat. Phys. Chem., 42, 175 (1993)
6) K. HAYASHI, S. OKAMURA, Emulsion polymerization of styrene in a flow system, JAERI M9214, 113 (1981)
7) J. TAKEZAKI, K. HAYASHI, S. OKAMURA, Molecular weight distribution of polymer latex by radiation-induced emulsion polymerization, Report Progr. Polym. Phys. Japan, 26, 557(1983)

8) K. MAKUUCHI, Radiation vulcanization of natural rubber latex, Encyclopedia of Materials Science and Engineering, Supl. Vol. 3, p. 1945, Pergamon Press, Oxford, (1995)
9) P. ICRE, Technological aspects of the industrial irradiation of rubber in the latex phase for the purpose of pre-vulcanization by an electron accelerator, Large radiation sources for industrial processes, p. 643, IAEA, Vienna, 1969
10) Radiation Application Laboratory of Shanghai University of Science and Technology, Radiation Chemistry, p. 143 Atomic Energy Press, Beijing (1975)
11) W. BEZ, Application of RVNRL in Europe, Proceeding of International Symposium on RVNRL, 26-28 Jul. 1989, Tokyo and Takasaki, JAERI-M 89-228, p, 383
12) W. BEZ, Status of RVNRL in German latex industry and its introduction to the European market, Proceeding of the Second International Symposium on RVNRL, 15-17 Jul. 1996, Kuala Lumpur, Malaysia, p, 121
13) K. MAKUUCHI, F. YOSHII, T. TAKEI, S. KINOSHITA, Feroza Akhtar, Vulcanization of natural rubber latex with low energy electron accelerator, Nippon Gomu Kyokaishi (J. Soc. Rubber Ind., Japan) (Japanese), 69, 500 (1996)
14) M. E. HAQUE, K. MAKUUCHI, H. MITOMO, K. IKEDA, F. YOSHII, T. KUME, Radiation vulcanization of natural rubber latex with low energy accelerator, Proceedings of the Takasaki Symposium on Radiation Processing of Natural Polymers, 23-24 Nov. 2000, Takasaki, JAERI-CONF-2001-005, p. 157
15) Nguyen Quoc Hien, N. NAGASAWA, Le Xuan Tham, F. YOSHII, Vo Huy Dang, H. MITOMO, K. MAKUUCHI, T. KUME, Growth-promotion of plants with depolymerized alginates by irradiation, Radiat. Phys. Chem., 59, 97 (2000)
16) Kieu Ngoc Lan, Nguyen Duy Lam, T. KUME, Application of irradiated chitosan for fruit preservation, Proceedings of the Takasaki Symposium on Bilateral Cooperations– Radiation Processing of Natural Polymers–, 1-2 Nov. 1999, Takasaki, JAERI-CONF-2000-003, p. 101
17) Le Xuan Thama, N. NAGASAWA, S. MATSUHASHI, N. S. ISHIOKA, T. ITO, T. KUME, Effect of radiation-degraded chitosan on plants stressed with vanadium, Radiat. Phys. Chem., 61, 171 (2001)

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5.4 Treatment of Foods with "Soft-electrons" (Low-energy Electrons)

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Abstract

Electrons with energies of 300 keV or lower were defined as "soft-electrons". Soft-electrons can eradicate microorganisms residing on the surface of grains, pulses, spices, dehydrated vegetables, tea leaves and seeds, and reduce their microbial loads to levels lower than 10 CFU/g with little quality deterioration. Soft-electrons can inactivate insect pests infesting grains and pulses and inhibit sprouting of potatoes.

1. Introduction

Since most of the microorganisms contaminating dry food ingredients such as grains, pulses and spices reside on their surfaces, and some insect pests infesting grains and pulses reside on the surface. Therefore, the inner parts do not have to be exposed to heat, gas or radiation for decontamination or disinfestation. The penetration capacity of an electron beam is controlled by the energy; electrons with lower energies display lower penetration capacities[1]. We have defined low-energy electrons at 300 keV or lower as "soft-electrons". Soft-electrons penetrate only the surface of food, while gamma-rays and electron beams at high energies penetrate foods and UV does not penetrate even the surface (Fig.1). Therefore, the quality changes of food caused by soft-electrons are expected to be much more limited than those caused by gamma-rays or high-energy electron beams with much higher penetration capacities. It is expected that soft-electrons can decontaminate/disinfest dry food ingredients such as grains, pulses and spices with little quality deterioration. We carried out studies on the efficacy of soft-electron treatment of foods and agricultural products for decontamination, disinfestation and sprouting inhibition. We will review our studies on soft-electron treatment of foods.

2. Penetration capacity of soft-electrons

Dry ingredient samples were treated with soft-electrons under rotation to expose all the sample surfaces to electrons with low penetration capacities. A grain rotator was developed which enabled samples to rotate by shaking and vibrating them simultaneously at variable speeds. The rotator was placed under the window of a Van de Graaff electron accelerator (Nissin High Voltage Engineering Co., Ltd., Kyoto, Japan), which generated electrons at acceleration voltages of 170-300 kV. The distance between the window of the electron accelerator and the plastic tray of the grain rotator was 17 cm.

Penetration capacities of soft-electrons at different energies were determined based on depth-dose curves. Several pieces of radiochromic film dosimeter (RCF)(5.94 mg/cm^2, FWT-60-00, Far West Technology Inc., Goleta, California, USA) were stacked together in layers at the bottom of the plastic tray of the grain rotator which was placed under the window of the electron accelerator at a distance of 17 cm, and irradiated with electrons for 60 min at different acceleration voltages of 170 kV – 200kV. Absorbance at 510 nm of all RCF films before and 30 min after irradiation were measured and the dose absorbed by each RCF film was determined according to the method of McLaughlin et al.[2]

Energies of electrons at a distance of 17 cm (air) from the window (50 micron thick titanium) of the electron accelerator were lower than those of the electrons at the window (acceleration voltage). The energies of electrons irradiating samples at 17 cm from the window were estimated to be 60, 75, 90, 100, 130, 160 and 210 keV for acceleration voltages of 170, 180, 190, 200, 225, 250 and 300 kV, respectively, based on the mass stopping power of air and titanium[3, 4]. Depth-dose curves of electrons at various energies were developed by plotting all the absorbed doses determined with RCF films[5]. The penetration capacity of electrons at 60 keV was about 6 mg/cm^2 and that at 75 keV was about 10 mg/cm^2, while those at 90 and 100 keV were lower than 17.82 mg/cm^2 (5.94 mg/cm^2 x 3 pieces). Doses absorbed by the first RCF film for 1 h were about 30, 58, 70 and 110 kGy at 60, 75, 90 and 100 keV, respectively[5].

3. Decontamination of food ingredients

3.1 Decontamination of grains

3.1.1 Sterility and viscosity of grains exposed to soft-electrons

Energies of electrons necessary to reduce microbial loads to less than 10 CFU/g were 75 keV for brown rice, 160 keV for rough rice, 75 keV for wheat and 130 keV for buckwheat (Table 1) [6]. The results suggested that most of the contaminating microorganisms resided in the region that the electrons with such low energies could reach. Gamma rays at 7.5-12.5 kGy were necessary to achieve the same levels of sterility.

Table 1 Sterility of grains exposed to low-energy electrons or gamma rays (CFU/g of grains)

	brown rice	rough rice	wheat	buckwheat
Control[a]	$4.1\text{x}10^{6}\pm4.6\text{x}10^{5}$	$4.7\text{x}10^{7}\pm1.5\text{x}10^{7}$	$2.7\text{x}10^{4}\pm1.2\text{x}10^{4}$	$1.4\text{x}10^{6}\pm6.8\text{x}10^{5}$
75keV, 8 μA, 10min	$5.1\text{x}10^{2}\pm2.1\text{x}10^{2}$	-----[b]	$1.2\text{x}10^{3}\pm8.3\text{x}10^{2}$	-----
75keV, 8 μA, 40min	<10	-----	<10	-----
100keV, 14 μA, 5min	$1.2\text{x}10^{3}\pm5.6\text{x}10^{2}$	$5.8\text{x}10^{5}\pm7.0\text{x}10^{4}$	$3.1\text{x}10^{2}\pm2.1\text{x}10^{2}$	$1.4\text{x}10^{3}\pm9.2\text{x}10^{2}$
100keV, 14 μA, 20min	<10	$6.3\text{x}10^{3}\pm1.3\text{x}10^{3}$	<10	$3.3\text{x}10^{2}\pm3.6\text{x}10^{2}$
130keV, 22 μA, 1min	$2.5\text{x}10^{3}\pm1.6\text{x}10^{3}$	$1.6\text{x}10^{5}\pm3.8\text{x}10^{4}$	$2.9\text{x}10^{3}\pm1.8\text{x}10^{3}$	$1.8\text{x}10^{3}\pm9.0\text{x}10^{2}$
130keV, 22 μA, 6min	<10	<100	<10	<10
160keV, 40 μA, 0.5min	$7.4\text{x}10^{2}\pm1.8\text{x}10^{2}$	$1.3\text{x}10^{5}\pm4.5\text{x}10^{4}$	$2.0\text{x}10^{3}\pm8.9\text{x}10^{2}$	$9.7\text{x}10^{2}\pm8.0\text{x}10^{2}$
160keV, 40 μA, 3min	<10	<10	<10	<10
gamma ray, 2.5 kGy	$2.2\text{x}10^{4}\pm3.6\text{x}10^{3}$	$3.2\text{x}10^{5}\pm4.2\text{x}10^{4}$	$2.5\text{x}10^{4}4\pm.7\text{x}10^{3}$	$2.0\text{x}10^{3}\pm1.2\text{x}10^{3}$
gamma ray, 5.0 kGy	$3.3\text{x}10^{3}\pm1.6\text{x}10^{3}$	$8.4\text{x}10^{4}\pm3.8\text{x}10^{4}$	$4.6\text{x}10^{3}\pm1.4\text{x}10^{3}$	<100
gamma ray, 7.5 kGy	$5.8\text{x}10^{2}\pm1.9\text{x}10^{2}$	$7.4\text{x}10^{3}\pm3.2\text{x}10^{3}$	$7.5\text{x}10^{2}\pm6.3\text{x}10^{1}$	<10
gamma ray, 10.0 kGy	<10	$6.3\text{x}10^{2}\pm3.2\text{x}10^{2}$	<10	<10
gamma ray, 12.5 kGy	<10	<100	<10	<10

a ; untreated sample
b ; data not obtained
(HAYASHI, T. et al., 1997) [6]

Viscosity of heat-gelatinized grain suspensions decreased with the energy of electrons (Table 2) [6]. Viscosity of brown rice and wheat treated with electrons at 75 keV was almost the same as that of untreated samples. Viscosity of rough rice and buckwheat exposed to electrons at 130 keV was slightly lower than that of untreated samples, but much higher than that of the samples irradiated with gamma rays at 10 kGy. The viscosity values of a grain suspension which was heat-gelatinized under an alkaline condition is a parameter for starch degradation[7,8]. The results suggested that electrons with minimum energy for decontamination did not degrade starch molecules inside the grains.

Table 2. Viscosity of 7.5% aqueous suspensions of grains exposed to low-energy electrons or gamma rays (mPa.s)

	Brown rice	Rough rice	Wheat	Buckwheat
Control[d]	211.1±12.5[c]	149.5±7.7[c]	287.4±18.2[bc]	211.3±21.6[c]
75keV, 8μ_A, 40min	206.0±3.5[c]	-----[e]	293.6±12.5[bc]	-----
100keV, 14μA, 20min	185.9±8.6[ac]	147.3±8.9[c]	246.6±10.8[ac]	199.9±25.4[c]
130keV, 22μA, 6min	146.7±11.9[ab]	137.3±7.3[c]	206.4±3.5[ab]	192.5±6.4[c]
160keV, 40μA, 3min	136.2±4.6[abc]	133.4±4.8[ac]	192.8±8.0[abc]	165.6±7.5[abc]
210keV, 40μA, 3min	88.5±3.0[abc]	105.5±6.8[ab]	133.6±3.6[abc]	108.7±0.9[abc]
Gamma-rays, 0.1kGy	198.4±4.1[c]	138.3±5.6[c]	246.5±3.4[ac]	189.6±12.2[c]
Gamma-rays, 0.5kGy	160.8±8.3[ab]	117.9±5.5[ab]	211.3±4.7[ab]	143.2±8.3[ab]
Gamma-rays, 10.0kGy	21.1±1.0[abc]	31.9±4.9[abc]	34.6±1.7[abc]	26.8±4.6[abc]

a, significantly different from Control ($p<0.05$)
b; significantly different from samples irradiated at 0.1 kGy with gamma-rays ($p<0.05$)
c; significantly different from samples irradiated at 0.5 kGy with gamma-rays ($p<0.05$)
d; untreated sample
e; data not obtained
(HAYASHI et al., 1997) [6)]

The applicability of soft-electrons to wheat depended upon the variety of wheat. Soft-electrons could decontaminate wheat grains of Australian Standard White (ASW), Shirogane and Western White (WW) varieties, but could not decontaminate those of Dark Nórthern Spring (DNS), Norin No. 61 and No. 1 Canadian White (1CW) varieties[9)]. No relationship was observed between the application of soft-electrons and the sensitivity of the contaminating microorganisms to gamma-rays. The difference in the application of soft-electrons was ascribed to the structure of the wheat grain. In varieties such as DNS, Norin No. 61 and 1CW, microorganisms would reside in areas which soft-electrons did not reach.

3.1.2 Quality of milled rice prepared from brown rice treated with soft-electron

Both Koshihikari and Nihonbare could be decontaminated with soft-electrons even at 60 keV[5)]. No significant difference in the viscosity was observed at any milling yield between the control and the rice grains exposed to electrons at 60-90 keV. Milling reduced the effect of electrons on the viscosity; milling of rice grains at a yield of 88% did not result in a significant difference in the viscosity between untreated samples and 100 keV-electron treated samples[5)]. However, milling did not affect the viscosity of rice irradiated with gamma-rays. The results suggested that soft-electrons degraded starch molecules near the surface of rice grains, which could be removed easily by milling. On the contrary, gamma-rays degraded all the starch molecules in rice grains most of which could not be removed by milling[5)].

TABLE 3 TBA values of rice which were exposed to low-energy electrons or gamma rays followed by milling (nmol/g of rice)

treatment	milling yield 100%[b]	92%[b]	90%[b]	88%[b]
control[a]	17.69±1.55	4.95±0.38	4.75±0.69	4.23±0.81
60keV, 4μA, 45min	29.68±2.66[c]	7.98±0.20[c]	5.18±0.70	4.75±0.57
75keV, 8μA, 30min	34.21±0.49[c]	9.05±0.83[c]	8.37±0.80[c]	5.43±0.77
90keV, 10μA, 25min	41.45±0.90[c]	15.55±3.96[c]	9.47±0.71[c]	9.43±0.93[c]
100keV, 14μA, 15min	57.66±2.47[c]	19.74±0.67[c]	14.33±0.28[c]	13.70±0.74[c]
gamma-ray, 7.5kGy	60.59±5.64[c]	46.59±3.96[c]	43.83±3.08[c]	43.23±4.70[c]

[a] untreated sample
[b] n=3 ; mean standard deviation
[c] significantly different from control ($p<0.05$)
(HAYASHI et al., 1998)[5)]

Thiobarbituric acid (TBA) value is a parameter of lipid oxidation. TBA value of brown rice increased with the energy of electrons. TBA values of brown rice samples exposed to electrons at 60-100 keV were significantly higher than that of untreated control (Table 3)[5)]. The use of gamma rays at 7.5 kGy resulted in a higher TBA value than that of electrons with energies of 60-100 keV. Milling decreased the TBA values of all the samples, especially those of electron-treated samples. Accordingly, the differences in the TBA values between the control and the electron-treated rice grains decreased markedly after milling. The difference in the TBA values between the control and the rice samples exposed to electrons at 60 keV was not significant at a milling yield of 90% or lower, and the difference between the values of the control and the rice samples exposed to electrons at 75 keV was not significant at a milling yield of 88%. The results suggested that most of the lipids oxidized by electrons at 60 and 75 keV were removed by milling at yields of 90 and 88%, respectively.

Hardness and stickiness under low and high compressions of cooked rice grains (90% milling yield) exposed to electrons at 60-75keV were almost the same as those of the control[5)]. Hardness and stickiness under low and high compressions of gamma-irradiated samples were lower than those of the control. Hardness and stickiness under low compression are parameters for rheological properties of the surface of cooked rice grains, and those under high compression are parameters for the properties of overall cooked rice grains[10)]. The results showed that rice grains which were exposed to electrons at 60-75 keV and milled at a yield of 90% displayed the same rheological properties as the control. The results indicate that milling at yields of 88-90% removed the portion of rice exposed to electrons at 60 keV which could eradicate most of the microorganisms contaminating brown rice.

3.2 Decontamination of other ingredients

Green tea leaves were exposed to electrons at 100keV reduced the microbial load to undetectable levels without affecting the color and aroma to an extent to reduce the commercial value[11].

Soft-electrons at 100 keV reduced the microbial loads of shredded dehydrated vegetables to levels lower than 10 CFU/g, although the time necessary for electron treatment was different[9]. Longer duration of electron treatment was necessary for dehydrated vegetable samples which required a higher dose of gamma-rays for disinfection. The microorganisms contaminating dehydrated vegetables showed the same resistance to soft-electrons as to gamma-rays. Black pepper could be decontaminated with electrons at 210 keV, while white pepper, basil and coriander could be decontaminated at 100 keV. Pulses such as soybean, adzuki bean and black soybean could be decontaminated with electrons at 60 keV[12].

4. Decontamination of Seeds

Electrons at 60-75keV reduced microbial counts of seeds of radish (Kaiware-daikon) and alfalfa to undetectable levels without any detrimental effects on the germination ability[13]. However, electrons at 90keV or higher lowered the germination percentage of radish sprout seeds and electrons at 100keV lowered that of alfalfa seeds. Soft-electrons could decontaminate seeds of mungbean without detrimental effect on germination[14].

5. Inhibition of Sprouting

Initiation of sprouting of potatoes was retarded by the treatment with electrons at 160keV, and the sprouting was inhibited by electrons at 250 keV or higher[14]. However, the tubers treated with electrons at 100 keV started to sprout at the same time as the untreated samples.

6. Control of insect pests

Soft-electrons with doses of 65 keV or higher at low doses inactivated eggs, pupae, larvae of red flour beetle and Indian meal moth, and adults of these insects could be inactivated by the treatment at higher doses[15].

References

1) HAYASHI, T. (1991): Comparative effectiveness of gamma rays and electron beams in food irradiation. *In* Food irradiation. ed. by THORNE, S. Elsevier Science Publisher, Inc., London, UK, 167-216.

2) MCLAUGHLIN, W. L. et al. (1979): The response of plastic dosimeters to gamma rays and electrons at high absorbed dose rates. *Radiat. Phys. Chem.*, 14, 535-550.

3) ICRU. (1984): Stopping powers for electrons and positrons. ICRU Rep. 37. International Commission on Radiation Units and Measurements, Bethesda, USA.

4) TABATA, T. & TANAKA, R. (1990): Fundamental data on electron beam dosimetry. *In* Radiation dosimetry of electron beams for radiation processing. ed. MORIUCHI.Y. Chijinshokan Publisher, Inc., Tokyo, Japan, 109-135 [In Japanese].

5) HAYASHI, T., OKADOME, H., TOYOSHIMA, H., TODOROKI, S. & OHTSUBO, K. (1998): Rheological properties and lipid oxidation of rice decontaminated with low-energy electrons. *J. Food Protect.*, 61, 73-77.
6) HAYASHI, T., TAKAHASHI, Y. & TODOROKI, S. (1997): Low-energy electron effects on the sterility and viscosity of grains. *J. Food Sci.*, 62, 858-860.
7) HAYASHI, T., TODOROKI, S. & KOHYAMA, K. (1993): Applicability of viscosity measuring method to the detection of irradiated spices. *J. Jpn. Soc. Food Sci. Technol.*, 40, 456-460.
8) HAYASHI, T., & TODOROKI, S. (1996): Detection of irradiated peppers by viscosity measurement at extremely high pH. *Radiat. Phys. Chem.*, 48, 104-104.
9) HAYASHI, T. (1998): Decontamination of dry food ingredients and seeds with "Soft-electrons" (low-energy electrons). *Food Sci. Technol. Int., Tokyo,* 4, 114-120.
10) OKADOME, H., TOYOSHIMA, H. & OHTSUBO, K. (1996): Many-sided evaluation of physical properties of cooked rice grains with a single apparatus. *J. Jpn. Soc. Food Sci. Technol.*, 43, 1004-1011 [In Japanese with English summary].
11) HAYASHI, T., NAKAOKA, M., TSURUOKA, M., TODOROKI, S. & MIIKE, M. (1999): Effects of soft-electrons on the sterility and quality of tea leaves. *J. Jpn. Soc. Food Sci. Technol.*, 46, 633-637 [In Japanese with English summary].
12) HAYASHI, T., TAKAHASHI, Y. & TODOROKI, S. (1998): Sterilization of foods with low-energy electrons ("Soft-electrons"). *Radiat. Phys. Chem.*, 52, 73-76.
13) HAYASHI, T. & TODOROKI, S. (1999): Effects of soft-electrons on the microbial counts and germination of seeds of radish sprout (Daikon) and alfalfa. *J. Jpn. Soc. Food Sci. Technol.*, 46, 754-757 [In Japanese with English summary].
14) TODOROKI, S. & HAYASHI, T. (2000): Disinfection of seeds and sprout inhibition of potatoes with low energy electrons. *Radiat. Phys. Chem.*, 57, 253-255.
15) IMAMURA, T., TODOROKI, S., SOTA, N., NAKAKITA, H., IKENAGA, H. & HAYASHI, T. (2002): Effect of 'soft-electron' (low energy electron) treatment on three stored product) insect pests. *J. Stored Product Res.*, (submitted).

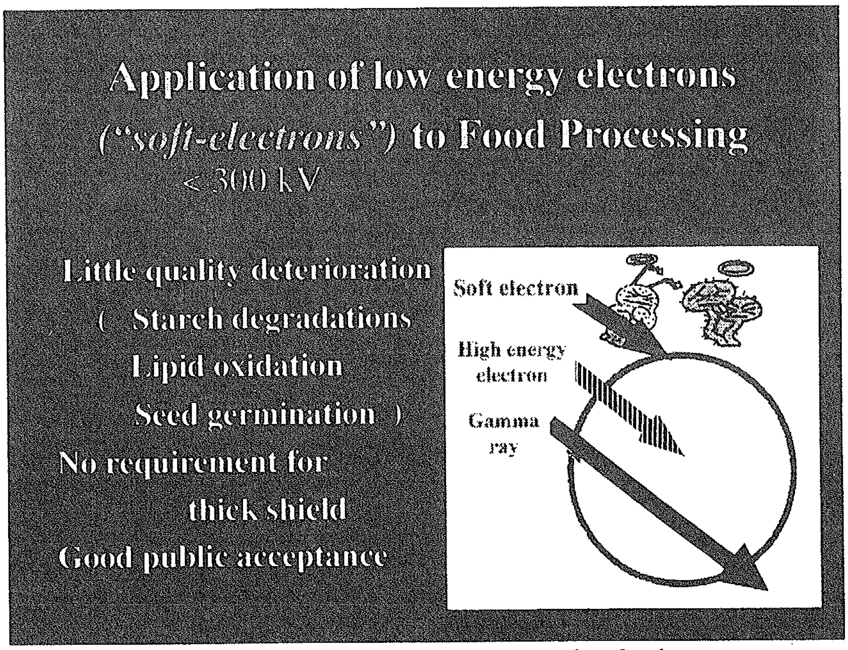

Fig.1 Penetration and advantage of soft-electron

5.5 Application to the Radiation Processing of Polymer

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Abstract

Polypropylene (PP) and biodegradable polymer (blend of poly(ε -caploracton) 30/polybutylenesuccynate70), PHB02 were irradiated with an electron beam to improve processability for production of thin film and foam. The processability of the polymer was improved due to enhancement of melt strength with irradiation at the dose range between 10 and 100 kGy. Increase of melt strength is due to entanglement of branch structure formed by irradiation. Possibility of high-speed production of thin film and production of foam have been achieved by this process. The soil degradation test showed that biodegradable polymer film buried in the soil was almost entirely degraded (97%) after two months and completely degraded after two and a half months. In the case of foam samples, 65% degradation was achieved after four months.

Radiation crosslinked water-soluble polymer form hydrogel, which absorb much water. The hydrogel prepared by irradiation of polymer in aqueous solution was applied as dressing for healing of wound. In order to evaluate the healing effect of the polyethylene oxide (PEO) hydrogel dressing, wounds formed on the back of marmots were covered by the hydrogel. The healing under the wet environment of the hydrogel dressing had three advantages, compared with that of gauze dressing, which gives a dry environment: (1) enhancement of healing rate, (2) facilitation for changing the dressing, i.e. the hydrogel can be peeled off without any damage to the regenerated skin surface, and (3) hydrogel dressing material does not remain stuck on the wound.

1. Introduction

Polymer materials can be well modified by grafting, degradation and crosslinking with high-energy radiation. These techniques are useful to induce new properties of polymer materials and application fields are expanded. Electron beam (EB) accelerator is classified to low energy EB (<300MeV) and high energy EB (>1 MeV). As you know well, the high energy EB is used for pre-vulcanization mobile tires, crosskinking of insulation cable and shrinkable materials and for sterilization. The low energy accelerators are used mainly for surface modification of polymer materials, wood and paper. 98% of polymer materials in radiation processing are modified by crosslinking techniques. Modification by grafting and degradation is a very few. Radiation crosslinking is effective for improvement of heat resistance and processability of polymer materials. Water-soluble polymer crosslinked by irradiation forms hydrogel, which absorbs much water in its network structure.

In this article, two topics are reported. One is improvement of processability of PP and biodegradable polymer with irradiation. Other one is application of wound dressing hydrogel formed by using radiation crosslinking techniques.

2. Improvement of processability of polymer materials

2.1 Processability of irradiated PP

Film and bottles are molded by an extruder and inflation using thermoplastics such as polyethylene (PE) or polypropylene (PP). Properties of these products are greatly affected by molecular weight, crystallinity, melt strength and molding techniques. Melt strength (melt flow) is important factor to control the process of molding. Since PP has low melt viscosity, it is difficult to produce thin film and foam by molding. PP having high melt strength can mold thin film with high speed and foam. Irradiation of EB can form branch structure for PP to induce high melt strength [1]. Irradiation process of PP, which establish high melt strength is shown in Figure 1. PP powder come to the belt from tank 10 and is irradiate by EB accelerator 25. After

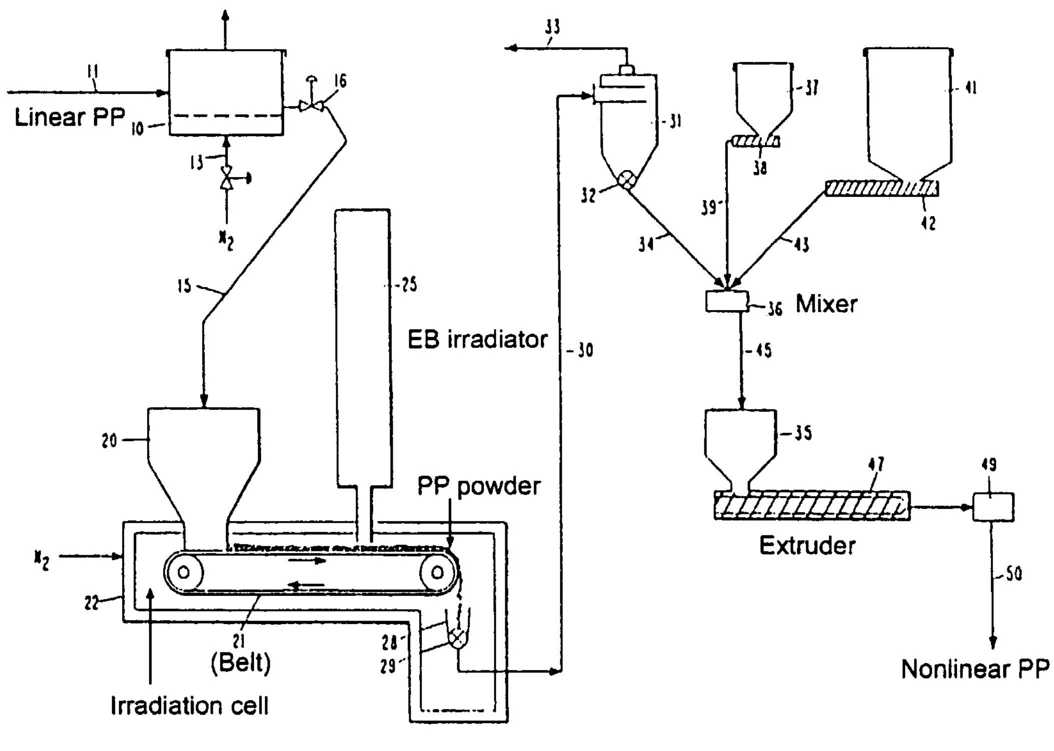

Figure 1 Irradiation system to produce high melt strength PP

that, irradiated PP powder is mixed with additives, antioxidant and nucleating agent in tank 36 and the mixture are palletizes in extruder 47. This modified PP is supplied to users for production of film, foam and bottles. Melt strength of PP increases remarkably at 50 kGy with irradiation in nitrogen gas atmosphere (Figure 2). Here, we report that EB accelerators from 500 to 4,000 kV are effective for production of high melt strength PP.

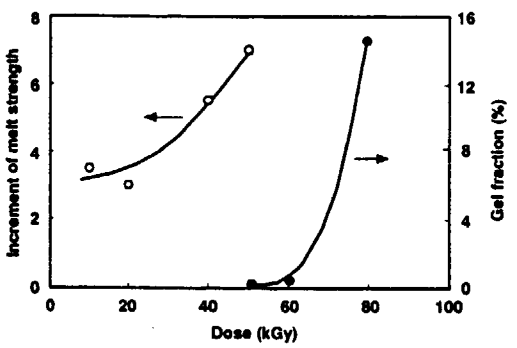

Figure 2 Melt strength of irradiated PP.

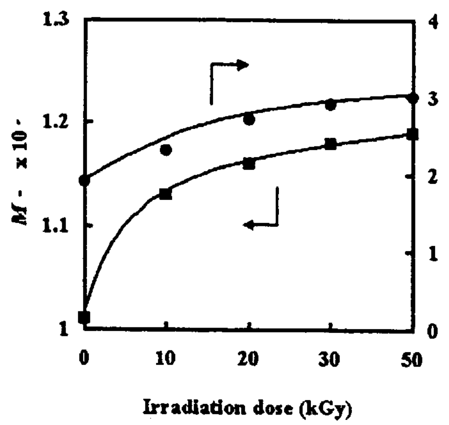

Figure 3 Molecular weight and polydispersity of irradiated biodegradable polymer.

2.2 Process ability of biodegradable polymer

Biodegradable polymer such as poly (ε -caploracton) and poly(butylene succinate) convert to carbon dioxide and water by bacteria under soil. So these polymers are environmental acceptable polymer. But biodegradable polymer has poor process ability as well as PP, because of low melt strength. Thus biodegradable polymer was irradiated at relatively small dose to enhance melt strength [2]. The polymer is still dissolve in chloroform, because no gel production. Figure 3 shows molecular weight of irradiated biodegradable polymer (blend sample of poly(ε -caploracton) 30/polybutylenesaccinate70, PHB02 produced by Dicel Chem. Industry Ltd.). The number-average molecular weight and polydispersity (Mw/Mn) increase with increasing dose. The increase in molecular weight is due to formation of a branched chain. To explain the behavior of the PHB02 sample, dynamic viscoelastic properties before and after irradiation are determined as shown in Figure 4. It can be seen that the dynamic modulus drop very steeply above the melting point, 100℃ for an unirradiated PHB02 due to melting of the crystalline part. On the contrary, the PHB02 irradiated with 30 kGy show a steady decrease in E' from the above melting point up to 230℃. A higher dynamic modulus of the irradiated PHB02 at an elevated temperature is probably due to the entanglement of the branch structures formed during irradiation. By this modification, the higher modulus for irradiated PHB02 still keep above the melting point for a wide temperature ranges. Thus, the melt down of polymer during a blow molding process can be prevented and process becomes easier.

Irradiated PHB02 was blow-molded at 140℃ to produce a film. The molding of unirradiated PHB02 was carried out by a slower speed of 2 m/min because of its lower melt strength, while for PHB02 irradiated at 30kGy, high speed molding at 30 m/min was achieved. Irradiated PHB02 has 15 times the molding speed compared with unirradiated PHB02 and this speed corresponds to the molding speed of polyethylene. In the molding of thin film, 7 μm was achieved as a minimum thickness.

In the foam production of polymeric materials, a blowing or foaming agent is kneaded to the polymer by using an extruder. After irradiation, the polymer is heated at a temperature higher than the decomposition temperature to the foaming agent; making a lot of bubbles in the polymer produces thereafter foam products. Polymer having a low melt viscosity is breaking during the forming process. Hence, it is difficult to produce foam for unirradiated PHB02. Figure 5

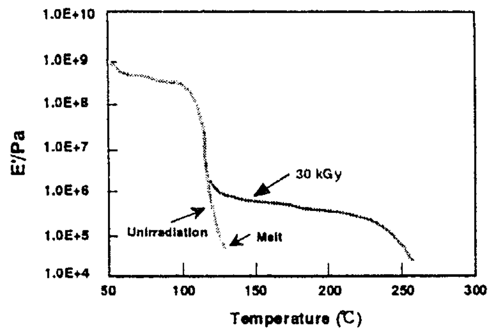

Figure 4 Dynamic viscoelastic property of irradiated biodegradable polymer.

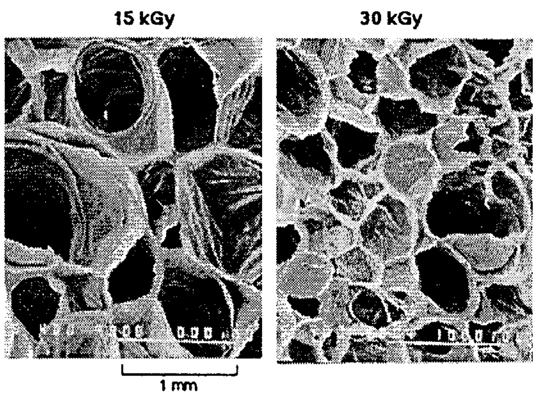

Figure 5 Cross-section of biodegradable foam.

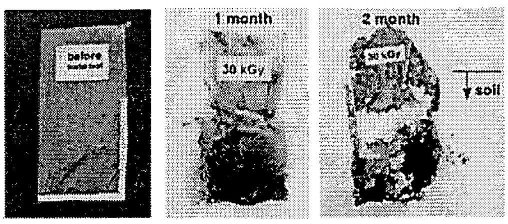

Figure 6 Biodegradable film as garbage bags before and after soil burial test.

shows the foam cross-section of PHB02 irradiated with 15 and 30 kGy, produced by molding at 110℃. A lower dose of 15 kGy has a larger hole than 30 kGy because of the lower melt strength. According to these results, hole size can be controlled by the irradiation dose.

2.3 Soil burial degradation test

To use PHB02 as garbage bags, the PHB02 film sample was buried together with garbage bags in the soil. Several factors such as temperature, pH, oxygen concentration, humidity and the availability of mineral nutrients affect the soil burial test result. As shown in Figure 6, it can be seen that after 2 months almost half of the garbage bags were well degraded, especially garbage bags, which were put inside the soil at 30 – 50 mm depth. In this case, since oxygen and moisture diffuse well, a lot of living microorganisms exist in this region. Hence, garbage bag films were degraded for this a reason. The degradation of foam was also evaluated by observing the appearance of the foam surface as shown in Figure 7. After one month (part 2) the color of the surface changed, but there was no significant change in the percentage of weight loss. After two months (part 3) some parts of the samples were degraded, but other part seem to have changed only in color. The degradation effects can be seen clearly after the samples was buried up to four months (part 4) and 65% degradation was achieved.

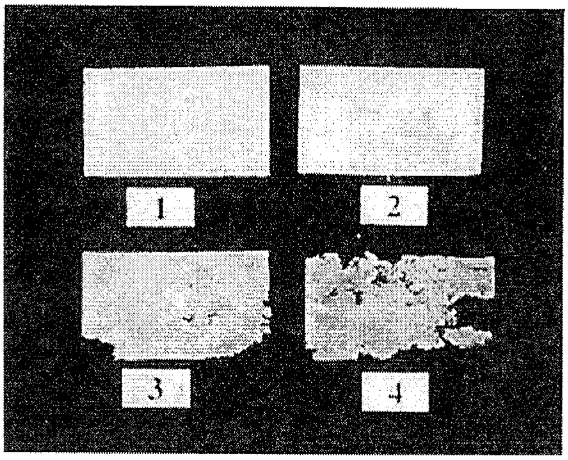

Figure 7 Soil burial test of foam.
(1) before burial test, (2) after 1 month
(3) after 2 months, (4) after 4 months

3. Hydrogel type wound dressing

In 1960, Winter found that moist environment of wound covered by wet material is effective for the healing process [3]. After that, hydrocolloid type dressing formed by blending of natural rubber latex and caroxymethylcellulose was developed. Hydrogen gives wet environment for wound, hence it was considered as useful for applications on wound dressing.

3.1 Crosslinking behavior of water soluble polymers, PEO and PVP were irradiated at various phases[4]. Irradiation was carried out at vacuum conditions except for aqueous solution. The PVA undergo crosslinking at molten state and in aqueous solutions, but crosslinking in solid phase at room temperature is not observed. PVP undergoes crosslinking at solid phase and aqueous solution by irradiation, however irradiation at molten state results in discoloration. Thus, this irradiation is not preferable for crosslinking of PVP. Three types of PEO with different molecular weight were irradiated to form hydrogel. Irradiation induces crosslinking of PEO at every examined phase. The crosslinking was remarkably affected by molecular weight and irradiation temperature. PEO gives the highest gel fraction at a temperature higher than its melting point, e.g. at 70℃. High molecular weight samples of PEO are better for crosslinking at every phase. The high molecular weight PEO (3.8×10^6) has gel fraction of 40% even 0 kGy, due to entanglements of molecules chains. Hence, gel fraction of 80% is obtained at low dose, 30 kGy. Figure 8 shows the gel fraction of middle molecular weight PEO (4×10^5) irradiated at three phases. Among them, irradiation in an aqueous solution gives the highest gel fraction and a required dose for crosslinking is the smallest. It is considered that acceleration

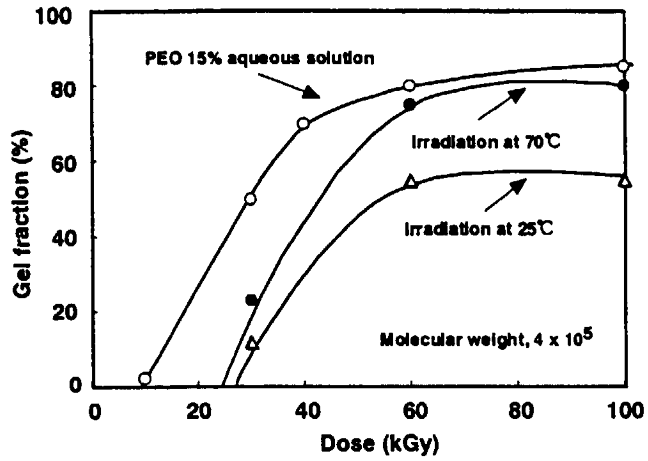

Fig.8 Crosslinking of PEO at various phases

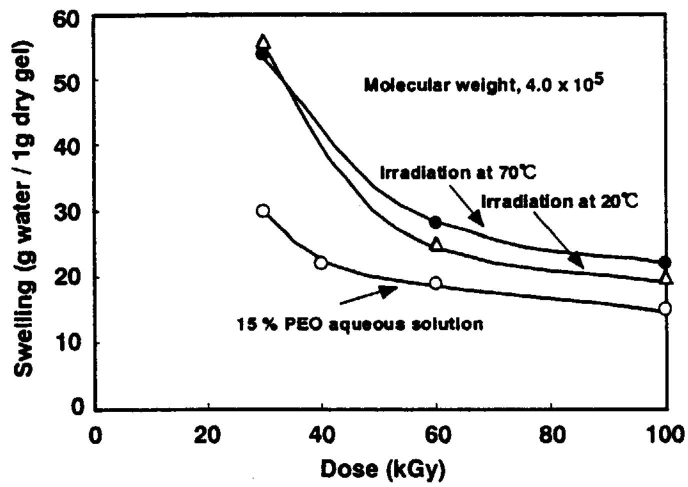

Fig.9 Swelling behavior of crosslinked PEO.

of crosslinking is due to a contribution of OH radical formed by radiolysis of water. To elucidate swelling properties, PEO irradiated at various phases were immersed in water for 48 hours. Swelling reflects crosslinking density and low swelling gels have high crosslinking density. According to Figure 9, PEO irradiated in aqueous solutions give the highest crosslinking density and 1g dry gel absorb water of about 20 g at 40 ~ 60 kGy.

3.2 Evaluation of PEO hydrogel for wound dressing

The PEO hydrogel was prepared for healing test of wound and applied as a dressing to five marmots. The γ-sterilized hydrogel was applied to the wound formed on the marmots back. The dressings usefulness was evaluated by taking weights of the marmots during healing and the weight of the hydrogel before and after use. Simultaneously the healing ratio was determined as well. The regular gauze dressings were applied as a reference. In both cases of the hydrogel and gauze dressing, the weight of marmots decreased 5 ~ 10 % in the initial period (up to 7 days) owing to the wound and after that time the weight increased gradually with healing. The dressing was changed three times, after 4, 7, and 11 days during the healing period. Figure 10 shows the area of wound,

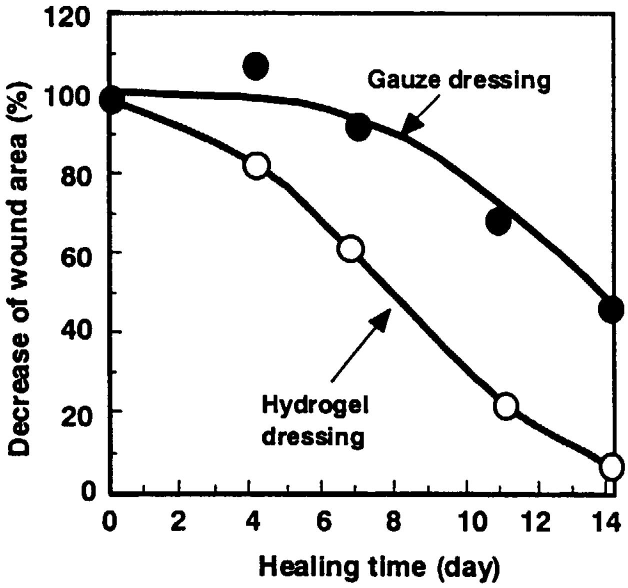

Fig.10 Healing of wound by gauze and hydrogel dressing

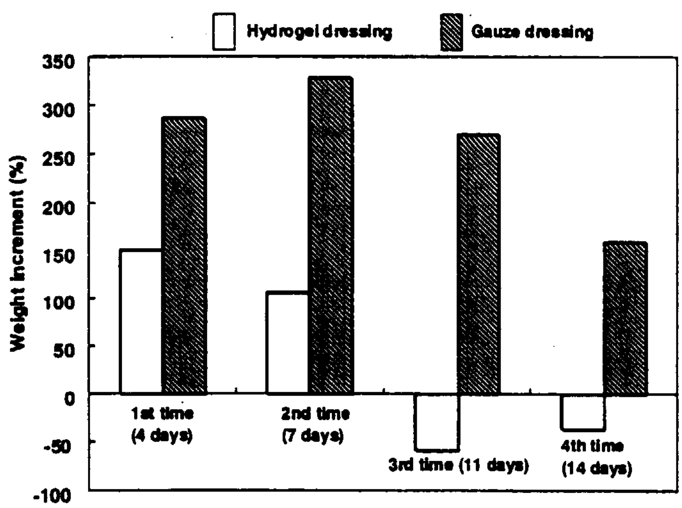

Fig.11 Absorption of effusion from wound of dressing during healing

which size decreases with time. The lower value for the shorter period reflects faster healing. An area of the wound covered by hydrogel decreases obviously with increasing healing period. Almost all wounds were healed after 14 days. On the contrary, the wound covered by gauze dressing reduced its size by only half a percent even after 14 days. According to these findings, healing is faster with the hydrogel dressing than with the gauze dressing.

We have reported that PVA hydrogel obtained by combination of acetalization and irradiation is durable after autoclave sterilization (121℃), and the hydrogel accelerates healing in comparison to gauze dressing [5]. The same tendency was also obtained in the case of PEO hydrogel. As shown in Figure 11, the weight of the hydrogel increases quickly at the earlier stages, up to 4 days, due to absorption of effusion produced on the wound. After that, the production of effusion ceases and weight of the hydrogel decreases due to evaporation of the water from the hydrogel. This means that the healing of wound proceeds smoothly with time. The hydrogel can be peeled off easily from the wound when the dressing needs changing. According to Figure 4, the weight of gauze dressing increases even 14 days, indicating that effusion from the wound continues due to the slower healing rate. Moreover, since the gauze dressing adheres closely to the wound, it gives additional damage for the wound during dressing change. It is concluded that wet environment formed by PEO hydrogel is effective for fast healing of wounds.

CONCLUSION

Melt strength of PP and biodegradable polymer increased by formation of branch structure in irradiation. This modification is effective for production of thin film and foam.

Radiation crosslinking of water-soluble polymers was carried out at solid and molten state, as well as in an aqueous solution. Among these phases, water-soluble polymer irradiated in aqueous solution induced crosslinking and formed hydrogel at the lowest doses. It was confirmed that PEO hydrogel crosslinked in an aqueous solution by irradiation is effective as a wound dressing. In conclusion, it was confirmed that relatively low energy accelerator is effective modification of polymer powder and synthesis of hydrogel sheet.

References

[1] U.S. patent No. 4,916,198 (1988).
[2] P. Nugroho, H. Mitomo, F. Yoshii, T. Kume and K. Nishimura ; Improvement of

processability of PCL and PBS blend by irradiation and its biodegradability, Macromol. Mater. Eng., 286, 316 – 323 (2001).

[3] Winter GD, A note on wound healing under dressings with special reference to perforated film dressing, J. Invest Dermatol, 45, 299 ~ 302 (1965).

[4] F. Yoshii, Y. Zhanshan, K. Isobe, K. Shinozaki, K. Makuuchi ; Radiat. Phys. Chem., 55, 133 ~138 (1995).

[5] F. Yoshii, K. Makuuchi, D. Darwis, T. Iriawan, Mt. Razak, J. M.Rosiak ; Heat resistant PVA hydrogel, Radiat. Phys. Chem., 46, 169 – 174 (1995).

5.6 EB Technology for the Purification of Flue Gases

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1.Introduction

Sulfur and nitrogen oxides in flue gas from coal-combustion boiler in thermal power plants, dioxins in flue gas from municipal waste incineration facilities and toxic volatile organic compounds (VOCs) in off-gas from painting or cleaning factories are one of the significant cause of destruction of forests and lakes by acid rain, photochemical smog, greenhouse effect, and cancer-causing/endocrine disruption in a living thing.

In Japan, emission of such air pollutants to atmosphere has been regulated from 1997. VOCs were especially controlled by the low named "Pollutant Release and Transfer Register" from 1999, by which companies should have responsible to report the government the record of their purchase(production)/transfer/storage/release of VOCs. Considerations of wastes based on the reduction, reuse and recycle in daily life are primary measures to conserve our environment, parallel with control technology development to support these measures.

Electron beam is the effective and easy controllable radiation source for treatment of flue gas. Compact self-shielded electron accelerators with acceleration voltages lower than 300 kV are also useable to gas amount up to about a few ten thousand m^3/h instead of MV-level accelerators installed in large shielded buildings. Such compact accelerators permit us to use them as parts in the conventional gas flow process of real-scale.

When flue gas or off-gas is irradiated by EB, most of energy is absorbed in air. Major components of such complex gases, namely nitrogen, oxygen, water and carbon dioxide form ions and excited molecules. Many oxidizing free radicals are formed in the course of neutralization of ions and stabilization of the excited molecules. Plenty of such radiation-induced radicals oxidize easily air pollutants even in very low concentration and decompose them into non-toxic substances or change them to removable substances through subsequent chemical reactions.

Outline of studies on EB treatment of flue gas/off gas done in JAERI so far is described in the present paper.

2.Purification of flue gas from a coal-combustion boiler in heat power station

Coal is not the main source of electricity production in Japan now, but is one of the alternatives in future. Coal-combustion gas contains SO_2 and NO_x, so that their removal from flue gas had been done by the wet chemical process involving large amount of waste-water treatment. Dry process using electron beam irradiation with spraying ammonia has been developed in stead of the wet chemical process, under collaborative work of Ebara corporation and JAERI from 1972 which is a pioneer of this technology development[1,2]. As above-mentioned, radiation-induced free radicals in air oxidize SO_2 and NO_x to form sulfuric and nitric acid, which immediately react

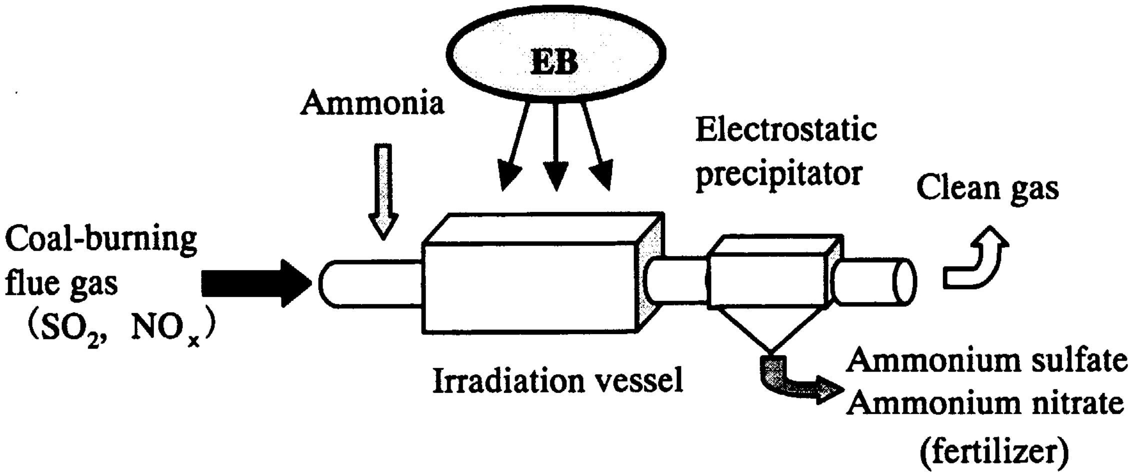

Fig.1 Typical flue gas treatment flow for removal of SO_2 and NO_x

with ammonia added under EB irradiation to form powdery ammonium sulfate and nitrate[2]. These are collected by electrostatic precipitator or bag filter and used as fertilizers. The process flow is shown in Fig.1 A potion of SO_2 reacts directly with ammonia without irradiation on the surface of pipe lining and radiation induced aerosols, so-called thermal reaction, and produce ammonium sulfate. The reaction of SO_2 depends on temperature during irradiation, while NO_x reacts proportional to absorbed dose at lower temperature than 100C[2, 3].

On the basis of laboratory-scale studies using model gases, JAERI, Ebara Corporation and Chubu electric power Co., Ltd. had the joint work to expand EB

Table1 Specification of EB application to a real-scale flue gas treatment in thermal power stations

	Chubu (JAPAN)	Chengdu (CHINA)	Pomorzarny (POLAND)	Maritsa-East (BULGARIA)
Flue gas rate(m^3/h)	620,000	300,000	270,000	10,000
Inlet cont.	1,500	1,800	400	5,500
SO_x (ppm)	160	400	250	320
NO_x (ppm)	11	8.5	6	22
H_2O (%)	92	80	70	90
Removal SO_x (%)	60	18	80	70
NO_x (%)	65	60	90	75
Gas temp. (℃)	6.7	3.2	4	1-2
Dose (kGy)	800kV, 500mA	800kV, 500mA	800kV, 375mA	800kV, 135mA
EB accelerator. Unit	6	2	4	1
Operation	2003-	1997-	2001-	2003-

treatment technology using a pilot plant in 1991-1993. The removal performance of higher than 90% and 80% are obtained at above 10 and 7 kGy, respectively, for treatment of flue gas containing 800 ppm SO_2 and 225 ppm NO_x at the flow rate of 12,000 m^3/h[3].

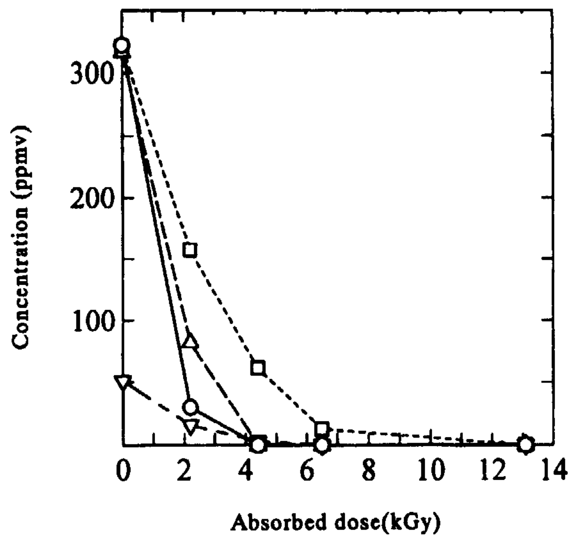

Fig.2.1 Decomposition of aliphatic VOCs

□Dichloroethylene ▽Trichloroethylene

○Tetrachloroethylene △Monochloroethylene

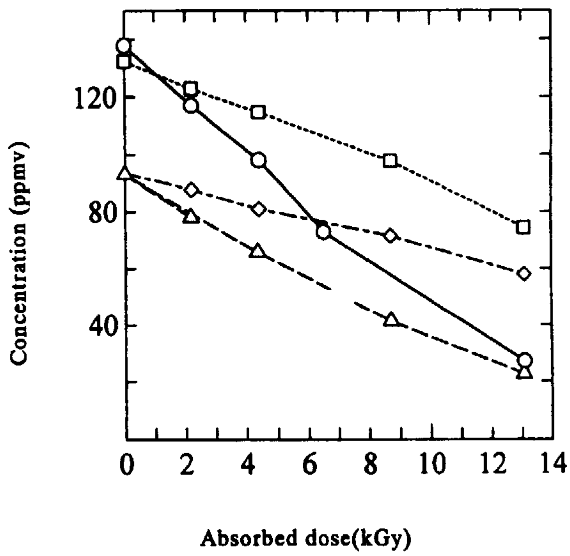

Fig.2.2 Decomposition of aromatic VOCs

□Chlorobenzene ◇Benzene ○Toluene△Xylene

The technology has also priority of cost performance both of construction and running cost considering through out of fertilizer, about 20% cost saving[1]. These achievements were applied to real-scale gas treatment at the thermal power stations such as Chengdu in China (operation started from 1997), Pomozany in Poland(operation started from 1997), Maritsa-east in Bulgaria (operation will start from 2003) and Nishi-Nagoya in Japan (operation will start from 2003).

3.EB treatment of toxic VOCs in air

EB treatment of toxic organic compound having high vaporization VOCs contained in off-gas from paint factories of washing/cleaning processes has been conducted mainly JAERI and Karlsruhe GmbH in Germany (terminated)[4-8].

For instance, chloroethene such as trichlooethylene and dichloroethylene, having double bond is decomposed completely to CO_2 and CO at a few kGy thorough chain reaction initiated by Cl radicals produced by the primary decomposition reaction, as shown in Fig.2.1. G-values of decomposition were in the order of tetrachloro-> trichloro-> trans-dichloro-> cis-dichloro-> monochloroethylene. These fundamental studies were mostly completed and will be applied to practical conditions in the near future.

While aromatic compounds such as chlorobenzene, xylene, and toluene have relatively low decomposition ratio of 50-80%, as shown in Fig.2.2. Aerosols are produced as about 30-60% of decomposed aromatic compounds, beside organic gaseous compounds such as carboxylic acids and aldehydes. Such gaseous products is further oxidized into lower molecular ones having lower toxicity. Further technology development on minimization of production of aerosols, removal of such aerosol with high efficiency is required for future development.

4.Decomposition of dioxins in flue gas from solid waste incinerators

Dioxins are classified into three groups: poly-chlorinated-di-benzo-dioxin (PCDDs), poly-chlorinated-di-benzo-furan (PCDFs), and some coplanar polychlorobenzen (coplanar PCBs). Each group has various compounds having different number of chlorine and their isomers, so that dioxins are about 220 compounds. Toxicity of dioxins is defined as total toxicity assuming all the dioxins are 2,3,7,8 PCDD having the highest toxicity, using unit of g-TEQ/m^3. Dioxins are very harmful but not easy to be decomposed in environment or our body, e.g., a half life is 10-12 years in soil. From this viewpoint, release of flue gas containing dioxin is controlled under no permission of its dilution.

Regulation of dioxin emission from the waste incinerators in Japan will be more strict from coming December 2002, e.g., 0.1 ng-TEQ/m^3 for a new 4-tons/h capacity incinerators. The development of technology to meet this requirement is urgent,

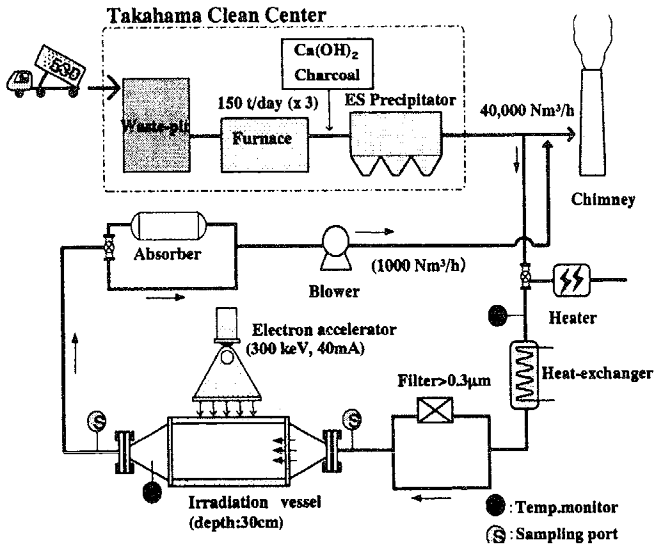

Fig.3 Apparatus for gaseous dioxin decomposition by EB

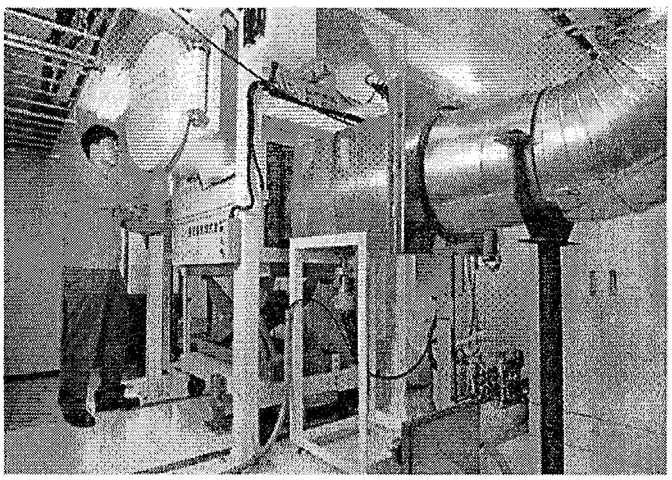

Fig.4 The low energy electron accelerator (drum) and the irradiation vessel in the decomposition-test apparatus (gas flow: right to left)

and should be extended to further suppression of dioxin emission in future.

In general, flue gas was released to atmosphere through electrostatic precipitators or bag-filters with splaying alkali chemicals and/or active charcoals to reduce dioxin amount in flue gas. These technologies need temperature control during operation and additional treatment process to lower remaining toxicity of collected waste. Treatments using catalysts, ozone and H_2O_2, high- temperature melting and so on have been tested for further treatment of flue gas and fly ash, but they are still under development. While electron beam technology for decomposition of dioxin after removal of fly ash have following advantages:

1) Dioxin in gas is decomposed into non-toxic substances without additional post treatment

2) Dioxin is decomposed even at very low concentration, which is difficult by filter or absorption process.

3) Control of temperature is not required in EB process.

4) Easy to attach with existing facilities because of its compact and simple process.

Karlsruhe GmbH in Germany studied decomposition of dioxin in flue gas from a model incinerator at 85C, with the flow rate of 1,000 m^3/h, using the electron accelerator with 200 keV and 40mA maximum. They report that decomposition ratio of 95-98% for PCDDs at 5-10kGy, and more than 90% for PCDFs at 10-15kGy[9)].

Extending these results, JAERI has carried fundamental experiment using real flue gas from incinerators of Takahama clean center under cooperation of the organization of Takasaki and other four town/villages hygiene facilities. The test apparatus was designed and constructed for treatment of flue gas at 200C with the flow rate of 1,000 m^3/h, 1/40 of the flue gas from one incinerator of 150 ton/day, using self-shielded-type electron accelerator of 300 keV and 40 mA at maximum, as shown in Fig.3 and Fig.4[11)]. The practical experiment under real gas conditions, complex and unstable composition gas and at elevated temperature as 200℃ is the first trial in the world. Gases before and after EB irradiation are sampled using absorption columns and pretreated through sophisticated process of extraction, condensation, purification and re-condensation of dioxins. The concentration of each isomers of PCDDs and PCDFs in the sample gases were measured with GC/MS(JEOL, JMS-700). Decomposition ratio before and after EB irradiation of 90% or higher was obtained

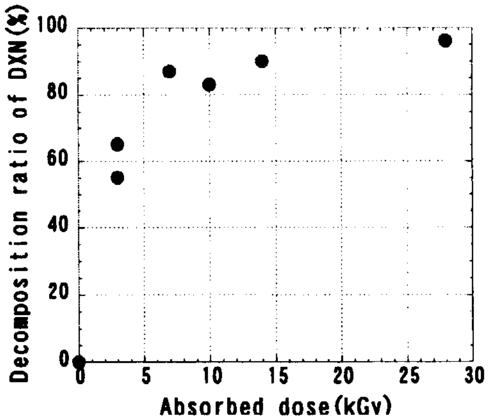

Fig.5 Decomposition ratio of gaseous dioxins (DXN) before and after EB irradiation

at above 15 kGy. Even initial concentration of around 1ng-TEQ/m^3 in incineration flue gas is reduced to 0.1ng/m^3 which is on the same level as the regulated emission border of dioxin concentration in the US and the EU. Concentrations for all the isomers were reduced showing the similar tendency, that means dechlorination of RCDD and RCDFs retaining their original structure was not observed and therefore possibilities of increase of toxicity causing reduction of Cl numbers. Cleavage of phenyl group, break of C-O bond, subsequent fragmentation included dechlorination might be occurred as dominant radiation-induced reaction. Low-toxicity of irradiated gas containing various fragment substances was also confirmed in terms of endocrine disrupter using enzyme immunoassay. Cost performance scale-up study considering efficiency and cost performance parallel with fundamental study on reaction mechanism will be continued aiming to apply to a real-scale incineration facilities.

Expansion of these flue gas purification technologies will be expected applying compact low-energy electron accelerators.

Reference

1) O.TOKUNAGA: "Environmental Application of Ionization Radiation", Chapter 6(p.99-112), Wiley & Sons, Inc.(1998)

2) O.TOKUNAGA N.SUZUKI: "Radiation chemical reactions in NOx and SO_2 removals from flue gas", Radiat. Phys. Chem., 24, 145-165(19843)

3) H.NAMBA, et al.: "Pilot-scale test for electron beam purification of flue gas from coal- combustion boiler", Radiat. Phys. Chem., 46, 1103-1106(1995)

4) H.R.PAUR: "Removal of volatile hydrocarbons from industrial off-gas, NATO ASI series, Vo;.G34, Part B, p.77-89(1993)

5) H.MATING, K.HIROTA, K.WALETZ, H.R.PAUR: "Product study of the electron bean induced degradation of volatile organic compounds (VOC), J. Aerosol Sci., 25, Suppl. 1, S325-S326 (1994)

6)T.HAKODA、 G.ZHANG and S.HASHIMOTO: "Decomposition of chloroethenes in electron beam irradiation", Radiat. Phys. Chem., 54,541-546(1999)

7) K.HIROTA, T.HAKODA, H.ARAI and S.HASHIMOTO: "Dechlorination of Chlorobenzene in air with electron beam", Radiat. Phys. Chem., 57, 63-73(2000)

8) S.HASHIMOTO, T.HAKODA, K.HIROTA and H.ARAI: "Low energy electron beam treatment of VOCs", Radiat. Phys. Chem., 57, 485-488(2000)

9) H.R.PAUR, W.BAUMANN, H.MATZING and K.JAY: "Electron Beam Induced Decomposition of Chlorinated Aromatic Compounds in waste incinerator off-gas", Radiat. Phys. Chem., 52, 355-359(1998)

10) S.HASHIMOTO, K.HIROTA, T.HAKODA and M.TAGUCHI: "Electron beam decomposition of organic pollutants in gases", Proceeding of the 23rd KAIF-JAIF seminar on nuclear industry, Souel, Korea, 251-263(2001).

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5.7 Report on Recent Over-exposure Accidents with a Medical Linac in Japan

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ABSTRACT-
On December 21, 2001, at a hospital in Tokyo, an engineer setting a medical-linac was over-exposed by the equipment due to lack of communication between workers. The exposed dose was initially reported as 1000 mSv (1 Sv), but later revised to 200 mSv at most. The outline of the accident and the statistical data on radiation exposure accidents in Japan and the world are briefly overlooked.

1. OUTLINE OF THE ACCIDENT [1]

1.1 Situation

The National Okura Hospital set a medical-linac for X-ray radio-therapy of cancer in a "linac-CT" room of a newly built building. Toshiba Medical Systems Co. (hereafter TMS) and its subcontractor were installing the equipment. An employee, at the age of 34, of the subcontractor was working in the space (controlled area) above the ceiling of the linac-CT room to set the controlling system. This employee is not assigned to work with radiation, and did not have a personal monitor with him.
The apparatus being installed is not opened to date, but the typical speculation of linacs and X-rays irradiators that TMS deals are as listed in Table 1.

Table 1. Typical speculation of medical accelerators.

X-ray Energy		EB Energy
Low	High	
4 MV		
6 MV		
4 MV		3-7 MeV
6 MV		5-12 MeV
6 MV	10 MV	5-14 MeV
4 MV	10 MV	5-15 MeV
6 MV	10 MV	6-21 MeV

1.2 Radiation Accident

Two employees of TMS, both assigned to a radiation worker, turned on the equipment for a test. The linac directed X-ray for some 5 minutes. The distance to the engineer above the ceiling was about 3 meters. The exposed man came down from the ceiling, and the two TMS workers realized what had happened, then altered the authorities (Ministry of Education, Culture, Sports, Science and Technology, MEXT).

1.3 Dose Estimation

TMS irradiated X-ray placing a dosimeter in the room, and the exposed dose was estimated to 1 Sv. The detail of trace irradiation, including the dosimeter used, is not opened. However, the man was exposed at the edge where the X-ray diffused, and the real dose can be lower than 1 Sv. Detailed dose evaluation is now underway at the National Institute of Radiological Sciences (NIRS) in Chiba.
About a month later, as his lymph vessels, white blood vessels, etc., shows no abnormality, the dose was presumed to be less than 200 mSv, which is assumed the lower limit to observe a radiation induced clinical symptom.

1.4 Hospitalization

The exposed man was initially hospitalized in Toshiba Hospital in Shinagawa ward. He was then sent to the NIRS to undergo more tests, and had not show acute radiation symptom such as nausea and doing well. At the time of hospitalization, MEXT did not believe that the situation is life-threatening while a drop in white blood cell count would appear in about 3 weeks (but it does not seem to appear as mentioned in the previous section, probably due to the actual lower dose).
The man has not shown any radiation symptom, and was discharged from the hospital on January 15, 2002.

1.5 Cause

Investigation has revealed that the exposed employee and the two TMS employees visited the linac-CT room separately on the morning, and they did not inform each other of the contents and schedule of their work. According to the TMS official, it seems that though the TMS employee(s) called to evacuate from the room, the noise from the equipment might have prevented. It is a kind of a human error lacking of communication and confirmation.

1.6 Exposed Dose and Dose Limits

As the exposed dose was initially reported as 1000 mSv based on TMS's trace experiment, though it was revised less than 200 mSv based on clinical observation of the exposed man, the news was astonishing to the public. Japanese law, the law concerning to prevention of radiation hazards due to radioisotopes, requires that the exposed dose for a radiation worker must be lower than 100 mSv for any consecutive 5 years and 50 mSv for any 1 year. In the case of a public, the dose must be less than 1m Sv. As the worker was not a radiation worker, he is a public. Therefore his dose limit should be 1 mSv per year but the dose was estimated to 200 times higher at most and widely alleged to be 1000 times higher just after the accident.

Japan experienced a criticality accident in September 1999 at Tokai-mura, and three workers of a uranium processing company were severely exposed (16-20, 6-13, and 1-4.5 GyEq, respectively) and two of them died. This criticality accident is the accident of the highest dose in Japan's nuclear history, and frequently cited on media with the current over-exposure accident by a radiation generator.

As an exposure accident by radioisotopes, Japan experienced a severe exposure accident in September 1971 at Chiba. It was misuse of Ir-192 gamma source for non-destructive testing at a shipyard. Five men were exposed and the highest of which is 1.2 Sv, losing his fingers after 22 years. Table 2 lists dose in these exposure accidents and dose limits in Japan.

Table 2. Dose in this and past exposure accidents and Dose limits in Japan

Dose or Dose limit	Remarks
16-20 GyEq	U processing facility criticality accident (1999)-worker A
6-10 GyEq	U processing facility criticality accident (1999)-worker B
1- 4.5 GyEq	U processing facility criticality accident (1999)-worker C
1.2 Sv	Ir-192 radiological testing source misuse (1971)
1 Sv	THIS ACCIDENT (2001)(initial)
200 mSv	THIS ACCIDENT (2001)(revised)
100 mSv	Five-year dose limit for a radiation worker
50 mSv	Annual dose limit for a radiation worker
1 mSv	Annual dose limit for a public

2. STATISTICAL DATA ON RADIATION USE AND INCIDENTS IN JAPAN

2.1 Dose of Radiation Workers in Japan [2]

Table 3 lists the dose for radiation worker in Japan in fiscal year 1999. Dose to about 150,000 workers in total are generally well controlled below the dose limit of 50 mSv, keeping the most of them less than 5 mSv, except one case. The case is for a medical doctor who works in radiology department of a hospital, engaging in angiography for X-rays treatment; he was cumulatively exposed and the dose through the year exceeded 50 mSv. Though the doses of radiation workers are well controlled, relatively higher dose cases are observed for Hospitals and Clinics, and Industrial Firms.

Table 3. Dose for radiation worker in Japan for fiscal year1999 [2].

Dose in mSv		≦ 5	5-15	15-20	20-25	25-50	50 <	Total
USERS	Education al	43592	4	0	0	0	0	43596
	Research	48778	26	0	0	0	0	48804
	Hospitals	22879	194	15	4	4	1	23097
	Industrial	26683	271	43	1	0	0	26998
	Others	1961	24	0	0	0	0	1985
DEALERS		1468	75	1	0	0	0	1544
WASTE DISPOSERS		1235	0	0	0	0	0	1235
LESSORS		2	0	0	0	0	0	2
TOTAL		146598	594	59	5	4	1	147261

Table 4. The number of radiation users and generators in Japan as of March 2001 [3].

	Users		Generators*									
	Total	G*	Total	C	S	L	B	V	CW	T	M	P
Total	4837	823	1144	68	29	850	13	43	84	23	33	1
Hospitals & Clinics	793	654	787	31	2	724	5	-	-	-	25	-
Educational Organizations	485	36	60	-	3	13	-	16	25	1	2	-
Research Institutions	713	60	152	15	18	44	1	25	29	17	2	1
Industrial Firms	1927	66	136	21	6	64	7	1	28	5	4	-
Others	919	7	9	1	-	5	-	1	2	-	-	-

*G: Generators, C: Cyclotrons, S: Synchrotrons, L: Linear Accelerators, B: Betatrons, V: Van de Graaff Accelerators, CW: Cockcroft-Walton type Accelerators, T: Transformer-type Accelerators, M: Microtrons, P: Plasma Generators

2.2 The Number of Radiation Users and Radiation Generators in Japan [3]

Table 4 lists the number of radiation users and radiation generators in Japan as of March 2001. There exist almost 5000 radiation users (including unsealed and sealed radioisotopes, and radiation generators), 823 users and1144 units of radiation generators. Among the categories hospitals and clinics are the biggest users in the number of radiation generators, reaching 70 % of the total units. With respect to generator type, radiation generators, reaching 70 % of the total units. With respect to generator type, linacs occupy nearly 80 % of the total. Most of the accelerators used in Hospitals and clinics are linacs. Research institution and industrial firms follow hospitals and clinics in the number of generators. Linac is again most widely used, and Van de Graaff and Cockcroft Walton type accelerators are secondly widely used.

2.3 Radiation Incidents in Japan [2, 4]

Table 5 list the number of incidents reported to the authorities through the fiscal year of 1958-2000, since the enforcement of the regulation. The total number of reported incidents amounts to 131 cases. Loss, exposure, and contamination occupying over 80% of the total incidents and are major three causes of radiation accidents. In recent years, the orphan sources, unreported usage of radioisotopes etc., are often revealed. The exposure accidents happened every year during 1970s, but after 80s, it happens almost once in five years reaching 29 cases in total. Especially, exposure accidents by radiation generations happened only 5 times, moreover, most of them were before mid-70s. It is indicative statistically, that radiation generators have potential safety than radioisotopes. Simultaneously, it must be pointed out that the most recent case and the current exposure occurred in sequential two years after twenty-five years having no accident. The outline of the five cases is briefly reviewed in the next section.

2.4 Outline of Exposure Accidents by Radiation Generators in Japan [4]

(1) In 1959, at a public research institute in TOKYO, an employee was exposed by a Linac while a test-operation as the interlock was turned off.
(2) In 1966, at a prefecture research institute in OSAKA, an employee was exposed by a Van de Graaff during irradiation.
(3) In 1974, at a national research institute in CHIBA, an employee was exposed to proton beams from a Cyclotron due to leakage at the beam shutter.
(4) In 1974, at a research institute of a national university in MIYAGI, 6 researchers were exposed by a Linac as the interlock was out of order.
(5) In 2000, at an electronics industry in CHIBA, 3 workers were exposed by X-ray from a non-destructive tester as they turned off the safety system for high efficiency.

Table 5. The number of radiation incident in Japan through the fiscal year of 1958-2000.

FY	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
E*		2					1		1				1	4	2	1	3	1	1	1	1	1
by G*		1							1								2					
C*				1			1			1		1	1		1		2		1	1		
L*	1	1	1	3		2		1		1	1	2		1	2	2	4	2	1	1	2	2
U*																	1					
Others			2				1			1						1		3	1			
Total	1	3	3	4	0	2	3	1	1	3	1	3	2	5	5	4	10	6	4	3	3	3

80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	Total
	1			1		1						1						2		3	29
																				2	6
3				1					1				1				1		1	3	21
		2	2		3		1	2	2	3	3	4	1	1	1		1	3	2		61
									1										4	5	11
																					9
3	1	2	2	2	3	1	1	2	4	3	3	5	2	1	1	0	2	5	7	11	131

* E: Exposure, by G: by Radiation Generator, C: Contamination and Discharge,
L: Loss and Theft, U: Unreported sources

3. STATISTICAL DATA ON RADIATION ACCIDENTS IN THE WORLD

3.1 Radiation Accidents by Radiation Generators in the World [5]

Table 6 lists major radiation accidents by radiation generators in the world during 1945-2000 according to IAEA [5], showing 27 cases in total. Because the definitions of a radiation incident in Japan and a radiation accident for IAEA are different, the radiation incident 1-4 in Japan (2.4) are not involved in Table 6. IAEA lists 105 radiation accidents by radioisotopes and 23 accidents by reactors. Table 7 lists radiation accidents by period and country, and Table 8 lists radiation accidents by period and source (radiation generator type), respectively. These tables indicate the following trends. The radiation accidents are generally decreasing in number, but spreading worldwide and die hard. Namely, in 1960s USA, European countries, and former Soviet Union are the place of radiation accidents, but recently Asian countries also experience radiation accidents. Accidents by X-rays and EB die hard, while spectrometers, diffractometers etc., have accidents only in early days.

Table 6 Radiation Accidents by Generators in the World.

Year	Country	Source	Year	Country	Source
1960	USA	Electron beam	1977	USSR	Proton accelerator
1960	USA	X-rays	1978	USSR	Electron accelerator
1961	UK	X-rays	1980	GDR	X-rays
1963	France	Electron beam	1980	FRG	Radiography unit
1965	USA	Electron accelerator	1984	Peru	X-ray
1965	USA	Diffractometer	1985	China	Electron accelerator
1965	USA	Spectrometer	1985/ 86	USA	Electron accelerator
1967	USA	Van de Graaff accelerator	1990	Spain	Radiotherapy accelerator
1967	USSR	X-rays medical diagnosis facility	1991	USA	Electron accelerator
1970	Australia	X-rays	1992	Viet Nam	Electron accelerator
1970	USA	Spectrometer	1995	China	Electron accelerator
1974	USA	Spectrometer	1995	China	Electron accelerator
1975	FRG	X-ray	2000	Japan	X-ray non-destructive tester
1975	FRG	X-ray			

Table 7. Radiation Accidents in the World by Period and Country

Period	USA	UK	FRA	USR	AUS	GER	PER	CHN	ESP	VIE	JPN	Total
-69	6	1	1	1								9
70-79	2			2	1	2						7
80-89	1					2	1	1				5
90-99	1							2	1	1		5
00-											1	1
Total	10	1	1	3	1	4		3	1	1	1	27

Table 8. Radiation Accidents in the World by Period and Source (Generator type)

Period	X-rays	EB	Van de Graaff	Proton Accelerator	Spectro-meter	Diffracto-meter	Radiography unit	Total
-69	3	3	1		1	1		9
70-79	3	1		1	2		1	7
80-89	2	2						5
90-99		5						5
00-	1							1
Total	9	11	1	1	3	1	1	27

3.2 Outline of Recent Exposure Accidents by Accelerators in the World [4]

(1) In 1995, at a hospital in Beijing, China, 2 patients were exposed by medical treatment with a Linac.
(2) In 1995, at a cable works in Tianjin, China, 2 maintain workers were exposed by an electron accelerator during a test-operation.
(3) In 1992, at a national research institute in Hanoi, Viet Nam, an experimenter was exposed by a Microtron due to a failure of the interlock system and mal-control.
(4) In 1991, at an industrial facility in Maryland, USA, an operator was exposed by a Dynamitron due to dark current.
(5) In 1990, at a hospital in Zaragoza, Spain, 27 patients were exposed by a Linac due to a circuit-failure of and mal-repair by a service engineer, and 11 died.

4. ANALYSIS OF RADIATION ACCIDENTS BY RADIATION GENERATORS IN JAPAN AND THE WORLD

It is widely accepted that a radiation generator is potentially safer than radioisotopes, because a generator can be turned off immediately in case of need, whereas radioisotopes emits radiation continuously. Advantage in safety of radiation generators to radioisotopes is statistically shown. Radiation accidents by radiation generators are mostly experienced in early days of 1960s and 1970s. In most cases, the accidents happened while the safety system was intentionally off, or out of order. The reason why the safety system was off is typically during a test-operation, or for high efficiency. On the other hand, there are many accidents by generators such that happened due to a mistake in operation or repair. Lack of communication, knowledge, technical skill etc., is likely to underlie behind them. Cultivation of good team work, safety culture and technical ethics are essentially important, as well as technical aspects such as the adoption of interlock system, improvement in technical ability of each worker, and technical transfer from maker to user, between countries, and between generations.

5. CONCLUSION

An over-exposure accident in Japan December 2001 was reported. The points are, (1) the situation is a medical-linac in a hospital, (2) the dose is 20 mSv at most (initially reported as 1 Sv) to a non-radiation worker, and (3) the cause is lack of communication. This accident can be a bitter but important experience, but the author hopes that it can not be an obstacle nor hesitant for potential users of low energy electron accelerators. Statistical data on radiation users and accidents in Japan and the world was reviewed. The outlines of past radiation accidents are introduced.

REFERENCES

[1] Newspapers of December 23, 2001, and later.
[2] White Paper on Nuclear Safety 2001, Nuclear Safety Commission of Japan, 2001.

6. Response to the Questionnaire from Countries

6.1 China, QUESTIONNAIRE

Radiation Application / Utilization of Electron Accelerator

Respondent : Zhan Wenlong

Organization : Institute of Modern Physics, Chinese Academy of Sciences

Tel : 0086-931-4969213 Fax : 0086-931-8272100

e-mail :

1. Present Situation

1) γ-ray irradiation facility / electron accelerator for commercial use

What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in your country at present ? Please fill in the following table :

① γ-ray irradiation facility for commercial use

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks

② Electron accelerator

Name of company / organization Installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use
Jilin Radiation Chemistry Institute	1984	RDI	3 MV	40 mA	Shrinkable tube
Tianshui Cable Works	1989	INP Russia	2.2 MV	25 mA	Irradiation cross-linking cable and wire
Yantai Cable Works	1991	IHEP and INPAC	2 MV	20 mA	Irradiation cable
Institute of Engineering Physics	1987	Nissin HV Co.,Ltd.	3 MV	10 mA	Shrinkable tube
Xian Wire Work	1993	RDI	2 MV	30 mA	wire
Institute of Radiation Protection, Taiyuan	1993	INP Russia	2.5 MV	30 mA	Shrinkable tube & cable
Changshou Cable Works	1994	INP, AC	2.5 MV	20 mA	cable

Liyang Cable Works	1994	INP, AC	2.5 MV	20 mA	cable
Xinhua Cable Works	1995	INP, Russia	2.5/1.5 MV	30/40 mA	cable
Guangdong Cable Works	1995	RDI	2.5 MV	40 mA	cable
Institute of Changcum Chemistry	1994-1997 4 sets	INP, Russia	2.5/1.5 MV	30/40 mA	Shrinkable tube
Institute of Nuclear Technology	1995	INP, Russia	2 MV	20 mA	Shrinkable tube
Kunming Cable Work	1995	INP, AC	2.5 MV	30 mA	cable
Shangsi Cable Work	1995	RDI	2.5 MV	33 mA	cable
HuangsiCable Works	1995	RDI	2.5 MV	40 mA	cable
Sichuan Cable Works	1993	Shanghai Pioneer Factory	2 MV	10 mA	Shrinkable tube
Shenyang Special Cable Works	1995	S.P.F	2 MV	10 mA	cable
Dayu Shrink-Tube Works	1995/ 2 sets	S.P.F	2 MV	10 mA	Shrink tube
Tianjin Tech-Physics Inst.	1995	S.P.F	2 MV	10 mA	Shrink tube
Yangzhong Cable Works	1995	S.P.F	2 MV	10 mA	cable
Jianghai-Minhang Cable Works	1996	S.P.F	2 MV	10 mA	cable
Shanghai-Minhang Cable Works	1996	INP Russia	2.5 MV	30 mA	cable
Tianjin Cable Works	1997	IHEP, AC	2.5 MV	20 mA	cable
Lanxi Cable Works	1997	INP Russia	2.5 MV	40 mA	cable
Huaian Cable Works	1997	INP, AC	2.5 MV	25 mA	cable
Zhunhua Cable Works	1999	INP, AC	2.5 MV	25 mA	cable
Shenzhen Special Plastic Product	2000	INP Russia	2.5 MV	30 mA	Shrinkable tube
Sijiazhuang Cable Works	2001	IHEP,AC	2.5 MV	20 mA	cable

2) Please state about the rules and regulation for the management of the irradiation facilities, specifically. (about safety control and the law)

There are concrete-iron wall and floor according radiation-protection law of China to guarantee the safety control for workers.

3) Please state about the present situation of radiation processing

Total amount of production of radiation processing is about 3-4 billion RMB Yuan each year including shrinkable tube, cable and wire, food and vegetable as well as sterilization.

2. Future plan

1) Electron accelerator utilization technology
In what field /application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table:

Field	Target	From when	Title (contents)	Remarks
Environment	Flue gas	now	Removal SO_2 and NOx	
EB cure	film	3 years ago		

2) Electron accelerator
What type of accelerator does your country plan to have for the future ?
Please fill in the following table:

When	Accelerator voltage	Beam current	Purpose of Use
2003	1.5 MV 800 kV	300 mA 400 mA	Removal SO_2 and NOx from gas

3. Others

Please describe your comments other than the above, if any.

6.2 Indonesia

QUESTIONNAIRE

Radiation Application / Utilization of Electron Accelerator

Respondent: Sugiarto Danu

Organization: Center for Research and Dev. of Isotopes and Radiation Technology National Nuclear Energy Agency (P3TIR-BATAN)

Tel: 62-21-7690709 Fax: 62-21-7691607

e-mail :

1. Present Situation

1) γ-ray irradiation facility / electron accelerator for commercial use

What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in your country at present ? Please fill in the following table :

① γ-ray irradiation facility for commercial use

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
1. Panoramic Irradiator	1979	125 kCi	75 kCi	Polymerization Sterilization Food Preservation	P3TIR-BATAN
2. Latex Irradiation	1984	400 kCi	215 kCi	Latex Vulcanization Sterilization Food Preservation	P3TIR-BATAN
3. Indo Gamma	1991		4 MCi	Sterilization Food Preservation	
4. Gamma Chamber	1998		10 kCi	Tissue Bank	Jamil Hospital

② Electron accelerator

Name of company / organization Installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use
1. P3TIR-BATAN	1984	Nissin High Voltage	300 keV	50 mA	R and D Wood Surface Coating
2. P3TIR-BATAN	1993	SXFEM, China	2 MeV	10 mA	R and D Wire and Cable
3. Gajah Tunggal Comp	1998	Nissin High Voltage	500 keV	20 mA	Tire

2) Please state about the rules and regulation for the management of the irradiation facility, specifically. (about safety control and the law)

Rules and regulation for the management of the irradiation is based on recommendation of International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) and described in Government Regulation No. 11-1975, No. 12-1975 and No. 13-1975.

3) Please state about the present situation of radiation processing

The activities of Research and Development of P3TIR-BATAN consist of radiation Polymerization, sterilization, food preservation, reprocessing industrial material and industrial dosimetry. Some experiences in radiation vulcanization of natural rubber latex, wood surface coating, sterilization and food preservation gave several advantages to some industry instead of know-how and transfer technology. Two private companies (Indo Gamma and Gajah Tunggal Company) have used radiation for commercial purpose. Indo Gamma used Co-60 for sterilization and food preservation whereas Gajah Tunggal used electron beam machine for vulcanization of tire.

4) Electronic accelerator utilization technology

What kind of ①research(es) and/or ②commercial use, has been done utilizing electron accelerator technology in your country up to now ?

Please fill in the following tables:

① Electron accelerator utilization technology - for research

Field	Target	From when	Title (contents)	Remarks
Polymerization	Wood, metals, rad. Curable mat'l ceramics, marble, etc.	1986	Radiation curing of surface coating	
	PE, PP, rubber,	1994	Radiation crosslinking	
	Cellulose/ wood	2000	Degradation of cellulose	

② Electron accelerator utilization technology - for commercial use

Field	Target	From when	Title (contents)	Remarks
Polymerization	Wood	1986	Rad, curing of surface coating of wood product.	Services
	Tire	1998	Crosslinking of tire	Production

2. Future plan

1) Electron accelerator utilization technology

In what field /application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table:

Field	Target	From when	Title (contents)	Remarks
Polymerization	Latex	2004 / 2005	RVNRL	
Environment	Waste water, Flue gas		Detoxification	

2) Electron accelerator

What type of accelerator does your country plan to have for the future ?

Please fill in the following table:

When	Accelerator voltage	Beam current	Purpose of Use
2003	300 keV	50 mA	·Radiation curing ·Radiation cross linking ·Slevilizahow (for Laboratory use)
2004 / 2005	5 MeV	100 mA	Sterilization, curing of composite, Sherilimtion, Pllouhon conhool.

3) What kind of support do you expect from the FNCA workshop ?

Expected support from the FNCA workshop :

a. Technical assistance and technology transfer of Japan as a long experienced country in technology to the FNCA countries.
b. A wider cooperation between the participants to promote research, development and application of electron accelerators suitable for each country need.

4) Education/training of human resources

Please describe your comments and desire on the training/ education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

Training / education plan for the utilization of electron accelerator should also cover:

a. Economical aspect for comparison study with conventional or another method.
b. Problem solving oriented.

3. Others

Please describe your comments other than the above, if any.

6.3 Korea

QUESTIONNAIRE

Radiation Application / Utilization of Electron Accelerator

Respondent : Byung Cheol Lee

Organization : Korea Atomic Energy Research Institute

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e-mail : bclee4@kaeri.re.kr

1. Present Situation

1) γ-ray irradiation facility / electron accelerator for commercial use

What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in your country at present ? Please fill in the following table :

① γ-ray irradiation facility

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
KAERI	1975 (1998)	176 cm	130,000 Ci	Research	Co60
Greenpia Tech	1986	~ 180 cm	1,000,000 Ci	Commercial	Co60

② Electron accelerators

There are more than 20 electron accelerators in Korea. Most of those are installed in factories for cables (9 installed / 8 operating), shrinkable tubes (1/1), radical tires (5/3), foams (3/3), tube/films (3/3), curing (1/1), etc. There are three accelerators operating for dedicated researches

③

Name of company / organization Installed	Year install-ed	Maker	Accelerator voltage	Beam current	Purpose of Use
LG Cables DongYang Cables Daewon Cables Daeryuk Ind. KDK KyungShin Co.	'84-'00 '96 '91 '97	3 NHV 2 EB Tech. 1 EB Tech. 1 RDI 1 RDI 1 BINP	~ 1 MeV	50~100 mA	Cables and Heat shrinkable tubes

		1 NHV			
Hankook Tires KumHo Tires		3 NHV 2 RDI	0.5 MeV 0.8 MeV	~ 100 mA ~ 100 mA	Tires
YoungBo Chemicals TongIl Co.		2 NHV 1 NHV	0.5~1 MeV	50~100 mA	Foam Sheet
Korea TetraPack		1 ESI	0.175 MeV	300 mA	Coating
Ceratech Co.		1 EB Tech.			Polymer
Dyeing Complex		1 EB Tech.			Wastewater
KAERI EB Tech. YoungNam Univ.	1975 2000	1 HVEC 1 BINP 2 EB Tech. 1 BINP	0.3 MeV 2 MeV ~1 MeV 0.8 MeV	25 mA 45 mA	Research

2) Please state about the rules and regulation for the management of the irradiation facility, specifically.

(about safety control and the law)

- There is no special regulation for "irradiation facility"
- For "fabrication" or "import" of radiation generator, need design approval. The documents for this approval are : design report, radiation safety report, quality assurance plan, etc.
- For "production", "sail", and "use" of radiation generator, need approval of government. The document for this approval are radiation safety analysis report, quality assurance report, radiation safety report, etc.

3) Please state about the present situation of radiation processing

Applications		Status in Korea (Commercialization)
Polymer modification	Flame resistant cables	OOO
	Thermo-shrinkable tubes, sheet	OOO
	Curing of tire cores	OOO
	Foam sheet	OOO
	Artificial leather	X
	Films of coating and packaging	X
Sterilization/ Disinfection	Sterilization of medical items	OO
	Preservation of spices, food	OO
	Disinfection of grains	OO

Environmental Protection	Flue gas purification Waste/Wastewater treatment Sludge treatment	O OO X
Others	Curing/Coating of wood, paper, etc. Semiconductors, PTC/NTC Ceramic composites Surface treatment of fabrics	OOO OOO X X

OOO: Commercialized, OO: Engineering, O: Research, X: No activity

4) Electronic accelerator utilization technology

What kind of ①research(es) and/or ②commercial use, has been done utilizing electron accelerator technology in your country up to now ?

Please fill in the following tables:

① Electron accelerator utilization technology - for research

Field	Target	From when	Title (contents)	Remarks
Enviromental purification	Waste water VOC SOx & NOx	1992 1998 1998	1. Purification of industrial wastewater. 2. Removal of heavy metals 3. Purification of aromatic and aliphatic VOCs 4. Purification of flue gases 5. Disinfection of waste water and swage sludge.	Youngnam University
Polymer and resin	PE & PP EB curable resins	1993 1998	1. Crosslinking of PE and PP 2. Grafting of monomers onto polymers 3. Curing of functional monomers 4. Grafting of hydrophilic and hydrophobic monomers onto fabrics 5. Coating of EB curable resin on wood, paper, plastic, steel, fabrics, etc.	Youngnam University
Curing of rubber	Natural rubber Artificial rubber		Curing of natural rubber and artificial rubbers	Youngnam University
Wastewater	Purification	1993		EB-Tech
Flue Gas	Purification	1994		EB-Tech

② Electron accelerator utilization technology - for commercial use

Field	Target	From when	Remarks

Polymer modification	Flame resistant cables	1984	LG Cables Co.
	Conductive material	1999	Ceratech
	Shrinkable tubes	1997	Hankook KDK
	Tire core	1991	Kumho Tire
	PE form	1991	Tongil Industry
Curing	Curing of print	1989	Hankook Teprapack
Waste water	Purification of dyeing waste water	2002	Daegu Dyeing complex

2. Future plan

1) Electron accelerator utilization technology

In what field /application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table:

Field	Target	From when	Title (contents)	Remarks
Enviromental Purification	1.Toxic waste waters 2.Cooling water 3. Animal wastes 4.Complex waste water 5.Incineration waste gases	1998- 2002- 2002- 1998- 2001-	1. Purification of toxic components included in W/W 2. Treatment of industrial cooling water. 3. Treatment of animal wastes 4. Purification of complex W/W 5. Purification of incineration gases	Youngnam University
Modification of materials	1.Fine Particles 2.Fabrics	2000- 1999-	1. Improvement of surface properties of fine particles 2.Manufacture of functional fabrics	Youngnam University
Reuse of Waste polymers	Cellulose, Teflon	2000-	Reuse of cellulose and teflon	Youngnam University
Drinking water	Disinfection	2002		EB-Tech
VOC	Purification	2001		EB-Tech
Bio-material		2002		EB-Tech

2) Electron accelerator

What type of accelerator does your country plan to have for the future ?

Please fill in the following table:

When	Accelerator voltage	Beam current	Purpose of Use
2003	1.0 MeV	50 mA	Fabrics
2002	10 MeV	10 mA	Research

3) What kind of support do you expect from the FNCA workshop ?

4) Education/training of human resources

Please describe your comments and desire on the training/ education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

3. Others

Please describe your comments other than the above, if any.

6.4 Malaysia, QUESTIONNAIRE

Radiation Application / Utilization of Electron Accelerator

Respondent: Dr. Khairul Zaman HJ Mohd.Dahlan

Organization: Malaysian Institute for Nuclear Technology Research(MINT)

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e-mail : khairul@mint.gov.my

1. Present Situation

1) γ-ray irradiation facility / electron accelerator for commercial use

What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in your country at present? Please fill in the following table :

① γ-ray irradiation facility for commercial use

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
Ansell	1977	4 MCi	~2.0 MCi	sterilization	medical products
MINT	1989	2 MCi	~1.5 MCi	sterilization	medical products/spice
Steriligamma	1993	6 MCi	~2.0 MCi	sterilization	medical products
ISOTRON	2001	4 MCi	~1.0 MCi	sterilization	Medical products

② Electron accelerator

Name of company / organization Installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use
MINT	1991	NHV	3.0 MV	30 mA	services
Sumitomo	1995	NHV	800 kV	100 mA	X-Link wires
	2001	NHV	2.0 MV	100 mA	X-link wires
W.R. Graces	1996		550 kV	60 mA	plastic film
S.K. Polymer	1997	ESI	150 kV	460 mA	plastic film

2) Please state about the rules and regulation for the management of the irradiation facility, specifically. (about safety control and the law)

- The company must get license to import radioactive materials or electron beam machine from the Atomic Energy Licensing Board of Malaysia.
- The company must has a Radiation Protection Office (RPO) certified by the Board.

3) Please state about the present situation of radiation processing

Radiation Processing Technology is used in industry for

- Sterilization of medical products
- Crosslinking of wire insulation
- Crosslinking of tubes /heat shrinkable tubes
- Crosslinking of heat shrinkable films
- Sterilization of pharmaceutical products/raw materials
- Pasteurization of spices

4) Electronic accelerator utilization technology

What kind of ①research(es) and/or ②commercial use, has been done utilizing electron accelerator technology in your country up to now ?

Please fill in the following tables:

① Electron accelerator utilization technology - for research

Field	Target	From when	Title (contents)	Remarks
X-link		1996	X-link	On-going
curing		1991	surface treatment, PSA and printing ink	On-going
flue gas		1999	flue gas treatment	On-going
wastewater		2002	wastewater treatment	New project

② Electron accelerator utilization technology - for commercial use

Field	Target	From when	Title (contents)	Remarks
X-link			wire insulation, plastic film, tubing	

2. Future plan

1) Electron accelerator utilization technology

In what field /application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table:

Field	Target	From when	Title (contents)	Remarks
X-link			polymer materials	
grafting			film	
curing			Adhesive and printing ink	
flue gas			flue gas treatment	
Wastewater Sterilization			Industrial wastewater treatment sterilization of medical disposable items	

2) Electron accelerator

What type of accelerator does your country plan to have for the future ?

Please fill in the following table:

When	Accelerator voltage	Beam current	Purpose of Use
	<1.0 MeV	100-200 mA	X-linking, grafting flue gas and wastewater treatment
	10 meV	10-30 mA	Sterilization

3) What kind of support do you expect from the FNCA workshop ?

It is expected that the FNCA Workshop to come out with a project that common to all member states that can help to upgrade the socio-economic of the country.

4) Education/training of human resources

Please describe your comments and desire on the training/ education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

Training/education on utilization of electron accelerator can be held in any FNCA countries with a support from Japan. Area of training can be identify by the representative of FNCA countries during the workshop.

3. Others

6.5 The Philippines

QUESTIONNAIRE
Radiation Application/Utilization of Electron Accelerator

Respondent: ESTELITA G. CABALFIN

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1. Present Situation

1) γ-ray irradiation facility/electron accelerator for commercial use
What type of γ-ray irradiation facility for commercial use and of electron accelerator do you have in the country? Please fill in the following table.

(1) γ-ray irradiation facility for commercial use

Name	Year Established	Shielding Capacity	Source Activity	Purpose of Irradiation	Remarks
Multipurpose irradiation facility, PNRI	1989	250,000 Ci	70,000 Ci	radiation sterilization; food irradiation	semi-commercial (pilot scale) service facility

(2) Electron accelerator

Name of company/ Organization installed	Year installed	Maker	Accelerator Voltage	Beam current	Purpose of use
Terumo Philippines	1999	Mitsubishi	10 MeV	28 kW	radiation sterilization (in-house)

2) Please state about the rules and regulation for the management of the irradiation facility, specifically about safety and control and the law

Philippine Nuclear Research Institute (PNRI) – regulates facilities with radioactive materials, such as Co-60 irradiation facility

Bureau of Health and Devices Technology (BHDT) of the Department of Health – regulates radiation emitting machines, such as electron accelerator and x-ray machine

3) Please state about the present situation of radiation processing:

a) Using electron accelerator

Commercial use: Terumo Philippines for in-house radiation sterilization of syringes

b) Using γ-ray irradiation facility
Semi-commercial use: PNRI offering irradiation service:
sterilization of empty aluminum tubes, orthopedic implants, bones, amnion dressings
microbial decontamination of empty gelatin capsules, carrageenan, spices and dehydrated vegetables

R&D: all using Co-60 irradiation
radiation vulcanization of natural rubber latex
carrageenan-PVP hydrogels as wound dressing
irradiated carrageenan as plant growth promoter
conversion of sugar cane waste (bagasse) by radiation and fermentation into useful products such as substrate for mushroom production and ruminant feed
shelf-life extension of meat products
microbial decontamination of herbal tea, dehydrated products, animal feeds

4) Electron accelerator utilization technology

What kind of (1) research(es) and/or (2) commercial use, has been done utilizing electron accelerator technology in your country up to now?
Please fill in the following tables:

(1) Electron accelerator utilization technology for research:
none yet because no electron accelerator is available for R&D

Field	Target	From when	Title (contents)	Remarks

(2) Electron accelerator utilization technology for commercial use

Field	Target	From when	Title (contents)	Remarks
radiation sterilization	syringes	2000	in-house radiation sterilization facility	

2. Future plan

1) Electron accelerator utilization technology
In what field/application does your country plan to develop the technology for commercial use in the future? Please fill the following table.

Field	Target	From when	Title (contents)	Remarks
radiation sterilization	medical products	2004		will propose for JICA funding
microbial decontamination	spices, herbs, dried vegetables	2004		

2) Electron accelerator

What type of accelerator does your country plan to have for the future?
Please fill in the following table.

When	Accelerator voltage	Beam current	Purpose of use
2004	10 MeV	10 mA	Radiation sterilization of medical and other products, Microbial decontamination of spices, dehydrated vegetables, raw materials for pharmaceutical and cosmetics Development of high value products from natural polymers through radiation

3) What kind of support do you expect from FNCA Workshop?

A self-shielded low energy electron accelerator on loan to countries without electron accelerator so that R&D work on application of electron accelerator can be initiated in these countries.
Collaborative R&D and exchange of information and experience on application of electron accelerator for natural polymers such radiation vulcanization of natural rubber latex (RVNRL), preparation of hydrogels from carrageenan

4) Education/training of human resources
Please describe your comments and desire on the training education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

Training on dosimetry for electron accelerator
Training on operation and maintenance of electron accelerator
Training or seminar on applications/utilization of electron accelerator

2. Others

Please describe your comments other than the above, if any. None

6.6 Thailand,

QUESTIONNAIRE
Radiation Application / Utilization of Electron Accelerator

Respondent : Mr. Chyagrit Siri-Upathum
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1. Present Situation

1) γ 'ray irradiation facility / electron accelerator for commercial use
What type of γ 'ray irradiation facility for commercial use and of electron accelerator do you have in your country at present? Please fill in the following table :

ℵ γ 'ray irradiation facility for commercial use

Name	Year established	Shielding capacity	Source Activity	Purpose of irradiation	Remarks
Kendal Gammatron Co.Ltd.	1984	500 kCi	150 kCi	Sterilization of medical supplies	Nakorn Prathom
Thai Irradiation Centre	1993	3 MCi	450 kCi	R&D on radiation processing	Government own (OAEP) Pratumthani
IBA S&I (Thailand) Ltd.	1999	3 MCi	1 MCi	Sterilization and others	Rayong
GAMMASTER (Thailand) Ltd.	2000	6 MCi	1 MCi	Sterilization and others	Chonburi

ℑ Electron accelerator

Name of company / organization installed	Year installed	Maker	Accelerator voltage	Beam current	Purpose of Use
Thai Klinipro Co. Ltd.	1997	Minilac USA	1.8-2.4 MeV	10 kW	Sterilization of doctor gown
IBA S&I (Thailand) Ltd.	2000	MEVEX Canada	15 MeV	8.5 kW	Upgrading of gem stone

2) Please state about the rules and regulation for the management of the irradiation facility, specifically, (about safety control and the law)

2) Please state about the rules and regulation for the management of the irradiation facility, specifically, (about safety control and the law)

- application for possesion of radioactive isotope source / electron accelerator with purposes and detail of safety assessment must be reviewed and evaluated by the national regulatory committee appointed by Thai government and endorsed by the Prime Minister with an assistance of OAEP

- inspection and control of radiation doses in working area and in the vicinity is to be checked and evaluated before first operation by authorized people of OAEP

- corrective action request and other recommendation to comply with the rules provided
  by OAEP must be responsive before licensing can be made

- renewal of the license must be done every year using the same procedure

3) Please state about the present situation of radiation processing

3.1 Commercial scale
- sterilization of medical supplies, pharmaceutical packaging, cosmetic bottles, cosmetics, dog chew, etc.
- food irradiation : frozen shrimp, frozen chicken, mung bean, onion, garlic, fermented pork
  sausage, seasoning, enzyme, herb, etc.
- gem stone irradiation : topaz, tourmaline, zircon etc.
- pasteurization of pharmaceutical products : eye ointment with various antibiotics, eye drops, herbal tea, injectable hormones, burn patches with chlorohexidine, etc.
- radiation vulcanization of natural rubber latex : for protective glove manufacturing

3.2 Research and development
- radiation processing of chitin/chitosan (supported by IAEA)
- radiation degradation of silk protein (bilateral agreement with JAERI)
- removal of latex protein by gamma irradiation
- grafting of acrylamide onto chitosan
- radiation processing of PE/NR blend

4. Electron accelerator utilization technology
   What kind of research(es) and / or commercial use, has been done utilizing electron accelerator technology in your country up to now ?
   Please fill in the following tables :

3 Electron accelerator utilization technology for commercial use

Field	Target	From when	Title (contents)	Remarks
sterilizati on		1997	disposable gown, feminine napkin	

2. Future plan

1) Electron accelerator utilization technology
In what field / application does your country plan to develop the technology for commercial use in the near future ? Please fill in the following table :

Field	Target	From when	Title (contents)	Remarks
Cross linking	x-linked wire & cable, heat shrinkable materials	2004	Heat resistant, low smoke, halogen- free electrical wire & cable as well as heat shrinkable materials are foreseen to be in need in the future eg. new air port, new subway, domestic uses in the country	need technical assistance

2) Electron accelerator
What type of accelerator does your country plan to have for the future ?
Please fill in the following table :

When	Accelerator voltage	Beam current	Purpose of Use
2004	2 MeV	50 mA	x-linking of wire & cable and manufacturing of heat shrinkable materials
2008	1 MeV	50 mA	R&D on radiation processing

3) What kind of support do you expect from the FNCA workshop ?

- technical assistance on installation/maintenance of an EB machine
- irradiation technique for wire & cable by electron beam

3) What kind of support do you expect from the FNCA workshop ?

- technical assistance on installation/maintenance of an EB machine
- irradiation technique for wire & cable by electron beam
- radiation dosimetry for electron irradiation

4) Education / training of human resources
Please describe your comments and desire on the training / education plan for the utilization of electron accelerator in order for us to identify the common needs of the FNCA countries.

- on the job training on installation/operation/maintenance of medium energy EB machine
- on the job training on x-linking of electrical wire & cable by EB machine in Japan
- on the job training on fabrication of heat shrinkable material by EB machine in Japan

3. Others

Please describe your comments other than the above, if any,

- as many as possible technical visits to electron processing plant during the work shop shall be very much appreciated

- provide an accessible source of Japanese host to support certain potential application of
  EB machine in each participating country eg. start from local raw materials

6.7 Vietnam

QUESTIONNAIRE

Radiation Application/Utilization of Electron Accelerator

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1. Present situation

1. γ - Ray irradiation facility/electron accelerator for commercial use

What type of γ - ray irradiation facility for commercial use and of electron accelerator do you have in your country at present? Please fill in the following table:

- *γ - ray irradiation facility for commercial use*

Name	Year estab_ed	Shielding capacity	Source activity	Purpose of irradiator	Remarks
SVST-Co-60	1999	2MCi	400 kCi	- Sterilization of Medical products - Food pasteurization - Polysaccharides degradation	Hungarian type
RPP-150	1991	1MCi	107 kCi	Food preservation	Russian type
Gamma Cell	1983 1987		16.5 kCi + 9 kCi	R&D (Present activity: 3 kCi)	Russian type

- *Electron accelerator: None*

2. Please state about the rules and regulation for management of the irradiation facility (about safety control and law)

- The National Radiation Safety Committee awarded the operation license to the irradiators in Vietnam. The operation of irradiators must comply with the Vietnamese Law of Radiation Safety and Control, which has been put into force since 1997.

- Irradiation of medical products bases on ISO 11137, 1995, Sterilization of health care products - Requirements for validation and routine control, ISO 11737, 1995, Sterilization of Medical devices – Microbiological methods.

- Food irradiation bases on Codes of Good Radiation Practice (ICGFI)

3. Please state about the present situation of radiation processing

- The operation of the irradiator in Hanoi has low effectiveness due to the lacking in products and low activity at present. It is necessary to modify the irradiator to meet requirements for sterilization of medical products and food irradiation. The project on modification of the irradiator was submitted for consideration.
- The irradiator at VINAGAMMA (Ho Chi Minh City) is running at full rate. At the beginning it is expected to use the irradiator for sterilization of medical products but now mainly for food processing. At present requirement for food irradiation is higher than ability of the irradiator at VINAGAMMA. The construction for new food irradiator is under consideration. It is expected to build at the end of 2003.
- The research and development work on radiation processing of natural polysaccharide for production of bio-compatible material used for burn treatment had been carried out in 1998-1999 and the product has been tested in hospitals with high appreciation of medical doctors. Researches on biodegradable material in film and plate forms is continuously conducted at VINAGAMMA in the frame of VAEC scientific project in the period of 2000 and 2001 and in the approved project by Ministry of Science, Technology and Environment (MOSTE) in the year 2002 and 2003. At Nuclear Research Institute Research and Development of plant growth promoter made from irradiated alginate has been pushed to a two-year trial production project upon the project approved by MOSTE (2002-2003).
- Besides food processing by using gamma radiation, material processing reveals more requirements in the future. Sooner or later using civil materials that are not harmful to human environment will become vital needs. It is expected that EB technology for producing such kinds of material need to be transferred soon.

4. Electron accelerator utilization technology: Not yet

2. Future plan

1. Electron accelerator utilization technology

In what field/application does your country plan to develop the technology for commercial use in near future? Please fill in the following table:

Field	Target	From when	Title (Contents)	Remark
Modified materials	Cooperation in research, test production and technology transfer	2003-2004	- Heat shrinkable materials - Wire and cable - Natural rubber latex - Biodegradable materials - Ptant goowth promoter - Others	

2. Electron accelerator

What type of accelerator does your country plan to have for the future?

Please fill in the following table:

When	Acc. Voltage	Beam current	Purpose of use
2003	(300) kV	(10+30) mA	R&D, Test production, Technology promotion, demonstration

3. What kind of support do you expect from the FNCA workshop?

- Information on fruitful aspects of EB application
- Establishment of Cooperation in the above mentioned titles
- Looking for other technology is feasible for transfer

4. Education/training of human resources

Please describe your comments and desire on training/education plan for the utilization of electron accelerator in order for us to identify the common needs of FNCA countries.

- Some previous cooperations so far should be continued in focusing on two objects: Heat shrinkable materials and Biodegradable materials.
- We expect to cooperate with JAERI in researches of the technology for production of biodegradable materials for foodstuff. At long last, the technology should be transfer and production should be commercialized. Therefore, We are needing a help from Japan in education/training not only in technological aspect but also in operation of an EB machine. Although the technology for production of heat shrinkable material is ready in Japan, but technological knowledge is still lacking in Vietnam. The enough training and education are also expected from Japan.

7. MINUTES of

FNCA Workshop on Application of Electron Accelerator

28 January – 1 February, 2002,

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7. MINUTES of

FNCA Workshop on Application of Electron Accelerator

28 January – 1 February, 2002, Takasaki, Japan

1 February 2002

This Workshop was sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and hosted by Japan Atomic Energy Research Institute (JAERI). It was held at the Takasaki Radiation Chemistry Research Establishment (TRCRE), JAERI, Takasaki, Japan. The main objective of the workshop was to discuss present status of utilization of electron accelerator in the FNCA participating countries and to formulate detailed program for cooperation.

The Workshop was attended by experts on application of electron accelerator from each of the participating countries, i.e. China, Indonesia, Korea, Malaysia, the Philippines, Thailand and Vietnam and 16 participants from Japan. Annex 1 shows the list of participants.

This is the first workshop of the FNCA project on Application of Electron Accelerator. The main objective of the project is to develop new technology using low energy electron beam irradiation system, which has a variety of applications and good safety feature, and to demonstrate its application.

A total of 17 papers including invited papers on the current status of application of electron accelerator in the participating countries were presented. The program of the workshop is given in Annex 2. The participants had the opportunity to discuss, exchange opinions and share their experiences on issues related to radiation processing and utilization of low energy electron accelerators in particular.

Each participating country presented proposal for the cooperation in the application of low energy electron accelerator, as shown in Annex 3.

At the Round Table Discussion on the fourth day of the Workshop, discussions were carried out to formulate details of the program for FNCA cooperation. The work plan of the project on the application of electron accelerators was formulated and agreed upon, as shown in Annex 4.

The major areas of interest of FNCA countries for cooperation were identified for application of low energy electron accelerator as liquid, thin film and granules. The mechanism of cooperation of the FNCA project would be in the form of research collaboration. Several countries who have low energy electron accelerators, China, Indonesia, Japan, Korea and Malaysia, have offered their facilities to be used for the project. Iwasaki and NHV will consider the possibility of offering their facilities for the project. It is recommended that low energy accelerator be made available in each FNCA participating country. In the meantime, countries without electron accelerators can make use of accelerators available in other member countries.

Radiation degradation of alginate in solution using low energy electron accelerator and technique for dosimetry were demonstrated by the radiation processing laboratory of TRCRE.

The participants visited Radia Industry Co., Ltd, Nissin Electron Service Co., Ltd and Iwasaki Electric Co., Ltd. They were impressed by the variety of electron accelerators and their industrial applications.

The Minutes of the workshop were discussed and agreed upon by all the participants. This will be reported at the 3rd FNCA Coordinators Meeting to be held in March 2002 in Tokyo, Japan.

The venue of next workshop on the application of electron accelerator for liquid will be held in autumn 2002 at JAERI Takasaki.

The participants expressed their sincere gratitude to the organizer and host institute for a well organized workshop and for their hospitality.

Annex 1. List of Participants in the FY2001 FNCA Workshop on Application of Electron Accelerator
Annex 2. Program of the FY2001 FNCA Workshop on Application of Electron Accelerator
Annex 3. Proposal of FNCA participating countries
Annex 4. Work plan for the FNCA Project on Application of Electron Accelerator

Annex 1

8. LIST OF PARTICIPANTS
FNCA WORKSHOP ON APPLICATION OF ELECTRON ACCELERATOR

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Annex 1

8. LIST OF PARTICIPANTS

FNCA WORKSHOP ON APPLICATION OF ELECTRON ACCELERATOR

January 28- February 1, 2002,
Takasaki, Japan

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Annex 2

9. FNCA Workshop on Application of Electron Accelerator

January 28 – February 1, 2002,

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Annex 2

9. FNCA Workshop on Application of Electron Accelerator

January 28 – February 1, 2002,
Takasaki, Japan

< Program>

Monday, January 28

9:00-9:30 **Registration**

OPENING SESSION

9:30-10:15 **Welcome Address**
Hiroshi WATANABE
Director General
Takasaki Radiation Chemistry Research Establishment, JAERI

Opening Address
Shinya TAKEUCHI
Director for International Nuclear Cooperation, MEXT

Remarks
Sueo MACHI
FNCA Coordinator of Japan

Introduction of Participants

10:15-10:45 (Break)

SESSION 1 **Introduction of Project and Application of Electron Beam**
Chairperson: Japan

10:45-11:00 **Outline of FNCA Project on Application of Electron Accelerator**
Tamikazu KUME, JAERI

11:00-11:30 **Scheme and Activities of FNCA**
Application of Electron Accelerator Worldwide
Sueo MACHI, FNCA Coordinator

11:30-12:00 **Application of EB in Japan**
Hiromi SUNAGA, JAERI

12:00-13:30 (Lunch)

SESSION 2 **Country Reports**
Chairperson: Vietnam

13:30-13:55 **Indonesia**

13:55-14:20	**Thailand**
14:20-14:45	**Malaysia**
14:45-15:10	**Korea**
15:10-15:30	(Break)
	Chairperson: Indonesia
15:30-15:55	**The Philippines**
15:55-16:20	**Vietnam**
16:20-16:45	**China**
SESSION 3	**Present Status of Electron Accelerator** Chairperson: China
16:45-17:15	**Low Energy Electron Accelerator** Masafumi OCHI, Iwasaki Electric Co., Ltd.
17:15-17:45	**High Energy Electron Accelerator** Masayuki KASHIWAGI, Nissin- High Voltage Co., Ltd.
18:00-	(Reception)

Tuesday January 29

SESSION 4	**Lecture on "Utilization of Low Energy Electron Accelerator"** Chairperson: Thailand
9:00-9:40	**Liquid: Radiation Processing of Liquid with low Energy Electron Accelerator** Keizo MAKUUCHI, JAERI
9:40-10:10	**Solid: Treatment of Foods with "Soft-Electrons"** Toru HAYASHI, Japan International Research Center for Agricultural Sciences (JIRCAS)
10:10-10:40	**Solid: Application to the Radiation Processing of Polymer** Fumio YOSHII, JAERI
10:40-11:00	(Break)
11:00-11:40	**Gases: EB treatment of purification of flue gas and dioxin** Takuji KOJIMA, JAERI
11:40-12:00	**Report on a Recent Over-Exposure Accidents by a Medical-Linac in Japan** Hisaaki KUDOH, Tokyo University

12:00 -13:30	(Lunch)
SESSION 5	**Demonstration of Low Energy Electron Beam Irradiation**
13:30 –15:30	**1) Irradiation of natural polymer**
15:30 –16:00	(Break)
16:00 –17:30	**2) Dosimetry and Evaluation**

Wednesday January 30

TECHNICAL VISIT

8:30	Start from Hotel
9:00-10:15	**Visit Radia Industry Co., Ltd. (Takasaki)**
10:45- 12:00	**Visit Nissin Electron Service Co., Ltd. (Maebashi)**
12:00-13:30	(Lunch)
13:30-14:45	Move to Gyoda
14:45-16:30	**Visit Iwasaki Electric Co., Ltd. (Gyoda)**
16:30-18:00	Arrive at Hotel

Thursday January 31

SESSION 6	**Round Table Disscusion on the Way of Cooperation among the FNCA Countries** Chairperson: Korea
9:00-10:10	**"Proposals from Member States"** **Indonesia** **Korea** **Malaysia**
10:10-10:30	(Break)
10:30-12:00	**The Philippines** **Thailand** **Vietnam** **China**
12:00-13:30	(Lunch)
13:30-15:00	**Discussion on "Work Plan"**

	Co-chairpersons: Malaysia and Japan
15:00-15:30	(Break)
15:30-17:00	**(Cont.) Discussion on "Work Plan"**

Friday February 1

SESSION 7	**Discussion (Conclusion)** Co-chairpersons: The Philippines and Japan
9:00-10:15	**Drafting the Workshop Minutes**
10:15-10:45	(Break)
10:45-11:45	**Adoption of the Workshop Minutes**
11:45-12:00	**Closing remarks**

Annex 3

10. Proposals for the Workshop from Countries

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Annex 3

10. Proposals for the Workshop from Countries

Proposal of China

China can develop a low energy electron accelerator

Interested in flue gas treatment and irradiation of granules

Education and training of youngsters

Expert exchange

Proposal of Indonesia

1. Technical assistance and technology transfer from Japan as a long experienced country to member FNCA
2. Cooperation between Japan Industrial Society and Indonesian Industrial Society in the field of radiation technology
3. Workshop should cover the cost estimation of the technology such as price, capita and production cost
4. A wider cooperation between FNCA members to promote R&D and application of electron accelerator
5. More technical visits to related industry

Proposal for R&D

Products

Liquid: radiation vulcanization of natural rubber latex
Solid: crosslinking of LDPE and paper
Gas: flue gas

Proposal of Korea

1. FNCA program supports

   Workshop

   Education program

   Travel expenses of members

   R&D (design of EB system)

   Hardware ?

2. Networking (Homepage)

   Contents

- EB activities of member countries/institutions/personnels
- Link to companies (EB manufacturers)
- Database : papers, regulations, tutorials, proceedings, etc.

Mission of delegates:

- Search members in each country
- Promote participation

Link to the FNCA homepage ?

Proposal of Malaysia

Most of radiation processing research projects that are being carried out at MINT are using high and low energy electron accelerators.

Low energy electron accelerator, 200 keV, 20 mA CURETRON is mainly used for radiation curing research such as coating, PSA and printing ink.

High energy electron accelerator,1-3 MeV, 1-30 mA, EPS3000, is used for crosslinkig, grafting and degradation of polymeric materials for the following applications:

hydrogel
polymer composites
polymer blends
polymer films, etc.

High energy electron accelerator, 1-3 MeV, 1-30 mA, EPS3000, is also used for R & D on environmental processing as follows:

flue gas purification
industrial waste water treatment
electron accelerator system

CURETRON at MINT is equipped with handling system to crosslink thin layer polymeric samples.
Coatings, adhesive, printing inks, thin polymer films and thin layer hydrogel – 15 x 15 cm tray inert system is available using nitrogen gas EPS 3000 can be used to study EB treatment of industrial waste water. Energy 500 keV to 1.0 MeV.
Conveyor cart of 60 cm x 60 cm x 3 cm size Project Proposals Crosslinking of thin layer polymer films using low energy electron accelerator.
Polymer film based on natural polymer such as sago starch in the form of hydrogel or polymer blends development of sago hydrogel and sago films are on-going projects at MINT, however at present crosslinking is being carried out using EPS 3000.
MINT is ready to receive scientists from the region for attachment/reseach work under IAEA, bilateral or FNCA programmes.

Project Proposals
Treatment of industrial waste water using electron accelerator energy 500-1,000 keV.

MINT has carried out survey on the status of industrial waste water in the dye conversion industry and food & beverages industry in Malaysia.
There is need to develop technology which is affordable and capable to protect the environment from industrial waste water in particular the COD treatment and sludge from solid suspension.
Majority of the companies are categorized as small and medium size industries – vol. waste water about 100-800 cum/h.

Proposal of the Philippines

A self-shielded low energy electron accelerator on loan to countries without electron accelerator so that R&D work on application of electron accelerator can be initiated in these countries.

Collaborative R&D and exchange of information and experience on application of electron accelerator for natural polymers such radiation vulcanization of natural rubber latex (RVNRL), preparation of hydrogels from carrageenan

Training on dosimetry for electron accelerator
Training on operation and maintenance of electron accelerator
Training or seminar on applications/utilization of electron accelerator

Proposal of Thailand

Introduction

Thailand has variety and large abundance of natural agro and marine origin products. Almost all of these products have been exported with little value-added. Example are NR latex and its products, rubber wood furniture and parts, frozen sea food etc. Recently, radiation technology has been introduced to these products and/or their wastes by R&D of FNCA`s member states, lead by research team from JAERI. This is a chalenge to bring bright future for rubber plantation, shrimp farms and related business. The cost effective in using low energy electron accelerator as a tool to add value to these products and/or their wastes are to bring about in this proposal. The role of FNCA / JAERI to share partnership with Thai side will undoubtedly be contributed to a fruitful results.

Objective

1. To learn more on the use of low energy EB to produce modified natural polymers for good uses in agricultural and medical/health care fields.
2. To develop process(es) using radiation technology for upgrading of natural resources available in the member states (test run is to be done at participating country(s) with low energy EB already available).
3. To install a low energy electron accelerator and use as a demonstration unit in introducing the developed process(es) to local industries in the participating countries.

Duration of the project: 2002-2005
Place to accommodate the demo unit:
Department of Nuclear Technology, Faculty of Engineering
Chulalongkorn University, Bangkok
Participants
Assoc. Prof. Chyagrit S.* (CU)
Assoc. Prof. Dr.Jariya B. (CU)
Ms. Jindarom C. (OAEP)
Mr. Manit S. (OAEP)
Assist. Prof. Dr.Suvabun C. (CU)
Dr. Prathana K. (OAEP)
* Project Leader

Work plan

FY 2002

1) Study on radiation degradation of chitin/chitosan, alginate for plant growth promotion using gamma irradiation.
2) Study on degradation of pectin, sago starch, cassava starch by gamma irradiation for using as centrifugation aids in manufacturing of HA latex.
3) Test operation of 1) and 2) using EB irradiation in Japan

FY 2003

1) Demonstration Test of EB system for oligochitosan, low M.W. polysaccharides for plant growth promotion and enhancement of latex centrifugation respectively. at a participating country with low EB available.

2) Study on the use of oligochitosan for prevention of stain by fungi in rubber wood
timber and rubber wood furniture parts
3) Installation of a low energy electron accelerator (in kind or matching fund of MEXT(Japan) / MTEC(Thailand) at Chulalongkorn University

FY 2004

1) Workshop and Test Operation of the EB system
2) Study on oligochitosan coated sago starch hydrogel for using as wound dresser.
3) Demonstration Test of the EPS for the above application.

FY 2005

1) Study on EB and enzymatic degradation of sago starch to L-lactic acid for preparation of biodegaradable plastic of poly lactic acid.
2) Workshop and Test Operation of the EPS for 1)
3) Demonstration Test of the EPS for 1)

Supporting Organization
1) FNCA / JAERI / MEXT, Japan for a self shielded 250 kV 10 mA electron accelerator and setting up.
2) National Metal and Material Research Centre, MTEC,Thailand for partial financial support of 1 M THB (0.23 M USD) per year for 3 years

3) ChulalongkornUniversity (CU), Thailand for partial financial support of 0.5 M THB (0.115 M USD) per year for 3 years, and in kind support of infrastructure : lab space, office space, telephone line, fax machine, copying machine etc.

Cooperation from local companies

1) Rayong Bangkok Rubber Co.,Ltd., Rayong, for test production of HA latex
2) South Land Rubber Co., Ltd., Hat Yai, Songkhla for test production of HA latex and latex gloves
3) Chalong Latex Industry Co.Ltd., Hat Yai, Songkhla, for test production of HA latex
4) SK Polymer Co. Ltd., Bangkok, for test production of medical rubber products from solid rubber
5) Bangkok Flower Centre Co. Ltd., Bangkok for testing of tissue cultured young orchid plant growth promotion by oligosaccharides
6) Green Polymer Plus Co. Ltd., Bangkok, for commercialization of oligosaccharide products

Proposal of Vietnam

A. Title of the proposed project

LOW ENERGY ELECTRON ACCELERATOR FOR RESEARCH AND DEVELOPMENT IN THE FIELD OF RADIATION PROCESSING IN VIETNAM

B. Implementation duration: 4-5 years

C. Start date: September, 2002

D. Implementation organization: Research and Development Center for Radiation Technology – Vietnam Atomic Energy Commission

E. Project objectives

1. Procurement of a low energy electron accelerator.
2. Research and development of the most feasible applications of radiation processing in the country towards the investment of industrial scale EB facilities in future.

F. Main content of the project

1. <u>Electron accelerator:</u>

- Voltage: 300 kV
- Current: (10 ÷ 30) mA

2. <u>Research and development</u>

R&D has the following objects:

- Heat shrinkable materials used in the field of electricity, communication, and foodstuff.
- Plant growth promoter
- Would dressing
- Cable and wire.

- Natural rubber latex
- Biodegradable materials used in foodstuff

G. Project schedule

1.2002 – 2003

- Finance settlement
- Research/training/technology transfer on production of heat shrinkable materials, Biodegradable materials

2. 2003 – 2004

- Installation of the facility and device/chain/conveyor
- Utilization of the facility to approve feasibilities of application to the industry

3. 2004 – 2005

- Semi-commercial production by using the facility
- Feasibility study on introduction of an industrial scale electron accelerator in the way maybe of join venture.

BBS board: announcement, news, discussion, etc.

Annex 4

11. FIVE YEARS PROGRAM FOR FNCA PROJECT ON APPLICATION OF ELECTRON ACCELERATOR .

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Annex 4

11. FIVE YEARS PROGRAM FOR FNCA PROJECT ON APPLICATION OF ELECTRON ACCELERATOR (Tentative)

	FY2001		FY2002		FY2003		FY2004		FY2005		Remarks
Overall Schedule	Nov. 2^{nd} FNCA (Japan)	Mar. 3^{rd} CDM (Japan)	Autumn 3^{rd} FNCA (Korea)	Mar. 4^{th} CDM (Japan)	Autumn 4^{th} FNCA (Japan)	Mar. 5^{th} CDM (undecided)	Autumn 5^{th} FNCA (undecided)	Mar. 6^{th} CDM (Japan)	Autumn 6^{th} FNCA (undecided)	Mar. 7^{th} CDM (undecided)	
Participating Countries	China, Indonesia, Korea, The Philippines, Malaysia, Thailand, Vietnam and Japan (total 8 countries)										
Schedule of WS	January 28 – February 1, 2002 (Japan)		Autumn, 2002 (Japan)		(Malaysia)		Undecided (China)		Undecided (Vietnam or Thailand)		
Contents of WS	• Project Programming and Information Exchange • Survey of Radiation Facilities in the Participating Countries. • Proposal for EB Application in the Participating Countries		**Main subject: Liquid** • Demonstration Test of EB System for Liquid • Review of the Irradiation Systems • Designing and Cost Analysis of EB Irradiation System		**Main subject: Thin Film** • Demonstration Test of EB System for Application Thin Film • Study on Optimum EB Irradiation System • Open Lecture		**Main subject: Granules** • Demonstration Test of EB System for Granules • Study on Optimum EB Irradiation System • Open Lecture		Main subject: Undecided • Demonstration Test of EB System for Application (Vietnam or Thailand) • Study on Optimum EB Irradiation System • Open Lecture		
Others	December: Sending out the Questionnaire (Present Status and Needs in Each Country)										

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国際単位系（SI）と換算表

表1　SI基本単位および補助単位

量	名　称	記　号
長　さ	メートル	m
質　量	キログラム	kg
時　間	秒	s
電　流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光　度	カンデラ	cd
平面角	ラジアン	rad
立体角	ステラジアン	sr

表2　SIと併用される単位

名　称	記　号
分，時，日	min, h, d
度，分，秒	°, ′, ″
リットル	l, L
トン	t
電子ボルト	eV
原子質量単位	u

1 eV=1.60218×10^{-19}J
1 u=1.66054×10^{-27}kg

表5　SI接頭語

倍数	接頭語	記　号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^{9}	ギガ	G
10^{6}	メガ	M
10^{3}	キロ	k
10^{2}	ヘクト	h
10^{1}	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

表3　固有の名称をもつSI組立単位

量	名　称	記号	他のSI単位による表現
周波数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	m·kg/s^2
圧力，応力	パスカル	Pa	N/m^2
エネルギー,仕事,熱量	ジュール	J	N·m
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	A·s
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束	ウェーバ	Wb	V·s
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光束	ルーメン	lm	cd·sr
照度	ルクス	lx	lm/m^2
放射能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量等量	シーベルト	Sv	J/kg

表4　SIと共に暫定的に維持される単位

名　称	記　号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリー	Ci
レントゲン	R
ラド	rad
レム	rem

1 Å=0.1nm=10^{-10}m
1 b=100fm^2=10^{-28}m^2
1 bar=0.1MPa=10^{5}Pa
1 Gal=1cm/s^2=10^{-2}m/s^2
1 Ci=3.7×10^{10}Bq
1 R=2.58×10^{-4}C/kg
1 rad=1cGy=10^{-2}Gy
1 rem=1cSv=10^{-2}Sv

(注)

1．表1－5は「国際単位系」第5版，国際度量衡局 1985年刊行による。ただし，1 eV および1 uの値はCODATAの1986年推奨値によった。

2．表4には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。

3．barは，JISでは流体の圧力を表わす場合に限り表2のカテゴリーに分類されている。

4．EC閣僚理事会指令ではbar，barnおよび「血圧の単位」mmHgを表2のカテゴリーに入れている。

換　算　表

力	N(=10^{5}dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘　度　1 Pa·s(N·s/m^2)=10 P(ポアズ)(g/(cm·s))

動粘度　1m^2/s=10^{4}St(ストークス)(cm^2/s)

圧力	MPa(=10bar)	kgf/cm^2	atm	mmHg(Torr)	lbf/in^2(psi)
	1	10.1972	9.86923	7.50062×10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	J(=10^7 erg)	kgf·m	kW·h	cal(計量法)	Btu	ft·lbf	eV
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813×10^{-4}	0.737562	6.24150×10^{18}
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1

1 cal= 4.18605J（計量法）
　= 4.184J（熱化学）
　= 4.1855J（15℃）
　= 4.1868J（国際蒸気表）

仕事率　1 PS(仏馬力)
　= 75 kgf·m/s
　= 735.499W

放射能	Bq	Ci
	1	2.70270×10^{-11}
	3.7×10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58×10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

(86年12月26日現在)

Proceedings of the FNCA Workshop on Application of Electron Accelerator January 28 - February 1, 2002, JAERI, Takasaki, Japan

R100

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