JAERI-M
90-194

PROCEEDINGS OF THE WORKSHOPS ON THE UTILIZATION OF ELECTRON BEAMS

November 1990

(Ed.) Sueo MACHI

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

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編集兼発行　日本原子力研究所
印　　　刷　いばらき印刷㈱

Proceedings of the Workshops on the Utilization of Electron Beams

(Ed.) Sueo MACHI

Takasaki Radiation Chemistry Research Establishment
Japan Atomic Energy Research Institute
Watanuki-cho, Takasaki-shi, Gunma-ken

(Received September 11, 1990)

Workshops organized by JAERI in cooperation with UTN, BATAN and JAIF on the utilization of electron beam (EB) were held in Malaysia and Indonesia on 17 and 20 July 1990, respectively. These proceedings compile 11 papers presented at the Workshops. Welcome remarks, opening address and closing remarks are also recorded. Trends in industrial application and recent advances in high EB machine in the world were presented as the first part of the Workshops. Potential application of EB machine in Malaysia and Indonesia were discussed. Details of the crosslinking of wire/cable and rubbers with EB were introduced as the practical applications of EB in Japan. BATAN presented the experiences on radiation curing with a low energy EB machine. Sterilization of medical products and food irradiation with EB were reported by JAERI and UTN. BATAN presented prospect of commercialization of food irradiation in Indonesia. Application of EB as well as γ-ray to agro-resources was also discussed with special interest in the production of animal feed.

Keywords: Electron Beams, Utilization, EB Machine, Industrial Application, Workshop, Proceedings

電子線の利用に関するワークショップ論文集

日本原子力研究所高崎研究所
（編）町　　末男

（1990年9月11日受理）

原研は，マレーシア原子力庁，インドネシア原子力庁及び日本原子力産業会議の協力のもとに，電子線の応用に関するワークショップをマレーシア（平成2年7月17日）とインドネシア（平成2年7月20日）とで開催した。本論文集は，これらのワークショップで発表された11の論文を収録したものである。日本における電子加速器の工業利用の動向，高エネルギー電子加速器の最近の進歩の紹介で始まり，マレーシア及びインドネシアにおける電子加速器の応用の可能性が述べられている。日本における電子線応用の実例としては，電線・ケーブルの橋かけとゴムの電子線加工が紹介されている。さらに，インドネシアにおける低エネルギー電子加速器による放射線硬化に関する現状と問題点が述べられている。また，医療材料の滅菌と食品照射及び農業資源への電子線の応用も紹介されている。

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PREFACE

Research and development on the application of isotopes and radiation are actively carried out in Asian countries. Their major interests are focused on the radiation processing. The Bilateral Research Cooperations between the Japan Atomic Energy Research Institute (JAERI) and the National Atomic Energy Agency, Indonesia (BATAN), the Nuclear Energy Unit, Malaysia (UTN) and the Office of Atomic Energy for Peace, Thailand (OAEP) in the field of Radiation Processing have been contributing to the progress in radiation processing in these countries. The main radiations which are used for research on the radiation processing in these countries are limited to gamma-rays from Co-60. While in Japan more than one hundreds electron accelerators are now used for the radiation processing in industries. These Asian Governments are very eager to install a high energy electron accelerator. They requested Japanese support on the technology transfer of electron beams technology. Based on those requests, JAERI organized Workshops on the utilization of electron beams in cooperation with UTN, BATAN and Japan Atomic Industrial Forum. The Workshops aimed at the introduction of Japanese experiences in the commercial application of electron accelerators. The Workshops were held in Malaysia on 17 July and in Indonesia on 20 July, 1990.

Dr. S. Machi, Dr. I. Ishigaki, Dr. K. Makuuchi and Dr. T. Kume of JAERI, Mr. M. Suzuki of Nissin-High Voltage Co. Ltd., Mr. S. Yamamoto of The Furukawa Electric Co. Ltd., Mr. S. Takahasi of JAIF, Mr. A. Kuroyanagi of Nissin Electric Co. Ltd. and Mr. T. Watanabe of NKK participated from Japan.

The Workshop in Malaysia named "Scientific Talk on Utilization of Electron Beam Machine" was held in an Auditorium of UTN. The numbers of attendant were 53 including UTN staffs. Utilization of the two electron accelerators which are going to be installed in UTN by Japan International Cooperation Agency (JICA) was discussed mainly in the Workshop.

The Workshop in Indonesia entitled "Radiation Technology Workshop on the Utilization of Electron Beam Machine as a Production Tool" was held in the Pan Sari Pacific Hotel, Jakarta. The numbers of participants were 86 including BATAN staffs. BATAN has a low energy electron accelerator in the Center for Application of Isotopes and Radiation

(PAIR). This machine has been used for the research on surface coatings of wood panel. PAIR hopes to install a high energy electron accelerator to expand the range of research and development activities to contribute the National Development Program.

These were our first workshops jointly organized and held in Malaysia and Indonesia. It is desirable that the Workshops will be held periodically to promote industrial application of radiation technology. These Proceedings compile all papers presented at both Workshops in one volume. I would like to express my sincere appreciation to all those who have contributed so much for the Workshops.

S. Machi
Editor in Chief
Takasaki Radiation Chemistry Research Establishment
JAERI

Photo. 1 Deputy Director of UTN delivering his welcome remarks

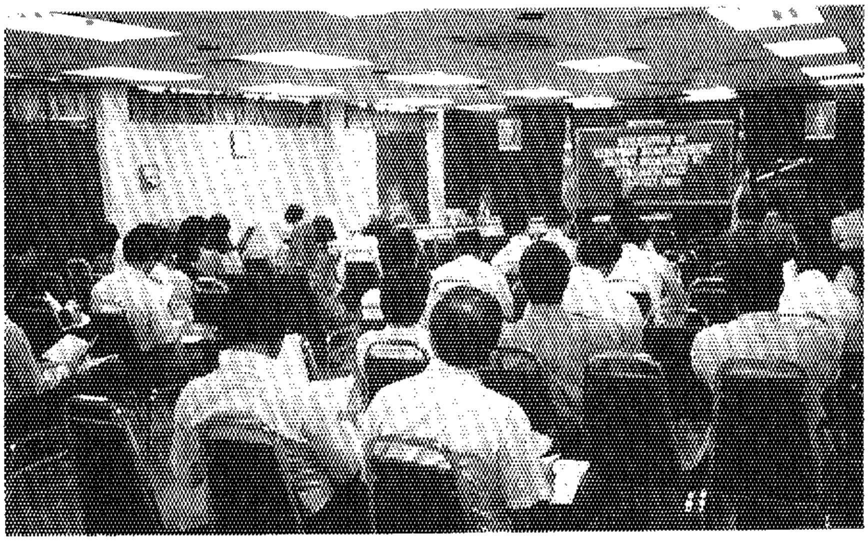

Photo. 2 A view of workshop participants in Malaysia

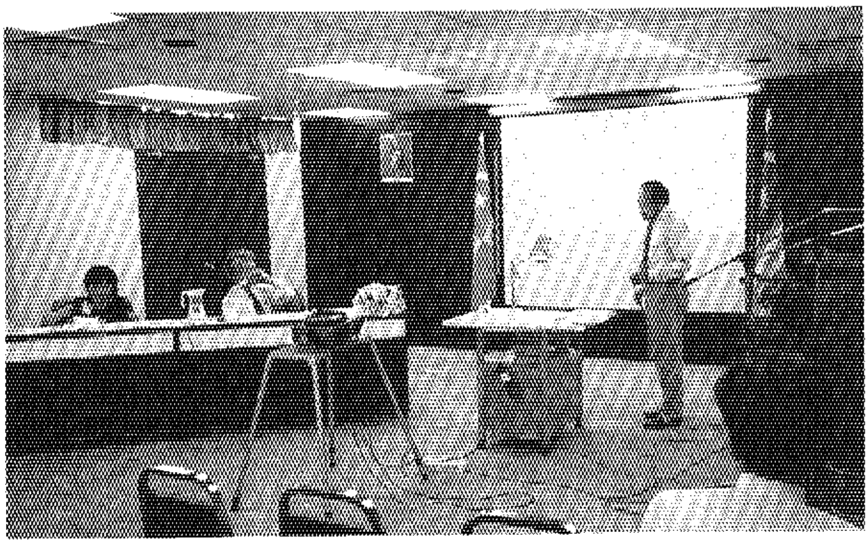

Photo. 3 A lecturer from UTN presenting his paper on food irradiation

Photo. 4 A lecturer from the Furukawa Electric Co. explaining EB crosslinking of wires

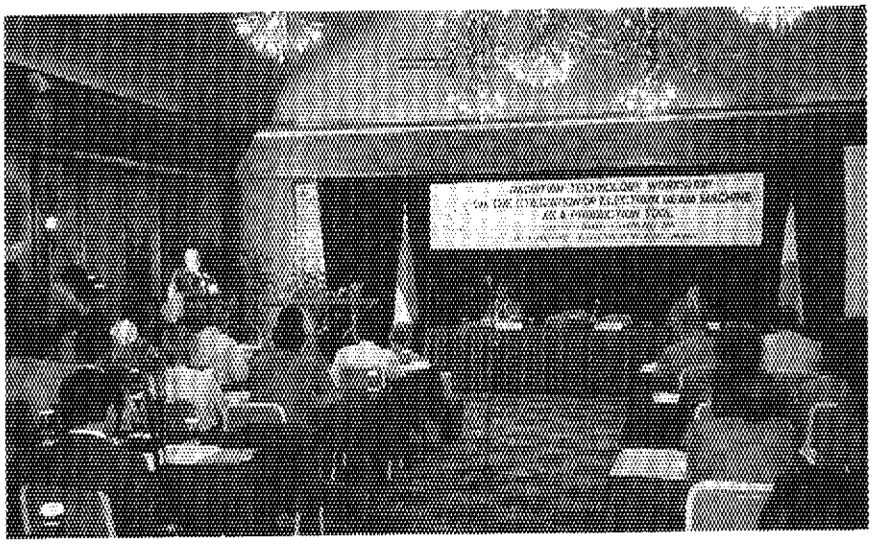

Photo. 5 Director General of BATAN delivering his welcome remarks

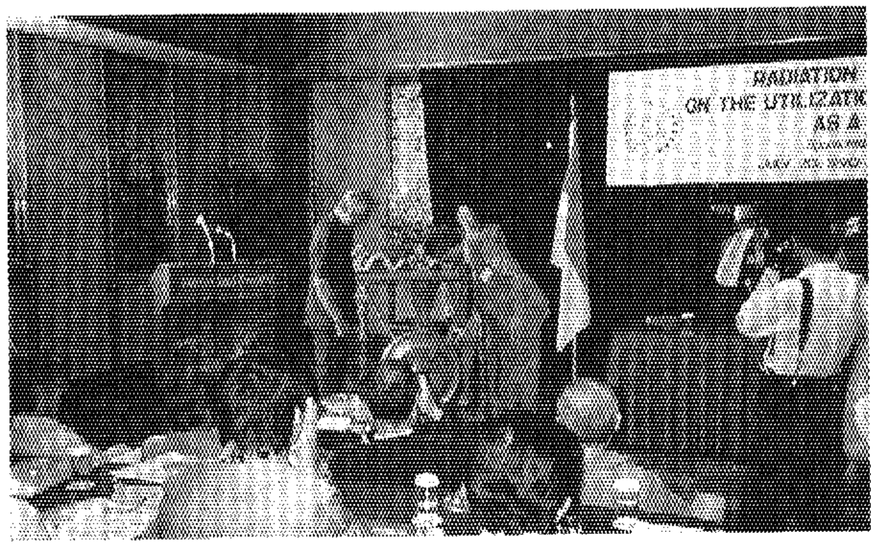

Photo. 6 Director Generals of BATAN and TRCRE jointly opening the Workshop officially

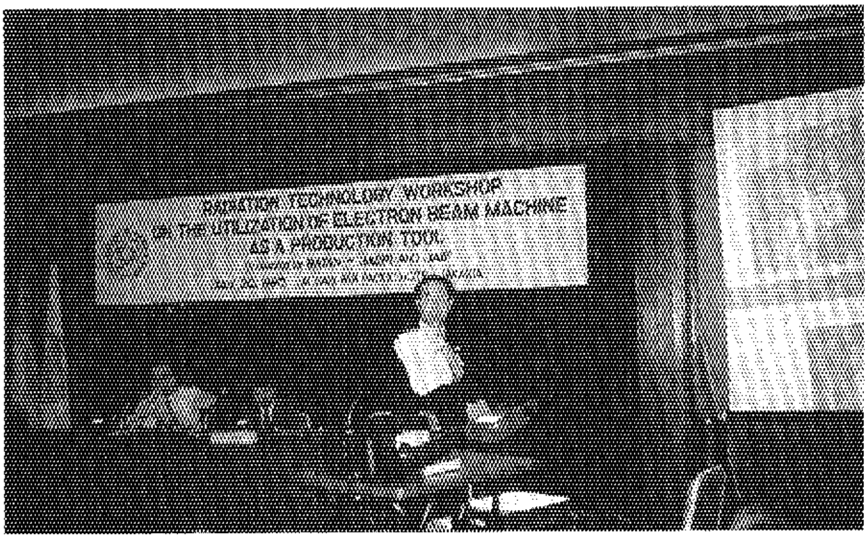

Photo. 7 A lecturer from TRCRE presenting his paper on EB processing of rubbers

Photo. 8 A lecturer from BATAN presenting his paper on EB processing in Indonesia

Photo. 9 Director General of TRCRE and Organizing Committee of BATAN jointly closing the Workshop

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1. OPENING

1.1 Welcome Remarks

KASBUN KAMAT

Deputy Director General, Nuclear Energy Unit

Assalamualaikum and Good Morning,
Dr. Machi, the DG of TRCRE,
Distinguished speakers,
Ladies and Gentlemen.

Let me begin by welcoming all of you to this scientific talk on "the utilization of Electron Beam Machine (EBM)" jointly organized by Japan Atomic Energy Research Institute (JAERI), Japan Atomic Industrial Forum (JAIF) and Nuclear Energy Unit (UTN).

Radiation Technology has been widely used in developed countries in industries such as sterilization of medical products, radiation curing of surface coating, radiation X-linking of wires and cables, vulcanization of natural rubber, upgrading of agro-industrial waste etc. In fact, this radiation technology had become a necessary tool to some industries as it offers more advantages and more effectiveness over the normal conventional method in improving the standard of production as well as the plant-operating efficiency. On the other hand, utilization of this technology in developing countries like Malaysia is still very few or more appropriately described as at its infancy stage.

It is generally acknowledged that as part of the strategy to improve industrial performance and achieve national economic growth, the use of modern technology is of paramount importance. This is especially true in the case of Malaysia since over the last few years the Government has been emphasizing the need for the country to industrialize. Of course in this context, radiation technology offers such an opportunity in the sense of the improvement in manufacturing, processing and production efficiencies. At the same time it may result in better utilization of indigenous raw materials in the manufacture of products both for domestic consumption and export.

Realizing the significant potential of the use of this technology in Malaysia, especially in enhancing downstream processing of primary products into value added products, UTN has embarked on R&D work using this technology, with the aim of developing expertise that subsequently could provide consultancy and advisory services to both the public and private sectors. Seminars and workshops are often organized to create more awareness among industries and the public with the hope that the rapidly growing domestic industries will pick up this technology. Today's talk is in line with our effort.

In facilitating the R&D work, UTN has constructed and installed Co-60 irradiating facility located at our branch in Jalan Dengkil and the facility has been operating since 1989. The large volume of irradiation request received from local industries, which sometimes extend beyond our capability, is a clear evidence of the potential and success of the use of this technology. UTN will be receiving 2 electron beam machines from Japan at the end of this year, under the bilateral cooperation between Japan International Cooperation Agency (JICA) and UTN. The availability of these EBM will further complement the existing facilities that will harness active R&D work to transfer the technology to the industries. Therefore I believe today's talk is timely organized for us to realize the potential of this technology for application in our country.

Ladies and Gentlemen,

Before I invite the speakers to present their papers, let me introduce the co-chairman of this talk, i.e. Dr. S. Machi, the Director General of Takasaki Radiation Chemistry Research Establishment of JAERI, seated next to my right. Allow me also to mention our appreciation to both JAERI and JAIF for sending the four speakers.

With that note, may I have the pleasure to invite Dr. Machi to deliver his opening remarks.

1.2 Welcome Remarks

DJALI AHIMSA

Director General, National Atomic Energy Agency, Indonesia

Dr. Machi,
Mr. Takahashi,
Ladies and Gentlemen,
Good morning,

It is indeed great honour and pleasure for me to be here in the opening session of the JAERI-JAIF-BATAN workshop on the electron beam machine in Jakarta, which will be held today in this hotel.

I appreciate very much and I would like to express my sincere thanks to the Japanese side, the Japan Atomic Industrial Forum and the Japan Atomic Energy Research Institute, Takasaki, for the initiative to hold this workshop on the electron beam machine in Jakarta.

As you may know that the electron beam machine technology has been widely used in the world for industrial purposes in industrial scale. Electron beam machine has come into use into industrial applications and develop benefit for the last 10 years, the last decade. We have seen the benefit, many benefits of the electron beam machine which has been used in the world today in the field of cable manufacturing, in the field of irradiation for sterilization, in the field of irradiation of food, and many other applications.

In Indonesia radiation technology is still in the development state in which BATAN has started the development of the technology of irradiation. BATAN had also started the use of the small electron beam machine for the use of wood surface coating technology in which my opinion had attracted the interest of some private sectors in Indonesia. In the radiation technology using Co-60 technique, I would like to say that I am very happy to see that private sectors had already shown the interest in the using of this technology for the manufacturing, for the sterilization of medical products in Indonesia.

I hope that in not too distant future commercial type of irradiation facility will be erected in Indonesia for commercial purposes.

Today we all hear from our Japanese counterparts, from the Japanese experts on the use and technology of electron beam machine. Which as you may know that about 60% of all electron beam machines which are produced in Japan, and we believe that our experts from Japan will share the experiences and the knowledge with our people and with our experts. And I also would like to say that the private sectors in Indonesia will obtain your experiences and knowledge in the use of electron beam machine.

I am glad to say that today in this workshop more private sectors are represented with this meeting. I hope that in the near future this interest of the private sector will develop and this technique in Indonesia will be used in our country for manufacturing of some items.

In this occasion, I would also like to mention that BATAN has started the initiative to erect electron beam machine for the purpose of research and development, but this machine can also be used for the private sector in order to start developing this technology for the manufacturing purposes.

BATAN had just started to study the technology of electron beam machine, and I hope that in a few years electron beam machine with a high energy can be ready to be installed and operated in Indonesia under a kind cooperation with Japan.

I hope that all Japanese colleagues and Japanese government could give us an assistance in designing for the software to develop this machine in Indonesia.

Ladies and Gentlemen,

I also would like to express my gratitude to the Japan Atomic Energy Research Institute, Takasaki, and Japan Atomic Industrial Forum for the enchancing of our bilateral cooperation in the field of nuclear energy. As you may know that Indonesia has already started the programme to erect its first nuclear power station in the Muria area in central Java. We hope this first power nuclear station will be in operation in the year 2003 about 13 years from today.

Ladies and Gentlemen,

With the spirit of cooperation between Japan and Indonesia, finally I would like to declare this workshop officially opens and I hope this workshop will be very successful until the end of the day, and I also hope that all Japanese colleagues could see not only Jakarta but also all the parts of our country, and to learn both the present progress of technology and our culture in Indonesia.

Thank you very much.

1.3 Organizing Committee Report
"Radiation Technology Workshop on the Utilization of Electron Beam Machine as a Production Tool"

NAZLY HILMY

Director, Center for the Application of Isotopes and Radiation, BATAN

Mr. Djali Ahimsa, Director General BATAN,
Dr. Sueo Machi, Director General, Takasaki Radiation Chemistry Research Establishment (JAERI),
Mr. Seiichiro Takahashi, Japan Atomic Industrial Forum,
Distinguished Speakers, Guests, Ladies and Gentlemen,

On Behalf of the Center for the Application of Isotopes and Radiation-National Atomic Energy Agency, and also on behalf of the organizing committee of the Radiation Technology Workshop, it is indeed my great honour to extend a most cordial welcome to all of you on this meaningful opening of this jointly BATAN/JAERI/JAIF workshop.

Allow me to report to you all that this workshop named "Radiation Technology Workshop on the Utilization of Electron Beam Machine as a Production Tool" is a conjunction with a bilateral research cooperation between BATAN and JAERI. Yesterday, we had a Steering Committee Meeting at CAIR-BATAN, Pasar Jumat. We discussed our second term of five years research cooperation from now on. We also discussed about the way to transfer of technology in which private sectors could be involved actively.

The workshop aims to provide the participants with the necessary information on the principles of different applications of radiation processing techniques in solving industrial problems. Radiation processing techniques, especially on the utilization of electron beam as a production tool is a specific and unique technique, so that sometimes only by using this technique any industrial problem can be solved more successfully in complement with other existing technique.

In this regard I would like to ask for an active participation from all participants. Let us like advantages of the valuable opportunity during the workshop.

Ladies and Gentlemen,

This workshop is attended by participants from industry, research institute, university, as well as from the government institution. Total number of participants are 80 persons. There will be 6 invited speakers from Japan and 3 from Indonesia who will give information and also present case studies to illustrate the use of this technique in practice. At the end of this workshop we have arranged a panel discussion.

In this occasion I would like to extend my appreciation to Dr. Sueo Machi from Takasaki Radiation Chemistry Research Establishment (JAERI) and Mr. Seiichiro Takahashi from Japan Atomic Industrial Forum (JAIF), for their endless efforts in supporting, stimulating, and guiding to the radiation processing group here in BATAN.

Thank you.

1.4 Opening Address

SUEO MACHI

Director General, Takasaki Radiation Chemistry Research Establishment,
Japan Atomic Energy Research Institute

Dr. Ahimsa, Director General of BATAN
Distinguished Guests,
Ladies and Gentlemen,

On behalf of JAERI, JAIF and members of Japanese delegation, I would like to thank BATAN for excellent preparation and hosting the workshop on application of electron beams. This workshop is organized jointly by BATAN, JAIF and JAERI to exchange up to date information on new development and trend of radiation application research in proper direction. This meeting is characterized by combination of speakers from industries and research institute.

Ladies and Gentlemen,

Nuclear technology is very beneficial for human being. Largest application of nuclear technology is electrical power generation using nuclear fission energy. In our country 30% of electricity is produced by nuclear power plants. Since Japan has not enough oil, gas and coal, then nuclear energy is indispensable. It has been also recognized that nuclear energy is better than oil and coal in terms of environmental pollution.

Another important use of nuclear technology is the application of radiation and isotopes for industries, agriculture and medicine. In Japan there are more than 100 electron beam machines for commercial production and research. The applications are still expanding in industry and medicine.

Ladies and Gentlemen,

I visited Indonesia two years ago last time. Yesterday I visited

PAIR-BATAN and was much impressed of the progress made in the project of surface coating of wood products and crosslinking of rubber latex. I was told that some of the products are in commercial use. I hope that BATAN will strengthen tie with industrial companies.

Ladies and Gentlemen,

Our Atomic Energy Commission (AEC) has made the policy to actively promote the international cooperation with Asian Countries. We are implementing cooperation through bilateral and multinational such as IAEA-RCA. Our cooperation between BATAN and JAERI in the field of radiation application is one of the most important cooperative programs.

Ladies and Gentlemen,

This workshop is the first one held in Indonesia. I hope it would be useful for both countries to enhance technology transfer of electron beam (EB) process to industries.

Thank you very much for your attention.

2. PRESENTED PAPERS

2.1 New Trends in Industrial Application of Electron Beam Machine

S. MACHI

Japan Atomic Energy Research Institute
Takasaki Radiation Chemistry Research Establishment

1. Introduction

Research and development of radiation processing applications have been carried out for more than 30 years resulting industrial applications in new polymeric materials, surface conversion, medical products sterilization and food irradiation. Nowadays, about 180 electron beam machines are used for radiation processing as shown in Table 1. Research and development have been carried out in Governmental institutes such as JAERI and private companies.

Environmental conservation is important task in Japan. Radiation processing for this purpose has been conducted. Radiation chemistry will provide fundamental theory to estimate the life time of organic materials used in nuclear plants under radiation. This paper reports the overview of up-to-date EB applications and its future trends in Japan.

2. Industrial Application of Radiation Processing

2.1 Radiation Crosslinking

Commercial application of electron beams to crosslinking wire and cable insulation materials is the biggest field of industrial application of radiation processing in Japan. Thirteen companies produce a variety of irradiated wires and cables, which can be used for wiring of electronic equipments and cars.

The radiation crosslinked polyethylene foam is used for interior of cars, shock absorbing materials such as cushion, and building materials for heat insulation and sound absorption, etc.

The heat shrinkable tubes and films are produced by five companies for packaging of food and other products, insulation of electrial parts and joints, connectors for telecommunication cables, corrosion protection for welded line of steel pipes, etc.

Radiation crosslinking of unvulcanized rubber sheets improves its mechanical properties (for instance, green strength) and enables easy handling of the sheets in building them into tires. Four tire manufactures are using electron accelerators in their production lines of tire.

2.2 Curing of Surface Coatings

This application is most widely used and still expanding in industries. Major applications are listed in Table 2. Further development of new applications will be expected in finding new formulation of coatings and substrates.

2.3 Radiation Grafting

Radiation grafting is well known to be one of the most promising methods to modify polymer materials.

JAERI and Yuasa Battery Co. have jointly developed the battery separator by preirradiation grafting of acrylic acid onto polyethylene film using EB and the process has been commercialized. This membrane has a high electric conductivity and excellent durability and was found to be used not only in silver oxide primary cell but also in Nickel-Cadmium secondary battery.

New deodorant has been developed by our Institute by using radiation grafting of syrene and chloromethyl styrene onto polypropylene fiber followed by sulfonation and quaternization. These products have much higher capacity of deodoring and adsorb acidic and alkaline pollutants. Commercial production is started in 1989 in Japan.

3. Environmental Preservation

3.1 Flue Gas

The studies on electron beam treatment of flue gases are being continued with flow-type irradiation experimental apparatuses. In the treatment of flue gas from a coal-fired boiler, the reaction mechanisms are studied by the irradiation experiments with N-15 labelled ^{15}NO and $^{15}NH_3$ and the experiments showed that about 20% of initial concentration of NO(400 ppm) were converted to nitrogen molecule (Fig. 1). Besides, the two-stage irradiation method are being studied for the reduction of the required dose for the removal of SO_2 and NO_x. The electron beam treatment of flue gas from a municipal waste incinerator is being studied by the electron beam irradiation of simulated flue gas (5 Nm^3/h) in the presence of alkaline powdery material to remove NO_x, SO_2 and HCl simultaneously.

3.2 Waste Water

In the study on radiation treatment of waste water, electron beam disinfection of secondary effluent from a sewage plant has been studied in batch and flow (10 m^3/h) experiments. The study showed that 99.9% and 99.99% of coliforms in effluent was effectively killed by the irradiation of 480 Gy and 600 Gy, respectively, and that the disinfection was not affected by the change of COD, SS, pH and temperature of the effluent. A "fountain-type" flow method was developed to generate fast and thin flow of effluent for effective irradiation with electron beam. In the study on treatment of supernatant produced from sludge treatment, COD could be reduced below 30 mg/l with the dose of 6 - 8 kGy by the combination process of electron beam irradiation and biological treatment.

3.3 Sewage Sludge

In the study on disinfection of dewatered sewage sludge with electron beam irradiation and efficient composting of the disinfected sludge, successful disinfection of the sludge was performed by the irradiation of thin and uniform layer of the sludge on a stainless steel conveyor. A large scale test was done with a pilot plant of treatment-capacity of 500 kg sludge/batch, and efficient composting was performed with controlling fermentation temperature and air flow-rate in the optimum ranges, and with frequent mixing in the fermenter. The produced compost is now under utilization test on vegetable growth as fertilizer. Figure 2 shows EB application to city water system.

4. Ion Beam Technology

In 1987 JAERI initiated new project to construct the ion beam irradiation facility (Fig. 3) at Takasaki including four ion beam accelerators shown in Table 3 and to promote research and development in the pioneering fields as summarized in Table 4.

Construction is divided into two phases. In the first phase, high and medium energy heavy ion irradiators will be installed, and the necessary irradiation building and control and research building will be constructed. These are expected to be in full operation by 1991. The second phase will be followed in 1991 - 1992, and dual and triple ion beam irradiation experiments can be carried out in 1993.

Exchange of scientists between JAERI and other domestic and foreign organizations is thought to be a key to success of the project, including international cooperation.

Table 1 Number of electron accelerator in Japan

Application Field	Number	Power	
		Energy (MeV)	Current (mA)
Research & Development	64	0.175 - 3.0	100
Curing	50	0.2 - 0.3	600
Wire & Cable Insulation	38	0.3 - 2.0	100
Pre-Curing of Tire Rubber	9	0.5 - 0.8	220
Shrinkable Tube & Sheet	8	0.3 - 3.0	100
Polyolefin Foam	6	0.5 - 1.0	100
Others	5	0.5 - 2.0	60
Total	180		

Table 2 EB curing processes in Japan

Year	Product	Company	Remarks
1988/89	Precoated Steel PVC-Laminated	Nisshin Steel	
1987/88	PCB (electro-conductive)	CMK	
1986	Micro Floppy Discs	TDK	
1986	Plastic Sheet Printing	Mitsumura Printing	175 keV, 300 mA
1985	Juice Carton Printing	Tetra Pak Japan	2 lines
1984	Gypsum Tile	Achilles	280 keV, 40 mA
1982	Precoated Steel	Dai-Nippon Ptg. Ellio	300 keV, 80 mA 2 lines
1979	Cement Roof Tile	Nakazato Sangyo	300 keV, 100 mA
1973-80	Motorcycle Parts (steel, ABS, PP)	Suzuki Motor	300 keV, 100 mA (2 heads)

Table 3 Accelerators and their main characteristics for the ion beam irradiation facility

Name	Type	Ion	Energy (Mev)	Maximum Current (μA)	Characteristics
High Energy Ion Beam Irradiator	AVF Cyclotron	Proton Deuteron He C Ne Ar Kr	5～ 90 5～ 55 10～110 30～330 50～550 100～700 200～630	40 40 30 5 5 5 1	·ECR ion source ·Wide Irradiation Field ·Pulsed Beam ·Vertical Beam ·Neutron Beam ·Combined Beam ·Microbeam
		Xe	310～620	0.1	
Midium Energy Heavy Ion Beam Irradiator	Tandem Accelerator (3MV)	Proton C Ni Au	0.8～ 6.0 0.8～15.0 0.8～15.0 0.8～ 9.0	5 5 5 10	·Microbeam ·Combined Beam
Midium Energy Light Ion Beam Irradiator	Van de Graaf Accelerator (3MV)	Proton Deuteron He Electron	0.4～ 3.0 0.4～ 3.0 0.4～ 3.0 0.4～ 3.0	300 150 300 100	·Microbeam ·Combined Beam
Low Energy Ion Beam Irradiator	Ion Implanter (0.4MV)	He Ni Au	0.025～0.4 0.025～0.4 0.025～0.4	50 30 30	·Combined Beam ·Ion up to Au

Table 4 Research items on advanced application of radiation by ion beam technology

RESEARCH AND DEVELOPMENT ON RADIATION-RESISTANT MATERIALS IN SEVERE ENVIRONMENT

1. Materials for Space Environment
   * Research on Space-Radiation Resistance of Semi-Conductor Devices and Sensors
   * Research on Space-Environment Endurance of Construction Materials for Satellites

2. Materials for Nuclear Fusion Reactor
   * Research on Radiation Damage Mechanism of First Wall and Breeder Blanket Materials
   * Research on Radiation Resistant Organic Composite Materials

RESEARCH ON BIO-TECHNOLOGY AND NEW FUNCTIONAL MATERIALS

1. Bio-Technology
   * Research on Environment-Tolerant Gene Resources
   * Research on Bionics Materials
   * Research on Ion-Beam Radiation Chemistry of Bio-Materials
   * Research on New Labeled Compounds

2. New Functional Materials
   * Research on Creation and Modification of Materials
   * Research on Novel Analysis Technology

RELATED RESEARCH

* Ion Beam Technology

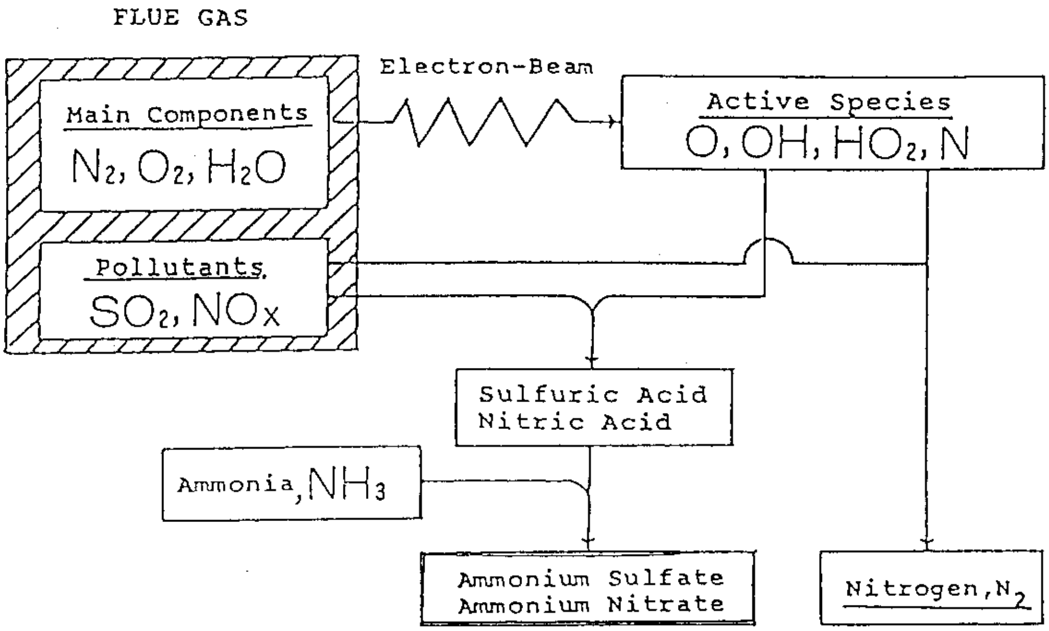

Fig. 1 Reaction scheme of stack gas treatment by electron beams

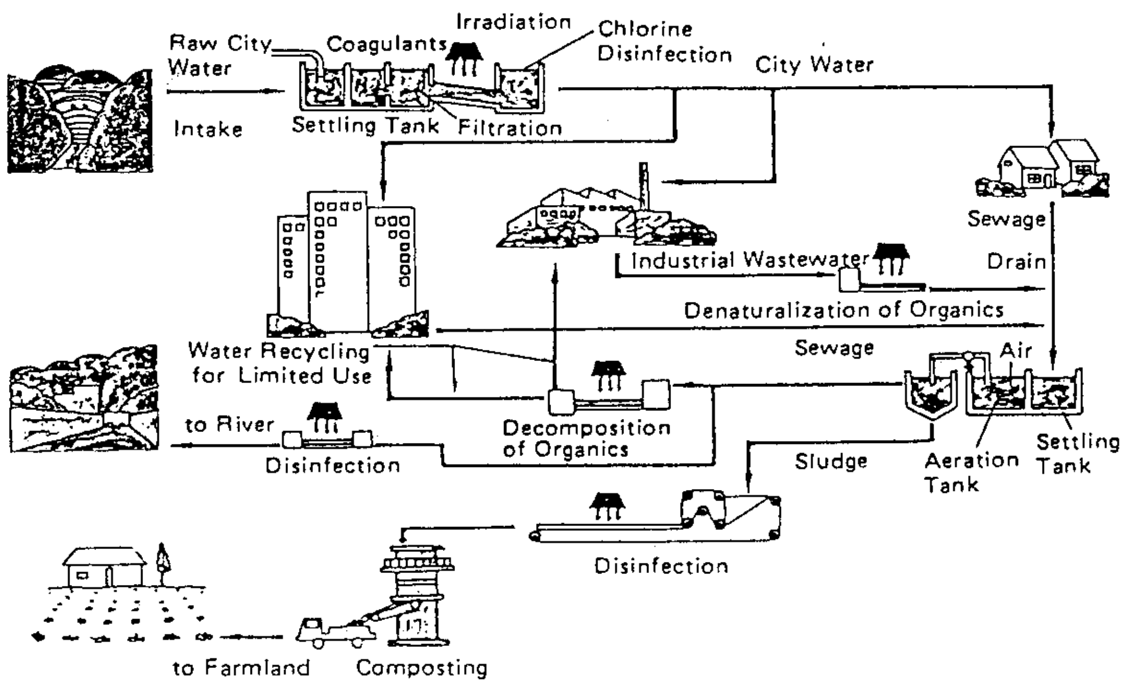

Fig. 2 Application of radiation in treatment systems for raw city water, wastewater and sewage sludge

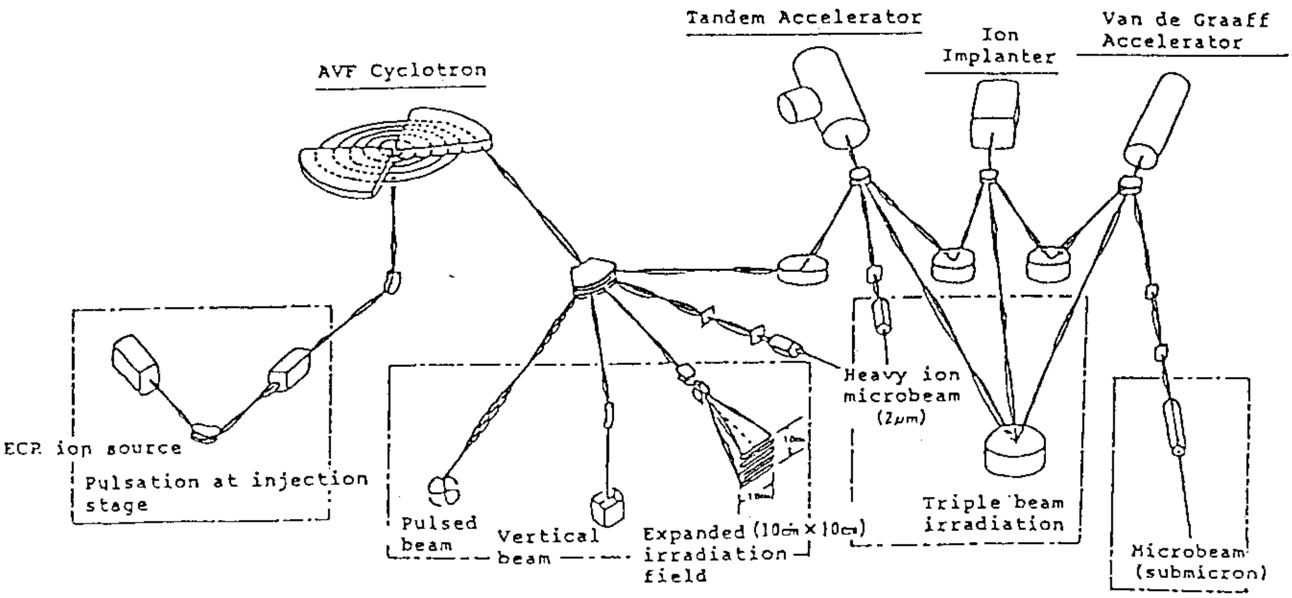

Fig. 3 Ion beam facilities under construction at TRCRE of JAERI

2.2 Potential Applications of Electron Beam Machine in Malaysia

KHAIRUL ZAMAN HJ. MOHD. DAHLAN

Nuclear Energy Unit

1. Introduction

Radiation processing was first introduced in Malaysia in 1982 with the inception of the project on Industrial Applications of Isotopes and Radiation Technology for Asia and the Pacific Region supported by UNDP, IAEA and RCA countries. Four activities are still being carried out under this project namely;

- Radiation Vulcanization of Natural Rubber Latex,
- Radiation Curing of Surface Coatings,
- Radiation Sterilization of Medical Products,
- Radiation Crosslinking of Wire and Cable Insulation.

These four projects are now becoming the main activities of radiation processing at UTN including the radiation processing of agro-industrial waste.

In the last 7 years, our activities in these areas are rather limited because of the absence of radiation sources and lack of other related facilities. However, in 1984 some work on RVNRL and palm oil waste were started using our self-shielded Co-60 with an initial activity of 10,000 Ci. In late 1988, we received the UV irradiation facility which enables us to start work on radiation curing of surface coatings. In early 1989 with the commissioning of our Co-60 plant which has the initial activity of 200 kCi, the work on RVNRL, palm oil waste and medical products sterilization have been intensified. During these period also we have been able to train our personnel in various fields of radiation processing.

2. Role of Radiation Processing Program of UTN

i) to carry out research in radiation processing technology,

ii) to encourage and advise related industries as regards to the use of radiation techniques in their processing,

iii) to provide technical assistance in the forms of expertise and training to relevant industries and research institutes.

2.1 Our Immediate Objectives are;

i) to create awareness to the industries on the potential applications of radiation technology including its benefits.

ii) to promote radiation as a means of sterilization of disposable medical products, rubber vulcanization, curing of surface coatings, crosslinking of wires and cables and processing of oil palm waste.

iii) development of infrastructure and manpower to support radiation technology.

2.2 Project Design and Management

Persuant to the above objectives, UTN has embarked on various activities in accordance to its role and responsibilities such as carrying out research, conducting training course, seminar, workshop in the above fields. Today's scientific talk is one of the activities which is jointly organized by UTN/JAERI/JAIF to create awareness to scientist and technologist on the potential applications of electron beam processing in industries. UTN also has concluded a bilateral technical co-operation with the Japan International Co-operation Agency (JICA) on the Industrial Application Project. Under this co-operation JICA will provide two electron beam machines (EBM) to UTN, low energy EBM and high energy EBM (specifications as in Table 1). In view of the low penetration of the electron beam, the use of the machines are specific. For low energy EBM 150 - 200 keV, the main use is for thin film applications such as the curing of coatings and the high energy EBM 500 - 3000 keV can be used for other applications such as shown in Fig. 1.

3. Current and Future Activities

It is generally acknowledged that in order to improve industrial performance and to achieve national economic growth, the use of modern technology is of paramount importance. Electron beam processing is considered as one of the modern and advanced technology that can offer an improvement in manufacturing, processing and production efficiencies. It has also been widely recognized that it can increase quality and added value to the products. The example of the industrial applications of electron beam processing is given in Table 2.

Some of these applications have been clearly explained and presented by the previous speakers. In my presentation, I will touch on some of the applications which have the potential to be introduced in Malaysia.

3.1 Radiation Curing of Surface Coatings

There are several industrial applications of low energy EB for curing of coatings on papers, plastics, metal and wood substrates, curing of printing inks and curing of laminating adhesives, pigmented coatings and release coatings. In Malaysia, the EB processing is not yet being used by industry. However, Ultra Violet irradiation has already been in operation in our industry for curing of coatings on plastics, parquet and curing of printing inks. Two UV lines have been installed in one of the parquet companies who produced UV-coatings parquet 1.5 - 1.6 million sq.ft/month for overseas market.

Looking at the development of Malaysian economy today and in particular the wood base industry, the Government has given a greater emphasis on the development of down strean industry for the manufacturing of semi-finish and finish wood products. Furniture manufacturing is one of the sectors which has been identified by the Industrial Master Plan to be developed further. On the other hand, the plywood, chipboard/particle board and laminate plywood are amongst the products which can be upgraded and secure higher value added for the manufacturing of finish products. The curing of coatings on chipboard/particle board and curing of adhesive for laminating plywood are the potential applications of EB processing in Malaysia (Table 3).

Beside the technical feasibility, the economic feasibility is very important before any technology can be adopted by industry. From subsector profile, it shows that our average capacity production of plywood is 24,000 m^3 and chipboard/particle board is 75,000 m^3 per year. Given the number of plywood and chipboard mills which are 42 and 3 respectively, the total production capacity is estimated as 1,008 million m^3 for plywood in which 67% is for export and 0.225 million m^3 for chipboard/ particle board in which 17% is for the export market. From the above figures, it shows that to reach the break-even figure of 40,000 cubic meters per annum for a commercial electron beam cured wood coating line (as reported by Universàl Wood, USA), it requires a total production of several plywood companies in Malaysia. However, the top 4 plywood companies in Malaysia have that capacity in which their production capacity in 1988 was above 40,000 m^3. On the other hand the chipboard/ particle board production is just sufficient.

The potential applications of EB curing on substrates other than wood are ceramic tiles, cement boards and gypsum boards. There are several ceramic tiles companies in Malaysia. One of the leading companies in ceramic tiles has the production of 1.9 million square meters per annum for wall tiles and 1.3 million sq.meters per annum for floor tiles. The company is in the process of acquiring two more automatic production lines for floor tiles. The cement board company is rather small with the production of 12,000 m^3 per annum. The total production of gypsum boards in Malaysia is 3.3 million sq.meters per annum and in the next 2 - 3 years its production is expected to increase to 10.0 million sq.meters per annum. The cement boards and gypsum boards are used for wall partition and for ceilings.

Radiation curable resins for the coatings are mainly imported from oversea. The cost of the resins would certainly add up to the production cost of the cured products. This has some effect on the economic viability of this technology. Therefore, it is important to develop radiation curable resins in the country in order to accelerate the application of this technology to industry.

3.2 Radiation Sterilization of Medical Products

The comparison between gamma sterilization and EB sterilization has been given by Dr. Ishigaki. There is no doubt that these two processes are complimentary, because of the different characteristic of gamma and EB radiation. High penetration of gamma radiation allows bulk sterilization of medical products. On the other hand, low penetration of EB radiation would allow only sterilization of thin products or at the surface of the products (Fig. 2).

At present, UTN already has its own gamma irradiation facilty with a source strength of 1.26 MCi. This facility is capable to process 150 m^3 of products per month at 2.5 Mrad dose. By the end of this year UTN will receive an EB machine for medical products sterilization project. The sterilizaton of medical products using EB is a new technology and the research work will be carried out with the co-operation of Japan International Co-operation Agency (JICA). There are several medical products which have the potential to be sterilized using EB irradiation such as rubber gloves, catheters, condoms, syringes and pharmaceuticals. Being a major producer of rubber gloves, the required volume of products to be radiation sterilized is not a major constraint. However, there are other factors which influence the industry in setting up their own irradiation plants. One of the factors is the uncertainty of the market price as experienced by the examination rubber gloves manufacturers currently. At the height of the boom, some 85 companies were in production and now it is estimated that only 25 companies remain, out of which 10 are multinationals. However, some of these companies turn to surgical and household gloves. In Table 4 the value and percentage of various rubber products being imported and exported from January to May 1990 is presented. From Table 4, it shows that latex goods still remain the major export earning of rubber products. The rubber products industry is expected to register impressive growth this year reaching 1.5 billion ringgit (1988 only 1.0 billion rgt) and rubber gloves alone raked in 700 million rgt. Three condom factories are now in operation and two new ones are coming up.

The increasing awareness on the part of the public and government with regard to public health and the risk of spreading hepatitis and AIDs prompted the high demand of radiation sterilized rubber gloves and other medical products in the world. Coupled with high sterility assurance and residual-free of the irradiated products, the radiation sterilization technique will become an important technique in the future.

3.3 Radiation Crosslinking

Radiation crosslinking of plastic is another technology which is expanding in several countries in Asia, Europe and America. In Malaysia, the crosslinked wire and cable insulation is already being produced by some of the wire and cable companies. There is a trend now to turn from

PVC and Paper Insulated wire to XPE. In many developed countries such as Germany, there is already standard requirement that the insulation material must be crosslinked; in halogen-free cables, with enhanced properties in case of fire, the sheath must also be crosslinked, in order to fulfill the requirements of the hot set test. With such a standard requirement, the crosslinked and halogen-free insulated wire and cable will dominate the world market. It is hoped that Malaysia will also follow soon in setting up the standard requirement to meet the fire safety standard, health and environmental requirements such as halogen free and less smoke cables.

Peroxide crosslinking, silane crosslinking and radiation crosslinking are the three methods used worldwide. The first two methods are well known by our industries. However, radiation crosslinking is viewed cautiously by many of us. It is not my intention to review the advantages of radiation crosslinking over the other two methods. However, it is important to note that radiation crosslinking is a potential technique.

Today, there are 17 cable manufacturers in Malaysia and of these, 7 are considered the major manufacturers. The major consumers of cables in the country are Syarikat Telekoms Malaysia Bhd (STM) and three electricity boards (LLN, Sabah Electricity Board and Sarawak Electricity Supply Corporation). In the private sector, the consumers are the housing developers, contractors, electrical appliance manufacturers and automobile manufacturers. In 1989, total demand for various products in the cable and wires industry was estimated to be worth $650 million and for 1990 it is estimated to be $800 million.

In order to support the plastic industry (including wire and cable industry) and to keep the economic growth, the government of Malaysia through Petronas, plans to construct polyolefin plants in a few years time. These plants will produce PE and PP. At present Malaysia has already produced PVC and PS. In the Sixth Malaysian Plan, the project strategies for the technological development of plastics industry in Malaysia stipulate the need for market expansion and increase utilization of locally produced commodity plastics resins, PE, PP, PS and PVC. Table 5 summarizes the domestic demand for these plastics.

The availability of plastic resins locally will encourage the research and development towards the application of EB processing and to promote its application in industry. This application is not only for wire and cable insulation but also for other applications such as crosslinking of plastic film, tubing, etc.

3.4 Other Potential Applications

Tyres have been targetted to play a leading role in the development of the rubber product industry under the industrial Master Plan. Radial steel car tyres, aircraft tyres, motocycle tyres, winter tyres, and high performance tyres are recommended to be priority during the 1990 - 1995 period.

The primary application of electron beam radiation in the rubber industry is in partially crosslinking (precuring) compositions requiring green strength. Green strength can be defined as that level of cohesive strength which allows as essentially uncured, polymer-based composition to deform uniformly, under stress, without sagging or nonuniform thinning. Such compositions include conveyor belt and transmission belt components, and components of pneumatic tires such as carcase piles, inner liners, etc. As an example, the inner liner of tyre component is an ideal shape and thickness for rapid processing using an electron beam. This relatively thin tyre component must be strong enough in its green, uncured state to withstand the rough handling of the tyre building drum, or the component must be partially vulcanized (crosslinked) to provide sufficient toughness and sufficient amount of "building tack" to aid in the building of the tyre. EB processing in this area is being used by several leading tyre manufacturers in Europe, USA and Japan.

The vulcanization of natural rubber latex using EB for the manufacturing of dip products is another potential area which requires extensive research work. Radiation vulcanization of natural rubber latex using gamma radiation is progressing well in Malaysia and to some extent it has been commercialized in Japan.

Radiation treatment of agro-industrial waste such as palm oil waste using gamma irradiation is under investigation. This is a collaborative work between UTN and JAERI. The possibility of using EB irradiation for such study will be looked into in the future program.

4. Conclusion

In general, the electron beam processing has a great potential to be used in industries in Malaysia. Since this is a new technology, it requires a concerted effort from the Government Agency such as UTN and other related agencies and the potential users (in this case the industries) to promote its application. Wood-base and rubber-base industries which are the important sectors in the Malaysian economy should take the advantages of this new technology. This is in line with the government policy to increase the manufacturing of finish products with an added value and higher quality.

At the same time in order to support the government strategies to develop the plastic industry in Malaysia, the electron beam processing offers a new processing technique to produce varieties and high quality products using local plastic resins. The electron beam processing also can contribute to the health, public safety and environmental protection through Good Radiation Practise and Good Manufacturing Practise.

Table 1 Specification of electron beam machine

LOW ENERGY ELECTRON BEAM MACHINE

Accelerator Voltage	150 - 200 kV
Beam Current	20 mA
Irradiation width	15 cm
Conveyor speed	3 m/min - 60 m/min
Sample size	15 cm x 15 cm
Dose uniformity	± 10%
Nitrogen gas	2 - 10^3 m /hr

HIGH ENERGY ELECTRON BEAM MACHINE

Accelerator voltage	500 - 3000 kV
Beam current	30 mA max
Irradiation width	120 cm max.
Conveyor speed	1 m/min - 20 m/min
Sample size	60 cm x 60 cm
Dose uniformity	± 5% at the nominal scan length.

Table 2 Industrial applications of electron beam processing

* heat resistance insulating wire
* heat shrinkable tubing, sheet and film
* pre-vulcanization of rubber tire
* polyethylene foam
* coating of magnetic tape, floppy disk, steel sheet or coil, wood products
* curing of adhesives, laminates and printing
* sterilization of disposable medical products
* decontamination of cosmetic products, some pharmaceuticals as well as raw materials in the pharmaceutical industry
* disinfection of sewage sludge
* treatment of flue gases from coal and oil-fired power plants

Table 3 Potential applications of EB-curing on some products

Wood Products.

	No. of Comp.	prod. million m3/year	export 1989 m3,
Plywood	42	1.008	670,520
Chipboard	3	0.225	41,130

Non-wood Products.

	No. of Comp.	production m2/year	export market.
Ceramic tiles	n.a	3,200,000 (one company)	local & oversea
Gypsum boards	1	3,300,000	"
Cement boards	1	12,000	"

Table 4 Rubber products-imported and exported by Malaysia from January to May 1989

	IMPORTS			EXPORTS		
	Value '000rgt	% of total	%change over'88	Value '000rgt	% of total	% change over'88
Tires	14,522	16.6	+41.0	51,781	9.1	-14.3
Inner tubes	2,119	2.4	+39.4	5,821	1.0	-28.8
Footwear	11,362	13.0	+56.8	51,458	9.0	+16.1
Latex goods	9,479	10.9	+39.4	409,944	72.0	+98.0
Industrial rubber goods	10,612	12.2	-21.4	7,270	1.3	+39.7
General rubber goods	39,241	44.9	+175.1	43,122	7.6	+4.3
Total	87,335	100.0	+62.8	569,396	100.0	+55.4

Table 5 Domestic demand for major plastic resin ('000 tonnes)

	1980	1981	1982	1983	1985	annual growth rate 1985-1995
LDPE	29.0	27.0	33.0	39.0	43.4	5.5%
HDPE	20.0	20.0	25.0	29.0	33.2	7.0%
PP	23.8	23.0	26.0	30.0	33.7	6.0%
PVC	22.0	21.0	22.0	27.0	30.3	6.0%
PS	7.5	8.4	9.5	13.0	15.7	10.0%
	102.3	99.4	115.5	138.0	156.3	

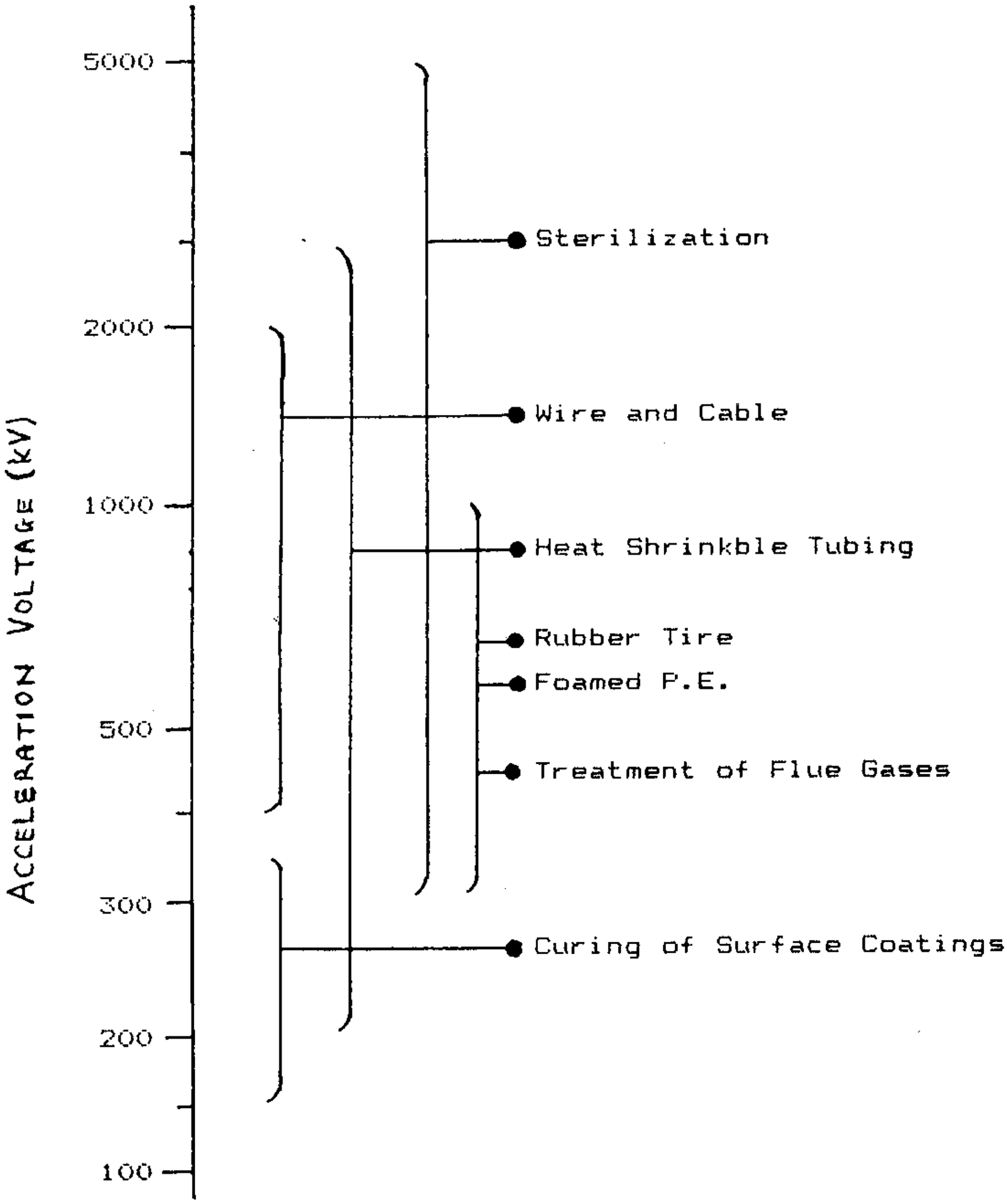

Fig. 1 Relationship between acceleration voltage of EB and its application

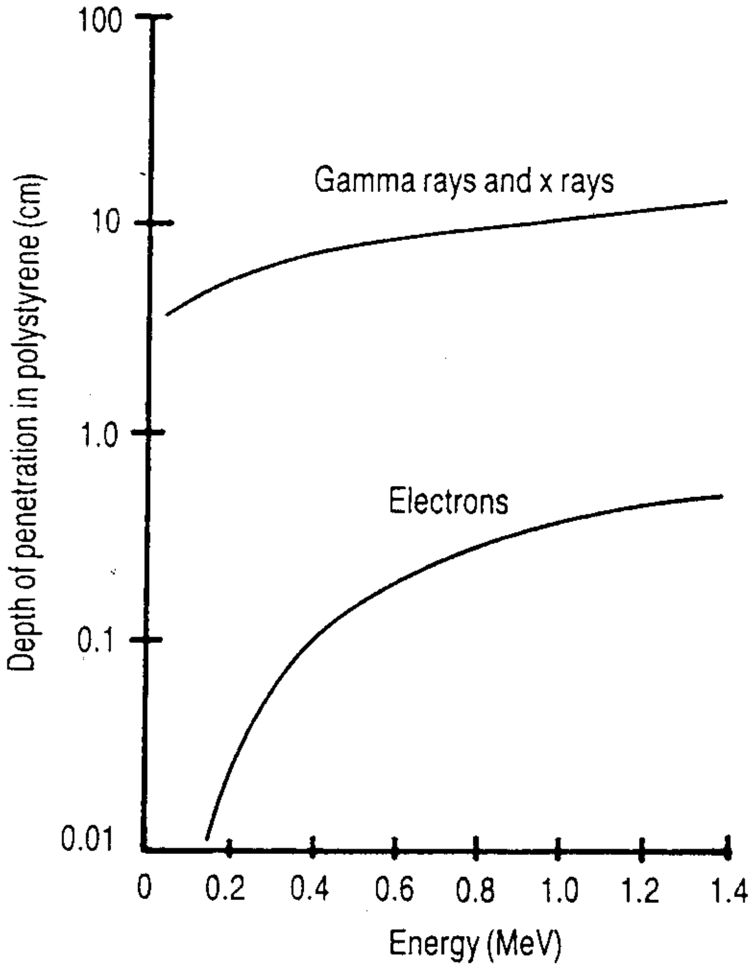

Fig. 2 Relationship between accelerating energy and penetration depth

2.3 Toward the Application of Radiation Technology in Indonesia

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1. Introduction

The utilization of high energy radiation for the production of industrial products is a relatively new generation of technology.

Today's radiation technology uses gamma rays from a cobalt-60 source and electron beams generated from machine as processing tool in industry to produce different kinds of high quality and specific products. Among the products are the sterilized medical products, the heat resistance wires and cables, the heat shrinkable films and tubing, the crosslinked polyethylene foam, the radial automobile tires, the ion-exchange membrane for battery separator, the computer floppy disk, the panel circuit board (PCB) and others[1~3].

Although the radiation technology has much been developed in USA, Europe and Japan, but it does not arrive yet in developing countries including Indonesia. However, research and development in this field have actively been conducted by National Atomic Energy (BATAN) since 1970th.

This paper presents the status report of the research and development activities as well as a conceptional steps toward the application of radiation technology in Indonesia.

2. Research and Development

In Indonesia, research and development activities in the field of radiation technology have been conducted by the Center for the Application of Isotopes and Radiation, National Atomic Energy Agency (PAIR-BATAN), Jakarta since 1970th. The R&D activities discussion can be classified into three subjects;

(1) Irradiation facilities,

(2) Research and development subjects,

(3) Man power situation.

2.1 Irradiation Facilities

The first gamma rays irradiation facility, Gamma-cell 220 (AECL), was installed in 1969 with an initial activity of 10 kCi. The irradiation facility was mainly used to study radiation chemistry of polymers, radiation microbiology which is needed to understand radiation sterilization and food preservation techniques, radiation mutation and radiation dosimetry.

In order to scale-up the laboratory experimental scale results obtained by the Gamma-cell 220 (AECL), a multi-purpose cobalt-60 gamma rays irradiator, IRPASENA, purchased from India (Bhabha Atomic Energy Agency) was installed in 1979. The initial activity was 75 kCi of a dry storage source system[4]. About 0.5 m^3 material can be irradiated in once at a batch conveyor system (see Fig. 1).

In 1983 a special design cobalt-60 rays irradiator for radiation vulcanization of natural rubber latex, namely IRKA was jointly constructed by BATAN and JAERI engineers in Jakarta, under a regional research cooperation of RCA UNDP/IAEA project. The irradiator is a pool-type source storage system and its initial loaded activity was 150 kCi. In this irradiator, the natural rubber latex can be vulcanized by gamma rays irradiation using a stainless steel vessel. Total capacity of the irradiation vessel is 1(one) tonnage.

In 1984, a low voltage electron beam machine (EBM 300 keV) purchased from Nissin-High Voltage Ltd. was constructed in the PAIR-BATAN in which also under the RCA UNDP/IAEA project's assistance[6]. The low voltage EBM is aimed to be used as a pilot-scale demonstration plant for radiation curing of surface coating technology. All member countries of RCA UNDP/IAEA project included Malaysia, Thailand, Srilanka, Philippines, India, Bangladesh, Japan, Australia, South Korea and Indonesia may have a joint program to employing the EBM plant. In addition to the EBM 300 keV, a unit set of wood coating equipment including sanders, roll coater as well as curtain coater equipments is provided. A UV source unit is also provided as a compliment to the radiation curing of surface coating experimental study.

2.2 Research and Development Subjects

The research and development activities are grouped into four subjects i.e. 1) polymer, 2) sterilization, 3) food and 4) dosimetry.

In the field of polymer, it was emphasized to modify natural basic polymers such as wood and rubber which are abundantaly available in Indonesia. The basic study on the effect of radiation on several kinds of synthetic polymers and monomers were also investigated.

In the field of radiation sterilization, the research activities have mainly made to gain the capability in radiation sterilization technology. For example, how to examine the initial and final contamination in irradiated products, how much irradiation dose to sterilize of medical products, psicho-chemical examination of irradiated materials, etc.

Researchers in the field of food irradiation have emphasized their effort to improve the quality of food products. For example, to sprout inhibition of onion and potatoes, to kill microbe in black/white paper and other spices, to prolong the self live of storage for salted fish, fresh fish and shrimp. In addition, the researchers are also conducting an assessment for appropriate packaging materials needed in food preservation works[7].

The research activity in the field of industrial radiation dosimetry has been aimed to achieve a capability in the measuring of absorbed dose and in the controlling of the irradiation dose requested for each processing run as well as to improve the working performance of the irradiation facilities. To do this, several types of dosimeters, irradiation techniques and the calibration of irradiation field and the determination of dose uniformity have been studied[8]. Table 1 lists some important R&D activities of PAIR-BATAN in the field of radiation technology and their present status.

2.3 Man Power

The man power concern to the R&D in the field of radiation technology increases from 20 persons in 1969 to 75 persons in 1990. The present man power is accommodated in two divisions, i.e. division of radiation processing (50 persons) and division of irradiation facilty (25 persons).

3. Toward the Application of Radiation Technology

Table 2 lists some examples of industrial products which can be produced by radiation technology. The related industries and the chemical reactions occurred during the irradiation processes as well as the typical irradiation source are also listed.

It has been mentioned in the above discussion that the policy R&D conducted in Indonesia was particularly concerned with the effort to improve and to modify natural basic polymers and also to gain mastering in a selective subject of established technology such as radiation sterilization technique.

The main progress of the R&D policy is a significantly success on the development of radiation vulcanization of natural rubber latex (RVNRL). Upon the intensive research cooperation among the RCA UNDP/IAEA member countries, it has been understood that the RVNRL may have a very promising application as a raw material for manufacturing biomedical products. This is because the RVNRL does not contain a carcionogenic agent of nitrosamine. In addition, the RVNRL does not contain sulfur element in their molecular chains since the crosslinking occurred C-C bonding instead of C-S-C bonding obtained by conventional vulcanization method. The latter will give a valuable advantage in which the rubber gloves or others made from RVNRL do not give SO_x pollution gas when the rubber gloves are burned out for disposal purpose. This is important for nuclear power plant to simplify the management of radwaste materials such as contaminated rubber gloves which are commonly used in the plant.

A manufacturing trial production of condom and surgical rubber gloves is being conducted at Banjaran Condom Factory and a surgical rubber gloves factory near Jakarta, respectively.

Based on the last 20 years' experience on R&D on radiation technology, a more conceptional step on the development of radiation technology in Indonesia is urgently needed.

Considering a typical strategic planning scheme of R&D in the field of radiation technology, the main contribution of radiation technology can be summarized into three areas, i.e. medical, industrial and agricultural. The radiation sterilization of medical products and the production of medical devices by irradiation techniques are among examples of the contribution of radiation technology in medical and health care program. The contribution of radiation technology in industrial area is quite clear as represented by several kinds of industrial products processed by irradiation technique. In area of agriculture, the results of mutation breeding in a major example can be drawn.

The radiation technology comprises of two supporting roots, i.e. irradiation facility and radiation processing. The two should be a complementary each other. The irradiation facilty involves the group engineers for maintenance, operating, and designing and manufacturing of irradiation facility. The radiation processing, on the other hand, comprises researchers who are responsible for formulation, materials design production, quality control and even for marketing of the products.

Regarding to the scheme, at least three aspects should be consolidated, i.e. man power education and training, R&D policy and the participation of industrial society.

In order to obtain a successful result on the production of materials by irradiation technique, it is necessary to accommodate multidiscipline man power particularly who has expertise in radiation chemistry, polymer science, material science and process engineering. As the education institutes in Indonesia do not concern with the above four professional disciplines, estimately the progress of radiation technology will be very slowly grown-up.

Table 3 lists some unversities in Indonesia who have held education on chemistry, chemical engineering, material science and nuclear engineering. It is expected all the four disciplines will be included on the above universities education programmes[9].

The R&D policy should be modified to be more emphasized on the technology transfer program. However, the R&D to obtain more added value of natural basic polymers which are abundantly available in Indonesia should be continued. International and bilateral research cooperation should be created and make efforts to produce a fruitful results.

The third aspects toward the application of radiation technology in Indonesia are the participation of industrial society on the R&D program as well as to the education program. In other words, a triangle relationship between education institution, research institute and industrial sectors should be established.

4. Conclusion

National Atomic Energy Agency of Indonesia has actively made efforts on the application of radiation technology in Indonesia. A lot of basic research in this field has been done and also some technology transfer has been successfully achieved. The development of RVNRL from laboratory scale to manufacturing trial experiment is an example for the progress of basic research on radiation technology. The capabilty of the Center for the Application of Isotopes and Radiation to give radiation sterilization services respresents a successful work on the technology transfer.

More efforts on the technology transfer program should be emphasized and interconnection between educational institutes, industrial sectors and research institutes should be created in order to accelerate the application of radiation technology as a part of the atomic energy contribution in Indonesia Development Program.

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Table 1 R&D activities on radiation technology and their present status

No.	R&D activities	Radiation source	Present status
1.	Radiation sterilization	Cobalt-60	Services and ready to commercialization
2.	Curing of wood surfaces	EB machine	Services and ready to commercialization
3.	Radiation vulcanization of natural rubber latex	Cobalt-60	Services and under manufacturing test for condom and surgical gloves.
4.	Radiation preservation of spices items	Cobalt-60	Ready to services
5.	Sterilized Amnion-chorion tissue used for treatment of burned skin.	Cobalt-60	Small scale production
6.	Dosimetry	Cobalt-60 and EB machine	Ready to service for calibration of irradiation field and go-no-go dosimeter.
7.	Biomass conversion	EB machine	Prelimenary study
8.	Enzyme immobilization by irradiation technique	Cobalt-60	Lab-scale study
9.	Thermoplastic elastomer	Cobalt-60	under development
10.	NR latex adhesives	Cobalt-60	under development
11.	Fruit preservation	Cobalt-60	Prelimenary study
12.	Alanine dosimeter	Cobalt-60	Lab-scale study
13.	Biomaterials	Cobalt-60	Lab-scale study
14.	Curing of mozaik surface coating	EB machine	Prelimenary study
15.	PVC lamination on plywood surfaces	EB machine	Prelimenary study

Table 2 Some typical industries, processes and products of radiation technology

Industries	Processes	Irrad. source	Products
Petrochemical	Crosslinking Depolymeri-zation	Med. to High Voltage EB machine	Polyethylene Lubricants
Coatings Adhesives	Curing Grafting Polymerization	Low voltage EB machine	Adhesive tapes Coated paper products, Veneered Panels Wood/Plastic composites
Electrical	Crosslinking Heat-Shrink Memory Semiconductor Modification	EB machine	Instrument, Telephone wires, Insulation tapes Zener Diodes, ICs
Food	Disinfestation Pasteurization Preservation	Co-60 & EB machine	Animal feed Grains, Cereal, Fluor, Fruits, Poultry, fish
Health Pharmaceutical	Sterilization Polymer modifi-cation	Co-60	Medical disposable Powder & Ointment Ethical drugs Membranes
Plastics Polymers	Crosslinking Foaming Heat shrink memory	EB machine	Food shrink wrap Gymnastic mats, toys, plastic tub-ing & pipes, Molded packaging forms
Rubber	Vulcanization Green strength Graded Cure	EB machine	Tire cpmponents Battery separator Roofing membrane

Table 3 List of universities that conducting chemistry course and polymer course in Indonesia

No.	Name of Universities	Faculty	Location
1.	Universitas Indonesia	Mathematic and Natural Sciences	Jakarta
2.	Institute Pertanian Bogor	- id-	Bogor
3.	Institute Technology Bandung	- id- and Engineering	Bandung
4.	Universitas Padjadjaran	- id-	Bandung
5.	Universitas Diponegoro	Engineering	Semarang
6.	Univeritas Gajah Mada	Math.& Nat.Sci. and Engineering	Yogyakarta
7.	Universitas Airlangga	Math.& Nat.Sci.	Surabaya
8.	Insitut Teknologi Sebelas Maret	Industrial Technology and Engineering	Surabaya
9.	Universitas Hasanuddin	Math.& Nat.Sci.	Ujung Pandang
10.	Universitas Sriwidjaja	Engineering	Palembang
11.	Universitas Riau	Math.& Nat.Sci.	Pakan Baru
12.	Universitas Andalas	Math.& Nat.Sci.	Padang
13.	Universitas Sumatera Utara	Math.& Nat.Sci.	Medan
14.	Universitas Syah Kuala	Engineering	Banda Aceh

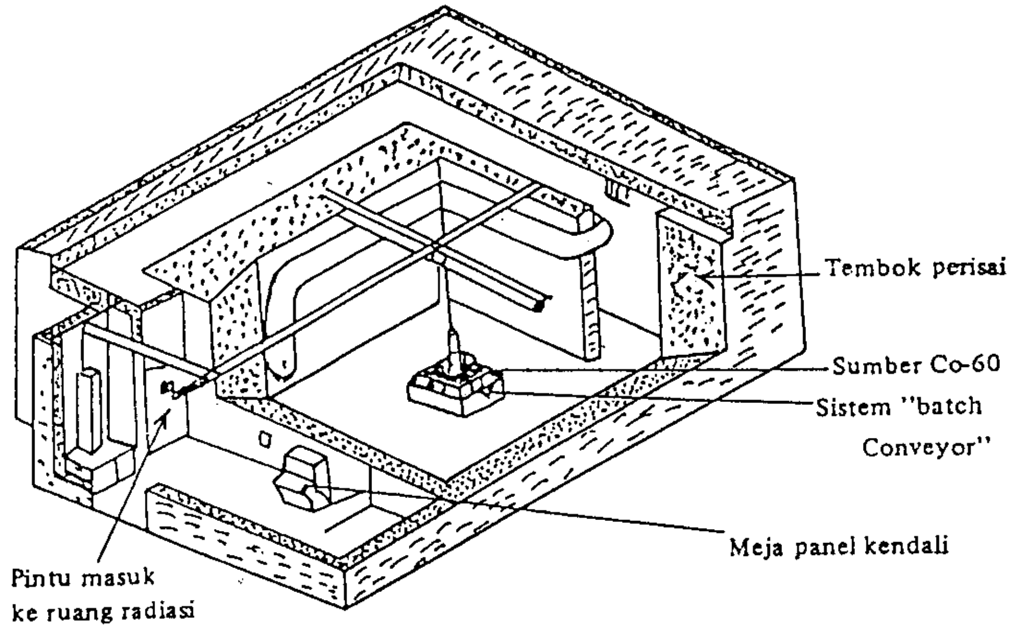


Fig. 1 A pilot scale Co-60 gamma rays irradiator, IRPASENA

2.4 Recent Advances in High Energy Electron Beam Machine

M. SUZUKI

Nissin-High Voltage Co., Ltd.

1. Introduction

Recently, there is remarkable progress in irradiating various materials by accelerated charged particles in order to modify the materials. Among charged particles, EB (Electron Beam) is used as means to give chemical reaction for crosslinking of high polymeric materials which have good irradiation effects in industrial fields since 1960s. In these some 20 years, the application has been extended from polymerization and synthesis to physical reaction such as sterilization of medical articles and disinfection of sewage or disintegration of bio-mass products.

In this paper, I will show the application fields of EB, the growth of EB machine, the penetration and dose of EB, the principle and construction of EB machine, and so on.

2. Application Fields of EB

Figure 1 shows the classification of the application fields based on the supply result of EB machine from Nissin-High Voltage Company (NHV). The share of R&D takes about 30% of all, and the annual growth rate of R&D from 1987 to 1989 in Table 1 is high such as 13%. Therefore, EB machine will be used in more industrial application fields in future.

3. Depth and Dose

Figure 2 shows the Depth-dose curves for accelerated electrons. Accelerated electrons diminish their energy after penetrating a certain depth of the irradiation material. In order to present a penetration capability of electrons, Depth-dose curves are widely used, which determine the relationship between penetration depth in a material of unit specific gravity and relative dose given to the material. Regarding the maximum thickness of a treated material, in many cases a thickness which corresponds to 60% of the relative dose on a Depth-dose curve is chosen. In case of curing, 80% is selected. When the material has density of ρ, measurement in the horizontal axis of the Depth-dose curve should be divided by ρ.

Figure 3 shows the optimum thickness for double bombardment (both sides irradiation). Thicker materials can be treated by lower acceleration voltage irradiation from both sides.

Table 2 shows the relationship among beam current, absorbed dose and processing quantity.

4. Principle and Construction of EB Machine

Figure 4 shows a principle of EB machine (also called EPS: Electron Processing System). This machine produces thermal electrons from cathode in a high vacuum, accelerates (give energy to) them in an acceleration tube by means of a high voltage electric field into a beam of high energy electrons, and this electron beam which is taken out to open air after passing through a titanium foil irradiates a material. As a result, the irradiated material undergoes a chemical reaction.

5. Shielding Against X-rays

X-rays generated as bremsstrahlung when electrons collide with material are quite high in penetrating power and harmful to the human body. Therefore, the shielding against X-rays is necessary.

Figure 5 shows an example of concrete-shielded type X-ray shielding room for EB machine of 800 kV and higher energy.

Figure 6 shows a 500 kV 65 mA self-shielded type EB machine for the crosslinking of wire and cable insulations. This EB machine is designed for reduced floor space and is able to readily relocated to meet the needs of changing production lines. NHV has succeeded in producing such self-shielded EB machine up to 600 kV.

6. Electric Power Efficiency of EB Machine

The DC power supply of NHV's EB machine adopts a Cockcroft-Walton circuit and the high frequency power supply applies the solid state inverters.

The frequencies of the inverters are 1 kHz or 3 kHz. 1 kHz is for machines up to 1.5 MV and 3 kHz is for about 1.5 MV. Therefore, this system produces good electric power efficiency. The electric power conversion efficiency from the wall (commercial 50 or 60 Hz) to the beam power is 85% for the machine up to 1.5 MV and 75% above 1.5 MV as shown in Fig. 7.

7. 5 MV EB Machine

Fig. 8 shows a 5 MV 30 mA EB machine to be delivered to Radia Industry Co. Ltd. in Japan for the sterilization of the medical products. The DC power supply uses a Cockcroft-Walton circuit with pessurized SF_6 gas in the vessel using relatively low frequency which provides low loss and stable operation. Therefore, this EB machine has a high electric power conversion efficiency and a high reliability.

This 5 MV 30 mA EB machine can also generate intense X-rays equivalent to 2.5 million curie cobalt-60 source by using X-rays target as shown in Fig. 9.

Table 1 Growth of EPS by the application fields in both cumulative installed number and cumulative aggregate capacity (in Japan and Asian countries)

		1987	1989/2
Research & Development	Number	35 or more	45 or more
	Capacity	553 kW or more	953 kW or more
Cross-linking of Wire insulations	Number	31	41
	Capacity	1,724 kW	2,323 kW
Foamed Polyolefin	Number	11	13
	Capacity	438 kW	546 kW
Heat-shrinkable Tubing	Number	7	7
	Capacity	456 kW	456 kW
Curing of Coating	Number	15 or more	23 or more
	Capacity	459 kW or more	598 or more
Rubber Tire	Number	8	10
	Capacity	540 kW	805 kW
Others	Number	2	3
	Capacity	61 kW	78 kW
Total	Number	109 or more	142 or more
	Capacity	4,231 kW or more	5,759 kW or more

Table 2 Capability and beam current

[Unit]
Generally, Rad or Gy is used as the absorbed dose unit.
rad=100erg/g (Gy=1J/kg, 1Mrad=10kGy)
[Processing Quantity]

Surface Irradiation(Film, Sheet or Paint)

Absorbed dose is calculated as follows

$$D=\frac{\Delta E}{\Delta R}100\frac{\eta I}{V\cdot W}$$

D : Absorbed Dose(Mrad)
I : Beam Current(mA)
V : Speed of Material (cm/sec)
W : Scan Width(cm)
η : Utilization coefficient of Beam current.
$\Delta E/\Delta R$ is energy loss according to acceleration voltage : E(MV).
And their relationship is as follows

$\Delta E/\Delta R$

E (MV)	$\Delta E/\Delta R$
0.3	3.6
0.5	2.9
0.8	2.45
1	2

Therefore, irradiation quantity is calculated as follows

$$S=V\cdot W\times 6\times 10^{-3}=0.6\frac{\Delta E}{\Delta R}\cdot\frac{\eta I}{D}$$

S : Irradiation Quantity(m^2 /min.)

Bulk Irradiation(Powder or Fluid)

Irradiation quantity is calculated as follows

$$M=\frac{360\,\eta P}{D}$$

M : Irradiation Quantity(kg/hr)
P : Acceleration Voltage×Beam Current(kW)
D : Absorbed Dose(Mrad)
η : Utilization Coefficient of Beam Current

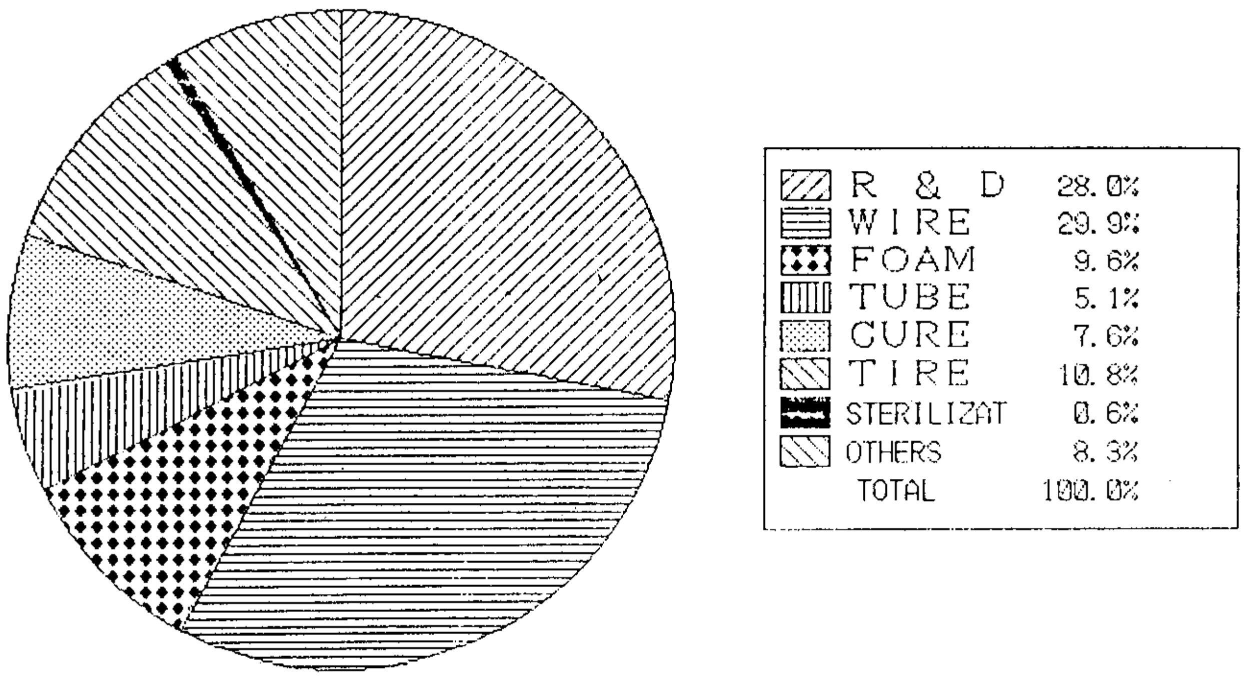


Fig. 1 Total number of EB system include "Under Construction" as of April 12, 1990

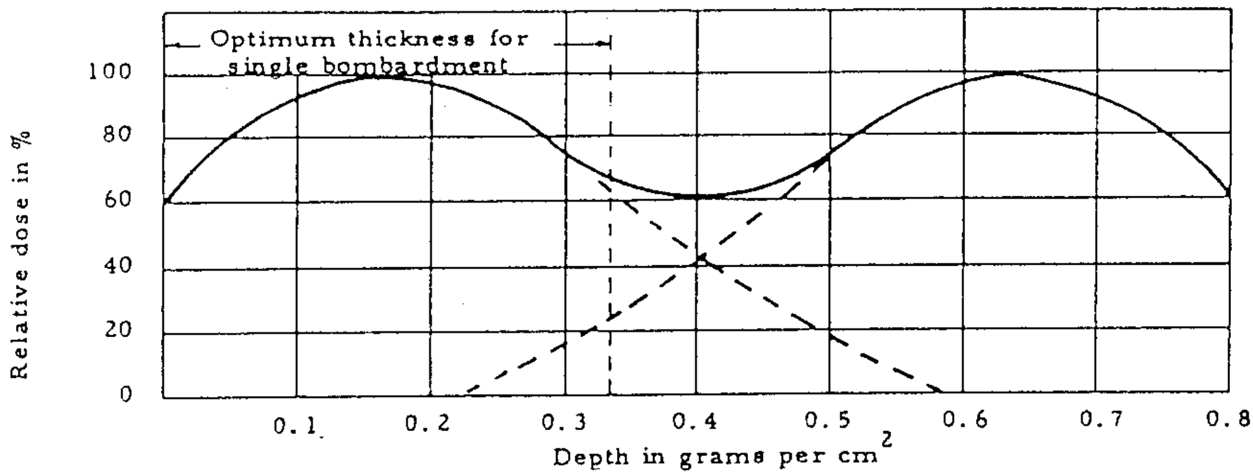


Fig. 3 Optimum thickness for double bombardment with 1 MeV-electrons

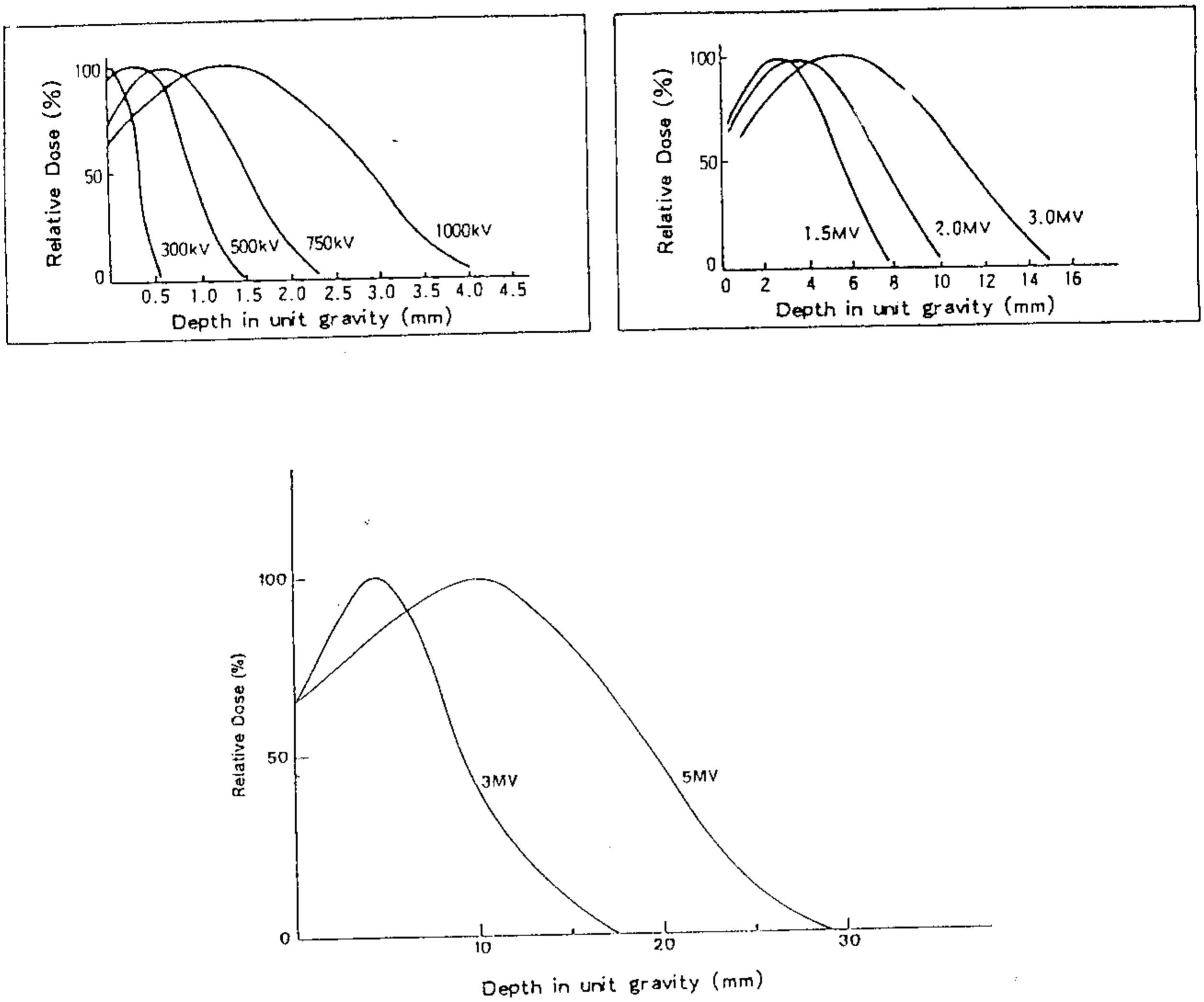


Fig. 2 Depth dose curves of electron beam

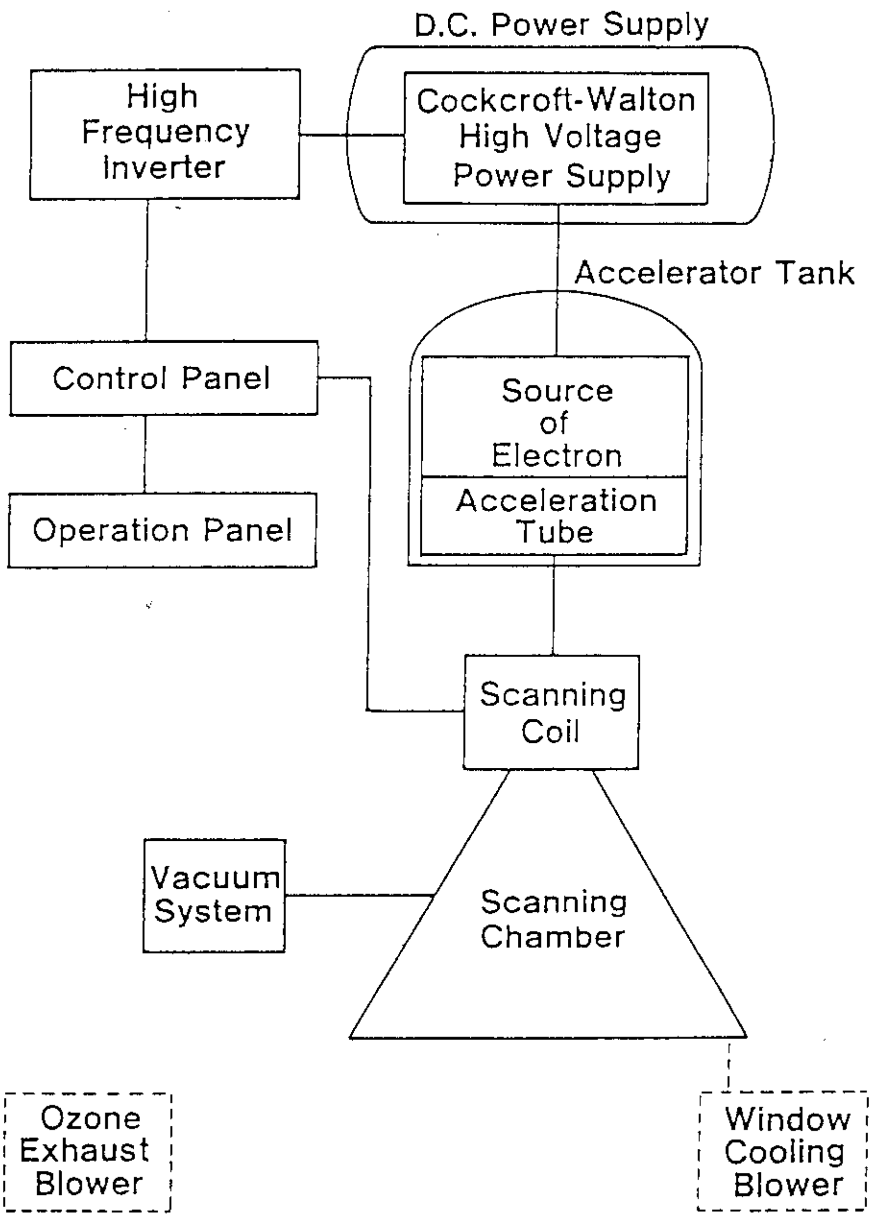
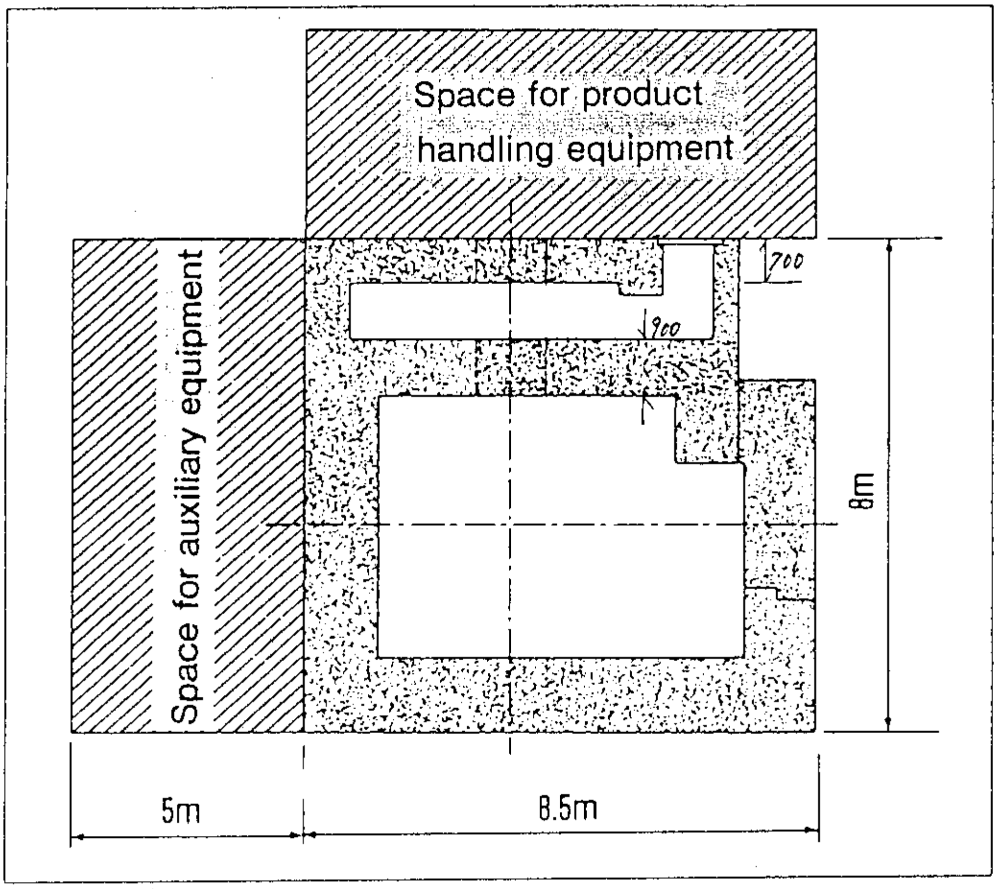
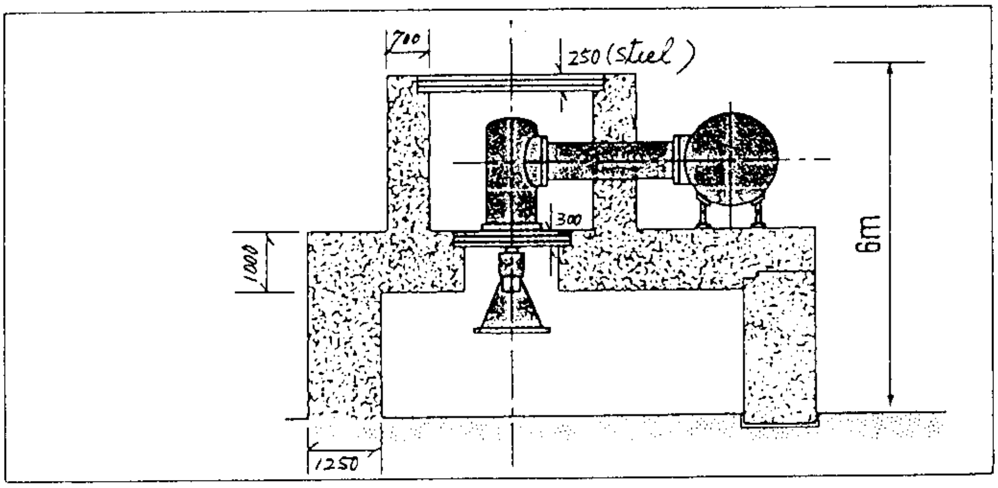


Fig. 4 Block diagram of EPS

Typical X-ray shielding for wire/film (800kV)



X-ray shielding plane view



X-ray shielding sectional view

Fig. 5 Concrete-shielded type

■OUTLINE

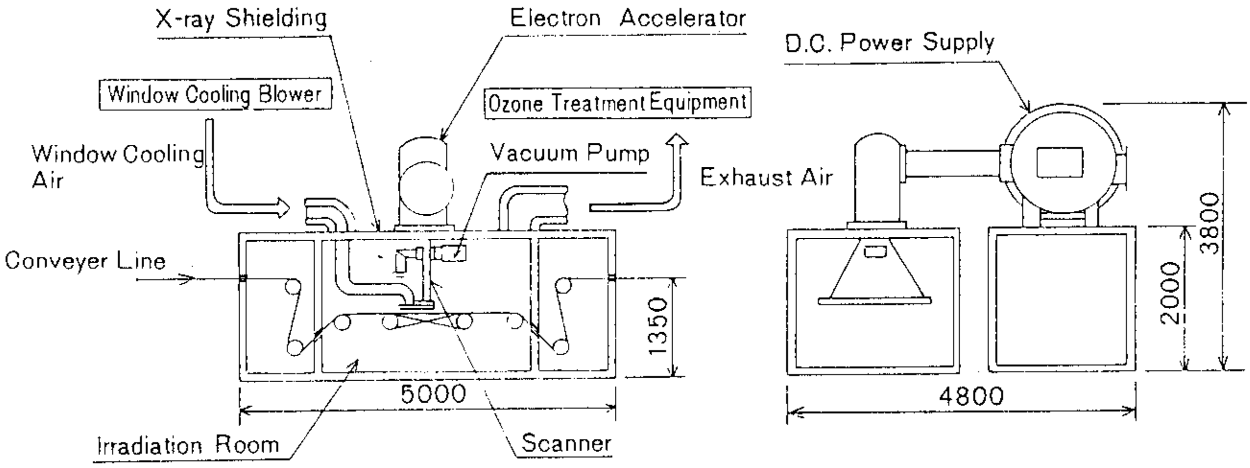


Fig. 6 Self-shielded electron processing system

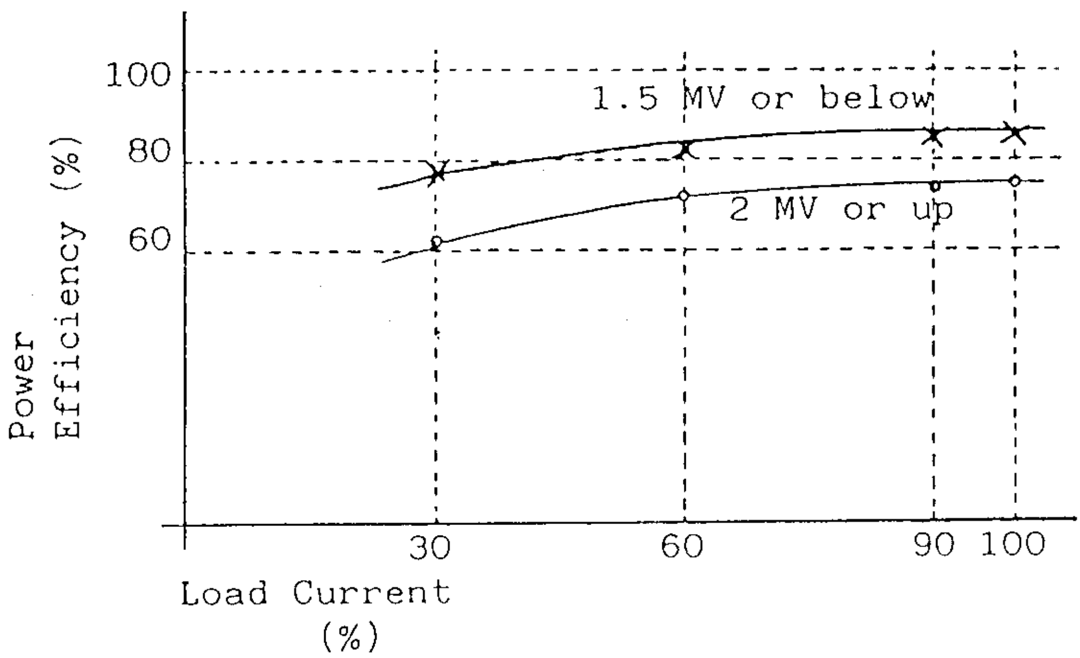


Fig. 7 The electric power conversion efficiency from the wall to the beam power

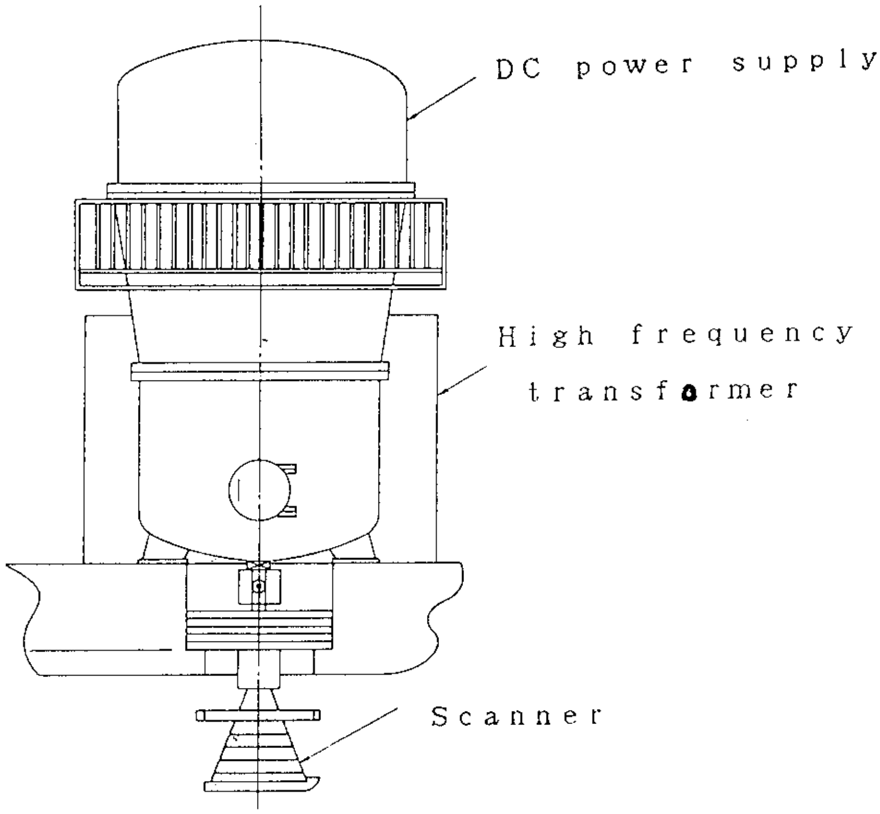


Fig. 8 5MV 30mA EPS

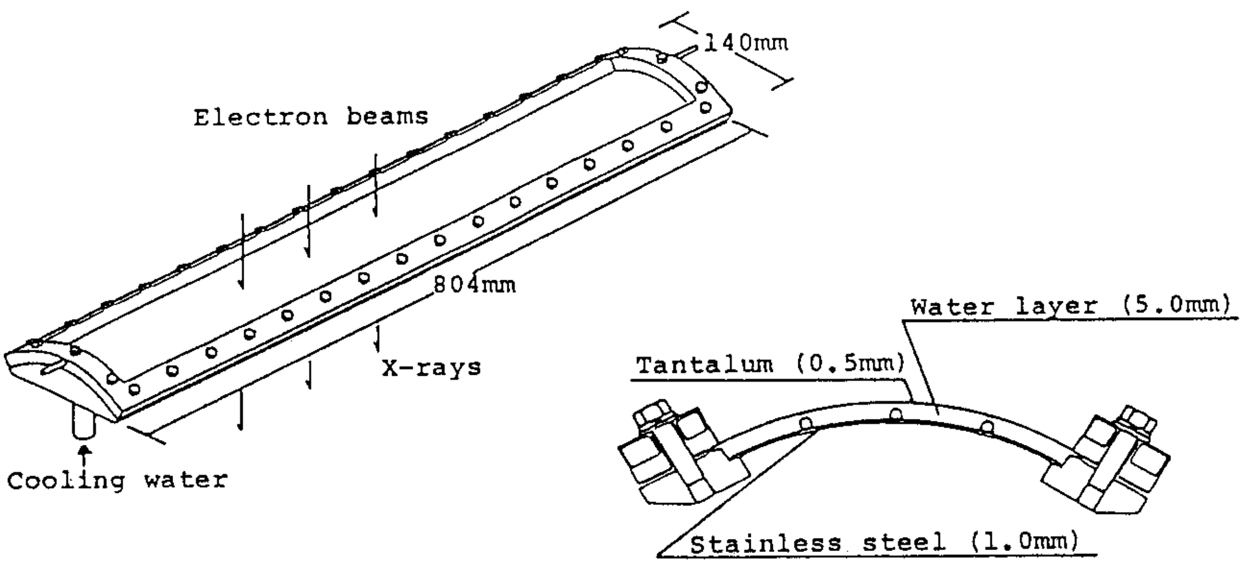


Fig. 9 X-ray target for the 2MeV 60kW accelerator

2.5 Crosslinking of Wire and Cables with Electron Beam

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1. Introduction

Since the first electron beam (EB) accelerators were established at wire and cable maker in Japan, about 25 years have passed. Firstly, crosslinked polyvinyl chloride (XL-PVC), crosslinked polyethylene (XL-PE) and crosslinked flame retardant polyethylene (XL-FRPE) insulated electronic appliance wires were produced by EB machine. Nowadays, large quantities of the EB crosslinked materials such as PVC, PE, FRPE, flame retardant polyolefine (FRPO) are used for insulation and jacket of electronic wire and cables.

This paper describes the reasons why the EB crosslinked production in wire and cable industry has been increasing year by year.

2. Market Share and Sale

38 EB accelerator machines are used for wire and cables, and its rate ranks first. There are 13 wire and cable makers using EB machine.

The annual sale of wire & cables using copper as conductor is about 1300 billion yen in 1988. Table 1 shows the market share of various applications at that time. The fraction of electronic appliance wire & cables is 11% and the annual sale of it is about 150 billion yen. More detailed market share about electronic appliance wire & cables is shown in Table 2. EB crosslinked techniques are used for many products in this field such as coil lead wire, crosslinked wire, multi-cores cable, flat cable, coaxial cable, audio cable and wire harness for electronic instrument. The total annual sale of such products is estimated roughly at 60 billion yen.

3. Advantages of EB

The advantageous properties caused by crosslinking are solder resistance, heat resistance and good mechanical property.

Figure 1 shows the result of deformation test of LDPE at high temperature. Figure 2 shows the appearance of the crosslinked and non-crosslinked wires after solder resistance test. Many customers use solder to connect wire and equipment. In order to remove the soldering liquid, the equipments connected wires are passed in high temperature oven. So a lot of non-melt type wire and cables such as EB crosslinked wire and cable are used in this field.

Another excellent merit of crosslinking is an increase of long term heat resistance. Normal polyethylene's rated temperature is 80°C, but the crosslinked PE or PO has a higher rated temperature such as 105°C, 125°C and 150°C. Normal urethane jacketed automobile controlled cable cannot use at 200°C, but the crosslinked cable can use at 200°C in short time.

Various kinds of irradiation crosslinked materials have a wide range of excellent properties which fill the gap between expensive heat resistant polymers and inexpensive general purpose polymers. This relationship is shown in Fig. 3~6. Recently, crosslinked fluoro elastomer insulated wires can be used instead of the expensive silicone rubber insulated wires. Table 3 shows the properties of various crosslinked products.

4. Principal Examination Methods

We have to check some properties of the products. Principal properties are tensile strength and elongation of conductors, insulations and jackets, deformation of insulations and jackets, gel fraction of insulations and jackets, solder resistance of wires or cores and flame retardancy.

Figure 7 shows a deformation test equipment. According to the wire size and its rated temperature, weight and temperature are different as shown in Table 4. A gel fraction is decided on the difference of the original samples weight and the sample weight immersed in solvent. The sample is wrapped by metal mesh, and immersed in a hot solvent for 24 hours, and then picked up and measured the weight. Typical solvents are THF for PVC and X-lene for PE.

A horizontal flame test method and a vertical flame test method are shown in Figs. 8 and 9.

5. Introduction of Some Products

The EB crosslinked products classified by the typical materials are shown in Table 5. AVX and AEX are used for wire harness in automobiles.

Most of the products has gotten the recognition of UL and CSA.

6. EB Processing System

EB processing system is shown in Fig. 10. To make the crosslinked wire and cables, some supplies and take-ups are necessary besides an EB accelerator. Normally line numbers in one EB accelerator is from two to eight. Standard scan horn length is 1.0~1.8 m nowadays. The EB machine of 0.5~2.5 MeV, 100 mÀ max. and the irradiation doses of 3~40 Mrad are used for crosslinking of wire & cables. The relationship between irradiation dose and another parameters is shown below.

$$D(\mathrm{Mrad}) = K\cdot(I/S)\cdot N$$

K: Efficiency of Eb, 0.5~3.0
I: Amperere (mA)
S: Line speed (m/min)
N: Turn number of one wire in one wheel

Figures 11 and 12 show the typical model systems of shrinkable film and foamed PE sheet.

7. Technical and Economical Comparison of EB Process with Competitive Process

7.1 Small Size Electronic Appliance Wire with A Thin Wall Insulation

A lot of wires composed by small size conductors of 36-28 AWG and thin thickness insulation of 0.1-0.3 mmt are used in the electronic appliances. In this field, another technique using shiran or peroxide cannot be used because they break out the many pinholes at extrusion process. Even if they do not break it out, they cannot apply for PVC crosslinking.

7.2 Power Cable

In 600 V class power cables, EB is applied to the thin thickness insulation such as 1.5 mmt maximum, and shiran is applied to more large thickness cables. The reason that EB cannot be applied to the large thickness cables is a capacity of EB machine. The penetration depth of 1.0 MeV EB accelerator is only 1.5 mmt maximum. High voltage power cables are manufactured mainly by chemical method in Japan and abroad.

Cost comparison was made on an example of radiation applications by a study group of JAIF, in comparison with chemical method "Catenary Continuous Vulcanization (CCV)", as shown in Fig. 13. The figure shows us that EB crosslinking is appropriate for a large scale cable production.

7.3 Polyethylene Foam (Foamed Sheet, not Wire and Cable)

In Japan, the highly foamed polyethylene sheets are produced by EB processing. The cost analysis made by the study group of JAIF shows in Fig. 14 that these two processes are advantageous or the reverse against each other depending on the amount of production if it is over or under 100 tons per month.

7.4 Energy Cost Comparisons between Radiation and Heat Process

In most practical radiation applications the dose required for given sufficient effects on polymer ranges between several to 40 Mrad. From the relationship below it is understood that with radiation 100 cal/g energy input onto materials are enough.

1 Mrad (= 10 kGy) = 10 joule/g

= 2.4 cal/g

The energy cost analysis for several radiation applications was made by the study group on radiation applications of JAIF. As an example the result of energy cost analysis on the wire and cable crosslinking is shown in Table 6. The conditions of energy and cost calculations are given for each method;

Product: the insulated core of cross sectional conductor size
22 mm^2 for 6.6 kV crosslinked polyethylene cable

Radiation method: acceleration; 1.5 MeV, 25 mA, dose; 25 Mrad,
beam utilization; 0.5, cost of electricity; 20 yen/kWh.
line speed; 23 m/min = 147 kg(PE)/hr
electricity consumption; 20.4 kWh (=0.14 kWh/kg(PE))
energy cost; 2.8 yen/kg(PE)

Steam curing method: extruder; 115 mm, L/D = 22,
curing tube; 8 in diameter 35 m, extrusion; 100 kg/hr,
cost of steam; 6,800 yen/ton.
line speed; 16 m/min = 100 kg(PE)/hr
steam consumption; 650 kg/hr (= 6.5 kg/kg(PE))
energy cost; 43 yen/kg(PE)

SF_6 gas heating method: 300 kWh/km
energy cost; 57 yen/kg(PE)

Shiran method: 400 kg/km
energy cost; 26 yen/kg(PE)

8. Control of Secutiry

EB machines are very convenient and its operation is not so difficult, so many EB machines are used in Japan. However, the facility has a possibility of a little X-rays leakage, so a licenser is needed to operate the facility, and operators have to be checked the condition of health and the quantities of X-rays periodically. In our factory the operators wear the film badge to measure the quantity of X-rays. But all of the operators have been working for more than 20 years completely without injury.

9, Conclusion

About 25 years have passed since the first EB machine was used in the wire and cable industry in Japan. Nowadays, new products, such as crosslinked urethane and crosslinked fluoro elastomer, are being used instead of the expensive conventional ones because they have excellent cost performances. In future, EB machines in wire and cable industry will be more and more increasing according to the excellent performance of crosslinking products.

Table 1 Market share of cupper metal wire and cable in 1988

TOTAL SALE : ABOUT 1300 BILLION YEN

NAME	SHARE(%)
CUPPER ONLY	6.8
COILE WIRE	12.2 (1.0)
APPLIANCE CORD	9.4
ELECTRONIC APPLIANCE WIRE AND CABLE	11.0(5.0)
POWER CABLE	20.4
BUILDING WIRE	16.4
AUTOMOBILE	16.6
TELECOMUNICATION CABLE	10.0

( ):ESTIMATED SHARE OF PRODUCTS PRODUCED BY EB

Table 2 Market share of electronic appliance wire and cable in 1988

TOTAL SALE : ABOUT 150 BILLION YEN

NAME	SHARE(%)
CROSSLINKED WIRE	9.0(9.0)
NON CROSSLINKED WIRE	8.6
MULTI-CORES CABLE	21.5(12.0)
FLAT CABLE	11.0(1.0)
FLUORO POLYMER INSULATED WIRE	8.3
COAXIAL CABLE	8.4(2.0)
AUDIO CABLE	3.2(1.0)
WIRE HARNESS FOR ELECTRONIC INSTRUMENT	26.2(15.0)

( ):ESTIMATED SHARE OF PRODUCTS PRODUCED BY EB

Table 3 Properties of radiation crosslinked polyolefin wires

Property	XLPE	Flame Retardant Crosslinked Polyolefin			
	S	NF	NFS	ER400	ER500
Electrical Properties					
Specific Volume Resistivity, Ω-cm, @ 20°C	$>10^{16}$	$>10^{15}$	$>10^{14}$	$>10^{15}$	$>10^{15}$
Specific Inductive Capacity, @ 20°C, 1 MHz	2.3	2.5	3.8	2.7	2.6
Dissipation Factor, @ 20°C, 1 MHz	0.0003	0.008	0.04	0.003	0.002
Mechanical Properties					
Tensile Strength, kg/mm^2	1.7 - 2.2	1.5 - 2.0	1.1 - 1.4	1.5 - 2.0	1.5 - 2.0
Elongation, %	400 - 500	400 - 500	200 - 400	200 - 400	200 - 400
Abrasion Resistance	Good	Good	Fair	Good	Good
Cut-thru Resistance	Fair	Fair	Fair	Good	Good
Heat-Resistance					
Heat Aging, 7 days, @ (°C)	(150)	(150)	(150)	(160)	(160)
Retention-T.S., %	> 70	> 70	> 70	> 70	> 70
Retension-El., %	> 65	> 65	> 65	> 65	> 65
Flexibility after Heat Aging, @ (°C)	(150) No cracking	(150) No cracking	(150) No cracking	(160) No cracking	(160) No cracking
Deformation, @ 120°C, %	< 40	< 40	< 40	< 40	< 40
Solder Bath Immersion	Pass	Pass	Pass	Pass	Pass
Flame Resistance					
Oxygen Index	18	25	26	29	25
JIS Horizontal Test	—	Pass	Pass	Pass	Pass
UL Vertical Test (VW-1)	—	—	—	Pass	—
Others					
Oil Resistance	Fair	Fair	Fair	Fair	Fair
Varnish Resistance	Fair	Fair	Fair	Excellent	Excellent
Copper Mirror Corrosion Test, @ 180°C	Pass	—	Pass	Pass	Pass
Cold Bend, @ (°C)	(-60) No cracking	(-60) No cracking	(-40) No cracking	(-55) No cracking	(-55) No cracking

Table 4 Conditions of deformation

Load	Wall Thickness	Less than 30 mils	250 g
		30 mils or heavier	500 g
	Buffed jaket		2000 g

Wire Rating °C	Oven Temperature °C
60	100
80	113
90	121
105	136
125	150
150	180

Table 6 Energy cost comparisons of various crosslinking processes for cable production

Crosslinking Process		Facility for Crosslinking	Energy Cost	
			¥/kg(PE)	Relative Value
Electron Beam Crosslinking		1.5 MeV, 25 mA	2.8	1
Chemical Crosslinking	Steam	Catenary Continuous Vulcanizer	43	15
	SF_6 Gas	Catenary Continuous Vulcanizer	57	20
"Sioplas" Process*		None	26	9

* Crosslinking by Silane grafting

Table 5 EB crosslinked products classified by typical materials

Material	Name	Applicable Conductor (mm Φ)	Thickness of Insulation (mmt)	Rated Voltage (Temp.)	Use
XL-PVC	Bx-VF	1/0.26 ～37/0.26	0.15 ～ 0.84	30～ 600 (105°C)	Internal Wiring of Appliance
	Bx-VC (AVX)	1/0.26 ～37/0.26	0.15 ～ 1.40		Internal Wiring of Appliance Coil Lead Wire'
XL-PE	Bx-S	1/0.26 ～37/0.26	0.16 ～ 0.84	30～ 600 (120°C)	Internal Wiring of Appliance
XL-FRPE	Bx-NF (AEX)	1/0.26 ～37/0.26	0.16 ～ 1.40		Internal Wiring of Appliance and Automobile
XL-FRPO	Bx-NFS	1/0.26 ～37/0.26	0.17 ～ 0.60	30～150 (120°C)	Internal Wiring of Appliance
	Bx-ER 400	1/0.26 ～37/0.26	0.20 ～ 0.84	30～600 (125°C)	Internal Wiring of Appliance Coil Lead Wire
	Bx-ER 500	1/0.26 ～37/0.26	0.20 ～ 0.84	30～600 (150°C)	
FULUORO RUBERR	BX-FR	1/0.26 ～37/0.26	0.20 ～ 0.84	30～600 (200°C)	
URETHAN JAKET	ALB CABLE	0.75mm^2 ×2C	0.5	30～150 (120°C)	Car Cencer Cable
XL-PEF + PVC	CUMPUTER CABLE	36～28AWG 1 ～48C	0.10 ～ 0.5	30 (105°C)	Signal Transmitable Cable
XL-FRPO	SHIRNKABLE TUBE		0.32 ～ 0.7	30～600 (150°C)	Heat Protecter and Insulation

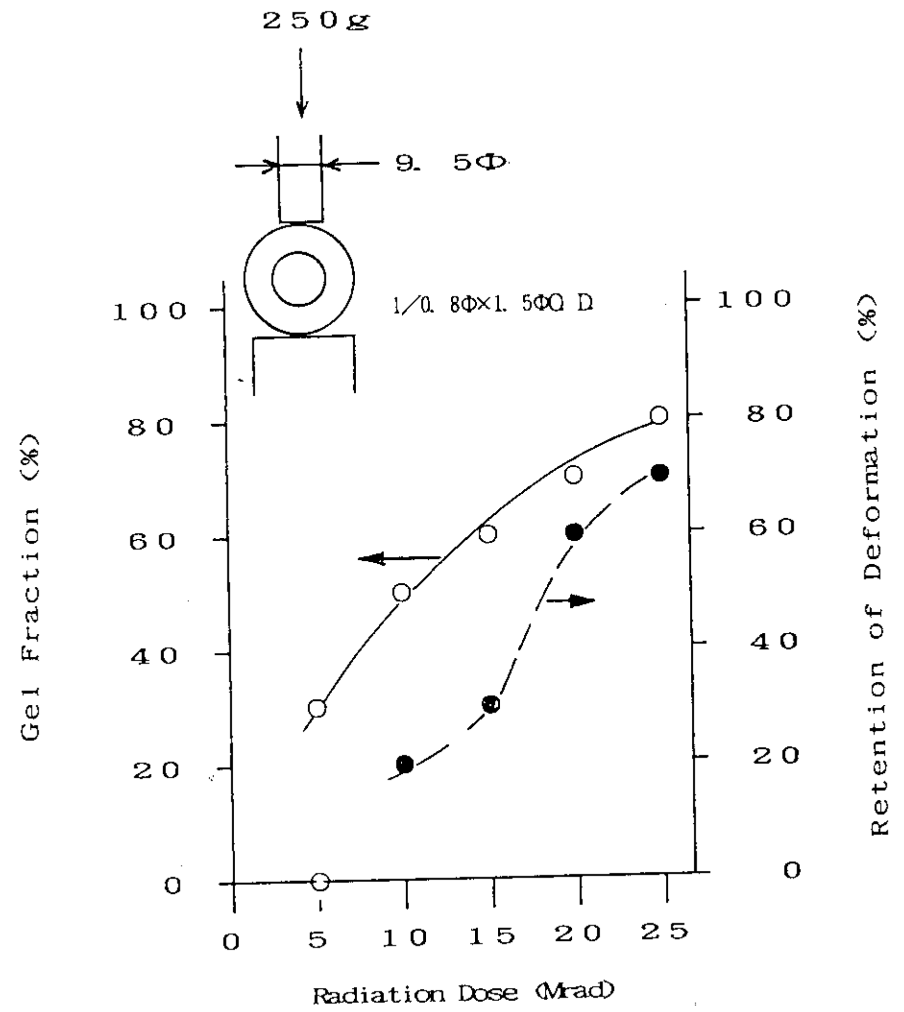

Fig. 1 Relationship of dose, gel and deformation

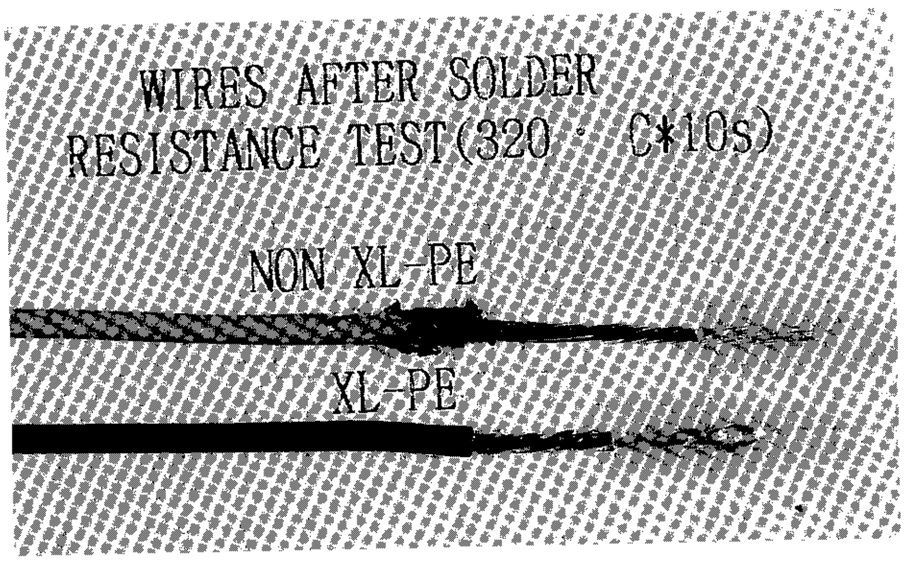

Fig. 2 Results of solder resistance test

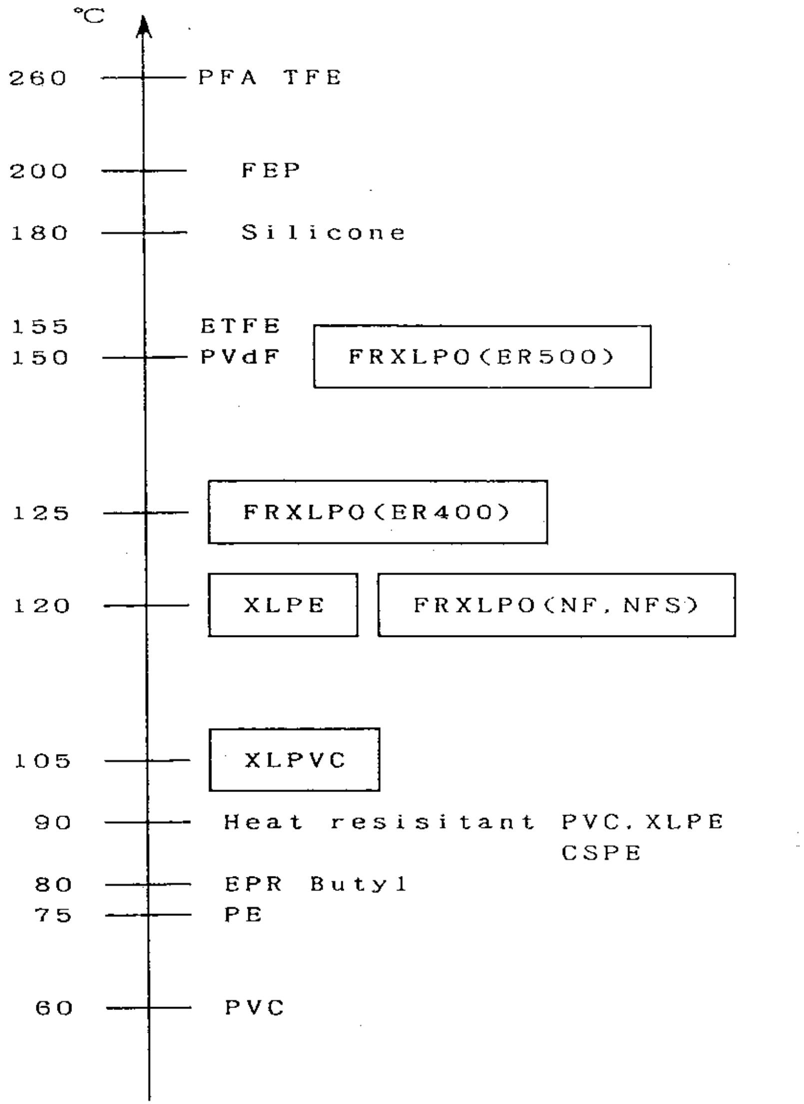

Fig. 3 Long term heat resistivity of various insulation materials

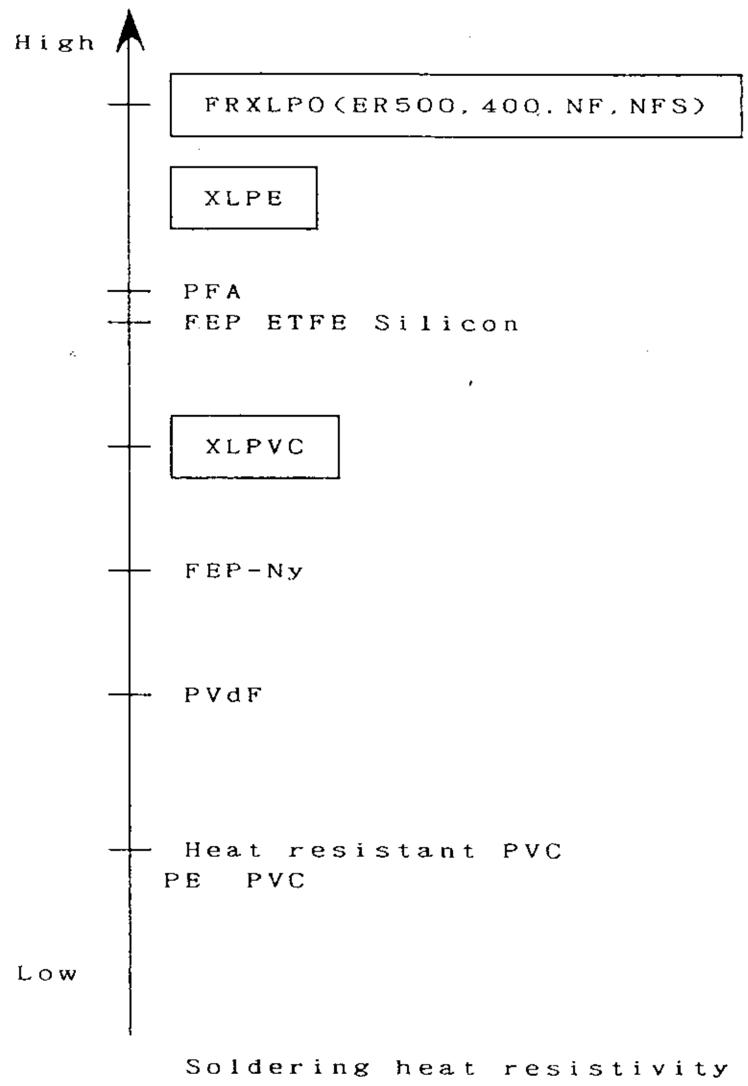

Fig. 4 Short term heat resistivity of of various insulation materials

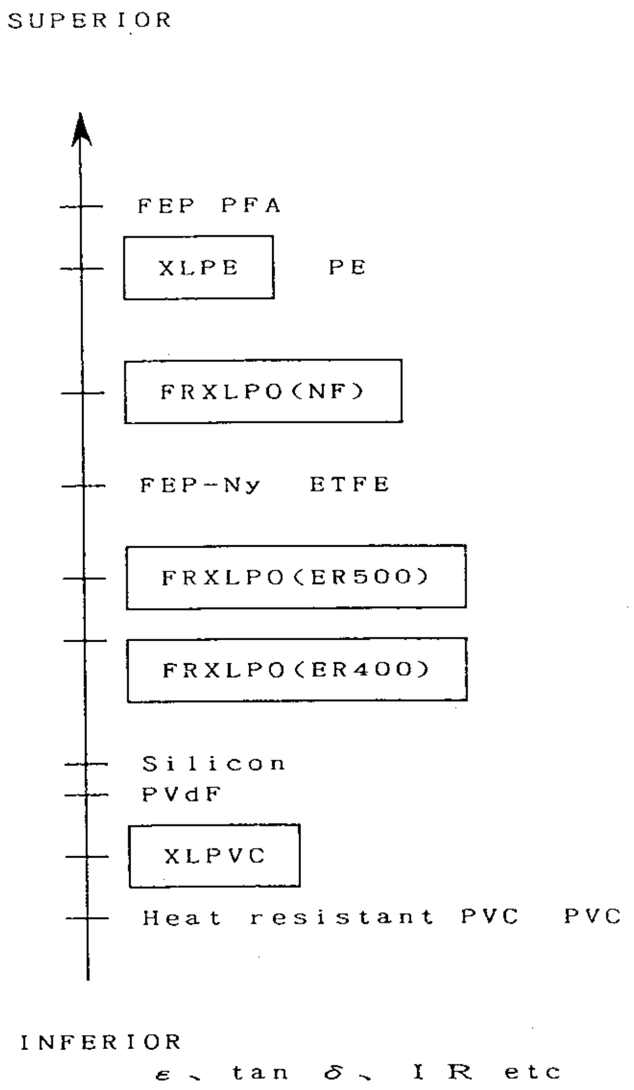

Fig. 5 Electrical property of various insulation materials

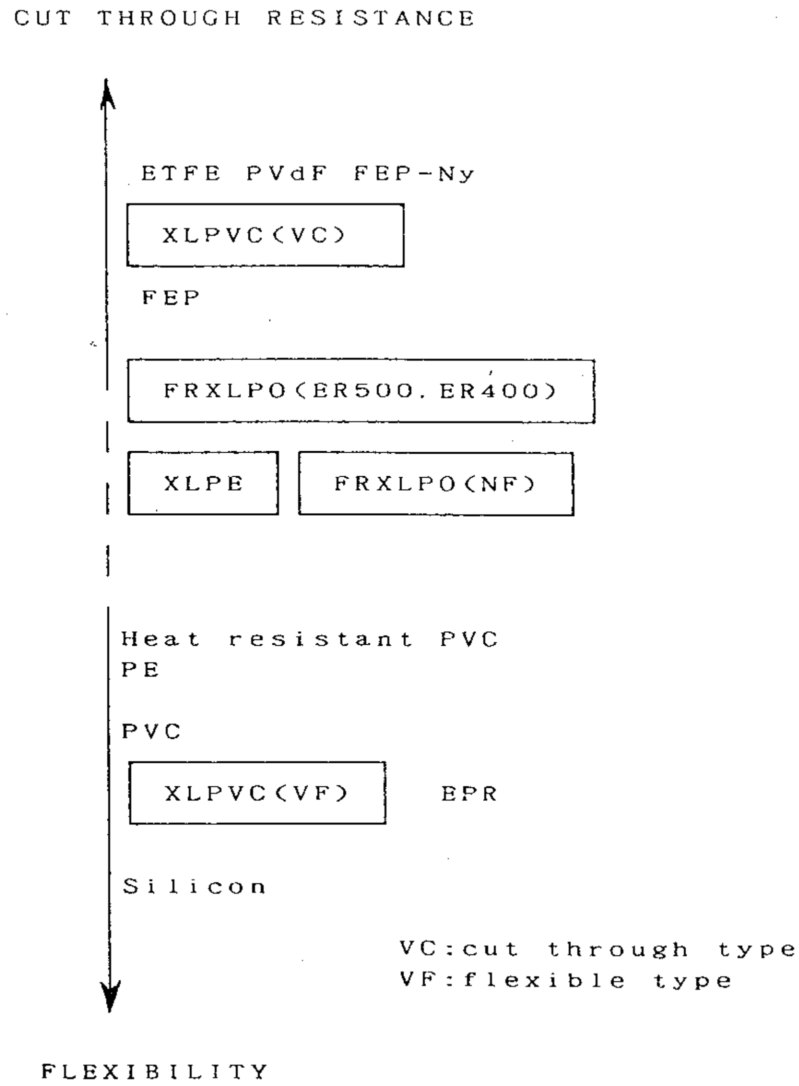

Fig. 6 Mechanical property of various insualtion materials

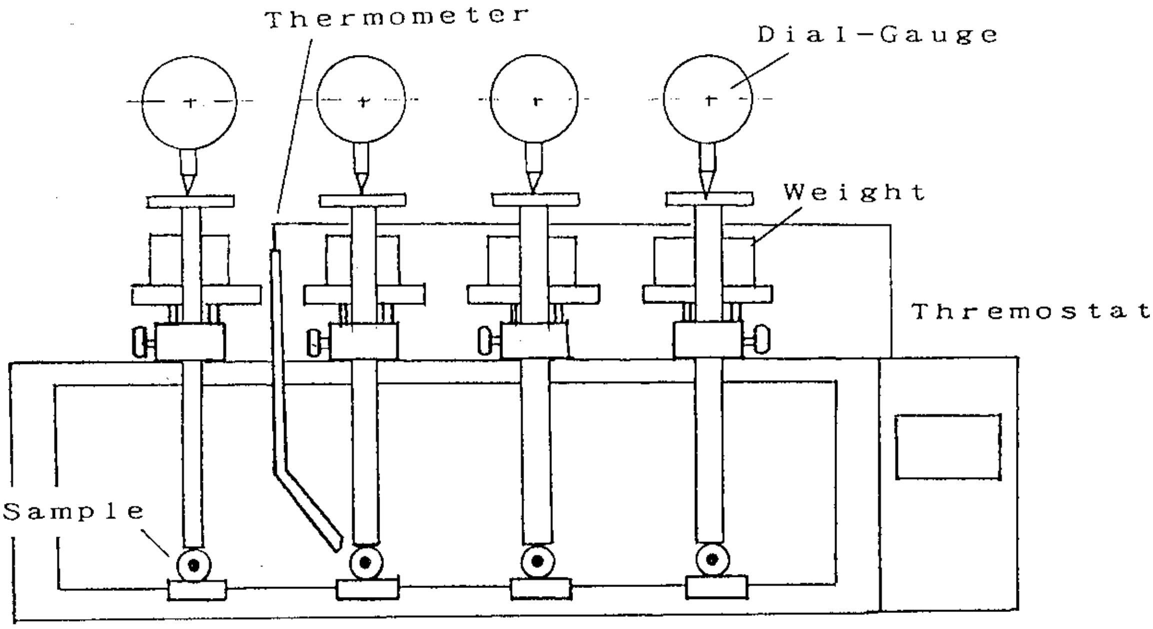

Fig. 7 Cross-section of a deformation test equipment

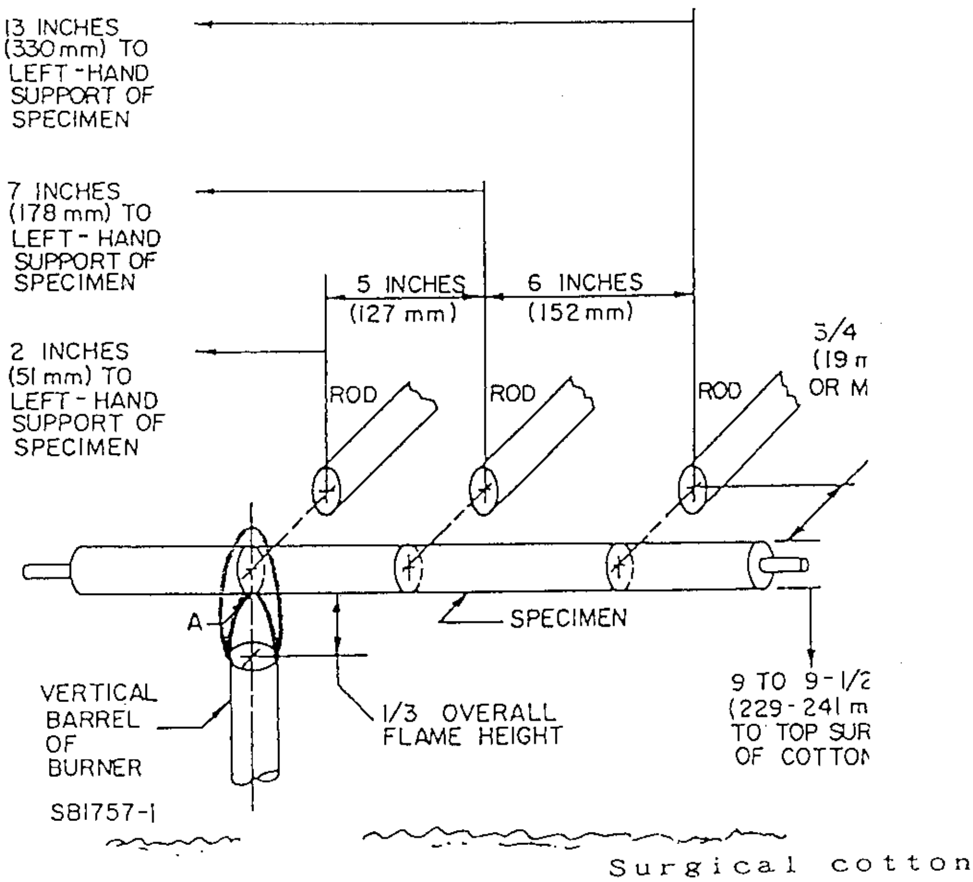

Fig. 8 Horizontal flame test

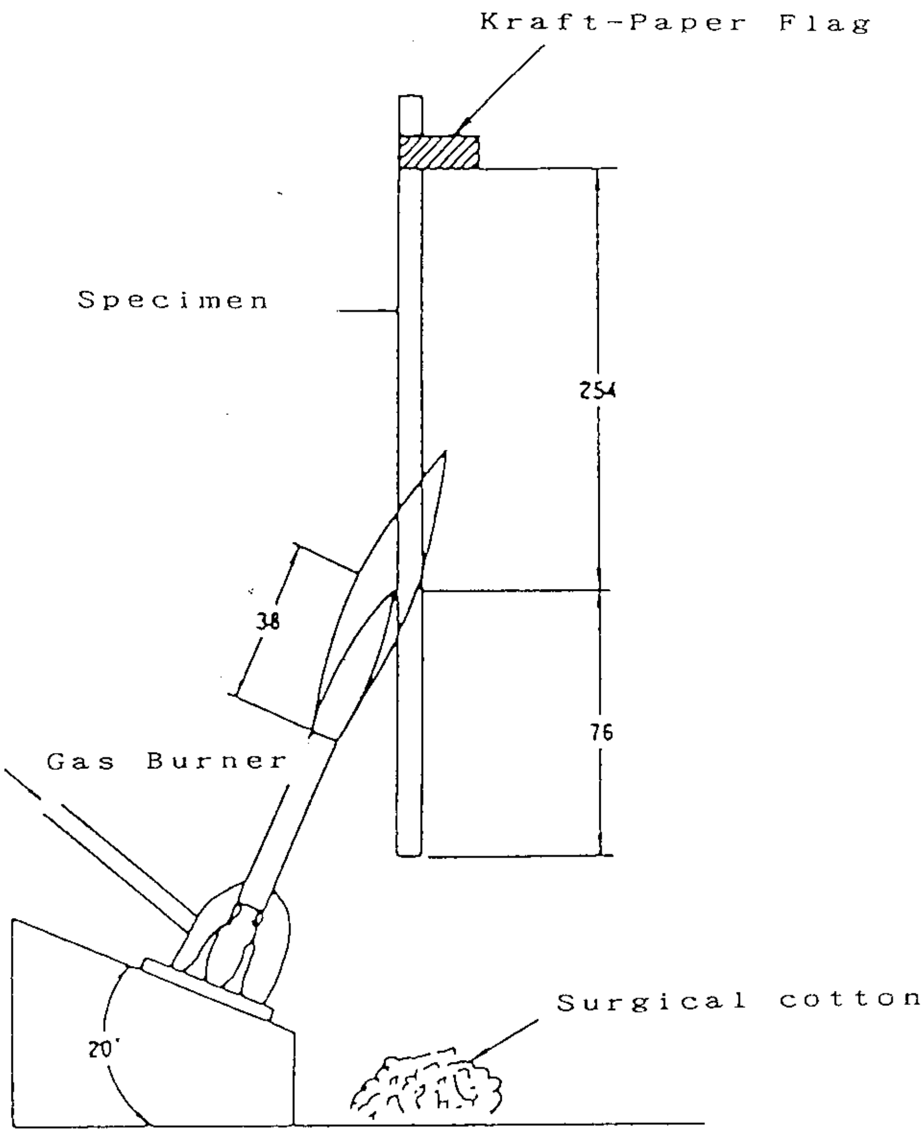

Fig. 9 Vertical flame test

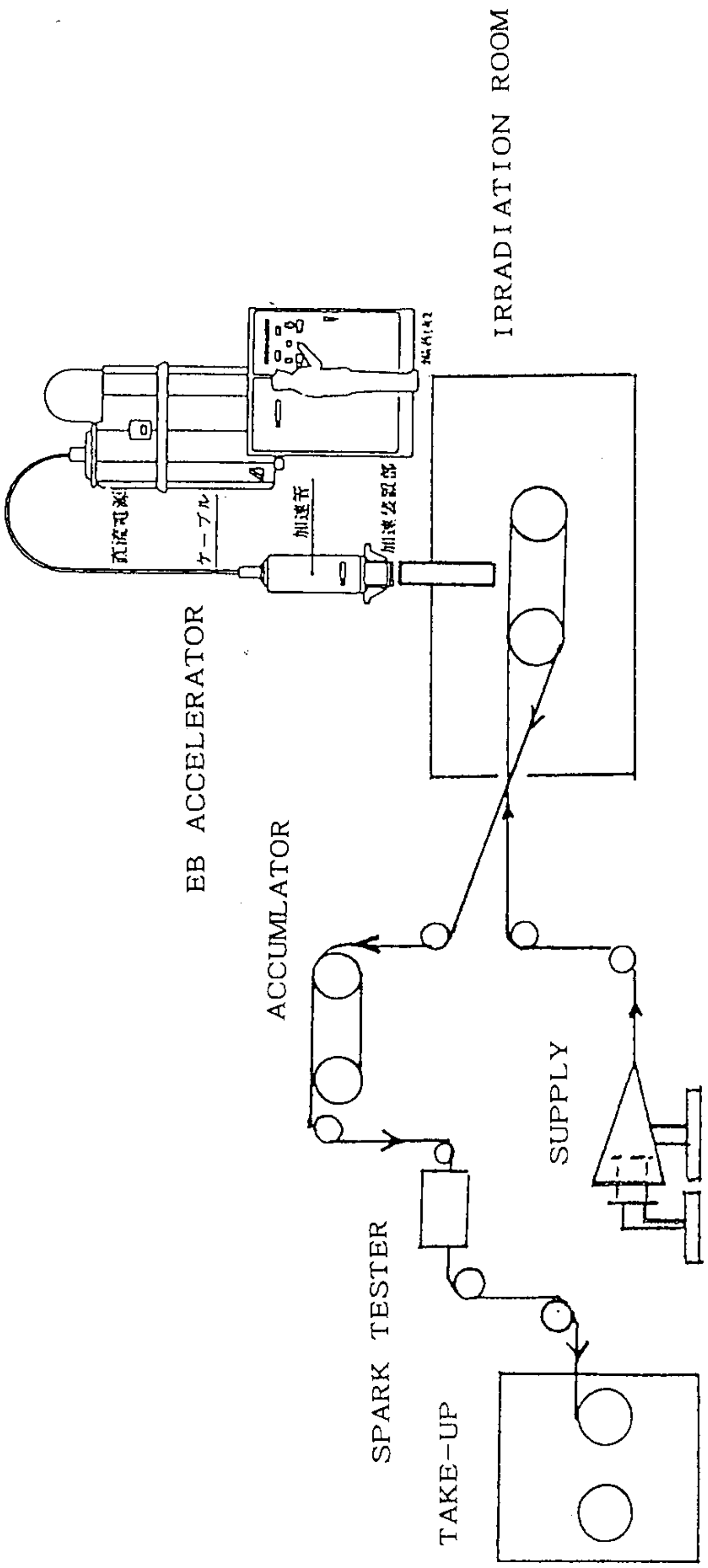

Fig. 10 EB processing system of wire and cable

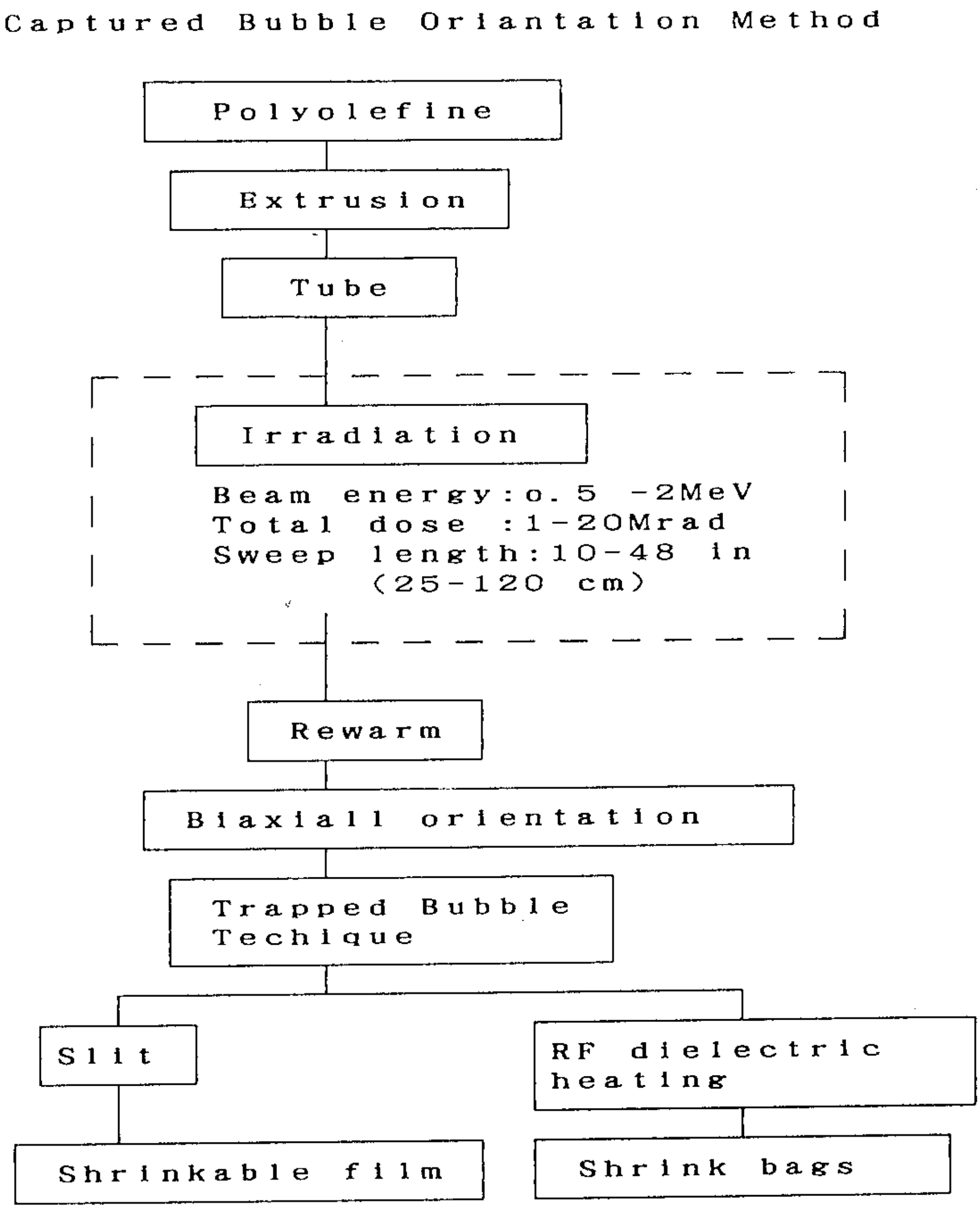

Fig. 11 Production technology of shrink film and shrink bags

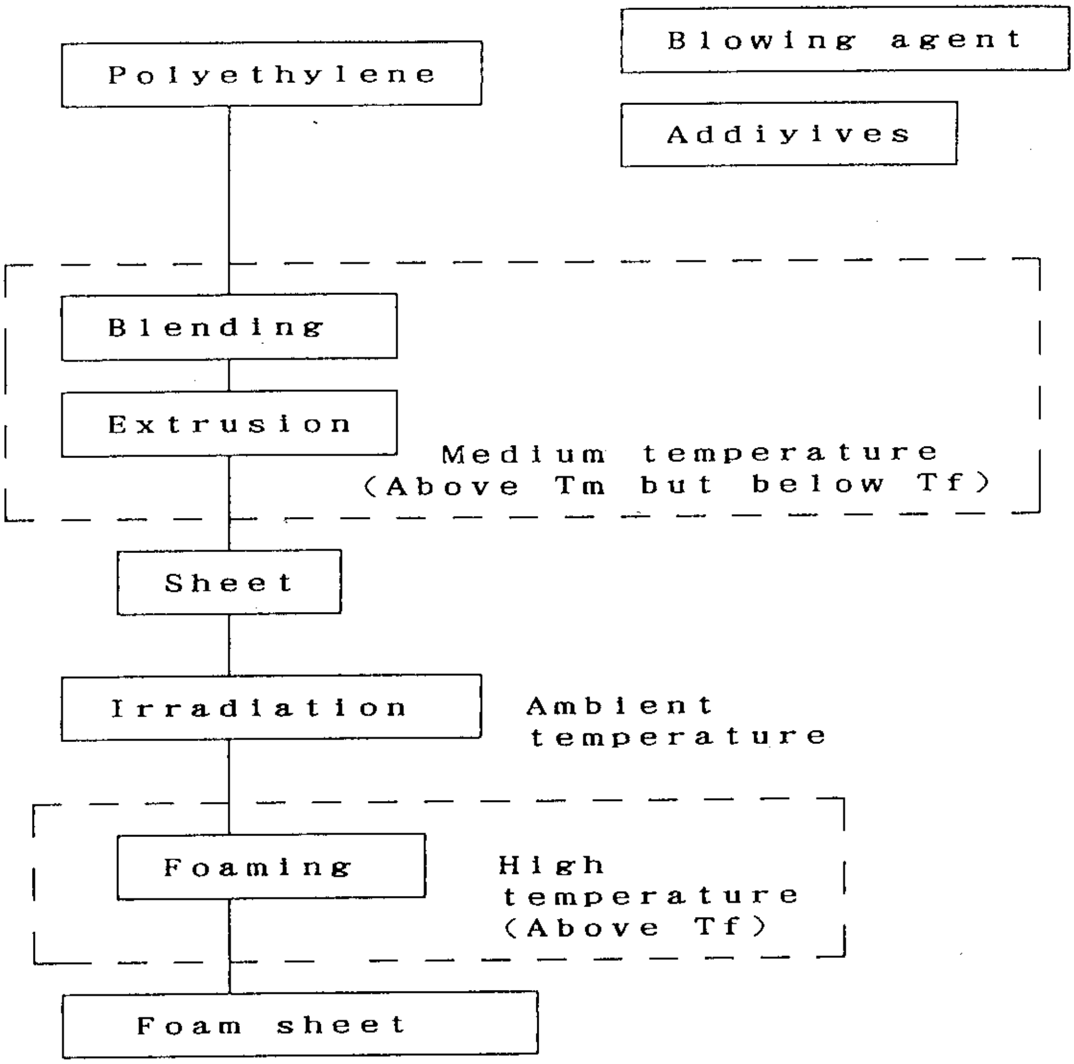

Fig. 12 Production process of continuous polyethylene sheet foam

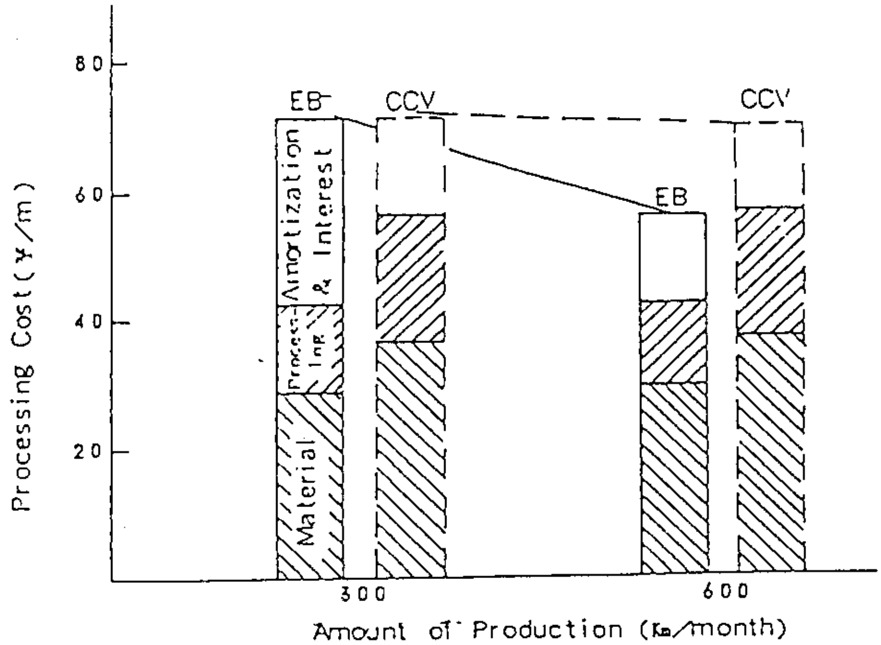

Fig. 13 Cost comparison between electron beam crosslinking and chemical crosslinking for a medium voltage crosslinked polyethylene power cable

Product: the insulated core of cross sectional conductor size 22 mm^2 for 6.6 kV crosslinked polyethylene cable.
Outer diameter; 13.5 mm^2, insulation thickness; 3.8 mm (inner semi-conductive layer 0.2 mm)

Irradiation: the accelerator of 1.5 MeV, 25 mA is used.
Total dose; 25 Mrad, two-directional irradiation
Line speed; 23 m/min.

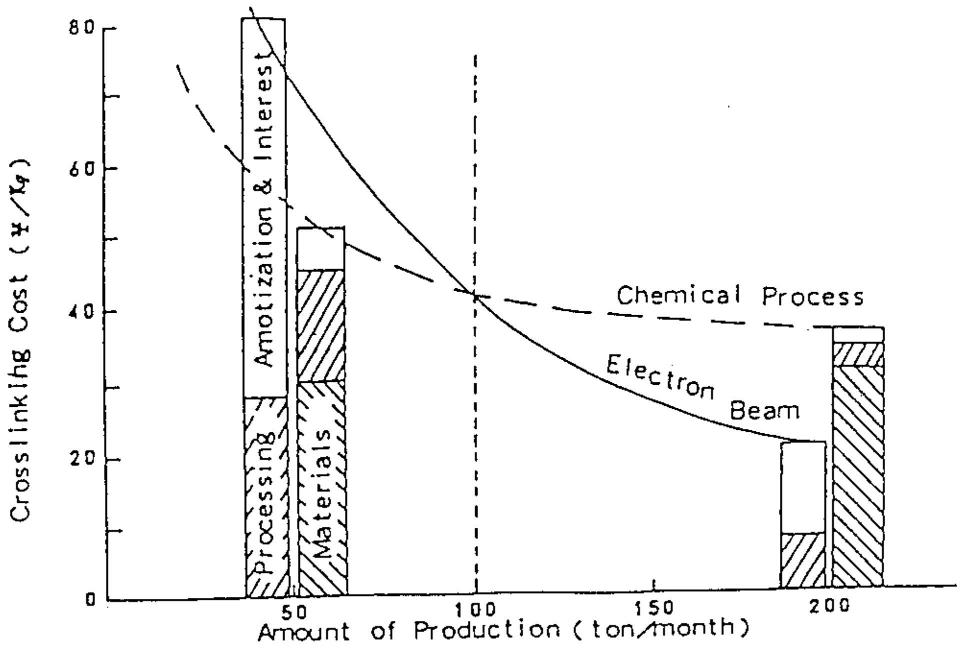

Fig. 14 Comparison of crosslinking cost between EB process and chemical crosslinking process

2.6 Electron Beam Processing of Rubbers

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1. Introduction

Natural rubbers (NR) are produced by a larger number of countries (Table 1). The biggest NR producing country is Malaysia at present time. However, the future Malaysian share of NR production is likely to decrease, while the share of Indonesia is expected to increase because Indonesia has increasing planted area (Table 2). Indonesia exports NR as raw materials and import NR products such as tires, belts and surgical gloves. Indonesia would obtain more foreign currency, if Indonesia could export rubber products. Future success in export of rubber products is dependent on development of new rubber technology. In this connection two EB processing of rubbers are discussed in this paper, tire manufacture and radiation vulcanization of NR latex (RVNRL). Both processings are deeply related to crosslinking (vulcanization) of rubbers which is the dominant reaction occurred in NR during EB irradiation. Physical properties of NR change by crosslinking, e.g., increases in solvent resistance, tensile strength and hardness and decrease in elongation at break.

2. EB in Tire Industry

Commerical application of EB processing of rubbers has progressed steadily in the manufacture of tires. About 10 medium energy EB machines are believed to be used in production of tires in Japan. A tire is composed of numerous components such as tread, sidewall, innerliner and body plies (Fig. 1). Those components must retain their shape and dimensions during construction and final vulcanization of the tire (Fig. 2). The innerliner, for example, tends to decrease in thickness and flow considerably, especially in the shoulder area of the tire during construction and subsequent vulcanization.

EB irradiation is used to partially crosslink the components to increase their green strength. The irradiated components will not decrease in thickness nor will flow as much as unirradiated components during construction and the vulcanization of the tire because the components hold their shape better (Table 3). The EB irradiated components are easier to mold and vulcanize. The advantages of EB irradiation of the components are as follows:

1) fast production rates
2) material reduction
3) minimizing rejects

The irradiation is achieved by simply placing the component on a conveyor belt which is passed under the scan horn of EB machine. EB technology developed for tire manufacture can readily be adapted to other rubber assembly operations in which greater green strength can contribute to increased efficiency in the assembly, molding and vulcanization processes.

3. Vulcanization of NR Latex

Following are the advantages of the radiation vulcanized natural rubber latex (RVNRL):

1) absence of nitrosamine (Table 4)
2) low cytotoxicity (Table 5)
3) absence of sulfur and zinc oxide
4) transparency and softness
5) simple process (Fig. 3)

Commercial production of rubber gloves from RVNRL began in March 1989 in Japan by using gamma-rays. Physical properties of the gloves are comparable with sulfur vulcanized gloves (Table 6). One of the most remarkable characteristics of the gloves is low evolution of sulfur dioxide gas and low level of remaining ashes by burning (Table 7). Medical devices such as optical laser balloon, drainages, and surgical gloves also have been developed. Test production of various rubber products such as comdoms, surgical gloves are now being carrying out in Indonesia using gamma irradiation facility in BATAN. RVNRL is suitable for the manufacture of baby-bottle tests to meet the latest strict legislation of these products in Europe (Table 8).

RVNRL is expected as a promising application of EB processing to manufacture medical and hygienic products. There is a big market of clean pre-vulcanized NR latex in the world. RVNRL with EB is expected to be the most clean pre-vulcanized NR latex because vulcanization can be carried out without any kind of additives with EB. EB irradiation facility for RVNRL has been designed using a 5 MeV, 150 kW EB machine (Fig. 4). This facility can vulcanize 10,000 tons of NR latex without sensitizer. The cost of EB irradiation will be lower than that of gamma irradiation (Tabel 9).

4. Conclusion

Natural rubber products such as tires, surgical gloves and catheters would be potential non-minyak, if the qualities are acceptable for export. Electron beam technology will be a useful tool to develop new manufacturing process for rubber products.

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Table 1 Natural rubber production

	1987		1988		% Difference
	'000 tonnes	% Share	'000 tonnes	% Share	
MALAYSIA	1,578.7	33.1	1,660.3	33.1	5.2
INDONESIA	1,190.0	24.9	1,200.0	24.0	.8
THAILAND	933.2	19.5	960.0	19.2	2.9
CHINA	237.6	5.0	240.0	4.8	1.0
INDIA	227.4	4.8	254.8	5.1	12.0
SRI LANKA	121.8	2.6	122.4	2.4	.5
Rest of World	486.3	10.2	572.5	11.4	17.7
	4,775.0	100.0	5,010.0	100.0	4.9

Source: IRSG Rubber Statistical Bulletin, Vol. 43, No. 8, May 1989.

Table 2 Area planted under rubber ('000 Hectares)

Year	MALAYSIA	INDONESIA	THAILAND	SRI LANKA	INDIA
1975				227.6	
1977	1,999.0	2,327.5			
1979			1,518.0		
1980	2,004.6				241.5
1987	1,903.5	3,007.0	1,717.0	205.1	394.0
1988	1,860.7				

Source: IRSG Rubber Statistical Bulletin, Vol.43, No.8, May 1989.

Table 3 Effect of EB irradiation on tire components

Innerliner

	Parts by Weight
Butyl Rubber	20
SBR 1502	33.5
Natural Rubber	45
Whole Tire Reclaim	20
GPF Black	50
Whiting	45
Tackifying Resin	10
Medium Process Oil	6.25
Stearic Acid	1
Zinc Oxide	5
Accelerator (Sulfenamide type)	2
Phenol Polysulfide	1
Sulfur	0.3

Precure - Innerliner Stock	0 Mrad	5 Mrad	10 Mrad	15 Mrad	20 Mrad
(1) Peak lbs., Green Strength	3.0	15.3	20.0	22.9	33.8
(2) Percent Recovery	8.0	31.5	42.5	80.0	Not Tested

Innerliner Gauge in Cut Tires

Spec	Initial IL Gauge, in.	Dosage, Mrad	Final IL Gauge, in.	% Gauge Reduction
A	0.055	0	0.037	33
B	0.055	5	0.042	24
C	0.055	10	0.049	11

Fleet Tests of Irradiated Innerliner and Veneer Strip

8.25-14 Bias, Load F1380#/tire, R1620#/tire 28 psi - Durability Test, Tires rotated, 20,000 mile inspection - Complete

Spec	Features	Wear Rating	Veneer Cuts and cracking	Open Liner Splice
A	0.055 ga IL 0.030 ga Veneer No irradiation control	100	Sli (4)	Sli (1)
B	0.047 ga IL @ 10 Mrad 0.024 ga Veneer @ 7.5 Mrad	91	Sli (4)	Sli (1)

Table 4 N-nitrosamines analysis of RVNRL

	Found	Permitted
Nitrosamines	nil	> 3× 10^{-8}
Nitrosatable amines	1× 10^{-8}	> 5× 10^{-7}

measured by MRPRA

Table 5 Contents of accelerators and cytotoxicity index of rubber products

Sample No.	Material	Accelerators (ppm) ZDMC	ZDEC	ZDBC	ZEPC	ZPC	MBT	MBTS	IC_{50}(%)
surgical gloves									
S-2	NNRL	-*1	-	1250	-	1880	-	-	4.7
S-3	NRL	-	-	676	-	4850	-	-	3.1
S-19	NRL	-	510	-	-	4950	-	-	1.5
S-24	NRL	-	-	-	-	-	-	-	26.7
urinary catheters									
C-1	NRL	-	452	832	1930	-	-	-	14.8
C-2	NRL	-	474	916	1700	-	-	-	12.9
C-3	NRL	-	-	-	-	-	48.7	179	85
C-4	NRL*2	-	-	3720	-	-	-	-	45.2
C-7	NRL			not analyzed					27
C-8	silicone			not analyzed					>100
radiation vulcanized NRLs									
R-1*3	RVNRL	-	-	-	-	-	-	-	74
R-2	RVNRL	-	-	-	-	-	-	-	84
R-3	RVNRL	-	-	-	-	-	-	-	95
R-4	RVNRL	-	-	-	-	-	-	-	>100
R-5	RVNRL	-	-	-	-	-	-	-	>100

*1 not detected
*2 Teflon coated
*3 The materials R-1 to R-5 differ from one another in washing period with 1% aqueous sodium hydroxide solution: R-1, 0 hr; R-2, 0.5 hr; R-3, 1 hr; R-4, 4 hr; R-5, 24 hr.

Table 6 Physical properties of gloves

		JIS Z-4810	RVNRL	Commercial
tensile strength (Tb, MPa)		24.5	37.8	41.0
elongation at break (Eb, %)		700	897	872
permanent set (%)		10	2.5	2.0
Tb after aging*		19.6	37.0	40.7
HCl resitance**	Tb	19.6	22.9	33.4
	Eb	600	897	850
NaOH resistance**	Tb	19.6	32.0	34.7
	Eb	600	920	917

* aged at 70°C for 48 h,

** immersed in 10% aq. soln. for 48 h

Table 7 Combustion analysis of gloves

		RVNRL	Commercial
Gases (mg/g)			
	SO_2	less than 0.2	19
	HCl	0.23	0.27
	NO_x	2.1	15.0
	HCN	0.002	0.015
	CO	56	330
Ashes (wt %)		0.5	2.2
Oxygen Index		15.8	16.8
Ignition Temp. (°C)		348	333
Calorific value(kcal/g)		10.3	10.4

Table 8 Legislation on N-nitrosamines in Europe

	Federal Republic of Germany	Netherland	Denmark	United[a] Kingdam	EEC[b]
Limit Preformed Nitrosamines	10	1	5	30 total 15 each	20 total 10 each
Limit Nitrosatable Amines [ppb]	200	20	50	--	200
Extraction Method	artificial saliva	artificial saliva	artificial saliva	Dichloro methane	not fixed

a Regulation for soothers only
b Draft directive 11/6/87

Table 9 Cost of RVNRL with gamma rays and EB

	Co－60	EB
Source	2MCi	5MV, 30mA
Power (kW)	30	150
Efficiency (%)	40	95
Annual operation (h)	6,000	6,000
Vulcanization dose (kGy)	10	250
Sensitizer	n－BA	none
Annual production (ton)	20,000	12,000
Annual operation cost	¥450M	¥250M
Cost/ton	¥22,500	¥20,850

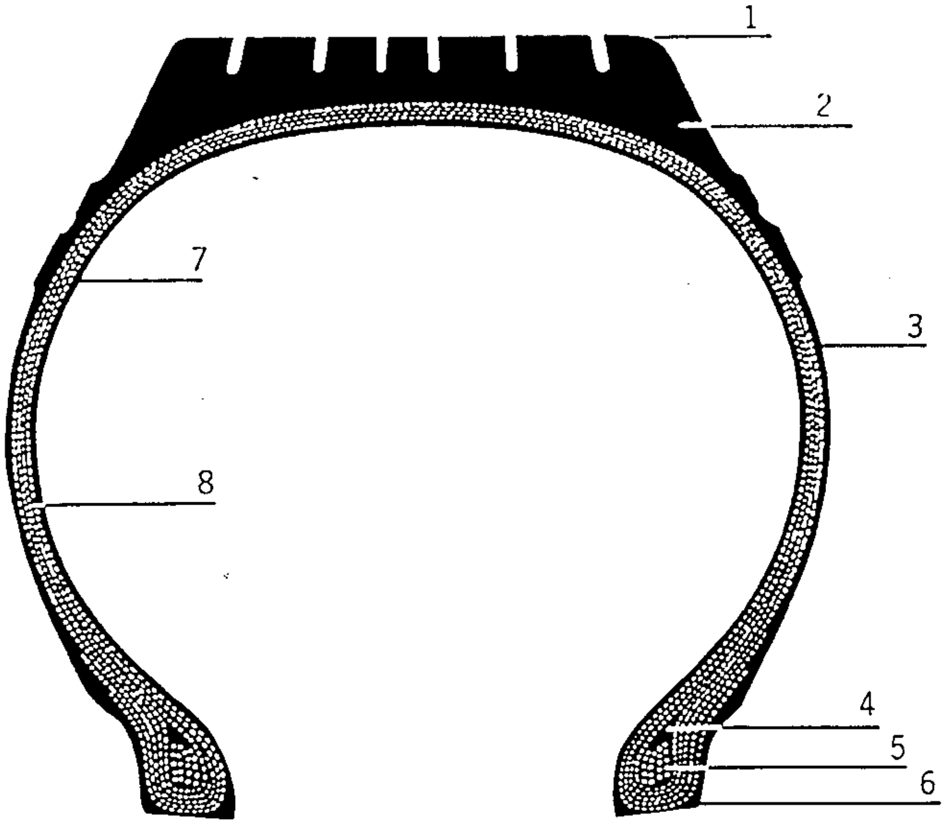

Fig. 1 Structure of tire

1, tread cap; 2, tread base; 3,sidewall, 4,bead insulation; 5, bead wire
6, chafer; 7, inner liner; 8, cord.

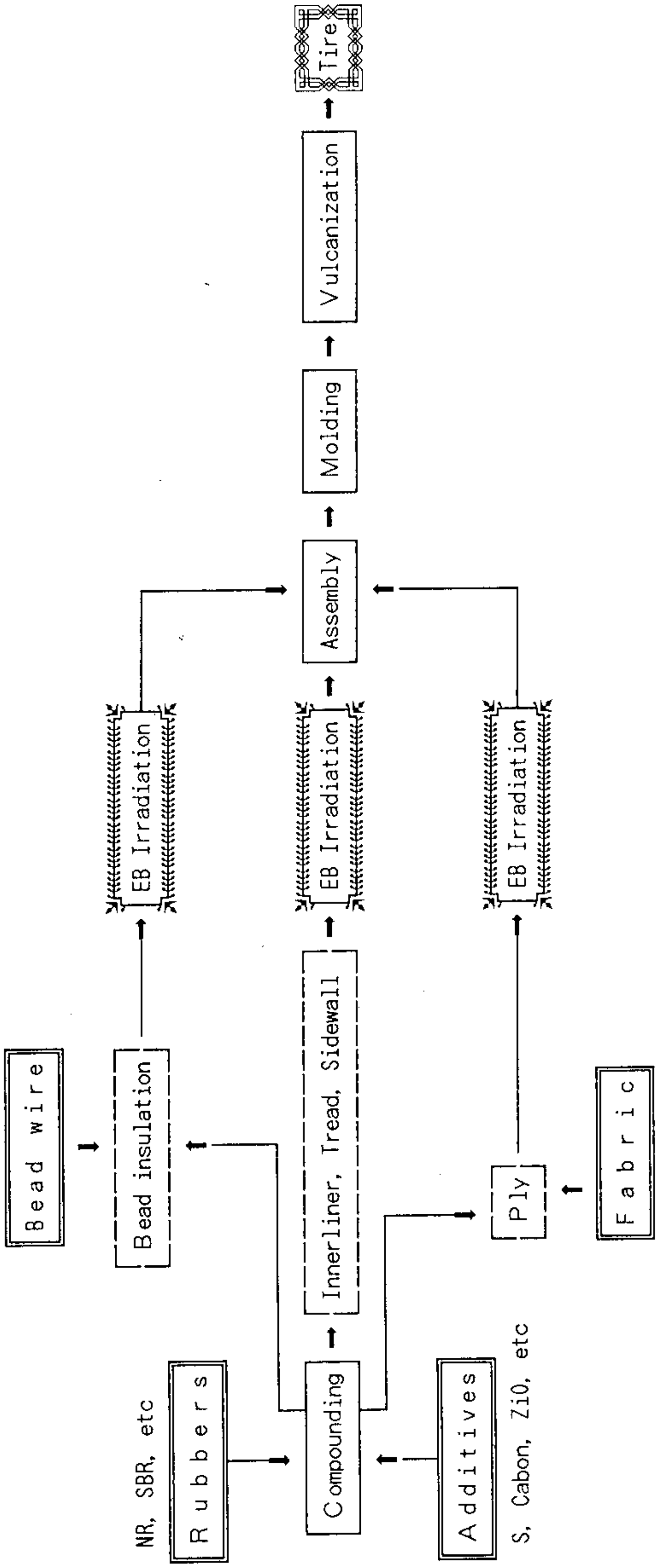

Fig. 2 Tire manufacture process

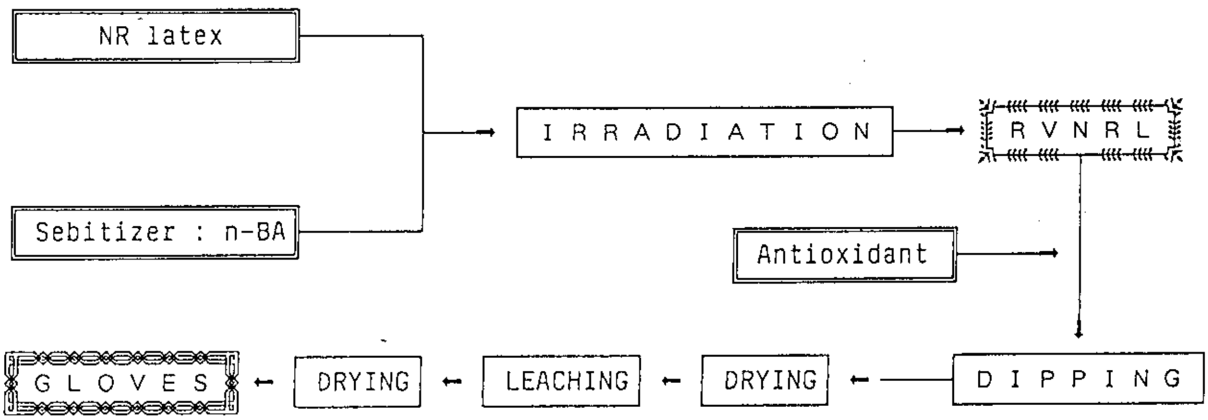

Fig. 3 Process for rubber gloves from RVNRL

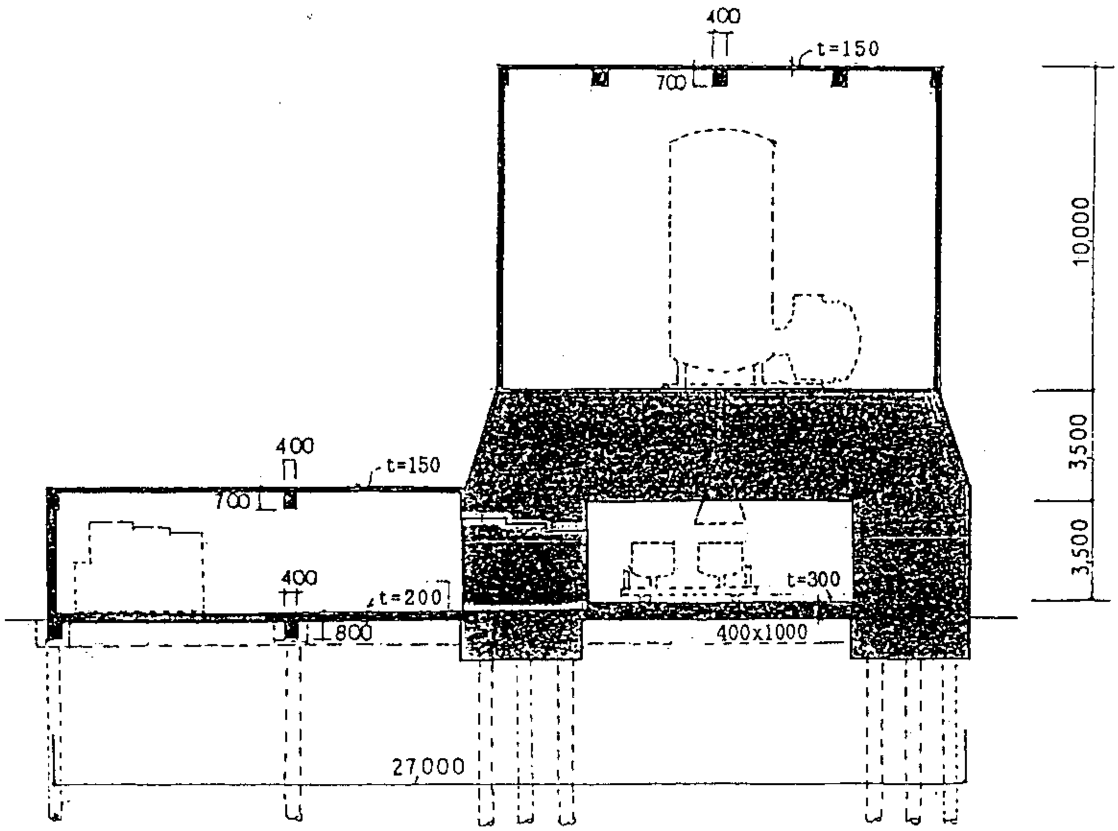

Fig. 4 EB irradiation facility for RVNRL

2.7 BATAN's Experiences on Radiation Curing

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1. Introduction

A pilot plant for radiation curing of surface coating on wood products had been installed in Jakarta on the end of 1984, under UNDP/IAEA-RCA Project and government of Indonesia. Total budget spent for the plant investment was about one million US dollars. The main objective of this plant was for training course, demonstration as well as for studying both technical and economic aspect of radiation curing of surface coating technology. This plant was equipped with one low energy (300 keV) Electron Beam Machine (EBM), scanning type, with a variable beam current, 50 mA maximum. A number of wood coating and wood handling equipments are also available in the plant.

Although the plant in the size is a commercial size, but technically it was not designed for a commercial application. For a typical application, flowsheet of the processes can not follow the available plant layout. In this case a batch process should be used. A number of activities had been carried out during the last five years, and the paper reports the experiences in using the pilot plant.

2. Principal of Radiation Curing of Surface Coating Technology

Radiation curing of surface coating technology is a modern technology of surface coating where no volatile diluent was used. This technology was based on using a coating material called radiation curable materials, a material which is able to cure under a high energy radiation such as electron beam. This material is a moderately viscous liquid which basically consists of a mixture of oligomers and monomers. Under a high energy radiation this material will react each other forming a three dimensional molecular structure, a hard substance physically. A typical physical characteristic of the cured materials: high hardness, chemical resistance, abrasion resistance and heat resistance.

3. Pilot Plant Specification

The plant is housed in a building of 720 square meters, steel construction, and located inside the Center for the Application of Isotopes and Radiation, Jakarta. Building construction and equipment installation were completed in the end of 1984, while until the end of 1989 there were some small modifications of the plant. A liquid nitrogen plant has been installed in 1989 in order to supply the demand of EBM for an inert gas.

Total fixed investment of the plant (excluded liquid nitrogen plant) was about one million US$ (Table 1).

3.1 Electron Beam Machine (EBM)

This machine was from Nissin High Voltage Co., scanning type with 120 cm beam width, 300 keV energy and variable beam current with maximum current 50 mA. Self-shielded EBM with power requirement about 35 kW and inert gas requirement about 100 NM3/hour (N2), or about 150 liter of liquid nitrogen/hour. The speed of conveyor is between 2.5m and 25m/minute. CONVEYOR speed and beam current determine the dose of irradiation (Fig. 1).

3.2 Ultra Violet Source

This radiation source is equipped with one UV lamp with radiation intensity about 80 W/cm width. The width of the lamp is about 120 cm and electrical power required is about 10 kW. The conveyor speed is between 3m and 6m/minute.

3.3 Wood Handling Equipments

A number of wood handling equipments are available in this pilot plant: sanding machine, roll coater, curtain coater, reverse roll coater and film laminator (Fig. 2,3).

4. Local and Regional Activities

The plant had been used for several regional training courses and now is being used for research and development and some radiation services.

4.1 RTC and Demonstration

The first Regional Training Course (RTC) and demonstration had been conducted from November 1984 to February 1985. This course was under IAEA direction, and followed by eight participants from Bangladesh, India, Pakistan, Thailand and Indonesia. The course appeared to be less successful: too much theory and laboratory work should be done, which was unnecessary for many practical works. Further more the participants were unable to see the superiority of the radiation curing of surface coating technology compared to the conventional one. However, at least the participant had received a lot of information regarding the basic knowledge of the technology.

The second RTC was from November 1985 to December 1985, which was much shorter than the first course. This course was followed by nine participants from Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Sri Lanka and Thailand. A more practical work in operating the pilot plant was given in this second course.

The third RTC was from September 1986 to October 1986. The materials presented in this course was almost the same with the second course. This third course was followed by ten participants from Bangladesh, China, India, Indonesia, Malaysia, Singapore, Sri Lanka and Thailand. As in the first and second courses, participants already received a basic knowledge regarding the technology, as well as a lot of practical experience on the pilot plant operation.

The last RTC was from 04 June up to 22 June 1990 and followed by fifteen participants. The participants were requested to make a brief presentation regarding the economic aspect of the technology and the prospect of the technology in the region. It was found that for many developing countries the problems are limited investment and market.

Although most of the participants were coming from industries, but up to recent time there was no indication that they had applied their knowledge received in the course for the benefit of their company. We are afraid that the knowledge received from the courses gradually evaporate from the mind of the participants from the RCA Member States.

4.2 Research and Development

It was found that radiation curing of surface coating technology on wood products was not a well-established technology, at least in the developing countries. Possessing an EBM does not mean having the capability to hold the technology, but still is in the first stage of development. Due to that reason, the activities during the last five years were focused on research, development and economic evaluation of the technology.

The main activities conducted were;

(a) Formulation/synthesis of radiation curable materials.

(b) Development of an optimum process for typical application.

(c) Economic èvaluation of the process/technology.

The unavailability of ready for used radiation curable materials, high cost of operation and plant maintenance, guided us to do these activities. It was found that for each kind of substrate coated needed a typical pretreatment and coating processing and resulting a different cost of production. The main purpose of this work was to reduce the production cost as much as possible by doing the best formulation and processing, and so a better market.

After years of doing R&D it has been established several processes of radiation curing, such as the process for coating on wood parquet flooring. This process consists of two steps of irradiation: irradiation of base coat/filter and irradiation of top coat. The formulation of radiation curable materials both for filler/base coat and top coat has been established. The economic evaluation has also been done: capital investment and production cost for a given plant capacity (Table 2 and 3). The products had been tested artificially for three years and showing a good result. A number of customers had sent several hundreds of square meter of wood parquet/panel to the pilot plant. Based on this experience it was found that the pilot plant was not suitable to be used as a commercial production plant: a better design of irradiation process (EBM) should be made, in order to reduce the production cost. The irradiation process should be done continuously in order to reduce the consumption of inert gas (liquid nitrogen). It was estimated that the inert gas consumption was reduced to one third by using a continuous irradiation process. It is very important because the cost of coating is mainly coming from the cost of liquid nitrogen and radiation curable material, while electricity, salary, maintenance, depreciation were only giving a small effect.

5. Troublesomeness in Operating the Plant

During the first five years of operation, a lot of troublesomeness were found, which mostly due to the lack of experiences and high cost of operation.

5.1 Cost of Operation

The pilot plant is a commercial size, but was not designed for commercial application. The cost of operation was found to be very high: liquid nitrogen consumption, raw wood panel and radiation curable material. Liquid nitrogen consumption of the machine is about 1000 liters for seven hours of operation.

A liquid nitrogen plant has been installed near the pilot plant, under IAEA technical assistance. However, the real capacity of the plant was found to be much lower than formerly expected and the operation cost of this liquid nitrogen plant was found to be high.

5.2 Radiation Curable Material

Radiation curing of surface coating technology actually was not a well-established technology, and so ready for use of radiation curable material with a reasonable price was not available locally.

Radiation curable material which was locally available was a solution of unsaturated polyester in styrene monomer, that was an oligomer based on backbone unsaturation. Such material showed a very low activity by radiation, and consequently required a very high dose of irradiation to cure the material (about 10 Mrad). The smell of this material is very hard due to the evaporation of styrene monomer. This is relatively a low price radiation curable material but resulting a great difficulty in the coating process.

Acrylated oligomers, which were based on side chain unsaturation, are very active radiation curable materials so far, but the price is relatively very high and unavailable locally. It should be imported specially for the purpose, and take a long time.

5.3 Lack of Experiences

In the first five years, no one of BATAN staff had any experience in operating the EBM and wood handling equipments. Training for the operation and maintenance of the pilot plant had been given to several technicians, but they need a little bit of time to be familiar with the equipments. Recently all maintenance of the EBM can be done by local staff, but spare parts for the machine still should be imported.

5.4 Commercial Liquid Nitrogen

An inert atmosphere is required for radiation curing of surface coating process. Flowing nitrogen gas into the irradiation chamber is done to meet the purpose. The gas is coming from a liquid nitrogen tank In this case a very high purity of liquid nitrogen is required. Usually the oxygen concentration in the irradiation chamber should be less than 1000 ppm.

It was found that the purity of commercial liquid nitrogen fluctuated relatively very high. The concentration of oxygen in the liquid nitrogen fluctuated from about 500 ppm to several thousand of ppm. This will make some difficulties in determining the dose to cure the radiatio curable material.

5.5 Equipment Lining

It is difficult to arrange the equipments in such manner that will be able to meet all of the requirements for a typical coating process. The equipments lining in the pilot plant was made to meet the least requirement of some coating process. For experimental production such lining has no problem in operation but will result in a great difficulty for commercial production: low efficiency and consequently high production cost.

6. Experiences with Customers

Several customers already sent thousands square meter of wood parquet mosaic, particle board and plywood to the pilot plant. The materials were coated using radiation curing process. The coated particle board and plywood were used mainly for making laboratory benches. These products show a superiority in chemical and heat resistant: suitable for laboratory and kitchen set. Based on this experience an optimum process for a typical application, has been established, economic analysis has been done and has been published anywhere.

It was found that the pilot plant in Jakarta is unsuitable for a continuous commercial production of wood parquet flooring or pigmented wood panel: the cost of coating process will be very high. This is because the irradiation system of the EBM is an uncontinuous system, while the inert gas should flow continuously. This will result in a high consumption of inert gas for coating of one piece of wood panel. It had been calculated that the inert gas consumption will be much reduced by using a continuous irradiation system.

The consumption of liquid nitrogen for the present plant is about 150 liter per hour. In the present system (uncontinuous), the speed of irradiation is about one panel (1.2 × 2.4m) per 70 second. The liquid nitrogen consumption has been calculated to be about 2.9 liter for one panel. If a continuous system is applied, the speed of irradiation will be about 7.5 m/minute, or about three panels/minute. Then the liquid nitrogen consumption will be about 0.95 liter for one panel.

7. Conclusion

Radiation curing of surface coating processes have been proved to be able to produce an excellent chemical and heat resistance coating. The products are suitable for making laboratory benches and kitchen set. A lot of achievements regarding the technology had been obtained using the pilot plant: technical and economical.

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Table 1 Description of the pilot plant investment

ITEMS	COST,US$	REMARKS
1. EBM, 300 keV,50 mA	540,000	UNDP/IAEA/1984
2. Wood handling equipments	128,500	BATAN/1984
3. Laboratory equipments	70,000	BATAN/1984
4. Building etc.	259,500	BATAN/1984
5. UV radiation source	15,000	IAEA/1986
6. Reverse roll coater and laminator	65,000	IAEA/1989
7. Building modification	12,000	BATAN/1989

Total = US$1,090,000

Table 2 Fixed capital investment for a plant with capacity about 5 million square meter of wood parquet per year

ITEMS	COST,US$
(a) Land , building (2,500 m2)	600,000.-
(b) First sander, 60 kW	40,000.-
(c) Second sander, 65 kW	60,000.-
(d) Direct roll coater, 2 kW	30,000.-
(e) First reverse roll coater,6 kW	40,000.-
(f) Second reverse roll coater,6 kW	40,000.-
(g) First EBM , 20 mA max.,175 keV	500,000.-
(h) Second EBM , 50 mA max.,175 keV	650,000.-
(i) Conveyor etc., 10 kW	90,000.-

TOTAL = $ 1,950,000.-

Table 3 Production cost of coated wood parquet for a plant with capacity of about 5 million square meter per year

DESCRIPTION	COST,US$
(A) Annual manufacturing cost.	
1. Raw material (variable)	
- wood parquet,5 million m2,a $7.70	38,500,000.-
- rad. curable mat.: 625,000 kg, a $ 8.33	5,206,250.-
- liq. nitrogen: 2,300,000 liter, a $ 0.50	1,150,000.-
2. Salary : 110 persons for 3 shifts,a $2,000.-	220,000.-
3. Electricity: 178x8,000 kWh, a $ 0.07	99.680.-
4. Maintenance : about 2% from fixed cap.	39,000.-
5. Quality control : about 10% of salary	22,000.-
6. Overhead : about 50% of salary	110,000.-
7. Depreciation: building 25 y; equipments 15 y	114,000.-
8. Tax & insurance : about 2% from fixed cap.	39,000.-
Total manufacturing cost =	US$ 49,499,930.-
(B)General expenses	
1. Administration: about 3% from manufacturing	1,364,998.-
2. Marketing: 5% from manufacturing cost	2,274,996.-
3. Interest : 12% from fixed capital	234,000.-
Total general expenses =	3,873,994.-
(C)Annual production cost : A + B	49,373,924.-
(D)Production cost/square meter:	
= (A + B) /5,000,000	US $ 9.87
(E)Coating cost/square meter: D - $ 7.70=	US $ 2.17

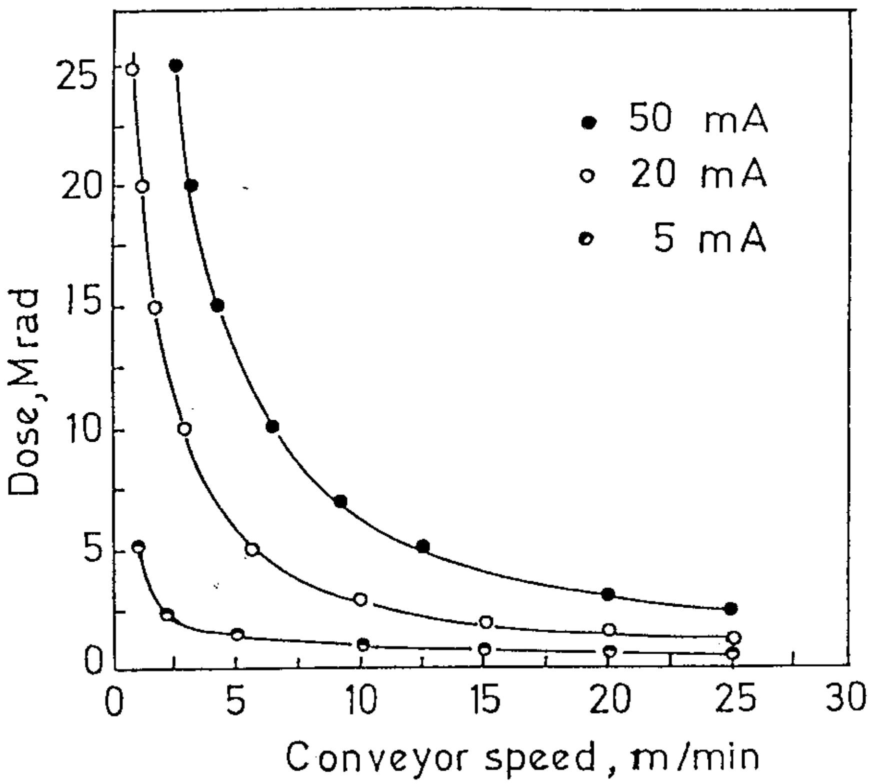

Fig. 1 Relation between EB irradiation dose, conveyor speed and beam current

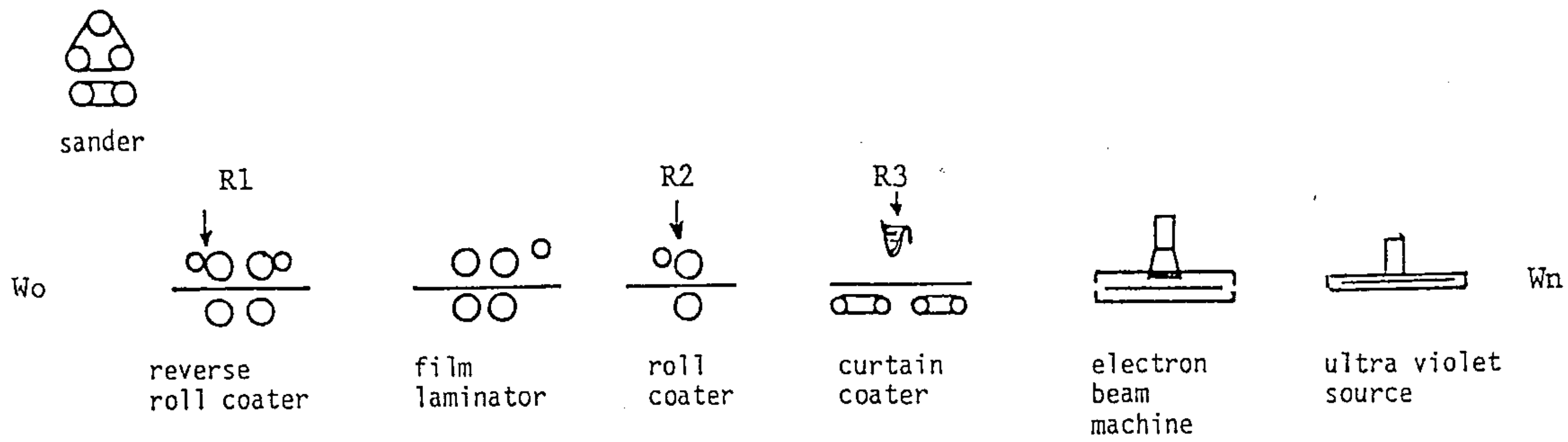

Fig. 2 Equipments lining in the pilot plant.
R1, R2 and R3 = radiation curable materials,
Wo and Wn = wood panel

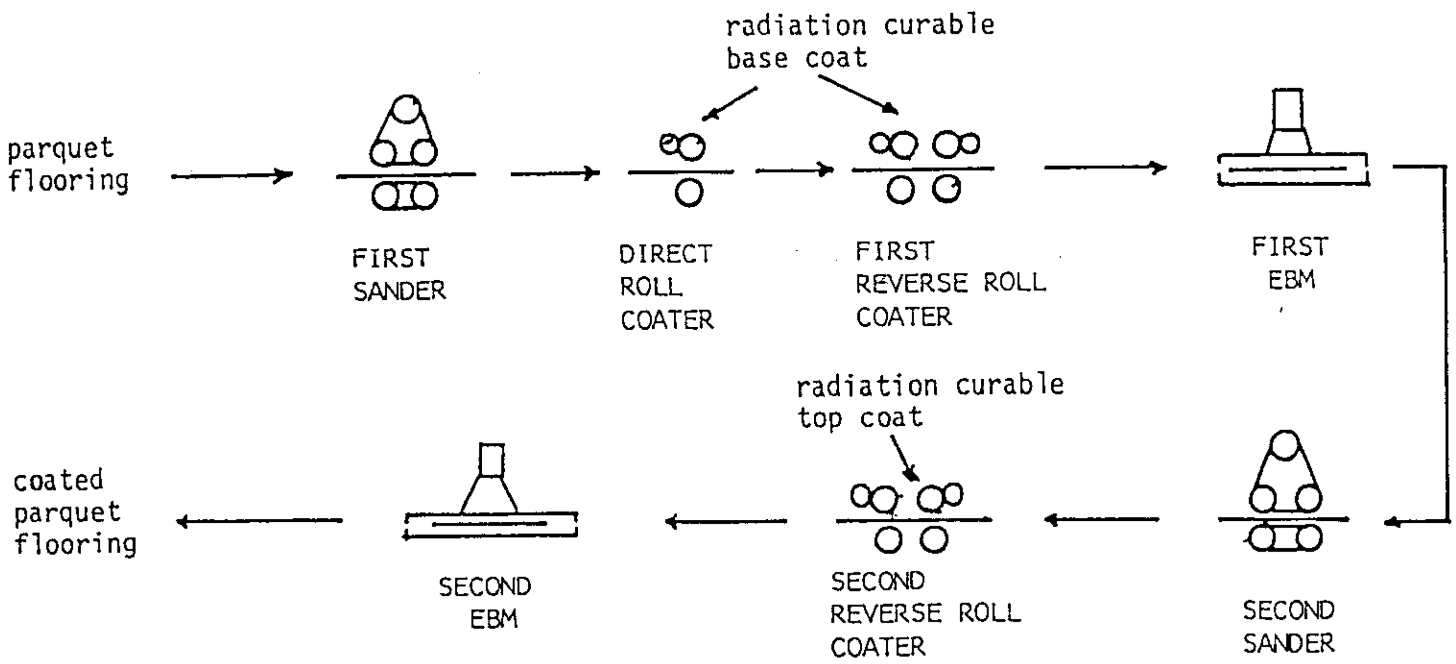

Fig. 3 Flowsheet of radiation curing of surface coating process of wood parquet flooring

2.8 Electron Beam Sterilization of Medical Products

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1. Introduction

Radiation sterilization of medical products is one of the biggest areas in which radiation is effectively used and has been rapidly growing the world over. Although ethylene oxide has been widely used for industrial sterilization of medical products, ethylene oxide is well known to be very dangerous not only to patients but also personnel working at the sterilization. On the other hand, the radiation processing has many advantages over than other methods (Table 1). In Japan, the first commercial facility for the sterilization was operated in 1969 and since then 8 commercial facilities with Co-60 are in operation. On the other hand, the radiation processing by using electron accelerator has been widely industrialized in the various fields using more than 180 electron accelerators (including for R&D). The application of EB for the sterilization has been strongly demanded due to the short supply of Co-60 sources, which are not commercially produced in Japan. In order to promote EB sterilization in Japan we studied it in comparison with gamma rays.

2. Biological Indicator and its Radiation Sensitivity

Sterility dose for the medical products is determined on the basis of the radiation sensitivities of contaminating microorganisms. In the EB sterilization of medical products, the EB sensitivities of microorganisms should be examined because of its short penetration and high dose rate as compared with gamma rays. Bacillus pumilus which is commonly used for gamma ray sterilization were found to be chosen as a biological indicator for EB sterilization (Fig. 1). The effects of oxygen and acceleration energy of EB on the sensitivities of B. pumilus were also studied. The EB sensitivity of B. pumilus were found to agree in vacuo or at a lower pressure of oxygen with those for gamma-rays and increased largely by adding trace amounts of oxygen to the system (Fig. 2).

3. Radiation Effects on the Materials

Durability of radiation sterilized materials is one of the most important factors to be examined for the industrial application of EB sterilization, since some materials used for medical products are easily deteriorated by ionizing radiation. In this report, radiation durability of polypropylene (PP), which is widely used for disposable medical devices, was studied. It was found that the radiation degradation of PP occurs during irradiation as well as after irradiation. Both degradations caused by EB were found to be smaller than those by gamma rays (Fig. 3, 4). In order to study the relationship between degradation and oxidation of PP, the degree of oxidation and depth of oxidation layer in the irradiated PP were determined by using the chemiluminescence method (Fig. 5). The degree of oxidation was found to be very high at the surface of the film where oxygen can diffuse during irradiation and decrease sharply with increasing depth from the surface. It was found that the degree of oxidation of EB irradiated PP was only one-half that for gamma ray-irradiated one. In the case of EB irradiation, oxygen can not diffuse so rapidly from the surface area of the samples as to react with radicals formed inside the materials, since irradiation is carried out at a very high dose rate in a short time as compared with gamma rays It is conclusively said that EB sterilization is more useful than gamma ray one for the materials deteriorated easily by radiation oxidation.

4. Irradiation Engineering

In the radiation processing, two types of radiation sources i.e., gamma rays from Co-60 and high energy electron beams are commonly used. Although EB processing seems to be more advantageous over than the gamma rays, one of the biggest drawbacks is lower penetration (Table 2). The thickness of products which can be effectively irradiated (penetrated) increases with increasing acceleration energy (Figs. 6, 7). On the practical irradiation, however, it is very impotant factor to make sure the penetration of EB throughout the products, since the medical product are not always homogeneous (Fig. 8). In order to apply EB sterilization it is very important to confirm the dose distributions for each product. The bulky and relatively homogeneous materials such as surgical gloves, gause, surgical suture, plaster, etc., can be uniformly irradiated with 3 MeV EB.

5. Conclusion

It is suggested that, despite a few drawbacks, EB method can be applied for the sterilization of medical products under the carefully controlled irradiation conditions such as energy of EB, packaging of medical devices, etc.

Table 1 Characteristics of radiation sterilization

Non-toxicity

Less Recontamination

Low Temp. Capability

Easy Control

Low Energy Process

Table 2 Comparison of EB and Co-60

	Electron Beams	Co-60 γ Rays
Energy	Variable ～ 12 MeV	1.33 MeV + 1.17 MeV
Energy Efficiency	High(～ 85 %)	Low(～ 30 %)
Penetrating Power	Low(～ 0.35 g/cm²/MeV)	High(～ 12 g/cm²)
Power	Large(100 - 150 kW/Unit)	Small(1 Mci = ca 15 kW)
Others	Shut-off of Power Source	Continuous Irradiation Periodic Replenishment of Source

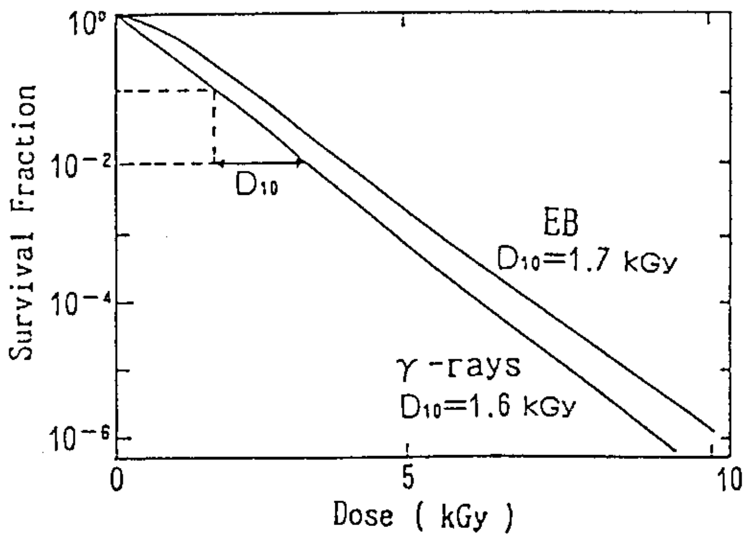

Fig. 1 Survival curves of B.pumilus E601 spores

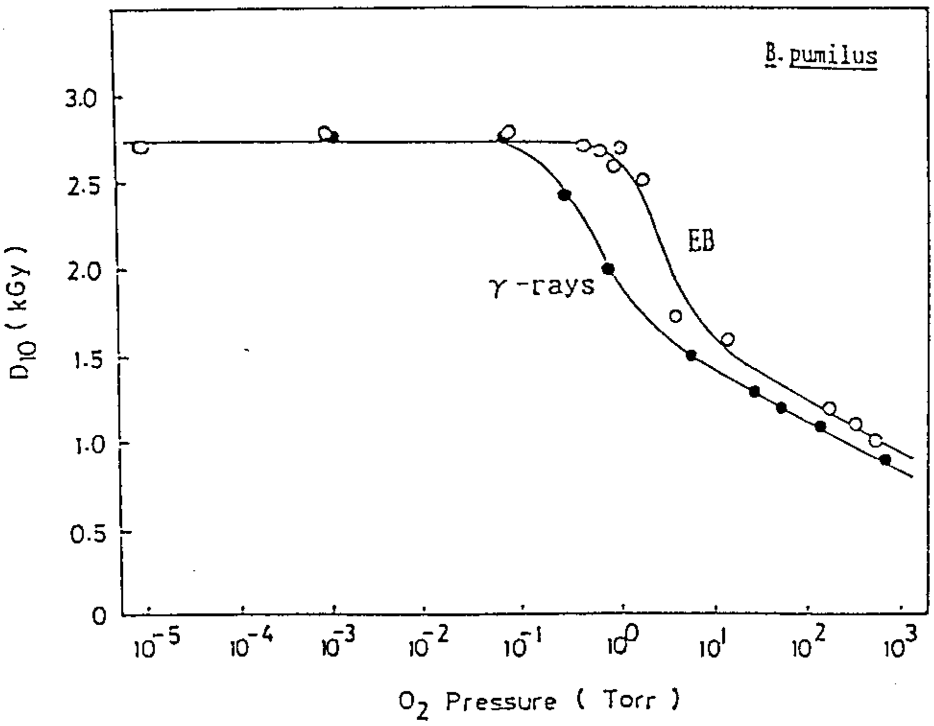

Fig. 2 Relationship between D_{10} value and oxygen pressure

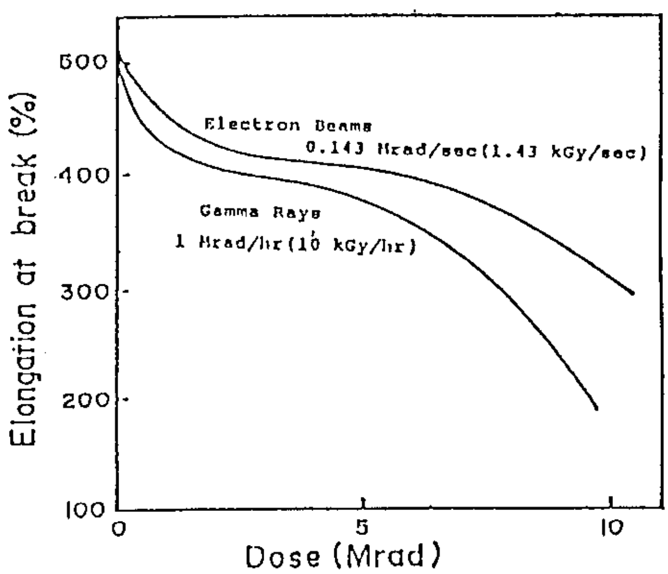

Fig. 3 Relationship between elongation at break and irradiation dose for polypropylene (CPP)

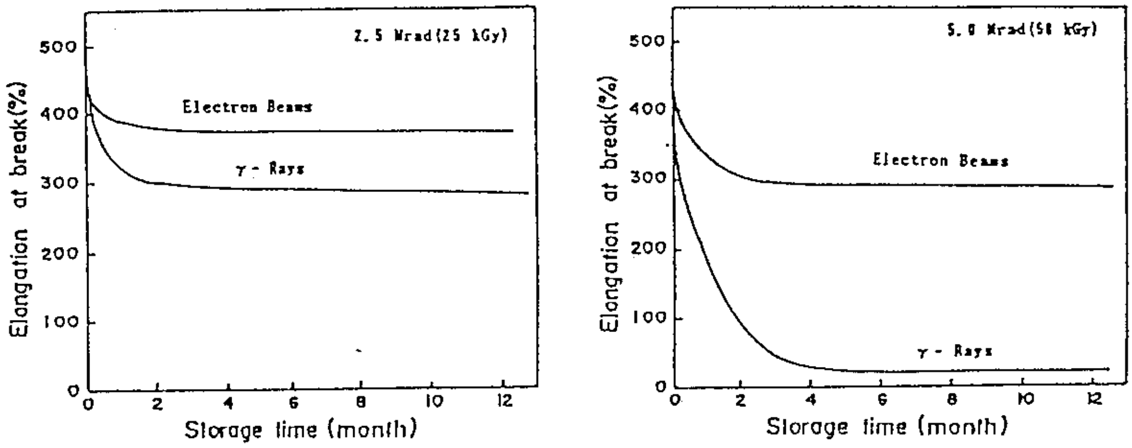

Fig. 4 Relationship between elongation at break and storage time for irradiated polypropylene (CPP)

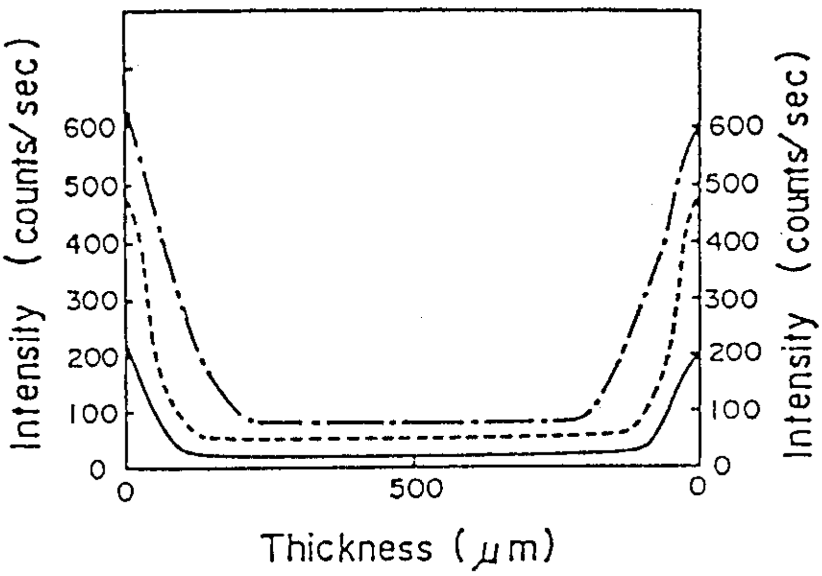

Fig. 5 Profile of the oxidative layer in the cross-section of irradiated polypropylene film

Irradiation Dose : 5 Mrad(50 kGy)

—·—·—	Gamma Rays,	0.2 Mrad/hr(2 kGy/hr)
------	Gamma Rays,	1.0 Mrad/hr(10 kGy/hr)
———	Electron Beams,	0.143 Mrad/sec(1.43 kGy/sec)

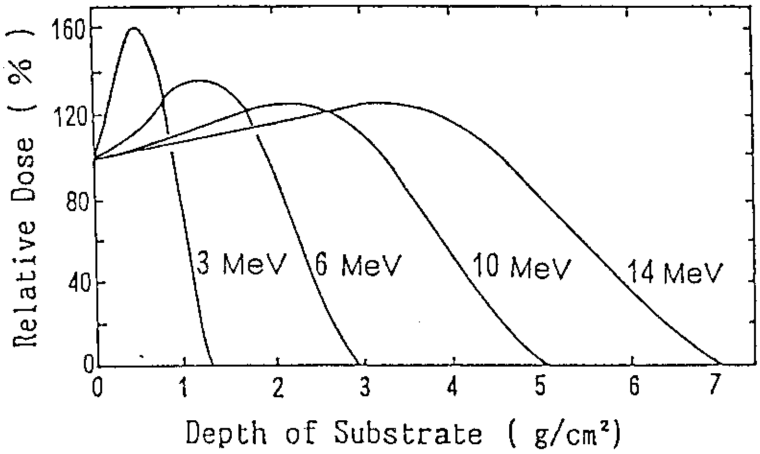

Fig. 6 Relationship between depth-dose distribution curves and energies of EB

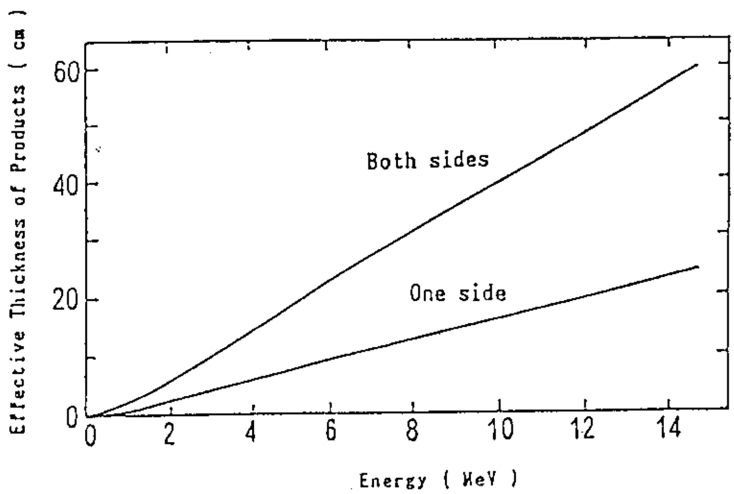

Fig. 7 Relationship between energy and effective thickness of the products (average density = 0.2)

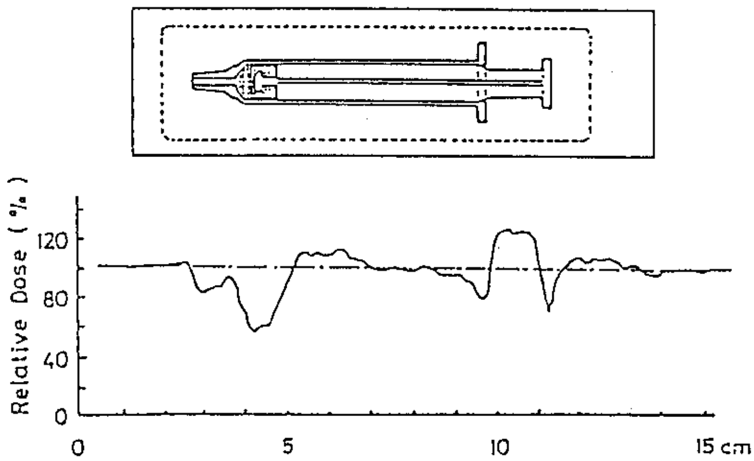

Fig. 8 Dose distribution for 3 ml disposal syringe

2.9 Using Irradiation for Preservation of Foods and Agricultural Commodities in Malaysia

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1. Introduction

The National Agricultural Policy was formulated to draw guidelines for the development of Malaysian agriculture until the year 2000. The most important aspect of the policy is to encourage the agricultural sector to increase productivity in order to attain self-sufficiency and promote exports.

Increasing agricultural and food production will undoubtedly be accompanied by a need to upgrade quality and simultaneously reduce post-harvest losses. To this end, there is a greater appreciation in Malaysia of the importance of food preservation during handling, processing and storage. Current preservation methods emphasize improvements in handling, drying, chilling, freezing and use of chemicals. There is also an urgent need to explore new areas of food preservation such as irradiation techniques either as alternative or integral components of the existing method.

Even though food irradiation has been studied for more than a quarter of century in other countries, the technology was only introduced at a research level in Malaysia in 1974 when a Co-60, gamma-cell 220 (AECL) was installed at the National University of Malaysia. With the formation of the Nuclear Energy Unit, research in this field has expanded considerably. Presently, UTN has a semi-commercial Co-60 facility suitable for R&D in Food Irradiation. The commercial use of irradiation and marketing of treated agricultural and food products is still prohibited unless prior approval has been obtained from the Director-General of the Ministry of Health under Food Regulations 1985 (P.U (A) 473/85) Part X. Para 396 (1)(2)(3).

Various agricultural commodities and food items have been identified as potential products to be irradiated on a large scale basis. These are rice, black and white pepper, frozen shrimps, cocoa beans and fruits and vegetables.

The objective of this paper is to review briefly the potential for practical applications in Malaysia of food irradiation in the context of local post-harvest handling and storage methods for food and agricultural commodities. For the purpose of this paper, it is assumed that these food and agricultural commodities will have been approved and consumers will have accepted the process.

2. Irradiation of Foods and Agricultural Commodities

2.1 Rice

Rice constitutes 20% of the food consumed by the Malaysian population. The average total production of the rice between 1980-84 was approximately 2 mil mt per annum. Over the same period, an average of 300,000 mt per annum has been imported to meet the shortfall of the consumers' requirement. Malaysia is currently 85% self-sufficient[1]. Whether this level of self-sufficiency can be maintained remains to be seen, especially as the cost for producing rice in Malaysis is high. In actual fact, the government is supporting both paddy and rice prices which most of the time are higher than the world price.

At present, post-harvest losses in rice are estimated up to 25%[2]. During storage, insect infestation remains the major problem which causes both quantitative (loss in weight) and qualitative loss (loss in acceptabilty). The country therefore needs to find effective measures to circumvent infestation during handling and storage. Current disinfestation methods use chemicals, either as contact insecticides (malathion and lindane) or fumigants such as phosphines. These methods may be cheap but they have a number of limitations. Chemicals are time-consuming and labour-intensive to apply, have poor penetrability and leaves residues. Also, with frequent application, insect may develop resistance to chemicals. Other technology available and recently tested is the use of CO_2/air mixture in confined environment to suffocate insects.

Irradiation provides an alternative treatment to chemical disinfestation of rice during storage. Our studies have shown that a dose of 1 kGy provides rice with the same degree of protection against insects as chemical. However, the cooking quality of irradiated rice deteriorates at dose above 1 kGy[3].

Irradiation is more attractive for disinfestation of imported rice than it is for locally produced rice which is only stored for a short period i.e. up to 3 months, in the godowns before being retailed. In contrast, imported rice may be kept in godowns for up to 18 months[4].

Rice imported into Malaysia is unloaded between January and September at 12 ports. The highest volumes enter through Port Kelang (21% - 63,000 mt), Penang (14% - 42,000 mt) and Kuching (11% - 33,000 mt). Installtion of irradiators at these ports might be feasible.

The most important aspect that should be considered to ensure success of an irradiation plant is the infrastructure for handling rice. At present, rice is imported in either just sacks (100 kg) or in unlined woven polypropylene bags (50 kg). These materials provide no barrier to reinfestation, especially as the bags are manually handled and stored with the aid of hooks which tear the bags. These would need to be changed, perhaps by palletization and forklift handling and the introduction of insect-proof bags if irradiation is to be an effective and beneficial disinfestation treatment for rice. Introducing EBM may require the product to be bulk-handled hence changing the method of storing rice in the country.

2.2 Black and White Pepper

Pepper is one of the most important cash crop in Malaysia. It was estimated in 1982, 32,000 families were involved in the enterprise excluding market intermediaries like middlemen, wholesalers and exporters. Malaysia produces an average of 25,000 mt per annum of black and white pepper (1980-1984). However, in 1985, the production is expected to be 18,000 mt and maintained at this level until now. Usually, 95% of the production is exported. Stored pepper is easily infested by insects such as <u>Lasisoderma serricone</u> and <u>Stegobium panicerun</u>[5]. It is also susceptible to microbial contamination particularly from potentially toxigenic molds during long storage periods and transportation. Studies by Tropical Research Institute[6] revealed that 44% and 100% of Malaysian pepper samples analyzed exceeded the limit recommended by ICMSF for molds (10^4/g) and total bacterial counts (10^6/g), respectively. However, generally, there is no microbiological specification for export spices except for certain countries such as U.S.A. and Australia. If other countries follow their lead, the export of Malaysian of heavily contaminated spices may be adversely affected.

Presently, only a small proportion of spices are disinfested and decontaminated by chemical fumigation: methyl bromide and ethylene oxide. Pepper is being commercially irradiated in several countries at doses up to 30 kGy. Ultraviolet light treatment has also been suggested but is ineffective due to poor penetrability. Although heat (70°C) is used for drying, because of its adverse effect on volatile components of pepper, it is not considered as useful decontamination technique.

Investigation at the National University of Malaysia and the Nuclear Energy Unit's laboratories[5,7] at doses between 2 and 9 kGy showed that irradiation is very feasible for insect control and reducing microbial load in pepper during storage. No adverse effects on the volatile components responsible for pungency in pepper were noted.

Irradiation can play a considerable role in upgrading the quality of Malaysian pepper for export. To save transport costs, the best site for a service irradiator for this purpose would be at Kuching because almost 90% of total pepper tonnage is produced in Sarawak. A multipurpose irradiator at the port for treatment of pepper, other agricultural commodities and the imported grains may be viable. Pepper Marketing Board (PMB) which is responsible for regulation, licensing, grading, market promotion, etc., could assist with the setting up of an irradiation for treatment of spices.

Black and white pepper are currently packed in gunny sacks for export. Such packaging provides no barrier for reinfestation. An improved method of handling, packaging and storage should be introduced to ensure success of irradiation treatment for this commodity. Another limitation might be seasonal variation in storage tonnage. Usually, sacks are stored for a maximum of 2 weeks before shipping.

Irradiation should be able to increase Malaysian export earnings by 'adding value' to our products. We are currently exporting 68% of pepper to Singapore for reprocessing and repackaging before arrival in consuming countries. Improving our infrastructure and processing of pepper at home should provide high revenue and offer an opportunity for direct exporting.

2.3 Frozen Shrimps

Malaysia is amongst the world's ten largest exporters of frozen shrimps. Although the quantity of exports is declining in recent years, the earnings through export of this product are still substantial. From 1980-83, the average export tonnage of Peninsular Malaysia was estimated approximately 5,228 mt per annum valued at M$58 million. Recently, export tonnage has been on the decline and only few numbers of factories are still in operation. Currently, there are less than 5 factories all over the country actively exporting frozen cooked shrimps mainly to Australia, Belgium, the Nethrland, Sweden and the U.S.A. The products are normally packed in 0.5-2.0 kg lots, quick frozen at -30 degree C and stored below -20 degree C for several weeks to 3 months before export.

One of the main problems with the Malaysian frozen shrimps is the failure of the export consignments to meet stringent quality control, especially microbiological specification of the importing countries. Rejection and detention of Malaysian frozen shrimps due to non-compliance with microbiological standards has become a regular feature. Although quality standards have improved since then, a few consignments of Malaysian frozen shrimps were rejected at Australian and New Zealand ports due to the presence of Salmonella and high level S. aureus. There are also regular reports of detention of Malaysian frozen shrimps by the USFDA because of decomposition, short weight and labelling. Many of the shipments were either destroyed, returned to exporters or directed to other destinations. The rejection of export consignments by importing countries resulted in substantial losses to both exporters and importers But damages go far beyond that. The credibility of all Malaysian frozen shrimps processor has been questioned. The usual safeguards, such as insurance against rejection losses have been withdrawn from the majority of Malaysian frozen shrimps exporters or only made available at extremely high premium rates. Therefore, rejection not only means a substantial loss in the form of earning but also loss of confidence on our products by the importing countries. Irradiation may assist in upgrading quality through elimination of pathogenic microorganisms.

2.4 Cocoa

Cocoa is the third most important agricultural commodities after palm oil and rubber. Between 1980-89, the average annual production of cocoa was approximately 90,000-100,000 mt, of which 86% was exported as cocoa beans.

The main post-harvest problem, though not critical, is insect infestation. Fungal growth becomes critical in prolonged storage if the moisture content of beans exceeds 8%. At present, fumigation using chemicals such as methyl bromide and prosphine, is used for disinfestation and reduction of microbial load during storage.

Irradiation up to 1 kGy is sufficient to disinfest cocoa beans during storage[10]. Irradiation with doses up to 5 kGy has been reported not to cause reduction of sugar or total amino acid. It should be pointed out that cocoa beans contain approximately 56% fats[11]. High irradiation doses may accelerate the onset of rancidity in stored beans. Irradiation of defatted cocoa powder should be considered to overcome the problem of rancidity and 'added value' to cocoa products for export. Special attention should be given to the infrastructure and marketing system of our cocoa beans before irradiation can be expected to achieve desirable results. FAMA reported that in 1986 there were 42 exporters, each handling more than 600 mt of cocoa products per annum. Exporters are usually associated with large trading houses from importing countries or a few locally based firms. They somehow have to be persuaded or convinced of the value of using irradiation to ensure the economic feasibility of setting up irradiation plant. As with other primary commodities, most is packed in jute sacks for export. This handling system would need changing to accommodate irradiation.

2.5 Fruits and Vegetables

Very limited data is available on the efficiency of irradiation for disinfestation of local fruits and vegetables. The presence of fruit fly has been a cause of concern for local producers, consumers and exporters. Existing conventional techniques for disinfestation are limited to problems of lethality and chemical residues. There is an urgent need to develop better and safer techniques. The effectiveness of irradiation for disinfestation of fruits for quarantine treatments has been demonstrated elsewhere[12~15]. Studies with local muskmelon showed irradiation can extend the shelf-life of fruit up to 3 days longer at room temperature with doses up to 5 kGy[2].

APPLICATION OF ELECTRON BEAM FOR IRRADIATION OF FOODS

Limited data are available on the application of electron beam machine (EBM) for irradiation of food in Malaysia. Electron beam irradiation of deboned chicken and grain in France and Russia have been cited in literatures[16]. Under the RCA programme, NEU compared the economic and commercial feasibilities of using gamma and electron particles for irradiation of pepper[17]. There is no cost advantage using one or the other if the throughput of pepper is less than 10,000 mt/year. However, above 10,000 mt, electron beam utilization is slightly cheaper compared to gamma irradiation (0.1 vs 0.15 m$/kg).

Other potential utilization of EBM in food irradiation is for disinfection and disinfestation of grains, frozen shrimps and cocoa beans.

3. Conclusion

From the proceeding overview, the following conclusions can be drawn:

a) Irradiation is a practical alternative to the present methods of preservation used in the country for disinfestation and decontamination of agricultural products and foods.

b) Irradiation can be installed as an integral part of the existing food processing system or as a service irradiator at the ports entry/embarkation. The latter should be feasible to cater for imported products such as grains, animal feeds, etc. and export commodities such as cocoa, frozen shrimps and pepper. Continuous flow of these products (import/export) would increase the efficiency of utilization of irradiator by reducing downtime.

c) Irradiation can only give satisfactory results in the present system provided there are some modification/changes in the methods of handling and storage of foods and agricultural commodities. Good handling and packaging practices to prevent reinfestation and recontamination pre- and post-irradiation will ensure high quality products for both local consumption and export.

d) EBM application in food industry may have potential for disinfection and disinfestation of pepper, grains/rice, cocoa beans and frozen shrimps. Due to the nature of EBM design, it may lack flexibility as compared to Co-60 for a wide range of food products.

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2.10 Application of Radiation to Agro-resources

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1. Introduction

A huge amount of agricultural resources such as cellulose, starches are discarded or under-utilized. Upgrading of these wastes into useful end-products can be expected not only to recycle the agro-resources but also to reduce pollution. Radiation treatment is presently being utilized for sterilization of medical products and preservation of foods in bulks. One of the objectives of irradiation on biological materials is disinfection of microorganisms and another is to improve the physicochemical properties. We have been studying the radiation processing on fermentation of cellulosic wastes, sewage sludge, starches, and recovery of proteins from wastewater of potato starch factory or slaughter-house (Fig. 1).

This report describes the conversion of oil palm wastes into animal feeds by gamma irradiation, and the composting of sewage sludge by EB irradiation. The determination of molecular size of enzymes in situ by radiation inactivation method is also described for the basic study of EB on biological materials.

2. Upgrading of Oil Palm Wastes to Animal Feeds

The cooperative research work between UTN and JAERI on upgrading of oil palm wastes was started in 1987. Empty fruit bunch (EFB) and palm press fiber (PPF) are major cellulosic solid wastes of the palm oil industry. At present these by-products are mainly burned and incinerated causing a considerable amount of smoke and pollution. Using gamma-irradiation, we have been investigating the upgrading of oil palm wastes (mainly EFB) to animal feeds by fermentation. The process shown in Fig. 2 is as follows: pasteurization of fermentation media using oil palm wastes by irradiation, inoculation of useful microorganisms, and subsequent microbial digestion of cellulosic materials as well as production of proteins.

2.1 Decontamination of Microorganisms by Irradiation

EFB samples collected from various mills were highly contaminated with bacteria and fungi. Figure 3 shows the decrease in numbers of microorganisms in EFB after irradiation. Bacteria in EFB was radio-resistant, and the dose required for elimination below the detectable level was more than 15 kGy. Fungi were eliminated below a detectable level by irradiation of 5 - 6 kGy. These results suggest that an irradiation dose of 5 to 10 kGy is sufficient for pasteurization of EFB since the decontamination of fungi is important for fermentation using useful fungi, the pH requirement of which is lower than the optimum pH for bacterial growth.

2.2 Effect of Irradiation on Chemical Components

Table 1 shows the change in components of EFB by irradiation. Alcohol-benzene extracts and hot-water solubles of EFB were slightly increased by irradiation up to 50 kGy whereas holocellulose and alpha-cellulose were slightly decreased at a high dose of 50 kGy and lignin content did not change. There is little effect of irradiation on the amount of alcohol-benzene extract and lignin. From these results it can be concluded that some slight degree of degradation in the chemical components of EFB has occurred by irradiation up to 50 kGy but the overall effects were not significant. These results show that the irradiation by 5 - 10 kGy on EFB is applicable for the pasteurization of fermentation media without any significant change in components.

2.3 Fermentation of EFB by Useful Fungi

Table 2 shows the degradation of crude fiber and production of crud protein in EFB fermented by various fungi. Among these fungi Coprinus cinereus was the most effective, and the crude fiber was decreased from 50% to 20% and the crude protein was increased from 2.6% to 13% by the fermentation at 30°C for 1 month. The result suggests that the radiation processing of EFB is effective for production of ruminant animal feeds by fermentation.

3. Composting of Sewage Sludge

Disposal of sewage sludge has been one of the most serious problems in Japan. Total amount of sludge is about 2.2 million ton/year in dehydrated form. It is known that land application of sludge benefits plant growth, crop production and soil conditioning. Electron-beam disinfection of sewage sludge cake and efficient composting of the irradiated sludge has been studied to develop a new treatment system of sewage sludge (Fig. 4). In this system, sludge cake is disinfected by electron beam irradiation and mixed with bulking agent to make the sludge aerobic. Seed compost is also mixed to start fermentation. Fermentation temperature is controlled from 40 to 50°C. After 2 or 3 days, compost is obtained.

3.1 Electron-beam Disinfection and Composting

Figure 5 shows the surviving fraction of total bacteria in sludge irradiated by 1 and 2 MeV EB at various sludge thickness. To kill bacteria effectively, the thickness of sludge layer must be less than 6 to 7 mm for accelerating voltage of 2 MeV and 3 mm for 1 MeV. Figure 6 shows the surviving curves of total bacteria and coliforms at various beam energies and dose rates. For the disinfection of microorganisms, no effects of dose rate and energy change were found in the ranges from 20 kGy/hr to 65 MGy/hr and from 0.5 to 2.0 MeV when the film was thin enough to allow electron beam penetration. Similar results were obtained with gamma irradiation.

It takes less than 0.2 second to eliminate coliforms by EB at dose rate of 10 kGy/sec whereas more than 20 days are required in heat disinfection of conventional composting (Fig. 7). As the optimum condition is available in irradiation-composting, the fermentation rate is very high and the composting time is about 1/4 or 1/3 in conventional composting.

3.2 Capital Cost Estimation

A pilot plant with treatment capacity of 500 kg sludge/batch was built and the capital cost was calculated. Figure 8 shows the capital costs for various treatment capacity. When the treatment capacity is larger than 50 ton/day, capital cost of irradiation-composting plant is slightly less than conventional composting plant. Total capital cost of the irradiation-composting plant is lower especially for large treatment plant because the scale of fermentor is 3 to 4 times smaller.

4. Molecular Size Analysis of Bioactive Substances

The molecular sizes of various bioactive substances can be measured by the radiation inactivation method. The high energy electron beam (10 MeV) and ^{60}Co gamma-ray are mainly used for radiation inactivation method. When the practical electron accelerator (3 MeV) is used for the method, the problems such as penetration and increasing of temperature come out. However, using the plate type glass ampoules (glass thickness 1±0.1 mm) for the irradiation vessels, relatively uniform dose distribution was observed and the temperature increased only from 21°C to 35°C by 0.77 mA, 100 pass (100 kGy). Using above condition for electron beam irradiation, the molecular size of three enzymes were calculated from D_{37} doses (Fig. 9). The molecular sizes obtained by electron beam and gamma-ray were 14,000 and 17,000 for lysozyme, both 33,000 for pepsin, and 191,000 and 164,000 for yeast alcohol dehydrogenase (Table 3). These values mostly agreed with the reported molecular weight, suggesting that the 3 MeV electron beam can also be used for the radiation inactivation under limited conditions. In the case of inactivation for small size enzymes such as lysozyme, the long irradiation time of 50 hr at 10 kGy/hr by gamma-ray whereas only a few minutes is enough by EB. Therefore, EB is especially useful for the radiation inactivation analysis of bioactive substances having small molecular size.

5. Conclusion

Radiation treatment is applicable for upgrading of agro-resources especially for disinfection of fermentation media. The penetration powe is much lower than that of gamma-ray but the dose rate is about 1000 - 20,000 times higher. Therefore, it can be concluded that EB is practically useful for the treatment of a large amount of oil palm wastes and sewage sludge under the controlled irradiation conditions. It could be expected to develop the utilization of EB on many kinds of agro-resources.

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Table 1 Change in chemical components of EFB by irradiation

Chemical component	Dose (kGy)			
	Unirradiated	10	25	50
Alcohol-benzene extracts	1.8	1.6	2.5	2.2
Hot water solubles	16.4	18.5	17.5	19.6
Holocellulose	60.3	58.1	59.0	56.4
(Alpha-cellulose	40.0	37.4	33.8	31.3)
Lignin	21.5	21.8	21.0	21.8

Values are means of duplicates and expressed as weight percentage based on moisture-free sample.

Table 2 Contents of crude fiber and crude protein in EFB fermented by various fungi

Fungi	Crude fiber (%)	Crude protein (%)
-	50.4	2.6
C. cinereus	20.1	13.1
P. flavellatus	45.0	4.3
A. niger	44.8	7.8
T. koningi	36.4	10.9

Table 3 Molecular size of enzymes obtained by radiation inactivation

	Reported MW	Obtained Mr	
		γ	e^-
Lysozyme	14,300	14,000	17,000
Pepsin	34,000	33,000	33,000
Yeast Alcohol Dehydrogenase	160,000	191,000	164,000

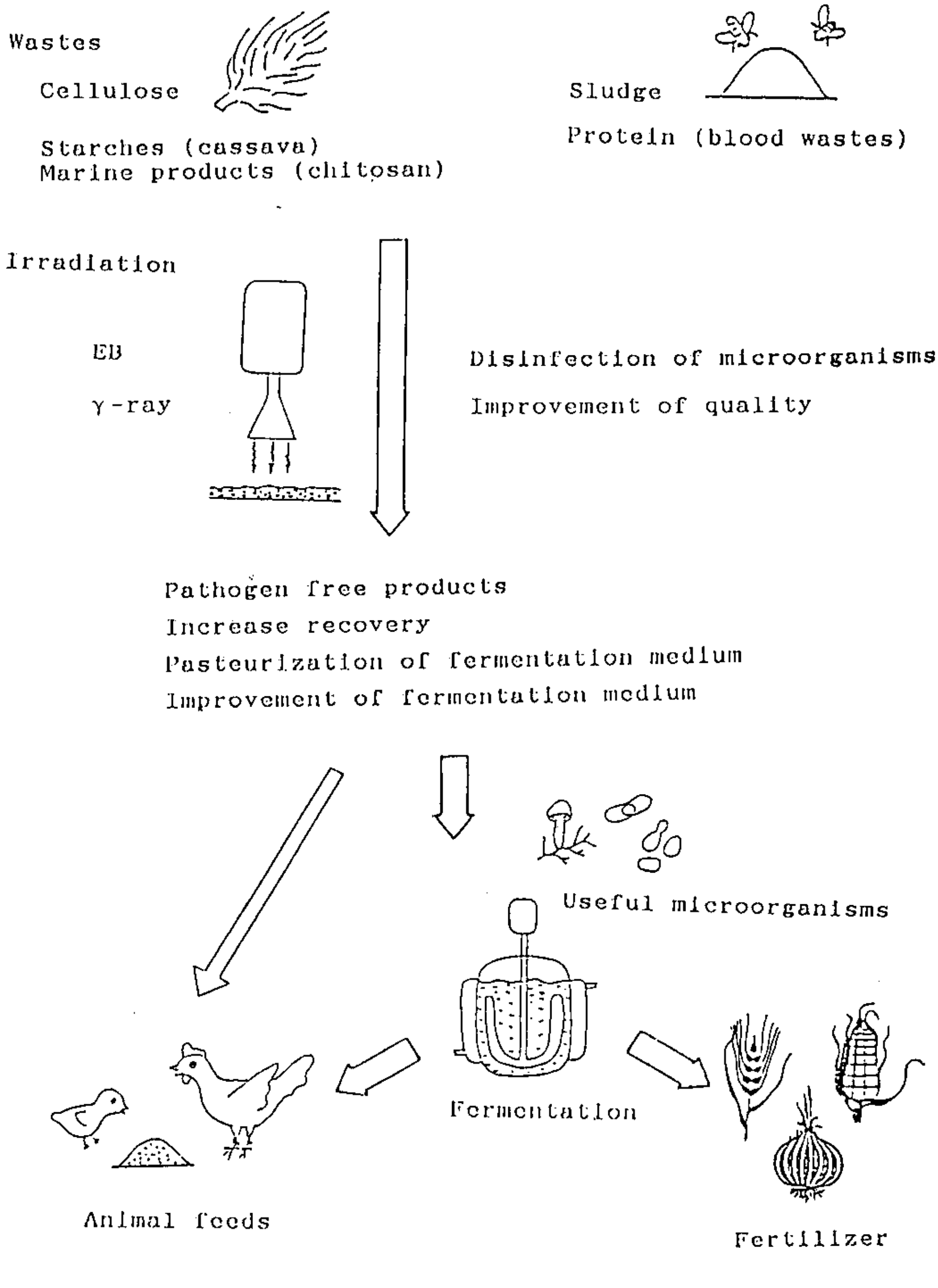

Fig. 1 Utilization of agricultural wastes by radiation

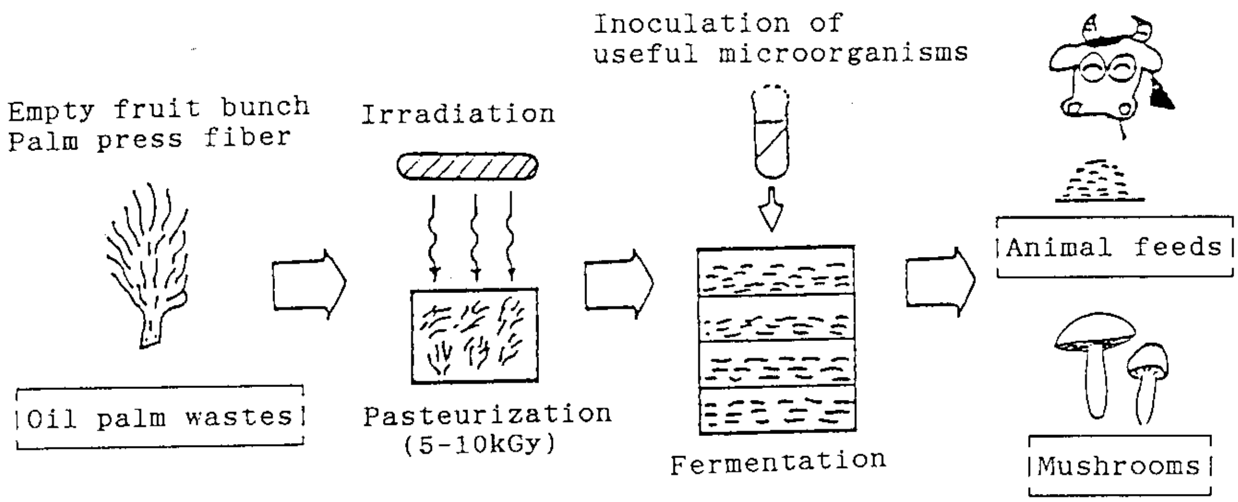

Fig. 2 Upgrading of oil palm wastes by irradiation

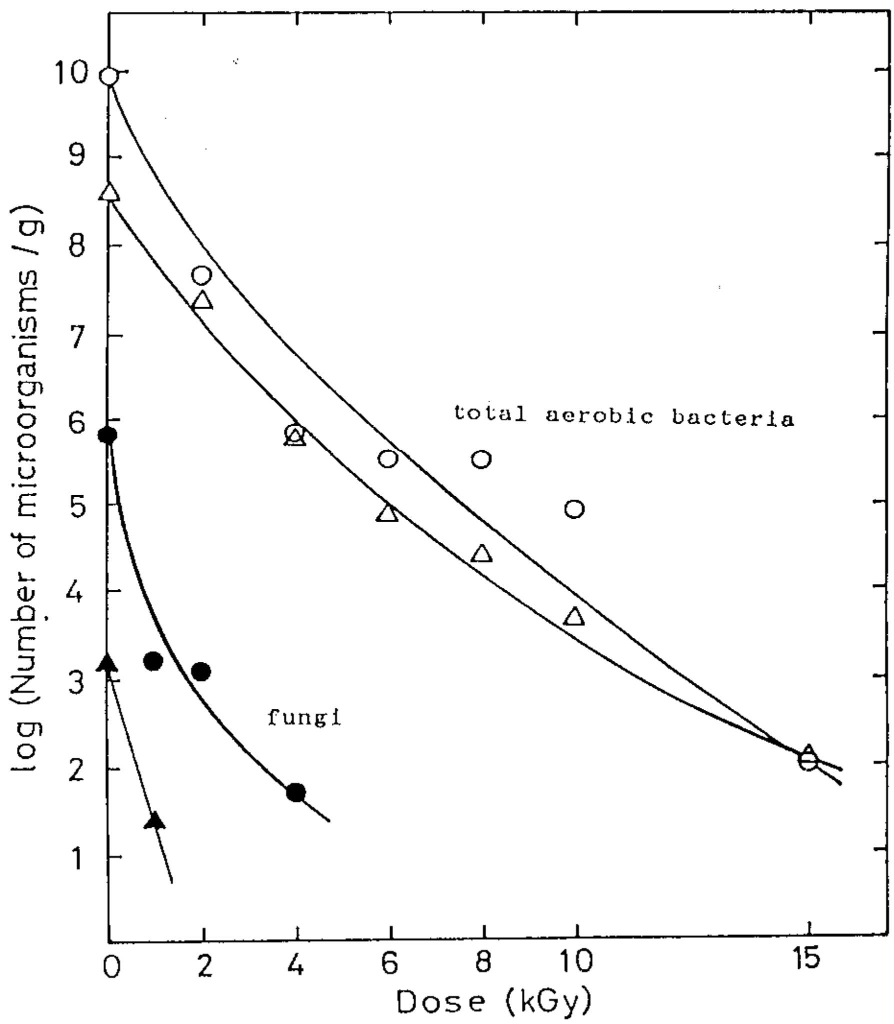

Fig. 3 Decrease in number of microorganisms
contaminating in EFB by irradiation

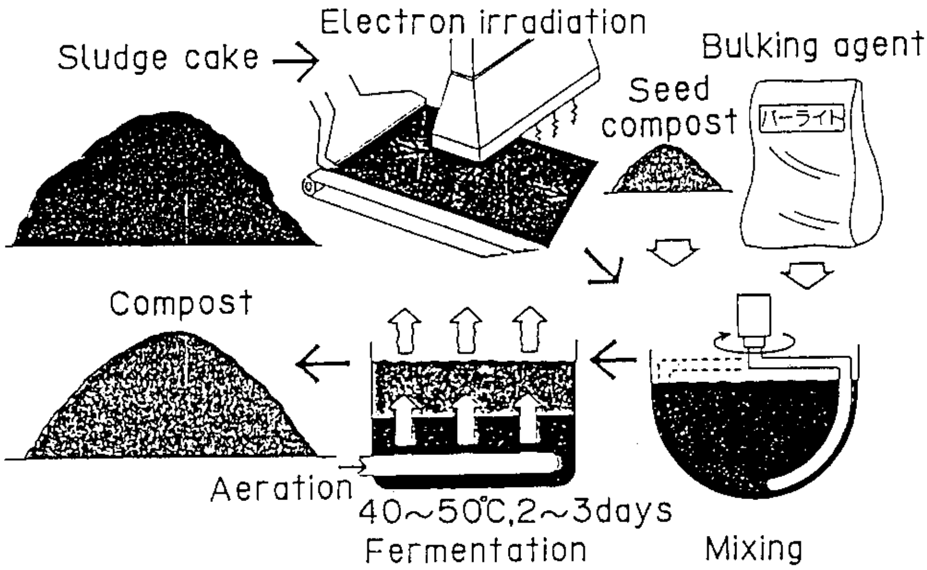

Fig. 4 Irradiation-composting system of swage sludge

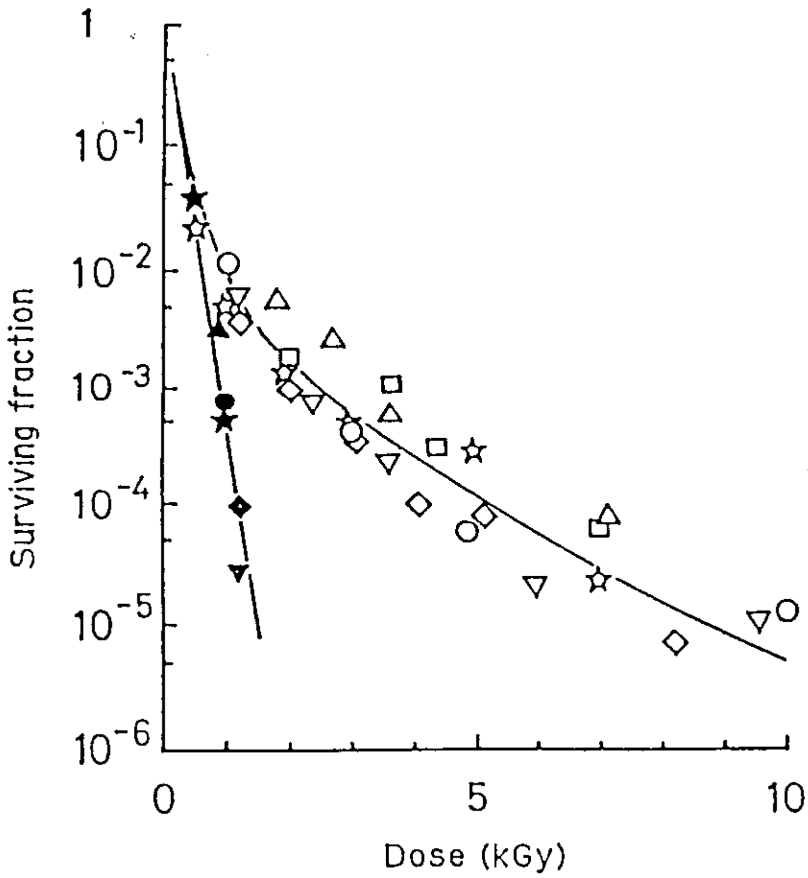

Fig. 5 Surviving fraction of bacteria vs. thickness of swage sludge cake

Energy and dose rate (MeV, MGy/h): 2, 0.02 (○), 2, 18 (△), 2, 36 (◇), 2, 65 (□), 0.5, 25 (▽). Sludge thickness: 1 mm. The result of γ-ray irradiation is shown by ☆. Open symbols represent total bacteria, and solid ones total coliforms.

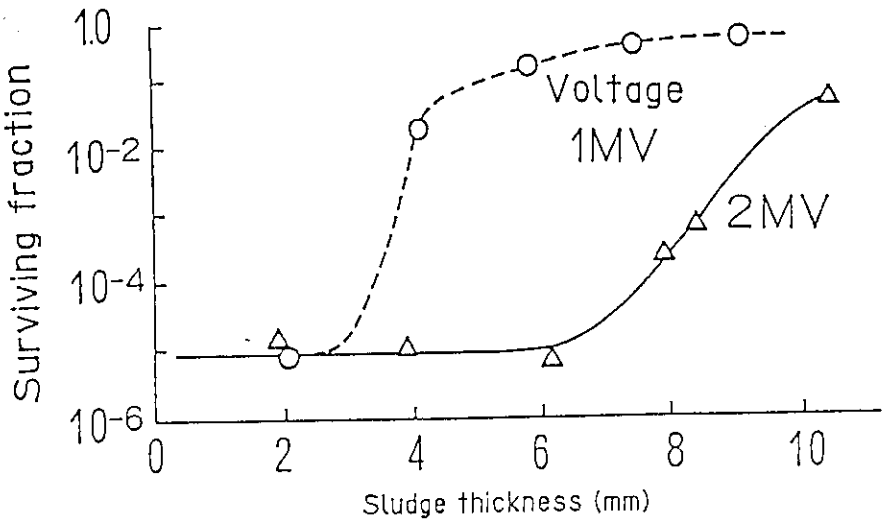

Fig. 6 Surviving curves for total bacteria and coliforms in swage sludge

Surface dose: 10 kGy, Dose rate: 10 kGy/sec.

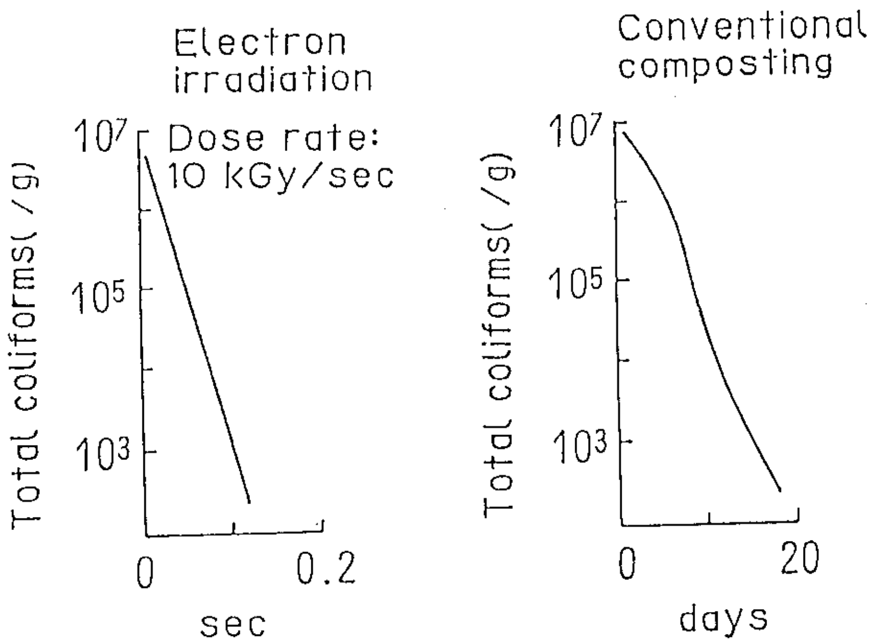

Fig. 7 Disinfection of coliforms contaminating in swage sludge by EB irradiation or heat of conventional composting

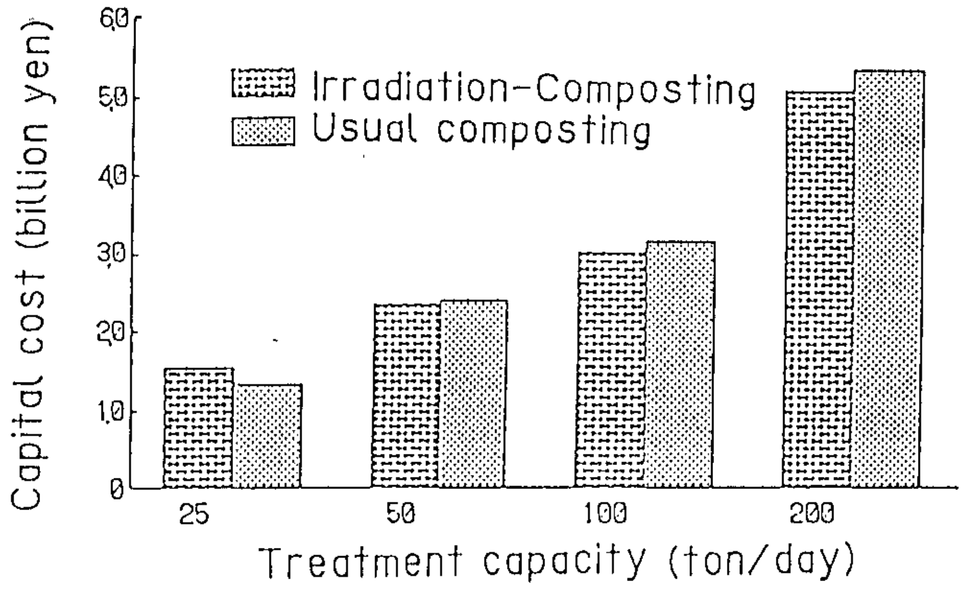

Fig. 8 Comparison of the capital costs for irradiation-composting and usual composting

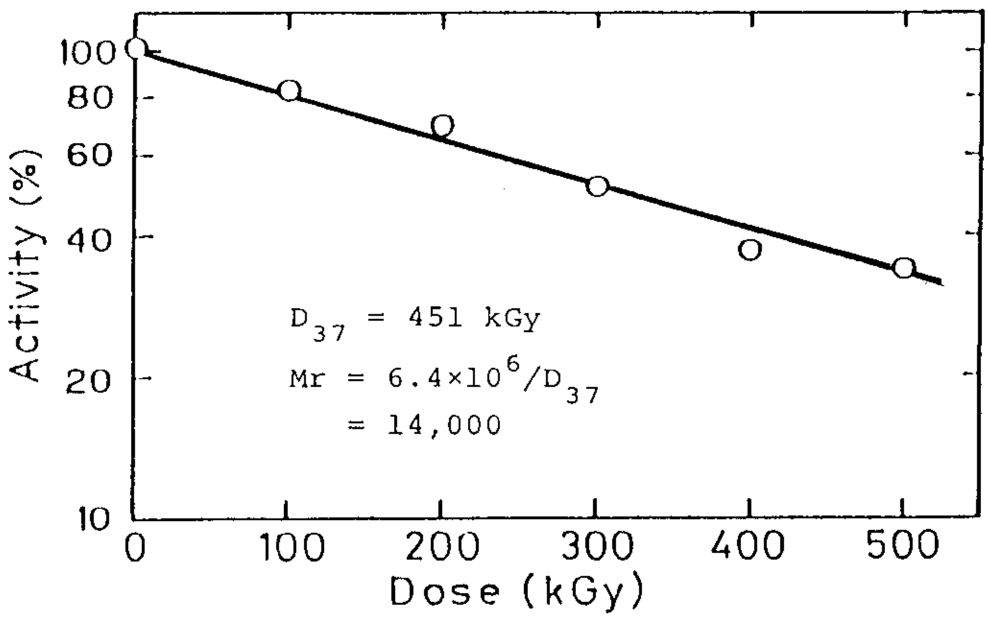

Fig. 9 Radiation inactivation of lysozyme

2.11 Prospect of Commercialization of Food Irradiation in Indonesia

NAZLY HILMY

Centre for the Application of Isotopes and Radiation, BATAN

1. Introduction

As a tropical country, Indonesia has high ambient temperatures and humidity which make food conductive to spoilage. Although production of some important food crops from 1986-1988 increase every year as shown in Table 1, the level of postharvest losses of the crops are also high, i.e up to 20% per annum[1~3]. According to FREDERICKS[4], the postharvest losses in ASEAN countries, i.e. Indonesia, Thailand, The Philippine, Singapore, Malaysia and Brunei Darussalam was 30% for grains, 20-40% for fruits and vegetables and 50% for fish. Those losses were caused mostly by lack of corresponding technological improvements in preservation, processing and distribution system.

Export of Indonesian typical tropical commodities from 1986-1988 that might be considered for international trade after irradiation, such as frozen shrimps, fish, spices, manioc, coffee beans, and cocoa beans also increased as shown in Table 2[2], but sometimes, a part of the commodities was detained by the importing countries, since the quality did not meet the requirements in the importing country. According to OLSEN[5], the share of developing countries in supplying the world market for those typical tropical commodities is high, i.e. 50-90%. Since the application of fumigant ethylene dibromide (EDB) and ethylene oxyde (ETO) has been banned by several countries the development of new technologies, such as radiation technology is needed. Limited volume of spices and herbal tea have been irradiated for commercial purpose in Indonesia since 1987.

2. Spices and Herbal Tea

At present there are 15 countries including Indonesia which have approved the application of radiation technology on spices and herbal tea to eliminate pathogenic microbes as well as to reduce the number of microbial content[6]. Indonesia has approved the food irradiation technology for commercial purposes since December 1987. According to EISS[7], about 20% of total spices and herbs used in Europe in 1985, and about

25% in 1986 has been irradiated, but only about 1% of spices used in USA has been irradiated.

The commercial application of radiation technology on spices and herbal tea or medicinal herbs for local consumption was increasing in Indonesia, i.e. about 20 m^3 in 1988 and 90 m^3 in 1989. The volume could not be increased due to the limited capacity of the existing irradiation facility.

Spices are one of the important Indonesian export commodities where radiation technology can be used. Export of Indonesian spices which mostly consisted of white pepper, black pepper, cassia vera, nutmeg, ginger and mace from 1986 to 1988 can be seen in table 3. Export of Indonesian black pepper, white pepper and nutmeg to countries that have accepted irradiated spices can be seen at Table 4, 5 and 6. It is hoped that in the future, all important countries will accept irradiated spices from Indonesia.

3. Availability of Irradiation Facility

At present there are two irradiation facilities available at CAIR which can be used to irradiate food, i.e. a panoramic batch type irradiator and latex irradiator. The panoramic plant is being modified since 1989 and the modification will be finished by April 1990. The radiation source of the plant will be increased up to 100 kCi. About 10^3 m of materials with density of 0.3 and doses up to 10 kGy can be irradiated each day. The source of latex irradiator will also be increased up to 150 kCi by 1991. In August 1990, the construction of a commercial irradiator located in Jakarta will be started and the construction will be finished by September 1991. The initial source loading will be 400 kCi and the source can be increased up to 2 MCi. This irradiator belongs to a national private company.

4. Information Transfer

Efforts to facilitate public acceptance and successful commercialization of food irradiation have been done continuously by disseminating all informations available or needed through mass media or seminars. All developments gained in this field are presented in regular seminar organized by the National Atomic Energy Agency at the Centre for the Applicaton of Isotopes and Radiation (CAIR) Jakarta in December almost every year since 1985. Such a Seminar or Symposium was held also in December 1989.

In February 1989, an exhibition of food preservation was held at The National Cooordination Meeting on Research and Technology in Jakarta. The meeting was attended mostly by private companies as well as government institutions. The aim of the meeting was to transfer the technology from government institution to private company.

Another important and very successful seminar was held in Jakarta on 29-30 May 1989, organized by the Indonesian Packaging Federation and Indonesian Packaging Institute in collaboration with National Atomic Energy Agency, and supported by the Departments of Industry, Trade, and Health. Topic of the Seminar was: "The Role of Packaging in Radiation Technology Application for supporting Non-Oil Export", in which food irradiation application was also discussed. The seminar was attended by about 150 participants mostly from private companies, and from research institutions, and government agencies concerned.

The government of Indonesia is very grateful to the IAEA for its support in this seminar by providing two expert speakers, i.e. Dr. G.G. Giddings from Isomedix Inc. USA, and Dr. J.G. Leemhorst from Gammaster B.V. The Netherlands. Their excellent presentations, as well as discussions concerning their practical experiences in operating commercial irradiator for giving services, including services in food irradiation are very valuable for promoting irradiation technology applications in Indonesia.

An exhibition and paper presentation on Future Prospect and Present Status of Rad. Technology in Indonesia was also held at Nat. Research and Technology Exhibition 1990 in Jakarta on 12 - 15 February 1990.

To facilitate continuous mutual communication concerning various aspects of radiation technology which has been started during the seminar, it was recommended to set up a "Communication Forum for Radiation Technology Application" in Indonesia. The establishment of this forum is now in process. This forum is intended for dialog and communication forum for discussing all problems related to either technical or non-technical aspects of radiation technology by all parties concerned or interested in this field. The secretariat at the Forum will be at the office of the Indonesian Chamber of Commerce and Industry, Jakarta[8].

5. Barriers and Constraints

Labelling, consumer acceptance and provocation against irradiated food by Indonesian Consumer Association are the main problems in application of food irradiation technology in trade. The same problems were also mentioned by LEEMHORST[9]. In 1989 there were 12 articles in daily papers that were against food irradiation as compared to 9 articles that accepted it.

Another important barrier and constraints on application of food irradiation technology in trade are the economical problems, and irradiation assurance.

6. Conclusion

Future prospect of commercialization of food irradiation depends on consumer acceptance, irradiation assurance, and economic feasibility of the process.

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Table 1 Total production of Indonesia crops 1986 - 1988 (1000 ton)

Crops	1986	1987	1988
Rice	27.014	27.253	28.403
Maize	5.920	5.155	6.806
Cassava	13.312	14.356	15.280
Soy beans	1.227	1.161	1.254
Peanuts	642	533	565

Source : The National Logistic Agency

Table 2 Exports of Indonesia by commodities 1986 - 1988 (ton)

Commodities	1986	1987	1988
Shrimps	1.968	2.972	2.811
Manioc	204.968	4.514.338	583.913
Ground nuts	1.455	1.602	1.960
Cocoa beans	33.170	37.228	57.357
Potatoes	21.872	34.289	57.045
Coffee beans	296.868	283.573	295.880

Source : Indonesia Central Bureau of Statistics

Table 3 Export of Indonesia spices (ton)

Commodity	1985	1986	1987	1988
White pepper	12.120	16.265	19.599	21.893
Black pepper	14.081	13.300	10.394	19.715
Cassia vera	17.235	21.749	15.153	14.181
Nutmeg	6.120	4.734	6.560	4.097
Mace	1.373	1.161	1.061	1.054
Ginger	11.176	16.604	27.260	31.115
Chillies	146	37	26	28
Vanilla	175	298	411	507
Cloves	60	724	761	2.567
Cordamon	514	727	1.249	2.200
Bay leaves	-	-	3	16
Turmaric	251	129	389	79
Other	259	210	398	789
Total	63.515	75.943	83.268	98.189

Source : Indonesia Central Bureau of Statistics

Table 4 Export of Indonesia black pepper to countries where spices irradiation has been legalized (ton)

Country	1986	1987	1988
U.S.A.	6.874	5.591	10.938
People.Rep.of China	-	5	70
Canada	10	10	160
Netherlands	30	227	235
Belgia & Luxemburg	10	-	-
Hungary	277	646	744
France	-	-	25

Source : Indonesia Central Bureau of Statistics

Table 5 Export of Indonesia white pepper to countries where spices irradiation has been legalized (ton)

Country	1986	1987	1988
U.S.A.	3.705	5.191	5.934
Canada	65	641	892
Netherlands	4.283	6.490	5.249
Belgia & Luxemburg	240	90	275
France	97	90	60
Hungary	455	290	855
Peop. Rep. of China	-	-	50

Source : Indonesia Central Bureau of Statistics

Table 6 Export of Indonesia nutmeg to countries where spices irradiation has been legalized (ton)

Country	1986	1987	1988
U.S.A.	263	604	704
Netherlands	1.892	3.134	1.351
France	540	441	444
Belgia & Lux	265	382	440

Source : Indonesia Central Bureau of Statistics

3. CLOSING

3.1 Recommendation Adopted at Panel Discussion in Indonesia

Recommendation Adopted at
Panel Discussion in Indonesia

Chairman: Mrs. NAZLY HILMY

Panelists:	Dr. Sueo MACHI	(JAERI)
	Dr. Dipo ALAM	(LIPI)
	Dr. Moh. SOLICHIN	(Kimia Farma)
	Mr. D.K. KARYANA	(Kabelindo)
	Mr. D. GUSTAM	(Sterilindo)
	Dr. Mirzan T. RAZZAK	(BATAN)

The following recommendations were adopted at the end of the panel discussions.

* There is a need for more interactions between industrial sectors and National Atomic Energy Agency.
* There is a need to establish and maintain cooperations between Japan's industrial society and Indonesia's industrial society, particularly in the field of radiation technology.
* There is an urgent need to provide a perfect education to the public about the importance of Radiation Technology as a part of the contribution of atomic energy for human prosperity.
* There is a need for conducting seminar, symposium and workshop at regular intervals.

3.2 Closing Remarks

Dr. Sueo MACHI

Director General,
Takasaki Radiation Chemistry Research Establishment, JAERI

Dr. Nazir Abdullah DDG-BATAN,

Dr. Iyos Subri DDG-BATAN,

Mrs. Hilmy,

Ladies and Gentlemen,

First of all, I would thank you very much for your participation to this workshop. I hope that you got useful information through the presentation and discussions.

As you understand, electron beam processing is very useful and unique technology to produce materials and component with excellent properties.

Some industrial companies even in Japan are quite conservative and reluctant to use irradiation technology due to a simple fear for radiation. Radiation, now can be controlled very well by proper shielding and radiation protection management.

Indonesia has lots of natural resources, so that to add value to resources by modern technology would be most important. I believe radiation is one of very important and useful technologies for this purpose.

In near future, I hope Electron Beam Machine (EBM) will be used in this country's industry.

Closing this workshop, I would express our sincere appreciation to BATAN for very nice hospitality and arrangement given to us. So that the meeting was very successful.

Thank you.

S. Machi

SUPPLEMENT

1. Agenda: Scientific Talks on Utilization of Electron Beam Machine

17th July 1990

at UTN, Kompleks PUSPATI, Bangi

Jointly Organized by
Japan Atomic Energy Research Institute (JAERI)
Japan Atomic Industrial Forum (JAIF)
Nuclear Energy Unit (UTN)

08:30-09:00	Registration
09:00-09:15	Welcoming remarks by Deputy Director General of Nuclear Energy Unit (UTN).
09:15-09:30	Opening remarks by Director General of Takasaki Radiation Chemistry Research Establishment (TRCRE), JAERI.
09:30-10:00	Presentation of paper: New Trends in Industrial Application of Electron Beam Machine (including Environmental Protection). by Dr. S. Machi, Director General of TRCRE, JAERI.
10:00-10:30	Recent Advances in High Energy Electron Beam Machine. by Mr. M. Suzuki, Manager, Technical Department, Nissin-High Voltage Co., Ltd.
10:30-11:00	Discussion
11:00-11:30	Coffee Break
11:30-12:00	Electron Beam Sterilization of Medical Products. by Dr. I. Ishigaki, General Manager, Radiation Processing Development Laboratory, TRCRE, JAERI.
12:00-12:30	Crosslinking of Wire and Cables with Electron Beam. by Mr. S. Yamamoto, Senior Research Engineer, Electric Appliance Material Lab., Research and Development Division, The Furukawa Electric Co. Ltd.
12:30-13:00	Discussion
13:00-14:00	Lunch Break
14:00-14:30	Food Irradiation with Electron Beam. by Mr. Mohamad Lebai Juri, Head of Food Irradiation Group, UTN

14:30-15:00	Application of Radiation to Agro-resources by Dr. T. Kume, Principal Scientist, Dept. of Research, TRCRE, JAERI.
15:00-15:30	Potential Applications of Electron Beam Machine in Malaysia by Dr. Khairul Zaman Hj. Mohd. Dahlan, Head of Radiation Processing Programme, UTN.
15:30-16:00	Discussion and Closing Remarks
16:00-16:30	Refreshment

2. Agenda: Radiation Technology Workshop on the Utilization of Electron Beam Machine as a Production Tool

Sponsored by BATAN-JAERI-JAIF
July 20, 1990 at Hotel Sari Pacific, Jakarta.

TENTATIVE PROGRAM

08:00-09:00	Registration
09:00-09:30	Opening Ceremony
	Report from OC Mrs. Nazly Hilmy
	Greeting by JAERI/JAIF Dr. S. Machi
	Keynote address and Opening remark
	by Dir. Gen. BATAN, Mr. Djali Ahimsa
09:30-10:00	Tea Break

Plenary Session I   Chaired by Dr. Mirzan T. Razzak

10:00-10:25	1. New Trends in Industrial Application of Electron Beam (Dr. S. Machi)
10:25-10:50	2. Recent Advances in High Energy EB Machine (Mr. M. Suzuki, Nissin)
10:50-11:15	3. EB Processing for Wire and Cable Application in Japan (Mr. S. Yamamoto, Furukawa Denki)
11:15-11:40	4. Electron Beam Processing of Rubbers (Dr. K. Makuuchi)
11:40-12:00	Discussion
12:00-13:30	Lunch

Plenary Session II Chaired by Dr. Dipo Alam + Mrs. R. Chosdu

13:30-13:55	5. Radiation Sterilization of Medical Products with EB (Dr. I. Ishigaki)
13:55-14:20	6. Radiation Technology in Agro-resources (Dr. T. Kume)
14:20-14:45	7. Prospect of Commercialization of Food Irradiation in Indonesia (Mrs. Nazly Hilmy)
14:45-15:00	Discussion
15:00-15:15	Tea Brek

Plenary Session III Chaired by Dr. Budi Santoso + Dr. R. Sofyan

15:15-15:40	8. BATAN's Experiences on Radiation Curing (Ir. Sundardi)	
15:40-16:05	9. Toward the Application of Radiation Technology in Indonesia (Dr. Mirzan T. Razzak)	
16:05-16:15	Discussion	

Plenary Session IV Chaired by Mrs. N. Hilmy

16:15-16:45	Panel Discussion	
	Dr. S. Machi	(JAERI)
	Ir. D. Gustam	(Sterilindo)
	Dr. Dipo Alam	(LIPI)
	Ir. D.K. Karyana	(Kabelindo)
	Dr. Mirzan T. Razzak	(BATAN)
	Dr. Moh. Solichin	(Kimia Farma)
16:45-17:00	Closing session Closing remark by Dr. S. Machi	

3. List of Participants

Scientific Talk on Utilization of Electron Beam Machine

1. Mr. Kenzo Yoshida,
   JICA Expert, c/o Nuclear Energy Unit.

2. Mr. Kiyoshi Honma,
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3. Mr. Sy. Ridzuan Sy. Ariffin
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