Present Status of Radiation Processing in Japan

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Introduction

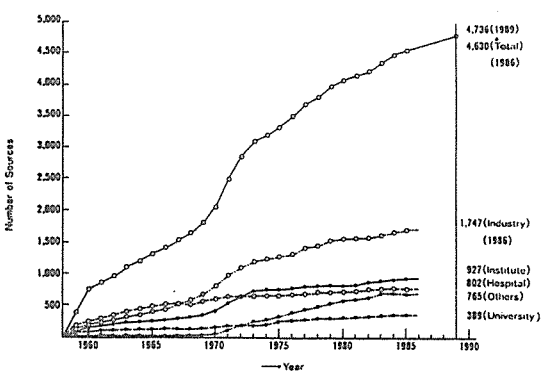
Present status of radiation processing in Japan is reviewed. Main radiation sources of ^{60}Co, electron accelerators and ion accelerators for processing are summurized, together with the world wide trends.

Radiation processes developed recently are listed in tables. Some of new processes will be introduced as the examples.

Radiation Sources

Number of locations where radiation sources above a certain level have been equiped are shown in Figure 1, as a function of year.

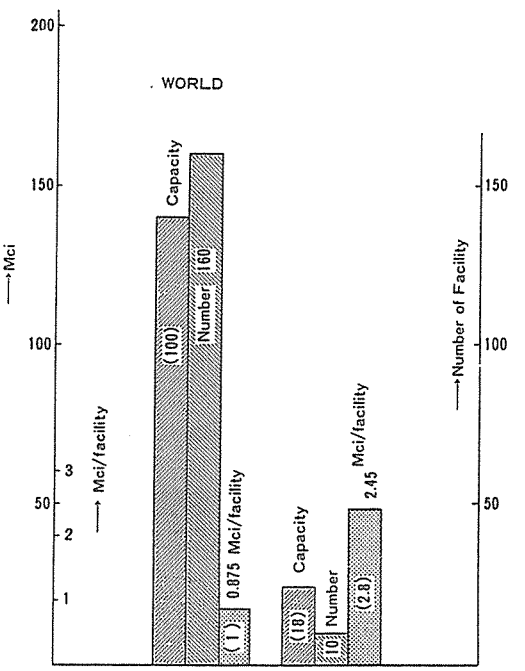
Fig 1. Statistics of Radiation Sources in Japan(1989)



Total number in 1989 is 4736, and about 800 locations have been registered during past ten years. This is increasing rather steady and is indicating the activity in this field.

^{60}Co irradiation facilities in both all over the world and Japan are demonstrated in the total capacity, the average capacity and the number of facilities, as shown in Figure 2.

Fig 2. ^{60}Co Irradiation Facilities (1989)

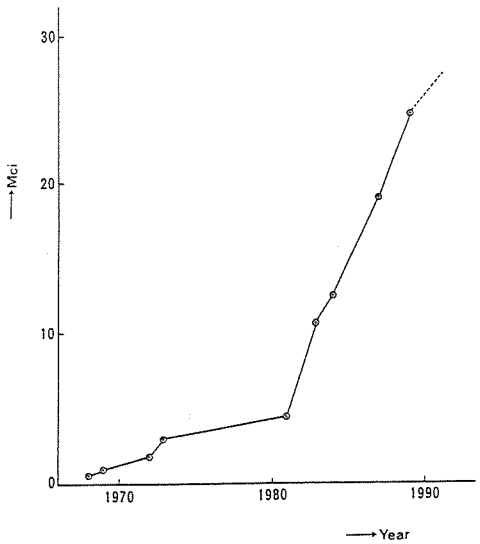


The total capacity in Japan is approximately 20% of the whole world, although the number of facilities is very small, suggesting the capacity for each is very big compared with other countries.

Cumulative capacity of ^{60}Co sources in Ja-

pan during last twenty years is shown in Figure 3.

Fig 3. Cumulative Capacity of ^{60}Co Sources Japan(1989)



It is interesting to note that a distinct change in the growth around 1980 appeared in the figure. Sterilization of medical supplies probably started to increase from the year.

^{60}Co irradiation facilities in Japan is summarized in Table 1.

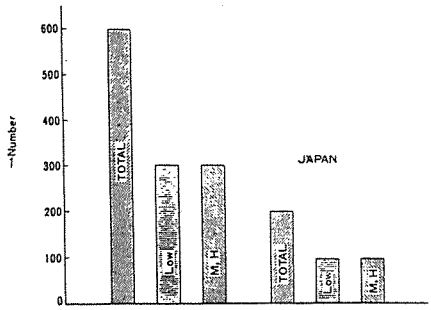
Table 1 Irradiation Facilities in Japan (1989)

Name	Establishment(year)	Location	Capacity(Mdor)	Purpose	Remark
Shihoro Agriculture Cooperative Association	1973	Hokkaido	1	Food Irradiation	0.2million
Japan RI Irradiation Service Co-op	1969	Tochigi	0.6	Sterilization, Improvement	0.3million
Radia Ind.	1972 1984	Gunma	1 2	Sterilization, Improvement	RIC-1 0.37million RIC-2 0.56million
Irradiation Development Association	1968	Gunma	0.5	Test Irradiation	JAERI 0.22million
Terumo	1983	Yamanashi	3×2 Machines	Sterilization	AECL-JS8900 5.8million
Japan Radioisotope Association Koka Laboratory	1981	Shiga	1.5	Sterilization, Improvement	AECL-JS7500 0.4million
Koka Radioisotope Laboratory	1987	Shiga	1.5	Sterilization	AECL-JS8500 0.4million
Japan Medical Supply	1987	Hiroshima	3×2 Machines	Sterilization	AECL-JS8900 2million
Nissio	1988	Akita	3	Sterilization	AECL-TYPE
Asahi Medical	1988	Ohita	1.5	Sterilization	

Number of electron accelerators for processing is shown in Figure 4.

Total number of electron accelerators for

Fig 4. Number of Electron Accelerators for Processing WORLD(1989)



processing in Japan is approximately 200 which is corresponding one third of the total in the world. Roughly, the half is for low energy machines with below 300 KeV, that means, other machines of medium and high energies correspond to the rest of half.

It is interesting to compare between those of the world and Japan. The scale is roughly one third, and the pattern is just the same.

Electron Accelerators for Processing

Main application fields of electron accelerators and their specifications are summarized in Table 2.

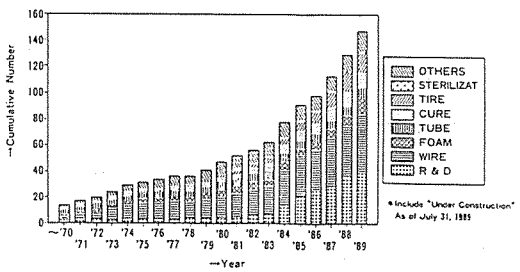
Table 2 Electron Accelerators for Processing in Japan (1987)

Purpose	Number	Energy Range max in Energy MeV	Current max in mA	Year
Research and Development	64	0.175~3.0	~100	1961~1987
Curing	50	0.2~0.3	~600	1972~1987
Wire and Cable	38	0.3~2.0	~100	1969~1987
Rubber Tire	9	0.5~0.8	~220	1972~1987
Shrinkable Tubing and Film	8	0.3~3.0	~100	1972~1982
Foamed Polymer	6	0.5~1.0	~100	1968~1986
Others (Grafting, Stag Gas)	5	0.5~2.0	~60	1970~1977
Total	180			

The number of accelerators are for 1987 and they are expected to be now more than

200 machines. The numbers together with the application fields produced by Nissin High Voltage are shown in Figure 5.

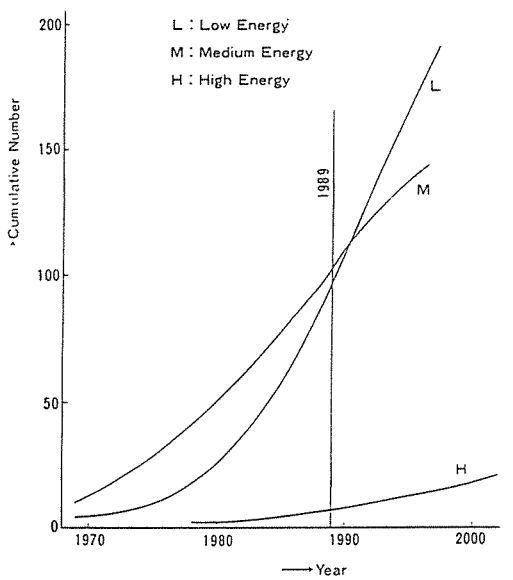
Fig 5. Total Number of Electron Accelerators(Nissin H.V.)



It is easily understood from the figure that how big the size of the markets is, what is the growth and how about the future trend.

Electron accelerators for processing could be divided into three different categories, that is : high, medium and low energy of electrons. The rough trends of the profile in the cumulative number of accelerators in Japan are indicated in Figure 6.

Fig 6. Electron Accelerators for Processing in Japan(1989)



The L and M lines are going to cross each other. They will cross within one year and the number will be approximately 110 for each.

Concerning the low energy machines, the status in the world is indicated in Table 3 for 1977.

Table 3 Electron Accelerators for Processing E<0.3MeV(1988)

	Japan	Europe	US	Pacific	Total
Research and Development	50(52)	18	40	0	108
Pilot	12(7)	35	45	2	94
Production	12(23)	30	65	5	112
Total	74(82)	83	150	7	314
	(1988)			1987	

It is interesting to note from the table that the commercialization of the process from the R and D or the pilot scale testing proceeds rather quickly in Japan, compared with other countries such as European countries and the United States.

Synchrotron Radiation Sources

It is well known that synchrotron radiation is very useful and powerful sources for both basic research and application in various fields including physics, chemistry, biology, medicine and engineering. Particularly, the application in advanced technology fields such as lithographic processes for microelectronics and semiconductor devices is one of the most important examples.

Concerning the development of the radiation source, there are two directions related to the size of machine, that is : one is along a large size of the machine with higher energy, higher current, extended functions and multi-purposes, another is along a compact size of the machine with rather simple function for specific applications.

The former is mainly for research and development and the latter for commercial, specific application.

Main big facilities in Japan are listed in Table 4. The 8 GeV machine will be the biggest machine in the world. This will be completed in 5 years in Harima, Kansai-area of Japan. The construction of the facility is performed by a JAERI-RIKEN team.

Two compact machines have been completed during last one year by industrial farms. NTT started the operation last January, and SHI just one month ago in December, 1989.

Table 4 Synchrotron Light Sources in Japan (1989)

Name	Energy GeV	Current mA	Emittance nm.rad	Notes
Photon Factory (KEK)	2.5	300	130	O, D
TRISTAN (KEK)	8.0	25	250	O, P
TERAS (ETL)	0.8			O, D
UVSOR (IMS)	0.75	100	160	O, D
8GeV SRF (Harima)	8.0	100	5	C, D

O : Operating, C : Constructing, D : Dedicated, P : Partly Dedicated
[France : 6.0 GeV, USA : 7.0 GeV]

Ion-Beam Sources

Ion beam machines have been used mainly for ion-implantation in the semi-conductor industry for a long time. Higher energy ion beams now become important in recent years for new developments such as deep ion-implantation or doping, three dimensional lithography, fine modification of surfaces and synthesis of new materials.

Cumulative number of ion-beam accelerators is shown in Figure 7 together with a rough estimate of number of total in the world.

It is obvious from the figure that the number increases very sharply during last 10 years and the growth rate was highest in the beginning of 80's. At present, approximately 50% of machines in the world are being operated in Japan.

This is indicating the activity of semi-conductor industry in Japan.

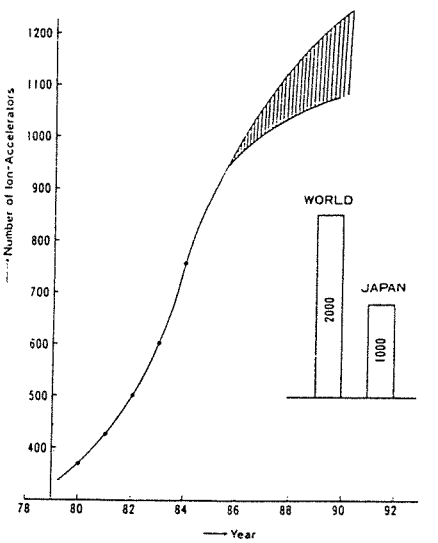
Radiation Processing in Japan

Some of recent developments of radiation processing are summarized in Table 5. Two commercial processes related to cables have been realized.

Table 5 Some of Recent Developments of Radiation Processing(1989)

Organization	Process	Remark
Furukawa Electric Ind	Radiation-Resistant Cable	Polyethylene +Br-Acenphthylene
Sumitomo Electric Ind	Thermal Resistant Cable	Polyurethane for Automubile (Sensor Cable)
Hitachi Cable Ind.	Plastic Heater	Polyethylene +Carbon Black
JAERI Sanwa-Kako	Flame-Resistant Polymer Foam	Grafting of Vinyl Phosphonates onto Polyethylene Foam
Tokyo Metropolitan Radioisotope Center	Flame-Resistant Fabrics	Grafting of Vinyl Phosphonates onto Fabrics
Ebara-JAERI	Odor Absorbing Plastics	Grafting onto PP films and Fabrics.

Fig 7. Cumulative Number of Ion Accelerators for Semi-conductor Industries(1989)



The commercial production of "plastic heater" will be started in very near future.

A new project for the development of flame resistant polymer foam has started under collaboration of a Government Organization called "Shin-Gijitsu-Kaihatsu-Jigyodan".

The new development was originated from Osaka Institute of JAERI under collaboration of Sunwa-Kako Ind.

A new process for producing flame resistant fabrics has been developed by Tokyo Metropolitan Radioisotope Institute.

The most active field in the radiation processing is radiation curing. This field has been expanding very rapidly in recent years in all over the world. Japan is not exception. Electron beam curing processes in Japan is summarized in Table 6.

Table 6 Electron Beam Curing Processes in Japan(1989)

Industrial Farm	Process	Year
Suzuki Automobile	Part of Motorbicycle (Steel, ABS, PP)	1973~1980
Nakazato Ind.	Cement Loof Tile	1979~
Ellio Ind. (Nippon Steel Co.)	Pre-coat Metal Sheet (Products A and B)	1982~
Akires (Taisei and Nippon Electro Cure)	Gypsum Panel (Art Printing)	1984~
Tetra-Pack	Printing of Paper Bag	1985~
TDK	Floppy Disk	1986~
Mitsumura Printing	Printing on Polypropylene Film	1986~
CMK-Toyo Ink	Printing Circuit Board	1987/1988~
Ellio Ind. (Nippon Steel Co.)	Pre-coat Metal Sheet White Board	1987/1988~
〃	Tunnel Panel	1988~
Nissin Steel	Pre-coat Metal Sheet (Products A,B and C)	1988/1989~
Dainippon-Printing	Hard Coat Transfer	1988/1989~
〃	Anti-Fog Film Coating	1989~
Hayashi Cement	HMC Panel (Art Printing)	1989~
Tonen Petro-Chemical	Biaxial PE Film	1990~
Kanzaki Paper Mtg.	Thermosensitive Coated Film	1990~

As is obvious from the Table that many new processes have been realized recently. More than 10 processes have been made open to public since 1986. It is interesting to note that all processes have their characteristic and unique aspects, compared with conventional processes.

A few commercial products for curing of coatings on steel sheets in forms of either coil or panel are the important examples.

Two International Conferences on radiation curing including ultra violet curing have been held twice in Tokyo (1986 and 1988) and the next one is planned to hold in Osaka in 1991.

Flue Gas Treatment

It is known that a unique process by using electron beam which treat waste flue gas in order to eliminate containing polutant components such as NO_x and SO_2 was, for the first time, proposed by Ehara Maf. Ind. and then the process has been developed by collaboration with Takasaki Radiation Chemistry Establishment, JAERI in the early of 1970's.

Since then, a big pilot plant was built by a research union of steel industries in Tobata, Kyushu. After the successful test, another bigger pilot plant was built in the United States. The test finished two years ago. Important technical information has been obtained by the test for the next step. A prototype plant, as the next step, after the big pilot plant, has been now proposed by Ebara International and some U.S. organizations. Takasaki Radiation Chemistry Research Establishment has been also proposing a big test plant, as the next step. The next one will be a commercial plant.

As everyone knows well, acid rain is destroying natural circumstances such as fore-

sts, lakes and rivers all over the world. Attention has been now focused on this problem and the electron beam process is one of the most powerful means to solve this important and difficult problem.

Table 7 Pilot Plant Test of Flue Gas Treatment(1989)

	Institution Year	Treatment Rate Nm^3/h	Accelerator	SO_x/NO_x (ppm)	NH_3 (ppm)	Temp °C
1.	EBARA 1974−77	1,000 oil fired	30kw 300−750kV 50mA	200/240	700	
2.	EBARA Steel Corp. 1977−1978	3,000~10,000 Sintering furnace	2×(10−45kw) 600−750kV 17−60mA	200/180 (1,900/620)	1~1.2	70−90
3.	EBARA Int. DOE Indianapolis 1984−1988	16,000~32,000 coal-fired	2×800kV 160kw	1,000/400	Stoich	66−149
4.	EBARA Int. DOE 500MWe 1990−	1,600,000 coal fired	11,628kw (1.8Mrad)	2,000/350	Stoich	82
5.	JAERI Takasaki 100MWe	300,000~400,000 coal fired	2~3,000kw (1.8Mrad)	——	Stoich	——

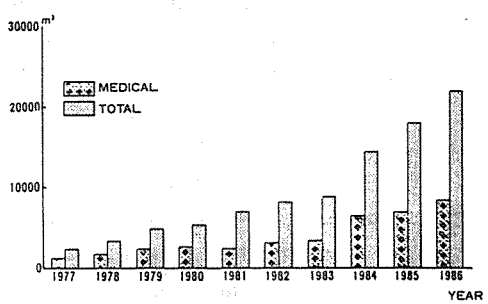
1, 2 and 3 : Pilot Plant TEST
4 : Prototype
5 : Conceptional Design (JAERI)

Sterilization of Medical Supplies

Figure 8 shows increase in total volume of packages treated by γ-sources as a function of year in Japan, under contract basis.

This is rather old data until 1986. However, one can understand the trend. The most significant progress has been seen in this field.

Fig 8. Irradiation Services in Contract Basis 2.5Mrads(1986)



Radiation sources for that purpose are at moment ^{60}Co. However, there is a strong movement to shift from ^{60}Co sources to electron-beam accelerators. In near future, high energy electron beam from a linear accelerator will be used for the sterilization purposes.

Table 8 Approved Items of Medical Supplies for Radiation Sterilization in Japan

1. Medicine
   - Medicine for wound
2. Medical product
   - Dialysis unit
   - Catherters
   - Hypodermic syringes
   - Needles
   - Disposable blades
   - Surgical suture
   - Birth control rings
   - Disposable scalpel
   - Tampon
   - Blood lancet
   - Artificial joint

Other Processes

Projects on treatment of both drinking water and waste water including industrial waste, city water and sluge has been carried out. Takasaki JAERI, Tokyo Metropolitan Radio-Isotope Institute and Osaka City Institute of Radiation have been actively engaging on these projects.

Conclusion

Activity in the field of radiation processing in Japan has been increasing. Radiation source started with ^{60}Co and now electron beam accelerators have become important. In future, ion beam sources will be extensively used as the tool of radiation processing.

Use of radiation and radio-isotopes has been contributing to the advancement in the field of high technology.