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CHINA NUCLEAR SCIENCE AND TECHNOLOGY REPORT

中国辐射加工新发展

THE NEW DEVELOPMENT OF RADIATION PROCESSING IN CHINA

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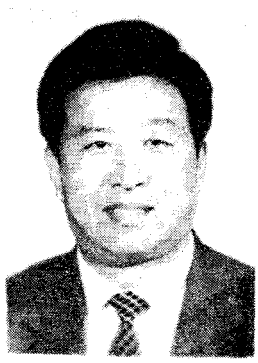

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中国辐射加工新发展

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摘　要

中国同位素与辐射行业协会（CIRA）对中国辐射加工现状进行了调研。结果显示，中国现有束流功率在 5 kW 以上工业用加速器 45 座，总功率为 2005 kW；有设计源强为 1.11×10^4 TBq 以上γ射线辐照装置 48 座，另有源强低于 1.11×10^4 TBq 的γ射线辐照装置 75 座，总装源量为 4.63×10^5 TBq。在中国，辐射加工主要用于生产化工产品（辐射交联线缆和热收缩制品），目前已出现一些产值超亿元的企业；辐射加工还用于食品灭菌和保鲜、医疗用品的灭菌消毒。烟道气的辐射脱硫和脱硝也正在开发利用中。

The New Development of Radiation Processing in China

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ABSTRACT

China Isotope and Radiation Association (CIRA) investigated the status of radiation processing in China's mainland. There are 45 accelerators each with beam power over 5 kW, the total beam power is 2005 kW. There are 48 γ facilities each with designed capacity over 1.11×10^4 TBq (0.3 million curies) and other 75 units with designed capacity less than 1.11×10^4 TBq. The total loaded capacity is 4.63×10^5 TBq, more than one third of the designed capacity. Radiation processing is mainly used in producing chemical-industrial products (as heat-shrinkable products and radiation cross-linked wire and cable) in China. Some enterprises with annual output value over a hundred million RMB have emerged. Radiation processing is also used in preservation and disinfection of food. In 1977, six kinds of hygienic standards for irradiated food were authorized. Radiation sterilization of disposable medical products, radiation desulphurization and denitration are also being developed in China.

1 RADIATION EQUIPMENT

1.1 Industrial electron accelerators

1.1.1 History and advances

Since 50's, China started to research and manufacture several types of accelerators. In 90's, with increasing requirement of applications and through intensified international technical exchange, we have improved the manufacturing level, now we can produce many kinds of industrial electron accelerators (see Table 1).

Table 1 The Industrial Electron Accelerators made in China

Type of Accelerator	Main Parameters			Name of Manufacturer
	Energy MeV	Beam Current mA	Beam Power kW	
Dynamitron	2.0	10	20	Shanghai Xianfeng Electric Manufacturing works.
	2.5	30	75	
	3.0	20	60	Shanghai Nuclear Research Institute
	3.0	30	90	Institute of High Energy Physics Academia Sinica
Cockcroft -Walton	0.5	30	15	Shanghai Xianfeng Electric Manufacturing works.
ICT	0.3	30	9	Beijing Research Institute of Automation for Machine-Building Industry Ministry of Machinery Industry
	0.6	45~50	24~30	
	1.2	6~10	7~12	
Electron Curtain	0.2	20	4	(same as above)
Single Cavity Linac	2.0	10	20	China Institute of Atomic Energy
Linear	5.0	0.14	0.7	Beijing Medical Research Institute
	14	0.12	1.5	China Institute of Atomic Energy
	12	0.25	3.0	Nanjing University

1.1.2 Industrialization development

Recent 10 years have been the period of a great development in EB processing application.

In September 1992, The Eighth International Meeting on Radiation Processing (IMRP-8) was held in China and was sponsored by CIRA. Before the meeting, there were 12 accelerators (6 imported machines included). This meeting promoted the development of radiation processing and the accelerators reached 23 sets (10 sets imported) in 1994. In that year, CIRA held a national meeting to further the

industrial development of radiation accelerators once again. The EB production lines reached 45 sets in 1997. The increase of power is even obvious. The power (879 kW) in 1994 had increased by 105% over 1992 (429 kW). The power (2005 kW) in 1997 has increased by 128% over 1994 (See table 2).

Table 2 The statistics of electron accelerators development*

Year	Before 1989	1990	1991	1992	1993	1994	1995	1996	1997
Accelerator number/ set	6	8 (2)	11(3)	12(1)	14(2)	23(9)	31(8)	38(7)	45(7)
Beam Power/ kW	204	319 (115)	409 (90)	429 (20)	469 (40)	879 (410)	1354 (475)	1669 (315)	2005 (336)

* (1) Beam power is over 5 kW.
(2) The numbers in the parentheses are the added numbers in that year.

During the 6 years from 1992 to 1997, the accelerator production lines were almost doubled every two years.

Table 3 shows the number of accelerators in use at present in China. Out of 45 accelerators, 21 were indigenous, it takes 47% of the total sets. The total beam power of 21 China made machines is 624 kW, 31% of total power. The imported machines are 24 sets, 53% of the total; beam power is 1381 kW, and 69% of the total. The imported machines were supplied by Russian, USA, France and Japan. There are 5 imported accelerators with beam power over 100 kW.

Table 3 List of accelerator manufacturer

Made in	number/ set	%	Beam power / kW	Power/ %
China	21	46.7	624	31.1
Russian	16	35.6	671	33.5
USA	5	11.1	490	24.4
France	2	4.4	190	9.5
Japan	1	2.2	30	1.5
Total	45	100	2005	100

These accelerators are distributed in 19 provinces and cities (see table 4).

1.2 Gamma facility

The application of γ-ray radiation in China started in agriculture in 50~60's. Recent 10 years have been the period of a great development in γ-ray processing application. By the end of 1998, we have operated 48 commercial γ facilities, each has a designed capacity over 1.11×10^4 TBq (0.3 million curies); the other 75 sets (including 2 Cs-137 γ-ray devices) have designed capacity less than 1.11×10^4 TBq for each one. In one word, there are 123 γ-ray facilities in China. The total loaded

Table 4 Distribution of accelerators in China/ set

Locations	Made in China	Imported	Total quantity
Anhui	1		1
Beijing		1	1
Gansu		1	1
Guangdong		2	2
Hebei	1	2	3
Henan		1	1
Hubei		1	1
Jiangsu	5		5
Jiangxi	1		1
Jinlin		6	6
Liaoning	1		1
Shandong	2		2
Shanghai	3	3	6
Shanxi		1	1
Shanxi		2	2
Sichuan	3	3	6
Tianjin	2		2
Yunnan	1		1
Zhejiang	1	1	2
Total	21	24	45

capacity is about 4.63×10^5 TBq (12.50 million curies), more than one third of the designed capacity (see Table 5). These facilities are distributed in 66 cities and counties in 28 provinces. There are 6 facilities with designed capacity over 1 million curies ($1Ci=3.7\times10^{10}$ Bq)(3 of the 6 sets are imported.). The Shenzhen irradiation center is the biggest one in China (See Table 6).

According to the requirement of radiation processing, we need 1.8 to 2.0 million curies of radiation source every year. But China can only supply 0.2 to 0.3 million curies. So most γ sources need to be imported.

Table 5 The statistics of gamma radiation facilities development*

Year	Before 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Sets	18	23(5)	25(2)	26(1)	32(6)	36(4)	43(7)	44(1)	47(3)	48(1)
Designed capacity/10^4 Curies	1350	1580 (230)	1660 (80)	1690 (30)	2120 (430)	2330 (180)	2650 (350)	2700 (50)	2860 (160)	2910 (50)

* (1) The designed capacity is more than 0.3 million curies.
(2) The figures in the parentheses are the increased numbers of that year.
(3) The figures in the list do not include the numbers in Taiwan Province.

Table 6 The distribution of ^{60}Co γ facility in China*

Designed capacity (million curies)	Number	Location
4.0	1	Guangdong province (Shenzhen)
1.5	1	Shandong province (Qingdao)
1.0	5	Beijing, Shanghai, Guangdong, Sichuan, Hebei
0.6	1	Heilongjiang (Daqing)
0.5	30	Beijing (2), Shanghai (1), Tianjin (1), Liaoning (3), Jilin (2), Heilongjiang (1), Hebei (1), Henan (2), Shandong (1), Jiangsu (3), Zhejiang (2), Hubei (2), Hunan (1), Fujian (2), Hainan (1), Sichuan (2), Yunnan (1), Shaanxi (1), Gansu (1)
0.3	10	Beijing (1), Liaoning (1), Shandong (2), Fujian (1), Sichuan (1), Shaanxi (2), Yunnan (1), Shanghai (1)
Total : 29.10	48	

* (1) The designed capacity is more than 0.3 million curies.
(2) The figures in the parentheses are the number of the facilities in the provinces or cities.
(3) The figures in the list do not include the numbers in Taiwan Province.

2 RADIATION CHEMICAL-INDUSTRIAL PRODUCTS

Radiation processing of polymer materials is one of the most important branches of radiation application in China. There are more than 40 varieties of products processed by means of radiation technology. Some enterprises with annual output value over 100 million RMB have emerged.

2. 1 Heat-shrinkable products

In China, the research on heat-shrinkable materials produced by using EB or γ-ray started almost at the same time as in the foreign countries.

Since 1987, the heat-shrinkable products have been developed rapidly. Some important manufactories are situated in the northeast part and southwest part of China. 10 accelerators are only used to produce heat-shrinkable materials. There are also 11 manufacturers not only producing heat-shrinkable materials but also wire and cable. There is a manufacturer who uses the accelerator for producing heat-shrinkable products and other things. As a whole, 22 accelerators are used for producing heat-shrinkable materials.

The main products include accessories of power cables and communication cables, various flame-retardant tubes and irregular-shaped tubes, anticorrosion wrapping materials for oil pipelines and heat shrinkable films. 4 enterprises with

annual output value over 100 million RMB have emerged.

2. 2 Radiation crosslinked wire and cable

In recent 10 years, the technique of Radiation crosslinked wire and cable has experienced rapid development. Currently, 34 accelerators are used to produce radiation crosslinked wire and cable. A number of γ facilities are used for the same work. The main products are 1~10 kV power cable, flame-retardant power cable, special crosslinked wire and etc. In the recent years, there are some enterprises who have the annual output value more than a hundred millions RMB. So, in this line, there is a great developing potentiality in China.

2. 3 Radiation Emulsion Polymerization

KG series printing and dyeing auxiliary produced by means of γ ray is a typical example of radiation emulsion polymerization realized in an industrial manufacture. Since 1986, 3 types including 6 products have been formed. So far, the University of Science and Technology of China have sold the technique to some provinces and cities. Among them, Changshu Applied Irradiation Technique Factory with output 2500 t is specifically engaged in manufacturing of the resin by means of γ-ray radiation.

3 FOOD IRRADIATION

In the field of radiation processing, preservation, sterilization and quality improvement of food by irradiation have been widely developed in China for a long time. Therefore, many achievements have been obtained. During 1984~1994, our authorities have approved 18 national hygienic standards for irradiated food including apple, garlic, potato and so on. In order to promote the development of food irradiation, the hygienic standard for 6 kinds of irradiated food was approved in 1977 (See Table 7).

According to the survey, more than 50000 t of irradiated food, such as garlic, spices, flavorings, dehydrated vegetables, etc., were sold in 1998.

4 RADIATION STERILIZATION OF DISPOSABLE MEDICAL PRODUCTS

Supported by State Science and Technology Committee, the first radiation sterilization test development base was built in Beijing in 1984. The facility was imported and a center of nationalization development had been built.

The research and popularization of γ-radiation sterilization of disposable medical products, including infuses, syringes, scalper, latex gloves, suture, gauze, absorbent cotton and other things have been undertaken in China for many years.

It is rather difficult to count the output because of packing containers not yet

Table 7 Hygienic standard for irradiated food

Categories	Purpose of radiation	Dosage/ kGy
Beans, grains and their products	control insect reproduction	≯0.2 (beans), 0.4~0.6 (grains)
Dried nuts and preserved fruit	control insect reproduction	0.4~1.0
cooked meat of livestock and poultry	Disinfestation, prolong guarantee time	≯8.0
Frozen packaged meat of livestock and poultry	Disinfestation	≯2.5
Dried spice	Disinfestation, prevention mildew and rot, prolong guarantee time	≯10
Fresh fruits and vegetables	check sprouting, postponement	0.1
	ripeness	0.1~0.5
	prolong guarantee time	0.1~0.5

unified in China. It was about 60000 cubic meters a year according to our estimation.

About 70% of the loaded capacity of cobalt source are used for radiation sterilization over the world. In China, however, only 30% loaded cobalt source is used for sterilization. So there is a large potential market in this aspect.

5 RADIATION DISPOSAL OF WASTE GAS

In China electrical power industry, the power more than 70% is generated by coal fired plant. So a lot of SO_2 and NO_x has been exhausted into environment. A pilot scale plant using EB technology to clean coal burning flue gases was constructed in Sichuan province; it is a joint project of China and Japan. Our government has paid more and more attentions to environmental protection. So, there is a great potential market in the field of radiation disposal of flue gases.

Tsinghua University and Beijing University, cooperated with Beijing Environmental Protection Bureau, are engaging in some scientific experiments and some achievements have been obtained. The Tsinghua University, Beijing University, Shanghai Nuclear Research Institute of Academia Sinica and other research institutes had made experiments by means of EB or γ-ray to irradiate waste gas and water, but the research is only in the beginning stage.

6 THE FUTURE TASKS

(1) We shall make efforts to increase the utilization efficiency of present equipment. By the end of this century, the annual output value of radiation chemical-industrial products will be 4 times of that in 1996.

(2) Developing and producing 15 to 25 kinds of cable and wires with special function. Series products of heat-shrinkable material shall be developed and have better functions.

(3) Set up 2 to 3 radiation-crosslinkable raw material supplying bases with 3000 to 5000 t capacities.

(4) Radiation sterilization of medical products, such as infuse injector, operating goods, and products of adhesive-bonded fabric, sanitary goods for women and children, food packing material, and more than 100 kind products should be popularized actively and should supersede the chemical methods of sterilization.

(5) Speed up the research and popularization of the food irradiation new technology. The food industry has become the second biggest industry in China. The main development of food irradiation shall be traditional food, small package food etc. We shall strengthen the radiation treatment of imported food and grain.

(6) We should do more researches on radiation curing of coatings by electron beams (such as thermosensitive materials, magnetic media, rubberized fabric, emulsion and thin rubber), construct engineering materials (wood/plastic composites, metal/plastic composites, high-quality material of heat insulation and fire resistant) and radiation dispose of industrial pollution.

(7) International exchange and cooperation in the field of radiation processing must be enhanced.

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