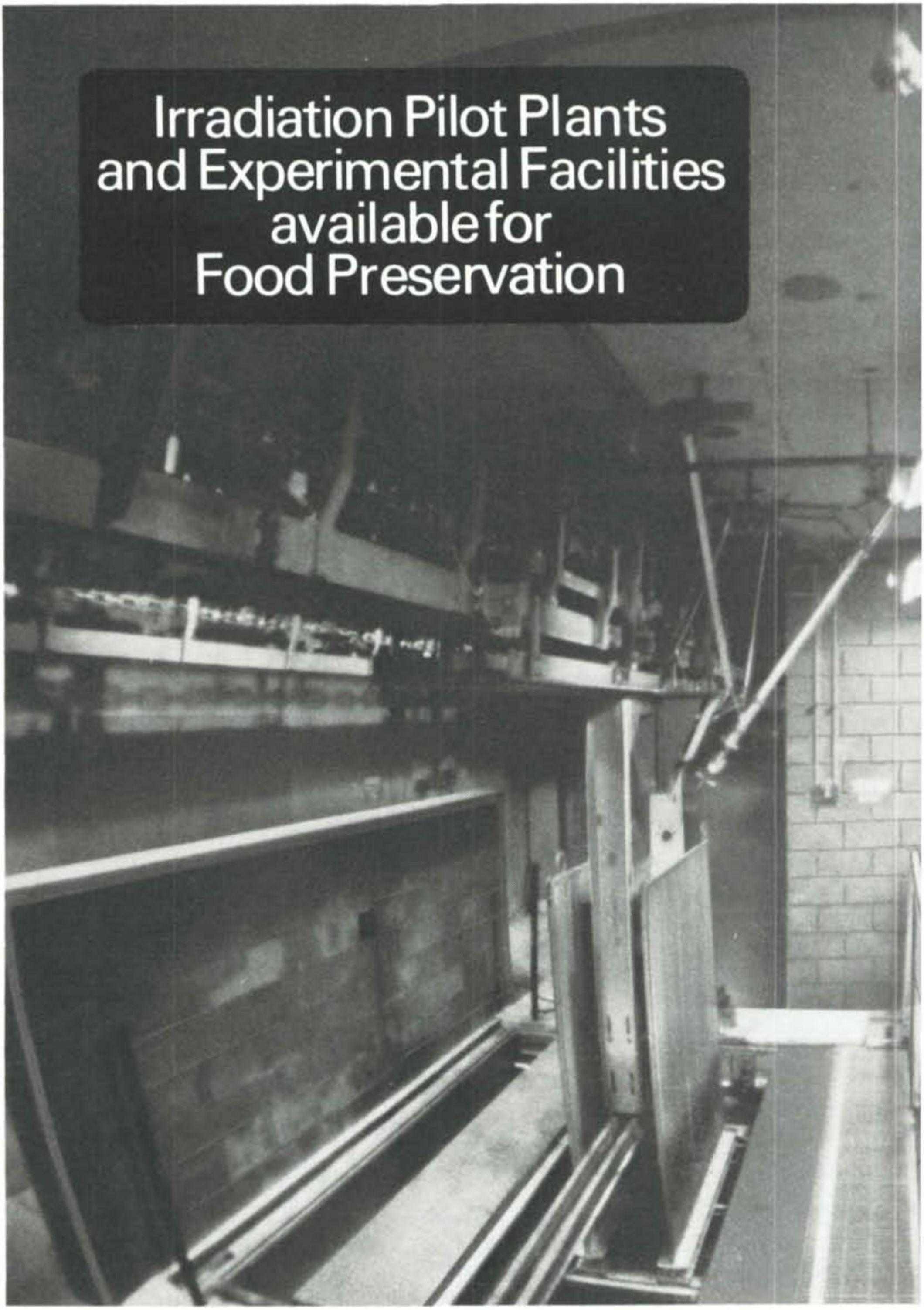
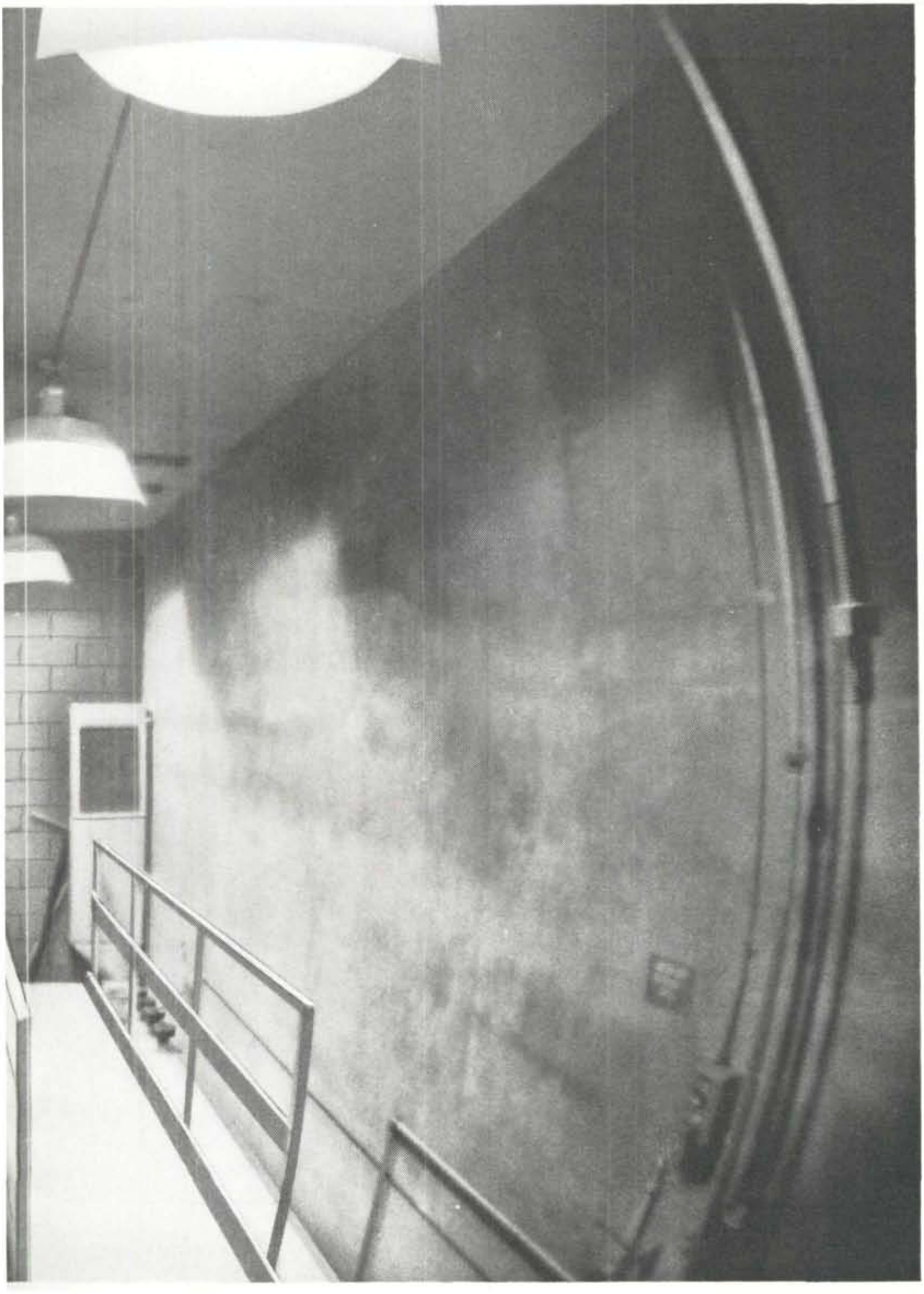
Irradiation Pilot Plants and Experimental Facilities available for Food Preservation



The multi-purpose irradiator at the US Army Natick Laboratory, Natick, Mass., USA. Photo: US Army



With the ever-increasing world food crisis mankind has to face today, the prevention of spoilage of perishable food is gaining in momentum. The World Food Conference (Rome, November 1974) of the United Nations clearly recognized the importance of food preservation and urged action in this field.

Irradiation is one of the recently discovered methods to preserve food. Its practical introduction largely depends on three main factors: (a) proof of the safety for human consumption of the irradiated product, (b) technological feasibility and (c) economic competitiveness of the process.

As data on safety for consumption ("wholesomeness") continue to become available, the number of countries authorizing the irradiation of certain food items is growing (present total: 17 countries), and the same is true for the number of licensed irradiated commodities (total: 23).

Under these conditions, testing of the technological and economic feasibility of food irradiation is a matter of increasing importance.

Economic feasibility of any industrial operation can only be studied in larger-scale experiments. Thus, they can only be performed with radiation sources larger than those found in laboratories, *i.e.* in pilot irradiators, capable of handling from a few hundred to a few thousand kilograms of material within a short period of time.

The Food Preservation Section of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture has attempted to collect data on the availability, for food preservation, of suitable irradiators in Member States. A preliminary list of these is shown below.

Although some of the information in the table is inevitably incomplete, especially as far as throughput capacity figures are concerned, it can be seen that a considerable number of pilot irradiators are already available for foods and feeds. Out of the 70 units listed, 58 are operational and 12 are under planning or construction.

On the basis of the source strength data [total equivalent to *ca.* 4,7 MCi* (or 174 PBq**) of ^{60}Co] obtained from Member States, an overall global throughput capacity of *ca.* 12 Mrad t h^{-1} (~33.4 kW or 120 kGy t h^{-1} or 33.4 kGy kg s^{-1}**) can be calculated. Hypothetically these sources would be suitable to irradiate at a dose level of 10 krad (100 Gy) and assuming 8 000 working hours per year, goods of a total quantity of 9,6 million tons per annum (Mt a^{-1}), or 12.8 Mt a^{-1} of a product requiring a dose of 7.5 krad (75 Gy) only. This would correspond to about 4% of the annual world crop of potatoes [dose requirement: 10 krad (100 Gy)], or to the global yearly crop of onions [dose requirement: 7.5 krad (75 Gy)], respectively.

As the data received from several Member States were incomplete, **explicit** throughput capacity data shown in the last columns account only for about half of the above total, *i.e.* *ca.* 5.6 Mrad t h^{-1} (~15.6 kW or 56 kGy t h^{-1} or 15.6 kGy kg s^{-1}).

---

* For the sake of comparison, it should be noted that the total source strength of the industrial irradiators – used to sterilise medical supplies, and to treat textiles and wood plastic combinations – is equivalent to *ca.* 38 MCi.

** Factors used to convert traditional values into SI units: 1 Ci = $3.7 \cdot 10^{10}$ Bq (becquerel), or 1 MCi = 37 PBq (P = prefix "peta" ~10^{15}); 1 rad = 10^{-2} Gy (gray), or 1 Mrad = 10 kGy; 1 Mrad h^{-1} = 2.78 Gy s^{-1} = 2.78 W kg^{-1}; 1 Mrad t h^{-1} = 2.78 kGy kg s^{-1} = 2.78 kW.

It appears that the overwhelming majority of the facilities utilises isotopes (only 8 of the 70 existing or planned irradiators use machine sources).

Food irradiation units of a total throughput capacity of *ca.* 6.3 Mrad t h^{-1} (~17.5 kW or 63 kGy t h^{-1} or 17.5 kGy kg s^{-1}) are reported by Member States to be under construction or in the planning stages at present.

It should also be noted that among the 30 States which already have or are planning food irradiators, about half are developing countries.

It would be highly appreciated if more detailed data could be made available on the irradiation units already listed, and if authorities with information on further pilot plants would notify the **Food Preservation Section, Joint FAO/IAEA Division on Atomic Energy in Food and Agriculture, A–1011 Vienna, P.O. Box 590, Austria.**

Country	Place	Name, Purpose	Source strength kCi [date]	Source strength kW*	Product	Throughput capacity t h^{-1}	Throughput capacity Dose (Mrad)	Throughput capacity Mrad t h^{-1}
ARGENTINA	Ezeiza, Buenos Aires	Semi-Industrial Irradiator Plant	460 [1975]	6.81	fish potatoes grain			
		Truck-mounted Gamma Irradiator	10 [1975]	0.15				
AUSTRIA	Seibersdorf	Multi-Purpose Irradiator	30 [1974]	0.44	animal feed	0.125	2.500	0.313
BELGIUM	Mol	RITA Multi-Purpose Irradiator	59 [1974]	0.87	potatoes shrimp wheat animal feed			
BRAZIL	Rio de Janeiro	Portable Irra-diator[a)]	106 [1972]	0.34	potatoes beans rice wheat onions	0.045	0.200	0.009
	Pernambuco	Onion Irradiator (Planning stage)	31	0.46	onions	2.500	0.008	0.020
	Piracicaba	CENA Gamma-beam 650	30 [1975]	0.44	beans grain			

Country	Place	Name, Purpose	Source strength kCi [date]	kW*	Product	Throughput capacity t h⁻¹	Dose (Mrad)	Mrad t h⁻¹
BULGARIA	Novi Krichim	Multi-Purpose Irradiator	34 [1975]	0.50	potatoes onions dried fruits	1.100–12.000[c)]	0.010	0.077[d)]
	Sofia	Multi-Purpose Irradiator	40 [1975]	0.59	wheat fruits chicken spices etc.			
CHILE	Santiago	Portable Irra-diator[a)]	100 [1971]	0.32	potatoes onions straw-berries etc.	0.045	0.200	0.009
	Santiago	Multi-Purpose Irradiator (Planning stage)	300	4.44	bulbs tubers grain fruits etc.			
DENMARK	Roskilde	Linear Acceler-ator (Planning stage)[b)]	–	8.80		0.500		1.000–2.000
EGYPT	Cairo	Multi-Purpose Irradiator (Planning stage)	400 [1976]	5.93				
	Cairo	Electron Beam Acceler-ator (Planning stage)[b)]	(1.5MeV)	37.50				
FRANCE	Saclay	Mobile Irradiator "IRMA" 400[a)]	190 [1975]	0.61		~0.200	~0.250	~0.050
	Saclay	Poséidon Multi-Purpose Pilot	200 [1975]	2.96	potatoes animal feed			
	Cadarache	Bag Irradiator (Planning stage)	180	2.66	maize starch (in 50 kg bags)	1.667	0.250	0.425 (max.)

Country	Place	Name, Purpose	Source strength kCi [date]	kW*	Product	Throughput capacity t h⁻¹	Dose (Mrad)	Mrad t h⁻¹
FRANCE (continued)	Dagneux	D_1 Multi-Purpose	850 [1975]	12.60				
	Dagneux	D_2 Industrial Pilot	160 [1975]	2.37				
	Dagneux	D_3 Multi-Purpose	820 [1975]	12.15				
GERMANY, FR	Karlsruhe	Linear Accelerator (Varian-V-7703)[b)]	(10MeV)	6.00	potatoes onions chicken spices etc.			
	Karlsruhe	Van-de-Graaff Accelerator[b)]	(1MeV)	0.25	meat spices etc.	0.200	0.100	0.020
	Karlsruhe	X-ray facility	(0.12MV)	60.00	potatoes onions etc.	0.200	0.010	0.002
	Hamburg Ship "Anton Dohrn"	On-board Fish Irradiator (X-rays)	(0.20MV)	30.00	fish	0.025	0.150	0.004
HUNGARY	Budapest	KÉKI Pilot Food Irradiator	60 [1974]	0.88	potatoes feed spices	4.000	0.010	0.040
	Budapest	Isotope Institute	80 [1974]	1.18	feed	0.030	2.500	0.075
INDIA	Trombay	Package Irradiator	100 [1971]	1.48	shrimps mango onions potatoes etc.	0.045	0.500	0.023
	Trombay	Portable Irradiator[a)]	100 [1971]	0.32	fish fruits etc.	0.045	0.200	0.009
	Trombay	Portable Grain Irradiator	28 [1971]	0.41	grain	0.225	0.015	0.003
INDONESIA	Jakarta	Multi-Purpose Irradiator (Planning stage)	40	0.59				

Country	Place	Name, Purpose	Source strength kCi [date]	kW*	Product	Throughput capacity t h⁻¹	Dose (Mrad)	Mrad t h⁻¹
ISRAEL	Yavne	Multi-Purpose Service Irradiator	100 [1975]	1,48	rodent feeds		2.500	
	Yavne	Mobile Gamma Irradiator (Planning stage)	60 [1976]	0.88	animal feeds	0.040	1.500	0.060
					wheat products	0.100	0.400	0.040
					spices	0.040	1.500	0.060
					potatoes	2.000	0.015	0.030
					onions	2.000	0.010	0.020
					garlic	2.000	0.010	0.020
ITALY	Casaccia Rome	Multi-Purpose Irradiator	60 [1974]	0.88	potatoes onions garlic etc.	2.000	0.010	0.020
	Fucino	Industrial Potato Irradiator (Planning stage)	300	4.44	potatoes onions	30.000	0.010	0.300
	Como	Gamma-tom S.p.a. Irradiator	150 [1974]	2.22	potatoes onions etc.			
	Bologna	Gamma-rad	140 [1974]	2.07	fruits vege-tables sausages animal feed			
JAPAN	Shihoro, Hokkaido	Shihoro Commer-cial Potato Irradiator	300 [1974]	4.44	potatoes	20.000[c)]	0.010	0.200[d)]
	Takasaki	JAERI Pilot Plant Food Irradiator	100 [1974]	1.48	potatoes onions rice fish sausages	5.500[c)]	0.010	0.055[d)]
	Takasaki	Radia Industry (Commer-cial)	240 [1973]	3.47	potatoes	12.500[c)]	0.010	0.125[d)]
					animal feed	0.220[c)]	2.500	0.550[d)]

Country	Place	Name, Purpose	Source strength		Product	Throughput capacity		
			kCi [date]	kW*		t h^{-1}	Dose (Mrad)	Mrad t h^{-1}
JAPAN (continued)	Tachigi	Irradiation Cooperative Association (Commercial)	300 [1970]	4.44	potatoes animal feed	15.000[c)] 0.230[c)]	0.010 2.500	0.150[d)] 0.570[d)]
KOREA, Rep. of	Seoul	On-board Ship Irradiator	30 [1971]	0.44	marine products	0.068[c)]	0.100	0.007[d)]
MEXICO	Mexico City	Gammabeam 650	50 [1973]	0.74	fruits			
NETHERLANDS	Wageningen	Multi-Purpose Irradiator	137 [1975]	2.03	potatoes onions mushrooms poultry strawberries feed spices	0.400 0.500 0.300 0.300 0.300 0.200 0.250	0.010 0.005 0.200 0.250 0.250 1.000 0.750	0.004 0.003 0.060 0.075 0.075 0.200 0.187
	Wageningen	Linear Accelerator[b)]	(3MeV)					
PAKISTAN	Lyallpur	Mark IV Research Irradiator	25 [1972]	0.37	fish potatoes onions garlic grain	0.066	0.200	0.013
POLAND	Lodź	Multi-Purpose Irradiator	20 [1973]	0.29	spices potatoes grains			
SOUTH AFRICA	Pretoria	Gammabeam 650	45 [1974]	0.66	subtropical fruits			
	Pelindaba	Package Irradiation Plant	370 [1974]	5.48	subtropical fruits			

Country	Place	Name, Purpose	Source strength kCi [date]	kW*	Product	Throughput capacity t h⁻¹	Dose (Mrad)	Mrad t h⁻¹
SPAIN	Madrid	Multi-Purpose (under construction)	500	7.41				
SWITZERLAND	Eidgen. Forschungsanstalt Wädenswil	Biological Research	30 [1973]	0.44				
THAILAND	Bangkok	Multi-Purpose Irradiator	20 [1974]	0.29	onions fruits fish grain etc.	1.000	0.008	0.008
UNION OF SOVIET SOCIALIST REPUBLICS	Bogutsharovo, Tula	Multi-Purpose Irradiator	136 [1971]	2.01		0.180	1.000	0.180
	Kanibadam	Dried Fruit Irradiator	35 [1971]	0.52				
	Dzherzhinskii	Potato Irradiator	50 [1971]	0.74	potatoes	3.000	0.010	0.030
	VNIIKOP Moscow	Multi-Purpose Irradiator	240 [1971]	3.55				
		On-board Ship Irradiator	91 [1971]	1.35	marine products	0.100	0.250	0.025
	VNIIZ Moscow	Grain Irradiator	35 [1971]	0.52	grain	0.400	0.010	0.004
UNITED KINGDOM	Swindon	Multi-Purpose Irradiator (Automatic)	750 [1974]	11.10	animal feed			
	Swindon	Multi-Purpose Irradiator (Batch)	250 [1974]	3.70	animal feed			
	Reading	Multi-Purpose Irradiator	400 [1974]	5.92	animal feed			

Country	Place	Name, Purpose	Source strength		Product	Throughput capacity		
			kCi [date]	kW*		t h^{-1}	Dose (Mrad)	Mrad t h^{-1}
UNITED STATES OF AMERICA	Savannah, Georgia	Grain Product Irradiator	26.6 [1971]	0.39	grain	4.500	0.050	0.225
		Mobile Gamma Irradiator	100 [1966]	1.48	straw-berries potatoes fruits etc.	0.500	0.200	0.010
	Gloucester, Mass.	Marine Product Irradiator	250 [1965]	3.70	marine products	1.000	0.250	0.250
	Gloucester, Mass	On-board Ship Irradiator						
	Honolulu, Hawaii	Hawaiian Product Develop-ment Irradiator	250 [1967]	3.70	papaya mango etc.	1.500	0.075	0.113
		Portable Irradiator Truck-mounted[a)]	100	0.32	straw-berries potatoes etc.	0.050	0.200	0.010
	Natick, Mass.	Multi-Purpose Irradiator	3600 [1974]	53.33	meat fish chicken etc.	0.270	6.100	1.647
	Natick, Mass.	Linear Acceler-ator[b)]			meat fish chicken etc.	0.300	6.100	1.830
URUGUAY	San José	Potato Irradiator (Planning stage)	100	1.48	potatoes onions garlic	10.000	0.010	0.100
YUGOSLAVIA	Belgrade	Multi-purpose Irradiator (Planning stage)	300	4.44	potatoes onions wheat etc.			

Legend: no sign in the third column indicates a ^{60}Co source

a) = ^{137}Cs
b) = electron source
c) = $m^3 h^{-1}$
d) = Mrad $m^3 h^{-1}$

* 67 480 Ci of ^{60}Co or 312 000 Ci of ^{137}Cs emit 1 kW of gamma radiation.