FUEL CHANNEL DETAIL WITHIN CALANDRIA

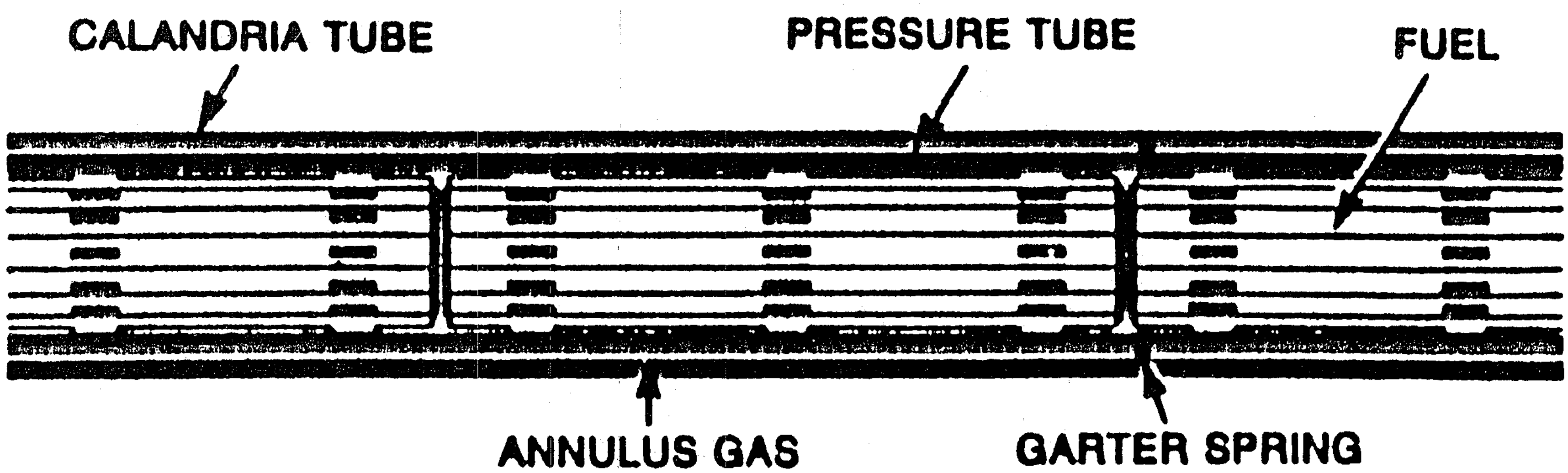
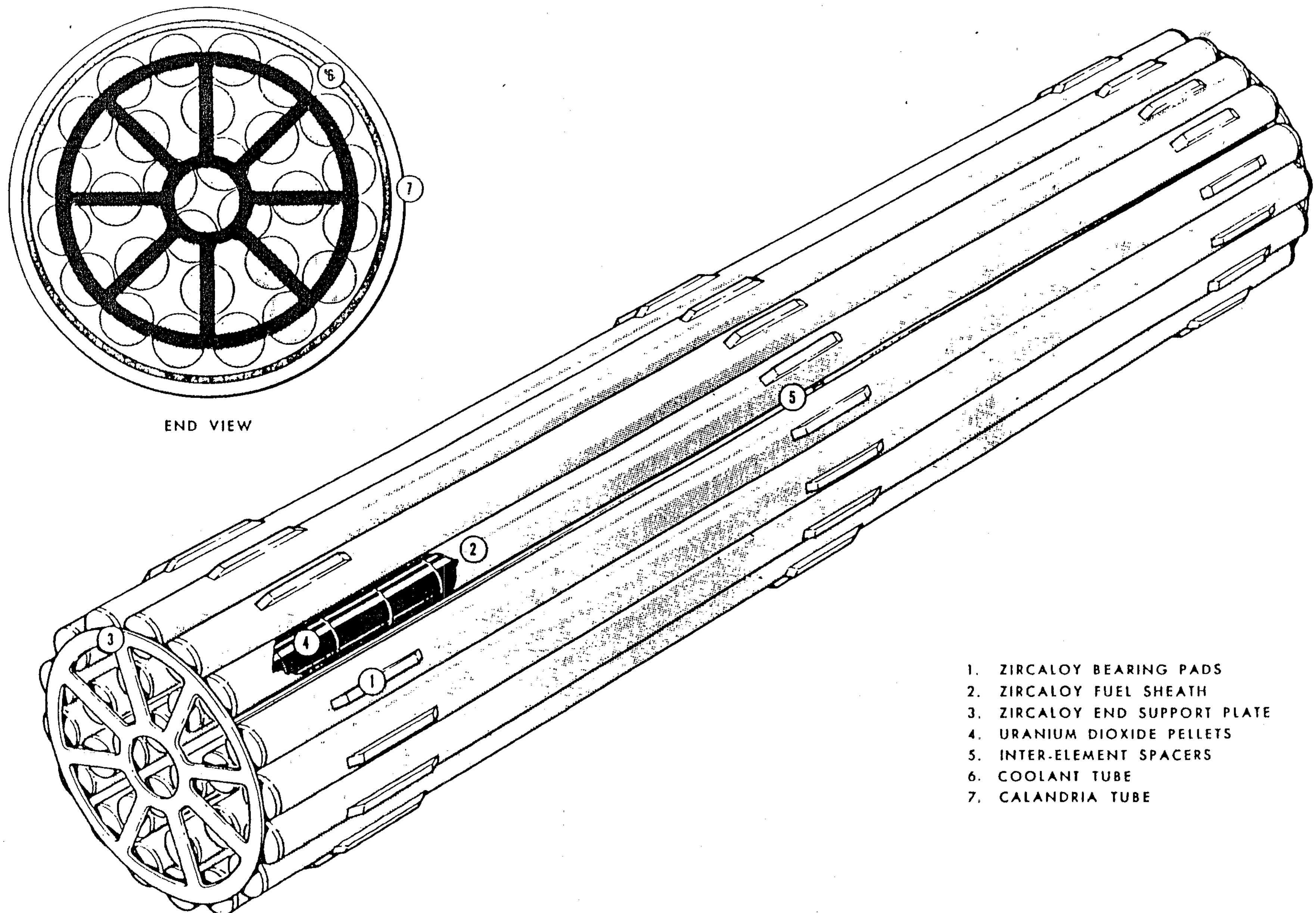


FIGURE 4 CANDU FUEL CHANNEL



1. ZIRCALOY BEARING PADS
2. ZIRCALOY FUEL SHEATH
3. ZIRCALOY END SUPPORT PLATE
4. URANIUM DIOXIDE PELLETS
5. INTER-ELEMENT SPACERS
6. COOLANT TUBE
7. CALANDRIA TUBE

5.2—1 28 ELEMENT FUEL BUNDLE

44 37500—5
1968

UNIFORM SPHERE HEAT FLOW

GENERAL EQUATION

$$\frac{d^2T}{dr} + \frac{2}{r}\frac{dT}{dr} + \frac{q'''}{k} = 0$$

$$r\frac{d^2T}{dr} + 2\frac{dT}{dr} = -\frac{q'''}{k}r$$

$$\frac{d}{dr}\left(r\frac{dT}{dr}\right) + \frac{dT}{dr} = -\frac{q''}{k}r$$

$$r\frac{dT}{dr} + T = -\frac{q'''}{2k}r^2 + c_1$$

$$Tr = -\frac{q'''}{6k}r^3 + c_1 r + c_2$$

$$T = -\frac{q'''}{6k}r^2 + c_1 + \frac{c_2}{r}$$

BECAUSE OF SYMMETRY ABOUT THE CENTRE

THERE IS NO HEAT FLOW WHERE $r = 0$

AND T IS A MAXIMUM AT THIS POINT

$$\frac{dT}{dr} = 0 \quad \text{AT} \quad r = 0$$

$$T = T_{max} \quad \text{AT} \quad r = \infty$$

THUS

$$c_1 = T_{max}$$

$$c_2 = 0$$

SUBSTITUTING BACK GIVES

$$T = -\frac{q'''}{6k}r^2 + T_{max}$$

HEAT LOST THROUGH SURFACE = HEAT GENERATED IN SOLID

$$q_r = q''' \frac{4}{3} \pi r^3$$

HEAT GENERATED IN SPHERE

$$q''' \qquad (J/s\ m^3)$$

HEAT CONDUCTED THROUGH SURFACE OF SPHERE

$$q_s = q''' \frac{4}{3} \pi R^3 \quad (J/s)$$

TEMPERATURE PROFILE

$$T = T_{max} - \frac{q'''}{6k} r^2$$

TEMPERATURE DIFFERENCE

$$T_{max} - T_{surface} = \frac{q'''}{6k} R^2$$

HEAT CONDUCTED THROUGH SURFACE OF SPHERE

$$q_s = (T_{max} - T_{surface}) \left(\frac{6k}{R^2}\right) \frac{4}{3} \pi R^3$$

$$= (T_{max} - T_{surface}) \left(\frac{2k}{R}\right) (4 \pi R^2)$$

$$= \frac{2k\, A_{surface}}{R} (T_{max} - T_{surface})$$

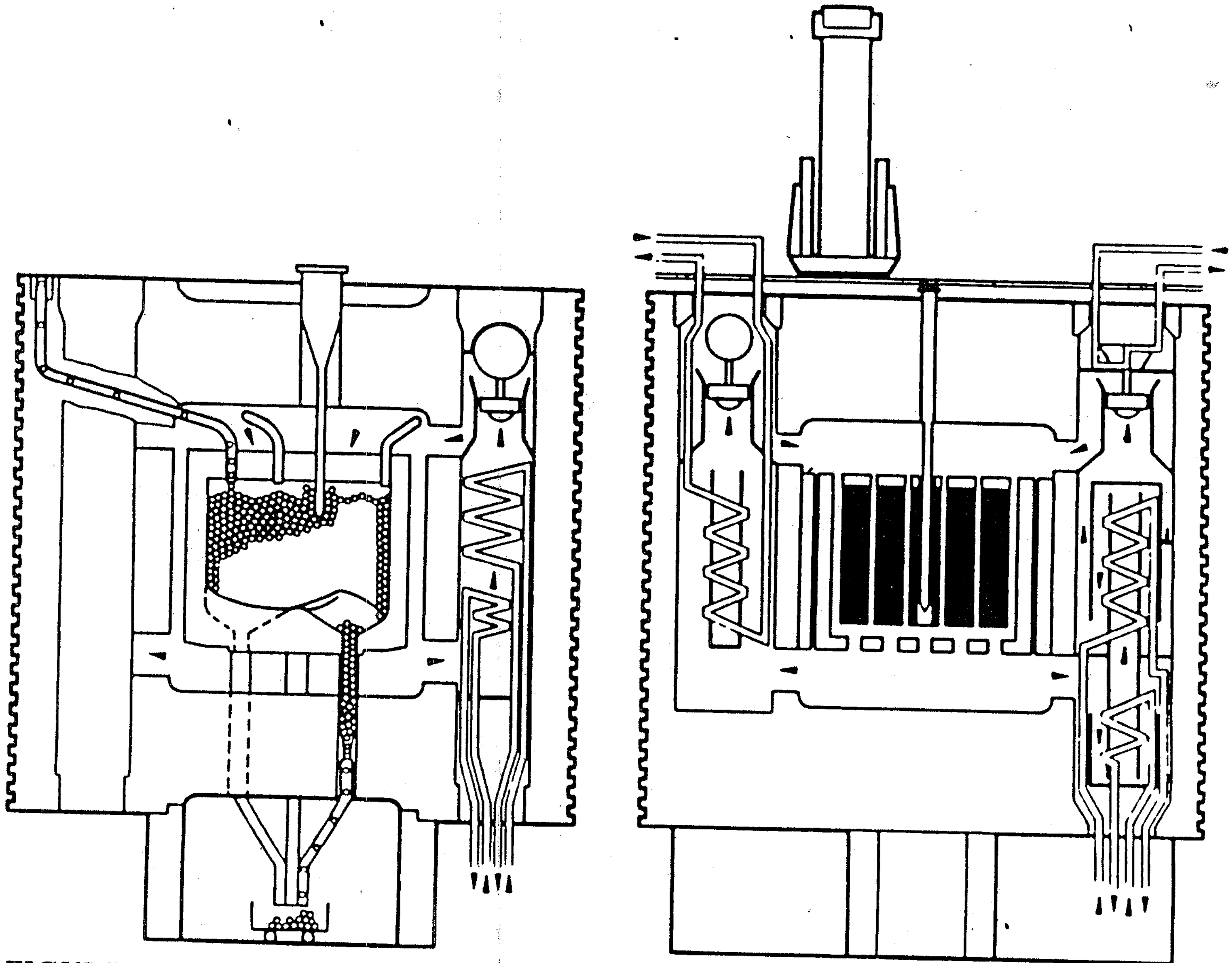


FIGURE 11-9
Comparison of the pebble-bed and HTGR gas-cooled reactor concepts. (From H. Oehme in "Gas-Cooled Reactors: HTGR and GCFR," CONF-740501, May 7–10, 1974.)

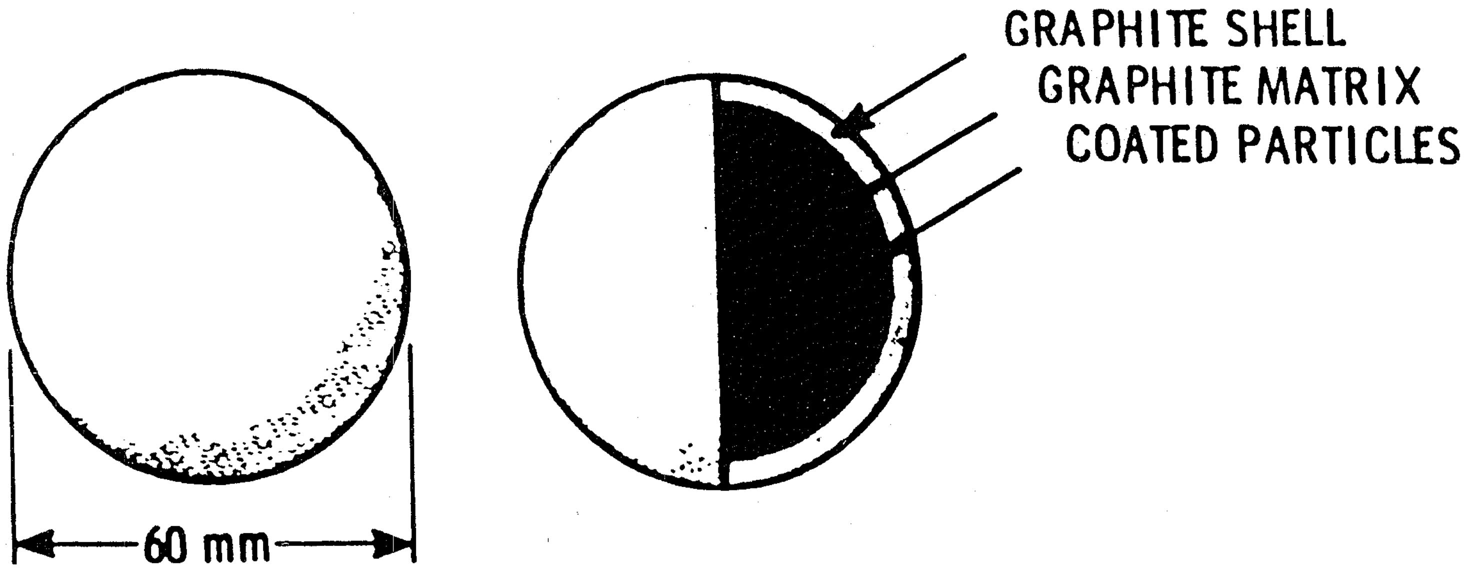


FIGURE 11-10
Fuel elements for the pebble-bed reactor.

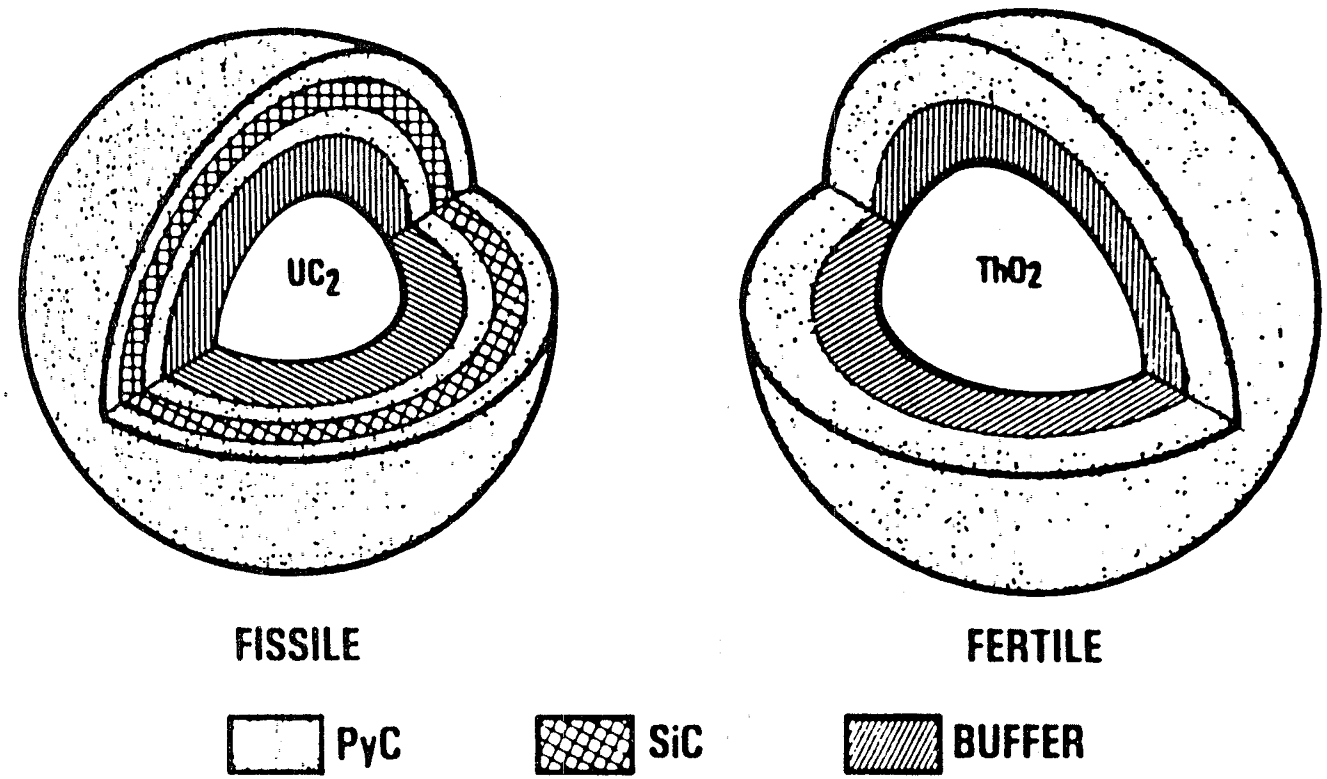


FIGURE 9-9
Fissile and fertile microsphere fuel particles for the high-temperature gas-cooled reactor [HTGR]. (Courtesy of the General Atomic Company.)

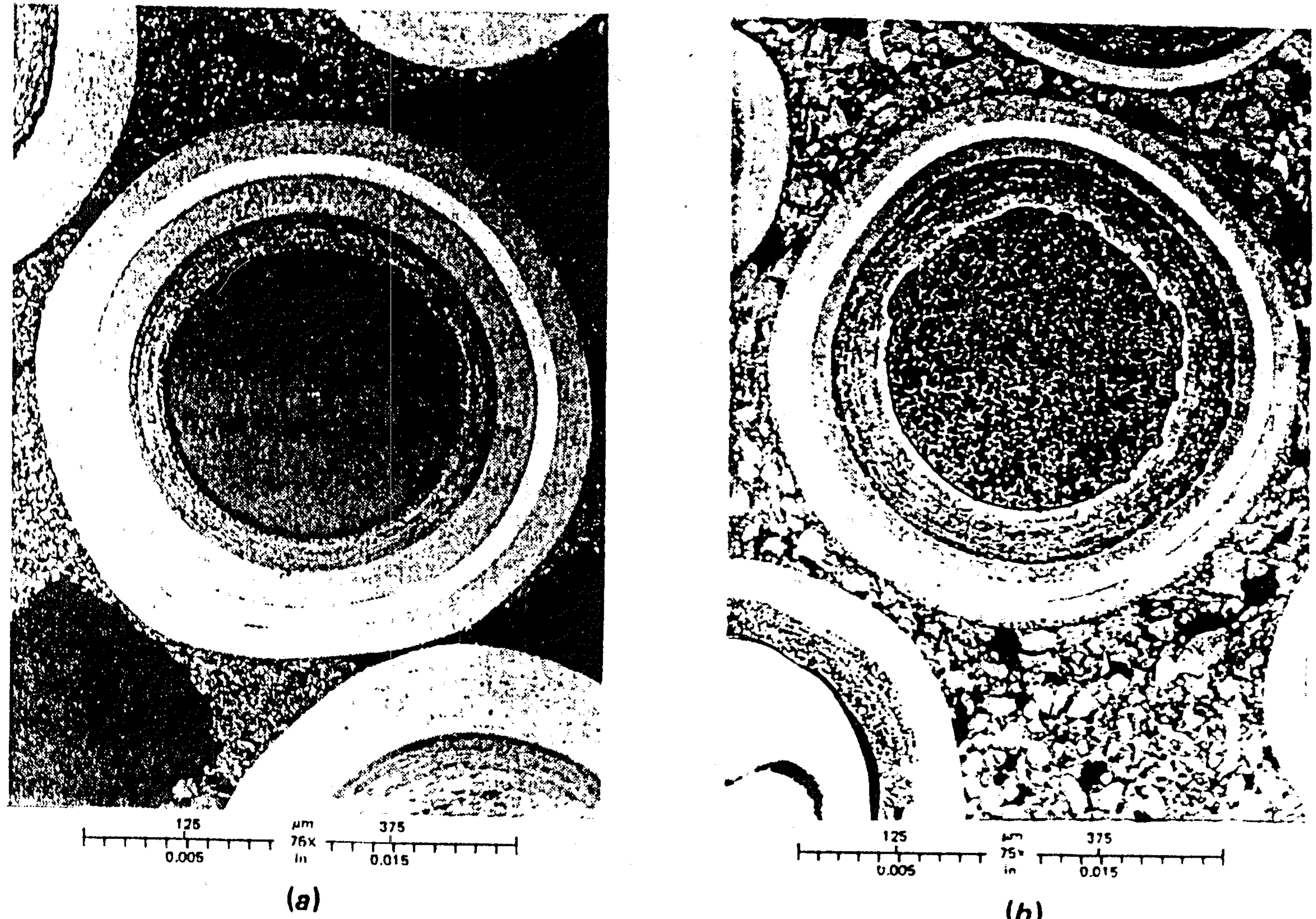
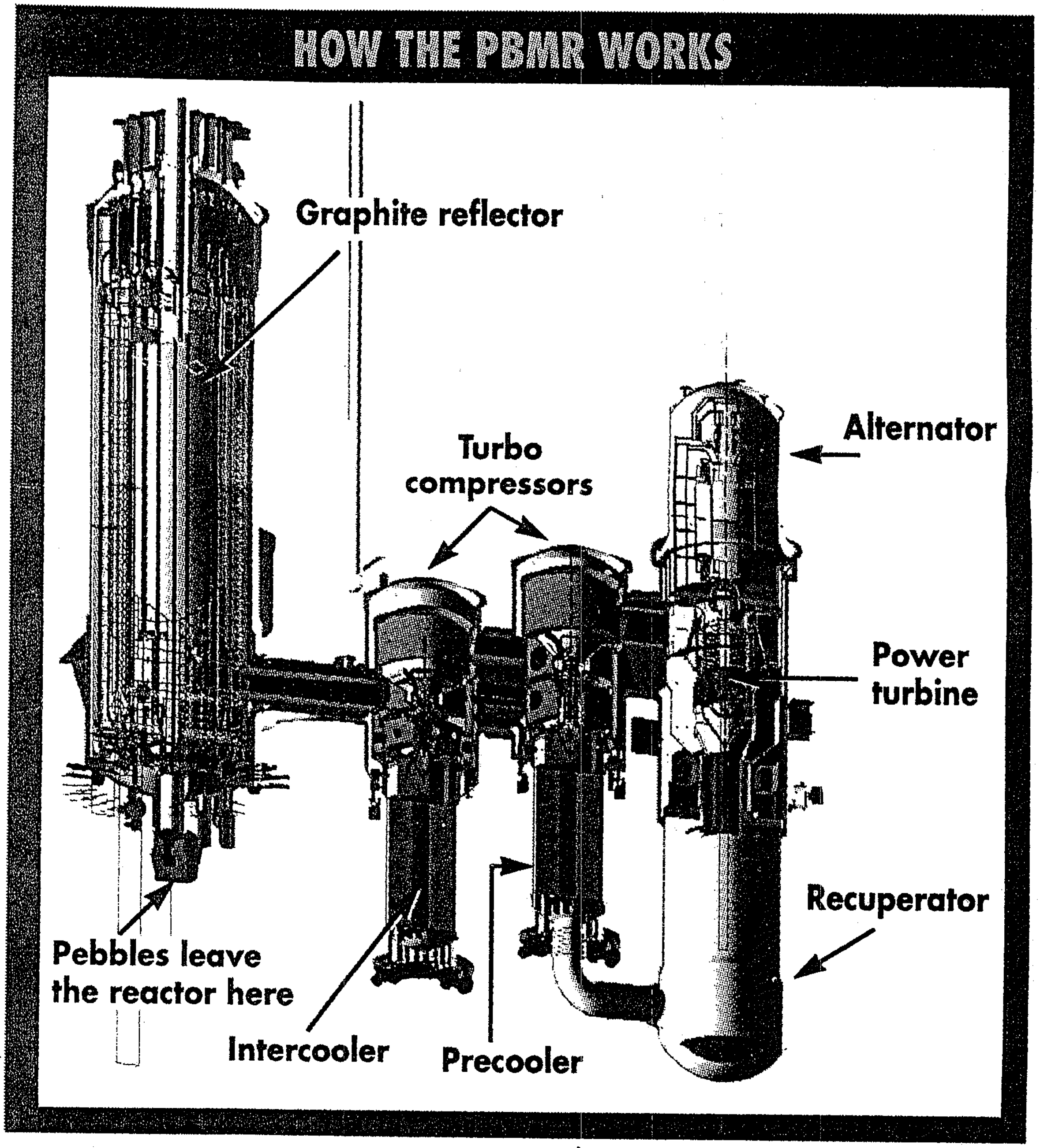


FIGURE 9-10
TRISO-coated (4Th, O)$_2$ fuel particles: (*a*) unirradiated, and (*b*) irradiated to 12 percent burnup at 1000°C. Magnification 75 ×. (Courtesy of Oak Ridge National Laboratory, operated by the Union Carbide Corporation for the U.S. Department of Energy.)


HOW THE PBMR WORKS
Graphite reflector
Turbo compressors
Alternator
Power turbine
Recuperator
Pebbles leave the reactor here
Intercooler
Precooler

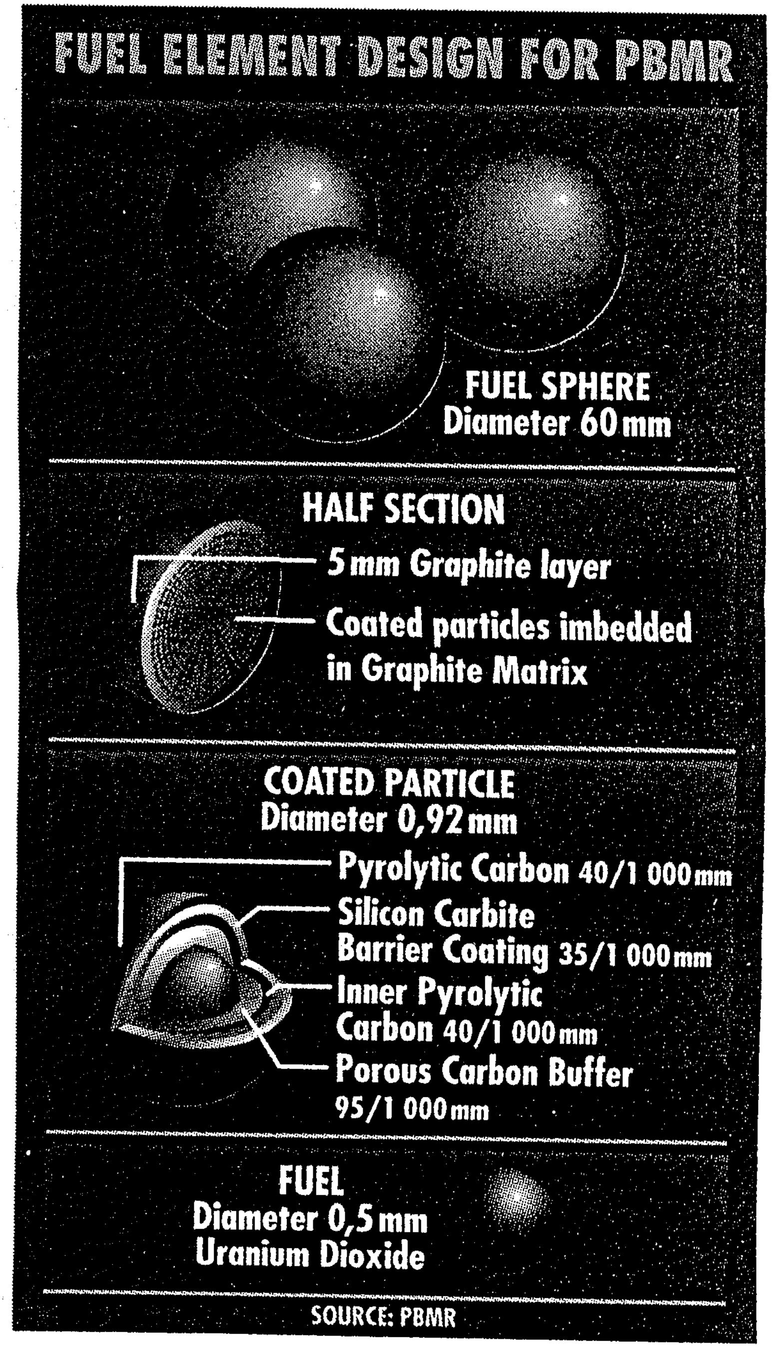

FUEL ELEMENT DESIGN FOR PBMR
FUEL SPHERE
Diameter 60 mm
HALF SECTION
5 mm Graphite layer
Coated particles imbedded in Graphite Matrix
COATED PARTICLE
Diameter 0,92 mm
Pyrolytic Carbon 40/1 000 mm
Silicon Carbite Barrier Coating 35/1 000 mm
Inner Pyrolytic Carbon 40/1 000 mm
Porous Carbon Buffer 95/1 000 mm
FUEL
Diameter 0,5 mm
Uranium Dioxide
SOURCE: PBMR

TABLE 11.4 **Uranium and Plutonium Ceramics**

	Melting Point (°C)	*Theoretical Density*	*Typical Density*
UO_2	2750	10.97	10.5
PuO_2	2280	11.46	—
UC	2400	13.63	12.97
PuC	1654	13.6	—
UN	2630	14.32	13.52
PuN	>2500	14.2	—