THE STUDIES

Why they were made, what they cover, thumbnail guides to detailed summaries that follow

Although private industry, under government contract, has been taking part in the atomic-energy program from its beginnings, the Atomic Energy Commission has sought ways in which industry could participate independently for maximum development of nuclear fission for human welfare. By the summer of 1951, AEC had arranged with four groups of two firms each to make, at their own expense, initial surveys of reactor technology.

These four groups were: Dow Chemical Co and Detroit Edison Co; Monsanto Chemical Co and Union Electric Co; Pacific Gas and Electric Co and Bechtel Corp; Commonwealth Edison Co and Public Service Co of Northern Illinois.

The "teams" independently agreed with AEC to: (1) determine the engineering feasibility of their designing, constructing and operating dual-purpose reactors to produce fissionable material and power (2) examine economic and technical aspects of building such reactors in the next few years (3) determine the possible research and development needed (4) recommend industry's role in designing, building and operating such reactors. To members of these teams, AEC made available pertinent data and research results.

To bring as much information as possible to interested industrial firms and engineers, the reports submitted by the study groups were screened and declassified versions prepared. These are now available in a single pamphlet, "Nuclear Power Reactor Technology" (Supt of Documents, U. S. Govt Printing Office, Washington 25, D.C.; 25¢)

In the pages that follow, you'll find the essence of the declassified material, streamlined for easy reading.

In reading the reports, bear in mind that, for security reasons, they're fragmentary—lacking, particularly, detailed data on reactor design. Also, the teams were instructed to consider dual-purpose reactors. Thus proposals are not necessarily those that would have been made if the studies had been directed to power-only reactors with plutonium produced having value only as fuel. Finally, the proposals are conditioned by the requirement that designs be such as might be built in the next few years.

While the proposals differ in regard to reactor designs, all teams concur in the belief that dual-purpose reactors are technically feasible and could be operated so the plutonium credit would reduce cost of power. Conversely, all agree that no reactor that could be built in the very near future would be economical on the basis of power generation alone.

IN BRIEF: Four approaches to atomic power

Dow Chemical—Detroit Edison

- Sodium-cooled fast breeder reactors give low fuel cost and high coolant temperature for efficient power production. This team concentrated on them.
- Simplified solid fuel elements get nod in design now under way, but aim is more "mobile" fuels, even fluids, for easier handling and reprocessing.
- Five reactor arrangements briefly itemized use solid, slurry and liquid fuels, vary from 7500 to 138,000-kw electrical output at 30% thermal efficiency.

Monsanto Chemical—Union Electric

- Sodium-cooled graphite-moderated reactors of two similar designs were studied:
- One has 1000-mw heat output. Using sodium temperature range of 650 to 300 F generates 3 million lb per hr of 150-psia saturated steam, 208,000 kw net.
- For other reactor (3000 mw) two power cycles were considered: (1) using full temperature range of sodium (900 to 300 F) generates 8.8 million lb per hr of 400-psia 746-F steam, gives 834,000 kw net output (2) rejecting heat of sodium below 500 F evaporates 4.8 million lb per hr, gives 554,000 kw net.

Pacific Gas and Electric—Bechtel

- Water-cooled thermal reactor and sodium-cooled fast reactor, both 500-mw heat output, were studied:
- Water-cooled reactor, with heavy-water moderator, develops 100,600 kw net, using 175 psia 378-F steam.
- Sodium-cooled reactor is much smaller physically, generates 1,600,000 lb per hr of 500-psia 750-F steam. Net electrical output is 145,300 kw.

Commonwealth Edison—Public Service

- Helium-cooled graphite-moderated reactor has 350-mw heat output, generates steam at 265 psia, 525 F. Net electrical capacity is 46,700 kw.
- Heavy-water-cooled, heavy-water-moderated reactor has 1064-mw heat output. Turbines operate on 180-psia saturated steam, develop 211,500-kw net.

Dow Chemical – Detroit Edison

Liquid-metal-cooled fast-neutron breeder reactor with fuel elements of solid uranium, under design by this team, offers high coolant temperatures for steam generation. They look to future reactors using liquid-metal fuel with continuous reprocessing

Dow Chemical–Detroit Edison studies aimed to obtain as many desirable characteristics as possible, using materials, processes and designs now existing in partly developed form. This led to concentration on a liquid-metal-cooled fast-neutron breeder reactor.

This type gives high coolant temperature needed for efficient power recovery. Fuel elements will be uranium alloy in solid form. It is planned to use uranium in the breeder blanket as fertile material for making plutonium.

Economical power reactors, in Dow-Detroit thinking, must meet these important specifications:

1. Use low-cost fuel: that is, be a breeder reactor that *(within itself)* converts thorium or depleted uranium to fissionable material. Throughout this report, "breeder reactor" means one that produces more fuel than it burns.
2. Reactor should be of fast-neutron type to produce an excess of fissionable material above its own needs.
3. Reactor should operate at high temperature. Core temperature of 950 to 1100 F may be possible.
4. Design should permit integration with a variation of improved extraction processes now under study at Ames and Brookhaven.
5. Unit should require minimum "exclusion area" (segregated area specified for public safety). Exclusion area can be minimized by continuous removal and segregation of fission products.
6. Reactor should use uncanned fuel, preferably mobile or fluid.
7. Reactor should be inherently self-regulating.

Operating Temperatures. Both power level of a reactor and rate of plutonium production parallel heat removal. More heat can be removed by lower coolant temperature, but production of *economical power requires a relatively hot* coolant. For a reactor to produce both power and fissionable material economically, fuel elements must be designed to operate at temperatures high enough so production of plutonium or other fissionable material will not be limited by power-generating requirements.

Commercial future for atomic power appears to depend on development of breeder reactors. Sale of surplus fissionable material will help offset high capital and processing costs, significant fuel costs of nuclear plants.

Process Integration. Use of liquid fuel, and closer integration of the reactor with the separation and decontamination processes, will reduce costs. Molten-metal processes may be developed into a superior separation method. This would be more compatible with present reactors and much cheaper than the aqueous (water-solution) processes. For one thing, it would avoid machining and jacketing fuel slugs.

Mobile fuels facilitate frequent and rapid processing. Also, a closely integrated processing system must be provided to recover pure plutonium and remove "hot" fission products. These aims can be achieved by the system outlined above. So most desirable fuel is one that can be liquid at all times.

If a solid fuel is necessary, then fuel elements must be so easily formed that they can be fabricated by remote control. Fuel elements cost from molten metal should meet this need.

Fluid fuels that can be considered for future development include:

1. *Eutectics* of uranium or of plutonium with melting points approxi-

I—Data on Five Proposed Reactor Arrangements Using Sodium Cooling

	A-1	A-2	A-3	B	C
	Radiator, liquid fuel, liquid coolant	*Radiator, slurry fuel, liquid coolant*	*Radiator, liquid fuel, solid fertile material, liquid coolant*	*Radiator, solid fuel, liquid coolant*	*Liquid-liquid, liquid fuel, liquid coolant*
Maximum heat output, kw	25,000	460,000	75,000	450,000	220,000
Max coolant temp for steam generation, F	900	1020	900	1020	930
Electrical output at 30% efficiency, kw	7500	138,000	22,500	135,000	66,000
Coolant material:	Sodium*	Sodium	Sodium	Sodium	Sodium
Max circulating velocity, fps	30	30	10 (30)	30	30
Temperature rise, C	130 (260)	120	140	280	300
Max temperature, C	480 (610)	480	480	550	500
Min temperature, C	350	350	340	270	200
Limiting factors on specific power	High heat release per unit volume in fuel requires very small fuel elements or large temperature drops	dc_p of coolant	High heat release per unit volume in fuel requires very small fuel elements or large temperature drops	dc_p of coolant	dc_p of coolant
Max coolant temperature limited by:	Corrosion	Corrosion	Corrosion	Corrosion	Corrosion

*Melting temperature, 98 C; boiling temperature, 883 C; thermal conductivity, 0.15 cal/cm/sec/C; density times specific heat (dc_p), 0.24 cal/cm³