Reactor loops at Chalk River

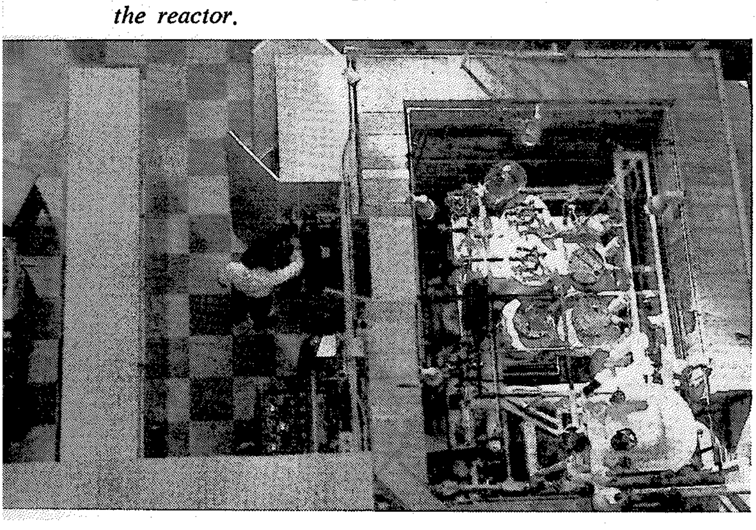
Though higher fluxes are now available elsewhere for experiments, the in-reactor loops of NRX and NRU are still unsurpassed for engineering tests of materials under simulated power reactor conditions

BY RONALD NEEDHAM*

VIEWED IN the light of the rapid growth of nuclear technology during the last decade, the useful life of Chalk River's NRX reactor, commissioned in 1947, might reasonably be supposed to have long since expired. In certain areas of research this is to some extent true; the value of both NRX and the more recent NRU (commissioned in 1957) for some experiments is gradually being surpassed by the still higher influx reactors and pulsed neutron sources now being built or planned in other countries. However, for engineering testing of materials under simulated power reactor conditions their value is still unsurpassed, and seems likely to remain so for a good many years.

Tests of this sort are usually carried out in reactor "loops," i.e. test rigs that pass through a reactor core, each rig individually cooled and controlled. Chalk River engineers helped pioneer this technology, and NRX had already been equipped with simple loops before its breakdown in 1952. Complex systems have now been developed at many places, but the very nature of the NRX and NRU reactors endow the Chalk River loops with a combination of desirable features yet to be equalled elsewhere. Firstly, the size and construction of the two reactors allows quite large test rigs, and hence full-scale test samples, to be inserted in the core. Neither reactor is pressurized, and thus removal and replacing in-core components is not complicated by the making and breaking of reactor pressure seals. Another advantage is that their neutron flux varies smoothly throughout their large cores, and also varies only gradually with time. Hence, when irradiating a large sample (or a string of smaller ones), intricacies arising from unknown or complex variations along the length of the sample (or string) are minimized. The high flux of both reactors is valuable, both to give high heat ratings without high enrichment, and to keep down the duration of individual experiments.

Here we see the X-7 "out-of-reactor" equipment compacted behind its shielding, of concrete-brick wall adjacent to the reactor.

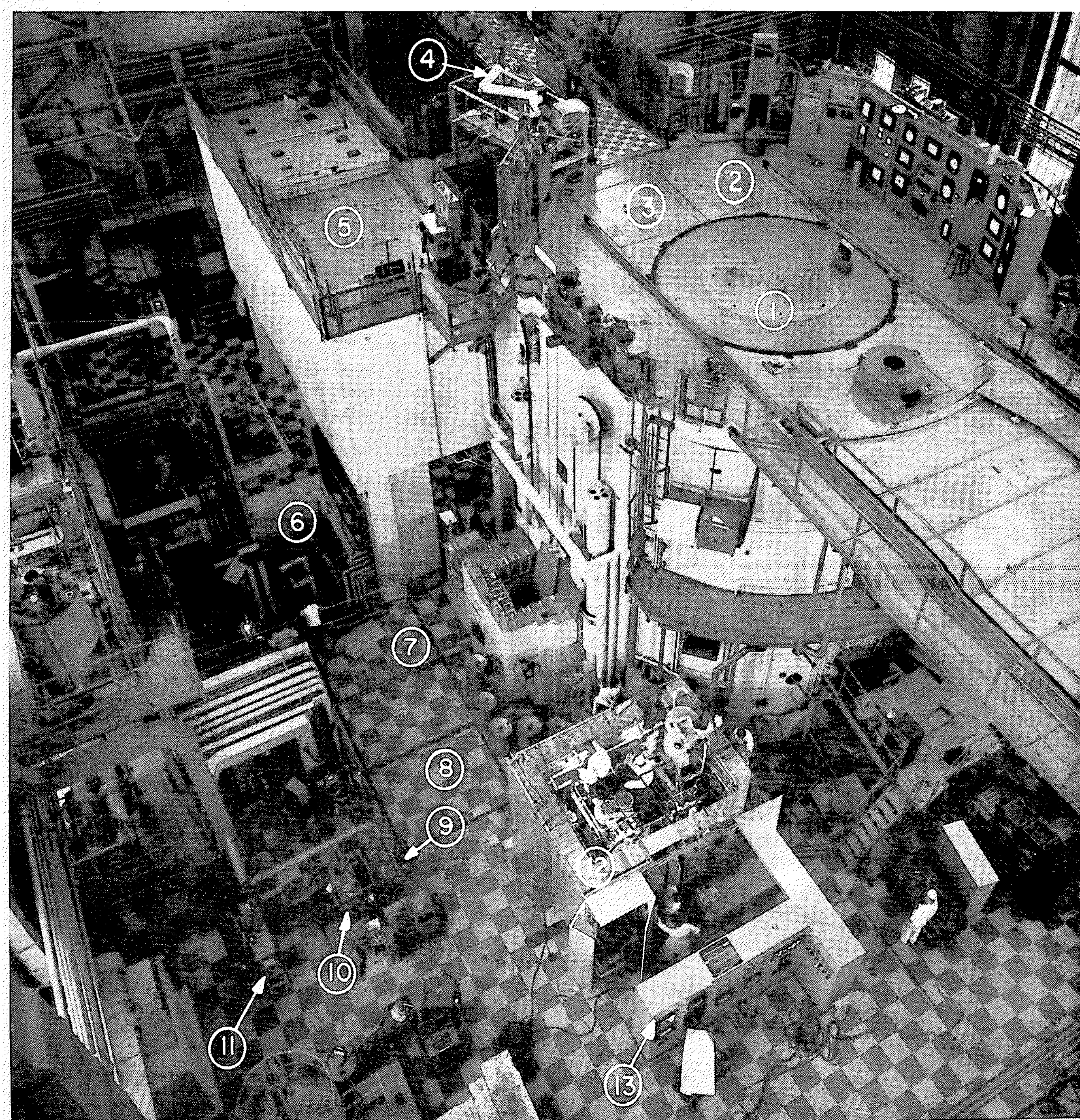


Loops are tightly scheduled

This unique combination of desirable features has attracted the attention of engineers and scientists in many other countries, and it is not surprising that the Chalk River loops are very tightly scheduled, many on collaborative programs with other organizations. Experiments in the NRX loops contributed to the design and operating conditions of the fuel in the U. S. nuclear submarines. The NPD and CANDU fuel elements were designed on the basis of full-scale loop experiments, including full-scale fuel failure tests on deliberately defected fuel-elements to ascertain the hazards involved in sheath failures. One NRX loop, the largest organic-cooled loop yet commissioned, is helping to unravel the new technology of organic cooling. Another loop is being used in collaboration with the UK Atomic Energy Authority to develop fuel for superheated-steam conditions; here temperatures are much higher than in the water-cooled loops and the fuel specimens glow red at full-power operation. This same loop can also be used for experiments with fog (wet steam) as well as with superheated steam. In neighboring NRU, the 2,200-kw E-20 loop has the greatest heat-removal capacity of any loop this side of the Iron Curtain, and, as far as is known, in the world, and its J-16 brother recently dismantled was not far behind at 1,500 kw. Here, too, facilities are being augmented. Extra "out-pile"

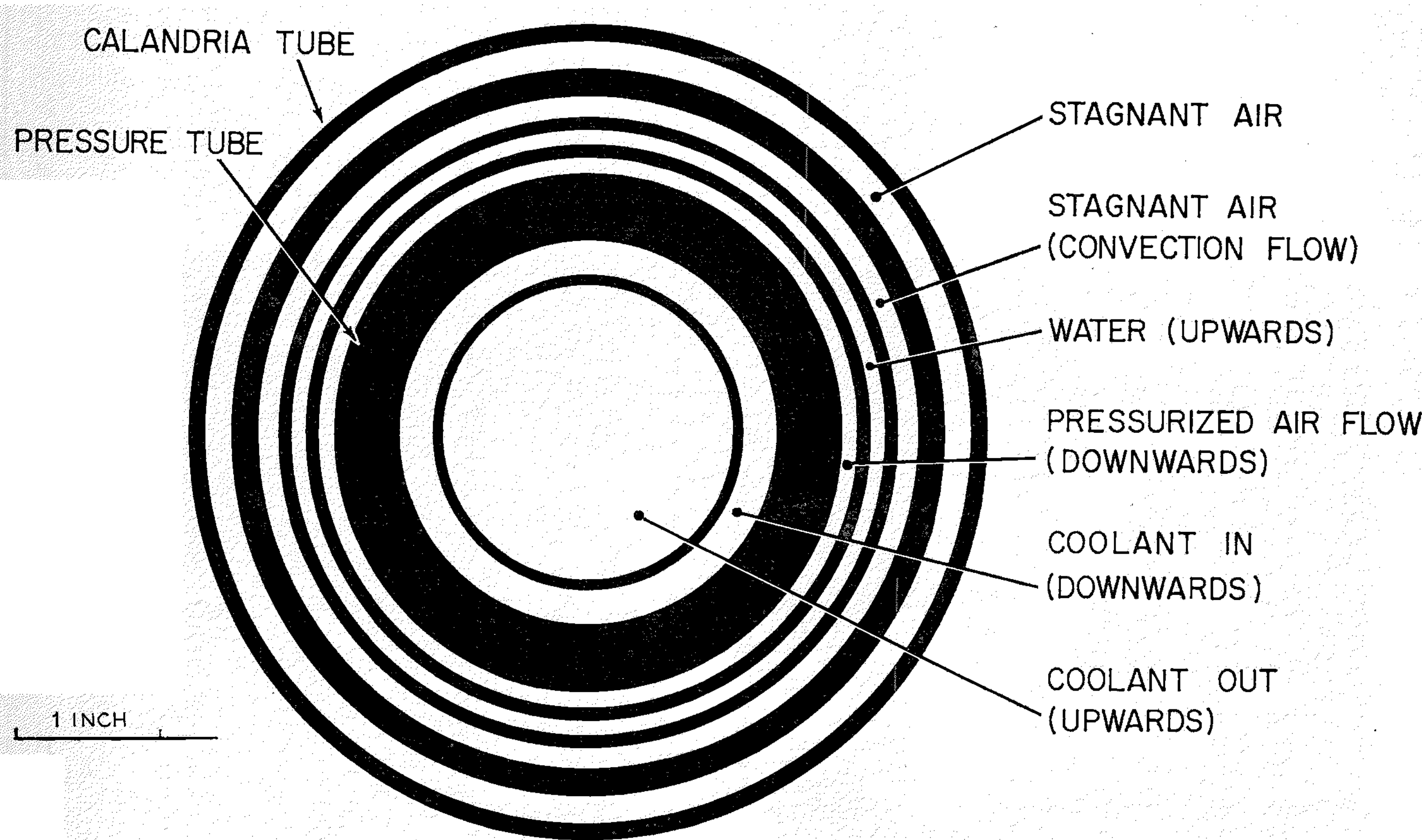
* *The irradiation facilities described in this article result from the combined efforts of many different groups at Chalk River and in industry. This text was prepared by Ronald Needham, Technical Information Branch, Atomic Energy of Canada Ltd., Chalk River.*

Walking along the east side of Chalk River's NRX reactor, one is literdlly framed by loop equipment, overhead, underfoot, and on either side. (1) The deck plate covering the reactor structure (2, 3) Shielding over the recombination rooms, through which loop piping passes to the "out-of-reactor" equipment (4) Line from X-7 loop to out-of-reactor station (5) Shielded room housing loop equipment. One concrete slab is lifted out of position during maintenance of X-4 loop (6) X-5 loop frame — concrete slab is removed during maintenance (7) Concrete slab over X-2 loop frame (8) Concrete slab over X-3 loop frame (9) X-3 loop glove box (10) X-1 loop glove box (11) X-2 loop glove box (12) X-7 loop, modifications are under way (13) Instrument and control panel of X-7 loop



equipment will allow boiling-water and fog-cooling tests in the E-20 test-section by mid-1963. The J-16 loop being replaced by a new facility for materials testing in a high fast neutron flux, and a large organic-cooled loop will shortly be installed at the E-12 lattice site. Allowance for a loop in this position was included in the design of NRU some ten years ago.

In common with those at other nuclear centres, the Chalk River loops find their widest application in testing prototype fuel elements and examining the compatibility of coolants and fuel-cladding materials under intense irradiation; they are also used to a lesser extent for the evaluation of mechanical components and instruments. The part of the loop that will contain the test specimens is assembled in a tube whose dimensions will permit its insertion in a vacant lattice position in the reactor. The fuel assembly to be examined is instrumented with thermocouples, pressure probes, and

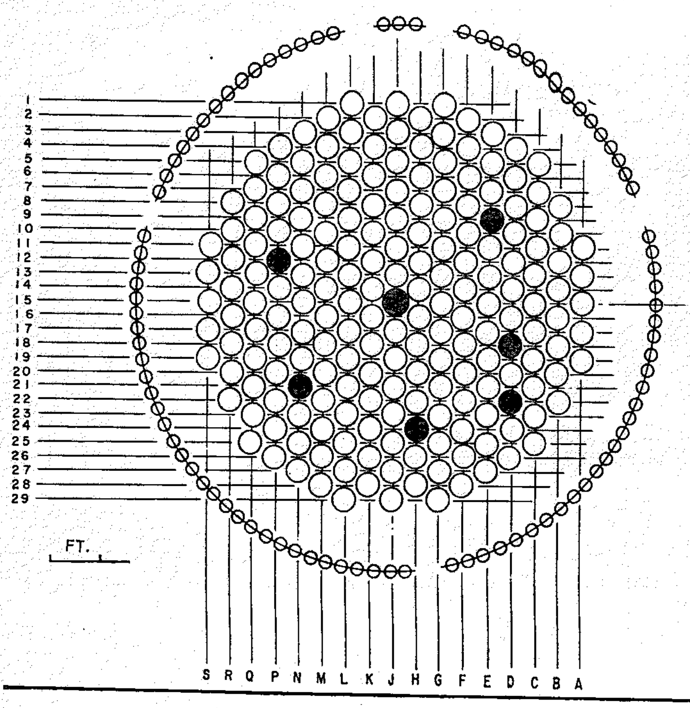


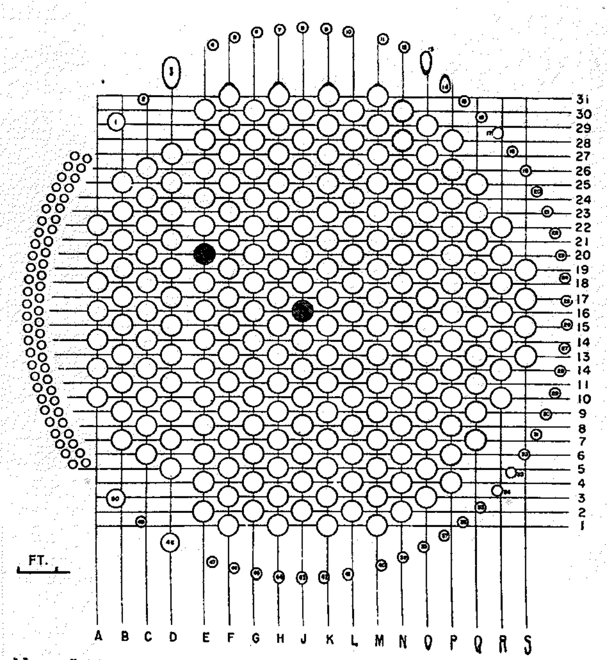
other devices prior to insertion in the loop; after insertion the necessary connections to the "out-pile" equipment (pumps, filters, surge-tank, heaters, coolers, degassing equipment, etc.) are made, the whole is thoroughly checked and the test started. The coolant is circulated at some preset temperature and pressure over the test-section for a period that may vary from days to months and, in some cases, even years. Meanwhile, frequent samplings of the coolant are analyzed for fission products, corrosion products, and deterioration induced by the intense radiation field. Even water has a very complex chemistry when exposed to intense radiation; organic coolants, with their more complex molecular structure, are little understood. A constant check on flow-rates and pressures at various locations in the loop also gives some indication of the condition of the sample, for example dimensional changes, and a constant monitoring indicates any release of radioactive materials into the coolant stream. Each of the main operating parameters is tied in with the main control system of the reactor, so that any serious condition instantaneously shuts it down, averting serious damage to the reactor or loop and reducing the inherent hazard to operating personnel.

Occasionally, as in evaluating the radiation stability of a new alloy or fuel design, it may be necessary to stop the experiment, remove the samples for examination, and then continue the test to higher radiation doses. More frequently, after the planned radiation dose has been reached, the sample will be removed to the remote-handling facilities in the laboratories, opened up, and examined in detail. Is there any general distortion? Are there ridges, collapsed areas, or other indications of possible sheath failure? Any crud deposits from the coolant, or corrosion? What about wear or fretting corrosion due to vibration of the assembly? Other questions can be answered only by destructive tests. Puncturing the sheath and measuring the fission gases evolved will give an indication of how much was released during the irradiation. Examination of the grain-growth in the fuel gives some indication of its heat rating and the temperatures reached during the irradiation. In this way it is possible to see if there were any local hot-spots. Sheaths and structural members are tested to see if their mechanical properties have changed; chemical and metallographic analyses of samples of these components may indicate why changes have — or have not — occurred. Finally, to fully understand the data obtained by the in-core tests, it may be necessary to compare them with the results obtained from tests on a similar assembly in an out-of-core section of the same loop, i.e. out of the neutron flux.

These are but a few samples of the loop experiments that occupy much of the effort available for applied research and development at Chalk River. They provide the information that gives AECL confidence in the CANDU-type reactor, and hopes for the more advanced concepts of organic- and steam-cooling. And it is the importance of such experiments that not only justifies the continued operation of "old" NRX, but makes it one of the leading research facilities in the world. ■

The inked-in circles in these diagrams of the NRX (left) and NRU (right) lattice configurations indicate the positions of the loops. The outermost ring of channels in each reactor passes through the neutron reflector, outside the reactor calandria.





Note: J-16 loop has been dismantled.

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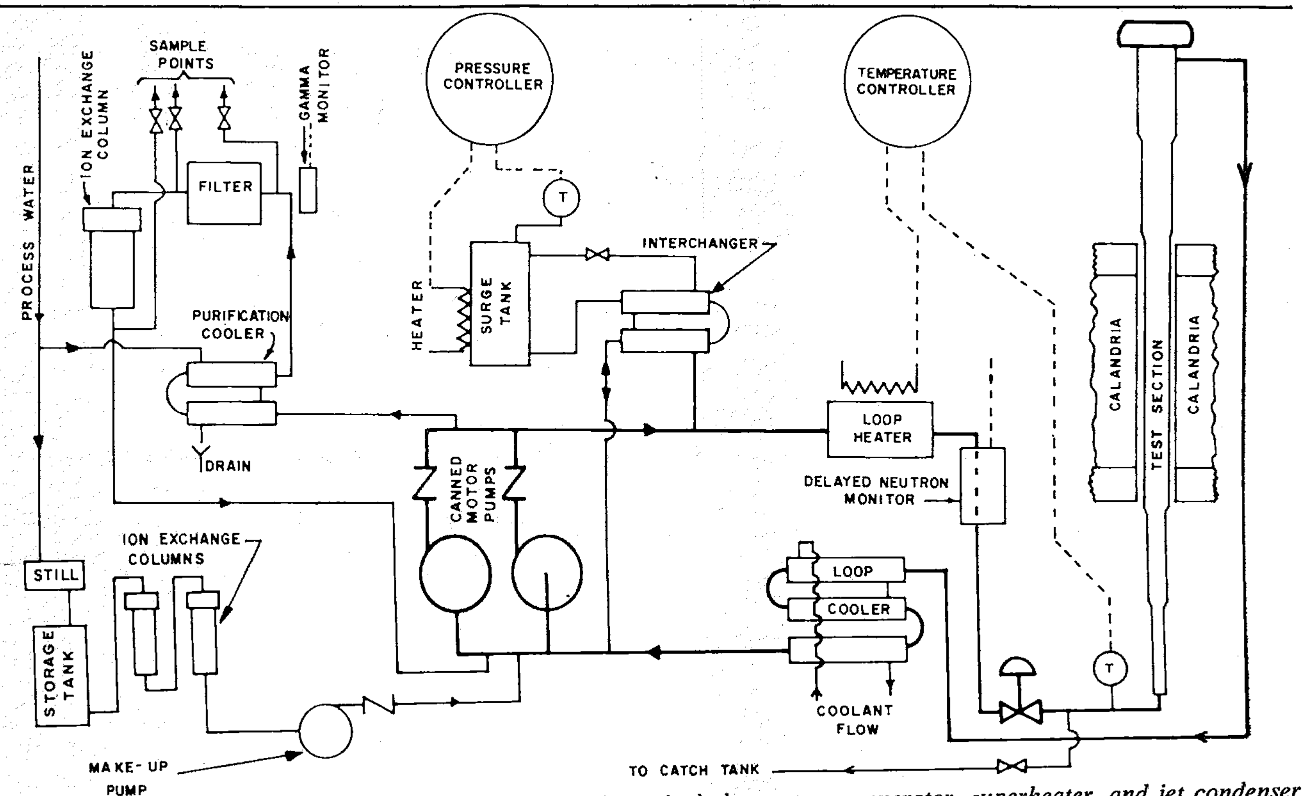

The main loop circuit in this simplified flow sheet of a typical loop is indicated by the heavy line. Specific loops are, of course, more complex. The X-4 loop, for example, includes a steam generator, superheater, and jet condenser in the main circuit.

DATA SHEET: NRX AND NRU LOOPS AT CHALK RIVER

REACTOR			NRX							NRU
LOOP			X-1	X-2	X-3	X-4	X-5	X-6	X-7	E-20
COOLANT			Water	Water	Water	Steam	Water	Water	Organics	Water
LATTICE POSITION			D-18	E-9	N-21	P-12	T-15 Central thimble	H-24	D-22	E-20
YEAR COMMISSIONED			1954	1954	1954	1961	1955	1955	1960	1959
MAXIMUM DESIGN PRESSURE		kg/cm² 16/in-	140 2,000	140 2,000	140 2,000	140 2,000	170 2,400	140 2,000	21 300	175 2,500
DESIGN TEMPERATURE		°C °F	260 500	260 500	260 500	454 850	288 550	260 500	425 800	340 650
PRESSURE TUBE TEST TUBE SECTION DATA	Material		Stainless steel	Stainless steel	Stainless steel	Stainless steel	Zircaloy-2	Stainless steel	Stainless steel	Zircaloy-2
	Inside diameter	cm in	2.6 1.025	2.6 1.025	2.6 1.025	2.4 0.94	9.7 3.82	2.6 1.025	3.7 1.45	9.2 3.63
	Wall thickness	cm in	0.254 0.10	0.254 0.10	0.254 0.10	0.272 0.107	1.73 0.682	0.254 0.10	0.125 0.049	0.953 0.375
	Flow direction		Up	Up	Down	Up	Re-entrant	Up	Up	Up
MAIN LOOP PIPING DATA	Material		Stainless steel	Stainless steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Carbon steel	Stainless steel
	Size	cm in	2.54 1	2.54 1	2.54 1	2.54 1	6.35 2.5	2.54 1	3.81 1.5	10.15 4
LOOP COOLANT DATA	Volume	litres ft³	77 2.7	77 2.7	77 2.7	96* 3.4*	350 12.3	77 2.7	570 20.	803 28.4
	Flow rate	litres/s gk/h gal(uk)/min. lb/h	0.87 — 11.5 —	0.87 — 11.5 11.5	0.87 — 11.5 —	— 320 — 700	6.0 — 80 —	0.87 — 11.5 --	2.3 — 30 —	14.4 — 190 —
	Heat removal	kw	50	50	50	25	550	40	200	2,000

*Includes volume in steam generators

See story overleaf ▶