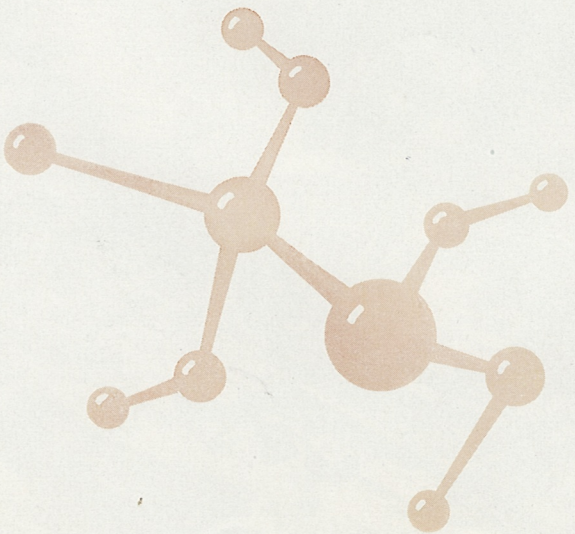
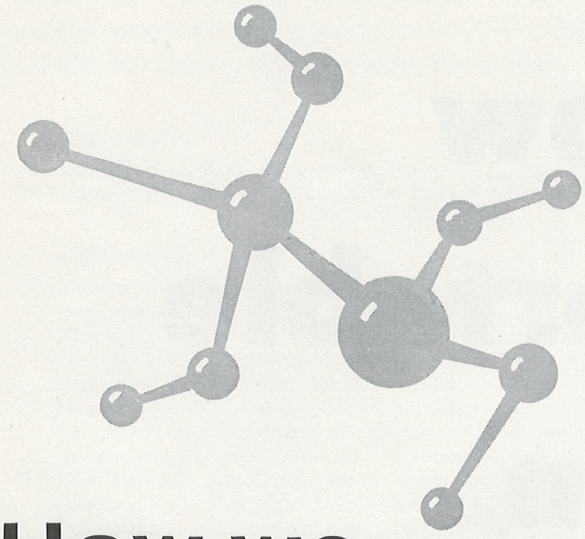
ALCO

How portable can a POWER REACTOR be?

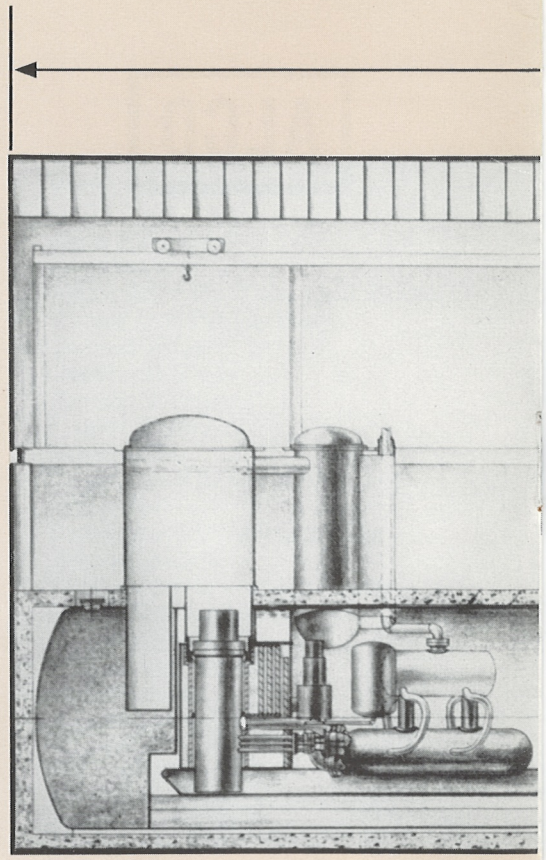


for the answer read . . . .

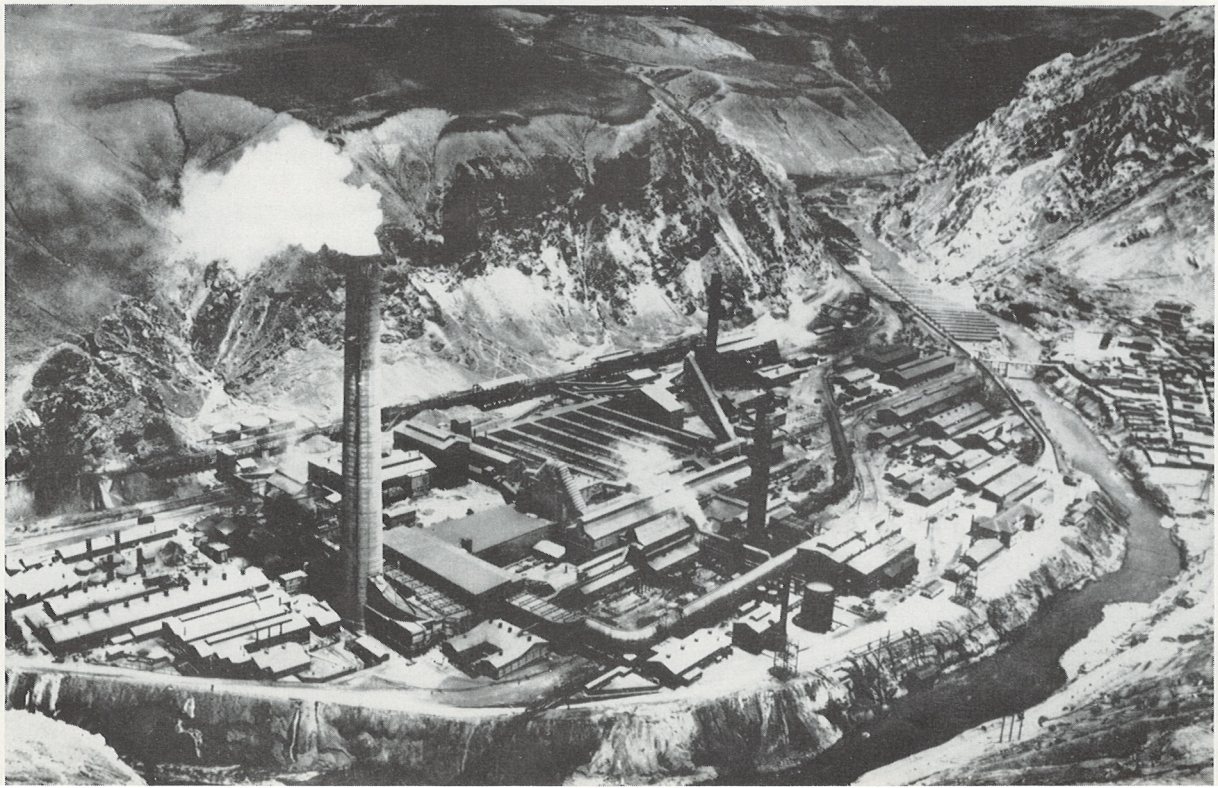


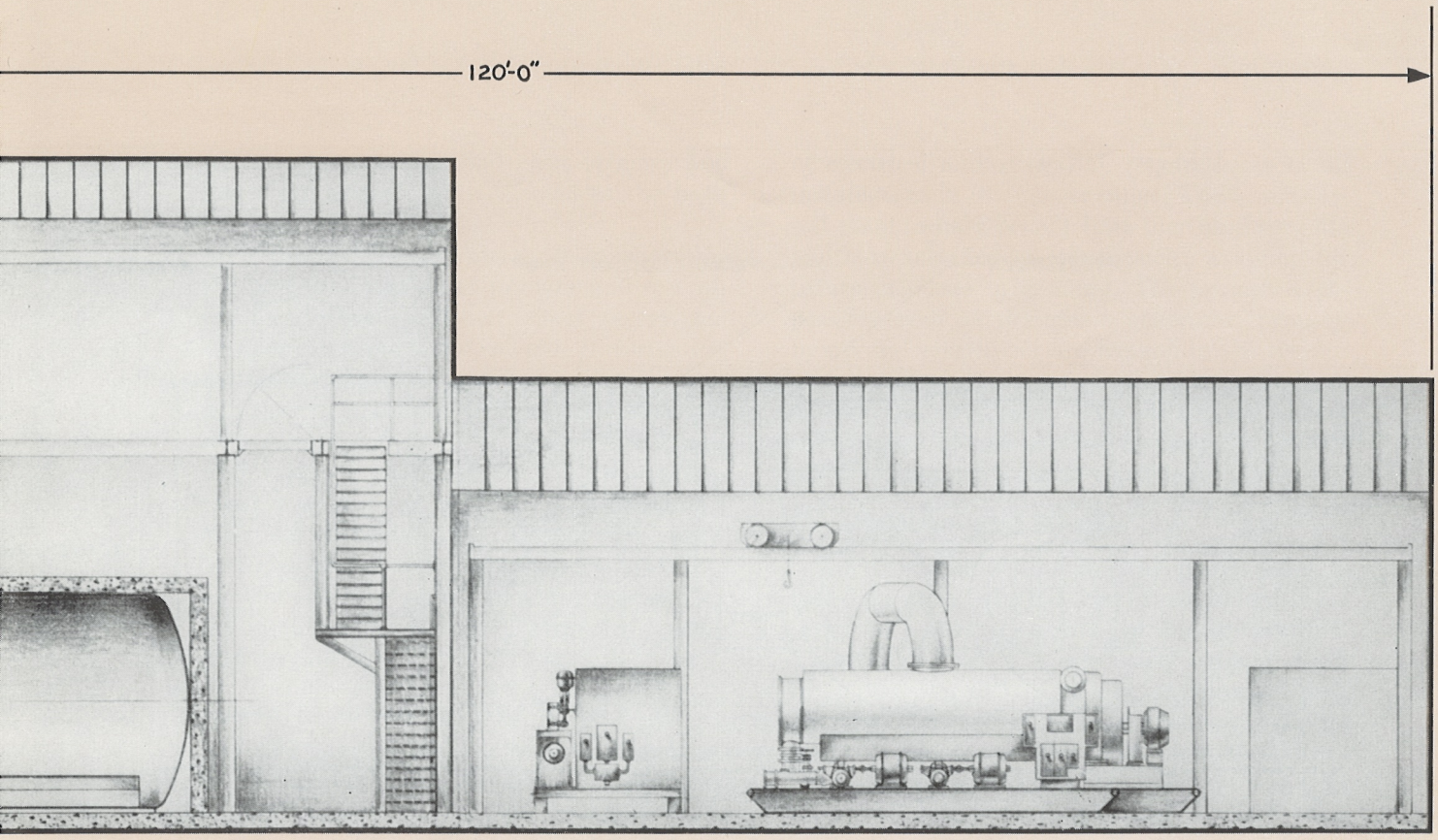
"How we package nuclear power"

by JOHN P. TULLY*



Packaged nuclear-electric power plant available from ALCO could be transported to remote sites such as this Peruvian copper mine and refinery to supply complete electrical power requirements.





Artist's conception shows ALCO's packaged nuclear power plant installed. Primary skid, weighing 84,650 lb, divided into two packages, is at left. It includes the reactor vessel, primary pump and piping, steam generator and other equipment. Secondary-system packages are at right.

Complete skid-mounted 2000-kw plant comes in packages ready for erection in remote areas

Since the completion of the Army Package Power Reactor (APPR-1) at Fort Belvoir, Va., ALCO has been actively engaged in the study and design of a packaged nuclear power plant suitable for remote-area installation. A major objective of this program was to obtain a completely packaged and preassembled system requiring a minimum of field assembly. As a result, all system components have been combined into a number of transportable packages or sections, none of which exceeds 30,000 lb or dimensions of 30 ft long by 9 ft high by 9 ft wide. These weight and dimensional limitations allow for air shipment of all packages and components.[1]

The design is based on the concept of APPR-1, which has proved to be extremely sound and relatively trouble-free since it was put into operation in April, 1957. Basic primary-system components such as fuel elements, control rods, control-rod drives, primary pumps, and fuel-handling equipment have proved very reliable under extensive testing and actual operation in APPR-1. Basic critical experiments, zero-power experiments, and actual full-power operation of the core at APPR-1 have provided valuable information in establishing the nuclear characteristics of the core of ALCO's new packaged reactor. Information available from the research and development program at APPR-1 helped to check the calculations on such items as core life, shielding, gamma heating in the reactor vessel wall, etc., in the packaged plant.

*Mr. Tully is a Project Engineer in ALCO's Atomic Energy Engineering Department, Schenectady, N. Y.

[1]While air shipment of ALCO's packaged reactor is possible, the only available aircraft capable of carrying such weights belong to the military. Sea and land shipments, however, can be made by existing commercial carriers.

General design philosophy

Recognizing both the desirable and undesirable features of the APPR-1-type plant, ALCO took the following approach in providing a plant which is easy to transport, erect, operate and maintain, and still improve on the established reliability and safety features of the APPR-1:

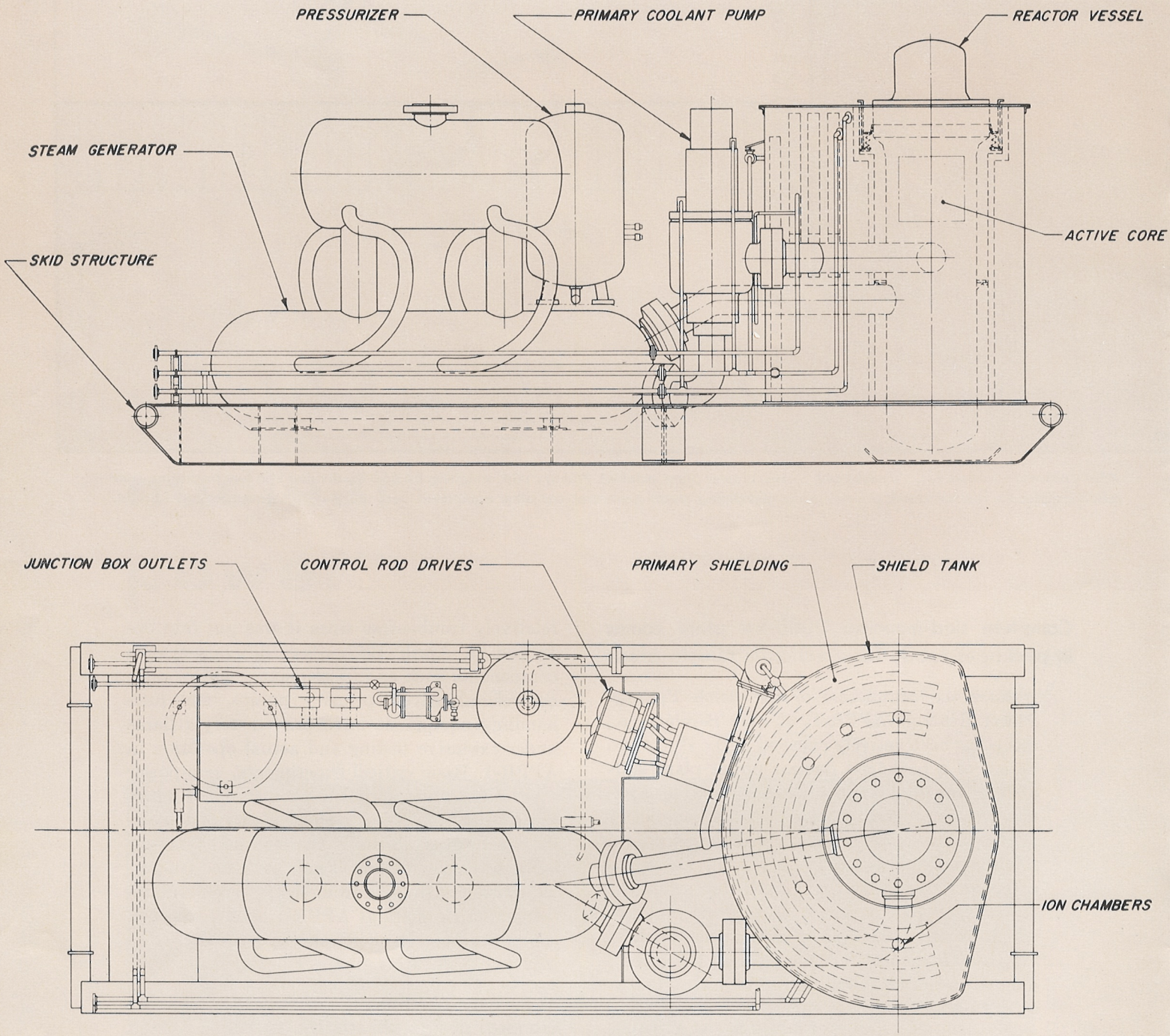


Figure 1—Elevation and plan view of skid-mounted primary-system package shows main components in position. The secondary-system mechanical and electrical equipment comes in seven other packages, all of which weigh less than 30,000 lb.

1. APPR-1 fuel element and basic primary and secondary systems were selected as the basis for the design.
2. An optimization study was made to determine the best combination of primary and secondary conditions and their effect on system components from a size, weight, performance, and cost standpoint.
3. In order to minimize field erection time and cost, components are mounted on skid bases. Prefabricated buildings and vapor containment are used, as well as quick-disconnect electrical connections and flanged pipe joints.
4. The grouping of components on the skids was worked out to provide maximum accessibility for maintenance and simplicity of assembly and operation.

Components already proved in APPR-1

The APPR-1 fuel element was selected as the best starting point for the design of the skid-mounted nuclear plant. This selection made available a great deal of critical experiment and actual operating experience and analytical data from which the core configuration, size, and performance could be established with maximum assurance of success. Studies showed that APPR-1 core size could be reduced by removing eight corner elements and still be capable of supplying up to 10 mw of heat. Zero-power experiments[2] are available, and establish initial reactivity for this core configuration. The five-control-rod array selected is the same as the APPR-1 pattern. The control-rod drives are identical to the ALCO-built APPR-1 drives, which have proved highly reliable.

By using these basic APPR-1 components, the need for critical experiments, zero-power experiments, fuel-plate fabrication development, and control-rod drive testing was eliminated. This considerably reduces the time and cost necessary to bring this plant into operation. The only development work required on major reactor components will be flow test to establish proper coolant distribution through the core.

Studies have shown that the size, configuration, and cost of a reactor of this type vary little between gross outputs of 2.5 tmw and 10 tmw. It was therefore deemed prudent to use the same basic reactor to supply the varying combinations of electrical and/or heating requirements of all installations in this power range. The lower output plants would benefit from increased core life and have installed reactor capacity available for future increases in demand. The primary components such as the steam generator, primary pump and pressurizer are flanged to the reactor piping and can be sized to meet the secondary-system requirements. The secondary-system components can be selected to meet the specific plant requirements for any particular site.

[2]These experiments were accomplished in ALCO's own Criticality Facility and helped to advance APPR-1 completion date by five months.

Core selection and lifetime

ALCO's skid-mounted nuclear power plant is based on using APPR-1 fuel elements in a 7 x 7 array with three elements per corner removed. This array results in an equivalent cylinder 20.16 in. in diameter and 22 in. high. It compares with the APPR-1 array of an equivalent cylinder 22.24 in. in diameter and 22 in. high. A most important consideration in this selection was that these fuel elements are undergoing actual testing under operating conditions in APPR-1.

The removal of eight corner fuel elements and the elimination of the thermal shield resulted in a drastic reduction of pressure vessel diameter. These changes allowed for redesign of the reactor vessel which resulted in extensive size and weight savings. Reduced core size and loading in the skid-mounted unit will affect reactor control and lifetime. Initial cold reactivity will be reduced from 15.4 per cent in APPR-1 to 9.7 per cent in the skid-mounted configuration. Assuming an 0.8 load factor, core lifetime for a 2000-kw design would be one year and approximately 1½ years for a 1200-kw design.

Optimization study

With the geometry of the core fixed, the next step was to analyze core heat removal. A range of coolant flow rates and coolant inlet temperatures were studied to determine the primary-system pressures necessary to meet the design criterion.

ALCO's computer center, which includes an IBM 650 digital unit and an analog computer, aided measurably in the selection of values. Programs were written for determining maximum fuel-element-plate surface temperature, for determining a range of secondary steam pressures, and system weight among others. A wide range of parameter values was obtained, and final selection of a primary pressure of 1750 psia and a

secondary pressure of 465 psia at full load were made to meet the criteria of portability, simplicity, and economy. Such factors as accessibility, physical size of components, vapor containment, problems of bolting and gasketing high-pressure flanges, control-rod drive seals and reliability had to be considered in making the final selection of operating conditions. In this phase of the program, sound engineering judgment and experience in operating APPR-1 took the place of computer results.

The range of parameters studied in this investigation were:

Parameter	*Minimum*	*Maximum*
Primary flow rate, lbs/hr	4×10^5	8×10^6
Reactor inlet temperature, F	425	575
Primary-system pressure, psia	1200	3200
Steam generator tube OD, in.	½	⅞
Coolant velocity in steam generator tubes, ft/sec	6	16
Secondary-steam pressure, psia	200	785
Condenser back pressure, in. hg. Abs.	2.5	30

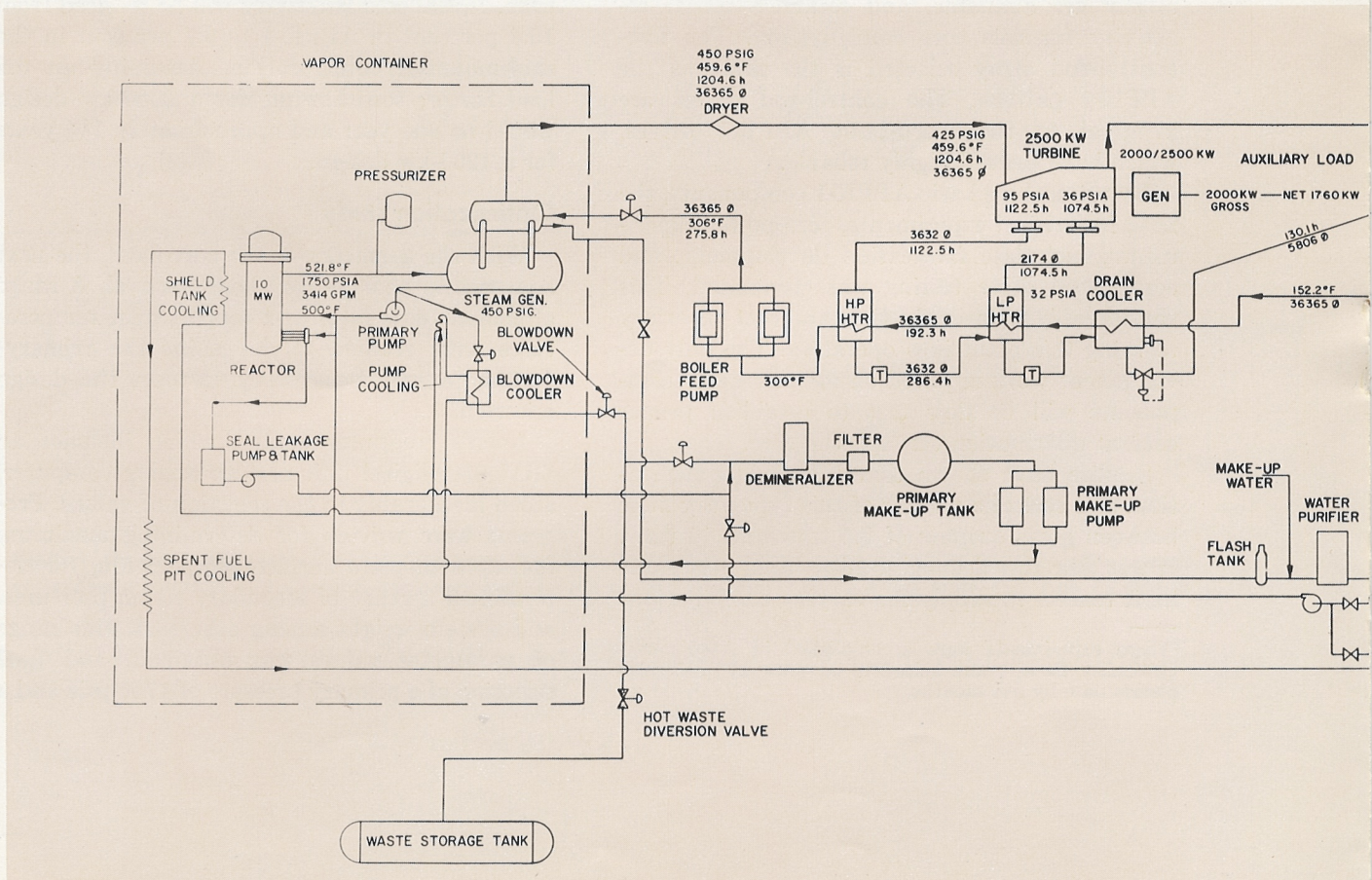
Stringent design conditions selected

Because of the numerous possible requirements and installation sites this basic skid-mounted nuclear 2000-kw plant could serve, it was necessary to assume a set of conditions which would point out the versatility of this concept. A complete study, design and analytical, was made of a 2000-kw electrical plant (1760-kw net output) located in a remote arctic site, permafrost terrain, cooling water for condenser not available, vapor containment necessary, 100 per cent standby diesel power, and complete plant shipment by air required. These extreme conditions readily assure that installation in areas with lesser requirements could be accomplished with savings in weight, complexity, and cost.

Skid mounting proves feasible

The excellent results obtained by the military in skid-mounting equipment during and after World War II and the subsequent use of this method in mounting commercial power packages made it a logical choice for this type of plant. The use of prefabricated buildings and vapor containment, in combination with the preassembled skid assemblies and prefabricated piping and wiring, cuts erection time and costs to a minimum. ALCO's extensive experience with diesel-electric packaged power units was of great value in this phase of the design study.

All primary and secondary packages have been



The design of ALCO's packaged reactor is based on the highly successful APPR-1 *(above)*, which has proved to be extremely sound and relatively trouble-free since it was put into operation in April, 1957, at Fort Belvoir, Virginia.

mounted on skid bases. The basic construction of the skid base includes two "H" beams at the sides jointed by crossties and a top deck. Both ends of the skid have draw bars mounted between the "H" beams. All electrical and instrument wiring has been incorporated in the skids and contained in conduits secured by ferrules to the crossties. The top decks provide mounting pads for installation of the various components. Mountings provide for thermal expansion wherever necessary. The skid base forms a rigid structure which eliminates the necessity for extensive foundations in installation. (*See Figure 1 on page 4 for view of skid mounting.*)

All components of the primary and secondary system are mounted on skids in such a manner as to provide a minimum number of connections at installation. All components are readily accessible for maintenance, including such work as replacing condenser and feedwater heater tube bundles, or pulling the generator rotor. It is possible, if desired, to assemble the complete power plant at the factory before shipment for a complete checkout of equipment.

Primary-system skid

The fully assembled primary skid, which weighs 84,650 lb and is 23 ft 4 in. long, 9 ft wide and 9 ft high, includes the reactor vessel, primary pump and piping, steam generator, pressurizer, blowdown cooler, seal leakage pump and tank, and the primary shielding. The reactor skid weighs 29,325 lb and the steam generator skid 25,500 lb. The removable shield rings which are shipped separately weigh 29,825 lb. The skids are bolted and doweled together in the shop and can be separated into two packages for air shipment. (*See Figure 1 for details of this skid.*)

Secondary-system packages

The secondary-system mechanical and electrical equipment is included in the following seven packages: the turbine-generator package (two sections); the condenser package; the air-blast cooler packages (two sections); the feedwater heater and feedwater pumps package, and the switchgear package.

Another ALCO atomic first

With the complete success of APPR-1 signifying its capabilities in the atomic energy field, ALCO continues to move forward. The skid-mounted portable reactor opens even wider vistas than its big sister on the Potomac River. The inherent portability of the design makes for simple, inexpensive erection and operation with the added possibility of subsequent removal and re-erection at a new site, if desirable. It has great potential in remote mining and logging operations, and other such applications.

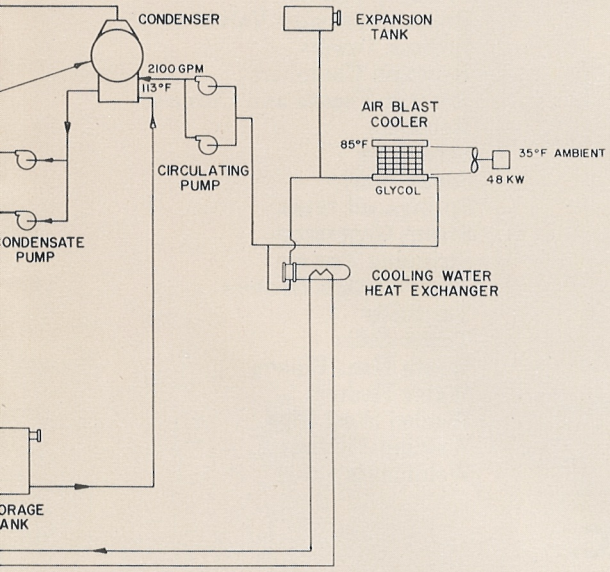


Figure 2—Typical heat-balance diagram for ALCO's skid-mounted package reactor. The same basic reactor can be used to supply varying combinations of electrical and/or heating requirements in power range from 2.5 tmw to 10 tmw.

For further information on ALCO nuclear reactors contact the sales office nearest you or write to ALCO Products, Inc., Dept. AE-3, P.O. Box 1065, Schenectady, New York.

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