THE ARCHITECTURE OF NUCLEAR BUILDINGS
NUCLEAR POWER PLANTS

by

BADRELDIN MOHAMED EZZAT LABIB

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Approved by:

Major Professor

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INTRODUCTION

The profession of architecture is concerned with the physical environment of man. Each civilization leaves a tangible record of its aims and beliefs through the expression of its architecture.

Architecture is the construction in which the human requirements and the building materials involved have been so dealt with as to furnish a practical and aesthetic solution, thus differing from the pure utility of engineering construction.

It is not intended that the reader, after studying this paper, be able to design a nuclear power plant. The design and construction of a nuclear power plant complex is so intricate that it is extremely difficult to describe intelligibly. It is hoped, however, that the reader will understand the basic types and have a better appreciation of the problems and prospects of such nuclear power plants, considered from the point of view of the architect.

THE ARCHITECT AND THE NUCLEAR AGE

The Architect

Architecture is a mixture of art and science. It is an emotional and intellectual exercise full of questions enough to keep some of its practitioners in long discussions and arguments. Oddly enough, the professional man as a rule has no great difficulty defining "Architecture" for the layman. Every reasonably sensitive and experienced architect knows what architecture is. He knows that the timeless principle of good design may be stated quite simply. It is integrity, wholeness, unity. It is the creation of a microcosm of nature, of truth, by the arrangement of the functional components of a building.

To be able to begin thinking about the architect of tomorrow, one must understand the architect of today. Today's architect should have a working knowledge of hundreds of materials and dozens of techniques and must try to keep up with the continuous stream of new products and structural methods, or adaptations of old ones, which the engineers and chemists feed to hopeful manufacturers. It is no longer possible for one man to keep the whole glutted bill of fare before his mind's eye as he plans what materials to use. It is no longer possible for one man to have anything more than an intelligent layman's understanding of most of the many specialized technologies involved in a large nuclear building. Yet one man only, the architect, must be in final control if the building is to be physically, functionally, economically, and aesthetically successful.

Architectural problems of the future will be so extensive that architects must collaborate with and study the work of others to enable them to comprehend and to cope with the population explosion and related tasks. The architect will be the ecologist of land and habitation. He will be the environmentalist. His training, talents, and sense of humanity prepare him for this role. To do this, he will have to abandon his preoccupations with the single building and encompass a vast new scale, although probably directed into some sub-fields. These sub-fields will have to do with the areas of operation. The main ones will be; politics - the architect-planner, technology and industry - the master builder, and aesthetics - architecture as an art form, assimilating all arts.

As architecture changes, so too will its tools. Computer technology is already with us, but undoubtedly in only its elementary forms. When the architect and planner learn to use its potentialities creatively, a great realm of design possibilities will inevitably open.

The Nuclear Age

This age resembles the end of the 15th century, when Columbus and his fellow explorers were opening a new world of limitless horizon. The accepted knowledge of the time, "the conventional wisdom", was shaken. Everything from religion to commerce, to boundaries of ideas had to be reevaluated and refitted to the new discoveries.

Today's Columbuses are the teams of scientists; the sailors who implement the discoveries are the engineering technicians. We have moved ahead so quickly that we have the opportunity of changing almost everything we do, at once. Change is inevitable, of course, it is the present rate of change that is bewildering, and to some men terrifying.

No examination of the impact of the new technologies has any validity unless we assume that the nuclear power will be used for peaceful purposes and never for all-out war.

The technological speed-up of the Nuclear Age, on top of the pace already accelerated since World War II, can be expected to produce more drastic changes and swifter ones than society has ever experienced. The challenge will be to accelerate the social and governmental processes so that the disorder of the lag behind technology does not overwhelm us. It is reasonable to predict that the widespread technical innovations will necessitate more complex social and economic adjustments.

The accelerated technology must be more strongly directed by some group of leaders. Humanists and social scientists will retain their importance through their ability to analyze and predict future change. Educators will gain in importance, for they will teach society how to cope with the changes. There will be an unprecedented need for retraining and nonvocational adult educations.

We are entering a period that will see a metamorphosis of the present metropolis into a balanced ecological region composed of a galaxy of new towns set in a natural environment and connected by a system of expressways and mass transit that will make all parts of the region as accessible as the parts of a small town. Cities will be ceaselessly renewing themselves in an organically changing pattern. The regional city will provide constant renewal as in nature, to meet the new demands of future generations.

No wonder the future nuclear power plant will be the service hub of the future city; a city totally electric and dependent for its functioning on the presence of a centrally located nuclear power plant.

No image of utopia has yet fired public imagination to the degree that it has the power to shape decisions. However, emotional and intellectual and spiritual satisfactions must be the basic principles in our new view of human destiny.

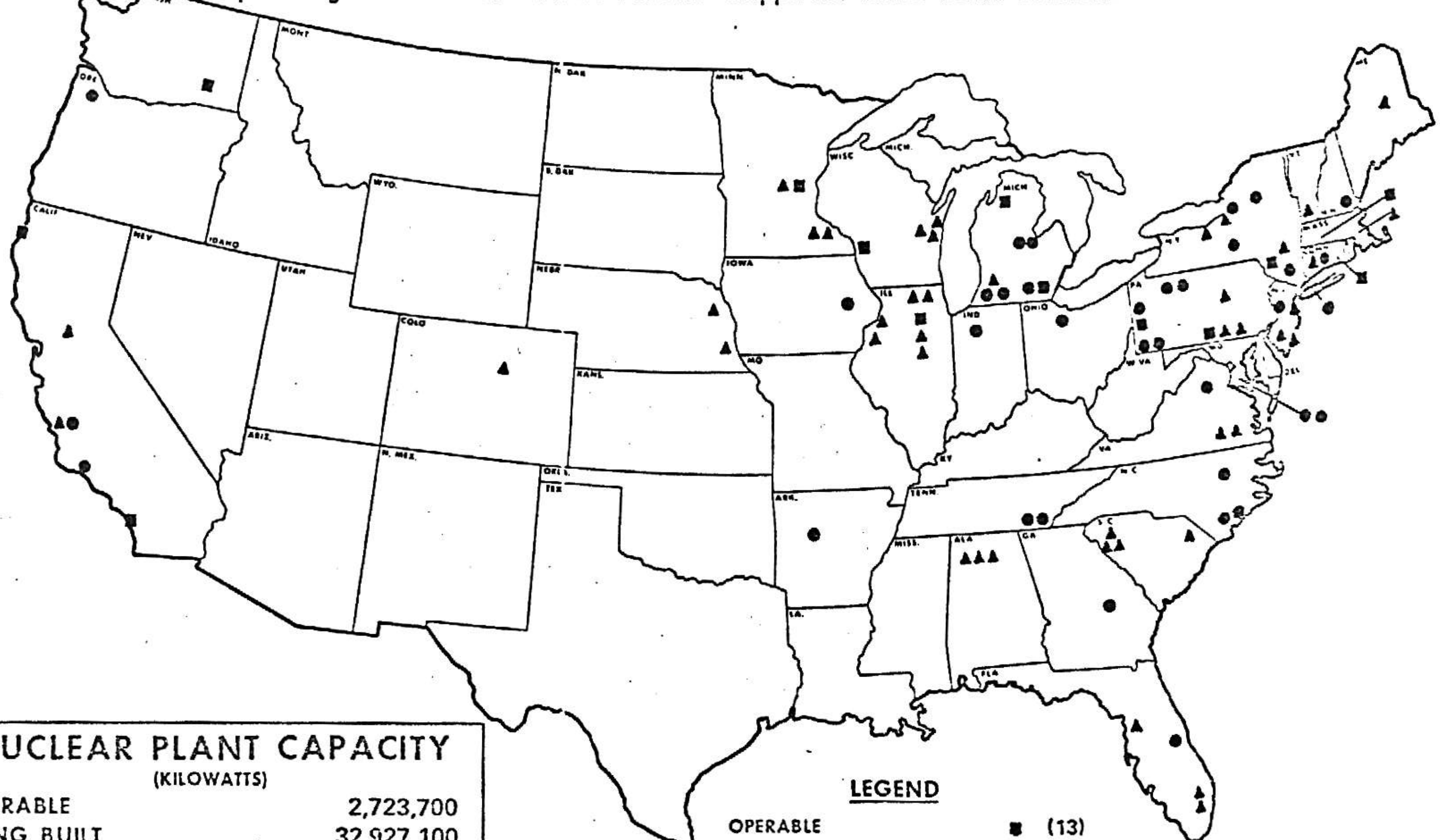
Atomic Energy in the United States

Energy is the basic tool of progress. No change, not even the mitosis of a single cell, occurs without the spending of energy. Everything around us consists of what nature has provided, and of man's work, which is spent energy. The need for vastly greater supplies of energy - to do vastly greater amounts of work and to satisfy not only our own increasing wants but also of the new nations - this is the central problem of the day. It would be appalling except for the fact that nuclear energy makes it possible to meet those needs. The total energy requirements of the world are growing as a parabolic function, first, because of the per capita increase in power usage due to a rise in living standards, automation and sophistication of labor mechanization, and, second, because of the increase in the world population. There has been a more intense need for all forms of power, in homes, factories, and on farms, and in transportation in land, sea, air and space. The Geneva Conference set 6000 billion kilowatt hours as the probable world production of electric power in 1975 - four times what was produced in 1955. Even if this much power could be produced in conventional plants, it could not be transported to where it was needed.

If we consider electric power alone in the U.S. the per capita use has increased from 1350 kilowatts per year in 1940, to 2580 in 1950 and 4160 in 1957. A further increase to 7360 is predicted by 1980. Electric energy, however, accounts for only 14% of the total energy utilized in the U.S. when translated into common heat units. The effect of this power demand on fossil-fuel consumption is equally as dramatic. It has been estimated that half the coal ever burned in the United States has been consumed since 1920 and half the oil and natural gas has been consumed since 1940.

NUCLEAR POWER PLANTS IN THE UNITED STATES

The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected



NUCLEAR PLANT CAPACITY
(KILOWATTS)

OPERABLE		2,723,700
BEING BUILT		32,927,100
PLANNED	REACTORS ORDERED	29,791,300
	REACTORS NOT ORDERED	7,400,000
	TOTAL	72,842,100

ELECTRIC UTILITY CAPACITY BY CONVENTIONAL MEANS AS OF SEPTEMBER 30, 1968: 284,341,314 KILOWATTS

LEGEND

OPERABLE	■	(13)
BEING BUILT	▲	(44)
*PLANNED (Reactors Ordered)	●	(34)

*8 more plants have been announced for which reactors have not yet been ordered.

U.S. Atomic Energy Commission
December 31, 1968

Almost all the electricity today is produced by turbogenerators. The turbines are driven by three basic energy sources; kinematic energy of water power, chemical energy of fossil-fuel combustion, and nuclear energy of fission. Twenty years ago water supplied 40% of all the electricity used in the United States; today it supplies a little less than 20% and is decreasing. New sources of water power (flood-control project, tide harnessing, etc.) are being developed, and pumped storage projects are being initiated to increase the use factor, hence the efficiency of central station plants. Chemical-energy electric generation by stationary diesel generators or gas turbine prime movers are used for limited power demands or as peaking suppliers to conventional baseloaded stream turbogenerators.

With the introduction of nuclear energy, a new heat source has been tapped that will help to conserve the fossil-fuel sources and may eventually lead to more efficient utilization of such power.

SITE	PLANT NAME	CAPACITY (Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,064,500	Tennessee Valley Authority	1971
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,064,500	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,064,500	Tennessee Valley Authority	1972
Houston County	SEALA Nuclear Generating Unit	829,000		1975
ARKANSAS				
London	Arkansas Nuclear One	850,000	Arkansas Power & Light Co.	1972
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	68,500	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station	430,000	Southern Calif. Edison and San Diego Gas & Electric Co.	1967
Corral Canyon	Malibu Nuclear Plant: Unit 1	462,000	L.A. Dept of Water & Power	1975
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas & Electric Co.	1973
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas & Electric Co.	1974
Clay Station	Rancho Seco Nuclear Generating Station	800,000	Sacramento Municipal District	1973
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Conn. Yankee Atomic Power Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1970
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	651,500	Florida Power & Light Co.	1971
Turkey Point	Turkey Point Station: Unit 4	651,500	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	858,000	Florida Power Corp.	1972
Ft. Pierce	Hutchinson Island	770,000	Florida Power and Light Co.	1973
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant	786,000	Georgia Power Co.	1973
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	715,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	715,000	Commonwealth Edison Co.	1970
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1972
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	715,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1970
Cordova	Quad-Cities Station: Unit 2	715,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1971
INDIANA				
Dunes Acres	Bailly Generating Station	515,000	Northern Indiana Public Service Co.	1974
IOWA				
Cedar Rapids	Duane Arnold Energy Center: Unit 1	545,000	Iowa Electric Light and Power Co.	1973
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	800,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	800,000	Baltimore Gas and Electric Co.	1974
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station	625,000	Boston Edison Co.	1971
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1963
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,126,000	Detroit Edison Co.	1974
Bridgman	Donald C. Cook Plant: Unit 1	1,054,000	Indiana & Michigan Electric Co.	1972
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1973
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1973
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1974
MINNESOTA				
Elk River	Elk River Nuclear Plant	22,000	Rural Cooperative Power Assoc.	1964
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1970
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1972
Brownville	Cooper Nuclear Station	778,000	Consumers Public Power District and Iowa Power and Light Co.	1972
NEW HAMPSHIRE				
Seabrook	Seabrook Nuclear Station	860,000	Public Service Co. of N.H.	1975
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	515,000	Jersey Central Power & Light Co.	1969
Salem	Salem Nuclear Generating Station: Unit 1	1,050,000	Public Service Gas and Electric Co. of New Jersey	1972
Salem	Salem Nuclear Generating Station: Unit 2	1,050,000	Public Service Gas and Electric Co. of New Jersey	1973
Newbold Island		1,100,000	Public Service Gas and Electric, NJ	1975
Newbold Island		1,100,000	Public Service Gas and Electric, NJ	1977
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1963
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1970
Indian Point	Indian Point Station: Unit 3	965,300	Consolidated Edison Co.	1972
Scriba	Nine Mile Point Nuclear Station	500,000	Niagara Mohawk Power Co.	1969
Rochester	R. E. Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1969
Shoreham	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1975
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1973
Verplanck	Verplanck: Unit 1	1,115,000	Consolidated Edison Co.	1975
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N.Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1974
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1976
•		821,000	Carolina Power and Light Co.	—
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Clermont County	William H. Zimmer Nuclear Power Station	840,000	Cincinnati Gas & Electric Co	1975
OREGON				
Rainier	Trojan Station	1,118,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1971
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1973
•		1,065,000	Philadelphia Electric Co.	1975
•		1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.–Ohio Edison Co.	1973
Goldsborough	Three Mile Island Nuclear Station: Unit 1	831,000	Metropolitan Edison Co.	1971
Goldsborough	Three Mile Island Nuclear Station: Unit 2	810,000	Metropolitan Edison Co.	1973.
•		1,052,000	Pennsylvania Power and Light	1975
•		1,052,000	Pennsylvania Power and Light	1977
SOUTH CAROLINA				
Hartsville	H.B. Robinson S.E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1970
Seneca	Oconee Nuclear Station: Unit 1	841,100	Duke Power Co.	1971
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,124,000	Tennessee Valley Authority	1973
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,124,000	Tennessee Valley Authority	1974
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.-Green Mt. Power Corp.	1971
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	780,000	Virginia Electric & Power Co.	1971
Gravel Neck	Surry Power Station: Unit 2	780,000	Virginia Electric & Power Co.	1971
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	790,000	Washington Public Power Supply System	1977
WISCONSIN				
Genoa	LaCrosse Boiling Water Reactor	50,000	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1972
Carlton	Kewaunee Nuclear Power Plant. Unit 1	527,000	Wisconsin Public Service Co.	1972

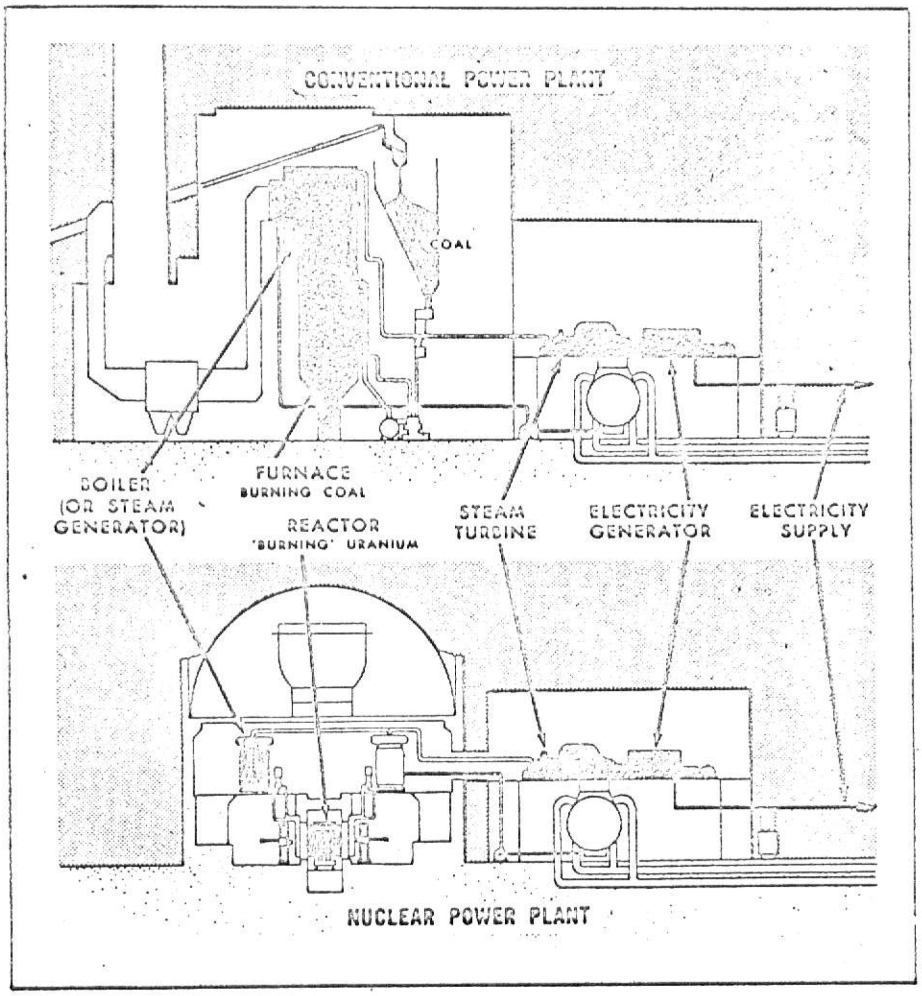
NUCLEAR POWER PLANT TECHNOLOGY

Nuclear power plants have often been described as ordinary plants with a nuclear reactor substituted for the conventional boiler as a source of heat. In a sense this is true - a reactor is just a substitute heat source. However, the licensing procedure, the checking of daily operations and monitoring, and the control and safety provisions, lead to the conclusion that nuclear plants are something apart.

The environmental and economical conditions existing in certain areas dictate the use of nuclear energy as well as the particular reactor design. England, because of a critical shortage of fossil-fuel, acted quickly to provide nuclear power and was the first country to develop electric energy from the fissioning process. The urgency of the situation made it necessary to use the simplest and most reliable reactor available at that early stage. Therefore, England developed the gas-cooled, graphite moderated, natural-uranium reactor to a high degree of usefulness and efficiency.

In the early 1950's fossil-fuels were relatively plentiful and less expensive in the U.S. (and to a large extent in Russia) and therefore it was less urgent to develop nuclear power which could not then compete with fossil-fueled generation. As a consequence, the longterm view was taken, and various reactor concepts were developed on which to base the most feasible and economical design for use in the future. The choice today in the U.S. is a light-water-cooled and moderated, enriched-fuel reactor, although much attention is still being directed to the fast breeder and high temperature gas-cooled converter type.

Based on conditions in December 1966, more than half of the free-world installed nuclear power capacity of 7756 Mega Watt Electric as produced by


CONVENTIONAL POWER PLANT
COAL
BOILER (OR STEAM GENERATOR)
FURNACE BURNING COAL
REACTOR 'BURNING' URANIUM
STEAM TURBINE
ELECTRICITY GENERATOR
ELECTRICITY SUPPLY
NUCLEAR POWER PLANT

gas-cooled reactors. These together with two plants in France and one in Italy account for 68.3% of the present nuclear-generated power. Operating water-cooled reactors presently have an installed capacity of about 30.3% of which approximately 76% represent plants in the U.S. Plants in Belgium, Canada, West Germany, Italy, Japan and Sweden produce the remainder of the total water-cooled plants; 22.6% are pressurized-water reactors and 7.7% boiling water reactors.

Engineering Principles

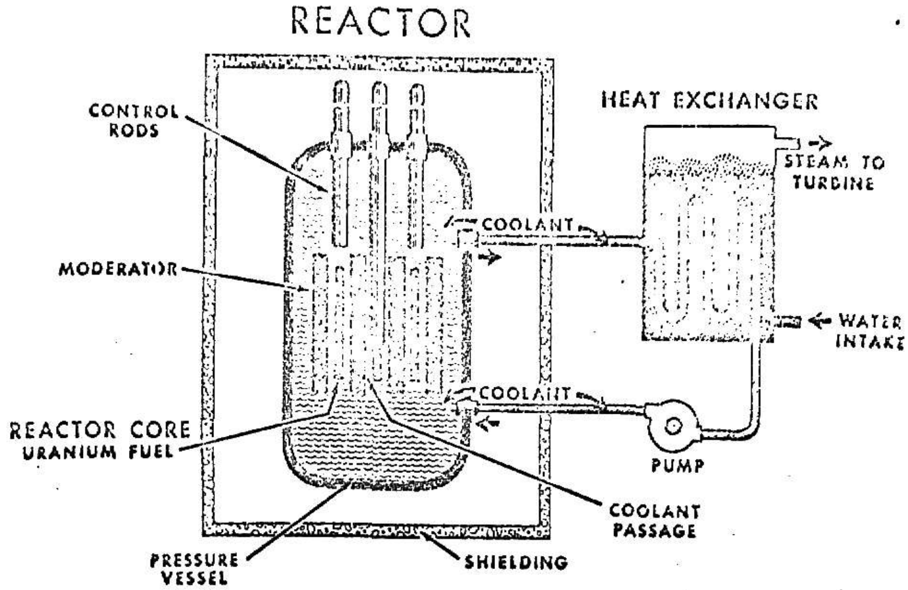
The source of energy for nuclear power plants comes from the fission process. A nucleus, upon absorbing a neutron, becomes unstable and splits into fragments. Some of the mass in the original nucleus disappears in the process and is converted into heat and other radiant energy. It is this heat that is of interest for the production of power. The highly penetrating deadly radiation that accompanies the fission can be regarded as something of a nuisance - a nuisance which results in much of the complication in the design of nuclear reactors.

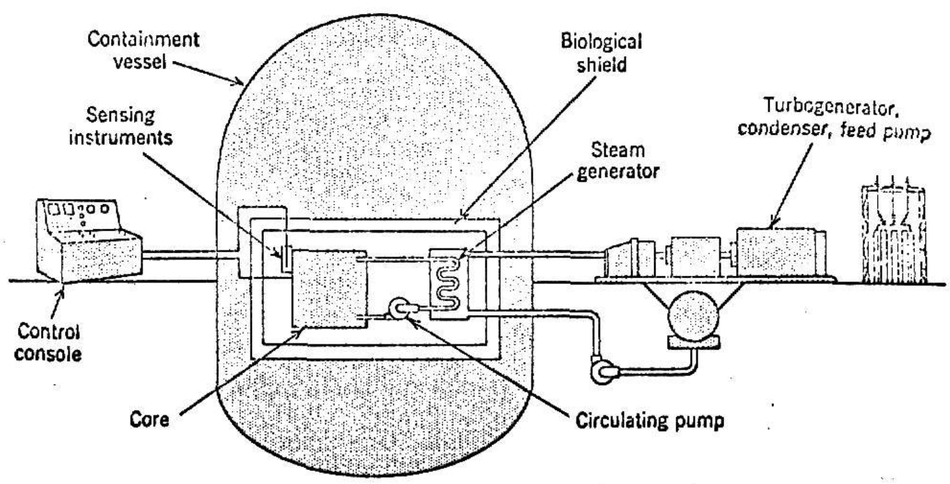
A reactor represents that part of a nuclear power plant where the fission chain reaction is made to occur, and where the heat is generated for operating power conversion equipment. The core of the reactor is typically an assemblage of fuel elements, control rods, coolant, and moderator. Reactor cores normally have a shape approximating a right circular cylinder with diameters ranging from 1 to 40 feet. The pressure vessel, which houses the reactor core, is commonly defined as a part of the reactor.

The fuel elements are made of plates or rods alloyed of uranium metal or ceramic. The plates or rods are usually clad in a thin sheath of stainless steel, zirconium, or aluminum to provide corrosion resistance, retention of fission and radioactivity, and in some cases, to provide structural support. Space is provided between the individual fuel plates to allow for passage of the coolant.

The coolant, which can be a gas, water, or organic or liquid metal, removes the heat produced in the fuel plates. A coolant, such as water, may also serve as a moderator.

The moderator, commonly water or graphite, is dispersed between the





Basic components of nuclear power reactors.

fuel assemblies. It serves to slow down, or moderate, the fast neutrons produced in fission. These lower velocities provide a better opportunity for the neutrons to cause further fission.

The control rods are made of a neutron absorbing material and, upon movement in or out of the core, vary the number of neutrons available to maintain the chain reaction. The rate of fissioning can thereby be controlled.

A reflector is often placed around the core to reflect back some of the neutrons that leak out from the surface of the core. The reflector is often of the same material as the moderator.

The support structures include the grid plates which position and hold the fuel elements and control rods as well as shrouds and skirts for directing coolant flow.

The reactor shield is an important component of a reactor installation. There are usually two shields: the thermal shield and the biological shield. The thermal shield is fairly close to the core and consists of a few inches of iron or steel; by absorbing much of the gamma radiation, the thermal shield protects the biological shield from possible damage due to overheating. The biological shield is generally a layer of concrete, several feet thick, which surrounds the reactor core and reflector; it is capable of absorbing both gamma rays and neutrons. As a precaution against the possible spread of radioactive materials, in the unlikely event that the reactor core is badly damaged, the whole system, including the shield and heat exchanger, is often enclosed in a steel containment vessel.

Basic Reactor Types

There is a large number of combinations, in regard to fuel material, moderator (if any), reflector, coolant and method of heat removal, which appears to be practical for power reactor designs. Some idea of the possibilities is given in the following table. In general, each system has both advantages and drawbacks, and without actual operating experience it is not possible to state definitely that any one is to be preferred over the others.

<u>Power Reactor Components</u>

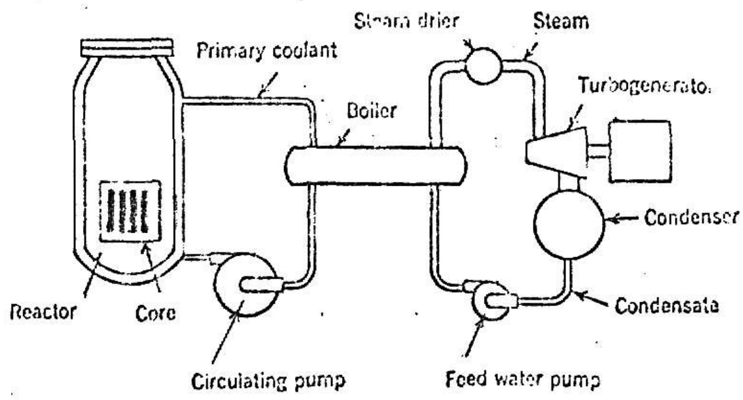
Nuclear Fuel	Moderator	Coolant	Method of Heat Removal
Natural Uranium	Heavy water berylium, berylium oxide or graphite	Ordinary water, heavy water, organic liquid, helium, carbon dioxide	Circulation of coolant through external heat exchanger (boiler)
Enriched uranium, (plus possibly Thorium-232)	Same as above also ordinary water or organic liquid	Same as above or sodium	Same as above or boiling water within reactor core; also circulation of fluid fuel
Uranium-235 or Plutonium-239 (plus Uranium-238 for breeding)	None (fast reactor)	Sodium	Circulation of coolant through external heat exchanger

Eight basic types have been studied in the research stages and have resulted in demonstration or commercial power reactors:

1. Pressurized-water reactor,
2. Boiling-water reactor,
3. Sodium-graphite reactor,
4. Fast breeder reactor,
5. Homogeneous reactor,
6. Organic cooled and moderated reactor,
7. Gas-cooled reactor,
8. High-temperature gas-cooled reactor.

1. Pressurized-Water Reactor

Fission heat is removed from the reactor core by water pressurized at approximately 2000 psi to prevent boiling. Steam is generated from secondary coolant in the heat exchanger.

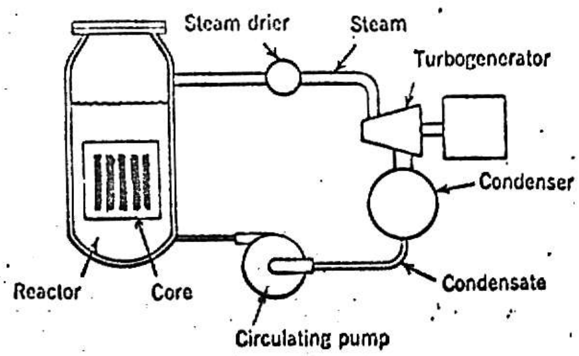


Major Characteristics

- Light water is the least expensive coolant and moderator.
- Water is a well-documented heat-transfer medium and the cooling system is relatively simple.
- High pressure requires a costly reactor vessel on a leakproof primary coolant system.
- High-pressure high-temperature water at rapid flow rates increases corrosion and erosion problems.
- Steam is produced at relatively low temperatures and pressures (compared with fossil-fueled boilers) and requires superheating to achieve high plant efficiencies.
- Containment requirements are extensive because of possible high energy release in the event of primary coolant system failure.
- High ·rrent density with enriched fuels yields a compact core.

2. Boiling-Water Reactor

Fission heat is removed from the reactor by conversion of water to steam in the core. It may be a single - or dual - cycle system.

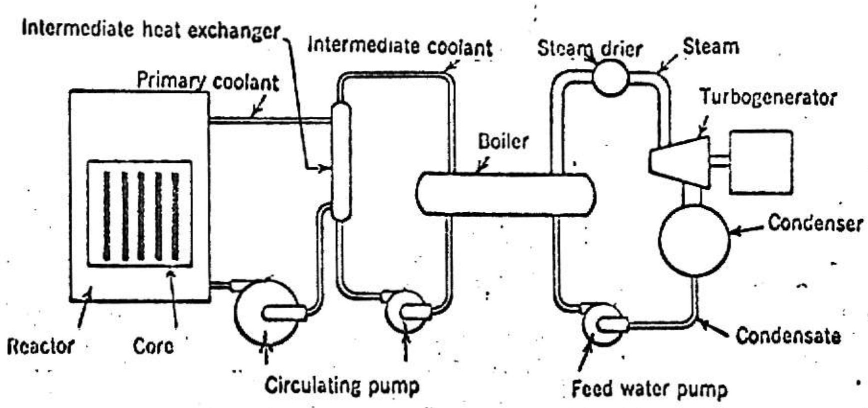


Major Characteristics

- Light water is the coolant, moderator, and heat-exchange medium, as in a pressurized-water reactor.
- Reactor vessel pressure is less than the primary circuit of the pressurized reactor.
- Steam pressures and temperatures are similar to those of pressurized water.
- Heat exchangers, pumps, and auxiliary equipment are reduced or eliminated.
- Has inherent safety characteristics in that power surge causes a void formation, thus reducing the core power level.
- Carryover of radioactivity to steam equipment is possible.
- Low pressure in reactor and primary coolant system reduces containment requirements.

3. Sodium-Graphite Reactor

Molten sodium metal transfers high-temperature heat from graphite moderated core to an intermediate exchanger. Intermediate sodium coolant transfers heat to the final water-cooled steam-generation equipment.

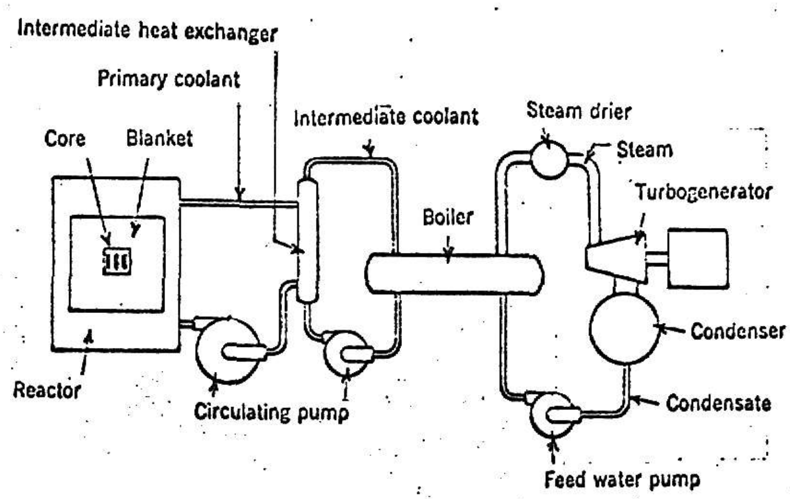


Major Characteristics

- The high boiling point of liquid metal eliminates pressure on the reactor and primary system.
- Permits high reactor temperatures.
- Steam is generated at relatively high temperatures and pressures.
- Corrosion problems are minimized.
- Low coolant pressures reduce containment requirements.
- Violent chemical reaction with water and high radio-activity of alkali metal requires a triplecycle coolant system with dual heat-exchanger equipment to minimize hazards.
- The core is relatively complex.

4. Fast-Breeder Reactors

Heat from fission by fast neutrons is transferred by sodium coolant through air intermediate sodium cycle to boilers as in the sodium-graphite type. No moderator is used. Neutrons escaping from the core into a blanket breed fissionable Pu-239 from fertile U-238.

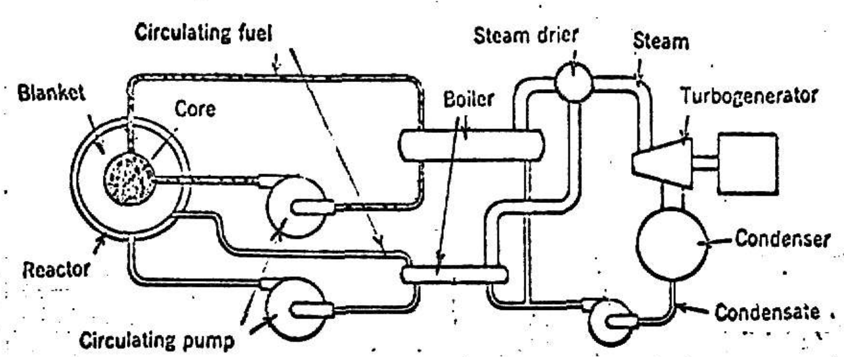


Major Characteristics

- Reactor is designed to produce more fissionable material than is consumed.
- Wide choice of structural materials as a result of low absorption of high energy neutrons is available.
- Low neutron absorption by fission products permits high fuel burnup.
- A small core with a minimum area intensifies heat-transfer problems.
- Core physics, including short neutron lifetime, makes control difficult.

5. Aqueous-Homogeneous

Heat formed in the core, which is a critical mass of solution or slurry of fuel and moderator, is carried by fuel solution to the heat exchangers to form steam. Slow neutrons from the core breed fissionable U-233 from Th-232 in the blanket.

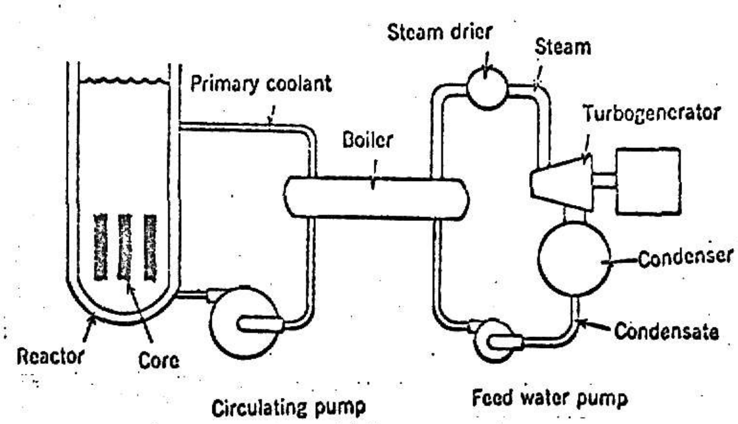


Major Characteristics

- The system has a high degree of inherent stability; mechanical control rods are unnecessary.
- Fuel-element problems are eliminated. Continuous processing of irradiated fuel is possible to remove fission products and permit maximum burnup.
- Fuel solution is highly radioactive and corrosive.
- Core and blanket, including primary system, must be kept at high pressure to prevent boiling.
- Precautions must be taken to avoid accumulation of critical mass outside the reactor vessel.
- Containment requirements are high, for radioactive material is circulated through the primary coolant and blanket loops.

6. Organic-Moderated Reactor

Heat is removed from the core by organic coolant at low or moderate pressure. Steam is generated in the boiler or heat exchanger.

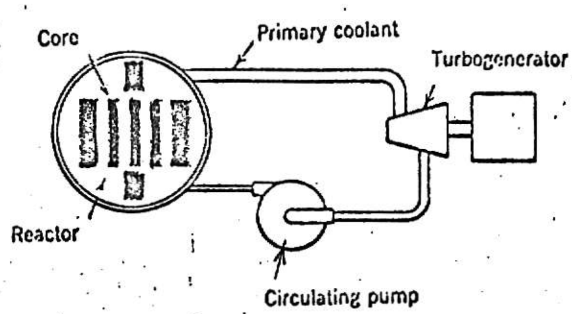


Major Characteristics

- High pressure in reactor and primary circuit is avoided, although higher temperatures can be achieved than in a pressurized-water reactor.
- Organic coolant becomes only slightly radioactive and causes little corrosion.
- Heat transfer characteristics are good but lower than water.
- Hydrocarbon coolant may deteriorate and cause fouling or scale formation on the fuel element.

7. Gas-Cooled Reactor

Heat removed from the core by gas at moderate pressure, is circulated through steam-generating heat exchangers that produce low- and high-pressure steam. It utilizes carbon dioxide gas, graphite moderator, and natural uranium fuel.

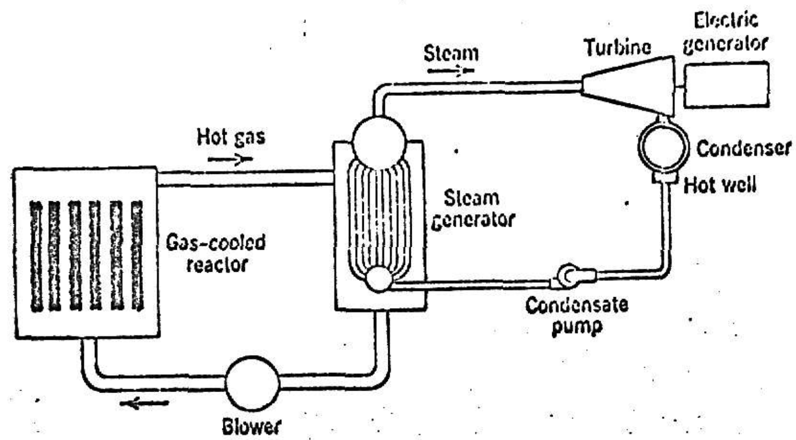


Major Characteristics

- Utilizes natural uranium fuel and relatively available materials and construction.
- Permits low pressure coolant and relatively high reactor temperatures.
- Containment requirements are moderate and corrosion problems minimal at low temperatures.
- Reactor size is relatively large because of natural fuel and graphite moderator. Power density (kilowatt output per liter of core volume) is extremely low.
- Poor heat transfer characteristics of gases require high pumping requirements.
- Steam pressures and temperatures are low.
- Carbon dioxide gas is relatively cheap, safe, and easy to handle.

8. High-Temperature Gas-Cooled Reactor

Heat from the reactor core is carried by inert helium to the heat exchanger for generation of steam or directly to a gas turbine; the gas returns to the reactor in a closed cycle.



Major Characteristics

- Good efficiency can be achieved in a dual cycle with a minimum gas temperature of 1400°F.
- High fuel burnup is possible and conversion of fertile material permits lower fuel costs.
- Minimum corrosion of fuel elements will be caused by inert gas.
- High temperature coolant minimizes the disadvantage of poor heat-transfer characteristics of the gases.
- Possible contamination of the turbine in a direct cycle is caused by fuel-element failure.
- Fuel-element design for long life is complicated by high temperatures.
- The worldwide supply of helium is limited.

Plant Siting

A reactor site criteria has been published by the United States Atomic Energy Commission; Rules and Regulations, Title 10 - Atomic Energy, Part 100.

For further guidance reference is made to Technical Information Document 14844, dated March 23, 1962, which contains a procedural method and a sample calculation that result in distance roughly reflecting current siting practices of the Commission. The calculations described in Technical Information Document 14844 may be used as a point of departure for consideration of particular site requirements which may result from evaluation of the characteristics of a particular reactor, its purpose and method of operation.

Typical are the following excerpts from the "Reactor Site Criteria":

> § 100.10 Factors to be considered when evaluating sites:
> Factors considered in the evaluation of sites include those relating both to the proposed reactor design and the characteristics peculiar to the site. It is expected that reactors will reflect through their design, construction and operation an extremely low probability for accidents that could result in release of significant quantities of radioactive fission products. In addition, the site location and the engineered features included as safeguards against the hazardous consequences of an accident, should one occur, should ensure a low risk of public exposure. In particular, the Commission will take the following factors into consideration in determining the acceptability of a site for a power or testing reactor:
> (a) Characteristics of reactor design and proposed operation including:
>
> (1) Intended use of the reactor including the proposed maximum power level and the nature and inventory of contained radioactive materials;
>
> (2) The extent to which generally accepted engineering standards are applied to the design of the reactor;
>
> (3) The extent to which the reactor incorporates unique or unusual features having a significant bearing on the probability or consequences of accidental release of radioactive materials;
>
> (4) The safety features that are to be engineered into the facility and those barriers that must be breached as a result of an accident before a release of radioactive material to the environment can occur.

(b) Population density and use characteristics of the site environs, including the exclusion area, low population zone, and population center distance.
(c) Physical characteristics of the site, including seismology, meteorology, geology, and hydrology.

(1) The design for the facility should conform to accepted building codes or standards for areas having equivalent earthquake histories. No facility should be located closer than one-fourth mile from the surface location of a known active earthquake fault.

(2) Meteorological conditions at the site and in the surrounding area should be considered.

(3) Geological and hydrological characteristics of the proposed site may have a bearing on the consequences of an escape of radioactive material from the facility. Special precautions should be planned if a reactor is to be located at a site where a significant quantity of radioactive effluent might accidentally flow into nearby streams or rivers or might find ready accesses to underground water tables.

(d) Where unfavorable physical characteristics of the site exist, the proposed site may nevertheless be found to be acceptable if the design of the facility includes appropriate and adequate compensating engineering safeguards.

§ 100.11 Determination of exclusion area, low population zone, and population center distance.

(a) As an aid in evaluating a proposed site, an applicant should assume a fission produce release from the core, the expected demonstrable leak rate from the containment and the meteorological conditions pertinent to his site to derive an exclusion area, a low population zone and population center distance. For the purpose of this analysis which shall set forth the basis for the numerical values used, the applicant should determine the following:

(1) An exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure.

(2) A low population zone of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose of 300 rem to the thyroid from iodine exposure.

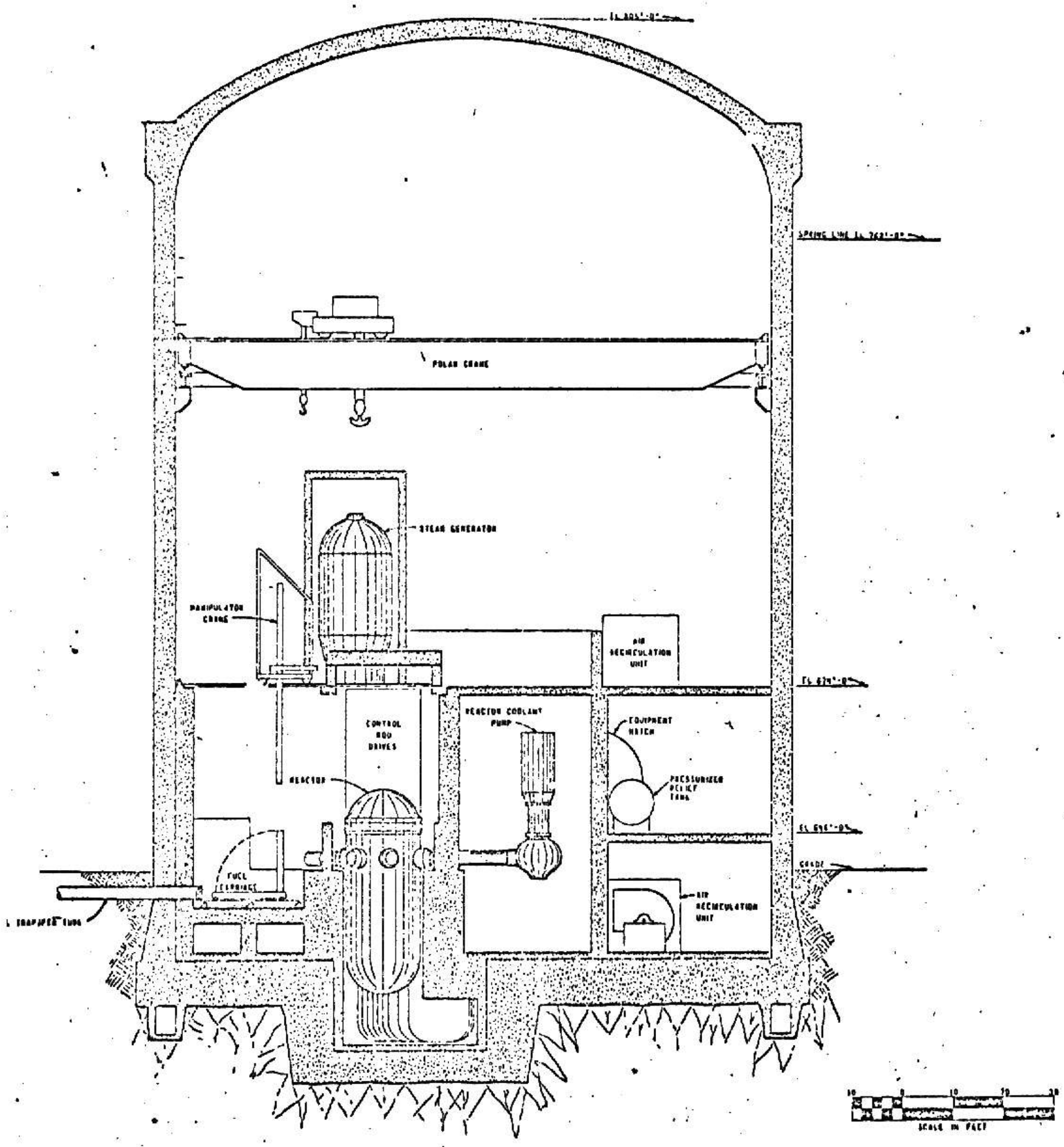
(3) A population center distance of at least one-third times the distance from the reactor to the outer boundary of the low population zone. In applying this guide, due consideration should be given to the population distribution within the population center. Where very large cities are involved, a greater distance may be necessary because of total integrated population dose consideration.

(b) For sites for multiple reactor facilities consideration should be given to the following:

(1) If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone and population center distance shall be fulfilled with respect to each reactor individually. The envelopes of the plan overlay of the areas so calculated shall then be taken as their respective boundaries.

(2) If the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area, low population zone and population center distance shall be based upon the assumption that all interconnected reactors emit their postulated fission product releases simultaneously. This requirement may be reduced in relation to the degree of coupling between reactors, the probability of concomitant accidents and the probability that an individual would not be exposed to radiation effects from simultaneous releases.

(3) The applicant is expected to show that the simultaneous operation of multiple reactors at a site will not result in total radioactive effluent releases beyond the allowable limits of applicable regulations.



SECTION B-B

REACTOR CONTAINMENT BUILDIN
CROSS SECTION

NUCLEAR UNIT
PUBLIC SERVICE COMPANY OF OKLAHOM

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1967

Containment

The design of a containment vessel, if required, is based upon an estimate of the total energy release for the "maximum credible accident." The potential sources of energy are:

- Nuclear energy,
- Chemical reactions between coolant and materials,
- Stored thermal energy of the materials within the reactor system.

From estimates of the total energy release, the containment vessel is designed to withstand the peak pressure expected and will contain all of the radioactivity. The requirement that radiation levels at the site boundary be limited to a relatively low value does not have a great effect upon the specifications for integrity of containment vessels. It is possible to fabricate these vessels with very low leakage rates. However, even if the containment vessel retains all of the fission products released from the reactor during an accident, the proximity of the site boundary may still require shielding around the containment vessel to protect off-site personnel from gamma radiation originating in the fission products dispersed in the vessel. As a result it is now fairly common to provide extra shielding at the wall of the containment vessel, either inside or outside.

The principal types of containment now being considered in the U.S. are illustrated in Figs. 1 through 6. Although most of these containment types are similar in many aspects and any categorizing must be somewhat arbitrary, they are classified according to these principal distinguishing

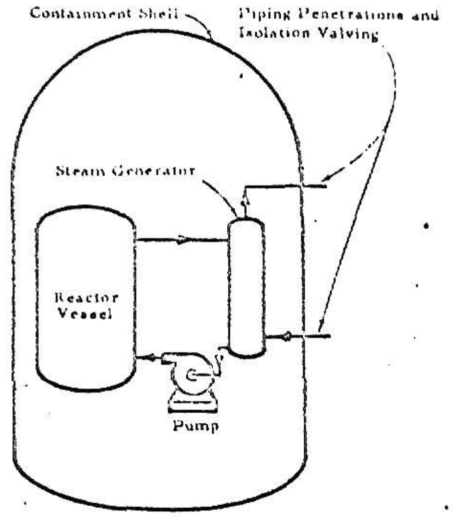

Figure 1. Pressure containment (shown with PWR, GCR or OCR)

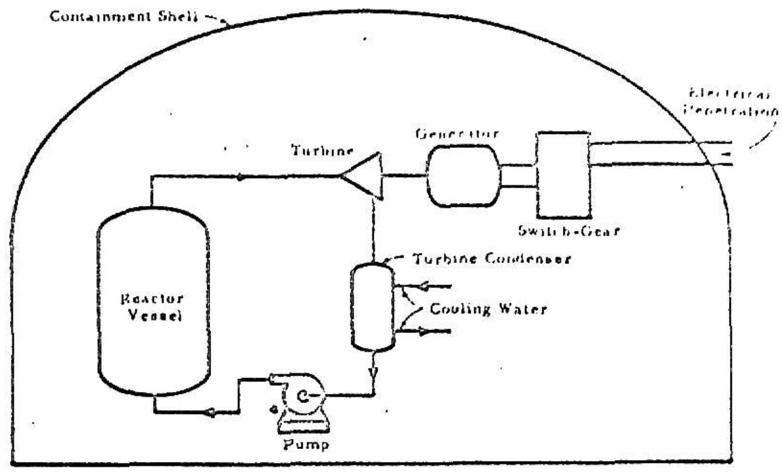

Figure 2. Low pressure containment (shown with BWR)

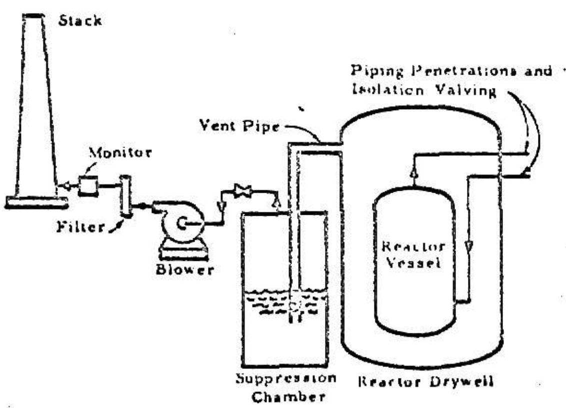

Figure 3. Pressure suppression containment (shown with BWR)

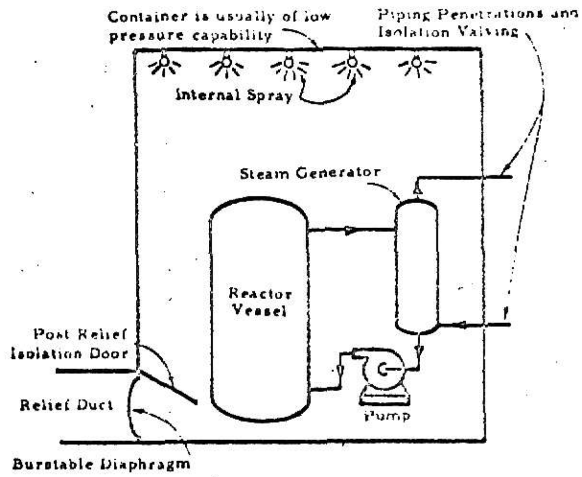

Figure 4. Pressure relief containment (shown with PWR)

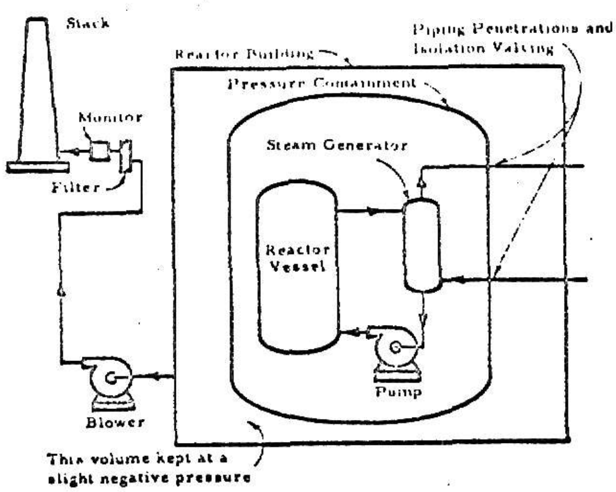

Figure 5. Multiple barrier containment (shown with PWR)

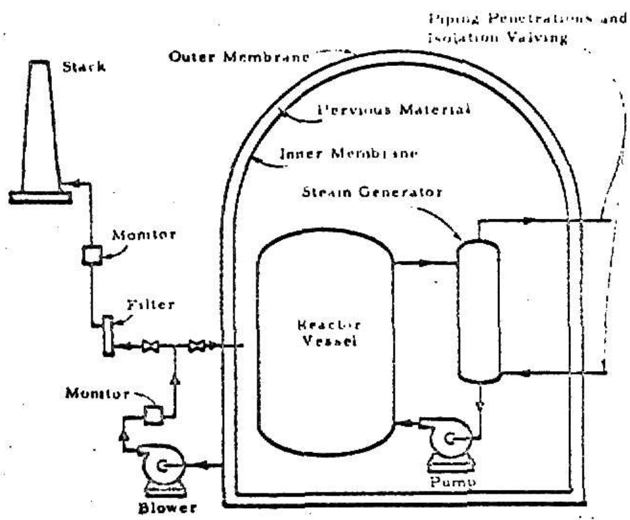

Figure 6. Multiple barrier containment (shown with PWR)

features. The Reactor Containment Handbook* contains information on these and other containment designs.

The containment building is usually required to house the complete primary coolant circuit of the reactor, comprising reactor vessel, ducts, heat exchangers, circulators, etc. It must envelop the refueling machine, which during the refueling operations forms an extension to the primary circuit. The building is therefore, of large size. Briefly the containment is a further line of defence, providing a shell which will contain the total energy that may develop as the result of any failure of coolant flow, etc.

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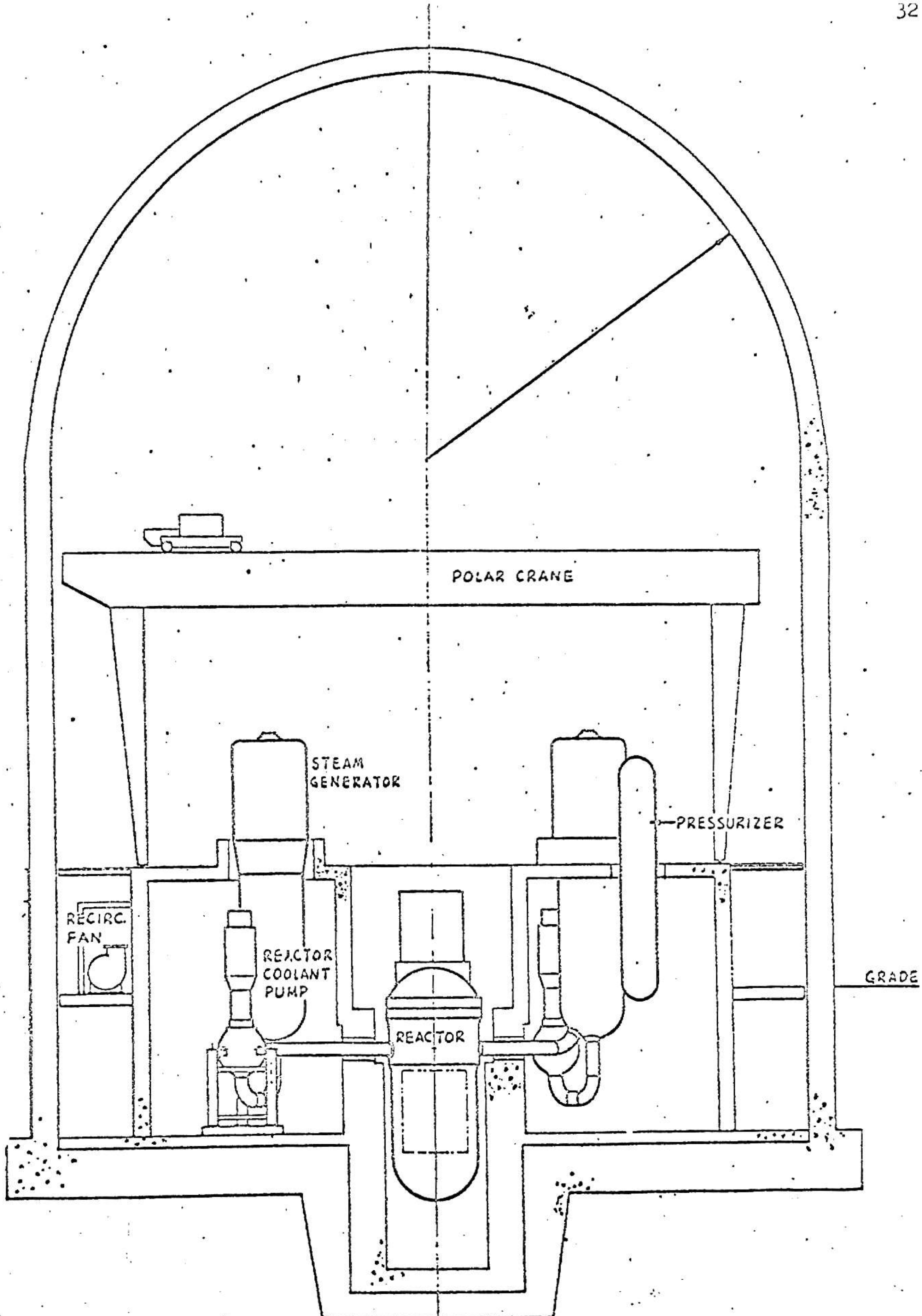
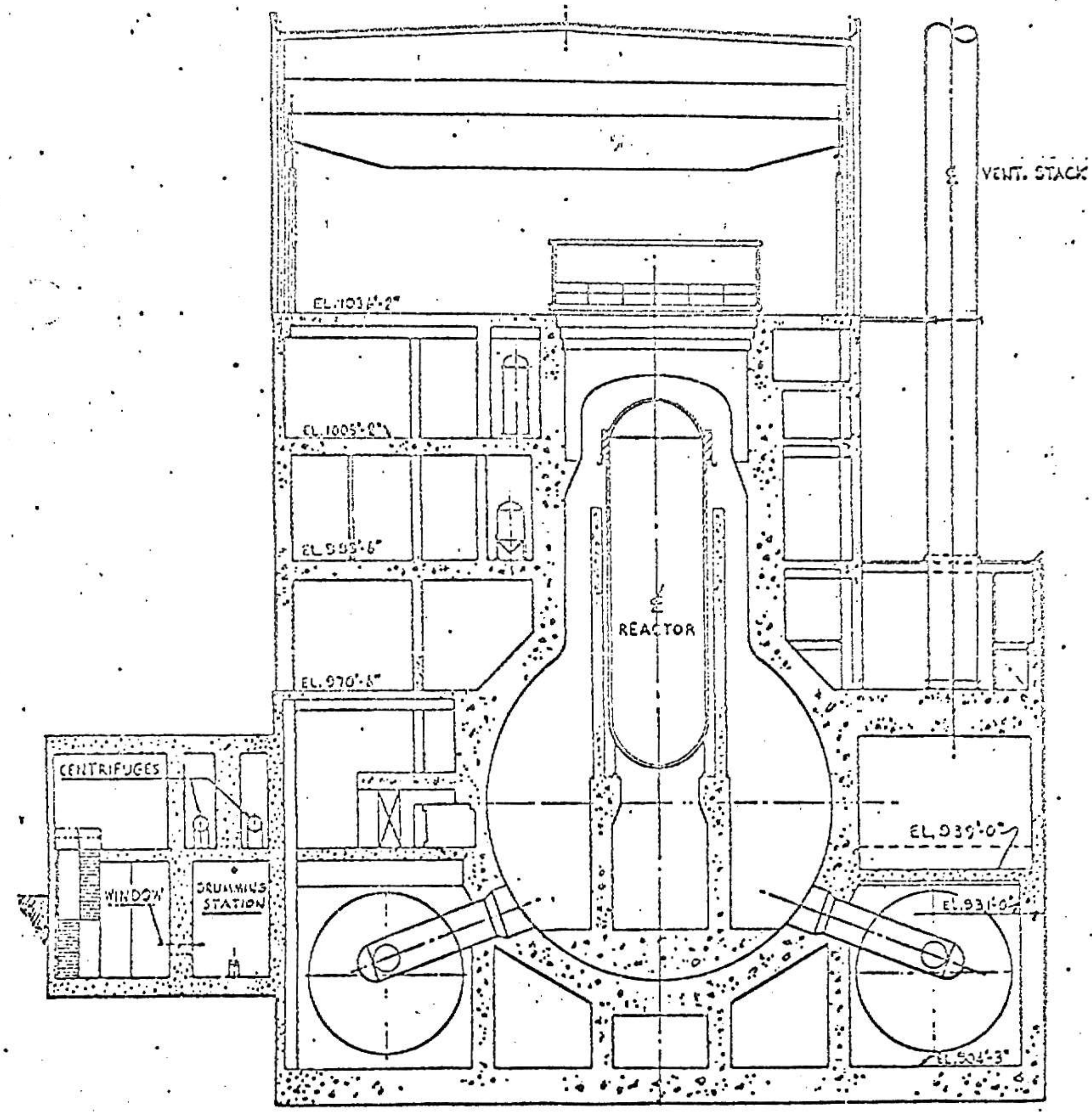
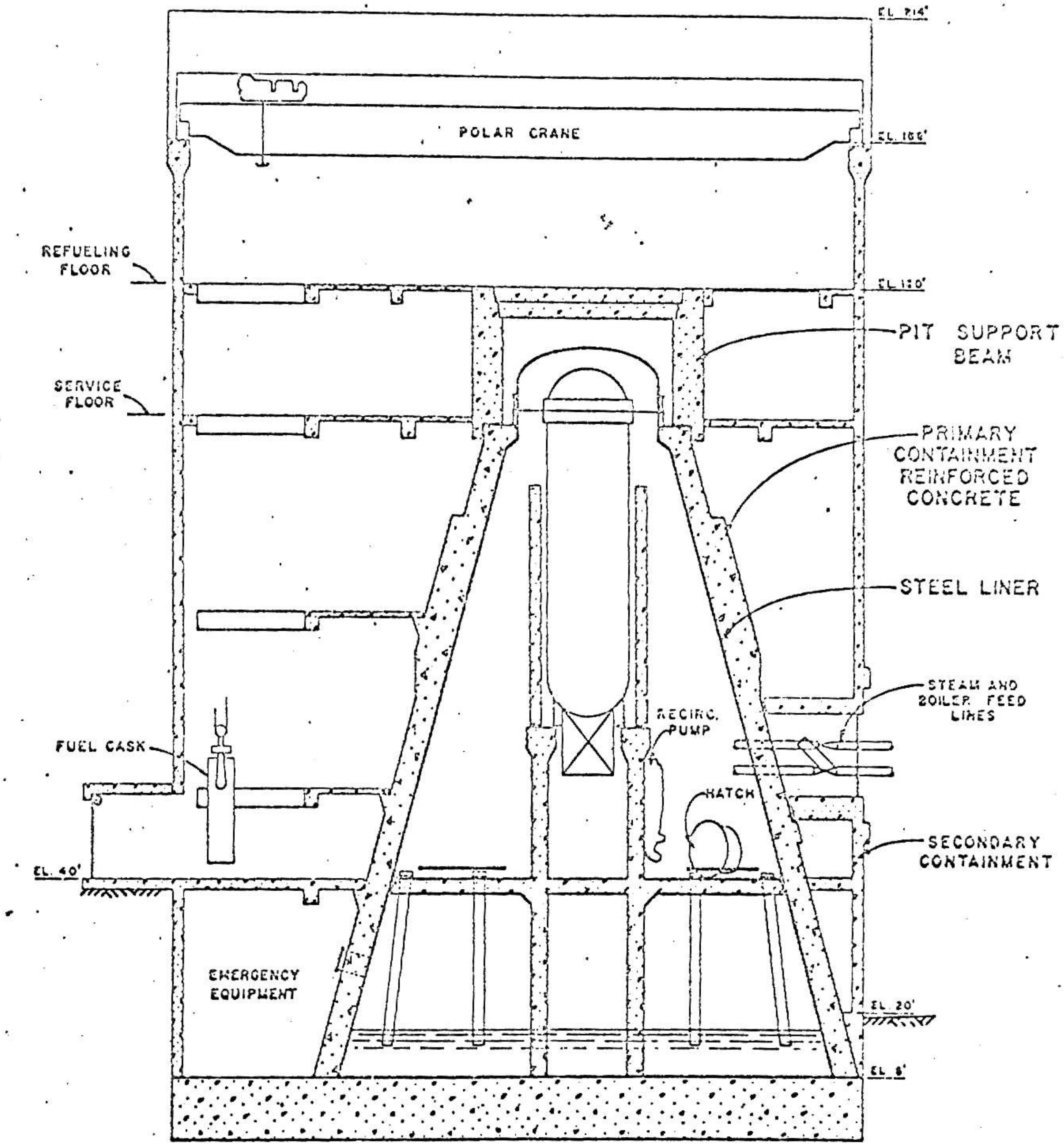
*U.S. Reactor Containment Experience. A Handbook of Current Practice, Analysis, Design, Construction, Test and Operation, Oak Ridge National Laboratory, ORNL-NS IC-5. Published 1964.



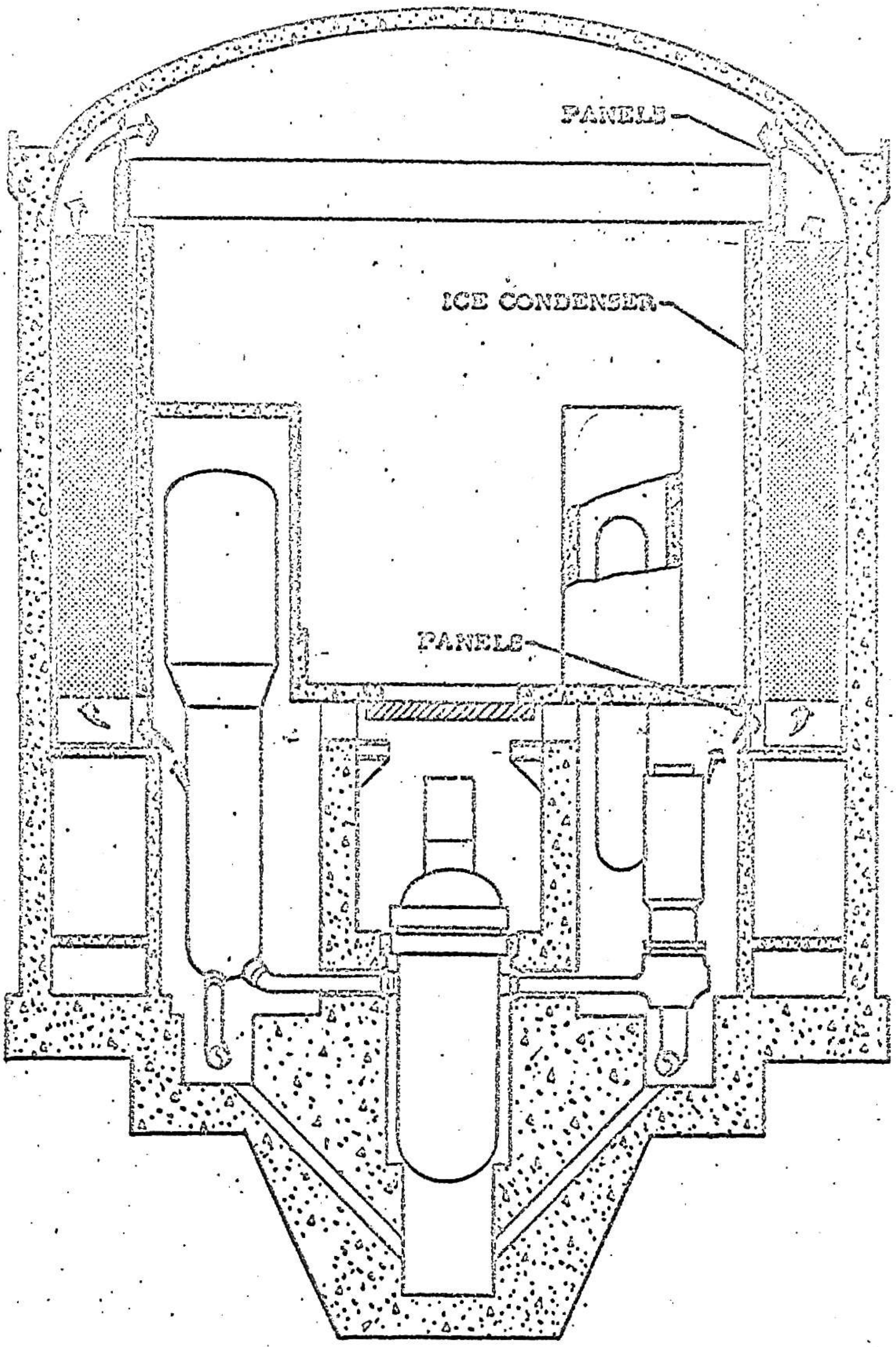
Containment structure for pressurized water reactor



Containment structure for boiling water reactor



COMPOSITE CONCRETE CONTAINMENT



VERTICAL SECTION OF ICE CONDENSER REACTOR CONTAINMENT

Waste Treatment

The greatest portion of radioactive waste is in fission products formed in the fuel elements as a result of consumption of fissile material; 99.99% of this fission product is retained in the fuel complex itself. The remainder, 0.01% must breach the fuel cladding if it is to enter the plant environs. Other hazardous wastes develop from the radiation induced in impurities in the coolant or in the structures and equipment exposed to the intense neutron radiation of the core.

The amount of high level waste formed in a nuclear plant generating electricity to serve the average family for 100 years has been estimated at approximately 1 gallon. Nearly all is collected, concentrated, packaged, and shipped offsite for burial. The remainder, a very small quantity, is safely diluted and dispersed under monitoring in plant effluent. The wastes may be liquid, gaseous, and solid and each is treated in a separate manner.

Liquid Wastes

A portion of the cooling water, which may become radioactive because of the presence of impurities, is continuously circulated through a resin bed purifier which acts similarly to water softeners. When the resin bed becomes saturated with impurities, the resin is taken offstream and rejuvenated by washing with a chemical solution or it is packed for burial. The washing from the rejuvenation process and other radioactive liquids, such as laboratory wastes, equipment decontamination washings, and coolant that has leaked through valve stems or pump seals, are pumped to hold up tanks. Some reductions of radioactivity occur during holdup because of the decay of shortlived isotopes. The holdup solution is transferred to an evaporator, where the radioactive matter is reduced to a sludgelike concentrate. The sludge is mixed with concrete and packaged in steel drums for burial.

The steam from the evaporators is condensed and monitored. It may be refiltered through resin beds or, if sufficiently low in radioactivity, dispersed under monitoring into the plant effluent. The amount of radioactivity thus released is kept to a small fraction of that allowed by AEC regulations.

Gaseous Wastes

The gaseous effluent from a nuclear plant, which may occur from dissociation of the coolant, is removed to holdup tanks to permit decay of short-lived isotopes. The remaining gases are monitored and diluted with air and discharged through a tall stack, when meteorological conditions are suitable for dispersion high into the atmosphere. This discharge is controlled in compliance with AEC regulations.

Solid Wastes

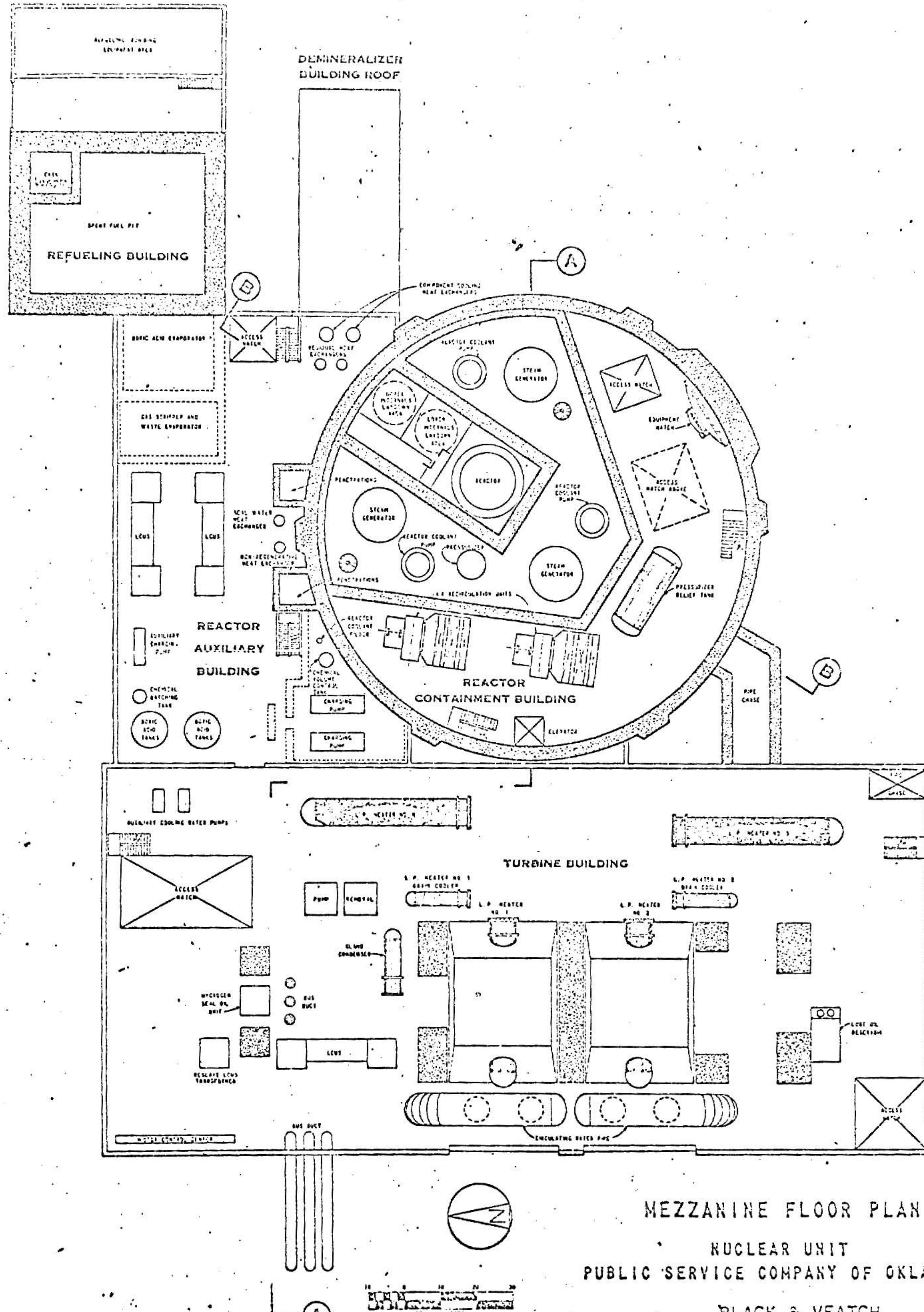
Good housekeeping in a nuclear plant dictates that any scrap materials or discarded objects that have become contaminated with radioactive matter be carefully collected and disposed of in a safe manner. In some plants these wastes (if combustible) are incinerated and the radioactive ash is mixed with concrete, drummed, and shipped for burial. In other plants they are mechanically compacted and packed with noncombustible solids, such as contaminated expendable tools, in concrete-lined drums and buried.

Fuel Handling

Although in a fossil-fueled plant one of the prime site considerations is fuel supply and storage, fuel handling for a nuclear plant is not a major consideration. Special equipment for handling, charging, discharging, storing and shipping, however, must be provided. The management of fuel during the burnup cycle and reprocessing of spent fuel are factors in the economics of nuclear power production.

Spent elements are intensely radioactive and give off some neutrons and highly penetrating gamma rays. Therefore they must be handled by remote means and shielded until the time in reprocessing that the fission products are removed. Spent elements also give off a great deal of heat. For both reasons spent elements are usually handled under water and stored in pools at the plant site to allow them to cool both radioactively and thermally before being shipped. The storage facilities are constructed so that the elements cannot form a critical mass. These pools are usually a massively built concrete chamber open at the top and filled with 40 ft. of water; 10 ft. of water will shield against gamma radiation the same as 4 ft. of concrete or 1 ft. of lead.

The elements are stored for about four months to permit the decay of shortlived isotopes. They are then placed in a heavy shielded cask.



MEZZANINE FLOOR PLAN

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PUBLIC SERVICE COMPANY OF OKLAHOMA

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Auxiliary Buildings

One of the principal auxiliary buildings in the reactor plant, housing the reactor and its associated structure, with electricity generating stations the turbine hall is of major importance. Then there are those buildings which are common to all industrial processing plants, such as the administration buildings, workshops, etc.

However additional facilities which are not normal for conventional power stations are provided in the case of nuclear power stations. These are the active element fuel stores, decontamination rooms, change rooms, laundries, health and physics laboratories, etc. Other structures include water pump houses, cooling towers, irradiated fuel and effluent treatment ponds and, in particular cases, the ventilation towers.

DESIGN CRITERIA

Within the next two decades nuclear power plants will be among the largest industrial establishments in the nation - representing an aggregate investment of some $80 billion.

There will certainly be small plants in the future in addition to the 250 or so large plants. However the siting problems will not be those of finding room for the proliferation of plants; instead, it will be insuring that the relatively small number of mammoth sized plants are adequately planned and located to meet twin goals - low-cost, reliable power and the preservation of the environment.

This is what the Energy Policy Staff of the President's Office of Science and Technology has reported, based on opinions of a selected Federal inter-departmental panel that considered the problems involved in siting large steam electric generating plants - nuclear and fossil.

The basic questions that the group has raised, but has not attempted to answer is what additional planning mechanisms or other actions are needed to identify and utilize in the best public interests, those prime sites that are best adapted to meeting the conflicting demands of environmental quality control, safety, and reliable economic electric power supply. The report discussed the need for power plant sites, physical requirements of sites, water pollution control and techniques for compliance, air pollution factors in power plant siting, fish and wildlife, aesthetic and recreational considerations, rural development considerations in station siting, reliability of service, transmission multipurpose plant siting, and the role of the states in power plant siting. It also included various technical appendices.

Siting

Since the ingredients of a prime site for nuclear power plants make it as attractive to many other industries, the architect should consider a large number of factors of public interest in siting and design of future nuclear power plants. Among these factors, the plants for nuclear power plant siting should:

- Comply with safety criteria as prescribed by the U.S. Atomic Energy Commission.
- Comply with air pollution criteria and standards as established by the states and the National Air Pollution Control Administration of the Department of Health, Education and Welfare (HEW).
- Comply with the water quality standards for thermal effects as established by the states and the Federal Water Pollution Control Administration (FWPCA).
- Develop the opportunities for public recreation at plant sites and avoid impairing existing recreational areas.
- Consider aesthetic values and give adequate attention to the appearance of plant facilities and associated transmission lines.
- Recognize the rural development considerations in plant siting.
- Consider the siting and accessibility requirements for reliability of service.
- Consider the impact on defence preparedness of particular sites and power plant capacities.
- Consider the routing of associated transmission lines and the problems of rights-of-way at various alternative plant locations.
- Assume that the plant will be of sufficient size to meet regional loads

including mutually agreeable arrangements for meeting the bulkpower needs of the small utilities.

- Consider prospects for combining nuclear power plants with other purposes such as desalting plants, industrial centers, and even new cities.

Under current Atomic Energy Commission criteria a nuclear power plant would occupy some 500 acres. Access to highway, railway, and water transportation are important requirements of a site, and an adequate supply of cooling water is a must.

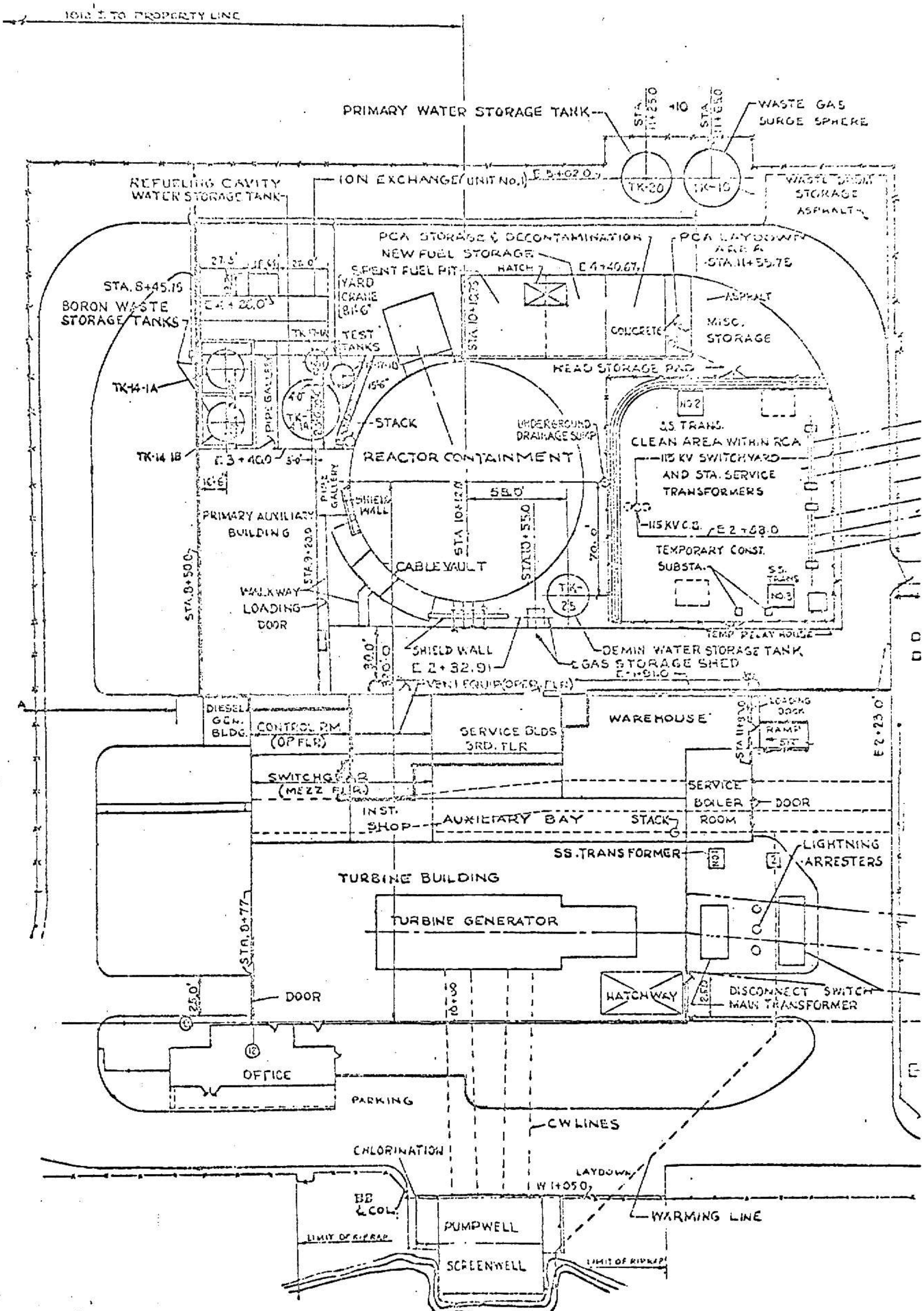
The interesting observation is that the current emphasis on engineering codes and standards focuses attention on plant characteristics, including its engineered safety features, and minimizes reliance on the availability of sites having a unique combination of highly favorable natural environmental advantages. Perfecting codes and standards to be employed with nuclear plants will thus permit a greater freedom in site selection.

Safety

The design of a nuclear power plant is typified by one outstanding goal - complete safety. All other aspects of the design - economically and technically important as they may be - are subordinated to the need of providing a system which, regardless of circumstances, will not result in any injury to the public. Complete safety is, of course, an ideal. No piece of machinery, a reactor included, can be designed so that there is not some risk involved. That risk, however, can be made very small. Certainly, reactors can be, and are being, built which present risks far lower than the common risks of our everyday life.

The safety requirements in a reactor structure are very severe. The containment shell so characteristic of nuclear power plants is the extra safety precaution provided for those reactors where it is conceivable that an accident could occur which would allow the release of fission products. The need for such containment shells has not been clearly established for all reactor types. Particularly some sodium-cooled reactors and gas-cooled, graphite moderated reactors do not use containment shells because of safety features inherent in these reactors.

Integrity and careful attention in the design of relatively minor features can influence very significantly the ease and hence the speed and economics of manufacture, erection and inspection, and the importance of this aspect is far greater in the case of pressure vessels for nuclear plants than with the conventional pressure vessels, where many detailed design solutions have been established by extensive, successful experience and are now accepted as standard practice within the various manufacturing and inspection organizations.



RADIATION CONTROL AREA

RADIATION CONTROL AREA
SITE

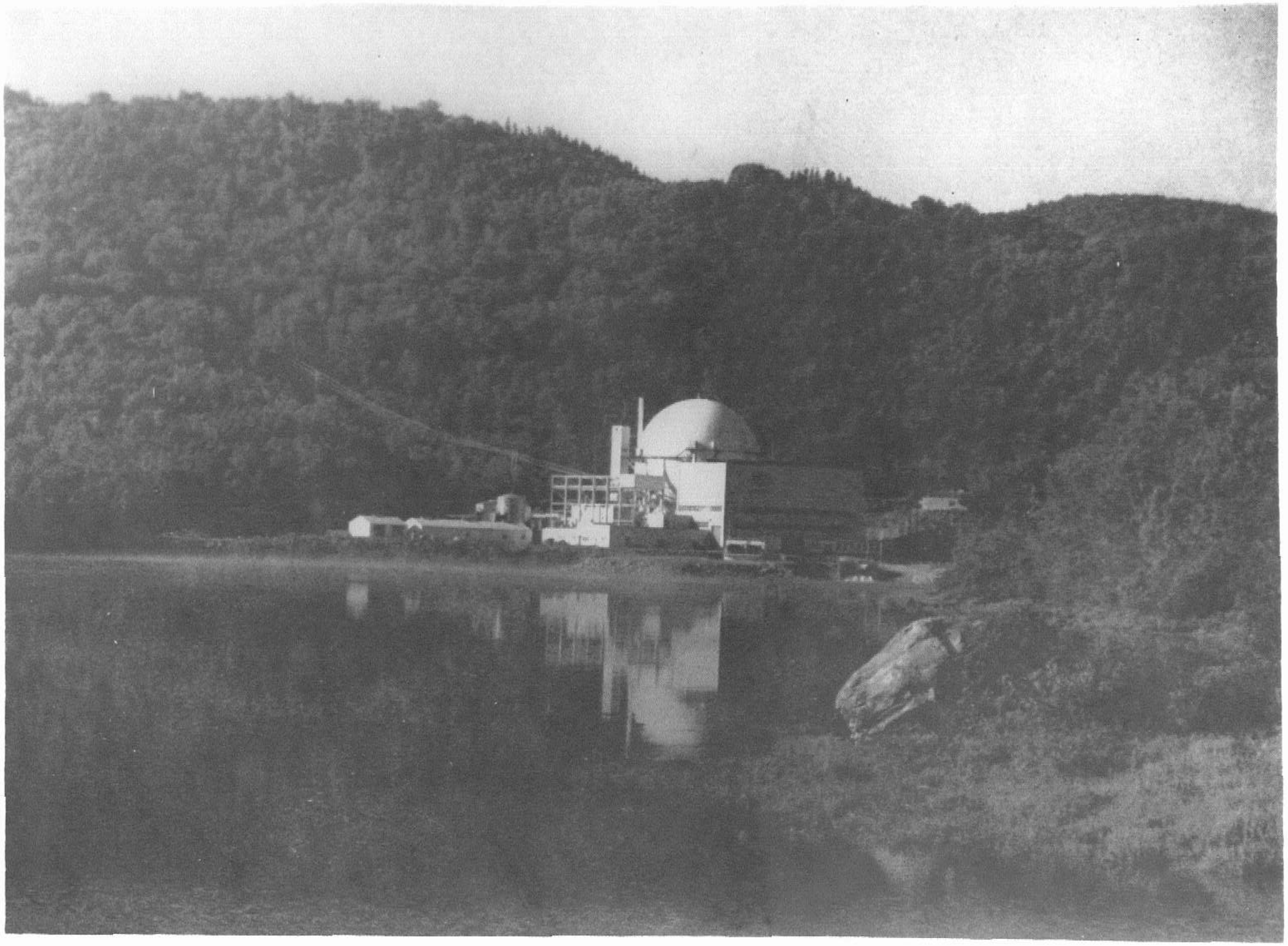
Novel problems, from the structural research point of view, as introduced by nuclear power stations, have given tremendous impetus to structural thinking. The use of pre-stressed concrete for pressure vessels has been under consideration for some time. The pre-stressed concrete vessel, due to its pre-stressing, is structurally more stable under load than when unpressurized. Moreover, catastrophic failure would appear to be almost impossible, in a properly designed vessel with a thin steel plate for thermal and leakproof lining.

The most important application of concrete is as radiation shielding. There are some general principles applied to the design of concrete shielding, apart from the thickness of the shield, which are determined by the radiation intensity and the properties of the concrete used.

The radiation shielding is designed according to the "Standards for Protection Against Radiation." It is divided into categories according to function and to the allowable dose rate in the area. The allowable dose rate is based on the expected frequency and duration of occupancy.

In questions of radiation protection, as with many other questions, proper attention to safety in the design stage greatly facilitates subsequent safety precautions. The system should be designed so that immediate shutdown is always possible. In general safety systems must operate on "fail-safe" system. In other words, the system must be such that if it fails, it automatically reverts to the safe positions. Furthermore there must be duplication of safety systems, independent, and operating under a different principle so that failure of the safety system in one case does not deprive the reactor team entirely of safety control. It is presumed that industrial safety procedures of the highest standard are in operation throughout the plant. The problem is unique, not only in regard to structure and materials and the special problems applying to shielding and safety measures, but also in connection with the layout and functional arrangement of specialist plants and the integration of a most complicated system of services. The architect must fully understand the problem, considering all factors, analyzing the program and various circulations and armed with the necessary knowledge in radiation shielding to assure the required safety through proper zoning and simplest solutions.

Yankee Atomic Power Station, Rowe, Mass.:
beautifying effect of water on industrial plant



Environment

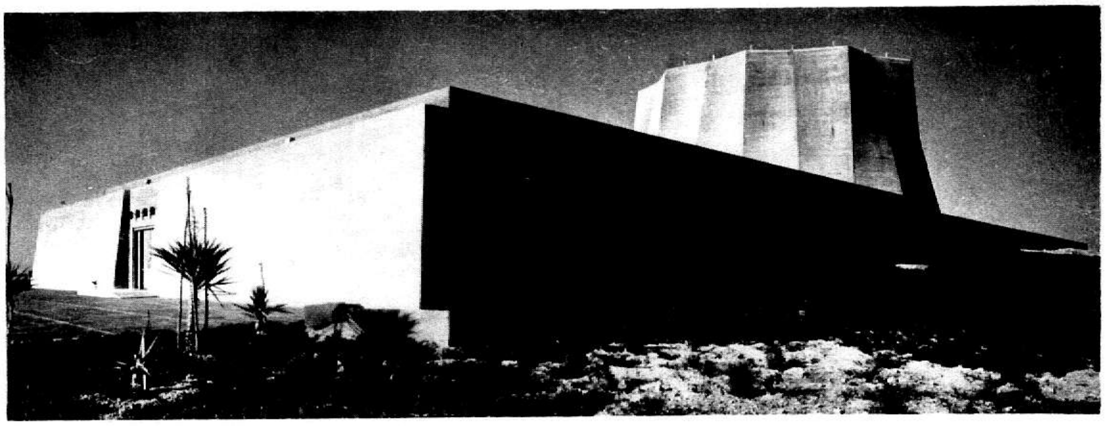
More is being done today than at any time in human history to understand our natural and man-made environments and bring man and nature into a more harmonious relationship. But a good portion of the public has been so saturated by our excellent pollution press coverage that they are now what we might call "environmentally uptight." In our increasingly urban and technological society, a return to the "great outdoors", enjoyment of the natural surroundings, and a new respect and fondness for wildlife are, understandably, growing. Of course, what is usually overlooked is the extent to which technology has made nature accessible to us as a friend to be understood and enjoyed rather than a foe to be overcome. Science and technology are meeting head-on the challenge of the environmental pollution that, admittedly, their productivity has helped create. But only through the proper application of science and technology we can solve our environmental problems and ensure a healthy, attractive and affluent society.

The first thing that comes to mind relating nuclear energy to the environment is the role of nuclear power plants in the problem of thermal effects and the magnitude of thermal discharge.

Ecologists have been concerned over discharge of thermal effluent for some time - concerned over the relation among thermal discharge, all kinds of pollution and the steady degradation of the total environment. Too little is known of the physical effect of heat on water and the changes heat can cause in aquatic ecosystems. Research is needed to determine the best way to add heated effluent to natural bodies of water. Some critics claim cooling towers will create fog and other unfavorable meteorological conditions, such as freak snowstorms or sheet ice on nearby roadways, but no one yet knows the extent of such an effect.

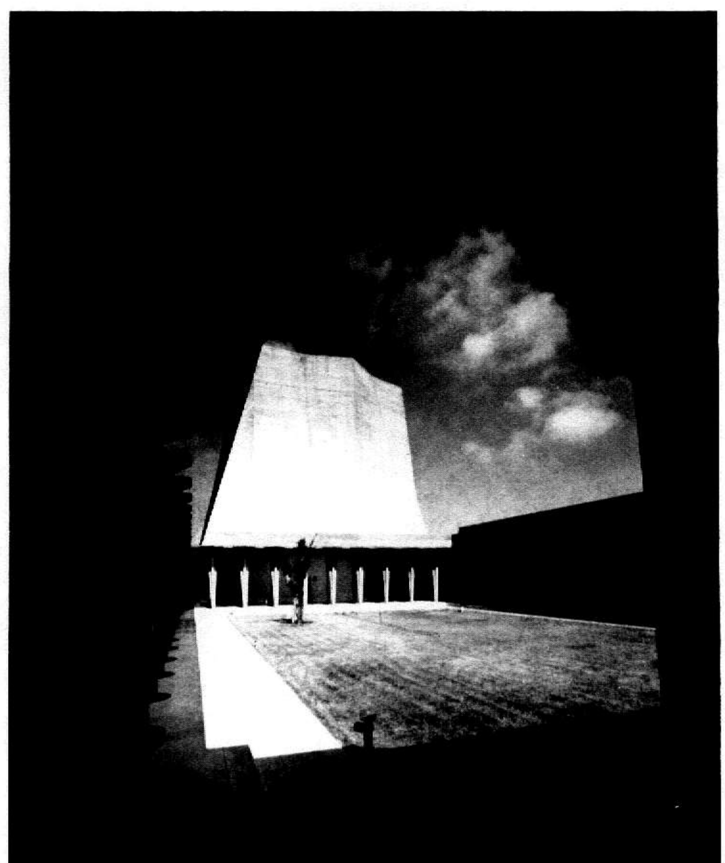
The vast amounts of heat being discarded as excess could be put to industrial or recreational use as part of carefully controlled environmental management. A study made by the State of Connecticut's Research Commission envisions revitalization of the state's fishing industry through use of nuclear waste heat to improve aquatic habitatus for commercial fish. Another use for thermal discharge is in making seasonal waterways usable the year around. Thermal discharge is also being heralded for potential recreational benefits. Warmed by water plant discharge, cooling lakes, as well as rivers and estuaries, could be used for swimming, boating and other water sports almost all year long. More exotic uses of waste heat have also been suggested: A Swedish village is already heated by reactor coolant; more of this might be done.

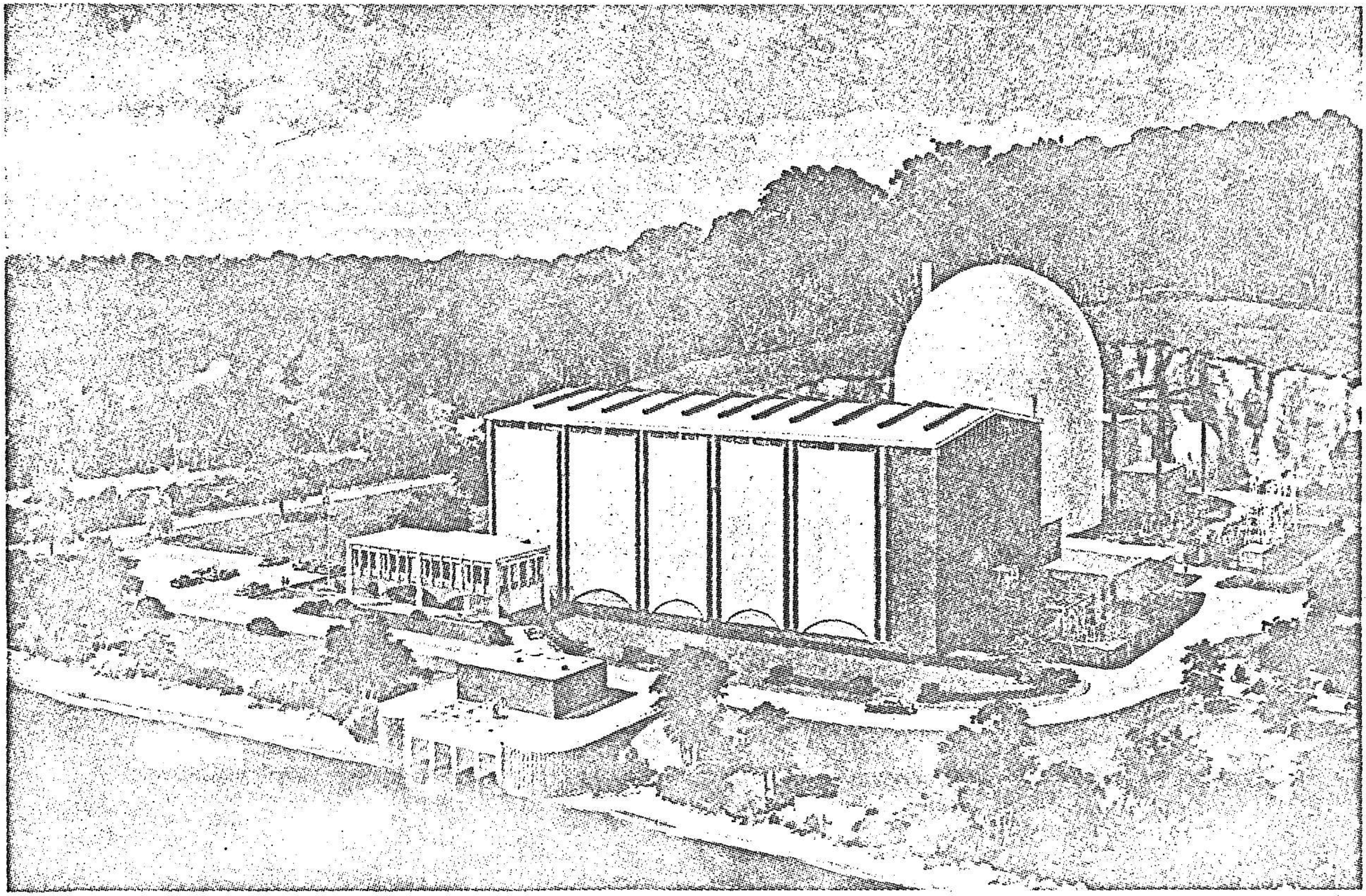
To be truly realistic, both aesthetics and economics must be considered in terms of the continued existence of the body of water. This will require more awareness of both present and future needs than some companies and individuals are willing to admit.



Nuclear reactor, Rehovot, Israel
(Courtesy Arnold Newman)

Inner court of the nuclear reactor, Rehovot, Israel
(Courtesy Arnold Newman)





HADDAM NECK PLANT ● CONNECTICUT YANKEE ATOMIC POWER COMPANY

Concepts

The American Institute of Architects (A.I.A.) had a committee, since July 1947, known as the A.I.A. Committee on Planning for the Atomic Age. In April 1950, a change took place in the functions of the committee. It became the A.I.A. Committee on Architecture and Nuclear Science, "to investigate and report with imagination upon the fundamental principles and specific applications of Nuclear Science to the Architecture of the United States in the immediate and distant future, with particular reference to the safety, design and environment of buildings for peacetime applications of Nuclear Science." The chairman of the board was Charles S. Haines of Voorhees and Walker, Smith, Smith and Haines, a man of considerable experience in the field of nuclear energy, and Frederick Arden Pawley, A.I.A., had become Staff Executive of this Committee.

Mr. Haines considered that the new types of buildings which are emerging from the A.E.C. program have distinct architectural possibilities; buildings to house particle accelerators, reactors and ancillary equipment. Mr. Haines stated that "the building must always remain subservient to the plant which it houses, the cost of which is many times that of the structure." The difficulty he had found was that the scientific requirements change so rapidly that it was a mammoth task to keep the services in order and to present a reasonably neat and finished appearance to the structure.

The only real solution is for the architect acting as a coordinator to lead the team of specialists to work with and not for this "master builder."

The architects should take a determined line in preparing for the role they have to fill - which is the directing of the buildings of all types of nuclear power plants. The task is not beyond them, they should have the capacity to deal with this new problem. It is understood that the architect-engineer's services include balance-of-plant design and engineering, preparation of overall plant specifications for bids, supervision of bid invitation procedures and bid evaluation. The engineer-constructor, often from the same company as the architect-engineer, normally has overall plant engineering and design responsibility, erecting the balance of the plant, and providing overall plant construction management. This involves (in co-ordination with the Nuclear Steam Supply System and turbine generation suppliers and the utilities) site preparation, erection of structures and improvements, auxiliary systems, management of construction labor, and scheduling of the project. The pattern of plant construction arrangements resembles the traditional fossil plant procurement by electric utilities.

It is imperative that the reactor and plant design not be involved in one isolated compartment and the architectural and civil engineering in another. The plant and building complex form an organic whole; optimum design can only be achieved by early consideration of the influences affecting all the elements in the complex and by a careful weighing of the properties attached to each element. This is why no clear character expression has yet appeared in such buildings; aesthetically they are poor and lack overall coherence in the massing of the elements, the expression of function and the orderly arrangement of the services.

The architect is merely called in as a "tidier up", to make engineers' design look better; pleasing to the eye. The man of taste realizes that his eye demands some functional justification for every appendage. Alternatively, if any quality that can be added is describable as beauty, then beauty is not the essential element of architecture. In a lecture at Rice University, Louis I. Kahn, F.A.I.A., said "if the architecture is right, you wouldn't add to it or subtract from it." In any case a building is more than meets the eye. Beauty is the promise of function, and function can be the inspiration for form. Form must make a statement, say something and be something, not babble without commitments. Form must have an idea, without it form is meaningless, and meaningless form has no place in architecture. If architecture is ordered space for fulfilling human needs, then form is space conditioning. Form orders and regulates space. This brings us to a third factor; economy. It is the kind of economy that Louis Sullivan talked about when he said buildings are "beautiful in their nakedness." William Hogarth described this kind of economy in 1753 when he talked about, Economy of forces as a kind of beauty; "Logic, economy, structural clarity of architectural solutions are by themselves a source of poetic satisfaction." It is the same economic beauty as that of a great athlete or a graceful ballerina.

In building for such a function as nuclear energy, true beauty must emerge from within. There is no tradition of beauty in the power station without achieving the ultimate integration of the structure and the machine.

CONCLUSION

The architect can not understand the forces acting on the architecture of nuclear power plants without a knowledge of the developments taking place in all other disciplines. Now the scene is dynamic. Technology along with changes involving social, economic, governmental and psychological factors, are perplexingly complicated. For the architect, this requires the development of related skills, research and education.

It is time to bring together the research workers, the analysts, the designers and the constructors to facilitate this transition from discovery to creative architecture and efficient engineering accomplishment.

There is no doubt that the greatest single problem in design is the design of a nuclear power plant. It is a massive structure, but if properly and honestly designed it can be visually most exciting yet nevertheless harmonious.

What is needed is a proper campaign by the profession in favour of greater architectural participation in the nuclear field.

APPENDIX

KANSAS STATE UNIVERSITY *Manhattan, Kansas 66502*

COLLEGE OF ARCHITECTURE AND DESIGN
SEATON HALL

November 7, 1969

Mr. Johnson, Philip C., A. I. A.
Philip Johnson Associates
375 Park Avenue
New York 22
New York

Dear Mr. Johnson,

This is to introduce Mr. B. E. Labib, an instructor here at the College of Architecture and Design. Mr. Labib has had eighteen years of practical experience, the latter part of which has been in industrial architecture for Egypt and Algeria. He has been with the college since September 1968 and is at present preparing his Master's thesis in the theory of the design of nuclear power stations.

Mr. Labib finds that the Nuclear Reactor of Rehovot, Israel, is one of the most successful examples for such buildings. I share with him the same feelings and I believe you would be of great help to Mr. Labib. He is in need of informations not only that available in published form but also your practical experience in that field.

Mr. Labib wishes to include in his master's thesis, in the theory of design of nuclear power stations, the following points related to the design of the Rehovot Nuclear Reactor:

a. The design concepts.

b. The character expressions.

c. The environmental aspects.

d. Your role in the design of that nuclear power reactor.

I feel you may be willing to supply him with some assistance in the above mentioned items. Any assistance you may provide for Mr. Labib will be greatly appreciated.

Sincerely,

Professor F. D. Miles,
Director of the Curriculum in Architecture

N.B. Please, for time saving, write directly to Mr. Labib on the following address:

B. E. Labib
P. O. Box 892

Manhattan, Kansas 66502

Philip Johnson & John Burgee, Architects

375 PARK AVENUE NEW YORK N Y 10022 PLAZA 1-7440

Mr. B. E. Labib
P. O. Box 892
Manhattan, Kansas 66502

13 November 1969

Dear Mr. Labib:

Alas, I do not have time for a long reply to your questions on the nuclear reactor in Israel.

As you probably know the facility itself was designed by an American engineering company, and all that I did was to put a shell over it. The Israelis wanted to make a handsome covering, and I hope I have done so. The "base" houses the laboratory's equipment necessary to the functioning of the facility. There is a great deal of joking in Israel, of course, that it looks Egyptian, but I don't think so.

If you have any specific questions I would be glad to answer them. Most of the design concepts seem really an attempt to house the awkward machinery in the best way I could considering the site overlooking the sea.

Yours sincerely,

Philip Johnson

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CHICAGO, ILLINOIS 60603

TELEPHONE - FINANCIAL 6-7600

CABLE ADDRESS - SARLUN-CHICAGO

November 26, 1969

Mr. B. E. Labib
P. O. Box 892
Manhattan, Kansas 66502

Dear Mr. Labib:

We have received a suggestion from Professor Chezem regarding the providing of certain data and diagrams, etc., which you are in need of.

We would certainly like, wherever practical, to respond to this type of request for information, but in this particular instance, we do not find ourselves in a position to do so.

As you can well appreciate, the actual designs for our clients are proprietary information, and we are not at liberty to release them to others.

A review of the material which you require indicates that it would be a substantial project in terms of manhours and expense. Accordingly, we must regretfully advise that we cannot provide the material for support of your master thesis.

Very truly yours,

W. R. Steur

W. R. Steur
Director of Engineering

/cg
cc: Professor Curtis G. Chezem
Kansas State University

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THE ARCHITECTURE OF NUCLEAR BUILDINGS,
NUCLEAR POWER PLANTS

by

BADRELDIN MOHAMED EZZAT LABIB

B.Sc. Arch. Engg., University of Alexandria, 1952

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARCHITECTURE

Department of Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

ABSTRACT

We have entered the Nuclear Age. We must therefore control this nuclear energy, well and safely for mankind everywhere. This age will give rise to a series of revolutionary modifications in the economic, social, cultural and political patterns of human society.

In architecture, the ideas and attitudes of societies find physical embodiment. To the architect falls the satisfaction of seeing beliefs and understandings take physical form, to become one of the structures of man's activities and the imprint of his society on the face of the earth. Buildings become, therefore, tangible symbols of the societies which call them into being.

It is now over thirty years since the discovery of nuclear fission. Nuclear energy has begun to come out of the laboratories as a great source of energy for the decades ahead. Within the next two decades the United States will triple its present electric power generating capacity. This will come from some 250 huge nuclear power plants of 2000 to 3000 Mega Watts each. The problem will certainly be insuring that the relatively small number of mammoth sized plants are adequately planned and located to meet twin goals; low-cost, reliable power and the preservation of the environment.

In the design of nuclear power plants, the architect has been either discounted entirely or else brought in to give a certain appearance to the work as a whole, usually when it is too late to do anything very much about it. The engineer is obviously the all-important person concerned and buildings are normally placed in the hands of consulting engineers. The value of the architect is not appreciated or considered, either from the overall planning aspect or for the more detailed portions of the plant.

The architect aspiring to a worth-while position in the field of nuclear energy must be prepared to educate himself in the basic principles of nuclear engineering and understand the technology of the nuclear power reactors, to study the aims and intentions of the engineers, and to discuss these in an intelligent manner. The training of the architect in detailed planning and the true arrangement of spatial relationships fit him perfectly for his task; the achievement of an entity. It is an intricate performance, the fusion of a variety of available elements into an end product in which design is truly related to function. Only the complete integration of structure and plant will ensure results both functionally, economically and aesthetically satisfying.