"NUCLEAR POWER FOR THE FUTURE"

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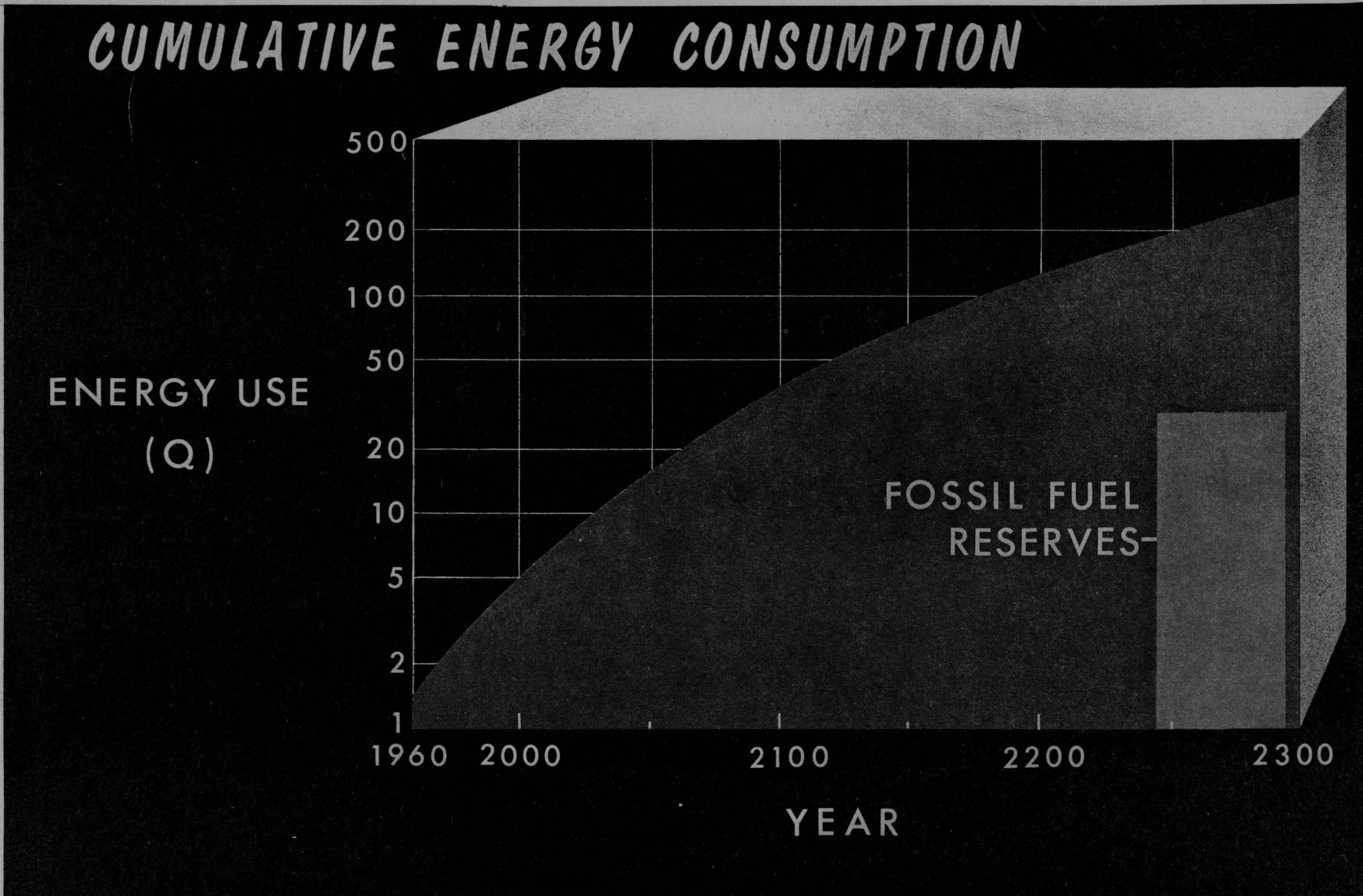
"NUCLEAR POWER FOR THE FUTURE"

Let me express my pleasure at visiting Wichita, and more particularly, my pleasure at this opportunity to discuss with you the Southwest Experimental Fast Oxide Reactor Project - the SEFOR Project. This project will result in the construction and operation of a nuclear reactor, which will be located about 20 miles southwest of Fayetteville, Arkansas, and about 200 miles southeast of Wichita. Construction work is now under way. The reactor and the associated facilities are estimated to cost about 12-1/2 million dollars. These costs will be borne by the Southwest Atomic Energy Associates, a group of 17 investor-owned electrical utilities operating in the southwest portion of the United States; the Karlsruhe Nuclear Laboratory of West Germany; the European Atomic Energy Community - EURATOM, and the General Electric Company. In addition, the United States Atomic Energy Commission is supporting the research and development program connected with the SEFOR project, and this is estimated to cost approximately 12-1/2 million dollars too. The project is intended to produce one product - knowledge. From the size of the investment involved and the wide base of support, I think you may gather that the knowledge we hope to gain is important. In my talk today, I would like to convey to you some of the reasons why we believe that the SEFOR project is important and significant, and also to give you some of the details of the project. Also, at the end of my talk, I would like to touch briefly on the subject of Nuclear Radiation and Nuclear Safety.

The SEFOR project is expected to play a major role in our search for a source of electrical power which will fulfill our needs for the foreseeable future. At this time, almost all of our power needs are supplied from fossil fuel sources, that is, oil, coal, wood, and so on. These fossil sources are stores of energy built up for millions of years by the action of sunlight on vegetation. In essence, we are now using the energy of the sun which has impinged on our planet in the past. However, in this century our appetite for power has increased so greatly that we are now able to see the point where this store of fossil fuel will approach the point of depletion. You have all read about the surplus of oil and know that there are many coal mines not yet working to full capacity, or even shut down, so that plainly when I speak of the future in this context, I am not talking about next week or next year, or even the next 10 years.

The situation is perhaps best illustrated by the first slide, which represents data taken from the 1962 Atomic Energy Commission report to the President. The curve shown in this slide represents the consumption of fossil fuel resources. The vertical bar to the right of the graph represents an estimate of the total fossil fuel resources available. Both curves refer only to the United States. The unit of energy used is the "Q" which is a billion billion British thermal units or 10^{18} Btu. This is a very large unit of energy and for perspective, I should tell you that the average consumption in this country today is about 1/20th of a "Q" per year. However, our consumption of energy is increasing at such a rapid rate that as you can see from the slide, in about 100 years we will approach the point where we will have depleted our total store of fossil energy reserves.

You will recognize, of course, that the figures in the slide are projections and, of course, are subject to large errors. Our reserves of fossil fuel might be

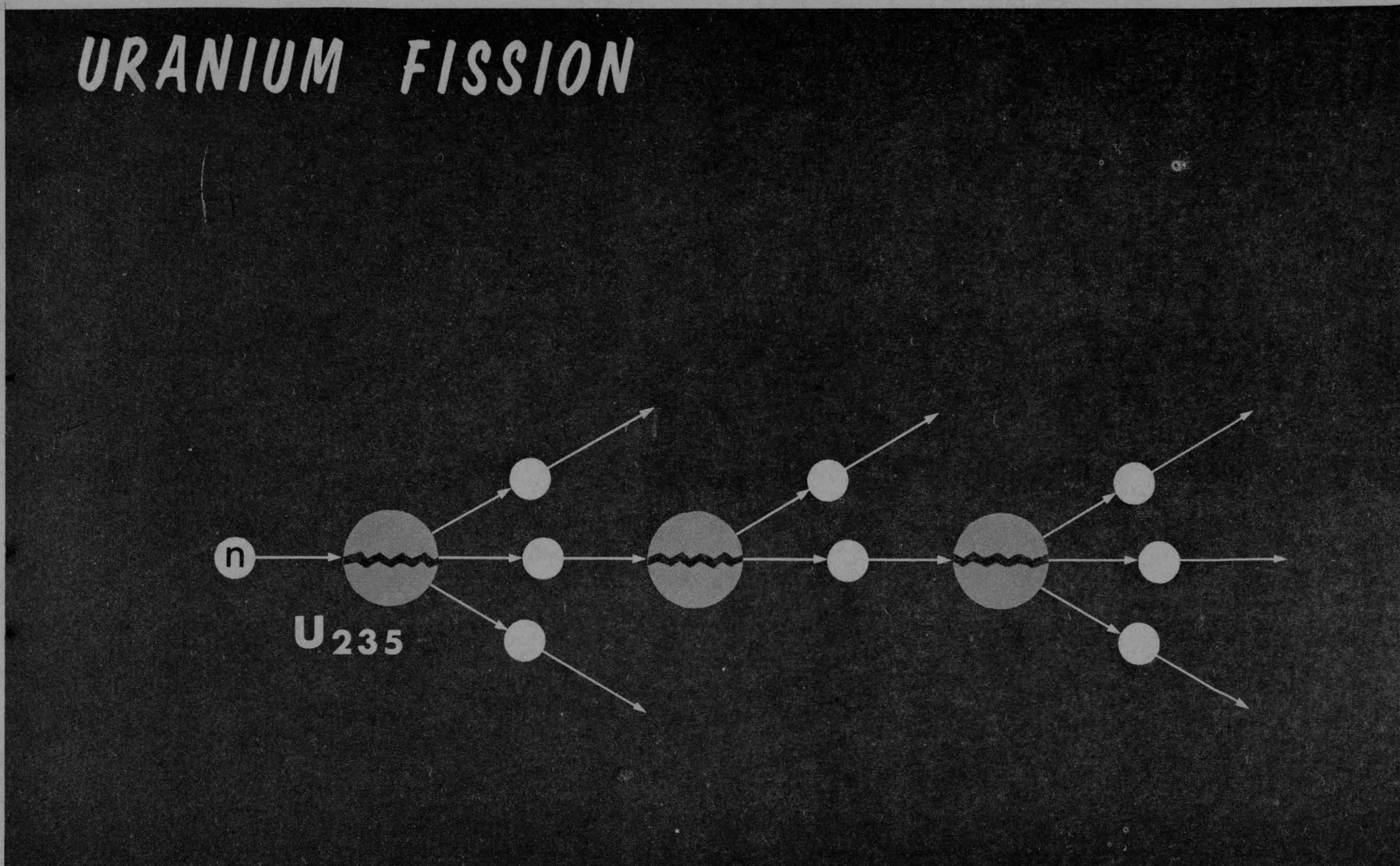

CUMULATIVE ENERGY CONSUMPTION
ENERGY USE
(Q)
500
200
100
50
20
10
5
2
1
FOSSIL FUEL
RESERVES
1960
2000
2100
2200
2300
YEAR

larger than that indicated on the slide and our consumption less than that projected, or perhaps more. The important point however, is that our fossil reserves are limited and that our consumption of power is increasing at such a rate that one must at least recognize the possibility that in the next century we may deplete our fossil fuel resources. Although the slide refers to the situation in the United States, the World situation is even less favorable with regard to long-term power requirements. The United States has a disproportionately large share of the World's fossil energy reserves in proportion to its population.

Today, nuclear power is the prime candidate to supply our long-term energy needs. Indeed, the Atomic Energy Commission has indicated that its major role is to develop nuclear power to the point where concern over future energy sources can be relieved. I would like, at this point, to discuss some fundamentals of nuclear power production.

The second slide schematically illustrates a nuclear chain reaction. A neutron striking the nucleus of a uranium 235 atom causes it to split, or fission. The two halves of the split U-235 nucleus, because they are highly charged, repel each other and move apart at a high speed. This speed is eventually converted into heat of the surrounding medium and this heat, in turn, is used in the simplest process to boil water. The resulting steam is then used to drive a turbine generator, which produces electricity. Thus, a nuclear power plant is similar to a power plant fueled by coal. In the one case, the heat used to boil water is produced by the burning of coal. In the other case, the heat is produced by the fissioning of U-235.

Turning back to the slide again, we note that when the U-235 nucleus splits, there

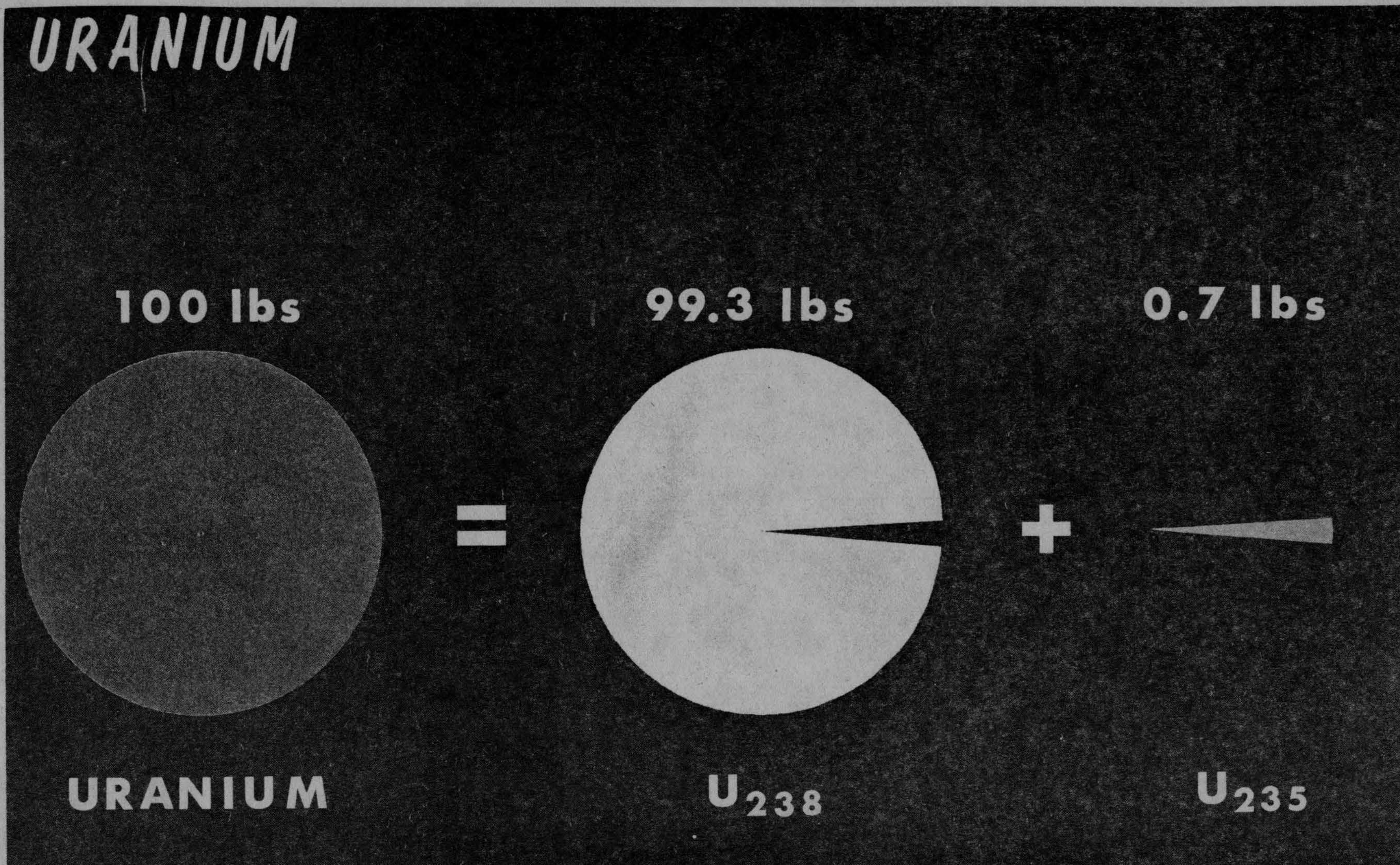

URANIUM FISSION
n
U235

are given off additional neutrons. In the illustration, 3 neutrons are given off when the first nucleus splits. Some of these neutrons will leak away from the region containing U-235, some of them will hit other materials which do not fission. In the illustration, one of the three neutrons hits another U-235 nucleus and causes it to split or fission. From the second fissioned U-235 nucleus, 2 neutrons are emitted, and one of these hits another U-235 atom.

You may already see how a nuclear reactor operates: Between two and three neutrons are emitted in a U-235 fission. If we put enough U-235 in a given region so that on the average one of the neutrons given off in a U-235 fission will strike another U-235 nucleus before it leaks away from the region or hits a nonfissioning atom, we will have a self-sustaining nuclear chain reaction. You may also infer from this slide the manner in which a nuclear chain reaction can be controlled. To turn off the reactor, one merely breaks the chain. This is done by mixing some nonfissionable material in with the uranium so that on the average less than one of the neutrons produced in a fission will strike another U-235 nucleus. Thus, if we started with 100 fissions occurrring in a second, during the next generation there might be 50 and then 25 and then 12 and then 6 and so on until the number of fissions occurrring per second, or the power level of the reactor had decreased to a very low level. Similarly, if one wished to increase the power level of the reactor, he would take away some of this parasitic material so that more than one neutron from a fission struck another U-235 nucleus. In this case then, if one started with 100 fissions per second, in the next generation there might be 200 and then 400 and then 800 and so on, until the power level reached the desired value. Then the nonfissionable material would be put back so that the power level stayed constant.

Now that you know how to design and operate a nuclear reactor, you can see that the fundamentals are quite simple. The major requirement is a supply of fissionable material which gives off more than one neutron each time a nucleus fissions. Uranium is the only naturally occurring material which has this property. More precisely, uranium 235 is the only naturally occurring material with this property. Uranium is composed of 2 isotopes; uranium 238 and uranium 235. These two different isotopes look and act alike from a material standpoint. If I handed you a piece of each, you could not tell the difference. Even a chemical analysis would not differentiate between them. But on the nuclear level they behave quite differently. Slide 3 shows that the proportion of U-235, the fissionable isotope, is very small in the naturally occurring uranium. Only .7% or 7/10ths of a pound out of every 100 lbs. of uranium consists of the fissionable U-235. The remaining 99.3 lbs. is the nonfissionable U-238.

Now, if we are considering the fissioning of uranium as our alternate source of energy for the future, let us look at the supply of uranium. The fourth slide, which is also taken from the 1962 AEC report to the President, shows the availability of our nuclear reserves in terms of that energy unit I described before - the "Q". There are two columns shown. In the first column, only the energy from the U-235 is shown. In the second column is shown the total energy which would be available if not only the U-235 were able to fission but also the U-238. Since there is approximately 140 times as much U-238 as U-235, the figures in the second column are approximately 140 times as large as those in the first column. The present cost of uranium is approximately $5 to $10 per pound. At this price and using only the U-235, one can see from the slide that the addition to our energy resources is not very great (remember that there are about 30 Q in our fissil fuel reserves). However, if we were able to utilize the U-238, we would greatly expand


URANIUM
100 lbs
99.3 lbs
0.7 lbs
=
+
URANIUM
U_{238}
U_{235}

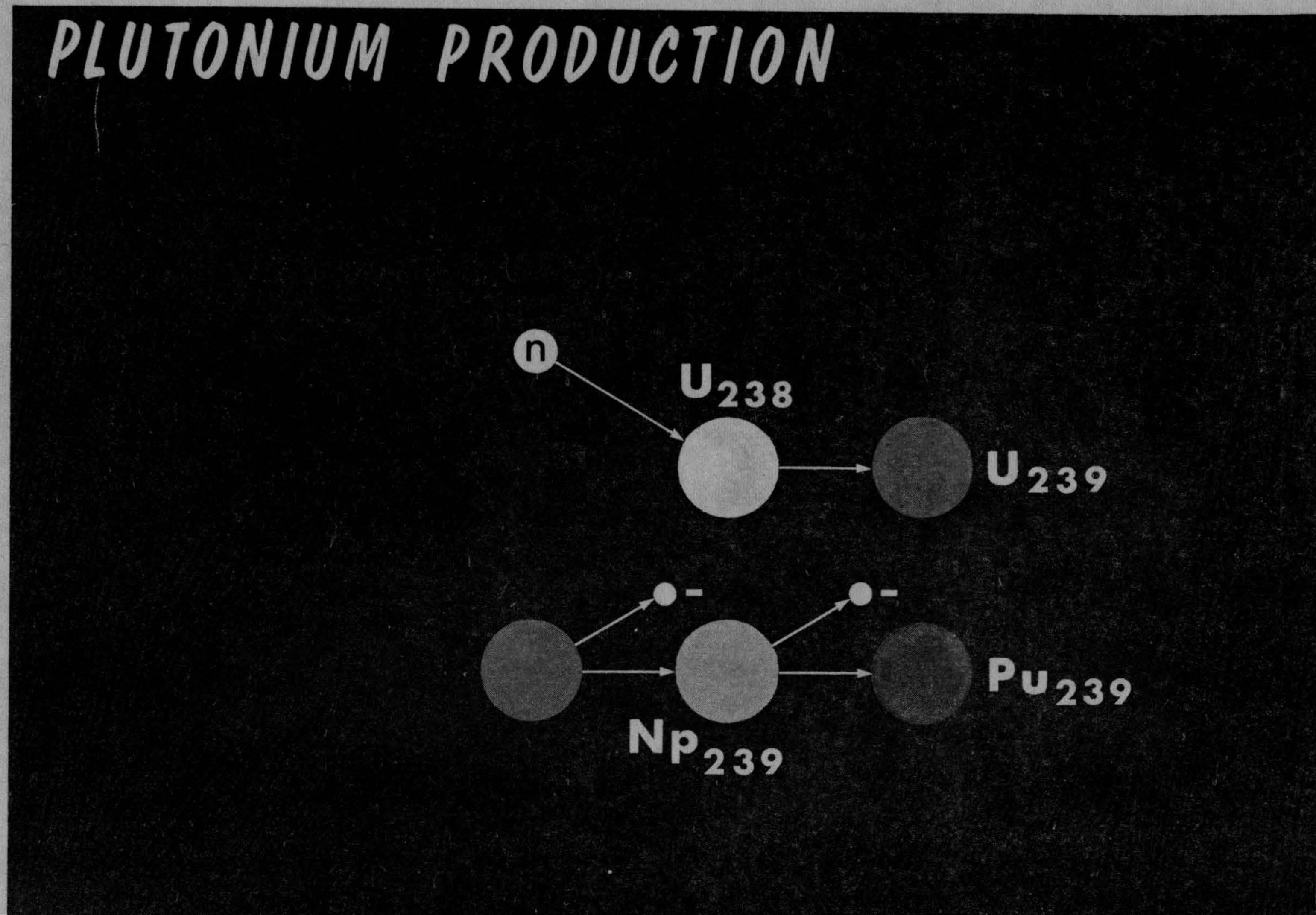
URANIUM RESOURCES

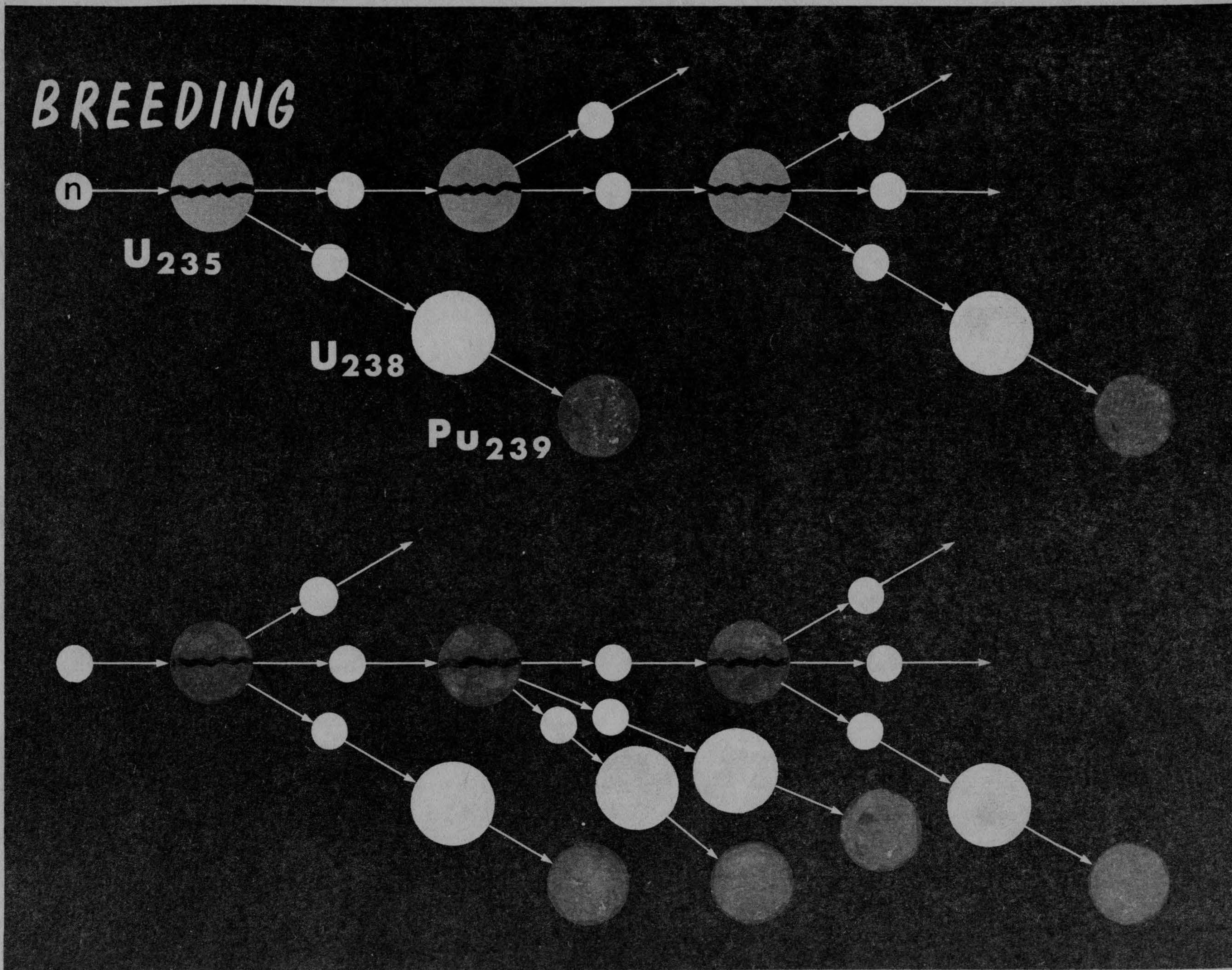
$ PER POUND OF OXIDE	ESTIMATED TOTAL RESOURCES	
	ENERGY IN U-235 (Q)	TOTAL ENERGY CONTENT (Q)
0 - 10	0.4	50
10 - 30	0.3	40
30 - 100	10	1,400
100 - 500	900	120,000

our nuclear fuel resources, and furthermore, since we would be extracting 140 times as much energy from the material which was mined, we could afford to pay a greatly increased price for this material. Thus, if we could find a way to utilize the U-238, we could increase our nuclear fuel supply to the point where concern over future power needs would be relieved. The SEFOR project is a major step in the development of a reactor which will let us achieve these objectives.

The next slide shows the way in which the nonfissionable U-238 can be turned into a fissionable material. When a neutron strikes a U-238 nucleus, the U-238 does not fission. Instead, it is converted into still another isotope of uranium - uranium 239. The uranium 239, in turn, converts itself into another material, neptunium 239, which in turn converts itself, via another nuclear reaction, to plutonium 239. Plutonium 239 is fissionable. Without going into the details of these transformations, the important thing to remember is that when a neutron is captured by U-238, the uranium 238 is converted to the fissionable plutonium 239. This fact allows us to speculate on the construction of a new type of reactor which produces more fissionable material than it uses during operation. Such a reactor is called a breeder reactor, and its fundamental method of operation is illustrated on the next slide.

At the top is shown the same chain reaction illustrated before. However, in this case, I have indicated that in addition to U-235, there is also U-238 in the core, and that some of the neutrons produced in the fission of U-235 are captured by the U-238 nuclei, and in turn, convert the U-238 to plutonium 239. If we do some accounting on the chain reaction shown at the top, we see that we have destroyed 3 U-235 nuclei and have produced 2 new plutonium 239 nuclei. In technical terms, we would have a breeding ratio of 2/3, and because we are producing fissionable


PLUTONIUM PRODUCTION
n
U_{238}
U_{239}
-
-
Np_{239}
Pu_{239}



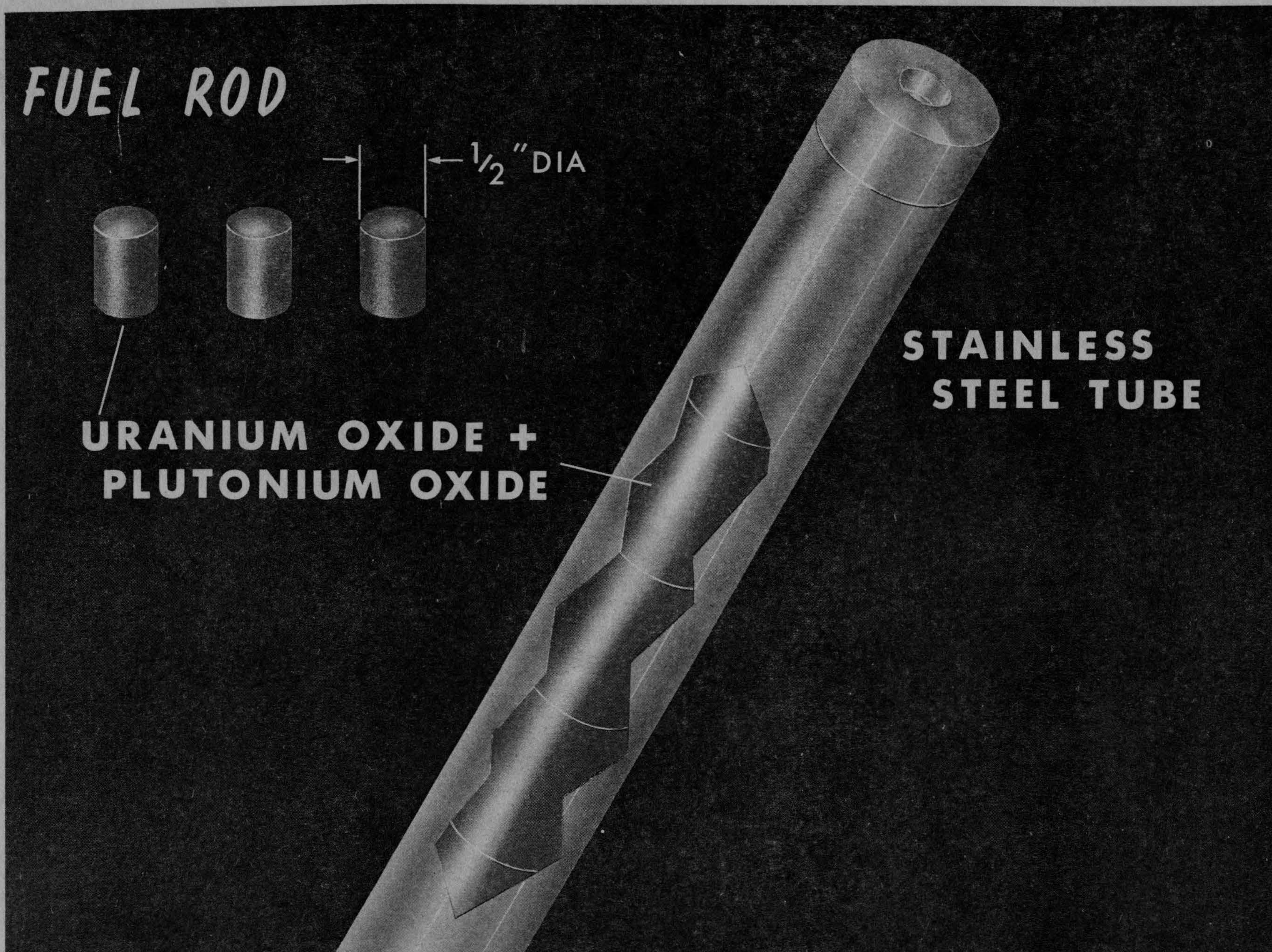
BREEDING
n
U235
U238
Pu239

plutonium to replace some of the used up U-235, we would extend our nuclear resources to some extent.

In the chain reaction illustrated in the lower part of the slide, we show a reactor which is fueled by plutonium 239. Plutonium has the characteristic that when it is fissioned it gives up more neutrons than does U-235. Thus, there is a higher probability that some of the extra neutrons produced can be captured in U-238 and thus produce additional plutonium 239. The lower part of the slide illustrates this possibility. Performing our accounting procedure on this chain reaction, one sees that we have destroyed 3 plutonium 239 nuclei by fission, but we have produced 4 new plutonium 239 nuclei, so that our breeding ratio is now greater than 1. Breeder reactors operating on this type of cycle are theoretically capable of converting all of our uranium 238 into plutonium 239. As they operate and produce power, they convert U-238 to Pu-239 and they end up with more plutonium 239 than they initially started with; thus the term "Breeders". To avoid confusion, I should emphasize that although we end up with more fissionable material than we start with, we are not producing something from nothing. We are merely converting our nonfissionable U-238 into the fissionable Pu-239. To sum up then, the breeder reactor provides a means to turn all of our U-238 into fissionable plutonium, and thus extend our energy resources to the point where we can relieve concern about energy needs for the future.

Some of you may have lost interest after I pointed out that our energy crisis would not manifest itself until some time in the next century. Perhaps some of you will be retired by that time. However, you may be interested in the fact that the breeder reactor has the potential for producing power at very low cost. Indeed if it is to see wide-spread use in this century, it must be justified on the basis of economics. The SEFOR reactor is a prototype of a breeder reactor which appears capable of producing low-cost power and thus, could be used in the near future for economic reasons while at the same time greatly expending our nuclear fuel resources for the future.

With this somewhat abstract description of the basic goals behind the SEFOR project, let me turn now to a description of some of the hardware which goes into a nuclear reactor, and in particular, into the SEFOR reactor. The next slide illustrates the form of fuel which forms the basic constituent of a nuclear reactor. The fuel, equivalent to coal in a fossil plant, is in the form of a mixture of uranium and plutonium oxide. This is a ceramic material which is pressed and fired into small pellets, cylindrical in shape as illustrated at the top of the slide. The artist has taken some liberties; in particular, the fuel pellets are in actuality black. They have the feel of unglazed ceramic tile or pottery. For the SEFOR reactor, the pellets will be about an inch in diameter; for other reactors they may be 1/4 or 1/2 inch in dimension. The pellets are loaded into a stainless steel tube, which is welded shut at the top and the bottom, and this tube containing the fuel pellets is called a fuel rod. In the past, breeder reactors have had fuel rods which contained the uranium and plutonium in a metallic form rather than in the ceramic form. These metallic fuel rods had a very short life in a reactor because they would distort under nuclear operation. Because of the care required to produce fuel rods, they are quite expensive, and as a result of the relatively short lifetime of the metallic fuel, the economics of the metallic breeders is poor. The ceramic fuel, on the other hand, shows promise of extremely long life under nuclear operation, and thus shows potential for producing low-cost power. The SEFOR reactor will be fueled with this ceramic fuel and one of its major goals is to demonstrate that

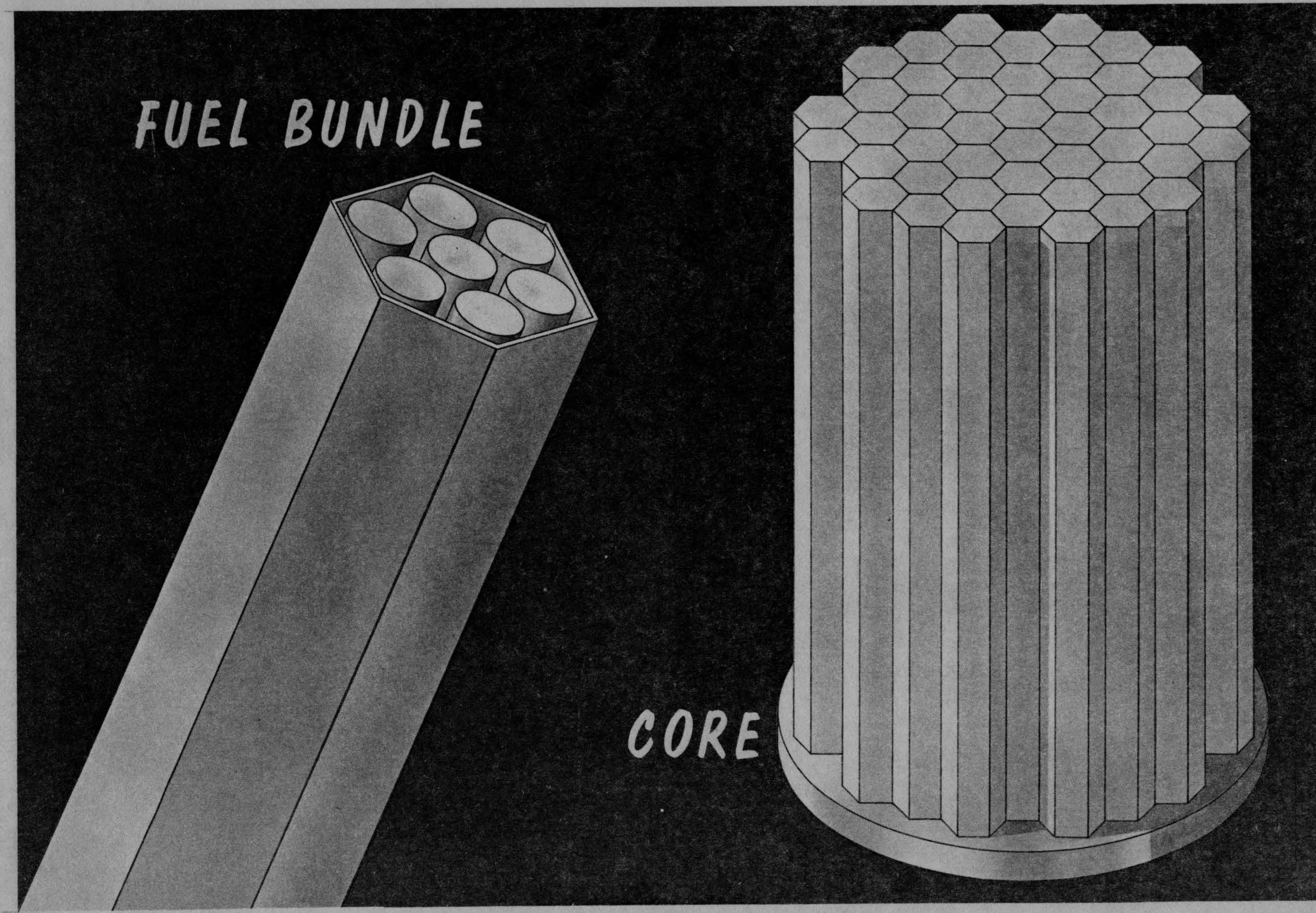

FUEL ROD
1/2 "DIA
URANIUM OXIDE +
PLUTONIUM OXIDE
STAINLESS
STEEL TUBE

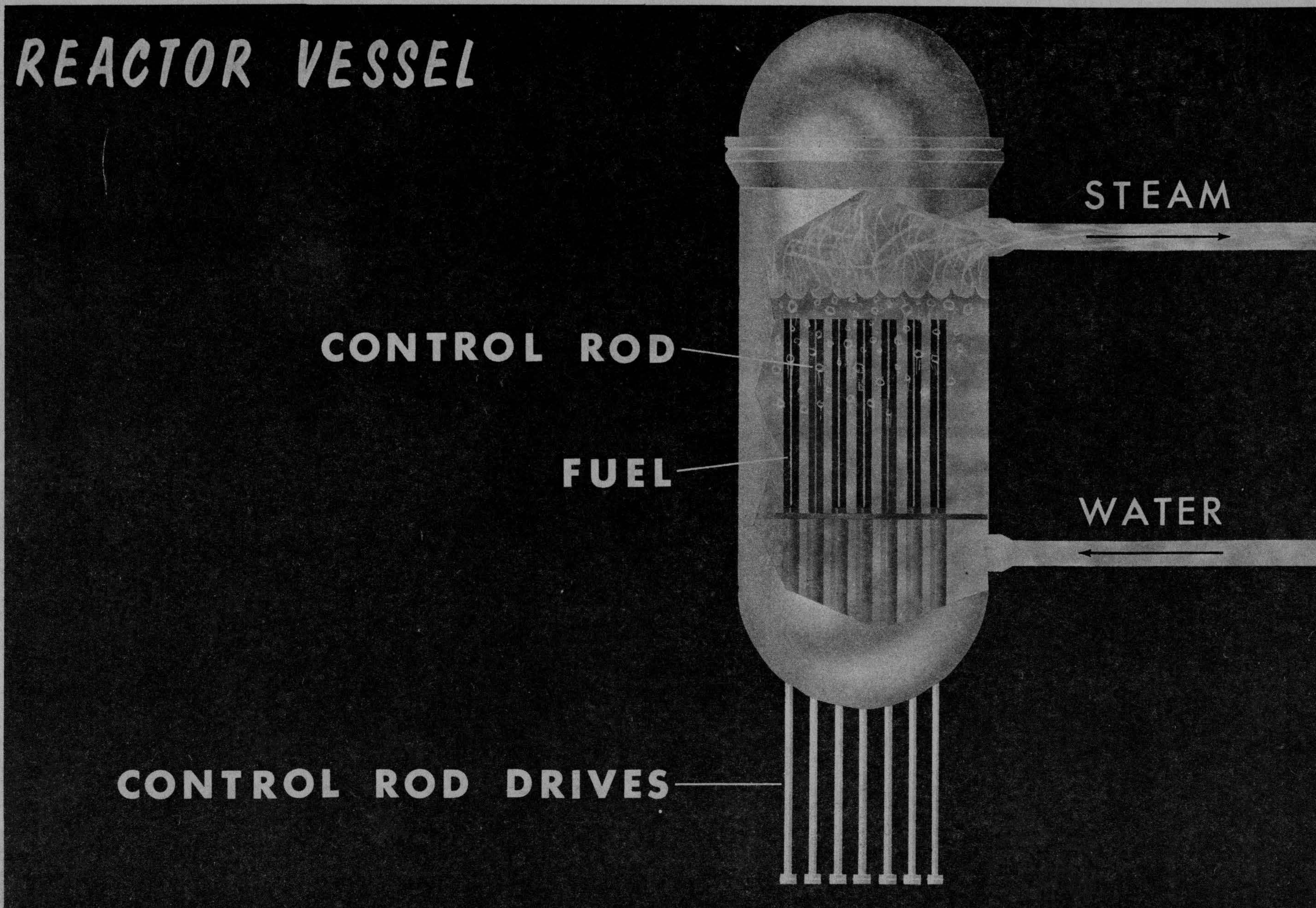
such a reactor with ceramic fuel will have the desirable operating characteristics which we predict for it.

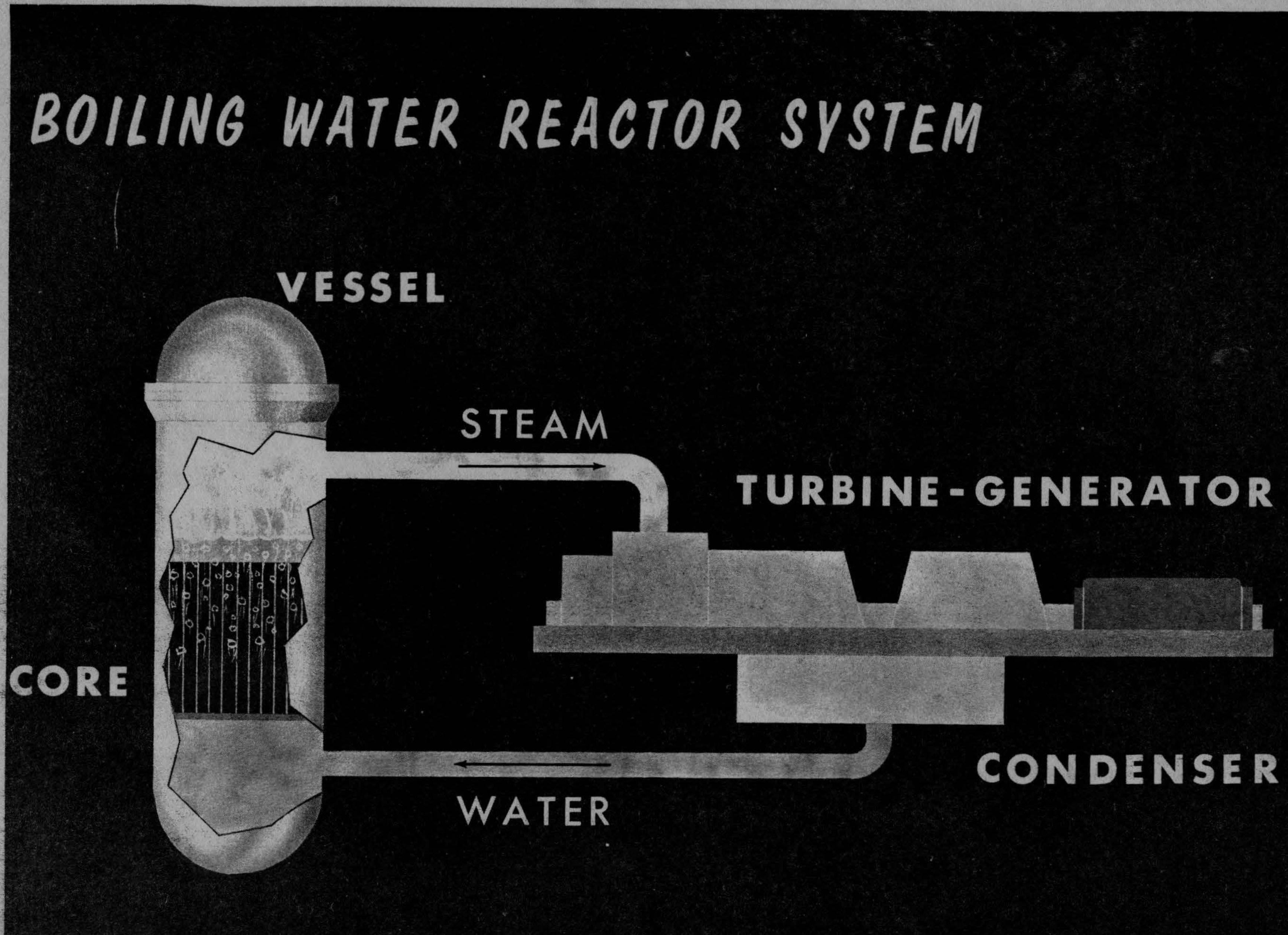
The fuel rods illustrated on this slide are now grouped into bundles to ease the handling problem. A bundle is shown on the next slide. It consists of an assemblage of fuel rods held together by mechanical fittings. A number of these fuel bundles are now grouped together to form the reactor core. As shown on the next slide, the reactor core is placed inside of a reactor vessel, arranged so that coolant flows into the reactor vessel, through the reactor core, and out of the vessel. The entire purpose of the reactor core is to heat the coolant; the energy of heat in the coolant is, in turn, used eventually to produce steam and drive a turbine generator. Also shown on this slide are a number of control rods. These work in the manner which I indicated before. Control rods usually contain Boron. Boron has a great affinity for neutrons. When the control rods are placed in the core, neutrons are absorbed by the Boron and the neutrons which are so absorbed cannot strike fissionable atoms and continue the chain reaction.

The next slide shows schematically the simplest type of nuclear power reactor. This is the boiling water reactor. As shown, water enters the reactor vessel at the bottom and flows through the reactore core. As it flows through the core, it is heated and boils. The resulting steam goes to a turbine generator which produces electricity. Steam is then condensed and flows back to the reactor vessel as water. This type of reactor, the boiling water reactor, is now being produced by the General Electric Company, and in many parts of the country, produces power more cheaply than fossil fuel power plants.

As you know, water is composed of two atoms of hydrogen and one atom of oxygen. In the boiling water reactor, the neutrons produced in the fission, which travel

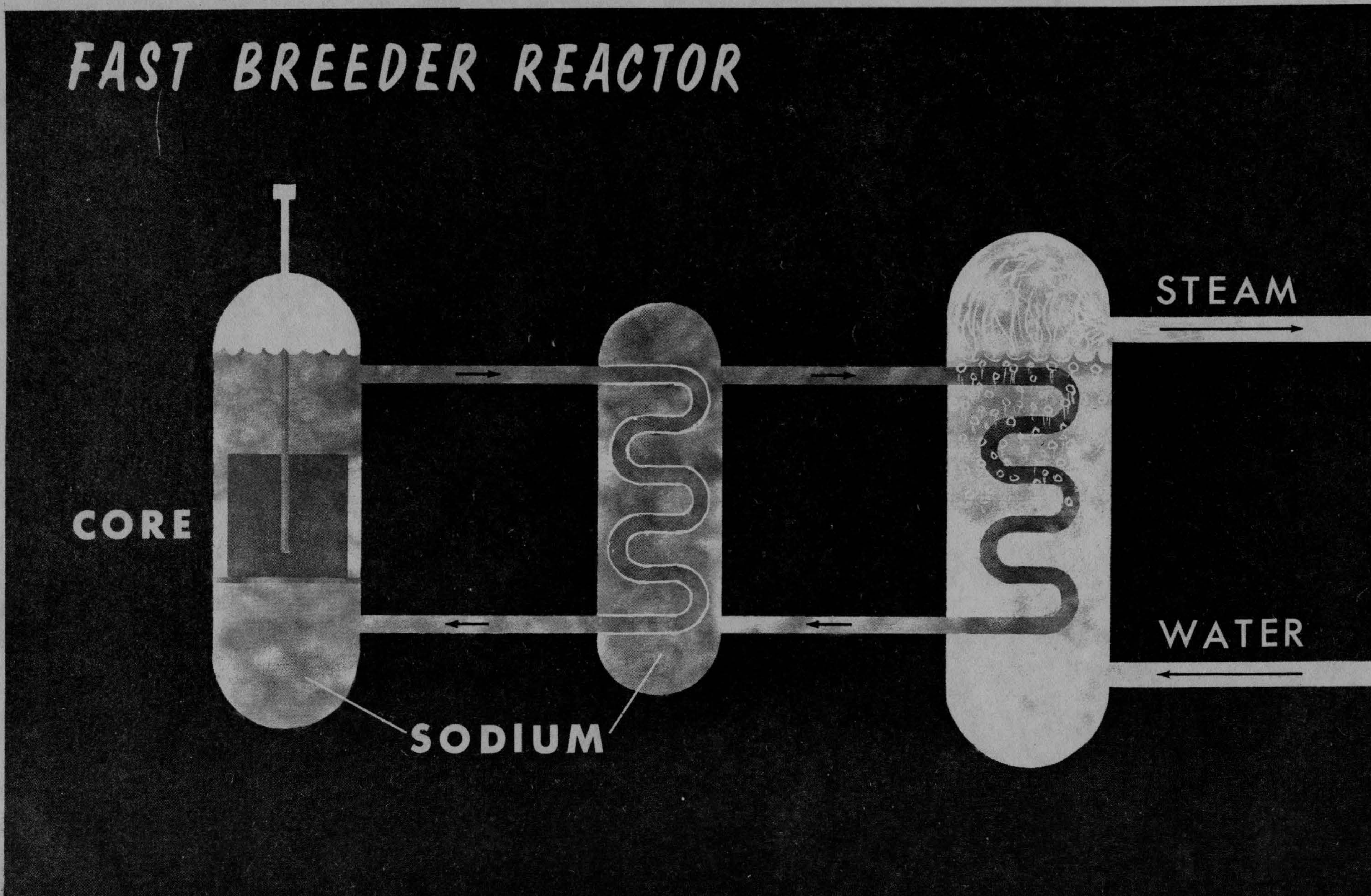

FUEL BUNDLE
CORE


REACTOR VESSEL
STEAM
CONTROL ROD
FUEL
WATER
CONTROL ROD DRIVES


BOILING WATER REACTOR SYSTEM
VESSEL
STEAM
TURBINE-GENERATOR
CORE
CONDENSER
WATER

very fast, strike the hydrogen nuclei in the water and are slowed down as a result. The hydrogen nuclei weigh about the same as the neutrons, and one may think of this slowing-down process as a series of collisions sililar to those that occur on a billard table. When the cue ball strikes another billard ball head-on, the cue ball stops, or is greatly slowed down, whereas the other ball is speeded up as a result of the collision. In the boiling water reactor, enough of these collisions take place so that by the time a neutron causes a fission, it has essentially lost all of the speed it initially had. This type of reactor is called a slow, or thermal, reactor because the neutrons when they cause fission are travelling at low speeds or velocities characteristic of the normal thermal agitation of the core materials. To achieve an efficient breeder reactor, we wish to avoid this slowing down or thermalization. This is accomplished by eliminating light nuclei, such as hydrogen, in the reactor core. When a neutron strikes a heavy nuclei, one may liken the situation to that of a billard ball striking a bowling ball. In this case, the billard ball bounces off the bowling ball and changes direction, but does not appreciably reduce its speed. These fast neutrons, when they finally cause a fission, result in more neutrons being emitted in the fission than would be the case for a slow or thermal neutron. A greater number of fission neutrons can result in a greater conversion of the U-238 into plutonium 239, and thus a higher breeding ratio. The breeders which utilize the fast neutrons to cause fission are called "Fast Breeder Reactors."

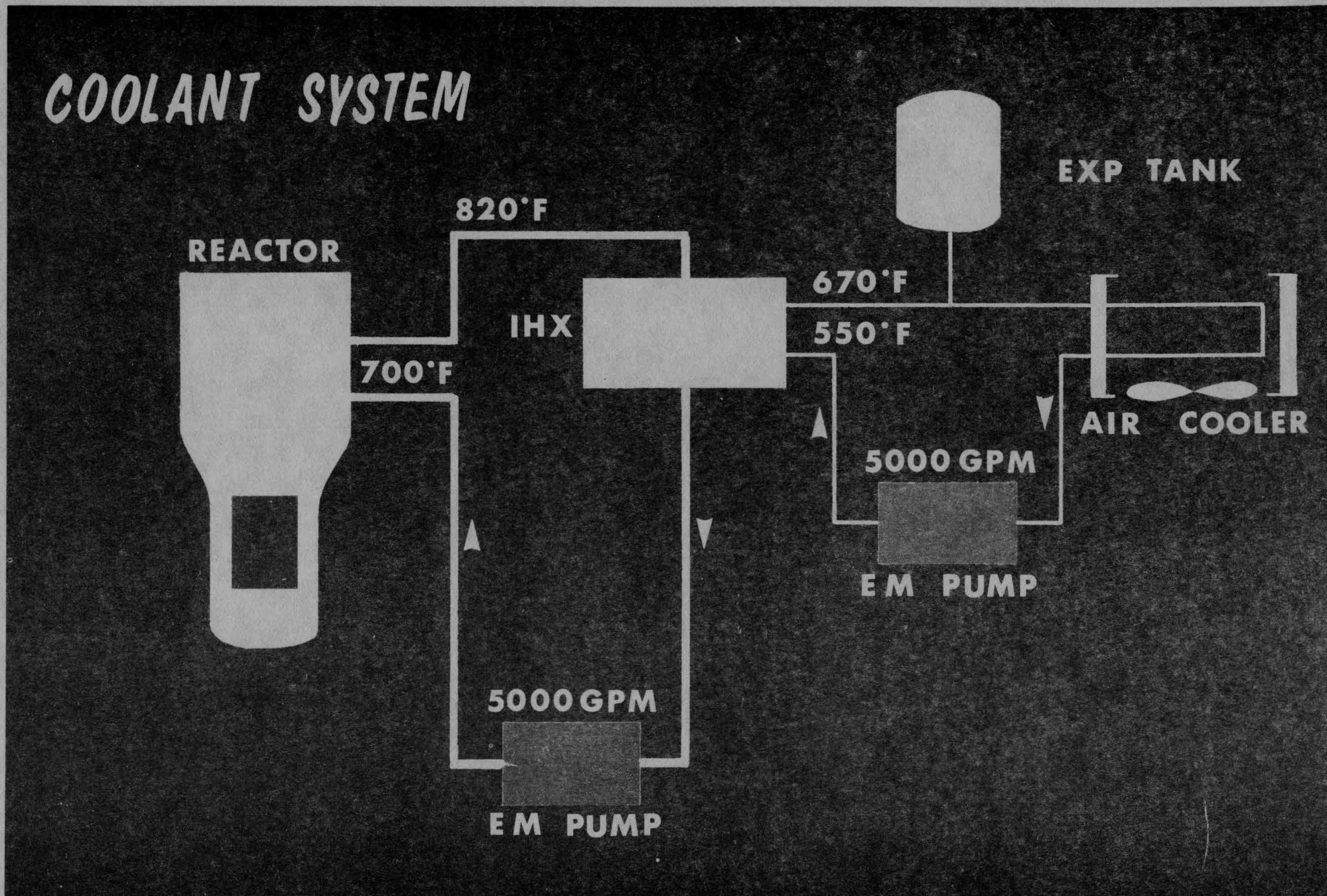
The prime candidate for the coolant for these fast breeder reactors is molten sodium. Sodium is a metal which melts at a little bit over 200^{o}F. In its molten state, it hasa silvery appearance and looks very much like mercury. It has very good heat transport and heat conductivity properties, which is what makes it desirable as a reactor coolant. The next slide shows schematically how a fast breeder reactor looks. The liquid sodium flows into the reactor vessel and up


FAST BREEDER REACTOR
CORE
SODIUM
STEAM
WATER

through the reactor core where it is heated. It then flows out of the reactor core and into a heat exchanger, and then back into the reactor vessel. In the heat exchanger, an additional stream of sodium flows past the sodium which was heated in the core and in this process, cools the sodium from the core while it itself is heated. This secondary sodium, in turn, flows into a steam generator where it heats water and causes it to boil. The resulting steam is then used to drive a turbine generator.

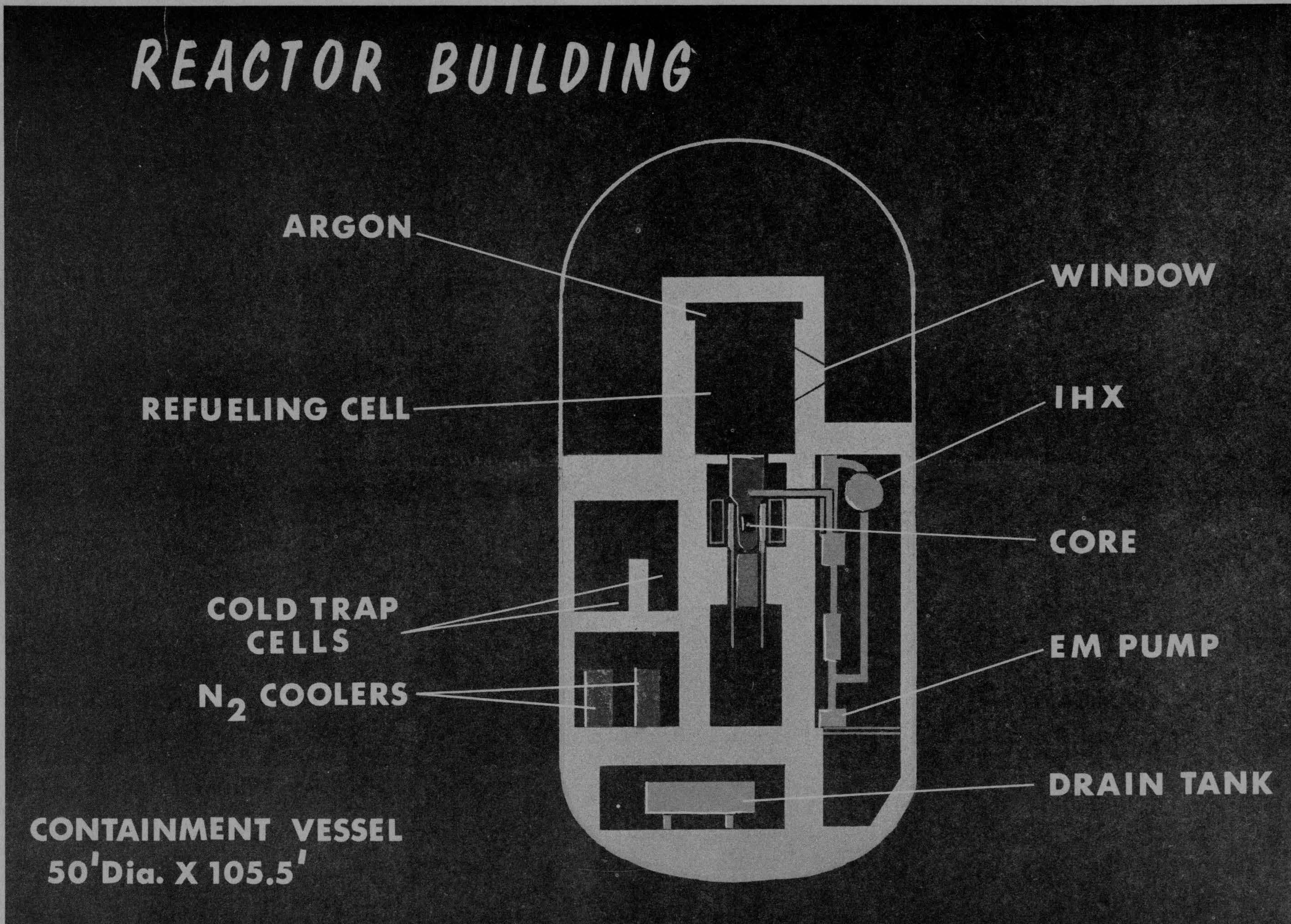
The reason for this intermediate heat exchanger is as follows: The sodium which flows through the core is made radioactive; however, the sodium in the secondary system is not radioactive. Thus, the intermediate heat exchanger transfers the heat but not the radioactivity. In the event that there were a leak in the steam generator, the water would react with the nonradioactive sodium. If major damage resulted it would be in a nonradioactive part of the system and repairs would be facilitated.

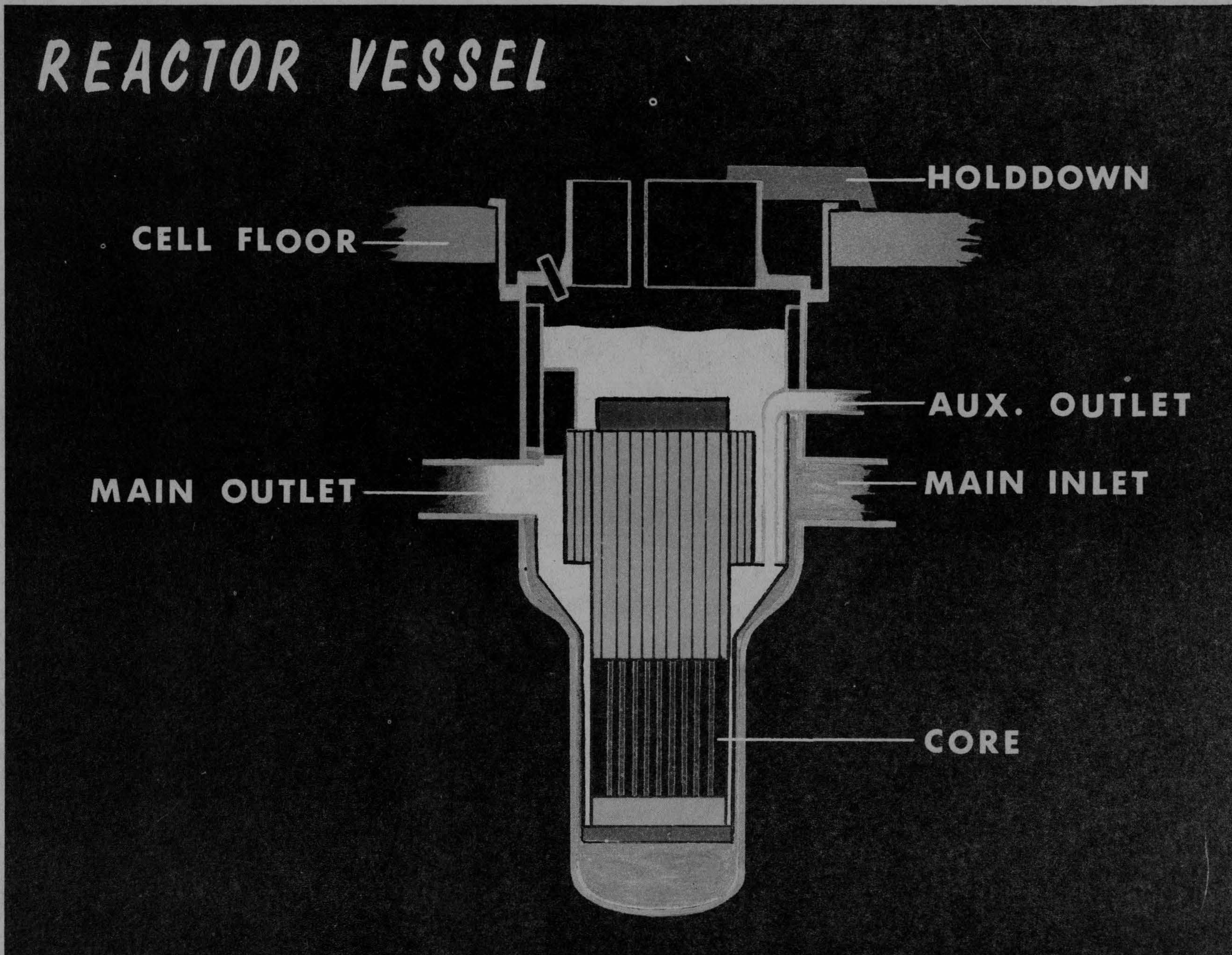
The next few slides are more specific to the SEFOR reactor design. As I mentioned before, the output from SEFOR is not electricity, but knowledge. The next slide represents the heat production and disposal system of SEFOR. SEFOR will generat about 20 million watts of heat. This power is produced in the reactor core and manifests itself by heating the sodium entering the reactor vessel from about 700° to 820°F. This sodium travels to the intermediate heat exchanger where it transfers the heat to the secondary sodium system. The secondary sodium, in turn, travels to a forced-air heat exchanger where it transfers its heat to the air, which flows through the heat exchanger. Thus, from SEFOR we will get both knowledge and hot air. There is not supposed to be any connection between these two products.


COOLANT SYSTEM
EXP TANK
820°F
REACTOR
670°F
IHX
550°F
700°F
AIR COOLER
5000 GPM
EM PUMP
5000 GPM
EM PUMP

The next slide shows an elevation of the reactor building, which contains the reactor core and reactor vessel, and all of the radioactive materials. The reactor building is about 50 ft. in diameter and 115 ft. high. This building is cylindrical in shape and is constructed of steel so that it is, in effect, a hermetically-sealed building. The reactor vessel, its associated piping, and the intermediate heat exchanger, all of which contain radioactive sodium and other radioactive materials, are contained within steel lined reinforced concrete cells which are within the reactor building. These cells have walls about six feet thick which reduce the radioactivity levels so that personnel can work outside of them.

The next slide shows the reactor vessel in more detail. Sodium flows through the inlet nozzle at the top of the vessel; down along the inner surface of the vessel; up through the reactor core, which is contained within a metallic shroud; up through shielding material, which is above the core; over the top of the shroud; and finally down and out through the outlet nozzle, which is also located in the upper region of the vessel. The over-all length of the vessel is about 15 ft., and its diameter in the upper region is about 6 ft. In the lower vessel region, opposite the core, the diameter is about 35 in. The reason for this odd shape of the vessel is that we place nickel reflectors in the region opposite the reactor core and outside of the vessel. These reflectors reflect neutrons, which leak out of the vessel, back into the core. We control SEFOR by raising and lowering these reflector pieces. When the reflectors are opposite the core, neutrons which would leak out are bounced back into the core and can participate further in the chain reaction. When the reflectors are lowered, these neutrons leak out and no longer participate.

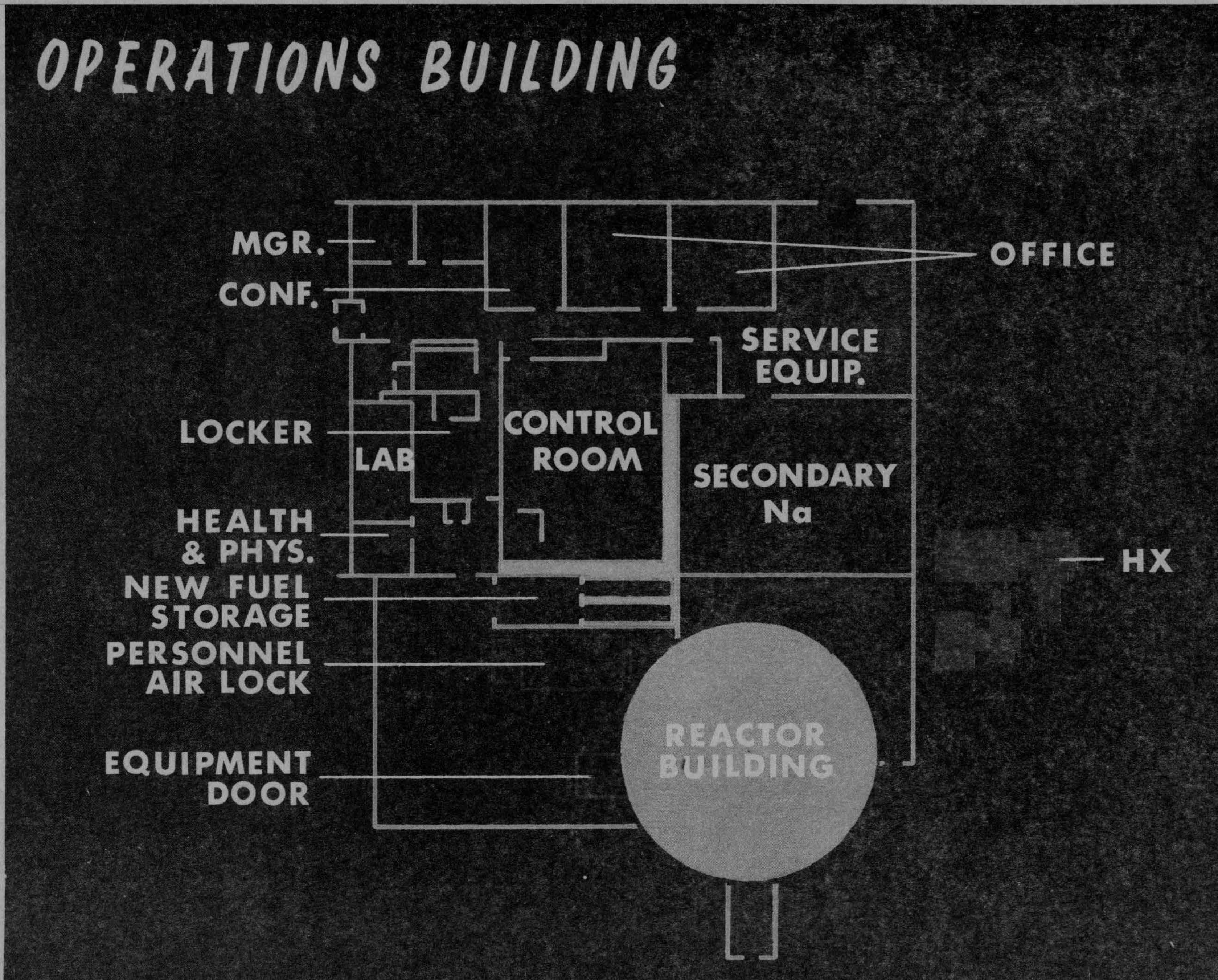

REACTOR BUILDING
ARGON
REFUELING CELL
COLD TRAP CELLS
N_2 COOLERS
CONTAINMENT VESSEL 50'Dia. X 105.5'
WINDOW
IHX
CORE
EM PUMP
DRAIN TANK

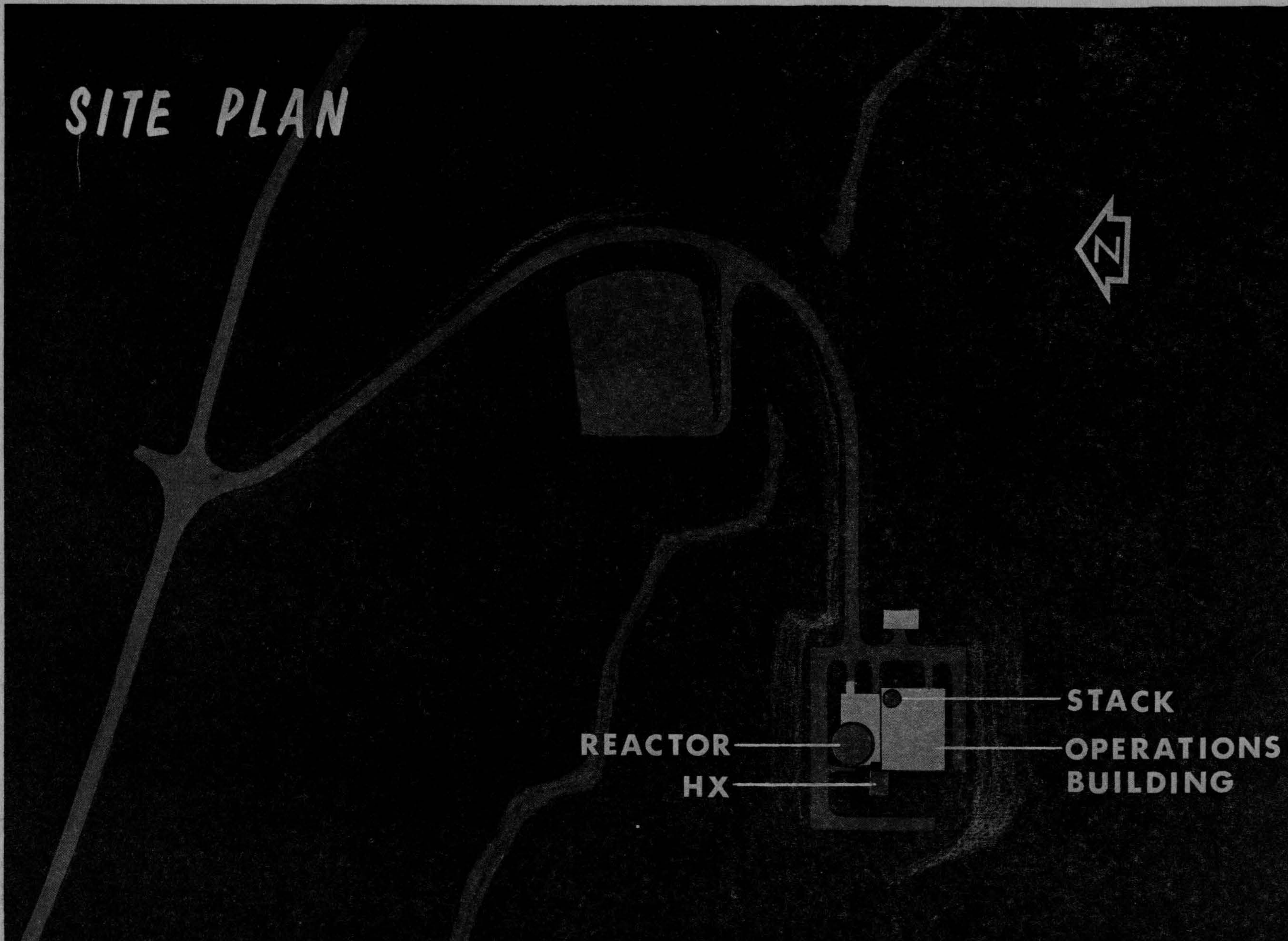

REACTOR VESSEL
HOLDDOWN
CELL FLOOR
AUX. OUTLET
MAIN OUTLET
MAIN INLET
CORE

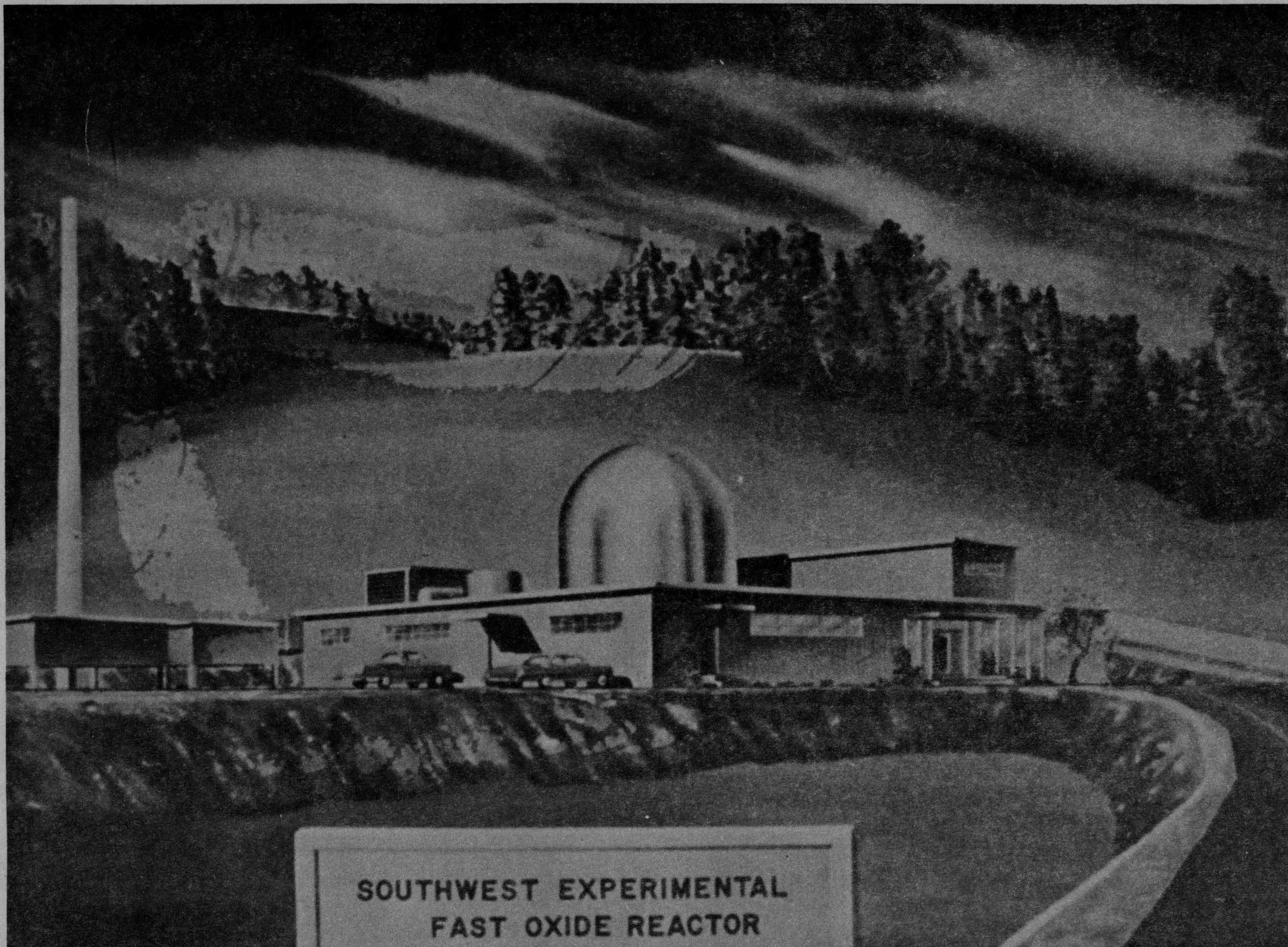
As I mentioned before, the secondary sodium which leaves the heat exchanger is nonradioactive. In SEFOR, this sodium is brought through the reactor containment building, and is brought to the operations building, which is a reinforced concrete structure. The next slide shows a plan view of this operations building. In it are contained the control room, from which all operations of the reactor and facility are monitored and controlled. It also contains equipment for the secondary sodium systems, electrical power supplies, and office space. Immediately outside of the operations building are the forced air heat exchangers, which exhaust the heat to the atmosphere.

An over-all view of the whole facility is shown in the next slide, which shows the reactor building, the operations building, the forced-air heat exchangers, and an additional building which is used for warehousing and additional office space. The next slide shows an artist's conception of the SEFOR facility. The SEFOR site is one of the most attractive of any reactor site in this country, and we hope that the finished facility will be in keeping with this.

Here are some nontechnical points that may be of interest to you. We expect to complete construction and start operation of the reactor some time during the latter part of 1967. As I mentioned before, the estimated cost of the facility is about 12-1/2 million dollars. During the peak of the construction activities, there will be about 160 people working at the site. As much as possible, we intend that these shall be paople from the southwest. In this regard, I might note that the structural work at the site, amounting to some 1.5 million dollars of construction work is being performed by the Martin K. Eby Company, which is a Wichita-based concern. After operation of the reactor starts, the facility will be manned by a permanent crew of about 30 people; about half of these are expected to be recruited from the local area, and the other half, who will be technical


OPERATIONS BUILDING
MGR.
CONF.
OFFICE
SERVICE EQUIP.
LOCKER
LAB
CONTROL ROOM
SECONDARY Na
HEALTH & PHYS.
HX
NEW FUEL STORAGE
PERSONNEL AIR LOCK
REACTOR BUILDING
EQUIPMENT DOOR


SITE PLAN
N
STACK
REACTOR
OPERATIONS BUILDING
HX


SOUTHWEST EXPERIMENTAL
FAST OXIDE REACTOR

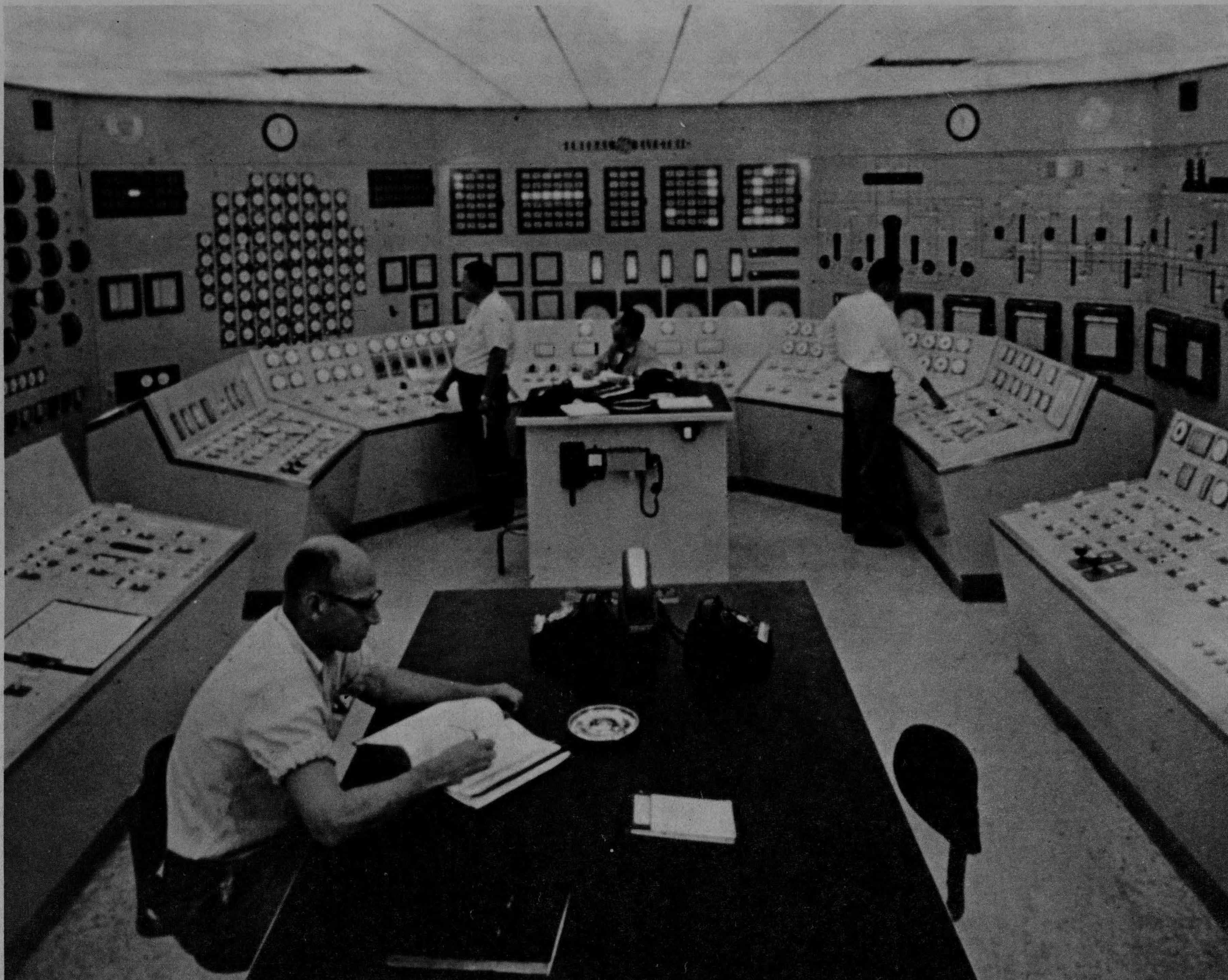
experts, will be long-term General Electric employees, stationed permanently at the site. In addition, we expect that several of our colleagues from the Karlsruhe Laboratory of West Germany, and from EURATOM, will also be assigned to the site. There may, in addition, be one or more AEC representatives in permanent residence. We also expect that there will be a succession of visits to the SEFOR site by high-level technical experts from this country and abroad, and by government officials.

Finally, I should point out that interest in nuclear energy is such that our Big Rock Point nuclear plant in Michigan, is the second largest tourist attraction in the State. It is not improbable that the SEFOR facility will also attract a considerable number of tourists, and I understand that the Southwest Atomic Energy Associates are now making plans to accommodate them.

A word now about the operating program at SEFOR. Our initial plans call for a three-year experimental program, with emphasis on gaining a thorough understanding of one of the important safety features of this type of reactor. SEFOR is being designed with a large negative Doppler coefficient. The Doppler coefficient operates in this way. When the fuel is heated, the Doppler coefficient acts so as to cause neutrons to be absorbed in nonfissionable material, and thus tends to shut down the reactor. In the event, therefore, that there were a malfunction of the reactor system such that its power was unintentionally increased, the fuel would heat up, the Doppler effect would come into play and the power level of the reactor would then be reduced. The Doppler effect is thus as inherent safety mechanism.

We will perform a number of tests designed to check our calculations of the way in which the Doppler effect will work. One of these series of tests will involve purposely increasing the power of the reactor and observing the way in which the Doppler effect shuts it down. If you were at the site when these tests were performed, what would you observe? I am afraid you would find it very dull. You would hear and see nothing unusual. However, in the control room you would find a number of physicists and engineers intently examining meters, strip charts, and oscillescopes. It is the data from these instruments which will represent the real output from the SEFOR project. This data will be collected and analyzed over a period of weeks and months both at the SEFOR site and at our facilities in San Jose, California where additional physicists and other technical personnel are located. Much of the data analysis will involve the use of large computers.

I do not have a picture of the SEFOR control room, since we have not yet completed its design. However, the next slide shows the control room at one of our nuclear power plants. The SEFOR control room will look similar, although it will be smaller. It too will have a high density of instrumentation. I show this slide because my colleagues in the public relations area tell me that the nuclear industry has done a poor job in explaining our business to the public. We have shown so many pictures of technicians in "Space Suits" with strange looking equipment that people have the impression that reactor control is difficult and that the operator stands tensely watching a control meter, ready to run when the meter moves a tenth of an inch off dead center. The reverse is true. A reactor is a complex piece of machinery that does require trained personnel to keep it in good running condition. However, control of the reactor is relatively simple. The reactor operator does keep the needles on the meters at their desired positions. To do this generally requires that he push the buttons which move the control rods about every ten or twenty minutes.



This discussion brings me to the last topic - safety. On any concrete basis of measurement, the nuclear industry has a safety record in which we can all take pride. For example, I have some statistics for the years 1960-1962, which examine the record with respect to 125,000 people involved in AEC contract work. In these years, there were 2.0 lost-time accidents per million man hours work in the nuclear industry. This compares to an average in all industries of 6.5 lost-time accidents per million man hours. As a matter of fact, in 1960-1962 the nuclear industry was fifth in terms of safety, behind the communications industry with 1 lost-time injury per million man hours, the electrical equipment industry with 1.6, the aircraft manufacturing industry with 1.6, and the automobile industry with 1.9 lost-time injuries per million man hours. The sixth industry, the chemical industry had 3.4, the highway construction industry had 30, and the oil well drilling industry 42 injuries per million man hours.

Now, of the injuries which did occur in the nuclear industry, most involved people falling off ladders or having similar mishaps. Only 35 out of a total of 6,500 lost-time injuries in AEC plants and laboratories from 1943 to 1960 were associated with overexposure to radiation. In other words, whereas one's chance of sustaining an injury of any kind in an atomic energy plant is only about one-third of that in industry as a whole, the chance of sustaining a radiation injury is less than 1/500 that of sustaining an injury in the average industry. To this one might add that in no case has a member of the general public received a radiation injury as a result of peaceful uses of atomic energy.

As in all industries, fatal accidents have occurred in atomic energy work. With no intention of minimizing this tragic loss of life, it is nevertheless proper to examine the record in the light of experience in other industries. Again drawing on statistics for AEC contractors, we find that there have been far fewer fatal accidents in U. S. nuclear installations than in industry as a whole, and those due to radiation have been rare. The average for all industry from 1950 to 1959 was 25 deaths per year per 100,000 employees. In the atomic energy industry, the comparable figure from 1951 to 1960 was 9.3. The figure for deaths caused by radiation is 0.4 per year per 100,000 employees. Stating this another way, there have been 7 deaths from radiation since the start of the nuclear program, over 20 years ago, to the present time (1966).

The above statistics indicate that the procedures and controls in the atomic energy industry are effective. Part of these controls involve careful analysis and review of reactor designs and proposed operating procedures before the actual construction of the plant starts. In the case of SEFOR, we have had extensive reviews by technical teams within the General Electric Company, and these will continue as the design progresses and construction takes place. For the past year, we have undergone a series of reviews with the Division of Reactor Licensing of the Atomic Energy Commission, and with the Advisory Committee of Reactor Safeguards, two government bodies whose function it is to assure that reactor design and operation will not represent a public hazard. The next slide shows the documentation provided to these bodies and perhaps indicates the thoroughness of these examinations. In a 100-page document, the Division of Reactor Licensing published their review of the SEFOR plant and concluded, in effect, that SEFOR will not constitute a hazard to public health. In June of 1965, a public hearing was held in Fayetteville before another AEC board consisting of a lawyer and two technical experts to review the proposed project before construction was permitted to proceed. This board also found that there were no unresolved safety questions. Finally, I might note that after completion of construction but before operation of the reactor is permitted, a similar set of formal reviews will take place.

I think I can state, without contradiction, that no other industry goes through the effort that we do to produce a safe product, and the statistics given above indicate that our efforts are successful.

In closing, I will touch on one other area bearing on safety. This is the release of radioactive material to the atmosphere as the result of nuclear plant operation. Although it is, in principle, possible to operate a plant so that there is no release of radioactivity, in actuality it is impractical. Nuclear plants, in general, do release radioactivity under controlled conditions. Is this controlled radioactive release contaminating our atmosphere? One has to gain some perspective to answer this question.

As the next slide indicates, there are some kinds of contamination you just can't eliminate. People are not generally aware that they are living in a sea of radiation produced from natural sources. That they are is illustrated in the next slide. The unit of radiation is called the rem, and the figures given in this slide are in one-thousandth of a rem, or in milli-rems. As you can see, the average individual receives about 180 milli-rem per year due to naturally occurring radioactivity. Nobody really knows what the effects of this naturally occurring radiation are. The generally accepted view is that unnecessary exposure to radiation should be avoided. However, perspective again must be used. No responsible individual would advocate that we evacuate Denver, Colorado, because the natural dose is about 50 milli-rem higher there than at locations at lower altitudes. Similarly, no one advocates elimination of jet planes although a cross-country trip by jet gives one a dose from cosmic rays of


There are some kinds of contamination....
you just can't control!

about one milli-rem. Actually, a person really concerned about exposures of this magnitude should refrain from eating beans, since they contain a relatively high concentration of potassium, which contains a radioactive isotope, potassium 40. Similarly, he should not build a house out of stone or concrete block, nor should he enter a tiled bathroom.

The point of this discussion is that we have naturally occurring radiation which forms a base upon which to evaluate the effects of release from nuclear plants. On the last line of the slide is indicated the estimated dose one would have received if he lived continuously at the site boundary of the Dresden Nuclear Power Station in Illinois, during 1962. The average over the past six years is between one and two mill-rem per year - about what one receives on a cross-country jet trip. This figure, incidentally, is calculated; it is too small in comparison with the natural background to measure.

Controlled release from nuclear plants is regulated by the U. S. Government. Nuclear plants are not permitted to release radioactive materials which would represent a hazard to the public. None of them do. Neither will SEFOR.

Ladies and gentlemen, this concludes my formal remarks. I hope I've been able to convey some of the reasons for our enthusiasm over SEFOR. It is rare that one has the opportunity to work on a project with both practical short-term economic goals, and important long-term implications for the future welfare of our country.

I should mention also our pleasure and appreciativeness at the fine treatment we have received in your section of the country. For our part, we expect to reciprocate by being a good neighbor. We think that those who can visit the site will enjoy meeting the people we'll be sending to Fayetteville. And, we hope to accomplish something at SEFOR that the utilities and people of the southwest will be proud of.

RADIATION IN NATURE

SKY (cosmic rays)	50	100 in Reno; 2 in jet flight
GROUND (1/4 time)	11	200 in France
BUILDINGS (3/4 time)	34	Depends upon materials
AIR (radon)	5	Low on west coast
FOOD	25	High in beans
TV-WATCH DIALS	2	
X-RAY DIAGNOSIS	50	Dental x-ray 1000
TOTAL Mrem/year	177	

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