Nuclear Energy

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Nov., 1988

The public views radiation as something new highly mysterious, invisable and extremely dangerous. But there is nothing new about radiation. Mankind has always been exposed to natural radiation at levels hundreds of times higher than it can ever expect to receive from the generation of nuclear electricity.

There is nothing mysterious about radiation. It is a relatively simple physical phenomenon, whose health effects are far better understood than those of air pollution, food additives, chemicals or almost any other enviromental threats. Radiation is the property that some elements such as uranium have of emitting alpha, beta and sometimes gamma-particles at 100,000 miles per second thru the disintegration of the nucleus. Radioactivity lends itself to exact scientific study, and has been extensively investigated for over 40 years. There is little disagreement within the scientific community over the health effects of radiation. Over 80% of the scientific community believe that the publics fear of radiation is exaggerated and 90% of scientists favor proceeding with the developement of nuclear power.

Nuclear power is perceived to be thousands of times more dangerous than it actually is.

Motor vehicles kill 50,000 per year (U.S.)

Cigarette smoking kills 150,000 yearly

Eleven other activities kill more than 1,000/yr.

Nuclear Power kills 10 per year

Burning coal is more dangerous than generating electricity from radioactivity.

Yet Fifty-six % of the American public were opposed to a nuclear plant in their community.

How Dangerous Is Radiation?

The great fear of course is the damage to body cells causing cancer and gene defects in future generations. Every person in the world is struck by about 750,000,000 of these radiation particles every year of life and this has always been true. It is even more when we include medical uses of radiation. But the chance of one of these particles causing cancer is very low. We accept this risk as one of the many risks that confront us in all that we do. Farther along in this paper, non-radioactive carcinogens as well as Radon, the product of radioactive degeration will be discussed.

Radiation exposure should be quantified in millirems. A millirem expresses the biological effect of radiation on the body. The only way to consider the risk of radiation is to think in quantitative terms, but rarely is this done in the news reports. In most cases the exposure from radiation is less than 1 millirem.

In the Three Mile Island accident, average exposures in the area were 1.2 Mrems. (A Boston newspaper on this happening had the headline "Radiation".) In the supposed leaks of low-level waste burial ground near Moorhead, Ky., no exposures were as high as 0.11 mrem but a Philadelphia newspapaer had the headlnes "Its Spilling All Over the U.S.")

How dangerous is 1 mrem? We can understand it better by comparing it with our exposure from natural sources. Cosmic rays are always bombarding us at the rate of 30 mrem per year; radioactive matter in the earth at 20 mrem per year; the walls of our homes at 10 mrem and from inside our bodies, 25 mrem per year, giving a total average of 85 mrem per year.

For each mrem of radiation received, our risk of dying of cancer is increased by 1 in 8 million. The risk corresponds to a reduction in life expectancy by 1.2 minutes. This is similar to crossing the street 3 times, taking 3 puffs on a cigarette, an over-weight person eating 10 extra calories or driving an extra 3 miles in the car. People living close to a nuclear power plant receive about 1 mrem per year extra exposure. If the public were convinced of such statistics, their anzieties would be relieved and nuclear power would be better accepted. But the media would rather concentrate on the unusual, the mysterious, so there is exaggeration and often overcovrerage.

With the fear of the public stimulated, the government responds with expensive protection measures against radiation but doesnt do as much for highway safety or against fossil fuel product contamination.

[Some genetic effects as inherated disabilities may arise in later generations]

Natural radiation is believed to be responsible for about 3% of the commonly found genetic defects. No actual evidence for radiation causing genetic disease in humans has been found. Even survivors of the A-bomb attacks in Japan, each of whom received 130,000 mrem, have not had children showing an excess of genetic defects.

Air pollution and chemicals can also cause genetic defects but the custom of men wearing pants is the most important human activity that causes gene abnormalities. The sex cells get warmed and the chances of spontaneous mutations are increased. A 1 mrem radiation is equivalent to 5 hours of wearing trousers with a high rise.

There are abnormal developements amoung children exposed to radiation in utero but cancer was not one of them. No cancer has been found in farm animals exposed to radiation experimentally. The animals exposed in the 3 mile island accident showed no increase in the number of deformed animals after the accident than before.

The fears that have been generated in people persist because radioactivity and nuclear power are not understood. Medical patients refuse x-ray radiation therapy, nurses would not work in a nursery when portable x-ray equipment was to be used even though they would receive only 100 mrem per year; about the same dosage they would get if they lived in Colorado.

All of the scientists involved in creating the A-bomb dreamed of applying the tremendous power of the atom for the benefit of mankind rather than for the destruction of human lives.

Early on there were overstatments that nuclear energy could power a car with vitamin-sized tablets or that such small pellets could heat a home through a northern winter. Years of research and developement gave us the reality of harnessed nuclear energy but many potential applications (e.g. atomic powered aircraft) were just too expensive.

Atomic scientists theoretically and actually could measure the amount of heat released when neutrons struck a fissionable atom such as Uranium 235. In addition to the heat energy and the 2-3 netrons that were released, the U-235 (with an atomic number of 92) divided into lower atomic weight elements such as Barium and Krypton whose atomic numbers are 56 and 36 respectively. The emmitted neutrons collide with other fissionable U-235 atoms splitting them, releasing more heat and more neutrons. This sustained reaction would be now a chain reaction. Trillions of these reactions occur each second.

In a nuclear power plant the fuel is a mixture of U-235 and U-238 but only the U-235 which is just 1% of the mixture can be burned. Some of the U-238 which cannot be burned is converted to Plutonium. The Plutonium can undergo fission and thus serve as a nuclear fuel. The reactor fuel is in small ceramic pellets of UO_2, each pellet containing the energy of a ton of coal. The pellets are loaded end to end in 12 ft. long tubes--fuel rods--made of a special metal alloy. 200 of these rods are packed into a square fuel assembly, in a lattice arrangement somewhat like a cross-word puzzle. At the top of the assembly is a control rod made of another special metal which can absorb or capture neutrons. When the control rod is withdrawn, the emitting neutrons are free to strike the U-235 giving fission and when it is reinserted the neutrons are blocked from colliding with the U-235 atoms. So, the amount of heat produced can be controlled. In a typical reactor core there may be 193 such assemblies.

Water is pumped through the reactor at 21,250 lbs. of pressure. The fissioning heats the water to 560 F. Hot water travels to a steam generator where it boils water giving steam in a secondary water circuit. This secondary circuit is not radiactive. The steam turns the turbine-generator and is then converted to water which is returned to the steam generator.

Other types of reactors include Boiling Water Reactors, Heavy-Water Reactors and reactors using an inert gas. The reactor vessel, steam generator, radioactive components are all in a primary containment, a building which is 200 ft. high with walls 3-5 ft. thick. This building can withstand the forces of earthquake, high winds (300 mph), or the crashing of a DC-10 into the structure.

The Fearsome Reactor Meltdown Accident

In the great majority of meltdown accidents, there would be no detectable effects on human health immediately or later. This would include 3 Mile Island. Here it was not a near miss to disaster. Again the press will not tell the public that there was no threat to the containment permitting the escape of any large amounts of radiaoactivity, even if there had been a meltdown which there was not.

Since the 3 Mile Island accident, there have been great improvements in instrumentation, operator training and knowledge. A graduate engineer is on hand at all times. There is elaborate control of materials and workmanship; intensified inspection programs, using x-ray and ultrasonic techniques, before going into production and then periodically after and while in production. Corrosion cracking and leak detection are constantly looked for in the piping.

How Secure is Containment?

If the reactor system breaks down, water and steam pours out into the containment building. Water is pumped in by the Emergency Core Cooling System. Some overflows, surrounds the fuel, boils into steam which escapes thru a break into the containment. The containment fills with steam plus an excess of water on the floor. A tremendous amount of heat is generated by radioactivity in the fuel, by chemical reactions of the steam with the fuel casing and by the burning of hydrogen that is formed. Now, will this heat raise the pressure of the steam to the point where it will exceed the holding power of the containment walls?

To counteract this threat, there are systems and back up systems to cool the containment atmosphere.

Two other ~~other~~ threats are important. One in which there is a steam explosion; in the meltdown, molten fuel falls into a water pool creating so much steam that the top of the reactor vessel is blown off and hurled up with a great enough force to break the top off the containment building. For this to happen, the molten fuel would have to strike the water in necklace bead size particles with half of them hitting the water inside one-half second, an obscure possibility. The situation was used in a movie, "The China Syndrome". The second threat could be an hydrogen explosion. Here the hydrogen would be produced gradually and explode or burn in small reactions. The hydrogen would never accumulate to a large enough volume to result in a severe explosion. In fact, at 3 Mile Island, there was such an explosion but the containment was not broken.

Defense in depth for avoiding a catastrophe is the principle. In reactor design, it is assumed that anything can fail. If quality assurance fails, inspections provide safety, if inspection fails, leak detections save the day, if that fails emergency core cooling systems protect the system; if the last fails, the containment is there. The probability of a meltdown can never be reduced to zero nor can the risk of anything we do or experience be reduced to zero whether it be fire, tornado, disease, toxic agents etc. The U.S. Regulatory Commission in 1975 sponsored the Rasmussen Study which estimated that a reactor meltdown may be expected once in 20,000 years of operaton, and that there would be no detctable deaths in 98/100 meltdowns. On the other hand, deaths resulting from burning fossil fuels are slow in coming on, not detectable at the time so they are not alarming . Motor vehicles kill some 50,000 Americans yearly whereas a meltdown every 10 years would only kill that many once in a million years. The worse meltdown would contaminate an area of 3000 sq. miles, an area of a circle with a 30 mile radius. There would be about 50,000 deaths. The probability is once a in billion years of reactor operation years. My chance of being a victim is 20,000 times less than the risk of being killed by lightning and 1000 times less than the risk of an airplane hitting my home.

The public misunderstands the probability aspect in the consideration of risk. Antinuclear popular television personalities, Dan Rather and Johnny Carson, dont talk about this concept. Reporters want an interesting story; nuclear reactors are an unknown, mysterious kind of thing. The idea of fear brought on by something not understood has been present in man from his beginning.

Understanding Risk

Everything we do involves risk, usually undetectable until morbidity or mortility strikes. We take a calculated risk in many of the things we do. In card games we try to follow the odds, if we can every remember what they are. But with nuclear reactors, every conceivable step in the operation has been studied from many different view-ploints so that quantitatively the risks are evaluated and known.

Loss of life expectancy study (LLE) is one way to express quantified risk. It is the average amount by which one's life is shortened by the risk under consideration. This has been applied to obesity, smoking, heart disease, the risk of being poor, uneducated, the types of employment, etc.

The risk from leaks from waste burial grounds to any member of the public gave a LLE of 10 seconds and the 3 Mile Island accident gave the average Harrisburg resident an LLE of 1.5 minutes. Our risk of being struck by lightening gave an LLE of 20 hours.

If all the energy in the U.S. were derived from nuclear power, each of us would show a LLE of 1.5 days. Nuclear accidents are tens of thousands of times less dangerous than moving from the N.E. U.S. to the West. No one considers this an added risk to their lives. Yet nuclear accidents cause great concern. These figures of LLE have been accepted in scientific journals and in debates with the leaders of the Union of Concerned Scientists (UCS). The risk-- the LLE, or the total number of deaths in the field of nuclear energy; this is the all-important question.

To accept the risk of nuclear power, the public must consider that a severe catastrophy where large numbers are killed is no worse than a situation where only a few numbers are killed but where the morbidity leading to mortality continues endlessly. Coal burning only for electricity production results in 10,000 deaths yearly-- an LLE of 13 days-- where as the LLE from nuclear industry is 1.5 days.

A comparison of the LLEs of other energy producing methods: Oil burning--4 days (involving pollution,fires)
Gas " --2.5 (Pollution, fires, explosions)
Solar 0.4 (risks in making the equipment)
Electrical technologies--5.0
Conservation
Small cars--50.0 days
Double the present amount bicycle--10
Sealing of buildings--24 days (Radon)

So, conservation is the most dangerous energy strategy ~~from the standpoint of~~ in comparison to radiation exposure, and it could suppress economic growth.

Nuclear Energy Waste

Radioactive waste is less of a hazard than the waste from any other large technicological industries.

1. In the burning of coal,

CO_2 produced at rate of 15 tons per minute (U.S.) and the threatening green-house effect

SO_2 produced at rate of 1 ton per 5 mins. causing acid rain, 25 deaths per yr., and $25 million in property damage.

NO_2 produced in the amount emmitted by 200,000 cars, causing acid rain and property damage.

Polycyclic hydrocargons causing cancer and gene defects

Ash about 0.5 tons every minute

Uranium and thorium residues releasing radon.

2. Nuclear plant waste

The waste is 5 million times lighter and billions of times smaller in volume than with coal.

It is radioactive.

~~ecolog~~The best way to handle it at the present time is to place it deep underground in the form of a "glass" or rock. Don Williams discussion of Nuclear Waste

Lets consider the waste from 1 large power plant for 1 year. The waste is inside the fuel rods--12 ft. long by 1/2" diam. 33% of these are removed each year. It could be dissolved in an acid at a reprocessing plant so that 99% of the uranium and plutonium would be removed and kept for future use. The remainder from reprocessing , about 0.5% (1.5 Ton) would be made into a "glass" in the form of 30 cylinders, each 12" diam and 10 feet long, weighing 1/2 ton. These would be shipped to a federal repository ~~where~~ and permanently emplaced deep underground. Nevada Mountain The principle hazard to underground waste is the possible contact with underground water, thence to rivers, wells and soil. Even then the amount of radiation from ground surface would result in little exposure to the human body for if it is going to affect us it must get inside our body.

If all the electricity now used in the U.S. were generated by nuclear power, we would need 250 plants and the waste from these could kill 10 billion yearly. But we produce enough Chlorine yearly to kill 400 trillion, enough phosgene to kill 20 trillion, enough NH-3 and HCN to kill 6 trillion, enough Barium to kill 100 billion and enough As to kill 10 billion--if, all of these got inside people.

The radioactive waste in the form of a rock 2000 ft. underground isnt going to increase surface radioactivity significantly and is only going to increase the total radioactivity in the top 2000 ft. by 1 part/million.

There are other carcinogens in our environment. Cd, As, Be, Ni, and Cr ~~are~~ present in coal. They end up in the ground and so get in food through the roots of plants. These will always be as toxic as when they entered the soil because they do not undergo radioactive break-down whereas radioactive substances decay with time.

One of these radioactive by-products in nature and from nuclear plant waste is Radon, a gas that is causing much concern at the present time. Uranium which is present in soil, rocks, bricks ,plaster and cement decays through some 14 steps and one of these steps is Radon. In the air it enters the lungs and decays to solid radioactive particles sticking to the respiratory surfaces, radiating all the time and inducing cancer. Sealing our homes seals in the Radon. The tailings from Uranium mining also contain Thorium which decays to Radon. If the tailings were covered by 3-4 ft. of soil, the Radon would decay by the time it reached the surface because the half life of Radon is only 5.5 days. Even after covering the tailings, the fatalitay is still higher with Radon than with nuclear power waste. Again, the media doesnt publize these facts. The tailings appear quite inocuous and unexciting.

Plutonium and Bombs

Uranium occurs in 2 types, U-235 and U-238 with only U-235 useful to produce energy. U-235 is 1% of the mixture. There is only a limited amount of the ore, probably enough to provide supplies of fuel needed by all nuclear plants built up to the year 2005. Uranium prices after that would be excessive.

But as the nuclear plant burns this mixture of U-235 and U-238, some of the U-238 is converted to Plutonium. Pu can undergo fission and thus be a nuclear fuel. Some of it does burn while in the reactor but some ~~goes to~~ is left in spent fuel where it can be extracted chemically. Pu could be burned in our power reactors or could be used in a breeder reactor whose fuel is a mixture of U-238 and Pu.

A Breeeder Reactor is one wherein the fuel mixture is plutonium and U-238. Some of the U-238 is burned andsome is converted to Plutonium. Much more U-238 is converted in the breeder to plutonium than in the common reactor, more than enough to replace all the plutonium that is burned. So a breeder produces energy plus plutonium. It only consumes the U-238. 30% more electricity is produced from a breeder reactors than from the reactors now in use. Since our nuclear energy program is now far behind those of France, England and Russia, we should begin to construct breeder reactors now. They will take years to complete but we have to look to the future. Reprocessing of spent fuel is the key part in present reactors. Through it Plutonium could be retrieved. In addition the high level waste would be cleaned up and the problems associated with the waste would be avoided. However the U.S. is showing no interest in reprocessing right now because of the economical factors.

A reprocessing plant in Barnwell, S.C. was proceeding well in 1976 when the government decreed an indefinite deferral of commercial reprocessing because of the national policy on discouraging proliferation of nuclear weapons. But there is great difference between a nuclear plant structured to generate electricity and one designed to make bombs. It's true that if a nation had a nuclear power reactor, and a reprocessing plant, it could reprocess the spent fuel to get plutonium with which to make bombs But a plant for generating nuclear electricity is large, highly complex. Its presence could not be kept a secret. Smaller nations couldn't manage it. But a small nation could produce a research reactor that would produce enough plutonium to make bombs. Another method is using isotope separation.

The link between nuclear power and proliferation of nuclear weapons is a weak and largely insignificant one. But the media doesnt give this impression. They rarely differentiate between power reactors and other types more suitable for making bombs, i.e. types capable of isotope separation or a research reactor. The last could not generate electricity. The International Atomic Energy Agency makes certain that plutonium from power reactors isnt being used in bomb manufacturing.

There is an international treaty on non-proliferation of nuclear weapons. Here a non-weapons nation having signed the treaty is entitled to a secure and uninterrupted supply of fuel for its power reactors in making electrical energy. Long ago, Pres. Carter thought we could guarantee that no nuclear weapons could be made if we stopped ~~selling~~ exporting nuclear fuel. (There could then be no reprocessing to get plutonium) This American political pressure failed. Nearly all the other countries continued in building reprocessing plants except the U.S.! (And the Barnwell, S.C. plant remained unfunished) Today we are far behind and our U.S. reactor export business is ended. France and Germany get the reactor business; Russia sells the fuel. Fourteen nations now have reprocessing plants. Five nations have nuclear weapons arsenals. Any small nation can develope a nuclear bomb. The important deterrant is that the nation threatening to use a nuclear bomb would pay a devastating price and the parties threatened would be guaranteed against attack by the large nuclear weapons powers. As long as the industrial nations are hard pressed for energy, there will be severe competition for energy sources such as oil. This could lead to a major nuclear halocaust. If the major nations had other andsecure energy sources, e.g. re-processing of power reactor fuel, there would be less concern over getting fossil fuel for energy. Third world nations only want our technology now. The media has not clarified these concepts; we are led to believe that our use of nuclear power adds substantially to th risk of nuclear war whereas in the U.S. nuclear power is used exclusively for production of electricity.

If a terrorist or a third world country wanted to make a bomb; they would need plutonium, hi grade U-235, (weapons grade material) or an assembled bomb. Designing and building a bomb requires experts in several fields contrary to publications. It is a very dangerous difficult and expensive procedure. It would be easier to use poison gas in a ventilator, dynamite in a sports arena dynamite a dam or poison a city water supply.

Ralph Nader has said that 1 lb of plutonium could kill 8 million people. Plutonium only affects humans when it is in suspension as a fine dust and then inhaled. Quanitatively it can be calculated that 1 lb. could eventually cause 2 million cancers. But there is no direct evidence that plutonium has induced cancer in humans. So the toxicity of plutonium is a theoretical one. If a pound of it were dispersed over a large city in the most effective way, it ould cause an average of 19 deaths due to inhaling during the 1st hour, 7 more deaths due to resuspension into dust during the 1st year and perhaps 1 more death over the remaining 10,000 yrs. that it remained in the top layers of the soil.

Now, let us consider the costs of Nuclear Power. Anti-nuclear activists have driven costs to the point where plants are uneconomical. In 1962, a plant cost $27 million; in 1970, the cost was $170 million; and in 1983 it became $1.7 billion. Inflation accounts for 1/3 of the increase; licensing delays by anti-nuclear activists deployment and changes in regulations while construction is going on are other important causes of increased cost. Many of the first plants are still operating well.

Regulatory ratcheting is a term used to express the tightening of regulations in the interest of safety and in conformance with the laws established by the Atomic Energy Commission and the National Reg. Commission.

Regulatory turbulence is the confusion that results when during the construction of nuclear plants new regulations become effective. Construction is not permitted to go on following the older regulations that were in effect when the plant was begun. The delays, redesigning, ordering new equipment all increase the cost. This creates difficult cash-flow problems, more borrowing, more interest to pay and additaional costs. The activists ignore these factors but attribute the increased costs to mistakes, incompetence, dishonesty, and profit motives.

In other countries, Russia plans to turn out 8 complete plants per year; France had 12 started in 1981, to be completed in 6 years (at a cost of $500 million each). U.S. plants started in 1975, (costing $110 million in 1981 money) are not yet completed. Many French plants use Westinghouse design and our supervisors. By 1981, 38% of French electricity was generated by nuclear power whereas only 13% in the U.S. and by 1985 it ~~will be~~ was scheduled to be over 60%. Japan's nuclear power program has moved steadily forward. Here 33 plants supply 23% of the electricity and 11 more are under construction.

Until the Chernobyl accident, the Soviet Union intended to build 66% of the planned nuclear capacity throughout the world, between 1990 and 1995. But their nuclear power schedules are not in line now. Even before Chernobyl, there were mishaps, and construction delays. By Nov. 1986, 2 of the 3 surviving units at Chernobyl had been restarted whereas in our country it took 6 years before the reactor adjacent to the damanged unit at 3 Mile Island was restarted. The Soviets do intend to get their nuclear program back on track. Further influence from the Chernobyl accident; Austria's only reactor which was never operated will be dismantled; the Philippines only reactor is to be a Sweden has stopped nuclear energy production

taken down and Greece intends to abandon their plans for a nuclear plant. Factions in Italy, Switzerland and Great Britain are gaining influence in their opposition to nuclear power. In the U.S. fewer engineering graduates enter the nuclear industry and fewer young politicians advocate its expansion. It would appear that the younger generation has not inherited the optimism for this type of energy that the men of the 1940s had when nuclear prospects were bright. The last year when a U.S. nuclear plant was ordered and not subsequently cancelled was 1974. Since then, orders for 108 reactors have been cancelled. By 1986, 14 nuclear plants were completed but only 3 are scheduled after 1989.

When the costs of nuclear electricity are broken down into fixed charges, operating and maintenance and fuel costs; nuclear energy and coal energy costs are very close. It is interesting that Russia favors the production of nclear energy for electricity even though it has the worlds largest coal deposites.

Utilities have difficulty raising capital to build new nuclear plants and can more easily turn to coal burning even though the cost of coal has to rise in the future. The fact that our utilities are privately owned makes mangement and regulation of nuclear plants more chaotic compared to the situation in all the other countries where the difficulties expressed above can be passed on quietly to the public by the authorities. Right now the best play for the U.S. is to build no new plants at all. But this is counterplayed against the need for more power as our electrical needs increases. Our electrical growth has fallen from 7% per year in the early 1970s to 1.8% since 1980. Right now we have cheap electricity from plants built many years ago. Our electricity cost will rise dramatically as these older plants wear out. Drastic changes in our philosophy in relation to nuclear energy will have to take place in the near future. We can eaily do what the French are doing because France is using our designs and equipment.

Some nuclear plants have been converted to coal burning ones

Solar energy can only be a supplement to our other sources of energy. The expectations by the public are unrealistic perhaps because the antinuclear activists envision rsearch efforts the future discovering new solar energy concepts.

The public polls in relation to nuclear energy are interesting. IN 1956, a Gallop poll gave 20% of the public opposed to nuclear power; in 1977, a Roper poll had 33% in opposition; in 1979, (after the 3 Mile Island affair), there was 56% against and in 1980, a Gallop poll revealed 73% against

In the future, the sources of technical mistakes will diminish as we become more familiar with the parameters of safety; personal error will always be with us but should be reduced to an ultimate low through scientific, and mechanical education of the employees along with enforced

a new type small
[illegible] reactor
called a modular
[illegible] temperature,
[illegible] cooled reactor
Estimated cost
billion,

The fuel composed
[illegible] billions of tiny
[illegible] encased
in a tough [illegible]
that will resist
[illegible] temp.
Immune to
meltdown

regulations and frequent plant inspections. The cost of nuclear energy for electricity should stabilize with greater know-how, moderinization, and the use of newer nuclear reactor concepts. This would be helped tremendously if all the plants were built in the same design and the whole operation were the same in every place. Finally through an extensive educational program, the fears of the people in relation to the generation of electrical energy by the use of a nuclear reactor could be removed.

As a non-nuclear scientist, it would appear that in the future, nuclear energy should provide us with 1/3 to 1/2 of our needed energy with coal, hydroelectric plants, wind and solar devices supplying the remainder.

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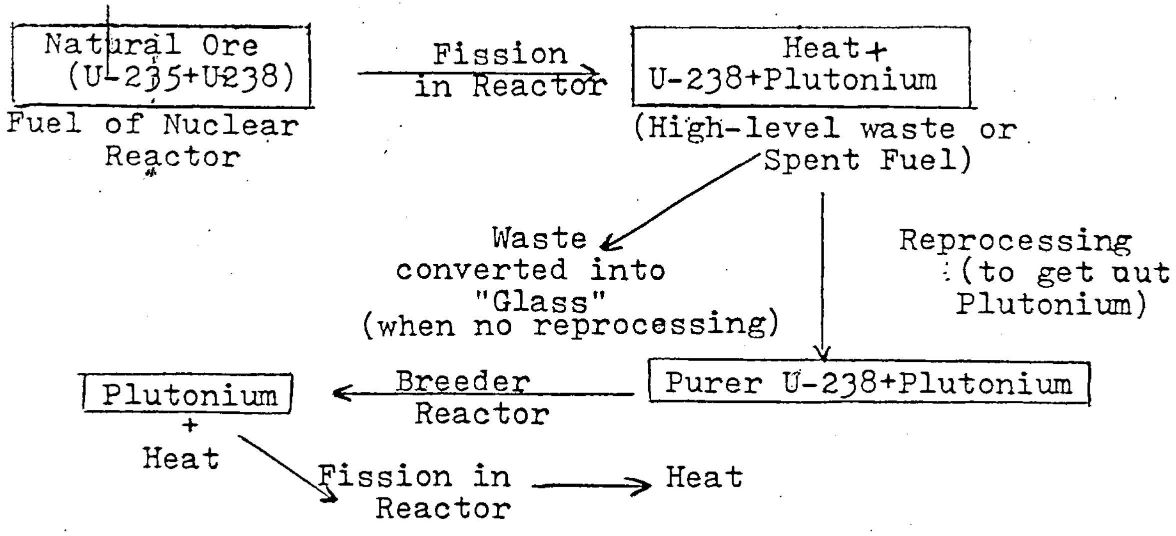
FIG.1



Flow-sheet in production of nuclear energy

2

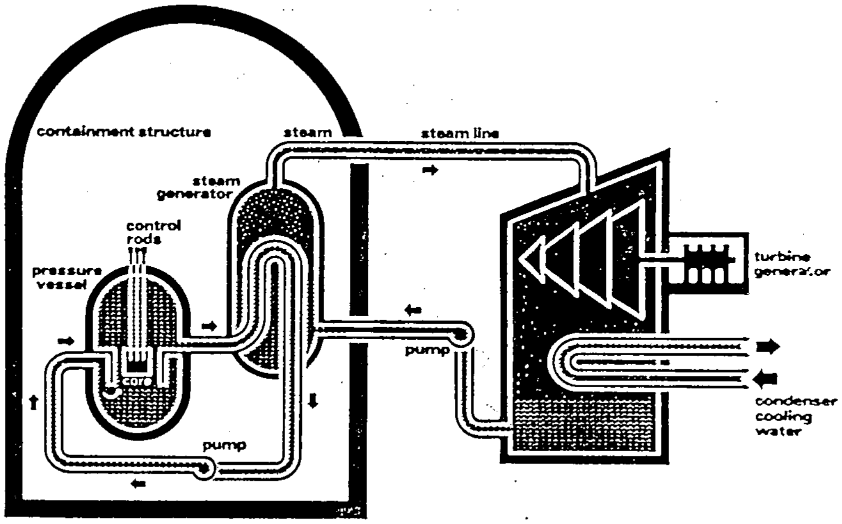


Fig. 12. Diagram (highly simplified) of a pressurized water reactor power plant. Water is heated to 600°F by energy released in fission reactions in the reactor (it is prevented from boiling by maintaining high pressure), and pumped to the steam generator, where its heat is transferred to a secondary water system. The water in the latter is thereby boiled to become steam, which drives the turbines. The turbine drives the generator, which produces electricity. It is necessary to condense the steam into water, greatly reducing its pressure, after it exits the turbine—otherwise there would be no tendency for the steam to rush through the turbine and thereby cause it to turn. The steam is condensed in the condenser by cooling it with water brought in from some outside source. The water formed by condensation of steam is pumped back to the steam generator to be reused.

3. LOSS OF LIFE EXPECTANCY (LLE) DUE TO VARIOUS RISKS

Activity or risk	Days LLE
Being male rather than female	2800
Heart disease	2100
Being unmarried	2000
Being black rather than white (in U.S.)	2000
Cigarettes (1 pack/day)	1600
Working as a coalminer	1100
Cancer	980
30 lb overweight	900
Grade-school dropout	800
Being poor	700
Stroke	520
15 lb overweight	450
All accidents	435
Vietnam army duty	400
Living in southeastern U.S. (South Carolina, Mississippi, Georgia, Louisiana, Alabama)	350
Mining or construction work (due to accidents only)	320
Motor vehicle accidents	200
Pneumonia, influenza	130
Alcohol	130
Suicide	95
Homicide	90
Occupational accidents (average)	74
Small cars (versus standard size)	50
Drowning	40
Speed limit 55 → 65 mph	40
Falls	39
Poison + suffocation + asphyxiation	37
Fire, burns	27
Radiation worker, age 18–65	12
Firearms	11
Diet drinks (one per day throughout life)	2
All electric power in U.S., nuclear (UCS)	1.5
Hurricanes, tornadoes	1
Airline crashes	1
Dam failures	0.5
Spending lifetime near nuclear power plant	0.4
All electric power in U.S. Nuclear (NRC)	0.03

5. SUMMARY OF THE NUMBER OF DEATHS CAUSED BY THE WASTE GENERATED BY ONE LARGE POWER PLANT IN ONE YEAR, OR BY TH[E] EQUIVALENT AMOUNT OF ELECTRICAL ENERGY PRODUCTION

Source	Deaths caused	
	First 500 years	Eventuall[y]
Nuclear		
High-level waste	0.0001	0.01
Radon emissions	−0.06	−500
Routine emissions (Kr,T,C-14)	0.05	0.3
Low-level waste	0.0001	0.0
Coal		
Air pollution	5	5
Radon emissions	0.11	30
Chemical carcinogens	0.5	70
Photovoltaics for solar energy		
Coal for materials	0.9	3
Cadmium sulfide	0.8	80

6. HOW SHOULD WE PROCEED WITH POWER DEVELOPMENT? RESULTS FROM REF. 2

	All scientists (%)	Energy experts (%)	Nuclear experts (%)
Proceed rapidly	53	70	92
Proceed slowly	36	25	8
Halt development	7	4	0
Dismantle plants	3	1	0

7. SUPPORT FOR NUCLEAR ENERGY[a]

Category	Number surveyed	Suppo[rt] ratin[g]
Nuclear scientists	72	7.9
Energy scientists	279	5.1
All scientists	741	3.3
Science journalists	42	1.3
Prestige press journalists	150	1.2
Science journalists at *New York Times, Washington Post,* TV networks	15	0.5
TV reporters, producers	18	−1.9
TV journalists	24	−3.3

[a] Scale runs from +10 for perfect support to −10 for complete rejectio[n]

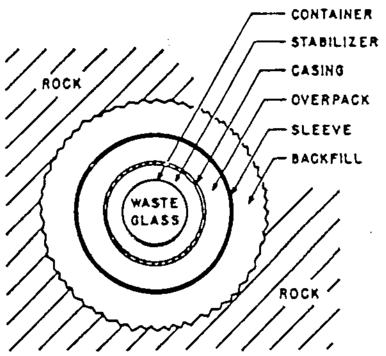


Fig. 18. Schematic diagram of buried waste package. Components are as follows: Waste glass—the waste itself, converted into a glass. Container—stainless-steel can in which glass is originally cast. Stabilizer—filler material to improve physical and chemical stability of waste. Casing—special material highly resistant to corrosion by intruding water; it should keep water out. Overpack—provides additional corrosion resistance and structural stability. Sleeve—liner for hole, gives structural support. Backfill—material to fill space between waste package and rock, swells when wet to keep water out; if waste becomes dissolved, adsorbs it out of escaping water.