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Atoms for Peace

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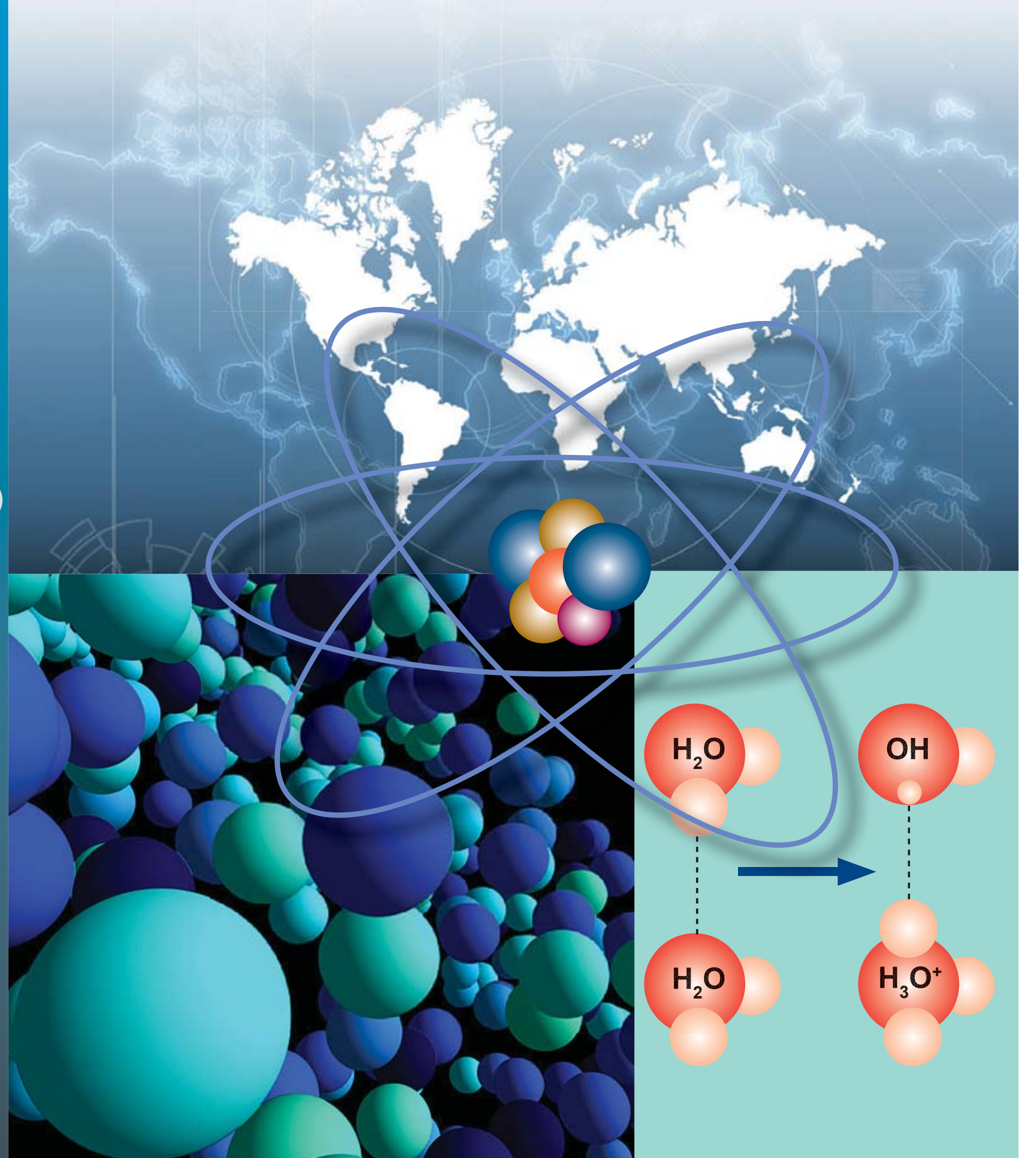

Atoms for Peace

Asoka Samaranayake

NATIONAL SCIENCE FOUNDATION

National Science Foundation

Science Books Series - 13

Atoms for Peace

To

MY BELOVED PARENTS

I see the waning moon and the white fading stars
in the sky,
I hear the sad rustling cry of dried leaves,
I know my beloved parents are hidden among them,
My mournful eyes are filled with tears;
this book is the
'Best Gift' I can offer them

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I thank my husband Mr Leslie Leelaratna for encouraging me to write this book and my daughter Miss Shalini Leelaratna who assisted me in completing this book.

My sincere thanks to the Directors of Buddhist Ladies College and the Principal.

ATOMS
Atoms are best known for the awful destructive force within them and for their ever present ability to result in the annihilation of mankind.

TODAY
Atoms have a much greater potential for good than for evil. Already their energy has made enormous contributions to medicine, industry, agriculture, research and many other fields.

and

TOMORROW
The development of atomic science holds out to man the promise of a bright future; of greater sources of power; of better standards of living; of improved health and well-being; of the greatest abundance the world has ever known.

CONTENTS

1. ATOMS IN OUR LIVES

You have read stories about a world made of anti-matter. In such a world, everything is symmetrically opposite-a mirror image of our own familiar world of matter. Right becomes left; negative forces are positive. The fearful and exciting characteristic of anti-matter is that when it comes into contact with matter, both explode and annihilate each other.

Scientists have discovered tiny particles of atoms in the form of anti-matter. While they may joke about what would happen if a man made of matter shook hands with a man made of anti-matter, they continue to search for worlds of anti matter which they believe must exist. They build increasingly powerful instruments to find out more about the true nature of atoms and the parts of which they are made. In time, their theoretical work reaches farther and farther from the laboratory. Some discoveries find their way into practical developments which help to serve you and people around the world in any number of ways. Certainly, you are not about to step aboard an atomic-powered spaceship which will carry you to the moon or faraway planets.

But there is a chance that you are using atomic energy to power your electrical tools and home appliances. You may be reading this book by light that comes from an electric power plant fuelled by atomic energy. Dotted here and there on the map of the world, one can locate power plants which provide electricity this way. But they supply only a tiny percentage of the world's energy.

More exciting atomic-energy frontiers are being explored in medicine, agriculture, space, and other areas of industry. As atoms are put to work for greater numbers of people, their energy can provide a life of greater abundance and dignity for all around the world.

As “atoms for peace” grows from a dream to a reality, exciting challenges unfold. But with the great hopes come great fears and problems. Is it safe to live near nuclear power plants? Will a nuclear-powered ship bring radioactive contamination to a port? Where will trained workers be found for the many new techniques that belong in the world of atomic energy? These are just a few of the questions in the minds of many.

Perhaps you will train to become an atomic scientist. The atomic-energy industry needs all the intelligent, hard-working men and women it can get. Almost every branch of the industry suffers from a shortage of people in teaching, basic research and industrial operation. As the benefits of atomic energy trickle into everyday life, you may be faced with important questions which need to be answered intelligently.

You need not be a scientist to grasp the basic ideas of atomic energy. They are no more difficult than many ideas you already understand. Although some atomic language may be new to you, it will appear again and again in your newspapers in the future. In your community, in your country and around the world, men are finding more and more uses for atomic energy.

This book is the story of peacetime uses of atomic energy, the immediate problems which face you because you are living in this atomic age, and the hopes which man has for the release of boundless energy from atoms.

2. WHAT IS ATOMIC ENERGY

Help yourself to a handful of atoms. You can reach anywhere, pick up anything, or just hold the air that is already in your hand, and you will hold billions of atoms. You live in a world of atoms which together make up the fragile wings of butterflies and the hard rocks of the mountains. Atoms make the white ice of glaciers and the black lustre of coal, the silver wings of a jet plane and the deep blue of the oceans. Everything in and on the earth, the moon, the sun and all other stars are made of atoms. Billions of atoms together make you and everything that exists.

Look at your handful of atoms. You can't see a single one, no matter how hard you look. Atoms can be seen in photographs made by special microscopes, but they must be magnified a million times. Here are some ideas which will help you to realize how small atoms are.

If you could make a row of copper atoms by placing them next to another, you would need 100 million to cover an inch.

If you find it difficult to believe anything can be so small, you are not alone. Everyone, even the most learned scientist, thinks atoms are amazing.

Not all the atoms you hold in your hand weigh the same amount. From the way atoms act, man has been able to compare their weights and list them in a table beginning with the lightest and ending with the heaviest. Hydrogen, the gas used in circus balloons, is very light in weight, so it is not surprising that a hydrogen atom is very light. Uranium, the ore made famous by the atomic energy program, is the heaviest, and its atom is the last in the table of atoms that exist naturally. Man has made heavier ones which follow uranium in the table.

Scientists make portraits of atoms like the drawing in this chapter, based on their knowledge of the way atoms act.

Suppose you could look at just one of the atoms you hold in your hand. What might you see? Pretend that you could magnify one atom so that it becomes as large as a big room. This room-sized atom is mostly empty space, but in the center is a speck about the size of a fly. This is the nucleus. This is the part of the atom from which atomic energy is released. This is the part which can be made to supply energy to run submarines, light houses, or destroy the world.

The amount of energy which might be released when the nucleus of one atom is split is very small. But man has learned to break apart the nuclei of billions of atoms and to harness their energy.

Look at your room-sized atom again. If you look carefully at the margin of the atom, you will see tiny bits of matter whirling around the nucleus much the way planets spin around the sun. These tiny bits are electrons. They are the parts of atoms which are involved in thousands of everyday changes, such as burning a match, baking a cake, digesting food, and growing. Billions of electrons which are not attached to atoms provide you with electricity each day.

The number of electrons which spin in paths around each atom depends on the kind of atom. If you are looking at a uranium atom, there will be ninety-two electrons spinning in paths around the nucleus. Each element has a different number of electrons, but all the atoms of any one element contain the same number. For instance, all uranium atoms have ninety-two electrons.

If you could look at the nucleus of your room-sized atom, you would see that it is somewhat like a package made of smaller parts. About thirty different kinds of particles might be present, but two kinds are most famous. One of these is a proton. Each atom has a number of protons in its nucleus which matches the number of electrons spinning around it. All kinds of atoms have one or more protons.

Another important kind of particle in the nuclei of atoms is a neutron. The neutron is so named because it is neutral. It has no electric charge and is bound together with the proton in the nucleus of an atom. All kinds of atoms, with the exception of hydrogen, have neutrons.

Now you know the three most famous particles of which atoms are made: (1) electrons, (2) protons and (3) neutrons. You know that atoms are composed of nuclei with electrons spinning around them and you know that the nuclei of atoms must be split before atomic energy can be released.

Think of the nucleus of an atom as a package in which the contents are tightly bound. Some kind of atomic nuclei seem to be more tightly "wrapped" than others. Perhaps some combinations of atomic pieces fit together better. Certainly, some kinds of atomic nuclei can be made to pop apart more readily than others. And some kinds explode suddenly by themselves. Such atoms are called radioactive.

When radioactive atoms split naturally, and when man smash atoms, some of the energy which was bound in their nuclei is released in the form of heat and radiation. This energy is known as atomic energy.

3. ATOM SMASHING

Atomic energy comes commonly from the splitting of atoms. It is also produced by the reverse process, the fusion of atoms. Long before man learned to break apart the nuclei of billions of atoms to produce explosive amounts of atomic energy, they learned to break them apart in atom smashers. By doing so, they learned much about the secrets of the way atoms are made. Scientists are still learning by smashing atoms. Long before the days of atom smashers, the nuclei of certain atoms in the earth broke apart. Atomic energy is not new. Some radioactive atoms are always breaking apart in a process that has been going on since the beginning of time.

Radioactive atoms are with you every day. Some of the atoms in your bones are exploding at all times, for minute amounts of phosphorus in your bones are radioactive. There are always some radioactive atoms in the soil beneath your feet, in the air you breathe and in the water you drink.

Man has been living with this much radiation since his first appearance on earth.

Minute amounts of radium are used in paint on the hands and numerals of some watches and clocks. If you accustom your eyes to darkness and hold a magnifying glass over such a watch, you may be able to see separate pin points of light. Atomic pieces from the nuclei of some of the radium atoms in the paint strike other materials and make them glow. You cannot see individual particles, but you can see the work they do.

You could not safely hold a handful of radium atoms, for radium can cause serious burns. When properly handled, strong amounts of radiation from radium can be used against cancer. In an underground room at the Roosevelt Hospital in New York City, doctors watch a patient through a water-filled glass window that is 2 feet thick. The window protects them from the rays of radium being used to treat cancer cells deep in the patient's body. A safety device is arranged so that the radium cannot become effective until everyone except the patient has left the room through an electrically controlled door. Then the treatment begins, and rays from twenty-five pellets of radium are pointed at the diseased tissue. Together these pellets weight 50 grams, about as much as a dozen pennies, but they are valued at a million dollars.

The amount of radium at the hospital is the largest in America. Many hospitals cannot afford more than a speck, but even the smallest amount is a valuable aid in the war against cancer.

A tiny pinch of radium may be kept in a glass tube in the vault of your hospital. Outside the glass tube, brass and lead shield workers from the rays that are constantly being produced.

Before the effects of atomic energy from radium were as well understood as they are today, tragedy took place at a watch factory in New Jersey. Here, women applied radium paint on the dials of wrist watches with finely pointed paintbrushes. Some of the women twirled the brushes on their lips to keep fine points on them. The tiny, tiny bits of radium which they swallowed became part of their bones, and after a number of years some of the women died from radium poisoning. A few of the diseased bones have been kept in laboratories for further study.

Even today a Geiger counter clicks when brought near one of these bones, for radium atoms break apart over a long period of time. Only one-half of the radium which was deposited in the bones of these women will change into new atoms in a period of 1,600 years. This period is called the half life of radium. Another half of the remaining amount will break apart in the next 1,600years, and so on.

The rate at which radium breaks down does not change. Powerful electric currents, heat, cold, strong acids, or even X rays have no effect on the number of atoms which break apart in any given time. Radium cannot be hurried.

When a radium atom breaks apart, new radio-active elements are formed, but these contain less energy than the radium. As more particles pop out from the nuclei of these new atoms, and more energy is released, other radioactive elements are formed. Little by little, according to a constant pattern, they break up into lighter elements. In doing so, they give out radiation and small particles which were once part of their nuclei. After a long series of such explosions, lead atoms are formed which are not radioactive.

Scientists say that they have smashed an atom when the nucleus has been made to absorb particles or give them off. The mysterious binding force which holds the nucleus together has been overcome. New particles have been added to the nucleus, or some of the protons, neutrons and energy which were in it have been released. This smashing is not the kind one might do to a pane of glass.

When atomic particles combine, the process is known as fusion. The sun produces energy because of the fusion which takes place among its atoms. Hydrogen-bomb explosions are likewise the result of fusion.

When atomic nuclei are broken apart, the process is called fission. The energy released by fission may cause great destruction, as in an atomic bomb, or it may do wonderful work, as described later in this book.

Uranium is somewhat like the father of a family tree in which radium is the fifth generation and lead is the last. The amount of energy produced from this process in nature is small compared with the amount which man has released from atoms.

How are atoms smashed? You might try hammering at atoms, but you could pound with all your strength forever without succeeding in breaking one single atomic nucleus.

You could not hit anything so small with a hammer any more than you could use a battleship to remove a speck from your eye. You would never have the strength to break apart the nucleus of an atom, for the mysterious force which binds it is stronger than you can imagine.

To pry open the nuclei of atoms, atom smashers use parts of atoms such as protons, neutrons, or electrons. They hurl these tiny particles at the targets at terrific speeds so that they get inside the nuclei of atoms. Sometimes they send the contents shooting in all directions.

Atom smashers are the big machines which produce fusion and fission on a small scale. They are used by scientists who are searching for more information about these tiny bits of material. A variety of atom smashers is used, but all have long names such as Van de Graff generators, cosmotrons, cyclotrons, betatrons and bevatrons. All atom smashers, which are known to scientists as particle accelerators, are expensive, costing millions of dollars to build.

You might think of these atom smashers, or particle accelerators, as atomic shooting galleries in which the targets are the atoms to be smashed, and the bullets, particles from other atoms-protons, neutrons, or electrons.

Even though most of each atom is empty space, enough of these particles hit their marks to jointly knock apart the nuclei of many atoms.

The atomic explosions which take place in atom smashers are silent ones. The whole process is mysteriously quiet except for the sounding of an alarm bell or whirl of a motor. No one can see the individual atomic bullets or the atomic particles which fly out of the targets. Geiger counters and other instruments measure and weigh invisible particles which may exist for only a fraction of a second. Cloud chambers with automatic cameras record their tracks. In such ways, man learn more about the amazing atoms of which the world is made.

There is still much to be discovered in these tiny particles. Many fascinating things will be revealed by the young people of today when they become the scientists of tomorrow. Some theories will be revised, for man's idea of truth changes as he learns more about the forces which control the world.

Some of the ideas which man had about atoms long ago are proving to be true. Einstein suggested in 1905 that matter could be changed into energy, and energy into matter. Today, work on atoms has borne out his theory.

If one could gather all the parts of an exploding atom, their total weight would be slightly less than the weight of the original atom. In atomic arithmetic, the pieces weigh less than the whole. Part of the material disappears in the form of atomic energy.

Energy is changed to matter when electrical energy is added to particles that are being prepared to strike their targets in atom smashers. In one atom smasher electrons become a thousand times heavier than normal because of the great amount of energy which is given to them to increase their speed to near the speed of light before they are sent crashing into their targets. To reach these high speeds, atomic bullets travel over long distances. In one bevatron, particles travel 300,000 miles in a circular path under the influence of an extremely strong magnet. Each time an atomic bullet races around the circle, its speed is increased by a sort of electrical nudge. Each time, a bit of energy is changed to matter, and the electron becomes heavier. Today, man can change matter into energy and energy into matter.

When a ton of coal burns, a very small amount of weight is lost. Even when the weight of ash and escaping gas is totaled, the amount is so small that it cannot be measured. Since the weight lost when atoms change places chemically when the nucleus is not split, is so very slight, man believed for many years that there was no change at all. This is just one of the many cases in which an idea had to be changed when more knowledge was gained.

Radium has been changing its substance into energy since the beginning of the world. Uranium is the main source of atomic energy which man has learned to control, but even in the case of uranium, not all of the energy which is locked in the nuclei is released. In the splitting of uranium atoms, man has released energy which is equal to about 1/10 of l percent of the matter of which atoms are made. If l kg of uranium could be entirely changed into energy, the energy produced would be as great as that released by the burning of 1500 tons of coal. When man learns more atomic secrets from his studies with atom smashers, he may learn how to put more of the energy from each atom to work.

4. SPLITTING THE NUCLEUS OF ATOMS

If you heard a telephone conversation like this one, would you know what it meant? “The Italian navigator has landed in the New World.” “How were the natives?” “Very friendly.” Such a conversation really took place on December 2, 1942, to announce the success of the first atomic pile. This was the first time man had released energy from atoms and had controlled it. This was the first large-scale atom smashing, and it could be stopped and started at will.

Since the United States was at war when this great event took place, no public announcement could be made. Instead, word travelled from Chicago to Washington in code. After you read the following story about the first atomic pile you will be able to understand the code.

An atomic pile is a device for splitting the nuclei of atoms. The first one grew secretly under the football benches of Stagg Field, Chicago, Illinois. Here, on the unused squash courts, men were trying to answer the question, “Is it possible that splitting uranium might release neutrons to split more atoms, and so on to form a chain reaction?”

Mousetraps are often used to illustrate what is meant by a chain reaction. If you arrange mousetraps on a table in rows, and drop a marble on the first one, this marble may set off a whole chain of mousetraps. Neutrons are somewhat like the marble. In any amount of uranium there are always some atoms which are breaking apart, so there are always some free neutrons. If enough uranium were brought together, these free neutrons might hit the nuclei of other uranium atoms, splitting them and releasing more neutrons. These might split more atoms and so on, making a chain of splitting atoms. If this could be made to happen, tremendous amounts of energy would be released.

Imagine the excitement of going to work each day on a serious experiment as important as this! No one knew exactly what would happen, but Enrico Fermi, the Italian scientist in charge of the project, and other great scientists working with him were almost certain that a chain reaction could be started.

The pile began with a layer of graphite blocks cut like bricks. Graphite, a form of carbon used commonly as “lead” in pencils, was used to regulate the speed at which neutrons would travel. With such control, neutron bullets would split more atoms.

On top of this layer, workers laid another layer of graphite in which uranium and uranium oxide were embedded in a suitable pattern. Not all the uranium was of the type that could be split by stray neutrons. Natural uranium is a combination of three kinds known as uranium 234, uranium 235 and uranium 238. These are isotopes, or chemical twins, which behave alike chemically but do not weigh the some. Isotopes are different forms of the same element which vary in weight because of more or less neutrons in their nuclei. The number of protons is the same; just the number of neutrons differs.

Uranium 234 appears in such very small amounts that it is not important. Uranium 235 is the isotope of uranium which can be split by neutron bullets. It appears in much smaller quantities than the uranium 238, for in every 1,000 atoms there are only about 7 atoms of uranium 235. In other words, one atom of uranium 235 is present for every 142.8 atoms of uranium 238. Since the isotopes exist together in nature and are difficult to separate, all three forms were present in the first atomic pile.

Layer after layer was put into place, with uranium in the bricks of every other one. Two crews of men worked in shifts almost around the clock, testing and measuring radiations. Slowly the pile grew larger.

Although no one knew exactly how much uranium would be needed or how high the pile must be before the furnace would begin to work continuously, they did know there must be a way of stopping a chain reaction. Earlier experiments had shown that when a neutron blasted a uranium nucleus, some of the matter in the atoms was changed into energy. Some would be in the form of heat, and some would be in the form of deadly radiation which could not be seen, felt, smelled, heard, or tasted. This made the experiment a dangerous one. Workers must be protected from radiations, and the pile must be controlled. For this purpose three rods of cadmium were used, since cadmium is a material which absorbs neutrons. By removing free neutrons, cadmium would break the chain. With the rods in place, the furnace would be almost inactive.

One rod was automatic, controlled by a motor which would push in the rod when the radiation reached a certain level. A second rod was controlled by a rope over a pulley. A man standing by the rope with an axe would cut the rope if the second rod was needed to stop the reaction. This rod was called Zip by the workers because it would zip back into place when the axe fell. A third rod could be removed and replaced by one man who operated it by hand.

The silent, flameless furnace would have its own self-starter. There would be no need to light its fuel, and no match could set a chain reaction in motion. When enough uranium had been gathered together, so that at least one neutron from each splitting atom of U 235 would be sure to strike another U-235 nucleus, a chain reaction should begin. How would they know when the furnace began to work? How would they know when free neutrons were colliding with uranium atoms and splitting them at a rapidly increasing rate? Instruments that counted the neutrons were built into the pile and would announce the amount of radioactivity with their clicking and the motion of needles on their dials.

The pile was begun in November, 1942. By December 1, 1942, routine tests showed that a chain reaction could be expected when the cadmium rods were removed the next day. Early on the morning of December 22, 1942, therefore, the crew was tense but ready. The man with the axe was standing by Zip; another man was ready to control the third rod. At Fermi's orders the first rod was automatically removed, and Zip was pulled out. The third rod was pulled out slowly, inch by inch. The instruments clicked, and measurements showed that the pile was seething with radiation.

About forty persons watched the test all morning with mounting excitement. Fermi called time out for lunch, for he knew that the crew needed a rest; then he proceeded with more tests after the men returned. When the rods were removed, neutron bullets collided with neighboring atoms, splitting them to produce smaller atoms, radiations, and atomic parts, including enough neutrons to split more atoms. By 3.25 in the afternoon, buzzing instruments and high-swinging needles announced the first chain reaction. For twenty-eight minutes the atomic furnace split atoms. Then Fermi ordered the control rods put back into the pile so that cadmium would capture the neutron bullets which were flying through the pile at a speed of 10,000 miles per second. Now many of them hit the cadmium and were absorbed. The chain reaction was stopped. Dangerous amounts of heat and radiation were no longer coming from the silent furnace.

Although the power generated in that first operation of an atomic furnace was less than the amount necessary to light a small electric light bulb, this was the most important occasion. This was perhaps the most important step in the beginning of the whole atomic energy program.

Now look at the famous telephone conversation again.
"The Italian navigator has landed in the New World." (Fermi has succeeded in producing a chain reaction, something new in the history of the world.)
"How were the natives?" (Is the reaction under control?)
"Very friendly." (Yes, the reaction is under control.)

Exactly what happened to the uranium atoms in this pile or in any pile of today is still somewhat of a mystery because no one knows the true nature of the binding forces which hold the nuclei of atoms together. But since the time of the first atomic pile, huge piles called nuclear reactors have been set up for various purposes throughout the United States and in other countries.

5. ACTIVATION ANALYSIS

Can you imagine how a nuclear reactor might help art experts obtain insights into the painting techniques of old masters? Or would you expect a nuclear reactor to play a part in helping police identify a clue as tiny as a billionth of a gram of paint, and thus point their finger at a criminal? This is done by "activation analysis," a technique described later in this book. It is one of a wide variety of ways in which nuclear reactors are being used today.

Although reactors are built in different sizes, use different materials for fuel, and even vary in the quality of fuel which is used, the basic principle behind each is the same.

Just as the mysterious pile described in the last chapter was controlled by cadmium rods, modern reactors are controlled by regulating the number of neutrons in the core or fuel area. Boron as well as cadmium rods can be used somewhat like blotters to absorb unwanted neutrons and maintain the proper level of operation.

Suppose you are in charge of a nuclear power plant. The fuel has been loaded into the reactor, and two sets of control rods are set at "in" position. When the loading is finished, you order the withdrawal of one set of rods. These are safety rods which can be used to shut down the reactor in case of emergency. You have the other set of rods partially withdrawn at a gradual rate, controlling this according to the readings on neutron-counting instruments. When the reactor becomes "critical" (the point at which the chain reaction becomes self-sustaining), the regulating rods are adjusted to maintain the operating level you desire.

Heat would be a great problem in the operation of a nuclear reactor if arrangements were not made to remove some of it. Neutrons and fission products are colliding on a massive scale with surrounding material, and in the process their kinetic energy is converted into heat. If a reactor is operated at a high power level, a level at which there is much activity, there might be enough heat to melt the core. In most reactors, heat is carried away from the core. This heat is then put to work in reactors which produce electricity, propel ships, or desalt water.

In addition to control systems and coolants, reactors need moderators for proper functioning. Sometimes the coolant serves as moderator in addition to carrying away the heat; sometimes separate materials are used. In either case, the moderator aids fission by slowing down the rate of motion of neutrons. Strange as it may seem, slow moving neutrons are more effective in triggering fission than fast ones. Collision slows the speed of neutrons, but some may be “wasted” by being absorbed by fission products if too many collisions are involved before they reach the speed at which they best trigger fission. Water, heavy water, graphite and beryllium are some of the materials which are used as moderators. They are well distributed among the atoms which serve as fuel to slow down neutrons without absorbing very many.

If you direct the operation of a nuclear reactor, you can be sure that you will do so from a place that is separated from the reactor by shielding. Biological shielding, the kind which protects people from radiation, is often composed of high-density concrete. You may work behind several feet or even many feet of such protection. In some cases, even the reactor vessel is protected from radiation. A steel lining is often used for this purpose.

Reactors have been described as a sort of three dimensional, high-speed game of pinball, cooled by a fan and controlled by rods. All of this game is being played in a box of fuel, with the pinball or neutron speed being controlled by other balls, the moderator atoms. And it is all carefully wrapped for the protection of those who play the game and against the damage it could do to itself.

Nuclear reactors are, of course, a most serious and dangerous game, with uses that are so important that their discovery has been compared with the discovery of fire. Early in the days of peacetime use of atomic fission, and when countries were striving to stockpile atomic weapons, many men searched for the fuel to build the cores of reactors. They combed the countryside much like the prospectors of the Gold Rush.

Fuel for a reactor must be a fissionable material, one that readily under goes fission when struck by neutrons. The only substance that occurs in nature which qualifies for reactor fuel is a form of uranium known as uranium 235. It occurs with uranium 238. For every 99 parts of uranium 238, only one part is uranium 235. But since uranium 238 can be converted into fissionable material, it too is valuable in the atomic-energy programme.

Actually, some uranium is at your doorstep, because it is found almost everywhere on earth. If you could remove the top soil from a square mile of earth to a depth of 12 inches, it would contain about 3 tons of uranium and 1/28 of an ounce of radium. But this amount is so slight that it is not worth the effort to recover or collect the material. Ores such as carnotite and pitchblende contain fairly large amounts of uranium, making mining them practical.

Suppose you have discovered some uranium ore in a Colorado canyon. At this point, the work of preparing it for a reactor has just begun. Ore must be mined and delivered to a place where it will be purchased. You cannot sell, or even give, your ore to anyone else, but would be glad to use the government's new paved highway which leads to the purchasing station, and to be sure of a buyer who will pay a fair price.

The ore on your trucks is weighed, sampled and tested to see how much uranium and other valuable mineral matter is present. The government of the United States will pay accordingly. Then the ore will be processed for use either in the defense programme or in one of the peacetime programmes described in the following chapters.

Much will happen to your ore before atomic energy can be released from it. Clay, sandstone and other materials must be separated from the uranium mineral, which is scattered through the ore in particles so small that it sometimes can be seen only with a microscope. At the mill, ore is crushed, powdered, and screened. It is roasted, washed, and put through more processes until it is much reduced in quantity but somewhat purer. From tons of ore, just a few bright yellow pounds may be left even though a standard process for extracting uranium has been perfected to the point of 99.99 percent recovery. More complicated processing will produce the gray black powder which is uranium oxide. This is shipped to a feeder mill, where it is purified and changed into a green salt which is a combination of uranium and fluorine. After still further processing, your uranium becomes a pure, bright, heavy metal, silvery white in color and just slightly softer than steel. Most of it is not the kind of uranium which will break apart and release large amounts of energy.

Only a small fraction of the uranium is the valuable uranium 235 which can be made to release energy. Not all uranium is alike, but you could not see any difference even if you could look at each atom separately. And this you cannot do.

Getting uranium ready for use as a fuel in a nuclear reactor is difficult, dangerous and exciting. Uranium 235 may be separated from uranium 238, or an entirely new substance may be produced, that is a man-made element. These two reactor fuels are being joined by others as more experiments lead the way. For instance, in some reactors uranium is combined with aluminum, in other with a substance known as zirconium hydroxide. Polonium 210 has promise as a heat source for small space-rocket engines. Thorium is another fuel which is used experimentally in reactors.

No matter what the fuel, all reactors work on much the same principle. Fission products from these reactors help us probe new horizons in agriculture, biology, medicine, industry, space, and other areas. Without atomic energy, many of these horizons would never have been explored.

6. ATOMS FOR THE BENEFIT OF MANKIND

You may someday work in a laboratory where men are learning more about the production of raw materials for reactors so that atoms can be put to wider use for the benefit of mankind. By the year 1965, about half of the U.S. Atomic Energy Commission's budget was being used for purposes other than weapons programs. Today all over the world major laboratories are operated by the Atomic Energy Commission. In these, and in industrial and university centers, scientists search for better ways of using atoms for peace.

By the waters of the Columbia River in the state of Washington, a vast atomic plant spreads over an area half the size of Rhode Island. This Hanford Atomic Project has been called one of the Seven Wonders of the world. One of its functions is the converting of uranium into a man-made element known as plutonium.

Plutonium is an important national resource which can be made to release tremendous amounts of energy when neutron bullets are shot at it. It can be safely stored for thousands of years, for it has a half life of 24,000 years. In that period of time, just half of any amount of it will decay. Plutonium can be used in times of war to protect the country, or in times of peace to work as a servant of man.

Suppose you could watch some uranium "cooking" in the mysterious furnaces of Hanford. Here, huge fortress like walls of concrete and lead protect workers from deadly radiations produced by splitting atoms. The reactor is several stories high, with many holes, each about the size of a silver dollar. Through one of these, a can containing your uranium will be pushed, along with hundreds of similar cans. When the loading is finished, these holes will be plugged with lead, metallic bars will be moved out, and free neutrons will dart about. Some will hit the nuclei of other atoms. Now a chain reaction begins and the furnace is in action.

No large pieces of machinery move, no smoke comes out, no fire crackles. You hear the soft hum of ventilators and pumps that push water through the reactor to absorb the heat. Men and women in white coats watch flashing red and green lights and dials and adjust instruments in the control room.

After months of "cooking," billions of atoms of uranium will have become plutonium, because neutrons will have been added to their nuclei. When the can is pushed out from the other side of the reactor into a canal where water is 30 feet deep, it looks just as it did before. But now it is "hot," or radioactive, giving off radiations which are deadly to living things. In the canal water there is a beautiful blue glow surrounding every can because of this intense radiation.

From now on, the uranium must be handled by mechanical hands. Workers cannot safely breathe the air around contents of the cans. By remote control, pure plutonium is separated from radioactive wastes so that it can be stored until it is needed.

Many new, exciting programs are being carried out at Hanford. For instance, in January 1965, the Batelle Memorial Institute assumed the responsibility for activities in life sciences. Not only is there broad concern for the effects of radiation on living things, but there are many studies in progress in other areas of biology in what is called the Pacific Northwest Laboratory.

Suppose you could visit the biology facilities on the Hanford Reservation. In addition to the main laboratory building, you would find a second one which houses a portion of the aquatic program and the studies in ecology (the relationship of plants and animals to their surroundings). There are 800 acres of land known as Rattlesnake Springs Ecological Preserve, where field studies are made, and there are large pastures where a herd of pygmy goats, 400 sheep, 450 miniature pigs, and 250 beagles take their exercise. These animals are effective stand-ins for the human race in experiments that will help to protect man. In one experiment where scientists are trying to find out more about the toxic effects of exposure to small amounts of both radioactivity and cigarette smoke, a number of beagles smoke up to twenty cigarettes per day.

Far across the land, scientists in the Brookhaven National Laboratory in Long Island, New York, are engaged in fundamental research, seeking more information about atomic energy. This information is shared with other scientists around the world, who develop new ways of applying it. In addition to the hundreds of United States scientists who work at Brookhaven, foreign scientists from over thirty countries participate in research projects as part of an international cooperation program.

An even more famous center for nuclear research and development is at Oak Ridge, Tennessee. In addition to preparing uranium for storage as a national resource in the interests of defense, vast numbers of experiments are helping to put the atom to work to improve the lives of people around the world.

At Oak Ridge, where the first atomic bomb was built, the “forbidden” city has become a tourist attraction. One of the factories which was formerly devoted to production of uranium has been converted to a new use and is now concerned with seeking ways to put nuclear fuel to work for peacetime benefits. Oak Ridge’s one remaining production facility turns out fissionable materials for a growing number of power plants which are providing electricity for everyday use. There and throughout the United States and other parts of the world, atoms are going to work to raise standards of living.

Scientists of the Atomic Energy Commission work in a wide variety of areas. They have developed ways to make parts from pure tungsten by squeezing the powdered metal at very high pressures. They have made the world's smallest incandescent light to help doctors conduct blood tests on astronauts. They search for answers to the riddles of cancer and other diseases; they graft plants; they analyze materials with an unbelievable degree of accuracy. You will read about many more interests and accomplishments of atomic scientists in the following pages.

7. RADIOACTIVITY

The ashes from a nuclear furnace cannot be collected by an ordinary trash man, for they are "hot," or radioactive. One nuclear reactor produces radiation equal to several tons of radium.

Since many of these ashes lose their radioactivity quickly, they can be stored behind shields until they are safe, and then they can be disposed of like ordinary industrial wastes. Some can be diluted with water until they are no longer dangerous.

Many of the waste products of other industries have been carelessly dumped into streams and rivers, where they have polluted water and created many problems. From the beginning of the atomic energy program, careful disposal of wastes has been a necessity, since no one can see, feel, or hear the deadly radiations from decaying atoms.

Collecting radioactive trash was not a problem before man learned to split atoms, for only about 3 pounds of radium have been made available in the whole world during the last fifty years. The amount of atomic trash has grown as the atomic energy program has grown.

Underground storage tanks, which house radioactive materials are filling up at a distressing rate. Some wastes can be burned, but care must be taken to prevent radioactive gases from spreading through the air. Some radioactive wastes are dumped at sea after they have been encased in concrete, a procedure which keeps radiation from getting through the case and also makes the wastes sink to the bottom. Certain areas are used as underwater cemeteries for these wastes.

Spaghetti-like strands of clay are used to absorb some atomic wastes. The clay is then baked into bricks which can be buried in the ground.

The Columbia River, which removes heat from the reactors at Hanford, where plutonium is being made, also removes some radioactive material. Cold river water is pumped into the reactors at a rate of thousands of gallons every minute. As the water travels through, the minerals in it are bombarded by neutrons. In this way they are made slightly radioactive and must be disposed of as carefully as other atomic trash. Before the water is returned to the river, it is stored in large basins until some of the radioactive materials decays.

Only a very slight amount of radiation is left when the water pours back into the river. Studies are constantly being made by scientists to determine whether this small amount has any effect on fish or other life in the river. The people who eat the fish must also be protected from radioactive food.

A special boat chugs up and down the river, while the crew collects samples of river water, fish and other river animals, and plant life. In addition to this, men in rubber boots and special protective clothing gather samples from the shallow areas of the river. These are rushed to laboratories, where they are examined to determine the exact amount of radioactivity which they have absorbed.

The studies show that no harm has come to the river life as a result of the small amounts of radioactivity which are released in it, but scientists will continue to go fishing and to check their catch for radioactivity so that there will never be a surprise increase of it in the river.

No single method of disposal is used, for the method of getting rid of radioactive material depends largely on its type, strength and length of life. Some chemicals remain “hot” for millions of years, while others become safe after a fraction of a second. When old, temporary buildings become “hot”, they’re painted so that loosely attached specks of radioactive materials will not spread. Then the buildings are taken apart, board by board, and buried. Even rats from such a building may be radioactive and must be carefully destroyed.

A small number of organizations have been approved by the Atomic Energy Commission to haul away "hot" wastes from hospitals, laboratories, and industrial plants which use small amounts of these materials. These atomic trash collectors charge for removing each 5-gallon can of atomic wastes. They make regular scheduled collection trips to customers by truck. An instrument on the front seat gives a constant check to make certain that the dangerous radiations from the trash are not leaking from the pails. Health "detectives" are constantly checking all areas near government projects and private industries which produce radioactive wastes. Even air from the buildings must be properly cleaned before it is released so that there is no possibility of spreading dangerous radiations where people, other animals, or plants might suffer from them.

At the Brookhaven National Laboratory, for example, men at sixteen stations are constantly testing the air for radioactivity. If they should find more than the amount which is known to be safe, the nuclear reactor at the laboratory would be shut down.

Inside the laboratory an instrument, called "Fido," is used to detect spilled radioactive material. It is a Geiger counter on wheels, connected to earphones. If the clicking which the operator constantly hears should suddenly become more frequent, he would know that some radioactive material had been spilled in that area.

The atomic energy program includes much research to find out how much radioactivity is safe, and to find better ways of handling radioactive wastes.

Some of the wastes from nuclear reactors include valuable radioisotopes. These are radioactive forms of elements, or isotopes, which were made "hot" in reactors.

As the peacetime uses of atomic energy increase, exploding atoms are sending out their rays in more places each year. More and more people work directly with radioactive materials. Some are employed directly by the Atomic Energy Commission; others work with radioisotopes in hospitals, research laboratories, and many different industries.

Perhaps you will work with radioactive materials in the near future. How will you be protected from their deadly rays?

In addition to protecting the nation from aggressors, the Atomic Energy Commission is charged with protecting its workers and those to whom they distribute isotopes, from the rays released by splitting atoms. A field known as health physics has developed, in which certain standards for safety are set. A health physicist protects people from radiation by developing suitable methods of working, checking against excess exposure, and giving warnings when necessary. He learns what radiation can do to individuals and sets limits of exposure. Any amount of radiation can be handled if suitable precautions are taken. If workers respect radiation, there is no need to fear it.

Many types of detection instruments are in constant use to protect workers. Badges are worn which contain film that can be developed, and the amount of exposure to radiation can be measured. Film badges are checked periodically, and careful records are kept for each worker. Since doses are cumulative, such records are important.

A Hand and Foot Counter can be used to check possible full body contamination. Other instruments have nicknames such as “Cutie Pie” and “Pee Wee”.

The kind of checking depends upon the amount and the type of radiation to which people might have been exposed. Radioactive materials produce one or more of the following types of radiation, all of which are invisible.

Alpha particles are one type. Each tiny alpha particle in such a ray is a combination of two protons and two neutrons which have come from the nucleus of a splitting atom. These rays are unable to penetrate the unbroken skin, but if they are liberated by a radioisotope which has entered the body, they can cause great damage. In the air they travel only about an inch and can be stopped by a sheet of paper.

Beta particles are electrons travelling at high speed as they are shot out from certain radioactive atoms. These invisible rays travel as much as a few feet in the air, but can be stopped by an inch of wood. They could go through about 1/3 of an inch of human tissue, causing severe burns.

Gamma rays penetrate deeply and can be stopped only by a great amount of concrete or lead. These are the rays, related to X rays, which are released by radium and uranium.

Neutrons can penetrate several feet of tissue and are therefore extremely dangerous. Protection is similar to that from gamma rays.

Even though these fast-flying particles and waves which come from radioactive atoms can cause severe damage to the human body, such care is taken by the health physicists that total yearly exposures for atomic energy workers are far under the safe limit. You may receive more radiation from an X ray of your digestive system than a worker might receive in an year, though he handled extremely “hot” materials day after day.

Suppose you are going to perform a small operation in which only moderate amounts of radiation will be released. For this you might use a dry box, or gloved box. This is a closed box with a glass front or top and gloves into which the worker can place his hands. A current of air which flows through the dry box is filtered to remove radioactive dust before it is sent out doors. Some larger dry boxes rotate so that the worker may reach any part of them.

Now you are planning to work with intensive radiation. You will work with materials in a “hot cave”, a huge box with walls and roof of thick concrete. These structures are sometimes called “hot cells,” but generally they are referred to as caves. First, the 7-ton concrete door is rolled out on railroad tracks, and the interior of the cave is checked with instruments to make certain that no radioactivity remains from the last experiment. Apparatus for the experiment is put in the cave, and part of it is placed in a clear plastic case. Everything is ready, but a “dry run” is made first to make certain that everything is in order.

Now a heavy lead pot is rolled in, and by means of a chain hoist, a specimen of uranium 235 in a lead container is laid upon a shelf. The hoist is removed, the door closed, and the experiment begins. No one touches the uranium or breathes the air around it. You can handle it with ease by using a master slave manipulator; which can be made to move just as your own hands. You can watch what you are doing through a protective, 3-foot-thick window made of colored glass.

While you work, a detection instrument draws in room air and passes it through filter paper, which is then tested for contamination.
You want to tell your assistant about a certain instrument in the cave. With great ease, you point to the instrument 6 feet away with one of your master slave manipulator with your own fingers. The master slave manipulator responds to every movement of your muscles. You place the uranium in its lead case, your assistant rolls open the door, and the lead pot is sent into the cave. Now the radioactive material is safely put away where its rays cannot reach any living thing.

At another hot cave, a worker is using a slave manipulator that is less complicated than the master one. By moving keys and switches, he controls the movements of a steel wrist and hand inside the cave. This slave manipulator cannot move in as many directions as the human hand or the master slave manipulator, but it can perform certain operations with ease.

In another building, an atomic energy worker is viewing his work on a special television screen which enables him to see all three dimensions when he wears special glasses. Using his master slave manipulator, he performs very delicate operations at a safe distance from the "hot" materials.

Other workers are inspecting materials in a deep waterpit. In this underwater workshop, rays from exploding atoms are stopped before they reach the people who handle them by remote control.

You might dress even more strangely than a man from Mars in order to work safely on some atomic projects. One type of suit is made entirely of plastic, with seams that zip together to form tight joints. A tank strapped to your back supplies air through a nozzle in the upper part of the suit. In this way you breathe pure air, and there is no danger that radioactive air will leak through an opening in your suit. It has no openings.

An even stranger suit is sometimes worn by repairmen who must work in areas where bulky suits are a nuisance. There a worker crawls into a thin plastic suit through the long tunnel-like tail which opens at a porthole in an adjoining room. Cables through the tubes supply air for breathing. Wearing asbestos gloves, workers can repair atomic machinery while on a leash made from the tail of their suits. They can move abut "hot rooms" in complete safety so long as they do not tear their suits.

An alarm warns of danger. A worker from an area where radioactive materials are being handled has smeared some on his clothing. As he passes through a door which is surrounded by Geiger-counter tubes the alarm tells him and fellow workers that he must be decontaminated. He hurries to the showers, where he scrubs while his clothes are buried with other radioactive wastes. For a period of time he will not work in radioactive areas, and doctors will make periodic checks of his physical condition to make certain that he is not harbouring radioactive substances in his body.

Every worker in the atomic energy program is carefully guarded. Every operation is done with great precaution. Even the dust mops are tested to make certain that they have not picked up radioactive dust. The Atomic Energy Commission carefully studies the amount of radioactivity which workers are permitted to receive, especially since radioactivity is cumulative in the human body.

8. RADIATION AND LIVING THINGS

Will atomic energy endanger the health of those who do not work in atomic industries? Health physicists who protect atomic energy employees also work to protect the public. An accident at a nuclear power plant could endanger people for miles around. Other scientists work to detect bombs which produce dangerous radioactivity.

Some day you may work with about thirty other scientists and technicians in one of the nuclear detection stations of an international program to detect secret nuclear bomb tests. You might be on a plane patrol, on a ship, an island, or in one of more than a hundred stations scattered throughout the continents of the world where earthquakes are common and most likely to occur, for here the detection is more difficult. No matter where you work, you will use many sensitive instruments. Some can detect tests by air waves, others by radio waves. Tests deep under the earth or ocean can be detected by the waves which they send through the ocean, the earth, or both.

Suppose there is never another bomb test and you never live near an atomic industry. Will radiation endanger you? There has been a rising tide of questions and worry about the danger of fallout. Not all of the radioactive debris from the first bombs has yet fallen to the ground.

Man is making many efforts to learn more about the dangerous radioactivity that he has added to the air around him. One hears today of requests for canned food that was processed before the days of atomic explosions to make a comparison between radioactivity then and radioactivity today. A nationwide continuous check of the common foods has been started by the Food and Drug Administration so that they can be prepared to protect the public if an increase in radioactivity should be noted.

The Atomic Energy Commission's Heath and Safety Laboratory is another watchdog of your atomic health. It's their duty to keep a daily check on radioactivity by analyzing everything from seal fins to soil samples. Leaves, for instance, can be burned to an ash and the amount of their radioactivity measured. Air can be sampled by exposing a 12-inch square of gummed paper on a rooftop in a city. Another piece of gummed paper is exposed in another city, and so on in many parts of the world.

Even though large-scale testing of nuclear weapons in the atmosphere stopped with the test ban at the end of 1962, the level of strontium 90 on the surface of the earth continued to rise through 1965. A large percentage of the radioactive strontium from tests has now fallen to the ground, and the level in milk hit its peak in 1964.

Scientists are especially concerned about radioactivity in milk. Material which falls on grass is eaten by cows and can reach people within a few days. Iodine 131 loses half its radioactivity in eight days, so that if it does not reach people soon after cows consume it, there is little danger. On the other hand, strontium 90 has a half life of twenty-eight years. At the end of twenty-eight years ½ of its radioactivity will still be present. At the end of the next twenty-eight years, ¼ will be present.

Plants which need calcium also take strontium along with it. Cows grazing in Wisconsin or New York take in the strontium which happens to be in their grass or feed. Some of the strontium is blocked out by the cow's body processes, but some gets into the milk. Larger amounts are absorbed by vegetables, especially those whose roots are deep in the soil. When the strontium gets into human beings, it behaves like calcium and is absorbed into living bone. Everyone on the earth may now have a measurable amount of strontium 90 in his bones which was not there before man learned to release atomic energy.

The Pasteurized Milk Network of the Public Health Service keeps watch on the radioactivity in milk through sixty-three stations in the Untied States, Puerto Rico, and the Canal Zone. Methods of removing excess radioactivity from milk are being perfected.

Another approach to studying the way in which the atomic age is affecting man is through the study of bones that have been removed surgically or have been obtained during autopsies. It has been reported that levels of strontium 90 reached their peak in children under five years of age in the year 1963.

Scientists are still trying to get a better understanding of fallout and its possible effects on health, despite the test ban. Although harmful effects have not been proved, they may exist. It is still questionable whether or not there is actual danger to people living today or to unborn generations from fallout radiation. So far the fallout radiation absorbed is much less than the amount received from natural phenomena such as cosmic rays. Except in cases of accident or leakage from an underground test, there is certainly no reason for alarm.

Today medical X rays may expose individuals to a far greater amount of radiation than fallout. Recent checks have been made of equipment, techniques have been improved to reduce radiation danger, and doctors have become more careful in the amount and frequency of exposure since people have become more conscious of the dangers of radiation. Recent reports indicate that X-ray studies in the United States do not involve any serious risk, but it is recommended that the exposed area be limited as much as possible. X-ray movies of the heart have been advised for all persons over forty even though they may not be aware of any heart trouble. This recommendation was made even though doctors are well aware that radiation effects are cumulative.

These X rays, fallout from tests made years ago, and natural radiation will be part of man's environment for thousands of years to come. Will nuclear-power plants add to what many people consider a present-day radiation hazard? Will the reactor in a power plant that produces electricity blow up? Such chances are virtually nonexistent. The reactor in such a power plant contains fuel that is only about 2 per cent fissionable, barely enough to maintain a chain reaction. Even if some amount of radiation should leak from the reactor accidentally, there are many barriers between this and the outside world.

After three years of operation of Consolidated Edison's atomic power plant in New York, the Hudson River was so free of radioactivity that the state proposed reducing the number of testing stations from twelve to seven. This plant, which is 30 miles north of Manhattan, provides electricity for about a million people.

While scientists and world leaders are concerning themselves with radioactivity in the atmosphere, some men are trying to find a drug that will protect people from radiation. One chemical, known as AET, has been found to be 100 per cent effective in mice that were exposed to deadly doses of radiation. Experiments are continuing on monkeys and on man.

Another approach to treating overexposure to radiation is transplanting bone marrow from healthy animals into those exposed to radiation. Several bone banks are storing human marrow in case of radiation accident.

Still another approach to the problem of anti-radiation drugs is the use of extract from mouse spleens. There is hope that such a drug taken from animals or a man-made duplicate may be developed to a degree that it could save a good percentage of people exposed to large doses of radiation.

The problem of protection from radiation is far from being solved. Radiation drugs and transplants are still in the experimental stage, but little by little man is learning to live with the atom and to use it for his benefit.

9. ATOMS FOR MEDICINE

Before 1930, radium was the only known element which broke apart fast enough to be used in the treatment of cancer and other diseases. Later, when artificial radioisotopes were made by bombarding targets in atom smashers, a trickle of these valuable materials was available to medical investigators and hospitals. They were extremely expensive and scarce, but they did add slightly to the meager supply of ray-giving atoms available for such purposes.

Now a quantity of radioisotopes, thousands of times as great is produced in nuclear reactors. In addition to the radioisotopes which are produced as nuclear ashes, most usable radioisotopes are "made to order" by placing a small amount of an element in a container in the reactor. Here the atoms will be the targets of millions of free neutrons which have been released by the breaking apart of uranium atoms. Some of the neutrons will succeed in entering the atomic cores of the target element. In this way, heavier isotopes of the element are produced.

Suppose scientists want to make cobalt with sixty particles in its center. Natural cobalt, which contains fifty-nine particles in its nucleus, is placed in an atomic pile. Now, countless billions of neutrons are flying about it in all directions. Many rush past the cobalt atoms in the comparatively vast spaces between their nuclei and their electron rings. From time to time a neutron hits its target and changes an atom of cobalt 59 into cobalt 60. Such atoms are radioactive, because now they have a number of particles which give them "atomic indigestion".

Some of this cobalt which has been "cooked" in an atomic furnace is being used to treat cancer. Thin tubes of flexible nylon are loaded with cobalt 60. These tubes are sewn into cancers so that the deadly rays from these radioactive atoms can destroy diseased tissue. As early as 1946, a variety of thin wires, slugs, and needles for medical purposes were changed from cobalt 59 to cobalt 60 at the Oak Ridge pile. After being tested on animals, these tools were put to work on human beings to do work which had formerly been done by the far more expensive radium. Later nylon sutures were loaded with radioactive cobalt wire. After removing cancerous tumors, a surgeon may sew this into tissues to take care of any cancer cells which may be left. Bullets of gold which can be planted in deep-seated tumors by means of a special gun are made radioactive at Oak Ridge.

Many private companies are producing radioisotopes for medical use. As they become more able to meet the demand from hospitals and other institutions, fewer radioisotopes will be shipped from government facilities at Oak Ridge. Until private industry takes over the task of supply, the strangest drugstore in the world will continue at Oak Ridge, Tennessee.

If you step inside this drugstore, you will not find a soda fountain, toys, and the usual assortment displayed in most drugstores, you can't even see the drugs unless you look in a mirror, for they are too "hot" to examine except by remote control.

Wires, needles, and beads of radioactive cobalt, gold, and other elements are just a few of the many medicines available from the Oak Ridge atomic drugstore.

Suppose you have an order for a radioactive liquid for a hospital. The "druggist" locates the bottle containing your medicine by looking in a tilted mirror which shows him what is stored behind a 2-foot concrete wall. Using a metal arm with metal fingers, he rolls out a small drawer which is full of bottles, grasps the correct bottle, and lifts it from the drawer. He uncaps the bottle by remote control, transfers some into a smaller bottle by a remote-control syringe, and caps both bottles. Clanging bells which are set off when Geiger counters register radiation from open drawers continue until the operation is completed.

Your bottle is safely tucked into a lead box through which the deadly rays cannot travel. It will be shipped to your hospital by airplane, train, or truck.

Although the average weight of a shipment of radioisotopes may be light as a feather, the total “package” may weigh 150 pounds. Containers for extremely “hot” orders weigh several tons.

These tiny amounts of radioisotopes are considered by many doctors as one of the most exciting developments in medical history. By tagging atoms with radioactivity, man can trace them on their journey through life processes and learn more about the events which occur inside living cells. Tagged atoms are somewhat like belled sheep. A shepherd can spot his flock when he hears the bell tied to one of them. A scientist can find a batch of atoms when a Geiger counter clicks near a radioactive one.

Any chemical which is part of a living cell can be made radioactive and used as a tracer. For example, at the Institute for Cancer Research in Philadelphia, Pennsylvania, radioactive carbon is ordered from an atomic drugstore of the Atomic Energy Commission. The carbon is used in living tissue. Tracing the path of ordinary carbon atoms in a life process is difficult because one carbon atom is just like another. Carbon 14, which is radioactive, is carbon with a tag or label. When the carbon in sugar is made radioactive, the sugar is labelled, but your body cannot tell the difference. The sugar containing radioactive carbon looks and tastes just like any other kind of sugar. You could use it on your cereal and never know the difference. But a Geiger counter could be used to follow its path, for millions of atoms in even a fraction of an ounce of such sugar are breaking apart every second. A Geiger counter can track down as few as four atomic explosions per second, so the path of radioactive sugar is easy to follow.

A mouse which has been fed radioactive sugar might be used in such an experiment. If a chemist finds a labelled carbon atom in fat from the mouse's body, he will know that the sugar has been converted into fat. He can study the rate at which this has taken place and learn more about the chemicals which have been formed along the way.

The radioactive carbon atoms which were swallowed by the mouse will continue to give off radiation for thousands of years. Since carbon 14 has a half life of 5,700 years, only one-half of the atoms will have broken apart in that period of time. As long as they are present in the mouse's body, a chemist can locate them with a Geiger counter. The mouse in this case is somewhat like the crocodile in Peter Pan, who swallowed the clock and gave himself away by the ticking noise. Tagged atoms will always give themselves away by the clicks which they make on a Geiger counter.

Day after day, experiments with tagged atoms from nuclear reactors are being made at research laboratories and hospitals all over the world.

One of these interesting studies shows that you won't be the same batch of atoms a year from now. About 98 per cent of the atoms in your body will be replaced by other atoms which you take in by breathing, eating, and drinking. This idea of atomic change in living things may help doctors to learn more about cancer and other diseases. The use of atoms as tracers is considered by many doctors to be as important to medicine as the discovery of germs and the invention of the microscope. This new tool may reveal secrets which might never have been learned by other methods.

Here is another example of tagged atoms at work in medicine. A doctor is searching for a tumor in the brain of a man on the operating table. X rays have not revealed a tumor, but the patient's symptoms make the doctor believe that there is one to be found. Labeled atoms of phosphorus have been injected into the patient on the preceding day. A brain tumor picks up phosphorus in greater quantity than does the surrounding tissue, and it cannot tell radioactive phosphorus from the ordinary kind. If a tumor is present, more exploding atoms of phosphorus will be present in the tumor than in other areas. Now the surgeon is searching for the tumor with a needle-like Geiger counter. Lights on the counting machine to which the needle is attached blink on and off at a fairly slow and even rate. The surgeon moves gently and slowly through the grayish brain tissue. Suddenly the light flashes in rapid succession, counting more than a thousand atomic explosions in a second. Here is the tumor, buried deep and hard to recognize. Now the surgeon removes it, using the needle-like Geiger counter to guide his scalpel.

In another hospital, a girl waits on the operating table after an accident which has crushed her arm. Will the surgeon have to amputate the arm? This depends on whether or not enough blood circulates through it. To determine this, doctors use radioactive sodium, in the form of radioactive table salt which has been added to ordinary table salt. As with the radioactive sugar, no one can see or taste the difference. But this tagged salt, when injected into a blood vessel, can be tracked with a Geiger counter because some of its atoms are breaking apart at all times. By showing adequate circulation through the arm, this radioisotope tells the doctor in a few seconds that amputation is not necessary.

These are just a few of the cases in which radioisotopes are playing "detective" in the field of medicine. In addition, radiations from atoms are being used against certain diseases in an effort to destroy them, to make patients more comfortable and to lengthen life.

For instance, at a number of hospitals radioactive phosphorus is used routinely to treat a blood disease known as Polycythemia vera. In this disease, red blood cells multiply much too rapidly. Formerly X-ray treatment of the whole body was used, but today a patient receives injections of radioactive phosphorus. By checking levels before and after an injection, effects can be easily observed. This new method of treatment is much more convenient for both patient and hospital staff.

A small number of other radioisotopes have been used to relieve certain disease symptoms. Radioactive iodine has been able to help patients suffering from Angina pectoris, a painful heart condition, and to treat some types of thyroid cancer. Radioactive gold helps in certain cancer cases to fight tumors and to relieve patients suffering from excess fluids in the body cavities. Radioactive strontium has been used successfully in treating noncancerous tumors and some cancers of the eye.

Pets and other animals benefit from radioisotope treatments, too. For example veterinarians use radioactive strontium to treat tumors in horse's eyes.

At Harvard Medical School and Massachusettes General Hospital a "positron scanner" is being used to spot tumors in the brain without opening the skull. A small amount of radioactive arsenic is injected into a patient's vein. Several hours later the tagged arsenic makes its presence known to scintillating counters, and a map of the brain is made to show where the arsenic has become most concentrated. Since a cancerous tumor absorbs more of the radioactive arsenic than normal tissue, its size and location can be successfully determined in many cases.

Cancerous breast tumors have been diagnosed by the use of radioactive potassium, which usually concentrates in cancerous tumors to a much higher degree than in those which are not.

Some of the radioisotopes from the atomic drugstore find use in cancer research at the Oak Ridge Hospital under the direction of Dr. Marshal Brucer, medical chairman of the Oak Ridge Institute of Nuclear Studies. The cancer-research wing is one of the world's first atomic hospitals.

Another atomic hospital is an eight-story building on the campus of the University of Chicago. The Argonne Cancer Research Hospital opened on March 14, 1953, under the direction of Dr. Leon O. Jacobson. The $ 4,200,000 used to build the hospital and the money necessary for its operation are provided by the atomic Energy Commission under the direction of the University of Chicago.

Doctors and nurses who come in contact with radiations day after day wear a badge which contains a film that can be developed to tell the amount of daily exposure. A record is kept of these amounts to make certain that they do not accumulate beyond safe limits. These badges are similar to those worn by workers in many atomic projects.

The sub-basement is 19 feet below the street. Here, in addition to the equipment which heats the building, provides hot water, compressed air, and other needs, there are special glass-lined tanks into which radioactive wastes are drained. Some “hot” materials lose their radioactivity after a short period of time and can be emptied into regular sewers.

In the sub-basement, too, rooms can be kept “hot” with constant radiation so that man can learn the effects on animals which have been placed there for study.

Here, also, are the high-voltage machines which “shoot” their rays at cancers.

Cancer is a lawless, uncontrolled disorderly growth of cells, which can be destroyed by radiation. Since cancer cells are rapidly growing and dividing, they are even more susceptible to radiation than most normal living cells in the human body. For this reason, X rays and rays from atomic explosions of radium have been widely used to treat cancers. By aiming at the center of the tumor and adjusting the amount of radiation, rays can be made to pass through healthy tissues without doing serious injury and still reach a deep-seated cancer.

New methods attempt to shoot stronger death-dealing blows at the target tumor with less damage to other tissues. Some units rotate the patient, other units move around him, so that the tumor receives a far more damaging amount of radiation than do other parts of the body. One of these machines sends electron bullets of 50 million volts of energy against cancer. Another, a rotating cobalt therapy unit, sends out rays similar to those which would come from millions of dollars worth of radium. Since cobalt 60 (radioactive cobalt) can be produced in a nuclear reactor, it is far cheaper than rare radium, which must be mined and processed.

You might see a patient being treated by a cobalt-60 rotational therapy unit, but you will not watch it in the same room. The patient is lying in a doughnutlike opening in the machine on a stretcher. With the operator of the machine, you can look through a special window which is 1 ½ feet thick and filled with a chemical (zinc bromide). Here you will be protected by a window which does not block the view but does block the rays. A doctor or technician who stayed in the room with the patient would be exposed to a dangerous amount of radiation. .

A bucket-sized container of uranium, weighing 850 pounds, shields the cobalt as it revolves around the track twice in one minute. The uranium will do the work of 3,300 pounds of lead, the material used in other therapy units to stop the powerful rays which come from the cobalt. The invisible beam will strike the healthy tissues of the patient over rather a large area, while it remains pinpointed on the tumor which forms the centre of the radiation circle. In this way, tumor cells will receive much greater doses of damaging rays than will the surrounding healthy tissues. This machine was first used in the spring of 1954. Early results were even better than doctors hoped they might be.

In the cobalt therapy room and in other rooms of the sub-basements, doctors use newly designed machines on cancers to learn more about the disease they are treating.

One floor above, in the basement, there is space for a cave in which “hot” isotopes can be handled by remote control. Next to this, there is a “hot” atom bank where radioisotopes in lead containers are placed in steel tubes set in 8 inches of solid concrete.

On the first floor of the Argonne Cancer Research Hospital are administrative offices and shops in which new types of equipment are made. Laboratories and offices fill the floor above. In these laboratories, doctors are making special studies on problems relating to cancer and radiation injury.

If you are visiting a patient, you will find him on the third or fourth floor of the hospital. Since there is a total of only fifty-six beds on the two floors, cases which are specially selected by the medical staff according to the needs of the patient and adaptability of his case to the research program.

As you walk down the hall, you will see signs on the doors of rooms telling the kind of radioactive material which has been used in the room, when it was used, and how intense the radiations are. The radioactive tag on one door shows that radioactive gold has been administered, another tag indicates radioactive phosphorus, another radioactive iodine, and still another radioactive chromium.

You are permitted to visit a patient who will soon be discharged, since his room is no longer “hot”. You find him resting in pleasant surroundings in a room whose walls are decorated in two shades of pastel green.

He is eager to tell you about his “atomic cocktail,” which contained radioactive iodine. His thyroid, a gland at the base of the neck, was not functioning properly. A healthy thyroid gland picks up about eight hundred times as much iodine as other parts of the body. A diseased thyroid picks up iodine at a faster or slower rate. To determine this rate, about 1/100,000,000 of an atom of radioactive iodine was fed to the patient in a drink which tasted like water. The doctor used metal tongs when handing the “atomic beverage” to the patient, since the doctor is exposed time and time again to the deadly rays and they build up in his body. The patient is exposed for only a short period. He can safely drink the radioactive iodine which has been carefully added to his glass of water.

The thyroid gland, healthy or diseased, absorbs radioactive iodine at the same rate as it absorbs ordinary iodine. A few hours after the patient drank his atoms, much of the radioactivity was picked up by his gland. From time to time, the amount was checked by placing a Geiger counter directly over his neck at the region of the gland. From the clicking of the counter, doctors learned whether or not his thyroid gland was absorbing too much or too little iodine.

The sixth floor houses the "animal farm". Here mice, rabbits, guinea pigs, and rats live in air-conditioned comfort so that they are available when research workers need them. About a thousand mice of a special strain are born each week. Many will be used in special radiation experiments in which they will receive X rays from two 250,000 – volt machines and radioactive chemicals, and perhaps have operations in the special animal operating room.

At one time the Argonne Cancer Research Hospital was considered unique in its use of atomic energy, but today radioactive materials are used routinely in hospitals throughout the United States. Precautions need not be taken much beyond those used in X-ray departments except in cases of spills. This is a rare circumstance, and routine tracking of any radioactive material makes the hospital safe at all times for patients, workers and visitors.

One outstanding medical center for probing horizons in the field of atomic energy is the one at Brookhaven National Laboratory. Here the great cosmotron and other atom smashers are used to learn more about cancer. In one type of treatment, billions of non-radioactive atoms of the chemical Boron are injected into the blood of patients who have brain tumors. This chemical gathers in a tumor, seeming to prefer it to other healthy tissues. Then the patient is exposed to neutrons from the nuclear reactor. Neutrons split the boron atoms, forming smaller atoms which are radioactive. Energy released in the process attacks the tumor cells, destroying diseased tissue. Most of the patients who are treated this way show definite improvement, although the work is purely experimental at the current stage.

More than 2,000 hospitals and medical groups in the United States use more than thirty different radioactive substances for diagnosing diseases. About six kinds are used in treating diseases. More and more studies are being made by doctors using radioactive substances to learn about how the body works. For instance, they are probing with atomic energy to gain precise knowledge of disturbances in the body's use of fats, sugars and proteins. This may lead to better ways of treating hardening of the arteries and other disorders.

Whole-body counters are being used in studies of physiology in both human beings and other forms of animal life. In one of these, the patient may walk into the counter, which looks somewhat like a large lead cylinder. Lead-glass windows enable doctors to watch the patients after they climb the stairs which lead into a 10-ton walled chamber. Here radioactive atoms in a person's body can be counted in 40 seconds. The shielding keeps out natural radiation that is always around everyone, so that the count will only be of the tracer which the doctors have placed in the patient's body – or the natural radiation already contained in the patient's body, if that is what is being measured.

The Atomic Energy Commission maintains a number of hospitals for medical research and treatment. In these and in other research institutes and hospitals, men are waging war against disease. Here are a few more examples of ways in which radioisotopes from nuclear furnaces are helping. At the University of California in Berkeley, a "gamma-ray scanner" searches a patient's body for cancerous thyroid growths that have spread from a diseased thyroid gland.

In a small number of hospitals here and there in the United States and Canada, cobalt therapy units called theratrons send their deadly rays against cancer. These were developed through the work of physicists of the Francis Delafield Hospital in New York and Atomic Energy of Canada, Ltd. Using cobalt from the Chalk River reactor in Ontario, Canada, a cobalt rotational therapy unit in the Lankenau Hospital in Philadelphia, Pennsylvania, sends radiations against tumors and cancers of many types. The radiations are the equivalent of those from 50 million dollars worth of radium. This is more than has ever been isolated for medical purposes. But the cost for the entire unit, cobalt included, was about $75,000. Man's new knowledge of how to split atoms has made this possible.

In some respects, cobalt 60 is superior to radium, but it does not last as long. No matter how many or how few patients are treated by a cobalt bomb, one-half of the cobalt atoms will have changed to stable nickel atoms after a period of five years, three months, and eighteen days. In the case of radium, half the atoms of any amount will only break apart in a period of 1,600 years. But the cobalt can be replaced with some that is fresh form a nuclear oven.

At the pile, more cobalt 59 is "cooking" in an atomic furnace. When it is ready, when enough cobalt 56 has turned into cobalt 60 - it will be placed under 10 feet of water. Here, it will be put into a container by remote control. From this time until it loses its radioactivity, a lead or uranium shield will protect workers from its rays. Its beams will be allowed to escape only when they are aimed at diseased cells.

Although results from the use of radioisotopes have not been as dramatic as some hoped they would be, their radiations open new avenues towards successful treatment. The powerful sources of radiation from nuclear furnaces and the tagged atoms join in the struggle of man against disease.

Just a few examples of the atomic energy to medicine have been cited in this chapter. Hundreds of advances have been made possible by radioisotopes, including new ideas about cerebral palsy, epilepsy, endocrine gland disorders, and many other diseases.

The understanding of various forms of anaemia has been increased by tagged atoms in red blood cells which help doctors to study their formation, survival, and destruction in the body. Blood substitutes and safer handling of blood for transfusion have been made possible by radioisotopes. Here alone the savings have been estimated at thousands of lives and millions of dollars.

The total contribution of radioisotopes and radiation sources made possible by the atomic energy program may become one of the most significant developments in the progress of medicine.

10. ATOMS FOR PRODUCING FOOD

“Atomic farms” are scattered through out the world. On many of them scientists are working to produce better strains of plants, discover better methods of using fertilizers, rid crops of insect pests, and learn more about the ways plants make food. Many are using atomic energy to learn more about farm animals so that they can be of more value to farmers.

You are not in danger of driving past a radioactive cornfield or of having a bottle of radioactive milk delivered at your door. Chickens from atomic farms will not lay eggs for your local store. Today all the work in atomic farming is being done by large research organizations. The government, at national laboratories such as Brookhaven, Argonne, and Oak Ridge, is playing a major part in this program. Many large colleges, universities, and agricultural research centers have put radioisotopes to work as tagged atoms on their experimental farms. Individual farmers will probably not use atoms themselves, but they will gain much from the use which is made of these new tools by investigators.

Government- directed fertilizer experiments with tagged atoms save huge amounts of money for farmers each year and bring better farm products to you. One research project conducted at North Carolina State College showed that the superphosphate in fertilizer which was being thrown on the ground was of little value to the growth of tobacco plants. About 4,000 tons of phosphate fertilizers are now being saved each year.

Farmers throughout the United States spend over a billion dollars a year for fertilizers. Radioisotopes are showing them how to get greater returns from their money. Tagged atoms are showing the amount and the kind of fertilizer best for each crop. The best time and the best method of applying the fertilizer can be determined. Before radioactive atoms were used in testing, man believed that plants drew all their food from their roots. Tracers showed that this is not the case. Fertilizer can be absorbed rapidly and efficiently from the leaves of fruit trees, tomato, potato, and other plants. With this knowledge, farmers can increase the absorption of fertilizers as much as tenfold by spraying the leaves with fertilizer rather then just applying it to the ground.

Some exciting work has been done with radioactivity in the fields for producing better strains of plants. Scientists have long known that exposure to certain radiations produces changes that are inherited from one generation to the next. These changes are called mutations.

Radiation is being used to produce mutations in apples, peaches, blueberries, and carnations. Out of these experiments may come made-to-order fruits and vegetables of beautiful colors and outstanding flavour. Further experiments may show scientists how to produce seeds that will grow in especially dry regions and others that thrive in rain-soaked areas. There may be crops that can grow in poor soil and some that can survive early frosts.

Atomic scientists who work with plants have succeeded in producing a variety of barley that gives a higher yield of both grain and straw. Atomic energy is just beginning to improve plants. Most of the contributions to agriculture will be made tomorrow by the young people of today. But some progress has already been made.

For instance, by shooting neutrons at oats, Dr Calvin Konzak of the Brookhaven National Laboratory has succeeded in creating a variety of oats that was resistant to a disease known as rust. In one and a half years he was able to develop a seed tailored to meet certain needs. With old methods of plant breeding, this would have taken at least ten years and cost a great deal of money.

Suppose you are trying to produce a strain of corn resistant to a disease such as leaf blight. This disease is so severe in Florida in the wintertime that about 25,000 acres of corn must be sprayed each year. A strain resistant to leaf blight would eliminate this spraying.

By radiating corn seeds at Brookhaven in the summer and growing the crop in Florida the following winter, tests can be made in less than a year to see whether or not resistance has been developed. Mutations occur very slowly in nature, but radiations can bring them about at a rapid rate.

Disease resistance is not the only aim of mutations by radiation. A variety of peanuts has been produced which yields about 30 per cent more crop per acre. Another one has been developed which has a size and shape better fitted to harvesting machines. These are few of the results of mutations brought about by radioactive atoms.

Not all mutations are good ones. When a crop is grown in a field that is exposed to radiation, the plants with desirable mutations are selected. A thousand may be thrown away for each one that may be an improved variety.

One way of exposing plants to radiations is through the use of a gamma field. You might see an acre field of corn which looks perfectly harmless, but the invisible rays which are bombarding the corn would harm you if you enter it. In the center of such a field, a small amount of cobalt 60 is enclosed in a stainless-steel pipe. This is the same cobalt-60 radioisotope which is being used widely in industry as a substitute for radium in x-rays, and which sends its rays against cancer. In the cornfield, the cobalt 60 is connected by cables to the control house in one corner of the field. No one enters the area until the cobalt 60 is wound down into a lead shield in the ground. Radiations that produce mutations in plants could injure a man.

In a 10-acre field, many different kinds of trees, shrubs, and vines are growing around a centrally located source of radiation. Branches which bear strange fruit are cut off and grafted to normal trees.

Mutations in tiny plants such as moulds can help man, too. Much of the drug penicillin is being produced today from a strain of the mould developed by mutations caused by radiation.

This artificial speeding up of mutations is the beginning of a new era in farming. There are hopes for the development of many new and better kinds of plants.

Plant diseases are being attacked in still another way. While man is trying to produce disease-resistant plants, nature is producing new strains of living things which cause disease. To help combat these, man is developing new chemicals and fungicides. They are also conducting studies on insects which attack plants.

“Hot” atoms are helping to provide information about some of the life habits of insects which have always puzzled scientists and farmers. For instance, 15,000 thirsty blowflies were provided with a drink containing radioactive phosphorus. This tagged the blowflies so that they could be identified again by radiations from the splitting atoms in their bodies. Baited flytraps were placed at various distances from the spot where the blowflies were released. From the examination of trapped flies, it was possible to show that blowflies can travel as much as 4 miles in the first day. Some were found to have travelled a total of 28 miles from the farm from which they were released. By learning more about the life habits of insects, scientists can find better ways of controlling them.

Female screw-worm flies lay eggs in cuts and scratches in cattle and other animals. When the eggs hatch, the worm-like insect feeds on the flesh of the animals, causing sores and sometimes even death. Millions of dollars worth of damage are caused by these flies each year.

Radiation has been a weapon against these insect pests. Large numbers of male screw-worm flies were made sterile by being exposed to cobalt. Since female screw-worm flies mate just once, those mating with sterile males have helped to reduce the number of these insect pests greatly.

Campaigns to eradicate the screw-worm in the southern United States have been so successful that other insects are being sterilized by radiation as a biological control weapon. The omnivorous leaf roller and the coddling moth attack many kinds of food plants, the former by drawing clusters of small leaves into rolls within which the larvae live and feed. Thus, these insects are shielded from insecticides, but radiation may prove a more powerful tool. Another target for irradiation control is the corn borer, an insect which causes as much as 94 million dollars worth of damage in a single year.

All these efforts are directed towards a better food supply from growing plants. Many scientists dream of making food directly from carbon dioxide, water, and energy, as plants do. This process of food making by plants, known as photosynthesis, is an extremely mysterious and complicated one. By using radioactive carbon, scientists have shown that two or three new chemicals are formed in the first two seconds after the carbon dioxide enters the plant. In one minute at least fifty different chemicals are made. If all the secrets of photosynthesis could be learned so that man could make food directly without depending on crops and soils, millions of underfed people in the world could benefit. Such an accomplishment might improve the standard of living more than any other that may result from the use of atomic energy.

In addition to trying to copy the food-making ability of plants, scientists are studying photosynthesis, hoping that they could help plants to produce more food. Plants go to sleep in the middle of the night. If they could be made to manufacture food at this time instead of napping, our food supply would be increased. Radioisotopes may help us learn how to do this.

Radioisotopes are helping to increase today's food supply also because of experiments with animals. At Oak Ridge, for example, a scientist used radioisotopes to study how hens make eggs. He found that some of the radioactive food fed to hens appeared in eggs laid as many as forty days later. An egg forms inside a chicken in about eight days, but from this experiment it is known that it may contain some of the food which the chicken had more than a month before. By learning more about how eggs are made, scientists hope to help farmers increase egg production.

A new pig and chicken fattener has been tested by radioactivity. This drug was fed to pigs to slow down their thyroid glands and make them grow faster and fatter with the same amount of food. Would the drug be present in the pork chops, where it might affect the health of those who ate them? Would roast chicken and scrambled eggs contain it? Tagged atoms showed that the answer was no, so farmers can safely use this drug to improve the size of their pigs and chickens.

A drug is sometimes used to slow the thyroid glands of cows. This makes them placid, with the result that energy which might be used in other ways is used in making more milk. Radioactive iodine is used in tests to check the effects of this drug on cows. A Geiger counter can be held over a cow's gland just as over a person's so that its clicks will tell what is happening inside.

How cows use food elements in producing milk is of major importance to farmers. Complicated processes can be followed in a cow's body because tagged atoms act somewhat like a motion-picture camera in tracing the paths of certain food materials. Radioactive substances in artificial feeds are being used to help complete the picture.

Radioactive sulphur is used in studies of feather formation in chickens and wool formation in sheep.

These are only a few examples of ways in which atomic energy is helping to increase knowledge that is of tremendous value to farmers.

What benefits the farmer, benefits the world. Problems that might have taken years to solve are being solved within a few months or even weeks. Some of them might otherwise have never been solved at all.

Scientists have hoped that food could be safely preserved by irradiation since the early days of atomic energy for peace. They have worked toward this end, experimented with pork and beans, with lobster and strawberries, and a long, long list of foods. Today some of their dreams have come true, for one can store many irradiated foods without the use of refrigeration, and enjoy their flavor and texture even though it may not be exactly the same as that of fresh foods.

The Quartermaster Corps of the United States Army conducted a major study in which foods were sterilized by radiation and fed to men and women in the Armed Forces. Careful studies made over a period of fifteen years by various groups have failed to show any danger from eating irradiated food. Bacteria which cause spoilage are destroyed, but the food itself does not become radioactive.

Imagine keeping uncanned bacon or chicken in your kitchen cabinet for two and a half years. When costs come down, you may find irradiated food in your supermarket. In addition to the advantage of easier storage, broad-scale food irradiation may bring you other benefits. Experiments with mangoes and papayas and other exotic foods are promising. Wine may be artificially aged and oranges may be more easily peeled and segmented.

There is hope that drugs may be sterilized by radiation. Atomic energy is playing a part in the world of drugs in another way, too. By growing certain drug-producing plants in an atomic greenhouse, radioactive forms of the drugs are developed. For instance, digitoxin, an important heart drug, is made from leaves of a purple fox-glove plant. Plants are grown in a tightly sealed, air-conditioned greenhouse containing carbon dioxide tagged with radioactive carbon. The plants use this radioactive carbon dioxide just as they would use the ordinary gas found in the air.

The tagged atoms enter various parts of the plant and are found in the purified digitoxin which is obtained from them.

Tagged digitoxin can be traced in the human body to learn how long it is retained. Experiments under the direction of Dr. E.M. Geiling at the University of Chicago have shown that the drug is retained in the body for a period of from forty to seventy days. This is far longer than doctors had thought. Such information enables doctors to provide more accurate doses for individual heart patients.

Other drug plants such as those that produce opium, belladonna, nicotine, and marijuana are being grown in atomic greenhouses so that more may be learned about the medicines made from these plants.

The weather inside atomic greenhouses is carefully controlled. Some people dream of a day when atomic energy might be used to control the weather of the world. They hope for cheap atomic power which might be used to produce rain when and where it is needed. They talk of heating ocean currents that flow near land to affect the climate of large areas. Certainly such weather control cannot be expected in the near future. Perhaps it will always be a dream.

Fallout has been used to trace the world's weather, for it marks air masses. In some cases, special radioisotopes have been added to high atmosphere explosions to tag air movements. Recently, an unplanned tag was added to the atmosphere when a nuclear device that was orbiting the earth in a satellite accidentally dumped its plutonium 238 as it burned up. This helped weathermen to determine that it takes about two years for such material to become evenly distributed over the surface of the earth.

Certainly, atomic energy is helping weathermen to learn more about the movement of air masses and the exchange of air between the northern and southern hemispheres; a better weatherman helps to make a better farmer and in turn more food for a hungry world.

11. RADIOISOTOPES

If you are trying to find a needle in a haystack, a Geiger counter will lead you to it if the needle is tagged with radioactive iron.

Tagged atoms, the radioisotopes which can perform man amazing tasks, are moving slowly into the production lines of numerous industries. This is a field in which the surface has only just been scratched.

More industries are buying atomic "trash" each year as many new uses are found for radioisotopes that are produced by nuclear reactors. In addition to making waste products available and preparing radioisotopes by "cooking" elements in atomic furnaces, the Atomic Energy Commission is cooperating by producing special materials which users need. For instance, piston rings can be sent to a reactor for exposure to neutrons. Then they can be put into an experimental engine to test engine wear.

The old method for testing engine wear with a certain oil was to weigh all parts of a cold engine, run the engine for several hours, then weigh all the parts again. The difference in weight showed the amount of engine wear when that oil was used.

The new method of testing engine wear with radioactive piston rings is much simpler and takes less time. After running the engine, the oil is drained off. The tiny specks of metal which were worn from the rings are now in the oil. Since they are radioactive, the amount can easily be measured.

One of the most exciting uses of atomic energy in the world of industry is activation analysis. When material is irradiated, each of its elements becomes an isotope and each isotope has a unique pattern of radiation. Scientists can identify the kind of materials in a substance by this method, and can also tell the exact amount of each component present. Using new analyzers and data-processing equipment, they can "fingerprint" a substance in minutes. Older methods took days or even weeks.

Suppose you are a geologist who needs to know what is beneath a certain area of land. You may be able to determine this by activation analysis of surface outcroppings rather than costly probing deep inside.

In chemical industries, oil refineries, steel plants, and many other areas, activation analysis is being used to precisely identify materials without destroying them. This method of using atomic energy has been called the "atomic age Sherlock Holmes," for it is helping to solve crimes. Picture a thief rushing away from the scene of the crime. He brushes against a doorway and an imperceptible amount of paint sticks to his clothing. Or perhaps a smudge of grease clings to him from a stolen automobile. Or a strand of human hair may be brought away from the scene of the crime. Activation analysis can identify such tiny particles and match them to help convict the criminal. Even though human hair from various heads contains traces of the same elements, the amounts of these present vary from person to person.

Farm products can be checked for traces of pesticides with this new tool, in which a sample of material is irradiated with nuclear particles. When some of the atoms of the pesticide are made radioactive, they reveal their identity even though they are present in amounts too small to be detected by other means.

Thickness of materials such as rubber, paper, plastics, thin metal, foils, and textiles is being measured by radioisotopes. Imagine a sheet of material such as Pliofilm speeding between rollers which control its thickness. A mechanical detective is mounted in such a way that the radioisotope is on one side of the material and the instrument which detects and measures its radioactivity is on the other. Neither of these touches the Pliofilm, but when it is just the slightest bit thicker, less radioactivity passes through to register on the instrument. When this happens, rollers are automatically adjusted, and the Pliofilm moves along with very slight variation in thickness.

Radioisotopes play watchdog in still other ways. Flaws in metal machine parts are readily found by certain radioisotopes. For a long time X rays and radium have been used to look through the perfect material. They reveal flaws somewhat the way X rays reveal flaws in teeth. Certain radioisotopes are being used in place of radium and X rays formerly used for this work, because they cost far less and are more convenient to use. Radioisotopes are used as an inspection tool for locating damaged parts and poor electrical connections in air frames of many aircrafts. Some of the places in the frame of such a plane are difficult to reach, but radioisotopes, such as cesium 137, can inspect parts with ease. Cesium 137 is one of the waste products of nuclear reactors. It is atomic trash which is being put to work.

Radioactive detectives can protect the machine operator, too. For example, the hands of a punch-press operator can be protected with a radioactive wristband. If he should fail to pull his hand away in time, the machinery could be stopped automatically by the radiation.

Some packages are inspected by radioisotopes as they pass down the production line. If a package is not properly filled, more rays pass between the isotope and the counter on the opposite side of the package. A warning light may glow, or a machine may be adjusted to knock out a faulty package.

Radioactive atoms can measure the height of molten metal in a foundry furnace, or measure the amount of water packed as snow on mountain peaks. No matter how hot or how cold, unstable atoms continue to break apart.

Suppose there is a water leak in an underground pipe near your house. If you had the job of finding it, you might have to dig up several lengths of pipe before you found the leak. A new and better way is to put atoms to work tracing the leak. Tagged atoms added to the water which goes into the pipe will leak out along with the ordinary water. Now you can follow the course of the pipe with an instrument that detects radioactivity. Where the clicks are more frequent, you can dig a hole straight down to the leak.

In some pipelines a variety of materials such as diesel oil, gasoline, and bunker oil flow along. Tagged atoms can act as markers to show where a batch of new material begins. Suppose gasoline is flowing through a pipeline. It is being followed by kerosene and then by diesel oil. At the end of the line, radioactive atoms announce the beginning of the kerosene and the beginning of the diesel oil. Without them, many barrels of material would be drained off and wasted in trying to find a place where a new batch started.

The petroleum industry uses radioisotopes in other ways, too. For instance, they can be used to turn on extra pumps to boost the flow when demand is heavy, and to turn them off when they are no longer needed. Radioisotopes measure the rate of flow and levels of liquids, find tools such as scrapers which are stuck in pipes, and do many other jobs, in which they act somewhat like a magic eye.

They act like a magic eye in soap tests, too, in which bacteria are made radioactive. You cannot see bacteria, for they are tiny, organisms much too small to be seen without the help of a microscope. But if bacteria are fed radioisotopes, they become radioactive and can easily be measured with a Geiger counter. To check the ability of various soaps and detergents to wash clothes, radioactive bacteria are placed on cloths, and each cloth is washed with a different soap. The bacteria remaining on each one are measured to learn how well each soap cleans.

When a bit of radioactive cobalt is fastened to mail carriers which travel through tubes, a Geiger counter can track one down if it becomes stuck in the tube. Radioisotopes enable scientists to examine water under the soil, to determine its age and the amount which comes from rainfall. Samples of soil can also be studied by using cobalt 60 at the location where engineering work is being done. With this new method, samples do not have to be taken away to a laboratory as they were in the past.

The bureau of Reclamation of the United States has used radioisotopes to study the effect of a weed killer on waterweeds, that grow in irrigation ditches and interfere with the flow of water. By applying weed killer tagged with radioactive carbon, scientists were able to trace its path in the plants. The information they gained was then used to provide better methods of applying the weed killer to control troublesome weeds in irrigation ditches.

Other experiments with radioisotopes test the wearing qualities of paint and floor wax, sterilize blood plasma, test the absorbing qualities of cold creams, and investigate hundreds of potential uses.

Fishermen who gather oysters from a river bed cannot see chemicals in the river which might pollute the oysters. Tagged atoms can trace the chemicals from a nearby plant even if they are added in tiny amounts to the chemical wastes dumped into the river. By testing water in the oyster beds for radioactivity, scientists can detect even a few parts of chemical waste per billion parts of water.

Around the world, tagged atoms work for man. They check the flow of underground streams through the Alps. In France, they check the air-tightness of underground Telephone cables, and help in work on under-sea cables between France and North Africa. These are just samples of peacetime atoms at work.

Atomic energy is just beginning to work for industry. Someday, all tires may be vulcanized by atomic radiations in two seconds instead of the usual two hours. The new method may produce tires that wear longer, too.

Irradiated plastic pipes may replace the metal ones that carry water to your home. At one time such pipes could be used only for cold water, for they became soft when hot water heated the plastic. Atomic irradiation changes the quality of the plastic so that it may be used even to hold boiling water or made into plastic bottles containing medicines, that must be heat sterilized.

Perhaps your house will be heated by atomic energy. a nuclear reactor for this purpose may be used to heat a group of buildings or to provide heat for industries which need high temperatures.

Atomic energy may bring tremendous changes in industry in the next ten or twenty years. It has just begun to work as a servant of industry.

12. ELECTRICITY FROM ATOMS

Someday you may work in an atomic power plant which supplies the electricity for an entire city. In power plants where energy comes from coal or falling water, workers are protected from danger in many ways. In an atomic power plant, special safety precautions must be taken. Film badges, protective clothing, mechanical hands to do jobs by remote control, detection instruments, and all the complications of the world of radioactivity will be present. If your work involves controlling the speed of the silent atomic furnace, you will sit behind a panel of instruments and lights much the same as those used at other reactors.

Many people who once feared living near atomic power plants have become convinced of their safety. One reactor that was designed to produce electricity in the state of California could withstand an earthquake as large as Alaska's 1694 upheaval. It could resist the fury of tidal waves as high as 50 feet-and no waves this high have ever been recorded in California.

In a nuclear power plant, automatic controls insert rods which shut down a reactor when monitoring instruments show that something has gone wrong. Both human and mechanical errors are anticipated, and safety devises are ready to protect people both inside and outside in case of emergency. Care taken to make nuclear power safe is just as great as that in other phases of the atomic energy industry.

For all commercial nuclear power plants, the method of producing electricity in an atomic power plant is much like that in others except for the reactor and the method of disposing of waste fumes. The fuel is used to produce heat. Heat is changed to steam. Steam under pressure will spin the blades of a steam turbine. The turbine turns a generator, which produces electricity that surges through wires to do many kinds of work. Steam is used in this way, just as it has been for hundreds of years.

Atomic power plants are slowly adding to the world's supply of electricity. The cost of electricity from atoms is falling in spite of problems caused by radioactivity. Reactors may cost many tens of million of dollars. Special materials of construction must be capable of standing terrific heat. Heat must be transferred from radioactive substances to those which are not.

Hundreds of reactor designs exist, but in all cases the reactors must be cooled to prevent extremely high temperatures at their cores. The material which cools the reactors, the coolant, serves another purpose. It also carries the heat to the heat exchanger, where it gives up some of it to water or another material. Now the hot material is not radioactive. The coolant may be heavy water, some type of gas, liquid metal, ordinary water, or other material.

One method of removing heat from the core of a reactor uses sodium, a silvery, dangerous metal. Handling liquid sodium is not an easy task. When it comes in contact with the air, liquid sodium bursts into flame. When it comes in contact with water, liquid sodium explodes violently. When it comes from the reactor, liquid sodium is radioactive. These are just a few of the problems which confront atomic power engineers.

In the United States, where energy requirements double about every ten years, it is no wonder that man look to splitting atoms as a supplement to the reserves of fossil fuels. As long ago as 1956, Queen Elizabeth II threw a switch at Calder Hall in England which sent electricity flowing into power lines from the world's first large nuclear power station. By 1965, there were nineteen nuclear power plants in Great Britain with many more in the planning stages.

The known reserves of fossil fuels in most of the developing countries are so small compared with needs, that full industrialization will have to depend on atomic energy. Cost and lack of technically trained people present great problems in such regions, but in spite of this India is basing plans for its future industrial development on the use of nuclear energy. In 1964, plans for two nuclear power stations were already underway there.

Will nations run out of nuclear fuels? In spite of the increasing number of nuclear reactors for the production of electricity, they supply only a very small percentage of the world's electric power. But as with coal and natural gas, supplies are not unlimited. At intervals of a year or more, a reactor is shut down and the spent fuel is replaced in its core. In the United States the used fuel is sent back to the Atomic Energy Commission, which removes the plutonium-a valuable by-product. Radioactive wastes are also removed and buried at sea or in isolated places. The remainder of the fuel element is reprocessed for further use in another or the same reactor at some future date.

One method of conserving fuel is the use of breeder reactors. Strange as it may seem, such a reactor produces more fuel than it consumes. The uranium 235 in the reactor is fissionable; the uranium 238 is not. Neutrons from the former, fire into the atoms of the latter, changing some of them into plutonium 239. These atoms are fissionable, so they can be split to produce more energy. Breeder reactors are still experimental, and it may be many years before commercial power plants will operate with them.

How wonderful it would be if all reactors could be made to operate on a basis of producing more fuel than they consume. Electricity to brighten the world and make work easier might be limitless in supply and even less expensive than it is today. Such a world is dreams away.

When scientists first talked of portable nuclear power plants, many people thought they were dreaming. Today, some mobile nuclear power plants can be trucked or flown to a site and started up in twelve hours. One pound of uranium is equal to 6,000 barrels of oil. For desolate reaches of the Arctic and Antarctic regions, power reactors in small packages seem to be a fine answer to the problem of supplying electricity and heat in the below-zero temperatures of polar nights.

One reactor had to be removed from the Greenland ice sheet after providing energy for Camp Century there for about three years. Heavy Arctic snows heaped upon it were shrinking the reactor tunnel. The reactor could have been overhauled, but it had largely served its purpose and the expense of repairs would have been great.

Although the heart of most small nuclear power plants is just a barrel-seized arrangement of uranium-filled tubes and rods, an entire station for the production of electricity for a polar base may occupy several buildings, each of which is as large as an ordinary house. Much as radios that were once bulky in heavy cabinets have been scaled down to pocket-size, so have nuclear power station parts been scaled down. Now they are produced so that they can be shipped in relatively small packages that can be squeezed onto cargo transport planes. Shipping nuclear power plants has been compared with transporting the sections of the immense Saturn rocket. For example, twenty-seven packages, each weighing about 30,000 pounds, were transported to a lonely Wyoming mountaintop where they were put together to make a medium sized plant for a radar station.

Packaging nuclear power plants is an exciting challenge which scientists have met well. Someday they may help to provide electrical power for developing countries where there are no good road, rail, or canal systems. They may be seeds of technology from which large industries can grow in desolate countries.

Electricity from splitting atoms comes through many different approaches. The power plants described in this chapter all produce relatively large amounts of electricity by converting atomic energy to heat which makes steam and which in turn is used to make electricity. Later you will read about other methods of producing electricity with atomic energy.

13. PRODUCTION OF LIMITLESS ENERGY

Man is trying to make miniature suns on earth. From them; they hope to provide limitless amounts of energy at a very little cost.

Countless numbers of hydrogen atoms change into helium atoms at all times in the sun. When this happens a small fraction of the mass of the hydrogen atoms changes into energy. This process goes on in the sun on a tremendous scale with several billion tons of hydrogen being converted into energy every second. This process is known as fusion.

Fusion, the combining of the cores of atoms, may seem to be a very simple process. But fusing atoms is a very difficult thing to do. The only practical way for pushing their cores together violently enough to overcome the electrical force which makes them repel each other is to set them in rapid motion. The way to set large numbers of atoms in rapid motion is to heat them. Reactions of this type are called thermonuclear, because they are caused by heat or thermal motions of the nuclei of atoms. From time to time, you may see a headline in your newspaper about breakthroughs in taming the hydrogen bomb or breakthroughs in thermonuclear reactions. Such progress in fusion is sometimes an increase in temperature, for almost unbelievable high temperatures are needed to produce energy or generate electricity on a practical scale. One instrument built for high temperatures is called a Perhapsatron because its builders thought perhaps it would work, perhaps not.

At tens of millions of degrees, atoms approach each other closely enough for their nuclei to fuse and the energy released by this fusion causes other atoms to be heated still more. This causes more fusion to take place. This is a type of chain reaction, and if the reaction proceeds far enough and quickly enough, there is an explosion. Such is the case when a hydrogen or thermonuclear bomb is ignited by the intense heat of a fission of an atomic bomb. Just as man learned to produce useful peacetime energy by controlling fission chain reactions, he is trying to make fusion chain reactions. Men are experimenting with controlled fusion of atoms in a number of interesting ways.

In laboratories all over the world, man has made use of electric currents flowing through gas instead of through wire to produce very high temperatures. The more electric current fed into the gas, the higher the temperature. Forms of hydrogen are used as the gas. One form is deuterium, double-weight hydrogen which is plentiful in the oceans of the world. Another form of hydrogen that is sometimes used with deuterium is tritium. This is triple-weight hydrogen which is man-made.

When heavy hydrogen is heated to extreme temperatures, its electrons are completely removed. The gas is broken up so that its negative electrons and positive cores are separated from each other and the gas is said to be ionized. It is called a plasma.

One great problem in producing sustained fusion is keeping the plasma hot. If deuterium nuclei touch the side of the container, the plasma is cooled to a point where fusion could not take place. To prevent this, scientists have developed a “magnetic bottle,” which can be thought of as an invisible bottle inside another bottle. This is possible because an electric current creates a magnetic force around itself. This force can be used to pinch a gas together, causing it to form a narrow column inside the tube. It is known as the “pinch effect.”

At the New York World’s Fair in 1964 and 1965, visitors witnessed a brilliant white flash and heard a loud clap of thunder when a giant pulse of electricity produced a brief controlled fusion of atoms. This action was repeated every six minutes, but it lasted just millionths of a second. To produce any useful electricity, fusion must be made to last at least a number of seconds, or perhaps minutes. Plasma in this experimental device was kept away from the quartz containers by a powerful magnetic field.

There are other promising approaches, too. One of several models of the stellerator, an experimental device at Princeton University in New Jersey, may achieve temperatures as high as 100 million degrees. When scientists can succeed in obtaining high enough temperatures for a long enough period of time, man can look for unlimited power from the hydrogen of the seas.

Unlike the power which comes from fission, the power from fusion is plentiful enough to last for a billion years or more. Another great advantage is the elimination of the disposal of huge quantities of radioactive waste.

The search for fusion power is one of the most difficult scientific tasks ever undertaken. At the same time, it is probably one of the most fascinating and one of the most important peacetime scientific projects.

Although the day of limitless power is coming closer, many scientists believe that it will be so far in the future that the power plants which produce electricity from the energy released by the splitting of atoms will see many more years of use. But this wonderful dream of man will come true because of the work of many brilliant scientists.

14. ATOMS AND SEA WATER

Scientists are dreaming of the day when atomic energy will provide limitless amounts of electricity from the “heavy water” of the sea. Through projects that are converting tremendous amounts of salt water to fresh water, scientists also hope to obtain electricity at the same time. Splitting atoms to desalt is much easier than fusing atoms in great enough quantity to provide usable energy. Someday, nuclear plants around the world may play a large part in helping to relieve the water shortage by converting salt water to fresh water.

Actually, there is exactly the same amount of water on the earth today as there was when the earth began, but other factors have changed. The population has expanded explosively, and industries draw increasing amounts of water from streams, rivers, and lakes. In the United States, about 350 billion gallons of water are used on a single day. This amount may rise to 1,000 billion gallons per day by the year 2020. Man looks to the sea for his water supply with greater urgency than ever before. And he looks to the atom to make this water usable.

Small amounts of water have been desalted in numerous places by numerous methods. You can desalt water in a tea kettle on your kitchen range. But providing fresh water from salt in large quantities, at costs that are not prohibitive, seems most likely to be accomplished by nuclear power plants. Millions of gallons are being desalted each day. Perhaps billions will gush daily into pipes leading from plants that make use of the peaceful atom.

Atomic desalination plants use uranium or thorium in reactors. Heat from the splitting of atoms changes enormous quantities of water into steam. Just as in a tea kettle, the pure water boils off. A residue of salt is left behind.

The brine and minerals which are left are unwanted, but there is a bonus that comes with atomic desalting. The reactors can also be used to produce electricity, as described in the last chapter.

Atomic energy may help man to explore the seas in new exciting ways. The first atomic submarines were built for defence, but today, plans are underway for a deep-diving research vessel that will be able to operate over an ocean floor several times the area of the United States. Present research crafts go up and down like elevators and have limited movements across the ocean floor. A nuclear powered submarine can search far and wide.

Building a submarine to be powered by atomic energy was a great step in putting atoms to work. In a snub-nosed, cigar-shaped submarine, the U.S.S. Nautilus, lies an atomic-powered engine which will long be famous for containing the first nuclear reactor to be used for transportation. On January 17,1955, atomic energy moved this submarine through the water. More U.S.Navy submarines, then a Russian icebreaker, followed. In 1959, a nuclear-powered guided – missile cruiser and the world's first nuclear-powered merchant ship, the N.S.Savannah, were launched in the United States.

The Nautilus completed 60,000 nautical miles without refueling on a charge of uranium about the size of a golf ball. This was the first atomic-powered fleet much as it shifted from sail to steam power about one hundred years ago. Someday, all of its missile-firing cruisers, aircraft carriers, and destroyers may use the energy that is locked in the cores of atoms. One by one, the Navy is laying the keels of atomic vessels.

The story of the men who worked almost ceaselessly to bring the first atomic submarine into being is one of brilliance and courage. Six years may seem a long time to those who have no idea of the problems involved, but it is really a very short one compared with the fifty years which some of the best scientists predicted that such a project would take.

Parts for an atomic submarine could not be ordered; they had to be designed. Nothing could be copied from another ship's engine, for this was the first of its kind. The first atomic submarine engine, Mark I was the great secret of the Idaho desert. In a desert region in Idaho, a fat, concrete, windowless building whose walls are 10 feet thick rises eight stories high above the surface of the desert. Inside this building, workmen pieced together the bottom and sides of the hull of a submarine that would never be closer than a thousand miles to the nearest ocean. Its nuclear furnace lies in its own private ocean, which is 50 feet in diameter and about 40 feet deep. Energy can be released from this nuclear power plant at the flick of a switch.

Mark I was built to fit into a submarine so that an almost exact duplicate could be built in the Nautilus 2,500 miles away in Groton, Connecticut. There, a roped-off area at one end of the shipyard was nicknamed "Siberia".

Parts which originated in twenty-three different states were tested, revised, and built into landlocked Mark I. Then they were duplicated and built into Mark II, the engine which would power the first atomic submarine. In "Siberia" at Groton, Connecticut, Mark II was assembled in the Nautilus hull.

The problems which were overcome by Admiral Rickover and his Navy men, the Atomic Energy Commission, Westinghouse Electric Corporation, and the Electric Boat Company are almost unbelievable.

Radioactivity created a special problem. Many operations were conducted behind 7 feet of concrete. A specially designed periscope made it possible for a worker to see what he was doing. Mechanical clawlike hands were used to handle materials. Other operations were conducted under 12 feet of water in an underwater workshop. Here workers could safely see and handle certain radioactive parts.

Special berating apparatus had to be developed so that the oxygen supply would not run out, and the carbon dioxide would be removed over long periods of time while the submarine was submerged.

A leak of radioactive water would be dangerous to the crew or to ships in surrounding water. Pipes, valves, and other mechanisms had to be strong and tightly welded so that they would be leakproof even under the shock of depth charges. The cooling system was so carefully welded that all the radioactive water which might leak out of it in 500 years would barely fill a thimble. This is just one example of the care which was taken in the construction of the Nautilus to protect the men who travel in this atomic-powered submarine.

From the beginning, no one could be absolutely certain that atoms could be harnessed to run a ship. Such a feat had never been accomplished before.

The uranium core of the reactor was the heart of the project. In addition to its creating the hazard of working with radioactive material, there was a danger that its energy might be released too fast, causing the reactor to "run away."

Mark I began to produce enough neutrons to sustain a chain reaction on March 31, 1953. Atomic piles were doing the same thing in many parts of the country, but could such a nuclear reactor be made to run steam turbines? On May 31, 1953, the landlocked submarine was "launched." A valve was turned on, the reactor produced heat, and turbines began to function. The propeller shaft whirred round and round; as it did so, atomic transportation was born.

In the Nautilus, water picks up heat from the reactor and carries it to a boiler, where non radioactive water is heated to produce steam. This steam runs the turbines which turn the propeller shafts.

If you looked at the Nautilus from the outside, you would not find it very different from other submarines. Her shape is more stubby, her bow is blunt, and her hull is exceptionally thick. These features, combined with the tremendous power and high speed made possible by the atomic engine, enable the Nautilus to manoeuvre underwater far better than ordinary submarines.

Today, nuclear-powered submarines cruise through the seven seas. By 1965, fifty-one nuclear submarines were part of the United States fleet. Twin atomic reactors supply the power for ships such as the U.S.A. Bainbridge, which can cross the Atlantic Ocean one hundred times without refueling. Other nuclear-powered surface ships have passed gruelling trials with flying colors and are now part of the United States Navy.

How would you like a cruise on a nuclear powered merchant ship? The N.S. (Nuclear Ship) Savannah sails the seas without a smokestack and can circle the globe about fifteen times without renewing its charge of nuclear fuel.

Perhaps you would prefer to travel by steamship for fear of radiation exposure. One scientist estimates that a passenger sitting in the “hottest” part of the nuclear-powered ship into which he was permitted to go would receive about the same amount of radiation as he would get from the luminous dial of his wrist watch. He would receive just this amount when sitting in the hold directly in front of the lead and concrete shield of the ship’s reactor. A two-foot shell of steel and redwood guards it against collision damage. Although the use of nuclear energy to power merchant ships got off to a slow start, there are now plans for small fleets of them.

Atomic scientists are proud of the many advances which the atom brings to the sea. Some are looking to the sea in an entirely different way in connection with atomic energy. These are the experts who are digging with atoms. They are trying to perfect ways of using nuclear explosives to enlarge harbors and perhaps build a sea-level canal across the Isthmus of Panama. Such a canal would eliminate the need for expensive and time-delaying locks, and scientists believe it could be dug with atomic energy at a cost far below that of conventional excavation.

Can atoms be used for digging? Would there be danger from radioactivity in such a procedure? Project Plowshare in the United States is trying to answer these questions. For a number of years, scientists have been making craters underground by setting off nuclear explosions. For a canal, they would dig a series of craters to make a big ditch. But this is not as easy as it sounds. In one experimental blast, a section of the crater wall collapsed soon after the explosion. Boulders rolled down its sloping sides for months afterwards. Many experiments will be needed before the science of digging with atoms is perfected.

Radioactivity is another problem which must be brought under control before scientists can join one sea with another by underground explosions. In one project where an experimental explosion was used to dig a harbor in Alaska, the problem of radioactivity was so great that the balance work could not be undertaken. Radioactive fallout concentrated in lichens in the area, and lichens provide food for caribou. Caribou in turn provide food for Eskimos.

Similar cases may occur in other countries. No one knows just how radioactive products would be distributed or would reach people in regions where there are different plants and animals and different weather conditions, from those where experiments have already been done. Years may pass before it is practical to dig with atoms to change a coastline or connect sea with sea.

15. ATOMS FOR TOMORROW

What part will atomic energy play as man reaches into space? Astronauts could live longer in space without food than without electricity, for they need power without which they cannot maintain their environment. Heaters, lights, ventilating fans, and carbon-dioxide removal units are vital to manned space flight. So are radio transmitters and receivers, control panel instruments, tape recorders, computers, and other communication systems. Life-support systems such as water-reclamation units, shower pumps, toilet facilities, waste disposal, and laundry facilities will all depend on electrical power. The overall success of a space flight ultimately depends on the supply of electricity. And this supply must come from atomic energy for all extended flights.

Energy from the sun is free, easy, and safe, but the use of solar mirrors is not practical for obtaining large amounts of electricity. Batteries of fuel-cell power were fine for short manned flights and for satellites that transmitted for a limited time.

Atomic power first travelled into space in June, 1961, in a generator that depended on isotopes. A whole series of power-supply systems that produced electricity from radioisotopes followed. Such units are simple and lightweight, but imagine the problems faced by atomic scientists charged with the task of building a nuclear reactor that could travel into space and safely supply large amounts of electricity.

Of course, it takes just a tiny amount of uranium to power a submarine, but the equipment which goes with it normally weighs hundreds of thousands of pounds. Obviously, such extra weight is not feasible in space flight. Tons of equipment had to be reduced to less than a thousand pounds.

Scientists at Atomic International, a division of the North American Aviation Corporation, tackled this problem of building a nuclear reactor which was light yet safe. They also had to be certain that the reactor would go into operation automatically when it was safely in orbit. These are just a few of the technical hurdles which challenged atomic engineers and scientists.

In the spring of 1965, tension mounted high on one cold, gray day in California. After fourteen years of planning and work, atomic scientists watched the first test flight of a nuclear reactor in space. About 3 ½ hours after the Atlas-Agena rocket roared off the launching pad, the midget reactor, which was barely larger than a five gallon gasoline can, began to function at 700 miles above the earth. Later a sustained chain reaction began and the tiny reactor supplied power for 43 days. This was the first of many tests of many kinds of nuclear reactors for space.

Someday, atomic rocket power may carry big loads far into space, making possible round trips to Venus, Mars, and even beyond.

Someday, electricity may be generated in full-scale reactors without the use of steam run turbines. This may happen in your neighborhood as well as on the moon, the reactor and other equipment may be installed beneath the surface, where it will supply electricity for the moon base and charge the batteries of the surface vehicles with which man will explore the moon.

Some statesmen feel that atomic energy is the key for long-term development of over half of the world. The future may bring such immense power requirements that only nuclear power can meet the needs. Perhaps only unlimited power from fusion will be the answer to energy requirements of tomorrow.

Living in an atomic age is a big problem. Perhaps you think atomic energy problems are too big for you and too difficult, that you can do nothing about them. The problem of atomic energy is too big for any one person or any one group. It is the responsibility of each citizen. You, working alone and with groups of people, can play an important part in helping to work towards the development of peaceful applications of atomic energy. You can help your country to survive.

Here are some ways in which you can help,

First, keep yourself informed about progress in the atomic energy program. By reading this book, you have already learned far more than many people know about the subject. You can talk about atomic energy to other people and gain their interest in this vital subject.

If you are planning a career in the field of atomic energy, discuss your ideas with your vocational counsellor and other teachers. Ask them how you might best prepare for work in which atomic energy is involved and for what type of work you are best suited. There are schools which offer training in handling of radioisotopes and which are especially equipped to prepare people.

GLOSSARY OF ATOMIC LANGUAGE

ALPHA RAYS One of the three types of rays released by radium and other radioactive elements. An alpha particle is composed of two protons and two neutrons tightly bound together.

ATOM the smallest particle of an element.

ATOMIC ENERGY Energy released when the nuclei of atoms are broken apart or put together.

BETA RAYS One of the three types of rays released by radium and other radioactive elements. Beta particles are electrons.

CLOUD CHAMBER An enclosed box filled with moist air or other gas in which moving atomic particles leave cloudlike trails.

COOLANT Material used to cool reactors and to carry heat away from reactors.

ELECTRON A tiny particle which may be found whirling around the nuclei of atoms, flowing through wires as electricity, or free in the air.

FISSION Splitting of atomic nuclei into two approximately equal parts with the release of energy.

FUSION Combination of small atomic nuclei or particles into larger ones with the release of energy.

GAMMA RAYS	One of the three types of rays given off by radium and other radioactive substances. They are similar to X Rays.
GEIGER COUNTER	An instrument for detecting radioactive particles. It consists of a tube containing gas which conducts electrical impulses with a clicking sound. Frequent clicks indicate the presence of radioactivity.
HALF LIFE	A way of explaining how fast radio-active atoms break apart. The period of time in which half of any amount of a radioactive substance will lose its radioactivity.
ISOTOPE	One form of an element. The isotopes of any element behave the same way but differ slightly in weight.
NEUTRON	A type of particle found in the nuclei of all atoms with the exception of ordinary hydrogen.
NUCLEUS (NUCLEI is plural)	The centre of an atom.