

"A LOOK AT NUCLEAR POWER WITH BINOCULARS" *

By Archer E. Knowlton, Associate Editor, "Electrical World", New York, N. Y.

SINCE last August hardly any single topic has commanded as much space in newspapers and magazines and time on the air as atomic energy. The larger part of that time attention has been devoted to the military potentialities and the immediate need for international control, if the otherwise inevitable destruction of civilization is to be averted. Everyone hopes that the nations of the world will arrive at some effective form of control. Meanwhile, much less attention has been paid to the constructive good which can come from commercial utilization of the astounding amounts of energy derivable from atomic fission.

As engineers we should focus our talents and our understanding on the orderly adaptation of that process to power purposes. Other professions meanwhile will be finding other applications. But, at the outset, it should be realized that atomic power is not yet commercially practicable and may not be for a decade or more. One can, with full confidence, be very skeptical about a British news report that an engineless automobile was seen moving about London propelled by atomic power or that an American locomotive will shortly be powered by inconsequential amounts of uranium.

To sense why it will take time it is desirable to review some of the facts that have been released about the atomic bomb: What atoms can be split? How are they manipulated to facilitate splitting? By what process are they split? Where does the energy come from? Can that energy be controlled as to timing, duration and intensity?

The logical approach seems to be one of viewing the difference between molecular and atomic energy.

The first industrial revolution was a molecular revolution. Molecules of water freed by application of heat darted around inside Watt's cylinder and pushed the piston upward. From that moment we date the still-continuing industrial revolution because it meant that man could do with mechanical power many things that had been impossible or too arduous by manpower.

The second industrial revolution is upon us. It is based on the potentialities of the atom rather than the molecule. This new industrial revolution

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has no more than started; in fact, the germ has only just manifested itself in tangible terms.

Many of us have probably wished at one time or another that we could have lived at the time of the Crusades or the Renaissance or the Reformation just long enough to have experienced being present at some great historical event. Well, we can undoubtedly tell our grandchildren that we saw the birth of a new era which can probably be put down as occurring at 5:30 A. M. on July 16, 1945, when the first atomic bomb trial at Los Alamos, N. M., made a compression crater 300 feet in diameter and 25 feet deep. We do not need to be a wildly imaginative Buck Rogers or a Jules Verne in order to sense the imminence of great things about us. It takes no great technical imagination to envision the importance of a suddenly appearing new source of energy which is thousands of times more powerful, pound for pound, than coal or oil.

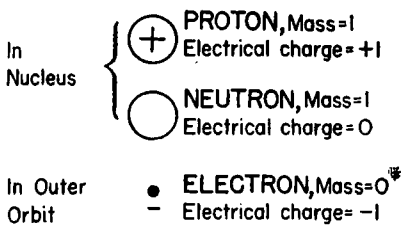
Recall, if you will, the comparative thermal properties of coal vs. wood, then of fuel oil vs. coal and finally of high-octane gasoline vs. fuel oil. Sizeable gains were achieved in each forward step, but nothing like a thousand or more to one in ratio. Yet each of these new fuels created a mild form of revolution of its own—the steam engine, the automobile and the airplane certainly did notable things to our economy, our social and political structures.

INTERNATIONAL IMPACT

So there is no reason to doubt that the energy released from the atom will make even more profound changes in our way of living. It has already made profound changes in our way of thinking. Over night the most rabid isolationist became a confirmed internationalist and vice-versa. More significant to us as engineers is the fact that the engineer, proverbially exhorted to participate in civic and national affairs, suddenly found a vehicle in which he, along with the physicist and electrophysicist and chemist could ride into international regard and eminence. For once the professional politician knew his limitations and sensed his complete dependence on the scientist and the technical expert. Back in November several members of Congress were attending classes conducted by the atomic physicists to learn what it was all about. There is hope for a country when its lawmakers begin to acknowledge the power of physical facts rather than oratory and buncombe.

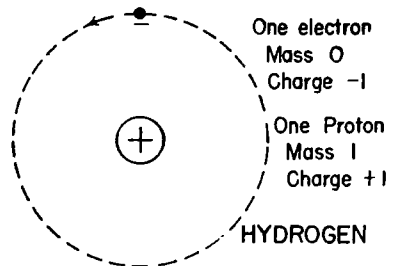
We have heard more recently that between the times of James Byrnes' resignation as director of economic stabilization and his appointment as Secretary of State he had disappeared from the public eye because he was

1 ATOM PARTS



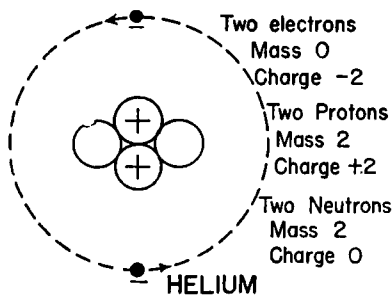
* Actually $\frac{1}{1850}$ of Proton weight

2 SIMPLEST ATOM



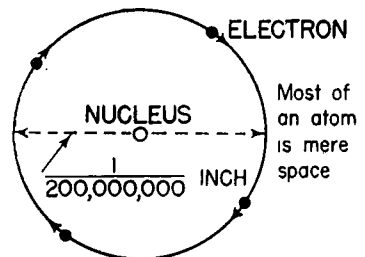
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3 TYPICAL ATOM



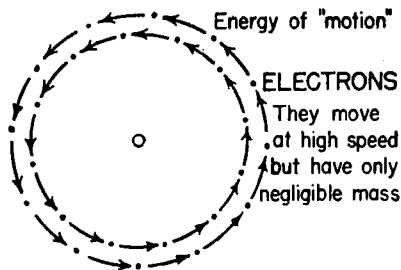
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4 ATOM SIZE



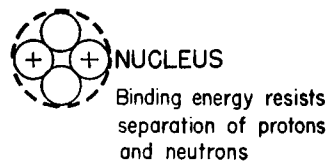
If the nucleus were a baseball, the electron would be a speck 2,000ft. away

5 ELECTRON ENERGY



Energy values are relatively small

6 NUCLEAR ENERGY



In 1 lb. of helium, nuclear energy = electricity enough to run a 100-watt bulb 13,000,000 years.

Courtesy "Electrical World"

assiduously studying the technology and the import of the atomic bomb. Knowing that, we could have considerably more confidence in his ability to spar with Molotov in negotiating the form of world control of the atomic bomb under the United Nations Organization.

It seems truly to be a case of "One World or None." There will be a book with that title published next Monday and it will afford an authentic supplement to the official Smythe report.

SCIENCE NEWLY DOMINANT

Henceforth, this will be a world in which science will command attention as never before. Neither radio, nor radar, nor television, nor stratosphere flights, nor massive governmental hydro works ever engrossed the conversation of the common man all over the world as has the atom bomb since the day it blasted Hiroshima. The world became science-conscious that day. The world this time seems to appreciate the awesomeness of the split atom as a weapon, and along with it the very great risk either that honest experimentation might accidentally get out of hand or that a new crop of paranoids like Hitler or Mussolini or Tojo could wreak terrible havoc on very short notice if not restrained and policed. As one girl in the subway put it to another, "Gee, they ought to be careful what they do with that stuff,—it's dynamite."

But I think it has at the same time become accepted that peace-time perfection of fission energy applications can transform this world of waning fuel resources into one of abundance and fine living. Whether that happens or not depends on who wins the race between technology and the humanities. We used to hear in college, and some of us used to teach the budding engineer, that he needed to leave his engineering learning with some appreciation of literature, economics, political science and the science of society generally. Otherwise, the disturbance of economic balance which his productive and labor-saving devices could cause would outstrip the capacity of the economist, politician, social expert and ecclesiast to have their own adaptations catch up. Never was that more forcibly demonstrated than when Hiroshima was devastated in a move to end the war quickly and save a million lives. It jolted the world like nothing physical had ever done before.

EVOLUTION OF THE PROGRAM

That affair at Hiroshima was no accident. It had been planned for over six years. Nuclear physicists had already tried to check the publication of further information on atom-splitting—in particular, those of European

origin who were working in this country sensed what this laboratory discovery could do to the world in the hands of an inhuman blitzer, if turned into a military weapon on a mass production scale. They failed in their effort to get agreement among physicists to withhold papers, so they swung their efforts toward interesting our government in undertaking a large-scale exploration. That bore fruit in 1939 and from then until 1942 the researches on component problems were quietly prosecuted at several universities.

It was in June of 1942 that the Army Engineer Corps set up the Manhattan District and started on the DSM project—meaning, very innocuously, the “development of substitute materials” From then on the job was to pick the most promising of the atom-splitting techniques of the physicist and convert them into large-scale production methods. It was undoubtedly the largest gamble ever undertaken. Literally thousands of new processes, equipments and controls had to be designed, coordinated and built. It was, however, eminently and catastrophically successful. As President Conant of Harvard told those who directed the enterprise, “If it should work, Congress never would investigate the 2 billions spent. If the bomb proved a fizzle, Congress would investigate nothing else.”

Why did the bomb work?

The Greeks had a word for indivisibility. Our word atom comes from it and denotes that property of indivisibility. But we all know now that one atom is heavier than another only because it has a greater number of constituent particles, usually protons, with a sprinkling of neutrons added; the electrons don't count much in weight. In another few years the physicists may be telling us that even protons and neutrons are in themselves divisible, but right now the consensus seems to be that they are not.

The picture the physicist has of the nucleus consisting of these protons and neutrons is one of a comparatively compact spherical arrangement. You can approximate the pattern by your own recollection of the glass globes filled with colored jawbreakers or balls of candy-coated chewing gum at the drug store or cigar stand. Imagine the glass non-existent and that the balls are held together by some very powerful binding force, each attracted to every other—more strongly, of course, to the one with which each is in contact. That binding force is not electrical and if it is gravitational it obeys something more potent than the inverse square law of either electric charges or masses of matter. Maybe at very short distances the law steps up to the third or fourth or even higher power.

In any event, the atom is held together in direct opposition to the natural effect of dispersion that should result from the mutually repulsive effect of the positive electrical charges on the protons. The neutrons carry no

charges—but don't get the idea that they are inconsequential deadwood; they are the real seat of atomic fission.

The electrons, as previously stated, play a negligible part in fission. They can be envisioned as a small swarm of flies describing circles in all planes around our candy jar and out to the full limits of the room and beyond. In the case of uranium, the 92 electrons are disposed in seven orbit shells. By comparison with the proton-neutron nucleus of any atom they afford a pretty flexible pattern. That nucleus is rigid, hard, resistant to deformation or distortion. Certainly it is resistant to shattering.

But, like many of the stony and glassy materials of engineering, the atom nucleus has critical phases in its attributes of rigidity. If we try to split that nucleus by bombarding it with projectiles, we can have one of several results, depending on the size and velocity of impact of the projectile. If the projectile should be a proton it never would hit the nucleus—its positive charge would react with the positive charge on the nucleus to deflect it. We could only, therefore, have used an uncharged neutron as the projectile. If the velocity is too low the projectile may bounce off or merely become imbedded in the nucleus. If a neutron stays imbedded it changes the atom into one of its isotopes—it is still the same atom because it has the same number of protons in the nucleus.

If the velocity of the neutron projectile is too high the neutron may plow right through the nucleus and leave a clean, but self-healing hole somewhat, I suppose, like a bullet through a lump of putty.

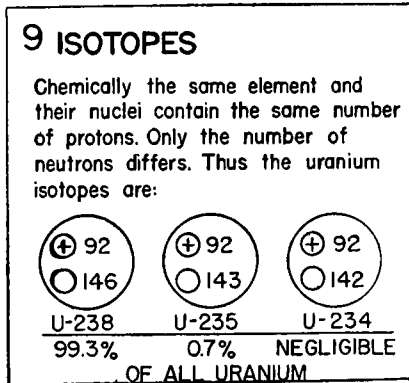
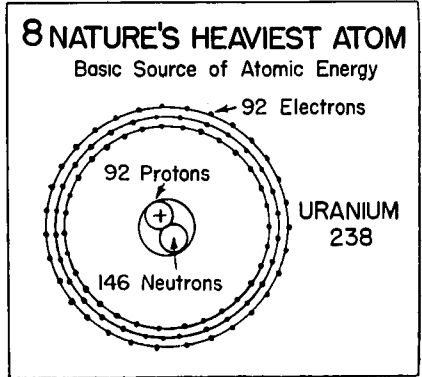
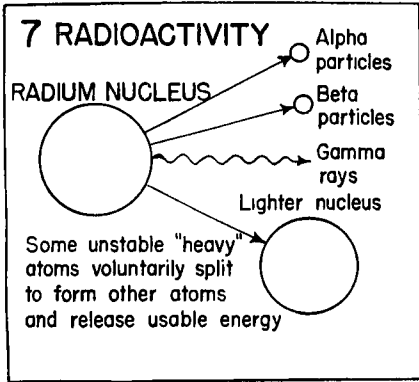
MECHANICS OF FISSION

But if the velocity of the neutron projectile is just right the result can be a jolting of the binding forces that lets the nucleus split into two parts that are then atoms of lesser atomic weight. This is downhill transmutation, but the real point of interest is that energy is released at the instant when the splitting takes place. This potential energy content of the atom resulting from the tension of the binding forces is terrific—thousands of times as great as the recovery of energy through the molecular process of combustion.

There is another factor in this matter of neutron bombardment and that is that the least stable, least shatter-resistant atom nuclei are likely to be the most complex ones and the heaviest ones, because they have more components at greater average distances from one another than atoms composed of fewer protons. In fact, the heaviest atom in Nature, uranium, has proven the easiest to split. It is the only one that has been split in quantity. No

one dares say that more plentiful and more widely available materials may not bow to fission in the next few years. When that happens the atomic police surely will have some beats to patrol.

Also, Einstein tells us that as a result of this wrapped-up energy one pound of anything contains 11,400,000,000 kilowatt-hours of energy.



Courtesy "Electrical World"

"Combustion" of just one pound of uranium could raise the temperature of 200,000 tons of water from its freezing to its boiling point.

This energy comes from the high velocity of the shattered fragments; their slowing down by the material through which they pass creates this heat.

These fragments, also, carry an electrical charge and this is the basis for the hope that some day nuclear energy can be directly transformed into

electrical energy without dependence on combustion and boilers and steam turbines.

So far we have derived only about one-tenth of one percent of the energy contained even in uranium. So what happened at Hiroshima and Nagasaki in August was an instantaneous release of 11,400,000 kw.-hr. multiplied by whatever number of pounds of active material there was in each of the two bombs.

No wonder that the bomb melted the sand of the New Mexico desert into glassy fulgurites when the first field experiment in July proved so astoundingly successful. A lightning flash expends only one or two kilowatt hours. One-fourth of the entire 50,000,000 kilowatts of generating capacity in the country would have to concentrate an hour's output into whatever fraction of a second the bomb explosion took in order to equal the intensity of heat release (per pound) that volatilized the steel and melted the concrete. In one ounce of mass of any kind resides as much potential energy as Boulder Dam can grind out in a whole month.

EXPLOSION VS. CONTROLLED RELEASE

All this discussion has been based on the bombardment of a single atom by a spray of neutrons travelling at the optimum speed for fission—not so slow as to bounce or become imbedded nor so fast as to shoot through.

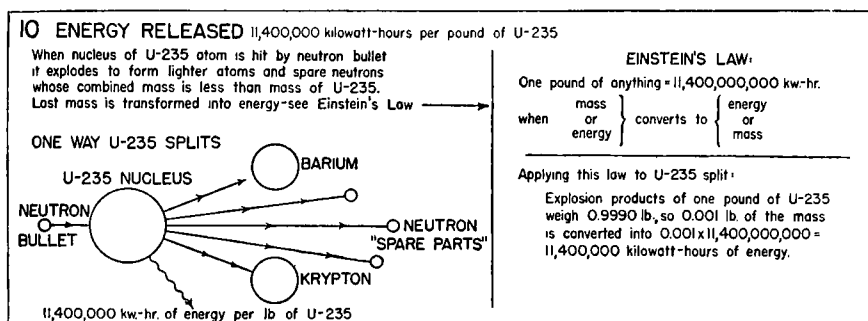
The optimum speed for the neutrons is said to be about 11,000 miles per second. That is about one-sixteenth the speed of light.

Utilization of atomic energy means using palpable masses. At Hiroshima the problem was to have *all* the atoms on the outside surface of the mass that was to be detonated by neutron bombardment. You might try to guess how you would design a spongy or lattice work disposition of several pounds of energetic material so that it won't go off until you want it to and then will all go off at once. I don't know the trick and I can't even guess and I doubt if any of you can guess, so there is no risk that any of us will divulge the secret on this occasion. When you stop to think of it, it was quite a trick and I think we should keep it very jealously to ourselves until the world is ready to be good and sensible.

But the trick in applying atomic energy in peaceful pursuits is to tone down the terrific energy release that marked the Japanese bombing affairs. Nothing known would stand up against such temperatures in machines designed to translate the atomic energy into useful mechanical or electrical form.

PILE CHAIN REACTION

There is, however, a milder manifestation of energy release and that is in the form of the very same chain reaction that was used at Hanford to create plutonium from Uranium-238. Plutonium is readily fissionable. Uranium in nature is U-238 containing about one part in 140 of U-235. U-235 is just an isotope of uranium; it has the same 92 protons but has only 143 neutrons instead of 146. U-235 is readily fissionable; U-238 is not. If a roaming neutron travelling at the critical velocity hits a U-235 isotope it splits the uranium atom into barium and krypton and releases the energy at the 11,400,000 kilowatt-hour per pound rate. The neutrons released by U-235 become projectiles in their own right, and those which



Courtesy "Electrical World"

travel at such velocity as to imbed in the U-238 all around them boost the U-238 to U-239, another isotope of uranium. But this converts itself into plutonium in a process which later changes two neutrons into two protons. With two protons added to the 92 of orthodox uranium, there are 94, which means that man has created an element. That plutonium element is less stable—the heavier the atomic weight the less the stability—than uranium, in fact, it is explosively unstable.

At Hanford, Washington, was the plutonium plant founded on the inherent chain reaction just described. Uranium material was packed into aluminum tubes and stacked with carbonaceous or graphitic material in between. The carbon slowed down the neutrons expelled from the U-235 so that a large percentage would imbed in the U-238 and make U-239 in plutonium form. A goodly part of the Columbia River had to be pumped through the pile to keep the temperature down and thus hold down the velocities of the neutrons so they would imbed in the uranium and thus be most effective in producing plutonium.

The present Hanford plants with water cooling operate at a very low temperature. If some liquid-metal coolant such as bismuth or sodium could be applied it would be possible to run to higher temperatures and maybe approach those used in prevailing power plants.

As it was, the Hanford plant put about 1,000,000 kilowatts worth of heat into the Columbia River. But it was low temperature heat and the urgency of the war demand for the explosive U-235 or Plutonium that prevented devoting any time or effort to the perfection of a high temperature pile operation which could have developed 1,000,000 kilowatts of useful power.

There had to be other stages in the process of making the uranium available for the two bombing operations in addition to the pile process, so that the active U-235 could be separated from the comparatively inactive U-238 or at least the U-238 enriched in U-235 content. Some of these processes as developed in connection with the bomb are the ones that will have to be the basis for any peacetime production of uranium in atomic energy form.

Plutonium being a different chemical element can be separated from uranium by solution in acid and the application of customary chemical reactions. But the isotopes of uranium are merely different forms of the same element and chemical means do not suffice to separate them from one another.

Four processes were investigated in the effort to concentrate the U-235. One was the thermal diffusion method. In its circulation of the materials in fluid form tended to concentrate the lighter U-235 at the top and the heavier U-238 at the bottom. It did not prove commercially effective, at least in the sense that any method of production can be rated as commercially successful, if it were only mildly successful for military purposes.

Another process was to project the mixture across a powerful magnetic field; the lighter U-235 would have less momentum and thus be deflected more by the magnetic field than the heavier U-238 with the greater momentum. The two diverging streams were divided by a splitter, the U-235 accumulating on one side and U-238 on the other.

Electrical engineers will be interested in knowing that the huge magnets had to be designed with a degree of field uniformity that did not vary more than one part in 5,000 and the power supply had to be regulated so finely that the variations would not exceed one part in 15,000. Otherwise the separation of U-235 would become ineffectual.

Centrifuging was the basis of the third process, the heavier U-238 whirling toward the outside and the lighter U-235 being removed from the central region. This process was not particularly successful.

One effective method was the one involving the molecule-by-molecule gaseous diffusion through porous barriers. Just like any lighter gas, the lighter U-235 passes more readily through the pores of the barrier than the heavy U-238. The mixture had to be passed through literally thousands of stages of porous partitions before the concentration reached the desired value for the purposes of the bomb. Probably this process could be much abbreviated and still produce acceptable concentration of U-235 for commercial use. But General Groves has stressed the very challenging problems that faced the scientists and engineers in the matter of metals that would stand the corrosive influences of uranium hexafluoride, the extremely fine clearances and tolerances that had to be met to prevent infiltration of impurities, the problems of lubricating the thousands of valves and the pumps.

These latter points ought to be of interest to the mechanical engineers who are members of the Connecticut Society of Civil Engineers. And not forgetting the civil engineers in citing these statistical startles, may I mention that the excavation for the trenches at the Hanford plant alone amounted to one-fourth as many yards as were required for the Panama Canal. Also, the concrete laid amounted to a third as much as Boulder Dam took. In brief, this party was in no sense monopolized by the physicists, chemists, mechanical and electrical engineers.

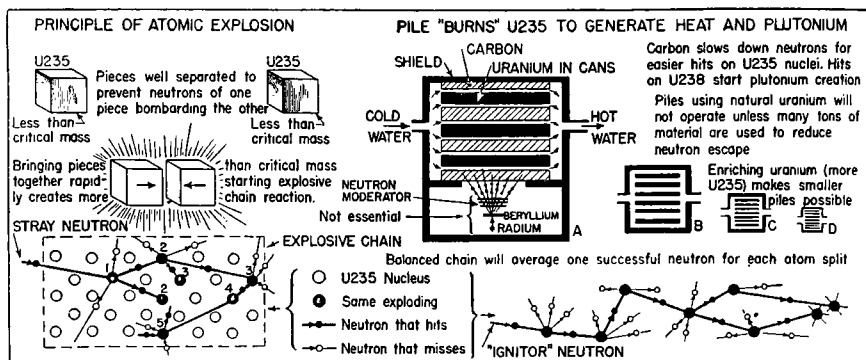
REGULATION AND CONTROL

Thus, in the chain reaction process there rests one direct source of heat energy. The atomic energy piles at Hanford generate heat continuously at a rate equivalent to several hundred thousand kilowatts. It just heats up the Columbia River. However, the nuclear physicists or fission engineers will have to regulate this process and confine the operations so that this form of self-perpetuating energy release can be applied practically to the heating of water, air or other fluids for space heating, steam boiler and turbogenerator or gas-turbine operations. The other source of energy release is the other extreme of explosive splitting of a very large proportion of the atoms in a given mass at one time.

Even after they modulate the processes—upward from the comparatively low temperature pile process or downward from the bomb-explosion solar-temperature process—they will still have to provide means for starting, stopping and regulating the moment-to-moment intensity. Otherwise, we will not have any approach toward what we can do today with fuels in combustion operations.

POPULAR FORECASTS UNSOUND

There is nothing implied in the preceding statements that in a year or two homes will be heated and automobiles driven by atomic energy. First, the process calls for critical amounts of material just as the bomb did. Second, the emission of radioactive energy will necessitate shielding with heavy walls of steel or concrete to protect humans in the vicinity. One of the scientists engaged on the atomic bomb project said that the shielding requirements would probably make a 100-kilowatt plant weigh about 50 tons. Proportion of shielding weight would presumably decrease for greater kilowatt capacities.



Courtesy "Electrical World"

The radiation from the Hanford pile was equivalent to that from several million pounds of radium. That is an index of the imperative need for shielding because the world has never isolated more than 2 pounds of radium, and you know how the little capsules containing mere milligrams have to be shielded by lead.

All the operations at Hanford and Oak Ridge were remotely controlled from behind massive protective barriers. It is not even likely that locomotives could be adequately shielded without enlarging tunnels, raising bridges and widening the separations from other tracks, platforms, etc. Experts say that a Navy ship is likely to be the first application of atomic energy in propulsion form. The primary reason is that one pound of uranium, even if only 1/1000 of its energy can be utilized, will carry the vessel as far as 1,500 tons of coal, or 250,000 gallons of fuel oil. The bunker space corresponding to the pound of uranium would be 60,000 cu. ft. in the case of coal and enough to store 5,000 barrels in the case of the fuel oil. And as for submarines, there would be no smoke, no fumes, no carbon dioxide, nothing to worry about but adequate provision of shielding against the beta rays.

CENTRAL POWER GENERATION

Next in order will come the turbogenerator application in the electric utility plant, affording another opportunity to deal with masses in the critical bracket, and assuring space enough to provide the shielding against the ruinous radioactivity that always attends the emission of neutrons and electrons from the arena of chain reaction fission. Whether the impending invasion of the utility field by the gas turbine will be retarded or accelerated by the lurking invasion of atomic energy remains to be seen. The Hanford-type of chain reaction could lend itself either to generation of steam or the heating of air or gases. If steam is produced in an atomic energy boiler, the present turbogenerator would still apply. If gases or air are heated we could put them through a gas turbine and use that as the prime mover. In short, people in the electric utility field feel pretty certain now that they will be using atomic energy on land as soon as anybody. A pound of uranium would run a metropolitan power system for a day; 400 tons would take care of the whole country for a year.

L. W. Chubb, director of Westinghouse research, has said recently that "controllable atomic energy generators of smaller size are possible now. However, as the size comes down the richness of the fissionable material must be increased. And costs rise astronomically with degree of enrichment."

It has been asserted that a utility boiler using uranium as fuel could be built and running by the end of this year; it could be efficient but it would be definitely experimental. It is promised that it would not be prohibitively costly to build or operate. It would take several years, however, to eliminate the inevitable defects just as the steam turbine took, the mercury turbine is taking and the gas turbine will take several years to be perfected before full commercial acceptance can ensue.

For a few days after Hiroshima, there were fears that central power was doomed; all anybody would need would be an occasional capsule of U-something and you could coast for years; your lighting, heat and deep freezing, your automobiling, radioing and everything would come from that one capsule. In that event, the electric and gas utilities would become little more than small retail establishments like drugstores or vitamin banks—one clerk with one 5-foot shelf could take care of the power needs of a whole metropolis.

That fear dissolved very quickly and with it should also have gone the dream of the public that atomic energy would mean free power. Would it not be possible to dig up a bit of earth in your own back yard and use it for fuel to ride gaily in all directions? Hardly soon or ever.

COST PROBABLY NOT PROHIBITIVE

How much does atomic energy cost? How much will it cost?

At 110 volts it takes 1.3×10^{17} electrons to make a kilowatthour. That is 130 million million electrons. It takes about 10,000 times that many electrons to make an ounce. So an ounce of electrons could be counted as worth \$5,000 if a kilowatthour is worth 5 cents. That puts electrons on an \$80,000 a pound price scale. Electrons are feathers alongside the protons and neutrons and it is not strange even though surprising that electrons by the pound are even more expensive than U-235 could be and still compete with familiar fuels.

Well, assume that as little as 100 pounds was really needed for both the Hiroshima and Nagasaki bombs. We are told by General Groves that the whole atomic bomb project cost \$2,000,000,000—that would mean that the uranium for the bombs cost \$20,000,000 a pound. It would be strange if the current cost had not been reduced to a small fraction of that hypothetical cost. It will only need to be diluted to \$15,000 a pound, however, before it has the energy value of a ton of coal at \$10 per ton. The same unit cost would let it equal fuel oil of 150,000 Btu. per gallon at 6 cents per gallon. Those who are familiar with the speed with which production and synthetic processes are perfected can rightfully doubt whether the uranium materials will long command any such fantastic price as even \$15,000 a pound.

All this means that we are headed for an atomic era. The technology was accelerated by at least one decade as a result of the phenomenal wartime achievements of the scientific brain trust corralled to do the job. They took atom-splitting out of the one-atom-a-day laboratory and set it up as a mass production operation in huge, precisely controlled and safely protected plants. All that is now needed is some form of international concord on means to curb the vicious perversion of these atomic forces to war and destruction so that mankind can apply them to constructive uses for the enrichment of human living. In this very program we should be ten jumps ahead of the rest of the world. We have perfected the know-how for producing the uranium in active concentration and have learned a thousand practical things that others would have to learn from the bottom up.

We certainly have the brains to perfect the equipments and controls needed to derive the industrial benefits from the application of atomic power. Meanwhile, we can count on the doctors to use the new form of radioactivity for cure and prevention of disease. The chemists will use the achieved technique of creating isotopes to accelerate the technology of making further isotopes of the elements that are contained in familiar foods and medicines. The biochemist will use the directly active materials as catalysts and the isotopes as tracers in studying life processes.

Isotopes are not uncommon; tin has 11 isotopes; hydrogen has two, one of which was the heavy hydrogen for which Dr. Urey won the Nobel prize. That extra neutron which converted hydrogen into deuterium looked like a good source for neutrons for atom splitting. In fact, the Germans, with typical military foresight, had corralled 5,000 tons of it in Norway, only to have a group of British and Norwegian commandos wreck the establishment and the accumulation.

All of these confident prognostications seem to add up to the assertion that we are witnessing the birth of a new revolution in society. It might well transcend the industrial revolution inaugurated by steam power because it opens up a wholly new supply of fuel. That new supply will turn out to be an inexhaustible one as soon as we learn to do with plentiful substances what we have done with the comparatively scarce uranium. It opens up numerous fields of medical and biological attributes never embraced in fuel power, even when you count in the coal-tar by-products of bituminous coal.

A boon, yes, but it by no means signifies that energy will be free and costless. The production cost of the kilowatt-hour attributed to fuel is only a small part of its cost at a point of delivery. Even if U-235 were only a mill a pound, as \$2 coal is, instead of \$15,000 a pound, the practical obliteration of the fuel cost would still leave the kilowatt-hour costing practically the same as now. Fuel cost is seldom more than a third of the over-all cost and often as low as a tenth of the delivered price of electrical energy.

Perhaps even more important than the energy utilization of the phenomenon of atomic fission is the fact that the perfection of the technique at the two principal plants called for the creation of several thousand new and improved products, new tools, new instruments, new process control devices, new production procedures and new safety measures. All of these are available for immediate adaptation in numerous other industries as well as in the production of fissionable uranium, regardless of the time it takes to get the first destroyer or the first utility turbine running on atomic power.

CONCLUSION

Ralph Waldo Emerson wrote the hymn commemorating that event of April 19, 1775, at Lexington and Concord which we associate with the beginning of our war for Freedom—

“By the rude bridge that arched the flood
Their flag to April's breeze unfurled
Here once the embattled farmers stood
And fired the shot heard 'round the world.”

Heard around the world was the blast at Hiroshima. It will reverberate for centuries and some day some equal poet will coin an immemorable phrase to register its significance on men's minds. While the diplomats are maneuvering to devise the international policing that will prevent militarists from shattering the world it behooves us as engineers to see that the fruits of the legendary Manhattan Project are channeled into avenues of beneficence and well being for all mankind. If they degenerate into cataclysmic warfare it will be because of the incompetency of the diplomats. If they rise into undreamed of heights of welfare for mankind it will be to the everlasting credit of the scientist and engineer. Everyone hopes in his heart it will be welfare and not warfare.