Romance of the Machine

BY MICHAEL PUPIN
Author of "From Immigrant to Inventor" and "The New Reformation"

"MACHINE CIVILIZATION" is a favorite topic of several noted European writers. They have nothing good to say for it. Some of them write of it as an American plague, which is invading Europe and threatening to undermine its ancient culture. "Americanism" is the name which these writers frequently give to this new civilization, and Americanism, in their opinion, is sordid materialism. This is indeed a severe indictment of the ideals of our democracy. But are these European critics qualified to interpret American life and its ideals? Is their indictment supported by evidence from American history, or by evidence against American science and engineering, which they hold responsible for the evils of the so-called Machine Civilization?

Every thoughtful student of American history knows that Washington, Franklin, Jefferson, and the other fathers of this country were idealists of the highest type. History has no greater idealist than Lincoln, the leader of American idealists in a struggle for a noble cause. Is it possible that these American idealists have founded a nation of sordid materialism? The history of America to the close of the Civil War answers this question with an emphatic "No!" What calamity, then, has happened since the days of Lincoln to drag this nation into the mire of materialism?

One of the most memorable events in the history of America since the Civil War is the well-known movement for higher intellectual endeavor. It started in 1863, when, with the sanction and support of Lincoln, the National Academy of Sciences was founded. Joseph Henry, Frederick Barnard, William Draper, Andrew White, Daniel Gilman, and several other idealists of the Academy were its spiritual leaders. Johns Hopkins University, founded in 1876, is its earliest visible record. The programme of the founders of this university was brimful of idealism; it is to-day the programme of all American universities. The universities are the guardians of idealism in all our higher intellectual endeavors. The idealism of science fostered in the research laboratories of the American universities has gradually been transplanted to the research laboratories of our industries. Our industrial leaders were quick to discover that the cultivation of scientific idealism in our universities and in the industrial research laboratories was the most effective means of advancing the creative power of American industries. They gave hearty support to the idealist in the research laboratories of our universities. This idealist retained his independence, but he blazoned the path which the industrialist followed. The leadership of scientific activity has remained in our universities throughout this period of the organization of our higher intellectual endeavors. These universities are responsible if during this period American civilization has become

a mere machine civilization drifting away from the ideals of the fathers of the country, of Lincoln, and of the other idealists who inaugurated our movement for higher intellectual endeavors. But the responsibility of the universities rests upon the shoulders of their disciples, the scientists and the engineers. They have preached and practised what they have believed to be the doctrine of scientific idealism. Has their doctrine misled this nation into the mire of sordid materialism? "It has," say the European critics of our civilization, "because it has created the worship of a heathen idol—the 'machine.' " These critics take no pains to prevent the inference that the materialism of the machine is the most important offspring of our national movement for higher intellectual endeavors. If their contention is true, then our boasted movement for higher intellectual endeavors has produced a result diametrically opposite to that sought by its spiritual leaders; the dream of Joseph Henry, of Barnard, and of other American idealists of a half century ago has vanished into thin air; their ideals have been dispelled by the everlasting clatter of the American machine, the alleged idol of American science and engineering.

American scientists and engineers deny that these European critics of our civilization are qualified to interpret the real meaning of the American machine or of any other machine. These critics display to the disciplined eye of the American engineer a wofully scanty scientific training; their ideas about the mission of machines in the shaping of terrestrial life, and in the guidance of the destiny of man, are vague, to say the least. Perhaps they would have a different story to tell if they knew a little more of the scientific side of the subject which they delight in discussing without the slightest hesitation or reserve. A study of the origin of the "machine" may, I hope, help to persuade these critics to reconsider their sweeping condemnation of the civilization which America has created with the machine's aid. I venture now to give them a brief story of the machine. The story of the primordial machines which nature constructed and has employed since the first dawn of life on this terrestrial globe must be told first. These are the primordial structures the operations of which suggested to the inventive genius of man the use of machines as developed by modern science and engineering.

THE COSMIC ENGINE

The most significant physical fact in the life of our planet is its motion through the vast energy stream of solar radiation. From this stream it inhales its breath of life. The sun-worship of the ancients testifies that long before science began to guide human experience man had recognized the existence of this relationship between solar radiation and terrestrial life. But in the sun-worship of ancient Asia and Greece man expressed his belief that herbs and fruits, the food for man and beast, were the only blessings which solar radiation brought to terrestrial life. Modern science has revealed that there are other blessings which solar radiation has stored up and is storing up for the benefit of man. Among these blessings are the stores of energy in wood, coal, and oil. We know to-day that this energy was destined to mould the structure of human civilization.

But energy and its power are modern concepts, whose full meaning became known when modern science had pene-

trated more deeply into the physical activities which guide the course of human history. This science revealed that the trustiest servant in these activities is the available energy which solar radiation has provided in the vast storehouses of our globe. The steam-engine, invented a little over one hundred and fifty years ago, supplied the earliest illustration of this new knowledge, the foundation of our modern industrial progress, and of the civilization which this progress has created.

It is difficult to form a comprehensive view of our modern civilization without some knowledge of the modern science of energetics. This science reveals a view of the physical universe which was unknown even as recently as two centuries ago. It is a universe of vast energy streams of stellar radiation fed by the energy sources of the luminous stars, including our central star, the sun. These energy streams fill every nook and corner of the universe with radiant energy, some of which will some day and somewhere become the breath of life of organic structures. There is no idle vacuum anywhere in the universe so long as these stellar energy sources are in action; but should they dry up, their radiation streams of energy would dry up, and the physical universe would be as dead as the deadest grave of ancient Egypt. The countless stars then would be just so many graves in the lifeless cosmic vacuum. Stellar radiation is the visible evidence of a living universe.

With this view of the universe one cannot fail to recognize that the energy stream of solar radiation is the primary source of physical power in the evolution of terrestrial life. This thought is forcibly impressed upon us when we contemplate the most striking features of the face of our mother earth. They are the lofty levels of the continents towering high above the ocean levels; the garb of vivid green which clothes the hillsides and valleys filled with the joys of organic life; the all-enveloping ocean of the terrestrial atmosphere. These terrestrial features exhibit a structure which, as if designed by a power engineer, is splendidly adapted for the work of harnessing the energy of solar radiation. A part of this energy is absorbed by the terrestrial atmosphere, and supplies the driving power which propels the trains of clouds loaded with the products of solar action upon the terrestrial waters. This precious load of water vapor lifted on high by solar radiation and driven by the atmospheric currents to the lofty continental levels, ultimately yields to the gravitational force. It descends upon the earth, and starts the missionary journey which carries its life-sustaining fluid to the thirsty hillsides and valleys. The scientific mind cannot fail to see in this cosmic operation the action of a cosmic engine which derives its driving power from the fires of our central star, the sun. The suggestion that a prosy machine, fed by the fires of the solar furnace, forms the foundation of the creative processes of our mother earth will perhaps shock the sensibilities of an æsthetic soul. Such a soul delights in the poetic fancy of the ancients, who saw in our central star a radiant sun-god bestowing upon terrestrial life the gifts of his benevolence. Not less shocking to some æsthetic souls is the story of science which says that countless terrestrial machines constructed by nature's hand are fed by this gigantic cosmic engine and that all of them are eternally busy in the upbuilding of life on our terrestrial globe.

PRIMORDIAL TERRESTRIAL MACHINES

Behold now the second striking feature of our mother earth, the hillsides clothed with the garb of vivid green of the flourishing forests! Each one of their countless millions of trees bristles with enormous multitudes of busy leaves inhaling the breath of activity from the life-giving energy of solar radiation. Each leaf is like a suppliant hand imploring heaven for the blessings of its radiation streams. Here we are witnessing one of the most important of the fundamental physical processes in the evolution of organic life on our mother earth. Each leaf with its green chlorophyl is kept busy by the stimulating action of the ultra-violet light of solar radiation; absorbing the molecules of carbon dioxide of the atmosphere; breaking these molecules up into carbon and oxygen; retaining the carbon and releasing the oxygen. This is the carbon which the tree needs for its bodily structure, and this is the oxygen which replenishes the power of our atmosphere to sustain animal life. No other physical process is more important in the evolution of terrestrial life than this separation of oxygen from carbon in the molecules of our atmosphere. In no other terrestrial process do we see in action so vast a number of machines employed in a mass production in comparison with which the mass production of human mortals is a vanishingly small affair. The physical activity of our "Machine Civilization" is a tiny and crude copy, only, of the activity of nature's primordial machines.

When the word "machine" is used in this connection it is not used as a mere figure of speech. The bodily structure of a tree is a machine, because it provides for the life processes of the tree suitable channels, just as the steel structure of the steam-engine provides for the flow of steam suitable channels in which, by its pressure and expansion, it can do useful work. But the bodily structure of the tree is a self-made and self-repairing machine. The life processes in its channels perform two different kinds of useful work. One product of its work is the fruit of the tree, food for man and beast; the other product is the carbon stored up in the body of the tree. This carbon represents a definite amount of solar energy which can be obtained by burning up the wood, that is by reuniting the carbon in the body of the tree with the oxygen of the atmosphere from which it had been divorced by the action of the chlorophyl when the tree was formed.

THE TERRESTRIAL STOREHOUSES OF ENERGY

Who can look at the genial flame of his fireplace without seeing in the burning log a new life rising as if by a resurrection from the organic life which the axe of the woodman had terminated long ago. This second life of the tree is short and sweet; it is a rejoicing of the carbon molecules in the reunion with their loving partners, the oxygen molecules of the atmosphere. When this brief rejoicing is over the energy stored up in the body of the tree is gone, and nothing remains but a few handfuls of ashes. They remind us of the self-made machine which served a useful purpose not only when it provided the life processes of a tree with suitable channels, but also after it was scrapped by the blows of the woodman's axe. Here is a machine which has two beautiful lives. During its first life it adorned the face of our mother earth, and supplied sweetness to the nurture of man and beast; during its

second life it carried to our fireside the beauties and comforts of its genial flame. Here is a machine which is a thing of beauty and a joy forever; it should remove the taint of materialism which some people attach to the word "machine."

A similar story can be told of every herb and of every blade of grass, and of every animal on earth; their material bodies are machines which provide suitable channels for the physical processes of life. A by-product of these processes is the increase of available terrestrial energy like that stored up in the carbon of a tree. A practically infinite number of these terrestrial machines, constructed by the patient and experienced hand of nature, is eternally busy giving comfort and joy to the present generation and storing up available energy for the comfort and joy of future generations. A vast deposit of energy thus stored up was hidden during millions of years in the bosom of mother earth. To-day these deposits are precious treasures of man; they aid him in his efforts to make human life worth living.

THE HIDDEN TREASURES OF ENERGY

Coal and oil are the earthly remains of scrapped machines constructed by the hand of nature many æons ago, and employed for aiding the life processes in the vegetable and animal kingdoms of our globe. The scrapping was not the work of the human hand, like that of the woodman and his axe; it was the work of terrestrial cataclysms which buried the bodies of prehistoric animals of the sea and land, and of terrestrial forests. Their graves were hidden in the deep recesses of the earth. Water and air were not admitted into these guarded graves, to indulge there their action of wasteful decay. The buried bodies rested in a peace incomparably longer than that of Tutankhamen in his royal grave. Delivered from their graves, they live again when the carbon of their molecules joins in happy wedlock with their former partners, the oxygen molecules, from which they were separated long before Adam began to pass his days of blissful idleness in the garden of Eden. The excavations which discovered those ancient graves of prehistoric organic structures, transformed into coal and oil, were more precious to laboring humanity than the excavations of ancient Egypt, Syria, Arabia, and Greece. These latter have revealed to man the glories of past civilizations, and they have an inestimable value. But the excavations which have brought to the terrestrial surface the carbon stored up in the scrapped machines which many æons ago were storing up available energy for a future civilization have even a greater value for the destiny of mankind. Their existence is a prophecy of what this future civilization promises. We have every reason to hope that it will be more glorious than any civilization which the world has ever seen. The countless primordial machines of nature, energized by our central star ever since terrestrial life began, would have accomplished nothing if they had not taught man how to employ their methods of operation and their products of available energy for the accomplishment of greater achievements than any which were possible without such methods. But they have taught him, and man has taken his lessons from nature ever since the light of reason became the guiding light of his life. One of the earliest evidences of these lessons is in Job's epic:

"But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee.

"Or speak to the earth, and it shall teach thee; and the fishes of the sea shall declare unto thee."

Job knew that the language of nature is an inexhaustible source of understanding; that man must learn it, and that to those who know its meaning it will reveal counsel and understanding.

MACHINES INVENTED BY MAN

An open-minded and unprejudiced interpretation of the language of nature is the primary object of science. It leads to an understanding which gives us glimpses of the eternal truth, and truth makes us free. This freedom is a deliverance not only from the burdens of ignorance, but also from the burdens of physical labor to which man was condemned when God said to Adam:

"In the sweat of thy face shalt thou eat bread, till thou return unto the ground." As soon as man understood the language of nature, addressed to him by her operations of the cosmic engine, he began to evolve the structure of the steam-engine. In this invention we see a glimpse of the eternal truth which enabled man to free himself not only from the errors of the belief in a *perpetuum mobile,* but also from some of the hardships of physical labors. The inventor planted the seed of hope in the soul of man that some day he would work out his salvation from the burdens of Adam's original sin; that hope is stronger to-day than ever before.

The invention of the steam-engine gave man a crude copy only of the cosmic engine. The mind of man, and his awkward hand, can never do more than make a crude copy of nature's subtle ways. The energy of the flame under the boiler of the engine is a morsel of the solar energy stored up in the carbon of nature's scrapped machines—wood, coal, and oil. The flame is a tiny terrestrial offspring of the solar flame of the cosmic engine. The duty assigned to it by the inventor is the same as that of the solar-energy stream when it lifts on high the water vapors of the terrestrial oceans. Expansions and condensations perform similar functions in one as in the other. The comparison could be carried farther for the purpose of pointing out in greater detail the resemblance between the engine invented by man and its cosmic prototype. But enough has been said to trace the steam-engine and its operations to their celestial origin, the cosmic engine. Remember that and you will speak with reverence of the heaven-born steam-engine and its operations.

The steam-engine is the earliest source of the man-invented power which propels the material progress of our modern civilization. Let us stop for a moment and glance at the speed of this progress. In the beginning of the nineteenth century there were barely half a dozen steam-engines in the United States; to-day there are hundreds of thousands. The gas-engine, the offspring of the steam-engine, was born less than seventy years ago, but already there are over twenty millions of them carrying comfort and joy to the American home. The steam-engine and its offspring, the gas-engine, have called into existence other machines to aid them in supplying the moving power to our civilization.

The mission of the cosmic engine is to supply energy to the life processes in the animal and vegetable kingdoms; similarly the mission of the steam-engine, and of its progeny, the gas-engine, is to supply the power of action to countless other machines invented by man for the purpose of guiding the progress of human society. Among these creations

of man's inventive genius the electrical machines occupy a place of honor. These machines, like those which supply them with the power of action, are also of celestial origin. The observing eye of Franklin deciphered the message of nature's thundering voice whenever the dazzling lightning pierced its fiery path from cloud to cloud, or from cloud to earth. The deciphered message disclosed to him the secret of the irresistible power of moving electricity. The disclosure of this secret guided the genius of man to the invention of the electrical machines, the offspring of the heavenly lightning. Moving matter and moving electricity were thus harnessed into the service of man. The harness in each case is a machine which has its origin in the heavens above. Each is a gift from heaven presented to man as a reward for his diligent study of the language of nature. Moving matter in the steam-engine and in its offspring, the gas-engine, and moving electricity in the electrical machines, supply the propelling force to our modern civilization. The energy of their motion feeds upon the energy morsels which solar radiation brought from heaven to earth, and which the earth stored up as coal and oil in the guarded depths of her bosom. These stored-up treasures waited millions of years until nature's lessons taught man how to use them. It is unthinkable that man, aided by these heaven-born machines, and by the celestial energy which drives them, and guided by the hand of loving nature, should use all these heavenly gifts for the purpose of creating a civilization which will fill the soul of mankind with sordid materialism. Even the blackest pessimist should revolt against so gloomy a picture of modern progress.

Modern civilization is called Machine Civilization, because the name connotes its most obvious physical characteristics. The name was invented and it is used always by writers who have an ill-concealed contempt for the "machine" and for the civilization which it has produced. Machine civilization has, it is true, reached its highest development in this country, and we are, therefore, accused of sordid materialism, of a worship of the machine. It is the worship of a heathen idol, our European critics tell us, and they hold our scientists and engineers responsible for the spread of this heathen worship.

Let us assume that this worship exists, but why is it a worship of heathen idols? Look at the pious peasant, kneeling by the roadside to pray before the wooden image of Christ crucified. It is not the wood and the paint of the image, but the spirit of Christ, which he worships—the spirit which brings him closer to God and assures him that he is the child of a loving creator. It is not the material machine and its material service, but the spirit behind them which the scientists and the engineers worship. This spirit has brought them closer to the bosom of mother nature whence it was revealed; a revelation which assures them that nature loves them and will guide them in their efforts to contribute to the evolution of a higher civilization, if they will but learn to understand her language. The machine is the visible evidence of the close union between man and the spirit of the eternal truth which guides the subtle hand of nature.

This is the spirit which inspired Galileo, Newton, Faraday, and other patient students of the language of nature. They laid the foundation of the machine civilization, to the superstructure of which this country has contributed so much. "Yes," say our European critics, "you have contributed much to the super-

structure, but what contributions have you made to its foundation? You make the machine, but you make no discoveries in abstract science; the useful attracts you, the abstract has no charm for your utilitarian mind." The answer to this charge is obvious. Franklin made a great discovery when his kite brought the lightning to earth and showed us that lightning is a motion of electricity carrying with it an irresistible power. Franklin had a practical mind, but he never hesitated to turn his thoughts to abstract problems of science. Benjamin Thompson, a practical Yankee engineer, was the first to show by experiment that heat is a form of energy obtainable from other forms of energy. The method suggested by his experiments was employed in the first demonstration that a given quantity of heat corresponds to a definite quantity of mechanical work. Thompson's practical turn of mind did not prevent him from thinking effectively about one of the most abstract scientific problems of his time. Joseph Henry discovered the momentum of moving electricity, a discovery which taught the world how to make an induction coil, thus aiding the physicists of our generation in such epoch-making discoveries as those of electrical waves and X-rays. William Draper's discoveries contributed a lion's share to the science of radiation when, eighty years ago, this great science was still in its infancy. Josiah Willard Gibbs of Yale discovered a new science, the science of Physical Chemistry. He is often called the Newton of this science. It was the solution of so abstract and novel a problem in science that not even Gibbs's most learned colleagues at Yale of fifty years ago understood its full meaning; the learned German professors needed over fifteen years to discover its great importance. There was not a single utilitarian thought in this historic essay entitled "The Equilibrium of Heterogeneous Substances." To-day it is the foundation of one of the most beautiful among modern sciences; it has revolutionized chemical philosophy. Michelson, a graduate of the U. S. Naval Academy at Annapolis, and an engineer by training, gave to the world the first accurate determination of the velocity of light. He also demonstrated that this velocity does not change with respect to the observer when both the observer and the source of light are moving together through space. These experimental achievements certainly dealt with one of the most abstract problems in science. They were the foundation upon which Einstein's philosophy built the wonderful structure of Relativity. This list of American discoverers could be considerably extended; it covers a part of the physical sciences only and does not include the American achievements in abstract sciences during the last forty years. But the above list of contributors alone should convince even the most pessimistic critic that America has contributed a very creditable share to the world of abstract science. It might have perhaps contributed even more, if it had devoted more attention to problems of abstract science and less to concrete problems the solution of which leads to the birth of a new machine. But the rapid growth of the United States demanded this; it needed sorely the aid of machines.

Procedure

BY JAMES B. CONNOLLY

Author of "Out of Gloucester," etc.

MARDEN glanced at the calendar above the chart-table. He tapped a date thereon with his pencil, the day on which they would be back to their naval base—if all went well.

A pleasant thought—to be getting back home after a submarine cruise. It was instructive—submarine service, a necessary experience to the young officer who would round out his professional training; and also, of course, there was the extra pay, an important item to a young married naval officer with no outside source of income. Yet it was a relieving thought that soon he would have it behind him.

Marden left his chart-table for another peek through the periscope; what he saw again was the open sea, his own and the three other subs of the flotilla steaming in line abreast of the mother ship.

The mother ship had survived from a class designed by a shore-going motor-car genius for the Big War emergency; and she looked it—a wall-sided contraption with a silhouette like a jigsaw puzzle. Merely to have to look at her was a pain to Marden's seagoing eyes.

The mother ship was rolling down her high slab sides to the slow swell, a swell that Marden did not like the look of. Too long, too sluggish, altogether too oily-looking it was; not a fleck of white water in a league of it. Wind soon to come or wind recently gone by was what such a swell meant; and as no wind to speak of had been met with since putting out from Panama Bay, wind soon to come it must be.

Marden came back to his chart-table, wishing he knew where he was. Submarines manœuvring offshore have to depend on the mother ship for their position; but for two whole days now the sky had been too cloudy for a shot at the sun, and the two nights in between hadn't furnished enough light for even a squint at some worth-while star; and so, to Mason's inquiry as to their position, Marden could only guess that they were off the Mexican coast with their Gulf of California rendezvous somewhere northeasterly.

Mason was the other commissioned officer of the submarine. He was an ensign, two years out of Annapolis, age twenty-four. Marden was a junior lieutenant, age twenty-nine. Submarines are peculiarly the business of young men. The oldest man in the crew was a bosun's mate named Laughlin. He was forty-five.

From Mason in the conning-tower came down word that it looked like some kind of a storm approaching. Officers in the submarine service do not run much to fuss and feathers. Marden was in dungarees and he was also bareheaded. He donned his officer's cap, his sole symbol of authority, and ascended the ladder to see about the storm.

There was no doubt of a coming storm; a tropic hurricane most likely. The heavens had gone black, the air was beginning to smell like something decaying.

The wind came, plenty of it; and rain, truly tropical rain; rain so nearly solid