Technocracy Study Course

TECHNOCRACY STUDY COURSE

AN OUTLINE OF THOSE ELEMENTS
OF SCIENCE AND TECHNOLOGY
ESSENTIAL TO AN UNDERSTANDING
OF OUR SOCIAL MECHANISM

AN ANALYSIS OF THE PRICE SYSTEM

TECHNOCRACY'S SOCIAL SYNTHESIS

For Members of Technocracy Inc.

TECHNOCRACY

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Technocracy

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Technocracy points out that this Continent has the natural resources, the physical equipment, and the trained personnel to produce and distribute an abundance.

Technocracy finds that the production and distribution of an abundance of physical wealth on a Continental scale for the use of all Continental citizens can only be accomplished by a Continental technological control, a governance of function, a Technate.

Technocracy declares that this Continent has a rendezvous with Destiny; that this Continent must decide between Abundance and Chaos within the next few years. Technocracy realizes that this decision must be made by a mass movement of North Americans trained and self-disciplined, capable of operating a technological mechanism of production and distribution on the Continent when the present Price System becomes impotent to operate. Technocracy Inc. is notifying every intelligent and courageous North American that his future tomorrow rests on what he does today. Technocracy offers the specifications and the blueprints of Continental physical operations for the production of abundance for every citizen.

Preface

Numerous groups of people are requesting information about Technocracy, and in many places study groups have been formed for the purpose of studying Technocracy and its underlying principles. The following outline lessons are designed to serve as a guide for study groups which are now organized and ready to proceed.

Technocracy is dealing with social phenomena in the widest sense of the word; this includes not only actions of human beings, but also everything which directly or indirectly affects their actions. Consequently, the studies of Technocracy embrace practically the whole field of science and industry. Biology, climate, natural resources, and industrial equipment all enter into the social picture; and no one can expect to have any understanding of our present social problems without having at least a panoramic view of the basic relations of these essential elements of the picture. All things on the earth are composed of matter and therefore require a knowledge of chemistry. These things move, and in so doing involve energy. An understanding of these relationships requires a knowledge of physics. Industrial equipment, as well as the substances of which living organisms are composed, are derived from the earth. This requires a knowledge of geology and earth processes. Man is himself an organism, and derives his food from other organisms. Hence, a knowledge of biology is necessitated.

The purpose of this Study Course is not to give any person a comprehensive knowledge of science and technology, but rather to present an outline of the essential elements of these various fields, as they pertain to the social problem, in a unified picture. Neither are these lessons a textbook. They are, instead, a guide to study. The materials to be studied are to a great extent already very well written in various standard and authentic references and texts in the fields of science.

At the end of each lesson there is cited a series of references. If one is sincerely interested in learning what Technocracy is about we do not know any other way that this can be achieved than by mastering the basic material contained in these references, or its equivalent from other sources.

The scope of materials in this course of studies is so broad that it is very doubtful that any group will have among its members a single person competent to discuss all topics. It is quite probable, however, that there may be individual members who are engineers, physicians, and people with training in other technical branches. The procedure therefore recommended for conducting the course is that of the seminar method—each member of the group is a student, and none is the teacher. Under this method there should be a permanent presiding officer, but discussion leaders should be chosen from among the group, with topics assigned on the basis of making the best uses of the talent afforded by the group. Thus, for the matter and energy discussions, use should be made of members with training in physics, chemistry, or engineering. For the biological discussions use should be made of physicians or people having training in biology. For the mineral resources people with a knowledge of geology should be the preferred leaders.

The above suggestions are offered only as guides. If special talent in the various fields should not be available, then any suitable leader can direct the discussion, using the outline and references as sources of information. The important thing is to get a comprehensive view of the problem as a whole, rather than of its parts as unrelated scraps of knowledge.

Lesson 1

AN INTRODUCTION TO SCIENCE

We wish it were possible for us to have a friendly chat with each student at the beginning of this Study Course, in order that we might impart to him something of the ‘feeling’ of science before he receives portions of its substance. Since a conversation is out of the question, we are offering this informal discussion, addressed to the student, as the next best thing.

Persons have previously come to Technocracy for one or more of many reasons, such as entertainment, instruction, etc. Some have come from a sense of duty which compels their to supporting that in which they honestly believe, and others have come out of sheer curiosity. We are well aware that the type of material presented in the general lectures you have heard, or in our literature, has not been adequate, either in form or substance, to afford a full understanding of what our work is. For those interested in learning more, this course of study is necessary. It means just that—study; and you should be warned that it will not be great deal of fun. Many of you will be entering the field of science for the first time.

The immediate activity of Technocracy directs itself towards two general ends. There is the analytical purpose which inquires into fundamental relations among the various parts of a Price economy, and which discloses the reasons for the collapse of such a System in any civilization that converts energy at a high rate. There is also the synthetic purpose that designs a control which will successfully operate just such a high energy civilization. Please do not think of the analytic aspect of Technocracy as the destructive aspect, for there is nothing destructive about it. It does not destroy the Price

System. The Price System destroys itself. Nor do we particularly like the antonym of 'destructive.' The word 'constructive' has been bandied about so much by leaders of the present system that it begins to have an odor all its own. We shall not, however, study either of these sides of Technocracy; not at once, anyway. We shall study, not Technocracy, as such, but the soil in which its roots are spread—science itself. It is appropriate for you to ask, at the outset of your course, what is this thing called science? How does it differ from something that is not science?

1.1 A Fact

Though there are a number of definitions current in dictionaries and writings of various kinds, we prefer to treat the matter at greater length. Perhaps there will be a definition, of sorts, later. We want you to have, at the end of this discussion, a fairly clear answer to your questions; a fairly clear idea of what is meant by a scientific mind, a scientific viewpoint, and a scientific approach to a problem. We shall commence by investigating the meaning of a very common word—the word 'fact'. That has a familiar sound. You have all been using it all your lives, and yet if you were to ask two people picked at random for the meaning of the term, you would get rather dissimilar explanations. To a scientist, 'fact' has a very specific and a very rigid meaning.

Please remember this definition, in essence if not in exact words. It is important serving as it does as the starting point of your studies. A fact is a close agreement of a series of observations of the same phenomenon.

Let us consider this for a while. We find a strip of steel and undertake a determination of it's length. The investigator lays a scale parallel to the unknown length and measures it. He reads the scale at, say, 10.0 centimeters, but he does not accept as a fact the probability that the strip is 10 centimeters long. He repeats the measurement taking care that his work is well done; that no errors that he might have formerly have overlooked affect the result. Possibly he uses a more accurate scale, one with a vernier[1], and let us say he reads the length to be 10.0 centimeters. In such a simple measurement as that of linear distance to one or two decimal places, probably two observations would be an extensive enough series to establish the fact that the length is

[1] A small movable scale that slides along a main scale; the small scale is calibrated to indicate fractional divisions of the main scale.

so many centimeters, but if accuracy to the fifth or sixth place were required our scientist would employ instruments more refined than the simple scale and undoubtedly he would make more than two determinations.

The most probable value for the velocity of light is 2.99796×10^{10} centimeters per second, which is, as you know, something over 186,000 miles per second. I do not know, and could not possibly guess, of how many observations this fact is the result. Likely many hundred. Once an apparatus is set up, successive, determinations can be made rather quickly.

In the definition just given, the word ‘observation’ is used in a broad sense. It means, of course, direct observation by our various sense organs, and it includes observations through an interpreter, as it were. In many cases the phenomena we are examining lie outside the field of our direct perception, and we then must devise ways of causing them to produce effects which lie within that field. For example: We are directly aware of electro-magnetic radiation having any wave length between approximately 0.4 and 0.8 micron. (A micron is one 10,000 of a centimeter.) We see this as light. We observe radiation shorter than 0.4 micron, that is, ultra violet light, or even X-rays, much shorter yet, by exposing to the radiation a special photographic plate protected against ordinary light. How do we observe radiation with the wave length of 3/4 mile, which is unrecordable by photographic processes? That particular wave length is in the range of marine signals, and we could detect it on a ship’s wireless.

We have said a fact is a close agreement of a series of observations. Now, what about those ‘facts’ that cannot in any manner be observed by man; those that, because of their remote or occult character, not only lie outside the field of his perception but refuse to exhibit themselves even through his most ingenious apparatus? It is implicit in our definition that there are no such facts. If and whatever such remote things are, they are not facts.

One more point, and we shall be finished with our definition. It is a sine qua non of scientific work that all observations must be susceptible to confirmation. They must be so carried out that they may be repeated at will, or, if they are not repeatable, must have such a nature that you and I can ourselves substantiate them if we care to do the requisite work. We make a careful distinction, you see, between verifiable and non-verifiable observations because from the former come facts, while from the latter comewell what? Many devious and wonderful things we shall not scrutinize in this Study Course. We assure you none of them is within the scope of science. Science is built upon facts as we now understand them. Science is, indeed, nothing more than a system of facts and principles elaborated from facts. It is indispensable, therefore, that we check the verifiability of observations before we accept them as a valid basis for fact.

Suppose we came upon a document signed by a dozen names and properly notarized. The document states that the undersigned have just returned from the planet Venus, where they erected a monument to Colonel Stoopnagle. We would have the perfect agreement of a series of observations of an event, and the statement cannot by any means be disproved. But even non-scientists would be apt to reject this as a fact.

If you are now offended by such a puerile illustration, here is another nearer home. Slightly more than a hundred years ago there was published a book purporting to be a translation from engravings on a number of gold plates, or tablets, dug out of a hill near Palmyra, New York. After the translation was made the plates were buried in another secret place. At the beginning of this book, preceding the translated text, appears the written testimony of eight men, saying that each of them had seen and handled the plates, that the plates were heavy, had the appearance of gold, and were covered with a curious inscription. These men were all devout Christians, and they called upon their God to bear witness, so that, all in all, the testimony is a very impressive document indeed. Clearly, the existence of the gold tablets cannot be reestablished today, since they have disappeared. Therefore their existence is not a fact, even though more than a hundred thousand people believe that it is. Only when, and if, the plates reappear, as all Mormons expect them to do some day, and are placed in a museum accessible to all of us, only then will their existence become a fact.

Assuming you have never visited Sydney, Australia, how do you know that there is a city by that name? You may have heard people mention it, or seen the name on maps, but perhaps something is being put over on you; perhaps it is all a great hoax. When Napoleon’s chief spy, Karl Schulmeister, was working himself high in the ranks of the Austrian secret service, he received almost daily a copy of a Parisian newspaper. He said an agent of his smuggled it across the border. Naturally, the Austrians got a lot of information about conditions in France. The truth was that the newspaper was printed solely for Schulmeister and the Austrian generals, and each edition consisted of only one copy. It was all false, all exactly what Napoleon wanted his enemies to know. Might it not be the same with Sydney? The reason each of you believes in the existence of this place is because you know that knowledge is the kind that can be verified. You know many persons must have checked its reality by going there. You know that if worst came to worst you could go there yourself. This, then, is a fact, one which like all facts of science, can be reestablished by anyone.

The student of science in our schools has laboratory courses in which he actually does check the work of others in simple experiments. This is done partly to develop his manual dexterity in that sort of thing, but mostly to drive into his head the knowledge that all observations may be so checked.

1.2 Defining Words

About all we have done so far in this discussion is to give you a definition, and to explain exactly what was meant by it. Why this insistence on exact meaning? We promised to tell you about science in general, and then proceed to split hairs about something so small as would surely make little difference in the composite whole. This brings us to another point. A scientist always knows exactly what he is talking about. That sounds like a boast, but it is really quite the opposite. It is just that a scientist pays attention to the exact definition of terms; he should never use a term beyond it's definition, and he should never use an undefined term at all. Many, quarreling with me on that last, will say one must somewhere use undefined terms. But we have a way out of that difficulty which will be indicated in a moment. Now, contrast a rigidly defined term with the expressions used in fields other than science–in finance, in politics, law, etc.

Suppose you were reading an article on economics and came upon the word 'price', as you undoubtedly would do many times a page. Now everybody is credited with knowing the meaning of 'price', but you, being a particularly inquiring individual, insist on exact definition. You would discover that almost every economist, when he bothers to elucidate his terms at all, attaching to the word 'price' a different meaning. Some define it as the measure of the ratio of the scarcity of money to the scarcity of any commodity. Others make no mention of scarcity whatever. Still others introduce psychological and social factors. Invariably you will find that a definition when given is followed by great amounts of explanatory and qualifying material. This means the definition represents what is in the author's mind, not what is in the minds of all users of the word. For example: The Encyclopedia Britannica starts off by regretting there is no exact meaning for the word, and presently works into the definition, 'Price is value expressed in terms of money.' Then comes the qualifying material which says, in effect, this does not mean values are determined independently of or prior to the determination of their prices, or that values of goods and money are determined separately. Some sort of an exchange is necessary, after which the values thus determined appear in the guise of money prices.

We are also told that the abstract notion of exchange value is a generalization of the simple idea of price. One who finds this less clear than he hoped would naturally try to discover what is meant by value, since price is expressed in terms of it. He would discover there are three conceptions of value: exchange value, subjective value, and imputed price. He would read the opinion that 'value is the greatest philosophical achievement of the 19th century' but nowhere would he find a statement of what it is. He would be gratified to learn there exists, however, if not an exact meaning, at least a theory of values, a theory that requires consideration of the following points: What is the nature of value? What are the fundamental values, and how are they to be classified? How may we determine the relative values of things, and what is the ultimate standard of value? Are values subjective or objective? What is the relation of values to things or of value to existence and reality?

Let us go no further into the matter of price, for it does not appear necessary to labor the point that a term whose meaning has not been specified by general agreement among men is unsuited for the rigorous transmission of intelligence from man to man. In this connection, however, we shall take up another little problem. A hunter is standing near a large tree, and a squirrel is hanging onto the opposite side of the tree. The hunter now moves in a circle completely around the tree until he regains his starting position, but at the same time the squirrel also moves around the tree in the same direction and in such a manner as it always faces the man, and as the tree is always between it and him. Now, the problem is this: Does the hunter go around the squirrel? The correct answer is not 'yes,' and it is not 'no.' The correct reply requires an exact definition of the verb, 'go around.' If we define 'go around' as meaning that the hunter is first south, then west, then north, then east, and finally south of the squirrel, he very obviously does go around it. But if we agree that 'go around' shall mean first opposite the squirrel's belly, then it's right side, then it's back, then it's left side, the answer is just as definitely 'no.' Here, again, we see the necessity for exact definition. It is inimical to the integrity of our thinking to use words loosely. Lack of careful definition sires more illegitimate offspring, widely varying sports that take the form of controversies, debates, arguments, than a whole countryside of rabbit farms. Many problems outside science would vanish into thin air if definition were exact.

Before we leave the subject, let us ask if anyone can define a term used in connection with measuring the strip of steel–the word ‘centimeter.’ How long is a centimeter? It is useless to say it is the 100th part of a meter; that, in effect, is saying it is twice one-half centimeter. One merely asks: ‘How long is a meter? Is there possible an exact definition of length not in terms of other units of length?’ Yes. In the International Bureau of Standards near Paris is a certain bar of metal–one only. It is an alloy of, I think, platinum and iridium. On this bar are two marks, and a centimeter is defined as one one-hundredth the distance between these two marks when the bar is at 0^{o} Centigrade. This is an example of the prosaic, matter-of-course way scientists have of going about things. If they cannot define a term in terms of other terms, they define it in terms of an object or system of objects in the external world. That is how we avoid using undefined terms. We trust the distinction between a definition and a fact is clear. You will have many of both in your studies.

A definition is an agreement, wholly arbitrary in character, among men; while a fact is an agreement among investigations carried out by men.

It is a definition that a centimeter is one one-hundredth the distance between certain marks on a certain bar at a certain temperature. It is a fact that a particular strip of steel is 10 centimeters long.

1.3 The Postulates

So far we have been talking about fairly fundamental things. Just how fundamental, you may ask, and is there anything more fundamental? Let us see if we can go deeper yet. Let us try to strike the very foundations of science. Science is a fair palace of lofty dimensions. Does it rise out of the massive earth rock itself, or is it erected upon sand and apt to crumble utterly should the unshored plain ever shift? You see, even if we fail to take you to the heights of science—an excursion that would occupy several hundred lifetimesat least we start you at the bottom. So let us descend toward that bottom to see if we can at any depth discard the relatively fundamental and deal with the absolutely fundamental. We have used the quality of agreement to describe the intrinsic character of both facts and definitions. There are in science agreements other than those of fact or definition. These are called postulates, and it is the postulates of science, three in number, that are the foundations of science. Now, a postulate is a curious mixture. It partakes of the nature of a fact in that it is a statement of fact, but differs from a fact in that the observations supporting it are not confirmable. A postulate partakes of the nature of a definition in that it is an agreement among men, but it differs from a definition in that it concerns no trivial matter of nomenclature, and in that it is certainly not arbitrary. A definition, as we know, is a mere shortcut in the language. Power is defined as the time rate of doing work. Obviously, we could go through all scientific literature, cross out the word 'power,' substitute the phrase 'time rate of doing work,' and entirely eliminate a definition from the vast amount of material the mind must handle. Definitions which can be done away with thus easily cannot be per se the fundamental things we seek. But there is no more essential, however complex, manner of stating a postulate. And there are no already existing propositions from which it may be deduced.

The first postulate states that the external world actually is. In other words, a chair, a pencil, a city, the mountains, rivers, oceans, continents really do exist. We can at once go to work on them without having to establish their existence.

The second postulate states that nature is uniform. This means we do not have to flounder about in a world wherein a sack of flour suddenly transforms itself into a fish, and that into an automobile, and that into an oil well. The second postulate is our protection against chaos.

The third postulate states that there are symbols in the 'mind' which stand for events and things in the external world. The total sum of all such symbols in all minds, after eliminating duplicates, would be the sum total of that kind of knowledge for us; and the sum total of all things and events meant by these symbols, provided the symbols should ever become complete in number, would constitute the entire physical world. This means, in effect, that the mind itself is uniform. Mathematicians will note that the third postulate establishes a one-to-one correspondence between all that is in our minds and all that is in the external world. A corollary of this is that there is nothing in all the world that has the priori quality of being unknowable. (In this paragraph the word 'mind' has been used in it's conventional sense. Later in the course we shall consider 'mind' from a somewhat different and highly interesting point of view.)

We shall not discuss the postulates further for the reason that a scientist has nothing whatever to say about them. Every scientist is agreed that so long as he shall live, he shall not ever question these postulates, nor require any proof thereof. They are the rules of his game, and he is no more concerned with rules of other games than a bridge player is about baseball rules. Is science built on a firm foundation? Yes. It stands, properly ordered and rock solid, upon the enduring base of its postulates. Take note too that science is forever impregnable against attack originating outside its postulates. The criticism of meta-physicians, of philosophers, of mystics, are categorically absurd; are invalidated at their very source by so originating. And bear in mind that it does not become you as scientists to discuss questions of ultimate truth, nor ultimate reality, nor anything else ultimate. as novelists or theologians if you like but not as scientists.

1.4 Science

Now, in a paper that purports to introduce you very informally to the field of science, why has no mention been made any of the sciences themselves, if only that you may know what they are about? We have not spoken of heat, sound, electricity, hydraulics, etc., which are branches of physics, nor of zoology, cytology, embryology, etc., branches of biology, nor chemistry and it’s branches. Why not? Simply because there are no sciences. There is only one science. It makes little difference what you call it. Call it the science of existence, or the science of the world, or just plain science. It is only very elementary phenomena we can identify as belonging exclusively to one or another of the name-labels that a hundred or so years ago were thought to distinguish one science from another. When we reach phenomena of any complexity—and you need not be told most of the world is very, very complex—we find the facts of one name-label mixing with those of another to such an extent as it is mere sophistry to think they should be treated separately.

Suppose we bring together two substances, carbon dioxide and water. Nothing much happens, as you know from your experience with charged water. Bring them together on the leaf of a plant in the presence of chlorophyll, and still nothing much happens. But allow sunlight to fall on the leaf, and these two simple substances will be synthesized into additional plant tissue, cellulose. Here we have light, chemistry and botany all in one reaction.

Consider deep ray therapy where advantage is taken of the fact that ma-

[2] The passage of high-frequency electric current, used, for example, to stop bleeding during surgery.

lignant tumor cells have three to four times the electrical condenser capacity of benign tumor cells. Here we have electricity, short-wave radiation, and human pathology becoming one problem. Diathermy[2] and radio surgery are other examples of the connection between medicine and what were once called extra-human phenomena.

Consider photopheresis, where a particle of gold or selenium or sulphur suspended in a strong stream of light moving towards the source of the light, even though that be directly above the particle. Thus we establish a liaison between light and that elusive thing, gravitation.

Consider the photolytic cell where an electrode of lead and one of copper oxide are immersed in a solution of lead nitrate. No current flows in the dark, but if light is allowed to strike the inner face of the copper oxide electrode a strong although not a steady current is produced. Here we have chemistry, electricity, and light functioning together. The wedding of biology and chemistry is expressed in the word biochemistry. If you undertake the study of chemistry you will reach something called physical chemistry, which might just as well be called chemical physics. The chlorophyll of plants mentioned a moment ago and the hemoglobin of your blood have very similar chemical structures. Your blood contains the same salts as sea water and in virtually the same proportions, not so much the sea of today as that ancient Cambrian sea that existed before ever there were warm-blooded animals. Do you see that there can be no frontiers within science; that there is, indeed, only one science?

1.4.1 Scientific Prediction

The two aspects of Technocracy, analytic and synthetic, which have formed the subject matter of lectures you have heard in the past, have already been pointed out. This would not be an effectual preface if we failed to show that these two aspects are characteristic of the whole field of science. The collecting of facts of all available kinds, by carefully repeated observations in all parts of the world by all types of interpreting apparatus, is clearly of an analytical nature. What do we do with these facts as they are collected? Is our work finished when we make a report in the literature and neatly file it on a library shelf? The high-energy civilization about us should demonstrate to anyone that this is not so. Facts are powerful tools in our hands, continually in use. They are good tools; but if you will again consider the definition you will see that no fact is absolutely certain, having been established by inductive methods. Fifty observations may have agreed very closely, but we cannot say positively that therefore the next fifty will so agree. We can say only that it is probable that they will. Thus does the great store of facts in the literature serve as a basis for what is most probable.

The mechanism of scientific progress is this: We start with any phenomenon we care to, from a simple electrical effect in the laboratory to a high-speed Diesel engine. We say, 'On the basis of what we have observed, such and such a modification will probably produce such and such a result.' Then it is tried if the probability is great enough. Sometimes it works and sometimes not. But out of the times it does work comes our intricate civilization with all it's marvelous technical accomplishments.

Science is in a dynamic sense, essentially a method of prediction. It has been defined as being the method of the determination of the most probable.

In tossing a coin, how does one know how many times heads will turn up? How does an insurance company know how many people will die next year? How does a geologist know where to drill for oil? How does the designer of a building determine how many elevators will be required? How does the weather bureau predict what the weather will be tomorrow? How can the astronomers predict to within a second an eclipse of the sun 150 years hence?

These are all illustrations of scientific predictions. Some of these predictions, as you well know, are more exact than others, but they are all based on the same fundamental principles of reasoning from the basic facts. When more facts are known, more accurate predictions can be made. That is what is meant by the most probable; not that by this method one knows exactly what will happen, but by it's use he can determine more nearly what will happen than by any other method.

But machines must be operated in accordance with their design. If you wish to speed up your automobile, you must press the accelerator pedal. Into this problem enter no abstract considerations whatever, such as, is it ethical to speed up an auto this way, or is this the best of all possible ways of doing it? The machine is built simply to accelerate in response to this one operation. This is a useful lesson to digest. No machine, no group of machines may be properly operated except as specified by their design. America’s idle factories, her wanton destruction of food supplies while her citizens remain undernourished are results of trying to operate a system by other criteria.

1.5 Engineering

Just a word or two about engineering. It is a frequently used term and some slight explanation of it should be offered. In the light of what has been said you can see that a scientific laboratory is not always a single building on a college campus. More often the dimensions of a laboratory coincide with the boundaries of a city or a nation. Suppose you have the problem of transporting a liter of sulphuric acid from one side of the room to the other. The best solution would be pick the bottle up and carry it across. It is very simple. Suppose, however you are confronted with the same problem on a somewhat larger scale. You receive a 10,000 gallon tank car of sulphuric acid on a railroad siding, and want to use the acid on the second floor of your plant. Now you must consider a number of things that did not enter into the smaller problem. What material will you install to convey the acid? What motive power will you use to propel it? Where will your storage tanks be located? Finally, do you buy in large enough quantities to warrant the erection of a sulphuric acid manufacturing plant on your own premises?

This is the engineering side of chemistry. On the basis of established facts, the solution that is probably the best must be found for each question. Similarly with other scientific work. Laboratory electricity is the production of electrical energy in a voltaic cell. Electrical engineering is the production of electrical energy by a waterfall, and the transportation of it a hundred miles at a hundred thousand volts.

Please recognize that we are still within the field of science, and remember no frontiers are set up anywhere in this field. There is only one science, and there is no essential difference between science and engineering. The stoking of a Bunsen burner, the stoking of a boiler, the ‘stoking’ of the people of a nation, are all one problem.

1.6 Summary

Since we are now actually to begin studies in this field, let us recapitulate the several pieces of equipment we have for the job.

First of all, there are five senses through which the external world is perceptible to us.

Next, we have a mind to reflect upon what is perceived. But it is now a critical mind, unwilling to accept knowledge until inquiry is made into the sources thereof. Let us indicate here, and let us emphasize the incomparable quality of that mind which is able to entertain something that it neither believes nor disbelieves, something upon which it withholds judgment until the source-observations have been verified, or their verifiability affirmed. This critical mind is aware of the uselessness of thought unless thought be clothed in exact terms. With this mind a simple experiment performed with the hands and viewed with the eyes weighs heavily, while the testament of however many men concerning nonconfirmable observations, even though that testimony be preserved between the finely tooled covers of a rare book, weighs much, much more lightly than a feather. We are continually aware that science is more than a dry catalog of facts; it is a dynamic and powerful tool before which all problems shall someday yield.

This, then, is the equipage we carry as we approach the physical world, that actual, uniform world our postulates give us. I think we should not find it burdensome.

Lesson 2

MATTER

The earth and everything upon it is composed of matter. Matter occurs in three principle physical states–solids, liquids, and gases. Examples of solids are rocks, wood, ice. Examples of liquids are water, gasoline, alcohol. Examples of gases are air, illuminating gas, water vapor or steam.

Molecules The smallest particle of any pure substance, such as water, iron or salt, which can exist without that substance changing its physical properties, is called a molecule. Thus, water is made up of millions of water molecules, each of which is, so far as we know, exactly like every other water molecule. These molecules are much too small to be seen by even the most powerful microscope. There are ways of measuring them quite accurately, however, as to weight and size.

Change of Physical State Matter can be changed from one physical state to another. Thus, by the application of heat, water can be changed from its solid state, ice, to its liquid state, water; and by further heating, to its gaseous state, water vapor. In a similar manner air, which is normally gaseous, by cooling and compression, can be converted into liquid air, and this by still further cooling, can be frozen solid.

2.1 Elements

There are compound substances and simple substances, or elements. Common salt, a compound substance, for instance, can be separated by electrical means into two substances—the metal element, sodium; and the poisonous gas element, chlorine. Water, in like manner, can be resolved into two constituent gases, the elements oxygen and hydrogen. Marble, similarly, can be divided into the elements carbon, calcium, and oxygen.

All of those last named substances are characterized by the fact they cannot be further subdivided. They are called chemical elements. Chemical elements are the building materials of which everything else on earth is composed.

There are only 92 chemical elements. Several of these are relatively common in everyday life. Among the better known elements are iron, aluminum, copper, tin, lead, zinc, silver, gold, platinum, oxygen, carbon, sulphur, hydrogen, nitrogen, chlorine, iodine and nickel.

Some of the elements are exceedingly rare, and have been obtained only in extremely minute traces. Other elements are very common.

Estimates based upon the averaging of thousands of chemical analysis show the upper 10 miles of the earth's crust to be composed of the following elements in approximately the percentages given.

The striking thing about this table is that by far the greater part of the materials comprising the surface of the earth is composed of only five or six chemical elements. Most of the familiar metals that are used daily occur in amounts of less than one-tenth of one percent of the surface rocks of the earth.

Atoms The smallest particle of a chemical element is called an atom.

Chemical Compounds A chemical compound is a substance of definite chemical composition, which is composed of two or more elements. Over 750,000 different chemical compounds are known.

Examples of chemical compounds are water (oxygen and hydrogen, abbreviated H_2O), salt (sodium and chlorine, abbreviated NaCl), and sugar (carbon, hydrogen and oxygen, abbreviated $C_{12}H_{22}O_{11}$).

Mixtures Most substances are not simple chemical compounds, but are rather mixtures or aggregates of various compounds. Wood, for instance, is composed of carbon, hydrogen, oxygen, and a small amount of mineral matter. Wood, however, has not a definite chemical composition, and is not

Table 2.1: Chemical Composition of the Outer 10 miles of the Earth:

Element	Amounts in Percent by Weight
Oxygen	46.59
Silicon	27.72
Aluminum	8.13
Iron	5.01
Calcium	3.63
Sodium	2.85
Potassium	2.28
Magnesium	2.09
Titanium	0.63
Phosphorus	0.13
Hydrogen	0.13
Manganese	0.10
Subtotal	99.29
All remaining 80 elements	0.71
Total, 92 elements	100.00

Table Data: Clarke, The Data of Geochemistry

a single chemical compound. Likewise the air is a mixture chiefly of two gases, oxygen and nitrogen.

2.2 Chemical Changes

A chemical change involves a change of chemical composition. The grinding of wood into sawdust is a mechanical change which does not affect the chemical composition of the wood; burning of wood, however, is a chemical change.

The burning of wood consists in combining the oxygen from the air with substances composing the wood. Without the added oxygen, wood will not burn. After the wood is burned, if all the gases given off are collected and analyzed, it is found that they consist of carbon dioxide and water vapor. A slight residue of mineral matter in the form of ash remains. Hence, wood+oxygen == water+carbon dioxide+ash

In a similar manner the burning of gasoline in an automobile results in water vapor and carbon dioxide. This can be seen by watching the steam issue from the exhaust pipes on a cold day.

gasoline+oxygen == water vapor+carbon dioxide

When chemical elements combine in such a manner as to form more complex substances from simple ones the process is called combination. The reverse process of breaking more complex substances down to form simpler ones is called decomposition.

Example of Combination:

$$4Fe + 3O_2 == 2Fe_2O_2$$

iron oxygen iron oxide

Example of Decomposition:

$$2H_2O == 2H_2 + O_2$$

water hydrogen oxygen

Indestructibility of Matter In all chemical changes of whatever sort it has been found that if all the materials are carefully weighed both before and after the change, while allowing nothing to escape in the meantime, the weight of the materials taking part in the change before the reaction will be exactly equal to the weight of the products resulting from the reaction. This is true not only for the whole, but is also true for each individual element.

2.3 Summary

All events on the face of the earth involve in one way or another the movement or change in the relative configuration of matter. The rains and the flow of water, the winds, the growth of plants and animals, as well as the operation of automobiles and factories are part of the movement of matter. Matter moves from one place to another, from one physical state to another, or from one chemical combination to another, but in all these processes the individual atoms are not destroyed; they are merely being continuously reshuffled.

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Lesson 3

UNITS OF MEASUREMENT

In the preceding lesson we have discussed some of the properties of matter. We have noted that all the materials on the surface of the earth are composed of various combinations of the 92 chemical elements. We have observed that matter can be transformed from one physical state to another or from one chemical combination to another, and that such processes are occurring continuously on the earth, but that in none of them is the matter destroyed; it is merely reshuffled.

Our next problem is to investigate the circumstances under which matter moves, or undergoes physical and chemical transformations. Before we can do this, however, it is necessary that we become familiar with our systems of measurement.

3.1 Mass, Length and Time

The three quantities that we deal with most frequently and hence are obliged to measure most often are mass, length and time.

The mass of a body is that property which gives it weight, or, more generally, causes it to have inertia or a resistance to any change of motion. A body has weight because of the attraction of gravity upon its mass. If gravity were reduced by one-half, the weight of a body, as measured by a spring balance, would also be reduced by one-half. For example, the weight of a given body on the earth is less by about one part in 200 at the equator than at the poles. Its mass, however, remains the same.

If gravity were zero, bodies would weigh nothing at all. Suppose under

this condition that we had two hollow spheres identical in outward appearance, one filled with air and the other with lead. Neither would have any weight. How could we tell them apart? All we would need to do would be to shake them. The lead ball would feel ‘heavy’ and the one filled with air ‘light’. If we kicked the lead ball it would break our foot just as readily as if it had weight because it would still have the same inertia and resistance to change of motion, and hence the same mass.

Length is an already familiar concept which needs no explanation.

Time is measured in terms of the motion of some material system which is changing at a uniform speed. Mechanically oscillating systems like pendulums and tuning forks are the basis for most of our time measurements and form the control mechanisms of our clocks. Our master clock is the rotating earth whose hands are the stars which appear to go around the earth with uniform angular velocity once per sidereal or stellar day.

3.2 Units of Measurement

The way we measure a quantity of any kind is to compare it with another quantity of the same kind which we employ as a unit of measurement. Thus we measure a mass by determining how many times greater it is than some standard mass; we measure a length by the number of multiples it contains of a standard length; and an interval of time by the multiples of some standard time interval. The choice of these standards is entirely arbitrary but if confusion is to be avoided two conditions must be rigidly observed:

1. Different people performing a measurement of the same thing must use standards which either are the same or else the two standards must have a known ratio to each other.

2. The other condition necessary is that the standard of measurement must not change.

Unintelligibility results when either of these conditions is violated. The first type of unintelligibility would result if one man measured all of his lengths with a measuring stick of one length and another man used a measuring stick of a different length without the two ever having been compared. The second type of confusion would result if we attempted to measure lengths with a rubber band without specifying the tautness with which it is to be stretched.

In the early days almost endless confusion in the units of measurement existed due to the failure to observe one or both of these conditions. All sorts of units of measurement sprang up spontaneously and were in general use. Such units of length as that of a barley corn, the breadth of a hand, and the length of King John's foot were not uncommon. Thus, it was customary to employ as units things like a barley corn which bear a single name but may vary considerably in size. The type of confusion that this could cause is illustrated by an apple dealer who advertised his apples at 25 cents per bucketful. He had on display several large size buckets filled with apples but when filling the customer's order he used a bucket much smaller in size; yet no one could say that he had not received a 'bucketful' of apples. The trick of course lies in the fact that there is no standard size of 'bucket'. The same liberties with a bushel measure would have landed our merchant in jail.

To eliminate this kind of confusion governments have had to establish standards of measurement so that today in the whole world only two systems of units are extensively used. These are the Metric system and the English system. It is to be hoped that soon there will be one only.

3.2.1 The Metric System

The Metric system was established by the French government immediately following the French Revolution. For the standard of length a bar composed of an alloy of platinum and iridium was constructed and is preserved at the Bureau of Weights and Measures near Paris. Near each end of this bar there are engraved transversely three fine parallel lines. The distance from the middle line at one end of the bar to the middle line at the other end when the bar is at the temperature of melting ice is defined to be 1 meter. This is the prototype of all the other meters in the world. Exact copies of this bar made by direct comparison have been constructed and distributed to the governments of the various countries of the world. In the United States this duplicate is kept at the Bureau of Standards in Washington. From this, additional copies are made and are obtained by manufacturers of tapes, meter sticks and other measuring scales from which these latter are graduated. Hence the meter stick that one uses in his laboratory is probably not more than three or four times removed from the original bar in Paris.

For units smaller and larger than a meter a decimal system of graduation is employed. Thus the centimeter is a hundredth part of a meter; a millimeter is a thousandth part of a meter; and a micron is a millionth part of a meter.

Going up the scale a kilometer is 1,000 meters. There are other multiples and submultiples but the above are the ones most extensively used.

Similarly, the unit of mass is that of a platinum weight kept at the Bureau of Weights and Measures and defined to have a mass of 1 kilogram. The gram is accordingly a thousandth part of the mass of this standard kilogram. Just as in the case of the meter, duplicates of the standard kilogram in Paris have been constructed and distributed to the various countries.

While both the meter and the kilogram are entirely arbitrary, when they were constructed an effort was made to satisfy two useful conditions. The original meter was constructed as accurately as possible to be one ten-millionth part of the distance along the earth's surface from the equator to the pole. This result of course was not achieved exactly so that by later measurements the earth's quadrant is found to be 10,000,856 meters. Still, however, we can say with considerable exactness that the circumference of the earth is 40,000 kilometers.

In a similar manner an attempt was made to have the mass of 1 gram be that of a cubic centimeter of water at 4^{o} Centigrade (the temperature at which water has its greatest density). Hence the kilogram is very nearly the mass of 1,000 cubic centimeters of water and for most purposes the mass of water can be taken to be 1 gram per cubic centimeter.

The unit of time is the second which is defined to be 1/86,400th part of a mean solar day or 1/86,164.09th of a stellar day. In addition to the second we have the familiar multiples, minutes and hours.

3.2.2 The English System

The unit of length in the English system of measurement is the distance between the centers of two transverse lines in two gold plugs in a bronze bar deposited at the Office of the Exchequer, when the bar is at a temperature of of 62 degrees Fahrenheit. This distance is the standard yard. A foot is defined to be one-third of a yard, and an inch one thirty-sixth of a yard.

The unit of mass in the English system is that of a certain piece of platinum marked ‘P. S., 1844, 1 lb.’, which is deposited at the same place as the standard yard. This is known as the standard pound avoirdupois.

The unit of time in the English system is the same as in the Metric.

3.2.3 Conversion Between Metric And English Units

These two systems of measurement are inter-convertible when we know the magnitude of a standard in one system as measured in terms of the corresponding standard unit of the other system. By very exact measurement it has been established that

1 meter = 1.093614 yards
= 3.28084 feet
= 39.37011 inches
1 yard = 0.914399 meter
1 foot = 30.4800 centimeters
1 inch = 2.5400 centimeters
1 kilogram = 2.20462 pounds
1 pound = 453.592 grams

Except for purposes of exact measurement one will rarely need to employ more than the first three or four of the figures of the above conversion factors. Hence, approximately,

1 meter = 39.37 inches
1 kilogram = 2.20 pounds

3.3 Derived Units

The foregoing units of mass, length, and time are said to be fundamental. By means of these we can also measure a large number of other secondary quantities which are accordingly said to be derived quantities. For example, area is a derived quantity depending upon length, and a rational unit of area is a square whose length of side is the unit of length. Similarly, the unit of volume is a cube whose length of side is equal to the unit of length.

Less obvious derived units are speed and velocity, and acceleration which are terms used in describing the motion of a body. When a body moves its speed is the ratio of the distance it travels in a small interval of time to the time required. It is thus measurable in terms of a length divided by a time, and so requires no other units than those of length and time already defined. We may express a speed in meters per second, kilometers per hour, yards per minute, or any other convenient length and time units.

The velocity of a moving body at a given instant is its speed in a particular direction. For example, two bodies having the same speeds, but one moving eastward and the other northward are said to have different velocities. A point on the rim of a flywheel rotating uniformly describes a circular path at uniform speed, but since its direction of motion is changing continuously, its velocity is also changing continuously.

Quantities like velocity which have both magnitudes and directions are called vector quantities.

The acceleration of a body is its rate of change of velocity. When the body is moving in a straight line this becomes equal to its rate of change of speed. For example, when an automobile is moving along a straight road, if it increases its speed it is said to be positively accelerated; if it decreases its speed the acceleration is negative. We commonly speak of the foot pedal for the gasoline feed as the 'accelerator'. The brake, however, is just as truly an accelerator. If an automobile is increasing its speed uniformly at the rate of a mile per hour each second, we say that the acceleration is 1 mile per hour per second. This is clearly equal to 1.47 feet per second for each second, or to 47.7 centimeters per second for each second. From this we see that an acceleration involves the measurement of a distance, and the division of this by two measured time intervals. If we make these two time intervals the same, then acceleration becomes: (distance/time)/time, or distance/$(\text{time})^2$. Thus an acceleration of one cm/sec^2 means that the body is changing its velocity by an amount of 1 centimeter per second during each second.

Acceleration, like velocity, is also a vector quantity. Its direction is that of the change of velocity. What we mean by this can be shown by representing the velocity by an arrow whose length is proportional to the speed, and whose direction is that of the motion. Suppose the motion is curvilinear with the speed continuously varying. The velocity vectors represented by arrows for successive times will have different directions and lengths. If we take two of these arrows representing the motion at two successive times only a short interval apart and place them with their feathered ends at the same point, their tips will not coincide. Now if we place a small arrow with its tail at the tip of the first arrow, and its tip at the tip of the second, this small arrow will represent, both in magnitude and direction, the change of velocity during the time interval considered. The average acceleration during that time is the ratio of the change of velocity to the time required to affect the change, and has the same direction as the change of the velocity.

If this type of construction is tried with respect to uniform circular motion, it will be seen immediately that the velocity is continuously changing in a direction toward the center of the circle. Consequently the acceleration is also toward the center of the circle. If the motion is not at constant speed this will not be true.

3.3.1 Force

We come now to the concept of force. Our primitive experience with force is by means of our muscular sense of pushing and pulling. We can render this measurable by means of the stretch of springs, or the pull of gravity on bodies of known mass. A dynamic method of measuring force is by means of the acceleration of a body of known mass. For example, suppose we construct a small car with as nearly as possible frictionless bearings, and run it on a straight horizontal track. Suppose that we pull the car by means of a stretched spring or rubber band kept at constant tension. The car will accelerate uniformly in the direction of the pull. Now, if we load the car with different masses and repeat the experiment, for the same tension of the spring the acceleration will be greater when the load is decreased, and less when it is increased. If we keep the load constant and employ different tensions on the spring, the acceleration will increase as the tension is increased.

Quantitatively, after correcting for any residual friction, what we learn in this manner is that the acceleration of the car is directly proportional to the tension of the spring, or to the applied force, and inversely proportional to the total mass of the car and its contents.

By experiments similar to this it has been shown quite generally and very exactly that this is true for any kind of a body undergoing any kind of an acceleration: The acceleration is proportional to the applied force (or resultant of the applied forces where several act simultaneously), and inversely proportional to the mass. The direction of the acceleration is the same as that of the applied force. Conversely, the applied force has the direction of the acceleration and its magnitude is proportional to the acceleration and to the mass of the body accelerated.

Since we already know how to measure acceleration in terms of length and time, and how to measure mass, this last fact enables us to measure forces in terms of masses and accelerations.

In this manner we define a unit of force to be that force which causes a unit of mass to move with a unit of acceleration.

In the Metric system, using the gram, the centimeter, and the second as our units of mass, length and time, respectively, the unit of force is that amount of force which will cause 1 gram of mass to move with an acceleration of 1 centimeter per second for each second the force is applied. This amount of force we call a dyne.

At the latitude of New York the pull of gravity on a mass is such that if it is free to move with no other forces acting upon it, starting from rest it will move in the direction of the force exerted by gravity with a uniform acceleration of 980 cm/sec, or 32.2 ft/sec^2. Since this is true for a mass of any size, then for a 1-gram mass the force must be 980 dynes, since the acceleration in this case is 980 times as great as that produced by a force of 1 dyne. For a mass of m grams the total force would have to he m times as great as for one gram in order to have the same acceleration.

We can obtain an approximate idea of the size of a dyne if we consider that a nickel coin (5 cents) has a mass of 5 grams. The force exerted by gravity upon this is therefore 5 x 980, or 4,900 dynes. Thus, approximately, a dyne is one five-thousandths part of the force exerted by gravity upon a nickel.

Engineers frequently use another method of measuring force. They take as their unit of force the pull of gravity on a unit of mass, or its weight. The difficulty with this is that gravity is not the same at different parts of the earth. It varies with elevation above sea level, with the latitude, and with certain other random disturbing factors. Hence, to be exact we must define what the value of gravity is to be. This is commonly taken to be 980.665 cm/sec^2 which is approximately the mean value of gravity at sea level and latitude 45^0. The pull of this standard gravity on a 1-pound mass is a pound weight. The corresponding pull of gravity on a kilogram of mass is a kilogram weight. Since a pound is 453.592 grams, and the attraction of this standard gravity on a gram mass is 980.665 dynes, it follows that a pound weight is the product of these two figures, or 444,820 dynes.

3.3.2 Work

When a force acts upon a body and causes it to move, work is said to be done. A unit of work is defined to be that which is done when a unit of force causes its point of application to move a unit of distance in the direction in which the force acts. In the English system when the unit of length is the foot and the unit of force the pound, the unit of work is the foot-pound. Hence the total number of foot-pounds of work done by a given force is the product of the force in pounds by the distance its point of application is moved in the direction of action of the force, in feet. The simplest example is afforded by the lifting of a weight. It requires 1 foot-pound of work to lift a 1-pound mass a height of 1 foot.

In the Metric system when a force of 1 dyne causes its point of application to move in the direction of the force a distance of 1 centimeter, the work performed is defined to be 1 erg. Like the dyne, the erg is a very small quantity so that a larger unit of work is useful. We obtain such a larger unit if we arbitrarily define 10,000,000 ergs to be one joule.

The conversion factors between the English and the Metric units of work are easily obtained by computing in both systems of units the work done in lifting a pound mass a height of 1 foot against standard gravity. In the English units this is simply 1 foot-pound. In Metric units the force, as we have already noted, is 444,820 dynes, and the distance 30.4800 centimeters. The work is therefore the product of these quantities, or 13,558,200 ergs or 1.35582 joules. Inversely, a joule is 0.73756 foot-pounds, or the amount of work required to lift a pound mass a height of 8.84 inches, and an erg is one ten-millionth of this amount of work.

3.3.3 Power

Power is the time rate of doing work. In the Metric system, when work is performed at the rate of 1 joule per second, the power is defined to be 1 watt. Work at the rate of 1,000 joules per second is a thousand watts or a kilowatt. In the English system, the unit of work is the horsepower. This unit was defined by James Watt, who attempted to determine the rate at which a draft horse could do work so that he could use this for rating the power of his steam engines. The result he achieved was that 1 horsepower is a rate of doing work of 33,000 foot-pounds per minute, or 550 foot-pounds per second. Since a kilowatt is 1,000 joules per second, or 737.56 foot-pounds per second, it follows that this is equal to 1.3410 horsepower, or that a horsepower is equal to 745.70 watts, or 0.74570 kilowatts.

A kilowatt-hour is the amount of work done by a kilowatt of power in 1 hour; a horsepower-hour is the amount of work done by a horsepower in 1 hour. These are accordingly units of work, the kilowatt-hour being 1,000 joules per second for 3,600 seconds, or 3,600,000 joules, and the horsepower-hour 33,000 foot-pounds per minute for 60 minutes or 1,980,000 foot-pounds. Also 1 kilowatt-hour bears to a horsepower-hour the same ratio as the kilo-

continued on the next page

watt to the horsepower.

3.3.4 Conversion Factors

While all of the conversions between the foregoing units of measurement are easily derived in the manner we have just seen, it is convenient to have at hand a table of conversion factors for ready reference. Such a table containing the factors that are most often used is given below. In this let us introduce for the first time here a system of notation for writing numbers that is widely used by scientists and engineers but may not be familiar to some of the readers. When dealing with very large numbers or very small decimal fractions it is bothersome and confusing to have to write out numbers like 2,684,500; which is the number of joules in a horsepower-hour, or 0.000,000,737,56 which is the number of foot-pounds in an erg. We may note that

$$2{,}684{,}500 = 2.6845\text{x}1{,}000{,}000 = 2.6845\text{x}10^6,$$

and similarly, that

$$0.00000073756 = 7.3756\text{x}1/10{,}000{,}000 = 7.3756\text{x}10^{-7}.$$

Any number, large or small, can be written in this manner which has many advantages over the longhand method. In the following table this system will be used for the very large and very small numbers.

In this table the factors are expressed to five or six significant figures. For all ordinary calculations only the first three or four figures are needed and all the rest can be dropped or set equal to zero. They are only needed when very exact measurements have been made and hence very exact calculations required. Most measurements are not more accurate than 1 part in 1,000, and calculation more exact than this is meaningless for such measurements.

Table of Conversion Factors

Imperial	Metric
Standard Gravity:	
gravity	= 980.665 cm./sec^2
	= 32.174 ft./sec^2
Force:	
1 dyne	= 1 gm. cm/sec^2

Table of Conversion Factors (continued)

Imperial	Metric
	= 2.2481×10^{-6} pound weight
1 pound weight	= 4.4482×10^{5} dynes
<u>Work:</u>	
1 erg	= 1 dyne-centimeter
	= 1×10^{-7} joules
1 joule	= 1×10^{7} ergs
	= 0.73756 foot-pound
1 foot-pound	= 1.35582 joules
	= 1.35582×10^{7} ergs
1 kilowatt-hour	= 3.6000×10^{6} joules
	= 2.6552×10^{6} foot-pounds
	= 1.3410 horsepower-hours
1 horsepower-hour	= 1.9800×10^{6} foot-pounds
	= 2.6845×10^{6} joules
	= 0.7457 kilowatt-hour
	= 745.7 watt-hours
<u>Power:</u>	
1 watt	= 1 joule per second
	= 0.001 kilowatt
	= 1×10^{7} ergs per second
	= 0.73756 foot-pound per second
	= 1.3410×10^{3} horsepower
1 kilowatt	= 1×10^{10} ergs per second
	= 1,000 joules per second
	= 737.56 foot-pounds per second
	= 1.3410 horsepower
1 horsepower	= 550 foot-pounds per second
	= 33,000 foot-pounds per minute
	= 0.7456 kilowatt
	= 745.7 watts
1 foot-pound/sec.	= 1.35582 watts
	= 1.8182×10^{3} horsepower

3.4 Examples of Work and Power

Lest we lose sight of the fundamental simplicity of the concepts of work and power and become confused by the array of conversion factors, let us consider a few simple examples.

(1) THE POWER IN CLIMBING STAIRS. How much power does a man generate in climbing stairs, for example? At an average rate of walking a man will climb a height of about 36 feet per minute. In so doing he is lifting his own weight. Suppose he weighs 150 pounds. Then his rate of doing work is 5,400 foot-pounds per minute, or 90 foot-pounds per second. Since a horsepower is 550 foot-pounds per second, and a watt is 0.73756 foot-pounds per second, it follows that he generates 0.164 horsepower, or 122 watts. This is in round numbers one-sixth of a horsepower. If he ran up the stairs six times as fast he would generate 1 horsepower. Running at such a rate, however, could only be maintained for a few seconds. Even walking at the above rate can be continued by few people for more than a few minutes. For example, few people can walk steadily, without stopping for rest, from the ground to the top of the Washington Monument which is over 500 feet high. Climbing for 8 hours would give an average rate much smaller than that of walking up a few flights of stairs, and so would reduce correspondingly the average power generated.

(2) LIFTING PACKAGES. Suppose a workman lifts packages from the ground to trucks 4 feet above the ground. In 6 hours he lifts 65 tons. How much work does he do, and what is the average power? The work done is 520,000 foot-pounds. This is 0.26 horsepower-hour, or 0.20 kilowatt-hour. The power averaged is 24 foot-pounds per second which is 3.3 watts, or 0.044 horsepower.

(3) PUMPING WATER. A man pumps water for 10 hours with a hand-pump. In that time he raises 14,000 gallons a height of 10 feet. What is his work and his average power? A gallon of water weighs 8.337 pounds. The work done is therefore 1,170,000 foot-pounds, or 0.44 kilowatt-hour. The average power is 44 watts.

(4) SHOVELING LOOSE DIRT. In 10 hours a man shovels 25 tons of loose dirt over a wall 5 feet 3 inches high. What is the work and average power?

The work done is 262,500 foot-pounds, or 0.10 kilowatt-hour. The power is 7.28 foot-pounds per second, or 10 watts.

(5) CARRYING A HOD[1]. In 6 hours a man carrying a hod raises 17 tons of plaster 12 feet. The work is 408,000 foot-pounds, or 0.154 kilowatt-hour. The average power is 18.8 foot-pounds per second, or 25 watts.

(6) PUSHING A WHEELBARROW. A man with a wheelbarrow raises 51 tons of concrete a height of 3 feet in 10 hours. The work done is 306,000 foot-pounds, or 0.115 kilowatt-hour. The average power is 8.5 foot-pounds per second, or 11.5 watts.

These examples give one a very good idea of how much useful work a man can do in a day. In work of these kinds we have counted only the useful work accomplished. In each case the work actually done was greater than that computed. In the wheelbarrow problem the total work performed should include the repeated lifting of both the wheelbarrow and the man himself. If the wheelbarrow load was 200 pounds and the man and empty wheelbarrow weighed another 200 pounds, then it is clear that the actual work performed would be twice that computed, not allowing for the friction of the wheelbarrow.

A kilowatt-hour of work will lift a ton weight a quarter of a mile high; a kilowatt of power will do this in one hour of time. Working under the most efficient conditions, it would take at least 13 men to do the same amount of work in the same time. Under less efficient conditions the number of men would be correspondingly greater.

This same kilowatt-hour is the unit for which we pay our monthly electric light bill at a domestic rate of 5—7 cents each. Commercial rates on electric power range from a few mills to a cent or so per kilowatt-hour. A workman whose pay is less than 25 cents per hour is working at practically starvation wages. The conjunction of these two facts is of rather obvious social significance.

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[1] A trough carried over the shoulder for transporting loads, as of bricks or mortar

Lesson 4

ENERGY

Now that we have become familiar with what is meant by work, let us consider a related but more general physical quantity, namely, energy. If anything has the capacity to perform work, it is said to possess energy. The amount of its energy is measurable in terms of the amount of work it can perform. Hence, energy is measurable in units of work—ergs, joules, or foot-pounds.

4.1 Potential Energy

A stretched spring does work when it contracts. A weight upon a table does work in being lowered to the floor. Work is done when a piece of iron is drawn to a magnet. Hence, each of those systems possesses energy which is manifested by the amount of work that it can do in changing from one position or configuration to another. Energy of this kind obviously is associated with the position or configuration of a material system and is known as potential energy.

Chemical systems, such as gunpowder, gasoline, coal, dry cells, storage batteries and the like, have the capacity of performing work when they undergo chemical changes. This too is potential energy and is dependent upon the internal configuration of the atoms with respect to each other.

4.2 Kinetic Energy

Imagine a flywheel mounted upon a horizontal axle with as nearly as possible frictionless bearings, and a cord with a suspended weight attached so as to

wind around the axle. First, wind the system up and then release it. As the weight falls, the flywheel will continuously increase its angular velocity. When the weight reaches its lowest position, the cord will begin to wind around the axle in the opposite direction, and the weight will be raised. At the same time the flywheel will be slowed down, coming finally to rest when the weight has regained its original elevation. Then, if not arrested, the process will repeat itself in the opposite direction.

In the initial and the final stages of this experiment the system possesses potential energy—that of the raised weight. In the middle stage, when the weight has reached its lowest position, its potential energy is a minimum. Still, however, the system has a capacity to do work as demonstrated by its lifting the weight back to its original elevation. This energy obviously resides in the motion of the flywheel. In fact, if we set a flywheel in motion by any method and then bring it to rest by having it lift a weight, we find that the number of joules of work it can do is proportional to the square of its angular velocity (number of revolutions per unit time).

In the same manner we can bring an automobile coasting on a level road to rest by making it lift a weight. The work it can do is found to be proportional to its mass and the square of its speed. In fact, the work it could do in this manner is:

$$\text{work} = \frac{\text{mass} \times \text{speed}^2}{2}$$

Bodies, therefore, possess energy in virtue of their state of motion. Work must be performed upon them to set them moving, and must be done by them in coming to rest again. This energy, due to motion, is called kinetic energy.

4.3 Heat

When work is performed on a system, it may not increase either the potential or the kinetic energy of the system. It may be completely dissipated by friction. An automobile or a flywheel can be brought to rest by means of brakes. A weight can be lowered at constant speed if properly braked. In all such cases heat is produced where the friction occurs. On a long grade the brakes of an automobile may become so hot as to burn out. Drills become heated when boring. Tools are heated by grinding.

The conclusion is that when a body loses kinetic or potential energy due to friction heat is always produced. Hence, heat must be a form of energy. Does a given amount of work always produce the same amount of heat? To answer this question we must devise a way to measure heat.

4.3.1 Measurement of Heat

To measure heat we must first distinguish between the temperature of a body and the quantity of heat it contains. Our primitive recognition of temperature is by means of our sense of feel. The quantity of heat a body contains is related both to its temperature and to the size of the body. Thus, a gallon of water contains four times as much heat as a quart of water at the same temperature. How the quantity of heat is related to the temperature can only be determined after we have found how to measure temperature.

4.4 Measurement of Temperature

Our sense of feel is not very reliable for determining temperatures, so we must devise a temperature measuring instrument. This we do by noting that gases, liquids, and solids all change volume as their temperature is changed. Usually, but not in all cases, the volume increases with increase of temperature. In addition to this we have certain invariant points of fixed temperature like that of melting ice, and boiling water at constant pressure.

By means of the expansion of a given material between these fixed temperatures we can measure intermediate temperatures.

We may define the temperatures of melting ice and of boiling water at a pressure of one standard atmosphere (one standard atmosphere is defined to be the pressure exerted by a column of mercury 76.0 centimeters high due to the attraction of standard gravity, or 1.01325×10^6 dynes per square centimeter) to be anything we like, but the choice of these temperatures determines the thermometric scale.

If we let 0° be the temperature of melting ice and 100° that of boiling water, we have the Centigrade scale. If we let 32° be the temperature of melting ice and 212° that of boiling water, we have the Fahrenheit scale.

For the intermediate temperatures our best thermometric substance is hydrogen gas. If we let V_0 be the volume of a given quantity of hydrogen gas at the temperature of melting ice and at a pressure of 1 atmosphere, and V_{100} that of the same gas at the temperature of boiling water and a pressure of

1 atmosphere, then by dividing the difference between these two values into 100 equal parts we have a volume scale for the gas to which we relate the corresponding temperatures. For example, at some unknown temperature the gas has a measured volume V. The temperature in °C. then is:

$$t = \frac{V - V_0}{\frac{V_{100} - V_0}{100}}$$

If V should be one-fourth the difference between V_0 and V_{100}, the temperature would be 25° C.; if one-half, the temperature would be 50° C., etc.

The same procedure is used for the Fahrenheit scale except in this case the interval between freezing and boiling is taken to be 180° instead of 100°, and freezing is defined to be 32°.

The familiar mercury thermometers are handier to use. They are calibrated, however, by temperatures originally established by a hydrogen thermometer.

4.4.1 Absolute Scale of Temperature

There is one more scale of great scientific importance that should be mentioned now because we shall need to make use of it in our next lesson. This is the absolute scale.

It is found by experiment that for each degree Centigrade between 0°C. and 100°C., the volume of hydrogen gas increases by a constant amount of 1/273.2 of its volume at 0°C., V_0. At this same rate of volume change, the volume would decrease to zero at a temperature of -273.2°C., which suggests that this may be the lowest possible temperature obtainable. Elaborate experimentation has demonstrated that this is the case, and temperatures within a fraction of a degree of this amount have been obtained.

It seems reasonable, therefore, to call the lowest possible temperature, the absolute zero of temperature. If we call this 0° absolute, and otherwise use the Centigrade scale, then the melting point of ice becomes 273.2° absolute and the boiling point of water 373.2° absolute.

Conversion factors between the thermometric scales are as follows:

$$1.8^\circ F = 1.0^\circ C$$

$$5^\circ{}_C$$

$$1.0^{\circ}F = \frac{36}{9}$$

We are now in a position to answer the question propounded earlier: How much heat is produced by friction from a given amount of work? To determine

$$x^\circ F = \frac{9}{5} T^\circ C + 32$$

$$x^\circ C = \frac{5}{9}(T^\circ F - 32)$$

$$x^\circ abs = T^\circ C + 273.2$$

4.5 Quantity of Heat

To measure the amount of heat, we require a unit of measurement, whose choice, like that of all other units of measurement, is arbitrary. In the Metric system we take this to be the amount of heat required to raise the temperature of 1 gram of water 1°C. We call this the gram calorie. A kilogram-calorie is 1,000 gram calories, or the heat required to raise the temperature of a kilogram of water 1°C.

In the English system the corresponding unit is the British thermal unit, or therm, defined as the amount of heat required to raise the temperature of 1 pound of water 1°F.

Since the heat required per degree varies slightly with temperature, for very exact measurements we must specify also the temperature at which the measurement is to be made. The most common procedure is to take the mean, or average, values over the range from 0°C. to 100°C. These will be understood to be the values employed here.

By converting °F. to °C. and pounds to grams we can easily determine the conversion factors between the English and Metric units:

1 kilogram calorie = 3.9685 British thermal units
1 British thermal unit = 251.98 gram calories
= 0.25198 kilogram-calories

4.6 Work and Heat

this all we need is a heat insulated vessel filled with water, into which a shaft from the outside extends and terminates in some kind of a brake mechanism. On the external end of the shaft is a pulley around which a cord supporting a weight is wound. The weight falls slowly and heat is generated by the brake inside the vessel. By noting the temperature rise and the quantity of water heated, the number of calories of heat can be computed; by knowing the weight and the distance it descends the amount of work can be computed. Then we know the quantity of heat generated by a known amount of work.

The first experiment of this kind was performed by Joule in England about 1845. Subsequently, numerous such experiments have been performed with great precision. As a result it has been found that a given amount of work always produces the same amount of heat: 4.186 joules of work produce 1 gram calorie of heat; 777.97 foot-pounds of work produce 1 B.T.U. of heat.

Thus, since 4.186 joules are equal approximately to 3.1 foot-pounds, it is clear that a 1-pound weight falling 3.1 feet will produce 1 gram-calorie of heat; if a 1-pound weight falls 778 feet and its energy is converted into heat, the amount of heat will be 1 British thermal unit. Hence, the heat generated by a waterfall 778 feet high would be sufficient to raise the temperature of the water at the foot of the fall 1 degree Fahrenheit. Actually, unless the quantity of water is large, a considerable fraction of this heat will be lost to the surrounding air and by evaporation of the falling water, but the heat generated, counting the above losses, is still 1 British thermal unit per pound of water.

Since friction is never completely eliminated, we see that in all processes involving work, energy in the form of work is continuously dissipated and an equivalent amount of energy in the form of heat is produced.

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Lesson 5

THE LAWS OF THERMODYNAMICS

In the preceding lessons we have already learned that matter on the earth is not destroyed, and that movements and changes of matter involve work or energy. We further learned that there is an exact relation between work and heat; namely, that when a given quantity of work is converted into heat the same amount of heat is always produced.

It was also pointed out in discussing the weight-and-flywheel experiment that if no friction were involved, and hence no heat produced, the loss of potential energy by the falling weight would be completely compensated by the gain in kinetic energy of the flywheel. After the falling weight had reached its lowest point it would be relifted by the flywheel which would slow down and lose kinetic energy as the lifted weight gained potential energy. Furthermore, the gain in potential energy would be exactly equal to the loss in kinetic energy and vice versa.

Hence we arrive at the conclusion that, in any purely mechanical system involving no friction and hence no heat loss, the sum obtained by adding all the potential energies and all the kinetic energies existing simultaneously is a constant.

5.1 The Conservation of Energy

5.1.1 Friction

When there is friction (which in reality involves all cases) heat is produced, and the amount of heat produced is proportional to the loss of kinetic and potential energy by the system. Since heat is a form of energy and 1 gram calorie of heat is equivalent to 4.18 joules of work, if the heat loss be stated in terms of joules instead of calories, it will be found that the energy appearing as heat is exactly equal to the loss of mechanical energy—potential and kinetic—by the system.

5.1.2 Energy of Evaporation

When water boils at a pressure of 1 atmosphere the temperature remains constant at 100˚C. If heat is added at a faster rate the water boils more vigorously but the temperature still remains constant. If this be continued long enough all the water will finally disappear as steam or water vapor. Here we have a case where energy in the form of heat is being added to a system without any increase in temperature of either the water or the vapor, but in which there is a progressive change of water from its liquid to its gaseous state. It follows, therefore, that the energy must be required to effect this change. By careful measurement of the amount of heat required to vaporize a known quantity of water it has been determined that 539.1 gram calories of heat are required to vaporize 1 gram of water at a pressure of 1 atmosphere and 100˚C.

At first thought it might appear that this energy has been lost. If the steam is made to condense back to water again, however, while at 1 atmosphere pressure and 100˚C., it has been found that 539.1 gram calories of heat must be extracted. Thus the heat of evaporation has not been lost but stored in the vapor.

This energy required to produce evaporation serves two purposes:

1. Part of it is required to pull the water molecules apart against their own mutual attractive forces and hence becomes stored as potential energy.
2. Part of it is required to perform the work of vaporization against the atmospheric pressure when 1 gram of liquid water expands into 1 gram

of steam.

Thus we may say that the heat of vaporization is employed to perform two kinds of work, an internal work against cohesive forces, and an external work against atmospheric pressure. When the reverse process occurs this energy is again released in the form of heat.

5.1.3 Chemical Energy

If 2 grams of the gas hydrogen are mixed with 16 grams of the gas oxygen and the mixture ignited by an electric spark while being maintained at a constant pressure of 1 atmosphere, there will be a mild explosion and 18 grams of water vapor at a greatly elevated temperature will result. If this water vapor be cooled down to the temperature of the original mixture (room temperature) it will become 18 grams of liquid water, but to produce this result it will be necessary to subtract 68,300 gram calories of heat. Thus we may write:

$$2H_2 + O_2 = 2H_2O + 2 \times 68,300 \text{cals}$$
$$4 \text{ grams} + 32 \text{ grams} = 36 \text{ grams}$$
$$\text{Hydrogen} + \text{Oxygen} = \text{Liquid Water}$$

It is also possible by means of an electric current to separate liquid water back into its components, hydrogen and oxygen, at room temperature and 1 atmosphere pressure. When this is done we find that the electrical energy required plus the heat that must be added to decompose 18 grams of water is equivalent to 68,300 calories.

While this is only an isolated instance, the same kind of thing is true for all chemical reactions. Some release energy; others require the addition of energy. In all cases, however, if a chemical change when proceeding in one direction releases energy, then an exactly equal amount of energy would have to be supplied if the constituents of the system are ever to be restored to their initial state.

Thus a storage battery releases energy upon being discharged, but the same amount of energy must be supplied if the battery is to be recharged. Coal and wood release energy in the form of heat upon being burned (reacting with oxygen) but this energy was originally supplied by the sun when the components of these fuels were originally combined.

Still other forms of energy are those of light, electricity, magnetism, and sound. Space here does not permit a detailed discussion of all these forms. Enough has already been said to lead one to suspect that energy is interchangeable among all of these and various forms. This is indeed the case.

5.1.4 The First Law of Thermodynamics

If we generalize the facts already noted we arrive at one of the most important conclusions of all science. Let us take any system of matter, and let us cause this to change from some initial state, A, to some final state, B. In this process a definite amount, E, of energy will be released in the process of transition. (If energy is absorbed E will be negative.) Now by any method whatsoever, let us restore the system to its initial state, A. In this case the same amount, E, of energy will have to be restored to the system as was originally released by it. Were this not so it would be possible to obtain more energy, E1, in changing the system from state A to state B than the amount E2 required to restore the system from state B to state A. In this manner a complete cycle would leave us with a surplus of energy which could be used in lifting a weight or in otherwise performing work. This would enable us to build a self-contained, self-acting machine that would operate continuously and perform work, a form of perpetual motion.

On the basis of our experience, however, we have never found it possible to build such a machine, and so we conclude that to do so is impossible. If this be so, then we must also conclude that it is impossible to obtain more energy when any system goes from an initial state, A, to a final state, B, than must be restored to the system in order to change it back from state B to state A.

Consequently, if this be true, it follows that either to create or to destroy energy is impossible. Thus in processes occurring on the earth when a given amount of energy in one form disappears an equal amount always appears in some other form. Energy may change successively from radiant energy to chemical energy to electrical energy to mechanical work and finally to heat, but in none of these processes is any of it lost or destroyed.

It is this indestructibility and non-creatablity of energy that constitutes the First Law of Thermodynamics.

5.2 Reversible and Irreversible Processes

5.2.1 Direction of Energy Transformations

It is not enough, however, to know that in processes occurring on the earth, energy is neither created nor destroyed, or that when an engine performs external work such as lifting a weight, an equivalent amount of energy must have disappeared somewhere else. We must inquire whether energy transformations occur with equal facility in opposite directions, or whether there is a favored direction in which energy transformations tend to occur.

To do this we may begin with simple instances of our everyday experience. If we could build a flywheel that was perfectly frictionless, once started it would turn indefinitely at constant angular velocity. Similarly a frictionless pendulum would swing with undiminished amplitude. In each of these instances the mechanical energy originally supplied would be retained in undiminished amount. In actual practice, however, we have never been able to completely eliminate friction; so the flywheel gradually slows down, and the pendulum swings with steadily diminishing amplitude of swing, both coming finally to rest. In each case the initial energy has been gradually dissipated by the friction into waste low-temperature heat.

Had we tried the reverse process, however, of supplying energy in the form of heat to the bearings of the wheel or pendulum while initially at rest, this energy would never have resulted in the wheels turning or the pendulums beginning to swing. Thus we observe that while there is a spontaneous tendency for mechanical energy to be converted into low-temperature heat, the process does not appear to be reversible.

In a more complicated case we might consider a waterfall such as Niagara. Here the water falls from a height of 167 feet. In falling, the potential energy due to height is converted into heat, and the water at the foot of Niagara is about one-eighth of a degree Centigrade warmer than it was at the top. Thus, the energy of Niagara is being continuously converted into waste heat.

Suppose, however, that a part of this water is made to go through a hydro turbine. Then over 90 percent of this energy is captured by the turbine, which, in turn, converts it into electrical energy. This electrical energy is then used to drive electric motors and drive machinery, to produce light, to heat electric furnaces, or to produce chemical reactions such as charging storage batteries or producing calcium carbide. If it drives an electric motor, friction exists in the motor and in the machines which it drives, and the

$$\Delta S = 0$$

energy is lost as waste heat of the bearings and the air, plus the heat losses in the windings of the motors due to electrical resistance. If it is used for lighting or for an electric furnace, again it produces heat. Light is absorbed and becomes heat. If the energy is used to produce a chemical reaction, such as making calcium carbide, this, when placed in water, reacts to release acetylene gas, which when burned in air, produces heat.

Now if we add to this apparently exceptionless tendency for all other forms of energy to be transformed spontaneously into heat, the further fact that heat always tends spontaneously to flow from regions of higher to those of lower temperature, we obtain the remarkable result that all other forms of available energy tend finally to be degraded into heat at the lowest temperature of the surroundings.

5.2.2 Entropy

Now we can introduce another type of quantity we have not dealt with heretofore. When a quantity of heat, Q, flows into a body at the absolute temperature T, let us agree to call the quantity Q/T the increase in the entropy of the body. If the heat flows out of the body the entropy of the body will, of course, decrease. If a body were heated from a lower temperature, T2, to a higher temperature T1, its entropy would increase, but to obtain the amount we would have to add up all the separate entropies step by step from the lower to the higher temperature. Thus for water, since 1 calorie raises the temperature of 1 gram approximately 1°C. or 1°A., the entropy-increases would be, when the temperature is raised from 273° A. to 278° A., approximately:

$$\Delta S = \frac{1}{274} + \frac{1}{275} + \frac{1}{276} + \frac{1}{277} + \frac{1}{278}$$

where ΔS (read delta S) is the increase in the entropy of 1 gram of water.

Now let us consider the entropy changes that occur in various energy transformations of the kind we have already considered. If we take any frictionless mechanical system such as a pendulum or flywheel at constant temperature no heat will be produced and no heat conduction will occur, consequently the entropy change will be zero for all such systems, and they are said to be isentropic or constant entropy systems.

If, however, friction exists, heat is produced and the entropy increases by an amount

$$\Delta S = Q$$

I

where ΔS is the increase of the entropy of the system, Q the amount of heat generated and T the absolute temperature.

Now let us consider two adjacent bodies, one at an absolute temperature T_1, and the other at T_2, T_1 being higher than T_2. The heat will flow by conduction from the hotter of the two bodies to the colder. Let a small quantity of heat, dQ, flow in this manner from the body at temperature T_1 to that at temperature T_2.

The entropy lost by the hotter body is dQ/T_1; that gained by the colder body is dQ/T_2. The total entropy increase of both bodies together will be the difference between these two entropies,

$$\Delta S = \frac{dQ}{T_2} \quad \frac{dQ}{T_1}$$

Now dQ is the same in both cases, but T_2 is less than T_1. Therefore dQ/T_2 is greater than dQ/T_1. Hence the total entropy change, ΔS, consists in an increase in the entropy of the two bodies taken together.

Thus we see that an idealized frictionless mechanical system involves a zero change of entropy, while any process involving friction, or heat conduction, results in an increase of entropy.

Now let us see if we can find a process that results in a decrease of entropy. A direct conversion of heat into work would be such a process. Suppose we could construct an engine which is self-contained and operated cyclically, that is, one that repeats the same cyclical operation over and over and which does nothing but take heat from a heat reservoir and lift a weight. This is manifestly no contradiction to the First Law of Thermodynamics, because we are not proposing to create energy, but merely to transform already existing energy from heat to work.

If T be the temperature of the engine and the heat reservoir, and if Q be the heat taken in at each complete cycle, then, since the engine returns at the end of each cycle to its initial state, its entropy remains unchanged. The lifting of a weight is an isentropic process. Consequently the only entropy change of the system is manifested by the disappearance of an amount of heat Q at temperature T per cycle. This would correspond to a decrease in the entropy per each cycle by the amount

$$\Delta S = \frac{Q}{T}$$

But no such engine has ever been built. If one could be built it could be made to run on the heat from the ocean or from the ground or the air. It would act both as a refrigerator and as an engine for doing work. Such a machine would not violate the principle of the conservation of energy, but it would still constitute a sort of perpetual motion machine in that it could operate from the heat of, say, the ocean and perform work, which could be transformed by friction back to heat, thereby maintaining the initial supply. This has been called perpetual motion of the second kind.

Our failure to build such an engine leads to the conclusion that to do so is impossible. This conclusion is based entirely upon negative experience and can be upset only by actually producing this kind of perpetual motion.

Another instance of a decrease of entropy would be given if heat flowed from a colder to a hotter body. By reasoning analogous to that employed for heat conduction from a hotter to a colder body, we arrive at the fact that if heat ever flowed from a colder to a hotter body the entropy of the system would decrease, or, the entropy change would be negative. But such a heat flow is contrary to all of our experience. All of our experiences thus far may be summed up by saying that in all processes of whatever kind so far observed, the changes in the entropy involved are such that the total entropy of the whole system either remains constant or increases.

5.2.3 Conversion of Heat into Work

Now if we have a difference of temperature between two heat reservoirs, the higher temperature being T1 and the lower T2, the entropy would increase if heat were allowed to flow directly from the one to the other by conduction. On the other hand, we know it is possible to operate a steam engine between these two different temperatures, using one for the boiler temperature and the other for the condenser.

In this case if an amount of heat Q1 be taken by the engine per cycle from the temperature T1, and Q2 be the heat discharged into the condenser at T2, then Q1- Q2 is equal to the work, W, done by the engine per complete cycle. The maximum possible value of the work, W, is obtained when we consider that the limiting case of the operation—the limit that the engine can approach but never exceed—is given for the case when the entropy change is zero.

For each cycle the entropy lost by the heat reservoir at temperature T1 is Q1/T1, while that gained by the condenser is Q2/T2, the entropy of the engine itself being the same at the completion of each cycle. Then if the total entropy change is to be zero,

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

or

$$Q_2 = Q_1 \frac{T_2}{T_1}$$

Now, since the work, W, done by the engine is equal to the loss of heat, $Q_1 - Q_2$,

$$W = Q_1 - Q_2 = Q_1 - Q_1 \frac{T_2}{T_1}$$

or

$$W = Q_1 \frac{T_1 - T_2}{T_1}$$

Thus the maximum possible fraction of the heat, Q1, taken from the higher temperature reservoir that can be converted into work is given by the fraction $T_1 - T_2/T_1$, which is the highest possible efficiency of the engine.

The nearer the two temperatures are together, the smaller the value of this fraction, becoming zero when the two temperatures become the same. Hence it is impossible to operate any heat engine except when a difference of temperature exists. Under no circumstances can the work produced from a given amount of heat or the efficiency be greater than that given above.

5.2.4 Reversible and Irreversible Processes

Now we come to the concepts of reversible and irreversible processes. A reversible process is in reality an idealization and occurs only in those cases for which the entropy change is zero. All actual cases involve friction or its equivalent and therefore result in an increase of the entropy of the system. Such systems are said to be irreversible and the entropy increase is a measure of their degree of irreversibility.

An irreversible process is characterized by the fact that when once it has occurred, by no process whatsoever can it be undone. For example, if a book is pushed off the desk and falls to the floor its potential energy is changed into heat and the entropy increases. It is physically impossible ever to put the book back on the desk and at the same time to restore everything else to the state it was in before the book originally fell. The book could be lifted back by hand but that would degrade chemically the energy inside the body. It could be hoisted by an electric motor, but that would discharge a battery. So with every other process of replacing the book. It is impossible to put everything involved back to its initial state. In consequence of this fact the universe has experienced a new event and has made a stride forward.

5.2.5 Transformations in an Isolated System

Now let us imagine a system completely isolated from all outside energy transfers, that is to say, that no matter or energy is allowed to enter or escape. For such a system we may imagine a large heat-proof, light-proof, sound-proof room. Let it be stocked with all sorts of physical and chemical apparatus and supplies such as storage batteries, gasoline, oxygen, food supplies, water, electric and gasoline motors, electric or fuel lights, etc. Into this room we will also place a physicist and then seal the door to isolate the system.

Now this isolated universe, as it were, is all equipped to run. Our physicist can have light and food, oxygen to breathe and water to drink. In addition to this he has engines and motors and an energy supply to drive them. To make the problem even more interesting we might even allow him soil and plant seeds so he could grow his own food supply.

What would be the future of this isolated universe? Merely from our everyday experience we would know that the food supply, the free oxygen, and the fuel would all diminish with time. The storage batteries would become discharged; the water would become contaminated; our miniature universe would run down so to speak; and, ultimately, if not rescued, our physicist would die from lack of food, oxygen, or water, and then disintegrate chemically.

Now it is instructive to analyze the problem thermodynamically. The room, by hypothesis, consists of an isolated system. The matter in the system is constant; the energy is constant; but both the matter and the energy are undergoing continuous transformations. If the matter is initially at state A it successively occupies states B, C, D, etc. at successive intervals of time.

Since, from what we have seen, all actual transformations of matter from any given state to the next successive state involve an increase of entropy, we may say that the entropy of the system is continuously increasing. Thus the entropy of state B is greater than that of state A; that of state C is greater than that of state B, etc. This being so, if the room were ever to regain any earlier state such as going from state D to state B, a decrease in entropy would occur. But this, we have seen, is impossible. Consequently we may say that when any isolated system has once occupied and passed through any given state it is physically impossible, by any method whatsoever, for it ever to regain that state.

Consequently the history of any isolated system may be regarded as the record of the changes of the material configurations and states of that system. These changes are however unidirectional and irreversible. Consequently it is a physical impossibility for the history of the system ever to repeat itself.

5.2.6 Unidirectional Nature of Terrestrial History

Now what we have said with regard to the room is equally valid with respect to the earth if we recognize that although it is not an isolated system the changes in the configuration of matter on the earth, such as the erosion of soil, the making of mountains, the burning of coal and oil, and the mining of metals are all typical and characteristic examples of irreversible processes, involving in each case an increase of entropy. Consequently terrestrial history is also unidirectional and irreversible.

In order to repeat the history since the year 1900, for example, we would have to restore to the earth the configuration that it had in the year 1900. We would have to put the organisms back to their 1900 state; we would have to put the coal, the oil, and the metals back into the ground; we would have to restore the eroded soil. But these are things which by no method whatsoever can be done.

5.2.7 The Second Law of Thermodynamics

It is this unidirectional tendency of energy transformations; this fact that all actual physical processes, at least on a macroscopic scale, are irreversible; this fact that no engine operating cyclically can convert heat into work without a difference in temperature existing and then only incompletely; the fact that heat flows only from regions of higher to those of lower temperature;

the tendency for the entropy of a system only to increase with time, that comprises the Second Law of Thermodynamics.

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Lesson 6

ENGINES

In the previous lessons we have found that while energy may be converted from one to another of its forms it is never destroyed. We also found that there is a fundamental tendency for all other forms of energy to change into heat, and for all heat to come to the same temperature. When a difference of temperature exists it is possible to convert heat into work, but if no temperature difference exists no heat can be converted into work even if, literally, oceans of heat exist.

6.1 Definition of an Engine

An engine may be defined as any type of machine which takes energy in any form and converts it into work.

The initial form of the energy converted may be mechanical, as in the case of wind and falling water; it may be chemical, as in the case of coal, oil and wood; it may be electrical, as in driving an electric motor from a power line; or it may be radiant energy, as in the case of using the sun's heat to drive an engine.

An engine which makes the initial conversion of energy into work is called a prime mover. In electric power systems mechanical or heat energy is converted first into work which is used to drive the electric generators. These convert work into electrical energy. The engine which drives the generator in this case is the prime mover. Electric motors converting this electrical energy back into work are not prime movers, but 'secondary movers,' instead.

Table 6.1: Engines

Examples of Engines Converting Mechanical Energy into Work:

Engine	Energy Used
Windmill	Kinetic energy of the wind
Sailing vessel	Kinetic energy of the wind
Water wheel	Potential energy of water

Engines Converting Chemical Energy into Work:

Engine	Energy Used
Steam Engine	Fuel—Coal, oil or wood
(a) Reciprocating type (piston)	
(b) Steam turbines	
Internal combustion engines:	
(a) Natural Gas (Methane) engine	Gas
(b) Gasoline engine	Gasoline
(c) Diesel	Fuel oil

Examples of Engines Converting Electrical Energy into Work:

Engine	Energy Used
Various forms of electric motors	Electrical energy from power lines or from electric batteries

The efficiency of an engine is defined as the ratio of energy converted into work, to the total energy initially supplied.

6.2 Efficiency of Engines

$$\text{Efficiency} = \frac{\text{work output}}{\text{energy input}}$$

Therefore, in order to measure the efficiency of an engine it is necessary to know both the total energy taken during a given time and the work done in that time by the engine.

In the case of a waterfall, the available energy per unit of time is determined by the amount of water passing through the water wheel in that time, and by the height of the fall. Suppose the fall is 100 feet high, and that 990 pounds of water per minute fall through the water wheel. In this case the energy input would be 990 x 100, or 99,000 foot-pounds per minute. Since 33,000 foot-pounds per minute is 1 horsepower, then the input into this wheel would be 3 horsepower.

Suppose the output of the wheel were only 2 horsepower due to frictional losses or to poor design of the wheel. Then the efficiency of this wheel would be:

$$\text{Efficiency} = \frac{2 \text{ h.p.}}{3 \text{ h.p.}} = 66.7 \text{ percent}$$

The maximum efficiency possible in this case would be 100 percent, with an output of 3 horsepower.

Modern hydro-turbine installations such as the 70,000 horsepower units at Niagara Falls have an efficiency of approximately 92 percent. That is, they convert into electrical energy 92 percent of the energy supplied by the water.

6.2.1 Efficiency of Heat Engines

In order to measure the efficiency of a heat engine we have to measure the heat supplied to the engine as well as the engine's output of work. We cannot measure the heat directly, but we can measure the fuel that is used; then we can determine the heat input if we know the amount of heat that is produced by a given amount of fuel.

6.3 Heat Value of Fuel

It was pointed out in section 4 that when certain chemical reactions take place heat is evolved. Also, for the same amount of substances taking part in a given reaction, the same amount of heat is always produced.

Now, the production of heat by the burning of a fuel results from the chemical reaction due to the chemical combination of that fuel with oxygen. Fuel plus oxygen equals waste products plus heat. If the fuel be of a particular grade, then the number of calories of heat produced by burning 1 gram is the same for all the fuel of that grade. The number of gram calories produced by burning 1 gram of the fuel, or the number of British thermal units produced per pound, is called the heat value of that substance.

Heat values are obtained by placing a measured amount of fuel surrounded by compressed oxygen in a gas-tight container. This is placed in a heat insulated vessel of water and the fuel ignited by an electric spark. When the spark occurs the fuel burns and the heat which is released is taken up by the water. The amount of water is known, and the rise of temperature is measured. From this the number of calories or British thermal units is obtained.

Table 6.2: Heat value of Fuels

Fuel	Gram Calories per Gram	British Thermal Units per lb.
Bituminous, low grade	6,000	11,000
Bituminous, high grade	8,000	14,000
Anthracite, low grade	7,000	12,500
Anthracite, high grade	7,500	13,500
Liquid fuel		
Gasoline	11,000	20,000
Fuel oils	10,500	18,500
Wood		
Oak	4,500	8,500
Pine	5,000	9,000

The average consumption of coal by central power stations in the United States in 1938 was at a rate of 1.41 pounds of coal per kilowatt-hour. This was a drop from a rate of 3.39 pounds in 1920. These figures are based upon a heat value of 13,100 British thermal units per pound of coal. At this value 1.41 pounds of coal contain 18,470 British thermal units. Since a kilowatt-hour represents 3,411 British thermal units, the average efficiency for the year 1938 is given by

$$\text{Efficiency} = \frac{\text{work done}}{\text{heat used}} \quad \frac{3{,}411 \text{ B.t.u.}}{18{,}470 \text{ B.t.u.}} = 18.5 \text{ percent}$$

The corresponding figure for 1920 is 7.7 percent.

Table 6.3: Engine efficiencies

Engine	Efficiency
Water wheels	70 to 92%
Steam engines	
(a) Locomotives	5 to 10%
(b) Stationary reciprocating engines	10 to 17%
(c) Steam turbines	15 to 30%
(d) Hartford mercury vapor station	33.1%
(e) Average of all central power stations in U.S. in 1932	17.3%
Internal combustion engines	
(a) Gasoline engine (automobile type)	15 to 28%
(b) Gas engines	25%
(c) Diesel engines	29 to 35%

The above discussion of engines has been presented in some detail not because we are interested in having the reader become an engineer, but because this, it is hoped, will help to clarify the relationship between matter and energy. It was stated at the outset that all the matter on the earth is composed of 92 chemical elements, and that, whether this matter is in the form of living organisms or rocks, its movement involves a degradation of energy.

Engines do not create work or energy; they are instead converters of energy—they convert energy from one form to another.

In our next lesson we shall show that the human body is itself an engine that converts energy into heat and work in strict and exact accordance with the laws of thermodynamics.

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The Story of Energy, Mott-Smith.
A Textbook of Physics, Grimsehl (Vol. II, Heat and Sound, pp. 153-173).
Thermodynamics, Planck.

Lesson 7

THE HUMAN ENGINE

In Lesson 6 we discussed various types of engines, and it was learned that engines do not create energy, but instead merely take energy in a form available for doing work, and convert a part of this into useful work. All of this energy is finally degraded into the unavailable form as waste heat. In the present lesson we wish to focus attention on a very remarkable engine that has not been previously discussed, namely, the human body.

7.1 Calories

A steam engine, as we saw, takes in coal and oxygen, and gives out, as products of combustion, water vapor, carbon dioxide, and cinders. Besides this it produces heat and work in driving the steam engine. In an analogous manner, the human body takes in food and oxygen, and gives out carbon dioxide, water vapor, and waste products. Besides this, heat is produced inside the body, and the body is enabled to do work. Human food is just as much a fuel as is coal or gasoline, or wood. The same kind of tests have been made to determine the heat value of food as were described in Lesson 6, to determine the heat value of coal, gasoline, etc. The apparatus that is used to determine the heat value of fuels is called a calorimeter.

The 'calories' contained in various kinds of food have become a household expression, but few people realize what is meant; what is actually meant is that food of a certain kind has been burned in a calorimeter and the heat produced by one gram of food has been carefully measured and stated in terms of kilogram-calories produced by one gram of food. Hence, the 'calorie'

that one commonly hears spoken of in regard to food is a kilogram-calorie.

7.2 Heat Value of Foods

There are three fundamental kinds of food substances: proteins, carbohydrates, and fats. Chemically, a protein consists of carbon, hydrogen, oxygen, and nitrogen plus a small amount of sulphur and mineral matter. Both carbohydrates and fats are composed of carbon, hydrogen, and oxygen. Examples

Table 7.1: Chemical content of food

Food	Carbon	Hydrogen	Oxygen	Nitrogen
Proteins	52%	7%	23%	16%
Carbohydrates	44.4%	6.2%	49.4%	0%
Fats	76.6%	11.9%	11.5%	0%

(Percentages in the above table are by weight.)

of proteins: White of eggs, curd of milk, and lean meat.
Examples of carbohydrates: Sugar and starch.
Examples of fats: Fat of meats, butter, lard, and olive oil.
Most foods are a mixture of proteins, carbohydrates, and fats.

Table 7.2: Fuel Values of food

Food	Kilogram Calories per gram
Protein	4.1
Carbohydrates	4.1
Fats	9.3

On the average, in temperate climates, out of each 100 grams of food eaten, approximately 16 grams are proteins, 75 grams are carbohydrates, and 9 grams are fat. This food is taken into the body, oxygen in the air is taken in by breathing, and combines chemically inside the body with the food. Energy in the form of heat and work is released.

Food + oxygen == carbon dioxide + water + waste products
+ energy (heat and work)

The heat produced by 100 grams of this average diet would be about 457 kilogram calories, provided all of this were digested.

This provides us with a scientific way of rating human beings; we can rate them by the amount of energy they consume or degrade per day. Men, on the average, consume about 2,800 kilogram-calories per day and women about 2,000.

The average energy consumed per capita per day by all the people in the United States, young and old alike, is about 2,300 kilogram calories.

The significant thing about all this for our purpose is that it is possible to determine exactly how much energy is contained in various kinds of foods, and then after they are eaten to determine how much heat and work they can produce. This latter is accomplished by placing a man in a large heat-tight calorimeter, and measuring very accurately over a given time period the amount of heat given off by his body. At the same time the amount of oxygen he breathes, and the amount of carbon dioxide that he gives off, are also accurately measured. If the person is lying quietly and doing no work, it has been found that the heat given off in a given time is exactly equal to that contained in the food 'burned' or oxidized in that time.

By this manner it is also possible to determine how much work a given amount of food can be made to produce, or the efficiency of the human engine. This is accomplished by having the man turn a crank or pedal a bicycle attached to an instrument called an ergometer. The ergometer measures how much work has been done by the man; the calorimeter at the same time measures the heat given off. In this case it has been found that the energy represented by the heat given off and the work done by the man are exactly equal to the energy contained in the food 'burned' during that time.

7.3 Efficiency of the Human Engine

Remembering that the efficiency of any engine is determined by the ratio of the work done by that engine to the total energy degraded in a given time period, it is now possible to determine the efficiency of the human engine. The maximum efficiency of the human engine has been found to be only about 25 percent. Due to the fact that the human engine, while still alive, never completely shuts down, and therefore never ceases to degrade energy, the efficiency is zero when no outside work is being done; that is to say, when the body is at rest. This basic rate of consuming energy while at rest amounts on the average to 1700 kilogram calories per adult person per day.

When physical work is done the rate of energy consumption very rapidly increases. A strong man doing heavy physical labor can perform approximately 2,000,000 foot-pounds of work in a ten-hour day, or one-tenth of 1 horsepower for a 10-hour day. In order to do this he will require approximately 5,000 kilogram calories per 24 hours.

By way of contrast, work involving little physical activity, such as writing, or various kinds of desk work, involve very little energy expenditure. It has been found that the additional energy required for intense mental work amounts only to about 4 kilogram-calories per hour. In other words the most difficult thinking requires additional energy per hour equal approximately to 1 gram of sugar or to one-half a peanut. Indeed, so small is the amount of energy required to 'think' that a housemaid engaged in sweeping and dusting the study of a college professor would expend as much energy in 3 minutes as the professor would expend in an hour of intensive study.

One frequently hears careless talk about 'nervous' energy, 'mental' energy, 'creative' energy and other such expressions, which imply not only that there are numerous unrelated kinds of energy, but that energy associated with the human body is different from energy as manifested in calorimeters and steam engines. It is also implied that human beings are somehow or other spontaneous sources of work or energy. From what has been shown in this lesson it becomes evident that all such expressions have no basis in fact, and are therefore sheer nonsense. There is only one fundamental energy which, as we defined above, is the capacity to perform physical work.

Engines of any kind are not creators of energy; they are, instead, converters of energy from one form to another in exact accordance with the first and second laws of thermodynamics. The laws of thermodynamics are no respecters of persons, and they hold as fast and rigorously in the case of the human body as they do in man-made engines.

A human body takes the chemical energy from food and converts it into heat and work on a 24-hour basis. Rarely as much as 10 percent of this energy taken in is converted into work. Consequently, in spite of anything we can do, man is a dissipater of energy and it is not possible for him by any amount of work he may do ever to repay the amount of energy that he required in doing that work.

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The Science of Nutrition, Lusk.

Lesson 8

THE FLOW OF ENERGY ON THE EARTH

In the previous lesson we have seen that all movement of matter on the face of the earth involves a corresponding change of energy. We have also seen that while energy may be manifested in various forms, such as heat, chemical energy, potential energy, kinetic energy, etc., and may be changed from one of its various forms to another, none of it is ever lost, but that all of it tends to be dissipated into waste heat. Engines, as we have seen, whether animate or man-made, do not create energy, but merely utilize a supply of available energy for doing work. The available energy used by various engines usually occurs in two forms—mechanical energy as in the case of waterfalls or the wind, and chemical energy, as in the case of fuels and food.

8.1 Energy of Running Water

The end product of all of this energy is waste heat, but until now we have not inquired as to where it came from in the first place. Take the waterfall for example, which is continually dissipating energy. The water in the river was originally derived from rain, and this was in turn evaporated principally from the ocean. Now we have already seen that to evaporate water requires energy. At ordinary temperatures 585 gram calories of heat are required to evaporate 1 gram of water. Since ocean water does evaporate, this heat must be supplied, but where does it come from? Obviously the only source of heat in the open ocean is the sunshine; the sun shines upon the ocean and other bodies of water, and its energy is used to produce evaporation. Another part of the sun's energy heats the earth's atmosphere, and, by causing it to expand, produces winds. In this manner the evaporated water is carried over the land. Then, upon cooling, the water vapor in the atmosphere condenses and falls as rain and snow, and this in turn produces rivers. Hence, the energy of a waterfall is originally derived from the energy of sunshine.

8.2 Energy of Plants and Animals

Where does the energy contained in food and fuels come from? We have already seen that when foods and fuels are combined chemically with oxygen the combustion produces chiefly carbon dioxide (CO_2) and water vapor, while in the process heat is released. Since heat is not spontaneously created, a similar heat supply had to be provided when water vapor and carbon dioxide were originally united to produce the food and fuel products.

A large class of foods, such as grains, vegetables, etc., are derived directly from plants. A large amount of fuels such as wood and coal are likewise plant products. Coal is simply the consolidated remains of forests which grew in past geological ages, and have been preserved from decay by being buried under great thicknesses of rock. Hence, most of the energy contained in our food and fuel is derived directly from plants.

Some foods, and to a slight extent some fuels (whale oil, for example,) are derived not from plants, but from animals. In all cases, however, the energy contained in the animal tissues was derived from the animals' diet of plants or other herbivorous animals. Thus we see that all energy contained in animal tissue, and used to operate the animal bodies, is derived directly or indirectly from the chemical energy of plants.

The energy contained in petroleum has not yet been discussed. It has now been established beyond a doubt that petroleum has been derived from plants and animals of the geologic past which have been preserved from decay by burial under great thicknesses of rock. Hence, this energy is also derived from plants.

8.2.1 Chlorophyl

It remains to be seen where and how the plants get their energy. It is a matter of common observation on farms that a weed such as a cockleburr, if growing alone on an open piece of ground, will reach only a moderate height of about 3 feet and will spread laterally until its lateral diameter is also about 3 feet. If the cockleburr, however, is only one of a thick patch of cockleburr plants growing about 6 inches apart, then it will develop a long, slender stalk reaching a height of 5 or 6 feet, with almost no leaves except a small tuft directly on top. This same type of thing is true for all kinds of plants. Oak trees in an oak thicket have long slender trunks, whereas the same kind of oak trees when alone will form the familiar widely-branching tree.

When plants are placed in a house or cellar where little sunlight is available, the leaves usually lose the familiar green color and turn white or yellow, the plant loses its vigor of growth, and eventually dies. Grass on a shady lawn frequently dies out, and has to be reset. Among plants the struggle for existence is, among other things, largely a struggle for sunshine. Raw materials from which plants are composed are chiefly carbon, hydrogen, and oxygen plus a small amount of nitrogen and mineral matter. Water is required by plants, and this water is derived from the moisture of the soil. The mineral matter, likewise, is the ordinary salts which are contained in solution by the water of the soil. The carbon is derived from the carbon dioxide which is contained in the air. The nitrogen is likewise derived from the air. We can represent this as follows:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{5H_2O} = \underset{\text{cellulose}}{C_6H_{10}O_5} + \underset{\text{oxygen}}{6O_2}$$

Cellulose plus lignin, a similar material, compose the woody material of plants. We have already seen that the chemical combination of wood with oxygen releases heat, as follows:

$$\underset{\text{cellulose}}{C_6H_{10}O_5} + \underset{\text{oxygen}}{6O_2} = \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{5H_2O} + \text{heat}$$

It will be noticed that the production of plant substance is chemically exactly the opposite from the burning of wood. Since energy is released when wood is burned, then an exact equal amount of energy must have been required when the wood was formed in the first place. Accordingly, the formation of wood may be represented:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{5H_2O} + \text{energy} = \underset{\text{cellulose}}{C_6H_{10}O_5} + \underset{\text{oxygen}}{6O_2}$$

Where does the energy come from? It has been found that, in this case, the energy is derived from the sunshine or other sources of light. This accounts for the fact that the plants seem to compete with each other for sunlight. The green substance in the leaves of plants is called chlorophyll. In the presence of chlorophyll solar energy is converted into chemical energy, as water and carbon dioxide combine to form plant substance.

8.3 Solar Radiation

Almost all of the energy used by man, whether derived from wind or water power, from coal or oil, or from other animals or plants, is derived ultimately from the sunshine. Exceptions to this are energy derived from tides, or from volcanic heat from the earth's interior. These exceptions are at present of little importance, and will probably continue to be so in the future.

From the foregoing it is evident that most of the activity—most of the movements of matter—on the face of the earth are directly or indirectly the result of sunshine. The energy contained in the solar radiation as it impinges on the earth has been measured. It has been found that the solar radiation upon a square centimeter of surface taken at right angles to the sun's rays will, if converted into heat, produce 1.94 gram calories of heat per minute of time. This relationship is strictly true only just outside the earth's atmosphere; on the earth's surface, the heat per minute is somewhat less than this due to the fact that some of the heat is absorbed by the earth's atmosphere.

It may give one a better idea of the enormous quantity of energy contained in sunshine if he consider that the average sunshine per day on one square mile at Washington, D.C., would, if converted into mechanical work, equal 20 million horse-power hours. It is easy to see what an enormous amount of energy per day the total solar radiation on the entire earth must be.

8.3.1 Flow of Solar Energy

As energy is not destroyed, we must now determine how, with such an enormous amount of heat arriving daily from the sun the earth does not get continually hotter and hotter. We have geological evidence that the intensity of sunshine on the earth has been practically the same for many millions of years. We also know that the earth has had about the same temperature during that time. Therefore, the earth must be losing energy at about the same rate it is receiving it.

Let us trace the energy received from the sun. Of the total energy contained in the solar radiation which impinges upon the earth, approximately 37 percent is reflected back into space. Another part of the energy of the sunshine is directly absorbed by objects upon which it falls and is converted into heat; still another part produces the evaporation of water; another part is consumed in expanding the gases of the atmosphere and the ocean waters, producing winds and ocean currents. Finally a part is converted by the chlorophyll of the plants into the chemical energy required by plant-eating animals and these latter finally become the food for carnivorous animals. As we have already shown, a part of the plant energy may be converted into mechanical work by means of man-made engines; in a similar manner the energy of waterfalls which ordinarily is dissipated as waste heat, may be made to drive machinery before finally being reduced to waste heat. The end product of all these processes is, however, low-temperature waste heat.

Due to the fact that the earth is not getting hotter, the earth must be losing heat at the same rate it is receiving heat from the sunshine. This loss of heat is accomplished by means of long wavelength, invisible heat radiation which the earth radiates out into space. This type of thing is well illustrated in the case of a closed automobile, parked in the hot sunshine. The temperature in the car stays several degrees higher than the temperature outside the car, which is due to the fact that sunshine, which is short wave radiation, passes readily through the glass windows. When it strikes the cushions of the car it is absorbed, and produces heat. These cushions then emit a long wave-length radiation, which can pass only with difficulty through the glass windows; consequently, the temperature of the interior of the car rises until enough heat can be radiated to allow the escaping energy to be equal to that coming in. Thereafter the temperature does not change. Clouds in the earth's atmosphere act in a similar manner—they tend to block the escaping long wave-length radiation. That is the reason it rarely frosts on a cloudy night.

8.4 Summary

Solar radiation impinges upon the earth as a short wave-length radiation, and thereafter undergoes a series of energy changes, each one of which, in accordance with the Second Law of Thermodynamics, is at a lower scale of degradation than that preceding it. Finally, it is re-radiated back into space as spent long wave radiation. During, and as a consequence of this process, the wind blows, rivers flow, and plants and animals grow and propagate their kind, and most of the other events on the face of the earth take place.

Since the total flow of energy on the earth is practically a constant, it follows that there is not likely to be any cessation or diminution of this process for a long time to come. While the total flow of energy on the earth's surface is essentially constant, the resulting picture, in terms of the configuration of the earth's surface and of plant and animal life, is continuously changing. This change is itself unidirectional and irreversible; that is to say, it never repeats itself.

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Lesson 9

DYNAMIC EQUILIBRIUM AMONG ENERGY-CONSUMING DEVICES

We have already seen that every sort of mechanism, both inanimate and organic—plant, animal and steam engine—is an energy dissipating device. Plants require solar energy; animals require chemical energy in the form of food derived either from plants or other animals; steam engines require the chemical energy of fuel. It is important to note here that particular kinds of energy-consuming devices can, in general, make use of energy only when it occurs in certain forms. Thus, a steam engine cannot utilize the energy contained in a waterfall, neither can a horse operate on the energy contained in coal or gasoline. Certain animals, the herbivores, can utilize only the energy contained in a limited variety of plants; other animals, the carnivores, can utilize only energy occurring in the form of meat. Most plants can utilize only the energy of light radiation. All of the energy used by every kind of energy-consuming device on the earth is, as we have pointed out, derived almost without exception, initially from the energy of sunshine. The energy of sunshine is a vast flow of energy. The existence of plants and animals is dependent upon a successful competition by each of the different species for a share of this total flow. A simple illustration will perhaps make this more clear.

9.1 Dynamic Equilibrium of Plants and Animals

Imagine an area of land in a temperate region having the usual array of vegetation peculiar to that area. Suppose that a block of this land of several square miles in area be completely fenced off in such a manner that no animals at all are allowed within this area. Under these conditions the grass, in the absence of animals, would become tall and of luxuriant growth.

Now, into this pasture with its luxuriant growth of grass, suppose that we introduce a pair of rabbits, one male and one female, without allowing any other animals within the region. Suppose, further, that we take a census at regular intervals of the rabbit population within this area. As we know, rabbits breed rapidly, and in a year's time one pair of rabbits produce about 12 offspring. Assuming no rabbits to die in the meantime, and this same rate of multiplication to continue, at the end of the first year the total rabbit population would be 14; at the end of the second year the population would have reached 98; at the end of the third year it would have reached 686. One might object to this on the ground that some of the rabbits would have died in the meantime, and this objection is well founded. Given a situation such as we have assumed here where the food supply is abundant and other conditions are favorable, it is a well established fact that animals multiply in such a manner that their birth rate exceeds their death rate, and as long as these conditions maintain, the population tends to increase at a compound interest rate. In the case of the rabbits we are considering, if the births per year were 600 percent and the deaths per year were 200 percent, there would be an expansion of 400 percent. This, while slightly less spectacular than the case where no deaths occurred, would still result in a very rapid increase in the rabbit population of the area. Under these conditions, if at the end of a certain time the rabbit population were 100, there would be by the end of the following year 500 rabbits in the area, and by the end of the year after, 2,500 rabbits, etc.

At this rate it is very obvious that it would not take many years for the rabbit population to reach an overwhelming figure. How long could this rate of growth continue? Is there any upper limit to the number of rabbits that can live in a given pasture area? There very obviously is. The rabbits eat principally grass and certain other small plants. For the sake of simplicity, we shall assume that the rabbits eat only grass. Grass, therefore, being the food, constitutes the energy supply for the rabbit population. Each rabbit in order to subsist must have a certain number of calories per day, and therefore, must eat a certain minimum amount of grass per day. In the initial conditions that we have specified, the grass supply far exceeded the needs of the rabbit population. Under these conditions there were no limitations on the rate of growth of the population. Finally, however, there would come a time when the number of rabbits would be such that the amount of grass per year required to feed them would just equal the rate at which grass grows. Under these conditions it is easy to see that if the rabbit population were to get any larger than this, the surplus would starve to death.

Our curve of the growth of the rabbit population, therefore, if plotted as a graph, would at first rise more and more rapidly with time. After that, the curve would begin to level off, signifying that the food requirements of the rabbit population was approaching the rate of growth of the grass of the region.

When these two things become equal, that is to say, when the rate at which rabbits eat grass is equal to the rate at which grass grows in the region, there will have been reached a state of dynamic equilibrium between rabbits and grass. If there should be a particularly good growing season, the grass would grow more rapidly, and the rabbit population would increase as a consequence; if this were followed by a drought, the grass would decrease and the surplus rabbit population would consequently die off.

Now suppose that in this pasture where a state of dynamic equilibrium between rabbits and grass has already been achieved, we introduce a disturbing factor in the form of a pair of coyotes. Coyotes live on meat, and since we have postulated that rabbits are the only other animals in the area, the coyotes will live upon the rabbits.

Now, what will happen? Since there is an abundance of rabbits the coyotes will have plenty to eat, and while this condition lasts they will multiply at their most rapid rate. At the same time, however, because of this, the death rate among the rabbits increases, and the rabbit population declines. Finally, there comes a time when the rate at which the coyotes require rabbits for food is equal to the rate at which the rabbits grow. Under this condition the rabbit population will stabilize at a lower figure than formerly, and the coyote population will also stabilize at a different figure. When this is attained there will then be a state of dynamic equilibrium between coyotes, rabbits and grass.

We could complicate the picture still further by introducing foxes, owls, field mice and the whole complex array of animals that one normally finds in such localities. With this more complex picture we would find exactly the same thing; that is, if left alone, each of these different species would tend to come to a stable population. In the case of each species a stationary population involves an equality between its birth rate and death rate. Its birth rate is dependent upon its available energy supply; and its death rate is determined in part by age and in part by the rate at which it becomes and energy supply in the form of food for other species.

A disturbance on either side of this equation, a change in the food supply, or a change in the rate at which it is eaten or dies, will disturb this dynamic equilibrium one way or the other.

9.2 The Dynamic Equilibrium of Man

The principles discussed above are just as valid for the human species as for coyotes or rabbits.

Suppose we consider man in his most primitive state, before he had invented tools and clothing, learned to use fire, or had domesticated plants and animals. What was his food supply? He must have lived on fruits, grass seeds, nuts, and other such plant products as were available and suitable for human food. He probably caught and ate small animals such as rabbits, rats, frogs, fish and perhaps insects. His population in a given area was therefore limited on the upper boundary by the rate at which he could catch these small animals, or could gather the plant foods. On the other side, such large predatory animals as bears, panthers, lions and saber-toothed tigers were lurking about, and it is entirely probable that our primitive ancestors formed a part of the natural food supply of these animals. This, as in the case of the coyote-rabbit equilibrium mentioned above, tended to further restrict the human population within a given area.

Now, suppose that this primitive species, man, learned to use such a weapon as a club, what effect would this have toward changing the state of the dynamic equilibrium? In the first place, with a club, a man could probably kill more animals for food than he could have caught using only his hands. This would tend to increase his food supply, and in so doing, would to that extent curtail the food supply of his predatory competitors. For example, suppose that with a club a man could kill more rabbits than he could catch with his bare hands; this would increase the human food supply and consequently tend to increase the human population in the given area. At the same time there would be a decrease in the rabbit population, and a corresponding decrease in the population of other animals depending on rabbits for food.

A club is a weapon of defense as well as a weapon of offense. With a club, a man would be able to defend himself from beasts of prey, and would accordingly decrease the rate at which he became the prey of other predatory animals.

The result of both of these, the increase of human food supply, and the increase in the expectancy of life of the human being, act in the same direction, namely, to disturb the balance in favor of an increase of human population in the given area.

Now, let our primitive man discover the use of fire. Fire, by its warming effect, would protect man from the winter cold, and doubtless decrease the number of deaths from freezing and exposure. This would prolong the average length of life, and consequently increase the population. Fire also is a powerful medium of defense in that it effectively prevents the depredation by predatory animals. This also tends to increase the expectancy of life. The use of fire also would permit man to invade new and colder territories. Thus, not only would learning to use fire tend to increase the population in areas inhabited by man, but it would enable him to reach a food supply in areas not previously accessible, and, consequently, to still further multiply by inhabiting a larger and larger portion of the earth.

The discovery of the use of fire is of even greater significance in another way. In this hypothetical development that we have outlined, prior to the use of fire the only part of the total flow of solar energy that had been diverted into the uses of man, prior to the use of fire, was that of the food he ate. The energy requirements of our primitive ancestors in the form of food was probably not greatly different from that of today, namely, about 2,300 to 2,600 kilogram calories per capita per day. No other energy was utilized than that of food eaten. With the discovery of fire, a totally new source of energy was tapped, and use for the first time was made of extraneous energy—energy other than food eaten.

This constituted one of the first steps in a long and tortuous evolution in the learning to convert an ever larger fraction of the total flow of solar energy into uses favorable to the human species. The results of this learning to direct the flow of solar energy, as we shall see in succeeding lessons, are among the most momentous of the events in the history of life on this planet.

References:

Animal Life and Social Growth, Allee.

Origin of Species, Darwin.

The Biology of Population Growth, Pearl.

Elements of Physical Biology, Lotka.

Lesson 10

ENERGY IN HUMAN HISTORY

In Lesson 9 we learned that all plant and animal species are in a perpetual state of competition for larger and larger shares of the total flow of energy from sunshine. The number of individuals of a particular animal species that can live in a given area is dependent in part upon the rate at which energy occurs in that area in a form suitable for use by that species; in part upon the number of competing species for energy in the same form; and in part upon the rate at which this same species becomes food, and therefore serves as the energy supply for still other species.

Under the strenuous competition for existence there develops in a given area between the various plant and animal species a state of balance, or, of dynamic equilibrium. This state of balance is precarious, and is subject to disturbances by a change of weather conditions and hence of food supply, or it can be disturbed by numerous other factors.

The human species, as we have seen, exists as a part of this dynamic ‘web of life’.

The history of the human species since prehistoric times is distinguished chiefly from that of other animal species in that during this period man has been learning progressively how to deprive a larger and larger share of the sun’s energy from the other animals and direct it into his own uses. This has resulted in the ascendancy of man, and has wrought unprecedented havoc among the other animals of the earth.

In our last lesson we saw that the use of a simple tool like a club gave man a decided advantage in the struggle for existence, and by increasing his food supply, made available for man's use a larger supply of the total flow of the sun's energy. We saw that the discovery of the use of fire, probably his first use of energy other than food eaten, gave him another decided advantage tending both to increase his length of life and to enlarge the area he could inhabit. The use, both of the club and of fire, tended to increase the human population of the earth.

10.1 Domestication of Plants

Let us review a few more of the high points of man's conquest of energy. Consider the domestication of plants. The first stage in the domestication of plants consists of taking those plants in a wild form which are suitable for food for man or his animals (or otherwise useful, as for clothing) and cultivating them for the purpose of increasing their yield. This cultivation consists chiefly of two things: (1) the removal of competing plants from the area under cultivation; (2) the loosening of the soil to increase the yield of the plants cultivated.

The net effect of this is that a very much greater portion of the solar radiation incident upon the area under cultivation is converted into forms suitable for food for man and his animals, or into other useful products, than was the case prior to such cultivation. The domestication of plants, therefore, is simply an artificial means of diverting a larger and larger proportion of the sun's energy (which formerly was, as far as man is concerned, wasted) into human usage.

10.2 Domestication of Animals

Consider the domestication of animals. Out of all the array of the animal species in regions inhabited by man only certain ones, such as sheep, goats, cattle and swine, were especially suitable for human food and at the same time amenable to domestication. Others, such as the horse, the camel, the ox, and the dog, were suitable for other uses than food, such as carrying burdens or otherwise performing work.

Here, as in the case of the domestication of plants, we are dealing primarily with a diversion of energy. Prior to the domestication of animals a given pasture area would have been roamed by the miscellaneous grass-eating herds, along with wolves, lions and other predatory animals preying upon these. In such an area man would have taken his chances in competition with the rest. Suppose, however, he domesticated one species of these animals, sheep, shall we say, and protected it from its natural enemies. Under these circumstances the biological equilibrium would be disturbed, and the protected species would multiply out of all proportion to the numbers it would have if not so protected. Because of their great number these domestic herds also would eat a far larger proportion of the grass in the area than they would have been able to do otherwise.

Thus the domestication of animals is a device whereby man has been able to convert solar energy represented in such vegetation as pasture grass, which is not in that form suitable for human uses directly, into forms such as meat, wool and skins, which are suitable for human use.

We see, therefore, that the domestication of plants and animals, by beginning with a disturbance of the biological equilibrium between plant and animal species, results in an increased food and clothing supply for man, himself, from a given area. Since, under primitive conditions, the human species tends always to expand faster than these devices tend to increase the food supply, it follows that the astounding result of each of these achievements must have been to increase the number of people who could exist in a given area, and, therefore, to increase the human population of the earth. The population of the Nile Delta during the time of the Egyptians, with their cultivation of plants, must have been vastly greater than the number which could have subsisted in the same area in its wild and undeveloped state.

The North American Continent affords a very interesting contrast of a similar kind. The Indians had few domestic plants, and almost no domestic animals. Their principal tools were fire, the bow and arrow, and the canoe. While the size of the Indian population prior to the European invasion can only be estimated, available figures indicate that the total population north of Mexico at the time of the discovery of America was less than 2,000,000 people. With the methods of energy conversion known to the Indians it is doubtful if the area in which they lived could have supported very many more than actually existed at that time. In other words, there was pretty nearly a state of dynamic equilibrium between the Indians and their food supply. The population of the United States alone is at the present time 131,000,000 people (1940). This has been made possible only by a far greater utilization or conversion of energy, than was possible by the Indians in their state of knowledge.

10.3 Discovery of Metals

Succeeding stages in the conquest of energy by the human species are represented by the discovery of metals and their uses. Metals provided better tools and weapons, both of offense and defense, than man had known prior to that time. This still further, in the manner we have indicated, disturbed the biologic balance in man's favor, and again he extended his conquest and increased his numbers.

Greater mobility also was achieved by the use of the camel and the horse as beasts of burden. Wheeled vehicles were devised, and boats of increasing sizes and improved modes of propulsion were developed. The combination of the use of metals, and the increased mobility brought the human species face to face with some of the hard facts of geology, namely, that metals in concentration suitable for human exploitation occur but rarely and only in certain localities of the earth's surface. Moreover, the ores of these metals occur at various depths beneath the earth's surface, and can only be mined with difficulty.

The ancients obtained important copper ores from the mines of the Isle of Cyprus. The Greeks obtained silver from the silver mines of Laurium. The ancient tin mines of Cornwall were exploited by the Romans, and probably even by the Phoenicians.

The methods of mining used were of the crudest. Only the simplest of hand tools were available, and with these a single miner working in solid rock could generally not mine much more than a basket of ore per day. The labor employed in the mine was primarily that of slaves, frequently working in chain gangs. In passages too small for adults, children were employed.

Few written records of the earlier mining practices have been preserved to the present time, due largely to the fact that the writing of the time was done primarily by the philosophers and others who felt it distinctly beneath their dignity to dirty their hands with the work-a-day labor of the world sufficiently to inform themselves on such processes. This much is known, however, that the mining methods of the ancients were sufficiently thorough in the localities worked by them that little has been left to be done by more modern methods except at depths greater than the ancients were able to penetrate.

This increase in the use of metals had the social effect not only of increasing the prowess of man but also of increasing the technical problems presented by the mining methods themselves that he was called upon to solve. The ancients found their operations curtailed and finally balked at depth by the inflow of ground water into the workings of the mines. If greater depths were to be obtained suitable pumps must be devised, and since the water flowed in continuously, pumping operations had to be maintained.

This required power. The solution of the problem, together with that of hoisting ores and rock from the mines, may very well be said to have laid the foundation stones for the future mechanical development.

Various kinds of windlasses and pumps were developed; at first only the muscle power of human beings was employed, then oxen working on tread-mills were used, and later in a similar manner horses were employed. Where suitable waterfalls occurred, water wheels were developed, employing the energy contained in the waterfall for pumping and hoisting. In other cases windmills were developed employing the energy of the wind for a similar purpose. Had only these sources of energy been available, the mining and consequently the industrial development of the future would have been seriously handicapped. The crying need was for newer and larger sources of energy.

10.4 Summary

We have thus traced the high points of the development of man's conquest of energy through its initial stages.

We have found that every new technical device—the domestication of plants and animals, the use of tools, such as the club, the boat, wheeled vehicles, and finally the use of metals—has each played its part in contributing to a diversion of an ever-increasing part of the sun's energy into uses of the human species.

The extensive use of metals was among the most significant and far-reaching in its effect of the events in human history. It not only disturbed the biological equilibrium resulting in an increase in human population at the expense of the other species, but it also, in a similar manner, gave certain peoples an advantage, due to their greater command of energy, over other peoples not so favorably equipped. This resulted in a disturbance of the equilibrium within the human species in favor of those with the greater command of energy.

References:

The Biology of Population Growth, Pearl.
Elements of Physical Biology, Lotka.
Man and Metals, Rickard.
History of Mechanical Inventions, Usher.

Lesson 11

EARLY STAGES IN THE USE OF EXTRANEOUS ENERGY

In previous lessons we have seen how the degradation of solar radiation in processes occurring on the earth's surface has resulted in the various forms of movement that matter on the earth's surface is continually undergoing. We have pointed out that the various life forms are in competition with one another for shares of the solar energy. We have seen, furthermore, how the human species, by learning to use fire, to domesticate plants and animals, and by developing various tools and weapons, first of stone, wood and bone, and later of metals, has been able to disturb the biologic equilibrium and gain for itself a disproportionate share of this solar energy as compared with other species. At first thought one might conclude that this would result in an improved human standard of living and general well-being, and in some cases this was true, but by and large the improvement as regards the individual does not seem to have been great.

11.1 Food, Fire, Animals, Wind, and Water

Consider the energy available per person during all this time. Before man learned to use fire, his sole available source of energy was that contained in the food he ate. This, as we have seen already, for an average population of young and old, amounts to about 2,300 kilogram calories per person per day. Since available evidence indicates that our ancestors at that time were approximately the same size we are now, they must have consumed energy in the form of food at about the same rate we consume it now.

Extraneous energy—energy other than food eaten—was, as we have just seen, introduced but very gradually. First, there was fire. This was the utilization of the heat contained in wood. Then there was the work of animals, the horse, the ox, the dog. At no time throughout early history was the number of domestic animals per capita very large on an average. Then came the use of the energy of the wind and running water, but these were only used locally, and were never (during this period) of great importance.

The tendency of the human species to multiply at a compound interest rate tended always during this early history to keep the population at approximately the maximum number that the means available were able to support. Estimating on the average the use of fuel to provide approximately 400 kilogram-calories per capita per day (average for all climates), and one domestic animal for every five people, providing an additional 1,600 kilogram calories per person per day, we would arrive at a total of extraneous energy of only about 2,000 kilogram-calories per capita per day prior to the extensive use of fossil fuels.

Thus we see that, great as were the strides made by the human race through the preceding history, the increase of the average standard of living, stated in the physical terms of energy consumption, was almost negligible. This can be seen in another way when one considers the abject poverty and squalor under which the great bulk of the people during all preceding history apparently lived.

During the ‘golden age’ of Athens only a relatively small part of the population was free. The preponderance of the people were slaves or serfs of some degree or other. History, as it has been handed down, has focused attention upon a few of the more illustrious of these free citizens; the others whose toil made this freedom of the few possible have been more or less tactfully omitted.

Under the glory that was Rome, one finds a similar or worse condition. At the height of the power of the Roman Empire most of the necessary work that was required, such as building, agriculture, and mining, was done by slaves. The campaigns of the Roman armies of this time, so the records of the Roman senate show, were largely directed for the acquisition of spoils, such as mines and the products thereof, and slaves. These slaves were worked to the limit of human endurance, and were, after a few short years of service, broken, discarded, and replaced by others obtained by new conquests.

11.2 The Use of Fossil Fuel

A totally new era in this unidirectional progression was entered when man began to tap a hitherto unused energy resource, that of fossil fuel—coal, and more recently, oil.

Coal and petroleum in small amounts, and largely as curiosities, have been known, according to available records, since the time of the ancients. Coal, however, as an energy resource first began to be exploited extensively in England in about the twelfth century. First, chunks of coal found along the seashore, came to be burned for domestic fuel; later, in the vicinity of Newcastle, coal was dug from the ground out of open pits. The fact that this coal could be more easily acquired, and, if purchased, was less expensive than wood, caused it to be adopted as fuel by the poorer classes. Shortly after, coal was shipped from Newcastle to London, where it came to be used as fuel, much to the annoyance of the royalty and nobility of the time; and, because of its smoke and sulphurous odor, laws were passed prohibiting its use. Somewhat later, coal from Newcastle found its way to Paris in exchange for boat loads of grain.

By the year 1600 the use of coal for domestic purposes in England had become a custom permanently established. Chimneys had been built, much to the disgust of the older generation, who considered that the young folks were becoming effeminate by not being able to endure the smoky atmosphere after the stalwart manner of their elders.

Coal found its way, also, into industrial uses. First the blacksmith, and then the glassmaker, found its use more and more indispensable. The iron mines of England, which, simultaneously with coal, were being developed, had up to this time depended upon a supply of charcoal for smelting purposes. The demand for wood for the making of charcoal, as well as for the building of English ships—men-of-war and merchantmen—was placing a heavy burden on English timber. Comments and complaints began to increase after the year 1600 about the exhaustion of timber. This placed a premium upon a method whereby iron might be smelted by the use of coal. In about the year 1745 such a process was discovered. Coal could be roasted into coke, and this latter used for the smelting of iron. Iron ores, like coal, were abundant in England. The union of these two components, coal and iron, was among the most significant events of human history. The more iron that was smelted the more coal was required. Also, the more iron that was made available, the more equipment requiring iron was devised. Thus we have a process which of itself appears to have no ending.

11.3 The Use of Gunpowder

Another important contribution to the use of extraneous energy that occurred during this period was the invention of gunpowder. While its exact date is obscured, gunpowder came into use in the Western World about the end of the thirteenth century. Gunpowder was composed of charcoal, saltpeter and sulphur. These, when ignited, react together with explosive violence, releasing energy as follows:

$$2KNO_3 + S + 3C \longrightarrow K_2S + 3CO_2 + N_2 + \text{heat}$$

Saltpetre Sulphur Charcoal Potassium Sulphide Carbon Dioxide Nitrogen

Of course, the first and most obvious use of this new form of energy, as with most others that can be so applied, was for weapons of warfare. Guns were developed, and those people using firearms exercised a very decisive advantage over those not so equipped, as well as over other animals. This still further disturbed the biologic equilibrium in favor of the human species over other animal species, as well as in favor of those groups of people having this energy resource over other peoples of the earth not so equipped. The conquest of the New World by the Europeans is due almost entirely to the superior energy technique of the Europeans as compared with that of the Indians. Bows and arrows were no match for firearms; wood and stone tools could not compete with tools of metal; little or no domestication of plants and animals rendered the Indian far inferior to the European in regard to the production of food.

So decisive is the matter of energy control that one may fairly state that other things being equal, that people which has a superior energy control technique will always tend to supplant or control the one with a lesser technique.

Another use to which gunpowder was applied which may have been of greater significance than its use in warfare, even though not so much noted in textbooks of history, was its application to mining, and later to other industrial purposes requiring blasting. Gunpowder as an industrial explosive came to be used in the mines of Germany in the late sixteenth century. It was employed in the mines of Cornwall in 1680. Before this time the tools of mining had been largely the pick and hammer and simple wedges and chisels. By employing gunpowder, holes could be drilled and blasts set off, thereby breaking out a very much larger quantity of ore with a given number of workmen than had ever been done previously. This acceleration in mining practice went hand in hand with the same acceleration in the use of coal that we have just described.

11.4 A New Problem

In both of these cases, as is always true of the introduction of a new technique, new and unsolved problems were created. The first coal mines, as pointed out, were shallow, open pits. The increased use of coal required the mining at continually greater depths. Ground water is usually encountered within a few tens of feet of the top of the ground. The deeper the mines and the larger the workings, the faster the rate of infiltration of water. This is true, both in metal mines and in coal mines, but due to the greater number and size of the coal mines it there presented a more serious difficulty.

In the earlier and smaller workings the water was bailed out by hand labor. Finally the problem became too large to be solved by this method, and pumps operated by treadmills driven by horses were introduced. At first treadmills, with a single horse, then with five, twenty, and a hundred were used. By this time the problem had obviously reached very serious proportions, because, if the mines were to be kept open, the pumps had to be operated continuously day and night, and the food required to keep two shifts of a hundred horses working on treadmills was a very serious problem in early eighteenth century England. A new solution had to be found.

References:

Man and Metals, Rickard.

Behemoth, The Story of Power, Hodgins and Magoun.

History of Mechanical Inventions, Usher.

Lesson 12

MODERN INDUSTRIAL GROWTH

We have traced the rather slow and tortuous evolution of the human species in the struggle for energy. We noticed in the last lesson that, with the learning to use the energy contained in coal, there seemed to be a quickening of the tempo of human affairs. Coal provided heat for domestic purposes, and for glass making. After 1745 coal was made into coke for the smelting of iron. The increasing uses for coal created a greater and greater demand for more coal. The increased rate of mining operations caused mining to be carried on at greater depths, with consequent pumping problems of continuously increasing magnitude. As we have pointed out, the use of as many as 100 horses, working on treadmills, created costs of upkeep for the horses which threatened to overbalance the proceeds from selling the coal. It was imperative that a better and cheaper method of pumping be devised. One of the first of these was that of Thomas Savery.

12.1 Development of the Steam Engine

Savery, in 1698, devised an engine consisting of a boiler and two steam expansion chambers, equipped with suitable valves operated by hand. These chambers were filled with water, and when the steam was turned into each of them alternately, water was forced upward; then, with the bottom valve open, and the steam inlet turned off, the condensation of the steam in the chamber produced a vacuum which sucked more water from the mine.

This engine was not very satisfactory, and was followed shortly after by the ‘atmospheric engine’ of Newcomen and Cawley in the year 1705. This engine consisted of a rocking beam, to one end of which was attached a pump rod and to the other a piston in a vertical cylinder. When steam was admitted to the cylinder the piston was lifted, and the pump rod lowered; next, water was injected into the cylinder to condense the steam, thus creating a vacuum below the piston, so that the atmospheric pressure on the top side of the piston forced it back down, lifting the pump rod, and thereby pumping water. Thus, the work stroke was done, not by the steam, but by the pressure of the atmosphere, hence the name ‘atmospheric engine’.

At first the valves of this engine were operated by hand, but this became tedious; and later, so the story goes, the boy who operated the valves became tired, and devised a system of strings attached to the rocking beam in such a manner that they opened and closed the valves automatically.

Such was the rate of progress at this time that it was not until 1769 that any material improvement was made on this engine. In that year James Watt invented a condenser so that the hot steam could be exhausted from the cylinder and condensed in a chamber outside, instead of cooling the cylinder down each time, as had been done previously. In 1782, Watt still further improved the steam engine by making it double acting, that is, steam was admitted alternately, first at one end of the cylinder, and then at the other, thus driving the piston in both its up and down strokes. At about this time the flywheel was added to the simple rocking beam.

By this time the age of power was well begun, and more and more uses were found to which the steam engine could be applied, as will be pointed out presently. Individual engines were made continuously larger. First there was only the single cylinder, then there developed successively the double-, triple-, and quadruple- expansion types of engines. The reciprocating engine reached its climax toward the end of the nineteenth century in the Corliss type. Of these the largest stationary units reached upwards of 10,000 kw., and stood with their cylinder heads approximately 30 feet above the axis of their cranks.

In 1889, De Laval, of Sweden, devised a steam turbine to operate his cream separator. In 1884 Sir Charles Parsons built a steam turbine which delivered 10 h.p. at 18,000 revolutions per minute. In 1897 steam turbines were installed in a small steamship named the Turbinia. In 1903 a 5,000 kw. turbine was installed in one of the central electric power stations of Chicago.

From that time on this form of steam engine has increased rapidly in size and usefulness. By 1915 a 35,000 kw. unit was installed in Philadelphia. In 1929, in the Hell Gate Station, New York City, units of 160,000 kw. each were installed. These represent the largest single engines ever built.

If 1 horsepower for 8 hours represents the work of 10 strong men, then for 24 hours 1 horsepower would represent the work of 30 men working 8 hours each. One kilowatt is one and one-third horsepower, and hence represents the work of 40 men for 1 day. Thus, one of these engines does the work in one day's time of 6,400,000 strong men. There are 5 of these engines in New York City at the present time. These 5 engines when running to capacity, do work equivalent to 32,000,000 strong men working at hard labor for 8 hours a day each.

12.2 The Railroad

Not only did coal mining create a problem of pumping water, but the coal had to be hauled varying distances over bad ground, either to the market or else to the seashore to be loaded in ships and transported by water. This created a serious problem in transportation, and early in the sixteenth century rails of timber were laid at the coal mines of Newcastle-on-Tyne. Carts carrying 4 to 5 tons of coal each were drawn by horses on these rails. These first rails were secured to cross timbers. In 1735 it was found that the rails could be made stronger and to wear longer if iron bars were fastened to their tops. In 1767 cast iron rails, 4 to 5 feet long, were substituted for the entire wooden rail. These cast iron rails were brittle and troublesome because of their short length and numerous joints. In 1820 these were replaced by wrought iron rails, 15 feet in length. Such were the first railroads.

The development of the steam engine and the rapid rate of increase in the use of coal led naturally to the casting about for a new kind of motive power. In 1804 Richard Trevithick built a steam locomotive which hauled 10 tons of coal at 5 miles per hour. In 1814 George Stevenson built an important locomotive that hauled 35 tons of coal four miles per hour up a 1 to 450 grade.

By 1825 there were all together 28 railroads in Great Britain, mostly mine roads, with a total mileage of 450 miles. In that year the Stockton

& Darlington Railway, 25 miles long, was put into operation. This may be considered the first modern steam operated railway.

At the opening of this road, a Stevenson engine hauled a train consisting of

The more modern forms of transportation are the automobile and the airplane. The beginnings of efforts to construct a self-propelled road vehicle

22 wagons of passengers and 12 wagons of coal, totaling 90 tons, at an average speed of 5 miles per hour. Later this road reverted largely to horses for motive power, reserving the steam locomotives for hauling freight, chiefly coal. By 1830 the Liverpool & Manchester Railroad, 35 miles long, was operating with an improved type of locomotive, and from that time on mechanical motive power has been indisputably established.

In the United States, as in England, railroads were first built for horse-drawn vehicles. In 1829 a 16-mile road from Honesdale to Carbondale, Pennsylvania, was built, and a steam locomotive of English manufacture introduced. The following year a 13-mile road from Baltimore to Prescott, Maryland, was opened.

12.3 The Steamboat

Similar advances were made in water transportation. In 1785 John Fitch ran the first successful steamboat in America. After this followed, in rapid succession, numerous other small steamers in inland and coastwise waters, both in Europe and the United States. In 1819 the S.S. Savannah was the first steam-propelled ship to cross the Atlantic Ocean. By 1838, two ships, the S.S. Great Eastern and S.S. Sirius, were in regular service. In 1837 and 1838 John Ericson introduced in England the screw propeller. This gradually replaced the paddle wheels, so that by 1870 all ocean-going steam-driven vessels were propelled by screws.

While the advances made in both railroads and in steamships since 1900 have been great, the trend has been one more of orderly evolutionary development, rather than of radical departures. Electrification of steam railroads was under way prior to 1910. This has been followed by Diesel-electric engines, and by steam locomotives of continually greater size, and of greater thermal efficiency. At the present time we seem to be on the threshold of a major departure in railroad equipment in the form of high speed, lightweight, streamlined trains propelled by Diesel engines.

12.4 The Automobile

were practically coincident with the locomotive. In the period from 1827 to 1836 Walter Hancock, in England, constructed several steam wagons that carried passengers over carriage roads. One of these is reported to have run 20 weeks, traveling a distance of 4,200 miles, and carrying 12,000 passengers. With the rise of railroads, motor vehicles for road use were virtually abandoned until about 1885, when the development of the gas engine by Daimler and others led to the motorization of the bicycle and then of the carriage. About 1895 the development of motor vehicles propelled by internal combustion engines or by electric motors began in earnest, leading to the modern automotive transportation.

12.5 Transportation by Air

The first abortive attempts at transportation by air date back to the early balloons, about the year 1783. Finally, in 1896, Langley's heavier-than-air machine made the first successful flight of its kind. In 1903 the Wright Brothers were the first to take off in a heavier-than-air machine propelled by its own power. Since that time aviation has developed by leaps and bounds, gaining particular impetus during the World War. Planes have become bigger and faster, and the cruising radius has progressively increased.

12.6 Summary

In the space here it is manifestly impossible to more than scratch the surface of the vast field of technological developments that have taken place since the first feeble beginnings.

Among the first industrial equipment to use power from steam engines was that of the textile industry. The changes wrought here were so great as to be characterized in history as the Industrial Revolution of the latter part of the eighteenth century. Corresponding developments beginning at various times can be traced in communications—telegraph, telephone, radio and television.

It becomes evident that our Industrial Revolution of the last two hundred years is a development radically different from that of any preceding period of the earth's history, and compared with which all earlier developments are insignificant in magnitude. Each development has come, not as a thing of itself, but only as a part of the picture as a whole. Steam or water turbines could not effectively be utilized until electrical equipment had been developed. This latter, in turn, had to wait until Faraday, Maxwell and others had discovered the fundamental principles of electricity.

Viewed with regard to the multiplicity of its details it would appear to be an endless and hopeless task for a single individual to obtain even approximately a comprehensive grasp of our modern industrial evolution. When one considers, however, that all of the equipment is composed almost entirely of a small number of the chemical elements—iron, copper, lead, zinc, etc., and that furthermore, the manufacture and operation of the equipment requires energy in strict accordance with the laws of thermodynamics, the problem is evidently greatly simplified. In other words, if it be known at what rate the industrial system has required the basic materials such as iron, copper, tin, lead, zinc, and if it be known at what rate it dissipates energy from the energy sources of coal, oil, gas, water power and plants, all of the innumerable details are automatically included.

Timeline of Industrial Technology

Prime Movers

1698-Savery steam engine
1705-Newcomen and Cawley, steam engine
1769-Watt, steam engine condenser
1782-Watt, double acting piston engine
1820 W. Cecil, engine, 60 r.p.m.
1823 Brown, gas vacuum engine
1849-Francis, water turbine (size 6 in. to 18 ft. diameter)
1876-Otto cycle internal combustion engine
1882-Pearl Street, New York, generating station
1883-De Laval, steam turbine
1884-Parsons, steam turbine
1895–Diesel, internal combustion engine
1903-First 5,000 kw. central station steam turbine, Chicago, Ill.
1929-160,000 kw. turbines installed. Mercury turbine

TransportationWater

1885-Hertz, Hertz’s oscillator; the real beginning of radio-telegraphy
1785-First successful steamship, John Fitch

1819-First steam-driven ship crossed Atlantic
1837-Screw propeller introduced (Ericson)
1897-Turbine engine used in steamships

Transportation—Land

Railroads
1750-Cast iron rails, 4 to 5 ft. long, first used (1767)
1800-Trevithick's steam locomotive (1804)
George Stevenson built improved locomotive (1814)
Wrought iron rails, 15 ft. long, first used (1820)
First modern railroad, Stockton to Darlington, England (1825)
First railroad in U.S., Honesdale to Carbondale, Penna. (1829)
George Stevenson introduced the 'Rocket,' improved locomotive (1829)
1850-First transcontinental railroad system in U.S. (1869)
First working electric railroad, Germany (1879)
1900-Electrification of steam railroads Diesel-electric locomotives

Other Vehicles
1800-Steam wagons, Walter Hancock, England (1827-1836)
1850-Gottlieb Daimler high-speed gas engine, Germany (1884)
Motorized bicycle (1885)
Benz, three-wheeled gas carriage (1886)
Geo. B. Seldon, patent on clutch and transmission system (1895)

Transportation—Air

1783-Montgoflier, first balloon, using heated air
1852-Gifford, first successful spindle-shaped gas bags, driven by steam engines
1884-M. M. Renard and Keebs, gas bag driven by electric motors, fed by electric batteries
1896-Prof. Langley, model aeroplane, driven by steam. Flight of three-quarters mile. First time in history that a motor-driven, heavier-than-air machine accomplished a successful flight
1900-Count Zeppelin, rigid form; capacity 399,000 cubic feet gas; driven by two Daimler benzene engines, 16 h.p. each. First means of passenger service in the air
1903-Orville and Wilbur Wright, glider fitted with a 16 h.p., four-cylinder motor. This machine made the first successful Right in which the machine

carrying a man had ever risen of its own power from the ground
1908-Louis Bleriot, the Bleriot monoplane. This was the first successful mono- plane. It was also the first machine to cross the English Channel from Bragues to Dover
1910–Fabre, first practical hydroplane By the time of the World War it was recognized that aviation was strictly an engineering science. Since then some of the most remarkable advances in the field of engineering have been made in this branch

Communication

1820-Oerstedt, made the discovery that an electric current flowing through a wire built up a magnetic field around the wire
1831-Faraday and Henry, discovered the converse of Oerstedt, i.e., that a magnetic field can be cut by a wire, and cause current to flow in the wire
1837-Morse invented telegraph system. This was the basis of most modern land systems
1876-Bell, telephone
1882-Dolbear developed wireless telegraph system, using electric static induction
1888–Lodge, developed a method of synchronizing two circuits, i.e., placing them in resonance
1896-Marconi developed a system, using the Hertzian oscillator, of radio-telegraphy for sending and receiving messages
1898-Braun developed the coupled circuit
1902-Poulsen and Tessenden, radio-telephone
1903-First trans-Atlantic wireless transmission
1907-DeForrest invented the three-element tube, permitting tubes to detect as well as amplify
1921-Broadcasting
1922-Freeman and Dimmel, A.C. tube, radio
1926-J. L. Baird, television

Textile Inventions

1733–John Key, flying shuttle
1770-James Hargraves, spinning jenny
1775-Richard Arkwright, roller spinning frame, using water power
1779-Samuel Crompton, spinning

1785-Edward Cartwright, power looms, using Watt engine, first for spinning and then for weaving

1793–Eli Whitney, cotton gin

NOTE: No attempt has been made here to include the numerous inventions that have revolutionized the textile industry in the last century. The above merely indicates the initial steps that were responsible for the Industrial Revolution.

References:

History of Mechanical Inventions, Usher.

Behemoth, The Story of Power, Hodgins and Magoun.

Lesson 13

INDUSTRIAL GROWTH CURVES

If one attempts to follow the industrial development that has taken place in the Western World since the year 1700 by attempting to take into account all of the separate inventions and technical developments that have occurred in the various fields of industry, he soon finds himself hopelessly involved. Order, however, readily emerges from this chaos when one considers that all of this industrial activity has been based in the main upon the use of a few relatively simple substances, chiefly, the few industrial metals—iron, copper, tin, lead, zinc, etc.—as the essential materials for machinery, and the use of a few basic sources of energy, chiefly, the mineral fuels, coal, oil and natural gas, and, of lesser importance, water power.

The most accurate quantitative picture of the rate and magnitude of our industrial growth, however, could be obtained by plotting growth curves of the production of these primary metals and of energy. In this lesson we are presenting, therefore, the growth curves of a number of our basic industries—the production of pig iron, coal, energy, railroads, and automobiles. These curves are plotted with the vertical dimension representing the quantity produced per annum, the horizontal dimension measured from left to right representing time in years.[1]

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[1] The data for these curves were obtained from the Mineral Resources of the U.S.A., U.S. Statistical Abstracts and Mineral Industry, Vol. 41. For 1933 figures the Survey of Current Business was used. These volumes contain the most authoritative figures that can be obtained.

13.1 Pig Iron

There are a number of highly instructive details to be observed about each of these curves. In the first case, they are not smooth, but are, instead, jagged or zig-zag. This is due to the fact that the production fluctuated from one year to the next. This is particularly noticeable in the case of pig iron.

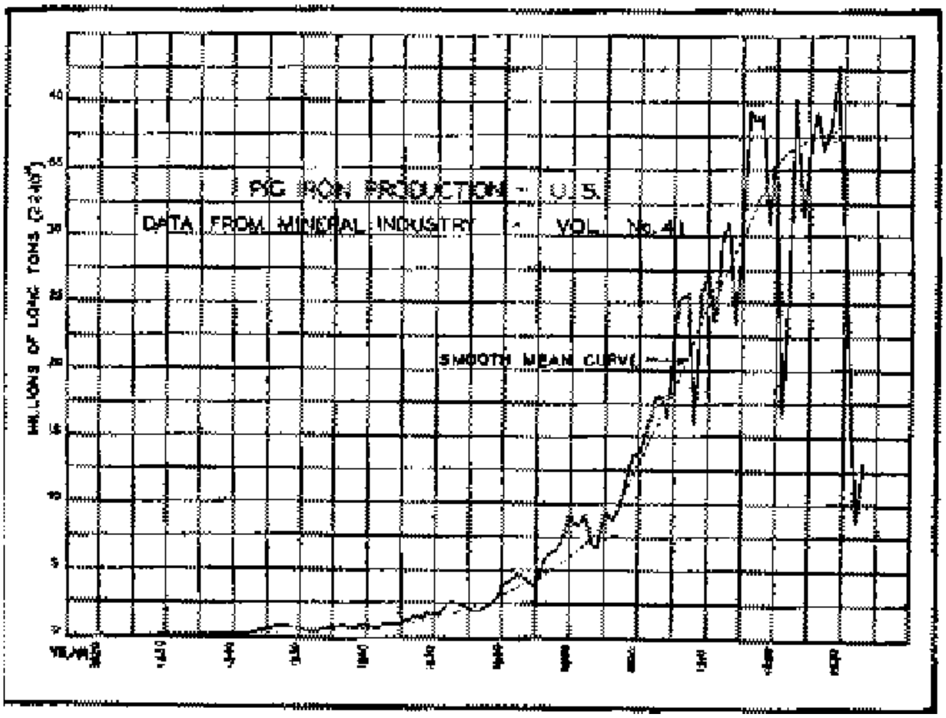

Figure 13.1: Pig Iron Production

In Figure 13.1 notice the drop in the production of pig iron during the depression of 1893 and 1894 and, after that depression, notice that the pig iron industry expanded for a number of years, and enjoyed uninterrupted prosperity.

Then came the depression of 1908, which shows up as a severe shutdown in the pig iron industry. This shutdown lasted one year, followed by a still further expansion and growth culminating in the large peak of production from 1916 to 1918, showing the effect of large war orders for steel.

Note next the depression of 1921. After this the pig iron industry recovered somewhat, but did not expand as rapidly. The highest peak of production in pig iron was reached in 1929. This was followed immediately by the enormous drop due to the present depression. [1932-33]

What were the actual magnitudes of these depressions? If we measure the graph, we find that the drop in production from peak to trough in 1893 and 1894 was 27 percent; in 1908 the corresponding drop was 38 percent; in the depression of 1921, the shutdown in pig iron was 57 percent from the previous peak of production; the drop since 1929 has been 79 percent. [to 1933]

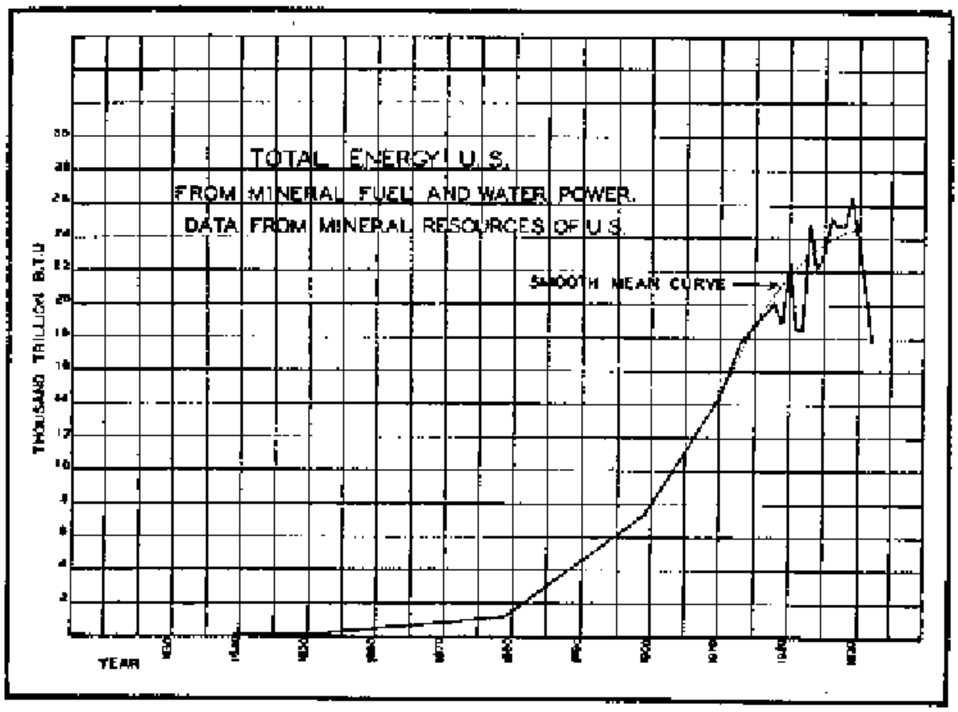

Figure 13.2: Energy Production

What does this mean? Simply this: that, stated in terms of physical measurements, each depression since 1894 has been progressively bigger than the previous. These up and down movements of the production curve are spoken of as swings or oscillations. The biggest oscillations since 1893-94 coincide with the financial depressions. Each one of these depression oscillations has had an amplitude or depth of swing approximately 30 percent greater than the one preceding. If one examines the other curves, that of coal, for instance, or of automobiles, he finds a similar situation. The larger the production becomes the larger become the oscillations; the largest being in each case that since 1929, both in absolute magnitude and also in percentage of the total production. (The smooth part of the total energy graph [Figure 13.2] for the time preceding 1918 does not indicate that there were no oscillations in this period in energy production because in this part of the graph the figures are all averaged for ten-year periods. This method of plotting smoothes out the oscillations.)

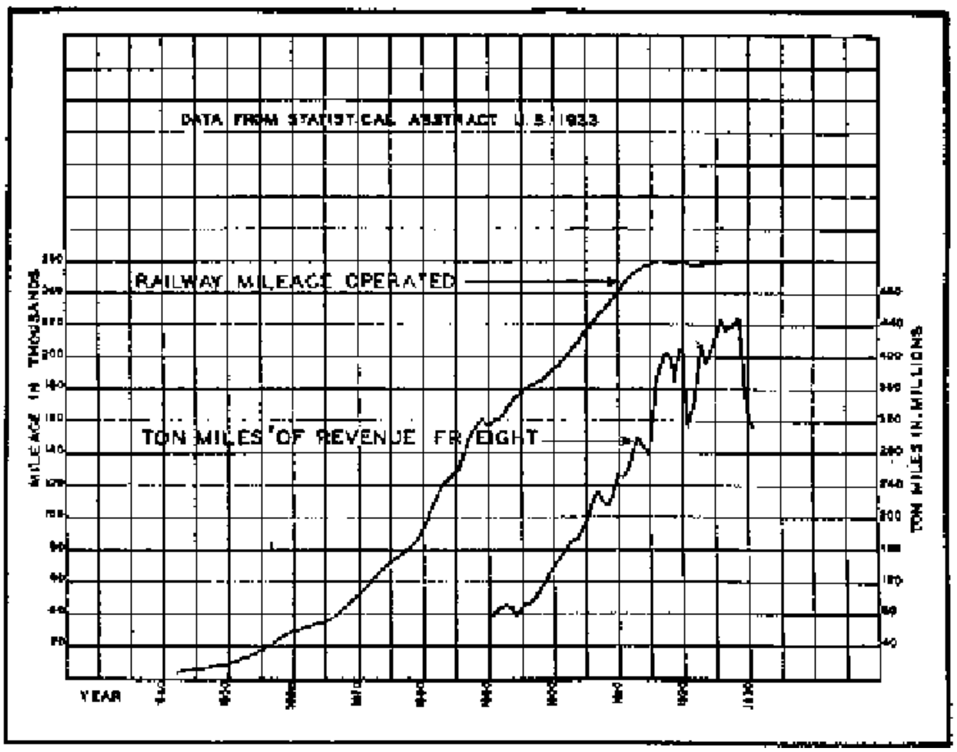

Figure 13.3: Railway Data

13.1.1 Growth of railroads

Figure 13.3 shows no oscillations because it represents the number of miles of railroad track in operation and this, of course, increases, but rarely decreases, from year to year. The oscillations of exactly the same kind as those exhibited by pig-iron, however, are found in the second railroad graph, that of ton-miles of revenue freight hauled. (One ton-mile is equal to one ton hauled one mile.)

13.2 Point of Inflection

Another feature to be observed about each of these growth curves is that represented by the smooth dotted-line curve. This dotted-line curve has in each case been drawn to represent the mean rate of growth. Notice in each case the S-shape of this curve. In the beginning it starts up very gradually, but each year the increase in production is greater than that for the year preceding and during this time period the curve is concave upward. Finally, in each case there comes a time when the growth begins to slacken, and the curve becomes convex upward and begins to level off rapidly. The point at which this smooth mean curve changes from concave upward to convex upward is called the point of inflection.

This point of inflection occurred in pig iron about the year 1905; in railroad trackage about 1885; in railroad freight haulage about 1910; in automobile production about 1921, and in ‘all energy’ about 1912.

Calculation shows that the state of growth before the point of inflection is reached has been a compound interest rate of growth; that is to say, that the production each year during that period was on the average a certain fixed percentage greater than that of the year before. In the case of coal and energy production this rate of increase was approximately 7 percent per annum during that same period. The same is true for pig iron. In other words, with the rate of growth that prevailed during that period the annual production was increased tenfold in 32 1/2 years.

All of the graphs mentioned thus far have been those of basic industries, extending back approximately a hundred years or more. Since not infrequently our economic soothsayers assure us that as older industries reach their saturation, or decline, newer and bigger industries always rise to take their places, it becomes a matter of some particular importance to examine the rise in growth of one of these newer industries. Of such industries, automobiles are by far the most striking example. The automobile industry practically began in the year 1900. Since that time it has risen into one of the greatest of our present industries, and has practically revolutionized our social life in the process.

13.2.1 Production of Automobiles

In what manner did the production of automobiles grow? A glance at the growth of automobile production in Figure 13.4 will indicate that the production of automobiles grew in a manner essentially similar to those older industries we have just discussed. In this curve, just as in those previous, there are zig-zag oscillations, by far the greatest being that since 1929.

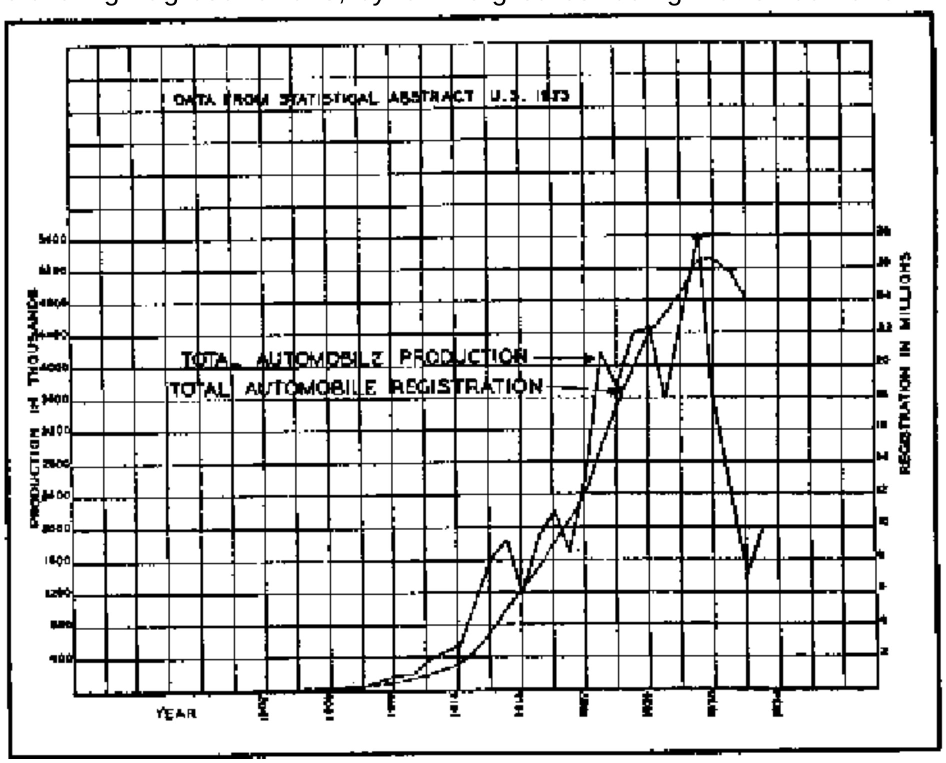

Figure 13.4: Automobile Data

The production of automobiles reached an all-time peak in the year 1929, with an annual production of 5,600,000 automobiles. From that time until 1932 the production dropped to 1,400,000 cars per annum, a shut-down of 75 percent. A mean curve of this growth of automobile production shows a distinct leveling-off since the year 1923. The point of inflection of the mean growth curve occurs about the year 1921-22. The broken line curve on the Automobile chart represents the number of registered motor vehicles in the United States. It will be noted that this number in 1929 was something over

26,000,000. Also notice that this curve has been leveling off since 1926.

13.2.2 Radio

Or, to select another new industry, radio is an excellent example. Unfortunately, reliable data are not available for plotting a growth curve of the number of radio sets. This much, however, we do know, that radio broadcasting began on a commercial scale about the year 1921. From that time it grew with amazing rapidity until by 1929 by far the greater number of people in this country had radio sets. Since that time the number of radio sets in operation appears, from such data as are available, to be increasing but slightly.

13.3 Biological Growth Curves

From the study of the foregoing graphs of the growths of various of our basic industries the persistent S-shape of each of the growth curves examined is a striking and singular phenomenon, and merits further investigation.

Dr. Raymond Pearl, in his book, Biology of Population Growth, has made an extensive study of types of growth, and has found that almost every growth phenomenon exhibits this same S-shape characteristic. One of his experiments consisted in placing a pair of fruit flies in a bottle, and letting them multiply while he kept a record of the increase of the fly population on successive days. When plotted as a growth curve after the manner of the charts above, the curve of the growth of the fly population would be indistinguishable from our mean curve of coal or pig iron production.

Bacteriologists have found that yeast cells or bacteria when placed in a test tube under conditions favorable for their multiplication increase in numbers in a manner identical to that discussed above. Dr. Pearl has found ample evidence that human populations obey the same laws of growth.

13.4 Fallacy of Economists

It is a simple matter to see why in the initial stages organisms and new industries should, under favorable conditions, expand at approximately a compound interest rate of growth. Since, until recently, most of the industrial development of this country has still remained in the compound interest stage, it has come to be naively expected by our business men and their apologists, the economists, that such a rate of growth was somehow inherent in the industrial processes. This naive assumption was embodied in the graphs and charts made by these gentlemen, in which ‘normal’ conditions were taken to be a steady industrial growth at the rate of 5 percent or more per annum. Such conditions being ‘normal,’ it was further assumed, without question, that such normal growth would continue indefinitely. We have already seen that the actual facts warrant no such assumption.

The question remains, however, as to why these growth processes have abandoned the original upward trend and tend to level off or reach a stage of saturation. The simplest case, perhaps, with which to answer this question would be that of the growth of fruit flies inside their bottle universe. Should the fruit flies continue to multiply at their initial compound interest rate, it can be shown by computation that in a relatively few weeks the number would be considerably greater than the capacity of the bottle. This being so, it is a very simple matter to see why there is a definite limit to the number of fruit flies that can live in the bottle. Once this number is reached, the death rate is equal to the birth rate, and population growth ceases.

Very little thought and examination of the facts should suffice to convince one that in the case of the production of coal, pig iron or automobiles, the circumstances are not essentially different.

13.4.1 Coal

As we have pointed out already, during the period from 1860 to 1910 coal production increased at the rate of 7 percent per annum. According to the report of the International Geological Congress in 1912, the coal reserves of the United States are about 3.8 million tons (3.8×10^{12} tons). Had our rate of coal consumption continued to grow at 7 percent per annum, all the coal reserves of the United States would be exhausted by the year 2033, almost exactly 100 years hence.

13.5 Theoretical Growth Curves

The exhaustion of coal or of any other mineral resource is, however, not something that happens suddenly, but occurs very gradually instead, by a process which is somewhat analogous to the dipping of water from a pail, when one is allowed to take only one-tenth of what remains each time.

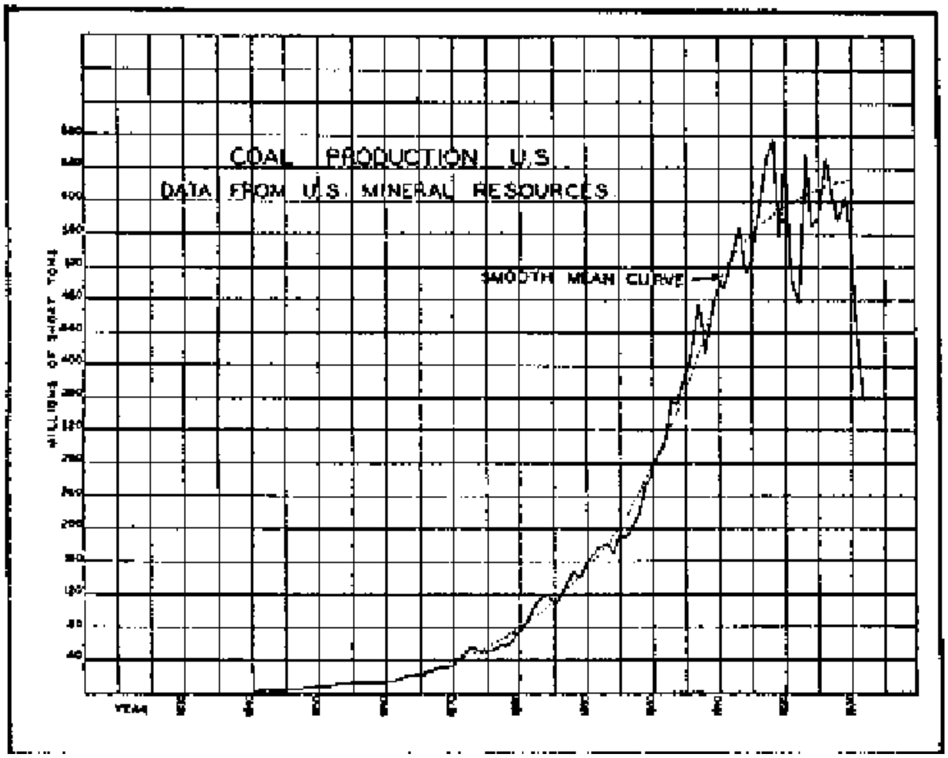

Figure 13.5: Coal Production

To show the various types of growth a chart of four theoretical growth curves has been inserted.

In Figure 13.6, Curve I represents pure compound interest at 5 percent per annum. It will be noticed that many physical types of growth approximate this curve in its lower parts, but ultimately, due to the fact that no physical quantity can increase indefinitely, all cases of physical growth must depart from this initial compound interest curve. The later stages in various types of physical growth are shown in Curves II, III and IV.

Curve II represents a type of growth which reaches a maximum, and thereafter remains constant. A familiar illustration of this type of growth is represented by water power. Power produced from waterfalls in a given area can increase until all the falls are harnessed. Thereafter, provided the installations are maintained, the production of such power remains constant.

Curve III represents a type of growth which reaches a maximum, then declines somewhat, and finally tends to level off at some intermediate level. In the United States the production of lumber follows such a curve as III. In the initial conditions virgin timber was slashed off, and the lumber industry grew until it reached a production peak. Then, as the forests diminished, the production of lumber tended to decline. The final leveling-off process will be reached when the production of lumber shall be maintained equal to the rate of growth of forests and reforestation.

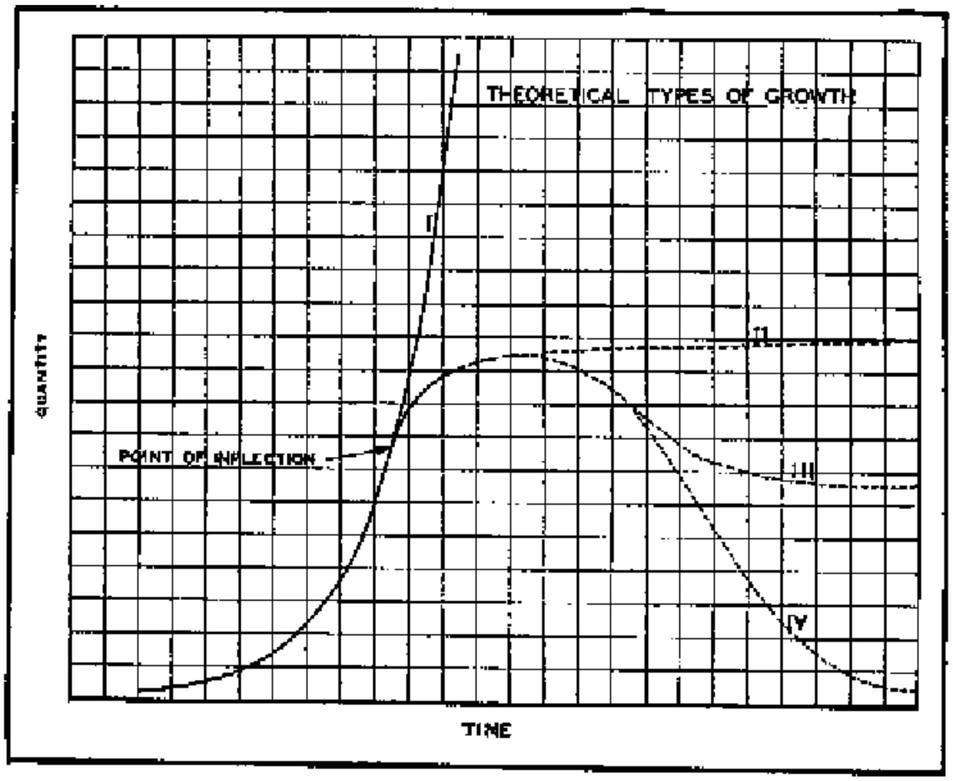

Figure 13.6: Theoretical Growth Curves

Curve IV is the type of growth curve characteristic of the exploitation of any non-recurrent material, such as all mineral resources. Coal, oil and the metals all exist in minable deposits in definitely limited quantities. One of the simplest illustrations of a curve such as type IV is illustrated in the life history of a single oil pool. In an oil pool the production rises as more and more wells are drilled, until it reaches a peak. From that time on the production declines year by year, until finally it becomes so small that the pool is abandoned. In most American oil pools the greater part of this history takes place within 5 to 8 years after the discovery, though the pool may continue to be operated for the small remaining amount of oil for 10 or 15 years longer.

In the case of mineral fuel, such as coal and oil, it is the energy content that is of importance in use. This energy is degraded in accordance with the second law of thermodynamics. Thus, coal and oil can only be used once. The case of the metals is somewhat different. Iron, copper, tin, lead, zinc, etc., can be used over and over again, and are never in a physical sense destroyed. In the process of using metals, however, there is a continuous wastage through oxidation and other chemical reactions, through the discarding of iron and tin in the form of tin cans, razor blades, etc. While this does not destroy the metal it disseminates it in such a manner as to render it unavailable for future use.

Primary metals are derived from naturally occurring ore deposits containing the metallic salts and other compounds at relatively high concentrations. Thus, there is a flow of metals from the limited deposits at high concentrations into industrial uses, and finally, by wastage and dissemination, back to earth again in widely scattered and hence unavailable forms. This process, like that of the degradation of energy, is unidirectional and irreversible. It follows, therefore, that the production of the rarer metals, such as are now most commonly used in industrial processes, must ultimately reach its peak and decline after the manner illustrated by Curve IV.

It is not intended to convey by the above calculations the impression that the leveling-off of our present growth curves is due as yet in any large measure to exhaustion or scarcity of resources. The resource limitations are cited only as an illustration of one of the many things that must eventually aid in producing this result.

13.6 Social and Industrial Results

The leveling-off of the production curves thus far has been due largely to a saturation in the ability to consume under our existing Price System limitations of the ability of the individual to purchase. There is a definite limit as to how much food an individual can consume in a given time; how many clothes he can wear out; and, in general, how much energy degradation he can account for. There is no question but that in many respects the people of the United States prior to 1929 were approaching some of these limits, and that accounts in some degree for the slowing down of the growth of production in many fields. There was an average at that time of one automobile per family. This fact, together with the consequent congestion of traffic, was sufficient to depress the rate of growth of automobile production.

Another important factor that is rarely taken into account in this connection is that, due to the change of rate in the operation of physical equipment, at the present time almost every new piece of machinery runs faster than the obsolete one which it displaces. There is a physical relationship in all physical equipment to the effect that for a given rate of output the faster machinery is made to operate, the smaller it needs to be. Compare, for example, the size of a 1 h.p. high-speed electric motor with a slow-acting gasoline engine of the same power. This relationship is true, whether the equipment be individual machines, whether it be a whole factory, or whether it be a whole industry. Since the production of consumable goods is leveling off, and the machinery is being continuously sped up, it follows that our industrial plants and equipment, instead of getting larger, may actually diminish in size.

The implication of this fact with regard to the demand for such raw materials as iron, copper, etc., is far-reaching. In our pioneer days, and during the period of most rapid growth, railroads, telegraph and telephone systems, power systems, and factories, had to be built, each requiring its quota of primary metals. Now that these things have already been built, the materials for the construction of new equipment are largely obtained by junking the equipment now obsolete. To appreciate the importance of this rise in the use of secondary metals, consider the fact that in the year 1933 the production of secondary copper was over 90 percent of that of the primary copper in the United States for that year.

13.7 Summary

In this lesson we have tried to show in quantitative terms what the leading facts of our industrial expansion have been. Man's learning to convert to his own uses the vast supply of energy contained in fossil fuelscoal and oil—has opened up a totally new and unparalleled phase of human history. It has been estimated that the effect of this upon the biological equilibrium of the human species has been such that the human population on the globe has approximately tripled since the year 1800. Areas like the British Isles, which, under a pre-technological state of the industrial arts, were able to support only from 5,000,000 to 8,000,000 people, now have populations of approximately 46,000,000, or a population density of 490 persons per square mile.

It has been shown that this industrial growth has been characterized in the initial stages by a compound interest rate of expansion of about 7 percent per annum in the United States. It has also been shown that not only is it impossible to maintain for more than a few decades such a rate of expansion, but that in the United States that period of most rapid growth has passed, and that already more or less unconsciously we have entered well into the second period of growth, that of leveling off and maturation.

Due to the physical limitations it seems at present that the days of great industrial expansion in America are over unless new and as yet untapped sources of energy become available. We have been told repeatedly that new industries have been and will continue to be sufficient to maintain the industrial growth as older industries slacken. Consideration of the graph of total energy which represents the motive power of all industries, new and old, indicates that, until the present, such has not been the case, and there are no prospects that it will be so in the future.

Foreign trade has been frequently invoked as a means of maintaining our industrial growth. Invariably in such cases, however, foreign trade has been discussed implicitly as a ‘favorable balance of trade,’ which implied that the amount exported will be in excess of the amount imported. Physically a ‘favorable balance of trade’ consists in shipping out more goods than we receive. Following this logic a ‘perfect trade balance’ should consist in a state of commerce wherein everything was shipped out and nothing received in return.

Under our present Price System, or monetary economy, an unbalanced foreign trade can only be maintained, as we are learning to our sorrow, for a comparatively short length of time. With a balance of trade there is no reason to expect any essential increase in the domestic production of this country by means of foreign markets for such a condition necessitates that approximately equal quantities of goods be obtained from abroad, and the net effect is zero.

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Lesson 14

MINERAL RESOURCES

In the United States in 1929, 55 percent of all revenue freight hauled by Class I railroads consisted of 'products of the mines'. This classification included only mineral products before manufacture. If the same products after manufacture had been included, the total would have been approximately 75 percent. Thus, modern high-energy civilizations, as contrasted with all previous ones of a low-energy character, may truly be called mineral civilizations.

In all earlier civilizations the rate of energy consumption per capita per day has been low, the order at most of 2,000 or 3,000 kilogram calories of extraneous energy. In the United States, in 1929, this figure had reached the unprecedented total of 153,000 kilogram calories per capita per day. The significance of this can best be appreciated if we consider that this figure is responsible for the railroads, the automobiles, the airplanes, the telephone, telegraph and radio, the electric light and power; in short, for everything that distinguishes fundamentally our present state of civilization from all those of the past, and from those of such countries as India and China at the present time. Stated conversely, if we did not consume energy—coal, oil, gas and water power—at this or a similar rate, our present industrial civilization would not exist. Ours is a civilization of energy and metals.

Inspection of the growth curves in Lesson 13 shows us something that is rather startling, namely, that most of this industrial growth in the United States has occurred since the year 1900. Stated in another way, if from those curves we compute the amount of coal or iron that has been produced and used since 1900, we would find this to be greatly in excess of all the coal and iron produced prior to that time.

14.1 Discovery of Minerals

It frequently is assumed by people interested in world social problems that such industrial growth as has taken place in North America and Western Europe is a mere accident of circumstances, and that it might equally well have occurred in India or China instead. A corollary to this assumption is that it is possible for these areas to develop high-energy industrial civilizations and that the only reason they have not done so thus far is due to the backwardness of the people.

Since we have found that high-energy civilizations depend upon the existence of abundant resources—energy and industrial metals—it is a very simple matter to determine the validity of such assumptions by considering the world distribution of these essential minerals.

Until 30 or 40 years ago, the knowledge of the world distribution of minerals was more or less in the category of the knowledge of the geographical distribution of land shortly after the discovery of the Americas. Maps of the known world in the sixteenth century showed certain land areas that were well known, such as parts of Europe, Africa and Asia; other areas which were but partially known, such as the eastern boundary of the only partially explored New World; and other parts of the world which were totally blank, due to the fact that no knowledge of these parts whatsoever was available.

In the mineral map of the world prior to 1900, there were still large blank places representing areas as yet unknown. Since that time these blank spaces have become almost non-existent. Quietly and unheralded, the prospector, followed by the geologist and the mining engineer, has penetrated to the utmost corners of the earth.

It is a well known geological fact that certain mineral resources only occur in large amounts in certain geological environments.

Oil, for instance, only occurs in sedimentary rocks which have not been too greatly folded or otherwise disturbed since their original deposition. In igneous rocks or in pre-Cambrian basement complexes, such as the region between the Great Lakes and Hudson Bay, or of the Scandinavian Peninsula, oil in large quantities cannot exist.

Iron ores, likewise, as Leith pointed out, have shown a remarkable tendency to occur in these very pre-Cambrian terrains of the United States, Brazil, India and South Africa, from which oil is absent. Other mineral resources have their own more probable environments. Since these various major types of areas are known, it follows that the geography of the future mineral discoveries for the entire world may now be fairly well predicted.

14.1.1 Methods of Discovery

The intensity of prospecting and the number of people engaged in the search for new mineral deposits have in the last few decades increased tremendously. The old-fashioned prospector, with burro, pick and hammer, has been replaced by the modern highly trained geologist and mining engineer, traveling by automobile and by airplane. Areas are now mapped by aerial photography. Geophysical instruments are now available which enable the oil geologist to discover salt-dome oil pools that are completely hidden beneath the surface of the ground. He has seismographs that enable him to make maps of geological structures at depths of 5,000 feet, and more, beneath the surface of the ground. For the use of the mining engineer there are electrical instruments capable of detecting metallic minerals buried several hundred feet under earth. By means of these methods the mineral geography of the earth is at present rather well known.

It is significant to note, as Leith has pointed out, that except for oil (and recently potash in the United States[1]), a major source of minerals has not been discovered in Europe since 1850, and in the United States since 1910. This seems to indicate that most of the discovering in these areas may have been done already.

14.1.2 Coal

What is the mineral geography of the world as it is now known? Consider coal, which is probably the best known of the major mineral resources.

It is interesting to note that the United States alone, according to the estimate of the International Geological Congress of 1913, possesses approximately 51 percent of the coal reserves of the entire world. Canada has about 16 percent of the world total. Of the remaining 33 percent, Europe has approximately a third, or 10 percent of the world's total. Asia, Africa, South America and Australia, all together, have only about 23 percent of the world's total coal reserves.

Within the last few years there has been discovered and New Mexico and Texas what promises to be the world's largest supply of potash.

14.1.3 Oil

In the case of oil, the United States in 1929 was producing 69 percent of the world's total production.

The proven oil reserves of the world in 1933 were, according to the estimate of Garfias, in a report read before the Society of Mining and Metallurgical Engineers, approximately 25 billion barrels. Of these, 48 percent, or 12 billion barrels, were in the United States. This estimate of reserves represents only the differential between discovery and consumption of oil. Should discovery cease a reserve of 12 billion barrels would last the United States only about 12 years at the 1929 rate of consumption.

14.1.4 Iron

The iron reserves of the world are localized chiefly in a few areas. In the United States most of the iron produced comes from the region around Lake Superior, and the Birmingham district in Alabama. Foreign iron ores, in greatest abundance, are to be found in such regions as England, Alsace-Lorraine, Spain, Sweden and Russia. In South America the largest reserves are found in Brazil. Other large supplies are found in India, South Africa and Australia.

The United States in 1929 produced slightly less than 48 percent of the world's total production of pig iron.

14.1.5 Copper

Next to iron, the most important industrial metal is probably copper. In 1929 the total world production of copper was 2,100,000 short tons, of which the United States in that year produced 1,000,000 short tons, or slightly less than 50 percent. Of our major metallic resources, copper is probably the nearest to a forced decline resulting from a gradual exhaustion of high grade ores. Within the last few years large supplies of African copper have rapidly come into a prominent place in world production. It is quite possible that Africa may become the leading producer of copper in the future.

From what has been said with regard to the production and reserves of coal, oil, iron and copper, it becomes evident that the United States is singularly well supplied with the world's essential industrial minerals. In fact, it would not be overstating the case to say that the United States has the lion's share of the world's mineral resources. She is by far the best supplied of all the nations of the world, and the North American Continent surpasses in a similar manner all the other continents.

14.1.6 The Ferro-alloys

The United States, however, is largely devoid of certain highly essential industrial minerals, the group known as the ferro-alloys—manganese, chromite, nickel, and vanadium. While these minerals are required only in small quantities, they are essential for most alloy steels which are used in industrial processes, and but for them, modern high-speed machinery would be impossible. So essential are these alloys that in war time they have come to be known as 'key' minerals.

It is interesting to note in passing that for the period from 1910 to 1914, Germany's importations of ferro-alloys were considerably in excess of her industrial requirements for that period. It is equally significant to note that at the present time the French importations are in excess of France's present industrial requirements. Fortunately, Canada is the world's leading producer of nickel.

14.2 Movement of Supplies

A review of the world mineral geography shows that by far the greater part of the world's industrial minerals are located in the land areas bordering the North Atlantic, Western Europe, the United States and Canada. Supplies of individual minerals occur in other parts of the world in quantities sufficient to be important in the world production. Examples of this are to be found in the case of oil in Venezuela and Colombia, copper and nitrates in Chile, tungsten in China, tin in Bolivia and the Dutch East Indies, and iron ores in Brazil.

It has long since become axiomatic in the iron and steel industry that iron ore moves to coal for smelting, and not the reverse. Iron ore, for instance, moves from the Great Lakes region to the blast furnaces of Gary, Cleveland and Pittsburgh. In Europe, the iron ores of Sweden and of Spain move to the coal fields of England, France and Germany.

A similar type of thing is true in the case of any essential industrial mineral when it occurs in a region devoid of sufficient other minerals to support a high-energy industrial system. Consider Colombia and Venezuela in the case of oil. Venezuela is third in the order of the oil producing countries of the world, and Colombia is sixth. Both countries have ample oil production to support an automobile traffic comparable to that of any other area. If one, however, should visit Bogota, the capital of Colombia, he would find only a few automobiles owned by government officials and the wealthier citizens. These can be driven around the town and for just a few miles out into the country, beyond which all automobile roads end. The cars have to be brought in by boat and by railroad. The country as a whole is almost totally devoid of automobiles, or of passable roads. Colombian oil, therefore, instead of supporting a domestic automobile traffic, flows to the industrialized areas of North America and Europe.

In a similar manner tungsten moves from China to the United States and to Europe, tin moves from Bolivia and from the Malay Peninsula, vanadium moves from Peru, copper and nitrates from Chile, and copper from South Africa.

14.3 Unequal Distribution of Resources

The significant thing about the world's mineral geography is that industrial minerals in quantities large enough to play significant roles in modern industry are very unequally distributed about the face of the earth, and moreover, tend to occur in a comparatively small number of point sources. Most of the world's iron, as we have pointed out, is derived from only about half a dozen regions. Most of the world's oil comes from a similar number of localities. The world's potash comes chiefly from the Strassfurt deposits in Germany. Most of the world's nickel comes from two sources, the Sudbury district of Canada, and from New Caledonia.

The social significance of this unequal distribution of the world's minerals is that industrial equality of the various areas of the earth's surface is a physical impossibility.

So long as the world's industrial motive power necessary to maintain high-energy civilizations is derived chiefly from the fossil fuels—coal and oil—the North American Continent and Western Europe will continue to dominate industrially the rest of the world.

The social idealist's dream of a world state and world equality is based on an utter failure to consider the physical factors upon which the realization of such a dream depends. Unless some new and as yet untapped source of energy becomes available, the 475,000,000 of people in China are likely to continue at approximately their present standard of living.

The problem of maintaining an industrial civilization is a problem which is peculiar separately to each major industrial area. The laws of thermodynamics are universal. They are exactly the same in China, India or Soviet Russia, as they are in the United States. The distribution of coal and oil in each of these areas, however, is radically different.

14.4 The North American Continent

Industrially, and from the point of view of resources, the North American Continent comprises the most nearly self-sufficient high-energy industrial area on the earth's surface. When the tropical vegetation of Mexico, Central America, and the West Indies is combined with the temperate products of the United States and Canada, very little in the way of vegetable products need be obtained from the outside world. Likewise, when the mineral products of this area, chiefly the United States and Canada, be pooled for a common industrial operation, an almost complete mineral independence is achieved. Geographically and industrially, therefore, the North American Continent comprises a natural unit.

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Lesson 15

MORE ABOUT GROWTH CURVES

In the lessons preceding, we have seen that the industrial growth of Western Europe and North America has, within the last 150 years, undergone a phase of development totally unlike that of any previous period in the world's history. Industrial growth, we have seen, has followed the now familiar S-shape curve, beginning with the period of most rapid growth, and gradually reaching maturity and leveling-off.

We have seen further that it was by no means accidental that this spectacular industrial growth should have occurred in Western Europe and North America rather than in Asia or South America, for the simple reason that large scale industrial growth requires that there be readily available a suitable ensemble of mineral resources, principally coal and iron, together with the accessory minerals yielding copper, lead, zinc, and the ferro-alloys. This required assemblage of mineral resources in amounts essential to large-scale industrial growth has thus far only been discovered in the countries bordering the North Atlantic Ocean, and, according to present available evidence, is lacking in such amounts in other parts of the earth.

A large class of phenomena grows according to this same S-shape growth curve—bacteria, yeast, biological populations of all kinds, including human beings, as well as all kinds of industry.

15.1 The ‘Decline’ Curve

There is another type of ‘growth’ curve, however, that behaves in a manner quite differently from these that we have discussed thus far. This is a type which decreases as those above increase. Perhaps this latter should more correctly be called a ‘decline’ curve instead of a ‘growth’ curve. We can speak of them as growth curves, however, provided we understand the word growth to mean a change of magnitude, whether smaller or larger.

As an example of this latter type of growth phenomenon, consider the amount of human time required to produce a single thing, for instance, to mine a ton of coal. This brings us face to face with the problem of how we shall measure the amount of human time required to do a particular thing. One of the measures of human time commonly employed is that of the ‘man-day.’ A man-day would represent one man working one day. Thus, five men working 3 days each would be employed for 15 man-days.

15.2 The Man-hour

The objection to the man-day as a unit of human employment rests upon the fact that different man-days are not ordinarily of the same length. There have been times, both in this country and in England, when men worked 16 hours per day. At that time a man-day would have been one man working sixteen hours. At the present time a man-day consists ordinarily of one man working 8 hours. Thus, a man-day with a man working 8 hours is only one-half as long as when the man works 16 hours.

It is this inconstancy of the man-day that makes it unsuitable as a measure of human employment. In order to accurately measure anything, one requires a unit of measurement which remains essentially the same. A far more suitable unit of measurement of human employment, therefore, is the man-hour.

A man-hour of human employment represents one man working one hour.

Now consider how many man-hours of human employment it must have taken, say 100 years ago, to mine a ton of coal. By considering the methods of coal mining then in use, we can arrive at some estimate of what this must have been. At that time practically all the coal mining in the United States was done entirely by hand methods—the digging with pick and shovel, and the hoisting with a rope and pulley or windlass. Coal mining was in its infancy, and only the most shallow seams were worked. If it had been possible by these methods to have worked the deeper seams such as are now worked with power machinery in the Pennsylvania anthracite fields, as well as the bituminous fields of the Middle West, the number of man-hours required per ton would have been enormously greater.

The best available data indicate that 100 years ago, one man could not mine on the average more than a ton of coal in one day of 12 hours; in other words, it took 12 man-hours to mine one ton.

In the industrial growth that followed, the coal mining industry, as we have already seen, increased enormously until by 1918 we produced 670 million tons of coal in one year. During all this period, slowly at first, and then more rapidly as the production grew in size, we improved our coal mining technique. First, steam pumps and power hoists were introduced; then blowing engines for the ventilation of the mines; explosives were used for breaking the coal and rendering more easy its extraction. Later, coal cutting machines and automatic loaders were introduced. More recently, large scale strip mining methods have been employed where giant electric shovels of 30 and 40 tons per bucketful strip off the overlying rock to depths of 50 or 60 feet. These are followed by smaller shovels which scoop up the coal seam thus uncovered and dump it directly into waiting railroad cars.

Figured on the basis of coal mined, the average rate of production of all the coal mined in the United States is approximately six tons per man per eight-hour day. Stated in terms of man-hours, this means that it now takes 8 man-hours on the average to mine 6 tons of coal, whereas, 100 years ago it required 12 man-hours to mine one ton of coal. Thus, the man-hours required per ton of coal mined has declined since 1830 from 12 to 1.33 man-hours per ton of coal.

If we had considered only the best modern practice, such as is represented in completely mechanized underground mines, or in the strip mines, a much greater drop would have been found. The strip mines average about 15 tons per man per eight hours. This represents approximately one-half man-hour per ton.

If complete data were available to plot a graph of the number of man-hours required to mine 1 ton of coal from the year 1830 to the present, one would find that the number, instead of getting larger with time, grows continuously smaller. In order to reduce the number of man-hours required to mine 1 ton of coal below the figures that have been reached already, it is not even necessary to invent any new machinery. One needs only to install modern labor-saving equipment in those mines which have not been so equipped; and by so doing, it will be possible to reduce the number of man-hours required to mine a ton of coal much below the figure that we now have reached.

In order to obtain an idea of the rate at which this mechanization of the coal mines is taking place, it is interesting to note that in the year 1923, 1,880,000 tons of bituminous coal were produced by mechanized mines; by 1931, the bituminous coal produced by mechanized mining had reached 47,562,000 tons, a growth of 25 fold in 8 years. This latter figure represents somewhat less than 10 percent of the total coal mined, so that there remains still to be mechanized approximately 90 percent of our bituminous coal mines. The process of mechanization in this field is continuing almost unabated right through the present depression. This will result in a continuous decline of the man hours required to mine 1 ton of coal.

A trend similar to that in coal mining has been taking place in every industrial field. The number of man-hours required to produce a bushel of wheat, a pair of shoes, a yard of cloth, a ton of iron, or to transport a ton-mile of freight, was greater 100 years ago than it has been any time since. A curve plotted in any one of these fields would show that the man-hours required to produce one unit of product has been, and still are, getting fewer.

15.3 Mechanization of Industry

Technocracy has previously called attention to some of the more spectacular instances of mechanization of industry, such as the A. O. Smith Company's plant in Milwaukee which produced, while running, 10,000 automobile chassis frames per day with a crew of 208 men, and similar instances. While it is true that industry as a whole has not attained the level reached in its own best practices, the trend in every field is in that direction. Every time a new plant is built, or a new piece of equipment designed that replaces older equipment which has become obsolete, this new equipment runs faster and requires fewer man-hours of human attention per unit of production than its predecessor.

Another example of such a decline curve which has already been mentioned briefly in a previous lesson is that of the size of the equipment required for a given rate of production. The faster equipment is made to operate, the smaller it will be in proportion to its output. A similar relation holds good in office floor space. With the old-fashioned method of having bookkeepers work over hand-written ledgers, a much greater amount of office floor space was required to keep the books of a given volume of business than is now required with modern high-speed bookkeeping machinery.

That this process is going on unabated is shown by computations made from the Federal Reserve Board indices of production and employment in the manufacturing industries. Computation from these indices based on some 69,000 industrial establishments show that the productivity per man-hour during the period from 1920 until June 1933, almost exactly doubled. One-half of this increase occurred since 1930. In other words, mechanization proceeds more rapidly during depressions than otherwise.

On the whole, mechanization of industry in this country, far from being near completion, has just begun. We are now in the transition from the period characterized by the hand-operated machine into that characterized by the almost completely automatic technological mechanism. Instances such as the A. 0. Smith plant and the Owens bottle machine are but forerunners of the general industrial development of the near future.

15.4 Decline of Man-Hours

Figure 15.1 represents schematically these two types of growth curve over the same time period but plotted to different scales vertically. The curve of production used here is essentially that of the growth of total energy. The declining curve is a composite curve based upon such fragmentary data as are available. The man-hours per unit in the early stages declined but slowly, and then more and more rapidly as industry expanded and became more mechanized.

A third curve is also shown which is derived by computation from the first two. It is a matter of simple arithmetic to compute the number of man-hours required to produce a given number of units if we know the number of man-hours required to produce one unit. Thus, the total man-hours of employment in productive industry for any given time is equal to the product of the number of units produced in that time, multiplied by the average number of man-hours required to produce one unit.

Curve III was obtained by multiplying at successive times the production by the man-hours per unit. Assuming that Curves I and II are a correct picture, then Curve III would represent the industrial employment for this period stated in total man-hours.

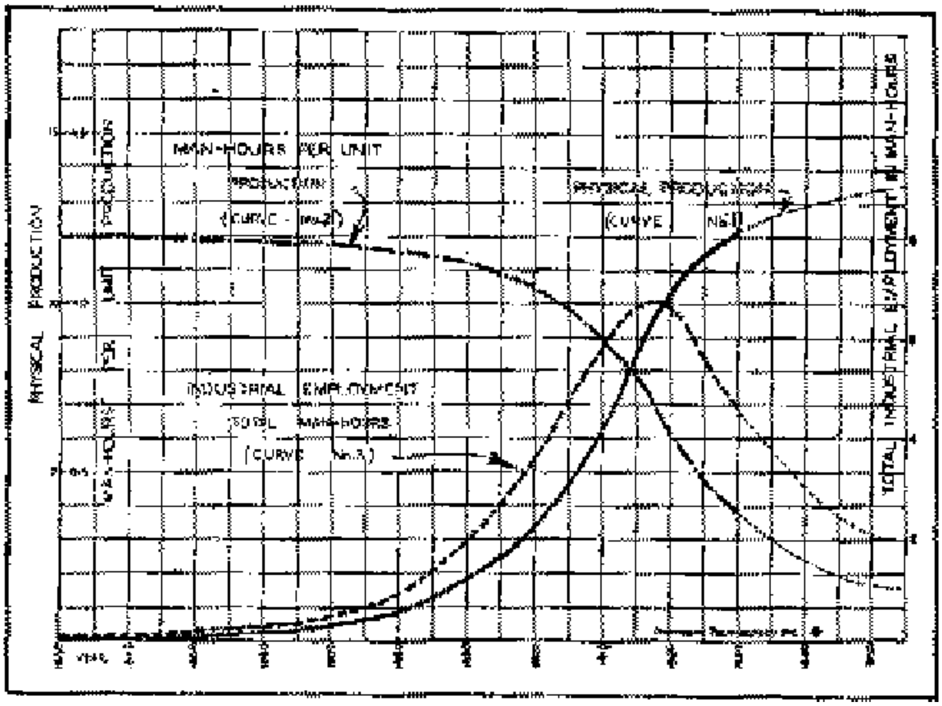

Figure 15.1: Three Curve Chart

In the early stages of industrial growth, the man-hours per unit were decreasing but slowly, consequently the employment grew at approximately the same rate as the industrial production. Then during the period of most rapid industrial growth, the increased use of labor-saving machinery with the consequent decline in the number of man-hours per unit produced tended to retard the rate of growth of industrial employment. During this period, new jobs were still being created due to the expansion of industry, faster than the old ones were being eliminated due to its mechanization. Finally, as industrial production began to level off with no corresponding slackening in the increase of mechanization, there came a time when jobs were eliminated by labor-saving machinery faster than they were created by expansion of old, or the creation of new industries.

This peak of employment has occurred at different times in different individual industries. In agriculture, the peak of employment as shown by the United States census, taken at intervals of ten years, was reached in 1910 with over 12,000,000 gainfully employed workers; by 1930 this number had declined to less than 10,500,000 persons.

The peak of employment in mining industries was reached in 1920. In the production of pig-iron the peak of employment, according to the United States Labor Bureau statistics, occurred in 1919. In the production of automobiles, the peak occurred in 1923. According to the Federal Reserve Board, the peak of industrial employment for all industries in the United States was about January 1920.

Much has been said by the apologists for the present system about new industries creating new jobs. Only recently, President Karl T. Compton, of Massachusetts Institute of Technology, and Professor R. A. Millikan, President of California Institute of Technology, broadcasted speeches by radio which have since been published in the Scientific Monthly on the thesis that science creates employment.

The essential burden of these gentleman's remarks consisted in such arguments as: The automobile industry employed more men than the wagon industry had previously been able to do. Therefore, new industries always will employ more men than the industries which they displace. Only a casual inspection of figure 15.1 would demonstrate the utter fallacy of any such careless type of reasoning. The automobile industry grew up during the period of most rapid industrial expansion when jobs were being created faster than they were being eliminated. The peak of automobile production was not reached until 1929, but that of automobile employment occurred in 1923. If production continues to level off no matter how slowly, and if the man-hour-per-unit production curve continues headed downhill, it follows that the total industrial employment stated in man-hours, which reached its peak about 1920, must continue to decline.

It is to be emphasized that these three curves as illustrated in figure 15.1 are all long-time trends, and do not include the effect of this or any previous period of depression. Note that there are no cycles in these curves. They have never repeated themselves, and there is never any going back.

Every new industry creates new jobs and eliminates old ones. Whether the number of man-hours per year of new jobs created by the composite of all new industries and expansion of old ones is greater or less than the number of man-hours per year of the old jobs eliminated depends entirely upon what stage in the growth of total industry is being considered. At all times prior to the occurrence of the peak in the curve of total man-hours per year the birth rate of new jobs exceeds the death rate of old ones and the hours of employment continuously increase. At all times subsequent to the occurrence of that peak (neglecting minor oscillations) the death rate of old jobs exceeds the birth rate of new ones and the man-hours of employment continuous decrease. Since, for American industry, this peak occurred about the year 1920, it is fallacious to employ events prior to that date as a basis upon which to draw conclusions which are supposed to be valid after that date. For the period of American industrial growth prior to 1920 it is entirely correct to state that the creation of new industries and the expansion of old ones increased the annual hours of employment; for the period subsequent to that date it is entirely incorrect to make the same statement.

It might be remarked in passing that total man-hours in industrial employment does not necessarily bear any relation to unemployment. If a total number of man-hours are required annually in industry, and if a total number of human beings are available as industrial workers, it is only necessary to properly adjust the length of the working day in order to accommodate any number of available workers. The trends depicted in figure 15.1 point inexorably to an ever-increasing unemployment or else to an indefinite shortening of the length of the working day.

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Lesson 16

THE PRICE SYSTEM

In the foregoing lessons we have discussed at some length the basic matter and energy relationships to which all events upon the earth, both organic and inorganic, must conform. We have learned in this manner that out of all conceivable things we might imagine to happen upon the earth, only those are possible for which the total matter involved is neither increased nor decreased, and for which the energy transformations are of such a nature that the occurrence does not amount to one kind or another of a perpetual-motion mechanism.

While this kind of analysis has long been fundamental in engineering when dealing with simple, small-scale problems, it has not been extensively recognized that the same technique is applicable and of fundamental importance to the far more intricate problems of the operation of a human social complex. In engineering, for example, it has long been known that if a steam engine be operated between a boiler at the absolute temperature T_1 and a condenser at the temperature T_2, the maximum possible fraction of the heat Q_1 taken from the boiler that can be converted into work is given by $[(T_1 - T_2)/T_1]Q_1$. This fact establishes an objective standard of performance. If the performance of the engine is much poorer than this, then it is known that a better engine can be built, and how much better.

A similar analysis may be made with regard to a human society operating within a given geographical area. When the material and energy resources available to that society are known the maximum rate of operation of a social mechanism in that area can be established to a reasonable approximation. If the observed operation be at a greatly inferior level to that which in this manner is known to be possible, then we know that there is room for substantial improvement. Furthermore, as in the case of the steam engine, faulty operation implies faulty design of the operating mechanism which can be corrected only by an improved design in which the faulty characteristics have been omitted.

In our brief review of world resources it appeared that many areas of the globe are so deficient in material and energy resources essential to a large-scale industry that their populations are effectually doomed to a low-energy standard of living—at least so unless and until technological advances render presently unknown resources available. We learned, however, that the Continent of North America is not so handicapped but with regard to climate, soil, biological, mineralogical, and energy resources is the most richly endowed continent on earth. In fact it has the resources and the man-power and the technological knowledge necessary to provide every human inhabitant with an optimum physical standard of living at a small and continuously decreasing labor requirement per individual. Yet if we consider the widespread poverty and squalor that is allowed to exist, the wastage and destruction of resources, the destruction of products and maintenance of enforced scarcity both by government and by private industry, and the wholesale unemployment we are obliged to conclude that the actual operation of our social mechanism is vastly inferior to its presently known potentialities.

Hence, we have a clear case of a mechanism whose actual operation is so far below that which is possible as to constitute both a social and technological scandal. That this should be so need not be surprising when it is considered that the fundamental elements of design and operation of our social structure grew up thousands of years ago to meet the needs of an agrarian economy, whereas the transition from such an economy to our present state of technological advance has occurred principally within the last century, and predominantly, so far as growth is concerned, since the year 1900. It is inconceivable that the institutions and customs which evolved to meet the needs of a society composed of hunters, peasants, sheep-herders, warriors, priests, petty merchants, and usurers should be adequate for the needs of a society operating a billion horsepower of prime movers with its consequent array of high-speed transportation, communication, and productive equipment.

A high energy civilization has needs peculiar to itself which must be explicitly recognized in any adequate design. Before we consider that problem, however, let us first examine critically some of the existing customs and folkways handed down to us from an agrarian antiquity, since it is in these that the principal faults of our present mechanism may be expected to lie.

16.1 The Concept of Property

One of the most deeply rooted of all these ancient concepts is that of property. So firmly fixed is this concept that ordinarily it is taken to be axiomatic; rarely does it ever occur to one to examine critically into its meaning. One speaks of 'my horse,' 'my dog,' 'my house,' 'my automobile,' with never a thought of just what constitutes the difference between a house that belongs, say, to Jones, and the same house if it belonged to Smith.

To make this even more clear, let us suppose that the house formerly belonged to Jones, and that he afterward sold it to Smith. Should a stranger, knowing neither Jones nor Smith, have observed the house from day to day, before and after the transaction, he would probably have been unaware that any such change had occurred. He might have noted that up until a certain date, Jones lived in the house, and that after that date Jones moved out and Smith moved in. The stranger would have observed only that there had been a change of occupancy of the house. Such change of occupancy, however, might have occurred with no change of ownership at all, as in the case of the change of tenants in a house that is rented.

What then constitutes property in a house? A little reflection will show that ownership of, or property in, a house consists entirely in what society will allow an individual to do with regard to the house. If the property in the house is Jones', that merely means that Jones is allowed by society to live in the house, to rent the house to someone else, to leave it vacant, or to tear it down. Jones may transfer parts of these privileges to other people for a consideration, as in the case of rental, or he may dispense with the privileges altogether, by sale, by gift or by forfeiture. In these latter cases, though the house remains, the right of property in the house is transferred to some other person.

The same line of reasoning applies to any other property. Thus, it becomes evident, as Lawrence T. Frank, of the Rockefeller Institute, has aptly remarked, that property consists not in a physical object, but is a mode of behavior with respect to a physical object.

The significance of this will be, perhaps, even more clearly understood if one should consider the difference between the ownership of an automobile in the middle of a 10-acre field and the ownership of the same automobile in the middle of Fifth Avenue at 2 o'clock on a busy afternoon. It would be the same automobile in either case with the same owner, but what society would allow the owner to do with his automobile in the middle of a ten-acre field is vastly different from what it would allow the same owner to do with the same automobile on Fifth Avenue.

A very similar type of thing occurs in the ownership of land. Suppose one owned a tract of land in the middle of an uninhabited wilderness. In such a case, the rights of property with regard to this land would be absolute, since, by hypothesis, there would be no society in such an instance to limit or curtail one's freedom of action; it follows that such freedom of action would be limited only by one's physical ability. He could cut or burn off the timber, cultivate or not as he saw fit, and build wherever it should please him. Suppose that some generations later a thriving city should spring up on this same tract of land. Then, if the original tract were large, it would doubtless be subdivided among many owners and into small tracts. Under these circumstances it becomes immediately obvious that the right of property in the same land would be totally different from the right of property when the area was a wilderness. Even though it were his own land, society would permit the owner only a very limited range of operations in this latter case; it would dictate to him that he could only build residence, industrial or business structures on his land, according to the city zone in which the land happened to be located. What is more, society would tell him within what specifications the wiring, the fire prevention equipment, the water supply and sanitation equipment must be built.

Property then, or more strictly, the rights of property, are quite relative, and are by no means the fixed and rigid privileges that in a more agrarian society they have been, or that is still unthinkingly implied when one occasionally becomes concerned over the possible discontinuance of private property.

In spite of this relative nature it still remains that almost every item of physical equipment that can be monopolized is at the present time considered to be the private property of individuals or groups of individuals. The land is owned, mineral resources are owned, in short, everything that is necessary for human existence and that can be so monopolized, has been taken over and monopolized by individuals or groups. The only reason that one does not pay a public utility charge on the air one breathes is that, as yet, there has not been found a way of enforcing such a monopoly.

16.2 Trade

As a corollary to the concept of ownership, and to the fact that every monopolizable thing is owned by some person or other, come concepts of trade and of value.

The simplest form of trade is that wherein one exchanges, say, ten sheep for one cow, a pound of butter for one dozen eggs, or in general, one kind of commodity or goods for another kind of commodity or goods. Such an exchange is called barter, and represents one of the most primitive forms of trade.

While, casually, barter would be thought of purely and simply as an exchange of goods, a little consideration will show that what actually is exchanged is the property rights in these goods. If Jones trades Smith ten sheep for one cow, the property rights that society allows Jones with respect to the sheep are transferred to Smith, and vice versa with respect to the cow. Since there are numerous kinds of transfer of physical goods which are not trade, it is important that one keep this distinction in mind. For example, if one goes into a restaurant and orders himself a meal which he pays for with money, he is engaging in trade. If he has ample money he may seek a very expensive restaurant and dine in style. If he has very little money he may seek a lunch wagon and content himself with a ham sandwich and a cup of coffee. A similar circumstance holds with regard to clothing. His choice of an expensive or a cheap suit of clothing may likewise be determined by his supply of ready cash. Both of these instances are examples of trade.

In an army, however, one is clothed and one is fed. In this case clothing passes from the quartermaster corps to the individual. While there is a transfer of custody of the clothing from the hands of the quartermaster corps to the hands of the soldier who is to use it, this clothing in both cases, before and after, is the property of the United States Army, and no trade is involved. What the soldier actually does is to sign an equipment sheet showing that he has received such and such equipment—this for the purpose of record. Here we have a transfer of goods from the custody of one person to the use of another without a trade having taken place in any sense of the word. A similar relation is true as regards a soldier's rations and housing.

Trade, then, consists in those exchanges, and those only, in which there is an exchange of property rights. In the case of the army when the quartermaster corps obtains its supplies from the manufacturer, this is accomplished by means of trade; when the quartermaster corps distributes these same goods to the soldiers for use or consumption, this latter distribution can in no sense of the word be construed as trade.

16.3 The Concept of Value

Intimately associated with the concept of trade is that of value. To consider the simple cases of trade represented by barter, as mentioned previously, it is evident that the number of sheep that would be traded for one cow would depend, among other things, upon the relative abundance in the particular locality wherein the trade was effected of cows and sheep. If sheep were very abundant and cows relatively rare, this ratio might be as high as 50 sheep for one cow; if the inverse relation were true this exchange might be effected for as few as one sheep for one cow. A similar relation holds between butter and eggs, between cotton and wheat, or between any other pair of exchangeable commodities.

It is this variable relationship between the amounts of one commodity that is exchangeable for another that is the basis of the concept of value. Value is fundamentally subjective, but is always expressed in the market place by the relative amount of one commodity that is exchangeable for another. The amount of one commodity that is exchangeable for another in different times, and in different places, varies widely. In general, the value of a product, that is to say, the amount of other products which is exchangeable for it, increases as that product becomes scarcer.

Thus, the value of diamonds at the present time is high only because diamonds occur but rarely, and are monopolized by the diamond syndicate, which allows them on the market at a very limited rate. Should a process be developed whereby diamonds could be manufactured for a cent or less per carat, their value would rapidly decline. In other words, it is only when a product is scarce that large amounts of other products need be offered in exchange for it.

The value of a thing has no relation to its social importance, for example, both air and water are completely indispensable for the maintenance of life. Air is so abundant that one need not exchange any commodity for its use. It is accordingly without value. Since the relative abundance of water varies from place to place, its value varies also. In a region of heavy rainfall and abundant water supply, both for the purpose of drinking and of irrigation, water has no value; it cannot be bought or sold. In arid regions, however, water both for drinking purposes and for irrigation, due to its scarcity, is bought and sold or traded in, and accordingly has value.

16.4 The Concept of Debt

Suppose that in an agrarian system of barter a horse is exchangeable for eight pairs of shoes. Suppose that the shoemaker wishes to buy a horse, and that a farmer who has a horse to sell needs a pair of shoes; then if the farmer should trade the shoemaker his horse and accept only one pair of shoes, the shoemaker would still owe the farmer seven pairs of shoes. These seven pairs of shoes which the shoemaker owes to the farmer are said to be the debt of the shoemaker to the farmer; the farmer is called the creditor, and the shoemaker the debtor.

In such a situation as this, there are two alternatives. The debt may be discharged gradually by (a) the farmer taking the seven remaining pairs of shoes one at a time in succession over an extended period of time, or (b) the shoemaker may give to the farmer at the time of the trade a written statement to the effect that he owes, and will pay, seven pairs of shoes. Such a statement constitutes a certificate of debt. The farmer may then take this certificate of debt to a merchant and trade it in exchange for other goods which he now needs. In this latter case, the shoemaker's debt of seven pairs of shoes will be transferred from the farmer to the merchant.

Suppose that instead of the shoemaker having given the farmer a debt certificate, stated in terms of shoes, it had been in the form of tokens, which, by common agreement of the community were acceptable, not only in payment for shoes, but also in exchange for all other goods of the community; then this latter token would constitute money. Money then constitutes a form of generalized debt certificate which is exchangeable not merely for a specific product, but for any purchasable product, which the community affords. It is expressed in denominations of value.

Assuming monetary tokens to be already in existence in a given community, one acquires them in exchange for goods or for services rendered. They therefore represent a deferred payment. The holder thereof may exchange them with other members of the community at some future time and receive goods or services in return. Money is, therefore, stated in denominations of value, and is exchangeable for goods or services of an equivalent value. Thus if two different commodities are exchangeable on a barter basis for each other,

the two are said to be of equivalent value, and each is exchangeable for the same amount of money.

It cannot be too strongly emphasized that money, as such, is not a commodity, but is instead mere tokens which by common social agreement represent debt owed by the community at large to their holders.

The substances used for money have varied widely from time to time, and from place to place. The North American Indians used wampum; some of the ancients used coins of copper, bronze, tin and iron. Some of the South Sea Islanders have used dog's teeth. Modern countries employ as their monetary standard chiefly the metals silver and gold.

It is true that in the early stages of the evolution of money a particular commodity was frequently chosen as a medium of exchange for other commodities. In these early stages this commodity fulfilled a dual purpose of a usable commodity and a certificate of debt payable in terms of other commodities on demand. In more modern times, this duality has been eliminated by the process of coinage. In the United States of America, copper is both a coin commodity and the material for a certain coin. In the form of a coin, copper represents merely a certificate of debt, and is usable accordingly. The value of a copper coin as a certificate of debt is very much greater than the value of the equivalent copper as a commodity.

It is customary among modern nations to adopt a particular metal, usually gold, as the base of the monetary system, in which case the value of gold as coin is taken to be equal to the value of an equivalent amount of gold as a commodity. That this relationship is purely arbitrary may be seen by the fact that nations have of late gone on or off the gold standard at will, and may by edict define the unit of value to be equivalent to any arbitrary amount of gold.

In a monetary economy, the amount of money exchangeable for a given unit commodity is said to be its price. The person who exchanges the commodity for money is said to sell the commodity; the person paying the money is said to buy the commodity.

16.5 Definition of a Price System

The foregoing discussion forms the basis for a definition of what is meant by a Price System. The fundamentals of any Price System are the mechanics of exchange and distribution effected by the creation of debt claims or the exchange of property rights on the basis of commodity valuation irrespective of whether property in that system is individually or collectively owned. Hence any social system whatsoever that effects its distribution of goods and services by means of a system of trade or commerce based on commodity valuation and employing any form of debt tokens, or money, constitutes a Price System. It may be added in passing that unless it be in some very remote and primitive community, none other than Price Systems exist at the present time.

References:

A Primer of Money, Woodward and Rose.
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Lesson 17

RULES OF THE GAME OF THE PRICE SYSTEM

The foregoing discussion of the concepts of ownership, of trade, of value and of money, has enabled us to define what is meant by the term Price System.

It has already been shown that money had its origin as an expression of debt or of deferred payment, and since by common social agreement it is universally acceptable, a given amount of money represents a general debt of society to the holder, with neither the particular debtor nor the commodity which is owed being specified. That is to say, that money constitutes a debt claim of a certain value against any individual, and for any commodity having an equivalent value.

17.1 Negotiability of Debt

Other forms of certificates of debt of a less general nature are likewise in common usage. If one person sells another his property rights in some object, say an automobile, he may not receive goods in exchange, or even money. He may, instead, receive an I.O.U., stating that there is owing to him a given sum of money which will be paid at the expiration of a given period of time. Such an I.O.U. constitutes another form of debt certificate. In this case, the certificate is more specific than in the case of money, in that it states that a particular person is the debtor. The holder of the debt certificate, however, may trade it to a third party in exchange either for goods or for money, in which case the debt is now owed to the third party.

Thus, certificates of debt, whether in the form of money, of promissory notes, or personal I.O.U.'s, are negotiable, and can be bought and sold or traded in, in exactly the same manner as property rights in physical equipment.

Other forms of debt certificates are bonds, mortgages, bank deposits, insurance policies, and bank notes.

17.2 Certificates of Ownership

Besides certificates of debt, another of the more common types of certification employed in the more advanced stages of Price Systems, are certificates of ownership. In a more primitive society, ownership of physical property is maintained largely by unwritten social agreement or by the physical prowess of the owner. In the more advanced stages, however, ownership in larger items of property is attested by some form of legal document stating that a particular person or corporation has the rights of property with regard to some particular thing. This may be an area of land, an automobile, a building, a book, an invention, a franchise, etc.

Certificates of ownership are of different kinds, depending upon the type of thing owned. Ownership in real estate is certified by title deed, in an automobile by bill of sale, in a consignment of goods by bill of lading, in the right to publish a book by copyright, and in the right to manufacture an invention by patent.

With the increase in size, complexity and rate of operation of the physical equipment of the Western World in consequence of the transition from a low-energy to a high-energy state of industrial development, there has occurred a corresponding change in the form in which ownership has been exercised. It has already been remarked that in an agrarian society ownership was largely individualistic; that is to say, that a particular individual possessed complete property rights in a particular thing. In the eighteenth century and earlier, with the growth of commerce and of industry, groups of men found it convenient to form partnerships, as for example, the partnership of Bolten and Watt. At the same time, trading companies were organized for the purpose of conducting large scale commerce.

These partnerships and trading companies, especially in the United States, have, chiefly in the period since the Civil War, been largely metamorphosed over into a form known as a corporation. A corporation is defined legally as a fictitious individual; that is, it can conduct business and own property exactly as an individual while at the same time being owned by individuals without these owners being in any manner liable for the corporation. An exception to this statement occurs in the case of certain double liability corporations such as national banks. In these the owner is liable for the debts of the corporation to an amount equal to his nominal monetary ownership in the corporation.

Ownership, in the case of corporations, is expressed in two stages. In the first place, the corporation owns title deeds, patents, copyrights, franchises, etc., in exactly the same manner as an individual; in the second place, the corporation itself is owned by individuals who are known as stock holders, the certificate of ownership in the latter case being the corporation stock. The ownership of a corporation stock conveys to the holder the right to participate in the corporation profits when these are distributed in the form of dividends.

17.3 Wealth

Another Price System term that needs to be considered here is that of wealth. The term, wealth, is taken to signify the monetary value of physical assets of all sorts and kinds, including land, mineral resources, live stock, as well as man-made equipment. The total wealth of the United States, according to the Statistical Abstract of the U.S., was, in the year 1922, 321 billion dollars. By 1929 this reached a peak of 385 billion dollars, and then declined by 1933 to approximately 300 billion.

This does not necessarily mean that there was more physical equipment in 1929 than in 1922 or 1933, because wealth is not a measure of physical equipment. It is, instead, a statement of the contemporary monetary value of that physical equipment, and, as we have pointed out previously, there is no fixed relationship between any physical object and its value. In other words, value does not, and cannot, constitute a measure of anything.

Wealth in the foregoing sense may more properly be considered to be national wealth, as contrasted with individual wealth. Individual wealth consists in actual certificates of ownership of physical wealth in the sense defined above, or else in certificates of debt stating that the individual has a claim upon a certain value equivalent. Thus, it is immaterial to the individual whether his wealth be in the form of certificates of ownership in, say, land, General Motors stocks, A.T. & T. bonds, or U.S. currency, so long as that wealth is readily convertible in equivalent value from one of these forms to the other. Hence, from the point of view of the actual mechanism of the Price System, there is no important distinction in an individual's wealth between ownership of debt-claims and the ownership of physical equipment.

Since the debt-claims are, in general, the more readily negotiable, it is simple to see how our present money-mindedness has arisen. It has become customary, not only for the layman, but for the business man, the financier and the professional economist, to think almost exclusively in terms of money or debt while taking only vaguely into account the fact that somewhere in the background, physical equipment exists and operates; that upon this operation the entire social structure depends; and that but for this, the entire debt and financial structure would fall like a house of cards.

17.4 Creation of Debt

Individual wealth, as we have seen, consists largely in debt-claims—money, bank deposits, bonds, etc.—and when not in these forms, is expressed in equivalent units of value, which now have come to mean the amount of debt-claims that could be acquired or exchanged for rights in physical property. Since debt-claims constitute a claim for property rights in physical equipment, and have the same validity as actual ownership, it becomes manifestly of some importance to inquire into the mode of origin of these claims.

Debt always signifies a promise to pay at some future date. Thus any incomplete barter—that is, a case where goods are delivered with the understanding that the goods in exchange will be received at some future date—constitutes a creation of debt. Similarly, if a corporation issues bonds, these bonds are purchased for money, and since money already constitutes a debt claim, and the bonds represent a new creation of debt, it follows that debt, unlike physical substance, can be created out of nothing. In other words, the process of floating a bond issue does not of itself involve any change in the amount of physical equipment, either before or after. A similar line of reasoning applies to mortgages on real estate, promissory notes and I.O.U.'s.

17.5 Banking and Credit

By far the largest single type of debt in the United States is bank debt, and banks are, accordingly, the largest creators of debt. Since this is true, and since banking forms the central nervous system of our entire debt structure, which, in turn, controls the operation of the physical equipment, it becomes a matter of some importance that the mechanism of banking be examined critically. There are many misapprehensions of the mechanism of banking, ranging from the popular misconception of a bank as merely a repository for the safe keeping of money, to the conception of a bank as an institution that takes in money from depositors, lends it to other people, and acquires its profits by receiving a higher rate of interest on the money it lends than it pays on that which it borrows. All of this, as H. D. McLeod, in *Theory of Banking and Credit* makes abundantly clear, is totally erroneous.

The essential mechanism of banking is as follows: a banker is a human being or corporation with a ledger and a vault for the safe-keeping of money and other debt certificates. A depositor brings money to the banker. The banker accepts the money, and records in his ledger a bank credit or deposit in favor of the customer equal in amount to the money brought by the customer. This credit or deposit entered in the banker's books is a statement of the debt of the banker to the customer. It is a statement, in effect, that the banker is obligated to pay the customer on demand or at the end of a certain period of time, depending upon whether the deposit is a demand or a time deposit, an amount of money up to the full amount of the deposit. Contrary to the commonly accepted notion, a *bank deposit* does not signify money, but signifies, instead, a *debt* due by the banker to the customer.

Now suppose that another customer calls on the banker and brings, instead of money, a promissory note from a reliable firm, payable 6 months from date. Suppose the amount of the promissory note was $1,000, and the prevailing rate of interest on paper of this sort was 5 percent per annum. In this case the banker would *buy* the promissory note from the customer after deducting or *discounting* the interest due 6 months hence at 5 percent per annum, amounting in this case to $25. He would not, however, pay money for this debt. He would, instead, enter upon his books a credit or deposit for the amount of $975, in favor of the customer, with no money whatsoever being involved.

This bank deposit of the second customer would be in no respect different from that of the first customer who brought money to the bank. Each deposit merely represents the legal right of the respective customers to demand money from the bank up to the amounts of their respective deposits.

The money in the bank does not belong to the depositors, but is the property of the bank, to do with as the banker sees fit, within his legal limitations. Thus, in bank records, the cash on hand represents always a part of the banker's assets because it is his property. The deposits, on the other hand, are among the banker's liabilities, representing his debt to others.

The banker knows from experience that under ordinary circumstances only a few of the depositors demand cash payment over a short time period, and that this is approximately balanced by other customers who deposit cash. By far the greater part of the payments made by the customers of the bank are made by check. If this check is written to another customer of the same bank it ordinarily is returned for deposit to the latter customer's account. This still involves no money but only the bookkeeping procedure of transferring a credit from the account of the first customer to that of the latter.

In case the receiver of the check is a customer of a second bank the procedure is only slightly more complicated, in that it involves a transfer of credit through the medium of a clearing house from the first bank to the second.

Thus, bankers have found that if customers have delivered to the bank $100,000 in cash the bank can then enter upon its books not only the deposits of these customers to the amount of $100,000, but it can also enter upon its books other credits, or deposits, to the amount of approximately $1,000,000, or ten times the amount of cash on hand to the credit of other customers in exchange for the debt certificates the bank has purchased from these latter.

Thus, we see that the real business of banking is that of the buying and selling of debts. The banker buys a debt from his customer, and out of thin air, so to speak, creates for this customer a bank deposit which is another debt, or as McLeod has stated it in Theory of Banking and Credit:

> At the present time credit is the most gigantic species of property in this country,[1] and the trade in debts is beyond all comparison the most colossal branch of commerce. The subject of credit is one of the most extensive and intricate branches of mercantile law. The merchants who trade in debtsnamely, the bankersare

[1] While this applies to England a similar situation holds in United States

> now the rulers and regulators of commerce; they almost control the fortunes of states. As there are shops for dealing in bread, in furniture, in clothes and other species of property, so there are shops—some of the most palatial structures of modern times—for the express purpose of dealing in debts; and these shops are called banks.
>
> And, as there are corn markets and fish markets, and many other sorts of markets, so there is a market for buying and selling foreign debts, which is called the Royal Exchange. Thus, banks are nothing but debt shops, and the Royal Exchange is the great debt market of Europe.

Consequently, when the deposits of a given bank are many times greater than the cash on hand, that bank is doing a thriving business, but when the deposits are equal to the cash on hand, the bank is doing no business at all, and has become merely a repository for money with a state of complete liquidity—a state that many of our larger banks at the present time are approaching.

17.6 The Compound Interest Property of Debt

Not only is debt, as we have seen, created out of thin air, but it has another property, according to the present rules of the game of the Price System, which is described by the term interest. According to this latter property, debt is expected to generate more debt, or to increase at a certain increment of itself per annum. This annual amount of increment expressed as a percent of the original amount, or principal, is called the interest rate. A conservative interest rate on investments has been considered of late to be around 5 percent per annum.

17.7 Growth of Debt

It is to be expected as a consequence of this property of spontaneous generation of debt out of nothing, that the total debt structure of a Price System would tend to increase indefinitely. This we find to be, indeed, the case. In a study, The Internal Debts of the United States (1933), edited by Evans

Clark, it is shown that in 1933 the long-term, or funded debts of the United States, amounted to 134 billion dollars. The short-term debts at the same time were 104 billions, giving a total internal debt of 238 billion dollars. This total of 134 billion dollars of long-term debts, as Clark points out, represents an increase of 96 billion dollars from the pre-war figure, which was only 38 billion dollars: 'Of this increase, 37 billion dollars came before the post-war depression (1921-22), 51 billion more came between 1921-22 and 1929, and 8 billion dollars developed during the current depression. In other words, long-term debts about doubled between 1913-14 and 1921-22; increased about 68 percent more between 1921-22 and 1929; and expanded a further 6 percent in the past four years, so that for every $1.00 of debts we carried before the war, we carry $3.53 today.'

It becomes especially significant now to consider what was pointed out in a previous lesson: that the physical expansion of industry was, in a period from the Civil War to the World War, a straight compound interest rate of growth at about 7 percent per annum. During that period, the debt structure was also extending at a similar rate of increment. Since the World War, as we have already seen, the rate of physical expansion has been declining, and physical production has been progressively leveling off. Thus, for the period prior to the World War there was a close correspondence between the rate of growth of the debt structure, and of the physical industrial structure. Since the World War, while the physical structure has been leveling off in its growth, the debt structure, not being subject to the laws of physics and chemistry, has continued to expand until now the total long and short-term debts are only slightly less than the entire wealth, or monetary value of all the physical equipment. As time progresses this discrepancy between the rate of growth of the physical equipment and that of debt must become greater, instead of less. The implications of this will be interesting to consider.

References:
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The Internal Debts of the U.S., Clark.

Lesson 18

THE FLOW OF MONEY

We have already shown that money, bank deposits, bonds, and various other forms of negotiable paper are all generically the same, namely, debt. While in 1933 the total long and short-term debts of the United States were estimated to have been 238 billion dollars, only about 9 billion dollars of this was represented by actual money in the form of gold, coins of various metals, U.S. currency, and various kinds of bank notes. Consequently in what follows we shall use the term 'money' merely to signify a circulating medium indiscriminately as to whether this medium be coin, currency, bank checks, or any other form of negotiable paper.

For our purposes the significant thing about money in this broader sense is that while it has the property of being created out of nothing or contracted into nothing in a manner quite unlike the physical operation of our industrial apparatus, it constitutes the mechanism of control over the latter. The first aspect of money, or debt, we have already discussed; it remains now to consider the manner in which it operates as an industrial control device.

18.1 The Flow of Goods

This latter aspect can be seen very simply when one considers the manner in which goods are made to move from the productive processes into consumption. All consumable goods have their original source in the earth. From the earth matter is moved by mining, by agriculture, or by some other process into some form of manufacture. From the factory the finished product moves to the wholesaler, thence to the retailer, and finally to the consumer.

After consumption the matter of which the ‘consumed’ goods are composed is returned in part to the earth in the form of garbage, ash, and other waste products; and, in some cases it is salvaged and returned to the factory as scrap metal, rags, and waste paper, to be used over again.

18.1.1 The Mechanism

Consider how these finished products move from the retailer to the consumer. This is where money enters the picture. The consumer hands the retailer, say, a five-dollar bill, and receives from the retailer a pair of shoes. This illustrates the process. In every form of consumable goods and services the consumer hands money to the retailer, and goods and services, dollar for dollar, move to or are placed at the service of the consumer.

If the consumers spend in this manner 1 billion dollars per day, then 1 billion dollars worth of goods and services are moved to the consumers, and if this rate be maintained the factories must produce goods at this rate, and industry booms. If, on the other hand, the consumers only spend 100 million dollars per week, or one-tenth of the previous amount, assuming prices to be the same in both cases, industrial production will be only one-tenth of what it was before, or by comparison, almost a complete shut-down.

This simple mechanism under a Price System method of industrial control, determines completely what industry shall do. If the money flows freely from the hands of the consumer to the hands of the retailer, goods flow freely in the opposite direction, and industry operates; if the money merely trickles from the hands of the consumer to the hands of the retailer, goods move in the opposite direction at a correspondingly small rate and industry shuts down. It remains to be seen what, determines this rate of monetary flow.

18.1.2 The Process

First, let us consider what happens to the money after the retailer gets it. The retailer must pay his help and a part of the money is used for this. He must also pay his rent, and a part goes for this. He has, besides, his light bill, telephone bill, and various other miscellaneous charges. He may have borrowed money from the bank or sold some bonds to obtain the capital with which to conduct his business, in which case a part of what he receives would have to be used to pay the interest. Finally, he must buy goods from the wholesaler to replace those he sold, and a greater part of the money which he receives goes for this. If, after these bills are paid, any money is left over this constitutes profit, and goes to augment his personal income, if the retailer be an individual; or, if the retailer be a corporation, these profits may be disbursed as dividends to the stockholders.

Exactly the same relationship that we have described between the consumer and the retailer exists between the retailer and the wholesaler, and between the wholesaler and the manufacturer. In each of these cases goods move from the wholesaler to the retailer when, and only when, money in the broader sense that we have defined, moves from the retailer to the wholesaler, and from the wholesaler to the manufacturer. Like the retailer, the wholesaler must pay his help, his landlord, his interest, light, telephone, and miscellaneous bills. Any surplus above these can be disbursed as profits. The manufacturer does an exactly similar thing, for he must pay all these bills, as well as purchase his raw materials. The raw materials, as we have pointed out, are derived originally from the earth, so that the last payment made in this series is that which goes to the farmer for his produce, or, as royalties, to the owners of mineral resources.

Now, let us review this whole process. Goods move in one direction, from the earth to the consumer, and back to the earth again; money moves from the consumer to the retailer, the wholesaler, the manufacturer, and finally the landowner. But this monetary stream is being tapped at each section of its length, and being fed back as wages, rent, interest, profits, etc., and becomes the income of various individuals, who are themselves consumers.

By the time this monetary stream reaches the ultimate landowner, who is the last person in the physical flow line, every cent that was originally paid to the retailer has been in this manner accounted for. Thus, if a million dollars passes from the consumer to the retailer, a million dollars worth of goods will be produced and consumed, and this same million dollars in the form of wages and salaries, rent, interest, profits, royalties, etc., will be paid out to individuals who are consumers, and will accordingly augment their incomes by the amount of one million dollars. Thus the sale of one million dollars worth of goods in this manner ultimately provides consumers with one million dollars, with which to buy another million dollars worth of goods. That is, provided that none of the million dollars originally spent is retained in any manner.

18.2 Saving

Let us suppose, however, that somewhere along the route a part of this money passes into the hands of corporations, and that these corporations are making a profit, only part of which they pay out as dividends, the remainder being held as corporation surplus. If, in this manner, out of each million dollars paid in by the consumer, 100,000 dollars was held out by the corporation as surplus, then only 900,000 dollars would be returned to the consumer. Consequently, the second time around the consumer would only be able to buy nine tenths as much goods as he bought the first time. Industrial operations would, accordingly, only be nine-tenths as great. This process would continue with industry shutting down one-tenth of its previous production for each time the money made its complete circuit until ultimately complete industrial paralysis would result. This, of course, assumes that the money which was saved by corporations was locked up in a vault or hoarded.

The same result would occur if individuals, thinking that they might need some money for illness or old age, instead of spending all they received, should decide to lock a part of it up and keep it. To the extent that this was done goods would not be bought, and industry would not operate. Thus we come to the conclusion that if prices remain the same, and if either corporations or individuals save by withholding from circulation a part of the money which they receive, the ultimate result will be industrial paralysis.

We must consider, however, the fact that there are various ways other than hoarding by which corporations and individuals can save. If a corporation wishes to manufacture and sell more goods than the current purchasing power is able to buy, they may do so by extending credit to their purchasers, or selling on the installment plan. In this manner they may pay out all the money in the form of cash which they receive and still show a book profit in the form of accounts receivable.

18.2.1 Investment

Another way a corporation can save without hoarding is to take the profits which are not disbursed as dividends and build a new plant. In this manner all the money otherwise withheld is fed back through the various channels of wages, salaries, etc., and the corporation is the possessor of a new plant.

In an exactly similar manner individuals may invest their savings in corporate stock, and thus help build new plants, or they may put them in savings banks or take out life insurance, in which case these latter agencies invest the funds in new productive equipment. Thus we see that if savings, whether corporate or individual, are reinvested in physical equipment they ultimately return to become the purchasing power of individuals, but in the process the country's capacity to produce has been increased.

That this is an endless process can be seen when it is considered that in the following year the new equipment will begin to produce, and then the purchasing power which heretofore has been sufficient to buy only the products of the existing plant will be inadequate to purchase the combined output of the old plus the new plant if prices remain the same. This difficulty can only be met (provided prices are not lowered) if the savings continue to be reinvested in the new equipment—so that at all times the money which is being paid out to consumers through the construction of new plants is sufficient to make up the deficit in consumer purchasing power caused by money being held out by individual and corporate savings.

18.2.2 Results of the Process

This, it will readily be seen, is a compound interest type of thing. Under the hazards that exist in a Price System it is imperative that both individuals and corporations save. If they save by hoarding they shut the existing plant down; if they save by building new plants they have a process which can only work provided the plant be continuously expanded and at an accelerating rate. That the latter policy is impossible to continue indefinitely simple physical considerations will show. As we have pointed out previously, no physical process can continue to grow at a compound interest rate for more than a limited period of time. The limitations of our natural resources on one hand and of our physical ability to consume on the other both require that this be so.

References:

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Lesson 19

WHY THE PURCHASING POWER IS NOT MAINTAINED

We have seen how, under a Price System, the rate of flow of money from the consumer to the retailer of goods and services acts as an industrial control mechanism. We have found that if individuals and corporations be allowed to save, the requisite purchasing power to buy the existing products of industry can only be maintained provided money is being paid back to the consumer through the construction of new plant or other capital goods, at a rate equal to that at which money is being lifted from the purchasing power for consumers' goods through individual and corporate savings.

19.1 The Inevitable Inflection Point

At first thought, from this simple consideration, it would appear that our physical production should expand indefinitely until blocked either by a physical limitation of the ability to produce or by a saturation of our ability to consume. The fact remains, however, that the inflection point of our industrial growth curve occurred some time around 1915, and since that time, as we have pointed out elsewhere, industrial production has been leveling off. That this leveling off was not due to an inability to increase production is to be seen when one considers the fact that in 1929, the year of an all time peak of physical production, little if any of our productive equipment operated with a load factor of more than 33 1/3 percent.

What we mean by load factor is the ratio of the actual production divided by productive capacity at continuous 24-hour-per-day full load operation.

Among the most continuously operated parts of our industrial equipment are the electric power system and the telephone system. The load factor on the power system in any but special branches rarely equals 40 percent of its productive capacity. The load factor on telephones is much lower than this. Most of our other industrial equipment in 1929 operated only one or two shifts per day for a limited number of days per year.

It has become customary in discussing present rates of industrial operation to compare them with the 1929 rate, and refer to the latter as being our 'industrial capacity'. Consideration of load factors shows quite conclusively that such was far from the case, the Brookings Institution and other professional apologists for our status quo notwithstanding.

19.2 Attempts to Maintain Production

The increasing deficiency of purchasing power for the purpose of buying our potential production is brought out by other corroborative facts. During the World War for the first time we found ourselves playing a significant role in world trade. This was affected through the mechanism of loans to foreign countries enabling them to buy our surplus products without our having to accept a corresponding amount of theirs in return. Due to the fact that our domestic purchasing power after the war was not sufficient to buy goods at the rate we were able to produce them, we tried to continue this method of getting rid of surplus goods by making still further foreign loans, and by preventing our own people from buying from abroad by building a tariff barrier so high as to make importation of foreign goods practically impossible.

The fact that these loans could never be repaid; the fact that a 'favorable trade balance' and that this amounts to a net physical loss to the country is, of course, well known. Yet such practices are not only in accord with the canons of 'good business'; they are dictated by the necessities of business expediency.

The significant aspect of this is that America's capacity to produce was during all this period in excess of the American public's capacity to buy, so that a surplus margin of production was maintained by promoting what amounted to installment selling abroad.

According to Mr. George W. Peek, in his report of May 23, 1934, to the President, the net increase of this debt owed to us by foreign countries for the period July, 1914, to July, 1922, was $19,305,000,000. For the corresponding period from 1923 to 1929, this debt was further increased by an amount of $2,572,000,000.

Since the American productive capacity was still in excess of the ability of the American public to buy, plus the installment selling abroad, a further increase of production was achieved through the mechanism of installment selling at home. In this process the debt built up by installment buying during the period from 1924 to 1929 amounted to $9,000,000,000, or approximately $2,000,000,000 per annum net increase.

The significance of this is that effective purchasing power, that is to say, purchasing power that was actually being used to purchase goods and services, and hence to keep industry operating, was falling further and further behind the ability to produce. Therefore the rate of operation actually was maintained through the device of selling abroad some 22 billion dollars worth of goods more than could be paid for, while at home in the latter part of this period at least 9 billion dollars worth of goods in excess of current purchasing power were sold. Had this not been done our industrial production would, of course, have leveled off faster than it did.

19.3 The Financial Structure

The question that all this leads us to is why was not the effective purchasing power sufficient? Why did it not keep pace with productive capacity? If savings are used to build new plants, do they not then become wages and salaries of the workmen, and hence feed right back into the effective purchasing power? This would have been true a century ago in the days of hard money; today, however, money no longer conforms to this simple picture. The total amount of hard money in existence in the United States in 1931 was only about 5 billion dollars. The amount of money represented by gold bullion, metallic coins, bank notes and United States currency totaled only a little over 9 billion dollars. When it is considered that in 1933 the total of all long and short-term debts, including money, amounted to 238 billion dollars, it becomes immediately evident how relatively insignificant the small amount of actual cash in existence is in such a picture.

19.4 The Process of Investment

The simple fact is that, when individuals and corporations save through the process of reinvesting, these savings are not, as naively supposed above, spent except in a small part in further plant construction. The greater part of all investments in this country since the year 1900, have gone into pure paper, without there having been a plant expansion commensurate with the amount of money invested.

The history of almost any great American corporation will bear this out. Most American industrial establishments which have since grown into positions of national consequence began in a small way under individual or partnership ownership; or else, like some of the earlier railroads as joint stock companies, the shares of which were sold directly to the public without their having been even listed on the Stock Exchange. Profits were plowed back into the business, and the plant expanded under its own savings. Debts were contracted, if at all, usually by short-term loans from the banks. Except in the case of the joint stock companies, ownership was maintained by a single family or by a small number of partners. In these formative stages securities speculation was a practice little indulged in, and the money obtained from the sale of securities was practically all used to expand the plant.

It has been the usual history in such cases that after the industry in question was well established, bankers and promoters became interested. Through their services reorganizations or mergers have been effected. Bonds and preferred stocks have been issued to the former owners and to banking groups interested in the reorganization, usually in amounts greatly in excess of the original capital investment. Over and above this, common stock has been issued, usually in an amount similar to that of the bonds and preferred stocks. These common stocks, however, have not been in general marketed by the corporation for the purpose of raising additional capital funds. They have, instead, been given away in the form of bonuses to bankers, promoters, and other interested insiders, or else issued as stock dividends for no monetary consideration whatsoever, and hence no addition to the plant. These stocks are in turn fed into the Stock Exchange by these interested insiders, until they are finally bought up by the investing American public. It is to be emphasized that the proceeds of such sales of common stock go to the insiders, and not to the corporations or into new plant.

A similar paper manipulation has been carried on in bonds and mortgages through the mechanism of the holding company. In this manner the paper of an operating company is used as security for issuing other paper of, say, a holding company, and this in turn re-hypothecated until several generations of stocks and bonds are issued and sold to an unsuspecting investing public, all with no backing whatsoever other than that of the original inadequate plant on which the first stocks and bonds were issued. In many cases such bonds are still in existence long after the equipment securing them has ceased to exist.

When one considers that such manipulations as these are the accepted methods of sound finance it begins to be evident why the money reinvested in industry does not become available in a corresponding amount as further purchasing power.

If it happens that new plant is built at a sufficient rate to supply the deficit in purchasing power all is well and good, but there is no necessary reason why this should be so. The great bulk of savings, both individual and corporate, are reinvested. Investment, we now see, consists in buying pieces of paper labeled usually as stocks or bonds. If the money spent for these pieces of paper were used to build a new plant this money would, in the manner we have already indicated, be largely paid out to workmen, and hence become effective purchasing power. If, however, the securities purchased represent, as is usually the case, merely paper floated by interested insiders upon a plant already in existence, this does not increase the productive plant, and thereby augment small incomes; it becomes, instead, the medium of debt creation held by the bankers and promoters, and its interest or dividends goes to further increase a small number of individual incomes which, in most cases, are already overwhelmingly large.

19.5 Income

The net result of this kind of procedure is to produce an ever-increasing disparity in the distribution of the national income. This disparity is well brought out by the Brookings Institution Report on *America's Capacity to Consume*, published in 1934. According to this report, in 1929 there were 27,474,000 families in the United States receiving an aggregate income of $77,116,000,000. Of these, 24,000,000 families, or 87 percent of the total number of families received incomes of less than $4,000 per annum, constituting only 51 percent of the total income. According to this report:

'Nearly 6 million families, or more than 21 percent of the total, had incomes less than $1,000.

'Only a little over 12 million families, or 42 percent, had incomes less than $1,500.

'Nearly 20 million families, or 71 percent, had incomes less than $2,500.

'Only a little over 2 million families, or 8 percent, had in comes in excess of $5,000.

'About 600,000 families, or 2.3 percent, had incomes in excess of $10,000.'

And further:

'The 11,653,000 families with incomes of less than $1,500 received a total of about 10 billion dollars. At the other extreme, the 36,000 families having incomes in excess of $75,000 possessed an aggregate income of 9.8 billion dollars. Thus, it appears that 0.1 percent of the families at the top received practically as much as 42 percent of the families at the bottom of the scale.'

These facts clearly show that the great bulk of the families receive incomes far below their physical capacity to consume, while a large part of the income goes to only a handful of people, and in an amount far in excess of their ability to consume. Bearing in mind that consumption is a physical operation, and that there are definite physical limits to how much food, clothing, etc., a single individual can consume, it follows that the great bulk of the consuming must, because of their preponderance in numbers, be done by those people with small incomes. The small number of people with the large incomes can account for only a small fraction of the total physical consumption. It is true that they build expensive houses in the suburbs, purchase rare and therefore expensive paintings, and indulge in various forms of conspicuous consumption. Still the fact remains that the amount of coal, gasoline, food, clothing, etc., that is actually consumed by a family with a million dollar per year income, is not at all commensurable with the magnitude of the income. While it is true that such families may employ a large coterie of servants, we must not lose sight of the fact that the money paid to these servants is *their* income, and that the consumption for which they are responsible cannot be credited to the millionaire family which employs them. Due to the impossibility of spending even in conspicuous consumption the total of such large incomes, it follows that it is these which are likely to be the source of the greatest savings. This presumption is verified again by the Brookings

Institution Report, according to which the aggregate saving of families of 1929 amounted to $15,139,000,000. Of this, 34 percent was derived from the 24,000 incomes above $100,000; 67 percent of these aggregate savings was accounted for from the 631,000 families with incomes above $10,000 per year.

In other words, the bulk of the consuming is done by people having less income than $10,000 per year; the bulk of the saving by those having incomes greater than $10,000 per year.

What is significant about all this is that industry, as we have remarked before, is geared to the rate at which people spend money for consumable goods. Now, it becomes evident that almost all of this money that is spent for consumable goods is accounted for by those people whose incomes are far below their physical capacity to consume. These small incomes are in turn derived almost entirely from wages and salaries or from agriculture. The wages and salaries paid by industry are determined on a value basis in which human beings compete with machines.

19.6 Profits, Technology and Purchasing Power

An individual business man is in business for the purpose of making money. If his particular business happens to be the operation of, say, a factory, he finds that there are two principal ways by which his profits can be increased. Other things being considered for the moment constant, he finds that his total profits can be increased by increasing his sales and hence the production of his product. The other way in which profits can be increased is by the lowering of the internal cost of production. It is a simple physical fact that a human being at his best can only do work at the rate of about one-tenth of a horse power (1-10th h.p. equals 1-13th kw.). Human beings at the lowest sweatshop rates cannot be paid much less than 25 cents per hour. Mechanical power, on the other hand, is produced at the rate of one kilowatt-hour per pound and a half of coal, and can be retailed at an industrial rate of about 1 cent per kw. hr. Thus it will readily be seen that when man-hours sell at 25 cents or more each, while kilowatt-hours can be purchased at an industrial rate of 1 or a few cents each, and when it is further considered that the kilowatt-hour will do 13 to 100 times as much work as a man-hour, and do it faster and better without any attendant labor troubles, it becomes evident that man-hours have slight chance to survive. Thus, one of the most effective

Of the factors which are supposed to counteract the process we have just described, one is the growth of new industry. Let us consider such a case.

ways of reducing internal costs is to substitute kilowatt-hours for man-hours.

We now see that almost the complete controlling mechanism of industrial production is the rate of expenditure of small wages and salaries. If the sum of small wages and salaries in a given year is 50 billion dollars, then industrial production for that year is only slightly more than 50 billion dollars, because small wages and salaries are almost entirely spent for goods and services, and the large incomes accrue to such a small percent of the total population that they account for a relatively unimportant fraction of the total consumption.

Since one of the fundamental rules of the Price System is that only through the acquisition of purchasing power can the individual subsist, it follows that as the only means of acquisition open to the majority is employment, then he who does not work does not eat. Collectively speaking, salaries and wages are directly proportional to the total man-hours required to operate the social system. Employment, as we have seen elsewhere, depends both upon the quantity of production and upon the man-hours required per unit produced. This process, we know already, is one in which total production is leveling and the man-hours per unit produced are continually falling.

In the earlier stages of such a process, production, while still increasing, falls further and further behind the plant's capacity to produce, because the wages and small salaries form a declining fraction of the retail price of the goods produced. This curtailment of production below the capacity of the existing plant tends to discourage the building of new plant. If, for instance, the capacity of existing shoe factories were 900 million pairs of shoes per year when the public was only buying shoes at the rate of 400 million pairs per year, this would lead to a curtailment in the rate of building new shoe factories. This same sort of thing is true for any other branch of productive industry. Since a large part of the wages and small salaries are derived from the construction of new plant, this curtailment of the capital industry results in a further reduction of wages and salaries, and leads to a corresponding decline of purchasing, and hence of the production of consumers' goods. Once this decline sets in, it is self-accelerating downward unless counteracted by means more or less foreign to the industrial process itself.

19.7 New Industry

Specifically what we want to know is, if present industry is not providing enough purchasing power to enable the public to buy its products when running at capacity, will a new industry make the situation better or worse?

Suppose that a plant manufacturing a completely new product is built. Suppose the plant cost $1,000,000. Most of this $1,000,000 goes to wages and salaries of the people who built it, and thus increases purchasing power with which to buy the products of the existing plant. Now let the new plant start operation, and let the retail value of its products be $10,000,000 per year. Suppose that only $4,000,000 per annum of this is spent for wages and small salaries. Then one would have a situation where $10,000,000 worth of new products are added to those which the public is expected to buy per year, but the consuming public—those receiving wages and small salaries—will only have been given $4,000,000 with which to buy the products. The other $6,000,000, if the product is sold, will all accrue to a small number of people in the large income brackets. If production is to be balanced, this small number of people must consume the $6,000,000 worth of products. The observed fact is that in general they do not, and cannot. If, therefore, the whole production is to be disposed of, the money to buy it must be derived in part from the already deficient purchasing power accruing from the older branches of industry.

This sort of relationship was not true in the earlier days of industry, because at that time employment was increasing as production increased, and small incomes comprised the greater part of the cost of production. This enabled the public to buy back the goods produced and yielded a purchasing power which expanded as the productive capacity expanded. The same technological factors that have enabled us to produce more goods with fewer men, have at the same time, rendered it impossible to sell the goods after they are produced. In the earlier days, new industry provided the deficit in purchasing power for current production, and at that time we could look forward to industrial growth with a corresponding prosperity; today we can look forward to neither.

This trend is well exemplified in the following table taken from the Abstract of the U.S. Census, 1932.

In this table comparative figures are given on the whole manufacturing industry of the whole United States for the years 1914, 1919 and 1929. The year 1914 is a normal pre-war year, 1919 is the year of the peak of war-time production, 1929 is the year of all-time peak production. It is interesting to note that the number of establishments rose from 177,000 in 1914 to a peak

Table 19.1: The manufacturing industry

Year	No. of Establishments	No. of Salaried Emloyees and Wage-Earners	Salaries and Wages in Millions of Dollars	Cost of Materials, Fuel, Purchased Electrical Energy in Millions of Dollars	Value of Products in Millions of Dollars	Value added by Manufacture in Millions of dollars	Horse-power
1929	221,000	10,198,000	15,216	38,550	70,435	31,885	42,931,000
1919	214,000	10,438,000	13,343	37,233	62,042	24,809	29,328,000
1914	177,000	7,859,000	5,342	14,278	23,988	9,710	22,291,000

of 214,000 in 1919, and then declined to 211,000 in 1929. The production for each one of those years was greater than the year preceding.

In a similar manner the total number of salaried employees and wage earners in industry rose from 7,589,000 in 1914 to an all-time peak of 10,438,000 in 1919, and then declined to 10,198,000 in 1929. The horsepower, however, rose continuously from over 22,000,000 in 1914 to more than 29,000,000 in 1919, and nearly 43,000,000 in 1929. Thus from 1919 to 1929 production was increasing, horsepower was increasing, and man-hours were decreasing.

For these same years the value of the products added by manufacture was approximately 10 billion dollars in 1914, 25 billion dollars in 1919, and 32 billion dollars in 1929. The amount paid out in wages and salaries for the same respective years was approximately 5 billion dollars, 13 billion dollars, and 15 billion dollars. The difference between these—the value added by manufacture minus the amount paid out in wages and salaries—gives us the remaining amount which goes to pay rent, interest, fixed charges and profits.

This remainder, therefore, goes largely to augment big incomes. It is significant that this latter amount rose from 4.4 billion dollars in 1914 to 11.5 billion dollars in 1919, and 16.7 billion dollars in 1929. Thus from 1914 to 1919, while the small income proceeds of industry were rising by an amount of 8.0 billion dollars, the large income proceeds rose 6.1 billion dollars; and from 1919 to 1929 the large income proceeds rose 5.2 billion dollars, while the small income proceeds—wages and salaries—rose only 1.9 billion dollars.

19.8 Debt Creation

We have already mentioned that this growing disparity between effective purchasing power and plant capacity leads first to a decline in the rate of increase of production, and next to an absolute peak followed by a decline in production. It follows that the only way this trend of events can be temporarily retarded is through the process of debt creation. When the public has not the requisite purchasing power, we grant it a fictitious purchasing power through the mechanism of installment buying. We find also that by a similar device applied abroad we can promote foreign trade, and can ship away our goods and receive debts in exchange. Also, through the mechanism of securities speculation and other forms of paper manipulations, we have multiplied our millionaires. They, in turn, allow a small part of their incomes to trickle back to the market place through the medium of servants, and other forms of ostentatious living.

Simple considerations will show that the debt process of balancing our national economy cannot long endure, for the fundamental property of debt, upon the validity of which all our financial institutions—banks, insurance companies, endowed institutions, etc—rest, is that the debt structure is expected to expand at a compound rate of increment per annum. To maintain a 5 percent per annum rate of expansion on our debt structure, and have it bear any fixed relation to physical production, or, in other words, to maintain a constant price level in the meantime, would require that industry expand at a corresponding rate.

As we have seen, during the period from the Civil War till the World War, American industry did expand at such a rate as to double its production every 12 years—a rate of growth of 7 percent per annum. During that period the monetary interest rate remained approximately stationary at about 7 percent per annum and our financial institutions were ‘sound.’ Since the decade of the World War industrial production has been leveling off and its rate of growth declining. In this situation the debt structure can do either of two things (or a combination of the two): (1) The interest rate can be kept constant, in which case the debt structure will expand faster than the industrial production and the ratio between debt and physical goods will continuously increase. This is pure paper inflation and leads to a corresponding increase in the price level or to a continuous decline in the amount of physical goods that can be purchased each year from the return of each dollar invested, which is, in effect, a decline in the interest rate. (2) The price level may remain stationary. In this case inflation is precluded so that the rate of increase of the debt structure must be held approximately equal to the mean secular rate of growth of production. This leads directly to a decline in the nominal rate of interest.

These deductions concerning the decline of the interest rate that must accompany the decline in the rate of industrial expansion are amply confirmed by the events since the year 1920. During that time the mean secular rate in industrial growth has been steadily decreasing. Accompanying this interest rate throughout that period has also been declining continuously until today the interest rates are the lowest in the last hundred years. Since there is no reason to expect more than temporary periods of future industrial expansion, there is no reason to expect any other than temporary reversals of this downward trend of the interest rate. Yet an interest rate approaching zero undermines completely our complex of financial institutions, because these depend upon a finite interest rate for their existence.

All of this series of events which we have been discussing more or less hypothetically is what has actually been happening in the United States since the World War. From the World War to the stock market crash in 1929, the deficit of purchasing power that had to be met to maintain an increasing industrial production was derived largely through the mechanism of private debt expansion at home and abroad. After the stock market crash, with the resulting standing army of 15 to 17 million unemployed, and an industrial production of approximately 50 percent of that of 1929, it became necessary in order to maintain the Price System, for the government to assume the debt creation function.

This is being accomplished by the Federal Government's borrowing about 4 billion dollars per annum more than its current income, and donating this under one pretense or another to the public to make up, partially, the deficit resulting from so called normal business activity. A similar, though perhaps smaller, debt expansion is being carried on by state and local governments, many of which are dangerously near bankruptcy at the present time. In the meantime the banks belonging to the Federal Reserve System are reported in the newspapers as holding the highest surplus in history, and the United States Government itself has become the most profitable field for investment.

Thus, America finds herself today in the position where private corporate enterprise has practically ceased to exercise the prerogative of creating debt and has voluntarily surrendered this prerogative to the Federal Government of these United States; so much so that the Federal Government has at this time become practically the sole creator of debt claims in large volumes for the sole purpose of sustaining the debt structure of this Price System by further Federal, debt creation for the benefit of the majority holders of debt claims, chiefly of private enterprise. Or, as Howard Scott has aptly remarked, 'When American business men find it no longer profitable to indulge in further debt creation it is only just and meet that their government should do it for them.'

In spite of all this so-called 'priming of the pump' by government expenditures, industrial production is still only slightly above the lowest point reached since 1929, unemployment is still variously estimated at from 10 to 12 million, relief figures are rapidly mounting to where, according to Relief Administrator Hopkins, there are now 19,500,000 people on Federal relief alone. Playing the game by the Price System rules, there is no prospect in the future for the situation to do anything but get worse rather than better. And all this in the midst of potential plenty!

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Appendix to Lesson 19 POPULATION GROWTH IN THE U.S.A.

Not only has industrial growth followed the now familiar S-shaped curve, with a rapid rate of growth at first followed by a leveling-off process, but population, we shall now see, is doing the same thing.

The population in 1800 was a little over 5,000,000; by 1830 it had grown to nearly 13,000,000; by 1860 it was 31,000,000; by 1900 it was 76,000,000; by 1930 it had reached 123,000,000; and by 1938 it was 129,000,000 or 130,000,000. If the population as taken from the United States Census be plotted as a growth curve, it will be found that the total growth is still increasing, but that the rate of growth is decreasing. The annual increment to the total population in 1914 was approximately 1,800,000, while in 1934 the annual increment had declined to approximately 800,000. If the total growth curve be analyzed mathematically, it will be found that from 1790 until 1860 it was expanding at a compound rate of increment of about 3 percent per annum, and that since 1860 this rate of increment per annum has been steadily decreasing, until for the decade 1920-1930 it was only 1.5 percent.

This still does not tell us anything about how long the population may continue to expand, but we have an independent method of approach to this latter question by means of the birth rate and the death rate. The birth rate and the death rate are ordinarily stated in terms of the number of people being born or dying each year per 1,000 of the population. Thus we find from the United States Census that the birth rate of the United States per 1,000 of the total population was 25 in 1915; by 1920 this had declined to 23.7; by 1930 to 18.9; and by 1936 to between 16 and 17 per 1,000. The death rate in the meantime has been almost stationary since 1920, at about 12 per 1,000. Now the present expectancy of life at birth in the United States is about 60 years.

It is obvious that if the number of people per 1,000 born each year is greater than the number of people per 1,000 that die each year, the population each year will become larger. If the number of people per 1,000 who are born each year is equal to the number of people per 1,000 who die each year, the population will neither increase nor decrease, but will remain stationary. Finally, if the number of people per 1,000 who die each year is greater than the number per 1,000 that are born, the population will decline.

It now remains to be seen what is the critical value of the birth rate above which the population will expand, and below which the population will decrease. In other words, if the average length of life is to be 60 years, how many people must be born each year to just maintain a stationary population? It would follow, of course, that once that state were attained the death rate would have to equal the birth rate. Under such a stationary state one-sixtieth of the population would die each year, and a like number would have to be born to make up this deficit. One-sixtieth of 1,000 is 16 2/3; hence the critical value of the birth rate at which the population will cease to expand is 16 2/3 per 1,000.

Referring to the figures given above, it will be noted that our birth rate has just now reached approximately that critical number and with the increase of education and of birth control information as well as of economic insecurity, there is every reason to expect that the birth rate will continue to decline. The death rate in the meantime is still about 12, but as the present population gets older and begins to die off more rapidly, this rate should increase. It is expected, therefore, that the death rate will become equal to the birth rate not later than the decade 1950-1960, and possibly earlier. At this time the population will cease to expand, and it will have a maximum number of probably not more than 135,000,000 people. Due to the fact that the birth rate will then be less than the critical number of 16 2/3, the death rate will become greater than the birth rate, and the population will begin to decline until it reaches some intermediate level at which it can become stabilized.

As the population approaches stabilization, the percentages of age divisions will shift. During the years of population growth, the larger percentages occurred in the younger age division; 40 percent were under 20 years of age, and about 20 percent were over 45 years in the year 1920. Assuming stabilization to be reached between 1950-60, it follows that the shift in population ages reached will be approximately 30 percent for those under 20 years of age, and those over 45 will be approximately 35 percent.

The above discussion is only a technical statement of fact. In discussions of this sort it is not unusual for certain religious groups to become very despondent over the prospects of a cessation of population growth. Militarists frequently try to offset such a tendency (witness Mussolini and Hitler) because more population means more cannon-fodder. The people, however, in this country who are likely to be most concerned by a stationary population are our business men and our real estate promoters. As we have pointed out, our past prosperity has been intimately linked up with expansion of production, and the expansion of production has been aided in no small part by the growth of population. Every business was expected to expand, if for no other reason than that the population was expanding. Every roadside village, with few exceptions, could expect to be bigger ten years hence with a corresponding enhancement of real estate values and increase in the business of pioneer merchants of the place. Did not Marshall Field's, in Chicago, for instance, owe its growth as a department store to the fact that Marshall Field got in on the ground floor while Chicago was little more than a village? What inconsequential village with an up-and-coming Chamber of Commerce does not dream of becoming a metropolis of tomorrow?

The leveling-off of the population growth curve merely means that this expectation will not be true for the future. After the population stabilizes, a gain in population by one town or city will only be at the expense of a corresponding loss of population by other areas. An increase in business by one organization will only be achieved by a corresponding loss of business to a competitor, or else by an absolute increase in the standard of living.

Let it be emphasized that all those who demand an increasing population have special interests, and their own private axes to grind. From the point of view of social well-being it is perfectly obvious that if the population is not stabilized before that time it will continue to expand until finally checked by the lack of the means of sustenance, with a standard of living comparable to that of India or China. On the other hand if the population is too small there will not be enough people to properly man and operate a high-energy civilization. Between these two extremes there is an optimum population, and that optimum is probably about the size of our present population.

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Lesson 20

OPERATING CHARACTERISTICS UNDER THE PRICE SYSTEM

In previous lessons we have described industrial growth in the United States, and have pointed out that under Price System operation and control it is becoming increasingly difficult, in accordance with the accepted rules of the game, to maintain industrial operation within the limits of social tolerance. As yet, however, we have made no inquiries into the operating characteristics of industry when at its best under a Price System control.

Attention has already been called to the fact that business is engaged not primarily in the making of goods, but in the making of money. If, in the course of making money, manufacture of goods happens to be indulged in, to the business man that is a mere incident rather than a matter of primary importance. From a social point of view, however, the only matter of consequence is the fact that somehow or other in the process, goods are manufactured and distributed.

20.1 Inferior Goods for Large Turnover

From the point of view of making money by the manufacture and sale of a given commodity, it is in general true that, other things being equal, the larger the number of units of this commodity manufactured and sold per annum, the greater the profit. Suppose, for example, that the commodity considered be razor blades. Now, to begin with, the razors that are already in use are of the old-fashioned pre-safety razor type. They are made of high quality steel, and will last, say, on an average, twenty years each, or approximately two razors per lifetime per each male inhabitant. It will be seen that, once the male population is supplied with razors of this type, there will be no further expansion of the razor business, except for replacement of the existing razors as they wear out, and to supply razors to the increasing population.

Now, if a way can be found to make all of these men throw away their present razors, and buy some new ones, this would immediately produce a big increase in the razor business. To accomplish this latter, suppose that we introduce on the market, supported by high-pressure ballyhoo[1] and salesmanship, a new type of razor, the safety razor. By this means, in about a generation, we succeed in coaxing the males of the population away from their old substantial razors and have them all using this new safety razor. Suppose that up until this time the safety razor has removable blades that will last, say, a month each, and can be replaced by new blades at a nominal sum. This simple change alone would result in an enormous increase in the razor blade business, for each man who originally used a single razor for twenty years would now buy 240 blades in that same time. This would be good business as compared with that of the pre-safety razor days, but even this has its point of saturation. The trouble with the razor blade business is that the blades last too long. This, of course, can be remedied by a slight change in the metallurgical content of each blade. The ideal blade for this purpose would be one which would shave fairly well for three or four times, and then be unalterably useless thereafter. The razor blade manufacturer has his own staff of metallurgists, who determine how such a product may be produced. This simple device alone multiplies the razor blade business by about seven times, without there having been a change in the sales price per blade.

By this time the razor blade business is becoming so remunerative (and besides, the original patents are expiring) that other companies are organized to cut in on the racket. These find that they can best get a foothold by turning out a slightly better blade than that produced by the original company. The public, discovering the greater merit of the new blade, promptly change their patronage from the old to the new. No sooner does this happen than it

[1] Sensational or clamorous advertising or publicity

is observed that the quality of the new blades drops to about the standard of quality possessed by the old. This is easily understood when one, upon scrutinizing the package of the new blades, discovers that, without its name or trade mark having been changed, its company has now been bought by the original company (doubtless with a watered stock flotation on the side), and that now both the new and the old blades are the product of the same original company.

By this time, however, other manufacturers have begun to cut in so rapidly that, if possible, a method must be found whereby the blades of these latter can be excluded, and only those of the original company used. This can be affected quite easily by making a new holder for the blade, and changing the shape of the blade in such a manner that it will fit both the old holder and the new, but so that the blades of the competitors will not fit the new holder. It is necessary, of course, that the purpose of this maneuver be concealed from the public. This is deftly accomplished by launching a nation-wide advertising campaign of ballyhoo about the years and years of research that have been devoted to the study of the improvement of razors. At last, it is announced, the great secret has been found; the trouble with the old razors was the corners, and now, as a result of this research, a razor has been produced without corners. Of course, it is necessary to entice the public to throw away their old holders and get the new ones. This can be accomplished by the selling of the new razors at a very reduced price, or else giving them away with tubes of shaving cream. Also, it makes matters more convincing if the one or two blades included with the new razor be of considerably higher quality than those that can be bought in separate packages.

In spite of all this, competitors still seem to get a foothold, so finally the directors of our original company are obliged to face the fact that perhaps the public is getting wise to their little game, and that what the public really wants is a better grade of steel in their razor blades. This demand on the part of the public is now met very nicely, and in true Barnum fashion, by an advertising campaign which confesses to the public that indeed the company has been lax, and that somehow or other without the officials ever having dreamed of such a thing, the research staff of chemists and metallurgists have allowed the quality of the steel to deteriorate. Now that the fault has been discovered, no such negligence on the part of the research staff would ever be countenanced again. As evidence of correction of this negligence, a new high quality blade would be issued, the Blue Blade. The public, of course, swallows the ballyhoo, and buys the Blue Blade, only to discover, after a short-time period, that its lasting qualities were no higher than those of its predecessors which were admittedly inferior. This is then followed by a Green Blade of the same quality.

In the meantime, a safety razor is developed abroad, the ‘Rolls Razor,’ which has the quality of steel and the durability of the old pre-safety razor product. Since the public wants a good razor, and its habits are adjusted to safety razors, it follows that, if this new razor were admitted at a price which allowed it to compete readily with the prevailing domestic razors, it would stand a good chance of wrecking the domestic safety razor business. This entry is prevented very effectively by erecting a tariff barrier so high against the foreign product as to render its importation, except in small quantities, almost prohibitive.

It might be mentioned, in passing, that a safety razor, the ‘Star’ was introduced to the American market in the 1890’s. People who bought this razor over forty years ago are still using it with the original blades. Business, of course, for this company could not have been very flourishing. It does not appear strange, therefore, that it should long since have ceased to exist.

What we have been pointing out in the foregoing is simply the fundamental conflict between production for social welfare, on the one hand, as contrasted with what is good business, on the other. It is not our purpose to intimate that the business men are at fault; we only want to point out that, under the rules of the game of the Price System, it is better business to maintain scarcity, and to turn out cheap and shoddy products which, like the Gillette razor blade, will be used a few times and then have to be discarded and replaced by another. It is also observed that if, under the same rules of the game, one fails to conform and produces, as in the case of the ’Star’ razor, a superior product, he does not long remain in business.

20.1.1 Foreign Trade and War

It is a simple matter to follow the thread of this same type of reasoning into any domain that one wishes to investigate, and one will always come to the same inevitable conclusion that what is socially desirable becomes, from the point of view of business, objectionable. Foreign trade and what the business man chooses to call a ‘favorable trade balance’ has already been mentioned. It is not amiss in this connection to mention the relationship between war and the munitions racket.

As a result of the good services of the Nye Committee of the United States Senate, it has now become fairly common knowledge that modern wars are promoted for reasons of business almost entirely; because, from the point of view of the munitions makers, it is good business to have a war every so often. It might also be pointed out that one of the most likely ways of temporarily solving the depression would be to promote a nice friendly war with somebody. This would solve the unemployment problem in two ways. Industry would boom, turning out war munitions and military equipment generally. This would absorb a considerable fraction of the present unemployed. Debts could be created through Liberty Loan drives or their equivalent, and money would flow freely. The remainder of the unemployed could be put in the army, and, preferably, be shot. This would solve their difficulties, and there would be prosperity for all while it lasted.

It is now being generally recognized that the United States went into the late war for business reasons. Neither will anyone deny that participation in the war brought about one of the most prosperous periods of United States history.

20.2 Curtailment and Destruction

We have mentioned previously that a Price System economy is of necessity an economy of scarcity. This is due to the fact that values go to pieces in the presence of abundance. No better illustration of this fact could be found than that of the present policy of government as exemplified in the Agricultural Adjustment Administration. Here the reasoning is, there was so much cotton, wheat, and so many hogs, that the farmer was not getting a sufficient price for his product. The Price System remedy, therefore, was to be found in a curtailment of production. If cotton, wheat and hogs were made scarce enough, the price would go up. The fact that 20 or 30 million people didn't have enough to eat was of no consideration—not under the Price System.

20.2.1 Low Load Factors

Another characteristic of industrial operation under the Price System is that of industrial load factors. The load factor of a given piece of equipment may be defined as its actual output in a given period, say a day or a year, as compared with its output under continuous full load operation for the same period. Thus, a factory that runs full-blast 24 hours for six months in the year, and is shut down for the remaining six months, would operate at a load factor on a year's basis of only 50 percent. Similarly, a plant that operated 8 hours per day, 365 days per year, would have a load factor of only 33 1/3 percent, because two-thirds of the time it would be shut down. In other words, a load factor of 100 percent means a continuous full load operation 24 hours per day, 365 days per year.

It has been remarked previously that little of our present industrial equipment operates at more than one 8-hour shift per day, except for brief rush periods, and that for only a limited number of days per year. On the other hand, if present productive equipment were operated at anywhere near a 100 percent load factor, such a plethora of goods and services would be produced that the American public would be sorely embarrassed to find a way to consume them, assuming that we had a suitable mechanism of distribution.

This prevailing low load factor is the result of two distinct causes: one is that the competition in a profitable field of production leads to the building of more plant than is necessary for the amount of production allowable, the second is that the actual production allowable must not be more than is necessary if scarcity is to be maintained, and prices kept up.

A low load factor may signify equally well either of two things. It means that there is more than the needed amount of equipment to maintain the current rate of production. This involves a wastage of capital equipment, not to mention the high physical cost involved in intermittent operation of such equipment. It means, likewise, that were the existing equipment operated to capacity, the resultant physical output would be very much greater than it now is, or was in 1929. On either of these counts a low load factor is objectionable. The average physical standard of living of our society is determined largely by the rate at which goods are produced and distributed. Hence it follows that any attempt at social betterment that does not take into account the operating of our industrial equipment at the highest possible load factor, and insists instead on dividing up the poverty while leaving the Price System enforcement of scarcity intact, is, no matter how well intentioned, sheer lunacy.

20.3 Housing

One of our biggest industries, and one which along with food and clothing most vitally affects us personally, is that of housing. There is probably no greater collection of outworn junk in this country than the houses in which we live, and our buildings generally. From the point of view of the physical cost of operation alone, the inefficiency of our present structure is so great that, if we should tear them all down and rebuild them on a technically efficient basis, it is estimated that the energy saving in the operation of the new structures would compensate in about twenty years' time for the entire cost of demolition and reconstruction.

From the point of public health and sanitary conditions generally, it would be safe to say that about three-quarters of the abodes at present occupied by American families are unfit for human habitation in a civilized community. Under our present Price System there does not exist a modus operandi for either the design, construction or operation of our housing industry, so as to allow the basic technical and social requirements to be complied with.

The same scale factor that has already been mentioned with regard to operating equipment applies equally well with regard to industrial and office floor space. Our business and industrial structures have heretofore been built on the assumption of a continued rate of growth. If in the past a given city doubled in size every forty years, why should it not also double in size the next forty years, has been the type of reasoning applied in this field.

Here, as elsewhere, the technological factor has upset the apple cart. Every time new industrial or business equipment, which has an efficiency greater than that which it replaces, is installed, it requires less floor space for the same output than the equipment which it renders obsolete and replaces. This is no less true in business offices than in factories. Compare, for instance, the amount of floor space occupied by the old-fashioned bookkeeping clerks working over hand ledgers, with that required by modern high-speed, semi-automatic bookkeeping machinery when both do the same amount of accounting. Now that the period of industrial expansion under Price System dominance is virtually over, it follows that in the future, due to the more widespread use of such equipment, the required floor space will decline, together with human employment. If such buildings as the Empire State, Radio City, and similar buildings in other cities are to be occupied in the future it will probably be by leaving vacant an equal or greater amount of floor space in other buildings.

20.4 Interference by Business Expediency

Perhaps the chief Price System method of control is interference. The very nature of property rights themselves is that other individuals than the owner of a given piece of equipment are enjoined by law to refrain from doing certain things with regard to that equipment. Note the fundamentally negative thou-shalt-not aspect of this relationship.

There is probably no branch of our social activity in which this sabotaging influence for reasons of business expediency is more keenly felt and more socially detrimental than in the domain of scientific research and technological development. While it is true that many of our industrial establishments and business organizations retain research staffs to carry on various investigations in fields that show promise of being commercially profitable, nobody knows better than members of these research staffs that, should a discovery or invention be made which would be, if it were put into effect, better for the public, but worse for the business of the company, such discovery or invention would either be kept secret or tied up in patents to interfere with anyone else making use of it, and then carefully and permanently shelved. It is true that technically trained men design our present equipment; it is equally true that, if the equipment be of the sort that is to be sold to the public, they are instructed to design it so that it will not last too long. It takes great metallurgical skill to produce a razor blade which will last only four days.

An excellent example of this form of business sabotage of technological advance is to be found in the speech of Frederick E. Williamson, president of the New York Central lines, before the Central Railway Club of Buffalo, January 10, 1935. In discussing the St. Lawrence waterway project, Mr. Williamson remarked: ‘I do not intend to discuss this subject in more than a word or two, but I do wish to point out that, regardless of whether the emphasis be laid on the shipway or the power angle, the net results to the railroads of the East and the Middle West, and to the railroad men employed on them, will be just as disastrous in either case. In the end, construction of the shipway, whether primarily for power or as a deepened waterway, would be a potent contribution toward breaking down the present rail transportation system.’

What Mr. Williamson has implicitly admitted here is that the St. Lawrence waterway is so far superior to the New York Central Railroad as a means of cheap transportation, that, should it be installed, the New York Central as a business organization would have a tough time making ends meet. In other words, were the power which is now going to waste in the St. Lawrence River to be utilized, and at the same time the river to be made navigable, the energy cost of freight transportation along this waterway would be more than offset by the power derived from the river itself. From the point of view of our national economy, this would be a net gain.

It is a matter of common knowledge that there have been few major technological advances in American railroad equipment for many years past until the advent of the recent streamlined trains. Speaking of these streamlined trains, Mr. Williamson remarks further: ‘All this has captured the popular imagination, and rightly so. A renaissance of railroading seems in sight. At the same time, it appears to me desirable to sound a warning lest public expectations be aroused to such an extent that disappointment must inevitably follow. In a plant as huge as a railroad, radical changes cannot be made overnight. It must be a gradual process of evolution within the limitations fixed by existing investment and immediate financial ability, as well as a reasonable experience in operation of new type equipment.’

Particular attention is to be paid to what Mr. Williamson aptly calls the ‘limitations fixed by existing investment and immediate financial ability’. It is precisely these limitations so peculiar to the Price System which are rapidly precipitating a social crisis. Mr. Williamson is quite correct that certain things cannot be done under limitations set by the Price System. Technologically, however, no corresponding limitations exist. But for the Price System limitations, the entire rolling stock of the American railroads would be scrapped and replaced by a modern technologically integrated system.

Even where the technical work, such as geological work in the exploration for useful minerals, is socially desirable, its effects are commonly offset by business practices in connection therewith. It is socially useful, for instance, to delineate oil structures, but one frequently wonders to what end when he watches the mad business rush of big and little oil companies, like so many buzzards fighting over a carcass, each trying to get his share, while the pool, in the meantime, is being drilled as full of holes as a pin-cushion and the gas pressure blown off into the air.

A similar paradoxical situation exists with the production and utilization of other mineral resources. The fluorspar-bearing area of southern Illinois and northwestern Kentucky is practically our sole source of supply of this useful mineral. From the point of view of our national well-being, it would behoove us to use this limited supply sparingly and wisely. It is to the advantage of the business interests, on the other hand, to find bigger and better ways of getting rid of fluorspar. Consequently it is interesting to note that the Illinois Geological Survey, capitulating to those interests, has had a research chemist trying to find a way to use fluorspar in concrete. Should this effort be successful, it is true that it would boom the fluorspar business, and, of course, it is not the concern of business men where we shall get our fluorspar in the future.

An interesting relationship between low load factors and the wastage of natural resources is to be found in coal mining. In underground coal mining two principal alternative methods are employed, the room-and-pillar method and the long-wall method. In the room-and-pillar method a part of the coal is mined and the remainder is left in the ground intact as pillars to support the roof. With this method, only about 50 percent of the coal is recovered, and, once the mine is abandoned, it is virtually impossible to go back and mine the rest. In the long-wall method all of the coal is mined along a lengthy straight wall, and the roof is allowed to subside gradually in the rear as the mining along the wall progresses. By this method approximately 90 percent of the coal is recovered from the ground. Since with the long-wall method the roof subsides slowly but continuously, the mining operations must be continued without cessation in order to keep ahead of the subsiding roof. The demand for coal, however, due to our low industrial load factor, is seasonal, and, since bituminous coal cannot be stored over long periods of time, the production at the mines has to be geared to coal consumption. Consequently the mines operate briskly for a season and then shut down. This shut-down period precludes an extensive use of the long-wall method, and consequently results in a wastage of not less than one-third of our coal resources.

On the purely human side of the picture the same type of consequences prevail. The general maintenance of poverty in the midst of potential plenty is too prevalent to need further comment here. One factor that might be mentioned is the general debasement of human beings under the pressure of economic insecurity. So effective is this pressure in our present society that the enjoyment of personal integrity has become one of the most expensive of human luxuries, because, unless one be of that small fraction of one percent in the higher income brackets, the price that he will pay for the privilege of indulging in personal honesty or integrity will almost certainly be his job; in other words, a salesman is not a liar because of the personal delight he takes in fleecing the public, but because he knows full well that if he told the public that the product he is asking them to buy is relatively worthless, if not actually harmful, he would soon be helping to increase the great army of the unemployed.

20.4.1 Institutional and Traditional Interference

A similar thing is true in the field of public health. About 1928 the Billings Hospital was opened in South Side Chicago as a part of the Rush Medical School of the University of Chicago. This was the best hospital in that part of the city, and, if operated at all, would be a very important contribution to the public health service provided for the people in that part of Chicago. The technical staff of this hospital was amongst the best that could be obtained. Operating as a part of a medical school, it would also maintain free or low priced clinical service to the students of the University of Chicago, and to the local community.

It is interesting to observe that the most violent objectors to this hospital were the local members of the American Medical Association, who took such strenuous action that they finally succeeded in having the entire staff disbarred from membership in the American Medical Association on the grounds of unethical practice. In other words, an adequate health service administered to the South Side of Chicago was ‘busting up their racket.’

Again, let it not be misunderstood what the essential elements of this picture are. Under the Price System a medical doctor is not only a public servant looking after the health of the community; he is also a business man with services to sell. Approximately one-half of his life and an enormous amount of money besides has been spent in acquiring his professional training. If this is to be compensated for, it means that the remainder of his life must be devoted to those activities for which a handsome fee can be collected. If his professional services are to be sold at the necessary price, these services must be kept scarce. A doctor has to make a living. The net result is the inadequate and incompetent public health service with which the American public is all too familiar.

In other words, the ‘load factor’ of our doctors and our hospitals is as far below capacity at the present time as that of our power plants. Stated conversely, if the public health personnel and equipment were allowed to operate at full load in the most efficient manner, according to present technical standards, it would be possible virtually to eliminate most contagious diseases within 10 years.

As this is being written (February, 1935), the American Medical Association, at its meeting in Chicago, is making its perennial attack upon socialized medicine.

A similar situation prevails in the field of education. Less than 15 percent of the youth of the nation is allowed the questionable privilege of a college and higher professional education. There is hardly a classroom in a modern university that is filled to capacity, for the simple reason that enough students are not able to pay the tuition fees to take the courses.

The quality of instruction suffers correspondingly because of economic controls which are exercised over those doing the instructing. The modern college instructor, with few exceptions, either conforms or gets out, voluntarily, or by invitation. No more striking illustration of this could be offered than the career of Thorstein Veblen, who was one of the few truly great men America has ever produced, and who was virtually ‘kicked out’ of every university in which he ever taught.

Within the curriculum of our institutions of higher learning the same sabotaging influences prevail. The Schools of Education, for instance, have, by playing politics with state legislatures, so completely tied up the public school system that it is now practically impossible for one to get a job in any public school in the country on the basis of technical training and competency. One may not, and frequently does not, know anything about the particular subject he is supposed to teach, but he must have the requisite number of courses in education as to how it is to be taught.

And then there is the slavery to the Ph.D. degree. If a graduate student in one of our institutions of higher learning wishes to pursue his studies, it is expected that he will do so with the intention of becoming a Doctor of Philosophy. It may, and commonly does, happen that the acquirement of technical competency in a particular field requires that the student pursue a course of studies entirely at variance with those prescribed in fulfillment of the more or less inane requirements for the Ph.D. Here, as elsewhere, economic pressure is brought to bear, and those who do not conform are rather effectively excluded from getting jobs they might otherwise acquire. It is needless to remark that the majority of the students of our higher institutions of learning are, accordingly, degree seekers rather than persons interested primarily in the acquisition of an adequate technical training.

The most tragic aspect of all exhibited by our present educational system, however, is to be found in the problems which the students themselves face. It is a commonplace fact of human biology that, when only a small percent of the population is financially well to do, talented youth is by no means confined to that segment of the population in the higher income brackets. An average figure of the cost per nine-month term of attending our present colleges and universities is around $800 to $1,000 per annum per student. When it is considered that this sum is only slightly less than the average annual income of the great majority of the families in our population, it is a simple matter to see, in the light of this, that the selection of those who shall and those who shall not receive training in our institutions of higher learning is determined almost entirely on the basis of pecuniary standing of the parents of the prospective students.

It is true that we have all been fed on the Horatio Alger myth of the poor boy working his way through college, but the fact remains that those who do this successfully are few, and many are the unchronicled, bright-eyed lads who ‘crack up’ in the attempt.

The final blow, of course, is dealt when the students have completed their formal education, only to find that in their field, too, there is over-production, and few people are willing to engage their services.

In our educational system, as elsewhere, the fault is not to be found in the individual members of the personnel. This state of affairs is the logical product of social administration under Price System rules. If the university president allowed his faculty too free a rein, it is quite likely that somebody might offend the bankers, and this would result in a corresponding diminution of endowment funds. If tuition fees were decreased sufficiently to fill up the class rooms the resulting decline in revenues might be serious.

20.4.2 Legal Interference

Just a word may be said about criminal activity and the police force. The term ‘crime’ is itself completely ambiguous, and there is no important distinction between socially objectionable activities that are legal and those that are illegal. One of the fundamental properties of money, however, is that it constitutes a standing social reward to any individual who, legally or otherwise, ‘gyps’ the public successfully. The tie-up of local political machines with such predatory activities, ranging from banking on the one hand to racketeering, gambling dives, and prostitution on the other, is too well known to need amplification. The police force in such a situation are merely ‘the hired boys’, having their orders whom to molest and whom to let alone. Politically, objectionable conscientious performance of duty on the part of the policeman can be very effectively handled through the mechanism of suspension, demotion, or transfer to an undesirable beat.

As a consequence of this tie-up between the political structure, with its police power, and the favored interests (whether these latter be Capones or Morgans, there is no particular distinction), it is relatively unimportant which particular things are legal and which are illegal. The line between the two is extremely difficult to discern. Both types of activity, whether legitimate business or avowed racketeering, are socially objectionable, though both are the direct consequence of playing the game according to the rules. The role played in this by the legal profession is principally that of finding ways and means within the existing statutes whereby any particular kind of activity, provided it pays well enough, can be shown to be legal. It is, of course, commonplace to anyone who has had any experience with courts of law, that to a very considerable extent the best lawyer wins, regardless of the merits of the case. And, of course, the most money hires the best lawyer.

In this connection it has been interesting to observe the activities of the major oil companies over the last ten or fifteen years with regard to unit operation of oil pools. Prior to about 1927 the rate of production of oil was sufficiently slow that a good price was maintained, and during that period the more oil produced the greater the profit. Now, there are many technical reasons why a single oil pool should be produced as a unit. Unit operation allows the most strategic location of producing wells and permits the maintenance of the gas pressure in the pool with which to force the oil out. If this gas pressure is blown off in non-unit operation, the gas is wasted, and the remaining oil has to be pumped, allowing a much lower recovery of oil than is possible under unit operation.

During the period mentioned above it was to the business interests of the large companies to get oil out of a given pool as rapidly as possible, because if they pumped fast enough they could produce not only the oil under their own land, but could also ‘steal’ a large part of the oil from the little fellows who happened to own adjoining tracts, but lacked capital enough to produce their own lands at the same rate. This practice was called the ‘law of capture.’ The legal staffs of the big companies at this time could demonstrate by any amount of legal briefs that such practices were entirely legal, just, and as they should be.

After 1927 one large oil pool after another was ‘brought in’ in rapid succession, pouring so great a flood of oil on the market that ruinous prices resulted, and, as a consequence, it became the interest of the big companies to curtail production in order to enforce scarcity and thus keep the prices up. The little fellows were also in a disadvantageous position, as even at ruinous prices, they had to produce or else go broke. Hence, should big companies curtail production while the little fellows continued to produce, the law of capture would for the first time have worked to the advantage of these latter, and to the disadvantage of the former. In the meantime, it has been highly illuminating to watch the same legal staffs render equally numerous briefs on the legality of unit operation and of curtailment and proration of oil production, enforced by the police power of the states.

'A criminal is a human being with predatory instincts but without sufficient capital to start a corporation.'

20.4.3 Political Interference

Intimately linked with the activities of the legal profession and with business enterprise is our political government, the general incompetence of which, from the local wards and precincts to the national government, is a matter of such commonplace knowledge as to require little comment here. Notable exceptions to this general statement are to be found in the purely technical bureaus, such as the United States Bureau of Standards, Geological Survey, Department of Agriculture, etc. It is significant that the technical staffs of these bureaus are not elected by popular vote, nor are they appointed by the political chieftains of the present or past administrations, and hence are not subject to political contamination. It need hardly be added that, were this not so, it is extremely doubtful that the work turned out by these bureaus would be of sufficiently high quality to merit scientific respect.

A system whereby governmental officers are chosen by popular ballot is immediately open to all the political chicanery that we are already familiar with, ranging all the way from the small town glad-handing and baby-kissing politician to the Tammany machines with their racketeering and patronage in our large cities, and finally to our national political government, with its deference to, and solicitation for, the interests of big business. When it is borne in mind that the public is, and of necessity must be, almost completely ignorant of problems, either of personnel or of policy, which they are regularly called upon at election time to solve, it becomes a very simple matter, by means of a suitable expenditure of money, using the mediums afforded by the press, the radio and public speakers, to play upon public prejudice, and hence to swing the results of any election to the desired end. While it is true that the illusion of alternatives is kept before the public through the device of opposing political parties, the fact remains that the similarity of the opponents in all fundamental particulars is so great that it makes virtually no difference at all, in the net effect to the country, who wins the election. In other words, no question of really fundamental importance is ever submitted to popular election. The real controls are exercised at all times behind closed doors and by a small minority of the population.

20.5 Propaganda

Among the most powerful devices in social control at the present time are the radio and the press. Just how powerful the press has been in the past can be seen when we review the propaganda which we were fed during the late World War. At the beginning of the World War we were a nation at peace with the world, and the great majority of the American people, were almost oblivious of the fact that Europe existed. Finally, the House or Morgan became dangerously overloaded with debts of the allies, and succeeded in involving, in some measure, a large number of American business men besides. Then, only a few weeks before our declaration of war, our Ambassador, Page, to England, cabled President Wilson that in order to maintain our preeminence in world trade, and to save Morgan, it would be necessary for the United States to enter the war on the side of the Allies. We entered, and, in the light of this, our entry into the World War 'to make the world safe for democracy' and the events that followed are extremely interesting.

The American public as a whole had little knowledge of, and little interest in European affairs, and, least of all, had they a hatred of the Germans or a love for the French. Consequently, to make it a successful war such a love and a hate had to be created synthetically. To this end the best liars and ballyhoo artists that could be obtained were set to work grinding out lies about the atrocities of the Huns and disseminating them from the lecture platform and the press to the American public. The results were those desired: America entered the war, large profits were made, and the gullible public swallowed it, hook, line and sinker.

The same devices that were used then with regard to the war have subsequently been used with regard to political and economic matters. Most of the major newspapers and magazines of wide circulation, such as the Saturday Evening Post, are chiefly organs of propaganda for favored business interests. While the control may be quite impersonal, it is none the less positive, because all of these papers depend very largely upon the goodwill of business interests for their advertising, which is a highly essential part of their financing program. If they print the right stuff, advertising and prosperity is theirs; if they don't, they stand a good chance of going out of business.

A very interesting example of such control of a journal was manifested in the case of The American Mercury. The Mercury had adopted a militant editorial policy and had opened fire with a very significant article upon the activities of the American Red Cross, showing conclusively that the latter had become almost entirely a tool of financial interests, and was engaged in enterprises of highly questionable merit. Other articles from a like point of view were to follow. Almost immediately the bankers of Alfred A. Knopf, the publisher, brought pressure to bear, and The American Mercury was promptly sold, to proceed henceforth under a new and doubtlessly less belligerent editorship.

Examples such as the foregoing, in every sphere of operation under a Price System, could be cited almost indefinitely. Under the Price System at its best there is not a single field of endeavor where the best technical standards are allowed to prevail. In other words, poverty, waste, crime, poor public health, bad living conditions, enforced scarcity, and low load-factors, are every one the direct and necessary consequences of the Price System. Let it be emphasized, however, that while certain individuals may be somewhat worse offenders than others, individuals are not to be blamed. The system being what it is, if one is to hold political office he will almost without exception find it necessary to indulge in the usual political practices. If one is to become a successful business man, he will only do so by engaging in those practices which characterize the activities of other successful business men. The fundamental law of survival under the Price System is that one must create debt claims against others faster than debt claims are created against him, or else he does not remain in business.

20.6 Summary

What we have tried to make clear is that it is the Price System itself, and not the individual human being, which is at fault. Granted the system, the human beings are obliged to act in accordance with its dictates, with the rather sorry results we have enumerated above. Consequently, no amount of doctoring of symptoms while leaving the fundamental causes of the disease intact will be of any appreciable avail. One does not eliminate bootlegging while prohibition in conjunction with a thirsty public exists; bootleggers are created thereby. Abolish prohibition and bootleggers largely disappear. One does not abolish or prevent war by pacifistic speeches, or by other means either, so long as foreign trade and the manufacture of munitions of war remain profitable. Neither does one abolish disease while poverty, malnutrition and other disease-breeding conditions continue unaltered, nor so long as the economic well-being of the medical profession depends upon the prevalence of disease in profitable amounts. Nor is crime ever abolished, either by coercive measures administered by officials whose activities are only slightly, if any, less socially objectionable than those which it is sought to suppress, or by any amount of moralistic railing or inculcation of doctrines of 'brotherly love,' so long as there continues to be offered a standing reward to all those who will 'gyp' society successfully. Granted the offer of the reward, socially objectionable activities follow as consequence; withdraw the reward and these activities automatically disappear. It is the Price System itself—the rules whereby the game is played—and not the individual human being which is at fault.

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Lesson 21

THE NATURE OF THE HUMAN ANIMAL

In lessons 2 through 15 it was our endeavor to present the fundamentals of the scientific basis of the phenomena that make up our complex social activities. In Lessons 16 through 20 we analyzed the existing social habits comprising our present Price System mode of control. We have shown on the one hand that there are no physical barriers, aside from human beings themselves, to the attainment on this Continent of an average physical standard of living which would be the highest we have ever known, and very much higher than that of 1929. We have shown likewise that our social activities as controlled by existing social habits, which we have termed 'the rules of the game of the Price System,' are rapidly forcing us to an impasse, due to the fact that these habits were largely acquired during a stage of relatively primitive technological development which was characterized by low-energy rates of operation, and scarcity in general. In the presence of a technological mechanism which has evolved to a high-energy operation with—for the first time in human history—the potentialities of plenty, the Price System rules of enforced scarcity are found to be no longer adequate.

Since it is human beings and their habits with which we are now obliged to deal, it is well that before proceeding further we inquire somewhat more deeply than heretofore into the nature of this human animal.

There is probably no field of scientific investigation in which more resistance has been encountered than in those domains which have affected the superstitions men have entertained about themselves. The history of science is littered with burnings at the stake, heresy trials, imprisonment of scientists whose works have contradicted, or otherwise cast doubt upon, popular superstitions.

21.1 The Solar System

Before the time of Copernicus the universe was regarded by the inhabitants of Western Europe as consisting of the earth at the center, with the sun, the moon and the stars revolving around it. A terrific furor was created when Copernicus had the audacity to suggest that it would greatly simplify matters if the sun were regarded as fixed at the center of the solar system, while the earth and the other planets revolved around it in circular orbits. The former system of thought, having the earth as the fixed center, has come to be known as the geo-centric system; the latter, propounded by Copernicus, is known as the helio-centric system.

All this seems rational enough to us now, and one may be inclined to ask what all the shooting was about. What earthly difference does it make whether one regards the earth as revolving around the sun, or the sun as revolving around the earth? That it evidently did make some difference is attested by the fact that, while Copernicus avoided the trouble by dying before his famous paper was published, his illustrious successor, Galileo, was imprisoned for defending it, and his health broken so badly that he died in consequence.

When one goes a little deeper into the matter, the reason for all this becomes evident. According to the prevalent superstitions, or folk-ways, backed up by all the authority of the Church, God had created man in his own image, and had created the earth as man's place of abode. Such being the case, God could not have done less than to place man, his most perfect and important creation, in the center of his universe, with all the parts of lesser importance revolving around. Now, if the sun were to be regarded as the center of the solar system, with the planets revolving around, the earth would be relegated to a position merely of one of the planets, and a lesser one at that. Consequently such a heretical doctrine constituted, should it be allowed to prevail, an undermining of the faith, not to mention an insult to God himself, and hence was under no circumstances to be tolerated.

In spite of all this the heretical doctrine did prevail and, while it may have been a blow to man's egotism to be removed from the center of the universe and to be condemned to an abode on a lesser planet, human beings seem to have been able to adjust themselves to this change, and to have got along for better or for worse subsequently.

21.1.1 The Age of the Earth

The next great blow to human egotism and superstition came when the geologists and biologists began to make certain significant observations about the rocks of the earth's surface. Late in the 18th century a Scotsman by the name of John Hutton made extensive studies of the stream valleys and canyons in the Scottish Highlands. Hutton, after long and careful study, arrived at the then astounding conclusion that the canyons in which the streams flow were cut into solid rock by the streams themselves. Again the fight was on. The whole thing was ridiculous and preposterous, men said, for was it not known already from the scriptures that the earth was created in the year 4004 B.C.? Since the canyons had not been visibly deepened during historic time, and since the earth was only a little less than 6,000 years old, was it not obvious that such canyons could not have been produced by running water in so short a time, and hence must have been present when the earth was created?

In this case, as before, scientific observation and induction had produced results squarely in contradiction to the inherited folkways. Hutton was attacked, not on the basis of the facts themselves, but on the basis of what men thought they knew already. It had not occurred to these critics that possibly their own source of information, having been handed down from a primitive and ignorant people of the remote past, may have itself been erroneous. In so square a contradiction as this somebody had to be wrong, and the more the evidence was examined, the more firmly was the Hutton theory established, and it gradually dawned upon the learned world that the earth was ancient beyond all comprehension, contrary to biblical tradition.

The implication of the studies of Hutton and his followers to subsequent human thought have been very great, indeed, for if the history of the earth was not in accordance with biblical tradition, was there not a suspicion that possibly the remote history of the human species might be somewhat at variance with the same account?

The next great step in this progression came from the biologists. Even before the time of Galileo, Leonardo da Vinci had observed the presence of sea shells in the rocks of Italy, in high mountains at great distances from the sea. To da Vinci this seemed to indicate that these rocks had once formed a part of the sea bottom or sea shore, and that when the shell-fish had died, their shells had been buried in the sands and muds which were subsequently lifted up into dry land and consolidated into solid rocks.

By his contemporaries these ideas of da Vinci's were accounted as being little less than insane, and were paid no particular attention. By the late 18th and early 19th centuries, however, other men began the study of the sea shells contained in rocks, and found themselves obliged to come to essentially the same conclusion reached previously by da Vinci. It was then discovered that the same strata or layers of rock over extensive areas always contained the same shells, but that the shells contained in different strata were different. Finally, it was reasoned that if these rocks were sediments deposited in a sea, the older rocks should be those at the bottom of a series, and the successively younger rocks should be successively higher, one above the other like the layers in a layer cake. Then it was observed that in certain regions of England and France, the nearer one got to the present sea shore, the successively higher and therefore younger beds contained shells that more and more closely resembled those contained in the present ocean.

Besides sea shells there were now beginning to be dug up here and there whole skeletons of large animals, the like of which do not exist on the earth today.

This was, indeed, a puzzle. Men were obliged to come to the conclusion that the earth was extremely ancient, and that regions which are now dry land had been repeatedly under the ocean in times past. Not only this, but the animals in times past had been different kinds of animals from those living at the present time. Still clinging as best they could to their folklore and theological doctrines, the men in the early 19th century had to revamp their ideas to include these new facts. This they did by deciding that instead of one divine creation there must have been several. God had evidently created the heavens and earth at some time in the extremely remote past, and, being an amateur at the art of creating, he had peopled it with some low forms of life. These, evidently, did not turn out to his liking, and in the meantime he developed some new ideas, so in order to try out his new ideas, he produced a great cataclysm, and wiped out all the forms he had previously created, and then repopulated the earth with a new set of creatures of somewhat improved design. This process was repeatedso men at that time thoughtuntil at last perfection was reached when God created man in his own image, together with the lowly beasts of the fields to do him service.

This beautiful picture was soon upset when the English geologist, Charles

Lyell, issued in 1831 his famous textbook, *Principles of Geology*, wherein it was shown that no evidence of a great worldwide cataclysm or catastrophe existed, and that the making of the mightiest mountains was probably accompanied by no more drastic phenomena than occasional earthquakes and volcanoes such as occur today.

21.2 Supernaturalism of Man

At about this same time new seeds of heresy were being sown by investigations in the fields of chemistry and medicine. The chemists were discovering that all matter on the face of the earth is composed of a small number of elementary substances which they called the chemical elements. With this knowledge came the ability to chemically analyze various substances and to determine of what elements they were composed. As a consequence it was soon discovered that the human body, instead of being something mysterious or supernatural, was composed of identically the same chemical elements as are found in air, water, rocks and other common substances. In addition to all this, the German physician, Robert Mayer, discovered that the energy released inside the body by food eaten is identically the same amount as would be obtained were the same amount of food burned outside the body.

The picture of the supernaturalism of man and the special creations received a final thrust when, in 1859, Charles Darwin issued his book *Origin of Species*. In this book Darwin showed that instead of species being separately created, animal and plant life undergoes gradual and very slow change, and by this evolutionary process, given a sufficient amount of time, entirely new life forms develop from primitive stock. Thus, life on earth according to this new notion of Darwin, must have begun at some time so remote that no record of it is available, and from these simple primitive forms all of the diverse species of plant and animal life, including *man, himself*, must have arisen.

This was too much, and the theologians were up in arms again. Dogs, horses, cows and monkeys may have evolved from lower life forms, but man—never! Man, after all, had a soul and a conscience. He could reason and could discern the difference between right and wrong. He was something above and apart from the brute beasts of the field. While this fight lasted for a period of 30 to 40 years, as usual the facts won out against tradition, and human beings, much as it hurt their egotism to have to do so, were so far removed from the pedestal upon which they had originally imagined themselves to be, that at last they were obliged to admit blood kinship with the other members of the animal kingdom.

But traditional ways of thinking are persistent and not easily outlived, and, even though it was granted that the human species is merely one out of many species of animals which had had a common evolutionary origin, still the notion prevailed that there was somehow or other an aura of the supernatural that differentiated man from the rest of the animal kingdom. Man, so it was thought, had a ‘mind’ and a ‘conscience,’ and even the vestige of a ‘soul’. Also there were ‘spiritual values’ which still kept the human species in a slightly elevated position. Then, too, men had ‘wills’ whereby they could decide what to do and what not to do.

The developments in the fields of physiology, biochemistry and biophysics, chiefly since 1900, are at last bringing us down to earth. Attention has already been called to the fact that the human body is composed chemically of the ordinary substances of which rocks are made. So are dogs, horses and pigs. In an earlier lesson, while discussing the ‘human engine,’ we pointed out that the human body obeys identically the same laws of energy transformation as a steam engine. This also is true of dogs, horses and pigs. These facts might lead one to suspect that human beings are very far removed from the semi-supernatural creatures they have heretofore supposed themselves to be.

21.2.1 Objective Viewpoint

There was still, however, the age-old puzzle of human behavior and of what we called ‘thinking.’ It might be remarked that the most minute anatomical dissection had never revealed anything that corresponded to a ‘mind’ or a ‘conscience’ or a ‘will.’ The reason for this is not difficult to find when one considers that all of these terms were inherited from an ignorant, barbarian past, and had never been subjected to scientific scrutiny. Let us remember that real scientific progress is at all times based upon the correlation of objectively observable (see, feel, hear, taste, smell, etc.) phenomena. When we subject such concepts as the human ‘mind’ to this sort of test they rapidly fade out of existence. When we observe a human being we merely perceive an object which makes a certain variety of motions and noises. The same is true, however, when we observe a dog or a Ford car. Only the form is different in each case, and the particular pattern of motions and noises is different. We observe, likewise, certain cause and effect relationships. If, for instance, we press the horn button on the Ford car, the Ford gives vent to a honk; likewise, if we step on the dog's tail the dog lets out a yelp. Thus, we can say in the case of these two mechanisms, the dog and the Ford car, that:

Pressing horn button produces honk.
Stepping on tail produces yelp.

We see, therefore, that when we begin to correlate what we actually observe, without introducing any of our inherited preconceptions, we can treat a dog with the same dispassionate objectivity which we are accustomed to use when dealing with Ford cars or radio sets.

21.3 Stimulus and Response

It was with exactly this point of view that the famous Russian scientist, Pavlov, began a series of experiments which have already resulted in some of the most profound changes in human knowledge, and in what human beings think about themselves. Early in the present century Pavlov began the study of dogs in the manner we have described. He observed, for instance, that when beefsteak was shown to a dog, the dog's mouth began to water and to drop saliva. This, mind you is just the kind of observation that one makes with a Ford.

With the car—one pushes the button; horn sounds.
In the case of the dog—one shows beefsteak; saliva flows.

In the case of the car we know that the horn is connected to the push button by an electric circuit, and that if this circuit is broken the pressing of the button will no longer cause the horn to sound. Likewise, in the case of the dog, Pavlov knew that there are nerves leading from the eyes and the nose of the dog through the brain to the glands which secrete saliva. Thus, the sight and smell of a beefsteak in the case of the dog is just as mechanistic a process as the pressing of the button is in the case of the Ford car. Should these nerves be severed by operation, as has been done in Pavlov's laboratory, the saliva is no longer secreted in the presence of the beefsteak.

This cause and effect relationship between the beefsteak and saliva flow, and other similar reactions occurring in animals, are called reflexes. If one should use the same terminology in the case of the automobile, he would say that the sounding of the horn is a reflex action occurring in consequence of the button having been pressed. The pressing of the button is called the stimulus; the sounding of the horn is called the response. In the case of the dog the stimulus is the sight and smell of the beef steak, the response is the flow of saliva.

Now, in order to observe and measure this flow of saliva more accurately, Pavlov performed a slight operation on the dog's face, and brought the salivary duct out and grafted it to the outside of the dog's face, so that the saliva flowed outside where it could be caught in a measuring device and accurately measured.

The dog was then put into a carefully shielded room, from which he could not see the outside, and into which no sounds from the outside could penetrate. A mechanical device was installed whereby the dog could be shown beefsteak without his seeing or hearing the operator. A metronome was also installed. The operator sounded the metronome, and no saliva flowed. Hence the stimulus, or the sound of the metronome, produced no response in the flow of saliva. Now the dog was shown beefsteak and the metronome sounded simultaneously. This was repeated 30 to 40 times, then the metronome was sounded alone. This time the saliva flowed upon the sounding of the metronome. That is, the stimulus, sound of the metronome, then produced the response, flow of saliva. In other words, the repetition of the sound of the metronome, together with the showing of beefsteak, somehow produced in the dog's brain a nervous connection between the nerves of the ear and the salivary glands, which did not previously exist. That this is so Pavlov demonstrated by removing the part of the dog's brain containing that particular connection, and, just as when one cuts the wire between the button and the horn on a car no honk can be induced, saliva no longer flowed at the sound of the metronome.

Now, let us see what this means. If the dog were able to talk and to describe his experience, he would doubtless say that he had heard the metronome so often, together with seeing and smelling beefsteak that finally every time he heard the metronome it made him 'think' of beefsteak. But we have been able to observe that what actually happened inside the dog was a series of very slight nervous and muscular reactions, including the secretion of saliva. Stated conversely then, this series of slight nervous and muscular reactions, including the secretion of saliva, is what 'thinking of beefsteak' consists of. It should have been stated that the amount of saliva flowing at the sound of the metronome was somewhat less than the amount flowing when beefsteak itself was present. Thus the reactions which take place in the dog when he 'thinks' of beefsteak are the same to those that occur when he actually sees and smells beefsteak, except for somewhat diminished intensity.

This new connection where a response is made to follow a stimulus for which no reflex previously existed Pavlov called a conditioned response. The new reflex set up in this manner he called a conditioned reflex.

An almost endless variety of experiments of the same sort have since been performed on dogs, monkeys, human beings, and all sorts of lower animals, even to snails. It has been found that conditioned reflexes of second and higher orders can be set up. For instance, if a black square is shown the dog, no saliva flows, but if the black square is shown 30 or 40 times, 15 seconds before the metronome is sounded, and then the black square is shown alone, saliva flows. This latter is called a conditioned reflex of the second order. In certain cases third order reflexes, but no higher orders, were established in dogs.

21.3.1 Thinking, Speaking, Writing

Experiments with human beings have given identically the same kinds of results, with the exception that the human being requires a smaller number of repetitions to establish a conditioned reflex than a dog, and he can sustain a higher number of orders of conditioned reflexes than a dog can. It is of this that a superior intellect consists.

We have already remarked that the series of nervous and muscular twitching involving the secretion of saliva, which takes place at the sound of a bell or other conditioned stimuli in the absence of beefsteak, is of what 'thinking of beefsteak' consists. It is now incontrovertibly demonstrated that all thinking is of this sort. If a certain object is placed in front of a human being and at the same time a certain sound is uttered, and this process is repeated a number of times, then if the sound is uttered without the object being present, the human being 'thinks' of the object, which means that inside him the same muscular and nervous twitching occur which were originally evoked only by the object itself. This is the basis of all language.

Suppose the object be a familiar tool used for digging soil, and that the sound emitted in connection with it is the word 'spade.' If these two are repeated together to a human being who never before saw such an object, or heard such a word, he is soon conditioned to a stage where the sound of the word 'spade' evokes in him a conditioned response essentially similar to that produced originally only by the object itself.

Now carrying this to the second order, suppose that the word ‘spade’ is spoken, and simultaneously the individual is shown a certain configuration of black marks on paper. After a few repetitions this particular configuration of marks will evoke the same response, only to a slightly lesser intensity, than was formerly evoked only by the word ‘spade,’ or by the spade itself. This is the physiological basis of writing.

Conversely, no conditioned response to a given stimulus can ever occur unless the subject has previously been through the conditioning experience involving this stimulus and the corresponding response. Thus, suppose that you are asked to think of ‘rideck,’ and you think just as hard as you can. Nothing happens. The reason nothing happens is that no conditioned reflex has ever been set up in your experience between the word ‘rideck’ and some unconditioned response due to some other cause. If, however, you hear the word ‘rideck’ tomorrow, in all probability you will have a response similar to, only somewhat less distinct than the one you are having now. Tomorrow the sound of the word ‘rideck’ will make you ‘think’ of this lesson.

Suppose, likewise, that the word ‘London’ is sounded. If you have never been to London this stimulus will evoke in you responses from a multitude of your past experiences with regard to the word. These responses will be those evoked originally by certain motion pictures that you have seen, geography textbooks, newspaper pictures and articles, and probably certain books that you have read. What is more, the responses probably will be more or less vague and indistinct and certainly different from those that would be evoked had you ever been to London yourself. Likewise the following black marks on paper, ‘Franklin Delano Roosevelt,’ will cause you to utter certain sounds, and will evoke within you responses reminiscent of certain pictures you have seen in the newspapers and the newsreels and a certain voice you have heard on the radio. The effect would be just the same to you, assuming that to be the limit of your experience, if the whole business were a hoax, and the pictures and the voice were of somebody else entirely, and merely put out for your illusion.

This latter type of thing, as a matter of fact, is exactly what was done during the World War, when we were told in the magazines and the newspapers about the Germans cutting off the hands of Belgian children. All we saw were certain black marks on paper, and we saw and heard certain people talking. Then we went out and acted as if Belgian children had actually had their hands cut off; which was exactly what was intended that we should do. However, no one has ever seen, then or subsequently, any of the Belgian children who were supposed to have suffered this misfortune. In other words, it was a pack of deliberate lies, and we, the uninformed public, were the unsuspecting and helpless victims thereof.

21.4 Suppression of Responses

Another thing that Pavlov discovered in his experiments on dogs was that, not only could responses be produced by conditioned stimuli, but they could also be suppressed or inhibited. In one case the dog's foot was given an electric shock. This produced a defense reaction. When, however, the shock was applied, together with giving the dog food for a number of times, the defense reaction was inhibited, and thereafter the electric shock caused a flow of saliva.

It was found that temporary inhibitions to the conditioned responses were always set up when stimuli foreign to the experiment were allowed to act upon the dog. Thus an unusual noise or the sight of a cat would completely inhibit the conditioned responses such as the flow of saliva. In general, strange stimuli always produced strong inhibitions of the ordinary conditioned responses, though they might or might not produce positive responses of other sorts.

In the case of human beings, striking examples of this type of temporary inhibition are to be found in such instances as stage fright (partial paralysis in the presence of an audience), microphone fright, the inability of one not accustomed to doing so to dictate to a stenographer, and the inability to move freely while at great heights.

In the case of the dog, a particular disturbing factor, if repeated often enough, loses its power to inhibit. Likewise with human beings, all of the above forms of temporary inhibition diminish rapidly with frequent repetition. The way to overcome stage fright is to appear before an audience frequently. The disappearance of the inhibition of movement at great heights is evidenced by the indifferent manner and freedom with which structural steel workers move about in skyscraper frameworks.

Another type of inhibition was produced in the dog by repeatedly sounding the metronome without presenting any food. On successive repetitions the conditioned response gradually diminished until it finally disappeared entirely. This is a fact that is well appreciated by farmers and ranchers. The farmer sets up a conditioned reflex in his hogs by sounding a certain call at feeding time. By daily repetition of this, within a few weeks the hogs become so conditioned that the sound of this call alone will cause them to come in from distances as great as the sound can be heard. If, however, the hogs are called repeatedly without being fed, the conditioned response will soon become inhibited and disappear, and the hogs will no longer respond to the call. A human example of this same type of inhibition is contained in the familiar story of The Boy Who Cried Wolf.

Likewise a farm boy, when brought to the city for the first time, is confused by literally thousands of simultaneous stimuli which are impinging upon him. He allows little to go unnoticed. He sees the flashing of the electric sign boards, the automobiles, the people, the street cars, and the elevated trains, all simultaneously, and so strong and uninhibited are his responses to these various stimuli that his motions are likely to be irregular in consequence. It is only after weeks of city experiences that he can walk along a busy street and pay no particular attention to anything. In other words, it takes some weeks to inhibit his responses to irrelevant stimuli such as electric signboards.

21.4.1 Involuntary Process

To summarize, Pavlov, by working experimentally with dogs, was able to demonstrate that there are certain inborn reflexes which are just as mechanical in their performance as is the relation between the pushing of the horn button and the sounding of the horn in an automobile. In addition to this, he demonstrated that there is some nervous mechanism in the dog, whereby, through a process of repetition or conditioning, formerly irrelevant stimuli can be made to set off any of these inborn reflexes. He also found that it is possible to remove, by operation, the upper part of the dog's brain, the cerebral cortex, without killing the dog or impairing the inborn reflexes. After this operation the dog could still walk, and if food were put into his mouth he would eat it, but the sight or the smell of food would have no effect upon him whatever. Consequently, after this operation, if not cared for, the dog would soon die, because he was completely unable to take care of himself. The reason that the sight and smell of food no longer affected him was that the nervous connection for the conditioned reflex between the sight and smell of food and eating was situated, at least in part, in the cerebral cortex which had been removed.

Thus a dog is a mechanism with certain inborn responses and an ability to set up, depending purely upon his individual experiences, an almost infinite variety of responses to new stimuli. This process is automatic and mechanical. The dog has no power, whatever, when being subjected to a given experience, to refrain from having the conditioned reflex established which occurs as a consequence of that experience.

We have dwelled at length upon Pavlov's experiment on dogs, merely because it is simpler to follow Pavlov in his classical experiments without danger of losing our objective point of view. We have digressed from time to time to point out equivalent cases in the behavior of human beings. Other workers both here and abroad have found that everything which Pavlov found to be true in the dog is true also in human beings. All habit formation, all language, all 'thinking' is nothing more nor less than the human being's response to miscellaneous stimuli, internal and external, in accordance with his existing conditioned reflexes. The human being differs from the dog principally in this respect—in the fact that he can acquire a conditioned reflex after fewer repetitions than the dog, and that he can sustain a higher number of orders of conditioned reflexes than can the dog.

21.5 Control of Behavior

Practically all social control is effected through the mechanism of the conditioned reflex. The driver of an automobile, for instance, sees a red light ahead and immediately throws in the clutch and the brake, and stops. This behavior is no whit different from that of a dog which hears a metronome and secrets saliva.

Of no less importance in social control are the conditioned inhibitions. If they are taken young enough, human beings can be conditioned not to do almost anything under the sun. They can be conditioned not to use certain language, not to eat certain foods on certain days, not to work on certain days, not to mate in the absence of certain ceremonial words spoken over them, not to break into a grocery store for food even though they may not have eaten for days. Of course, the human being rationalizes all this by saying that it is 'wrong,' or that his 'conscience' would bother him, but the interesting thing about 'wrong doing' and 'guilty consciences' is that they are only involved in those cases where one's past training has rigorously inhibited him from performing the actions in question.

It is interesting to observe a man with a 'conscience.' Suppose that he is put into circumstances where he is forced to do the things which he has been taught not to do. Suppose, further, that these forbidden actions are themselves pleasurable, that is to say, of themselves they set off no reactive or defense reflexes. The first few times the person is obliged to do the forbidden thing he does so with great hesitancy, and shows considerable signs of uneasiness. If, in that stage, he discusses the matter, he is likely to protest that 'it just isn't right.' If the action is repeated a number of times, however, and no ill consequences occur, the signs of uneasiness begin to disappear, and finally the action is taken with no hesitancy whatsoever. If, at this stage, the person comments upon his action, he is likely to remark upon how silly he must have been formerly to have been so diffident with regard to so harmless a matter.

If one observes a dog he will find an exactly equivalent mode of behavior. Suppose the dog is a farm dog which has been taught since he was a puppy that he may stay on the porch, but must never come into the house. Suppose further, that on a cold winter day someone takes compassion on the dog, and decides to invite him in to warm before a big log fire in the fire place. The door is opened and the dog is invited in, but he does not come; he takes a step or two in the doorway, looks uneasy as if he expects someone to hit him with a broom, and backs out. Finally lie is taken by the collar, and persuaded somewhat more forcibly to come in by the fire. While the fire is a delightful contrast to the cold out of doors, the dog still sits uneasily and appears ready to run at the slightest false gesture. After warming a while the dog is sent back to the porch. The second time he is asked in he comes, but still with considerable diffidence. After that he is likely to hang around the door in the expectation of a third invitation. Soon he sneaks in without being invited, and thereafter it becomes almost impossible to keep him away from the fire on a cold day.

These two cases, the man with a 'conscience' and the dog which has been taught to stay out of the house, are identical in all essential particulars. Both are conditioned inhibitions, and only signify that the animal in question (man or dog) has been subjected to an inhibiting influence in his earlier training.

One sees the same type of thing among farm animals. Most farm fences are of the nature of the red light in traffic, in that the farm animals, but for an inhibition to the contrary, would be physically able to jump them or tear them down if they tried. Wild horses, cattle or hogs, for instance, will jump over or tear down fences which hold the more domesticated members of the same species quite effectively. What is the reason for this? Can it be that the domesticated individuals are not as physically strong as their wild relatives?

This is usually answered to the contrary among farm animals by the familiar barnyard rebel—horse, cow or hog—which discovers how to jump or climb over fences and how to open gates and barn doors. The author knows of one hog which, when it was young, was given a slight encouragement in learning how to climb into a grain crib. This early experience seems to have removed the pig’s inhibitions concerning fences and barns, for thereafter with no further encouragement or training this pig learned how to open barn doors and how to climb over every field fence on the farm. Finally when he had grown and was placed in the pen with the fattening hogs, he climbed right out again. This was repeated until a pen was finally built of bridge timbers nearly five feet high, and tapered inward, so that it became physically impossible for him to climb out. The interesting thing about this is that every other hog on the farm could have done the same thing but for their carefully cultivated inhibitions to the contrary.

In this connection it is extremely instructive to observe a miscellaneous cross section of the human beings in any community. A certain small number of individuals always enjoy a greater freedom of action than the great majority of their fellows. These few are forever doing a great variety of things that the others dare not do. This difference is largely a difference in inhibitions. To carry the contrast to an extreme, consider a person raised entirely on a farm to be placed for the first time in a large city. While this person will not in general be without a quiet self-confidence, he will be extremely shy and loath to ask questions of strangers about means of getting about. If placed in social circles of unfamiliar dress and customs, his actions will be almost completely inhibited. By way of contrast the city-bred person, when placed in rural surroundings, is likely to be quite at ease with people, but almost helpless in case he is completely alone and there is no one to ask what to do.

A question frequently arises regarding the extremes toward which human beings can be driven in their conditioned actions. No better test in answer to this question is to be found than that provided by military service. In this case millions of adult men can be regimented and put through a conditioning process consisting of the familiar ‘squads right, squads left’ of the military drill, practice in handling firearms, and conditioning in assuming the proper attitude or deference toward the insignia of higher rank than those on the uniform of the particular soldier in question. Let it be emphasized that the attitude of deference and obedience on the part of a soldier to a superior officer is a case of pure conditioning with regard to the uniform the officer wears, and not with regard to the man himself. Place a man in the uniform of a buck private and he will evoke the response on the part of his fellows which they have been conditioned to give in the presence of the uniform of a buck private. Place identically the same man in the uniform of a general, and he will be accorded all the respect and deference to which a general is accustomed.

So strong are these conditioned responses on the part of the soldier to such stimuli as spoken commands, bugle calls, sleeve stripes, flags, etc., that when these stimuli are manipulated, the soldiers can be made to face even machine-gun fire and shrapnel.

21.6 Glandular Types

So far we have been talking about the reaction of a given organism to its external environment, and we have found that there is a great similarity in response, not only of human beings among themselves, but of other animals as well, to external stimuli. It has long been recognized, however, that there is a very fundamental difference in patterns of behavior in response to similar external circumstances by various human beings of the same sex, and an even more marked difference of response between members of opposite sexes. Even Shakespeare recognized this difference as shown by the remark of Julius Caesar:

> 'Let me have men about me that are fat,
> Sleek-headed men and such as sleep of o'nights:
> Yond Cassius has a lean and hungry look
> He thinks too much: such men are dangerous.'

It is a matter of commonplace observation that fat men are likely to be jolly and good-natured, whereas the lean and hungry type are more likely to be caustic, nervous, jittery, and, as Shakespeare expressed it, dangerous. It is only recently, however, that physiological knowledge has advanced to the point where it is now known that being fat and jolly or lean and dangerous is almost exclusively a matter of difference in internal secretions of certain of the endocrine glands of the body. If a certain combination of secretions from these various glands takes place a person becomes fat and jolly; if a certain other combination of secretions occurs the person becomes lean and has a pattern of behavior of the type that is more commonly observed in lean people.

These fundamental differences of behavior are even more marked between the opposite sexes. In the mammals and many other animals the male is commonly larger than the female, and is inclined to be belligerent and stubborn. The male hog, for instance, not only is larger than the female, but also has long protruding tusks on each side of his mouth. The male deer has antlers. The male chicken has a large comb, long tail and neck feathers, and fighting spurs. The female not only is different in appearance from the male in most species, but also has a distinctly different mode of behavior. Besides, this mode of behavior varies widely from time to time, as in the case of the setting hen or a hen with chicks as contrasted with the same hen at other times; or as in the case of a mammalian mother with young, as contrasted with the mode of behavior of the same female at other times.

21.6.1 The Endocrine Glands

In the past we have been content to obscure these distinct modes of behavior behind such expressions as ‘motherly love’ and other terms equally meaningless. What is now being learned is that these distinct modes of behavior, as well as bodily differences of form, are due very largely to a difference of internal secretions of the endocrine glands in the various cases.

Farmers have long known that castration of male farm animals produces a marked physiological change, as well as a change in the mode of behavior. A bull, for instance, has a deep-throated bellow, is squarely built, is stubborn to the extreme, and is inclined to be quite dangerous. Castration changes this almost immediately. The castrated animal becomes docile and easily manageable; he also loses all interest in the opposite sex. He loses his square-built shape and tends to become taller and more rotund. Similar changes are noticed in the males of other species. It follows, therefore, that some very potent secretion must be present in the non-castrated male which is no longer present after castration. This secretion has been called the male hormone.

There is a similar type of thing with regard to the female ovaries. Just as in the case of the male, where castration produces a metamorphosis to a form which is intermediate to that of the distinctly male and the distinctly female characteristics, so the removal of the ovaries of the female causes the disappearance of the distinctly female characteristics. If, for instance, the ovaries are removed from a chicken hen, she develops longer tail and neck feathers and other external features intermediate to those of a hen and a rooster, and resembling those of a capon.

There is a case on record where a prize laying hen, on which accurate records had been kept, finally quit laying and began to develop a large comb, long tail and neck feathers, and fighting spurs like a rooster. Not only did the hen begin to look like a rooster, but she also began to act like a rooster. She developed the male tendency to fight, and also developed the male sexual behavior. The result was that this former prize laying hen actually began to produce fertilization. Thus we have a case of a single chicken which during the course of its lifetime was successively both the mother and the father of offspring.

Principally within the last decade or two, various ones of these internal secretions have been isolated chemically and, in some cases, produced synthetically. It is found simply that very minute amounts of highly potent chemical substances, such as adrenaline, which is produced by the adrenal medulla, thyroxin by the thyroid gland, pituitary extract by one of the pituitary glands, female hormone by the ovaries, male hormone by the testes, and various other internal secretions by the other endocrine glands, are injected into the blood stream, and that to a very great extent the state of health, shape of the body, and fundamental modes of behavior are thereby profoundly affected. If these substances are injected into the body from the outside they produce the same effect that would be produced were they secreted by the body itself.

We have already mentioned the metamorphosis in the physiological processes, body shape, and modes of behavior of animals which have been artificially deprived of certain of these secretions, the male or the female hormones. Both of these hormones are now being obtained in concentrated form, and experimental investigation of their effects upon animals is proceeding apace.

Some years back experiments, which have since become classical, were performed upon chickens. From a normal chicken hen, for instance, the ovaries were removed. This deprived the hen of the female hormone, and she developed the capon-like features already described. Then she was injected daily with a concentrated solution of male hormone, obtained in this case from bull testes. Under this treatment, the comb, neck wattles, neck and tail feathers began to grow, and within a few weeks the former hen became metamorphosed in all outward appearance into a rooster—a slightly squatty rooster to be sure, but a rooster, nevertheless. Now, when the injection of male hormone was discontinued these features gradually subsided, and the squatty rooster became a capon again. Similar experiments have been performed with guinea pigs. A normal young male guinea pig was castrated and allowed time enough to reach a stage of sexually neutral equilibrium in the absence of the male hormone. Ovaries were then transplanted into his body, which began the secretion of female hormone. Under this influence the guinea pig developed enlarged mammary glands and a general body contour resembling that of a female guinea pig. Finally, after this metamorphosis had taken place, the guinea pig was given injections of an extract obtained from the anterior pituitary gland. It might be remarked that it is the secretion from the anterior pituitary gland which sets off the milk producing function of the mammary glands. After the injection of the pituitary extract lactation was produced, and this formerly male guinea pig actually nursed a litter of young when they were given to him. The experiment ended there. It is entirely likely that there are still other hormones, possibly those from the posterior pituitary, which, had the guinea pig been injected with them also, would have produced in him a full-fledged case of 'mother love.'

While the foregoing experiments have regarded principally animal species other than the human, this is largely because these other animals are more amenable to experimentation than are human beings. Clinical data, however, indicate that essentially the same phenomena that have been observed with regard to dogs, cats, guinea pigs, and farm animals generally, are equally true for human beings. Over-secretion or under-secretion of any of these endocrine glands in the case of the human being produced pathological states that affect the whole body and mode of behavior in varying degrees. Diseased ovaries, for instance, causing insufficient secretion of female hormone, frequently cause the development of a coarse, masculine voice and other masculine characteristics, including the growth of beard. These pathological conditions have been, in some cases, successfully treated by an operation involving the removal of the tumor or other disturbing factor, or else by continuous injections of the hormone in which the patient was otherwise deficient.

21.7 Results on Behavior

It is very important that one distinguish the difference between modes of behavior resulting from external conditioning and those occurring as a result of glandular and similar differences which are frequently inherited. These differences are excellently shown in the case of farm animals. Different varieties of farm animals of the same species are frequently quite different in their fundamental modes of behavior, even though their external conditioning is practically identical.

Hogs afford an excellent illustration. A razor-back pig can be raised along with a litter of Poland-China pigs of the same age. The whole litter can be subjected to practically the same sort of conditioning, but still when they are grown, the razor-back will be lean and wild, and will fight furiously at very slight provocation to protect its young. The Poland-China pigs, if well fed, will incline to fatness, and will be tame, stolid and unexcitable. Even if cross-bred with Poland-Chinas, the wild and excitable characteristics of the razor-back will persist for several generations.

A similar thing is true of cattle. In the pioneer days the range cattle and the razor-back hogs, as well as the mustang pony, were breeds which evolved from ordinary domestic stock imported from Europe. Under wild environmental conditions this formerly domestic stock underwent a rapid evolution, with the development of those characteristics best suited to survival under such conditions. Among the outstanding characteristics thus accentuated were wildness, tendency to fight for young, and ability to endure on little feed. It is precisely these characteristics which differentiate this stock from its domestic counterpart, which is biologically inferior. The old range cow, like the razor-back hog, was not only wild, she was also a fighter. If a range cow with a calf were corralled, any person molesting the calf would do so at his own risk and there was a high probability that he would be put up a tree or over the fence. The tendency of the range cattle to stampede when collected in herds is now famous in song and story.

No amount of domestication of the range cattle ever more than slightly altered those inherent modes of behavior. During the transition period while the range cattle were being replaced with white-faced Herefords, it was not uncommon for a range calf to be raised among Herefords. This more genteel (if one prefers) environment had little effect on the fundamental tendencies of the range stock. The range calf would grow up lean, wild, and with a propensity for fighting.

A similar thing has been observed in turkeys. The present domestic breed of turkeys has been evolved since the settlement of America by Europeans, from the native wild stock indigenous to this Continent. The evolutionary process here is in the opposite direction from that of the razor-back hog and the range cow. In the case of turkeys, a part of the original wild stock has been gradually domesticated, leaving another part of the original wild stock as a biological control for comparison.

There have been cases where the eggs of wild turkeys have been found, and hatched by a domestic turkey along with a number of eggs laid by domestic turkeys. Here, again, is a case where the young wild and domestic turkeys are brought up under identical environmental conditions from the date of hatching. As this flock of young turkeys grew up the wild members were easily detected by the difference between their mode of behavior and that of domestic turkeys. At any slight barnyard commotion, such as the barking of dogs, for instance, the domestic turkeys would fly to the top of nearby fences, while the wild turkeys would fly to the top of the tallest pecan trees in the vicinity.

What we are getting at here is that, granted all the similarity in the basic physiological structure of different individuals of the same species, there are also inherent individual differences which are probably in part glandular, and which no amount of conditioning or training can iron out. Certain individuals are excitable. They flare into a rage on short notice, and from slight provocation, and cool down equally quickly. Others are long-suffering, and are slow to anger, but having become angry, may require days or weeks to subside to normal.

The basal metabolisms of some varieties of the human species have, through some evolutionary process, become peculiarly adapted to the tropics. Others have in like manner become adjusted to temperate, and still others to Arctic climates. All this has nothing to do one way or the other with the superiority or inferiority of one variety of race of human beings with respect to another. It is merely an observation that human beings differ, both individually and racially, and that such differences are fundamental.

21.7.1 Peck-Rights

Much light in recent years has been thrown on the problem of individual differences by observations made on various sorts of animals. It is a common observation, for instance, around any barnyard that certain individuals for no apparent reason, assume priority and take precedence over other members of the same species. In a dairy herd, for example, coming from the pasture to the barnyard, a certain cow always goes through the gate first, and the others follow after in their proper order. Or, between two cows, it is observed that one will hook the other without the second one fighting back. If a strange cow is introduced into the herd there may be a bit of fighting until she establishes her proper rank, but after that rank is once established it remains fixed.

Within recent years a German biologist has made extensive studies of similar relations among chickens. He found that in a given flock of chickens there existed a fixed system of what he called ‘peck-rights’—which chicken pecked which. He found, for instance, that between A and B, say, A would peck B, but B would not peck A. Hence, A was said to have a ‘peck-right’ over B. This man studied the peck-rights between every pair of chickens in a given group, and he found the system, though complicated, to be quite rigid. Sometimes the peck-right system would form a closed chain. That is, A would peck B, B would peck C, C would peck D, and D would peck A.

According to press reports a series of similar experiments has recently been made at the University of Wisconsin, using apes. According to this report, pairs of strange apes of like sexes were placed in a cage together and allowed to remain there until they established a state of mutual tolerance. It was found in each case that there was no such thing as equality between the two members of the pair. There might be quarreling in the earlier stages, but once equilibrium was established, one of them always assumed priority over the other thereafter; one was definitely No. 1, and the other was No. 2. No. 2 in one pair might be No. 1 in another pair, but in any given pair there was nothing that corresponded to the concept of equality.

One sees identically this same type of thing among any group of children on a playground, or among any group of workmen of the same rank on a job. Certain individuals dominate, and the others take orders. These dominant ones need not be, and frequently are not, large in stature, but they dominate just as effectively as if they were.

In the Declaration of Independence there occurs the familiar line: ‘We hold these truths to be self-evident, that all men are created equal...’ This concept is philosophic in origin and, as we have seen, has no basis in biologic fact. Upon biologic fact, theories of democracy go to pieces.

21.7.2 Functional Priority

The greatest stability in a social organization would be obtained where the individuals were placed as nearly as possible with respect to other individuals in accordance with ‘peck-rights,’ or priority relationship which they would assume naturally. Conversely, the most unstable form of social organization would be one in which these ‘peck-rights’ were most flagrantly violated. Examples of this latter type of instability are to be found in the case of the army during the late World War, and in many business organizations at the present time.

In the case of the army, several million men were hastily put under arms, so that there was little opportunity in advance, had any provision to do so been made, to choose the officers on the basis of spontaneous natural priority. Instead, following the well known West Point tradition of catering to the 'right people,' and to what is 'socially correct,' the officers were picked largely on the basis of the social prestige of their families, their college training, and other superficial considerations, but with little or no regard for their ability to command the respect of the men under them. Their positions consequently were maintained largely by military police power, and many an officer fared badly once the protection of that police power was relinquished. This accounts for the reputed high fatality of officers at the front from bullets in the back, and for the scores of others who took a proper beating upon the discharge of the men serving under them.

The same thing is true of business organizations. The weapon of control in this case is the police power of the state and the club of economic insecurity which is held suspended over the heads of the workmen. There are few business organizations today whose administrative staffs, selected largely upon the basis of favoritism to relatives, and upon pecuniary considerations, are not to a great extent inverted with regard to the question of natural priority. In such organizations this state of inversion is maintained under the protection of the police power of the state, and by means of the weapon of economic insecurity which the relatively incompetent staffs are enabled to wield over the heads of the workmen. Were these artificial controls removed, it need hardly be added, these functional incompetents would find their existences extremely unsafe until they gravitated back to the level where they properly belonged.

A very great amount of confusion exists as a result of mistaking social position for ability. For example, there are few of the 'Park Avenue' crowd, most of whom have inherited money but have never done anything in their lives in evidence of superior intelligence or functional capacity, who do not adopt an attitude of extreme condescension towards such people as farmers, members of the skilled trades, and other such people whose functions are the most vital (and require among the highest degrees of intelligence) of any that exist at the present time. Likewise, the professors of a university view with considerable condescension the activities of the skilled mechanics in the university machine shops, little realizing that it takes a considerably higher order of intelligence, both as regards training and in every-day performance thereafter, to be a master mechanic, than it does to become and remain the 'learned' Professor So-and-So.

No better example of this particular type of intellectual insolence need be sought than that afforded by Professor Ortega Y. Gasset in his book, Revolt of the Masses. In this book the writer is decrying the rise of the masses and uses the illustration of an African savage who has learned to drive an automobile and to use aspirin. What the professor does not appear to realize is the irony of his own situation, namely, that in the world of action his own position is practically identical to that of the savage he is describing—one of complete functional incompetence. Professor Ortega y Gasset is a Jesuit Professor of Philosophy at the University of Madrid, and, as such, so far as is publicly known, has never done anything of more importance in his entire life, than to read books, talk, and write more books.

21.8 Social Customs

These facts lead us to the recognition of two things: first, that human beings, through the mechanism of conditioned reflexes, all react to their environment with a distinct cause and effect relationship; and second, that while human beings all react to their environment in this manner, there is considerable individual variation in the specific reactions of various individuals. In spite of individual differences, however, the degree of uniformity of reactions in a large cross section of people to similar environmental conditions is truly remarkable.

This fact is well brought out in the social customs of primitive peoples. In all primitive peoples the biological necessities of food, clothing and shelter to whatever extent is necessary, and reproduction, are always complied with, but the precise social customs and folk-ways such as marriage and other ceremonies, the ownership of property, etc., vary between extremely wide limits. Every conceivable marriage relationship such as polygamy, monogamy, and polyandry, together with all sorts of minor variations between these is the fixed and rigid custom of some tribal people somewhere. Similarly this holds true with customs pertaining to rights of property. These customs vary from almost complete communal holdings of all property by a tribe as a whole, to cultures with highly individualistic customs of property rights.

The point is that there is no such thing as a 'correct' or 'right' system of social customs. Within each one of these tribes their own particular set of folkways is taken as the basis with respect to which the customs of all other tribes are judged—and almost invariably condemned. In any given tribe there is the usual latitude of range in individual differences, but in spite of these differences the early conditioning of the youth of the tribe is such that upon growing up all the members of the tribe of like sex present a remarkable uniformity of customs and behavior. In other words, it matters little what the particular set of customs or folkways happens to be, the conditioning of the youth of the tribe is in each case always such as to insure their carrying on in accordance with the best tribal traditions.

The same type of things occurs in the educational process in general. So similar, for instance, are the colleges and universities of this country that there is remarkable uniformity in the products turned out. On the other hand, within a given university one sees excellent illustrations of the uniform reactions of an ordinary cross section of students to different environments in the cases of different professors. It very commonly occurs in colleges that there is a Professor A, who is completely uninteresting and succeeds in inhibiting or putting to sleep almost all the students who come under his tutelage. Under Professor B, on the other hand, practically all of the students who come into his classes become intensely interested in the subject matter at hand. Were these two professors each to give his private opinion of the intelligence of college students, Professor A would likely say that all students are stupid and lazy; Professor B would say that, quite on the contrary, he had found college students in general to be alert and intelligent. Both would be correct, for under Professor A even the most brilliant of students would appear stupid, and under Professor B even the dull-witted ones would show at least a faint sparkle of intelligence.

One sees the same type of thing among workmen on various jobs. It is a simple matter to stand on the sidelines and criticize a gang of workmen for their lack of enthusiasm and apparent indolence, but if one places himself on the job as a member of the gang and under the same circumstances, it is observed that he soon acts in essentially the same manner as the others do. An excellent illustration of this came to the author's observation in the case of what was known as an 'extra gang' on the Union Pacific Railroad. This gang consisted of about 80 men, and was under the direction of a tough Swede by the name of John Swanson. Under Swanson's leadership this was an efficient and well organized body of men with an excellent esprit de corps. After making a record in laying four complete railroad switches in one day, Swanson would take a look around at the men and remark, 'Well, boys, we didn't do much today, but we sure will give it hell tomorrow, won't we?'

Finally Swanson left the gang for a two-week vacation. During his absence the acting boss was an old-time section foreman, who had not done anything in years more vigorous than to sit on the railroad embankment and watch the Mexicans dig weeds. The section foreman spent the two weeks sitting on a flat car smoking a pipe, and as long as the men made the slightest pretense at work he appeared to be quite contented. Within one week this highly efficient gang of workmen was almost completely demoralized. They were becoming disgruntled with the job, and were volubly wishing that John Swanson would hurry back.

The significant thing here is that we are dealing with identically the same men in both cases. An outside observer, watching this gang perform under the leadership of John Swanson, would have described it as a fine gang of workmen. Another observer, describing the gang under the direction of the section foreman, would have described it as being composed of a completely shiftless lot, and here, again, both would have been correct. An ordinary cross section of workmen react to competent leadership by becoming a competent crew, while the same ordinary cross section of individuals under incompetent leadership tend towards a state of complete demoralization.

In other words, when any large number of individual human beings under the same set of environmental circumstances tend to behave in a certain specific manner, it is safe to say that any other similar cross section of human beings under the same circumstances would respond in a like manner.

This basic fact shows the futility of all moralistic approaches to the solution of social problems. Such an approach always consists of the pious hope that human beings can be instructed to do the 'right' thing, regardless of how contrary this happens to be to what their environmental controls dictate.

It is the same moralistic approach that is back of the current stupidities of the liberals, the communists and others, whose chief form of activity consists of signing protest lists—protests against war, protests against fascism, protests against capitalism, etc.—or else in the equally futile hope that they are going to educate the voting public to cast their ballots in the proper manner, while all the controls which produce the opposite effect are allowed to remain intact.

What we are pointing out is simply this: regardless of what occupation a man may pursue, the chances are highly in favor of his being obliged to pursue that occupation in approximately the same manner as it is pursued by others. One may not like bankers, lawyers, policemen, or politicians, but if he happens to follow any one of these professions he will soon find out that if he does not indulge in the same objectionable practices common to that profession, he will soon be seeking employment elsewhere. Thus, bankers, lawyers, policemen, and politicians, as well as the members of other professions, are merely ordinary human beings who are obliged to operate under a set of controls which are peculiar to the particular profession considered; any other human being under the same controls is likely to behave in a similar manner. This being the ease, the only possible way of eliminating those types of behavior which are socially objectionable, and of replacing them with types of behavior which are socially unobjectionable is to alter the controls accordingly. No amount of social moralizing ever has, or ever will, effect this to any appreciable extent.

21.8.1 Social Change

This, of course, raises the question as to just how social change comes about. The answer is that social change comes about spontaneously. Human beings, when fed, housed and clothed, in a manner which is not too uncomfortable, and when permitted normal social relationships among themselves, tend to crystallize their routine activities into non-varying social habits. These habits are buttressed by folklore and the sanction of religion. Any attempt made to change them will produce a reactionary response. If, however, for any reason whatsoever, these habits become incompatible with the same biological necessities of food, clothing, etc., the social habits are always observed to be readjusted in a form which is compatible with the fulfillment of those necessities.

It has already been pointed out in earlier lessons that present day social complexes are evolving and undergoing change at a rate faster than at any previous period in history. That, moreover, this evolution is a unidirectional and nonreversible process. At no two succeeding times is our social mechanism the same. Since human beings themselves are only one component of this evolving mechanism, they find themselves inextricably bound up with its evolution, and since stationary habits are only possible under stationary environmental conditions, it follows that with an environment which is in a continual state of flux, social habits have to change accordingly.

At the present time we find those of our social habits, which we have termed the ‘rules of the game of the Price System,’ becoming increasingly at variance with the biologic necessity that 150,000,000 people have to eat.

Under these circumstances it follows that social change will occur spontaneously until a new set of relatively stable habits are acquired which are compatible with an environment characterized by a high-energy social mechanism on the one hand, and, on the other hand, by the biological fact that 150,000,000 people are going to be fed, clothed and housed. ‘Social change,’ Howard Scott has succinctly remarked, ‘tends to occur at a rate directly as the approach of the front of the stomach to the spine.’

21.9 Summary

It was remarked at the beginning of this lesson that most of the fundamental advances in human knowledge have been opposed because these advances have contradicted what men have thought they knew about themselves. Little by little, as scientific knowledge has advanced, human ignorance and superstitions have retreated, until now, for the first time, we are able to view fairly objectively the fundamental nature of this human animal which we may summarize as follows:

1. The human animal is composed of chemical atoms which are derived from the ordinary inorganic materials of the earth, and which ultimately return to the place from which they come.

2. The human being is an engine taking potential energy in the form of chemical combinations contained in food, and converting this potential energy into heat, work and body tissue. The thermodynamic processes involved, while more complicated in detail, are in exact accordance with the laws of thermodynamics, and are in no essential particular different from the corresponding processes in man-made engines.

3. The human animal responds to its external environment through the mechanism of the conditioned reflex, which is a purely automatic but tremendously complex, nervous control mechanism. These conditioned reflexes are, however, subject to control and manipulation through the device of manipulating an individual’s environment. An individual’s present conditioning is always the resultant of all of his own past experiences. The more nearly the environment of a large number of people is kept identical, the more nearly are the human products identical. This is the reason for the great similarity among individuals of various

groups, for example, college students, policemen, politicians, Rotarians, farmers, or soldiers. In other words, within the limits allowed by their physiological differences, all human beings respond alike to a like external environment. These conditioned reflexes are sufficiently strong that, so long as the human beings are amply supplied with the basic biological necessities, food, necessary amounts of clothing and housing, and gregarious and sexual outlets, they will perform in a routine manner without upsetting either their conditioned responses or their conditioned inhibitions. They will literally face bullets in preference to social disapprobation.

4. There are basic physiological differences among individuals which are partly inherent and partly acquired through differences in diet, secretions of the endocrine glands, etc. It is these basic physiological differences among various human beings that upset all philosophic theories of equality, and hence any governmental theory of democracy. In any group of human beings having practically the same external environment certain individuals always tend to be dominant, and others with regard to these are submissive and constitute the followers. If there were only two men on an island, one of these men would be No. 1 and the other would be No. 2. If this spontaneous natural order of priority among men is inverted by an artificial means whereby the submissive type is made superior to the dominant type, a socially unstable situation is thereby created.

5. Human social habits and institutions tend to remain stable or else to undergo change extremely slowly, except in the case of a rapid change of the external environment, especially when this latter affects the basic biological necessities. When human beings are fed, clothed, and housed in a manner compatible with good health, are not obliged to do an uncomfortable amount of work, and are permitted normal social intercourse with their fellows, social habits and customs tend to become crystallize about this particular mode of procedure. Let any change of environment develop in such a manner that the biological necessities can no longer be met by activities according to the old habits, and these latter will be rapidly abandoned. For instance, just now the social habits and customs of some 20,000,000 people, most of whom until recently have been self-supporting, and many of them well-to-do

citizens, but who are now on relief, are undergoing rapid and profound change. Social stability, on the other hand, is restored when a new set of social habits and customs are formed that so conform to the dictates of the new environment as to satisfy the basic biological necessities.

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Lesson 22

TECHNOCRACY: THE DESIGN

In the preceding lessons we learned that the events occurring the earth are events of matter and energy, and that they are limited by the fundamental properties of matter and energy. In addition to this we have noted some of the more important characteristics peculiar to organisms, and singling out one particular species, man, we have followed its rise to supremacy during the past several thousands of years.

We have observed that this rise of the human species and corresponding adjustments, both up and down, of the other species or organisms, have been due almost entirely to the fact that the human species has progressively accumulated new and superior techniques by which a progressively larger share of the available energy could be converted to its uses.

We have seen that notwithstanding the fact that this progression has been slowly under way since times prior to the records of written history, the greater part of this advance, in actual physical magnitude, has occurred since the year 1900, or within the lifetime of nearly one-half of our present population.

It is due to the progress of these last few decades, that for the first time in human history, whole populations in certain geographical areas have changed over from a primary dependence upon agriculture for a livelihood to a primary dependence upon a technological mechanism, constructed principally from metals obtained from the minerals of the earth, and operated in the main from the energy contained in fossil fuels preserved within the earth.

Hence, this technological development has come to be localized in those geographical areas most abundantly supplied with the essential industrial minerals, such as the ores of iron, copper, tin, lead, zinc, etc., and the fossil fuels, coal and oil. We have observed further, that the Continent of North America ranks first among all the areas of the earth in its supply of these essential minerals, with western Europe second. Consequently, this technological development has reached its greatest heights in the areas bounding the North Atlantic with the production or rate of conversion of extraneous energy per capita having reached a far greater advancement in North America than in Europe.

22.1 The Arrival of Technology

We have also reviewed some of the paradoxes and the problems that have arisen in North America due to the conflict between the physical realities of this technological mechanism, and the social customs and folkways handed down from countless ages of low-energy agrarian civilizations.

It is to the problem of the elimination of this conflict that we now turn our attention, but before proceeding further let us get it entirely clear as to just what the conflict is.

In the past we operated more or less as independent productive units. The industry of the whole population was agriculture and small-scale, handicraft manufacturing. The interdependence among separate productive units was slight, or they were so loosely coupled that the opening up or shutting down of one unit was of slight consequence to the others. This was because any given essential product was not produced by one or two large establishments, but by innumerable small ones. The total output of that product was the statistical result of all the operations of all the separate, small establishments. Consequently, the effect of the opening or closing of any single establishment was negligibly small as compared with the total output of all establishments. The probability that a large fraction of all establishments of the same kind would open and close in unison was also negligibly small.

In the past, human labor, while not always the sole source of power, was so essential a part of the productive process that, in general, a decrease in the rate of production only took place when there was also an increase in the number of man-hours of human labor expended. During periods in which there was no technological improvement this relationship between production and man-hours was one of strict proportionality.

In the past there was individual ownership of small units, so that the exchange of goods on a barter or simple, hard-money basis resulted in a stable operation of the productive mechanism. Individual wealth could be, and was acquired, in recompense for diligence, thrift, and hard labor.

Those were the days of the spade, the wooden plow, homemade clothing, the ox-cart, and more recently, the horse and buggy.

Today, all that has changed.

As time progressed, the population grew and the production increased. Productive units which began as small handicraft units were enlarged; new ones were established; some of the old ones dropped out. The average rate of output per establishment became so great that the total number of establishments of each given kind required for the total production, began to decrease, until today, for a large number of essential products, only a dozen or so establishments can produce at a rate equal to the consuming capacity of the entire population. In some instances, one single plant at full load operation can produce at such a rate.

While this trend has advanced further in some industries than in others, it is present in all industries, including even the most backward of them—agriculture. Since the cause for this development, namely, technological improvements, still exists in full force, there can be no doubt that this trend will be continued into the future.

When, however, all products of a given kind come to be produced, as is the case today, by only a small number of productive establishments, under the ownership and control of even a smaller number of corporate bodies, and when the financial restrictions that bear upon the one bear also upon the others, the probability that all will increase or decrease production in unison with the amplitude of the oscillations approaching that from capacity output to complete shutdown, amounts almost to a certainty.

Since the amount consumed over a period of a few years is, in general, equal to or less than the amount produced in that time, these oscillations in the productive process, and the forced restrictions upon production, can only result in a restriction and curtailment of consumption on the part of the public. When this curtailment becomes so severe as to amount to privation on the part of a large proportion of the population, the controls causing the restricted production will have long since passed their period of social usefulness and will be rapidly approaching the limits of social tolerance.

In the present, as contrasted with the past, the great majority of the population is in a position of absolute dependence upon the uninterrupted operation of a technological mechanism. In the United States today, there are approximately 30 million people who live directly upon the soil, whereas almost 100 million people live in towns and cities. These latter are strictly dependent for food, water, clothing, shelter, heat, transportation and communications, upon the uninterrupted operation of the railways, the power plants, the telephone and telegraph systems, the mines, factories, farms, etc. Even the farmer of today would be in dire straits were his gasoline supply, his coal, his factory-built tools, his store-bought clothing, and even his canned foods not forthcoming.

In all preceding human history, until within the last two decades, an increase in production was accompanied by an increase in the man-hours of human labor; today, we have reached the stage where an increase of production is accompanied by a decrease in man-hours.

This is due to the facts that the motive power of present industrial equipment has become almost exclusively kilowatt-hours of extraneous energy, and that we have learned that in repetitive processes it is always possible to build a machine that will perform the given function with greater speed and precision, and at lower unit cost than it is physically possible for any human being to do.

Every time new equipment is devised, or old equipment redesigned, the newer operates in general, faster and more automatically than its predecessor, and since, as yet the accomplishments in this direction are small compared with the possibilities, it is certain that this trend will continue also into the future.

In the remote past, the rates of increase of population and production were negligibly small; in the recent past the rates of growth of both population and production have been the greatest the world has ever known; in the present and the future the rates of growth of both population and industrial production will approach zero as the leveling-off process continues.

In the past, when man-hours of human labor formed an essential part of wealth production, it was possible to effect a socially tolerable distribution of the product by means of a monetary payment on the basis of the hours of labor expended in the productive procedure.

At the present and in the future, since the hours of labor in the productive processes have already become unimportant, and shall become increasingly less important with time, any distribution of an abundance of production, based upon the man-hours of human participation can only lead to a failure of the distributive mechanism and industrial stagnation.

22.1.1 The Trends

Now it is this complex of circumstances that forms the basis of our problem and also of its solution. We have the North American Continent with its unequaled natural resources. We have on this Continent a population that is more nearly homogeneous than that of any other Continent. This population has already designed, built and now operates the largest and most complex array of technological equipment the world has ever seen. Furthermore, this population has a higher percentage of technically trained personnel than any major population that has ever existed. It has the highest average consumption of extraneous energy per capita the world has ever known. Its resources exist in such abundance, that there need be no insurmountable restriction on the standard of living due to resource exhaustion, at least into the somewhat distant future.

Now the analysis that we have made shows that while both production and population are leveling off to a maximum, the physical maximum of production will be set by the maximum physical capacity of the public to consume, which contrary to the credo of the economists, is definitely limited and finite.

We have also seen that it is only possible to approach that maximum by a continuation of the processes that now so markedly differentiate our present from the past, that is, by an increased substitution of kilowatt-hours for man-hours; by a continuous technological improvement of our equipment towards greater efficiency and automaticity; by a continued integration of our productive equipment from smaller into larger units and under unit control and operation; and by an improvement of the operating load factor, approaching the ultimate limit of 100 percent.

These are the trends and there is no possible way of reversing them. Since each has its own limits—essentially those stated above—it follows that in time we shall approach those limits. But as and when we do approach them, the very requirements of the operation of our industrial equipment will dictate a directional control and a social organization designed especially to meet these particular needs.

From such a state of operation the unavoidable by-products will be the smallest amount of human labor per capita, the highest physical standard of living, the highest standard of public health and social security any of the world's populations have ever known.

22.2 The Solution

The above is our social progression and the goal is almost reached. Whether we as individuals, may prefer that goal or some other is irrelevant, since we are dealing with a progression that is beyond our individual or collective abilities to arrest. Since this progression unavoidably conflicts with our horse and buggy ideologies and folkways, it is not to be found surprising that restrictive and impeding measures are attempted; but as to the final outcome one has only to recall the similar restrictive measures that were attempted with respect to the introduction of the use of the bathtub and of automobiles as well as with respect to most of the other major innovations of the past. Invariably the old ideologies of the past go, and new ones conforming more nearly to the new physical factors, take their places.

The conflict that we are now in the midst of is precisely of this sort—a conflict between physical reality and the antiquated ideology of a bygone age. In the case of the automobile, the ultimate solution came by abandoning the attempts at suppression and by devising control measures to fit the physical requirements of the thing being installed. Since the horse and buggy was physically different from the automobile, it is obvious that traffic measures and road design adequate for the former would be inadequate for the latter and no solution was possible which was not formulated in recognition of this fact.

So today, with the operation of our technological mechanism, the control measures that must and will be adopted are those that most nearly conform to the technological operating requirements of that mechanism.

These requirements can only be known by those who are intimately familiar with the technical details of that mechanism our technically trained personnel; though prior to there being a general recognition of this fact, we may expect to witness performances on the part of our educators, economists, sociologists, lawyers, politicians and business men that will parallel the performances of all the witch doctors of preceding ages.

It was a recognition of the fact that we are confronted with a technological problem which requires a technological solution, that prompted the scientists and technologists who later organized Technocracy Inc. to begin the study of the problem and its solution as early as the year 1919.

Out of that study a technological design expressly for the purpose of meeting this technological problem has been produced. An outline of some of its principle features are presented in what follows.

22.3 Personnel

First, required resources must be available; second, the industrial equipment must exist; and, third, the population must be so trained and organized as to maintain the continuance of the operation within the limits specified.

This brings us to the question of the design of the social organization. To begin with, let us recall that the population falls into three social classes as regards their ability to do service. The first is composed of those who, because of their youthfulness, have not yet begun their service. This includes the period from infancy up through all stages of formal education. After this period comes the second, during which the individual performs a social service at some function or other. Finally, the last period is that of retirement, which extends from the end of the period of service until the death of the individual. These three periods embrace the activities of all normal individuals. There is always another smaller group which, because of ill-health, or some other form of incapacitation, is not performing any useful social service at a time when it normally would be.

The social organization, therefore, must embrace all those of both sexes who are not exempt from the performance of some useful function because of belonging to one of the other groups. Let it be emphasized that these groups of a population are not something new, but are groups that exist in any society. The chief difference is that in this case we have deliberately left out certain groups which ordinarily exist, namely those who perform no useful social service though able to do so, and those whose services are definitely socially objectionable. It is the group which is giving service at some socially useful function which constitutes the personnel of our operating organization.

What must this organization do?

It must operate the entire physical equipment of the North American Continent. It must perform all service functions, such as public health service, education, recreation, etc., for the population of this entire area. In other words, it has to man every job that exists.

What other properties must this organization have?

It must see to it that the right man is in the right place. This depends both upon the technical qualification of the individual as compared with the corresponding requirements of the job, and also upon the biological factors of the human animal discussed previously. It must see to it that the man who is in the position to give orders to other men must be the type who, in an uncontrolled situation, would spontaneously assume that position among his fellows. There must be as far as possible no inversion of the natural 'peck-rights' among the men.

It must provide ample leeway for the expression of individual initiative on the part of those gifted with such modes of behavior, so long as such expression of individual initiative does not occur in modes of action which are themselves socially objectionable. It must be dynamic rather than static. This is to say, the operations themselves must be allowed to undergo a normal progressive evolution, including an evolution in the industrial equipment, and the organization structure must likewise evolve to whatever extent becomes necessary.

The general form of the organization is dictated by the functions which must be performed. Thus, there is a direct functional relationship between the conductor and the engineer on a railway train, whereas there is no functional relationship whatever between the members-at-large of a political or religious organization. The major divisions of this organization, therefore, would be automatically determined by the major divisions of the functions that must be performed. The general function of communications, for instance—mail, telegraph, telephone and radio—automatically constitutes a functional unit.

22.3.1 Operating Example

Lest the above specifications of a functional organization tend to frighten one, let us look about at some of the functional organizations which exist already. One of the largest single functional organizations existing at the present time is that of the Bell Telephone system. What we mean particularly here is that branch of the Bell system personnel that designs, constructs, installs, maintains and operates the physical equipment of the system. The financial superstructure—the stock and bond holders, the board of directors, the president of the company, and other similar officials whose duties are chiefly financial, are distinctly not a part of this functional organization, and technically their services could readily be dispensed with. This functional organization comprises upwards of 300,000 people. It is of interest to review what it's performance is, and something of its internal structure, since relationships which obtain in organizations of this immensity will undoubtedly likewise obtain in the greater organization whose design we are anticipating.

What are the characteristics of this telephone organization?

1. It maintains in continuous operation what is probably the most complex single sequence array of physical apparatus in existence.

2. It is dynamic in that it is continually changing the apparatus with which it has to deal, and remolding the organization accordingly. Here we have a single organization which came into existence as a mere handful of men in the 1880's. Starting initially with no equipment, it has designed, built, and installed equipment, and replaced this with still newer equipment, until now it spans as a single network most of the North American Continent, and maintains inter-connecting long-distance service to almost all parts of the world. All this has been done with rarely an interruption of 24 hours per day service to the individual subscriber. The organization itself has grown in the meantime from zero to 300,000 people.

3. That somehow or other the right man must have been placed in the right job is sufficiently attested by the fact that the system works. The fact that an individual on any one telephone in a given city can call any other telephone in that city at any hour of the day or night, and in all kinds of weather, with only a few seconds of delay, or that a long-distance call can be completed in a similar manner completely across the Continent in a mere matter of a minute or two, is ample evidence that the individuals in whatever capacity, in the functional operation of the telephone system must be competent to handle their jobs.

Thus we see that this functional organization, comprising 300,000 people, satisfies a number of the basic requirements of the organization whose design we contemplate. It is worthwhile, therefore, to examine somewhat the internal structure of this organization.

What is the method whereby the right man is found for the right place?

What is the basis on which it is decided that a telephone circuit will be according to one wiring diagram and not according to another?

The fitting of the man to the job is not done by election or by any of the familiar democratic or political procedures. The man gets his job by appointment, and he is promoted or demoted also by appointment. The people making the appointment are invariably those who are familiar both with the technical requirements of the job and with the technical qualifications of the man. An error of appointment invariably shows up in the inability of the appointee to hold the job, but such errors can promptly be corrected by demotion or transfer until the man finds a job which he can perform. This appointive system pyramids on up through the ranks of all functional sub-divisions of the system, and even the chief engineers and the operating vice-presidents attain and hold their positions likewise by appointment. It is here that the functional organization comes to the apex of its pyramid and ends, and where the financial superstructure begins. At this point also the criteria of performance suddenly change. In the functional sequence the criterion of performance is how well the telephone system works. In the financial superstructure the criterion of performance is the amount of dividends paid to the stockholders. Even the personnel of the latter are not the free agents they are commonly presumed to be, because if the dividend rate is not maintained there is a high probability that even their jobs will be vacated, and by appointment.

The other question that remains to be considered is that of the method of arriving at technical decisions regarding matters pertaining to the physical equipment. If the telephone service is to be maintained there is an infinitely wider variety of things which cannot be done than there are of things which can be done. Electrical circuits are no respecter of persons, and if a circuit is dictated which is contrary to Ohm's Law, or any of a dozen other fixed electrical relationships, it will not work even if the chief engineer himself requests it. It might with some justice be said that the greater part of one's technical training in such positions consists in knowing what not to do, or, at least, what not to try. As long as telephone service is the final criterion, decisions as to which circuits shall be given preference are made, not by chief engineers, but by results of experiment. That circuit will be used which upon experiment gives the best results. A large part of technical knowledge consists in knowing on the basis of experiments already performed which of two things will work the better. In case such knowledge does not exist already it is a problem for the research staff, and not for the chief executive. The research staff discovers which mode of procedure is best, tries it out on a small scale until it is perfected, and designs similar equipment for large scale use. The chief executive sees that these designs are executed.

Such are some of the basic properties of any competent functional organization. It has no political precedents. It is neither democratic, autocratic, nor dictatorial. It is dictated by the requirements of the job that has to be done, and, judging from the number of human beings performing quietly within such organizations, it must also be in accord with the biological nature of the human animal.

22.4 Organization Chart

On the basis of the foregoing we are now prepared to design the social organization which is to accomplish the objectives enumerated above. This organization must embrace every socially useful function performed on the North American Continent, and its active membership will be composed of all the people performing such functions in that area. Since, as we have pointed out before, there does not exist in this area any sequence of functions which is independent of, or can be isolated from, the remaining functions, it follows that in order to obtain the highly necessary synchronization and co-ordination between all the various functions they must all pyramid to a common head.

The basic unit of this organization is the Functional Sequence. A Functional Sequence is one of the larger industrial or social units, the various parts of which are related one to the other in a direct functional sequence.

Thus among the major Industrial Sequences we have transportation (railroads, waterways, airways, highways and pipe lines); communication (mail, telephone, telegraph, radio and television); agriculture (farming, ranching, dairying, etc.); and the major industrial units such as textiles, iron and steel, etc.

Among the Service Sequences are education (this would embrace the complete training of the younger generation), and public health (medicine, dentistry, public hygiene, and all hospitals and pharmaceutical plants as well as institutions for defectives).

Due to the fact that no Functional Sequence is independent of other Functional Sequences, there is a considerable amount of arbitrariness in the location of the boundaries between adjacent Functional Sequences. Consequently it is not possible to state a priori exactly what the number of Functional Sequences will be, because this number is itself arbitrary. It is possible to make each Sequence large, with a consequent decrease in the number required to embrace the whole social mechanism. On the other hand, if the sequences are divided into smaller units, the number will be correspondingly greater. It appears likely that the total number actually used will lie somewhere between 50 and 100. In an earlier layout the social mechanism was blocked into about 90 Functional Sequences, though future revision will probably change this number somewhat, plus or minus.

The schematic relationship showing how these various Functional Sequences pyramid to a head and are there coordinated is illustrated in Figure

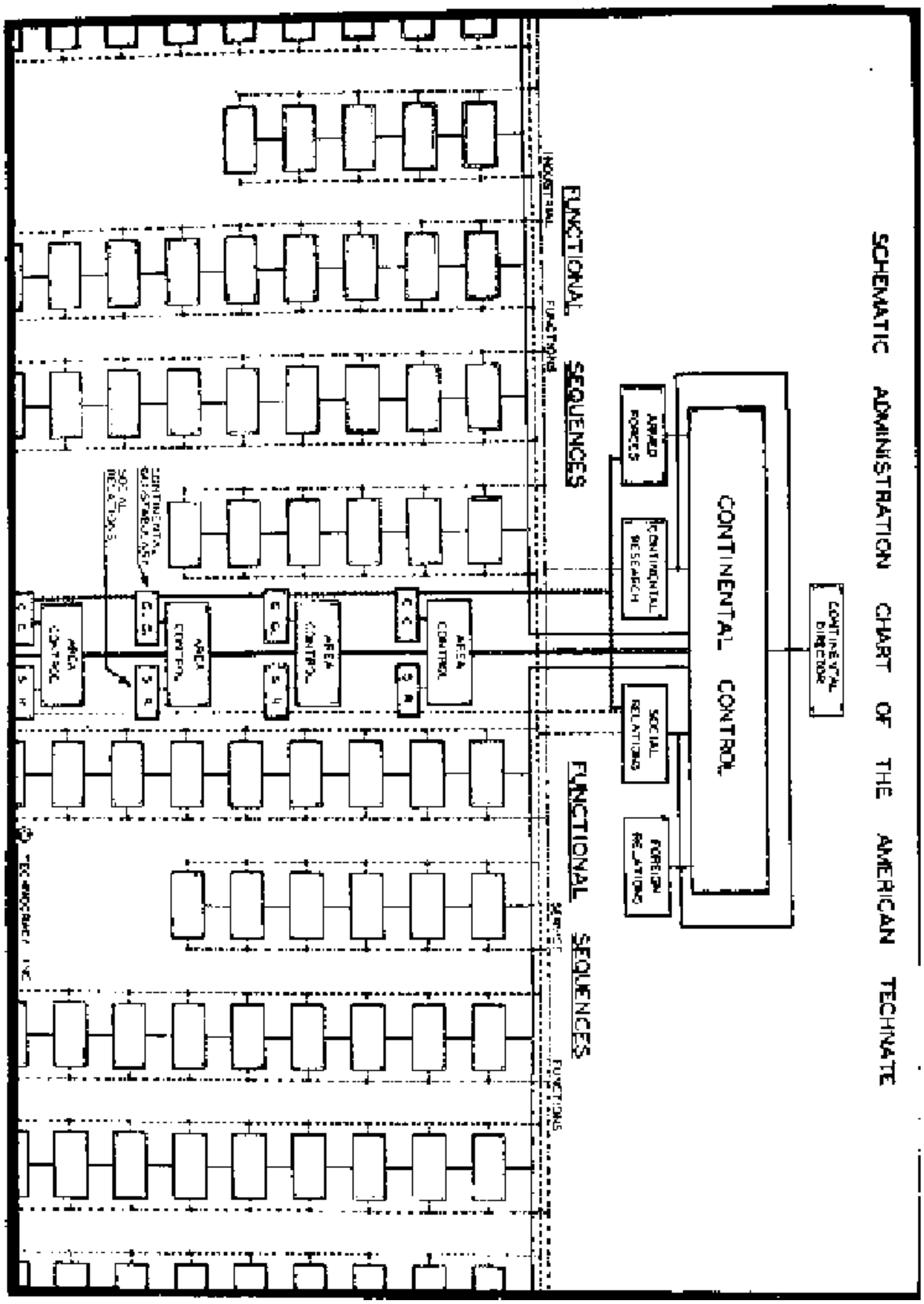

Figure 22.1: Admin Chart

22.1. At the bottom of the chart on either side are shown schematically several Functional Sequences. In the lower left-hand corner there are shown five of the Industrial Sequences, and in the lower right-hand corner are five of the Service Sequences. In neither of these groups does the size of the chart allow all of the Functional Sequences to be shown. On a larger chart the additional Functional Sequences would be shown laterally in the same manner as those shown here. Likewise each of the Functional Sequences would spread downward with its own internal organization chart, but that is an elaboration which does not concern us here.

22.4.1 Special Sequences

There are five other Sequences in this organization which are not in the class with the ordinary Functional Sequences that we have described. Among these is the Continental Research. The staffs described heretofore are primarily operating and maintenance staffs, whose jobs are primarily the maintaining of operation in the currently approved manner. In every separate Sequence, however, Service Sequences as well as Industrial Sequences, it is necessary, in order that stagnation may not develop, to maintain an alert and active research for the development of new processes, equipment and products. Also there must be continuous research in the fundamental sciences—physics, chemistry, geology, biology, etc. There must likewise be continuous analysis of data and resources pertaining to the Continent as a whole, both for the purposes of coordinating current activity, and of determining long-time policies as regards probable growth curves in conjunction with resource limitation and the like.

The requirements of this job render it necessary that all research in whatever field be under the jurisdiction of a single research body, so that all research data are at all times available to all research investigators wishing to use them. This special relationship is shown graphically in the organization chart. The chief executive of this body, the Director of Research, is at the same time a member of the Continental Control, and also a member of the staff of the Continental Director.

On the other hand, branches of the Continental Research parallel laterally every Functional Sequence in the social mechanism. These bodies have the unique privilege of determining when and where any innovation in current methods shall be used. They have also the authority to cut in on any operating flow line for experimental purposes when necessary. In case new developments originate in the operating division, they still have to receive the approval of the Continental Research before they can be installed. In any Sequence a man with research capabilities may at any time be transferred from the operating staff to the research staff and vice versa.

Another all-pervading Sequence which is related to the remainder of the organization in a manner similar to that of Research is the Sequence of Social Relations. The nearest present counterpart is that of the judiciary. That is, its chief duty is looking after the 'law and order,' or seeing to it that everything as regards individual human relationships functions smoothly.

While the Sequence of Social Relations is quite similar to that of the present judiciary, its methods are entirely different. None of the outworn devices of the present legal profession, such as the sparring between scheming lawyers, or the conventional passing of judgment by 'twelve good men and true' would be allowed. Questions to be settled by this body would be investigated by the most impersonal and scientific methods available. As will be seen later, most of the activities engaging the present legal profession, namely litigation over property rights, will already have been eliminated.

Another of these special Sequences is the Armed Forces, Sequence of. The Armed Forces, as the name implies, embraces the ordinary military land, water and air forces, but most important of all, it also includes the entire internal police force of the Continent, the Continental Constabulary. This latter organization has no precedent at the present time. At the present the internal police force consists of the familiar hodge-podge of local municipal police, county sheriffs, state troopers, and various denominations of federal agents, most of the former being controlled by local political machines and racketeers. This Continental Constabulary, by way of contrast, is a single disciplined organization under one single jurisdiction. Every member of the Constabulary is subject to transfer from any part of the country to any other part on short notice.

While the Continental Constabulary is under the discipline of the Armed Forces, it receives its instructions and authorization for specific action from the Social Relations and Area Control.

This Sequence—the Area Control—is the coordinating body for the various Functional Sequences and social units operating in any one geographical area of one or more Regional Divisions. It operates directly under the Continental Control.

The Foreign Relations occupies a similar position, except that its concern is entirely with international relations. All matters pertaining to the relation of the North American Continent with the rest of the world are its domain.

The personnel of all Functional Sequences will pyramid on the basis of ability to the head of each department within the Sequence, and the resultant general staff of each Sequence will be a part of the Continental Control. A government of function!

22.4.2 The Continental Control

The Continental Director, as the name implies, is the chief executive of the entire social mechanism. On his immediate staff are the Directors of the Armed Forces, the Foreign Relations, the Continental Research, and the Social Relations and Area Control.

Next downward in the sequence comes the Continental Control, composed of the Directors of the Armed Forces, Foreign Relations, Continental Research, Social Relations and Area Control, and also of each of the Functional Sequences. This superstructure has the last word in any matters pertaining to the social system of the North American Continent. It not only makes whatever decisions pertaining to the whole social mechanism that have to be made, but it also has to execute them, each Director in his own Sequence. This latter necessity, by way of contrast with present political legislative bodies, offers a serious curb upon foolish decisions.

So far nothing has been said specifically as to how vacancies are filled in each of these positions. It was intimated earlier that within the ranks of the various Functional Sequence jobs would be filled or vacated by appointment from above. This still holds true for the position of Sequence Director. A vacancy in the post of Sequence Director must be filled by a member of the Sequence in which the vacancy occurs. The candidates to fill such position are nominated by the officers of the Sequence next in rank below the Sequence Director. The vacancy is filled by appointment by the Continental Control from among the men nominated.

The only exception to this procedure of appointment from above occurs in the case of the Continental Director due to the fact that there is no one higher. The Continental Director is chosen from among the members of the Continental Control by the Continental Control. Due to the fact that this Control is composed of only some 100 or so members, all of whom know each other well, there is no one better fitted to make this choice than they.

The tenure of office of every individual continues until retirement or death, unless ended by transfer to another position. The Continental Director is subject to recall on the basis of preferred charges by a two-thirds decision of the Continental Control. Aside from this, he continues in office until the normal age of retirement.

Similarly in matters of general policy he is the chief executive in fact as well as in title. His decisions can only be vetoed by two-thirds majority of the Continental Control.

It will be noted that the above is the design of a strong organization with complete authority to act. All philosophic concepts of human equality, democracy and political economy have upon examination been found totally lacking and unable to contribute any factors of design for a Continental technological control. The purpose of the organization is to operate the social mechanism of the North American Continent. It is designed along the lines that are incorporated into all functional organizations that exist at the present time. Its membership comprises the entire population of the North American Continent. Its physical assets with which to operate consist of all the resources and equipment of the same area.

22.5 Regional Divisions

It will be recognized that such an organization as we have outlined is not only functional in its vertical alignment, but is geographical in its extent. Some one or more of the Functional Sequences operates in every part of the Continent. This brings us to the matter of blocking off the Continent into administrative areas. For this purpose various methods of geographical division are available. One would be to take the map of North America and amuse oneself by drawing irregularly shaped areas of all shapes and sizes, and then giving these names. The result would be equivalent to our present political subdivisions into nations, states or provinces, counties, townships, precincts, school districts, and the like—a completely unintelligible hodge-podge.

A second method, somewhat more rational than the first, would be to subdivide the Continent on the basis of natural geographical boundaries such as rivers, mountain ranges, etc., or else to use industrial boundaries such as mining regions, agricultural regions, etc. Both of these methods are objectionable because of the irregularity of the boundaries that would result, and also because there are no clean-cut natural or industrial boundaries in existence. The end-product, again, would be confusion.

A third alternative remains, that of adopting some completely arbitrary rational system of subdivisions such that all boundaries can be defined in a few words and that every subdivision can be designated by a number for purposes of simplicity of administration and of record keeping. For this purpose no better system than our scientific system of universal latitude and longitude has ever been devised. Any point on the face of the earth can be accurately and unambiguously defined by two simple numbers, the latitude and longitude. Just as simply, areas can be blocked off by consecutive parallels of latitude and consecutive meridians.

It is the latter system of subdividing the Continent on the basis of latitude and longitude that we shall adopt.

By this system we shall define a Regional Division to be a quadrangle bounded by two successive degrees of longitude and two successive degrees of latitude. The number assigned to each Regional Division will be that of the combined longitude and latitude of the point at the southeast corner of the quadrangle. Thus the Regional Division in which New York City is located is 7340; Cleveland, 8141; St. Louis, 9038; Chicago, 8741; Los Angeles, 11834; Mexico City, 9919; Edmonton, 11353, etc.

In this manner all the present political boundaries are dispensed with. The whole area is blocked off into a completely rational and simple system of Regional Division, the number for each of which not only designates it but also locates it.

It is these Regional Divisions that form the connecting link between the present provisional organization of Technocracy and the proposed operating one depicted in the foregoing chart. In the process of starting an organization the membership of a particular unit is much more likely to be united by geographic proximity than as members of any particular functional sequence. Accordingly, the provisional organization is of necessity, in the formative period, built and administered on a straight line basis where the individual administrative units are blocked off according to the Regional Divisions in which they happen to occur. As the organization evolves, the transition over into the functional form that we have outlined occurs spontaneously. Already the activities of the organization embrace education, publication and public speaking, as well as research. As time goes on not only will these activities expand but other functions will be added. As fast as the membership in the Functional Sequences will allow, Sequences of Public Health, Transportation, Communication, etc., will be instituted. Even in this formative period a network of amateur short-wave radio stations between the various Regional

Divisions is being built. None of these occur overnight, but as the organization evolves there will be an orderly transition over to administration along the functional lines as indicated.

22.6 Requirements

Now that we have sketched in outline the essential features of the social organization, there remains the problem of distribution of goods and services. Production will be maintained with a minimum of oscillation, or at a high load factor. The last stage in any industrial flow line is use or consumption. If in any industrial flow line an obstruction is allowed to develop at one point, it will slow down, and, if uncorrected, eventually shut down that entire flow line. This is no less true of the consumption stage than of any other stage. Present industrial shut down, for instance, has resulted entirely from a blocking of the flow line at the consumption end. If the production is to be non-oscillatory and maintained at a high level so as to provide a high standard of living, it follows that consumption must be kept equal to production, and that a system of distribution must be designed which will allow this. This system of distribution must do the following things:

1. Register on a continuous 24-hour time period basis the total net conversion of energy, which would determine (a) the availability of energy for Continental plant construction and maintenance, (b) the amount of physical wealth available in the form of consumable goods and services for consumption by the total population during the balanced load period.

2. By means of the registration of energy converted and consumed, make possible a balanced load.

3. Provide a continuous 24-hour inventory of all production and consumption.

4. Provide a specific registration of the type, kind, etc., of all goods and services, where produced, and where used.

5. Provide specific registration of the consumption of each individual, plus a record and description of the individual.

6. Allow the citizen the widest latitude of choice in consuming his individual share of Continental physical wealth.

7. Distribute goods and services to every member of the population.

On the basis of these requirements, it is interesting to consider money as a possible medium of distribution. But before doing this, let us bear in mind precisely what the properties of money are. In the first place, money relationships are all based upon ‘value,’ which in turn is a function of scarcity. Hence, as we have pointed out previously, money is not a ‘measure’ of anything. Secondly, money is a debt claim against society, and is valid in the hands of any bearer. In other words, it is negotiable; it can be traded, stolen, given, or gambled away. Thirdly, money can be saved. Fourthly, money circulates, and is not destroyed or canceled out upon being spent. On each of these counts money fails to meet our requirements as our medium of distribution.

Suppose, for instance, that we attempted to distribute by means of money, the goods and services produced. Suppose that it were decided that 200 billion dollars worth of goods and services were to be produced in a given year, and suppose further that 200 billion dollars were distributed to the population during that time with which to purchase these goods and services. Immediately the foregoing properties of money would create trouble. Due to the fact that money is not a physical measure of goods and services, there is no assurance that the prices would not change during the year, and that 200 billion dollars at the end of the year would be adequate to purchase the goods and services it was supposed to purchase. Due to the fact that money can be saved, there is no assurance that the 200 billion dollars issued for use in a given year would be used in that year, and if it were not used this would immediately begin to curtail production and to start oscillations. Due to the fact that money is negotiable, and that certain human beings, by hook or crook, have a facility for getting it away from other human beings, this would defeat the requirement that distribution must reach all human beings. A further consequence of the negotiability of money is that it can be used very effectively for purposes of bribery. Hence the most successful accumulators of money would be able eventually not only to disrupt the flow line, but also to buy a controlling interest in the social mechanism itself, which brings us right back to where we started from. Due to the fact that money is a species of debt, and hence cumulative, the amount would have to be continuously increased, which, in conjunction with its property of being negotiable, would lead inevitably to concentration of control in a few hands, and to general disruption of the distribution system which was supposed to be maintained.

Thus, money, in any form whatsoever, is completely inadequate as a medium of distribution in an economy of abundance. Any social system employing commodity evaluation (commodity valuations are the basis of all money) is a Price System. Hence it is not possible to maintain an adequate distribution system in an economy of abundance with a Price System control.

22.6.1 The Mechanism of Distribution

We have already enumerated the operating characteristics that a satisfactory mechanism of distribution must possess, and we have found that a monetary mechanism fails signally on every count. A mechanism possessing the properties we have enumerated, however, is to be found in the physical cost of production—the energy degraded in the production of goods and services.

In earlier lessons we discussed in some detail the properties of energy, together with the thermodynamic laws in accordance with which energy transformations take place. We found that, for every movement of matter on the face of the earth, a unidirectional degradation of energy takes place, and that it was this energy loss incurred in the production of goods and services that, in the last analysis, constitutes physical cost of production. This energy, as we have seen, can be stated in invariable units of measurements—units of work such as the erg or the kilowatt-hour, or units of heat such as the kilogram-calorie or the British thermal unit. It is therefore possible to measure with a high degree of precision the energy cost of any given industrial process, or for that matter the energy cost of operating a human being. This energy cost is not only a common denominator of all goods and services, but a physical measure as well, and it has no value connotations whatsoever.

The energy cost of producing a given item can be changed only by changing the process. Thus, the energy cost of propelling a Ford car a distance of 15 miles is approximately the energy contained in one gallon of gasoline. If the motor is in excellent condition somewhat less than a gallon of gasoline will suffice, hence the energy cost is lower. On the other hand, if the valves become worn and the pistons become loose, somewhat more than a gallon of gasoline may be required and the energy cost increases. A gallon of gasoline of the same grade always contains the same amount of energy.

In an exactly similar manner energy derived from coal or water power is required to drive factories, hence the energy cost of the product would be the total amount of energy consumed in a given time divided by the total number of products produced in that time. Energy, likewise, is required to operate the railroads, telephones, telegraphs and radio. It is required to drive agricultural machinery and to produce the food that we consume. Everything that moves does so only with a corresponding transformation of energy.

Now suppose that the Continental Control, after taking into due account the amount of equipment on hand, the amount of new construction of roads, plant, etc., required for the needs of the population, and the availability of energy resources, decides that for the next two years the social mechanism can afford to expend a certain maximum amount of energy (equivalent to that contained in a given number of millions of tons of coal). This energy can be allocated according to the uses to which it is to be put. The amount required for new plant, including roads, houses, hospitals, schools, etc., and for local transportation and communication will be deducted from the total as a sort of overhead, and not chargeable to individuals. After all of these deductions are made, including that required for the education and care of children and the maintenance of hospitals and public institutions generally, the remainder will be devoted to the production of goods and services to be consumed by the adult public-at-large.

Suppose, next, that a system of record-keeping be instituted, whereby a consuming power be granted to this adult public-at-large in an amount exactly equal to this net remainder of energy available for the producing of goods and services to be consumed by this group. This equality can only be accomplished by stating the consuming power itself in denominations of energy. Thus, if there be available the means of producing goods and services at an expenditure of 100,000 kilogram calories per each person per day, each person would be granted an income, or consuming power, at a rate of 100,000 kilogram calories per day.

22.7 Income

Now let us see what further details will have to be incorporated in this distributive system in order to satisfy the requirements we have laid down. First, let us remember that this income is usable for the obtaining of consumers' goods and services, and not for the purchase of articles of value. That being the case, there is a fairly definite limit to how many goods and services a single individual can consume, bearing in mind the fact that he only lives

24 hours a day, one-third of which he sleeps, and a considerable part of the remainder of which he works, loafs, plays, or indulges in other pursuits many of which do not involve a great physical consumption of goods.

Let us recall that every individual in the society must be supplied, young and old alike. Since it is possible to set arbitrarily the rate of production at a quite high figure, it is entirely likely that the average potential consuming power per adult can be set higher than the average adult's rate of physical consumption. Since this is so, there is no point in introducing a differentiation in adult incomes in a manner characteristic of economies of scarcity. From the point of view of simplicity of record-keeping, moreover, enormous simplification can be effected by making all adult incomes male and female, alike, equal. Thus, all would receive a large income, quite probably larger than they would find it convenient to spend. This income would continue without interruption until the death of the recipient. The working period, however, after the period of transition would probably not need to exceed the 20 years from the age of 25 to 45, on the part of each individual.

Still further properties that must be incorporated into this energy income received by individuals are that it must be non-negotiable and non-savable. That is, it must be valid only in the hands of the person to whom issued, and in no circumstances transferable to any other individual. Likewise, since it is issued on the basis of a budget expenditure covering two years, it must only be valid for that two-year period, and null and void thereafter. Otherwise it would be saved in part, and serve to completely upset the balance in the operating load in future periods. On the other hand, there is no need for saving, because an income and social security is already guaranteed independently to each individual until death.

The reason for taking two years as the balanced-load period of operation of the social mechanism is a technological one. The complete industrial cycle for the whole North American Continent, including the growing period of tropical plants, such as Cuban sugar cane, is somewhat more than one year. Hence a two-year period is taken as the nearest integral number of years to this industrial cycle. All operating plans and budgets would thus be made on a two-year basis, and at the end of that time the books would be balanced and closed for that period. No debts would be possible, and the current habit of mortgaging the future to pay for present activities would be completely eliminated.

If, as is quite likely, the public find it inconvenient to consume all their allotted energy for that time period. the unspent portion of their allotment will merely be canceled at the end of the period. The saving will be effected by society rather than by the individual, and the energy thus saved, or the goods and services not consumed, will be carried over into the next balanced load period. This will not, as will be amplified later, throw the productive system into oscillation, because production will always be geared to the rate of consumption, and not to the total energy allotment. In other words, if for a given balanced load period the total energy allotment be equivalent to that contained in, say four billion tons of coal, this merely means that we are prepared if need be to burn four billion tons of coal, and distribute the resultant goods and services during that time period. This merely sets a maximum beyond which consumption for that time period will not be allowed to go. If the public, however, finds it inconvenient to consume that amount of goods and services, and actually consumes only an amount requiring three billion tons of coal to produce, production will be curtailed by that amount, and the extra billion tons of coal will not be used, but will remain in the ground until needed.

22.7.1 Energy Certificates

There are a large number of different bookkeeping devices whereby the distribution to, and records of rate of consumption of the entire population can be kept. Under a technological administration of abundance, there is only one efficient method—that employing a system of Energy Certificates.

By this system all books and records pertaining to consumption are kept by the Distribution Sequence of the social mechanism. The income is granted to the public in the form of energy certificates.

These certificates are merely pieces of paper containing certain printed matter. They are issued individually to every adult of the entire population. The certificates issued to an individual may be thought of as possessing some of the properties both of bank cheque and of a traveler's cheque. They would resemble a bank cheque in that they carry no face denomination. They receive their denomination only when being spent. They resemble a traveler's cheque in that they possess some means of ready identification, such as counter-signature, photograph, or some similar device, so as to establish easy identification by the person to whom issued, and at the same time remain absolutely useless in the hands of anyone else.

The record of one's income and its rate of expenditure is kept by the Distribution Sequence, so that it is a simple matter at any time for the Distribution Sequence to ascertain the state of an unknown customer's balance. This is somewhat analogous to a combination bank and department store, wherein all the customers of the store also keep bank accounts at the store bank. In such a case the customer's credit at the department store is as good as his bank account, and the state of this account is available to the store at all times.

Besides the properties enumerated above, our Energy Certificates also contain the following additional information about the person to whom issued:

The background color of the certificate records whether he has not yet begun his period of service, is now performing service, or is retired, a different color being used for each of these categories. A diagonal stripe in one direction records that the purchaser is of the male sex; a corresponding diagonal in the other direction signifies the female sex. In the background across the face of the certificate is printed or water-marked the two-year balanced load period, say 1936-37, during which the particular certificate is valid. Also printed on the certificate is additional data about the recipient, including the geographical area in which he resides, and a catalogue number, signifying the specific Functional Sequence and job at which he works.

When making purchases of either goods or services an individual surrenders the energy certificates properly identified and signed. These surrendered certificates are then perforated with a catalogue numbers of the specific item and amount purchased, and also its energy cost. These canceled certificates then clear through the bookkeeping apparatus of the Distribution Sequence.

The significance of this, from the point of view of knowledge of what is going on in the social system, and of social control, can best be appreciated when one surveys the whole system in perspective. First, one single organization is manning and operating the whole social mechanism. This same organization not only produces but distributes all goods and services. Hence a uniform system of record-keeping exists for the entire social operation, and all records of production and distribution clear to one central headquarters. Tabulation of the information contained on the canceled Energy Certificates day by day provides a complete record of distribution, or of the public rate of consumption by commodity, by sex, by regional division, by occupation, and by age group.

With this information clearing continuously to a central headquarters we have a case exactly analogous to the control panel of a power plant, or the bridge of an ocean liner, or the meter panel of a modern airplane. In

(a) Insure a continuous distribution of goods and services to every member of the population; (b) enable all goods and services to be measured in a the case of a steam plant the meter panel records continuously the steam pressure of the boilers, the fuel record, the voltage and kilowatt output of the generators, and all other similar pertinent data. In the case of operating an entire social mechanism the data required are more voluminous in detail, but not otherwise essentially different from that provided by the instrument panel in the steam plant.

The clearing of the Energy Certificates, tabulated in all the various ways we have indicated, gives precise information at all times on the state of consumption of every kind of commodity or service in all parts of the Continent. In addition to this there is also corresponding information on stocks of materials and rates of operation in every stage of every industrial flow line. There is, likewise, a complete record on all hospitals, on the educational system, amusements, and others on the more purely social services. This information makes it possible to know exactly what to do at all times in order to maintain the operation of the social mechanism at the highest possible load factor and efficiency.

22.8 A Technocracy

The end products attained by a high-energy social mechanism on the North American Continent will be:

(a) a high physical standard of living, (b) a high standard of public health, (c) a minimum of unnecessary labor, (d) a minimum of wastage of nonreplaceable resources, (e) an educational system to train the entire younger generation indiscriminately as regards all considerations other than inherent ability—a Continental system of human conditioning.

The achievement of these ends will result from a centralized control with a social organization built along functional lines, similar to that of the operating force of any large functional unit of the present such as the telephone system or the power system.

Non-oscillatory operation at high load factor demands not only functional organization of society but a mechanism of distribution that will:

common physical denominator; (c) allow the standard of living for the whole of society to be arbitrarily set as an independent variable, and (d) insure continuous balance between production and consumption.

Such a mechanism is to be found in the physical cost of production, namely, the energy degradation in the production of goods and services. Incomes can be granted in denominations of energy in such a manner that they cannot be lost, saved, stolen or given away. All adult incomes are to be made equal, though probably larger than the average ability to consume.

Such an organization has no precedence in any of the political forms. It is neither a democracy, an aristocracy, a plutocracy, a dictatorship, nor any of the other familiar political forms, all of which are completely inadequate and incompetent to handle the job. It is, instead, a Technocracy, being built along the technological lines of the job in hand.

For further discussion of distribution refer to the offical pamphlet, The Energy Certificate.

Lesson 23

INDUSTRIAL DESIGN AND OPERATING CHARACTERISTICS

It appears to be little realized by those who prate about human liberty that social freedom of action is to a much greater extent determined by the industrial system in which the individual finds himself than by all the legalistic restrictions combined. The freedom of action of a pioneer was determined principally by his available mode of travel which was chiefly afoot, by rowboat, horseback, or by animal drawn vehicles. His freedom of communication was similarly circumscribed. His activities in general were accordingly restricted to a relatively small area and to a moderately narrow variety. These restrictions were technological rather than legal. The pioneer could only travel a limited number of miles per day, not because there was a law against traveling more than that, but because the technological factors under which he operated did not allow it.

It is seldom appreciated to what extent these same technological factors determine the activities of human beings at the present time. In New York City, for example, thousands of people cross the Hudson River daily at 125th Street, and almost no one crosses the river at 116th Street. There is no law requiring the individual to cross the river at 125th Street and forbidding him to cross it at 116th Street. It merely happens that there is a ferry at the former place which operates continuously, and none at the latter. It is possible to get across the river at 116th Street, but under the existing technological controls the great majority of the members of the human species

find the passageway at 125th Street the more convenient.

This gives us a clue to the most fundamental social control technique that exists. No other single item exerts more than a small percentage of the influence exerted by the immediate physical environment upon the activities of human beings. Leave the physical environment unaltered, or the industrial rates of operation unchanged, and any effort to alter the fundamental modes of behavior of human beings is doomed largely to failure; alter the immediate physical environment of human beings, and their modes of behavior change automatically. The human animal accepts his physical environment almost without question. He rarely decides to do a particular thing, and then finds himself obstructed by physical barriers. Instead, he first determines the barriers and then directs his activities into those paths where insurmountable barriers do not exist. It is these considerations that render the matter of technological design and operation of equipment of the most fundamental significance. There are standards of design and operation that are wasteful of resources and injurious to the public health. There are other standards of design and operation that are conducive to the general social well-being and lacking in the socially objectionable elements.

In an earlier lesson we laid down the social end-products that will inevitably result from technological operation of the social mechanism. Among these end-products were: a high standard of public health, a minimum of unnecessary drudgery, a high physical standard of living, and a minimum wastage of non-replaceable natural resources.

A high standard of health will result if all human beings are properly fed, clothed, housed, and have all their other biological needs adequately cared for. A minimum of drudgery will be achieved with all routine tasks eliminated or performed as automatically as possible. Natural resources will be utilized with a minimum of wastage if all industrial processes have the highest physical efficiency, and all products will give the greatest amount of service per unit of physical cost.

It will be recognized that it is precisely these criteria that are implicit in a control of industrial operation based upon a minimum degradation of physical energy, as contrasted with our present Price System criterion of industrial control based upon a maximum of profit. It is into these two fundamentally opposed control techniques that all the thousand and one present day paradoxes are resolved. Social end-products are a dependent function of the industrial mode of operation. The criterion determining the mode of operation happens at the present time to be a maximum of profit under a Price System control technique. Granted the continuance of the latter, all gestures at altering the former are futile.

It is our purpose now to review several of our major industrial fields, and to point out the change in design and operating characteristics that would be instituted under the criterion of a minimum of energy cost per unit of use or service produced.

23.1 Load Factor

One of the first things to be considered in this connection is the matter of operating load factors. A load factor of any piece of productive equipment may be defined as the ratio of its actual output over a given time period to the output that would have resulted in the same time period had the equipment been operated at full load throughout the time. If an engine, for instance, which develops 100 h.p., operates at full load for 24 hours it will produce 2400 h.p. hours of work. Suppose, however, that the engine is operated only intermittently during that time and actually produces but 600 h.p. hours of work in 24 hours. The load factor for that period would then be 600/2400, or 25 percent. The load factor would have been zero had the engine not operated at all, or 100 percent had it operated at full load throughout.

There is a fundamental relationship among production, operating load factors, and the capacity of productive equipment. A load factor of 10 percent merely means that the equipment is producing one-tenth of its productive capacity. Now if this same productive capacity were maintained, and the load factor raised to 50 percent, production with the same equipment would be five times as great as with a load factor of 10 percent. If the load factor were 100 percent the production would be 10 times as great.

If we consider the converse aspect of the same thing, suppose that there is no need of increasing the production of a given kind of product. In this case let us suppose that the load factor is 10 percent, and that load factor is again raised to 50 percent. If production is not increased we can only achieve this result by junking four-fifths of the plants engaged in that particular kind of production.

Hence it follows that a high load factor, no matter whether used for increasing production or for reducing the amount of plant required for a given production, results always in a diminution in the amount of productive equipment per unit produced, and results correspondingly in a reduction of the energy cost per unit produced.

23.2 Quality of Product

Still another factor of comparable importance to that of the operating load factor is the quality of the product. All products are produced for the purpose of rendering some sort of use or service. The total energy cost of this use or service is the energy cost of producing and maintaining the product.

Take an automobile tire for example. The use of the automobile tire is the delivery of so many miles of service. The energy cost of this service per 1,000 miles is the energy cost of manufacturing an automobile tire divided by the number of 1,000 miles of service it renders. Now, suppose that the energy cost of making an automobile tire that will give 20,000 miles of service is some arbitrary figure, say 100. The cost per 1,000 miles would be 5. Consider another automobile tire which will deliver 30,000 miles of service, but costs 120 to produce. The cost per 1,000 miles of service of this latter tire is only 4. Hence it is a better tire than the former because its cost per 1,000 miles of service is less. Suppose, however, that it were possible to make a tire that would last 100,000 miles, but that the cost of producing this tire were 600. Then the cost per 1,000 miles would be 6. This tire, therefore, though longer lived, is actually a more costly tire than either of the other two because the cost per 1,000 miles of service is greater.

It is always possible to find an optimum quality of product for which the cost per unit of use or service is a minimum, and it is this quality which, according to our energy criterion, is the best. Products either longer lived or shorter lived can be built, but they have the disadvantage that the service which they render is more costly than that rendered by the product of optimum quality.

It is interesting to apply these two criteria, the load factor and the quality of product, to present day industrial operations. Probably the highest load factor of any of our industrial equipment is that of the central power stations. It is only rarely in heavy industrial districts that the load factors of the central power stations are greater than 40 percent. Much more commonly the figure is somewhere around 30 percent. Another of our more continuously operated sets of equipment is the telephone. The busiest lines in the telephone system are the ‘long haul’, long-distance trunk lines, that is, lines such as those from New York to Chicago, and comparable or greater distances. The load factor on these lines for a complete two-way conversation is only four hours of operation out of each 24, or a load factor of 16 2/3 percent. In our less continuously operated equipment, such as factories of all denominations, mines and agricultural equipment, production is intermittent, and the load factor of the equipment is even lower. Few agricultural implements are in use more than a few weeks per year for 8 or 10 hours per day. Few factories run 24 hours per day except for brief rush periods. Most of the remainder of the time they are on one eight-hour shift for a limited number of days per week or else completely shut down.

In the field of automotive transportation the service rendered is passenger miles of transportation. The average passenger capacity of automobiles is about 5. The average number of passengers carried is considerably less than this. The average time of operation per automobile is approximately one hour out of each twenty-four, giving an operation load factor of only 4 or 5 percent, or a passenger-mile load factor of probably not more than half of this amount. If the operating load factor of automobiles could be, stepped up to 50 percent on a 24-hour per day basis, the passenger miles would be ten times that of the present for the same number of automobiles, or else there would be required only a fraction as many cars as we now have.

Considering the quality of products the results are equally bad. Consider razor blades. Suppose that 30 million people shave once per day with safety razor blades, and suppose that these blades give three shaves each. This would require a razor blade production of ten million blades per day, which is the right order of magnitude for the United States. Thus, our razor blade factories may be thought of as producing shaves at the rate of 30 million per day at current load factors. Now suppose that we introduce the energy criterion requiring that razor blades be manufactured on the basis of a minimum energy cost per shave. Then the blades, instead of lasting three days, would be more likely to last three years or longer. Suppose they lasted three years. What effect would this have upon our productive capacity in shaves? Technically it is just as easy to manufacture a good blade as a poor one. Thus the productive capacity at the current load factor would be ten million good blades instead of ten million poor ones per day. But ten million good blades at a life of three years each are equivalent to 1,095,000,000 shaves per day, instead of the 30 million now produced by the same equipment. Since the number of shaves per day is not likely to be materially increased, with the longer lived blade what would happen would be a junking of approximately 99 percent of the present razor factories, thereby eliminating enormous wastage of natural resources.

Low load factors arise from various causes under Price System control. Perhaps the chief cause of low-load factors is the uncertainty of future demand. The individual plant, as we have noted, runs or shuts down in accordance with the orders for goods which it receives. The total purchasing power is sufficient to buy only a small fraction of the goods that would be produced were the existing plant operated wide open. Consequently the existing plant spends the greater part of its time being shut down or else idling at only a small fraction of full load. This defect is inherent in the Price System, and is a direct consequence of the use of money itself.

23.3 The Calendar

Another prevailing cause of poor load factors is the calendar. With our present calendar practically everybody works on the same days, and is off on the same days. This introduces traffic jams and small periods of peak loads on our transportation system, and on our places of recreation, as well as on the industrial equipment. In order to improve the load factor on traffic and on the amusement places, it is necessary for these peaks to be eliminated so that the traffic on one day is the same as that on any other, and for the traffic in any hour of the day to be so adjusted that no extreme peak loads occur.

The technological control that we have postulated removes the element of over-building in productive equipment. A revision of the calendar smoothes out the most offensive of the remaining irregularities. The day and the year are major astronomical periods, the significance of which cannot be ignored. The week and the month have no such significance. It is true the month is nominally the period of the moon. Actually, however, our months vary in length from 28 to 31 days, with an average length of 30 and a fraction day. The time elapsed from new moon to new moon is 29 and a fraction days, so that the phases of the moon shift about a third of a month in the course of one year. So little cognizance is now taken of the moon's period that the greater part of the population, if asked at any particular time to give the phase of the moon, would have to look it up in an almanac. Consequently, the only astronomical periods that need be considered are those of the day and the year.

Technocracy's calendar is, accordingly, based on the day and the year.

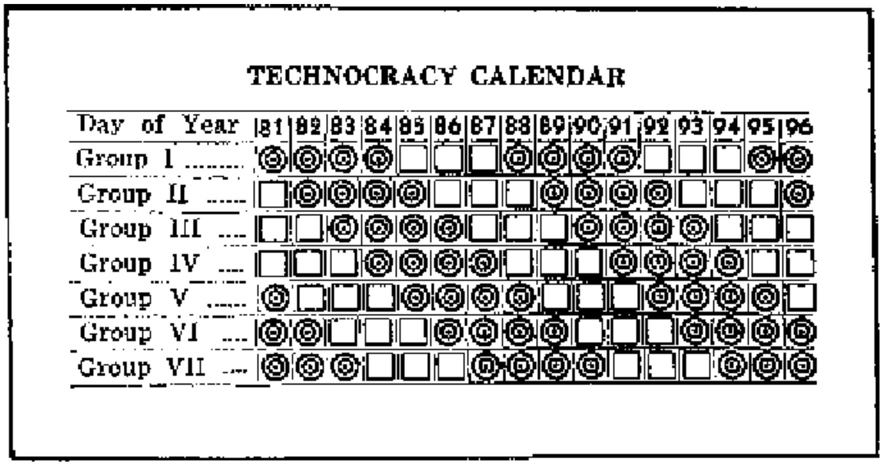

Figure 23.1: Technocracy Calender

The year consists of 365.2422 mean solar days. The Technocracy calendar, therefore, would consist in numbering these days consecutively, starting on the vernal equinox from 1 to 364 days, plus 1 zero day (2 zero days leap years). The work period would run for four consecutive days for each individual, followed by three days off. Not taking into consideration the vacation period, every day is a day off for three-sevenths of the working population—all adults between the ages of 25 and 45.

In Figure 9 this is shown diagrammatically for 16 consecutive days chosen arbitrarily during the year. The working population is divided into seven groups, each of which has a different sequence of working days and of days off. The working days of each group are indicated by the circular spaces and the days off by the blank squares. On a basis of 660 annual work-hours and 4-hour daily shifts we arrive at 165 working days, or 41 as the nearest whole number of periods of working days and days off—a total of 287 days. There remain, then, 78 succeeding days as a yearly vacation period for each individual.

Within each group there will be different shifts, the number of shifts depending upon the number of hours worked per day by each individual. If, for instance, the working day were 8 hours, there would be three 8-hour shifts. If the working day were 6 hours, there would be 4 shifts of 6 hours each, and if the working day were 4 hours, there would be 6 shifts of 4 hours each. There will be a transitional period involving large scale reconstruction during which a longer working day of six or possibly eight hours will be retained. Once this period is over, however, there is little doubt but that the working day can be cut to 4 hours.

Numerous questions immediately arise regarding what could be done if two people, husband and wife, for instance, belonged to separate groups, and had their days off on separate days. This need cause no apprehension, because it is a mere administrative detail to transfer a person from one group to another, and since the circumstances under which each group works are identical, there will be in general just as many people wishing to be transferred from Group II to Group I as from Group I to Group II, so that such transfers automatically balance in the end.

In the matter of shifts, however, this is not quite the case, so that in order to make them equal it will probably be found necessary to rotate each individual in such a manner that he works an equal amount of time on each shift during the course of the year.

The effect of this calendar on the load factors of the industrial mechanism would be tremendous. It means that almost the same amount of activity would be going on every hour of the 24. The traffic would be about the same every day and every hour of the day. Each day would be a working day for four-sevenths of the working population, and a day off for the remaining three-sevenths. Consequently, centers of recreation would not be deserted, as they now are, during week days, and then jammed beyond capacity the remainder of the time. Instead, ample recreation facilities could be provided so that at no time would the playgrounds, swimming beaches, parks, theaters, or other places of recreation be overcrowded.

Consider also what this means to the central power system. In this case there is a daily cycle of lightness and darkness which is unavoidable. This results in a big load being thrown on the power plants at night due to the necessity of lighting. A large part of this load, of course, goes off during the day. If lighting were the only function of a central power system, such oscillation would remain. However, a large part of the function of a central power system is to provide the motive power for industrial equipment. Certain industrial equipment may be intermittent in its operation, slow freight haulage for example. Now if these intermittent industrial operations are so arranged that they go into operation only during the off-peak load of the power plant, this will enable the maintenance of the load of the power plant at almost 100 percent.

23.4 Transportation

Consider transportation under such a mode of control. Transportation falls naturally into two major classes, passenger and freight. Passenger transportation requires, in general, speed, safety and comfort. Freight transportation may be either fast or slow, depending on the nature of the goods being transported. For passenger transportation the principal modes of conveyance are rail, water, highway, or air. For freight transportation there may be added to the above modes of conveyance a fifth, pipe line, and perhaps a sixth, wire. The transmission of energy over a high tension power line and the shipment of coal by freight car are both different aspects of the same thing, namely, the transportation of energy.

In freight transportation, as in all other fields, one of the great problems that would have to be solved is that of which mode of transportation involves the least energy cost per ton-mile. Take the shipment of coal, for instance. Is it more economical of energy to ship the energy contained in coal by freight car, or to hydrogenate the coal and transfer it by pipe line, or to build the power plants near the coal mines and ship the energy by high tension transmission lines?

There is another major problem in freight handling, and that is the matter of freight classification and individual consignments. At the present time all freight is shipped to individual consignees, with the great bulk of it in small lots. Most of this would be eliminated. The supplies for a city, for instance, would all be shipped in bulk quantities to the warehouses of the Distribution Sequence, all goods of a single kind going together. The freight handling terminals and the design of the cars themselves could be made such that the loading and unloading of freight could be handled with the greatest dispatch by automatic methods. From these major freight terminals, goods would be moved locally to the various centers of distribution, from which they would be distributed to the population of the immediate vicinity.

In the matter of passenger transportation the same criteria would be used in the design and operation of passenger equipment as elsewhere. Trains involving the least energy cost per passenger mile would be operated. It goes without saying that such trains would be the lightest, the most streamlined and the most efficiently powered that could be built. Whether Diesel-electric power units mounted on the trains themselves, or whether power derived from stationary central power plants will prove to be the most efficient, and hence the preferred mode of propulsion, is still to be determined.

Since by far the greater number of passenger miles of transportation are delivered by automobiles operating on public highways, particular significance attaches to this mode of transportation. To appreciate the importance of automobiles in our national economy, one needs only to consider that in, 1923 passenger automobiles in the United States had an installed horsepower capacity of approximately 453,000,000 h.p. All the other prime movers combined at that time were only 231,000,000 h.p., giving a grand total of 684,000,000 h.p. of prime movers. By 1929 this grand total reached over 1,000,000,000 of installed horsepower, with automobiles occupying as great if not greater proportion as in 1923. In 1923 the h.p. capacity of passenger automobiles was 66 percent of the total of all the prime movers in the country. In that year the number of passenger automobiles was about 13,000,000. By 1929 this had reached 23,000,000, with the horsepower per automobile increasing simultaneously.

Now, getting back to load factors, we have already remarked that the average load factor of all automobiles is only about 5 percent. This means then that at the present we have approximately 800,000,000 installed horsepower in passenger automobiles alone which are operating only about 5 percent of the time. Or it means that if we could step this load factor up to 50 percent, or 10 times what it now is, we could obtain the same number of passenger miles with one-tenth of the automobiles now in operation.

There is a corresponding problem involved in the design and servicing of automotive vehicles. Today there are about two dozen separate makes of automobiles being built in the United States. This means that as many different factories have to operate, and that a corresponding number of complete systems of garages and service stations must be maintained.

The factors that are uppermost in present day automotive design are those of flashy appearance and other superficialities that make for ready sales; while it is as carefully seen to that the wearing qualities are kept low enough to insure a quick turnover because of the short life of the product. To this end all sorts of fake devices are used, the latest of which is fake streamlining.

In the matter of fuel efficiency, by far the most efficient type of internal combustion engine is the Diesel, which operates on fuel oil or distillate. Although automobile and airplane Diesels have long since been proven to be entirely practicable, they have for a number of years past been carefully withheld from use in automobiles. There is, however, a limit to the extent to which so fundamental an advance as Diesel engines can be withheld, and now, at last, the dam has broken. In trucks, tractors and buses Diesels have been coming in at a very rapid and accelerating rate during the past two years, and now one manufacturer announces a Diesel motor as an optional choice in an automobile. While it is true that a part of the phenomenally low cost of Diesel operation at present is the low cost of fuel oil, and that as the demand for this increases, the monetary price will rise, the fact still remains, however, that Diesels do the same work for fewer gallons of fuel than any other engines in existence.

Under an energy criterion it follows that all automotive vehicles would be powered with the most efficient prime movers that could be designed—high-speed Diesels, unless and until something better can be devised.

The same considerations would apply to all the various trick devices for insuring rapid obsolescence and turnover in vogue today. To care for these and other defects of the function of automotive transportation necessitates a complete revision from the ground up. Consequently, to improve the load factor it will be necessary to put all automobiles under a unified control system whereby they are manufactured, serviced, and superintended by the Automotive Branch of the Transportation Sequence.

This means, in the first place, that there would be only one basic design of automobile. That is, all automobiles that were built would have interchangeable parts, such as motors, wheels, chassis, springs, etc., except insofar as they differed in those elements of design fitting them for different uses. In these minor differences there would be as many different varieties as there were uses, such as two-passenger and five-passenger capacity, light trucks and similar variations. It goes without saying that, in accordance with our criterion of least energy cost, the cars would be really streamlined, which would require that the engine be placed in the rear, rather than in the front; they would be powered with the most efficient power unit that could be devised.

As regards use of the automobiles, the change of administration would be even more profound. Whereas, at the present time, one buys an expensive automobile, and leaves it parked the greater part of the time in front of his house as evidence of conspicuous consumption, the automobiles that we are speaking of would have to be kept in operation. This would be accomplished by instituting what would resemble a national ‘drive it yourself’ system. The Automotive Branch of Transportation would provide a network of garages at convenient places all over the country from which automobiles could be had at any hour of the night or day. No automobiles would be privately owned. When one wished to use an automobile he would merely call at the garage, present his driver's license, and a car of the type needed would be assigned to him. When he was through with the car he would return it either to the same garage, or to any other garage that happened to be convenient, and surrender his Energy Certificates in payment for the cost incurred while he was using it.

The details of this cost accounting for automotive transportation are significant. The individual no longer pays for the upkeep of the car, or for its fueling or servicing. All this is done by the Automotive Branch of the Division of Transportation. In this manner a complete performance and cost record of every automotive vehicle is kept from the time it leaves the factory until the time when it is finally scrapped, and the metal that it contains is returned to the factory for re-fabrication. In this manner the exact energy cost per car-mile for the automotive transportation of the entire country is known at all times. Similar information is available on the length of life of automobiles and of tires. With such information in the hands of the research staff, it becomes very definite as to which of various designs is the superior or the inferior in terms of physical cost per car-mile.

The total cost of automotive transportation includes, of course, the cost of manufacturing the automobile. If, for instance, the average life of an automobile were 300,000 miles, the total cost for these 300,000 miles would be the cost of manufacturing the automobile plus its total cost of operation and maintenance during its period of service. The average cost per mile, therefore, would be this total cost including the cost of manufacture, divided by the total distance traveled, in this case 300,000 miles.

Where there are millions of automobiles involved the same type of computation is used. In this case the average cost per mile would be the average cost for the millions of cars instead of for only one. This would be the total cost of manufacture, operation and maintenance of all automobiles of a given kind divided by the total miles of service rendered by these cars. Since automotive costs can best be kept low by maintaining high operating load factors, it becomes necessary that all automobiles be kept in as continuous operation as is practicable. In other words, automobiles when away from the garages should be in operation and not parked ostentatiously in front of somebody's house. This can be taken care of rather effectively by charging the individual for the use of the automobile on a mileage-time basis as follows:

1. if while the automobile is out its operation has been maintained at a rate equal to or greater than the national load factor for all automobiles,

charge is made on a mileage basis only;

2. if the load factor of the car while out is not kept equal to the average load factor, the charge is made on the basis of the number of miles that the car would have traveled during that time had it operated at a rate equal to the average national load factor for automobiles.

Suppose, for instance, that the average national load factor for all automobiles were such that each car traveled on the average 240 miles each 24 hours, or an average of 10 miles per hour. Now, if a person had an automobile out and he used it an average of 10 miles or more per hour, he would be charged for mileage only. If, however, he kept the car 24 hours, and only drove it 30 miles, he would be charged for 240 miles, for that is the distance the car should have traveled in 24 hours.

This simple proviso has the dual effect of improving the load factor of all automobiles, and at the same time reducing the average cost per mile, by making the delinquents pay for keeping automobiles out of service.

23.5 Communication

The field of communication includes mail, telegraph, telephone, radio and television. All of these forms of communication plus any others that may be developed are in the domain of the Communication Sequence. Under an energy criterion the same question arises here as elsewhere. Namely, of two equally effective modes of communication which has the least energy cost per unit? The unit in this case is a given number of words transmitted a given distance.

Technically there is no question that all communication of the entire Continent could be conducted by telephone if the energy cost indicates that this is not too expensive. It is equally possible to do the same thing by telegraph. Facsimiles, or photographs so accurate as to be scarcely detectable from the originals, are now being sent by wire as a matter of daily newspaper routine. Whether the energy cost of handling the entire communications by telephone or by telegraph is less than by mail, available data are not sufficient to decide. They indicate, however, that the cost by wire would be at least as small as by mail, if not smaller.

Suppose that the mails be maintained even if at a considerably reduced volume. One of the great technological improvements awaiting introduction into this branch of activity is that of automatic sorting. Few more drudgerous jobs exist at the present than those of the postal clerks who spend year after year poking letters into pigeon-holes. Technically it is possible to devise a mail system whereby a letter will be transmitted from one side of the Continent to the other virtually untouched by human hands. One way whereby this could be done would be by uniform sized envelopes bearing code addresses of black and white spaces, a different combination corresponding to every different mail distribution center. This would permit sorting by photo-electric cells.

In the matter of radio the same unification of equipment would be effected. Instead of having dozens of different kinds of radio sets, there would only be one kind for each specific purpose. That kind, needless to say, within the physical limitations set, would be the best that could be built. The individual radio set would be a part of the Radio Branch of the Communications Sequence, just as the individual telephone is now a part of the telephone company and not the property of the user.

23.6 Agriculture

Just as far-reaching implications are met when one applies the same criteria to agriculture. Agriculture is the nearest to the primary source of energy, the sun, of all our industries. Agriculture is fundamentally a chemical industry wherein matter from the soil and the atmosphere are combined with the help of solar and other energy into various use products. Only now are we beginning to appreciate the latitude of usefulness to which agricultural products can be put. From time immemorial products of the soil have been the source of human food and clothing. But many more products from the soil have been wantonly wasted—wheat straw, corn-cobs, and numerous other products are normally burned or otherwise destroyed.

From a technological point of view, agriculture is still probably our most primitive and backward industry. Land is cultivated in small patches by people whose knowledge is largely of a handicraft type handed down from father to son. Soils are allowed to waste away by erosion or by lack of fertilization; farm implements are used for the most part for only a few weeks per year each, and more often than not left standing exposed to the weather the remainder of the time.

While it is true that agriculture as it is practiced on most of our farms today is largely in a handicraft stage only slightly different from that of the ancients, the same cannot be said of the scientific knowledge of agro biology. Modern agrobiologists look upon plants merely as mechanisms for converting certain inorganic substances—principally phosphates, potash and nitrogen—known as plant foods into forms useful both as foods and as raw materials for industrial uses.

Soil, as such, is of no importance except as a container of plant foods and as a support for the growing plant. It follows, of course, that any other container for properly proportioned plant foods, used in conjunctions with a suitable support for the growing plant, would constitute an alternative to an agriculture based upon tilling of the soil.

Consider, however, that the soil still be used as the agricultural base. In this case all soils contain an initial amount of usually improperly proportioned plant foods, and will, without other attention than primitive tilling, produce a modicum of various kinds of crops. Since each crop grown extracts a part of the supply of plant food initially present in the soil, it follows that if succeeding crops are produced without a corresponding amount of plant food being added, the soil will gradually be exhausted of its initial supply and become ‘run down’ or worn out. Such a soil can be rejuvenated by merely adding the plant foods in which it has become deficient. Hence it follows that over any long-time period there must be maintained an equilibrium between the plant foods added to the soil and those taken out, if continued producing power without soil exhaustion is to be maintained.

This brings us to the question of yields to be expected per acre. Modern agrobiologists have determined that where soil is utilized as the medium of crop culture, and where crops are grown under ordinary out-of-door conditions, there is a theoretical maximum yield per acre which any crop may be made to approach, but none to exceed. This maximum is determined by the amount of nitrogen that may be extracted from the soil per acre. The maximum of nitrogen extraction that may not be exceeded by any one crop in a given cycle of growth is approximately 320 pounds per acre. In order that 320 pounds of nitrogen be withdrawn it is required that there be present 2,230 pounds of nitrogen per acre. By knowing the amount of nitrogen withdrawn from the soil to produce one bushel of corn, of wheat, or of potatoes, one ton of sugar cane, or one bale of cotton, one has merely to divide this amount into 320 pounds of nitrogen per acre in order to determine the maximum possible yield of the crop considered. These maximum possible, or perultimate yields, together with yields that have already been achieved, are

The significance of these facts is that our American agriculture is oper
ating at an extremely low efficiency—less than 10 percent of the theoretical

given by O. W. Willcox as follows:

Table 23.1: Crop yields

Kind of Crop	Calculated Perultimate Yield	Known Yielding Power	Yield Power of Perultimate in Percent
Corn	225 bu.	225.0 bu.	100.0
Wheat	171 ”	122.5 ”	71.6
Oats	395 ”	245.7 ”	62.2
Barley	308 ”	122.5 ”	39.7
Rye	198 ”	54.4 ”	27.4
Potatoes	1330 ”	1156.0 ”	86.8
Sugar beets	53 tons	42.3 tons	80.0
Sugar cane	185 ”	180.0 ”	97.2
Cotton	4.6 bales	3.5 bales	76.1

Source: Reshaping Agriculture, O.W. Willcox (1934), p. 66.

As compared with the above maxima, Wilcox gives the average crop yields per acre for the United States as follows:

Average yields of crops in the United States compared with the possible maxima:

Table 23.2: Average crop yields

Kind of Crop	Aver. Acre Yield, U.S.	Percent of Perultimate	Percent of Known Max
Corn	25.5 bu.	10.8	10.8
Wheat	14.4 ”	8.4	11.7
Oats	30.4 ”	7.7	12.3
Barley	24.1 ”	7.8	19.6
Rye	12.8 ”	6.4	23.5
Potatoes	114.9 ”	8.6	9.0
Sugar beets	11.1 tons	20.9	26.1
Sugar cane	16.4 ”	9.1	22.4
Cotton	0.32 bales	6.9	9.1

maximum, and only about 15 percent of actual best performance under field conditions. Furthermore, in the light of present technical knowledge in the field of agro biology, it would be no difficulty at all to step this production up to at least 50 percent of the perultimate maximum. Even today almost every year that passes sees new records broken in actual crop yields per acre.

An average agricultural efficiency of 50 percent means that the same agricultural production as at present can be achieved on one-fifth of the land area now in cultivation, with one-fifth or less of the man-hours now required.

An even more fundamental and technological approach to agricultural production is to be found in those cases where the soil is no longer considered necessary as a container for plant food or as a supporter of the growing plant. Such an example is to be found in the case of the process currently in use in California and elsewhere. In this process the plant food is dissolved in water which is contained in a long shallow trough. Above the water, and supported by wire netting, is a bed of excelsior in which the seeds are planted. The roots extend downward to the water. The excelsior and wire netting support the plants. In this manner optimum conditions can be constantly maintained and almost phenomenal production results.

Further technological control of environmental factors and the speeding up of growth rates and shortening the period required to mature a crop are as yet little touched, but offer broad domains for the technologist in agro biology in the future.

Regardless of whether the agriculture of the future ultimately remains predominantly in the out-of-doors farming stage or comes to resemble an agricultural factory, the fact remains that the application of the technological methods will revolutionize it to where present methods are truly primitive in comparison.

Suppose that out-of-doors agriculture remains predominant. Large scale operations require large tracts of land worked by machinery gigantic in size as compared with any that present day farmers are able to employ. Land-breaking to depths of two to three feet is not at all impracticable with equipment designed for that purpose. Such deep plowing in conjunction with run-off control of the water supply would practically eliminate drought hazards. Proper fertilization and tilling would do the rest. Only the best land and agricultural climates need be utilized because with such yields as could be obtained by those methods little more land than is contained in the state of Illinois would be required for all agricultural produce for the United States.

Needless to say, all present farms and land divisions would be eliminated.

Agriculture would be only one division of a vast chemical industry which would convert the raw materials of the land into use products and in turn supply to the land its requirements in fertilizers and plant food. Tracts of probably tens of miles square would be worked as a unit. Equipment would operate 24 hours per day, and be rotated in such a manner that each piece of equipment would be in as continual operation as possible throughout the year.

The farm population would live in conveniently situated towns from which they would commute to the fields. They would thus combine the advantages of healthful out-of-doors work with those of urban life with its social and educational facilities.

This would, of course, leave vast domains to be reconverted either to grazing or forest lands. Forests, national parks and playgrounds could then be instituted on a scale never known since the country was in its virgin state as found by the original pioneers.

23.7 Housing

So great is the effect of habit on the human animal that it becomes almost impossible for one to detach himself sufficiently to take an objective view of the subject of housing. Our houses and our buildings and structures generally resemble our clothing in that they attain a certain convention and thereafter we tend to accept them without further question. It never occurs to us to ask whether the prevailing convention is better or worse than other possible styles. The training of our architects is such as to tend to perpetuate this state of affairs. Aside from draftsmanship and a small amount of elementary training in strength of materials and other structural details, our students of architecture spend most of their time studying the architectural details of the ceremonial buildings of the past—temples, cathedrals, palaces and the like. This accounts for the fact that power plants are seen with Corinthian columns, banks with Gothic windows, and libraries resembling Greek temples.

The problem of designing buildings in accordance with the functions they are to perform seems rarely to have occurred to architects.

The successful architect of today is either one who has developed an architectural firm that receives commissions for designing large and expensive buildings, such as skyscrapers, hospitals, courthouses, and the like, or else an individual practitioner who knows sufficiently well the pecuniary canons of good taste to receive commissions for the design of residences in the expensive residential sections of our cities and their suburbs.

If an architect wishes to be really 'modern,' he then proceeds to do something 'different.' He designs houses made completely of glass or metal, and hung from a post. The two basic questions that seem never to occur in connection with these endeavors are: 'What is the building for'? and 'Would it be practicable to house the inhabitants of an entire continent in such structures'?

This brings us to the technological foundation of the whole subject of housing, namely, what are the buildings for? What do we have to build them with? What does it cost physically to maintain them? And how long will they last?

The physical cost in this field is arrived at in the same manner as in the physical cost in any other field. The physical cost of housing 150,000,000 people is the physical cost of constructing, operating and maintaining the habitations for 150,000,000 people. The cost per inhabitant per year is the total cost per year divided by the number of inhabitants.

If housing is to be adequate for 150,000,000 people, and at the same time physical cost of housing is to be kept at a minimum, there necessitates a complete revision of design, construction, and maintenance in the whole field of housing. It requires that the construction of houses be kept at a minimum cost, that the life of each house be a maximum, and that the cost of maintaining each house, including heating and lighting, be a minimum. It requires, furthermore, that the materials used be those of which there is an ample supply for the construction and maintenance of approximately 50,000,000 dwellings. This immediately rules out the whole array of 'modern' designs of metal houses, where the metal involved is chromium and other similar rare metals, which are indispensable as alloys of steel and other metals for industrial uses.

The requirements of low cost construction would necessitate that the housing be of factory fabricated types, where the individual units can be turned out on a quantity production schedule ready for assembly, just as automobiles are now turned out by automobile factories. There would be a limited number of models, depending upon the type of locality in which they were to be used, their size and the type of climate. Any of these different models, however, could be assembled from the same units—wall units, doors, windows, bathroom, kitchen equipment—as any other model; the difference being that these standard units are merely assembled in different combinations.

Instead of thousands of separate individual architects designing houses, there would be only a few basic designs, and these designs would be made by the best technical brains that could be had for the purpose. The building would be designed for use, for long life, and for minimum cost of construction and maintenance. Incorporated into the design of the house would be the design of the furniture as an integral part. The houses would not only be heated in winter, but cooled in summer, and air-conditioned throughout the year. The lighting would be indirect, and with intensity control for the best physiological effects.

While there is a wide variety of possible materials, the fundamental conditions that must be fulfilled are abundance, low energy cost of fabrication, and high degree of heat proofing and soundproofing qualities, as well as a structural framework rendering it vibration-proof against such impacts as occur in the ordinary activities taking place inside a dwelling. In other words, one should be able to make all the noise he pleased, or do acrobatic flip-flops, in such a house without a person in the next room being able to detect it. The building should be proof against not only the leakage of heat from the inside out, or vice versa, but also completely fireproof.

The method of heating in such a structure also would be radically different from those now employed. It is quite likely that a thermodynamic type of heating, based on essentially the same principle as our present gas flame refrigerators would prove to be the most efficient. In this case, however, when the house is to be heated instead of cooled, the cold end of the mechanism would be placed outside the house—probably buried in the ground—and the warm end placed inside the house. The fuel, instead of being used to heat the house directly as is done now, would merely be used to operate the refrigerating mechanism which would pump heat into the house from the outside. By such a method, theoretical considerations indicate that a house can be heated at only a small fraction of the energy cost of the most efficient of the direct heating methods obtainable.

This method of heating has the additional advantage that by changing only a few valves the system could be made to run backwards, that is, to pump heat from inside to outside of buildings, and thus act as a cooling device during warm weather, which would be analogous to our present refrigerator, only on a larger scale.

23.8 Design

The end-products of design are radically different if one lays out the whole scheme of a given function in advance and then works down to the details, from what they would be if one started on the details and worked from them to the more general complex. For example, the steamship Normandie has been able to break world speed records and to exhibit other points of functional excellence merely because these high points of performance were written into the specifications before a single minor detail was ever decided upon. The design of a ship to meet these broader specifications automatically determined that the minor details be of one sort rather than a number of others. The specification that the Normandie was to be the fastest steamship ever built automatically determined the shape of the hull, the power of the engines, and numerous other smaller details.

Suppose the procedure had been in the reverse order. Suppose that some one person decided independently upon the shape of the hull; suppose that a second designed the engines, determining what power and speeds they should have. Let a third design the control apparatus, etc. It is a foregone conclusion that a ship designed in any such manner, if she remained afloat or ran at all, would not break any records.

For any single functional unit the design specifications for the performance of the whole must be written, and then the details worked out afterwards in such a manner that the performance of the whole will equal the original specifications laid down.

The trouble with design in a social mechanism heretofore has been that neither the specifications nor the design has ever gone beyond the stage of minute details. We have designed houses by the thousands, but no one has ever designed a system of housing on a continental scale. We have designed individual boats, automobiles, locomotives, railway cars, and even articulated streamlined trains and individual airplanes, but no one has ever designed a continental system of transportation. Even these latter units are only individual details in the design of a whole operating social mechanism. Even a design that embraced whole functional sequences would be inadequate unless it in turn was guided by the super design of the entire social mechanism.

So far we have only been suggesting some of the details of the type that would result from such a shift of viewpoint and of administration as would be entailed in a transfer from the present politico-economic Price System mode of social administration over to the functional technological type that we have outlined. In such a change no single detail, big or small, would be left untouched. There would be a whole re-allocation of our industries. Our present centers of trade and commerce, as such, would dwindle into insignificance for the simple reason that trade and commerce would cease to exist. Centers of industry might or might not come to occupy the same places. The entire array of man-made buildings and equipment of the whole North American Continent would have to be junked and replaced by more efficient and better functioning structures and equipment. Along with redistribution of industry would come a redistribution of population. It is not improbable that New York City and other similar localities would be mined for the metal they contain.

New towns and cities would have to be designed as operating units from the ground up, and these designs would again be only details of the super-design for the whole mechanism. There are a number of essential design elements that must be taken into account in the design of a town or a city:

1. There must be adequate housing and recreation facilities for the population.

2. There must be an adequate distribution system for the supplies that will be consumed by the city, both by the populace individually and by the city itself.

3. There must be an adequate system of waste disposal, sewage, garbage and the like.

4. There must be adequate facilities for local traffic, pedestrian, vehicular, etc.

5. There must be adequate facilities for local communication.

6. There must be a system of water supply, of heat, gas and electric power.

7. There must be trunk connections for traffic, supplies, water, energy, and so on, between the city and the world outside.

8. The design must be such as to allow for any probable expansion in the population with a minimum of readjustment.

23.8.1 Standardization

In the field of more general design, standardization of more essential parts will be carried as nearly as possible to perfection. Outside of industrial circles it is little realized what standardization means. In the maintenance of even the present rate of industrial operation, suppose, for example, that every separate manufacturer of electric light sockets produced a different size. If these sizes were as many as a few dozen almost hopeless confusion would result. Suppose likewise that every different state in the union used a different sized railway gauge, as is the case in Australia. This would mean that all trains would have to stop at the state lines and transfer freight and passengers, because a train from Illinois would not be able to run on the Indiana tracks. These examples are taken merely to show the importance of such progress in standardization as has already been made. Few people realize that our present quantity production in automobiles is rendered possible entirely by the standardization of machine parts. Many automobile parts have to fit with an accuracy of one ten-thousandth part of one inch. In order that all such parts in a quantity production flow line turning out thousands of units per day may be mutually interchangeable, it is imperative that all these parts be standardized with that degree of accuracy. Most of the difference in cost between a Rolls-Royce and a Packard is due to the fact that the Packard is produced by standardized quantity production methods, whereas the Rolls-Royce is produced by handicraft methods where every individual bearing is fitted separately and, in general, parts are not mutually interchangeable. If the Packard of today were built by the same hand methods employed in the Rolls-Royce, it would be no whit better than it is now, but it would have to sell for a price comparable to that of the Rolls-Royce, and for the same reasons.

Most of our industrial progress up to the present time has been rendered possible through standardization. The trouble is that standardization has not been carried nearly far enough as yet. There are too many different arbitrary sizes and varieties of what is functionally the same-commodity. Take a simple product like soap. Chemically there are only a small number of separate basic formulas for soap. The number of brands of soap on the market, however, runs into the thousands.

Not only has the achievement of standardization made possible our quantity production methods, but the lack of standardization has at the same time been in no small part responsible for our low industrial load factors. In many fields, particularly in those of clothing and automobiles, the lack of standardization has been promoted as a highly remunerative racketthe style racket. If styles can be manipulated properly it is possible to increase the consumption of goods by rendering the styles of the old goods obsolete long before the goods themselves are worn out. Thus clothing, which might last two years, is discarded at the end of a single season because it is out of style. Last year's automobile is traded in on this year's new extra-fancy model.

The effect of all this upon the load factors of the industry concerned is to cause it to run with a short spurt at peak production while getting out the new model or the latest style, and then idling or remaining completely shut down for the rest of the year. In men's clothing, for example, with a relatively small variety of stabilized styles and an ample variety of materials and color combinations, clothing could be manufactured, if need be, for a year or even two years in advance, and thus completely even out the peaks and troughs resulting from seasonal demands for different kinds of clothing. Overcoats, for example, could be manufactured the year round with a high load factor, but at a rate just sufficient for the annual output to be equal to a single winter's needs.

23.9 Unnecessary Activities

As yet little emphasis has been placed on the fact that by far the greater part of all employees are engaged in one kind or another of financial accounting or other similar socially unnecessary activities. Even in so industrial a unit as a flour mill it is common for the number of employees engaged in the purely business operations of the plant to be considerably greater than the number required to operate the flour mill. In our electric light and power systems the bulk of the employees are the office clerks, the meter readers and repair men. Only a small percentage of the total staff are required for the socially necessary industrial function of operating and maintaining the power system.

All this is aside from the unnecessary duplication that exists. One single store, for instance, could supply all the distribution services required by a population of 10,000, or so, with only a matter of a couple of dozen employees, whereas in actuality there were in 1929, 683,751 retail stores employing 3,081,000 people (including the proprietors) serving a population of 48,000,000 in all the cities of the United States of populations over 30,000[1]. This means that in the cities of over 30,000 in the United States there was at that time one retail store employing on the average 4 1/2 people full time for every 70 members of the population, or one employee in a retail store for every 15.5 members of the population.

1 15th Census of the U.S., 1930, Retail Distribution; and U.S. Statistical Abstracts

In 1930 there were over six million people in the United States engaged exclusively in trade. This is, of course, in addition to the employees already mentioned whose jobs are largely financial, rather than industrial. There were over four million clerical positions, consisting of bookkeepers, accountants, and the like in the United States in 1930.

The point of all this is that, with a re-design of our social mechanism along the lines indicated, there will be a much larger number of jobs which will cease to exist than of new jobs which will be created. This would not imply then, as it does now, that there would be unemployment. It merely signifies, on the one hand, that we are assured of an ample supply of human services for all possible contingencies while operating the mechanism at the highest output per capita ever achieved. It means, in addition that all this will be accomplished simultaneously with a shortening, rather than with a lengthening of the working day.

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