have been just as sensible, and no more absurd, to pretend that in the Taylorized shops they only accepted as workers young women seated on foot stools who rested all the time. As a matter of fact, besides studying the work of loading pig iron, Taylor did research work on the inspection of balls used in bicycle bearings.

In a serious study it is childish to note only those details which make an impression on superficial minds. What would one say of a child who, in studying geometry, would notice only the color of the binding of his class book without reading the theorems? As a matter of fact the examples given by Taylor tend to illustrate a fundamental idea which is really the basis of his system of organization. One must never undertake a piece of work without having given ample time for a study of it —without having examined the most advantageous conditions for its accomplishment. Before he put the very muscular man to work on pig iron, Taylor had spent long days in determining the most convenient load, the least fatiguing gait and the time necessary for rest. He did the same thing for the inspecting of balls for bicycle bearings, for shoveling and for working in metals, etc.

This admonition to reflect before acting will perhaps seem gratuitous. What man with any sense does not apply this rule by instinct? As a matter of fact the studies required by Taylor are of a totally different order from simple, banal reflection. They are infinitely longer and more costly.

The Scientific Method

The method proposed by Taylor for the preparatory studies before starting a piece of work is no other than the literal application of the scientific method. This method has been known for a long time, but its application to industrial problems is a great novelty. Let us recall in a few words the scientific character of Taylor's studies.

He is above all else a convinced determinist; he knows that by maintaining constant the conditions of a phenomenon one is sure to obtain a constant result. In industry the wastes in manufacturing are always the consequence of changes in the mode of operating. Hence the necessity of defining rigorously and in the most minute detail all the conditions of each article manufactured, to exact of all the workmen the employment of the same routine for the same work.

Moreover, in each particular case there is one procedure which is more advantageous than any other, and only one. It is often said in the shops that several routines are equivalent and can be used interchangeably. You may be very sure then, that they are all equally bad. If we represent a particular case — the net cost, for example — by coordinates in space, we obtain a surface, showing one single low point corresponding to a horizontal tangent plane. Any parallel (i.e., horizontal) plane at a higher level will cut the surface and trace upon it a closed curve; that is to say, at an infinite number of points for which the net cost will be the same, but necessarily greater than the minimum.

Finally the value of any industrial result, as of that of any natural phenomenon, is a function determined by a certain number of variables or factors; this function is expressed by an algebraic formula which constitutes the law of the phenomenon. A knowledge of the laws, the essential object of science, permits us to fix the size of each of the factors so that we may obtain the desired result with mathematical accuracy. Taylor has expressed the laws of the cutting of metals by very complex algebraic formulae. The determination of these formulae, or laws, is the essential object of the application of science to industry.

This determination of the laws demands numerous experimental measurements whose determination is protracted and costly. These standards constitute the most important part of the scientific method and also the most difficult. It is not necessary to go into the reasons for this difficulty. The laws of industrial phenomena express themselves often by the functions of a dozen variables, as is the case in the cutting of metals, while the laws of pure science are not generally concerned with more than one or two variables. It is quite obvious that the importance of the measurements necessary for the establishment of the laws increases with the exponential function of the number of variables. If one wished to proceed in the study of industrial problems with the minutiae common to scientific laboratories one would be obliged to make several millions of observations: the life of several generations of men would not suffice for the task.

In order to accomplish the desired end it is indispensable to put some limits to one's work, and to this end to follow certain rules on which Taylor

has always insisted. In the first place, rigorously define the conditions of each experiment; never neglect any detail under the pretext that it seems at first sight unimportant. Without this precaution the whole work may be lost. In the second place, never vary from one experiment to another by more than a single factor, keeping all the others rigorously constant. In his research on putting greens Taylor sowed a thousand squares of grass, placed two by two beside each other and never changed one from the other save by one single condition. Finally, limit the studies to the zone of the size of the variables that are probably important, always exceeding this limit by a little, however, in order to better assess the degree of the variation of the phenomenon under observation.

One of the great advantages of science, that is to say of the knowledge of laws applied to measurements of precision, is to permit the passing on of the results once obtained from one man to another. This is impossible, on the contrary, for chance workmanship; science alone can be taught. All over the world all manufacturers employ the formulae given by Taylor for the cutting of metals; they temper all their high speed steel for example at 1200 degrees. Without this standard they would have to be satisfied with the chance indication of cherry red for the temperature of the tempering. This temperature might easily vary through three hundred degrees and a large part of the tools thus tempered would be unusable. Some of them would melt like soft metal; the others would shatter like glass. An exact standard eliminates this cause of loss.

After such a brilliant success it would seem that the use of the scientific method would have spread rapidly in industry. Unhappily this has not been the case. All engineers know the composition of high speed steel, the temperature for tempering, the economic advantage of high speed for cutting, the fact that the tools need regrinding after short periods of use; they fail to interest themselves on the contrary in the infinitely painstaking method by which these results have been obtained. They never dream of making application of it to new industrial problems.

This refusal tends to a regrettable situation in our scientific teaching. Our industrial leaders, our engineers, our chemists fully realize the essential value of science; they possess very extensive data but they ignore everything about the scientific method and the experimental practice of standardizing. They do not really believe in the power of science. This whole attitude of mind must be changed.

The Human Factor

In every industrial operation the cost of labor is one of the most important elements in the total cost and one of the most difficult to regulate properly; so the study of the human factor has been one of the principal preoccupations of Taylor. He attacked this problem with a vision unknown before him and by entirely new methods; he applied the experimental method to it as to the other factors of production. This he did from a triple point of view. The workman's function in a shop is not just like that of a machine; he is still a thinking and a feeling being. His ideas and his feelings, therefore, must be studied with the same respect as his work.

In the study of manual work, Taylor introduced time study into the factory, that is to say a measurement of the time necessary for each operation. This measurement permits one to choose intelligently the most economical methods and to determine for the workman the time necessary for a given task. This time study does not include merely the sum total of an operation but each of its elementary parts, each distinct motion made by the workman. This is indispensable in order to recognize and separate the useless motions and to eliminate or to correct the faulty ones. Moreover, as the same elementary operations are reproduced in many different factories, their study, once made, may serve in all similar cases.

Along with the measurement of the speed of work, it is necessary to be able to measure the fatigue resulting for the workman from this work. Taylor expressed the hope that the physiologists would succeed in giving us some day the appropriate technique. Unfortunately they have not done so as yet. One must be content with experimental guesses about fatigue and more often simply with the statement of those most interested. The difficulty of this problem arises from the fact that it is not ordinary fatigue which it is necessary to measure but only over-fatigue. All work produces fatigue, and it is relatively easy to measure it. But to eliminate that we should have to eliminate all