for their purpose the saving of time through the avoidance of delays and interruptions.

Incidentally we can see this purpose as the general cause of the outpouring of his ingenuity in mechanical invention. His great steam-hammer was designed to work faster than any other thing of its kind. He built a new chimney on top of an old one to save "a loss of at least one or two months in time." And here is the machine-tool table he invented early at Midvale, the table being the part of the machine on which work is placed to be operated on. It usually takes much time to set the work on the table and secure it by clamping, and Taylor just could not stand the spectacle of the machine standing idle while this was being done. So what he invented was a "false" table, or one that was separable from the machine; this, of course, permitting new work to be made entirely or nearly ready on a table while the machine continued busy. Then his study of cutting tools led him to invent a new tool holder further to expedite the work. This, roughly described, enabled a tool to be held in various positions to correspond to various surfaces, and thus made it possible for one tool to take the place of several of different shapes.

In writing about Taylor's metal-cutting investigation at Midvale, Barth says:

> This implied, besides the study of the possibilities of the cutting tools themselves, also a study of the properties of each machine dealt with, in a manner that had probably never been undertaken or thought of before. Through these studies of the machine-tools themselves, Mr. Taylor was able to furnish greatly improved detailed specifications for new machines to be purchased, so that very early in his career he also exerted some influence on the machine-tool building industry, of which I, as draftsman at the works of William Sellers & Company, was made cognizant as far back as the early eighties.[1]

Still another investigation he started at Midvale had for its object the finding of "some rule, or law, which would enable a foreman to know in advance how much of any kind of heavy laboring work a man who was well suited to his job ought to do in a day." His first step was to "look up all that had been written on the subject in English, German, and French," and what he found was that

> . . . two classes of experiments had been made: one by physiologists who were studying the endurance of the human animal, and the other by engineers who wished to determine what fraction of a horse-power a man-power was. These experiments had been made largely upon men who were lifting loads by means of turning the crank of a winch from which weights were suspended, and others who were engaged in walking, running, and lifting weights in various ways. However, the records of these investigations were so meager that no law of any value could be deduced from them.[2]

His purpose was to discover, not what man could do "on a short spurt or for a few days," but "the best day's work that a man could properly do year in and year out and still thrive under." Two first-class laborers, to whom were paid double wages, were selected for these experiments, and for weeks Taylor's time-study man recorded every element connected with their work which was "believed could have a bearing on the result." At Midvale these experiments "resulted in obtaining valuable information," but for the development of the law "governing the tiring effect of heavy labor on a first-class man," Taylor again had to wait until he went to Bethlehem and there had the assistance of Barth.

He deliberated and analyzed and investigated and experimented all along the line. For the qualities of equipment and materials he refused to take the salesman's or the manufacturer's word. When electric lamps were installed at his boring mills, he kept records of the consumption of current of several varieties so that he might determine the most economical.

A thing to be noted about his deliberation is that he did not wait until it was all nicely polished off before he proceeded to experiment. As he was a fallible human being, and so could not determine from the beginning all the knowledge he must seek, his deliberation naturally was subject to a continual process of correction and extension. There, for example, was his original thought that the essence of the problem as to the speed at which cutting tools could be run lay in their shapes and angles; after months of experimenting he learned that this was only one of twelve elements in his speed problem. This illustrates that with any scientist deliberation probably is as much the effect of experimentation as the cause, the one reacting on the other.

In his later years Taylor came to exclaim against the folly of trying to make sure you are *entirely* right before you go ahead. It was his wisdom that you can safely go ahead if only you are sure that your general direction is right—and you should not spend too much time trying to make sure even of that; you at least can proceed with caution. "You learn more with a poor start," he said, "than with no start at all." Evidently this principle of learning through acting governed him as far back as his days at Midvale. It is to be observed, however, that his early-established rule of doing no experimenting himself until he had exhausted all available means of learning what experimenting already had been done in the field concerned was one from which he never deviated.

As his time study or his metal-cutting investigation made it necessary for him to experiment at or with various machines, these machines were withdrawn from the regular work of the shop. This signifies that if he did not actually set up a laboratory, he did what amounted to the same thing. Certainly his was the laboratory *method*. However, nothing like his laboratory ever had been shown before in the sense that its purpose was to determine best shop ways with a view to their standardization. And this brings us to that great principle of his which during his lifetime few people, whether apart from industry or of it, were able to grasp.

From the very outset his principle of standardization appears. He found that the big obstacle to getting the maximum production was the then universal difficulty of rewarding workers equitably according to their accomplishment, and deliberation showed him that at the bottom of this difficulty was the fact that management had "no proper standards for a day's work." Thus it was really to establish proper *standards of accomplishment* (and so be able to set equitable piece-rates) that he began his experiments.

Now, there are jobs where the difficulty of maintaining the desired quality of work is so great that the time element is comparatively negligible, but they are the exception which proves the rule that, because of the relation between speed and economy, a proper standard of accomplishment is fundamentally one of speed or of the time needed to produce work of the desired quality. Hence Taylor's "laboratory" was fundamentally concerned with determining standard times. And that this was a problem possible of solution only by Taylor's method of job analysis should be clear when it is considered that you cannot determine with accuracy the total time a job should take until you resolve it into its elementary operations and time these. Once having determined these elementary times, however, you have data for any new jobs that may come into the shop, since all jobs simply represent different combination of the same elements.

But there is the fact that the time even an elementary operation should take all depends upon the *way* it is performed. This means that to determine the quickest times for adoption as standard, Taylor had to determine the best ways. How could he have done this save through his method of motion study? So there in the "laboratory" was the young man he employed to specialize in this study and the first-class workman who was selected to cooperate with that young man; these two experimenting with all the small details pertaining to the handling of materials, tools, and machine—the lifting to the machine of the metal to be cut; the putting of such tools as drills and reamers into the machine; the measuring with calipers, gages, or scales; the starting of the machine; the changing of the feed or speed; the adjusting of various parts of the machine.

And in the meantime there was Taylor conducting with the help of Sinclair and Gantt the experiments necessary to determine what the actual cutting time of the machine should be. True, he did not get very far with this problem at Midvale; nevertheless, he there succeeded in tracing out laws and getting formulæ and tables which, though crude in the light of the ultimate development, enabled him early to establish standard combinations of feed and speed for certain operations such as the boring and turning of steel tires for locomotive wheels, the net result being a marked reduction in the machine time. And this illustrates, by the way, that the one best way of doing a thing is always relative to time and place, or the existing stage in the development of the art.

But now let us fix our attention on those certain operations. For them Taylor not only had the data which enabled him to determine what the machine time should be, but also the data yielded by his motion study which enabled him to determine what the handling time should be.

So far, all very well. But it is to be observed that these data were developed under laboratory conditions. All the conditions were *under control*. Both the machine and the belting which delivered power to it had been brought up to standard condition and kept there. The cutting tools had been of the same quality of steel, had been subjected to uniform tempering, and had been ground to the same shapes and angles. Likewise the tools used for setting and holding the work in the machine and for measuring it had been of a certain kind and had been kept in a uniformly good condition. Moreover, these tools always had been on hand as wanted, and the same thing was true of the metal which was cut. Finally, there is the fact that the workmen who had cooperated in the time and motion study had been picked out as first-class men for the particular jobs studied, and also had been under control in the sense that, by the offer of an extra wage, they had been induced faithfully to carry out the detailed instructions.

Obviously, then, as Taylor wished to make practical

[1] Barth's "Supplement to Frederick W. Taylor's 'On the Art of Cutting Metals;'" *Industrial Management*, September, 1919.

[2] *The Principles of Scientific Management*, p. 54.