The changes in motivation as far as they result from work are a legitimate component of industrial fatigue. It is only the external social factors, such as a pressure for a "slow-down," that make a legitimate use of production curves impossible. It appears that fundamental research on industrial fatigue should be carried out in miniature industrial plants combining the realism of actual working conditions with the objectivity and detachment of the laboratory.

B. TYPES OF FATIGUE

On the basis of performance records one can distinguish three types of work fatigue: "exhaustion-fatigue," "tiredness-fatigue," and "boredom-fatigue." The first type of fatigue is almost completely a product and object of laboratory studies; only under pathological conditions, such as telegraphists' cramp, does work production drop to zero. Tiredness-fatigue results from moderately hard to hard work. Boredom-fatigue is an important industrial problem, its importance increasing parallelly to the increase in the number of jobs involving light, repetitive work.

1. Exhaustion-fatigue

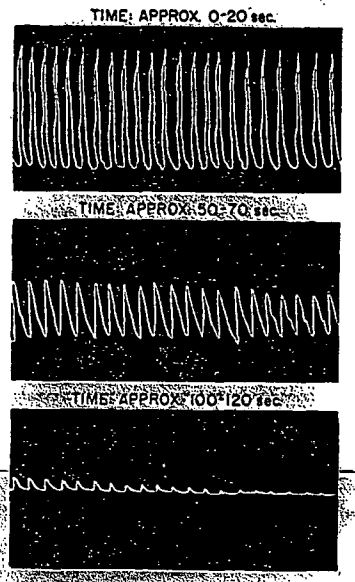


FIG. 6. Exhaustion-fatigue of an isolated muscle (frog gastrocnemius) electrically stimulated at approximately 1-second intervals. Weight lifted was equal to 100 grams. Magnification ratio (fulcrum to writing point: fulcrum to muscle hook) = 16.4/1.8 = 9.1.

The term "fatigue" in the strict but limited sense of "muscular fatigue" is defined as a decrease and finally a temporary loss in irritability and contractility of a muscle brought on by its continued activity. In its purest form the exhaustion-fatigue can be demonstrated in an isolated muscle attached to a balance beam, with the "work" consisting of lifting a weight attached to the other end of the balance arm. In Figure 6 we observe a progressive decrease in response, recorded as the height to which the weight was lifted, in the face of standard, repeated stimulation applied directly to the muscle. The contractions of the muscle exposed to electrical stimuli of equal strength and following each other at equal, short intervals diminish steadily in height until finally the muscle does not contract at all even though the stimulation is continued.

In human experiments in the laboratory we find essentially similar work curves when a man lifts a weight by flexing his index finger; with suitable load after 30 to 50 lifts no movement of the finger can be produced voluntarily. Another kind of exhaustion-fatigue is produced in the laboratory when a man runs on the treadmill until he can no longer continue.

Although the physiological mechanisms involved in the three examples of exhaustion-fatigue are very different they are all characterized by a cessation of the work activity.

2. Tiredness-fatigue

In output records obtained in physically "fatiguing" work we usually observe an initial rise, referred to as the "warm-up" effect, followed by progressive decrease in output. In contradistinction to exhaustion-fatigue the terminal performance is far above zero. This type of fatigue is illustrated in Figure 7. The subjects were performing moderately hard work by walking on a motor-driven treadmill at the speed of 3.5 miles per hour and at 5 per cent grade. At half-hour intervals a 5-minute test of manual speed and co-ordination[69] was inserted. The score represents the total number of times a ball-bearing was passed through a vertically held, 1-foot-long conduit pipe. The work curves are typical examples of tiredness-fatigue. The final scores are 4 per cent and 13 per cent, respectively, below the maximal score.

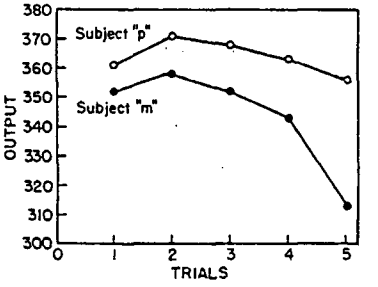


FIG. 7. Tiredness-fatigue in man, laboratory data. Performance in a test of manual speed and coordination, performed at half-hour intervals while walking on treadmill.

Similar output curves were obtainedin medium-heavy and heavy industrial worl.[70] The output (Figs. 8 and 9) is expressed in terms of percentage of maximum production attainable if all workers would reach the highest daily output at the same hour. In the medium-heavy muscular work involved in the operation of "radiator solder" the morning output increases up to the third hour and

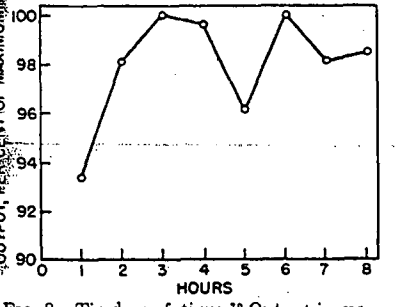


FIG. 8. Tiredness-fatigue.[70] Output in medium-heavy industrial work—radiator solder—during an eight-hour day.

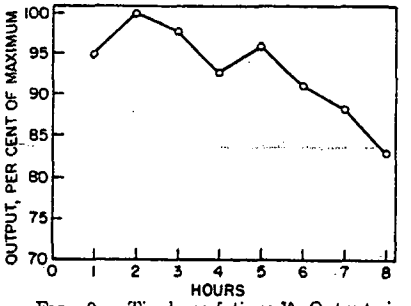


FIG. 9. Tiredness-fatigue.[70] Output in heavy industrial work—ramming molds—during an eight-hour day.

[69] J. Brozek, *J. Gen. Psychol.*, *31*, 125 (1944).
[70] *U.S. Pub. Health Service Bull.* No. *106* (1920).