surroundings, the location of controls and instruments, and the way the operator performs his duties. A functional concept of accidents should be maintained throughout—that is, the errors that may occur while the operator is working at the machine should be anticipated. The repetition or recurrence of near or real accidents clearly indicates a need for redesigning. Another consideration relates to human limitations. It should be assumed that no worker is a perfect one. In fact, he may be far below the ability assumed by the designer. If his duties are too complex, the cumulative burden is great and he may reach or exceed his limits of attention and ability. Finally, a wide margin of safety should be provided to eliminate any possible situation that places the operator near his maximum ability with regard to aptitude or effort, especially when adverse factors are present.[6]

1. Operational Job Analysis

No engineer would accept an assignment to design a motor unless he was also provided with information as to what the motor was for, the conditions under which it would operate, and the type of load it was expected to handle. In other words, specifications are required and these rest upon an analysis of the job the motor is to perform. If we view an employee as an intricate industrial machine, then before he is assigned to a given task, the work should be analyzed in terms of demands to be placed on this human machine. No engineer would design a motor to operate under conditions of extreme cold without considering the possible damage that might result from this operating condition and providing the necessary safeguards, such as proper tolerances, lubricants, and the like. Surely, the human machine should receive as much consideration as a motor. The potentialities of job analysis for the prevention of industrial accidents are very great, but thus far they have been only partially exploited and developed.

Job analysis can be divided into three broad areas: the surround, the machine, and the operator. The surround refers to the operational area within which the operator is required to perform. For example, poorly lighted areas or passages are one of the conditions among which the operator must sometimes perform his work. The second area is the machine. Job analysis can be applied to equipment design with resulting improvement in operator safety and corresponding reduction in industrial accidents. The third area, which deals specifically with the selection and placement of personnel, is generally not included in human engineering.

The hazardous features and conditions of some jobs are evident upon casual inspection. No special professional skill is required to determine that a power-driven ripsaw is potentially dangerous to the hands of the operator. The services of a safety engineer are not required to reach the conclusion that the operator may come in contact with the blade. His services become valuable, however, in deciding what kind of a safety device should be employed and just how it should

[6] R. A. McFarland, *Human Factors in Air Transport Design*. McGraw-Hill, New York, 1946.

be designed and used. Common sense and unaided observation can, in some instances, be adequate to identify the potential dangers of a job.

The dangerous aspects of other jobs can be identified by knowing some of the technical features of the equipment. For example, the danger inherent in some hydroelectric generators when there is a sudden loss of load can be deduced from characteristics of the generator, the turbines, and the controlling valves.

Direct observational and logical procedures can often utilize some of the special techniques that have been developed as aids in locating the danger spots in a job. Such aids as motion-picture photography, interviews with experienced operators, and analysis of control movements and forces become especially useful for jobs that are intricate, those that are part of a more complicated system of men and equipment, and those in which failures and accidents rarely occur. Each of these methods is a tool useful in abstracting from an operator's performance those items that involve danger to the operator, his fellow workmen, or the installation and its personnel.

In such studies, the concept of an error rather than an accident is often preferable because of the additional latitude in the connotation of the term "error." Since corrective action can be taken by the detection of "near accidents," attention is given to both potential and real accidents. A search for errors in performance may uncover near accidents or events that would result in catastrophe under special circumstances. Indeed, many accidents can result only when more than one error is made. In some systems, one may make an error and the mistake will be compensated for by another operator or by some characteristic of the machinery. Serious trouble may develop only when more than one error is made somewhere in the system within a limited period of time. Thus, some errors can be thought of as sufficient conditions for an accident, whereas other errors are necessary, but not sufficient, conditions for an accident. A program for reducing accidents must consider both kinds.

Even when attention is directed to errors so as to include instances in which serious trouble might have developed but did not, an observer might spend many hours watching a competent operator without finding enough cases to permit proper study and evaluation. Accordingly, special techniques are needed to accentuate the error aspect of the performance either by experimentally increasing the frequency of errors or by telescoping time so that an adequate sample of errors is available for study. Some of the typical methods used in this kind of job analysis will now be examined.[2]

a. Time-and-Motion Study.—Time and motion study has made little direct contribution to problems in safety. To a considerable extent this can be attributed to a misunderstanding of the nature and purpose of this type of analysis. Time and motion study is simply a means for obtaining a description of current methods of work. It is when the findings from the time and motion study are used as a basis for setting up new and presumably improved methods of work that disagreement comes.