limits of comfort, discomfort, and physiological harm are indicated for several variables. This chart was prepared specifically with reference to commercial vehicle design and operation but may have some applicability in other industries.

A. TEMPERATURE AND HUMIDITY

In view of the evidence indicating the effect of heat stress on accident rates in various types of work, temperature control for the working area must be considered a necessary part of any program in human engineering. For moderate to heavy manual labor, Vernon, Bedford, and Warner have shown that accident rates among mine workers bear an orderly relation to temperature. Near 60° F. accidents were at a minimum, with two- to threefold increases at temperatures approximating 80° F.[94] In light manual work involving an element of manual dexterity, Osborne and Vernon conducted studies in British munitions factories, that show that both cold and heat stress increase the frequency of accidents in manual operations concerned with shell manufacture.[95] Accidents were at a minimum at 67° F. and increased both above and below this temperature. It is to be assumed that the 35 per cent increase noted at 50° F. is an effect primarily on manual dexterity. The increase with higher temperatures may reasonably be attributed to decrease in general alertness and to increased physiological stress of uncomfortable heat. In skilled work involving minimal physical exertion, Mackworth has shown that during long periods of work, errors increased from an average of 12 per hour to more than 90 per hour as effective temperature was increased from 79 to 97° F.[96] In the sense that errors in skilled acts may be considered accidents, such data are convincing evidence of the deleterious effect of heat stress on human adjustment.

It is thus quite clear that control of the heat loss of workers is important in relation to accident susceptibility. In addition, the provision of a controlled atmospheric environment is a factor in employee morale. In a general sense, the imposition of any stress such as heat or cold will probably produce poorer performance over a long period, which is likely to be characterized by higher accident incidence. To some degree, such a higher accident frequency may reflect both a conscious and an unwitting protest against a subjectively stressful and uncomfortable environment. There are, however, some physiological circumstances of an objective nature that can contribute to an understanding of increased accident susceptibility at elevated temperatures.

At high temperatures, the diversion of a large portion of the heart's output of blood to peripheral areas for cooling purposes reduces the reserve in the circulatory supply to the brain areas responsible for work integration and precision in movement and discrimination, with the attendant possibilities for personal error. The observed effects of high temperatures on accident rates can be tentatively attributed to this factor. Moderate cold stress, though uncomfortable, is usually associated with an alert mental condition. Quite probably the accidents associated with excessively cool conditions are related to chilling of the extremities and a general decline in manual dexterity or, where falls are involved, to a decline in the precision of foot placement.[2]

The advantages of air conditioning should be seriously considered for all industrial operations carried out for any length of time under conditions of high temperatures, either atmospheric or environmental in origin. The requirements of customer or passenger comfort frequently necessitate air-conditioning equipment in stores, offices, and various forms of transportation. In industry, however, the worker must sometimes perform his job under conditions of moderate to intense heat. The added expense of such air-conditioning equipment must be considered, of course, but only in the light of the attendant increase in the safety, health, efficiency, and morale of the worker. In many industrial operations, the over-all advantages of this equipment could well justify the initial financial outlay. For a complete discussion of the problems involved in work under conditions of excessive temperatures see Chapters VIII and XXI.

B. NOISE AND VIBRATION

If quantitative data can be presented to the engineer in regard to limits of control for noise and vibration, an important contribution could be made to the improvement of efficiency, the lessening of fatigue, and the reduction of the possibility of accidents. Those principles related to noise that are especially important from the standpoint of safety may be summarized as follows. (*1*) Sudden loud sounds tend to speed a worker's movements. This effect is noticeable even when the sound is unrelated to the worker or his task (for example, a foreman's call bell), but it is even more marked when the sound is related to the immediate task (for example, a signal to proceed with the next operation). Although this principle can be used to advantage in some situations, its possible effect upon operator errors must be scrutinized carefully. (*2*) Sudden loud sounds may also tend to disrupt sequences of movements. Photographs of movement sequences often show irregularities for a few seconds after a fairly loud sound. Quantitative specifications for the suddenness or the loudness of these distracting sounds have apparently not been worked out systematically. (*3*) Increased sound levels or added noises may increase error rates at least temporarily; and, conversely, decreased intensity levels or disappearance of sounds may reduce error rates. These effects are likely to be more pronounced when there is a prevailing belief among the workmen that the noise affects their work adversely.[2]

The masking effects of one sound by another have a direct bearing upon the problem of communications among workmen. The principles of masking that are especially important are (*1*) as the intensity level of the disturbing sound is in-

[94] H. M. Vernon, T. Bedford, and A. G. Warner, The relation of atmospheric conditions to the working capacity and accident rate of miners, *Indus. Fatigue Research Bd. Rept. No. 39*, London, H. M. Stationery Office, 1927.

[95] E. E. Osborne and H. M. Vernon, Two contributions to the study of accident causation, *Indus. Fatigue Research Bd. Rept. No. 19*, London, H. M. Stationery Office, 1922.

[96] N. H. Mackworth, Effects of heat on wireless operators, *Brit. J. Ind. Med.*, 3, 143 (1946).