PROCEEDINGS of the HUMAN FACTORS SOCIETY - 22nd ANNUAL MEETING - 1978

HUMAN FACTORS DESIGN PROBLEMS OF FIRE FIGHTERS

by

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ABSTRACT

Problems of job and equipment design that contribute to the occupational health and safety of fire fighters is reviewed. The job of fighting fires is physically demanding and most fire fighters do not have a fitness level to minimize the stress. The equipment used by the fire fighters needs to be redesigned to reduce the job related stress.

INTRODUCTION

The occupation of the fire fighter is the most dangerous occupation in the United States. It is more dangerous than mining, although deaths of large groups of fire fighters do not occur in a single fire. Balanoff (1976) reports the causes of death shown in Figure 1. Forty-four and a half percent of the fire fighters deaths are caused by heart attacks at the scene of the fire or shortly after leaving the scene. The large percentage of deaths from heart attacks

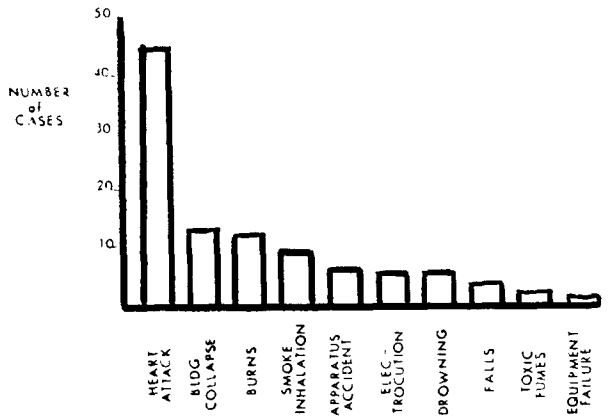


Figure 1. Causes of Death Among Fire Fighters

results from poor physical fittness level of the fire fighter doing a job with equipment and procedures that have not been designed within the capacities of the people performing it.

A seperate study of non-fatal injuries including twenty-one fire departments spread throughout the country (Atwood, 1971) detailed the parts of the body injuried (Table 1) and the types of injuries (Table 2) and the causes of injury (Table 3). Back and hand injuries account for 50% of the injuries tabulated by body part, cuts and sprains account for 67% of injuries tabulated by type, and lifting and pulling and handling tools and equipment account for 42% of the injuries tabulated by cause. These tables suggest that the equipment needs to be redesigned to minimize cuts and sprains caused by using the equipment.

TABLE 1. PARTS OF THE BODY INJURED

	Percent
Back	.29
Hand	.21
Foot	.12
Eye	.12
Knee	9
Leg	9
Wrist	8

TABLE 2. TYPES OF INJURY SUSTAINED

	Percent
Cuts	.39
Sprains	.28
Burns	.20
Smoke Inhalation	3
Miscellaneous	.10

TABLE 3. CAUSES OF INJURIES

	Percent
Lifting & Pulling	.24
Handling Tools & Equipment	.18
Falls	.12
Accident on Way to Fire	7
Falling Objects	6
Building Collapse	6
Handling Hose	5
Ventilating	2
Overhauling	2
Miscellaneous	.18

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This paper will review the job of the fire fighter for problems in the physical conditioning of personnel and for equipment design problems that contribute to the high level of injury and death of fire fighters.

Initial Training of Fire Fighters

The traditional training of fire fighers consists of two areas. First, the technical aspects of fighting fire and secondly, the physical training intended to develop the physical ability of the fire fighter such that they can perform their duties. The techniques of fire fighting include the design features of buildings which facilitate the burning of a fire, the necessity for through searching in the rafter areas, between walls and other areas where fire can exist even after flames are not visible, ventilation techniques, suppression techniques, rescue techniques for victims, and proper use of the various tools associated with the task of fire fighting. The physical training area would include training to increase the physical strength of the person, (the muscle strength of the person), to increase the aerobic capacity of the individual, and finally to increase the flexibility in the various joints of the body. The idea behind the physical training is that the fire fighting job is a physically demanding job which only people in good physical condition are capable of performing. The physical requirements of the job has been the reason used for many years to prevent females from becoming fire fighters simply because it was felt that women were physically incapable of doing many of the tasks required of a fire fighter. Today many of the fire fighting recruits that do not make it through training fail because they are unwilling or incapable of completing the physical training aspect of their training program.

The Job of the Fire Fighter After Training

The job of the fire fighter after training is an interesting contrast to the training given to the fire fighters. Probably less than 10% of the fire fighters' time is actually spent fighting fires and more than 90% of their time is spent eating, sleeping, watching television, washing the fire engine or other activities that require little or no physical conditioning to perform. Although the percentage of time actually spent fighting fires is rather small, when it does occur the fire fighter is required to go from inactivity to full activity in a very short time. The fire fighter is quite likely to be asleep and have to respond very rapidly to a fire alarm and within minutes from being asleep, have to be fully active in an attempt to surpress a fire.

Besides the routine at the fire station which places emphasis upon activities which require no physical conditioning to perform, there is little or no opportunity to maintain physical conditioning while on duty at the fire station. The fire fighter must remain close to the station so that he is capable of responding to an alarm within seconds which eliminates physical conditioning activities such as jogging which takes a person away from the immediate area of the fire station. There is also a reluctance by city government to provide facilities and to permit the firemen to use the facilities that would create the image in the public mind that the fire fighters job is one of a resort type where they spend their time playing games at the taxpayers expense. Therefore, the fire fighters are restricted in the type of games they may play to maintain their physical conditioning level. Additionally, very few fire services require fire fighters to maintain the physical conditioning level obtained during training.

A third factor that contributes to the decline of physical conditioning level of a fire fighter is the promotion scheme used in the fire service. The terminology used to describe the promotion scheme is not universal from one fire service to another but in general they all have basically the same promotion system. The first job for a graduate of the fire academy, who would be in his twenties, would be a fire fighter. This person is the one that is mainly involved in fighting the fire, they are the ones that are working the hoses, carrying out any victims, or doing whatever is required. So these people are physically active at the fire scene. A person who is a good fire fighter would be promoted to a driver, who drives the fire vehicle and operates its controls at the fire scene. This individual will be in his late twenties or perhaps early thirties and is physically inactive at the fire scene since his primary function is to operate the pump and other controls on the fire truck. A good driver will eventually be promoted to captain when he is in his mid to late thirties. The captain is the front line command officer for the fire department and because of this he will again become physically active at the fire scene. Not only does he direct the activities of the fire fighters involved in surpressing the fire but he himself is quite likely to engage in surpressing the fire as well as direct the activities of the other people. A person who is promoted to captain would be in the mid to late thirties and has spent five to ten years as a driver, so not only is age and the decrements in physical capacity that occurs as a person becomes older against the person at this time, but he has spent a number of years on a job where he has not been required to be physically active.

So we have at least three factors that work against the fire fighter in maintaining his physical conditioning level or in a very real sense his ability to perform his job in a safe and healthy fashion, these being the percentage of time actually spent in fighting fires, the

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lack of opportunity and the lack of a requirement to maintain his physical conditioning level and a promotional scheme which further reduces the opportunity for the fire fighter to maintain his conditioning level.

The combined effects of these conditions are shown by the high rate of heart attacks among fire fighters. A study (Ratliff and Hoag, 1978) of fire fighters performing routine tasks shows the value of conditioning programs. Subjects were selected from the fire service of a large city which had a voluntary conditioning program. One group consisted or ordinary fire fighters whose physical fitness level was low, while the second group was drawn from participants in the conditioning program. Figures 2 through 5 present the average heart rate of each group during a four minute period. Notice that the low fitness group has a higher heart rate than the high fitness group. When it is considered that the high fitness group is able to tolerate high heart rates better than the low fitness groups, the significance of the differences is increased.

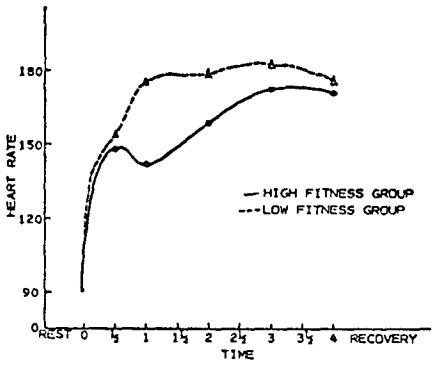


Figure 2. Heart Rate of Fire Fighters Performing Roof Ventilation with Axe.

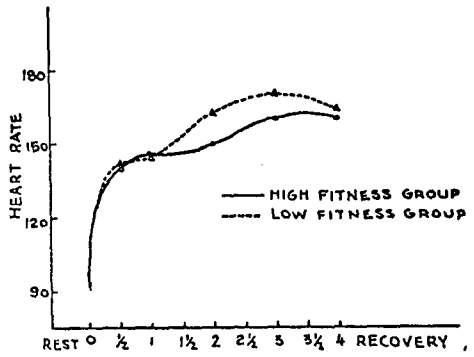


Figure 3. Heart Rate of Fire Fighters Performing Ceiling Pike.

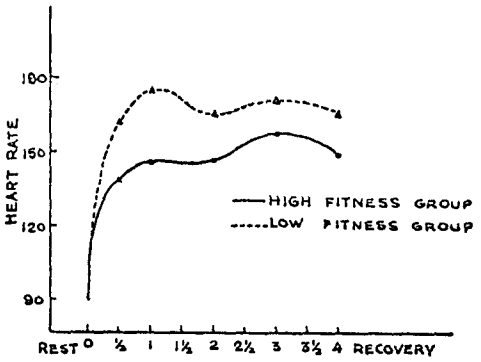


Figure 4. Heart Rate of Fire Fighters Performing Power Saw.

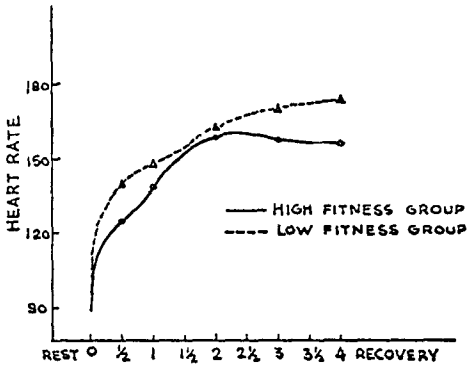


Figure 5. Heart Rate of Fire Fighters Performing Advance Hose.

The Equipment

As all of us has witnessed at fires, fire fighters wear a fire hat designed to protect him from injury due to falling debris, a heavy coat to protect him from the water and the flames plus heavy boots to protect his feet from the water, sharp objects he might step on and from burning. These items are questionable from a protection point of view but that is not our interest here. From a human factors point of view these clothing contribute significantly to the physical stress that the fire fighter is under. The clothing, especially the turn-out coat, is not designed to permit the fire fighter to cool himself by the normal cooling

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functions, primarily perspiration. Because it pervents or at least minimizes heat reduction due to perspiration, the heat stress that a fire fighter finds himself exposed to is considerably greater than what other wise exists. Studies in New York City indicate that the heat stress situation can be severe with temperatures reaching as high as perhaps 400°F with significant radiant heating components associated with them.

Another piece of the equipment which is necessary but can also create substantial problems for the fire fighter is the air pack and respirator used by firemen in situations where the air quality due to high carbon monoxide concentration and smoke is degraded to the point where it is no longer breathable. The primary problem with the respirator is the almost immediate fogging of its lenses which requires the fire fighter to perform his work from instinct more than from visual information he receives. They are also uncomfortable and therefore many fire fighters are reluctant to use the respirators until the last possible moment.

Fire suppression equipment used by the fire fighters (shown in Figure 6) such as the saws, axes, pike poles, hose nozzle, portable generators and fans have never been looked at from a human factors design point of view. For example, let us look at the pike pole which is used by the fire fighters to pull down ceilings and perhaps walls after a fire has been extinguished, but they need to make sure there is no fire between the rafters which might break out after the fire fighters have left the scene. This pike pole, shown in Figure 6, which can be anywhere from ten to twenty feet in length depending upon the type of building, is a long wooden pole with a medal spike and hook at the top. This medal spike and hook is thrust through the ceiling by the fire fighters, twisted and then pulled out of the ceiling with a jerking motion. Because of the length of the pike pole the bending movement on the arms is substantial plus the jerky motion creates high momentary loads on the muscular-skeletal system. Besides the physical stress associated with the pulling down of the ceiling there is substantial debris on the floor and dust and dirt in the air. It would be easy for the fire fighter to trip in the area and poor air quality can create respiratory problems for the fire fighters. It is not uncommon to see a fire fighter using the pike pole without using a respirator. Other tasks such as holding a hose and directing the stream of water on the fire require large static forces to be placed upon the muscles of the fire fighter.

The fire fighter is not free to stop performing his function when he is tired as would be the case in industrial situations, because the surpression of the fire requires that he maintain his function even though excessive fatigue might be developing. Only when the fire fighter feels that his life or his health is in immediate danger due to the task would you see a firemen voluntarily terminating a particular job. It is the function of the captain to relieve fire fighters but the captain is frequently over burdened with directing fire fighters.

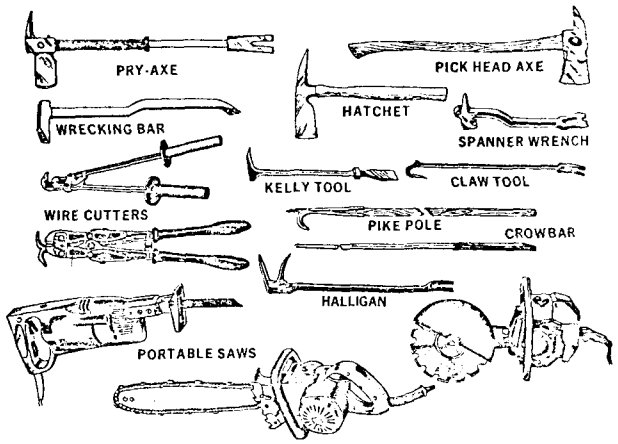


Figure 6. Some of the Tools Used by Fire Fighters.

CONCLUSION

As the cumulative effect of all these factors that have been mentioned we observe that the fire fighter is employed in the occupational group which has the worst health and safety record. The human factors specialist can help solve the problems by applying their skills to designing the job and the equipment as they are doing in the military, aero-space and industrial environments.

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