IV. PRESENT EQUIPMENT, STANDARDS, PROCEDURES, AND TRAINING EVALUATION

Present Equipment

Standard exit and egress facilities include fixed, portable, and job-made ladders, stairways, ramps, and horizontal exits. Vehicle-mounted elevating and rotating work platforms and personnel hoists also can be utilized as means of egress in emergency situations. Additional equipment specifically designed for use as emergency means of egress from height include controlled descent devices, slides, and chutes.

(a) Controlled Descent Devices

Controlled descent devices are manufactured and marketed by several foreign and domestic firms. [13-17] Their basic function is to lower to the ground one person at a time while he is suspended by a line. Common to all is the need for an overhead attachment configuration capable of supporting the weight of the person as well as that of the device, line, harness, etc.

These devices may be used where vertical escape from height is possible. The maximum height from which a person might descend with a controlled descent device is limited by the length of line which is provided for escape. The manufacturer of the unit specifies and makes available the type of line which is suited to the device. The line may be nylon or polyester, solid braid or reinforced with wire.

State and local governmental agencies have approved safety equipment. Design and performance specifications have been established for the approval of certain types of controlled descent devices in the United States by the Underwriters Laboratory. [17] In addition, Japan has also established such specifications and currently requires all such devices to be tested and approved. [18]

One of the descent methods makes use of a device which applies friction to the descent line. [13,14] Attached to the unit is a belt, sling, or "chair" into which the person is firmly buckled. These devices are compact and lightweight--one unit including the descent line is intended to be kept with the worker. In case of an emergency, he first secures the descent line, attaches the unit to the descent line, snaps his suspension attachment into the device, and steps off the structure. By applying hand or finger pressure to the device, additional friction can be transmitted to the line to slow or stop the descent.

Such devices can, in case the worker employs a lifeline, be attached to the lifeline and serve to lower him if he should fall or his equipment should fail.

With another type of controlled descent device, [15-17] the descent line from which the person is suspended drives a system of gears. This gear mechanism imparts a braking action to the line, thereby controlling the rate of descent. The gear unit is attached to a fixed point overhead. In case of an emergency, the worker buckles into a chest sling which is attached to one end of the rope, throws the remaining portion of rope (the "loose" end) to the ground, and steps off the structure.

With this type of controlled descent devices, as one person is descending, another chest sling at the opposite end of the rope is raised. This can provide means of escape for other persons; however, only one person at a time can descend.

One of these units is preset by the manufacturer to lower a person at a rate of about 3 ft/sec. [17] The mechanism of this type of device requires periodic inspection and maintenance, as well as protection from any environmental effects. Design and performance specifications have been established for listing of this type of device by a recognized testing laboratory. [17]

(b) Slides and Chutes

Inflatable slides are installed on passenger aircraft to provide means of egress in times of emergency. [19] However, extensive modification of elevated workstations would be necessary to accommodate installation of the device.

Inflatable slides to abandon ship have been tested successfully by the US Coast Guard [20]; they have also been tested with satisfactory results in evacuation from off-shore oil well drilling platforms 65 feet above the surface of the water. [21]

Slide cables used in combination with an escape seat having a manually controlled braking system are available. [22] This type of device is used for escape from derricks and towers. This device requires prior mounting of both ends of the slide cable and depends on the user's proficiency for safe braking. It has the characteristic of providing an angled escape route from the elevated worksite.

Chutes are available for escape from multistory buildings. [23] They are designed primarily for permanent installation in completed buildings. Certain types, with a permanent anchoring device at ground level, provide an angled escape route from windows. Other types provide controlled vertical descent (without bottom anchoring means) by firmly constricting around the body, thus allowing safe access to the ground.

(c) Helicopters

The wide availability of helicopters operating from fixed base locations [24] throughout the United States, Canada, and Puerto Rico has led to their use as a means of rescue. [25] Such use situations come about when persons are beyond the reach of rescuers with standard fire department or rescue corps equipment.

Recognizing the fact that helicopters are finding increased use in industrial applications where specialized lifting requirements exist, an ANSI subcommittee (B30.12) has been established to develop safety standards for the use of helicopters as a lifting medium. [26]

Present Standards

Subpart E of the OSHA General Industry Standards 29 CFR 1910.35-1910.40 is based entirely on the National Fire Protection Association (NFPA) Life Safety Code. [27] The code deals with life safety from fire and similar emergencies as is stated in Chapter 1, section 1-3. [27] It covers construction protection and occupancy features to minimize danger to life from fire, smoke, fumes, or panic before buildings are evacuated. It specifies the number, size, and arrangement of exit facilities sufficient to permit prompt escape of occupants from buildings or structures in case of fire or other life-threatening conditions.

The principal thrust of the code is to ensure adequate means of egress from occupied buildings of the following types: places of assembly, schools, institutional buildings, residential buildings, stores, offices, industrial buildings, and storage buildings.

Chapter 14, section 14-1, paragraph 14-111, of the Life Safety Code lists the general requirements for egress from occupied industrial buildings. [27] Section 14-1, paragraph 14-1111(d) also outlines egress requirements for open industrial structures and for various types of industrial operations, which are applicable to the problem of egress from elevated workstations. These requirements are for operations conducted in the open air as distinguished from those enclosed within buildings. Such open-air operations are found in oil refining and chemical processing plants. Platforms having a roof or canopy, but no walls, are used for access to outdoor elevated equipment. [27] In section 14-5, paragraph 14-5111, the code recommends that exit facilities shall provide "reasonable safety... in so far as applicable, with due allowance for the increased safety inherent in any open structure where any heat, smoke, or fumes will not be confined by walls or roofs." [27] Examination of this statement leads to the conclusion that requirements in the code relating to worker egress are lacking in specific definitions, making it necessary to employ a significant degree of judgment when attempting to apply these requirements.

The ANSI standard concerning steel erection, A10.13, paragraph 10.1.5, [28] requires that at least one stairway be installed to within four floors or 60 feet, whichever is less, of the uppermost working floor. A tubular steel scaffold with stairs is acceptable as a stairway. This requirement attempts to provide a means of emergency egress; however, it is inadequate for two important reasons: 1) only one stairway is required; should it be blocked in an emergency, no alternate means of egress would exist, and 2) the requirement for installation of the stairway to within four floors or 60 feet of the uppermost level does not provide any requirement for means of egress from the top working floors. Although ladders or personnel hoists are the normal means of access to the top working floors, no requirements are included in the standard to specify minimum numbers of ladders based on employee population at levels above those requiring permanent stairways. Requirement for maximum travel distances between ladders also is not set.

Another consensus standard, ANSI B30.11, section 11-1.8, paragraph 11-1.8.4, [29] requires that means be provided for emergency descent to the ground from monorail and underhung crane cabs. This is the only consensus standard for cranes that requires a means of emergency egress, should the normal means be blocked by fire or other emergency. This standard also specifies physical qualifications for crane operators in recognition of special requirements in section 11-3.1, paragraph 11-3.1.2. [29] It specifies minimum visual acuity, color perception, and hearing performance for acceptability and lists a history of epilepsy or of a disabling heart condition as sufficient reason for operator disqualification.

ANSI B30.2.0 [30] is in apparent disagreement with ANSI B30.11. [29] In addition to the physical qualifications stated in the foregoing, ANSI B30.2.0 recognizes the need for operator trainee visual depth perception, field of vision, reaction time, manual dexterity, coordination, and no tendencies to dizziness. In addition, this standard considers loss of arm, hand, leg, foot, or gross loss of function thereof as causes for denial of acceptance into an entry level training program for crane operators.

Because of the unpredictability of individual behavior under emergency situations, it is difficult to consider all physical, mental, and emotional factors which could adversely affect responses to emergencies. It is, however, predictable that a significant proportion of people who work at high workstations might exhibit degraded responses if they had physical defects, emotional instability, nervous disorders, anxieties, tendency to dizziness, restricted field of vision, poor coordination or depth perception, or the presence of chronic diseases such as arthritis, asthma, emphysema, hypertension, etc. Other considerations include the effects of drugs and medications.

Further, it would be beneficial to determine prior to employment if the employee has an aversion to height or if he is aware of the dangers implicit in working at high workstations. It might also be of value to alert those workers to the relative potential for emergencies which might, in order to secure a means of egress, require of them performances not generally expected in the daily routine of their duties.

The requirements for emergency devices and communications equipment relating to roof powered platforms are found in OSHA standard 29 CFR 1910.66, (c) and (d). Although these requirements provide an alternate means of lowering the platform in the event of normal operating mechanism failure, the degree of reliability and expediency in an emergency situation, such as fire, is questionable. Sending workers to the roof to operate the emergency device may be impossible, or it may subject them to unwarranted danger.

As required in (d) (8) of the above OSHA standard, employees on type T platforms must wear lifelines and safety belts to prevent falls.

Another OSHA standard, 29 CFR 1910.37(n) (1), requires weekly testing of alarm systems where they exist. This, however, ensures operational reliability only and not the effectiveness of employee response to such alarms. Installation of such systems is required by OSHA standard 29 CFR 1910.36(b)(7) in buildings or structures to provide adequate warning for escape. Although this standard requires the employers to conduct orderly fire drills, no requirement is made concerning the frequency of the drills.

OSHA construction standard 29 CFR 1926.501(a) requires that stairways, ladders, or ramps for use during the construction period be provided on all structures of two or more floors (20 feet or over in height). However, no attempt is made to specify minimum numbers of egress means based on employee population and travel distances between the means of egress.

Under the construction standard 29 CFR 1926.150(f) (1), priority must be given to the installation of fire walls and exit stairways. Because of the lack of specific requirements, this standard is open to varying interpretation and judgment.

In addition to the above standards' treatment of the problem of emergency means of egress, there is an additional requirement in 29 CFR 1926.150(e)(1) intended to apprise employees of emergency situations. However, the standard is not definitive in that (1) maximum travel distances to the communication equipment are not established, (2) inspection of the system for continuing reliability is not required, and (3) no evacuation procedures or drills are required to assure that employees will intelligently respond without confusion and panic if an alarm is sounded.

Present Procedures

It is important to determine to what extent industry and labor unions have recognized the high egress problem by installing hardware or requiring formal emergency egress procedures. On the basis of information received from industry, labor unions, and others, it is concluded that very few private employers have recognized the problem of emergency egress for workers in high machinery and structures.

One company concerned with overhead crane operations, (D Van Dyke, written communication, August 1973) provides three methods for emergency egress: (1) An escape rope in the crane cabs; (2) company fire brigade ladders for access to the crane in order to employ a controlled descent device for extricating the employee; and (3) aerial platforms for use in emergency egress situations. Significantly, this company, although it recognizes this potential problem, has no formal written procedures covering worker egress from elevated workstations.

Another company reported that the selection of experienced, well trained, and physically fit iron workers for working at elevated workstations is considered essential. (B Kerns, written communication, August 1973) They also recognize the fact that weather conditions must be carefully evaluated, since winds and slippery surfaces caused by the weather conditions can also significantly increase the hazard potential.

Another corporation has installed controlled descent devices in some of its facilities. (J Ellis, oral communication, October 1973) This was a decision made at one of the corporation's facilities after an appraisal of the potential hazard. In other locations, the corporate representatives considered the problem of no consequence and elected not to make any provisions for emergency egress.

Another corporation [31] acknowledged that crane safety devices can be considered component parts of the cranes. In any case they should be maintained in good condition and replaced or repaired at once if failures occur.

A British steel firm [32] provides "some means of emergency escape from the (crane) cab," in addition to the stairways and walkways which normally provide a means of access.

A US petroleum company, [33] in a series of booklets pointing out process hazards and suggesting ways to correct them, requires escape routes from certain high areas. The company specifically requires at least two exits from all buildings and enclosures (except small storage or equipment areas that are rarely entered by personnel). In addition, stairways and ladders should be located on the outside of structures, and stairways requiring escape traffic to pass through a process equipment structure to get from the end of one stair to the beginning of another must be avoided.

The National Aeronautics and Space Administration has installed slide cables for emergency egress for support workers during launch preparations for space vehicles. (R Herrington, oral communication, December 1973) The system was developed because of the danger associated with rocket fueling operations using nitrogen tetroxide or liquid oxygen, where the effects of an explosion could be fatal to personnel working at or near the rocket. At the height where workers are servicing the vehicle (approximately 300 feet for the Saturn V booster), a cable approximately 1,500 feet in length is attached to the rocket tower and anchored at its opposite end at ground level. At the worker location, a cab is suspended on the cable by a pulley mechanism. In case of an emergency, all personnel would enter the cab at the same time and "ride" it down the cable to ground level. The workers review the alarm signals, which will be used to alert them of the need for emergency egress from the tower, prior to launch preparation.

The need for a cab, rather than an individual means of traveling down the cable, was demonstrated by the results of tests where individuals evacuated the tower by sliding down the cable. It was found that the weight of several persons individually sliding down the cable produced vibrations on the cable or standing waves that caused a danger of loss of the person's grasp; hence, a completely enclosed cab was considered necessary.

The Federal Aviation Administration requires controlled descent devices in air traffic control towers where it is impractical to install a fixed conventional secondary means of egress, such as a steel ladder. [34]

For some time, a large national union organization has been concerned with the problem of worker egress from high machinery and structures in industry. (F Grimes, written communication, July 1973) They have proposed the following revised language to the ANSI B30.2 Committee for Overhead and Gantry Cranes:

> "An emergency means of exit shall be provided from each crane cab to allow the operator to safely and expeditiously remove himself from the cab and descend to a safe area. If it is not practicable to provide safe walkways, ladders, etc., an exit device consisting of an automatic speed-limiting device, permanently installed in or immediately accessible from the cab, shall be used.

"In addition to overhead and gantry type cranes, this regulation shall apply to all employees working on high machinery and structures where secondary means of egress is not provided.

"Rope and rope ladders are prohibited."

Another national union has been concerned with the emergency escape devices and procedures for overhead cranes. (M Glasser, written communication, July 1973) It is their feeling that further research and development work must be performed regarding emergency escape systems.

Present Training Practices and Requirements

(a) Life Safety Code

There are no present standards which specify training requirements for egress from high places. Life Safety Code 1970 NFPA No. 101, [27] suggests fire exit drills for various buildings including mercantile, office, and industrial occupancies. Section 17-8, paragraph 17-8111 states, "In any building subject to occupancy by more than 500 persons or more than 100 persons above or below the street level, employees and supervisory personnel shall be instructed in fire exit drill procedures in accordance with section 17-11 and shall hold practice drills periodically where practicable." Section 17-11, paragraph 17-1113, recommends that drills be held at unexpected times to stimulate the unusual conditions occurring in a fire. [27]

(b) Rescue and Escape Systems from Tall Structures (RESTS)

The RESTS program of NASA, which was designed for evacuation of launch towers, recommends prolonged and concentrated drills on the actual system, in addition to classroom training and periodic surprise drills. Their estimates of total training time includes 8 hours of classroom training and 16 hours of equipment familiarization and practice. The frequency of fire drill type training was to be determined through analysis of performance. [7]

(c) Emergency Reactions

Merely providing means of egress from high places does not guarantee that they will be used effectively, or at all for that matter. There are no adequate statistics available to indicate how many workers have been injured or have died because of ineffective or inappropriate behavior when trapped in high places. In most of those cases where workers have been trapped in crane cabs or on towers, or left hanging from lifelines, the problem has been that there was no means of egress and no really effective action open to the worker. Therefore, human behavior in other similar situations provides the best information available concerning emergency reactions in such cases.

The reactions of humans during fires, especially in tall buildings, may often be inappropriate. Occupants may often choose the route they normally use rather than fire-protected stairways. [2,35] The National Transportation Safety Board reports of aircraft ditchings contain numerous examples of ineffective behavior. In a typical case, in spite of a ten-minute warning of an impending ditching of a DC-9 aircraft, the purser misunderstood the urgency of the situation. Several passengers and stewardesses were still standing, and at least five other passengers did not have their seatbelts fastened at impact. After the ditching, not one of the five 25-man life rafts had been successfully deployed. Twenty-two of the 63 people on board ultimately died when the aircraft sank fifteen minutes after impact. [36] In a study of 43 cases where evacuation was required following accidents to tricycle-landing-gear transport aircraft, it was found that descent devices were used in only seven of the fourteen cases where it was available and should have been used. [37]

Another important behavior pattern which occurs in such situations is inaction. However, Johnson [38] in a paper presented in 1969 indicated that his search of the literature led him to the conclusion that no experimental study had been performed aimed primarily at determining what precedes or causes inaction, under what conditions it occurs, who is likely to manifest it, or how it can be controlled.

These facts point out that, in spite of the availability of physical means of egress, these are frequently not used to their full potential, as a consequence of which there have been needless injuries and deaths. One way to improve the likelihood of appropriate action is through proper human factors design of egress methods. In the development of egress procedures, human behavior patterns should be considered so that the procedures are as easy to follow or operate as possible. Where this is not possible, the only way to provide any assurance that emergency egress paths and equipment will be used effectively is through training.

There apparently have not been any controlled studies dealing with the specific problem of training for emergency egress. Studies of aircraft evacuations come the closest in terms of overall applicability. Evacuations of buildings during fires have only been reported on a case-by-case basis and sometimes only through newspapers. Information must be drawn from related fields in a piecemeal fashion.

(d) Training Elements

Emergency egress actually involves a number of elements, all of which should be considered in the development of training guidelines. These can be summarized as follows:

(1) Perception of the emergency situation.

(2) Recall of information relative to appropriate action.

(3) Choice of the correct action.

(4) Performance of the chosen action.

The presence of an emergency situation means that the worker will be operating under some degree of psychological or physical stress.

(1) Perception of the emergency situation

Appropriate perception will require some degree of training. For a number of reasons, workers may not know of the emergency situation until it is too late. Where emergency alarm systems are used, it is necessary that workers be able to hear the signal and then know what it means. In many cases, the ambient noise level, some types of hearing protectors, or the remote location of the work station may prevent the worker from perceiving the warning signal.

In these cases, the worker must be trained to detect emergency conditions through his own senses. This training should include apprisal by the employer of possible hazards which might create an emergency condition. Even if warning signals appear to be adequate in terms of their sensory input, they may not be responded to properly under emergency conditions. It is obvious that if the worker does not know what the warning signal means he will probably not respond properly. Seeing others responding correctly will not necessarily produce correct actions. In the aircraft ditching reported earlier, [36] in spite of the pilot's warning to fasten seatbelts, over 10% of the passengers did not do so.

Hoffler et al [39] have reported the results of an experiment in which subjects were instructed to don an oxygen mask upon decompression of the room. In spite of a loud warning tone (which they were informed would precede decompression), the noise of escaping air, and condensation in the room, 4% of the subjects never indicated appropriate recognition of the emergency condition. Davis [40] cited numerous examples of train wrecks in which engineers should have known the meaning of signals, but for some reason failed to respond. He concluded that, if a signal is to be perceived correctly, its strength, duration, or insistence has to be much greater than expected. Where this is not feasible, training must be intensive enough to overcome this inadequacy. This type of training is probably the most significant element in smaller buildings where egress is through nearby doors which lead directly out of the building. In these cases, the means of egress is probably the same in emergencies as it is during normal conditions.

(2) Recall of information relative to appropriate action

The second element involves recall of information relative to appropriate action. Although lack of recall may take place with the passage of time unless practice (ie, reinforcement) intervenes, it is difficult to predict the rate and amount of loss of retention of a given task. These rates of loss of retention are always specific to the task. The one principle more important than any other is that the amount of retention depends on the level of proficiency achieved during initial learning. [41-43] At one extreme, studies have shown that the reading of instruction sheets is very ineffective.

Berkun [44] had young men in basic training read an instruction manual on ditching before they were taken up in an airplane. An emergency situation was then simulated and subjects were asked to recall the instructions on ditching procedures. An average of only 4.9 out of 12 answers were correctly recalled under these stressful conditions. A nonstressed control group recalled 7.6 out of 12 correctly. This was after an interval of less than one hour following the reading of instructions.

Johnson and Altman [45] conducted an experiment to find out the value of instruction cards on airline passenger behavior during a simulated evacuation. Sixty percent of the subjects who were given no instruction card jumped onto the escape slide while 40% sat down on the slide. Use of instruction cards which emphasized jumping raised the percentage to 73.5%. All the subjects read the cards instructing them to jump. Nevertheless, many failed to jump. Therefore, they either did not understand the instructions, forgot within a few minutes, or consciously elected not to comply with the instructions.

Simple demonstrations have also proved to be ineffective on occasion. Johnson [46] demonstrated the donning of a lifejacket before a group of subjects and then evaluated their performance of the same action. Although 38% of those in a control group which did not witness the demonstration were able to don the jacket correctly, only 52% of the instructed subjects were able to do it correctly. However, the demonstration did result in a 45% timesaving for those who were able to do it correctly. The fact that only 38% and 52% in the two groups were able to correctly don the jacket is particularly discouraging since the jackets used were designed to conform to Technical Standard Order C 72-A which stated in Section 4.1.1 that the device "...must be simple and obvious thereby making its purpose and actual use immediately evident to the user." It also stated in Section 2.1 that where something is "...not obvious to the user, clearly worded instructions must be provided." [47] There were instructions on the jackets used. These findings are supported by evidence from actual ditchings. [48]

Another study reported that the typical demonstrations of emergency oxygen equipment given on commercial aircraft were frequently ineffective. As many as 15% failed to put on the mask and over 50% did it incorrectly in an experimental situation. [49] The conclusion from these studies supports the concept that demonstrations and instructions need reinforcement, eg, by drills or practice to be effective even in relatively simple procedures.

Well-learned instructions generally will be retained for longer periods of time. Davis and Moore [50] compiled the results of 24 studies involving the retention of meaningful material. The results indicated that retention leveled off at about 60% after approximately 90 days. Nearly all of the loss occurred within the first 20 days. There is insufficient research information to indicate what part of the learned material would be retained over the longer period. Depending upon what is lost and what is retained, a 60% retention level might be far from adequate, especially when there might be additional lack of recall due to stress. None of the Davis and Moore studies were conducted under stressful conditions.

(3) Choice of correct action

The third element involved in evaluating training requirements is the choice of the correct action or the decision making process. In emergency egress situations this process is usually limited to deciding whether the emergency requires escape, and, if so, by what means of egress. Although these seem to be rather simple decisions under normal conditions, under the stress of an emergency they may often be wrong. Improper decisions are made for a number of reasons. Stress may cause a person to perceive things differently than they are in reality. Preoccupation may result in a misinterpretation of the seriousness or urgency of the situation. Or, normal emergency reactions may distort logical reasoning. Thus, the correct decision involved in securing a seatbelt in the face of an impending ditching seems rather obvious, and yet in one study [48] several passengers were standing and others did not fasten their seatbelts in the DC-9 aircraft ditching reported previously. Reports from survivors indicated that some people did not believe the emergency was real.

In a series of studies of psychological stress in man, Berkun et al [51] reported that subjects who had been led to believe that they were in danger from an artillery attack (explosions were set off around their post) were told that they would be rescued if they could repair their radio and indicate their position. In spite of these instructions, 10 out of 24 chose to abandon their post and escape on their own. Five of these subjects reported, incorrectly, that they had been told to leave. In another case where the danger was due to fire, 2 of 13 escaped; when the hazard was radiation, 3 of 26 left after a period of time. These decisions were based on the subjects' evaluations of the seriousness of the situation and on their judgment of the type of action most appropriate at that time.

These results indicate that people might make inappropriate decisions especially where instruction has been inadequate. For example, when a man is being instructed that he should use a particular door, he should also be told which doors cannot be used and why, eg, fire doors which close automatically. Likewise, the nature and seriousness of possible hazards must be explained to increase the likelihood of proper emergency action. For example, the urgency of escape from radiation exposure is not obvious to the senses, thus workers looking around for a fire or for another obvious sign may decide that the alarm is false. Berkun et al [51] reported that approximately half of the subjects interviewed minimized the seriousness of the situation. All their experiments were conducted with "green" soldiers in their first four weeks of basic training. Troops with more experience (6 months to 6 years) performed more rationally under all conditions.

(4) Performance of the chosen action

The fourth element relates to the manner in which the emergency behavior is carried out. Assuming the worker has initiated the appropriate action, the question is how effectively can he perform. The level of performance of a particular skill depends on the difficulty of the task, the extent of training, or practice, the type of training, the interval since the last training, and on various external factors. In most cases, it is difficult to determine whether the level of mental skill, motor skill, or perceptual-motor skill is a limiting factor in performance. Since learning is oriented to specific tasks, it is difficult to generalize on the relative efficiency of the acquisition of skills at these different levels. However, it is generally held that motor and perceptual-motor skills are retained much longer than mental skills. [41-43] Therefore, in tasks involving a significant amount of procedural behavior as well as perceptual-motor behavior, the retention of procedural skill is probably the limiting factor. [52,53] Wherever possible, therefore, procedural aspects should be minimized.

Motor skills, such as riding a bicycle, are generally considered to be well retained. [41-43] The method of measuring retention in most cases has been to determine the time saved in relearning a task. This criterion is important in terms of determining the quantity and frequency of retraining required to maintain a desired level of skill. However, a high level of motor skill does not help if the action being taken is an erroneous response to the emergency. Experimental studies [41] have indicated a fairly substantial decrease in performance with time elapsed since training. However, this decrease in performance is overcome within the first few minutes or by trials of practice. Under emergency conditions, however, there is usually no second chance, so the initial response must be adequate. In an emergency, the worker will not have a chance to practice his skills on the descent device before using it. Further, there may be no one around to correct an erroneous decision of a worker whose first impulse has led him to the wrong exit. Fleishman and Parker [41] reported "the retention of proficiency in a complex, continuous control, perceptual-motor skill is extremely high, even for no-practice intervals up to 24 mo." However, an examination of subjects' initial responses indicate decreases of 50% for a 9-month interval and 67% for 24 months. Ammons et al [43] reported retention of initial performance levels of 75% after 1 month, 50% after 6 months, and 31% after 1 year. None of these studies involved retention under stress. 3

Training in the fire service is quite similar to maintenance of emergency egress behavior in that the safety and success of the operation depend critically on speed and require maximum performance. Skills are used at infrequent intervals, but when needed, actions must be performed at a high level of proficiency often under situations of extreme stress. In spite of the critical nature of this training, there is only one known controlled study [52] concerning required training intervals. In that study, firefighters were trained on a novel task closely related to their normal duties. This experiment showed that skill deteriorated significantly within 1-4 months from lack of practice. After 1 month, the time required to complete the task increased by 50%, after 2 months by 84%, after 3 months by 91%, and after 4 months by 100%. Performance ratings decreased by 31% within 1 month.

This study [52] indicates that performance on emergency egress procedures involving perceptual-motor skills, such as operating emergency descent devices or even using ladders, can deteriorate to unacceptable levels within a few months.

(A) Performance under stress

Emergency egress by its very nature means there will be some degree of psychological stress involved. Aside from the fact that stress, such as life-threatening situations, may result in inappropriate behavior, there is ample evidence [54] that it also causes decrease in performance. But where speed of movement is the only action required, such as in a "turn and flee" reaction, the stress may increase arousal and motivation levels resulting in a better performance. In most other situations, stress will be detrimental. Berkun [44] found a 10% decrement in cognitive verbal behavior and a 33% drop in performance on a radio repairing task when subjects thought they were exposed to some form of physical danger. Another group who thought they had injured someone demonstrated an 18% decrement in performance. It is significant that both experienced subjects and better performers were less affected by stress. Hammerton and Tickner [54] also suggested that training apparently could reduce the effects of stress. Based on a laboratory study of performance under stress, Pronko and Leith [55] concluded that the "least behavioral disintegration occurred when (subjects) were prepared with adequate reactions for a possible emergency." Preparation in this study involved pretraining on the task.

(B) Environmental stress factors

Other factors which have been shown [56] to have an effect on performance and which might be encountered in the workplace are: heat, cold, decompression, vibration, noise, poor visibility, and air contaminants. A rise in body temperature to only 99.1 F may impair performance; cold affects hands and dexterity, resulting in noticeable decrements in performance; hypoxia caused by decompression can also affect performance adversely, especially on unfamiliar tasks; vibration produces decrements in visual perception and precise hand movement. [56] Noise may affect performance by interfering with communications. Finally, some types of toxic contaminants in the air may impair behavior in a variety of ways depending upon the type and concentration.

The most important factor in improving retention and reducing effects of stress is the initial level of learning. [41,42,43,53]

Overlearning, ie, practice after success has been achieved, results in longer and better retention especially on procedural skills. Goldstein [57] has pointed out that overlearning involves learning to such an extent that decision making becomes unnecessary. This increases the likelihood that appropriate task performance of emergency procedures will occur under stressful conditions. Consequently, the time required to relearn is substantially reduced.

(e) Scope of Training

The scope and extent of initial training should be based on the type of hazard and the method of egress. The type of hazard will dictate:

(1) Whether speed is essential.

(2) The likelihood that workers may sustain injury before or during egress.

(3) The likelihood that alternative means of egress may be necessary.

(4) Whether protective clothing will be worn.

(5) If external factors such as darkness, heat, chemicals, smoke, etc, will impede egress.

(6) The consequences of mistakes.

The method of egress will determine:

(1) Whether workers are protected from hazards during egress.

(2) The possibility of failure or malfunction of the egress route or device.

(3) The speed of egress.

(4) Whether injury or disablement will affect the use of the means of egress.

(5) Whether individuals will be dependent upon the cooperation of others in the use of the means of egress.

(6) The consequence of poor performance.

Because of individual differences, training should be based on success rather than mere numbers of sessions or amount of time. Since there is no substitute for actual hands-on practice, initial training should, at some stage, include practice on the actual means of egress. Where standard means of egress are used, they should present no problems except perhaps for ladders. Where special means of egress, such as controlled descent devices, are used, additional problems may arise especially when the height is considerable. The training and practice may present a hazard in and of itself. First of all, the possibility of apparatus malfunction must always be considered. Secondly, the consequences of mistakes may be serious. Training on the means of egress should not create a greater hazard than originally existed. One manufacturer of a controlled descent device has recommended raising the device and worker up a few feet off the ground with a crane and then releasing them. (J Ellis, written communication, October 1974) This would substantially reduce the probability of injury but should not constitute a complete training program. The worker must be trained to set up and secure the apparatus and lower himself. Although most people who work at elevated workstations are probably not acrophobic, lowering themselves on a controlled descent device or ladder can still be traumatic. Training should include at least one descent from the workstation since it has been shown [58] that this type of fear, ie, acrophobia, is some function of height, and willingness to drop from a particular height does not guarantee an equal willingness to do so from a greater height. A net or lifeline should be used during training as it will reduce the chances of injury.