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EMERGENCY EGRESS FROM ELEVATED WORKSTATIONS

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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Center for Disease Control
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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. The National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices, to provide relevant data from which valid criteria for effective standards can be derived. Recommended standards for the control of occupational hazards, which are the result of this work, are based on the best available information. The Secretary of Labor will weigh these recommendations along with other considerations such as feasibility and means of implementation in developing regulatory standards.

It is intended to present successive reports as research and epidemiologic studies are completed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on emergency egress from elevated workstations by members of my staff, the valuable constructive comments by the Review Consultants on Recommendations for Emergency Egress from Elevated Workstations, by the ad hoc committee of the American Society of Safety Engineers, and by Robert B. O'Connor, NIOSH Consultant in Occupational Medicine. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies that reviewed this criteria document on recommendations for emergency egress from elevated workstations. Lists of the NIOSH Review Committee members and of the Review Consultants appear on the following pages.

John F. Finklea, MD

John F. Finklea, M.D.
Director, National Institute for
Occupational Safety and Health

The Office of Research and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and recommended standard for emergency egress from elevated workstations. The National Loss Control Service Corporation developed the basic information for consideration by NIOSH staff and consultants under contract No. HSM-99-73-79. Robert H. Arndt, Ph.D., School for Workers, University of Wisconsin, developed most of the information for the training portion of the document. Maurice Georgevich had NIOSH program responsibility and served as criteria manager.

REVIEW COMMITTEE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

Alfred C. Blackman, C.S.P.
Assistant Director for Safety

Bobby F. Craft, Ph.D.
Deputy Associate Director for Programs
Cincinnati Operations

Joseph R. Dixon
Office of the Assistant Director for Safety

Edgar F. Seagle, Dr. P.H.
Division of Occupational Health Programs

James B. Walters
Division of Technical Services

Department of Labor Liaison:

Robert Mahon, C.S.P.
Office of the Deputy Assistant Secretary

Richard Sauger
Office of Standards

NIOSH REVIEW CONSULTANTS ON RECOMMENDATIONS FOR EMERGENCY EGRESS FROM ELEVATED WORKSTATIONS

Marion L. Jones, P.E., C.S.P.
Director, Division of Occupational
Safety and Health
Texas State Department of Health
Austin, Texas 78756

Vincent Pollina, C.S.P.
Corporate Director, Safety and Security
A.O. Smith Corporation
Milwaukee, Wisconsin 53201

John B. Silaz, III, C.S.P.
Manager, Corporate Safety
The Coca Cola Company
Atlanta, Georgia 30301

Erwin R. Tichauer, Sc.D.
Director, Division of Biomechanics
New York Medical Center
New York, New York 10016

James E. Wolfe
Director, Research and Education
International Molders and Allied Workers Union
Cincinnati, Ohio 45206

CRITERIA DOCUMENT: RECOMMENDATIONS FOR A STANDARD FOR EMERGENCY EGRESS FROM ELEVATED WORKSTATIONS

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I. RECOMMENDATIONS FOR A STANDARD FOR EMERGENCY EGRESS FROM ELEVATED WORKSTATIONS

The National Institute for Occupational Safety and Health (NIOSH) recommends procedures and equipment for worker emergency egress from elevated workstations as set forth in the following sections. The standard is designed to assure workers of the availability of a means of emergency egress during situations in which there could be a threat to life, health, or safety.

Compliance with the standard should therefore prevent bodily injury or death resulting from: (1) unavailability or insufficient capacity of egress facilities; (2) unfamiliarity with emergency procedures and egress facilities; (3) inadequate identification and illumination of egress facilities; (4) lack of awareness of an imminent danger or present emergency; and (5) physical or medical conditions which adversely affect the worker's ability to make effective use of egress facilities.

Sufficient equipment and knowledge of its proper use exist to permit compliance with the recommended standard.

Section 1 - Definitions

(a) Approved: Listed or approved by the appropriate state or local government or by a nationally recognized testing laboratory such as Underwriters Laboratory.

(b) Occupancy Load: The total number of persons that may legally occupy a workstation at any one time.

(c) Unit of Exit Width: Each 22-inch wide segment of a standard means of exit. For purposes of this standard, fixed, portable, or job-made ladders of standard construction shall constitute one unit of exit width. Requirements for standard means of egress are expressed in units of exit width and are determined according to occupancy load.

(d) Workstation: Any place to which an employee is assigned either on a regular, temporary, or occasional basis for the purpose of completing an assigned task.

(e) Open Structures: Buildings under construction and operations conducted in the open air such as those often found in oil refining and chemical processing plants where platforms, sometimes having roofs or canopies but no walls, are used for access to outdoor elevated equipment.

Section 2 - <u>Means of Egress</u>

(a) For purposes of this standard, means of egress is defined as a method of access to a separate area that is safe or leads to a safe place.

(b) Means of egress shall be classified as standard or special.

(1) Standard means of egress:

(A) Stairways

(B) Fixed industrial stairs meeting the requirements of 29 Code of Federal Regulations (CFR) 1910.24 or 1926.501.

(C) Ramps meeting the requirements of 29 CFR 1910.23 or 1926.500.

(D) Horizontal exits, such as doorways and walkways.

(E) Fixed ladders meeting the requirements of 29 CFR 1910.27 or 1926.450.

(F) Portable ladders meeting the requirements of 29 CFR 1910.25, 1910.26, or 1926.450.

(G) Job-made ladders meeting the requirements of 29 CFR 1910.25 or 1926.450(b).

(2) Special means of egress:

(A) Approved controlled descent devices, slides, and chutes.

(B) Vehicle-mounted elevated and rotating work platforms meeting the requirements of 29 CFR 1910.67.

(C) Scaffold stair towers meeting the requirements of 29 CFR 1910.29(c).

(D) Personnel hoists meeting the requirements of 29 CFR 1926.552. Such personnel hoists shall have an immediately available auxiliary source of operating power in the event the normal electrical power is interrupted.

Section 3 - Environment

(a) Height of Workstation

(1) These requirements apply to all workstations occupied by one or more employees for purposes of working at heights of 15 feet or more above floor or grade level, or at any elevated workstation where normal egress may be impeded by the consequences of a highly hazardous situation. (Examples of elevated workstations are maintenance platforms, elevated storage tanks, and crane cabs. Examples of highly hazardous situations are the presence or use of flammable, highly reactive, or toxic chemicals.)

(2) Additional requirements apply when the workstation is 80 feet or more above floor or grade level. (Examples include structural steel erection, television tower construction and maintenace, bridge painting, and water tower construction and maintenance.)

(b) Workplace Hazard Classifications

(1) Low Hazard Situation: Situations where there is not a reasonable probability that danger to life, health, or safety may suddenly develop.

(2) High Hazard Situation: Situations where there is a reasonable probability that danger to life, health, or safety may suddenly develop.

(c) General Requirements

(1) Every workstation or open structure 15 feet or more above the permanent or temporary floor or ground level, in a low hazard situation that is designed for an occupancy load of 10 employees or more, shall be provided with at least two means of egress. (Examples of such workstations include maintenance platforms and elevated storage tanks.)

(2) Every elevated workstation above the permanent or temporary floor or ground level, in a high hazard workplace where egress may be impeded by obstructions, shall be provided with at least two means of egress without regard to the minimum number of employees occupying the workstation.

(3) Egress facilities must be available and useable at all times in buildings under construction. Such egress facilities shall consist of doorways, walkways, and items listed in Section 2 - Means of Egress. The capacity of the combined means of egress shall be sufficient

for the occupancy load, but in no instance shall there be less than 2 means of egress remote from one another.

(4) The capacity of a unit of exit width shall be as follows:

(A) Standard egress facilities (as listed in Section 2 - Means of Egress, paragraph b, items 1, A-G).

(i) Stairways--One unit for each 60 persons.

(ii) Ramps--One unit for each 60 persons.

(iii) Horizontal exits--One unit for each 100 persons.

(iv) Ladders (standard fixed, job-made, or portable)--One unit for each 15 persons (Note--A standard fixed, job-made, or portable ladder conforming to applicable standards will be considered as one unit of exit width.)

(B) Special egress facilities (as listed in Section 2 - Means of Egress, paragraph b, items 2, A-D). Special devices shall be installed by the employer only after evaluation of the workplace egress needs, with due consideration to the capacity limitations of such devices.

(5) Emergency egress facilities shall be positioned as far from each other as practicable provided that they are so arranged that travel of more than 100 feet from any point to the nearest means of emergency egress will not be necessary, except in high hazard situations where travel distances shall not exceed 75 feet.

(6) On every workstation of such size, arrangement, or occupancy that a fire or other emergency may not in itself provide adequate warning to the workers who may be occupying the workstation, emergency

alarm facilities shall be provided as necessary to warn workers of the existence of fire or other emergency so that they may escape, or to facilitate the orderly conduct of egress drills. Where employees are required to work alone and away from direct contact with supervisory personnel or other employees, a reliable means of warning shall be provided, eg, two-way radios, telephones, "intercoms," or alarms.

Section 4 - Medical

(a) All employees shall have made available to them preplacement medical examinations. These examinations shall include medical and occupational histories.

(b) For those employees working at heights of 15 ft or more, but less than 80 ft, these examinations shall include observations of depth perception, fields of vision, reaction time, manual dexterity, coordination, and any abnormal tendencies toward dizziness.

(c) Preplacement examinations for employees working at elevated workstations of 80 ft or more above grade shall also include:

(1) Tests of visual acuity to ensure at least 20/30 Snellen (or equivalent) in one eye, and 20/50 in the other, if necessary with corrective lenses. Tests of color perception to ensure ability to distinguish those hazards or warning signals applicable to the job.

(2) Tests of hearing, with or without hearing aids, to ensure at least 15/20 for ordinary conversation in one ear, or alternatively, a hearing loss of not more than 20 db in the normally tested frequencies.

(3) Observations of strength, endurance, agility, coordination, and speed of reaction sufficient to meet the demands of the work or operation, as applicable.

(4) Evidence of other defects, such as cardiovascular disease, epilepsy, diabetes, or emotional instability which could render the employee a hazard to himself or others in an emergency situation.

(d) The medical requirements of this recommended standard do not apply to employees working in buildings under construction where the workstation is enclosed by the exterior building walls and where the permanent floors have been installed, even though the workstations may be at or above the 15-foot outside grade level.

(e) These examinations shall be reviewed yearly and repeated at a frequency determined by the responsible physician in order to provide the worker with current evidence of physical ability to perform the job safely and meet the requirements of egress.

(f) The employer shall ensure that pertinent medical records are maintained and are available for review during the term of employment. These records shall be available to the medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, of the employee, and of the employer.

Section 5 - Posting

(a) Instructions for proper use of any special devices used for emergency egress shall be prominently posted in all workstations subject to this standard.

(b) Instructions for evacuation procedures established by the employer shall be posted in places readily accessible to employees, in each work area subject to this standard.

(c) Instructions shall be printed in English. They shall also be printed in the predominant language of non-English-speaking workers, if any, unless these workers are otherwise informed. All illiterate workers also shall be so informed.

(d) Each path of escape from the work area to a place of safety shall be so arranged or marked that the route is unmistakable. Arrows pointing to exit routes or "Exit" signs may be used for this purpose.

(e) The minimum level of illumination along the entire path of egress shall be not less than 5 foot-candles (preferably 10-15 foot-candles) with provision to maintain this level in the event of power failure.

Section 6 - Apprisal of Employees of Hazards Associated with Elevated Workstations

All employees who work at an elevated workstation as defined in this standard shall be instructed and kept informed by their employer with respect to their duties in the event of emergency situations. Their attention shall be directed to placards (see Section 5 - Posting) and they shall be properly trained in means of escape (see Section 7 - Work Practices).

Section 7 - Work Practices

(a) Emergency procedures shall be developed by the employer and made available in written form to the immediate supervisor for implementation. This plan shall include the company policy statement regarding emergency plans, a description of warning and communications procedures, diagrams showing emergency egress routes, and a list of available emergency equipment. This plan of emergency procedures shall be reviewed and, if appropriate, updated when changing conditions within the workplace limit the effectiveness of the plan, but in no case less than annually.

(b) All employees who work in locations covered by this standard shall be trained according to the following rules:

(1) All employees who work on a regular, temporary, or occasional basis shall be trained in the use of required means of emergency egress. Training shall not be considered complete until the supervisor or other employer-designated official (eg, safety or training officer) judges that an acceptable degree of proficiency in the use of the means of egress from the high workstation has been attained. The trainee's judgment of the adequacy of his training should be properly considered.

(2) Initial training shall be conducted prior to assignment to the workstation. This training shall include:

(A) Apprisal of the type and severity of recognized hazards which may produce emergency situations.

(B) An explanation of the means of detecting the presence of an emergency, including alarm systems.

(C) Training in the use of any other protective equipment, such as respirators, which may be required during egress.

(3) Each individual covered by this standard shall participate in training drills designed to maintain proficiency at intervals no longer than three months or at another interval determined by the judgment of a professional safety engineer.

(4) All training shall be designed and conducted in such a way as not to create an unnecessary hazard. Where the nature of egress might create a falling hazard, training shall be conducted with the same means of egress but at heights lower than 10 feet or with a lifeline attached to the employee.

(5) Where feasible, initial training shall include use of the special egress procedures and equipment. Periodic training shall also include use of such procedures and equipment.

Section 8 - Preventive Maintenance, Inspection, and Recordkeeping Requirements

(a) All egress facilities shall be inspected and maintained as often as is necessary to ensure that they are clearly accessible and in proper operating condition. Such inspections shall consider weather, exposure to corrosive atmospheres, and other adverse conditions which could affect the operation of the equipment.

(b) All alarm and communication systems and components shall be tested as often as is necessary to ensure that they are in reliable operating condition.

(c) The employer shall maintain a written record of all training including drills, inspections, tests, and maintenance required. The records shall be retained for a period of three years from the date of training, inspection, test, or maintenance. These records shall be available to the authorized representatives of the Secretary of Labor and of the Secretary of Health, Education, and Welfare.

II. INTRODUCTION

This report presents the criteria and the recommended standard to meet the need for safety procedures and equipment for emergency egress from elevated workstations. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare, under Section 21(c)(1) of the Occupational Safety and Health Act of 1970 to "...develop and establish recommended occupational safety and health standards."

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultation with others, developed criteria upon which standards can be established to protect the safety of workers from exposure to hazards. The recommended criteria for a standard should enable management and labor to develop better engineering controls resulting in safer work practices, but they should not be used as a final goal.

These criteria for a standard are a part of a continuing series of criteria developed by NIOSH. The proposed standard applies only to emergency egress from elevated workstations as applicable under the Occupational Safety and Health Act of 1970.

The criteria are based on a comprehensive survey and evaluation of current regulations from the following:

(1) Occupational Safety and Health Administration.

(2) American National Standards Institute.

(3) National Fire Protection Association.

(4) Federal Aviation Administration.

(5) California Safety Orders.

(6) Japan Fire Regulations.

Additionally, a literature search was conducted in order to review the technology pertaining to human escape from elevated areas, including those involving industrial areas and buildings under construction.

III. EFFECTS OF EXPOSURE

Extent of Exposure

An emergency egress situation is one in which the usual means of egress, for one or more workers, has been blocked or eliminated, and there is a need for prompt escape, because of a work accident, fire or explosion, power shutdown or other disaster. As will be developed later in this document, egress is normally a problem at elevations of over 15 feet.

From data taken from the 1970 census of the United States, it is estimated that approximately 2.4 million workers could be working, on an occasional or regular basis, at a height of over 15 feet or more above the grade or floor level. The census data are summarized in Table VII. [1]

While the number of individuals who work at elevated workstations is important in determining the extent of exposure, it is also important to determine the frequency of occurrence of high egress emergency situations. Statistical data to identify such occurrences are not reliable because many high egress emergency situations have been described as "falls" or "burns." For example, a crane operator burned in his cab due to lack of egress has a "burn" injury, while one who jumps has a "fall." [2] Newspaper articles often relate events concerned with workers falling from heights [3,4]; however, they fail to give details covering the emergency situation which the workmen faced.

Historical Reports

In 1783 Sebastian Lenormand made a descent from the top of an observatory in France. Using an umbrella-like device, he landed safely and regarded the apparatus as a new means of escaping from fires in tall buildings. [5] De Haven [6] in 1942 reported eight cases where adult men and women survived after jumping or falling from heights of between 55 and 146 feet. Although this report examined bodily injuries due to falls, ie, the mechanical and physical laws interacting between the human body and the impact medium, its importance relates primarily to efforts to reduce injury resulting from impact and not to providing alternate means of egress from an elevated workstation.

Since World War II, US Army parachute training injuries at Fort Benning, Georgia, have been closely followed. [5] The injury rate has been consistently below 1%. However, the data are of little applicability, because practice jumps from heights offering any potential for significant injury are made with harness-suspension and descent devices. Thus, the use of these built-in safety measures are not representative of the type of emergency situation faced by workers where an alternate means of egress from an elevated workstation is required.

Effects on Humans

Very little research, if any, has been conducted in the area of the psychological stress on humans during the need for emergency egress from high workstations, according to a written communication from M Wilson, American Psychological Association, December 1973.

A "threat-to-life" psychological stress test situation was described, however, in the final report of a research project conducted for the National Aeronautics and Space Administration by the Martin Marietta Corporation. [7] The results of the tests indicate that persons under stress could experience a loss of operational efficiency of up to 34 %. Additional statistics cited in the report show that under emergency situations, 10 times as many men as normal may be required to operate equipment with which the men are familiar. Analysis of these data indicated that psychological stress during emergencies may lower operating efficiency within a group by as much as 90%.

This report concluded that, as a result of the breakdown of reasoning and decision-making processes during emergencies, the following items should be made an essential part of egress systems:

(1) A minimum of decision-making should be required on the part of the user.

(2) The egress procedure should be as simple as possible.

(3) The egress procedure sequence should be as close as possible to commonly used procedures.

Three recommendations in the report [7] also are of prime interest in the development of egress systems.

(1) The system should be reliable, safe, and fast.

(2) The system should be simple to operate.

(3) The personnel who will use the system should have extensive training in its use.

There is also a lack of published data documenting the physical effects on the human body of jumping or falling from high machinery or structures in industry. (Written communications from A Harrison, National Technical Information Service, US Department of Commerce, and from IJ Bhambri, Smithsonian Science Information Exchange Inc, 1973)

Swearingen et al [8] tested the maximum gravitational force (G-force) the human body could tolerate while in various positions when subjected to vertical impact. A total of 500 test drops were made with 13 volunteers in a specially constructed drop mechanism. G-force tolerance was determined by progressively increasing the impact loadings to the point where subjects complained of severe pain.

Some of the test drops were conducted with the volunteers in a standing position with knees bent slightly, allowing the trunk, head, and arms to sustain less severe impacts. This is the position that would be assumed in reaching grade level after jumping from height during an emergency. However, because the construction of the test mechanism limited the height from which test drops could be made, it was impossible to determine maximum G-force impact tolerances with the body in this position.

Because the study concerned only G-force tolerance, it failed to include sufficient data to extrapolate the heights from which the drops were made. Moreover, those tests which did establish maximum G-force tolerances were conducted with the body seated in a rigid chair, seated in a chair containing shock-absorbing material, standing with knees locked, or squatting with knees fully flexed. These positions could not realistically be expected in case of voluntary jumping from heights.

Of significance, however, is the fact that this study demonstrates a feasible method of determining the heights from which a person could jump without injury.

Injury data from the states of California, [9] Florida, [10] New York, [11] and Pennsylvania, [12] although reflecting reliable recordkeeping, are inadequately classified to allow identifying the number of injuries from emergency egress. For example, California includes in "falls or slips from elevation," [9] falls by workers from loading docks, slightly elevated platforms, vehicles, down steps, etc.

Florida includes in its accident data "falls to a different level" covering 1967 through 1972. [10] Included are scaffold falls, falls from walkways and platforms, falls into excavations, shafts, floor openings, and falls from roofs and wall openings. There is no information relating these injuries to the lack of emergency egress facilities.

As with California and Florida, data from New York and Pennsylvania reflect the same concerns--accidental falls, presumably including, but not limited to, egress situations in high structures and machinery. [11,12] Insurance industry statistics have not been made available for this review. However, it is understood that these data include incomplete information with respect to emergency egress facilities. For example, falls from elevations include falling in holes, off platforms, through wall openings, etc, without further identification of causes.

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.

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.

V. DEVELOPMENT OF STANDARD

Basis for Previous Standards

The accepted consensus standard on the subject of emergency egress is the Life Safety Code, National Fire Protection Association Pamphlet No. 101. Its origin dates back to 1913 when the Committee on Safety to Life of the National Fire Protection Association (NFPA) was appointed as is stated on page 101-V. [27] During its early years, the committee devoted its attention to a study of historic fires involving loss of life and analysis of the causes of loss of life. This work led to the preparation of standards for the construction of stairways and fire escapes for fire drills in various occupancies, and for the construction and arrangement of exit facilities for factories, schools, and other buildings. These standards form the basis of the present Life Safety Code.

Early committee work resulted in the development of a series of pamphlets on egress and life safety, which were later consolidated into a comprehensive guide known as the Building Exits Code, first published in 1927. In 1942, the Coconut Grove Night Club fire in Boston focused public attention on the importance of adequate exits and related fire safety features. This interest was further stimulated by a series of hotel fires in 1946. The Building Exits Code was thereafter increasingly used for regulatory purposes. However, because the code contained many advisory provisions, the committee reedited the entire document, limiting the body of the text to requirements suitable for mandatory application.

In 1963, the Safety to Life Committee was reorganized and subsequently prepared the 1966 edition of the code. At that point, the title of the code was changed to the Code for Life Safety from Fire in Buildings and Structures.

As stated in section 1-2, paragraph 1-2111, of the Code, the purpose of the present Life Safety Code [27] is to specify measures which will provide that degree of public safety from fire which can be reasonably required. The code covers construction, protection, and occupancy features to minimize danger to life from fire, smoke, fumes, or panic before buildings are vacated. It specifies the number, size, and arrangement of exit facilities sufficient to permit prompt escape from buildings or structures in case of fire or other condition dangerous to life as is stated in section 1-3. [27]

The present Life Safety Code was designed to make it adoptable by municipalities to serve as a legal basis for requiring construction of buildings with concern for the life safety of the occupants. It is a comprehensive effort to develop a universal set of regulations. For that reason, and since many lack the capabilities to develop one of their own, or evaluate other municipalities' life safety regulations, many have adopted the code, or portions thereof.

The code outlines the general egress requirements for industrial occupancies. Although the major thrust of these requirements is directed toward egress from occupied buildings, it also outlines egress requirements for open industrial structures. Examples of such structures are those found in oil refining and chemical processing plants where equipment is in the open, and platforms, sometimes with roofs or canopies to provide shelter, but with no walls, are used for necessary access.

It is within this classification of open industrial structures that the emergency high egress hazard is greatest.

The American National Standards Institute (ANSI) has not developed a comprehensive consensus standard dealing with emergency egress from high workplaces. The chairman of the committees producing three ANSI standards which might have been expected to be concerned with worker egress from high places assessed the system by which ANSI develops safety standards. He stated that one weakness in the system is the absence of meaningful statistics to point out the need for standards in highly specialized areas such as worker egress from high places. (R Moore, written communication, November 1973)

However, some ANSI consensus standards have alluded to the problem of egress from high locations under emergency conditions. [28-30] Because the subject is treated in a cursory manner within the standards, the basis for the consideration of the subject has not been discernible.

The State of California Construction Safety Orders contain several standards dealing with the problem of emergency egress. [59,60] They require the use of an approved descent control device in combination with a lifeline and safety belt by employees using boatswains chairs and workers performing scaling and drilling operations on steep slopes. When adopting these requirements, California established a height of 15 feet or one story as the point above which workers must use the devices specified. The decision to specify 15 feet was arrived at through professional judgment on the part of those responsible for drafting the standard. (H Crabtree, oral communication, February 1974) Because the standard was ultimately adopted, it can be inferred there was no substantial public comment against this decision.

An auxiliary means of escape is required by the California Petroleum Safety Orders [61] covering drilling and production operations on derricks and masts. The hazards involved in these operations, when workmen are in the derrick above the wellhead, are blowouts and fires. The use of slide cables as an auxilliary device was effective in a number of instances. (G Bunker, written communication, January 1974)

The basic OSHA guideline on the subject of worker egress is Subpart E of the General Industry Standards. It is based on NFPA Life Safety Code No. 101. Subpart E established necessary features of building construction, arrangement, and equipment to facilitate safe egress in the event of fire or other emergency.

The subject of worker egress is treated in additional OSHA General Industry Standards. These include a requirement for an emergency electrical operating device on roof powered platforms which will permit lowering of workers stranded on platforms if the normal operation device should fail. Another provides for emergency operation of the main drive machine by manual cranking to permit lowering of the workers. Additionally, emergency communications equipment must be provided for each powered platform to provide communications between persons on the disabled platform and those operating the emergency lowering device. Another requirement, in 29 CFR 1910.261, Subpart R, is for at least one unobstructed exit on each floor at each end of a digester building.

In summary, worker egress from elevated workstations has been subordinated in importance by the standards-producing and standards-adopting agencies. The need for definitive standards on the subject has not been demonstrated by the amassing and analysis of relevant statistics. Specific language relating to the subject has, in some cases, been dropped during the standards-adopting process because of the technical nature of the requirements, their economic impact, or their potential for generating negative reaction on the part of factions within the labor/management arena.

When the subject has been included in consensus standards, it has been treated as an adjunct to the general concern of the standard, ie, to ensure that the worker is adequately protected against mechanical hazards.

Basis for Recommended Standard

The recommended standard is intended to provide all workers whose workstation requires their presence on an occasional, periodic, or daily basis, at a height of 15 feet or more above grade level, with a means of egress that considers three of the following hazard elements included in the Life Safety Code of the National Fire Protection Association [27] section 2-1, paragraph 2-113:

(1) Height of the workstation.

(2) Hazards associated with the occupancy of the work process.

(3) Number of persons exposed.

This recommended standard applies to all elevated workstations 15 feet or more above grade level except in high hazard situations. Lacking any definitive statistics or results of studies, professional judgment any definitive statistics or results of studies, professional judgment indicates that 15 feet above grade level be established as the lower limit for the standard proposed. In one instance, [62] this height was included in a safety standard concerned with worker occupancy of elevated workstations.

A study conducted for the city of Chicago [63] included the concept of recognizing the different evacuation and rescue procedures associated with emergencies in buildings having occupancies at varying heights. This concept is valuable in recognizing the egress needs of persons working at different levels and ensuring that the additional needs will be met.

Therefore, in the proposed standard, additional requirements are recommended for workstations above 80 feet in height. These are recommended because conventional firefighting ladder equipment cannot reach above 80 feet to provide a means of egress. [63] Furthermore, with high machinery and structures in industry, it is reasonable to assume that fewer means of egress are available as the height of the workstation increases.

Requirements for meeting more stringent medical qualifications have been included in the standard for those who work at heights of 80 feet or more above grade level, because they must rely more heavily on their physical, mental, and sensory attributes when using a means of egress from an elevated workstation under emergency conditions.

In their Life Safety Code, [27] section 4-2, paragraph 4-212, the NFPA recognized that different types of occupancies exhibit varying degrees of potential for fire. Similarly, the need for egress can be related to the hazards associated with the work process or type of facility and equipment. Therefore, the proposed standard includes, as has the Life

Safety Code, [27] paragraph 4-213, more extensive requirements for those workplaces where there may be a greater propensity for emergencies.

In consideration of the comparative speed of egress when using ramps, stairs, horizontal exits, and ladders, it seems reasonable to require the lowest ratio of workers to unit exits for ladders and the highest ratio to horizontal exits. Results from studies to validate the specific ratios selected are not available; these ratios were previously recommended by NFPA [27] and on review, professional judgment indicates that they are reasonable and should be required. The standard recommends provisions for dual egress from elevated workstations 15 or more feet above grade or floor level with a designed occupancy load of 10 or more workers. This is judged sufficient to permit a prompt evacuation of the site during emergency egress.

It is obvious that the need for egress facilities from elevated workstations is affected by the number of persons who must use those facilities in time of emergency. For standard egress facilities, therefore, the proposed standard requires evacuation capacity (expressed in units of exit width) based on the greatest number of people who would necessarily avail themselves of the means of egress during an emergency. The number of persons upon which the evacuation capacities are based were originally established by the NFPA and are the requirements of the Life Safety Code [27] as stated in section 5-1, paragraphs 5-115/5-116 and section 14-2, paragraph 14-213. A unit of exit width is defined as 22 inches as a sufficient representation for emergency egress purposes of the width of a worker. This unit is used by the NFPA in their code and is judged to be a reasonable value despite the fact that it will not be a comfortable width for some workers.

During the development of the proposed standard no data were found which indicated a definite quantitative relationship between the effects of the lack of emergency egress and the need for it. Therefore, a conservative approach has been taken to provide increased protection for workers who are exposed to the hazard associated with the need for emergency egress from elevated workstations.

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VII. TABLE

NUMBER OF WORKERS HAVING POSSIBLE
NEED FOR EMERGENCY MEANS OF EGRESS FROM
HEIGHTS IN EXCESS OF 15 FEET*

Occupation	Number of Workers
Brickmasons and stonemasons	139,967
Carpenters	631,460
Carpenters' helpers	34,799
Cement and concrete finishers	60,856
Construction laborers	484,199
Cranemen, derrickmen, and hoistmen	74,958
Drillers, earth	14,648
Electricians	233,619
Heavy equipment mechanics	50,971
Mixing operatives	3,438
Oilers and greasers	5,121
Painters	209,551
Plumbers and pipefitters	243,293
Roofers and slaters	58,007
Structural metal craftsmen	2,966
Structural metal workers	49,175
Tile setters	23,943
Welders and flame cutters	63,438
Total	2,384,409

*Limited to the following SIC major groups:
Crude petroleum and natural gas extraction, construction, chemicals and allied products, petroleum refining, metal industries (includes blast furnaces, steel works, rolling and finishing mills, other primary iron and steel industries, primary aluminum industries, other primary nonferrous industries).

Taken from 1970 Census data [1]

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