



DESIGN CRITERIA FOR PACKAGES AND CONTAINERS

- A Report on the State of the Art -

New York 15 October 1972

Prepared in compliance with: Order # HSM 73-587

Requisitioned by: Dr. C. Powell / Olivia Azadian

Under Requisition: #20 41 USC 252 (C) (3)

Submitted to:

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Acknowledgements

The task of preparing this document was a massive one due to the complexity of the problem. The time required to assemble the data contained herein exceeded by far the capacity of one individual and required the additional efforts of three associate investigators. Even under those circumstances, this document could only have been completed, because of preparatory work conducted for several years and supported by a Training Grant from the Division of Grants, a research contract on the "Biomechanics of Lifting" from the Physiology and Ergonomics Branch and work done in connection with the preparation of parts of a text entitled "Industrial Environment: Its Evaluation and Control" supported by the Division of Training, all of the National Institute of Occupational Safety and Health. The investigators are indebted to NIOSH whose foresight and innovative sense for national priorities did make this work possible.

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Scope of Project

I

The requisition asked for a comprehensive evaluation of research needs for the development of criteria for recommended standards for the design of packages and containers to include: comprehensive evaluation of research needs--review pertinent literature, determine gaps in research, recommendations of actions necessary to fill such research gaps.

Pursuant to this request correspondence as well as telephone conversations with Dr. Charanjit S. Mahrok, Safety Criteria Manager, National Institute for Occupational Safety and Health, took place. These discussions were most helpful in further defining the scope of the task to be performed. During discussions it emerged that the National Institute for Occupational Safety and Health wished particular attention to be given to a recommendation made by A. D. Little, Inc., which reads as follows:

"Design Criteria for Packages and Containers"

II-1

Objective:

Develop criteria for size, shape, weight and labelling of packages or containers to reduce over-exertion injuries.

Background:

The major causes of industrial lost time accidents is over-exertion. Despite the increasing use of machines to move heavy objects, palletization, and containerization, many back injuries occur when workers try to lift individual packages or containers. Although most containers have instructions and cautions to prevent damage to the contents, most do not have instructions and cautions to prevent over-exertion

injuries to the worker who moves or lifts the container.

Proposed Project Description:

The project must include:

- (i) Human factors evaluation of handles, lift points--their design and location.
- (ii) Evaluation of effectiveness of weight markings, instructions or codes to assist workers in determining best lifting method.
- (iii) Development of criteria and standards for packages and containers design including handles, shape factors, weight, etc."

Analysis of the "Arthur D. Little Work Statement"

II-2

The stated objective should be modified. It addresses itself specifically to "over-exertion injuries" which constitute by no means the only type of injury and lost time accident experienced in the manual handling of packages and containers. The objective should be amplified and perhaps read...to reduce all injuries from all causes, be it over-exertion, accidental dropping of a container, falls while handling a container, injuries sustained by filling or emptying, or injury caused to a third party by the handling of poorly designed containers...". The term "injury" should be interpreted broadly. Container caused injuries are by no means restricted to the trunk or back. A considerable percentage of traumatogenic incidents stemming from manual handling of packages involves hands, fingers, feet, as well as many other structures of man's anatomy.

The claim that"...the major cause of industrial lost time accidents is over-exertion..."cannot be substantiated. Several authorities

report (Kottke) (McGill) that a high percentage of back injuries involve either no weightlifting at all, or lifting of weights substantially below what is considered to be a safe maximum. The National Safety Council reports in Accident Facts--1971 that manual handling of objects constitutes 22.6 per cent of all reported cases. A careful search of various literature sources makes it highly probable that this refers specifically to lifting injuries. On the other hand, falls which constitute 20.4 per cent of all reported cases of compensable work injury are often associated with cumbersome materials-handling of unwieldy but not heavy objects. Injuries to arm, hand and fingers constitute 33 per cent of all compensable injuries. A large percentage of these injuries is associated with the handling as well as opening, loading or filling or emptying of packages and containers. While complete statistics on a nation-wide scale are not available, a statement that about 50 per cent of all compensable injuries in industry are associated with the manual handling of materials, packages and containers could be deemed to be reliable, although it is based on the subjective experience of the Project Director and his discussions with various medical directors of industrial corporations as well as insurance executives.

Likewise the term "lost time accident" is unnecessarily loose. The wording "lost time" implies that only such injuries come under consideration which must be legally reported and fully disable the worker over a period of time, which may vary from state to state, from industry to industry and from insurance company to insurance company. Injuries stemming from materials-handling are among the prime examples of bodily harm where the worker, in order to maintain his ability to

earn a livelihood, has to continue his activities, sometimes for many months, while suffering discomfort, pain and ill health. It is due to the protracted periods of only temporary disablement and transfer to "light work" without need to actually discontinue employment that the term "lost time accident" be broadened to read "injury caused by accident".

The work statement comments "... despite the increasing use of machines to move heavy objects, palletization, and containerization many back injuries occur when workers try to lift heavy packages and containers...". Here again, the statement should be broadened. Design criteria for packages and containers aiming at the maintenance of occupational safety and health should be directed towards the prevention of any and all injuries stemming from materials-handling. Very often materials-handling injuries do not occur DESPITE but BECAUSE OF the increased use of mechanical equipment.

The increased use of machinery has caused pallets as well as many containers to be so designed as to fit the operating characteristics of existing fork-lift trucks, cranes, etc., while no consideration has been given to the operating characteristics of man. Furthermore, in the opinion of the Project Director the vast majority of injuries occur when handling objects too small or unsuited for mechanized materials-handling.

The final sentence of the background section of the work statement relating to the failure to provide instructions and cautions to prevent injuries to the worker who moves or lifts the containers is an excellent one. It is unfortunately only too valid and major efforts should be

made to research this important area.

Findings

III-0

The reduction in injuries stemming from manual materials-handlings is of greatest possible national significance, both from a humanitarian as well as an economic point of view. Reliable authors (Rosse, Clawson) (National Safety Council) report that injuries to the musculoskeletal system due to trauma at work are nearly double the number of those stemming from automobile accidents. A most conservative estimate of cost, based on the aforementioned as well as other literature references, would come to more than \$1½ billion per annum including medical expenses, lost wages and property damage. The total number of individuals involved in all kinds of accidents associated with materials-handling ranging in their effects from slight discomfort and pain to partial or permanent disablement and finally death, exceeds 3½ million, of which nearly 3,000 had some degree of permanent disability, while slightly less than 3/4 million individuals were temporarily disabled for measurable periods of time.

As the project under discussion attempts to deal with the cost of effective prevention of what may be termed one of the nation's "largest epidemics" it deserves to be pursued energetically, on both a broad scale as well as in depth.

Four broad areas were defined which require urgent attention by way of research effort, be it intramural with NIOSH itself or extramural through contractors. These are:

1. Search of current literature as well as other published and

unpublished information and other sources of information.

2. Biomechanical research into the physical response of the back as well as other structures of the body to the efforts required by manual materials-handling.
3. Behavioral research into optimal modalities of affixing information to containers relating to the safety of handling.
4. A very narrow albeit well-defined area where it is already possible to formulate general criteria rather than rigid standards.

This report hereunder presents a discussion of each of the above mentioned items in Sections III-1,2,3, and 4, consecutively:

Search of Current Literature as Well as Other Published and Unpublished Information

III-1a

A massive search of available literature has led to the conclusion that there is a great paucity of reliable research reports and other published information relating packaging, package design and containers to occupational safety and health at least in the United States. The majority of pertinent research and development in this area seems to be conducted overseas, in Europe (including Eastern Europe--especially Czechoslovakia, Hungary, Poland, U.S.S.R. and Yugoslavia), England and Australia and Japan. Much useful work has also been done in France, Sweden, Finland and Canada.

The following is a quote from Contract #L-71-182, entitled: "A proposal to Assemble, Translate and Manage the Compilation of International Work Safety-Health Standards and Regulations". In this document on page 2 the need for international literature search is emphasized as follows:

"Section 2 : Although attempts are made to acquaint American practitioners with foreign safety and health standards (e.g., CIS

abstracts) there have been inadequacies in such efforts. One is a limitation implicit in information drawn exclusively from standards. Many nations employ codes and regulations to enforce work safety-health requirements, but such documents tend to be screened out during the assembling of standards. Another is the interpretive bias that occurs during the abstracting process. The abstractor necessarily must approach each document whenever accurate knowledge of the original text's requirements is needed. It becomes, therefore, necessary to refer to the source which in the case of the international standards usually is printed in a foreign tongue. A third is the randomness of the available abstracted data. The absence of a uniform system for classifying the information limits its meaningful use. It is difficult under the circumstances to conveniently distinguish differences between the related standards and to formulate serviceable conclusions about the comparative values. ...Therefore, the degree of confidence that one can attach to the up-to-dateness and completeness of the existing foreign safety-health standards abstracts is limited.

Inasmuch as the primary objective of international compliance standards must be to embody practical, effective, specifications in their requirements, it becomes important to have authoritative knowledge about the efficacy of each standard....."

Our own evaluation of the existing bibliography as related to the occupational safety and health aspects of containerization, packaging and package handling involved three qualified professional researchers for a period of approximately three weeks and only a most superficial scanning of literature could be performed because of the difficulties in obtaining material from overseas and the time delays involved in

negotiations with international organizations, representatives of foreign powers and major corporations. It is our consensus that the areas treated in books, journals, and abstracts are primarily concerned with the economic, commercial and engineering aspects of containerization and packaging. Articles concerned with occupational safety and health are very scant and scattered. Those few references which were found to be pertinent consider in the majority very briefly only the more obvious criteria of containerization and packaging. Some of these are the need to remove sharp edges, to limit the weight, to locate handles approximately in line with the center of gravity and some means of distinguishing between the lifting capacity of males, females and minors. It is also evident that whatever relevant information could be found was contained in a fashion not easily recognizable in literature as related to lifting as an economic or biologic process. Often the title related to "cost cutting" in manual materials-handling methods in general. Any reference to packaging was incidental.

Especially in text books on containerization and packaging as well as in trade journals the following terms are repetitively and frequently mentioned under lifting safety.

Mechanization and Container Damage

New materials for container construction

Standards of sizes for shipping

Packaging and market appeal

Protect contents from shock

Preserve contents from the natural environment

Protect against pilferage

Labelling

Closure of package

Carton tensile strength

Cushioning of contents

The lack of concern for occupational safety and health among packaging and materials-handling engineers in this country is well illustrated by William J. Grinnel, Vice President, Technical Activities Society of Packaging and Handling Engineers. He writes in Package

Development--March/April 1971:

"Wanted: Volunteers to Develop Packaging, Handling Standards".

".....The lack of such standards tends to add costs to and inhibits the effectiveness of distribution functions... First, packaging and materials-handling engineers must assume the full responsibility in protecting their products through their entire life cycle from production to consumption..."

"Only through such group action can the necessary results (uniformity, reproducibility, cost reduction, loss prevention) be achieved..."

Evidently, the recently established Society for Packaging and Handling Engineers' standards program will not be concerned with criteria primarily concerned with the occupational safety and health. Among the very few publications in the English language addressing themselves directly to the shape of the package handled are: (Himbury), who in only one instance shows one figure illustrating an improved carrying handle and briefly discusses the characteristics of a poor carrying handle. (Brown), who describes lifting styles and in one instance compares in one table the metabolic cost of various modalities of body configuration .

during materials-handling. He also described how a poorly designed container can be conducive to poor and dangerous body posture. Finally, he brings several examples of proper and improper package handling to attention. The same author has compiled a bibliography on lifting which will be published shortly. The third authoritative source (Bulletin 110 U.S. Department of Labor) addresses itself to the important aspect of training for accident-free materials-handling but does not provide a basis for standardization of containers.

The following more accessible literature sources were perused, however, nothing specific relating container design and packaging to occupational safety and health was discovered.

<u>Section A:</u>	<u>Type of Reference</u>
1. <u>Occupational Safety and Health Abstracts</u> , CIS-International Occupational Safety and Health Information Center, Geneva, Switzerland	Abstract
2. <u>Packaging Abstracts (British)</u> , Packaging Division of the Printing, Packaging and Allied Trades Research Association. (PATRA Library Service), Leatherhead, England	Abstract
3. <u>Government Reports in Science and Technology</u> , National Technical Information Service, Dept. of Commerce, Springfield, Virginia	Abstract
4. <u>Industrial Hygiene Digest</u> , Industrial Hygiene Foundation, Pittsburgh, Pennsylvania	Abstract
5. <u>Ergonomics Abstracts</u> , The Ergonomics Information Analysis Center, Birmingham, England	Abstract
6. <u>Index Medicus</u> , U. S. Dept. of Health, Ed. & Welfare, Public Health Service, National Institutes of Health, U.S. Govt. Printing Office, Washington, D.C.	Index
7. <u>Excerpta Medica</u> , Excerpta Medica Foundation, Amsterdam, The Netherlands	Abstract

8. Engineering Index, The Engineering Index, N.Y. Index
9. Modern Packaging Encyclopedia, McGraw-Hill Journal
10. Modern Packaging, McGraw-Hill Journal
11. Package Engineering, Cahners Publishing Co. Inc.,
Denver Colorado Journal
12. Package Development, Scarborough Publishing Co.,
Briarcliff Manor, N.Y. Journal
13. Handbook of Engineering Physiology, T.A.D. Inc.,
Cambridge, Mass. Book
14. J. F. Hanlon, Handbook of Package Engineering,
McGraw-Hill 1971 Book
15. D. R. Woodley (ed.), Encyclopedia of Material Handling,
Macmillan, 1964 Book
16. S. Himbury, Kinetic Methods of Manual Handling in
Industry, Occupational Safety and Health Series No. 10,
International Labor Office, Geneva, Switzerland, 1967 Book
17. E. Grandjean, Fitting the Task to the Man, Taylor and
Francis Ltd., London, 1969 Book
18. K. F. H. Murrell, Human Performance in Industry,
Reinhold, N.Y. 1965 Book
19. E. J. McCormick, Human Factors in Engineering, 3rd
ed., McGraw-Hill, 1970 Book
20. L. C. Barail, Package Engineering, Reinhold, N.Y. 1954 Book
21. G. Jones, Packaging Information Sources, Management
Information Guide No. 10, Gale Research, Detroit, Mich. Book
22. Bonnell's Packing and Shipping Directory, Bonnell
Publications, New Jersey Newslet
23. Maritime Cargo Transportation Conference--November 30, 1957--
National Academy of Sciences--National Research Council
Publication 795 Report
24. W. Crowell and K. Weidenmann (ed.), "Packaging: An Inter-
national Survey", Praeger, N.Y. 1968 Report
25. M. Fisk (ed.), Encyclopedia of Associations--National Organi-
zations of the U.S. 7th ed., Gale Research Co., Detroit Michigan Book

- | | |
|--|--------------|
| 26. <u>Subject Guide to Books in Print</u> (1971), R.R. Bowker Co., N.Y. | Book |
| 27. W. J. Grinnel, "Wanted: Volunteers to Develop Packaging, Handling Standards," <u>Package Development</u> , March/April 1971 | Article |
| 28. J. R. Brown, <u>Lifting in the Industrial Environment: An Interim Report to the Labor Safety Council of Ontario</u> | Survey |
| 29. A. Koskela, L. Noro, and O. Pekka, "Observations Concerning Problems Connected with Lifting," <u>Work-Environment-Health</u> , Vol. 5, No. 1, 1968 | Article |
| 30. <u>Containerization: A Bibliography</u> , Hampshire Technical Research Industrial Commercial Service, Southampton, England 1969 | Bibliography |
| 31. J. I. McConville and H. J. E. Hertzberg, <u>A Study of One-Handed Lifting: Final Report</u> , Yellow Springs, Ohio, Antioch College, May 1966. Rep. AMRL-TR-66-17, Contract AF 33(616)6792, Project AF-7184, Task 718408, AD-637, 764, 24pp. | Report |

The following literature references were located but could not be obtained in time:

Section B

- | | <u>Type of Reference</u> |
|--|--------------------------|
| 1. <u>In-plant transport-Productive, easy and safe</u> (Innerbetrieblicher Transport-produktiver, leichter, unfallfrei). Romstedt, W., and Ott, G. Verlag Tribune Am. Treptower Park 28-30, 1193 Berlin (Eastern Sector) 1970. 104pp. Illus. | Book |
| 2. <u>Safe manual handling</u> (Handtransport-arbeitssicher). Romstedt, W., and Scholtissek, W. Schriftenreihe (Arbeitsschutz Aktuell Interessant" Heft 16, Verlag Tribune, Berlin (Eastern Sector), 1969. 22pp. | Pamphlet |
| 3. <u>Industrial safety handbook</u> . Edited by Handley, W. McGraw-Hill Publishing Company Ltd., Maidenhead, Berkshire, United Kingdom, 1969. 600pp. Illus. 211 Bibl. refs. | Book |
| 4. <u>Aids to materials handling</u> . Safe Working in Industry No.1, Department of Labor and National Service, CIS Section, P. O. Box 2817 AA Melbourne 3001, Australia, 1970, 12pp. Illus. 4 bibl. refs. | Pamphlet |
| 5. <u>Five minutes on occupational safety and health questions</u> (Piec minut o sprawach BHP) Sanicz, W. Wydawnictwo zwiazkowe CRZZ, Warsaw, Poland, 1971 96pp. | Pamphlet |

- | | <u>Type of</u>
<u>Referen</u> |
|--|----------------------------------|
| 6. <u>Occupational safety in road transport</u> (Ohrana truda na predpriyatijah avtomobilnogo transporta) Salov, A.I. izdateelstvo "Transport", Basmannyj tup. 6a. Moscow | Article |
| 7. <u>A Critical analysis of two hundred accidents in small-sized industries in Calcutta.</u> Mitra, S.K. and Rao, M.N. "Indian Journal of Industrial Medicine, "Calcutta, India, June 1970 Vol. 16, No. 2, pp. 75-80. 4 bibl. refs. | Article |
| 8. <u>Annual report of H. M. Chief Inspector of Factories 1969.</u> Command No. 4461, Department of Employment and Productivity, London. H.M. Stationery Office, P. O. Box 569, London, S.E.1, 1970. 124pp. | Report |
| 9. <u>Container-Hanbuch</u> , Hamburg, Deutscher Verkehrs-Verlag, 1968 | Book |
| 10. W. Herdeg (ed.), <u>Packaging: An International Survey of Package Design</u> , Zurich, 1959, 1970 | Book |
| 11. <u>Manual Lifting and Carrying</u> , CIS Information Sheet No.3 International Occupational Safety and Health Information Center, Geneva, Switzerland 1962 | Pamphlet |
| 12. <u>Military Applications</u> Top-level military planning points to packaging changes; Anon. Package Eng. c 16 n 2 Feb. 1971 p.30-31, 34. The Engineering Index. | Article |
| <u>Evaluation of Information Obtained from International Organizations and Governmental Organizations of the United States</u> | III-1b |

The International Labor Organization has clearly recognized the "problem" of rational packaging to avoid injury due to manual handling. In 1966 an ILO conference in Geneva was held to investigate "the maximum permissible weight to be carried by one worker". During this conference the problem of proper packaging was recognized, however, no clear, good, guidelines were presented in the final report, nor was any direction for research into the problem suggested.

The conference proceedings indicate clearly, however, that the

Swiss insurance industry has developed its own standards for the rational design of packages, (Viviani). Material published by other specialized agencies of the United Nations including UNESCO, GATT and WHO did not yield reportable findings. The U. S. Armed Forces have performed research and published data on package size versus weight for one-handed lifts (Air Force Systems Design Handbook). The Department of Defense has issued MIL-STD-626C on standards for package design.

Industrial designers (Dreyfuss) evaluate a product by five criteria:

1. Utility and Safety
2. Maintenance
3. Cost
4. Sales appeal
5. Appearance

As the current state of the art of package design, at least in this country, is relatively unconcerned with safety, it is evident that conventional industrial design methods are not applied when containers are designed.

The American National Standards Institute has issued a number of national standards related to packages and containers, but not related to their safety. There is, however, Standard Z53.1 Marking: Physical Hazards, Color Coding. There are a large number of national and international organizations actively concerned with packaging and containerization. Many of these have issued guidelines and standards binding to their members. Those documents all relate to the dimension of the container with respect to the needs for shipping--they also relate to the merchandise shipped, as well as packaging cost.

Modern Packaging reports that after a steady drop in the past two

decades packaging costs are rising again for the first time in 18 years. The paper referred to here is significant because it discusses the true priorities of packagers, among which safety of package handling is not listed. The same paper also states that some industries spend as much as 30 percent of the sales dollar on packaging. Great caution is recommended in the development of standards so that safety standards do not clash with existing binding technological standards and any work produced without the cooperation of at least the major professional and industrial association engaged in packaging could precipitate an adverse reaction among engineering as well as industrial organizations.

A complete list of organizations contacted is not submitted, only those who could possibly make a meaningful contribution in the formulation of criteria and appear to have a legitimate vested interest in this field are enumerated.

1. Packaging Institute
342 Madison Avenue
New York, New York 10017
2. Society of Packaging and Handling Engineers (SPHE)
Jackson Boulevard
Chicago, Illinois 60604
3. Research and Development Associates for Military
Food
90 Church Street
New York, New York 10004
4. Containerization Institute
15 East 40th Street
New York, New York 10016
5. National Institute of Packaging, Handling and
Logistics Engineers
Washington, D.C. 20044
6. Package Design Council (PDC)
New York, New York 10017

7. MH5 Committee of the American National Standards Institute
8. British Consulate-General
Information Officer
New York, New York
9. German Consulate
Information Officer
New York, New York
10. National Safety Council
425 North Michigan Avenue
Chicago, Illinois 60611
11. International Labor Organization
345 East 46th Street
New York, New York 10017
12. College of Insurance (Library)
50 William Street
New York, New York
13. National Council of Workmen's Compensation
200 E. 42nd Street
New York, New York 10017
14. Insurance Information Institute
110 William Street
New York, New York

Professional organization which should be consulted include:

Ergonomics Committee of the American Industrial Hygiene Association

The American Congress of Governmental Industrial Hygienists

The American Society for Testing of Materials

The American Society of Mechanical Engineers

The Work Measurement Division of the American Institute of Industrial Engineers.

The complexity of the problem is furthermore compounded by the frequent disagreement between established authorities in the field. A good example is presented in:

Publication # 5 of the International Labor Office (Occupational Safety and Health Series) entitled: "Maximum Permissible Weight to be Carried by One Worker"

In this publication a paper by Viviani suggests a package of approximately 16" x 20" x 24" with a maximum weight of approximately 110 lbs".....as a practical load suited to a human being...." In the same volume Dusquiet goes categorically on record with a statement that the maximum weight for a package of 30 inches cube should not exceed 30 lbs. The reason for these disagreements will be explained later in this report under the heading of "Biomechanical Research Into Physical Responses of the Back". The principal result from a survey of accessible literature as well as organizations is that currently there exists no consensus or even an approach to consensus of professional opinion in any of the areas of major importance of packaging as related to occupational safety and health among either professional organizations, individual authorities, or industrial associations.

With respect to ongoing activity, perhaps the most accessible as well as the most knowledgeable agency is the Physiology and Ergonomics Branch of the National Institute of Occupational Safety and Health. This branch has established good formal as well as informal communications with most organizations doing back and lifting research in this country. The officers of the Physiology and Ergonomics Branch are, in the opinion of the investigators, competent individuals in

the evaluation of the quality and progress of ongoing research in this field.

Recommendation

III-1c

That a task force be appointed to conduct an organized literature search into the field of packaging as related to Occupational Safety and Health. This should include at least one representative of the Physiology and Ergonomics Branch of NIOSH, and one representative of The Center for Safety of New York University, which is currently a contractor to the U.S. Department of Labor charged with the Assembly, Translation, Management and Compilation of International Work Safety Health Standards, Codes and Regulations. It should also contain members with a good command of technological and medical Czech, Hungarian, Polish, Russian, Serbic, Swedish, Finnish, French and Japanese languages.

This task force should be charged to conduct or direct in-depth research and critical evaluation of existing literature on health and safety aspects of packaging, recognizing that much information is hidden in many publications relating to fields cognate to but not readily identifiable with packaging.

Biomechanical Research Into the Physical Response of the Back as well as Other Structures of the Body to the Efforts Required by Manual Materials-Handling

III-2a

The following is a quote from Ramazzini translated into English: from "De Morbis Artificum" published in Latin in 1700 "...We see that porters suffer injuries in many ways by their trade so the practitioner should know their special and peculiar diseases.... therefore, let me suggest to the physician the study of mechanics, Why do porters find it easier to carry their loads on one shoulder, stooping and leaning forward instead of holding themselves erect.... because for what the poet says is true "A LOAD PROPERLY CARRIED WEIGHS LIGHT". It is wonderful to see how easy the womenfolk of peasantry carry huge baskets on their heads and walk erect and agile themselves because the weight is placed on a bone which is very strong and arched,

the skull, and is directly above the vertebra..."

The following is a quote from National Health Research and the Problem of Back Pain by Professor John R. Glover appearing in the transactions of the Society for Occupational Medicine (1970) 21, pp. 2-12:

This paper does not attempt to cover the whole subject of back pain but simply those areas where "more research is obviously needed because our knowledge is poor or nil..." Glover then further comments on the absence of reliable data conducive to the prevention of injuries during manual handling and lifting and concludes "...how, therefore, can we compare the incidence of back pain in two work forces? The ideal situation would be where all the employees under the same occupational health scheme are split categorically into twin factories with identical conditions. One could watch both groups for a year and record the incidence of back pain cases and the time lost due to back pain. Then one could put preventive or therapeutic measures into one factory but not the other--the second acting as a control group...Twin factories are almost essential for comparing preventive measures, for example, the teaching of a good method of manual handling and lifting. For one can hardly teach half the men in a works on a random basis--the other half would soon get to know and presumably would expect those with the new knowledge to use it...." This, of course, poses the ethical issue whether in good conscience a control group may be exposed to a risk while preventive measures are applied to the other. The answer is CLEARLY NO. No, this is not acceptable, neither morally nor ethically, nor legally. Glover already recognizes the use of ergonomics (i.e., biomechanics) in the elimination of hazards from

lifting situations. As experimental research in the field does not provide the conditions for the establishment of reliable data and criteria the problem resolves into a need for biomechanical study under laboratory conditions.

Numerous epidemiological studies of back injuries, ALBEIT NOT RELATED TO PACKAGE DESIGN AND STANDARDIZATION, have been made. None of them have produced data of statistical significance. The Journal of Occupational Medicine in October 1972, Volume 14, #10, P785ff. carries an article by Gimlet entitled "THE GREAT BACK X-RAY CONTROVERSY". The summary states: "An analysis has been made of a study on low back x-rays which was presented at the 1956 Annual Meeting of the Industrial Medical Association. Various weaknesses in the study invalidate the conclusion reached."... Similar contradictions between eminent authors and authorities were already mentioned in the previous section in this report. The main reason for deficiencies of epidemiological studies is that an epidemiological survey to be successful must investigate a definitive model of cause and effect relationships. Several authors (Tichauer), (Tichauer, Miller and Nathan) have already commented that the modalities of lifting with respect to kinesiology and the location of points of maximal biomechanical stress as applied to the musculoskeletal system vary with age, sex, somatotype, heel height, package size and bulk/weight ratio of the load. A further important variable is the distance of the center of mass of the load lifted from the lumbar spine. Posture induces additional variability into circumstances surrounding lifting technology.

Finally, freedom of head movement is essential for the maintenance of upright posture (Joseph), (Tichauer, Miller and Nathan).

When a package is unduly high or in other ways interferes with the freedom of head movement as a means of effective adjustment of the center of mass of the body in order to compensate for body sway, then the occupational hazard of falls is induced.

There are also many hidden causes of high stress concentration on the vertebral column. Much research has been performed with the force platform since Larue's days (Broucha), (Barany), most of which has yielded few if any results of practical usefulness. Most of this research was directed at finding the exact location of the center of mass of the human body during lifting. For this purpose it is not necessary to conduct laboratory research. The center of mass of the body and load combined is obviously positioned over the soles of the feet above a line in a coronal plane located somewhere between the sesamoid bones of the big toes and the heels; if it were otherwise, on the grounds of theoretical physics, the lifting individual could not maintain upright posture.

The subject of much less study, in spite of its great significance, has been the stresses exerted upon the back during the aggregation to and segregation from the human body of an external load. In both instances the center of mass of the body as well as the body load aggregate experiences a violent shift in the sagittal direction. The forces generated and acting upon the lumbo-sacral joint (or any risk exposed anatomical failure point) are particularly high during segregation. This is so because an individual requires about half a second to hoist from the time of contact with the load to the moment when the weight handled is lifted from the ground; while it takes only 1/400 of a second, or approximately one-tenth of the

time of aggregation to let go of the load. Consequently, when a load of approximately 30 lbs. (close to the maximum legal limit for women in many states) is lifted by a seated or standing worker, then the force of aggregation according to the location of the point of pick-up may vary from a minimum of 3 lbs. Ft. to a maximum of roughly 60 lbs. Ft.. However during segregation the force acting on the lumbosacral joint will vary between 400-3,000 lbs. Ft.. The magnitude of the forces of aggregation and segregation depends on the points of pick up and release of the load as well as on the configuration of the package handled.

The above is only cited as one of numerous variables that existing research data fails to consider. This invalidates many of the results of existing research and, therefore, no meaningful standards can be formulated. It also shows that standardization of packages alone and without consideration of the general industrial environment will not accomplish the purpose of protecting the worker. In the case mentioned the very same parcel may be quite safe to handle or extremely unsafe to handle depending not on the design of the object manipulated but solely upon the location of the point of pick up and the point of release.

The Physiology and Ergonomics Branch of the National Institute of Health has recognized the magnitude of the problem and has among others issued Contract # HSM-99-72-13 entitled "The Biomechanics of Lifting and Materials-Handling" (Project Officer Mr. D. Badger). This organization should be approached in order to ascertain scope, nature and magnitude of the various federally-sponsored research grants and contracts related to the preview of this report and which are either in progress, under negotiation or planned at this instance.

Other variables which must, by needs, in one way or the other affect the design of packages are now discussed in some detail:

Sex:

III-2b

Women employ different mechanisms of lifting and container handling as compared with men. Males appear to obtain stress relief best by "thoracic lifting" while women prefer to have the load rest against the anterior surface relations of the pelvis. This, particularly in the case of smaller packages and containers is conducive to handling with extended elbows in the case of women and with flexed elbows in the case of men. In the female the hip sockets are located antero-laterally to the vertebral column so that any load handled imposes a "couple" acting on the lumbo-sacral joint greater than would be the case in males so that, depending on package configuration, the object handled by a female may be up to approximately 15 per cent "heavier" (i.e., in the physiological sense) than in the case of male.

There are also numerous other sex variables and structural and anatomical differences between male and female and these account for the fact that entirely different biomechanical processes are employed by both sexes when handling objects of identical design, dimension and weight.

Current legislation as well as administrative practices specifically forbid any discrimination in task assignment on the basis of sex. Therefore, if any criteria or standards are to be formulated

which involve the design of packages as related to handling safety, the differences in biomechanical lifting modalities between the sexes must be fully explored and researched in detail so that any standard, to be implementable, will suit the biomechanical operating characteristics of both men and women.

Somatotype:

III-2c

Within the context of the following, the term "arch" indicates spinal responses which produces a more concave lumbar configuration while the term "straighten" indicates a reverse activity resulting in a flatter lumbar curve. Lumbosacral adjustments when lifting light, small packages occur randomly, positive and negative, for both body types; the range, however, is more limited for the endomorphs. Generally, in response to loads of light weight, ectomorphs tend to arch while endomorphs tend to straighten. When handling small packages of heavier weight, the ectomorphs tend to respond consistently by arching. The endomorphs, however, respond randomly at these levels by either arching or straightening. Bulky loads produce effects markedly different from compact loads. Ectomorphs show reduced range of adjustment for lighter weights but, as the weight increases so does the range of adjustment. Variation in arching occurs in a likewise manner. Endomorphs show a random variation when arching under light weights, but with heavy weights their responses become more uniform. Also generally speaking, pronounced endomorphs maintain balance and stable location of the center of mass of the body-load aggregate by head movement, during static holding of a load. Ectomorphs make the adjustment

necessary to maintain the center of gravity over the soles of the feet quite frequently by changes of the configuration and angles between the pelvis and femur and between the femur and tibia with resulting changes in the configuration of the ankle joint.

It follows logically from the aforementioned that these differences in biomechanical material-handling mechanisms between somatotypes will also cause the location and magnitude of maximum stress concentration during package handling to shift from one anatomical structure to the other according to body build. There is a great difference in stress tolerance between the anatomic links in the kinetic chain of lifting.

Therefore, the influence of somatotype upon preferred modalities of lifting needs to be researched in depth before any satisfactory standards suited to the entire population can be developed.

To enumerate and discuss in some detail all variables affecting the modalities of package handling would go beyond the scope of this document, would make it unwieldy and would also be of dubious value at this instant. The effects on the safety of materials-handling of almost any of the variables mentioned before have not been adequately validated as yet by "hard" laboratory research which is still ongoing under various contracts of the Physiology and Ergonomics Branch of the National Institute of Occupational Safety and Health.

Recommendation

III-2d

- (a) That biomechanical research into materials-handling conducted currently, planned, or under negotiation, be it in the form of in-house research, grant support and/or contract under the auspices of the Physiology and Ergonomics Branch of the National Institute of Safety and Health, be energetically pursued in order to provide adequate "hard" data as well as basic criteria for the formulation of binding standards for package design at a future

date. Furthermore, these efforts should be broadened and deepened in order to produce in the shortest possible interval of time reliable data relating to most biomechanical parameters of package design and handling. Especially materials-handling research should be amplified to include research into the biomechanical effects of hazards relating to the opening and closing of containers, as well as to the filling and emptying. Currently, many large and deep boxes are hazardous to empty because of the necessity of deep bending in order to be able to remove the last of the contents. Also some of the current containers are engineered for ease of filling and closing but are quite hazardous and difficult to open.

Hands, fingers and eyes are the principal exposures to such hazards. Other containers are easy to open but difficult to load and close.

Here again anatomical structures other than the back are risk exposed. Because of the diversity and commonness of such hazards it is necessary that some degree of priority be given to the last-mentioned type research. However, every conceivable care should be taken not to dilute ongoing research.

- (b) That an epidemiological study be conducted under field conditions in a wide range as well as a large number of industrial and service industries in order to establish correlation, association, colligation and interaction of age, sex, somatotype, workplace design and package design, package size, bulk weight ratio of the load handled, the location of lift points, the nature of lifting aids employed, the mass distribution within the package and coding.
- (c) That once this basic data discussed under (a) and (b) has been established or as soon as a substantial part of the data has been gathered, research into mathematical modelling as a rational basis of criteria formulation for packaging standards be initiated. It is confidently stated that computerized mathematical models will be the final vehicle for the definitive development of standards.

Mathematical models predicting behavior of the anatomical III-2e structures of the back under stress have been developed by several authors (Orne) (Liu). Most of these, however, are applicable only in extreme circumstances, such as automobile or aircraft crash injuries and not to ordinary work situations.

Some have investigated the dynamic strength of the spine as a result of problems posed by the high incidence of spinal trauma resulting from the ejection from aircraft (Higgins et al).

A non-linear model of the spine exists already (Toth). Likewise,

spinal models based on data collected by x-ray techniques have been produced (Jones).

Good computerized models to predict the physiological response to work stress and optimal modalities of materials-handling are very few (Chaffin and Kilpatrick) (Martin and Chaffin). It is basic to the nature of a model that its predictive capability is limited by the comprehensiveness of its input and that its reliability is limited by the quality of the input data. As industrial modelling techniques exemplified by the three aforementioned authors are relatively new, the models are naturally limited in scope and usefulness as yet. The inclusion of the data to be generated by further biomechanical and field studies into models by investigators who already have developed expertise in this kind of work will achieve three very important results:

- (i) It will be possible to evaluate quickly, inexpensively and objectively, current industry and technology standards of package design with respect to their relevance to occupational safety and health.
- (ii) It will be possible to achieve rapidly consensus of Government, Professional and Industrial Organizations about standards of an implementable nature.
- (iii) It will be possible to modify and adapt these standards as continuous changes in work force and technology demand. This is important because the present deplorable lack of data, knowledge and know-how in the field of materials-handling stems largely from the fact that originally

"safe materials-handling" techniques were developed on the basis of industrial conditions as they existed approximately in 1928 and were (because computers had simply not been invented) considered permanent cook-book rules and never converted to dynamic models.

Behavioral Research Into Optimal Modalities of Affixing Information to Containers Relating to the Safety of Handling

III-3a

The Compliance Operations Manual of the United States Department of Labor, Occupational Safety and Health Administration, January 1972, reaffirms that the employer is responsible also for the actions or unwillingness of employees to comply with the provisions of the Act or established safety practices--it may be presumed that this includes "standards". On the other hand, industrial practice shows how difficult it is in many instances to obtain compliance with even a simple and obviously beneficial instruction which requests the wearing of safety glasses. The fullest use should be made of behavioral science know-how in order to achieve acceptance and voluntary compliance with safety instructions by individual workers as well as trade unions.

Recommendation

III-3b

It is recommended that a task force be appointed to study the feasibility of enhancing product safety of packages and containers by distinctive marking and coding. Such coding should bring all essential information immediately to the attention of the employee. As the educational background, as well as language of common use varies widely among different ethnic groups of the working population, it is desirable that maximum recourse be taken to coding by color and logotype quite similar to the Canadian system of highway marking. The coding should bring to attention immediately and without possibility of mistaken interpretation the following information:

- (a) Whether the package can be safely handled by one single individual, if not how many persons should be engaged in the manipulative process.
- (b) Whether it is hazardous to handle, and the nature of the hazard (e.g., the spilling of chemicals, possible injury to hands, possible instability, etc.)
- (c) That side of the container which should be proximal to the worker's body. Current practice marks only the side of the package which should be "up" in order to protect the contents and even this simple instruction is very frequently ignored.
- (d) The marking should also make clear if, and what lifting aide, such as gloves, handles, hooks, slings, trolleys, fork-lift trucks, etc., are recommended or compulsory.

The task force should include at least one representative of the Behavioral and Motivational Branch of the National Institute of Occupational Safety and Health, one representative of the American National Standards Institute, one representative of the Society of Packaging and Handling Engineers, one representative of Employer and one representative of Employee Organizations and one representative of the National Safety Council.

General Criteria for Handling and Design of Packages
and Containers Subject to Manual Handling

III-4a

Containers manually handled in industry should be designed to comply with two different sets of specifications. These are:

- (a) Technical specifications
 - (b) Ergonomics specifications
- (a) Technical Specifications should:
- (1) Protect the contents of the container.
 - (2) Conform to dimensional standards, aiming at maximum economy in shipping.
 - (3) Enhance market appeal.
 - (4) Permit easy identification of the nature and quantity of the contents.

(b) Ergonomics specifications should :

- (1) Avoid the generation of potential anatomical failure points in the man-task system (Tichauer)
- (2) Keep the vector sum of all moments to be exerted upon exposed anatomical structures to a minimum.
- (3) Permit the maintenance of postural stability and integrity during the entire container-handling process.
- (4) Ensure that the entire work situation, the container, modalities of handling, the worker, lifting aids such as hooks and handles as well as the physical environment surrounding the lifting situation including conveyor belts, pallets, etc., conforms as far as possible to the Ergonomics Guide to Manual Lifting published in the American Industrial Hygiene Journal, Volume 31, 1970, pp. 511-516 and to the prerequisites of biomechanical work tolerance as formulated by Tichauer and published (in press) in "The Industrial Environment: Its Evaluation and Control" Chapter 32, Table II.
- (5) Cause the center of mass of a container to be preferably located in a coronal plane passing through the mid-palm areas of the worker's hand.
- (6) Cause containers to be clearly labelled to identify hazards which could be generated by careless handling. Such markings should be in the form of logotype or color coding and should especially concentrate upon risks to the back, to the hand and possible spillage of contents. They should also clearly indicate the nature of any lifting aids, handles,

hooks, gloves, etc. necessary. Finally, such markings should identify packages which need more than one worker for safe handling.

- (7) Make containers amenable to safe handling within the physical capacity and preferred work methods of either sex and the widest possible range of somatotypes.
- (8) Make container design an exercise in applied ergonomics. Thus such factors as climate, the need to wear gloves or sensory feedback needs of the worker should be determined during the design process. Consideration should also be given to the physiological capacity of the worker. Container design should include an assessment of the metabolic energy demands of the container handling process for the entire duration of the working day and particular care should be taken to curtail the magnitude of work stress occurring under peak operating conditions.
- (9) Not consider weight alone to be the principal element contributing to the severity of a container handling task.

Employees exposed to other than occasional container handling situation should receive adequate instructions in their handling. Instruction should be received during a pre-paid employment period. The "vestibule training" program of R.C.A. is cited as only one of the many viable programs in safe container handling already operated by industrial enterprises in this country.

Employers engaged in operations of a certain magnitude and employing a number of workers to be specified should be obligated

to provide their container designers with guides to ergonomic container design and their supervisors and employees with guides to ergonomically correct container handling.

Only if the aforementioned general criteria are followed can it be expected that the workmen's performance will be at acceptable levels of economic efficiency concurrent with the freedom from hazard and the physiological and emotional well-being to which employees are both legally as well as morally entitled.

Recommendation

III-4b

That a task force be appointed to explore the feasibility of converting the abovementioned very general criteria into more specific and detailed form. The work of this task force should result in a manual of criteria for the design and handling of containers with respect to the maintenance of Occupational Safety and Health. Such a task force should include at least one representative of the Safety Criteria Division of the National Institute of Occupational Safety and Health, one representative of the Physiology and Ergonomics Branch of the National Institute of Occupational Safety and Health, one representative of the American Society of Safety Engineers, one representative of the Industrial Medical Association, union representatives to include both sexes and representatives from universities and other institutions of learning which conduct research and training projects, be it under grants or contracts under the auspices of the National Institute of Occupational Safety and Health if these projects are related or cognate to container design or materials handling. It can be confidently expected that such a task force having the appropriate membership would soon reach consensus and produce a viable and implementable interim document with at least some sections which lend themselves to the enforcement of compliance. Given the right setting of a conference type environment such document could be produced in draft form within one week provided that each member of the task force is given lead time to prepare himself. Prior to the convening of such a task force a secretariat should be established and charged with a formal analysis of the more pertinent literature and practices. The minimum time required to achieve this would be approximately six months.

The formulation of binding standards relating to the safety aspects of container design and handling is an urgent necessity in

III-4c

order to:

- (a) Make American industry again competitive in many overseas markets as well as the domestic market.
- (b) To protect the nation's human resources.
- (c) To save at least \$1 3/4 billion per annum currently necessary to defray the cost of materials-handling injuries. It is that state of near emergency which paradoxically demands the greatest caution in formulating rigid standards just as yet. The experience of this as well as that of other countries teaches that it is impossible to draw reliable conclusions from data not collected. Rather than dilute current research efforts and to divert scientific manpower engaged in such research, a consortium approach should be developed. Organizations capable of conducting reliable research in this field should be identified and approached to explore the possibility of assigning priority research to that organization best equipped to pursue the specific investigation under consideration. Contractual clauses should include the obligation to submit for evaluation, publication and piecemeal standard formulation results as soon as they have been reliably validated. The Compliance Operations Manual, January 1972, United States Department of Labor, Occupational Safety and Health Administration states on page X-10:

"...engineering controls afford the best protection to employees....such controls remove the cause of potential hazardous conditions and afford the work-

er maximum long-range protection...."

This is a valid statement.

Recommendation

III-4d

Those organizations in the field of Industrial Engineering, Safety and Industrial Design, with research capabilities in the field of Ergonomics and Biomechanics related or cognate to the design of containers and their safe handling should be identified and catalogued. Such cataloguing should include a description and evaluation of personnel, facility and records of research productivity. This catalogue should be treated as a "Reserved" document and could serve as a general guide for the selection of contractors and grantees. In this catalogue the intramural facilities of NIOSH should certainly not be neglected and in view of the fact that research conducive to standards is likely to require extensive experimentation with man as a subject, particular attention should be paid to those research, safety and engineering organizations which have a well-established and ongoing close association with a major center of medical or health research and which have a proven record of successful multi-disciplinary cooperation.

The above expression of caution against over-hasty proceeding has been made in view of the relatively large research gaps as pertaining to materials-handling. These are particularly serious inasmuch as experience shows that the accident frequency related to materials-handling is no less than in areas where "Rules of Safe Lifting" based on current know-how are enforced, than in places where a fairly cavalier attitude with respect to lifting safety prevails.

III-4e

Many industrial physicians agree that over-stress of the back and the hand in occupational situations may be a cause of frequently observed osteo-arthritic conditions associated with specific occupations (Hunter). In spite of their frequency they are dismissed with passing remarks relating to the constant carrying of heavy loads by dock laborers, coal heavers, workers engaged in transportation in tanneries and other occupations related to materials-handling. In

spite of the seriousness of the situation no longitudinal studies of significance establishing "hard" cause and effect relationships between traumatogenic vectors in the working environment and traumatic osteo-arthritis seem to exist. That ulnar deviation of the wrist in continual hand tool usage leads to tendonitis and carpal tunnel syndrome has been well established (Tichauer). Likewise, it is common medical knowledge and need not be further documented that dorsi-flexion of the wrist concurrent with pronation under exercise stress is conducive to tennis elbow. Nevertheless, in spite of the fact that the handles and other assistive devices used to manipulate packages and containers frequently require these two specific maneuvers no research results appear to exist which state whether ulnar deviation or dorsiflexion and radial deviation of the wrist are conducive to any occupational diseases of the forearm and hand acquired during materials handling. Without such knowledge no rational standards and no truly "safe" standards of container handles and other assistive devices can be formulated. By way of further example, it is stated that currently no reliable information about optimality of shape of container configuration is available. Nine elements intrinsic to all industrial lifting tasks have been identified (Tichauer). These are:

- | | | |
|--------------------|------------------------------|---------------------|
| (a) STATIC MOMENTS | (b) GRAVITATIONAL COMPONENTS | (c) INERTIAL FORCES |
| sagittal | isometric | acceleration |
| lateral | dynamic | aggregation |
| torsional | negative | segregation |
| | (d) FREQUENCY OF LIFT | |

All of them are of different mechanical dimensions. They all have in common that they affect metabolic activity, fatigue rates, accident frequency and other undesirable by-products of a poorly designed task. Sophisticated mathematical conversion techniques (Starr) to make these elements isodimensional have been already validated. The objective evaluation of the relative severity of lifting tasks with respect to body configuration, workplace lay-out and shape of object handled, is now feasible through the computation of the vector sums of all elements of a lifting task intrinsic to a specific job. However, such evaluation currently requires a high degree of skill and mathematical maturity as well as an objective means of job analysis not available to most enterprises. They have a sound basis in theoretical biomechanics but no experimentation under laboratory or field conditions needed to validate these computational methods to a degree to make them a basis for binding standards has yet been completed. Research is currently in progress (Ayoub) (Chaffin) (Kilpatrick)(Tichauer). The rational basis of much of the data generated by the Human Factors Branch of the Air Force is not available.

It has been established that any lifting task imposing a sagittal bending moment upon the lumbar spine exceeding substantially 250 lbs. inches constitutes "heavy work" and that such a task must be carefully designed in order to avoid injury. It can safely be deduced from existing work (Tichauer) that bulky and light loads are less safe to handle than compact and heavy ones, but again the true quantitative relative relationships remain to be developed.

Finally, it must be stated that all research results available in the U.S.A. concern themselves with "lifting" per se and not with the relevance of container design and container handling methods to the maintenance of occupational safety and health.

Final Conclusion and Recommendation

IV

There is not sufficient data available for the formulation of reliable standards as related to container design, labelling and handling. Loosely formulated standards would not protect the working population, would be unenforceable and could lead to alienation between governmental agencies, labor and management. It is, therefore, necessary to proceed along the slower, but both in the long run as well as the short run, more fruitful avenue of purposeful and accelerated research in this field and to produce draft standards as soon as the information to support them becomes available.

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