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Workplace Safety Symbols: Current Status and Research Needs

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ABSTRACT

Although written signs are a common means of conveying safety information in the workplace, pictographic symbols can be a more effective way of providing the same information. Symbols are independent of a particular written language, and can be more accurately and rapidly perceived than the comparable word message. Despite the many advantages of safety symbols, they can be ineffective or even dangerous if the intended meaning is not accurately communicated. As a result, there is a great need for careful evaluation, consistent application, and eventual standardization for safety symbols.

This report documents an initial assessment of current symbol use and future requirements. It includes a review of the technical literature on symbol research; observation of safety sign and symbol use in the workplace; compilation of commercially available symbol referents; and review of national and international standards. Based upon these sources, an initial list of 40 symbol referents is presented along with research priorities for evaluating the effectiveness of symbols for these referents.

EXECUTIVE SUMMARY

Signs are a common means of conveying warnings and information in the workplace, and so play an important role in worker safety. Traditionally, signs have conveyed information through written messages. In many instances, however, pictograms or symbols may be a superior means of communicating safety information. As a result, there has been a tremendous growth of interest in the use of symbolic signs beginning with highway information and now including product and workplace safety applications.

Among the potential advantages of symbolic signs over comparable word signs (researched mainly for highway signs) are: independence from written language (which is important especially where foreign languages or functional illiteracy occur), rapid and accurate perception, shorter reaction time, perception at greater distances, rapid and accurate learning of symbol meaning, and maintained effectiveness under conditions of stress, distraction, or visual degradation. However, if not properly developed, symbols can be ineffective, and even dangerous, as in cases where a meaning opposite to the intended message is conveyed. As a result, the need for careful evaluation, consistent application, and ultimately standardization is critical for safety symbols.

In support of the development of effective workplace safety symbols, the National Institute of Occupational Safety and Health (NIOSH) has sponsored a project at the National Bureau of Standards (NBS) to evaluate the use of pictographic signs in the workplace. This project will consist of three general tasks: (a) determination of the kinds of safety or hazard situations which require symbols; (b) development of a set of candidate symbols for each situation; and (c) experimental evaluation of the effectiveness of the symbols in communicating the intended meaning.

This report documents the findings from the initial phase of the project. This includes (a) a review of the technical literature on symbol use; (b) observations on safety sign use documented at six site visits to various factories representing diverse industries; (c) information obtained from sign manufacturers; (d) information on commercially available symbolic signs, and (e) a review of national and international standards for symbols.

Based upon these sources an initial list of 40 symbol referents (meanings) is presented. Examples of symbols for each referent are now being collected. These referents and selected symbols will be researched in the next two phases of the project. Finally, research priorities for the investigation of safety symbols are discussed, focusing on the determination of the meaningfulness of the symbols.

These priorities will be used to develop a testing program which will be implemented during the next phases of the project. The outcome of testing will suggest procedures for evaluation and a preliminary set of symbols for further research and development.

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SI CONVERSION

The units and conversion factors given in this table are in agreement with the International System of Units or SI system (Systeme International d'Unites). Because the United States is a signatory to the 11th General Conference on Weights and Measures which defined and gave official status to the SI system, the following conversion factors are given.

Length

1 inch = 0.0254* meter
1 foot = 0.3048* meter

Area

1 square inch = $6.4516^* \times 10^{-4}$ meter^2
1 square foot = 0.0929 meter^2

Volume

1 cubic foot (ft^3) = 0.0283 meter^3

* Exactly

1.0 INTRODUCTION

1.1 NEED FOR SYMBOL USE

Written signs have traditionally provided information to guide, protect, and inform people in buildings in the United States. Written signs are common in the workplace, where they play an important role in worker safety. More than 5.6 million people were injured, and at least 4500 were killed, in workplace accidents in the United States in 1978 (Bureau of Labor Statistics, 1979). Injury is most likely during the first month on the job, and the "incidence of injury or illness decreases with length of service in all age groups" (National Safety Council, 1979, p. 26). Signs may be particularly important in alerting the new worker, who is less familiar with existing hazards and precautions. Despite the prevalence of written signs, however, they may not be the best way of conveying necessary information. As a result, there has been a tremendous growth in the use of pictograms or symbols. With these, the information is conveyed pictorially, often without word labels.

The modern use of pictograms began with the development of standardized traffic symbols in Europe in the early part of this century. Currently, there is increasing use of symbols within the United States for transportation systems, hazard warnings, fire safety, and public information. For example, the Department of Transportation (DoT) successfully sponsored the implementation of standard symbols for motorists, and has proposed other symbols for public information in transportation facilities. Increased concern for worker safety and consumer protection has sparked interest in the United States in the use of symbols as a viable means of communicating safety information.

The increasing interest in symbol use can be seen from the various national and international groups that are developing standards for symbols. At the national level, the American National Standards Institute (ANSI) has recently chartered the Z535 Committee on Safety Colors, Signs, Symbols, and Product Alerts while the National Fire Protection Association (NFPA) has sponsored a subcommittee on Visual Alerting Signs and Symbols. Both of these committees are working toward the development of voluntary standards for worker safety and fire safety symbols. The Society of Automotive Engineers (SAE) has also sponsored the development of a set of standard automotive symbols. In the international realm, the United Nations (UN) has developed signs and symbols for labeling hazardous materials for transport. Finally, the International Organization for Standardization (ISO) has three committees dealing with standards for symbols. These include the Technical Committee (TC) 21 on Equipment for Fire Protection and Fire Fighting; TC 80 on Safety Colors and Signs; and TC 145 on Graphic Symbols. There are not yet any national standards in the U.S. for workplace or worker safety symbols, however.

The reasons for developing symbols for use in workplaces lie in the numerous advantages of symbols. The primary advantage, of course, is that pictures communicate information without the use of written language (Mead & Modley, 1968; Modley, 1966). Symbols have been used in Europe because the prevalence of international travel and trade created the need to overcome language barriers (Kolers, 1969). Even within the U.S., there are large numbers of people who do not read or speak English well. Because there are no established criteria for functional literacy, estimates of illiteracy vary widely from about 2 million to about 64 million adult Americans (Kirsch & Guthrie, 1977-1978; Washington Post, 1979). Furthermore, Bureau of the Census data, collected in 1976, indicated that English was not the usual language for about 8 million people in the U.S. Of these, about 5 million reported difficulty in speaking or understanding English. (There were no reported data on reading skills). For those whose native language is not English or who are functionally illiterate, symbols could be the only visual warnings for preventing accidents and providing protection.

1.2 REQUIREMENTS FOR RESEARCH ON WORKPLACE SAFETY SYMBOLS

An overview of the research literature on symbols (presented in more detail in Section 2.0), underlines some additional advantages of symbols. Among the major advantages are that pictograms can, in some cases, be perceived more rapidly (Janda & Volk, 1934), more accurately (Walker, Nicolay & Stearns, 1965), and at a greater distance (Smith & Weir, 1978) than words. Reaction time may be shorter to symbols (Smith & Weir, 1978), even under conditions of stress (Smillie, 1978). Symbol meanings can often be rapidly learned and accurately remembered (Walker, et al., 1965), with minimal confusion among alternatives (Green & Pew, 1978). Symbols may also be superior to words under conditions of interference either by distraction from another task (King & Tierney, 1970) or by visual interference or degradation (Ells & Dewar, 1979). These advantages of symbols over words may not be true under all conditions, however.

Most of this research has focused on highway signs, with some attention to applications such as automotive machinery and product labeling. Yet these experiments have, for the most part, ignored the use of symbols to convey safety messages within buildings. As a result, their effectiveness has rarely been evaluated.

Although symbols can be more effective than written signs, their effectiveness depends heavily upon selecting symbols which are readily understandable. Simply drawing a picture is not sufficient. The picture must be evaluated in a systematic research program. Yet, this evaluative stage is rarely done, because symbols are typically developed and implemented in response to an individual, specific need. Although the creator of a symbol may understand its meaning perfectly, this message may not be communicated to anyone else. Collins and Pierman (1979) noted that several fire-safety symbols developed by ISO TC 21 failed to communicate the intended meaning to a large percentage of U.S. subjects. In fact, some of the symbols communicated a meaning which was the opposite of the intended message. Figure 1 shows a proposed ISO symbol to

Figure 1. Proposed ISO Symbol for "No Exit" (Blind Alley)

indicate a blind alley (no exit). Not only did Collins and Pierman find that few people identified this meaning correctly (2%), but one-third of those tested thought it meant exit or safe area. A situation in which a symbol communicates an opposite meaning illustrates the most serious problem with the use of symbols. As a result, before symbols are standardized, particularly for safety situations, their effectiveness in communicating the message must be evaluated.

Once a symbol has been developed to fill a specific set of needs and researched to determine its effectiveness, it should be standardized for a given application. A major problem currently is that anyone who feels the need for a symbol develops one, often without reference to existing symbol sets. Figure 2 shows an example of eight different conceptualizations for symbolizing "restricted entry." Each of these basic forms may have several graphically distinct renditions in use. This illustrates how the same message may have several different graphic images. If the representation of each of these symbols is very different, the potential for serious confusion is great. Therefore, there is a need to develop consistent and ultimately standard sets of safety symbols for use in workplaces. Because the signs currently used in workplaces provide critical information for preventing accidents and for providing personal protection, failure to develop and implement consistent, well-recognized symbols is potentially dangerous.

The task of developing effective workplace symbols is threefold. First, a determination must be made of the kinds of situations which require symbols. Exactly what messages, or referents, need to be conveyed and for which hazards? Secondly, a set of candidate symbols must be selected for each referent, particularly where there have been numerous attempts to symbolize a given referent. Thirdly, the various proposed symbols must be evaluated to determine if they, in fact, communicate the desired meaning to the target audience. In this process, it is important to realize that because some situations are more difficult than others to symbolize, the process of developing effective symbols must be an evolutionary one.

In the following pages we will review the research literature; describe site visits and conclusions from visits to factories; review catalogues and correspondence with numerous sign manufacturers; develop a list of symbol referents for further investigation; review national and international standards for symbol use; and discuss requirements for assessing the effectiveness of worker safety symbol evaluation methods.

2. OVERVIEW OF SYMBOL RESEARCH LITERATURE

2.1 BACKGROUND

Before symbols are implemented as part of a communication system, their effectiveness in conveying information and producing the desired behavior must be evaluated. For a symbol to elicit a behavioral response, a series of psychological processes must be completed. These include

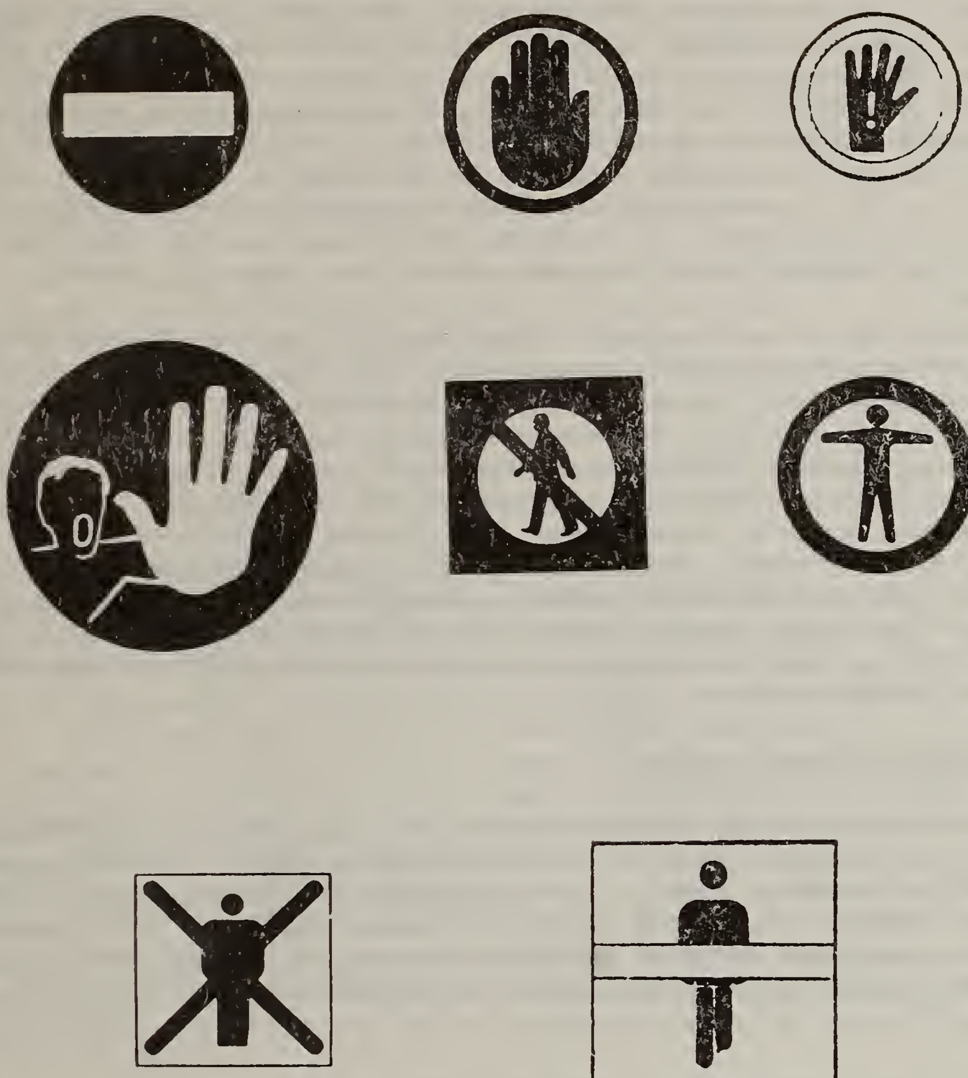

Figure 2. Symbolic Conceptualizations of "Restricted Entry" (Some of these symbols may be privately copywritten).

detection, discrimination, recognition, and understanding (or identification). (For a complete discussion of perceptual information processing, see Dember and Warm, 1979.) A symbol must be effective at each stage of this process if it is to be a reliable means of communication. Research on symbols has focused on various stages, asking such questions as: How detectable is the symbol? How discriminable is it from all other symbols? How recognizable is it when seen in a different context? How well does it communicate the desired meaning? How effectively does it alter behavior? In addition, some experimenters have assessed people's attitudes toward, and preferences for, specific symbols.

In the literature review that follows, it will become apparent that some stages of the communication process have received relatively little research attention. Furthermore, most symbol systems have not been studied systematically. For the most part, researchers have concentrated on detectability and understandability as the major research areas for symbols. Although the bulk of the research has concentrated upon highway symbols, this review will discuss the application of symbols in four areas: road and highway symbols; vehicle and machine symbols; public information and directional symbols; and product hazard symbols. Workplace safety symbols have received little research attention, although some relevant experimental results will be discussed at the end of this review.

2.2 HIGHWAY SYMBOL RESEARCH

The bulk of the highway symbol research has centered upon a comparison of the effectiveness of word and symbol signs, typically for response accuracy or reaction time. In several other instances, a set of symbols has been directly evaluated for its understandability. Finally, several investigators have assessed the effectiveness of highway symbols in terms of perceived meaningfulness, discriminability, or alteration of behavior.

2.2.1 Direct Comparison of Word and Symbol Signs

One of the first highway symbol experiments was conducted by Janda and Volk (1934) who assessed the speed of reaction to 20 signs and symbols. They also assessed the correctness of response by having subjects push a lever in the direction indicated by the various symbols and signs. Reaction time was shortest for the symbols and greatest for the words alone with a total difference of 200 msec. In addition, speed of response increased with repeated trials. The authors claimed consequently that word signs are a relatively poor way of conveying information to people.

In a later comparison of word and symbol signs, Walker, Nicolay, and Stearns (1965) compared both the accuracy of understanding and the ease of learning for international highway symbols and U.S. highway (word) signs. The authors presented seven black and white signs and symbols for .06 sec tachistoscopically after five minutes of familiarization.

Subjects identified the nature of the sign or symbol in writing, after it was presented briefly. This procedure was repeated using colored stimuli for a new set of subjects. Finally, subjects defined the meaning of the symbols in a subsequent test of retention. In all cases, the authors found that the international symbols were identified significantly more accurately than the word signs regardless of color and delay before re-testing. They attribute the better performance of symbols to their perceptual simplicity and visual integration.

A number of researchers have used a measure termed "glance legibility" to assess the effectiveness of word and symbol signs. As defined by King (1971, 1975), glance legibility is the percentage of correct matches between a symbol (or word) stimulus and an answer chosen from an array of symbols or words. The tachistoscopic presentation of the test stimulus is limited to brief exposures. Both the time to make the match and the accuracy of the match are recorded. Glance legibility essentially measures the recognizability of a symbol.

King (1971) used the glance legibility procedure to compare the meaningfulness of two series of 10 symbols each with one series of 10 road signs for 208 subjects. First, King had subjects give a definition for each symbol. Then, King presented each symbol briefly (.05 sec and .3 sec) so that subjects could match it against an answer array of 9 symbols. King found that there were significant differences in the accuracy of response for the two series of symbols; the series which contained prohibitory symbols proved to be especially difficult to define. When glance legibility was assessed, the percentage of correct matches decreased for word signs as presentation time decreased, but not for symbol signs. There were no differences in correct response between the two series of symbols, however. Finally, 65 percent of King's subjects claimed that the symbol signs were easier to match than the word signs. Thus, although the word signs may have been initially more meaningful, under short presentation times, symbols were more recognizable and more accurately matched.

In a subsequent experiment, King (1975) used the glance legibility approach to study the effects of delayed stimulus presentation, with and without interference during this delay, upon the accuracy of symbol recognition. Under actual driving conditions, there is typically a time interval between observing a highway sign and acting upon it. In addition, the driver usually performs some other driving-related task during this time interval. Consequently, King (1975) repeated his earlier experimental procedure but delayed the subject's response for intervals of 5 and 10 seconds and added an interference task during another 10 second interval. The symbols, signs, and presentation durations used in King (1971) were repeated. For the short (.05 sec) viewing conditions, the percentage of errors increased for both the 10 sec delay and interference conditions. In addition, even more errors ocurred for the word signs under interference conditions. King suggested that his results indicate that symbols retain their superiority under difficult viewing conditions.

Plummer, Minarch, and King (1974) also used the glance legibility task to compare reaction time and response accuracy for 10 highway word and symbol signs. They presented a single word or symbol for 200 msec. Subjects selected an answer from an array containing either 3 words or 3 symbols which was presented for 6 sec. Each comparison was repeated 3 times for a total of 60 observations for each subject. In addition 10 subjects received special training on highway symbol signs. The authors found that the reaction time, or time to select an answer from the answer array and depress the correct button, was slower for symbol signs than for word signs. The response to symbols was significantly more accurate, however. Prior training decreased reaction time but did not affect accuracy. Finally, individual symbols varied both in response time and recognition accuracy.

Dewar (1976) used the glance legibility procedure to determine the effects of a prohibitory slash upon symbol recognition. Fifteen symbols were studied under four different ways of symbolizing prohibition: slash superimposed on the symbol, symbol superimposed on the slash, partial slash, and circular red surround. Both normal and degraded viewing conditions were studied. In each, legibility was greatest for symbols with a red surround and least for symbols with the symbol superimposed upon prohibitory slash. Nevertheless, because the use of a red circle to indicate prohibition would not be effective for most color defective people, Dewar recommended the use of a partial slash.

It is important to remember that Dewar's (1976) experiment was a recognition experiment in which he did not assess the meaningfulness of the various prohibitory conditions or compare different permissive and prohibitory versions of the same symbols. Nevertheless, his results do indicate that the slash can impair the detectability of the symbol underneath. As as result, it is particularly important to ensure that the underlying symbol is not overly complex. Resolving the issue of complexity is, in itself, a difficult question which deserves further research.

In a later experiment Dewar and Ells (1977) compared accuracy scores from a glance legibility experiment with the meaningfulness of the same symbols using the semantic differential. The semantic differential measures the meaningfulness of a word or idea by having subjects rate the sign on a set of scales made up of bipolar adjective pairs. In a test of 20 traffic symbols, Dewar and Ells found that meaningfulness as defined by the semantic differential was highly correlated with the accuracy of a subject's definition of a symbol. In a second experiment, Dewar and Ells were able to correlate glance legibility with semantic meaningfulness only for word signs, not for symbol signs. The authors did not explain this lack of correlation but suggested that both semantic differential and glance legibility measures are needed to provide a complete picture of a symbol's meaningfulness and recognizability.

In a reaction time experiment which did not use the glance legibility procedure, Dewar, Ells and Mundy (1976) compared the effectiveness of word and symbol signs for 3 tasks of increasing complexity. In the first task, subjects were shown slides of 26 signs (half verbal and half symbolic) and asked to classify 20 of these as either regulatory or warning. Reaction time was measured from the onset of the slide to the onset of the verbal (classification) response. In a second task, Dewar et al. introduced a "loading" task which required subjects to classify and respond to specific numbers while classifying the signs. In both tasks, reaction time was shorter for word signs than for symbol signs, although this difference decreased for signs which occupied a smaller visual angle. The authors suggested that the reaction time was faster for word signs because the subject's response was the same as the message on the word sign. Use of the loading task increased reaction time for all signs. In the third task, visual distraction in the form of a motion picture of a highway was added to the sign slides. Subjects were also instructed to maintain a constant speedometer reading (which the experimenter varied). In this task, with both visual distraction and loading, the superiority of the word signs disappeared and the symbol signs performed better. As a result, the authors suggested that the verbal reaction time procedure validly predicts legibility distance for symbols only under conditions of attention demands and visual distractions similar to those experienced during normal driving.

In a very recent assessment of reaction time for traffic signs and symbols, Ells and Dewar (1979) used a measure designed to be less biased toward verbal response. In this study, the experimenter first read a traffic sign message aloud. The subject then viewed a slide of a traffic sign and responded "yes" or "no" if the visual sign and the verbal message were the same. The time to initiate the verbal response was measured. Stimuli were viewed under both normal and degraded conditions. In this experiment, reaction time was always shortest for symbolic measures. In addition, response time increased more for verbal signs than for symbolic signs under degraded viewing conditions. Thus, the change in response method enabled the more rapid detectability of symbolic messages to be measured under all viewing conditions.

These experiments indicate clearly that symbolic signs can be more effective than verbal signs, if the response measures and viewing conditions are chosen appropriately. Because the use of a strictly verbal labeling response would appear to bias the reaction time data toward word signs, Ells and Dewar's (1979) experiment offers an interesting experimental approach alternative. Nevertheless, the use of reaction time as a measure provides an index of some of the demands of actual driving, where the speed of responding to a sign's message can be critical.

2.2.2 Assessment of Meaningfulness

In a different experimental approach, highway symbols have also been directly evaluated in terms of their understandability. Assessment of meaningfulness has typically been made to determine if a set of symbols is accurately understood. Speed of response has not been a critical variable in these experiments.

In one of the first assessments of highway symbol meaningfulness, Brainard, Campbell, and Elkin (1961) evaluated the effectiveness of 30 European symbol signs. Meaning was assessed first by having subjects either give a definition for each symbol or select the correct answer from an array. Following this, subjects received a brief training period after which they again provided definitions for each of the symbols. Next subjects sketched their idea of an appropriate symbol for each of 16 definitions. Finally, a new set of subjects gave definitions for each of the new symbol signs.

Brainard et al. found a high correlation between the answers for both the definition and selection answers, although there were fewer correct answers for the definitions (54% rather than 74%). Training improved the percentage of correct answers to nearly 100 percent for both response modes. The analysis of the drawings revealed common stereotypes for at least 9 of the 16 definitions and common elements for the majority of the symbols. Testing of symbols based upon these stereotypes revealed that the percentage of initially correct answers to them was greater than for the European symbol signs in all instances. The signs with the lowest scores tended to be more abstract or to use a prohibitory slash. Brainard et al. found that the meaning of prohibitory signs was frequently reversed, although brief training on all symbols improved accuracy to near 100 percent. It should be remembered that this experiment was published in 1961, before the current extensive use of prohibitory circle-slash signs by the Department of Transportation, so that more recent studies might have not unearthed a similar problem.

Griffith and Actkinson (1977, 1978) also evaluated the understandability of highway symbols. They determined the effectiveness of 128 road symbols used in Germany for U.S. Army personnel. They found that at least 10 of the 128 signs were misunderstood by more than 50 percent of the subjects, and that the overall percentage of errors upon first exposure was quite high. In addition, they also found that memory cues and verbal elaboration were not significantly effective as training procedures, although each reduced errors somewhat. As a result, these authors questioned the ready interpretability of many highway symbols and claimed that their subjects had trouble with more abstract and less directly representational symbols.

Although Griffith and Actkinson did not comment upon it, the very large number of symbols studied (128) may have caused problems--particularly since some contradict U.S. practice. In some instances, for example, a red circle alone was used to indicate prohibition, with the slash used to lift the restriction, so that the meaning became in essence a double negative.

By contrast in the U.S., a red circle is used with the slash to indicate prohibition. As a result, it is not surprising that Griffith and Actkinson's subjects had problems with these symbols.

2.2.3 Behavioral Observations of Symbol Effectiveness

The meaningfulness of symbols has also been assessed directly by determining their effectiveness in altering behavior. Forbes, Gervais, and Allen (1963), for example, developed a lane-control symbol in a set of laboratory experiments, and then tested its effectiveness on the highway. In the initial tests, the authors determined that a red "X" appeared to be most effective in controlling traffic lane use. This symbol was then tested under actual highway conditions, in which a lane was closed off by a lightweight barrier. Presence of the barrier was indicated by the red "X" for some of the trials. The number of drivers who made the correct lane change and the distance from the barrier at which this change was initiated was improved by the red "X". Thus, Forbes et al. found a symbol which tested well under both laboratory and actual highway conditions.

In a similar experiment, Dewar and Swanson (1972) evaluated a set of symbols in a laboratory setting and then tested one of these symbols under actual driving conditions. Initially, they compared twenty-three word and symbol signs by having subjects define each one when presented under short viewing conditions (.04 sec). The signs were presented first by themselves, and then in a picture of a road intersection. For the most part, the symbols were recognized more accurately than the words, although some combinations of symbols and words reduced understandability compared with either alone. In a subsequent highway experiment, the relative effectiveness of positive (prescriptive) and negative (proscriptive) symbols for "no left turn" was determined by counting the number of cars making illegal left turns at an intersection. The positive symbol appeared to be more effective in altering behavior in the desired direction than the prohibition symbol.

2.2.4 Visibility of Highway Symbols

In the final experiment to be reported on highway symbols, the discriminability of a symbol was determined for different visibilities. Smith and Weir (1978) evaluated the effectiveness of eight different directional symbols under conditions of blur and low contrast. "Blur" simulated the effects of different visual acuities upon visibility, particularly for nighttime conditions, while "contrast" simulated the effects of glare, as from bright sunshine. Eight levels of both blur and contrast were studied. In both experiments, subjects judged the direction in which the symbols pointed. Smith and Weir also determined subjective assessments of each of the 8 directional symbols. In this phase, subjects arranged photographs of the 8 symbols according to their suitability as a directional indicator. Smith and Weir found that although two symbols tested particularly well in terms of visibility criteria, one of these symbols was ranked as the least acceptable symbol. As a result, they suggested that criteria for symbol effectiveness must consider not only detectability and discriminability but also subjective response. The most effective symbol should perform well under all criteria.

2.3 AUTOMOTIVE AND MACHINERY SYMBOLS

Pictograms and symbols are also used to mark controls and to provide operating information in cars, trucks, and machinery. The impetus for this application derives from the international sale of machinery and equipment and the consequent need to convey equipment operating information accurately without the use of written language. Because symbols can be smaller than a comparable word phrase, they are preferred to lengthy written instructions for providing operating information.

Unlike highway symbol research, research into automotive-machinery symbols has focused on evaluating the effectiveness of one or more sets of symbols for a particular referent. Rarely have researchers compared symbols with words or evaluated reaction time. Rather, the focus has been upon determining the meaningfulness of a set of symbols for a particular audience.

Cahill (1975, 1976) evaluated the interpretability of some of the symbols proposed by Dreyfuss (1966) for use on farm vehicles and industrial machinery. She studied the effects of both context and previous experience upon the understandability of ten selected symbols for 30 male subjects. Context was provided by using a drawing of the interior of a cab for a piece of heavy equipment so that subjects could locate the appropriate place for each symbol, and perhaps derive some meaning from this "context". Half the subjects received context; half did not. All subjects viewed slides of the symbols and provided definitions for each. Subjects were considered "experienced" if they had operated, designed, or serviced heavy industrial or farm equipment. Determination of experience was made only after all subjects had completed the experiment.

Analysis of the results indicated that context and previous experience facilitated accurate recognition of the symbols, although there was wide variability in the understandability of individual symbols. Furthermore, although context improved performance, it did not alter the relative ranking of the understandable symbols. Cahill (1976) noted that the understandability of the symbols appeared to be influenced by the kind of graphic representation used. For example, symbols such as "fuel," "horn," and "turn signal" were understood by most subjects. Cahill commented that these symbols are fairly direct pictorial representations of commonly encountered objects. Other symbols such as "engage" and "choke" were understood by very few subjects; neither received a correct response from the "no context" group. Cahill (1976) claimed that, because these symbols are conceptual rather than pictographic representations, they are not at all familiar even to technologically sophisticated users. In these instances, although experience and context can provide useful cues, symbol design is critical in determining the understandability of a particular symbol.

In a study of automotive control symbols, symbol design was also found to be a critical variable. Wiegand and Glumm (1979) evaluated the effectiveness of a single set of symbols for automotive controls. They tested a set of symbols proposed by ISO by having 125 U.S. subjects match pictures of 25 symbols to a list of 35 definitions. The percentage of correct identification was above 80 percent for 20 of the 25 symbols. Yet, two of the symbols, "choke" and "master lighting switch" performed poorly enough to warrant redesign. Wiegand and Glumm suggested that knowledge of the understandability of a set of symbols can be used to indicate where additional design or education is needed.

One of the best ways of selecting a set of symbols for standardization is to test several different graphic representations for each idea (referent). Thus, Heard (1974) evaluated the effectiveness of three different symbols for each of 24 referents for a very large number (2593) of licensed drivers in four countries. She studied three age groups as well: 16-25, 26-55, and over 55.

A total of 54 symbols were studied--three variations of each of 15 ISO symbols and one variation of 9 other symbols. These symbols were tested in the appropriate location in an actual automobile or an automotive mock-up. As subjects were read a driving scenario which involved each of the 24 symbols, they touched each control at the appropriate place, using the symbol for identification. The time to find and touch the correct symbol was measured to the nearest 0.5 sec. Accuracy of response was also recorded.

Heard was able to select one symbol for each of twelve referents based upon significant experimental differences between the symbols in the three proposed sets. For recommendation, a symbol had to be understood correctly by more than 75 percent of the subjects and be confused with other symbols no more than 5 percent of the time. Based upon these criteria, Heard (1974) recommended a set of symbols which performed significantly better than all other symbols in an actual vehicle under simulated driving situations.

Green and Pew (1978) also examined the effectiveness of 19 pictographic symbols used in automotive displays. They employed fifty subjects in a series of five tasks. First, they determined the subjects' familiarity with the symbol, by having them circle those that they were "reasonably sure" that they had seen before. Secondly, in a determination of "association norms" for each symbol, subjects were read driving scenarios similar to those used by Heard (1974) and asked to indicate which of several symbols was appropriate for each scenario. In the third task, subjects made estimations of the magnitude of the "communicativeness" of each symbol, (or how well it conveyed the desired meaning). In the fourth task, subjects were given training until they could associate each label correctly with the appropriate symbol. Finally, reaction time was assessed by recording the amount of time until the subject could respond "same" or "different" to a picture of the symbol and a label read by the experimenter.

Green and Pew found that education (technical vs. non-technical), road experience, and specific vehicle experience all affected a subject's symbol knowledge. In addition, analysis of task 1, familiarity, indicated that most symbols were unfamiliar; the mean number of familiar symbols was 2.6 out of a possible 19. The second task indicated that only 6 out of 19 symbols tested met Heard's acceptance criteria of minimum 75 percent recognition and maximum 5 percent confusion. In fact, many of the symbols which were confused with each other were also rated as being very poor for communication. Nevertheless, subjects were able to learn the symbol label pairs of the fourth task relatively rapidly (usually in 3 trials). Results for the fifth task, reaction time, indicated both a pronounced learning effect and variation in a subject's ability to do the task rapidly.

When Green and Pew examined correlations between tasks, they found that neither familiarity nor associative strength was strongly correlated with reaction time measures. Rated communicativeness, however, was highly correlated with associative strength and reaction time. Hence, this measure could conceivably be used as an effective measure of the utility of a symbol. The authors also noted that although sex and technical ability affected the initial recognition of a symbol, these did not appear to affect performance on the other tasks. Furthermore, although reaction time decreased with learning, it was affected by the discriminability of an individual symbol. Finally, the authors concluded that it is important to interview subjects to understand why specific symbols are mistaken and confused. The numerous confusions and mistakes reported by Green and Pew underline the need to research the understandability of specific symbols.

Because previous research had shown variability in the understandability of symbols, Green (1979) explored the development of better symbols for automotive controls and displays. First, Green had subjects draw symbols for each of seven referents. Then another group rated the meaningfulness of the six or seven most frequently drawn symbols for each referent.

In the first phase, 43 subjects drew pictures of seven referents--heater, air conditioner, fresh air vent, radio volume, radio tuning, tire pressure, and lamp failure. Three judges then scored these ratings by giving them labels such as "fire" or "snowflake" or some similar term. The drawings were then grouped by label and the most frequently suggested drawings were used as stimuli for the second phase. In the second phase, 62 subjects gave estimates of the informativeness of the newly drawn symbols. Subjects were given sheets upon which the referent (label) appeared in the center surrounded by four to ten candidate symbols. Subjects made magnitude estimations of the informativeness of each suggested symbol for the various referents. Analysis of the data indicated that subjects were able to agree upon at least one symbol for each referent. These symbols did not always agree with those in common use, however. Green (1979) concluded that having people draw symbols for proposed referents (the "production method") should be the first step in data collection for symbol research. Magnitude estimation should then be used to select the "best" of these symbols for a given referent for further study.

In a study of symbol discriminability, Green and Davis (1976) explored the effects of variation in the orientation of automotive symbol controls. Previous research, such as Heard (1974), evaluated the recognizability of automotive symbols placed in an upright position only. Yet symbols placed upon controls are often rotated away from upright, and consequently may not be rapidly or accurately identified.

Green and Davis presented ten subjects with three different symbols which varied in orientation. Subjects were given a page with numerous pairs of symbols, one of which varied in orientation. Half of the varied symbols were also reversed (mirror image). Subjects judged whether the symbol pairs were the same (S) or different (D) (mirror image reversed). Analysis of the results indicated that increasing the rotation of the symbol away from upright significantly affected response time for deciding if both members of the pair were the same. Green and Davis commented that this delayed reaction could be hazardous in an actual driving situation. As a result, because a driver could have difficulty in responding appropriately in an emergency, control symbols should always be mounted in an upright position. The problem of rotated symbols is greatest for controls which themselves can be moved away from a "normal" position.

2.4 PUBLIC INFORMATION SYMBOLS

The third application of symbols to be discussed is that of public information symbols. These are symbols which provide primarily directional information to the general public. Intended to be understood by a wide variety of people who do not speak a common language, they are frequently used in transportation facilities.

Research in this area has typically focused upon the meaningfulness, or understandability, of a set of symbols. For example, Easterby and Zwaga (1976) assessed the meaningfulness of various symbols for six informational referents under the sponsorship of the ISO. In a three stage experiment, they determined the "best" symbol for the following referents: drinking water, information, stairs, taxi, toilets, and waiting room. First a small sample of subjects from the U.K. and the Netherlands ranked a large number of symbols in terms of their "appropriateness" for a given referent. Three symbols were chosen from these rankings for each referent for further research. In the second phase, subjects from six countries gave meanings for each of the three symbol sets.

Easterby and Zwaga found that subjects were able to provide a more-or-less accurate definition for some symbols. Other symbols, however, received few correct definitions and a high percentage of "don't know" answers. Symbols that were readily understood were highly pictorial rather than abstract.

In the third phase, groups of subjects from six countries matched each of six referents against a group of 24 symbols. Different groups received one of three versions of the symbols being tested for the six referents. (Eighteen of the symbols merely provided choice alternatives). Each subject matched only one version of a symbol for each referent. Easterby and Zwaga found that the matching test allowed them to select a "good" symbol from a set of symbols, but was limited by the quality of the symbol set. Thus, the matching test would not allow subjects to indicate that none of the symbols was particularly effective. As a result, the authors recommended that a matching test be done after recognition testing has indicated the most "meaningful" symbols.

Both the matching and recognition test data provided valuable insights into the confusion between symbols, as well as the kinds of alternative answers given by subjects. These data were instrumental in selecting the set of public information symbols currently recommended by ISO.

The other major evaluation of the effectiveness of public information symbols was commissioned by the U.S. Department of Transportation (DoT). First, DoT sponsored the design of a set of 34 public information signs by the American Institute of Graphic Artists (AIGA). After compiling a list of existing symbols for each referent, the AIGA (1974) then designed what they considered to be the best symbol for a given referent based upon this compilation.

The list of symbols developed by the AIGA is currently under evaluation by the Franklin Research Institute. In an interim report, Freedman, Berkowitz, and Gallagher (1976) used a variety of both paper-and-pencil and performance tests to assess the symbols. These tests were designed to assess the recognizability of the symbols, elicit confusions, and provide an indication of the relative difficulty of the symbols. While the initial tests were designed as input to a subsequent, large-scale testing phase, they did indicate that the symbols varied widely in initial recognizability. For example, only eleven of the 34 symbols were understood by all subjects.

Following completion of the paper-and-pencil tests of appropriateness, subjects completed a "walking rally." In this test, subjects followed the symbols to various locations within a building. Time to arrival and correctness of the destination were monitored. Freedman and Berkowitz (1977) also administered matching and multiple choice tests at an airport and a subway station, and are in the process of a large-scale test of the 34 symbols at a variety of transportation facilities.

Preliminary comparison of the paper and pencil data with the field data indicated few differences in the subjects' responses. Because about 9 symbols were missed by a large number of subjects, the authors proposed several criteria for effectiveness. They suggested that symbols which are recognized by 60 percent or fewer people are clearly unacceptable, while those recognized by more than 80 percent are acceptable. Finally those recognized by 60-85 percent need some improvement. The Franklin Research Institute is currently testing these criteria and test procedures.

These two research projects have assessed the meaningfulness of public information symbols with large groups of people--people who would likely use these symbols. Unlike the highway symbol research, no assessment of the speed of detection was made, nor were the symbol signs directly compared with word signs. As with automotive/machinery applications, meaningfulness or understandability appears to be the most useful characteristic by which to evaluate public information symbols, and certainly is the most frequently used by researchers.

2.5 PRODUCT LABELING SYMBOLS

Another emerging application of symbols is that of product labeling. While the Canadians, the British, and the Common Market (EEC) have all proposed or adopted standards for warning consumers of potential hazards, there is little if any research on the effectiveness of these symbols. In addition, several controversial product labeling symbols have been produced in the U.S. These include "Mr. Yuk," produced by the Pittsburgh Poison Control Center, to replace the skull-and-crossbones to warn children of poisonous substances, and the lawnmower and CB antenna symbols developed by the Consumer Product Safety Commission (CPSC) to warn consumers of potential accidents. While these symbols generated much discussion, only the effectiveness of Mr. Yuk has been researched. "Mr. Yuk" has been found to be understood by small children as indicating a hazardous ("yuky") substance, although its effectiveness for adults has not been determined.

One of the few extensive assessments of product labeling symbols was conducted in Great Britain by Easterby and Hakiel (1977a, 1977b, 1977c). In their first study, Easterby and Hakiel (1977a, 1977b) had people design signs to convey fire, poison, and caustic hazard information. Subjects were provided with a selection of image forms and colors, background colors and shapes, enclosure shapes and colors, surround shapes and colors, and supporting field colors.

Analysis of the results indicated that red was the perferred color for fire signs while black was preferred for poison. Both red and black were equally liked for caustic. Easterby and Hakiel (1977b) commented that these colors appear to be chosen to indicate the identity of the hazard, and, consequently, reinforce the function of the image. The stereotypes generated in this series of studies were used to construct signs for a subsequent study of the understandability of product-warning signs.

In the final study, Easterby and Hakiel (1977c) evaluated product-labeling signs by first having students rank-order a set of symbols in terms of their effectiveness in conveying a given message. This procedure reduced the large number of symbols found in a compilation of existing symbols to 4 symbols for each of 3 hazards (fire, poison, and caustic). The ordering experiment revealed that subjects preferred symbols which described the hazard (descriptive) to symbols which prohibited a hazardous action (proscriptive) or prescribed a course of action to avoid a hazard (prescriptive). Furthermore, when there were several versions of a somewhat similar image, subjects preferred the visually more complex image to a graphically simplified one. It is not clear, from the authors' description, whether a complex image is also more graphically representational.

The symbols selected from the pilot test were then studied in a nation-wide survey of 4000 respondents in the U.K. The survey consisted of a recognition test in which each subject provided meanings for each of 17 signs--5 test signs and 12 contextual signs that might be found on consumer goods or in public environments. The five test signs included the poison, caustic, and fire symbols developed earlier, as well as electrical and general hazard symbols. All 4,000 respondents judged the 12 context signs, while only 500 respondents judged each variant of each hazard sign.

Analysis of the results indicated that attributes of the sign (image, color coding, and shape coding) and characteristics of the respondents (age, sex, household composition, and experience with signs) all influenced the recognizability of the signs. They suggested that symbols which have been extensively simplified from a graphic standpoint do not perform as well as more complex images -- which one can infer, resemble the intended referent more closely.

Easterby and Hakiel (1977c) concluded, however, that the single factor which primarily affects recognition performance is image content. Other factors such as color and observer characteristics are important, but ultimately the understandability of the sign will depend on the symbolic image chosen.

2.6 SAFETY SYMBOLS

Although there do not appear to be any studies which have assessed the effectiveness of symbols for workplaces, two studies have examined aspects of safety signs. One (Collins & Pierman, 1979) evaluated the meaningfulness of fire safety symbols. The other (Laner & Sell, 1960) determined the effectiveness of safety posters. Although Laner and Sell did not assess symbol use, their work is of interest because it measured the effectiveness of safety messages directly in terms of changes in unsafe behaviors.

Collins and Pierman (1979) reported an experiment in which they determined the understandability of 22 "fire safety" symbols proposed by ISO. They asked 143 subjects to provide a short definition for each symbol. Three judges rated the answers as "correct," "incorrect," or "no response." In addition a tally was kept of the number and kind of incorrect answers. The percentage of subjects responding in each of the three ways was calculated for each symbol.

The authors found that some symbols such as "fire extinguisher," "no smoking" and the conventional U.S. "exit" sign were understood by almost all the subjects tested. Yet other symbols such as "blind alley," "do not block" and "break glass" were understood by less than 20 percent of the subjects. In addition, several symbols were given a meaning opposite to that which was intended. Thus, the "no exit" or "blind alley" symbol was interpreted as "exit" or "safe area" by almost all subjects who gave a definition for this symbol. Altogether over 95 percent of the subjects either misidentified or did not respond to this particular symbol.

The authors commented that an instance in which a symbol is given a meaning opposite to that which is intended is potentially very dangerous. They recommended that before symbols are adopted, particularly those which communicate emergency information, their effectiveness must be evaluated. A safety symbol must be understandable before it can begin to alter behavior and prevent accidents.

Laner and Sell (1960) examined the effectiveness of safety messages in altering unsafe behavior. Although safety posters with various sorts of warning messages have typically been used in an effort to stop unsafe acts, their effectiveness in actually modifying these behaviors has rarely been assessed. Effectiveness could be measured by studying accident rate reduction directly, except that the frequency of accidents is so low that the experiment would be inordinately long. Laner and Sell also rejected the idea of measuring poster effectiveness in terms of the extent to which a poster could be recognized, remembered, or liked because these measures do not assess actual behavior.

Consequently, Laner and Sell (1960) selected a behavioral measure which could involve an operation that was potentially dangerous, frequently carried out, and readily measurable--namely, the hooking back of chain slings onto a crane hook when not in use. Seven steelworks participated in the experiment in which posters depicting safe steelworking practices were developed and displayed. First a baseline of behavior was established over five weeks without poster display. Then the posters were displayed. Behavior was measured for five weeks, followed by a lapse of 7 weeks without measurement, concluding with 2 additional weeks of measurement.

Laner and Sell found that the posters had a positive effect in the six test steelworks (substantial for four of these) but no effect in the seventh, or control steelwork. Furthermore, they noted that the behavior affected by the posters was at least maintained, if not improved, following the seven week period in which behavior was not measured. The authors suggested that these posters were effective either because they acted as perpetual reminders or because they established or reinforced working habits which were self-maintained. They also found that the increase in safe behavior was greatest in those shops with low ceilings where the unsafe practice constituted the greatest hazard to personnel. They concluded that posters may be more effective if the message they carry can be seen to be directly relevant to the situation. Such a conclusion may be extended to the use of safety symbols as well. In addition, the use of a behavioral measure--reduction of unsafe acts--is perhaps the ultimate measure of a sign or symbol's true effectiveness. Its use should be explored more for all applications of symbols.

3. DEVELOPMENT OF WORKPLACE SAFETY SYMBOL REFERENTS

3.1 OVERALL PROCEDURES

The preceding review of research on symbols indicated that researchers typically began their evaluative process with an existing set of symbols for specific referents. These symbols were developed primarily by standards organizations, graphic designers, and manufacturers, so that the role of the researcher was confined to evaluating these specific images.

The case for evaluating symbols for workplace safety is a bit different, however, in that there is no single set of existing symbols. Rather, numerous symbols abound for some referents while few symbols exist for other referents. Further, the most important set of referents to symbolize has not been determined. Because there are no complete standards in the U.S. for either symbols or referents for signs for workplace safety, the first task in an assessment of symbols for workplaces is to determine the symbols that are currently used and the kinds of general situations which appear to require hazard warnings. Secondly, a list of symbol referents which is broad enough to be applicable to most workplace situations must be developed. Finally, specific symbols for these referents must be selected and evaluated experimentally. NBS is following these 3 steps in its evaluation of worker safety symbols.

In this section the various sources used to develop an initial listing of safety symbol referents are outlined. Three major sources were consulted. These included site visits, sign catalogues, and national and international standards. Each of these will be reviewed in turn. Finally a list of symbol referents based upon all of these sources is outlined.

3.2 SITE VISITS

One source of information about current symbol use was observations made during visits to six industrial sites. Six plants were visited to provide familiarity with sign usage in the field. The sites were selected to represent as wide a range of industries as possible and included: the manufacture and assembly of heavy equipment engines; the manufacture of ceramic glass; the final assembly of aircraft; the chemical manufacture of vinyl acetate based resins; shipbuilding (manufacture, assembly, and repair); and oil refining. These sites not only provided a range of major industries, activities, and hazards, but also a spectrum of philosophies in workplace safety practices and sign use. Consequently, the plant visits provided invaluable background for this project.

Table 1 summarizes some of the findings of the site visits. For each plant, this table outlines plant size, activity, hazards, and comments on sign usage. This information is based on our interpretation of observations and conversations with plant personnel, and should not be interpreted as reflecting official statements or policy of the company or as critical evaluations on our part.

Appendix A presents a listing of signs observed, organized by type of sign (prohibition, safety gear, etc.). Although many signs contained more than one type of message (e.g., "caution-lead work--no eating, drinking, or smoking"--"gloves and shoes required"), they are presented in only one of the categories in Appendix B. For each generic referent (e.g., "wear hearing protection"), every sample of specific wording was recorded to give an indication of the variability of the signs and any subtleties or differences in meaning. These observations were confined to safety signs observed in the workplace, and exclude signs on vehicles, machines, and tools. Posters and admonitions (e.g., "safety first") were not included.

3.2.1 Generic Hazards and Common Injuries

Each industry has a unique set of major hazards associated with its activities, such as explosion, extreme heat, caustic chemicals, fire, etc. The most frequently reported injuries, however, usually appeared unrelated to these major threats and were similar from plant to plant. These common injuries included slips (especially where oil, ice, or chemical substances could be on the floor), hand and finger injuries, back injuries, eye injuries, and cuts. Safety officers often expressed the opinion that workers were cautious about major hazards and were more likely to be injured where work was routine and repetitious. Somewhat in contradiction, equipment maintenance workers appeared to have especially high injury rates relative to other employees, and this was often attributed to the novel or unfamiliar tasks required of the maintenance staff. As is obvious from Appendix A, safety signs seemed to be most frequently related to potential hazards, or protective gear rather than to common injuries.

Table 1. Site Visits

Kind of Plant	Approximate Size	Activity	Typical Hazards	Sign Usage
Heavy Equipment Engines	300 employees	manufacture and assembly of engines and power trains	fire corrosion high noise level oil slicks on floor	extensive use of eye protection signs color coded hazard areas few symbols signs placed near high hazard areas
Ceramic Glass	600 employees	manufacture and packaging of glass and glass products	extreme heat high noise cuts from breaking glass	color coded areas for eye protection extensive feedback on current plant safety record few symbols
Aircraft Assembly	700 employees	final assembly of aircraft	explosion fire flying objects	extensive warnings about explosion eye protection and fire safety signs at intersections color coded hazard areas few symbols
Chemical	600 employees	manufacture of vinyl acetate-based resins	fire corrosion explosion slips and falls in outdoor areas	extensive warning about localized high hazard areas few symbols except "ear protection"
Shipbuilding and Repair	23,000 employees	ship building, repair and manufacture of associated products	slips, falls explosion lifting of heavy equipment fire radiation	extensive use of pictograms for protective equip-ment many safety posters
Oil Refinery	900 employees	oil refining shipping, receiving chemical production	explosion poisonous chemicals carcinogens noise dust burns fire	extensive warnings about localized hazards lengthy word signs on hazard identifi-cation & avoidance "no smoking" symbol

3.2.2 Use of Pictographic Signs

In general, the six plants relied heavily upon word signs. Because employees were believed to be generally literate in English, there was little perceived requirement for pictographic signs. Nevertheless, the DoT hazard warning symbols for material transport were in widespread use, as were symbols for vehicle operating instructions and precautions. Neither of these can be directly transferred to workplace safety symbols, however.

One plant did deliberately use a large number of pictograms, primarily to remind personnel to wear safety equipment. This plant had a noticeable number of illiterate employees as well as foreign visitors. Symbols were also believed to be "eye-catching." In other factories, some specific hazards were symbolized pictographically. These included "no-smoking" at one site where there were foreign visitors, and "high noise area--ear protection required" in another plant. Other than these examples, however, the common practice was to use word signs--often quite lengthy word signs.

3.2.3 Alternatives to Signs

Two alternative strategies to the use of safety signs were observed. One strategy is to institute a general policy regarding some hazard, and then only indicate where this policy is suspended. For example, in a chemical plant, where a threat of fire or explosion is prevalent, smoking and matches may be generally prohibited except where noted.

The other common alternative to specific safety signs is to indicate general information or warning by color coding of particular areas through colored lines on the floor or on definite hazards. (In contrast to color coding of signs, here the color is the entire message.) For example, yellow lines are commonly used to indicate a general hazard area while red bands are used to indicate fire fighting equipment. Such color coding contrasts with the more specific messages about hazards or procedures contained in workplace signs.

The colors encountered were:

Red: fire related (equipment, sprinkler lines, alarm), emergency alarms, hazard (e.g., cranes, flags or tags on dangerous or broken equipment)

Orange: explosives

Green: safety (protective equipment, eye wash, emergency shower), delimit safe walkways

Yellow: hazard

White: delimit safe walkways

The yellow hazard warning was particularly frequent, and used in the following ways:

- denote hazardous areas limited to knowledgeable personnel
- indicate moving parts, equipment, and guardrails
- indicate overhead hazards such as cranes
- denote areas where some safety equipment is mandatory (hard hats, safety glasses, or hearing protection)

In some factories, because the use of color coded areas dominated safety communication, signs were relatively infrequent. In contrast to signs, this coding could be spatially precise, indicating the exact location and extent of the hazardous area. While the prevalence of the yellow hazard indication suggests the need to adopt a good pictogram indicating a general hazard, the use of such a symbol as an alternative or supplement to simple color coding requires consideration (for some applications).

3.2.4 Sign Context

One question addressed during the site visits was, how are signs presented? In other words, where are they typically located, how are they illuminated, where are they located with respect to the hazards they represent, and what is the background against which they are presented? Although such details are expected to vary, there were highly idiosyncratic practices and extreme variability in sign presentation among the sites visited. Even the same message (e.g., eye protection required) was presented in many different ways: signs were placed on stands in the aisles, or mounted on walls (sometimes well above eye level and out of the usual visual field), or above entrance ways, or on fixtures and equipment. Often, signs were presented in clusters, rather than singly. Lighting varied from signs poorly placed in shadow, to ones placed in bright illumination. Warnings were sometimes placed at entrances, sometimes located around the workspace, and other times mounted on or near the hazard. Sometimes warning signs were difficult to see due to clutter, poor maintenance, or blending into the background color. (In some cases the predominant workplace color was yellow to yellow-green, making yellow warning signs obscure). As a result, no "typical" or "representative" contexts were identified. What is a familiar context in one setting appears unusual in another plant, or even in another section of the same plant due to differences in hazards, layout, and sign usage.

3.2.5 Most Frequent Signs

Table 2 indicates the types of generic safety messages that occurred with high frequency across the various industries. The messages in the table are given in general form (e.g., restricted admittance), even though the wording of individual signs may have varied (e.g., authorized personnel only, positively no admittance, restricted area, do not enter, etc.). While the messages in Table 2 represent commonly occurring and

Table 2: Common Generic Messages From Site Visits

Hazards;

General
Electrical
Flammable
Explosive
Heat
Caustic, acid
Overhead
Noise
Slip/Trip/Watch Your Step
Vehicles
Radiation

Safety and Emergency Gear;

Eye Protection Required
Hard Hat Required
Foot Protection Required
Hearing Protection Required
Caustic-Handling Gear Required

Breathing Gear
First Aid
Emergency Shower
Eye Wash
Fire Alarm
Fire Extinguisher
Fire Hose

Prohibitions;

No Smoking
No Flames, No Hot Work
Do Not Touch, Keep Away From

Egress, Access;

Walkway
Exit, Emergency Exit
No Exit
Restricted Admittance
Keep Area Clear
Keep Door Open
Keep Door Closed

important workplace signs, they should not be viewed as a complete list, given the limited number of plants visited.

3.3 SIGN CATALOGUES, PUBLICATIONS, AND MANUFACTURERS

3.3.1 Catalogues and Publications

In addition to the site visits the following sources were reviewed for information on symbol availability: sign catalogues, sign manufacturers, individual company guidelines, and compilations of pictorial signs (Dreyfuss, 1972; Modley & Myers, 1976).

A list of the most frequently occurring kinds of symbols was compiled from this review and is given in Table 3.

The review of catalogues and publications indicated many common symbols. These fall into categories such as protective gear, hazard warnings, prohibited actions and information about fire and safety instructions. In addition, at least one catalogue offers an extensive list of unusual symbols to fit most hazards. This report, however, concentrates upon the most frequently occurring symbols as being representative of current offerings from sign manufacturing catalogues.

3.3.2 Information From Sign Manufacturers

To assess the extent of the demand for and the use of symbolic signs, twelve sign manufacturers were contacted. They were asked for any available information on sign use, including the most frequently purchased signs, the most frequently requested symbolic signs, and the perceived demand for symbolic signs.

Although the responses differed greatly in terms of the detail provided, there seemed to be a feeling that the demand for pictorial signs was increasing. One manufacturer of both written and symbolic signs observed a "very significant increase in the demand for pictorial signs," estimating an increase of "about 10 percent or better per year for the past five years." Another company still produced mainly written messages because it felt some messages could not be adequately conveyed symbolically. However, it added that this could change if there were changes in the standards to accommodate symbols. In general, the responses indicated industry interest in symbolic signs and concern over issues of standardization and effectiveness. Some sign manufacturers expressed a need for some form of agreement, but also indicated concern about proprietary rights for symbols developed by individual companies.

The manufacturers noted that many of the most widely requested pictographic signs were not safety related (e.g., men, women, handicap access, etc.). Perhaps the most frequently cited symbolic safety sign was "no smoking." While this pictogram varies somewhat, nearly all examples provided used the familiar image of a burning cigarette with

Table 3. Symbols Typically Available From Sign Catalogues

Prohibition;

No smoking
No open flame
Do not enter
Authorized personnel only
Keep out/no trespassing
Do not touch

Protection;

Eye protection
Hard hat area
Hearing protection/noise area
Respirator required/self-contained breathing apparatus
Foot protection required
Hand protection required
Face protection required
Protective clothing required
Protective belt/harness required

Hazards;

Radiation area
Electric shock/high voltage
Corrosive/caustic/acid
Flammable
Fork lift trucks/vehicles
Explosive
Poison
General hazard
Overhead hazard
Slippery surface/danger of falling
Laser
Falling objects/flying objects
Hot surface/danger of burns
Biological hazard
Crushing/entanglement

Fire;

Fire extinguisher
Fire hose and reel
Fire alarm
In case of fire, use stairway
Do not use water to extinguish
Fire exit
Fire hydrant

Information;

First aid
Safety shower
Eye wash
Smoking area/smoking permitted
Direction

Exit
Keep door closed
Stretcher
No exit/door blocked
Pedestrian crossing/crosswalk

a prohibitory slash through it. Figure 3 presents collected examples of this image to illustrate the range of graphic variation. Other frequent symbolic signs included those for protective gear (glasses, ear protectors, hard hats), flammable hazards, and fire equipment (extinguisher, hose). Although quantitative information on the use of these signs was not available, many additional examples of pictograms were provided during the review of sign catalogues (see section 3.2).

There appears to be only partial correspondence between the pictograms that appear to be most in demand from manufacturers and the written signs most frequently observed on plant visits. Although the pictograms -- for "no smoking," "protective gear," and "fire equipment" -- do in fact represent a subset of the most frequently encountered messages, it is that subset that can be most plainly and literally represented by a simple picture. Other frequent messages -- related to egress, restricted access, general hazard, doorways -- appear less in demand as pictographic signs. Correspondingly, the graphic representation of these messages varies much more from company to company. This suggests that developing an explicit consensus representation for such messages may be an important step in increasing demand for these symbols. Such a consensus may arise through the ANSI Z535 subcommittee on safety symbols which has begun to identify referents for further investigation.

3.4 REVIEW OF SYMBOL STANDARDS

Another source that was reviewed is that of national and international standards for symbols. As noted earlier, there is no standard in the U.S. for workplace symbols, although ANSI has recently chartered the Z535.3 Subcommittee on safety symbols. The current OSHA standard does not deal directly with workplace safety symbols except for those for radiation and biohazard. DoT does use the international (U.N.) standard for symbols for the transport of hazardous materials. Because these symbols appear upon containers used in factories, they should be reviewed for consistency with workplace symbols. In addition, individual companies and government agencies have developed their own standards (see the proposed Air Force Standard, DoT Transportation Symbols, Du Pont Symbols, and FMC symbols). These symbols are applicable only upon a specific and limited basis. Symbol and sign referents used within the U.S. are given in Appendix B. In addition, referents from other countries in North and South America are given for comparison purposes.

At the international level, the International Organization for Standardization (ISO) TC 80 has drafted a standard (DIS 3864.3) for worker safety symbols which is currently under consideration. The EEC directive (R/1455) provides a similar set of symbols and referents, as do many other national standards: Great Britain (BS 5378), Australia (AS-1319), Netherlands (NEW 3011), and France (NF X08=003). See Tables 4 and 5 for a listing of common referents from these international standards.

Symbol standards which tend to vary from the ISO norm are those from countries outside Europe. The Canadian Standard (CAN 3-Z321-77) provides

Figure 3. Graphic Variation for a Single Conceptualization for "No Smoking" (Some of these symbols may be privately coywritten).

Table 4. Symbol Referents Standardized by ISO and the EEC for European Application

ISO - DIS - 3864.3

Safety Signs

Prohibition Signs

1) Smoking prohibited
2) Fire, open light, and smoking prohibited
3) Thoroughfare prohibited for pedestrians
4) Water as extinguishing agent prohibited

Mandatory Action Signs

5) General mandatory action - exclamation point
6) Eye protection must be worn
7) Respiratory protection must be worn
8) Head protection must be worn
9) Hearing protection must be worn
10) Hand protection must be worn
11) Foot protection must be worn

Warning Signs

12) General warning, caution, danger, risk
13) Caution - risk of fire
14) Caution - risk of explosion
15) Caution - risk of corrosion
16) Caution - toxic risk
17) Caution - risk of electric shock

Information Signs

18) First aid
19) General indication of direction

The EEC Directive (R/1455) adds the following referents:

1) Not drinking water
2) Caution - radioactive material
3) Beware - overhead load
4) Beware - industrial trucks
5) Emergency exit with 3 symbols

Table 5. Common International Referents for Symbols from the Australian, British, Dutch and French Standards

Prohibition

No smoking
No open flame
No pedestrians
Do not extinguish with water
Not drinking water

Warning

Flammable material - risk of fire
Explosive material - danger of explosion
Toxic matter - danger of poison
Corrosive matter - risk of corrosion
Radioactive material
Risk of electric shock
General danger
Danger - overhead load
Danger - industrial trucks
Caution - laser beam
Danger - biohazard
Slippery when wet
Danger - compressed gas
Danger - insufficient clearance

Safety Instruction - Mandatory Action

Eye protection required
Hard hat required
Ear protection required
Respirator required
Safety gloves required - hand protection
Safety shoes required - foot protection

Information

First aid
Direction
Emergency exit
No admittance
Fire extinguisher
Eyewash
Shower
Stretcher
No trespassing

a list of referents and suggested glyph (image) content for some 50 signs related to the occupational environment. The Uruguayian standard lists 8 symbols warning of hazards (UNIT 131-58). The Bolivian standard (NB20.1-003) lists only 6 hazard-warning symbols. The Philippines do not appear to have a standard for worker safety symbols although they have adopted the U.N. (DoT) standard for symbols for the handling of goods (621.798.7). Although the Japanese standard (Z9103-1965) provides hazard warning signs and symbols for 8 situations. Table 2 of Appendix B provides symbol referents from non-European standards.

3.5 SYMBOL REFERENTS RECOMMENDED FOR STUDY

After reviewing the wide range of symbol referents collected from sign catalogues, sign manufacturers, site visits and sign/symbol standards (both national and international), a list of 40 referents was compiled for further experimental study. This list which is presented in Table 6 is based primarily upon the frequency of occurrence of a particular referent in each of the sources. Additional referents will be added as the need arises.

Table 6 represents the authors' judgment of the importance of the specific referents for testing purposes, and should be viewed as an initial prioritization, which may be altered following consultation with safety experts.

The referents are given in intentionally general form (e.g., "eye protection required"). At some point, further discrimination among referents may be required (e.g., "safety glasses," "safety glasses with side shields," "safety goggles"), depending upon the need to provide information about a specific hazard or action.

Table 6 is, of necessity, an incomplete list of important workplace safety messages. It contains messages that occur generally across various industries, rather than ones of particular importance in specific work areas. Nevertheless,the selected items should be widely applicable. This list is a compilation of symbol referents, or the message to be communicated, rather than a list of symbols. A compendium of different symbol images for each of the referents identified in Table 6 is being developed. The compendium will be based upon variations in image content rather than upon sign shape or color. It is intended to show some of the differences in imagery within categories, and provide the basis of a set of images for further testing. As an example, Figure 4 presents examples of "No Smoking" symbols in addition to the variants already presented in Figure 3. Thus Figures 3 and 4 together illustrate for one referent the collection of images to be represented in a compendium.

Table 6. Selected List of Symbol Referents

<u>Access/Egress</u>;	Restricted access, do not enter Exit No exit Emergency exit	Pedestrian pathway Direction Keep area clear, do not block Keep door closed Use stairs in case of fire
<u>Prohibition</u>;	No smoking No open flame	Do not use water to extinguish
<u>Protection</u>;	Eye protection Ear protection Head protection Foot protection	Breathing Hand protection Face protection
<u>Hazard</u>;	Electricity Fire Explosion General Radiation Corrosion Poison Overhead	Hot Slips, trips, watch your step Entanglement Fork lifts, vehicles Starts automatically Laser
<u>Emergency</u>;	Fire extinguisher Alarm call point First aid Safety shower Eye wash	Fire hose Stretcher

Figure 4. Further examples of "No Smoking Symbols in addition to those in Figure 3 (Some of these symbols may be privately copywritten).

4. NEEDS FOR RESEARCH ON WORKPLACE SYMBOLS

4.1 EFFECTIVE SYMBOLS: RESEARCH FOCUS

Sections 2 and 3 reviewed research methods and results, and developed a list of referents for workplace symbols. In developing the list of symbol referents, it became clear that there is no single set of existing workplace symbols. The number of images for each referent varies from 2 to over 20. As a result, the development of effective symbols for workplace safety will require selecting several plausible symbols for each referent, testing the understandability of each symbol, and selecting the most understandable symbol based upon experimental results.

To be effective, a symbol must be understood; it must communicate the desired meaning to all those who encounter it. While understandability is a critically important criterion by which to evaluate a symbol, it is not the only one. A symbol must also be detectable at a given distance under specific light levels. A symbol must be discriminable, or distinguishable from other symbols within a particular set. A symbol must be recognizable, or be remembered and identified under different circumstances. A symbol must be graphically satisfactory and command attention. Finally, a symbol must alter behavior in the intended direction and facilitate conformance with the message. A fully effective symbol performs well in each of these areas. Understandability, however, is the key which unlocks the whole process of conveying a safety message.

As a result, the priority for research on safety symbols is to determine the understandability of the various images proposed for each referent. In this way, the most understandable image can be selected for a given referent. Determination of understandability is particularly critical for workplace safety symbols, where the consequences of failure to understand could lead to serious injury.

4.2 PROCEDURES FOR EVALUATING UNDERSTANDABILITY

As noted earlier, evaluation of understandability should proceed in several stages. Where a large number of different images exist for a given referent, this number must be reduced if further research is to be practical. The process of reduction is best done experimentally, through the use of a ranking procedure. In a ranking procedure, subjects order a set of images according to how well they believe that each image conveys the meaning of the referent. Easterby and Zwaga (1976) followed this procedure with small groups of subjects in two countries to select three sets of public information symbols. Similarly, Heard (1974) and Green (1979) had subjects rank images for automotive displays and controls according to meaningfulness. Use of rank-ordering can reduce a large set of symbols to a more reasonably sized set for subsequent testing. It also ensures that the set of images tested is at least somewhat meaningful. As a result, ISO TC-145-SC1 recommends rank-ordering as the best procedure for reducing the size of a set of images.

When a large number of images does not exist, or where no existing image appears to be meaningful for a particular referent, use of the "production method" can be valuable. In this method, subjects are given a referent and asked to draw a symbol which conveys this meaning. Brainard et al. (1961) used the production method to generate highway sign images. Similarly, Green (1979) used this method to develop images for automotive controls. In conjunction with a graphic artist, the production method is advantageous in producing a large number of images which are meaningful to the subject group, and which can then be reduced through rank-ordering. Once a set of symbols has been ranked according to meaningfulness, the highest ranked images must then be evaluated for their understandability to a new, larger group of subjects. Because of the large number of existing images for most workplace safety referents, the production method may be needed only at a later stage where no image has tested well for a particular referent.

Assessment of understandability has been done in several ways. The most common method is to ask subjects to provide a verbal definition of the symbol. As examples, Brainard et al. (1961), Walker et al. (1965), Dewar and Swanson (1972), Cahill (1975), Easterby and Hakiel (1972), and Collins and Pierman (1979) all asked subjects to provide definitions for symbols in applications ranging from highway to automotive to safety. Fewer researchers have used matching or multiple choice procedures, among them Brainard et al. (1961), Freedman et al. (1976), and Lerner and Collins (in preparation). In this procedure, subjects are given a list of meanings for each symbol and asked to select the correct one. Comparisons of multiple choice and definition methods have found that although the the percentage of correct answers is typically somewhat higher for multiple choice procedures which appear to provide some context and additional information about the symbol, the ordering of correct responses for both methods is similar (Brainard et al., 1961; Lerner and Collins, in preparation). In a related "matching" type of procedure, subjects are asked to select a symbol which "matches" the referent from a larger set of symbols. Used by Freedman et al. (1966), and Easterby and Zwaga (1976), this procedure provides information on the confusability of items within a set of symbols. Easterby and Zwaga (1976) recommend its use as the final step in a complete evaluation of symbols to eliminate confusion from a coordinated set of symbols.

Another general evaluation method involves the use of ratings, such as category scales and the psychophysical procedure of magnitude estimation, in which a subject is given the referent message and is asked to provide a numerical estimation of how meaningful each symbol is. This procedure has been used by Dewar and Ells (1977), Green and Pew (1978), and Green (1979). Rating scales may be less useful for determining whether a subject knows precisely what a particular symbol means, since no measure of response correctness is obtained.

Once a set of symbols has been tested for understandability, a decision can then be made about each symbol's adequacy. However, there is no obvious criterion for an "acceptable" symbol. Nonetheless, some consensus exists in the literature. Heard (1974) considered symbols to be understandable if they were defined correctly at least 75 percent of the time with only 5 percent confusion with other symbols. Freedman and Berkowitz (1977) suggested that scores below 60 percent correct response indicate an unacceptable symbol, scores above 85 percent correct indicate an acceptable symbol, and scores between 60-85 percent correct indicate symbols which require improvement. Brainard et al., (1961) suggested that symbols which have correct responses over 85 percent fall into the high recognition category. While these researchers agree that 75-85 percent correct recognition indicates that the symbol is meaningful, this cut-off should be contingent upon the demands of the specific symbol set and method of evaluation.

In fact, since some methods (e.g. matching or multiple choice) could produce a higher percent of recognition than other methods (eg, definition), the stringency of the criterion may need to vary with the procedure. Lerner and Collins (in preparation) have further suggested using confidence ratings to supplement the percentage correct measure.

On the other hand, the relative performance of the various symbols, regardless of absolute levels, also provides valuable information about the effectiveness of the symbol set. As a result, the choice of criterion should depend upon the kind of evaluation procedure employed and the eventual application of the symbol. Where context information is given by the test format, the criterion for acceptance should perhaps be higher.

In another approach to setting criteria, the latest draft of the ISO TC 145 addendum to ISO 7000/DAD 1 suggests the criterion should be based upon the level of risk. It suggests that for small risks, an 85 percent correct response for the ISO recommended matching test is desirable. For larger risks, a level of 95 percent correct response is recommended with no other referent greater than 1 percent (confusion). Unfortunately, large and small risks are not defined. These two approaches suggest that both risk level and evaluation procedure as well as the eventual application should be considered in setting criteria for symbol acceptability.

If none of the workplace safety symbols evaluated for a given referent meet the predetermined criterion for understandability, then the symbol must be redesigned, or an intensive educational program must be developed and implemented. The production method could be profitably used at this point to suggest new graphic renditions. Similarly, the confusions generated by existing symbols can be reviewed to determine what graphic features create problems. Once a symbol has been redesigned, it should then be re-evaluated.

4.3 OTHER RESEARCH CONSIDERATIONS IN DETERMINING SYMBOL EFFECTIVENESS

Assessing the meaningfulness of a symbol is a critical element in the initial evaluation. However, a complete description of the performance and usefulness of a symbol requires further considerations. One important test procedure is a behavioral one, in which subjects must perform the action indicated by the symbol. This procedure, although rarely used, can be one of the most critical, for it indicates not only that subjects can define a symbol, but further that the symbol is effective in eliciting the indicated action. The problem in using this technique is to determine some measurable activity and then measure the frequency or accuracy of its occurrence with and without the symbol. Thus, Janda and Volk (1934) asked subjects to push a lever in the direction indicated by the symbol while Heard (1974) had subjects touch automobile controls that were represented by symbols. Freedman et al. (1976) observed whether subjects could correctly negotiate their way through a museum, following directions provided only by symbols. Forbes et al. (1963) determined the lane position where motor vehicles swerved to avoid a highway barrier with and without a lane change symbol, while Dewar and Swanson (1972) counted the number of times that vehicles made illegal left turns in full view of a "No left turn" symbol. Each of these experiments determined whether a symbol effectively altered behavior in the desired direction. Such a determination appears to be the logical final step in an assessment of symbol effectiveness in a given situation. Unfortunately, in many cases, particularly with safety signs, there is no explicit overt behavior associated with the message. While actual reduction in accident rates could be measured, the rarity of such events would require large scale, long term studies. Nevertheless, the use of protective gear and the avoidance of prohibited acts could more easily be studied as a function of the type of warning message or symbol.

Another set of considerations in determining the effectiveness of a symbol is its performance under special conditions. These might include unusual physical environments such as smoke, dust, or poor illumination, or unusual states of the observer such as haste, distraction, panic, injury, drug or alcohol effects. Finally, such practical considerations as manufacturing costs or the potential for disfigurement or other vandalism must be taken into account before implementing a specific symbol.

Nevertheless the primary need for research on workplace safety symbols remains the experimental determination of the relative understandability of symbols proposed for each referent.

5. CONCLUSION

In support of the development of effective workplace safety symbols, the National Institute of Occupational Safety and Health (NIOSH) has sponsored a project at the National Bureau of Standards (NBS) to evaluate the use of pictographic signs in the workplace. This project consists of three general tasks: (a) a determination of the kinds of safety or hazard situations which require symbols and selection of appropriate safety messages; (b) development of a set of candidate symbols for each situation; and (c) experimental evaluation of the effectiveness of the symbols in communicating the intended meaning. This report documents the initial phase of the project.

In the preceding pages, we have reviewed the current use and status of workplace symbols. At this point, there is no consistent use of specific symbols to convey particular safety information. There is no agreement upon the referents or messages to be conveyed, nor upon the images to depict these messages. There are, however, numerous proposed and commercially available images for almost every common safety message. As a result, there is a great need to determine which messages should be standardized, and which images should be selected for these messages. In this report we have presented a list of messages which have high priority for initial consideration. In addition, we have discussed and recommended a number of procedures for the experimental selection and evaluation of workplace safety symbols. Throughout, the focus has been upon the need to evaluate the understandability of safety symbols because of the importance of accurate communication of the safety message.

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APPENDIX A

LISTING OF SIGNS OBSERVED

Type of Message	General Referent	Specific Wording or Image
Hazards	General hazard	Caution--hazardous area (NFPA hazard symbol) (demarcation lines, usually yellow) (yellow parts and rails) (tags, pennants)
	Electrical hazard	Danger--high voltage Danger--_____ volts High voltage _____ volts (color coding of equipment for voltage--green (lowest), yellow, red)
	Heat	Caution--hot, do not touch HOT Danger--burns Caution--hot water Hot water Danger--hot Danger--resin is packed hot.
	Flammable and Explosive	Flammable-keep fire away Class B, C explosive (Flammable liquid symbol) (AF explosive symbol) (orange doors indicate explosives) Danger--propane Danger--acetylene vent Liquid nitrogen
	Radiation	Danger--radiation area--keep clear Reactor plant controlled material Caution--radioactive material Pictogram of radiation symbol
	Chemical, caustic, acid	Caustic Danger--acid Danger--acid wastes Caution--hazardous chemical Danger--chemical unloading Warning--mercury in use Mercury handling Danger--caustic wash above Danger--caustic methanol solution Danger--phenol Danger--phenol and formalin storage Caution--nitric acid Danger--sulphuric acids Warning--mercury in use Danger--benzene--cancer hazard (H_2S area marked in magenta and yellow) Do not touch. Material will not wipe off and a severe burn will result
	Noise	Caution--high noise area Caution--high noise level Maximum exposure in this area ____ hours

Type of Message	General Referent	Specific Wording or Image
	Overhead, cranes	Danger--men working overhead Caution--watch crane Warning--watch for crane Caution--Keep clear of crane--no walking Watch your boom (Hooks and ends of cranes yellow)
	Pressure	Danger--high pressure air HP valve
	Traffic	Caution--lift truck operating area Caution--pedestrian crossing
	Automatic start	Danger--starts automatically Caution--conveyor automatically controlled--lock out before servicing
	Other	Caution--open pit Caution--aircraft on jacks Fragile--handle with care Stop--tank car connected ("Blue Flag" rule)
Safety Gear	General Gear	Warning--use safety equipment Think--wear proper safety equipment Wear your safety gear
	Head	Hard hat area Notice--hard hats required Danger--hard hat area Hard hats (Yellow lines to denote hard-hat area) Pictogram of head in hard hat
	Eye	Eye protection required in this switch room Notice--eye protection required beyond this point Safety first--eye protection required in this area Caution--eye protection required Caution--do not enter without eye protection Eye protection required when disconnecting hoses Caution--do not enter without wearing safety glasses Are your glasses on? Eye protection required in this area Notice--safety glasses required in this area Safety first--safety glasses required Caution--safety glasses required Caution--safety glasses required in this area Notice--safety glasses required beyond this point (Lines on floor to denote safety-glasses area) Wear your goggles when grinding Safety first--wear goggles when grinding Goggle area Save your eyes--do not operate without safety glasses and face shield Pictogram of safety glasses

Type of Message	General Referent	Specific Wording or Image
	Chemical, caustic	Acetaldehyde--Flammable corrosive--wear face shield, goggles, rubber gloves Wear face shields and chemical goggles when opening filter Caution--contains sodium hydroxide (caustic)--wear gloves and face shield when working around tank Caution--chemical goggles, face shield, rubber gloves and apron required when handling phenol, caustic acid, or other corrosive material Caution--goggles, face shield, and rubber gloves MUST be worn when drawing ammonia (. . . when working in screen) Hazardous raw materials list (matrix of corrosivity, toxicity, required gear)
	Foot	Pictogram of shoe with deflected arrow
	Hearing	Caution--high noise area--ear protection required Hearing protection required Notice--ear protection required in this area Hearing protectors must be worn inside yellow lines in forming department Caution--wear your ear protection in this area Engine testing--hearing protection required Think--if high noise work starts, use your ear protection Ear protection required--mandatory ear protection required beyond this point Pictograms of ear protectors, and hard hat with ear protectors
	Heat, fire	Asbestos suits only Kiln suits
	First aid station	First aid First aid room Dispensary Clinic To the dispensary Pictogram of cross (usually in conjunction with word sign)
	Stretcher, blanket	Hospital stretcher here Stretcher Safety blanket Fire blanket
	Eye wash and shower	Eye wash station Emergency eye wash Emergency eye wash--relieve line pressure before applying to eyes Caution--emergency eyewash only Safety first--eye wash fountain Eye wash and emergency shower Emergency shower--eye wash Pictogram of cross, emergency shower Emergency shower (Green circles on floor and green lights used to indicate location of shower)

Type of Message	General Referent	Specific Wording or Image
	Breathing	Gas mask inside Breathing air Air masks Safety first-self contained breathing equipment in this building Caution--if H_2S alarm is blowing, fresh air equipment must be used to enter unit
	Alarm	Fire alarm Fire Fire department will respond Emergency alarm--for fire/crash--activate horn Notice--if gong rings, notify _____ In case of emergency call ___________ Emergency air horn--open air valve to summon help Emergency whistle Phone, telephone Caution--H_2S alarm light Caution--leave the area if the H_2S alarm horn blows Caution--leave the area if the H_2S alarm siren sounds Warning--do not enter room when alarm sounds, Halon 131 being released (red stripes on walls and columns) (red bulbs)
	Firefighting	Fire extinguisher Fire extinguisher here Fire station Use CO_2 extinguishers only in this building H_2O CO_2 Fire hose In case of fire, open door and pull lever (on deluge system) Water spray system Entering sprinkler zone Sprinkler water Water spray curtain Water spray--fire protection valve Foam truck inside Foam 832 (numbers refer to foam lines) (red stripes, columns, boxes, bulbs)
	Other	Ladder for emergency use only Deluge system for vapor control Emergency propane and oxygen cut off
Access, Egress	Exit	Exit Out Pictogram of arrow
	Emergency exit	Emergency exit Fire exit Emergency exit--do not block Fire door--do not block
	No exit	No exit

Type of Message	General Referent	Specific Wording or Image
	Keep open, clear	Keep door open at all times Notice--Keep this doorway clear Do not block doorway Fire station--keep clear Caution--keep this area clear Keep this doorway free of obstruction so fire door can close
	Keep closed	Keep door closed Keep fire door closed
	Traffic	Danger--this is not a walkway Notice--No thoroughfare Stop (on floor) Use lined walkways only (Use of lined walkways, usually yellow, but also white, red, or green)
	Restricted Admittance	Do not enter Caution--work and storage area--do not enter Do not enter without #1 operator's permission Keep out--authorized personnel only Danger--keep out Danger--keep out--electrical hazards Danger--construction area--Keep out Danger--keep out of plate storage area--authorized personnel only--violators subject to disciplinary action No admittance--authorized personnel only Positively no admittance No admittance--paint factory employees only Authorized personnel only Authorized personnel--keep out (Company) personnel only Unauthorized persons keep out Unauthorized personnel keep out Unauthorized persons keep out at all times Restricted area--authorized personnel only Controlled area No trespassing Trespassing forbidden Trespassing forbidden--for fire only Fire permit required for entry into air conditioning room Notice--persons with pacemaker--do not enter this area--microwave oven in use Danger--pacemaker wearers do not enter this room Pictogram of horizontal bar inside of circle
Prohibitions	No Smoking	No smoking No smoking beyond this point Positively no smoking beyond this point No smoking--protect your job Danger--No smoking in this area No smoking--$25 fine No smoking beyond this door No smoking in catwalk or ramp Equipment--no smoking Danger--fuel storage--no smoking

Type of Message	General Referent	Specific Wording or Image
	No Smoking (cont.)	Danger--restricted area--no smoking--no hot work
		Smoking--carrying matches--open lights--positively prohibited
		Flammable--no smoking within 10 feet
		Pictogram of circle, slash lighted cigarette, and of diamond, X, lighted cigarette
	Other Flammable-Related	Flammable--keep fire away
		Danger--no welding
	Other prohibitions	Danger--do not open
		Danger--do not open while in operation--high velocity particles
		Do not throw trash in this area
		Notice--No storage permitted
		Butts only--no trash
		Do not throw cigarette butts on floor
		Place no objects on roof curbing
		Do not park or place material under this stretcher
		Danger--do not stand here
		Do not park closer than 6 feet from tracks
		Ride bus, no walking (words in 3 languages)
		Caution--general purpose fork lift. Trucks not permitted in this area
		Caution--battery operated vehicles not permitted in this area
		Danger--do not start this machine
		Do not turn off agitator
		Caution--stay off furnaces
		No liquids (water, coffee, tea) in this area
		Caution--lead work--no eating, drinking, or smoking--gloves and shoes required
		Do not hump this car
		Caution--used lumber--do not use
		Caution--do not use (on lumber)
		Pictogram of circle, slash, walking figure
Procedures	Avoid entanglement	Caution-Keep closed while in operation--moving parts
		Caution--do not operate this machine without guards in place
		Warning--keep guards in place while machine is in operation
		Keep hands out of moving equipment
		Hands off
		Fire use only--hands off
		Danger--keep off
		Caution--stay clear of rocker when using
		Caution--tie back long hair before operating buffer

Type of Message	General Referent	Specific Wording or Image
	Authorized use only	This machine to be used by qualified operators only Caution--authorized personnel only to operate equipment This shipyard is red tag country--If you don't know, keep your hands off and ask--Danger
	Falls	Keep manhole covers closed Before ascent secure platform locks Caution--to avoid a fall, please use handrails Be stair wise--(1) one step at at time, (2) walk, don't run, (3) use handrail Walk, don't run--safety first
	Hose	Keep lines and hose off ladder Safety first-coil hose after using
	Vent, valve	Danger--vent to safe location Caution--shut off N_2 and open vent prior to opening standpipe All petcocks on engine must be open and water valves shut off before moving hoses
	Doors, lids	Keep lid down Caution--keep doors closed when spraying Lock door if room unattended
	Chock wheels	Caution--chock wheels before loading Chock trailer wheels while loading or unloading
	Machines and Equipment	Caution--operate automatic lubrication system before starting this machine Caution--shut down pumping operation before entering Lock out field disconnect before entering Did you check this (with picture of a torch)
	"Housekeeping" related to hazards	H_2O_2--Flush spills immediately FOD--foreign object deposit Safety--empty catalyst container must be returned Keep cylinders chained (with picture of chained cylinders) (Various signs indicating general housekeeping responsibilities)
	Other safety procedures	Deposit all flame-producing devices before entering this area Slow-sound horn Asbestos material only
Maximum Limits	Weight	Caution--maximum floor loading, 150 lbs/sq ft This floor will safety sustain a load of _____ pounds Maximum capacity _____ tons
	Persons	Personnel limit - 10 persons Maximum number of persons _____
	Other	Explosive limits--15 pounds Danger--do not exceed rated capacity

APPENDIX B

Table 1. Sign Wordings or Symbol Referents Which Have Been Suggested as Standard for Various U.S. Applications

OSHA Standard 1910.145

Examples of Wordings

Danger Signs

(1) Danger - keep off - electric current
(2) Danger - no smoking, matches, or open flame
(3) Danger - men working above
(4) Danger - not room enough here to clear men on cars
(5) Danger - keep away
(6) Danger - men in boiler
(7) Danger - insufficient clearance
(8) Danger - 2,300 volts
(9) Danger - keep out
(10) Danger - crane overhead
(11) Danger - keep out
(12) Danger - biological hazard

Caution

(1) Caution - do not operate, men working on repairs
(2) Caution - hands off switch, men working on line
(3) Caution - working on machines - do not start
(4) Caution - goggles must be worn when operating this machine
(5) Caution - this door must be kept closed
(6) Caution - electric trucks - go slow
(7) Caution - this space must be kept clear at all times
(8) Caution - stop machinery to clean, oil, or repair
(9) Caution - keep aisles clear
(10) Caution - operators of this machine shall wear snug-fitting clothing - no gloves
(11) Caution - close clearance
(12) Caution - watch your step
(13) Caution - electric fence

Safety Instruction Signs

(1) Report all injuries to the first aid room at once
(2) Walk - don't run
(3) Report all injuries no matter how slight
(4) Think, if safe go ahead
(5) Make your work place safe before starting your job
(6) Report all unsafe conditions to your foreman
(7) Help keep this plant safe and clean

Direction Signs

(1) This way out
(2) Fire exit
(3) Fire extinguisher
(4) To the fire escape
(5) To the first aid
(6) Manway
(7) This way to first aid room

Informational Signs

(1) No trespassing under penalty of the law
(2) This elevator is for freight only, not for passengers
(3) No admittance except to employees on duty
(4) No admittance
(5) No admittance, apply at once
(6) No trespassing
(7) Men
(8) Women
(9) For employees only
(10) Office

Standardized Hazard Warning Symbols adopted by DoT, U.N. and EEC

(1) Flammable liquids
(2) Flammable solids
(3) Flammable gas
(4) Toxic gas
(5) Compressed gas
(6) Toxic substance
(7) Harmful substances - keep away from food
(8) Corrosive substance
(9) Organic peroxide
(10) Oxidizing substance
(11) General hazard - multi-load of different substances
(12) Dangerous when wet (substances which in contact with water emit flammable gases)
(13) Spontaneously combustible substances

APPENDIX B

Table 2. Non-European Standardized Symbols

Canadian Standard

Signs and Symbols for the Occupational Environment

REFERENT		GLYPH CONTENT
(1) Alert	-	exclamation point
(2) Breathing protection required	-	front view of head with respirator
(3) Bus	-	front view of bus
(4) Cafeteria	-	knife and fork
(5) Car	-	front view of car
(6) Chemical burn	-	drops falling on hand - index and second fingers disintegrating
(7) Coffee shop	-	cup and saucer
(8) Compressed gas	-	view of gas cylinder
(9) Direction	-	arrowhead with stem
(10) Drain	-	funnel connected to an s-drain top
(11) Drinking water	-	human face with angled container
(12) Electrical hazard	-	zigzag line tapering vertically
(13) Elevator	-	box enclosing males and females with arrows pointing up and down
(14) Explosion hazard	-	horizontal lines, sumounted by simulated explosion with radiating particles and wedge shaped lines
(15) Eye protection	-	front view of head with eye protection
(16) Eyewash	-	drops spraying up to a side view of an eye
(17) Fire alarm	-	disc with hammer and convector lines on both sides of disc
(18) Fire axe	-	side view of a complete fire axe
(19) Fire extinguisher	-	side view of fire extinguisher showing cylinder and hose
(20) Fire hose	-	curled fire hose in form of a spiral with a nozzle at the bottom
(21) Fire hydrant	-	front view of a fire hydrant plug
(22) First Aid	-	Greek cross
(23) Foot protection	-	side view of foot protection
(24) Hair protection	-	front view of a head with a hair net
(25) Hand protection	-	front view of glove - fingers extended
(26) Head protection	-	front or side view of head with head protection
(27) Hearing protection	-	front view of head with ear protection
(28) Flammable	-	horizontal line surmounted by flames
(29) Man	-	front view of male figure showing head, 2 arms and 2 legs
(30) Men at work	-	side view of human with shovel
(31) Open flame	-	flaming match
(32) Overhead crane	-	side view of hook with safety catch and with pulley and cables above
(33) Parking	-	Sanserif capital "P"
(34) Phone	-	side view of a handset
(35) Poison	-	skull and crossbones
(36) Running	-	side view of person running - 2 arms and 2 legs
(37) Safety lane	-	side view of human walking between 2 broken lines
(38) Security	-	policeman's shield
(39) Shower	-	drops spraying from a side view of shower head
(40) Slippery floor	-	horizontal line, with a human figure that has lost its balance
(41) Smoking	-	smoking cigarette
(42) Stair	-	side view of risers and treads
(43) Start	-	hand, with index finger extended and almost touching side view of a button or switch
(44) Stretcher	-	view of a stretcher with Greek cross inside
(45) Touch	-	Hand, with index finger extended and almost touching horizontal plane or line
(46) Truck(s)	-	side view of a truck
(47) Valve	-	2 closed arrowheads pointing at each other sumounted by a capital "T" as illustrated
(48) Vending	-	side view of hand holding the representation of a coin and inserting same into vertical slot
(49) Waste	-	hand throwing an object into a receptacle
(50) Woman	-	front view of a skirted female figure showing head, 2 arms (at approximately 60° from the horizontal), and legs (together)

Categories

(1) Regulatory - Prohibition
Mandatory

(2) Warning - Caution
Danger

(3) Information - Emergency-related
Miscellaneous

APPENDIX B

Table 3. Non-European Safety Referents

Chinese Z1002	
Red -	Fire protection equipment and apparatus Fire exit signs Fire alarm boxes Fire buckets and pails Fire hose location Fire hydrants Fire pumps Fire sirens Post indicator values for sprinkler system Sprinkler piping Safety cans Barricades Danger signs Emergency stop bars Wire blocks Flat work ironers Stop buttons
Orange -	Energized equipment Switch box door Unguarded hazards Picker guards Safety starting buttons Pulleys Tranmission guards Rollers Cutting devices Power jaws
Yellow -	Stumbling Tripping Caught in between Construction equipment - bulldozers, tractors Guy wires Locomotives Door ways Low beams and pipes Trucks, trailers, fork lift, cranes Pillars, posts, columns Freight car loading plates Piping systems
Green -	Stretchers Gas masks Safety showers
Blue -	Elevators Ovens and vats Kilns Valves Vaults Scaffolding Ladders
Purple -	Labels and tags
Black - White -	Traffic Housekeeping Aisles Stairways Food dispensing equipment
All Colors -	Follow Munsell System

Uruguay - UNIT-131-58

Calor - heat
Comburentes - oxidizing
Corrosivos - corrosive
Electricidad - electricity
Explosivos - explosive
Inflamables - flammable
Radiaciones - radiation
Toxicos - toxic

Bolivia DGNT-NB-20.1-003

Calor - heat
Electricidad - electricity
Explosivos - explosive
Inflammables - flammable
Radiaciones - radiation
Toxicos y corrosivos - toxic and corrosive

Japanese Standard Z9103-196J

No fire, no open flame
Danger
Attention - watch out
First aid
No entry, no trespassing
Under repair
Radiation
Arrow

NBS-114A (REV. 9-78)

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Although written signs are a common means of conveying safety information in the workplace, pictographic symbols can be a more effective way of providing the same information. Symbols are independent of a particular written language, and can be more accurately and rapidly perceived than the comparable word message. Despite the many advantages of safety symbols, they can be ineffective or even dangerous if the intended meaning is not accurately communicated. As a result, there is a great need for careful evaluation, consistent application, and eventual standardization for safety symbols.

This report documents an initial assessment of current symbol use and future requirements. It includes a review of the technical literature on symbol research; observation of safety sign and symbol use in the workplace; compilation of commercially available symbol referents; and review of national and international standards. Based upon these sources, an initial list of 40 symbol referents is presented along with research priorities for evaluating the effectiveness of symbols for these referents.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

communication; hazard; pictograms; safety; signs; standards; symbols; visual alerting; warnings

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