10 *RESEARCH IN ACCIDENT PREVENTION*

THE READINGS:

INCREASING ATTENTION is being paid in accident research to the evaluation of the efficacy of preventive measures. But this is a substantially new trend. Relatively few accident countermeasures—some in use for decades—have yet been subjected to adequate scientific scrutiny. As a result, it is usually impossible to specify the return achieved in accident prevention per dollar spent and how the efficiency of that expenditure can be increased.

This is a serious deficiency in light of the substantial evidence that intuition, "common sense," and traditional assumptions constitute an inadequate and even erroneous basis for understanding the causation of accidents and for planning and evaluating attempts at their prevention. For example, Garrett has pointed out that

> until the last decade, it was widely accepted as a "fact" that when an automobile accident occurred, occupants who were thrown from the car were safer than those who remained inside. Indeed the connotation of the phrase "thrown clear" was that the ejectee who survived this experience would otherwise have been killed. Although such incidents have in fact been documented, a 1954 Automotive Crash Injury Research (ACIR) report[1] showed that they were the exception rather than the rule . . . that door opening was both a frequent and a hazardous event: In injury-producing automobile accidents, about 44 percent of the cars had one or more front doors opened, and, contrary to general opinion, occupants who were hurled through these doors were often "thrown clear" to eternity—not to safety.[2]

Among other widely accepted assumptions now known to be incorrect was the premise that heavy intoxication is an accident preventive. Thus, as recently as 1956 an authoritative text stated that

> It is the slightly intoxicated driver who characteristically demonstrates impairment of judgment more than impairment in sensory functions or psychomotor responses who is the real threat. . . . The "cockeyed drinker" constitutes neither a pedestrian nor a driving problem. Most of these individuals are either too drunk to drive or to walk and hence sleep it off. . . .[3*]

Similar evidence of the danger of basing programs merely on common sense is exemplified by the results of Barmack and Payne's evaluation of the Smith System of driver training and by McMonagle's documentation of increases in accidents after the installation of traffic control devices at some locations (see below). It is likely that many additional examples will be found when other preventive measures are studied objectively.

Despite such strong evidence against basing programs on unsupported presumptions, programs of this kind continue to be introduced, often with dogmatic public assurances as to their efficacy. Although conceivably justifiable as a stopgap until adequate evidence can be marshaled, this process has tended to delay the necessary fact-finding during much of the past half century, a period in which, in the highway accident field alone, more than 1.4 million drivers and pedestrians were killed in the United States. The introduction of unevaluated measures contrasts sharply with practice in other public health areas. There, before measures of prevention are *permitted* to be used, it is customary to document not only their pertinence, efficacy, and cost but their safety as well. The chlorination, filtration, and

* For research evidence to the contrary, see McCarroll and Haddon, Chap. 3, Haddon *et al.*, Chap. 4, and references 4 and 5.

fluoridation of public water supplies, the pasteurization of milk, and the Salk and Sabin vaccines have been among the many measures thus evaluated. Parallel procedures are employed in the evaluation of new drugs and most new surgical and other clinical procedures. Until similar evaluation can be achieved with accident countermeasures, there is little basis for believing that we are preventing as many accidents as our available resources permit, or that many measures are preventing rather than causing accidents.

In essence, accident prevention measures attempt to interfere with the sequences of events that culminate in damage to animate or inanimate structure. This interference is of three broad types. The first type attempts to prevent the potentially harmful chemical or physical forces from reaching the body or other structure to be protected. The second type attempts so to modify their interaction with that structure that damage is reduced or prevented. The third type attempts, through emergency, early and late clinical, and other care to lessen the long-range consequences of damage not prevented by measures of the first two types. Since research is concerned with measures of each of these kinds, we shall consider them in order.

Measures Directed at Factors Leading to Accidents

Measures designed to prevent potentially harmful chemical or physical energy from reaching a susceptible structure may attempt, in the order of preference, (1) to prevent the marshaling of the hazardous energy per se; (2) to prevent or modify its release; (3) to separate it and the susceptible structure in time or space; and (4) to interpose a barrier that blocks the energy from reaching the structure to be protected.[6, 7]

The prevention of damage from a nuclear device can illustrate these four initial levels of prevention. First, its manufacture might be prevented. Second, its use might be prevented. Third, the nuclear device and the persons and structures to be protected might be separated by a safe distance. Fourth, blast, thermal, and radiation shelters might be employed. It is both theoretically and practically useful to analyze in similar terms all measures which seek to prevent potentially harmful energy from reaching susceptible structures. This applies not only to chemical, mechanical, electrical, and thermal energy but also to such newer hazards as ionizing radiation and magnetic energy dangerous to biological and other systems.[6, 7]

All of these levels of *pre*-accident prevention are exemplified by measures long in use, such as lessening the manufacture of nitroglycerine in favor of safer explosives, restrictions on the discharge of firearms, the separation in space and time of pedestrian and vehicular traffic streams, and the use of insulation on electrical and thermal devices. Nonetheless, the failure to analyze accidents in such terms has made it difficult to determine the exact portions of the causal sequences that offer the greatest possibilities for research and prevention. Neither accident research nor accident prevention will have come of age until this is done skillfully and as a matter of course.

There is little well-designed research on the prevention of the marshaling of given forms of energy in hazardous amounts—for example, by prohibiting the manufacture of fireworks or by limiting the conditions under which vehicles are set in motion or electricity is generated at hazardous voltages and frequencies.† Similarly, there is little research on the modification or elimination of environmental components that favor traumatic interference with normal bodily energy exchange,[6, 7] as in the case of refrigerators that are so designed as to permit the entrapment and suffocation of young children.

BEHAVIOR OF YOUNG CHILDREN UNDER CONDITIONS SIMULATING ENTRAPMENT IN REFRIGERATORS

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The following paper is an already classic study of human behavior in relation to a specific man-made environmental hazard. The study was one result of public pressure and Congressional concern which had led in 1954 to attempts to require the manufacturers of refrigerators to modify their models so that entrapped children would be able to escape.

The hearing on the proposed legislation,‡ which was opposed by refrigerator manufacturers and the Secretary of Commerce, led to "a request that the National Bureau of Standards [of the U.S. Dept. of Commerce] work with the refrigerator manufacturing industry . . . to develop performance criteria for evaluating safety release devices." The resulting investigation by an exceptionally competent research group for the first time placed the problem in qualified hands, a development which might have taken place much earlier had the subject involved a more classic public health area. As we shall note below, however, the manufacturing standard subsequently promulgated by the Secretary of Commerce was sufficiently inconsistent with the results of this work to make it likely that deaths would continue to occur. This illustrates a common problem in accident prevention: the failure to apply research results properly.

† One of the factors that make electrocution more likely with currents of some types is their ability to render those who make contact with them physically incapable of breaking loose. Reference 8 describes research to determine characteristics of electric currents that permit the breaking of contact.

‡ The record of this hearing,[9] like that of hearings before the Roberts Committee (see below), illustrates (1) the contending forces which influence the public safety; (2) the tendency of many concerned with accidents to predicate their control on completely unevaluated presumptions; and (3) the common tendency, when dangerous products are discussed, to emphasize public education, local police action, and measures other than product modification or elimination. No mention was made during the hearing of the fact that there had apparently been no well-documented instance of the *widespread* elimination through public education and local police action of any type of accident due substantially to the characteristics of a dangerous product. (This is still the case in 1964.) In addition, no mention was made of the fact that such accidents have often been successfully eliminated through the redesign of equipment, as in the development and compulsory use of the automatic railroad coupler and the airbrake.[10]

See reference 11 for an earlier and somewhat different report of this work.

EACH YEAR a number of young children perish as a result of entrapment in iceboxes, refrigerators and freezers. As numbers go, these are few compared with accidental deaths from other causes, but the thought of even a small number of helpless children suffocating needlessly is so appalling as to have created widespread interest in the problem.

Because of increasing public awareness of the fatalities resulting from entrapment of young children in refrigerators during a period of several years preceding 1956, manufacturers, engineers, governmental bodies and others became interested in methods for alleviating this hazard. Congressional hearings on proposed legislation resulted, in 1955, in a request that the National Bureau of Standards (NBS) work with the refrigerator manufacturing industry represented by the National Electrical Manufacturers Association (NEMA) to develop performance criteria for evaluating safety release devices. Considerable progress was made toward this objective by mid-1956, at which time Congress passed an Act which required "certain safety devices on household refrigerators shipped in interstate commerce" that would allow the doors of such refrigerators to be opened easily from the inside. It further required the development of standards for such release devices. Such standards were published in the Federal Register of August 1, 1957. They require that all devices meet at least one of three specified performance requirements, and specify in some detail tests for the purpose of determining compliance with these requirements.

Consideration of the problem by NBS and NEMA made clear that it was not only an engineering problem, but also a problem in child behavior and so the aid of the Children's Bureau was enlisted.

In developing performance criteria for release devices, it was necessary to correlate the mechanical forces required to keep refrigerator doors securely closed against their gaskets and the forces young children are able to exert when seeking to escape from entrapment. Because no data were available on this point, late in 1955 the Children's Bureau and the NBS conducted tests on children in nursery schools in an attempt to gain this information. In this preliminary experiment, some 60 children between the ages of 2 and 5 years were tested in an experimental enclosure, which simulated a refrigerator only with respect to inside dimensions. The enclosure was camouflaged to represent a gay red "Santa Claus chimney," with a window and door. The children were urged to use, and were rewarded for using, their utmost strength in competitive pushing against the door, from both sitting and standing positions. These tests indicated that a significant proportion of the young children tested failed to exert forces in excess of 10 pounds. However, practical manufacturing considerations make it hard to design for assembly-line production a release device which will respond to a direct push of this magnitude on a refrigerator door and which, at the same time, will permit the refrigerator door to seal so as to allow the refrigerator to perform satisfactorily its primary function—food preservation.

A further investigation was therefore undertaken during the summer of 1956 to provide additional information on the force efforts of children, as well as information on child behavior in general with respect to release devices currently obtainable, the experiment being carried out under conditions simulating actual entrapment as closely as possible. No studies had previously been made under such conditions, insofar as could be determined.

From death certificates and newspaper accounts of refrigerator deaths, a few facts are known and some assumptions can be made. The age range, for all practical purposes, is 2 through 9 years, with the peak

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The summary, 13 tables, and all photographs have been omitted.]

between 3 and 6. Males far outnumber females. Children enter refrigerators singly or in groups. In one instance four, and in another case five, children died together, while a number of situations are recorded in which two children were fatally entrapped together. Some of the refrigerators are abandoned in dumps but many are in homes, only temporarily in disuse (as in empty apartments), or are in the process of defrosting. Some children probably get into refrigerators as into a playhouse, some probably are hiding from companions, a few are shut in by playmates.

Part I. Behavior Study

In designing an experiment to simulate as closely as possible the real situation precautions had to be taken to protect the experimental subjects. If a real refrigerator were used or the nature of the experiment disclosed, children's interest in exploring refrigerators might be aroused. But more important still, entrapment in an enclosed dark space is a fear-provoking experience. If it had not been for the dearth of information and the important use to be made of the results, the originators of the plan would not even have considered subjecting children to fear-provoking conditions.

In an effort to make the entrapment bearable, not only by the children but by the experimenters, a time limit was proposed. On the advice of consultants to the experiment—a child psychiatrist, child psychologists and pediatricians—a time limit of 3 minutes was set as the maximum time that a child might safely and excusably be allowed to cry.

Especial care was taken to see that both before- and after-test experiences were pleasant and that the children left in a cheerful, relaxed frame of mind.

Setting for the Tests

The ideal environment for such an experiment, it seemed clear, would approach what children are used to in the home or at play. However, practical problems and the time schedule agreed on for the study precluded the possibility of conducting the experiment in children's homes or at nursery schools. These considerations dictated the choice finally made—that of a former residence on an estate now a part of the NBS grounds. Trees, shrubs and spreading lawns, together with a large terrace, contributed much to the environment. Two very large first-floor rooms, with the adjoining tiled terrace, were used for an office, reception quarters and testing space.

In the office-reception room, toys, crayons, coloring books and puzzles were provided for the children, also magazines for parents to read while their children were taking part in the tests.

Test Equipment and Facilities

Test enclosure and recording equipment: The plywood test enclosure resembled a child's playhouse, with door, roof and chimney. The inside dimensions ($40 \times 18 \times 25$ in.) were based on the measurements of a number of currently available household refrigerators of 8 to 11 ft capacity, and represent, approximately, the maximum inside dimensions excluding the space occupied by the freezing unit. A safety-glass panel formed the ceiling of the enclosure so that motion pictures of the child could be taken from above. A 16-mm motion-picture camera and illumination equipment designed for infrared photography were housed under the roof. Forced ventilation provided for the child's comfort while in the enclosure.

Several identical doors were constructed into which different release devices were inserted, thus saving time when changing from one release mechanism to another. A snooperscope, which replaces an infrared image with one of ordinary visible light, was used behind the enclosure for observing the children. Under the low intensity of infrared illumination used, the children were in what seemed to them total darkness. Microphones and tape recorders picked up sounds the children made, comments of the observer, and time and force readings during the tests.