

# RESEARCH IN ACCIDENT PREVENTION

MEASURES DIRECTED AT FACTORS LEADING TO ACCIDENTS	616
MEASURES TO PREVENT OR REDUCE DAMAGE	680
THE EVALUATION OF POST-ACCIDENT PREVENTIVE MEASURES	720
THE ROLE OF PREVENTIVE MEASURES IN CAUSATION	720

## THE READINGS:

Behavior of Young Children Under Conditions Simulating Entrapment in Refrigerators	617
An Experimental Field Test of the Smith-Cummings-Sherman Driver Training System	630
The Effects of Driver Improvement Actions on Driving Behavior	638
The Use of "Control Groups" in Highway Accident Research	658
The Lackland Accident Countermeasure Experiment	665
Relation of Traffic Signals to Intersection Accidents; Case Histories from Michigan Signalization Experience	674

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<sup>1</sup> 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.<sup>2</sup>

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. . . .<sup>3\*</sup>

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.<sup>6, 7</sup>

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.<sup>6, 7</sup>

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,<sup>6, 7</sup> 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

—*Katherine Bain, M.D., Marion L. Faegre, B.A., Robert S. Wyly, B.S.*

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,<sup>9</sup> 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.<sup>10</sup>

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

[Reprinted, with permission, from *Pediatrics*, 22:4, Part I, pp. 628-647, 1958.]  
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 × 18 × 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.

**Conventional release devices:** The release devices furnished by the household refrigerator manufacturing industry were of two broad classes of construction. One general type included devices which responded to the application of a force to the inside of the door panel, the most effective area being near the latch edge of the door (D 1, D 2). The second general type included devices which responded to manipulation by hand (D 3). Obviously escape by means of the latter type of device depended not only on a child's finding and having the strength to use a releasing mechanism that covered a limited area, but also on his familiarity with operating similar mechanisms.

**Specially designed escape devices:** Observations of the children's exploratory search of the interior of the playhouse led to the investigators' hunch that what the children were seeking might be a door-knob—something familiar to most of them and one of the things they are eager to manipulate and conquer as soon as they can walk.

To test this possibility, a doorknob linked to the latching mechanism was made (D 4). In order to help children find it in the dark, a circular plastic rim containing luminescent material was attached. This knob triggered the door's latching mechanism if turned slightly in either clockwise or counter clockwise direction or if it was pushed in or pulled out.

When it became obvious—early in the test program—that some children were going to remain very quiet and move about very little, another experimental device was engineered (D 5). A push-open door linked with a floor panel riding on ball bearings enabled a child to release himself with as little as one-half the effort required without the movable floor panel. This door could be opened by a very slight forward, backward, or sideways movement of the floor panel such as would result if the child pushed on the door or on any wall of the enclosure. A child weighing

between 30 and 50 pounds would not have to push very strenuously to produce the small force (6 to 12 pounds, depending on point of application) that would open the door for him.

Device D 6 was very similar to device D 5 except that it was designed to indicate the maximum force efforts of the child and to permit his release only at the discretion of the observer.

### *Test Plan*

**Test subjects:** Tests were set up for ages 2, 3, 4, and 5 years, with equal numbers of children at each age, and of each sex. Insofar as practicable each of two experiments handled equal numbers of children of each age. Most of the test subjects were obtained as the result of a letter distributed among the NBS staff, broadly describing the nature of the study and inviting their co-operation. The response was immediate and generous. Personal acquaintances and neighbors brought in a scattering of other subjects of the required ages.

The 201 children tested came from 157 families.

**Records:** A record card was kept on each child. Parents filled in their own names, years spent in school and occupation, as well as the children's names, sex and birth dates. Each child's height, weight, date of test, and his reactions before and after the test were recorded.

Sounds made by a child while in the test enclosure, comments on his behavior made by the observer, also time and force readings spoken into microphones during the testing were recorded on tape and later transferred to record forms.

A moving-picture record of each test had been planned. Unfortunately, the required infrared film was not obtainable in sufficient quantity and, in consequence, the test behavior of only the first 42 and last 48 subjects was recorded on film.

### *Test Procedure*

A feature of the original plan that was

adhered to in practically all cases was that each child should be accompanied to the test by one or both of his parents, or by a close relative. In a few instances where this rule was not observed, children were brought to the test by their nursery-school teacher, a substitute mother figure with whom they felt comfortably at home.

After greeting the parent and child, the experimenter who was to handle the child during the test made friends with the child. Once children's attention was diverted to the toys, most of them played happily until it was time for them to go with the experimenter to play ball on the terrace. Parents remained in the office while each child was taken individually to the test room.

Separation of a child from his parents sometimes required finesse, especially in the case of younger children. Once the child was left in the hands of the experimenter, she could almost invariably establish an easy relationship, and get him to go willingly with her to the terrace and from there to the test room. In only three cases were children so unco-operative that attempts to test them had to be abandoned.

After playing on the terrace, the experimenter weighed and measured the child in the test room, and then led him gradually down the room toward the test enclosure. Older children were often curious about the enclosure from the time they entered the room, but the attention of the younger children usually had to be drawn to it. When the experimenter considered the time was right, she signalled the engineer behind the scene to start the color cartoon which lured the children into the "playhouse."

The sound track with its music and Donald Duck chatter drew most of the children into the playhouse. In some cases the experimenter bent down to look at the movie and told the child what was going on in order to interest him in going inside.

As soon as a child became absorbed in the movie, the experimenter told him she was going back to the office, or otherwise tried to convey to him the idea that he was being

left alone. At this point an observer, who could see the child from behind the playhouse in a mirror placed high on the wall, closed the door of the enclosure. Simultaneously the cartoon stopped, the playhouse became dark, a shutter closed the screen, sound- and force-recording equipment began to function, and the overhead camera began taking infrared pictures. Now that the child was shut into an enclosure from which most outside sound was excluded, the observer and engineers in charge of observing and recording behind the booth could speak all pertinent information into microphones, to be preserved on tape. This information included comments on the child's behavior, as seen through the snooperscope, time readings at 10-second intervals, and, in one series of tests, the force output as registered on a gage and observed through a telescope. The child's vocalizations were also recorded on tape.

If a child did not release himself, the observer determined from his behavior when to let him out. This determination was formed on the basis of the amount of effort he was exerting and the degree to which he appeared to be disturbed.

Outside, the experimenter, who had started away or given that impression when the child entered, was there to comfort him the moment he emerged. The cartoon was at once continued on the outside screen and the child was invited to watch it or to fetch his parents to watch it with him and to see the playhouse. This proved to be an effective way to calm him, take his mind off his experience in the playhouse, and help him carry away a happy impression of his visit.

#### FINDINGS

*Success in Escaping:* A child's success in escaping depended on at least three factors: the device with which he was dealing, his age and size, and his behavior. Greatest success was achieved with device D 2, which required a releasing force of 12 pounds directed against the door panel



near the latch edge (or more, if applied elsewhere), device D 4 equipped with a knob to be turned, pushed or pulled, and device D 5 with a movable floor panel. Two-thirds to three-fourths of the children taking part in tests making use of these devices let themselves out. In tests in which device D 6 was used, the child could not escape, but he was considered successful if he exerted a maximum force in excess of 15 pounds. Success with each of the six devices was affected by age and height and weight. Boys and girls got out with equal ease. Other factors not determined in these tests may have influenced success, such as the child's intelligence or the socio-economic group from which he came. The only measure of the latter factor obtained in the study was the combined years of education of the parents. A higher rate of success was associated with fewer years of education of the parents.

*Behavior in the Test Enclosure—General Response to Entrapment:* Particularly striking was the wide range in behavior shown by the children in response to the entrapment situation, varying from complete inactivity to violent panic. Three major behavior patterns were observed:

1. Inaction, with no effort to escape or only slight effort (24%).

These were the children who stood or sat patiently, apparently waiting to be let out or for the movie to come on. Some made slight exploratory movements, gently touching the door or walls. A few knocked politely, saying "Please let me out" or "I'm ready to come out now." A few were almost motionless. Some cried gently, others made no sound and apparently were unconcerned. More than one child sat quietly for 15 minutes. Age was not a factor in determining which children would show this passive behavior. A few more girls than boys were in this group.

2. Purposeful effort to escape, without violence (39%).

These children went to work, usually immediately, to find a way out—pushing, feeling, or trying to manipulate a knob or

device, if present. Some were quiet, others cried or called out, but at the same time made direct efforts to let themselves out. This kind of behavior, equally characteristic of boys and girls, increased with age.

3. Violent action, with or without purposeful effort to escape (37%).

These were the children who kicked, banged, jumped up and down, threw themselves against the door, or exhibited anger. Many of these directed their violence toward escape, but some panicked to the degree that no purposeful effort was apparent. This type of behavior decreased with age and was somewhat more characteristic of boys.

This marked variation in behavior obviously influenced success in getting out. The four passive children who escaped did so because the slight shift of their weight on the movable floor (device D 5) opened the door for them.

Greatest success (86% of Group 2 above) was achieved by those who went about the job purposefully, but most of these were also the older children. Panic, anger and violence interfered with success, so that the group with this type of behavior (Group 3 above), most of whom were also younger, achieved success in only 32% of the cases.

*Behavior in the Enclosure—Specific Acts:* In early consideration of the problem of release devices it had been presumed that children would push, yet not all did so. Considering only the four devices (D 1, D 2, D 5, and D 6) in connection with which pushing was appropriate and when no release gadget was present to attract the child's attention, 67 (61%) of the 110 children pushed to some degree. About the same number knocked, banged, slapped or kicked the door or walls. When confronted with a gadget which could be grasped (D 3 and D 4), 18% pulled it; 9% pushed it; and 40% made turning motions.

Hand movements of some of the children were particularly noticeable. About one-fourth of the children put their hands to their mouths or faces. A small number made curious twisting, twining and picking

movements of the fingers or clenching and clapping of the hands. Very few sucked the thumb or fingers and none masturbated. Wringing the hands, as an adult does, was observed in several children.

With sound recordings available on all children it was possible to determine the vocal response they made to entrapment. Some children were silent, with a range from only 6% of the 2-year-olds to 50% of the 5-year-olds. About a quarter of the children screamed, the younger children more often showing this behavior than the older ones. Many of the children called for help.

Although as they entered the playhouse they had been told the experimenter was leaving, some called to her to be let out. But most of the children called "Mommy" or "Mother" even though she was well out of earshot. Only six children called "Father" or "Daddy" (5 girls and 1 boy) although about one-third of the children who called for help had been accompanied to the test by father alone or by both parents.

**Duration of Test:** Time in the enclosure was short for most children. One-fourth got out by themselves or were released in less than 10 seconds and three-fourths either got out by themselves or were released in less than 3 minutes. One-half of those who released themselves did so in less than 10 seconds. If a child became panicky and seemed much upset, he was immediately released. If his disturbance seemed mild or moderate the limit of 3 minutes agreed upon through psychiatric and psychological consultation was adhered to. A few inactive children remained in the enclosure for relatively long periods, six in this group staying over 10 minutes.

**Behavior on Entering and on Leaving the Enclosure:** There was little resistance to the test situation, but the small number reluctant to leave their parents (17%) or resistant to entering the playhouse (13%) contributed more heavily to the group characterized by violent action in the playhouse than did the co-operative children.

Upon escape or release the experimenter

was right there to comfort the child if necessary and to show the movie on the outside screen for the child's entertainment. One-third of the children emerged unruffled; about half were upset but could be comforted or distracted by the movie; and a small group (11%) emerged from the enclosure upset. These were the younger children and also those who had shown a violent reaction in the playhouse.

**Force Exerted by the Children:** Device D 6, designed to indicate the horizontal force exerted by children (Table XIV) no matter where the force was applied, was used to test 31 children. This force was found to range up to a maximum of 29 pounds. The average by age group

TABLE XIV.—MAXIMUM HORIZONTAL FORCES BY POUNDS, EXERTED BY CHILDREN (ACCORDING TO AGE) ON DEVICE D6\*

2 Years	3 Years	4 Years	5 Years
14.5	12.3	17.3	16.7
14.5	6.8	23.4	19.0
19.0	9.0	11.2	16.7
16.7	14.5	15.6	22.3
14.5	16.7	10.0	29.0
0.0	5.6	12.3	10.0
10.0	7.9	19.0	22.3
13.4	—	10.5	29.0
Av. 12.8	10.4	14.9	20.6

\* Designed to measure horizontal force without permitting self release.

ranged from 10.4 pounds for 3-year-olds to 20.6 pounds for 5-year-olds. The average for 2-year-olds was 12.8 pounds. A study of the data did not reveal why the 3-year-olds exerted less force, on the average, than did the 2-year-olds.

Though direct measurements of forces exerted with other devices were not made, the fact that some children released themselves with devices set at specific thresholds indicated the minimum force they exerted at the moment release occurred. Device D 1 required a force of at least 18 pounds to effect release, and D 2 a force of at least 12 pounds. Using the results for children who released themselves in tests using these devices, and combining these results with those for children exerting various forces

measured by D 6, Figure 10 is derived.\* From this it can be seen that 25 to 30% of the children taking part in tests in which horizontal force was an appropriate effort exerted in excess of 18 pounds and 65% exerted in excess of 12 pounds.

#### DISCUSSION

No experiment could be designed to reproduce all the conditions actually present in a naturally occurring entrapment. The kind of child who gets entrapped in a refrigerator is unknown. Is he bold and aggressive and may he therefore be expected to be active in releasing himself? Or does he often seek solitude? What kind of child is lured in, or shut in, by companions? The best the experimenters could do was to take from a volunteer population a sample chosen with the aid of competent statistical advice and containing children of ages known to be susceptible to this type of tragedy. Obviously no test would have been considered that involved depriving a child of oxygen, so it is possible only to speculate as to a child's activity in an atmosphere in which oxygen depletion was taking place.

Probably the greatest differences between the experimental situation and real life lay

in the fact that the children knew people were not far off, and in the protection provided against psychologic trauma. The experimenters who handled the children were warm, friendly people, fond of and widely experienced with children, who first developed rapport with each child to be tested. Having got a child's confidence they were unable to bear his fear reaction long (in contrast to the observer who, having developed no such relationship, could be more objective). His cries brought a quick appeal by the experimenter for his release. How a child would ultimately have solved his problem was therefore often not determined. Left in the enclosure longer some children might have quieted down and released themselves. Success, therefore, is possibly underestimated.

The wide range of behavior of the children was especially interesting in light of the purpose of these experiments—to provide data for the development of performance standards for release devices. If one assumes that behavior of these children was generally typical of those entrapped by chance, then a significant number will probably not release themselves by the use of any currently practical device requiring purposeful physical effort. A device utilizing their purposeless movements would increase the escapes. The movable floor panel device was developed for this purpose, and showed some promise in this connection in the few tests in which it was used. However, problems in its manufacture and sanitary care, and the impracticability of making its releasing features accessible from all spaces in which a child might become entrapped, appear to place serious limitations on it. In addition, were it sensitive enough to be effective for passive children, it might interfere with normal use of the refrigerator.

The association of lower education level of parents with degree of success might possibly be explained on the grounds that parents with no more than grade or high school education may give their children more opportunity to play independently than parents with college or advanced degrees.

\* There are at least three possible sources of error in the observed force values for device D 6. First, friction, weight, weight distribution on the floor panel, and direction of applied force may have affected the directly observed force values. Second, the person who observed the force gage probably was unable to read with great precision the values indicated by the sometimes-fluctuating needle. Third, the calibrated accuracy of the force gage affected the results.

Computations based on the calibration data taken for device D 6, loaded centrally with a weight of 34 pounds on the floor panel, showed that the maximum deviation of applied force from that indicated by the calibration curve used in the preparation of Figure 10 and Table XIV was  $-1.7$  and  $+1.5$  pounds for rearwardly directed forces (as in the case of a child pushing on the door) and sidewardly directed forces, respectively. The corresponding average deviation was  $-1.2$  and  $+0.4$  pounds. Available information indicated that the calibrated accuracy of the force gages used in the calibration of device D 6 and in the tests was within  $\pm 0.2$  pound. It is estimated that the person who watched the force gage while children were in the enclosure was able to read the maximum forces indicated by the fluctuating needle within  $\pm 0.5$  pound.

The turning movements made by many children when taking part in tests utilizing a device that could be grasped, suggested that the household doorknob was familiar enough to all children to be useful. This proved a valid assumption.

Fundamental to the establishment of performance requirements relating to devices that release by pushing was knowledge of children's pushing behavior. Would a child push? Where? With how much force? Not all children pushed; some directed their efforts to walls rather than to the door, some to the hinge rather than the latch side of the door. Others let themselves out accidentally when they leaned against the door or when in their violent activity they bumped against it. The size of the space, the size of the child and chance all played a part here.

#### PART II. FOLLOW-UP STUDY

Though the experiment produced data which can be expected to save lives, the investigators would still have been uncertain of their justification if the subjects had been harmed. The complacency with which most of the children took the testing, and the ease with which those who became upset could be comforted, reassured the directors of the experiment that it was permissible and justifiable. Nevertheless, more objective data on the aftereffects, if any, seemed desirable to round out the experiment. Deep-seated anxieties in the children could not be uncovered without extensive psychological testing, and even if such deviations were found their relation to the experiments could not be determined, since previous personality studies of the children had not

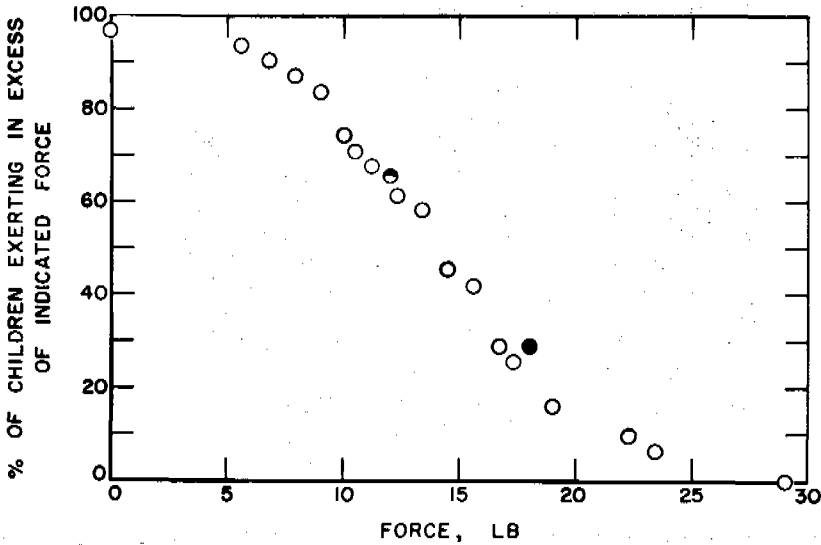


FIG. 10. Horizontal components of forces exerted by children, ages 2 through 5 years.

<i>Device</i>	<i>Number Tested</i>	<i>Number Who Released Themselves</i>	<i>Symbol</i>
1	31	9	●
2	32	21	◐
6	31*	0	○

\* All released by observer.